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Attention: Elsa Weir

Dear Elsa,

Eastside Active Faults Study 2021 Update

1.0 INTRODUCTION

The Bay of Plenty Regional Council has identified an area for proposed development near Rotorua; the area is called Eastside (Figure 2.1). GNS Science was commissioned to assess the presence or absence of active faults in the Eastside area and to map the active faults, with attributes compatible with the Ministry for the Environment Active Fault Guidelines (MfE Guidelines; Kerr et al. 2003). Our analysis identified several likely active faults in the southwestern corner of the Eastside area (Faults 1–3, Figure 2.1) which is a location of current land development. The purpose of this report is to re-evaluate the faults in light of field investigations and to constrain the rates of activity (slip rate and recurrence interval, RI) of the faults for the purposes of applying the MfE Guidelines for development of land on or close to active faults (Kerr et al. 2003).

2.0 METHODOLOGY

This report uses (1) field observations and (2) slip rate and recurrence interval (RI) calculations.

Field observations

Brad Scott (GNS Science) visited the site of Fault 2a on 27 May 2021. The field work involved a walk around at the site of Fault 2a and collection of photos. In addition, photos of the area were also taken from a helicopter on the afternoon of 27 May by Brad Scott.

Slip rate and recurrence interval calculations

We use a four-step process to constrain the fault recurrence intervals:

1. Estimate landform age using information from geological maps and published journal papers. The geological maps used are Nairn (2002) and Leonard et al. (2010). The primary paper for estimating the lake shoreline ages is Marx et al. (2009).
2. Create topographic profiles across the fault scarps and use a slip-rate tool developed by GNS Science to estimate the fault slip rate given information known about the age and measured offset (with uncertainties).
3. Compare slip rates of the Eastside area faults with slip rates of faults elsewhere in the Taupo Volcanic Zone. Select a fault with a comparable slip rate where the RI is constrained by paleoseismology (i.e. where a fault trench has data about the number and timing of past earthquakes). We cross-check the estimated RI of Fault 1 with information from non-offset of lake shorelines.
4. Apply the recurrence intervals from a fault with similar slip rate to the faults of the Eastside area and categorise the faults into RI Classes defined by the MfE Guidelines. The recurrence interval for the Opawhero fault is obtained from fault offset data in Villamor et al. (2011).

