BEFORE THE ENVIRONMENT COURT AT AUCKLAND **ENV-2020-AKL-000064**

I MUA I TE KOOTI TAIAO O AOTEAROA TĀMAKI MAKAURAU ROHE

IN THE MATTER	of an appeal under the first schedule of the Resource Management Act 1991 (**RMA**)
BETWEEN	**AWATARARIKI RESIDENTS INCORPORATED** Appellant
AND	**BAY OF PLENTY REGIONAL COUNCIL** First Respondent
AND	**WHAKATĀNE DISTRICT COUNCIL** Second Respondent and Requestor of Plan Change 17

STATEMENT OF EVIDENCE OF MAURICE JAMES MCSAVENEY ON BEHALF OF WHAKATĀNE DISTRICT COUNCIL

ENGINEERING – DEBRIS FLOW

10 August 2020

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1. EXECUTIVE SUMMARY

1.1. It was widely recognised soon after the 2005 event that the impact which that event had on the residents on Awatarariki fan should not be allowed to happen again.

1.2. It was accepted that the disaster had been caused by a large debris flow and that there was much evidence that such debris-flow events had happened there before and would happen again if nothing were done.

1.3. The debris-flow processes, hazard and risk distribution at Matatā were studied to currently accepted international standards, based on the recognised sparse data provided by the one confirmed event that could be investigated.

1.4. The 2005 debris flow at Awatarariki fan was estimated by the best available techniques to have a volume of about 300,000 m^3. In my opinion this means that the volume was greater than 200,000 m^3 but probably less than 400,000 m^3. It is unlikely to be improved on.

1.5. No engineering solution was found that would mitigate the impact of a 2005-sized event on fan residents.

1.6. A decision has been made by the Whakatāne District Council (the **District Council**) not to proceed with any engineering mitigation work.

1.7. Some of the remaining residents on the fan consider that they could accept the high risk to their life of a future debris flow of undetermined magnitude. I do not support that position.

2. INTRODUCTION

2.1. My full name is Maurice James McSaveney.

2.2. My evidence is given on behalf of the District Council in relation to:

(a) Proposed Plan Change 1 (Awatarariki Fanhead, Matatā) to the Operative Whakatāne District Plan (**PC 1**); and

(b) Proposed Plan Change 17 (Natural Hazards) to the Bay of Plenty Regional Natural Resources Plan (a private plan change request from the District Council) (**PC 17**) (together referred to as the **Proposed Plan Changes**).

2.3. My evidence relates to the physical effects of the events which led to the Proposed Plan Changes. My evidence will cover:

(a) The cause of the 2005 debris flows at Matatā;

(b) Debris-flow phenomena including variabilities such as size, behaviour and predictability;

(c) Debris-flow triggering mechanisms (such as the complex inter-relationships between rainfall intensity, soil pore pressure, geology, slope angle etc.) that make it difficult to identify when a debris flow might occur;

(d) That a debris flow is a natural hazard;

(e) Description of the Awatarariki debris flow in 2005;

(f) A description of the geomorphology of the Awatarariki catchment;

(g) Analysis of the rainfall, geological and run-off processes during the 18 May 2005 storm event resulting in debris flows in the catchments behind Matatā, and in particular, the Awatarariki catchment, and that debris flows are a natural process;

(h) Discount breakout floods from log dams or debris dams as being the initiating trigger for the May 2005 debris flows;

(i) Preliminary estimate of 200,000 m^3 as being the volume of solid material deposited on the Awatarariki fan from the 2005 debris flow (note this was subsequently increased to 300,000m^3 by Tonkin and Taylor Ltd which was factored in to the risk assessment that Tim Davies and I later peer reviewed);

(j) Evidence of previous debris flows from the Awatarariki catchment, including commentary on their size (e.g. as stated in the GNS Causes and Mitigation Report at section 2.9-2.10 and Figures 2.9.1 and 2.10.1);

(k) Likelihood of future debris flows and area of risk;

(l) Peer review of the Tonkin and Taylor Ltd Supplementary Risk Assessment – Debris Flow Hazard, Matatā, including confirmation of the high, medium and low debris flow risk areas delineation and conclusion that the high risk area is unsafe for residential use; and

(m) Use of AGS (2007) as an appropriate risk management framework to assess debris flow risk from the Awatarariki catchment.

2.4. I attended the public hearing of submissions to the Proposed Plan Changes held in March 2020 and presented expert evidence to the Hearing Commissioners.

3. QUALIFICATIONS AND EXPERIENCE

3.1. I hold the positions of Emeritus Scientist at GNS Sciences and Visiting Professor at the State Key Laboratory of Geohazard Prevention and Geoenvironmental Protection, Chengdu University of Technology, Chengdu, China. Until 2015, I was a Senior Engineering Geomorphologist at GNS Sciences.

3.2. My qualifications include BSc (Hons) in Geology from University of Canterbury (1966) and 54 years of post-graduate research in Earth-surface processes including a PhD (1976, The Ohio State University, USA).

3.3. I have been active in the field of Earth-surface processes research for 55 years. My expertise relates to Earth-surface processes of which debris flows are one of the many dangerous ones. My hazard research is often cited in urban and rural plans, but I do not claim expertise in District plans or plan changes. In 2007, I advised Thames-Coromandel District Council of the need to consider high-magnitude, low frequency debris flows in respect to planned buildings at Thames District Hospital. In China I have recently researched with colleagues the 2018 failure of debris-flow mitigation works installed after a 2010 disastrous debris flow at Yangjia Gou, Beichuan County, Sichuan.

