crater lake ice-cave had been entered before the 1946 volcanic eruption of Mt. Ruapehu. It was believed to be blocked.

There seemed to be very little official concern of the blockage and the known recurring floods - probably because the area was remote, little private property was at risk, and only a few bridges were wrecked. However, Mr W.P.Mead - a Surveyor and pioneer developer of Mt. Ruapehu, had interests which were both accountable and vigilant.

The authors' adventure - a Ruapehu Regatta of three miniature rubber boats - was to depth the new lake and to explore the ice-cave. This became more dedicated to suit Mead's requirement. He wanted to relate the lake bathymetry to his survey references and to easily observed *signs* of crater lake change.

Crater lake had been depthed at its mid-point about 1936. The 1946 eruption had evaporated that lake. Mason's Report for the Board of Inquiry, noted that the ices cliffs of the Inner Crater remained intact through the eruption, even though the lake had evaporated.

METHODOLOGY

The Ruapehu Regatta was simple and non-technical, but important observations were made and reported (Figs 1 - 4). Healy J., the Superintending Geologist, saw fit to submit this as Exhibit Nos. 26 - 27- 28 to the Board of Inquiry in 1954.

In April 1950, the author made a lone land circuit of Crater Lake to look for the ice cave, and to find a convenient access to launch his rubber boats. He met Mason in the crevasse area above Crater Lake. Mason was visiting there to plan a different N.Z. Canoe Association venture. Mason's report and his photographs become especially important. They link and compare the crater from the period of evaporation 1946, filling 1950, and the disaster aftermath of 1953/54. As related later, Mason was of assistance to both Healy in his Geology Report and to Christie in his Ministry of Works Report. Mason's own Report and photos cross reference both.

Mason's photos (Figs 2 - 3 - 8) of a set of 18 photos were of the crucial recurrence period 1950. The crater lake had begun to exceed its old sill height. The photos also cross reference with the aerial photo map of November 1948. This was used by the author for bathymetry plotting. (Fig 4). This gives a specific reference to the 1948 shoreline and to certain rocks at water level 2 years before and soon after the disaster. In particular (Fig 3) shows the size of crevasse movement above the ice-cave entrance. It also shows a most important evidence of the ice cliffs collapsing as the lake level rose. The high lake level caused an undercut of the ice cliffs until the lake increased in area by almost one-fifth (Fig 5).

OBSERVATIONS

The author was overseas as a Marine Engineer at the time of the inquiry. The Ruapehu Regatta became important only as a catalyst that caused the Mason photos to be taken at a crucial period. The boats used were inflatable life-rafts of air force fighter pilot vintage. They had collapsible aluminium paddles for an awkward propulsion. The boats folded to a parachute-pack size. The inflated boat was only 1.5m sitting length, but sufficient for the purpose.

The bathymetry was simple and basic. Each boat was linked with a cord-length of 1 chain (7m) to ensure a 1 chain grid pattern of plumbdepth progress. 16oz lead sinkers (.5kg) weighted each plumb line. Lines were knotted at 1 fathom spacing (2m approx.) and code knotted at 10 fathom intervals. A floating thermometer was observed. About 25 soundings were taken along a line south to Tahurangi Peak. A maximum depth of 44 fathoms recorded the extent of the infill of the craters main vent.

A galvanised steel gauge was erected - 20/5/50. It's top was 6ft above W.L. Various rocks up to 17ft above W.L. were marked with paint. In the period to 29/1/51, five attempts to observe lake levels were frustrated by unsafe weather conditions. There was no' sign of the gauge or painted rocks. It was estimated that the lake had risen 12 or 15ft in 9 months. The receding ice cliffs were not visible in the fog conditions.

Mason's Report 1954 details further.

An interesting and important comparison is available between the crude craft of the Author and the sophisticated remotely controlled catamaran used by Geophysics Division 1985 (Figs 9 & 10).

The catamaran instrumentation was unable to record over gaseous bubbles of the crater main vent and northern vent. This has an indirect support of Vause 1993 in matters of wave energy transmission, via single phase fluid, and via gaseous *two* phase geothermal water.

Dawson and Sorrell (Fig 9) located a main vent and a northern vent and temperatures sufficient to suggest that a density drive circulation could exist (Vause 1993).