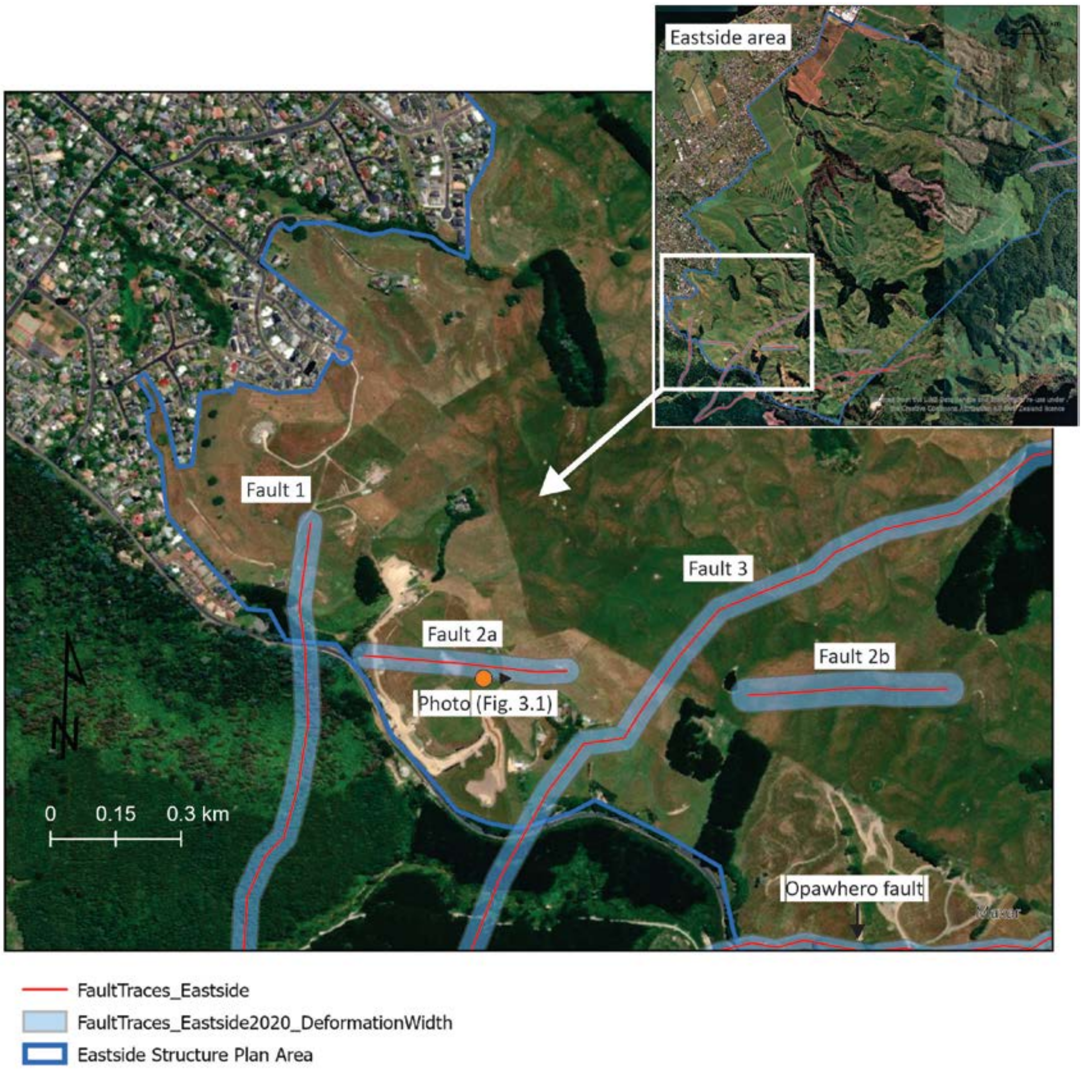


Figure 2.1 Fault mapping in the southwestern Eastside area from Clark (2020).

