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Attention: Stuart Milsom

Dear Stuart,

Active fault investigation for 66 McFetridge Drive, Rotorua

1.0 INTRODUCTION

Land subdivision for residential housing at 66 McFetridge Drive, Rotorua (Figure 2.1), is being investigated. On the southeast side of this property, an active fault was previously mapped by Villamor et al. (2010). The fault was identified from examination of high-resolution topographic data called LiDAR (Figure 2.1). The fault has an 'expression' of "unknown" in the Villamor et al. (2010) database. The expression attribute describes how clearly a fault is expressed in the landscape, and, in this case, the description of 'unknown' means that the feature is ambiguous. That is, it is not known if the feature identified is an active fault or not. Very little is known about this active fault (here called **Fault A,** Figure 2.1). It does not have a known recurrence interval, nor has its precise location been studied in detail, and it has not been the subject of prior field studies by earthquake geologists. Due to uncertainty around the precise location of Fault A, it has a 140 m fault avoidance zone (FAZ) around it. The FAZ is comprised of the fault location uncertainty zone (± 50 m) and a 20 m setback either side of the fault. This FAZ crosses several of the proposed subdivided properties within the 66 McFetridge Drive subdivision.

The Ministry for the Environment guidelines for 'Planning for development of land on or close to active faults' (hereafter referred to as the MfE Guidelines) describes a risk-based approach for development on or close to active faults (Kerr et al. 2003). The risk associated with ground-surface fault rupture is a function not only of the location and activity of a fault, but also the type of structure/building that may be impacted by rupture of the fault. For a site on, or immediately adjacent to, an active fault, risk increases both as fault activity increases (i.e. fault recurrence interval and Recurrence Interval Class decrease) and Building Importance Category increases. The RI Class of Fault A is unknown.

In accordance with the MfE Guidelines, the options for development on or near Fault A are (i) avoid building footprints within the 140 m wide FAZ, (ii) better define the location of the fault though field studies so that the FAZ can be narrowed or (iii) constrain the recurrence interval of the fault so that it can be assigned a RI Class and then assess the type of development that could occur within the FAZ. The focus of this report is (iii): better constraining the recurrence interval of Fault A from existing information without undertaking field investigations.

2.0 INVESTIGATION OF FAULT A

Fault A was mapped along a distinct lineation (i.e. a straight to semi-straight step) in the landscape identified in high-resolution LiDAR topographic maps (Villamor et al. 2010; Figure 2.1). Similar steps also lie to the southwest around the lake (orange arrows, Figure 2.1), but they have a more arcuate shape and are clearly formed by lake-shore erosion. However, Fault A is more linear and lies directly along strike (along a straight line projection) from another prominent active fault 3.8 km to the east (here called **Fault B**, Figure 2.1). Fault B has a strong topographic expression in the landscape and is almost certainly an active fault. Despite some similarities with the arcuate features to the southwest, the lineation at Fault A was mapped as an active fault because of its along-strike relationship to Fault B. It therefore follows that we should treat Fault A and Fault B as the same fault, and this means that we can use the landforms in between Fault A and Fault B to constrain the fault recurrence interval.

