BEFORE THE ENVIRONMENT COURT
I MUA I TE KOOTI TAIAO O AOTEAROA
TĀMAKI MAKAURAU ROHE

ENV-2020-AKL-000064

IN THE MATTER: of the Resource Management Act 1991

AND

IN THE MATTER: of an appeal pursuant to clause 14 of the First Schedule to the Act

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

AND: **WHAKATĀNE DISTRICT COUNCIL PLACES AND SPACES**

Section 274 Party

STATEMENT OF EVIDENCE OF GREGORY PHILLIP KOTZE – GEOTECHNICAL HAZARD AND RISK ASSESSMENT

10 August 2020

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Qualifications and Experience

1. My full name is Gregory Phillip Kotze. I am a Senior Technical Director in Engineering Geology and a Principal of GHD Pty Ltd (**GHD**), based in Sydney, Australia. I have held this position for 23 years.

2. Prior to this I was employed by LongMac Associates Pty Ltd as their Chief Engineering Geologist.

3. I have degrees in Geology and Geophysics from Macquarie University in Australia and a Diploma Of Education also from Macquarie University.

4. My professional memberships include:

   - Fellow, Australasian Institute Of Mining & Metallurgy, Chartered Professional Geologist
   - Member, Institution Of Engineers Australia, Chartered Professional Engineer, NER (National Engineers Register)
   - Member, Australian Institute Of Geoscientists, Registered Professional Geoscientist.

5. I have read the Expert Witness Code of Conduct set out in the Environment Court's Practice Note 2014 and I agree to comply with it. I confirm that the issues addressed in this statement of evidence are within my area of expertise, except where I state I am relying on the specified evidence of another person. I have not omitted to consider material facts known to me that might alter or detract from my expressed opinion.

Background and Scope of Evidence

6. I was engaged by the Bay of Plenty Regional Council (**Regional Council**) in July 2018 to undertake a review of the geotechnical hazard and risk assessments that had been carried out by Whakatane District Council (**WDC**) in relation to proposed Plan Change 17 to the Bay of Plenty Regional Natural Resources Plan (**PC17**).

7. I prepared a report dated 31 October 2019 (**2019 Report**). This evidence produces that report, which is **attached** as Annexure A, and summarises its scope, limitations and conclusions reached. I also comment on the planning evidence of the Regional Council to put my evidence in context.

Summary of 2019 Report

Scope of 2019 Report

8. The scope of my instructions as set out in section 1 of the 2019 Report were essentially to undertake a review of geotechnical hazard and risk assessments that had been carried out for debris flow hazards on the Awatarariki Fanhead at Matata, Bay of Plenty.

9. I undertook a site visit of the Awatarariki Fanhead on 31 July 2018. My report was finalised and provided to the Regional Council on 31 October 2019. I understand it was attached as Appendix 5 to the s42A report of Mr Olliver, the reporting officer on PC17 and the inter-related proposed Plan Change 1 to the Whakatane District Plan (**PC1**).

10. I have not been asked to undertake, and nor have I undertaken, a site specific assessment of individual properties on the Fanhead.

Limitations of 2019 Report

11. Corporate limitations of the report are described in Section 6 of the report. Specifically, my 2019 Report acknowledges that it is limited to a technical assessment, from a geotechnical perspective, and for specific application at Matata.

12. In addition, the 2019 Report notes at page 3 that the question "*is the degree of policy response proposed (prohibiting residential activity) in excess of what is required (to reduce risk from high to medium and lower if reasonably practicable)?*" was one that was better addressed by way of independent planning and policy expertise.

13. That comment was an acknowledgement that, whilst geotechnically feasible, the implementation of an approach as described in the 2019 Report, whereby individual properties are subject to detailed assessment to enable the quantification of specific risk calculation parameters, which in turn could facilitate a prioritised and progressive retreat programme based on geotechnical risk levels, would require over-arching concurrence with and inclusion in planning and policy deliberations.