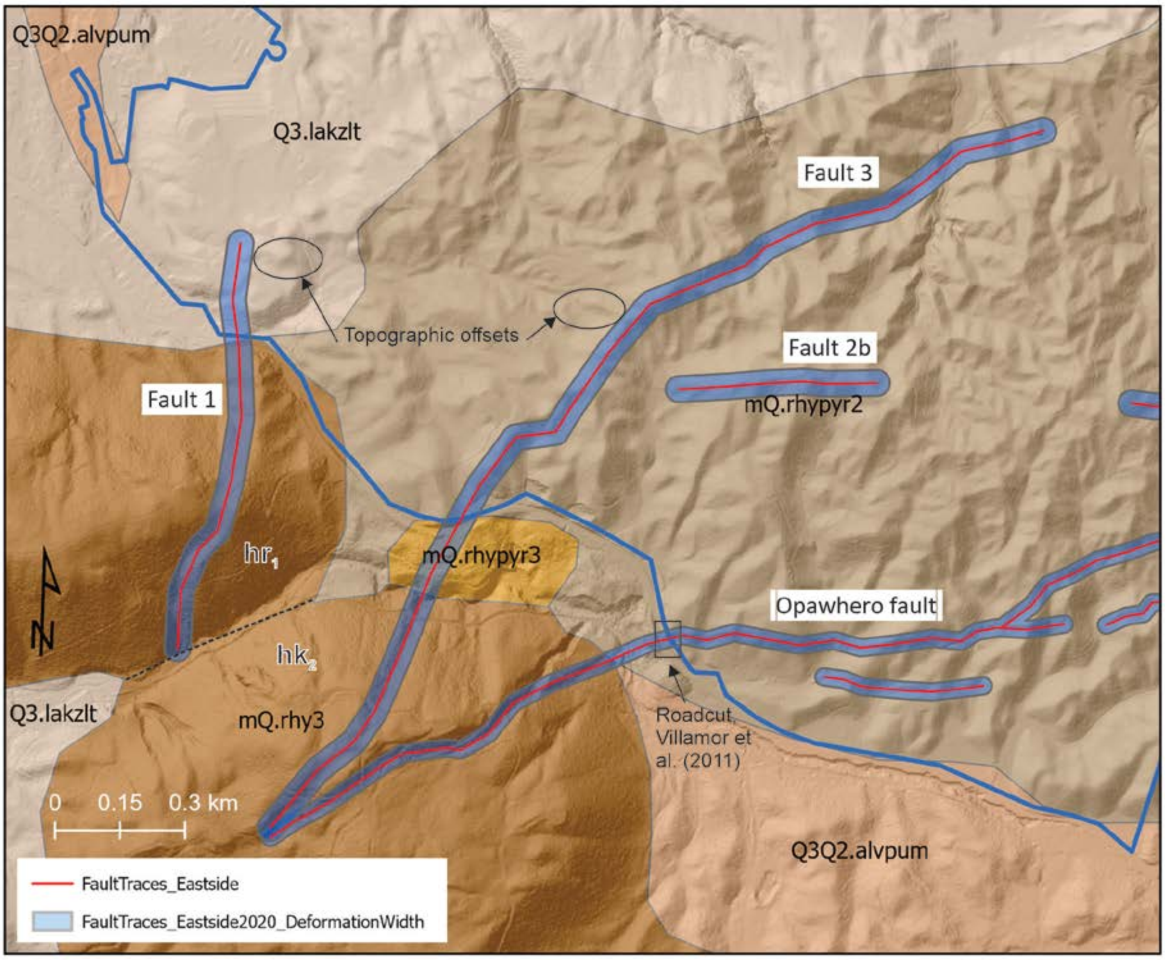
3.0 RESULTS

3.1 Field Observations and Re-Classification of Fault Mapping

A major objective for undertaking field work along Fault 2a was to check the small, sharp scarp at the eastern end of Fault 2a. This small, straight scarp was the main reason that Fault 2a was identified at this site, but we had concerns it could have been formed by human activities (e.g. an old driveway or farm race). In the field it became clear the scarp was natural but most likely marks the edge of a debris flow, rather than being a fault scarp (Figure 3.1). The debris flow forms a lobe within the valley and has quite straight sides. In this case the debris flow edges were along the strike of the other subtle fault scarps (Faults 2b and 2c, Figure 2.1). When we remove the debris flow edge scarp from consideration, there is no reason to keep a fault line in the location of Fault 2a. The western end of Fault 2a does follow a gully but there is little reason to consider this as a fault-controlled gully. As a result of the field investigation, we removed Fault 2a from the active faults map of the Eastside area.

Figure 3.1 A photo looking along the strike of Fault 2a, the sharp topographic step is best explained as the edge of a debris flow rather than an active fault. Photo credit: Brad Scott, GNS Science VML254349. Location of photo shown in Figure 2.1.

Observations were made in the field of another possible fault near Fault 2a, this was observed from the offset of ridgelines and hillsides at two locations (see circled topographic offsets in Figure 3.2). We have reviewed the lidar topographic maps in the area of this fault and conclude that while it could be a fault, it is unlikely to be a recently active fault (i.e. active within the last 25,000 years). There is little expression of a fault through most of the valleys that link the offset ridgelines, indicating the possible fault is either very old or not a fault.



Unit	Description	Approximate age	
Q3Q2.alvpum	Late Pleistocene fluvial deposits	27,000 - 12,000 yrs	Leonard et al. (2010)
Q3.lakzlt	Late Pleistocene lake deposits	60,000 - 19,000 yrs	Leonard et al. (2010)
mQ.rhy3	Undifferentiated Middle Pleistocene rhyolite	523,000 - 128,000 yrs	Leonard et al. (2010)
mQ.rhypyr2	Middle Pleistocene Okataina Group rhyolite pyroclastics	523,000 - 128,000 yrs	Leonard et al. (2010)
mQ.rhypyr3	Undifferentiated Middle Pleistocene rhyolite pyroclastics	523,000 - 128,000 yrs	Leonard et al. (2010)
hr_1	Rotorua rhyolites	350,000 - 280,000 yrs	Nairn (2002)
hk_2	Kapenga rhyolites	180,000 - 60,000 yrs	Nairn (2002)

Figure 3.2 Revised fault mapping of the eastern portion of the Eastside area and the geological map of Leonard et al (2010) over a lidar hillshape topographic map. The landform ages are listed in the legend below the map. These landform ages are used to assess the fault slip rates.