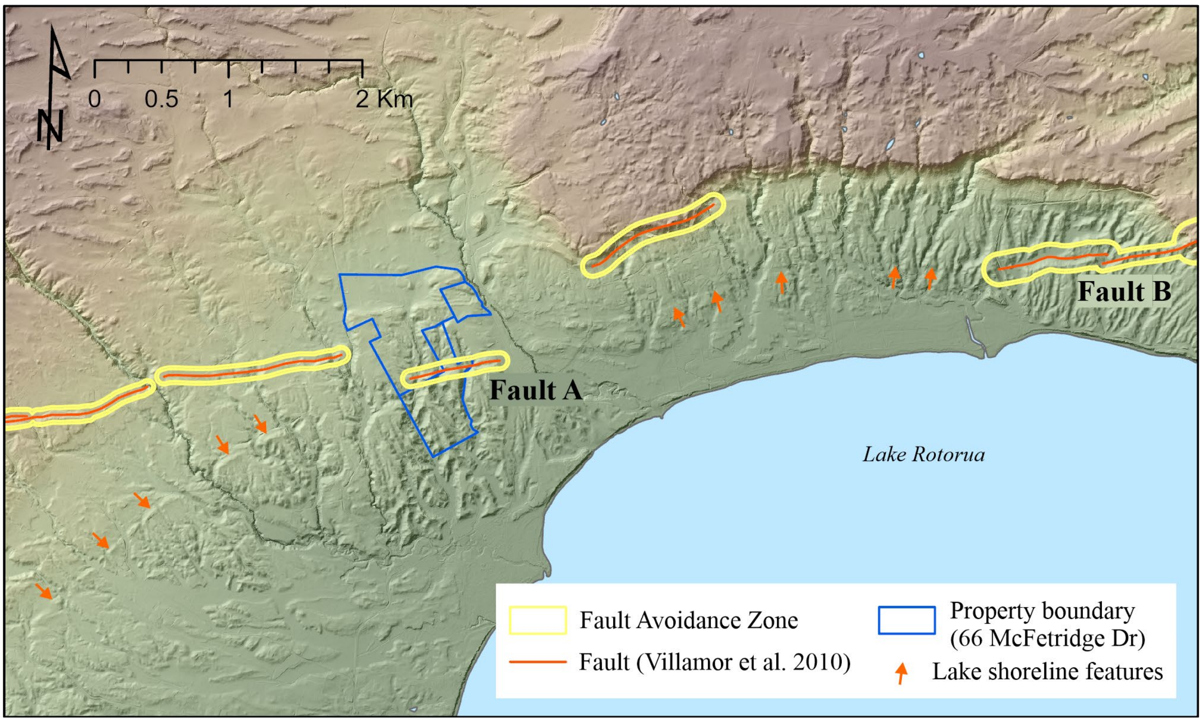

Figure 2.1 Topography of the northern Lake Rotorua area in the vicinity of 66 McFetridge Drive (blue property boundary). The topographic data is a 2 m resolution LiDAR digital elevation model from the Bay of Plenty Regional Council. The faults and FAZ are from Villamor et al. (2010), and the names ‘Fault A’ and ‘Fault B’ are specific to this report. Arcuate lake shoreline features discussed in text are pointed out by the orange arrows.

There is no surface expression of an active fault between Fault A and Fault B in the LiDAR data (Figure 2.1). This means that the last occurrence of a surface-rupturing earthquake on Fault A and Fault B was prior to the formation of the landforms in between the two faults. The landforms in between Fault A and Fault B are gently sloping and dissected former lake shorelines. Below, we explain how the former lake shorelines were formed (from Clark et al. [2019]):

> *Lake Rotorua is located within the Rotorua volcanic caldera. The caldera formed around 240,000 years ago by collapse of the ground after the eruption of the voluminous Mamaku Formation (Milner et al. 2002; age of the Mamaku Formation from Gravley et al. 2007). A large lake occupied this subsided area after the caldera formed (Marx et al. 2009). Since its formation, Lake Rotorua has reached different topographic levels as a consequence of blockage and establishment of lake outlets responding to the tectonic and volcanic activity around the lake. The modern lake shoreline is at 280 m above sea level (asl).*

The former lake shorelines present between Fault A and Fault B have been mapped in several publications (Kennedy et al. 1978; Marx et al. 2009), and the progression over time in understanding the age of past volcanic eruptions has resulted in some different information about the precise age of the shorelines. Here we defer to the most recent age information in Marx et al. (2009). In the northern area of Lake Rotorua, the most topographically prominent shorelines are at ~349 m asl and ~293 m asl (blue lines in Figure 2.2). The projection of the fault between Fault A and Fault B crosses the land between the 349 m and 293 m shorelines. The 349 m shoreline is associated with a highstand (highest topographic level reached by the lake at certain time) at around 36,000 years ago (Marx et al. 2009). The most recent age estimate of the 293 m shoreline associates the shoreline with the Rotoma and Mamaku volcanic eruptions at 9500–8000 years ago (Marx et al. 2009). This means that the shoreline formed at approximately 9500 to 8000 years before present and the lake level has fallen progressively since ~8000 years to its current elevation. If we take the youngest possible age for the 293 m shoreline at ~8000 years ago, and we can see that this has not been displaced by a fault, then we can reason that Fault A and Fault B have not had a surface rupture in the last ~8000 years. **The recurrence interval of Fault A and Fault B must therefore be >8000 years.** It is possible that the recurrence interval of Fault A and Fault B is significantly longer than 8000 years because the land surface between the 349 m and 293 m shorelines is not displaced, and this land ranges in age between 36,000 and 8000 years.