Circulation should rise from the higher altitude and marginally hotter north vent and to sink to the lower cooler main vent. Mason identified Ngapha and small boiling springs on the bench, or beach, where they camped after the Tangiwai Disaster (Fig 8). Those fumaroles would have been deep under the ice-cliffs which had previously covered the bench level. It is likely that such geothermal energy would usually vent with less resistance at the lake edge. Such boiling features can exist under ice.

DISCUSSION

Three aspects concerned the Author to purse and present this paper warning of the next lahar as a recurring event.

1. The difficulty to access important Tangiwai Crater Lake information.

2. The author's reaiisation that the cause of the lahar event should be documented for accountable action.

3. The complacent attitude "it cannot happen again".

1.1 The author had a clear recollection of his several letters related to his 1950 crate lake survey, and to its warning. He wondered at what Mr Healy had presented to the proceedings as Exhibit 28. He expected the Inquiry Proceedings be publicly accessible for research of recurrent dangers. Instead he encountered a stock reply "an Inquiry was held and nobody was to blame". The Government Printers' account is all that seemed allowable or available.

But that showed Healy had submitted only one of several author's letters, photos and a map. The author concluded that Mr Healy was a courageous officer to present what seemed a clear evidence that the office of Geology (in terms of say Erebus Disaster) was at least aware of the pending danger. The outcome of the proceedings was interesting.

It was conclusive that a lahar had burst from the lake outlet. That report appeased the public interest. "An Act of God" was established as the cause of the Tangiwai Railway Disaster.

Archive files show that an appropriate court room drama concentrated attention on the train and the bridge. Minute details were cross-examined.

2.1 Many years later the author had cause to review Exhibit 28 for adequacy of warning. Further research was guided to Archive House where the 5 files of New Zealand Railway Department had been deposited. A copy of Christie's 5 page report was made to his own M.O.W Department - not for the inquiry. Christie's report was precise in engineering and specific in measurement. It was probably more useful about Crater Lake and the ice-cave, than Healy's more general report of some 24 pages. A cross-examination of Healy has not been located on Railway files.

2.2 Many authoritative witnesses must have observed a visual warning that the lake was one fifth larger in surface area and that its high ice cliff cover had vanished into the lake. A few witnesses provided one-off photos, but no report makes comment on the huge bench or beach which support the ice cliff glacier.

Of more importance is the relationship of the bench or beach - only 1 or 2 metres above the ice cave outlet sill. (Fig 8).

Most householders are aware of the recent alarm raised, of a potential landslide moving into Lake Dunstan Hydro Scheme in the South Island.

Most householders have recall of horror stores of what can be expected if the Polar Ice Caps melt, and raise the world sea level - Tangiwai was Similar.

2.3 The author is adamant that no-one could be blamed for failure to be aware of the hidden bench. Except that usually the ice cliffs had to be supported on land. i.e. The ice was not floating on a warm water lake.

Colloquially, the ice-cliffs slid off the warm water encroachment like butter off a hot plate. Mason reported seeing ice - the size of a small house - break off the glacier face and to cause 2m high waves to race across the 500m lake and impact on the blocked outlet barrier wall.

2.4 Healy's report was supported by Prof. Cotton of Victoria University. Healy was also separately supported by Christie, to reveal an unsuspected feature (Fig 7). The existing crater lake was walled off by a lava-flow sill, across a larger old dormant ice filled crater below Ruapehu Summit.

That is, the warm lake water exits the central crater over a sill and then waterfalls down the barrier wall in an almost vertical 54m drop inside of the ice cave of the larger crater. It then exits some 70m below lake level, as a source of the Whangaehu River (Fig 6). Christie established the lake outlet sill as 8295ft ASL.

2.5 Healy and Christie agree in their reports on the nature of the outlet sill as a lava-flow base, covered with volcanic debris which is combined with a pug-like sealant. The crest of this natural "earth" dam is detailed by Christie and photos by Mason. (Figs 9 - 10). The bathymetry shows an ideal safe-buttress from the floor of Crater Lake. The pug-sealant is reported to be periodically erupted over the snow slopes. This suggests that the crater containment is similarly sealed against sub-surface leakage (erosion).