3.4. My CV is attached to this evidence as **Appendix 1**. Previous projects and publications I have been involved with that are relevant are set out below:

(a) Whitehouse, I. E., & McSaveney, M. J., 1985, Debris flows at Chelsea Creek, State Highway 6: Haast River section. Report WS 1001, Ministry of Works and Development, Christchurch;

(b) McSaveney, M. J., Whitehouse, I. E. 1986, A geomorphological appraisal of flood protection measures on Black Birch fan, Mount Cook. Report WS 1081, Ministry of Works and Development, Christchurch;

(c) Whitehouse, I. E., & McSaveney, M. J., 1986, Arthur's Pass roading project: geology, geomorphology, and hazards assessment. Report for Ministry of Works and Development, Christchurch;

(d) McSaveney, M. J. 1988, Appraisal of natural hazards to urban land-use in the vicinity of the proposed Glentanner Park development. Report presented to Mr Ian Ivey, Glentanner Station and Mackenzie County Council, January 1988;

(e) McSaveney, M. J. 1988, Statement of evidence in the matter of Appeal TPC 71/87 (Town and Country Planning Act 1977) between Alpine Hotels Ltd (Appellant), and Mackenzie County Council (Respondent) and Ian K. Ivey (Applicant);

(f) McSaveney, M.J.; Davies, T.R.H.; Gough, J.D. 1995 Natural Hazard Assessment for Mount Cook/Aoraki Village & Environs. Institute of Geological & Nuclear Sciences Client report 49500D.11. 79 p. figures;

(g) Gough, J.; Johnston, D.; McSaveney, M.J. 1999 Community response to natural hazard risk at Franz Josef Glacier. Lower Hutt: Institute of Geological & Nuclear Sciences. Institute of Geological & Nuclear Sciences science report 99/10. 35 p.;

(h) McSaveney, M.J. 2002. Assessment of debris-flow mitigation measures at Walter Peak, Queenstown. Institute of Geological & Nuclear Sciences client report 2002/127 for Locations Management, Queenstown. 24 pp.;

(i) Whitehouse, I.E., McSaveney, M.J., 1990. Chapter 19: Geomorphic appraisals for development on two steep, active alluvial fans, Mt Cook, New Zealand. In: Rachocki, A., Church, M.A., (editors) Alluvial Fans a field approach, John Wiley & Sons Chichester, England. p 369-384.;

(j) McSaveney, M.J. 1995. Debris flows and bridge losses at Waterfall Creek, SH6 at Lake Wanaka, New Zealand. Institute of Geological & Nuclear Sciences Science Report 95/21. 18 p. 11 Fig.;

(k) McSaveney, E.R., McSaveney M.J. 1998. Beware of falling Rocks - landslides. Chapter 4 In: G. Hicks and H. Campbell (eds) Awesome Forces: the natural hazards that threaten New Zealand. Te Papa Press, Wellington, New Zealand. p 72-97 (plus 2nd edition 1999);

(l) McSaveney, M.J., Glassey, P.J. 2002. The fatal Cleft Peak debris flow of 3 January 2002, Upper Rees Valley, West Otago. Institute of Geological & Nuclear Sciences Science Report 2002/03. 28 p.;

(m) McSaveney, M.J.; Beetham, R.D.; Leonard, G.S. 2005 The 18 May 2005 debris flow disaster at Matatā: Causes and mitigation suggestions. Institute of Geological & Nuclear Sciences client report 2005/71. 51 p. Available at www.geonet.org.nz/landslide/report 9.pdf and also www.easternboprecovery.org.nz/pdfs/reports/IGNS_report_July05.pdf.;

(n) McSaveney, M.J., Davies, T.R. 2005. Chapter 25: Engineering for debris flows in New Zealand. in Jakob, M., and Hungr, O. (eds). Debris-flow hazards and related phenomena. Praxis Press. Chichester 739 pp.;

(o) Davies, T.R.H.; McSaveney, M.J. 2008. Principles of sustainable development on fans. Journal of hydrology, New Zealand, 47(1): 43-65 2012; and

(p) McSaveney, E.; McSaveney, M.J. 2012. Landslides : beware of falling rocks. p. 62-83 In: Hicks, G.R.F.; Campbell, H.J. (eds)

Awesome forces: the natural hazards that threaten New Zealand (Second Edition). Wellington, N.Z.: Te Papa Press.

4. MY ROLE

4.1. I was the lead author of the report "The 18 May 2005 debris flow disaster at Matatā: Causes and mitigation suggestions (July, 2005)" which established that the event of 18 May 2005 had been a debris flow and a type of landslide in the then internationally recognised nomenclature. This report was instigated under a GNS Sciences contract with the Earthquake Commission to quickly gather information on major landslide events before ephemeral information is lost. As part of this investigation, on June 24, 2005 we overflew the area in a helicopter in the company of Mr T Bassett of Tonkin and Taylor. The report was not written specifically as advice to the District Council, although it was published as a client report to Council and is distributed on the Council website.

4.2. I subsequently have been engaged by the District Council to provide review comment on a student thesis (Dan Costello, University of Auckland MSc) and several Tonkin and Taylor reports on aspects of the events at Matatā. The last of these was the "Hind" report in 2015. In 2007, I lead a Geosciences Society 1-day field trip "An introduction to sunny Matatā and its great debris flows." On 15 August 2019, I again overflew the Awatarariki debris-flow catchment by helicopter. I last inspected the lower portion of the Awatarariki catchment on 24 July 2020, for the purpose of viewing some of the changes since 2005.

4.3. In preparing this evidence I have reviewed the following documents and reports:

(a) The 18 May 2005 debris flow disaster at Matatā: Causes and mitigation suggestions (July, 2005);

(b) Principles of sustainable development on fans, 2008;

(c) Peer Review: Awatarariki debris-flow-fan risk to life and retreat-zone extent, November 2015;

(d) McSaveney, M.J., Davies, T.R. 2005. Chapter 25: Engineering for debris flows in New Zealand. in Jakob, M., and Hungr, O. (eds).

Debris-flow hazards and related phenomena. Praxis Press. Chichester. 739 pp;

(e) Daniel Larson, 2005 available at the following link: http://daniel.larsen.net.nz/daniel/stories/story.104367.html; and

(f) Shearer, I. 2005. Draft report to Matatā recovery projects, Part D Historical Research.

5. CODE OF CONDUCT

5.1. I confirm that I have read the Code of Conduct for Expert Witnesses contained in the Environment Court Consolidated Practice Note 2014. I agree to comply with the Code when presenting evidence to the Court. I confirm that the issues addressed in this brief of evidence are within my area of expertise, except where I state that I rely upon the evidence of another expert witness. I also confirm that I have not omitted to consider material facts known to me that might alter or detract from the opinions.