Summary of Conclusions of 2019 Report

14. The conclusions of my 2019 Report may be summarised as follows:

(a) The quantitative assessments of Loss of Life risk carried out for debris flow hazards at Matata to date have been in accordance with "industry best practice" through the adoption of AGS 2007 guidelines. The risk calculations carried out have produced a "high" risk level evaluation, with subsequent regulatory control and proposed Council plan changes for "retreat" from residential activity on the Awatarariki Fanhead;

(b) My risk assessment review, however, has identified that a number of factors in the risk calculations carried out have been assumed to be common across numerous properties, which is considered likely to have resulted in Loss of Life calculation outcomes that are potentially higher for some properties than would be the case if property-specific calculation parameters had been determined and adopted;

(c) The risk calculation parameters that have been generalised across properties relate to dwelling type and structure, human occupancy rate, and age/fitness of occupants. I consider it likely that a range of these parameters exist across the fanhead and that the adoption of property-specific parameters in risk calculations may have produced risk level outcomes for some properties that are at or near the "moderate" / "medium" risk zone category, rather than "high";

(d) From a purely geotechnical perspective, it would be feasible, with further work, to specifically risk assess each individual property and to implement a staged or progressive strategy of risk management based on specific calculation outcomes, commencing for example with voluntary retreat, followed by retreat from "high" risk of Loss of Life (greater than 10^{-4} per annum) properties and potentially in turn retreat from "moderate/"medium" risk of Loss of Life (10^{-4} to 10^{-5} per annum) properties;

(e) It is acknowledged that, whilst feasible from a geotechnical perspective, any decision to implement a staged residential retreat strategy, based on risk calculation outcomes, would require an ongoing risk assessment strategy to be also established, as well as consideration of disciplines other than geotechnical, such as policy, planning and other local government requirements.

Consideration of Proposed Planning Response

15. I have had the opportunity to review the draft planning evidence provided by Mr Gerard Willis and Mr John Olliver on behalf of the Regional Council.

16. I note that my 2019 report was provided in response to a specific brief from the Regional Council regarding the geotechnical feasibility of an alternative option to blanket retreat. That report was provided based on my experience in Australia, where some local and state government bodies have undertaken property-specific risk assessments in the manner I described.

17. However, as I noted in my earlier report, such an approach would require that property-specific risk profiles are reviewed and amended if conditions on a specific property change in the future, and therefore relies upon rigorous management. These matters were addressed in Section 4 of my 2019 Report.

18. While such an approach could be geotechnically feasible, as I noted in the 2019 Report it must also be subject to compatibility with planning and policy considerations. In the current case I note that the New Zealand and local planning context is covered in the evidence of Mr Willis and Mr Olliver. It is also my understanding that, since my report was written, there have been a number of property owners within the Fanhead who have elected to receive the voluntary managed retreat funding. These matters will all have bearing upon the determination of the appropriate planning response to the situation at Matata.

19. Finally, I understand from the evidence of Mr Olliver that at the submission stage the Appellant questioned whether it was appropriate for PC 17 to rely upon the Australian Geomechanics Landslide Risk Management methodology (AGS 2007) as the methodology for assessing natural hazard risk.

20. As stated in the 2019 Report, the development of the AGS 2007 was conducted under the auspices of the Australian Geomechanics Society National Committee and was subject to extensive peer review. The suite of papers is recognised as an Industry Standard by practitioners and regulatory authorities. I personally contributed to AGS 2007 and have practised in the application of its principles to a range of governmental bodies in Australia seeking a recognised and defensible means of landslide risk assessment and management. Accordingly, I am of the opinion that AGS 2007 is an appropriate methodology for assessing natural hazard risk in this instance.

Greg Kotze
10 August 2020

Annexure A   2019 Report

"Annexure A"

CONFIDENTIAL

31 October 2019

Donna Llewell
Bay of Plenty Regional Council
PO Box 364
Whakatane 3158
New Zealand

Our ref: 12/502846/
Doc version: FINAL

Dear Ms Llewell

Technical Assessment
Debris Flow Risk Management
Awatarariki Fanhead, Matata, Bay of Plenty

Executive Summary

- Following the 2005 Awatarariki debris flow at Matatā, the ongoing debris flow hazard has been subject to a risk assessment for Loss of Life. The adoption of "industry best practice" guidelines (by Tonkin & Taylor in their 2015 report) has produced a "high" risk level evaluation, with subsequent regulatory control and a proposal for "retreat" from residential activity on the Awatarariki Fanhead.
- The Tonkin & Taylor report of 2015 has been subject to technical assessment, as documented herein. This assessment has identified that several factors in the Loss of Life calculations carried out were assumed to be common across numerous properties. It is considered that the use of more detailed and property-specific parameters may result in some risk level evaluations that are "medium" rather than "high".
- This assessment concludes that the Tonkin & Taylor report is robust and in the circumstances a cautious approach is not unreasonable.
- From a technical perspective, it could be feasible with further work, to specifically risk assess each individual property and, to implement a staged or progressive strategy of risk management, (i.e. commencing with voluntary retreat followed by retreat from "high" risk properties and in turn retreat from "medium" risk properties). Rigorous management, planning and policy considerations, along with other local government considerations would also apply.