Figure 3.2 shows our revised fault mapping for the eastern part of the Eastside area. Fault 2a has been removed. The deformation width around Fault 2b has been narrowed slightly from 40 m to 30 m after consideration of the topographic profiles we evaluated across this fault, and the northern extent of Fault 1 has been shortened slightly after closer examination of the lake shoreline/fault intersection.

3.2 Slip Rate and Recurrence Interval Calculations

3.2.1 Landform Age

To calculate a fault slip rate, it is necessary to know some information about the age of the surface that is offset by the fault. The main geological units in the Eastside area and their age are shown in Figure 3.2. Faults 1–3 mostly cross rhyolites generated from the Okataina Volcanic Centre between 523,000–128,000 years before present (Leonard et al. 2010). The mQ.rhy3 unit of Leonard et al. (2010) was subdivided in an earlier, more detailed geological map by Nairn (2002) and slightly narrower age ranges are given for units hr_1 and hk_2 (Figure 3.2). Fault 1 crosses Rotorua rhyolites (350,000–280,000 yrs) and Fault 3 crosses younger Kapenga rhyolites (180,000–60,000 yrs). The northern end of Fault 1 appears to cross lacustrine sediments in Figure 3.2 but the more detailed geological map of Nairn (2002) shows the northern end of Fault 1 at the contact between the lacustrine sediment and rhyolites (Figure A1.1). We use the geological unit ages presented in Figure 3.2 in our slip rate calculations. Both the oldest and youngest ages are used to capture the uncertainty range in age of each unit. Slip rates for the Opawhero fault were attained from offset tephra horizons exposed in a roadcut across the Opawhero fault (Villamor et al. 2011).

3.3 Slip Rate Calculation

The slip rate is calculated at multiple locations along each fault and the range reported incorporates the uncertainty in the offset measured and age range of the offset surface. Minimum and maximum slip rates are calculated using the maximum and minimum bounds on surface age respectively, while the preferred reported slip rate is the mean of the slip rates along each fault, calculated using the midpoint of the surface age range.

We have calculated slip rates for Faults 1, 2a, 2b, and 3 (Figure 3.2). Figure A1.2 shows the location of all points along the faults where the slip rate was calculated. The slip rates are shown in Table 3.1. Faults 1, 2 and 3 all have slip rates of 0.02 mm/yr.

The Opawhero fault has the sharpest topographic expression in the lidar, indicating it is the most active fault within the study area. At a roadcut along Tarawera Road, the soil on top of the Rotorua tephra (~15,700 years old) is offset 2.5 m at the fault line. Taking the age of the Rotorua tephra and the Waiohau tephra (~14,000 years old) that buried the Rotorua soil, we get a slip rate of 0.16–0.18 mm/yr.

Table 3.1 Slip rates for the Eastside area faults.

Fault name	Preferred slip rate (minimum – maximum)
Fault 1	0.02 (0.01–0.04) mm/yr
Fault 2b & 2c	0.02 (0.004–0.06) mm/yr
Fault 3	0.02 (0.01–0.08) mm/yr
Opawhero fault	0.16–0.18 mm/yr

3.4 Recurrence interval estimation

In parts of New Zealand where the active faults present as a single strand, it is possible to estimate an earthquake recurrence interval using the fault slip rate. In these cases, the single-event displacement is divided by the slip rate. This relationship is not suitable for use in the Taupo Volcanic Zone due to the characteristics of the faults, whereby most major faults have multiple strands at the surface which makes the definition of a slip rate and single event displacement difficult.

In this study, to constrain a first order value for RI of Fault 1, 2 and 3 in the Eastside area, we have searched the TVZ for faults that (1) have a similar slip rate to the Eastside area faults, and (2) have RI data derived from paleoseismic trenches. Only one equivalent fault could be found because most trench excavations in the TVZ have been conducted on the higher slip rate faults. The Hone trench on a strand of the Ngakuru fault shows a fault slip rate of 0.09 mm/yr and displacement of tephra layers within the trench show a recurrence interval of 8,300–12,500 years (Villamor, unpublished data).

