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VOLCANIC HAZARD MANAGEMENT IN TONGARIRO NATIONAL PARK

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ABSTRACT

Volcanic hazards are a significant concern on Mt Ruapehu in Tongariro National Park. The presence of a hot acid lake over a historically very active vent surrounded by glacial ice and seasonal snow create a very significant lahar risk to visitors of the popular Whakapapa area. Although this hazard is confined to paths in valleys known from historical events, updated lahar maps are needed to account for ice retreat and improved understanding of lahar behaviour.

Additional significant hazards during eruptions at Crater Lake or the other volcanoes and any new vents include: ballistic blocks, pyroclastic surges (lateral or downslope blasts of turbulent fluidised material) nearer the vent, and fallout of ash at greater distances. These hazards can be zoned into circular areas around the vent, the radius of the zone depending on the size of the eruption and wind characteristics.

Management of these hazards is by a combination of warning systems, surveillance, research, planning and rational siting of facilities. The principal element at Whakapapa is a Lahar Early Warning System which activates sirens and messages directing people to predetermined safe areas. A Lahar Response Plan gives precise instructions to key personnel during EWS activations. Heavy rime and snow have rendered the system inoperable at times during the last two winters and a hardware upgrade is being sought.

Various research and monitoring projects over the years have improved our understanding of volcano behaviour and hazards, but none have accurately or consistently predicted eruptions. Eruptions involving sources of external water (e.g., crater lakes) are inherently difficult to monitor and have not been predicted successfully anywhere in the world. Increased seismic activity and rising Crater Lake temperatures have been used as indicators for some eruptions, but have given only a few minutes warning for others. An experimental system installed in early 1993 will improve surveillance while it transmits lake temperature and acoustic data via ARGOS satellites in near real time.

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1. INTRODUCTION

On the night of 24 December 1953, the attention of the New Zealand public was focused on the tragic events of Tangiwai. One hundred and fifty one lives were lost in the raging waters of the Whangaehu River when the Auckland-Wellington Express train plunged off what remained of the rail bridge which had, minutes before, been destroyed by a massive lahar, or volcanic mudflow, released from the Crater Lake of Mt Ruapehu.
Since 1953, there have been 6 further lahar events originating from Crater Lake; fortunately, none of which resulted in loss of life. Two of these events (1969 and 1975) did however cause considerable damage to facilities on Whakapapa Skifield, road bridges at Whakapapa Village and hydro-electric tunnel intakes on the Tongariro Power Scheme.

It requires little imagination to appreciate the significant threat to life that these events pose should they occur during the height of a busy ski season when thousands of people (Table 1) are concentrated into the known lahar paths passing through Whakapapa Skifield and Village.

This paper describes the nature of the volcanic hazards in Tongariro National Park and identifies those agencies with an interest or responsibility in managing for them. It also describes the current management approach and the blueprint for dealing with them more effectively in the future.

Table 1 Visitor statistics 1992, Tongariro National Park

Facility	Visitor Numbers
Whakapapa Skifield	180000 [1]
Whakapapa Visitor Centre (DOC)	187725 [2]
Chateau Resort Hotel	26565 [3]
Skotel Resort Hotel	20195 [3]
Whakapapa Holiday Park	18220 [3]
Tongariro Northern Circuit Huts (x4)	7848 [4]
Tongariro Crossing Walk	25501 [5]
Turoa Skifield	140587 [1]

1 Total number of skiers during the five and a half month opera ting period (June-November). Peak day total Whakapapa = 5650, Turoa = 4432. Anticipated 100% increasein Whakapapa Skifield skier numbers over next 10years (D.Mazey, pers. comm.).
2 Door counter figures over 12 month period. Peak day total = 1548 (Jan '92). Average increase -6% per year.
3 Total bed-nights over 12 month operating period.
4 Ketetahi, Mangatepopo, Waihohonu and Oturere huts. Total bed-nights over 12 month operating period. Peak month total = 1335 (Jan'92).
5 Total number of track users, as taken from electronic track counter after calibration.