2.6 Christie's photos (Fig 6) show several ice cave streams cascading over the waterfall - sufficient to suggest that the sill has been long established as a permanent safe outlet for a future conservation datum level.

COPY.

Dr. L. Allen,
N.Z. Geological Survey Dept.,
Rotorua.

11, Parr St.,
Frankton Junc.

EXHIBIT No 28

Dear Sir, 5th Feb. 1951,

You may reooll my sending you some mope end samples of tho Ruapehu Crater Loke about April of loet yeor. In your letter of 10th Nay you mentioned that the few samples I sent were being forwarded to tho Dominion Laboratory. There were only a few of the "eggs" in a bottle of lake rater, [illegible]

[illegible] The original samples were collected 4 days after a report of activity (smoke column) from Ruapehu. Tho original samples also contained a yellow-green fluid which appears to bo exactly the same as the "scum" which con ueuelly be seen on the lake surface.

In my last letter I mentioned I was erecting a water leval gauge to watch tho rate of increasy in levul. The gauge was put in 1 month after our boating venturo und about 2 ft. rise had taken place. The gauge was erected on 20/5/50 with its top 6 ft. above water and various rocks up to 17 ft. above water level were marked with paint. On the 29/1/51 the gauge woe submerged and all the rocks were submerged or had fallen in by fairly extensive erosion. I had 5 attempts at reading the gauge on various trips but on each occasion tho weather was too bad to get down to the lake eufely.

As nom as I can estimate the lake hoe risen between 12 and 15 ft, above tho 20/5/50 level and as I cannot find any sign of ttia big "ice cave" outlet of the pre-eruption days I am wondering just what will happen in two or three years time. Tho saddle between the Pyramid and Tuhurangi is not very wide and is only about 70 to 100 ft. above water level.

An interesting feature while I was there was tho breaking off of tho snow slopes below Pare-to tai Tonga. The broken face is about 50 ft. high and 50 yds. or so long. All the old surface levels showed quite plainly in the cross section (about 6 or 7 prominent black lines with one about 30 ft. up and about 6" thick which I supposed would be volcanic ash.

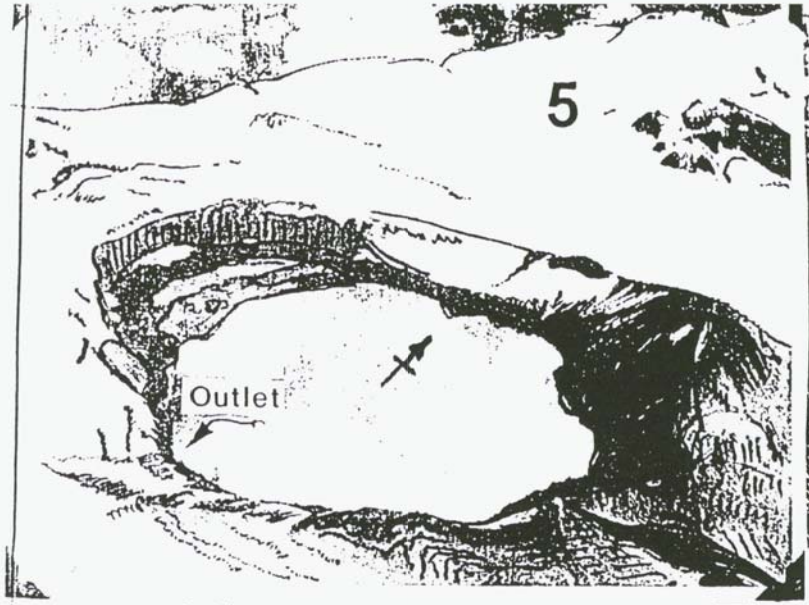
At present I am working up a party to visit White Island, [illegible] should you or any of your staff wish to accompany us they would be very welcome, or if there is any special activity the Dept. is watching I would be pleased to try and get information for you.