This comparison suggests Faults 1, 2 and 3 of the Eastside area would all have RIs of at least 5000 years. This comparison is only possible because the Eastside area faults are more isolated from other faults compared to the faults in the area of the Hone trench site. The fault where Hone trench is located is in proximity to faults that have higher slip rates and in such a setting the low-slip fault traces could have recurrence intervals similar to the nearby faster slipping faults (i.e. the low-slip faults rupture together with the fast-slip faults), or the low slip faults can have long recurrence intervals (such as at the Hone trench). In the Eastside area, faults are more isolated, and all seem to be of low slip rate, and thus we do not expect a large variability in recurrence interval as they will not interact with nearby higher-slip faults. It is therefore appropriate to use information from the Hone trench to derive an approximate recurrence interval for the low slip-rate faults in the Eastside area.

To cross-check the RI of Faults 1, 2 and 3, we can compare the offset and non-offset landforms across Fault 1. Fault 1 offsets Rotorua rhyolites in the south but at its northern end, the fault projects northward into lacustrine sediment. The lacustrine sediment is not offset by the fault so the last surface-rupturing earthquake on Fault 1 must have been prior to deposition of the lacustrine sediment. The lacustrine sediment is dated by Leonard et al. (2010) at 60,000–19,000 years, but in this particular location the lacustrine sediment lies between the 240,000–220,000-year lake shoreline and the ~60,000 year lake shoreline (Figure 3.3, Marx et al. 2009). This means the lacustrine sediment has a maximum age of 240,0000 and a minimum age of ~60,000 years. Taking the youngest possible age for the lacustrine sediment, we see that Fault 1 has not offset a landform that is ~60,000 years.