2. VOLCANIC HAZARDS

2.1 Hazard Types

Tongariro National Park contains three currently active volcanoes and at least twelve vents which have erupted in the last 10 000 years. Mount Ruapehu (2797 m), a composite andesitic stratovolcano, is most dangerous both locally and regionally. This is because:

1. It is very active; having erupted over sixty times since 1945;
2. It contains a hot acid $10^7 m^3$ lake in the active crater; and
3. Summit glaciers and seasonal snowfields help (a) and (b) create a major lahar risk.

The smaller stratovolcanoes of Tongariro and Ngauruhoe are more likely to be hazardous locally only.

Based on the historic and pre-historic records, Houghton *et al.* (1987) have identified several possible forms of volcanism on Ruapehu, and other hazards which may or may not accompany surface volcanism. These include:

1. Phreatomagmatic explosions and lava dome activity at Crater Lake;
2. Dry vent eruptions (strombolian or sub-plinian) at some point along the northeast-southwest lineation, including new or old vents;
3. Summit or flank extrusion of lava flows;
4. Cone or flank collapse and formation of debris avalanches;
5. Melting of tephra-bearing glacial ice contaminating water supplies;
6. Collapse of the southeast wall or rock sill bounding Crater Lake creating a catastrophic lahar;
7. Sudden release of lake water into the Whangaehu Valley, due to displacement by ice, magma injection at depth or other processes.

Planning has focused on understanding and mitigating the effects of (1) and (2) (Table 1). Although potentially catastrophic, processes such as (4), (6) and (7) are not normally considered in current planning as they are infrequent on human time scales or otherwise confined to the Whangaehu River flood plain. Lava flows (3) are normally hazardous to property only, not life, and (5) has become virtually negligible due to massive ice loss over the last forty years.

2.2 Hazard Zones

The hazard zones of eruptions and explosions can be generalised into three types (Houghton *et al.* 1987) (see Fig. 1, and Table 3, below):

Zone A - Around the vent, a nearly circular region of total destruction and extreme risk to people due to erupted volcanic debris (e.g., rocks and boulders, otherwise known as ballistic clasts) and surges (warm and wet) or pyroclastic flows (hot and dry) of turbulent fluidised material;

Zone B - Valley-confined tongues of extreme risk from lahars on Ruapehu; and

Zone C - A larger circular region enclosing all possible downwind lobes of fall-out of airborne material (ash or tephra) creating deposits of appreciable thickness.