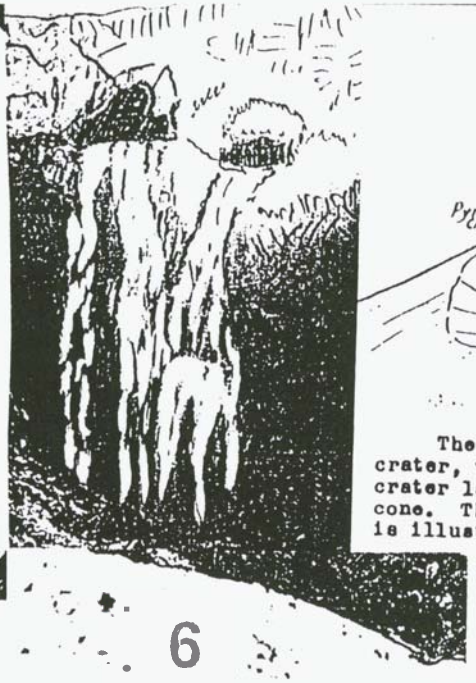
If anyone is likely to come with us would you let me know in the next few weeks as we will be going by special bus.

Yours faithfully, L.S. Vause

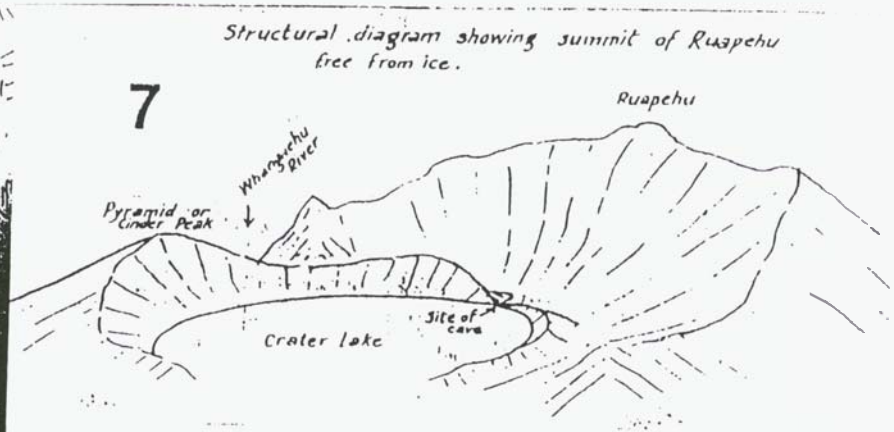
e 26 Contour map and three photographs of Mount Ruapehu.
27 Analyses of samples of water.
28 Letter from Mr L. S. Vause produced by Mr J. Healy.
29 Maintenance Codes.
30 List of lahars-and-floods prepared by Mr J. Healy.

The lake burst - 151 died.
Review of Exhibit 28.
1. Written warning not heeded.
2. The lake is rising/
3. The glacier is receding.
The crevasse over outlet
- collects dam debris, and
- supports debris wall