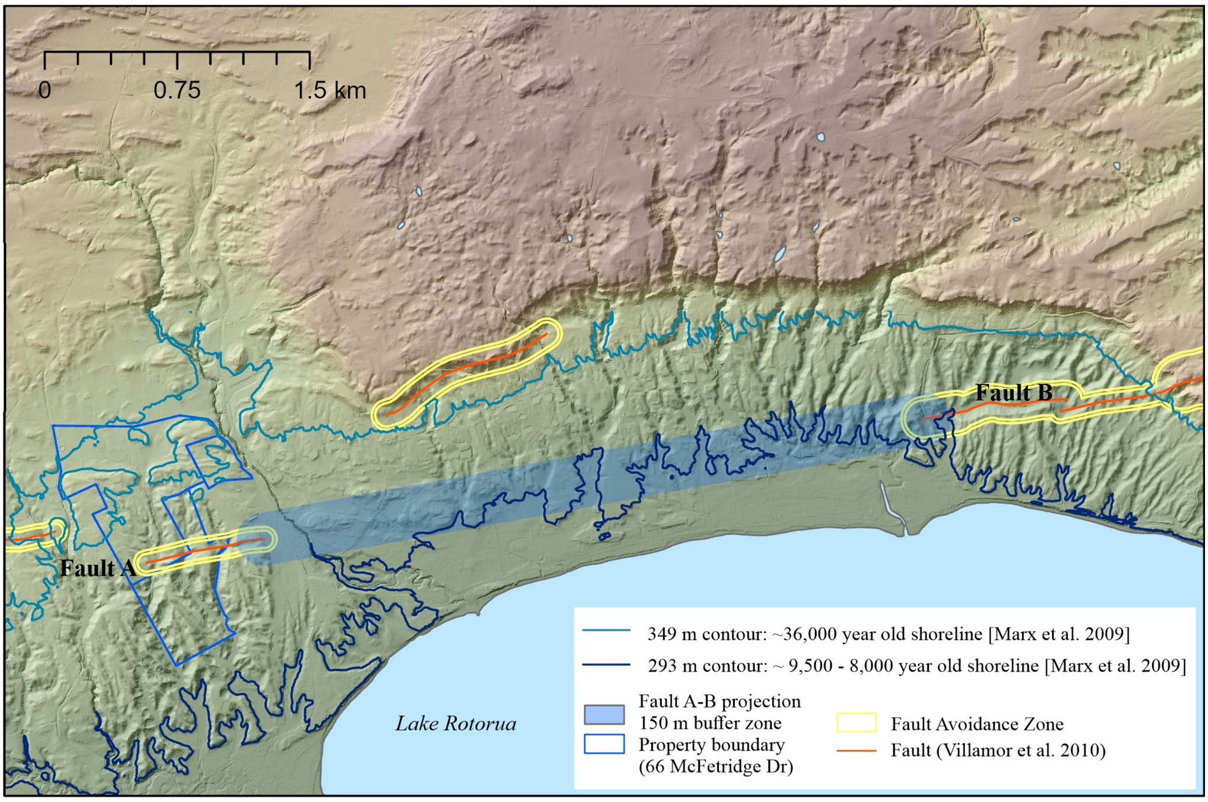

Figure 2.2 Topography of the northern Lake Rotorua area in the vicinity of 66 McFetridge Drive with the 349 m and 293 m contours highlighted. These elevations correspond with the approximate positions of former lake shorelines at 36,000 years and 9500–8000 years, respectively. The zone of the fault projection between Fault A and Fault B is shaded blue, and no offset of the 293 m shoreline can be seen along this fault projection zone or anywhere in the area between Fault A and Fault B.

Geological maps can also be used to confirm the long (>8000 years) recurrence interval of Fault A and Fault B. The 1:250,000 geological map (QMap, Leonard et al. 2010) shows that the geological units in between Fault A and Fault B are Late Pleistocene lake deposits (59,000–24,000 years old) and Holocene alluvial deposits (14,000–0 years old) (Figure 2.3). The projection of the fault (and a 150 m buffer around the fault projection) crosses both of these units, and we do not see any surface expression of a fault. The Holocene alluvial deposits could be very recent, so the absence of offset on this unit is not useful for constraining the recurrence interval. The Late Pleistocene (yellow) lake deposits are not offset, so if we take the youngest age of these deposits as 24,000 years, this suggests that the fault has not had a surface rupture in the last 24,000 years. However, we believe that the lake shorelines offer a more precise method of landform dating than the more generalised geological map, so we prioritise the 8000-year-old shoreline age when constraining the recurrence interval of Fault A and Fault B. Note that, in Figure 2.2, Fault B appears to have surface expression across the land surface between the ~349 m elevation and ~293 m elevation, but the geological map shows that this land is 61,000-year-old Rotoiti Formation ignimbrite (Figure 2.3) not the Late Pleistocene lake deposits.