6. THE CAUSE OF THE 2005 DEBRIS FLOWS AT MATATĀ

6.1. The 18 May 2005 debris flow at Awatarariki Stream, Matatā was triggered by exceptionally heavy rain falling on already saturated ground over much, if not all of the upper catchment area. Although the rain was the trigger, the cause of the debris-flow event was the many slope failures which were triggered by the rainfall which caused landslides to fall into already flooded stream channels. The evidence for widespread slope failures is two-fold:

(a) Debris flows occurred more-or-less simultaneously in almost every tributary stream in the catchment area, and in most adjacent catchments in the Matatā area; and

(b) There were a great many more debris-avalanche scars on the steeper slopes after May 2005 than were present before 2005 as shown by space imagery available on Google Earth.

6.2. Measured rainfall at Awakaponga (5 km from Matatā) was 302 mm in 24 hr, 94.5 mm in 1 hr, 30.5 in 15 minutes. The 30.5 mm in 15 minutes fell close to the end of the storm. It is not unusual for storm rainfalls to peak near the end of a storm. Such intense rainfalls would be widely expected to trigger many slope failures on steep slopes anywhere in the world. They are not threshold values at which one or two failures might occur: they are values at which many failures would be expected, as indeed occurred.

6.3. There is a pattern discernible in the distribution of debris avalanches on steep slopes around the catchment of Awatarariki Stream. There are fewer avalanche tracks in the northeast corner and at the southwestern head of the catchment. The abundant avalanche tracks form a wide band which crosses from the escarpment immediately west of Awatarariki, and extends to south east of Awakaponga. I have seen similar patterns of debris avalanches tracks in the western Southern Alps, where they have arisen from the passage across the landscape of high-intensity convective rain showers.

7. DEBRIS-FLOW PHENOMENA INCLUDING VARIABILITIES SUCH AS SIZE, BEHAVIOUR AND PREDICTABILITY

7.1. A debris flow is a dense mixture of sediment and water which flows under the influence of the mass of sediment that it contains. The most common analogy is to liken the flow to that of pouring wet concrete. The proportion of sediment to water in debris flows is highly variable. There is no characteristic ratio of water to sediment, even in a single debris flow, and the ratio does not remain constant during the flow. The flow characteristics of a natural debris flow are determined by the interactions between the sediment particles and the proportion of water present.

7.2. The quantity of sediment in a debris flow developed from a debris avalanche is determined both by the amount of debris in the avalanche, and by the amount of loose sediment in the stream channel that is able to be eroded by the growing debris flow. There is no necessary relationship between the amount of rain and the size of a triggered debris avalanche. There are however crude relationships between the amount of rain and the number of debris avalanches, and the number of debris avalanches and the total volume of debris contributed to the stream channel by debris avalanches. The amount of water flowing in the stream channel at the time is another variable, as is the amount of erodible material in the channel. All of these quasi-independent variables go to make it impossible to predict the size of a debris flow in a natural channel where none of these variables is known, even though the qualitative circumstances under which a debris flow is likely to occur is easily predictable (as has been described above).

8. DEBRIS FLOW IS A NATURAL HAZARD

8.1. Debris flows are globally recognised as dangerous and therefore by definition they are a hazard. Not all debris flows are natural: a recent debris flow with multiple fatalities in Brazil was initiated by the collapse of a mine-tailings dam and therefore should be considered as an anthropic hazard. But the debris flow in Awatarariki Stream in May 2005 was an entirely natural hazard, the like of which has occurred many times in the distant past.

8.2. The treatment of debris flows as a type of landslide hazard is not globally universal. In the Russian Federation debris flows are treated as a flooding hazard for historical reasons that arose from the government ministry that dealt with them in the former Soviet Union. In Japan, debris flows are regarded as a sediment hazard.

8.3. The 2005 report on the Matatā debris flows summarised the then-extant New Zealand statutes and regulations concerning debris flows among New Zealand natural hazards. Since I retired from employment in GNS Science in 2015 I have spent considerable time outside of New Zealand and have not had need to closely follow tends in New Zealand legislation and regulations relating to hazard and risk. I have read the evidence submitted by Dr Saunders dealing with the current thinking on debris flows as an element of natural hazard risk in New Zealand. It has evolved substantially for the better since 2005, and along the lines that I hoped that it would evolve.

9. DESCRIPTION OF THE AWATARARIKI DEBRIS FLOW IN 2005

9.1. I did not witness the 2005 debris flow, but I have read several accounts written by people who were present on the Awatarariki fan while the event was occurring. The independent accounts written by the late Neville Harris and by Daniel Larsen are very informative. Mr Harris made no reference to time during what was evidently a very significant event in his experience. Mr Larsen provides several mentions of time which indicate a duration of more than an hour during which the flow behaviour varied, but remained dangerous. Both refer to serious flooding of rushing dirty brown water carrying logs and boulders. Mr Harris referred to the railway bridge being blocked by logs several times before the bridge was swept away. Both refer to pulsing flows. Neither of these two witnesses appears to have been familiar with the concept of debris flow, and refer throughout their accounts to a flood with logs and boulders.

9.2. When I visited the area on 23–25 May and 9–10 June, 2005, the evidence for the recent passage of a debris flow in the Awatarariki Stream was unequivocal to me, both in the nature of the huge boulders transported in the event, and in the presence of a U-shaped stream channel scoured in bedrock in the catchment upstream of the fan. In preparing my evidence, I have repeatedly read the evidence of the eyewitnesses in an attempt to discern if there might have been a moment in the events described when a true flood might have transformed to a debris flow. Mr Harris's description of the railway bridge becoming clogged with trees which then broke free and moved as a block to lodge at the culvert under the highway, suggests to me that debris avalanches had already occurred in the Awatarariki catchment, and that debris flows were already occurring. This interpretation is in accord with the times mentioned by Mr Larsen and the unambiguous times recorded for the torrential rain at Awakaponga.