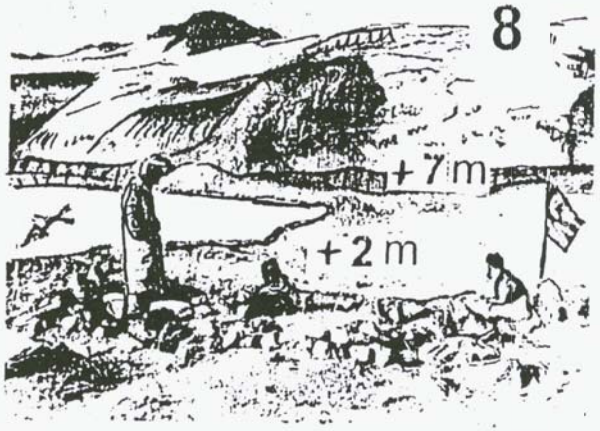




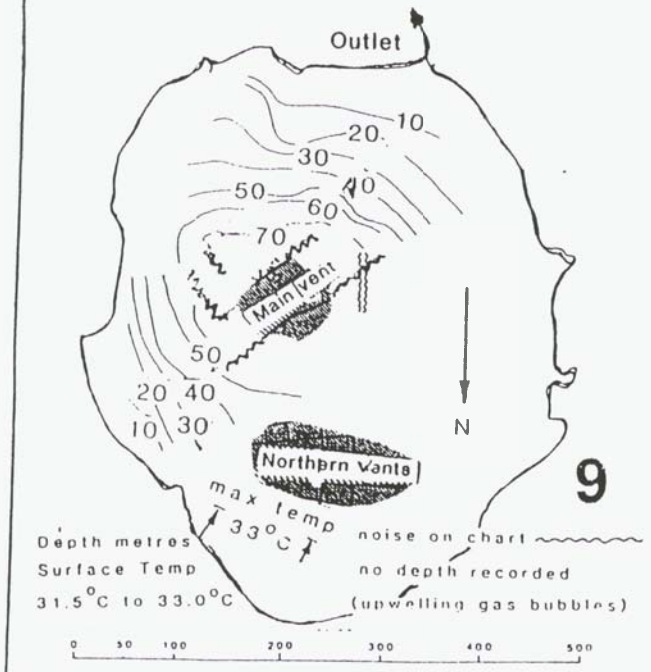
An Air vie w of crater lake from South East. Note water level well b elow promontory and snow in gully terminating at previous water level. 28.12.53 (Y182).



The outer rim of the summit of Ruapehu is that of a large crater, within which there is a central vent, now occupied by the crater lake and surrounded by the remains of an inner volcanic cone. The probable shape of the crater, if no ice were present, is illustrated in the following diagram.

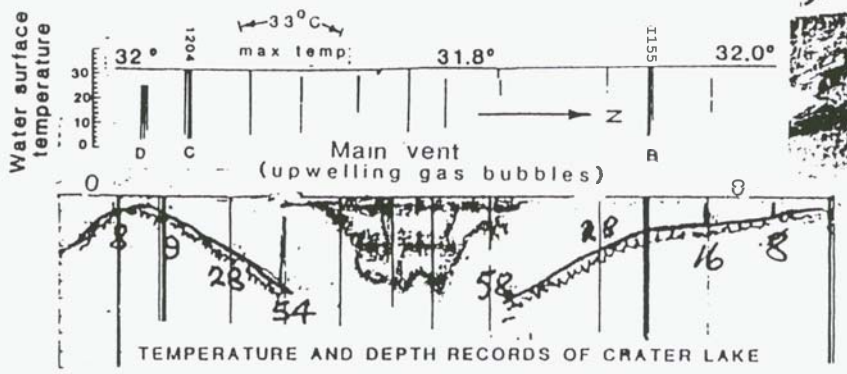


Photograph L. Stream from Crater Lake dropping over rock face where it issues from channel beneath ice. Remains of collapsed ice in mid-foreground.



BATHYMETRY CRATER LAKE MOUNT RUAPEHU
1983-11-29

16.2.54



TEMPERATURE AND DEPTH RECORDS OF CRATER LAKE
MOUNT RUAPEHU (1983-11-29)

10

Geophysics Division
Department of Scientific and Industrial Research
Wellington, New Zealand.

Masons Camp 24.2.1954 was beside hot fumaroles. The flat area is about 2m above lake level. The camp site was 7m below lake level of 24.12.53. The great ice cliffs had receded at least 70 metres.

GEOPHYSICS DIVISION
TECHNICAL NOTE NO. 96 SEPTEMBER 1995

G.B. Dawson
and G.K. Sorrell

3. THE CAUSE OF THE LAHAR (as cause of the disaster)

3.1 The author considers how and when the offending debris deposits on to the long established sill.

3.2 So that the office accountable for public safety and lahar damage may arrange appropriate remedy.

3.3 There may have been a direct deposit fiom the ash showers during the 1946 eruption. Mason reports say that the ice cliffs remained, even though the lake evaporated. That is, the sill was shielded by the ice cave structure from a direct deposit.

3.4 Mason's 1950 photos (Fig 3) shows the magnitude of the crevasse faulting above the ice cave. The author *suspects* that a large catchment of volcanic debris gravitates into the crevasse and falls onto the sill area. It may be sluiced there by rain, or melted in the periodic El Nino type glacier recession periods. 1948-50 was a period of alpine recession.

3.5 Christie and Healy reports refer to the ease of scraping away the debris and sealant-pug down toward the underlying lava sill. Debris disposal over the waterfall *can* be safely arranged by a double sand bag technique. Confined space is but a challenge to cave explorers. But the mountain climate restricts maintenance work to summer conditions (Vause observation).