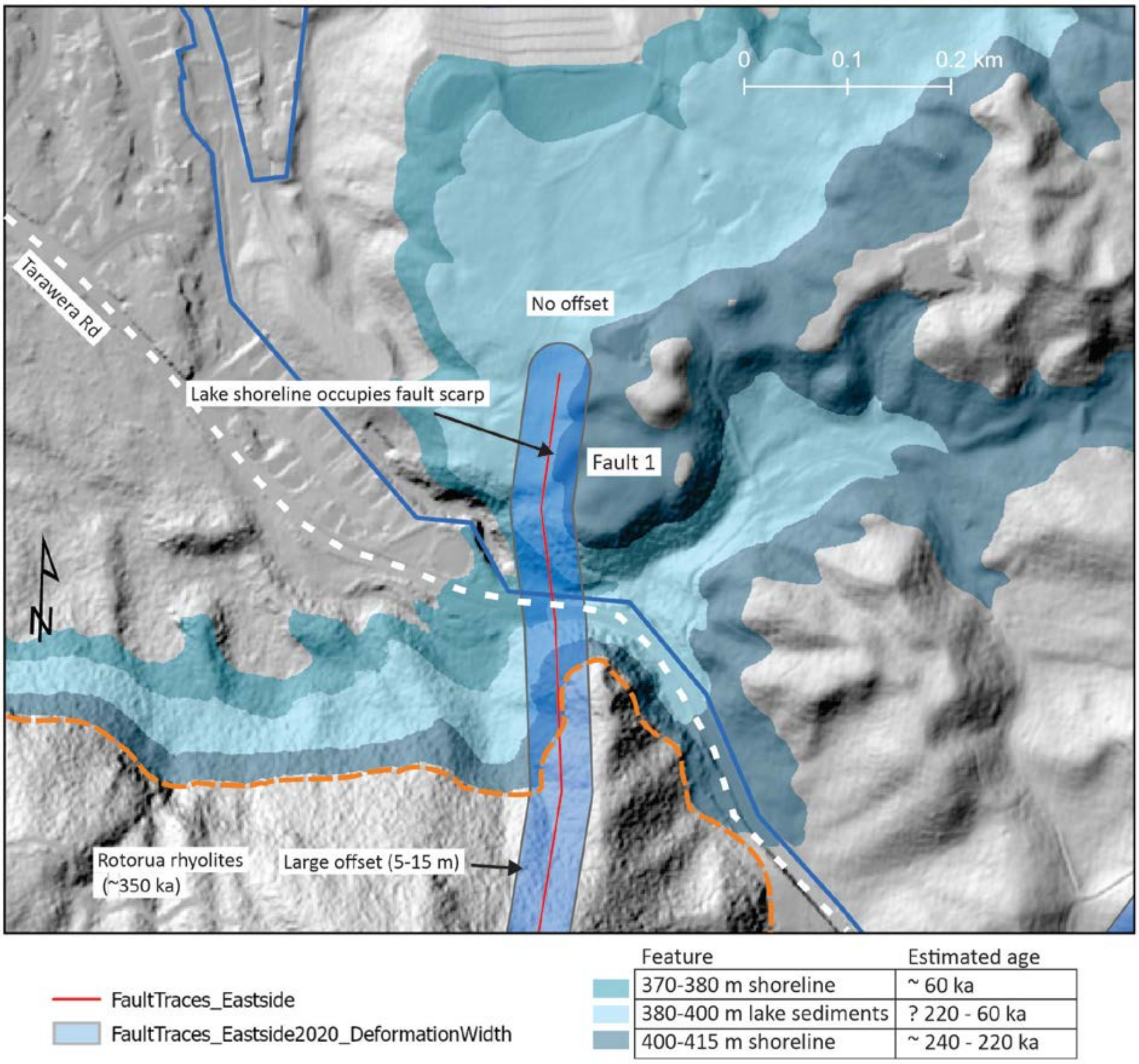


Figure 3.3 Past lake shorelines and their ages, and relationships to the offsets on Fault 1. Lake shoreline ages and elevations from Marx et al. (2009).

3.5 Recurrence Interval Classes

Following the MfE Guidelines, we assign Faults 1, 2b, 2c and 3 to RI Class IV (Figure 3.4, Table 3.2), and the Opawhero fault is assigned to RI Class II.

Faults 1, 2 and 3 have a slightly lower slip rate than the Ngakuru fault strand at the Hone trench site. The minimum RI for the Ngakuru fault is 8300 years, therefore this RI is within the RI range of >5000 to ≤10,000 years for Class IV faults. We place faults 1, 2 and 3 within the same RI Class of IV. Fault 1 appears to have not ruptured in the last ≥60,000 years and could possibly be within RI Class V or VI. However, to enable Building Importance Category (BIC) 3 constrictions (important structures) or BIC 4 constructions (critical structures with special post disaster functions), as are allowed on RI Class V and VI faults, we recommend a higher level of fault investigation is undertaken to better define the location and recurrence interval of these faults.

The Opawhero fault has a slip rate of 0.16–0.18 mm/yr and there is 2.5 m of fault displacement on the post-Rotorua (<15,700 years) tephra sequence. Using established relationships between fault length, displacement, slip rate and recurrence interval (from Stirling et al. 2012), we calculate a recurrence interval of 2930–3150 years for the Opahwero fault (assuming a fault length of 8 km, which is slightly longer than the surface trace of 6 km). A recurrence interval of ~3000 years places the Opawhero fault within RI Class II (>2000 years to ≤3500 years, Table 3.2). There is a possibility that the RI of the Opawhero fault is longer if the size of the fault has been underestimated (i.e. its length or depth) or the single-event displacement is underestimated, so we recommend that if development within the fault avoidance zone of the Opawhero fault cannot be avoided, then a more detailed study of the RI be undertaken in the form of paleoseismic trench excavations. The roadcut across the Opwhero fault on Tarawera Road only shows total displacement at the top of the Rotorua tephra and the details of single-event displacements post-15,700 years cannot be determined from the road outcrop.