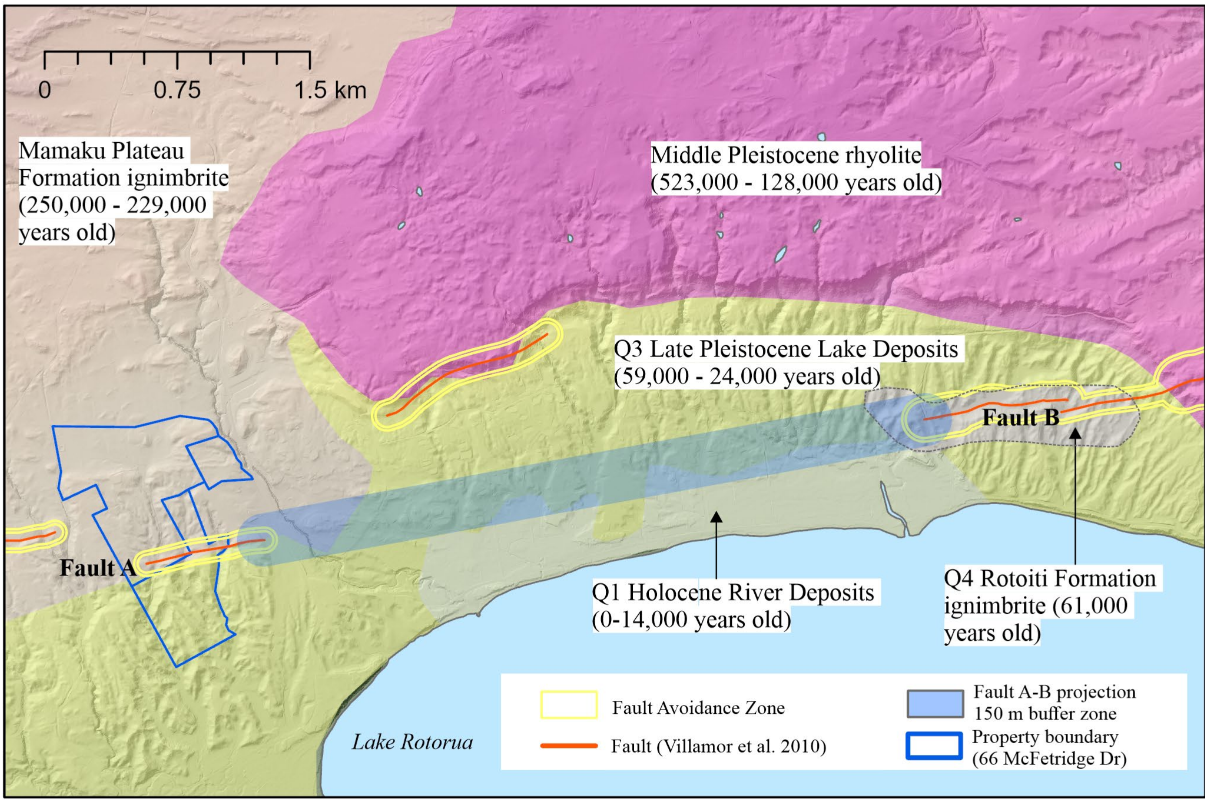

Figure 2.3 Geological units of the northern Lake Rotorua area, overlain on a digital elevation model. Geological units and labels are from Leonard et al. (2010). The fault projection between Fault A and Fault B shows no offset of Quaternary 3 Late Pleistocene lake deposits or of the Quaternary 1 Holocene river deposits.

3.0 RECURRENCE INTERVAL CLASS OF FAULT A AND RELATIONSHIP TO MFE GUIDELINES

The >8000-year recurrence interval for Fault A and Fault B places these faults in Fault Recurrence Interval [RI] Class IV (>5000 to ≤10,000 years), according to the MfE Guidelines (Table 3.1; Kerr et al. 2003). We suggest that this is a minimum recurrence interval and that the faults could have a longer recurrence interval, as landforms older than 8000 are also not offset.

Table 3.1 Relationship between fault recurrence interval (RI) and Building Importance Category (BIC) (source: Kerr et al. 2003). Note: Faults with average recurrence intervals >125,000 years are not considered active.