4. CONCLUSION

- One of the several letters from the author to Healy discussed ways to open the ice cave to the skies. It seems that nature can achieve the impossible in moments! e.g. 1953 Lahar opened the outlet.

- There is already a strong complacency suggesting "It cannot happen again"- e.g. we have spent much money on alarm gadgets and on expert advice.

This paper concludes:

1. That it is inevitable that the ice cliffs will build again over the vast low level bench. The ice cave outlet will bridge - over, once again.

2. Crevasses will continue as catchments for dam-building debris. This is a recurring disaster cycle, as a dam height is directly related to a vast ice cliff collapse. Thus, as self destructing higher lake-level melts more ice, more quickly until the dam bursts - and a lahar occurs.

5. A SIMPLE COST EFFECTIVE SOLUTION

5.1 Advise the office accountable for public safety of crater lake and for flood damage resulting from negligence of "housekeeping" of the sill level.

5.2 Provide a crude lake level gauge comprising of a tripod of poles weighted into the lake bed at a shallow and conveniently observable location - North End. A floating pole becomes a sufficient indicator of Tripod Top relative to water level. A metre rise in lake level is sufficient to warn of action needed to clear a blocked sill. A 2 metre rise indicates alarm that the crater lake is at a level to melt the ice cliff catchment resting on the low level bench. Lake area is almost constant for 2 metres above sill level - then rapidly increase area by one fifth - under the ice cliffs.

5.3 Thus an accountable obvious warning had been adequately given for the sill to be cleared back to a datum outlet level. This is a simple safe and low *cost* summer exercise for an adjacent army of engineers and prison farm labour. The debris has been demonstrated to be easily shifted with shovels. The high lake water sluices debris over the waterfall. Sluicing slows, as velocity stops when datum is reached.

5.4 Sluicing stops - at the wide lava sill level. This has been proven by the 1953 lahar and by evidence of other old ice caves at this level - reported by Christie (Fig 6).