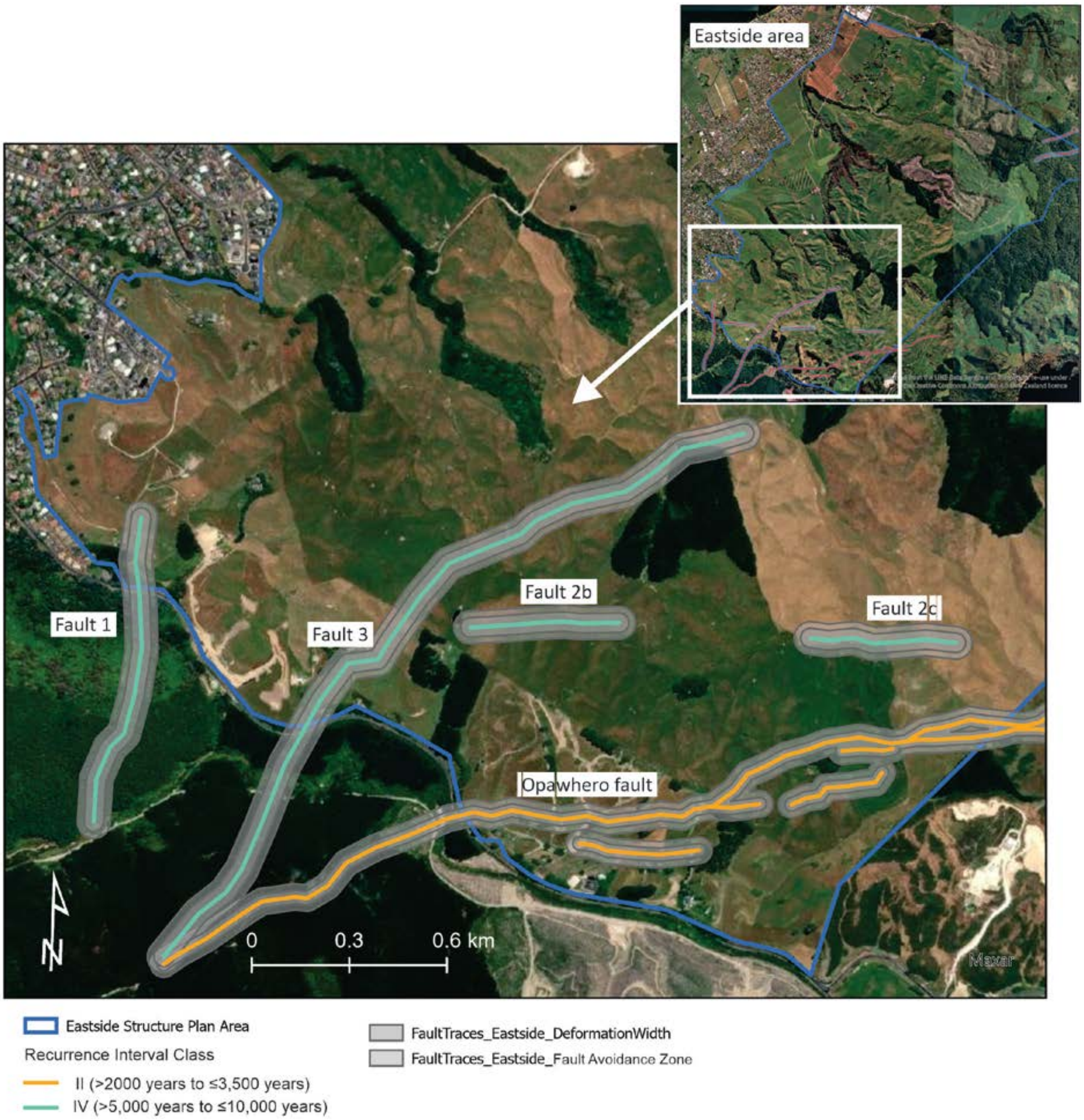


Figure 3.4 Revised fault mapping and Recurrence Interval classification of the Eastside area faults.

Table 3.2 Relationship between fault recurrence interval (RI) and Building Importance Category (BIC) (Source: Kerr et al. 2003), and the classification of the Eastside area faults.

<table>
<tr><th rowspan="2">Recurrence Interval Class</th><th rowspan="2">Fault Recurrence Interval</th><th colspan="2">Building Importance Category Limitations (Allowable Buildings)</th><th rowspan="2">Eastside area faults</th></tr>
<tr><th>Previously Subdivided or Developed Sites</th><th>‘Greenfield’ Sites</th></tr>
<tr><td>I</td><td>≤2000 years</td><td>BIC 1</td><td rowspan="2">BIC 1</td><td></td></tr>
<tr><td>II</td><td>>2000 years to ≤3500 years</td><td>BIC 1 and 2a</td><td>Opawhero Fault</td></tr>
<tr><td>III</td><td>>3500 years to ≤5000 years</td><td>BIC 1, 2a and 2b</td><td>BIC 1 and 2a</td><td></td></tr>
<tr><td>IV</td><td>>5000 years to ≤10,000 years</td><td rowspan="2">BIC 1, 2a, 2b and 3</td><td>BIC 1, 2a and 2b</td><td>Faults 1, 2b, 2c, 3</td></tr>
<tr><td>V</td><td>>10,000 years to ≤20,000 years</td><td>BIC 1, 2a, 2b and 3</td><td></td></tr>
<tr><td>VI</td><td>>20,000 years to ≤125,000 years</td><td colspan="2">BIC 1, 2a, 2b, 3 and 4</td><td></td></tr>
</table>