9.3. There are two very remarkable features of the debris flow at Awatarariki Stream. As is noted also in the evidence of Professor Davies, the Awatarariki debris flow moved in a very low gradient channel. Professor Davies offers no explanation, but I note that the principal source of sediment for the debris flow was deeply weathered Matahina ignimbrite and weakly consolidated weathered pumice sand. These water-saturated materials are easily crushed and abraded to yield a fine sandy slurry which would have facilitated continued movement of the debris flow on a lower than usual gradient. The debris flows gradually transitioned near the seaward edge of the fan to a thick sandy debris flood. In effect, the break-down of water-saturated pumice continued to add water to the debris flow.

9.4. The second remarkable feature of the debris flow of 2005 was the absence of fatalities or even injuries. None of the people carried by the flow on the Awatarariki fan were exposed directly to the debris: they were inside homes or vehicles. Through much of the event there was heavy rain falling at Matatā and consequently few people moving about outdoors on foot other than a few people alerted to danger and checking on the safety of neighbours. The State highway had been closed by bridge washouts earlier in the day, so the only reported traffic on the highway across the fan was a heavy truck which crossed the highway culvert before the culvert was destroyed. This was early in the debris-flow event.

10. A DESCRIPTION OF THE GEOMORPHOLOGY OF THE AWATARARIKI CATCHMENT

10.1. The steepland catchment of Awatarariki Stream consists of an upland plateau which has been deeply dissected by the Awatarariki Stream in a box canyon. The canyon is cut into mantling tephra deposits and Matahina formation, down to and into soft, weakly cemented sandstone and siltstone. The soft siltstone appears to be somewhat resistant to erosion and forms the bed and banks of the stream channel from where loose sediment has been scoured by the debris flow. This probably is because the siltstone is more cohesive than many of the other units, and its softness allows it to absorb impacts without fracturing. Boulders of siltstone were carried long distances in the debris flows, even though they fall apart on drying.

10.2. The weakly to moderately welded ignimbrites and their associated interbeds of the Matahina Formation range widely in erodibility. They stand in high, steep, to very steep slopes above the deep narrow stream channels which are floored mostly on soft siltstone. The more strongly welded components of the ignimbrites are columnar jointed (with regularly spaced cracks) from contraction during cooling from high temperature. These vertical cracks promote ready failure of the strongest rock in the catchment, and the formation of many large to very large boulders in the stream bed. Most of these boulders are too large to move in normal stream flood flows and are moved only by debris flows.

10.3. It is the steep slope angles more than the character of the rocks that make the catchments so prone to debris flows. The steep slope angles arise because the catchments are small, but large enough that their streams have cut to the foot of the ancient sea cliffs. The larger coastal catchments further to the west of Matatā are too large for debris flows in them to propagate to the coastal plain.

10.4. Although the 2005 debris flow removed much stored sediment from the bed and banks of the Awatarariki Stream, it did not remove all of it. The removal of the stored sediment destabilised many of the slopes beside the stream, and within weeks of the event there was already enough material in the stream channel to supply another debris flow of similar magnitude. This sediment has continued to accumulate over the past 15 years.

11. DISCOUNT BREAKOUT FLOODS FROM LOG DAMS OR DEBRIS DAMS AS BEING THE INITIATING TRIGGER FOR THE MAY 2005 DEBRIS FLOWS

11.1. What we know of the rainfall intensities on 18 May 2005, and what we know of the distribution of landslips, debris avalanches and multiple debris flows in the Awatarariki catchment are quite sufficient to explain the cause and severity of the event that occurred on the Awatarariki fan. I know of no evidence to support a hypothesis that this event was caused by breakout floods from debris dams, although elsewhere such breakout floods have caused debris flows. I am familiar with one such site at Yangjia Gou in China where two large fatal debris flows have occurred in the last 10 years from break-out floods from the same debris dam (see paragraph 17.2 below).

11.2. I do not dispute the presence of so-called debris dams in the catchment: I only dispute that they caused the event. It is characteristic of steepland streams for sediment to be irregularly stored along the course of the channel behind accumulations of large boulders and ephemeral debris dams (in forested catchments). It also is typical for large debris flows to entirely scour their channels to bed rock. Hence, a traverse up any of the streams in the upland area around Matatā between debris flow occurrences would always encounter a series of alternating alluvial flats and torrent areas around rotting fallen tree trunks. It has been suggested that perhaps the size of future debris flows from Awatarariki Stream could be reduced by maintaining a channel clear of debris dams in the upper catchment. To do so, however, would require the maintenance of a roadway along the channel to provide access and the roadway itself would provide ample debris to feed a growing debris flow.

11.3. I note also the evidence of Professor Davies and Dr Phillips that catchment management practices will not significantly diminish the life safety risk to residents on the Awatarariki fan.

12. PRELIMINARY ESTIMATE OF 200,000 M^3 AS BEING THE VOLUME OF SOLID MATERIAL DEPOSITED ON THE AWATARARIKI FAN FROM THE 2005 DEBRIS FLOW

12.1. In the 2005 report, I wrote "We have only crudely estimated the volumes of solid material. For Awatarariki Stream, the fan length is about 300 m and width, about 300 m. An average sediment depth of about 2 m leads to a volume estimate of about 100,000 m^3. Some 10% of this is "large woody debris" – the larger remnants of the trees. Perhaps about as much again of sediment and woody debris did not stop on the fan and is now in the lagoon and beyond." This "crude estimate" summed to 200,000 m^3. Subsequently, T & T used LIDAR and aerial photography to obtain a much less crude estimate of about 350,000 (±50,000) m^3. I have reviewed the evidence used to make this estimate, and compared it with the larger Costello thesis estimate (600,000 m^3) which did not state an error limit. In my opinion the T&T estimate is well founded and unlikely to be improved upon.

12.2. In view of the very real uncertainty in gaining an accurate estimate of the volume of debris delivered onto the fan head by the 2005 debris flow, I am particularly reassured by the numerical modelling work described by Mr Hind which suggests that the true volume of debris on the fan makes very little difference to the risk to life on the fan.