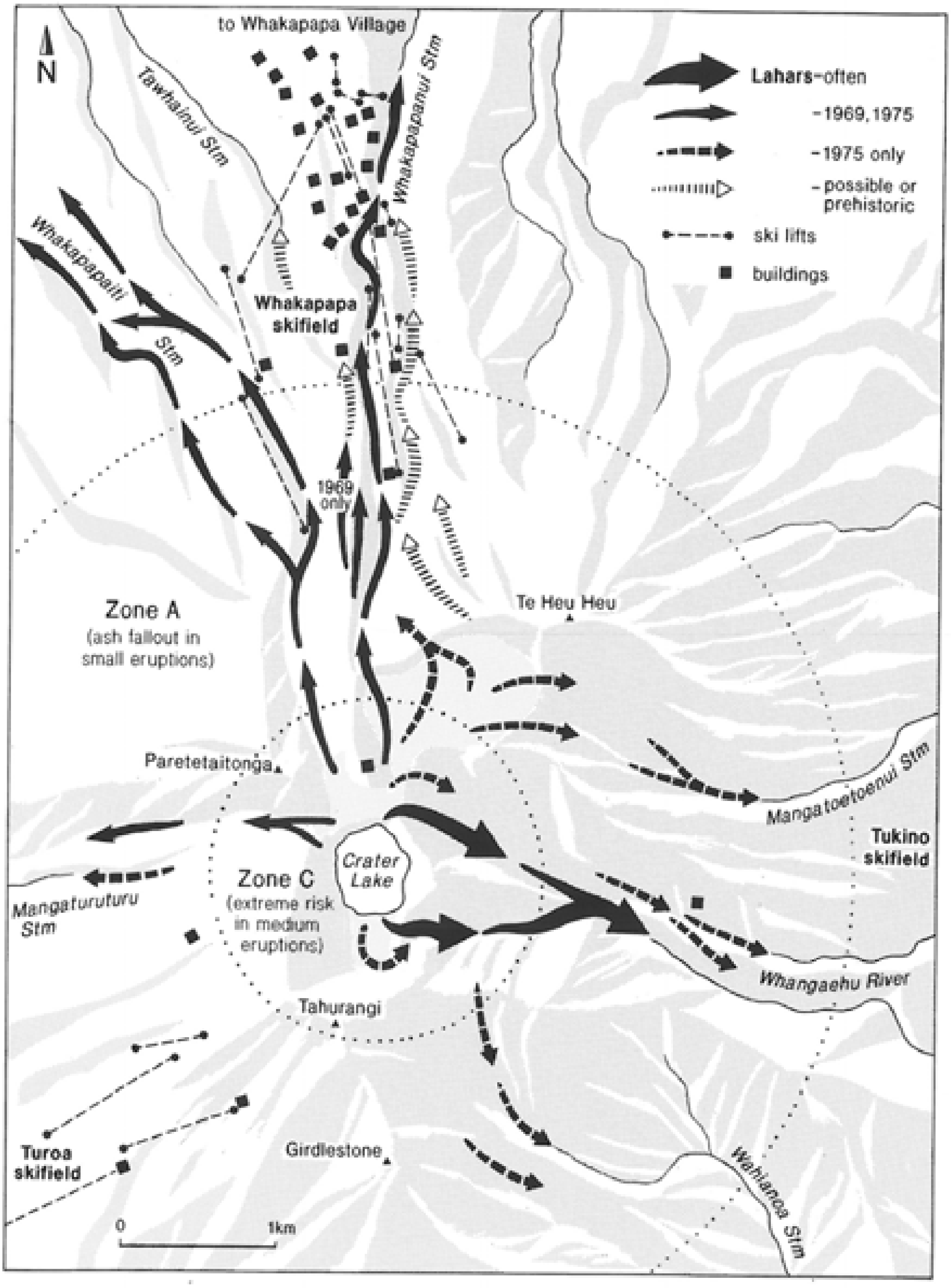

Fig. 1 Historical Lahar and Other Hazard Zones on Mt Ruapehu. (Adapted from Healy *et al.* 1978 and Nairn *et al.* 1979)

The size of these zones (see Table 3) depends on the magnitude and type of the eruption, the volume of ejected lake water and snow and ice melt, and wind direction and speed.

Lahars associated with phreatomagmatic eruptions from Ruapehu's Crater Lake are the most likely serious hazard in Tongariro National Park. Lahars down the Whakapapa Valley pose the highest volcanic risk to human life in New Zealand (Houghton *et al.* 1987; Fig. 1, Table 2, Table 3).

Table 2 Main volcanic hazard types and potential effects in Tongariro National Park

Hazard Type	Potential effects on	
	People	Property
Lahar (mud flow)	Drowning, injuries.	Damage to skifield installations, buildings, roads and rail bridges.
Tephra Fall-out	10 mm - Asthma and eye irritation. 100 mm - Respiratory problems. 1 m* - Injury or death.	Transport immobilised, roof water pollution, telephone failure and building collapse.
Ballistic Blocks	Deaths, injuries and burns.	Damage and fire.
Pyroclastic Flows and Surges	Deaths, injuries and burns.	Destruction.
Toxic Gases†	Respiratory problems and poisoning	Nil

* Less if water content high.
† No historic incidents.

Table 3 Indicative Size and Location of Volcanic Hazard Zones in Tongariro National Park.
(Adapted from Houghton *et al.* 1987)

Eruption Size	Return Period for Ruapehu*	Zone Radius		Zone B
		A(km)	C(km)	Ruapehu Lahars
Small	1–3 years	0.5	3–5	Whangaehu Valley
Medium	10–30 years	1	10	4 main valleys†
Large	100 years	3–5	>100	All valleys‡

* Return periods may be longer than this as they were calculated during a period of frequent volcanic activity.
† Lahar risk high (5–30% of lake water ejected) especially in Whangaehu, Whakapapaiti, Whakapapanui and Mangaturtara valleys.
‡ Lahar risk extreme (30–>60% of lake water ejected).

Lake water ejected by even medium sized eruptions ponds in ice covered craters and valleys north of Crater Lake and drains through at least three low points into valleys in the Whakapapa Skifield, where skiers tend to concentrate, and down past Whakapapa Village. Lahars in 1969 and 1975 were estimated to take only 3-4 minutes to reach the skifield, leaving little time for evasive action.