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1 Introduction

GHD Limited (GHD) has been engaged by Bay of Plenty Regional Council (BoPRC) to undertake a review of geotechnical hazard and risk assessments that have been carried out for debris flow hazards on the Awatarariki Fanhead at Matatā, Bay of Plenty. The review was undertaken initially in accordance with the Project Briefing Sheet and Detailed Methodology provided to GHD by BoPRC on 28 June 2018. In accordance with those documents, the scope of work carried out comprised:

- A review of the hazard and risk assessments referenced in "Input Requirements" being:
  - The Australian Geomechanics Society – Landslide Risk Management 2007 risk assessment methodology
  - Quantitative Landslide and Debris Flow Hazard Assessment Matatā Escarpment, November 2013
  - Supplementary Risk Assessment Debris Flow Hazard Report, Matatā, Bay of Plenty, July 2015
  - Peer Review: Awatarariki debris-flow-fan risk to life and retreat-zone extent – M.J. McSaveney, T.R.H. Davies, 17 November 2015
  - Operative Bay of Plenty Regional Policy Statement 2014 (RPS) including (5b) natural hazards provisions operative July 2016
- A site visit to the Awatarariki Fanhead on 31st July 2018
- A review of the RPS natural hazards policy framework
- "Consider and report on whether the degree of policy response proposed in Proposed Plan Change 17 (prohibiting residential activity) is in excess of what is necessary (to reduce the risk from high to medium or lower if reasonably practicable)". In particular, we were asked to consider:
  a. "Whether listing fewer properties for which residential activity is to be prohibited would reduce the currently assessed high risk to medium. In other words, could a number of properties remain occupied in the Awatarariki Fanhead hazard area? If so, how many? Would they need to be selected spatially or could they be chosen on some other basis?
  b. Whether the removal of individual residents at a date later than 31 March 2021 affects the hazard risk. If so, what date, how many residents, and from which properties?"

The above issues were initially addressed, in our draft technical assessment report to BoPRC, dated 22 August 2018. On 19 August 2019, we subsequently received a letter of that date from BoPRC, which comprised a "clarification scope request" to enable completion of our draft document, in order to inform the pending Resource Management Act (1991) Plan Change(s) hearings process.

That report was finalised on 31st October 2019.

2 Background

Following the 2005 Awatarariki debris flow at Matatā, the debris flow hazard and its associated risk were assessed and peer reviewed. The assessed "high" risk on the Fanhead has led to regulatory controls on the use of land to be proposed by way of plan changes.

Land use is controlled under the Resource Management Act 1991 (RMA). Under the RMA, each region is required to have a regional policy statement and may have regional plans; each district is required to have a district plan. District plan rules can control future development; only regional plan rules may limit existing use rights.

A regional rule has been proposed to prohibit residential activities on identified high risk residential sites with effect from 31 March 2021.

The Bay of Plenty Regional Policy Statement 2014, through its natural hazards provisions that were made operative in July 2016, requires a risk management approach to natural hazards. The RPS, which is to be given effect in regional and district plans, provides natural hazards policy whose application depends on the level of risk – high, medium or low – and thresholds to define those levels of risk. In the RPS, risk means the likelihood and consequences of a hazard. The consequences to be used in the RPS risk assessments include Loss of Life (absolute numbers and the annual individual fatality risk), the extent to which building functionality is compromised, and loss of service from lifeline utilities.

The risk assessment underpins the policy and regulatory responses in Proposed Plan Change 17 (Awatarariki Fanhead) to the Regional Natural Resources Plan and Proposed Plan Change 1 to the Whakatāne District Plan.

The debris flow risk assessment was undertaken while the RPS natural hazards provisions were being formulated but before they were made operative. Based on the risk being evaluated as "high", land use controls have been proposed to give effect to the RPS policy direction. The question has arisen: is the degree of policy response proposed (prohibiting residential activity) in excess of what is required (to reduce risk from high to medium and lower if reasonably practicable)?