13. EVIDENCE OF PREVIOUS DEBRIS FLOWS FROM THE AWATARARIKI CATCHMENT

13.1. There is irrefutable evidence for previous debris flows at Matatā. The evidence shows that large prehistoric debris flows built the land beneath Matatā over the last 7000 years. One of the previous debris flows delivered the huge boulders that were used as landscaping features on the fan of Awatarariki Stream before 18 May 2005.

13.2. Dr, The Honorable Ian Shearer (Shearer, 2005) lists 28 floods that have occurred in the eastern Bay of Plenty in the last 137 years. Some of these have affected Matatā. Several of these can be confirmed as debris flows. One in 1869 destroyed a flour mill on what we presume to be the fan of Awatarariki Stream. The boulders from another in 1950 were illustrated in the Whakatāne Beacon of 1 June 2005. This is likely to have been from Waitepuru Stream because historical vertical aerial photographs held by GNS Sciences bracketing this time show evidence of a debris flow in that stream between 26.9.44 and 18.4.61. Floods in 1906 and 1939 may also have been associated with debris flows, although we are unable to see features on 1944 aerial photographs consistent with a large debris flow in 1939.

13.3. Drainlayers installing underground pipes for dwellings on the Awatarariki fan reported encountering large boulders below the fan surface prior to the 2005 debris flow. T&T attempted to excavate into the fan in an attempt to obtain organic material that could be radiocarbon dated. No organic material was found. It is assumed that past organic material as was deposited in 2005 had been completely oxidized in the freely draining fan deposits.

13.4. The name “Awatarariki” translates as “Goosepimples” which may imply that the fan area at the time of Māori arrival had an appearance somewhat similar to the area of “goose-pimpley” surface which it has had again since 2005. Oral tradition of the use that an invading Māori group made of a lone Pohutukawa tree on the upper fan implies that the fan has always been an open area with isolated trees (suitable for an historic battle). All of this is consistent with the occurrence of past debris flows in the last 1000 years or so.

13.5. There are anecdotal reports of large boulders on the sea floor offshore of Awatarariki fan that provide a favourable habitat for crayfish. The only source of large boulders on the sea floor in this area is from past large debris flows. Since the current coastal landform forms a barrier to the passage of debris flows, the presence of boulders offshore likely relates to debris flows occurring at times of lower sea level.

13.6. The steep escarpment which forms the backdrop to Matatā is the remnant of an ancient sea cliff which was last trimmed by the sea around the time that modern sea level rose and stabilised around its current height with respect to the land. This roughly constrains all of the current coastal landforms in the area to the last 6000 years or so, which implies a high rate of delivery of sediment from the catchments behind the escarpment.

13.7. The highly dendritic development of the box-canyon landscape of the Awatarariki catchment is diagnostic of a geomorphology developed mostly by repeated sapping of steep slopes by very many debris avalanches such as occurred in 2005 (and with associated debris flows to remove the fallen solid materials from the channel). The circumstances which led to the development of this geomorphology were not altered by the occurrence of the 2005 debris flow. Hence future occurrences of large debris flows issuing from the catchment are a certainty, in the absence of a radical change in the catchment morphology.

14. LIKELIHOOD OF FUTURE DEBRIS FLOWS AND AREA OF RISK

14.1. Key to development of an estimate of the likelihood of future debris flows on the fan is development of a history of past debris flows and their magnitudes. In the time since 2005 there has been no progress in this development. However, through the use of numerical modelling the "Hind" report suggests that the area of high risk on the fan is somewhat insensitive to the magnitude of debris flows at low return periods (low probability).

14.2. Although we cannot speculate on the likelihood of future debris flows in terms of probability, we can state that the future occurrence of debris flows as large as, or larger than, in May 2005 are inevitable.

15. PEER REVIEW OF THE TONKIN AND TAYLOR LTD SUPPLEMENTARY RISK ASSESSMENT – DEBRIS FLOW HAZARD, MATATĀ,

15.1. I was a party with Professor Davies to a peer review of the T&T "Hind" report. We accepted that the report made good use of the available data using internationally accepted quantitative analysis techniques. We accepted that in modified form it depicted significant areas of adequately quantified high risk to life.

15.2. However, I endorse the opinion of Dr Massey that it is not the role of the technical expert to conclude that any area is fit or unfit for any particular use.

16. USE OF AGS (2007) AS AN APPROPRIATE RISK MANAGEMENT FRAMEWORK

16.1. I accept that AGS (2007) presents a framework for risk management of an area at risk of a known and quantifiable hazard. It is not the only framework for risk management. Like all such frameworks, implementation of the risk assessment arrived at, is subject to a public policy decision which involves elected officials deciding on the level of risk at which they will tolerate the deaths of other people. Some people are reluctant to make such decisions, and would rather they were made by others.

17. LESSONS FROM SOME DEBRIS-FLOW MITIGATION STRUCTURES IN CHINA

17.1. A large mountain area of Sichuan Province in China was severely affected by the Wenchuan earthquake in 2008 which triggered tens of thousands of landslides. Subsequently, the debris from many of these landslides has given rise to some immense debris flows. Some cities were abandoned because of this debris-flow damage. The monsoon rains of 2010 gave rise to some particularly disastrous debris flows when the 2008 landslide deposits were mobilised. As a result many roads and bridges which had been quickly replaced after they were destroyed by the earthquake had to be rebuilt. Below Wenjia Gou (meaning “the valley of the Wen family”), much of the rebuilt town of Qingping was destroyed by a 2010 debris flow originating from the deposit of the Wenjiagou rock avalanche of 2008 (the name given to the rock avalanche and its deposit in the international literature). This debris flow destroyed a debris-flow detention dam built across the river post-2008. This large debris-flow detention dam was grossly under-designed for the event which occurred. Subsequent to 2010 a new and substantially larger dam was built, much of the catchment runoff is now intercepted above the landslide deposit and diverted into another catchment, and the landslide deposit morphology has been very substantially modified to make for a likely more stable channel. The lower portion of the rock avalanche is now cropped for soy beans, and the debris-flow fan from 2010 is now in large-scale Kiwifruit orchards.