The Whakapapa holiday park, main residential area and, potentially, the Chateau Hotel are threatened within approximately 20 minutes by medium to large lahar events. Both road bridges above and below the village have been damaged in past lahars. Should those bridges be damaged or destroyed, the logistics and dangers of evacuating the public off the mountain would pose considerable problems, especially if air transport is prevented by ash fall-out.

3. AGENCIES AND ROLES

The management of volcanic hazards within Tongariro National Park has largely been limited to the provision of "warning" systems that advise of an impending physical threat from lahar. This reflects a reactive response to historical events, such as the Tangiwai disaster and the damage to property from the 1969 and 1975 lahars. Consequently, existing warning systems have been focused on those areas and facilities recognised as being in the direct path of such events. These, and the agencies primarily concerned with their safety, are as follows:

Whakapapa Skifield - Ruapehu Alpine Lifts, Department of Conservation, Civil Defence, NZ Police, Ruapehu District Council.

Whakapapa Village -Department of Conservation, Chateau Resort Hotel, Skotel Alpine Hotel, Ruapehu Alpine Lifts, Whakapapa Shuttle, Civil Defence, NZ Police, Ruapehu District Council.

Tongariro Power Scheme -Electricity Corporation of New Zealand.

Tangiwai Rail Bridge -New Zealand Rail.

The Police and Civil Defence hold the legal responsibility for public safety within New Zealand national parks. The present policy on public access to national parks allows freedom of entry and generally unrestricted access to all parts of them. While recreationists accept responsibility for safe risk-taking, the park management and commercial operators accept a moral responsibility for their general safety (Dingwall *et al.* 1989). This includes the locating of facilities, such as new lifts and buildings, away from known lahar paths (see below).

In its role as the land manager, the Department of Conservation (DOC) has assumed responsibility for the maintenance and update of the lahar Early Warning System (EWS) and Lahar Response Plan (see below). At around $10 000 per annum, the cost of providing for this service is apportioned amongst those benefiting; namely DOC, the club lodges, commercial operators and, ultimately, the park users, through ski-lift tickets and hotel tariffs.

4. HAZARD MANAGEMENT

4.1 History of Monitoring

In the years after Tangiwai, monitoring and warning systems were installed to address the threat to rail and hydro-electric facilities around the boundaries of Tongariro National Park. Little more than lip service was given, however, to addressing the risk to the immediate park users. Surveillance of the Tongariro volcanoes was carried out by the then DSIR prior to 1951, with actual seismic monitoring commencing after the Tangiwai disaster. This was of little value however in providing warning of an immediate volcanic threat associated with frequent small eruptions as typified by Ruapehu Crater Lake.

The obvious risk to Whakapapa skifield and village, as evidenced by the 1969 and 1975 lahars, prompted the then Department of Lands and Survey, in conjunction with the DSIR and the Ministry of Works and Development, to instigate the development of a system by which at least some warning could be given of lahars threatening these two areas. In 1985, this system became a reality when the EWS was finally commissioned.

4.2 Lahar Early Warning System

The EWS constitutes the principal element in volcanic hazard management within Tongariro National Park. The system relies on the detection and computer analysis of volcanic tremor centred upon Mt Ruapehu. In the event of the computer determining that an eruption, and possible lahar, may have occurred, a series of sirens and voice recorded messages are automatically triggered on Whakapapa Skifield and in Whakapapa Village. These direct the public to leave the valley floors immediately and proceed to predetermined safe zones.

While never having been put to the test, the DOC is confident that the theory and software controlling the operation of the EWS could see it perform as intended should a lahar event occur. Due to its age and recent climatic extremes, the same level of confidence is not, however, held for the satisfactory performance of the equipment hardware. Equipment failure and impaired telemetry, due to massive ice build-up around Dome Shelter, have seen the system rendered inoperable on several occasions during the last two winters.

The potential for lahars to affect Turoa and Tukino skifields is not discounted, but they are much less frequent than at Whakapapa. Turoa Skifield might be affected by major lahars as seldom as once every 5000 years although significant lahars may run down the Mangaturuturu Valley every 100-200 years (Hodgson and Neall 1993). The location of these skifields away from the historically more recent flow paths has lead to no provision of automatic lahar warning systems covering these two areas.