It is GHD opinion that this question is better addressed by way of independent planning and policy expertise.

3 Review of Previous Hazards and Risk Assessments

A key aspect of the scope of work requested of GHD was to "review previous hazard and risk assessments and formulate desk-top options involving modified assumptions and assess their risk". It was noted that only assumptions relating to the timing of or necessity for the removal of dwellings are to be modified; descriptors of the hazard itself are to be retained. As the removal of dwellings is a potential outcome as a response to the results of a "high" Quantitative Risk Assessment (QRA) Loss of Life calculation, we have reviewed (and challenged) the assumptions made for each parameter in the Loss of Life equations that have been documented to date for Matatā.

From a geotechnical perspective and for specific application at Matatā, "risk" is considered as a measure of both the probability and severity of a future debris flow, such as occurred from the Matatā escarpment and onto the Awatarariki Fanhead in 2005. Probability can be described as an estimate of "likelihood" of occurrence and, severity pertains to "consequences" of the debris flow occurring. The elements at risk from a future debris flow at Matatā include people (life), property and, infrastructure services, with emphasis placed on potential Loss of Life.

We have reviewed the assessments of Loss of Life documented by Tonkin & Taylor (T&T) in their November 2013[1] and July 2015[2] reports. It is noted that the 2013 document presented a "broad study" and that the "available information was not adequate to assess the risk to individual properties." The 2015 supplementary risk assessment, however, presents quantitative assessments of Loss of Life risk following the methodology presented by the Australian Geomechanics Society[3] in the benchmark suite of documents on Landslide Risk Management (Australian Geomechanics Journal Volume 42, No 1 March 2007), widely known as "AGS 2007".

The development of AGS 2007 was conducted under the auspices of the Australian Geomechanics Society National Committee and was subject to extensive peer review. The suite of papers is recognised as an Industry Standard by practitioners and knowledgeable regulatory authorities. The guideline for regulators has been generally adopted as an international guideline. The author of this technical assessment (Greg Kotze) and its reviewer (Andrew Leventhal) were both contributors to AGS 2007 and have practised in the application of its principles to a range of governmental bodies seeking a recognised and defensible means of landslide risk assessment and management.

In accordance with the guidelines contained within AGS 2007 and, as appropriately adopted by T & T, the risk of Loss of Life for an individual person can be calculated from the equation:

$R_{(LoL)} = P_{(H)} \times P_{(S:H)} \times P_{(T:S)} \times V_{(D:T)}$ where:

- $R_{(LoL)}$ is the risk (annual probability of Loss of Life (death) of an individual), being the person most at risk from the debris flow hazard;
- $P_{(H)}$ is the annual probability of the instability (debris flow) event occurring;
- $P_{(S:H)}$ is the probability of spatial impact of the debris flow impacting a location taking into account the travel distance and travel direction given the event occurs;
- $P_{(T:S)}$ is the temporal spatial probability (e.g. of the location being occupied by the individual) given the spatial impact;
- $V_{(D:T)}$ is the vulnerability of the individual (probability of Loss of Life of the individual given the impact)

[1] Quantitative Landslide and Debris Flow Hazard Assessment Matatā Escarpment, November 2013

[2] Supplementary Risk Assessment Debris Flow Hazard Report, Matatā, Bay of Plenty, July 2015

[3] The Australian Geomechanics Society – Landslide Risk Management 2007 risk assessment methodology

The parameters adopted by T&T (2015) for their analysis of risk of Loss of Life are discussed in Section 6 of their report and summarised in Table 6.2 therein. We have reviewed each parameter in turn as summarised below:

- $P_{(H)}$: annual probability of debris flow occurring. T&T have based their estimates of this parameter on the annual return period (ARI) of the rainfall event that triggered the 18 May 2005 debris flow, being ARI = 200 to 500 years, with related interpretations for events of larger and smaller volumes. The author considers those assumptions to be appropriate given the paucity of data on historic debris flows. Similarly, the assessment that debris flow volumes and materials such as occurred on to the Fanhead in 2005 could be replicated in a future event is considered reasonable given the catchment.
- $P_{(S:H)}$: probability of spatial impact of the debris flow impacting a location taking into account the travel distance and travel direction given the event. T&T have assumed a probability of 1.0 (100%) for all locations in their Risk Zones 1 and 2 on the Fanhead.
  We understand that no individuals were buried in the 2005 debris flow. Accordingly, of most relevance to potential Loss of Life from debris impact is boulder strike. It was observed on site by the author that a large accumulation of boulders was concentrated (presumably during site re-establishment after the 2005 event) between Clem Elliott Drive, Kaokaoroa Street and Arawa Street (SH2). With the assumption that these boulders remain in place, it is considered reasonable that this boulder field would be likely to impede (at least locally) flows of future debris. It is also considered possible that the existing Kaokaoroa Street, which currently provides a relatively narrow debris pathway, could become constricted with debris containing timber (fallen trees) amongst other materials. The above conditions have the potential to provide some buffer effect and/or deflection of debris, whereby the $P_{(S:H)}$ for some properties on the Fanhead would be less than 1.0 and possibly as low as 0.7. That is, the potential is considered to exist for future debris travel distance and debris travel direction to be subject to some disruption by the existing boulder field. This in turn, may contribute to a lower risk level calculation outcome for some properties.
- $P_{(T:S)}$: temporal spatial probability (e.g. of the location being occupied by the individual) given the spatial impact. T&T have assumed a temporal spatial probability of 7.5×10^{-1} (0.75) as a common factor for all property locations on the Fanhead that is, an overall 75% occupancy rate. The author considers this assumption could be questioned. The temporal spatial probability for an individual can vary between properties in a number of ways, including occupancy rate and dwelling type. Some examples of factors that influence temporal spatial probability include:

  – 24 hour/day occupancy (retiree)

  – 12 hour/day occupancy (worker/student)

  – 2 day/week occupancy ("week-ender")

  – 12 weeks/year (holiday letting)

  The above variables can be quantified and incorporated into $P_{(T:S)}$ determinations. In overview, a retiree living at home 24 hours per day warrants a higher temporal spatial probability factor than an adult who works away from home during business hours five days per week or, a "week-ender" only occupant. Whilst the author is not familiar with the residential demographics of the Fanhead it is considered reasonable that a range of temporal spatial probabilities exist. This factor ($P_{(T:S)}$) can also be influenced by residential layout and the location most occupied by the person most at risk. For example, the locations of bedrooms with respect to debris flow travel paths can also influence temporal spatial probability. Where applicable, lower occupancy rates and specific residential layout may contribute to lower risk level calculation outcomes for some properties.

- $V_{(D:T)}$: vulnerability of the individual (probability of Loss of Life of the individual given the impact). T&T have assumed a vulnerability of 0.75 for properties in Risk Zone 1 and 0.2 for properties in Risk Zone 2. However, the author considers that a range of vulnerabilities are likely to exist across the Fanhead. Vulnerabilities can be influenced by a number of conditions, which include dwelling type. For example, given debris flow impact, the vulnerability of an individual upstairs in a two-story masonry house can generally be expected to be lower than the vulnerability of an individual in a single storey timber dwelling. Also, the aged and infirmed as well as infants have a higher vulnerability than able-bodied adults. AGS (2007) notes in the commentary to the Practice Note (C6.4) that the assessment of vulnerability is subjective but also that for persons below a landslide (debris flow in this instance), the velocity of the landslide has a major effect on vulnerability. Persons who are near the toe of a landslide which will travel a long distance are likely to experience a high velocity impact and will have higher vulnerability than persons who are near the limit of travel (or run-out) of the landslide or debris flow. This is relevant to the extent of debris outflow on the Awatarariki Fanhead. It is considered likely that vulnerabilities in the order of 0.1 may be locally applicable, which would not be inconsistent with the fact that there were no fatalities in the 2005 event. Where applicable, lower vulnerability factors may contribute to lower risk level calculation outcomes for some properties.

The product of the above-described factors, results in an arithmetic outcome, expressed on a sliding scale with scientific notation and which enables the risk level outcome to be categorised against criteria presented in AGS 2007, summarised as follows:

Loss of Life Risk for person most at risk	Equivalent Descriptors	Criteria for Existing Developments
$>10^{-4}$ / annum	High to Very High	Unacceptable
10^{-4} to 10^{-5} / annum	Moderate	Tolerable
$<10^{-5}$ / annum	Low to Very Low	Acceptable

It is noted from their Table 6.2 that the T&T (2015) risk levels for Loss of Life in Risk Zones 1 and 2 range from 1.13×10^{-2} pa to 7.5×10^{-4} pa for shorter return period events and from 1.13×10^{-3} pa to 6×10^{-4} pa for longer return period events. In accordance with AGS 2007 guidelines these risk levels range from high to very high and would be considered “unacceptable” for residential developments. As mentioned above however, the T&T Loss of Life calculations have incorporated some factors assumed to be common across numerous properties, including $P_{(S:H)}$, $P_{(T:S)}$ and $V_{(D:T)}$. It is the author’s consideration that this may have resulted in Loss of Life calculation outcomes that are potentially higher for some properties than would be the case if property-specific parameters were adopted.