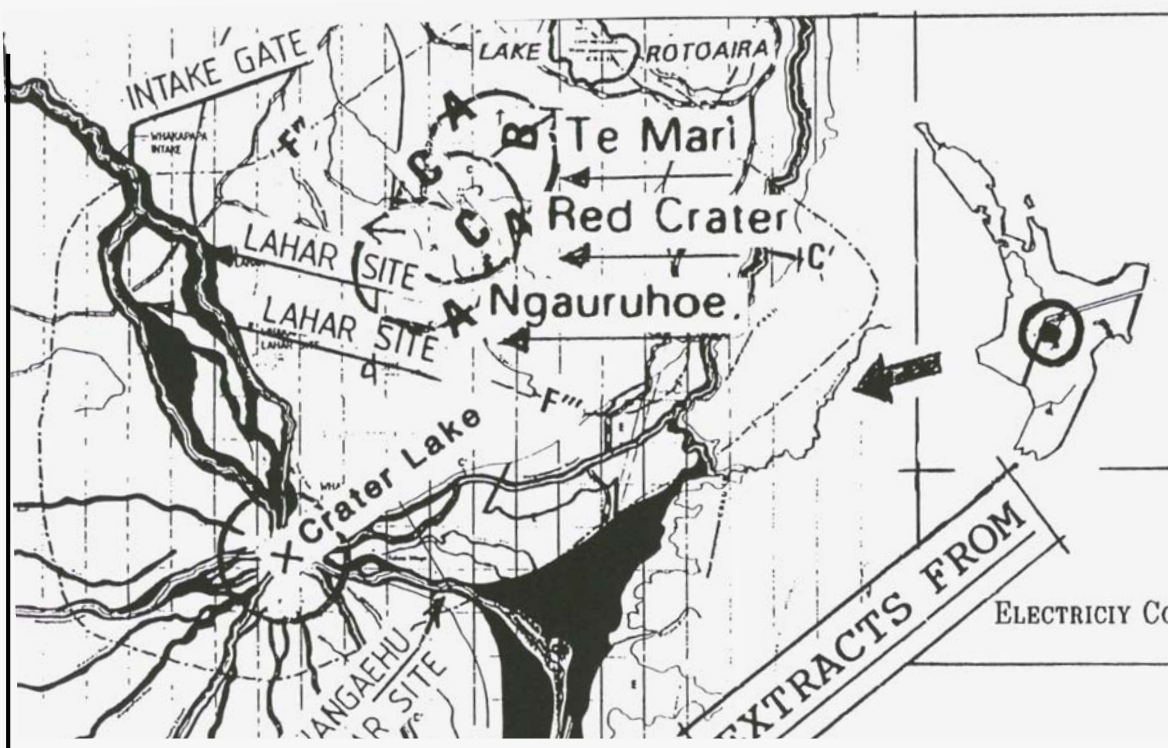
POST SCRJPT

The Board of Inquiry 1954 made recommendations for warning devices on all *streams* leading to Railway Bridges between Waiouru and National Park. Conly and Stewart 1986 refer to an electrode alarm system installed in the bed of the Whangaehu River 11km above the railway bridge. This system is said to be monitored each shift by a Taumarunui train patrol. *An* electric water level recorder installed on the south side of Mt Ruapehu provides a back-up alarm, of warning time for trains to be stopped.

PROTECTION

ECNZ have provided lahar protection equipment on all catchment waterways, on both the Eastern and Western diversion of the Tongariro Power Scheme. Standing instructions provide a monthly test procedure and names the Production Supervisor Operations (Tongariro), as responsible for trip testing as specified in the Local Standing Instruction LS1/008/1993.

The adapted plan of Lahar Risk for Tongariro National Park (Fig 11) shows a comprehensive protection plan for typical lahar returns ranging from intervals of 20-200 and 20,000 year frequency.



EXTRACTS FROM

ECNZ has a series o
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These sites exist to
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ELECTRICIY CORPORATION OF NEW ZE

KEY TO VOLCANIC

NOTE Lahar paths are stylised estimates of the areas like
shown in orange(D) and blue(E), we are dealing with even
Water contamination would also occur in the hydro-electr
lahar path

The red circles mark a radius of three kilometres from Rua
Within this distance blocks on ballistic trajectories. pyrocla
large eruptions. The directions most likely to be followed
arrows(B) within these circles.

Areas affected by lahars from: eruptions in Crater Lake. R
typical return intervals of about 25 to 50 years); Blue Lake
and Ketetahi thermal area.

Minor lahars or contamination of water courses

Areas expected to be affected by lahars from eruptions at
typical return intervals of about 220 to 270 years). See no

Minor contamination in the event of a lahar of the size sh

Areas likely to be devastated as a result of collapse of the
interval in the range 10 000 to 100 000 years is likely.

The Tongariro National Park and surrounding
risk from various forms of volcanic activity.