Following the automatic activation of the Early Warning System, a transition from an electronic response to a human one takes place.

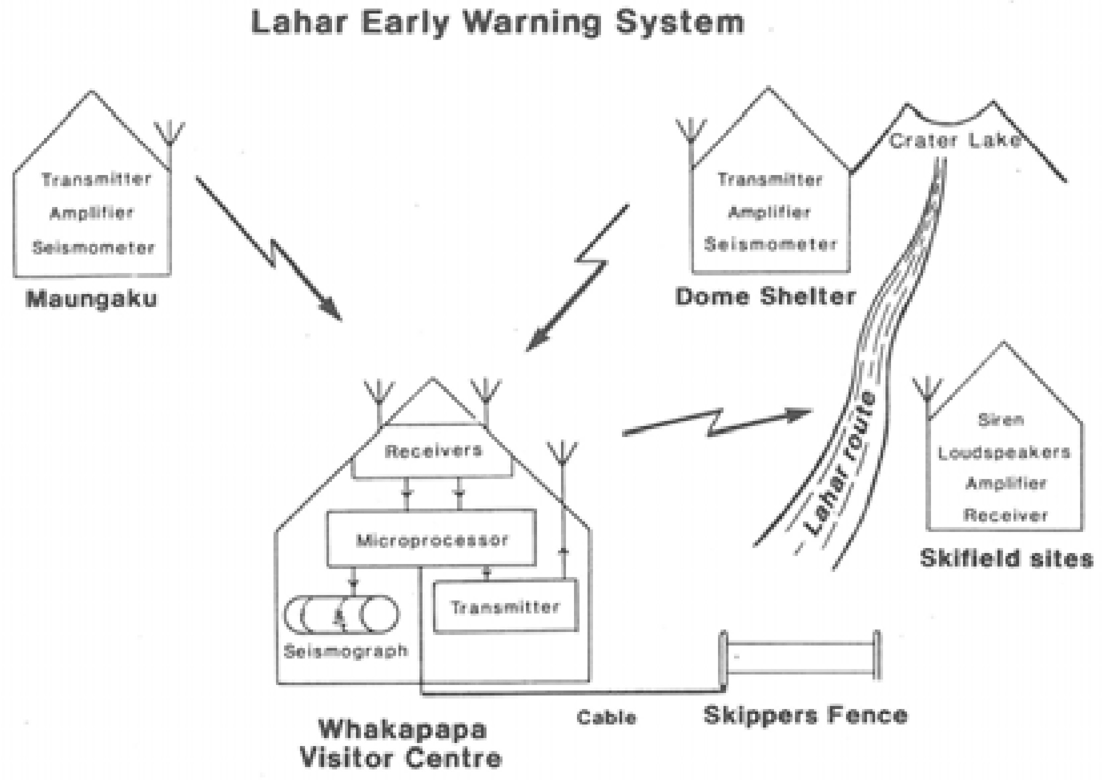

Fig. 2 Lahar Early Warning System (Hurst 1986).

4.3 Lahar Response Plan

Developed in 1985 to coincide with the commissioning of the EWS, the Lahar Response Plan gives precise instructions on the action to be taken by the key skifield and village operators in the event of the EWS being activated. With only minutes of warning of a lahar entering both the skifield and village, an immediate, controlled response by staff is essential if injury and loss of life are to be minimised.

The Lahar Response Plan was reviewed in 1991 and a comprehensive test was successfully carried out as part of the Ministry of Civil Defence's *Nga Puia Volcanoes* campaign in October of that year (Montgomery 1992).

4.4 Current Hazard Surveillance and Assessment

Ruapehu, Ngauruhoe and Tongariro are monitored by seismographs, deformation studies, lake or fumarole temperature and composition, and various other studies (Hurst 1986). None of these techniques, or earlier ones now discontinued, have enabled eruptions to be accurately or consistently predicted although some have helped define periods of increased probability of eruption. They have also helped us understand more about eruption mechanisms and have provided experience for new and better surveillance systems. The problem at Ruapehu is that small eruptions constitute a finite risk to significant numbers of people and structures. Eruptions of these sizes have never been consistently and accurately predicted at any volcano.