4 Discussion

In consideration of all the above, it is the author's opinion that the T&T Risk Assessment report of July 2015 is robust and has utilised what is regarded by the geotechnical community as "industry best practice" through the adoption of AGS 2007 guidelines. As described above however, in the T&T Loss of Life risk calculations several factors were assumed to be common across numerous properties (including $P_{(S:H)}$, $P_{(T:S)}$ and $V_{(D:T)}$). This may have resulted in a degree of conservative generalisation in some risk calculation outcomes. Nonetheless, this possibly cautious approach is not considered unreasonable, given that the only way to avoid that potential is to carry out rigorous property-specific Loss of Life risk calculations which factor in the position, dwelling type and structure, occupant movements and demographics, for each individual property. The acquisition of such data would require interaction with individual property owners or occupants. Put simply, a property comprising a single storey timber dwelling, housing a large family with infants, will be characterised by a higher Loss of Life risk than a property comprising a 2 storey masonry dwelling that houses two able-bodied adults who work away from home on week days. It is considered likely that many combinations of factors affecting Loss of Life risk exist for properties on the Fanhead.

The position outlined above is in no way to suggest that unacceptably high Loss of Life risks do not exist on the Awatarariki Fanhead. The point to be made is that quantitative risk assessment methodology can produce a range of results for adjoining or nearby properties which are highly dependent on the specifics of dwelling structure, occupancy rates and occupant demographics. Until the specifics of dwelling type, occupancy rate and occupant demographics are factored in to the QRA Loss of Life assessment process for each existing individual property on the Fanhead, the delineation of properties that do and properties that don't require "Retreat" orders based on Loss of Life risk cannot be confirmed quantitatively.

It must also be pointed out however, that a decision to retreat from residential activity based on the risk profiles of individual properties alone, would require that such risk profiles are reviewed and amended as and when conditions on that property change in the future. For example, variations in occupancy rates, the introduction of more vulnerable occupants and changes in building conditions (either deterioration, or, renovations / extensions) all have the potential to change the risk profile and Loss of Life risk assessment outcome for that property. Mechanisms and governance would be required whereby Loss of Life risk could be reviewed and acted upon as appropriate into the future. That is, should a property with a currently tolerable (10^{-4} pa to 10^{-5} pa) Loss of Life risk level be permitted to remain on the Fanhead, mechanisms and governance would be required whereby intervention would occur should conditions alter such that an unacceptable (greater than 10^{-4} pa) Loss of Life risk level develops on that property.

The adoption of 10^{-4} pa as the threshold for high and unacceptable Loss of Life risk for the person most at risk in an existing development, as recommended in AGS 2007, is also consistent with the Bay of Plenty Regional Policy Statement natural hazards framework. Appendix L of the RPS presents a methodology for risk assessment that is consistent in approach to that of AGS 2007, through the determination of AIFR or Annual Individual Fatality Risk. Appendix L states that if the AIFR is greater than 10^{-4} pa the risk category is high, if the AIFR is 10^{-4} pa or less but greater than 10^{-5} pa the risk category is medium and, if the AIFR is 10^{-5} pa or less the risk category is low. This categorisation is consistent with that of AGS 2007, as summarised above. The 10^{-4} pa to 10^{-5} pa category correlates with a "moderate" descriptor in AGS 2007 and a "medium" descriptor in RPS. Those descriptors can be regarded as interchangeable herein. Furthermore, the RPS acknowledges that other risk assessment methodologies are also recognised by BoPRC providing that they constitute a RRAM or Recognised Risk Assessment Methodology an example of which is AGS 2007. The adoption therefore by T&T of AGS 2007 guidelines for application at Matatā in their report of 2015, is considered by the author to be appropriate in principle.