LAHAR PROTECTION

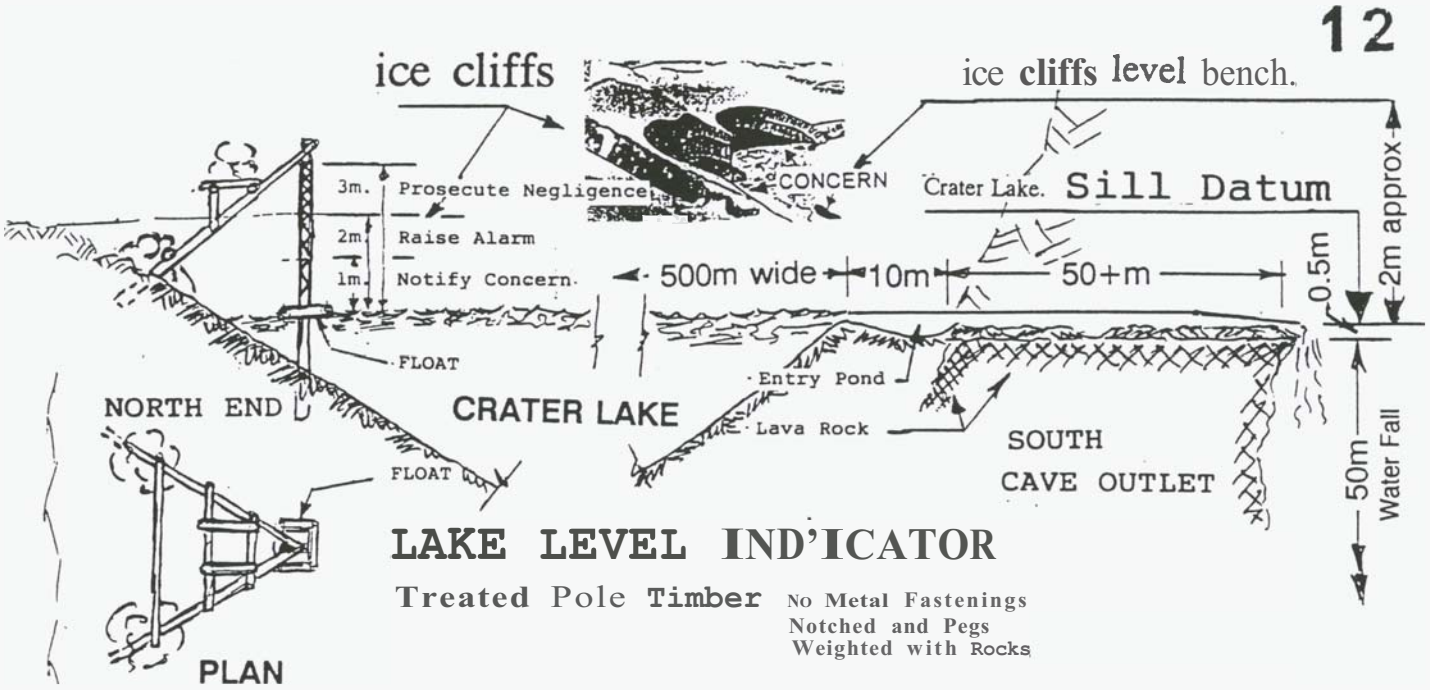
EQUIPMENT

LOCAL STANDING INSTRUCTION

TGO/OPS/LSI/008

Policies, Procedures and Tests

Policies, Procedures and Tests



5. A SIMPLE COST EFFECTIVE SOLUTION:

.1 Advise the office accountable, for public safety of crater lake and for flood damage resulting from negligence of "housekeeping"of the sill level.

.2 Human inspection sees more than a mechanical sensor.

This paper provides for negligible risk of the 1953 type lahar repeating. Bathymetry shows a sloping buttress containment of the crater lake. Eruptions are expected to evaporate the lake or "slop" a small flood over the outlet sill. The sill (1954) was seen to be a substantial 50m lava rock wall separating the lake crater from the ice filled outer dormant crater. Mt Ruapehu is not expected to burst apart (e.g. Tarawera) and lahar its water in unpredictable direction.

This paper does not comment on reasonableness of Government or Corporate application of the Board of Inquiry Recommendations made almost 40 years ago. It is assumed that neither of the above systems "fails - safe" instantly, as in a fire-alarm system. The Railway system could fail - "unsafe" for 1 shift, and ECNZ for a month, until the next scheduled test. The 1953 lahar reached Tangiwai Bridge in about 4 hours. NB: There is always an unavoidable chance of normal *stream* debris, e.g. a tree log, from preventing the best of safety gates from an effective closure.

COMMENT

The annual wreath ceremony "Lest we Forget". It would be appropriate for the Minister accountable for crater lake to provide the wreath lest his office forgets its duty. That is perhaps a multi-purpose cost effective reminder that some "ambulance" services are needed at the bottom of lahar lake mountains. But vigilant "housekeeping" of the lake outlet sill - i.e. avoiding the cause of the lahar at it's source, surely the most logical cost-effective protection - conservation priority - still needed.

METHOD

A boat and shovel procedure - if and when a half yearly inspection of a novel lake level indicator shows a blockage of 1 metre rise has occurred. A slow release of 1 metre of water from a 500 metre wide lake is not expected to exceed deluge rainfall effects on the catchment. A low level acid water dilution pond could be bulldozed when necessary.

ACKNOWLEDGEMENTS

This paper would not have been necessary had previous warnings been headed - but this is a timely acknowledge of the next lahar - *An* Act of God, avoidable by man's accountability for public safety.

This paper would not have been possible without the public access of Archive House - Wellington, and the assistance of the Geothermal Institute of the University of Auckland, and of Eastern Region Fish and Game Council for typing, and of many organisation interests of our Tongariro National Park as a heritage to protect.

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