17.2. Another river subject to recurrent debris flows from a 2008 landslide deposit is at Yangjia Gou (“the valley of the Yang family”) which I visit yearly. After a large fatal debris flow in 2010, a series of 8 massive concrete pile structures were installed across the river to stabilise the channel bed from further scour. The bases of these 1-m diameter piles were installed to a depth of about 5 m in the landslide debris forming the channel bed and stood about 5 m high in the channel. By 2017 coarse sediment had built up against the upstream side of these debris retention structures as it was supposed to do. A severe storm in the summer of 2018 triggered another fatal debris flow in Yangjia Gou and the lower three of these structures were destroyed by debris-flow scour on the downstream side of the structures to below the bases of the piles which then fell over. The engineering design of the structures had underestimated the required depth of the piles. Other mitigation structures further downstream also failed but they were cut through by the continual passage of abrasive sand in the water over a period of 8 years. These debris-flow mitigation works were all well-constructed, but grossly under-designed for the environment in which they were placed. They have been repaired and replaced with more robustly constructed structures, and telemetering flow-monitoring equipment has been installed to eventually provide more robust data for engineering design should they fail again.

17.3. The Chinese engineers responsible for the design of debris–flow mitigation work have much experience but little quantitative data for the particular area of Sichuan affected by the 2008 Wenchuan earthquake. Their knowledge is growing quickly, but lives have been lost while they gain it.

17.4. There are other areas of China where debris flows occur annually each wet season. The local peoples do not live on the areas subject to debris flows, but they are experienced at using such areas for cropland, growing mostly legumes such as soy beans and peanuts.

17.5. Applying what I have learned from my China experiences to Matatā, It is very easy to underestimate the size and power of a debris flow. I would be very wary of letting a group of even experienced debris-flow engineers conduct experiments that place lives at risk while they "fine-tune" a mitigation structure to get it to work. This is the situation that has been proposed repeatedly for Awatarariki. I commend the wisdom of the people who called a halt to such experimentation.

18. RESPONSE TO GROUNDS OF APPEAL

18.1. With reference to the appeal by the Awatarariki Residents Incorporated (the **Society**) I make the following responses.

18.2. New Zealand is a signatory to the UN-supported Sendai Declaration of 2015 (see Professor Davies' evidence), which is why New Zealand supports a risk-based approach to disaster reduction. In my past role as Editorial advisor to the Board of Representatives of the International

Consortium on Landslides I helped draft the Sendai declaration. PC 1 is a significant contribution of disaster risk reduction on Awatarariki fan.

18.3. Managing hazard risk is accomplished by managing risks to people and property. It is not achieved by managing hazards.

18.4. The adopted approach has been an event-based approach: it is intended to prevent such disasters such as happened in 2005 from happening again.

18.5. There have been a great many, extensively reviewed, cost-benefit analyses of the engineering options for mitigation of the risk on the Awatarariki fan at all levels of government. The option of foregoing engineering mitigation solutions was not taken up lightly.

18.6. Historic land uses (such as the adjacent District Council operated quarry, farming and logging) did not contribute to the 2005 event in any way. Nor could catchment maintenance assist to avoid or mitigate risk. It is scientifically inappropriate to try to manage the hazard: hazards are unmanageable.

18.7. The precision of the modelling of risk of landslide and debris flow, the modelling of probability of fatality or injury; and the science as to assessment of risk properties identified as “high risk” have been detailed at great length in numerous reports (which are on the District Council website). The analyses of probability and consequence have been conducted to internationally very high standards. The risk assessments have been shown to be robust to a large range of input values. No assertions of risk of fatality to Society members and their families have been made. The risk assessment has been shown by Mr Hind to be robust. In our professions we are prohibited by law from conducting the experiments that would demonstrate the fragility of Society members or anyone else on the Awatarariki Fan.

18.8. We all agree that risk involves probability and consequence. The Society claims that a different approach to acceptability of risk is required in relation to existing residential activity, as distinct from land use planning for future residential use however is flawed. Prior to 2005, the District Council and purchasers of property on the fan were reliant on some technical expert’s opinion that the land was suitable for residential use (i.e.

that there were no unacceptable risks associated with the land). Unfortunately, at a very early point in the process of deciding to offer the land for residential use, someone made a critical mistake, probably in ignorance, of not recognising what to me are clear signs of past debris-flow activity on the fan. I commend Council for bravely attempting to rectify that person's mistake through PC 17.

18.9. The Australian Guidelines on risk assessment are the most appropriate standard to apply. The Guidelines are fit for purpose and widely used. Their use in New Zealand for the purpose of land-use changes requiring mandatory withdrawal from high-risk lands has been tested in New Zealand by an independent hearing panel chaired by Sir John Hansen with respect to land-use changes in the Port Hills area of Christchurch.

19. CONCLUSION

19.1. There are very sound technical reasons why there are no guidelines on how to design safe homes on a debris-flow fan.

19.2. Debris flows are a type of landslide and can involve very large quantities of coarse sediment arriving and depositing very rapidly, but in unpredictable ways.

19.3. Although the triggers of debris flows are qualitatively well understood, there is no deterministic relationship between the size of trigger and the size of the resultant debris flow. In the case of Awatarariki Stream, very heavy rain triggered many debris avalanches which turned into debris flows when they fell into the already flooded stream. These debris flows coalesced before reaching and depositing on the Awatarariki fan.

19.4. Much of the very fine material which made the debris flow of 2005 so mobile continued beyond the fan where it mixed with fine sediment from other sources and some went out to sea. This made it impossible to determine the true volume of the 2005 event.

19.5. We can be certain that if rainfall of the intensity that triggered the debris flows of 2005 were to occur again, there would be further debris flows, but they would not be of similar size to the debris flow of 2005; they might be smaller they might be larger. This natural uncertainty creates great difficulty in developing a successful engineering design, if engineering measures were to be undertaken to mitigate future debris flow damage.

19.6. A well accepted technical method of coping with such uncertainty is to use numerical modelling (as has been documented in Mr Hind's evidence). Numerical modelling is a safe and very useful way of testing the sensitivity of one's decisions to various necessary assumptions about debris-flow behaviour. Numerical modelling has been used extensively in investigating possible solutions for risk reduction at Awatarariki.