It is noted that other criteria are included in the RPS risk assessments, in addition to Loss of Life, which are the extent to which building functionality is compromised and, loss of service from lifeline utilities. Whilst assessments of these criteria require more than geotechnical input alone, it is evident from the 2005 event that future debris flows in Matatā have the potential to damage buildings and hence compromise their functionality and sever the railway at the bridge site and block SH2 with debris, which would manifest as losses of services from lifeline utilities.

5 Conclusions

i. The quantitative assessments of Loss of Life risk carried out for debris flow hazards at Matatā to date, have been in accordance with “industry best practice” through the adoption of AGS 2007 guidelines.

ii. The ability of the adopted (ARI) rainfall event (as correlation with debris flow probability of occurrence $P_{(H)}$) to generate similar debris flow volumes and materials as occurred in May 2005, is considered to be appropriate. However, the incorporation of several factors assumed to be common across numerous properties (including $P_{(S:H)}$, $P_{(T:S)}$, and $V_{(D:T)}$) is considered likely to have resulted in Loss of Life calculation outcomes that are potentially higher for some properties than would be the case if property-specific calculation parameters were used.

iii. If the specifics of individual dwelling type and structure, occupancy rate and occupant demographics are factored in to QRA Loss of Life analyses for each dwelling on the Fanhead, it is possible that a percentage of Loss of Life assessment results will be above 10^{-4} per annum (pa) and a percentage will be below 10^{-4} pa. Properties with Loss of Life risk outcomes above 10^{-4} pa would warrant Retreat procedure. Properties with Loss of Life risk outcomes below 10^{-4} pa, which is the threshold for entry into the “moderate” / “medium” risk zone category, could warrant further consideration for remaining. From a Loss of Life risk perspective, existing dwellings with an assessment outcome below 10^{-4} pa could remain, until such time as (if and when) the risk profile for that property was to increase, which could be after 31 March 2021.

iv. The Loss of Life risk assessment value of 10^{-4} pa could be adopted as a differentiator between the requirement for retreat and the potential to remain, either in the short term, or longer, subject to the adoption of a considered management strategy agreed to by all stakeholders. It is understood that a precedent of this nature was set in Christchurch subsequent to the Canterbury earthquakes. It is also noted that the adoption of 10^{-4} pa as a differentiator, would be consistent with the Bay of Plenty Regional Policy Statement, in which the adopted upper limit of “medium” annual individual fatality risk is $10^{-4.}$

v. The approach outlined above would require further investigation including initial interactions with individual property owners in order to quantify specific risk calculation parameters for each property. Subsequent ongoing review of property details would be required, to identify future potential cases of increased Loss of Life risk to (unacceptable) levels above 10^{-4}. Such an approach would require rigorous management. It is also acknowledged that the decision to implement such an approach would require the consideration of disciplines other than geotechnical, such as policy, planning and other local government requirements.

vi. Nonetheless, it would be feasible at Matatā to implement a staged or progressive strategy of risk management commencing with voluntary retreat, followed by the retreat of all properties with the “unacceptable” Loss of Life risk greater than 10^{-4} pa. This in turn could be followed by progressive retreat over time of properties with Loss of Life risk below 10^{-4} pa, as these properties become available and/or increase in risk profile. Such a strategy would constitute a progression of risk reduction both for individuals and from a societal perspective. It is pointed out however, that whilst any property where a Loss of Life risk is greater than 10^{-4} pa remains, there will also remain a corresponding unacceptable annual individual fatality risk on the Awatarariki Fanhead.

vii. It is also pointed out that any managerial reliance on a calculated value of annual fatality risk requires that such calculations are undertaken with due diligence and are subject to appropriate peer review and joint consideration with managerial bodies.

6 Scope and Limitations

This report has been prepared by GHD Limited (GHD) for Bay of Plenty Regional Council and may only be used and relied on by Bay of Plenty Regional Council for the purpose agreed between GHD and the Bay of Plenty Regional Council as set out in section 1 of this report.

GHD otherwise disclaims responsibility to any person other than Bay of Plenty Regional Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Bay of Plenty Regional Council and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

7 Closure

Should you require any further information, or assistance with any aspect of the above, please do not hesitate to contact us.

Sincerely
GHD Limited

Prepared by:
Greg Kotze
Senior Technical Director – Geology

Reviewed by:
Andrew Leventhal
Senior Technical Director -Geotechnics