RI Class	Fault RI	BIC Limitations (Allowable Buildings)	
		Previously Subdivided or Developed Sites	**'Greenfield' Sites**
I	≤2000 years	BIC 1	BIC 1
II	>2000 to ≤3500 years	BIC 1 and 2a	
III	>3500 to ≤5000 years	BIC 1, 2a and 2b	BIC 1 and 2a
IV	>5000 to ≤10,000 years	BIC 1, 2a, 2b and 3	Bic 1, 2a and 2b
V	>10,000 to ≤20,000 years		BIC 1, 2a, 2b and 3
VI	>20,000 to ≤125,000 years	BIC 1, 2a, 2b, 3 and 4	

On ‘Greenfield’ sites (i.e. previously undeveloped land), allowable buildings across RI Class IV faults are BIC 1, 2a and 2b (Table 3.2). These are ‘Timber-framed residential construction’ and ‘Normal structures and structures not in other categories’ (see table below for further details).

Table 3.2 Building Importance Categories and representative examples. For more detail, see Kerr et al. (2003).

BIC	Description	Examples
2a	Timber-framed residential construction	Timber-framed single-story dwellings
2b	Normal structures and structures not in other categories	• Timber-framed houses with area >300 m^2 • Houses outside the scope of NZS 3604 ‘Timber Framed Buildings’ • Multi-occupancy residential, commercial and industrial buildings accommodating <5000 people and <10,000 m^2 • Public assembly buildings, theatres and cinemas <1000 m^2 • Car parking buildings

4.0 SUMMARY

This report is a desktop assessment of the RI Class of ‘Fault A’, the fault that crosses the property at 66 McFetridge Drive, Rotorua. We have assumed that Fault A and Fault B are the same fault line, as this is the basis on which Fault A was mapped by Villamor et al. (2010). All existing knowledge of the age of the landforms and geological units suggests that Fault A and Fault B have not had a surface rupture in the past 8000 years. This suggests that the fault recurrence interval is >8000 years, and we place Fault A in RI Class IV (>5000 to ≤10,000 years) according to the MfE Guidelines for ‘Planning for development of land on or close to active faults’.

Yours sincerely,

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5.0 REFERENCES

Clark KJ, Villamor P, Lee JM. 2019. Bay of Plenty regional active fault mapping for growth areas. Lower Hutt (NZ): GNS Science. 44 p. + appendices. Consultancy Report 2018/143. Prepared for Bay of Plenty Regional Council.

Gravley DM, Wilson CJN, Leonard GS, Cole JW. 2007. Double trouble: paired ignimbrite eruptions and collateral subsidence in the Taupo Volcanic Zone, New Zealand. *Geological Society of America Bulletin*. 119(1–2):18–30. doi:10.1130/b25924.1.

Kennedy NM, Pullar WA, Pain CF. 1978. Late Quaternary land surfaces and geomorphic changes in the Rotorua Basin, North Island, New Zealand. *New Zealand Journal of Science*. 21(2):249–264.

Kerr J, Nathan S, Van Dissen RJ, Webb P, Brunsdon D, King AB. 2003. Planning for development of land on or close to active faults: a guideline to assist resource management planners in New Zealand. Lower Hutt (NZ): Institute of Geological & Nuclear Sciences. 71 p. Client Report 2002/124. Prepared for Ministry for the Environment.

Leonard GS, Begg JG, Wilson CJN, compilers. 2010. Geology of the Rotorua area [map]. Lower Hutt (NZ): GNS Science. 1 folded map + 102 p., scale 1:250,000. (Institute of Geological & Nuclear Sciences 1:250,000 geological map; 5).

Marx R, White JDL, Manville V. 2009. Sedimentology and allostratigraphy of post-240 ka to pre-26.5 ka lacustrine terraces at intracaldera Lake Rotorua, Taupo Volcanic Zone, New Zealand. *Sedimentary Geology*. 220(3–4):349–362. doi:10.1016/j.sedgeo.2009.04.025.

Milner D, Cole J, Wood C. 2002. Asymmetric, multiple-block collapse at Rotorua Caldera, Taupo Volcanic Zone, New Zealand. *Bulletin of Volcanology*. 64(2):134–149. doi:10.1007/s00445-001-0191-0.

Villamor P, Ries W, Zajac A. 2010. Rotorua District Council hazard studies: active fault hazards. Lower Hutt (NZ): GNS Science. 28 p. Consultancy Report 2010/182. Prepared for Rotorua District Council.