The ideal surveillance system must report on eruption precursors or detect the onset of eruptions in real or near real time and be able to withstand the harsh alpine and volcanic environment. Historical activity has shown that lake temperature and seismic activity are reasonable, but not failsafe, precursors. The EWS provides automatic analysis of volcanic tremor on the seismometer at Dome within minutes of occurrence (Latter 1986 and see below).

Considerable effort has gone into systems for monitoring Crater Lake temperature. An important database of manual measurements every month or so, was supplemented in 1989 with data loggers continuously recording temperatures sampled on an hourly basis; with data downloaded during the monthly visits (Scott 1991). Early 1993 saw an important development with the installation of an experimental system which transmits lake temperatures and acoustic data via ARGOS satellites and thence to the Institute of Geological and Nuclear Sciences (IGNS) in near real time (T. Hurst, pers. comm.). This system is expected to transmit data at least until the winter ice up.

The Department of Conservation recognises the need to improve monitoring and research at Crater Lake. Recently increased funding for volcanic hazard assessment by IGNS should see continued improvements in this area.

4.5 Other Volcanic Hazard Management

The mere fact that the mountains of Tongariro are active volcanoes means that they hold strong appeal as a recreational and tourist destination. While this invariably means that, by venturing onto their slopes, the public is placed at risk from the effects of an eruption, the extent to which the DOC manages for this risk reflects the remote chance of such an event being encountered by anyone individual.

For back-country users, this risk management by the DOC is largely limited to maintaining a close liaison with IGNS so as to be well informed of any increase in volcanic activity. This will enable the issuing of warnings through the media and closures of areas if appropriate to minimise the number of people entering the likely danger zones (e.g., Table 3).

While it is anticipated that there would be little difficulty, or opposition, to issuing public warnings and imposing restrictions on access to the areas surrounding Mt Tongariro and Mt Ngauruhoe, the same can not be said for Mt Ruapehu. The scale of the commercial activities on Ruapehu means that any public warnings or restrictions on access, due to increased volcanic activity, must be well founded otherwise considerable opposition can be expected.

The absence of any automatic warning systems to warn of the threat of other volcanic hazards, such as airfall ash or toxic gases, can be attributed to two main factors:

1 - The lack of any significant threat or damage from these forms of hazard in the past.
2 - The difficulty of achieving prompt evacuation away from the dangers which these hazards pose.

It is anticipated, however, that the Lahar Response Plan, respective skifield safety plans and the district civil defence plan will provide, as intended, for an appropriate level of response and co-ordination should these hazards become a reality.

4.6 Facility Design and Placement

The Tongariro National Park Management Plan (Tongariro-Taupo National Parks and Reserves Board 1990) requires that any new buildings or structures within the park will "as far as possible be designed, located, serviced and landscaped to ensure a high standard of safety of the structure". This policy will be achieved by requiring the preparation and acknowledgement of detailed environmental impact assessments on all major projects. With public safety being an integral part of any such assessment, no new facilities are likely to be approved for construction in known areas of high risk.

5. THE FUTURE

In response to the out-dated technology of the EWS, our current systems and thinking being based on historical events of 18 years ago, and the increased pressure for commercial development on Mt Ruapehu, two major investigations have been identified as being necessary for our continued effective management of the lahar threat:

1. An investigation into the up-grade or replacement of the EWS hardware.
2. A reassessment of the lahar threat on Mt Ruapehu.

This latter investigation would take into account the landscape changes that have occurred on Mt Ruapehu in the last 18 years, as a result of wasting of its glaciers, and the changes in scientific understanding of the effects of trajectory, wind strength and wind direction on an eruptive column. In the current climate of user pays, these investigations will be dependent on joint venture financing by those government agencies and commercial operators with a vested interest in the outcome.

To meet our responsibility for effective management of the volcanic hazards within Tongariro National Park, there must be a commitment from both the public and private sector to:

1. Constantly up-date our understanding of the natural processes involved, and the improvement of monitoring where possible.
2. Diligence in our attention to appropriate facility design and placement.
3. The on-going development and testing of emergency systems and procedures.

This need for commitment is made all the more important by the one thing of which we can be certain:

"that, at some stage in the future, the mountains of Tongariro will erupt again. "

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