19.7. On reflection about my contribution to the technical background about the debris flow at Awatarariki in May 2005, I have asked myself two hypothetical questions which I comment on as follows:

What if the 2005 debris flow had been a bit larger?

19.8. My report on the event would not have been the least bit different. The true volume and return period of the 2005 debris flow and the areas affected by the debris flow were not in the least bit relevant to any of the subsequent engineering analyses. The analyses would have been based on different input values but would have reached the same conclusions – possibly in just as much inordinate time.

What if some residents had been killed in the 2005 event?

19.9. The entire legal process would have been very different. Maybe, some decisions would have been made quicker. Fan residents would have been very sad about the fatalities but maybe not so annoyed about the Proposed Plan Changes.

Maurice James (Mauri) McSaveney

10 August 2020

APPENDIX 1 – CV

PROFESSOR MAURI MCSAVENEY: CURRICULUM VITAE AND PUBLICATIONS

Dr Maurice (Mauri) James McSaveney
Quaternary & steepland geomorphologist
Engineering geomorphologist

New Zealand Citizen
Born at Christchurch, New Zealand, 17th April, 1945

Address:

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Education:

B.Sc.(Hons) Geology, 1966, University of Canterbury, New Zealand
Ph.D. Geology, 1975, The Ohio State University, Ohio, U.S.A.

Professional memberships:

Member of the Geological Society of New Zealand
Member of the New Zealand Hydrological Society
Member of the New Zealand Society for Earthquake Engineering
Member of the New Zealand Geotechnical Society
Member of the editorial boards of “Landslides” and “Engineering Geology”

Languages

English

Countries of work experience

New Zealand, Antarctica, China, Japan, Europe, North America, Papua New Guinea, India

Fields of special competence:

Engineering geomorphology, steepland geomorphology, geomorphic mapping, dating of geomorphic surfaces, Quaternary geology, glacial geology, steepland hydrology, landslide seismology, coastal geomorphology and tsunami studies, natural-hazard assessment including earthquakes, coastal, river and slope processes, quantitative erosion assessment, erosion processes, rheology of earth materials, landslide kinematics, environmental-impact assessment, palæoseismicity, scientific editing, post-doctoral research mentoring

Experience:

2015-Present

Emeritus Scientist, GNS Sciences, New Zealand and Visiting Professor, State Key Laboratory of Geohazard Prevention and Geoenvironment Protection, Chengdu University of Technology , Chengdu, Sichuan, China.

In these roles, Dr McSaveney devotes his energy to mentoring young professionals in the continuing pursuit of scientific excellence, innovation and creativity.

1988 to 2015

Pure and applied geomorphological research on diverse topics in New Zealand and overseas, GNS Sciences (Institute of Geological and Nuclear Sciences Ltd, formerly DSIR Geology & Geophysics, and before that New Zealand Geological Survey, transfers through continuing restructuring).

Dr McSaveney wrote, spoke, consulted and provided expert opinion on a wide range of topics involving the development of New Zealand's landscapes, making use of his established reputation for applying innovative techniques to quantitative research in Earth Surface processes.

1976 to 1988

Research in alpine hydrology and erosion processes, Water and Soil Division, DSIR. (formerly Water & Soil Directorate, Ministry of Works & Development) Research into climate, hydrology and erosion processes of the Southern Alps. Dr McSaveney guided a multidisciplinary team of scientists investigating factors influencing erosion in the Southern Alps. The group's studies measured the exceptionally high rates of natural erosion there, and were part of research that has forced a major reappraisal of the extent to which humans have modified erosion in New Zealand. Specific studies have included: the distribution of rainfall across the Southern Alps; the distribution of catastrophic landslides in the Southern Alps; the role of large landslides in modulating sediment supply of Shotover River; hydrology and erosion in an area receiving more than 12,000 mm annual rainfall; earthflow deformation, rates of rock weathering for age determination; natural hazards to urban development in mountainous terrain.

1967 to 1976

Research Associate, Institute of Polar Studies, The Ohio State University, Columbus, Ohio: Glaciological, glacial geological and geomorphological research in Colorado, Alaska, and Antarctica. Dr McSaveney's most lasting research accomplishment here was his analysis of the mechanics of the now classic Sherman Glacier rock avalanche, triggered by the Great Alaska Earthquake of 1964.

1967 (April to June)

Glacial Geologist, Lime & Marble Ltd, New Zealand Review of Mines Department records of sluicing claims, Central Westland

1963 to 1966

Student, University of Canterbury, New Zealand, majoring in geology,

Track record

- Natural hazard assessments including flooding, debris flow and earthquake hazards, review of performance of existing protection works, and recommendation of further protection options in New Zealand and India.
- International contributions to understanding the mechanics of long-runout landslides.
- Geomorphic overviews for major engineering projects in New Zealand
- Geomorphic reviews of engineering failures in New Zealand
- Tsunami hazard studies and tsunami research in New Zealand and the south Pacific
- Authored and coauthored numerous research papers and conference presentations.

Professional positions held	
2016-present	Visiting Professor, SKLGP, Chengdu University of Technology, Chengdu, Sichuan, China
2015-present	Emeritus Scientist, GNS Science, Lower Hutt, New Zealand
1990 - 2015	Engineering Geomorphologist, GNS Science, Lower Hutt, New Zealand
1988 - 1990	Geomorphologist, DSIR Geology and Geophysics, Christchurch, New Zealand
1976 - 1988	Group leader, Hydrology Centre, Ministry of Works and Development, Christchurch, New Zealand
1967 - 1976	Research Associate, Institute of Polar studies, Columbus, Ohio, USA

Present research/professional speciality

Geology: Hazard Assessment; Landslide Risk Assessment; Paleoseismology; Hazard mapping; Lahars and debris flow; Geomorphology; Fluvial Processes; Geomorphic Hazards; Engineering Geomorphology; Erosion Processes; Alpine Slope Processes; Landslide Processes; Earthquake effects

Total years research experience	54 years

Professional distinctions and memberships (including honours, prizes, scholarships, boards or governance roles, etc)	
2016 – present	Visiting Professor, State Key Laboratory of Geohazard Prevention and Geoenvironment Protection, Chengdu University of Technology
2013 – present	Vice-chairman, International Research Network on giant landslides
2012 - 2015	International Consortium on Landslides Board of Representatives: Editorial advisor
2012	The International Consortium on Landslides: Best Paper Award for 2010
2012	Japan Society for the Promotion of Science (JSPS): 2012 Invitation Fellow for research in Japan
2011	The Second World Landslide Forum: 1st Place - "Landslides of the World" photo contest: Impacts of Landslides
2010	Kyoto University: Invited Guest Landslide Researcher, DPRI
2010 - present	Department of Geological Sciences, University of Canterbury: Adjunct Associate Professor
2008	American Geophysical Union: Editor's citation for excellence in refereeing - JGR Earth Surface
2005	4th International Conference on Debris-Flow Hazards Mitigation International Advisory Committee: Member

2004	NATO Advanced Research Workshop, Bishkek, Kyrgyzstan: Invited Keynote Speaker
2004	American Geophysical Union: Editor's citation for excellence in refereeing for JGR-Planets
2003 - present	Editorial Board, Landslides: Member
2002 - present	International journal "Landslides" Editors-in-Chief: Member
2002	NATO Advanced Research Workshop, Celano, Italy: Invited Keynote Speaker
2000 - present	New Zealand Geotechnical Society: Member
2000 - present	IAEG: Member
2000	International Gravelbed Rivers Workshop: Invited speaker
1998 - present	New Zealand Society for Earthquake Engineering: Member
1989 - present	Geosciences Society of New Zealand: Member
1977 - present	NZ Hydrological Society: Member
1974	Geological Society of America: North Central Section, Best Student Paper

Total number of *peer reviewed* publications and others	Journal articles	Books, book chapters, books edited	Conference proceedings	Citations
	78	12	23	1799

Research publications
Peer-reviewed journal articles
2018 Zhang, Ming ; McSaveney, MJ. (2018). Is air pollution causing landslides in China?. Earth and Planetary Science Letters. 481. 284-289. 10.1016/j.epsl.2017.10.045. 2018 Shugar, DH; Clague, Jj; McSaveney, MJ. 2018. Late Holocene activity of Sherman and Sheridan glaciers, Prince William Sound, Alaska. Quaternary Science Reviews 194: 116-127 2018 Sassa, Kyoji ; Guzzetti, Fausto ; Yamagishi, Hiromitsu ; Arbanas, Zeljko ; Casagli, Nicola ; McSaveney, MJ ; Dang, Khang. (2018). Landslide Dynamics: ISDR-ICL Landslide Interactive Teaching Tools, Volume 1: Fundamentals, Mapping and Monitoring. 10.1007/978-3-319-57774-6. 2018 Hu, Wei ; Huang, Runqiu ; McSaveney, MJ ; Zhang, Xiang-hui ; Yao, Lu ; Shimamoto, Toshi. (2018). Mineral changes quantify frictional heating during a large low-friction landslide. Geology. 46. 10.1130/G39662.1. 2018 Carey, J.M. ; Crutchley, G.J. ; Mountjoy, Joshu ; Petley, Dave ; McSaveney, M.J. ; Lyndsell, B. (2018). Slow episodic movement driven by elevated pore-fluid pressures in shallow subaqueous slopes. Geomorphology. 329. 10.1016/j.geomorph.2018.12.034. 2017 Zhang, Ming; McSaveney, MJ. (2017). Rock-avalanche deposits store quantitative evidence on internal shear during runout. Geophysical Research Letters. 10.1002/2017gl073774. 2017 Zhang, Ming ; McSaveney, MJ ; Shao, Hai ; Zhang, Chenyang. (2017). The 2009 Jiweishan rock avalanche, Wulong, China: Precursor conditions and factors leading to failure. Engineering Geology. 233. 10.1016/j.enggeo.2017.12.010. 2017 Hu, Wei ; Xu, Qiang ; Wang, Gonghui ; Scaringi, Gianvito ; McSaveney, Mauri ; Hicher, Pierre-Yves. (2017). Shear Resistance Variations in Experimentally Sheared Mudstone Granules: A Possible Shear-Thinning and Thixotropic Mechanism. Geophysical Research Letters. 44. 10.1002/2017GL075261. 2017 Hu, Wei ; Xu, Qiang ; Wang, Gonghui ; Scaringi, Gianvito ; McSaveney, MJ ; Hicher, Pierre-Yves. (2017). Supporting Information for "Shear resistance variations in experimentally sheared mudstone granules: a possible shear-thinning and thixotropic mechanism". 2016 Massey, C.I., Abbott, E., McSaveney, M, Petley, D.N., Richards, L. 2016. Earthquake-induced displacement is insignificant in the reactivated Utiku landslide, New Zealand. 11th International Symposium on Landslides, Naples, Italy June 2016. 2016 Massey, C.I. ; Petley, Dave ; McSaveney, M.J. ; Archibald, Garth. (2016). Basal sliding and plastic deformation of a slow, reactivated landslide in New Zealand. Engineering Geology. 208. 10.1016/j.enggeo.2016.04.016. 2016 Massey, C ; Della Pasqua, F ; Francois-Holden, Caroline ; Kaiser, Anna ; Richards, L ; Wartman, J ;. McSaveney, MJ ; Archibald, Garth ; Yetton, M ; Janku, L. (2016). Rock slope response to strong earthquake shaking. Landslides. 14. 10.1007/s10346-016-0684-8. 2016 Massey, C ; Abbott, E ; McSaveney, M ; Petley, Dave ; Richards, L. (2016). Earthquake-induced displacement is insignificant in the reactivated Utiku landslide, New Zealand. 10.1201/b21520-5. 2016 Jiang, Yao ; Wang, Gonghui ; Kamai, Toshitaka ; McSaveney, MJ. (2016). Effect of particle size and shear speed on frictional instability in sheared granular materials during large shear displacement. Engineering Geology. 210. 10.1016/j.enggeo.2016.06.005. 2016 Davies, Tim; McSaveney, MJ. (2016). Comment on “The Reduction of Friction in Long-Runout Landslides as an Emergent Phenomenon” by Brandon C. Johnson,

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