4.0 SUMMARY

The active faults of the southwestern corner of the Eastside area have been re-evaluated after field investigations and a more detailed study of the recurrence intervals of the faults. One fault has been removed after it was shown to more likely be a debris flow margin than an active fault. The remainder of the faults have been assigned an RI Class of II (Opahwero fault) or IV (Faults 1, 2 and 3). According to the MfE Guideline, residential development can be permitted on RI Class IV faults as the risk of fault displacement is low. This remains a largely desktop study and should the forecasted land use change in the future and the development of higher importance building be under consideration, we recommend revisiting the fault recurrence interval classifications.

Yours sincerely,

Kate Clark
Earthquake Geologist

Genevieve Coffey
Earthquake Geologist

Brad Scott
Volcanologist

5.0 ACKOWLEDGEMENTS

We thank Pilar Villamor for her advice and peer-review of this report.

6.0 REFERENCES

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APPENDIX 1 ADDITIONAL MAPS

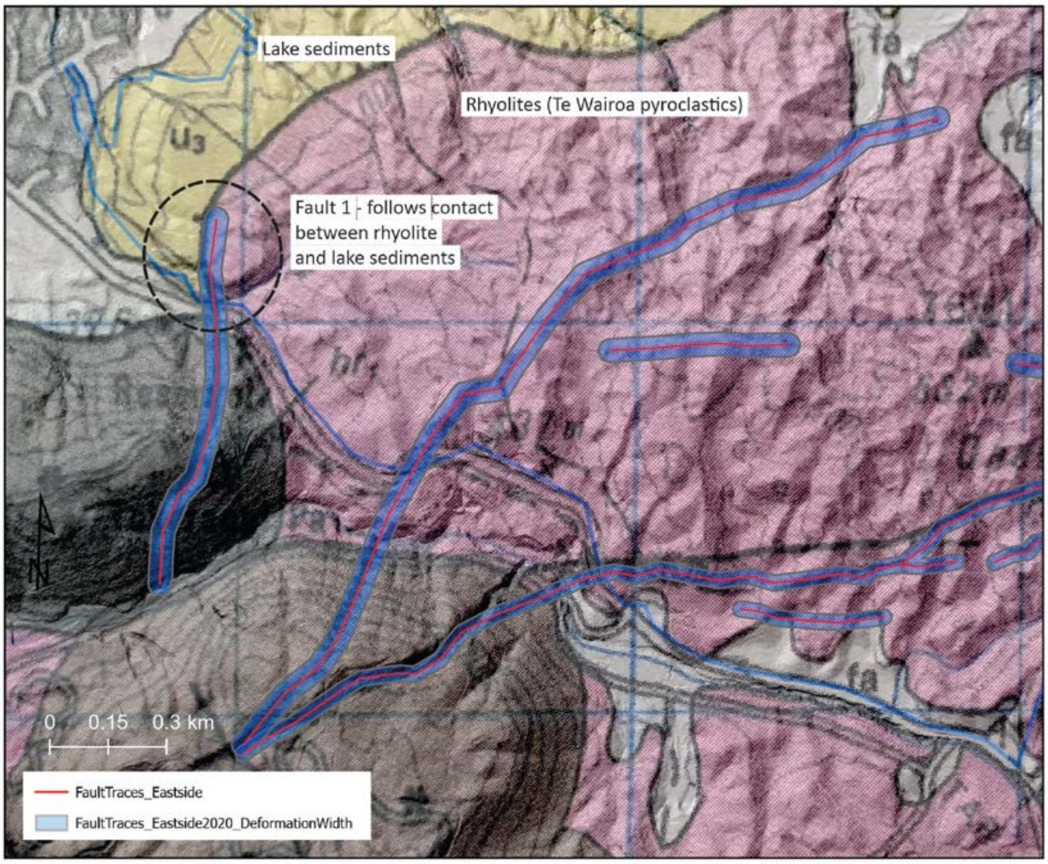

Figure A1.1 Geological map by Nairn (2002) showing the location of Fault 1 at the contact between rhyolites and lake sediments.

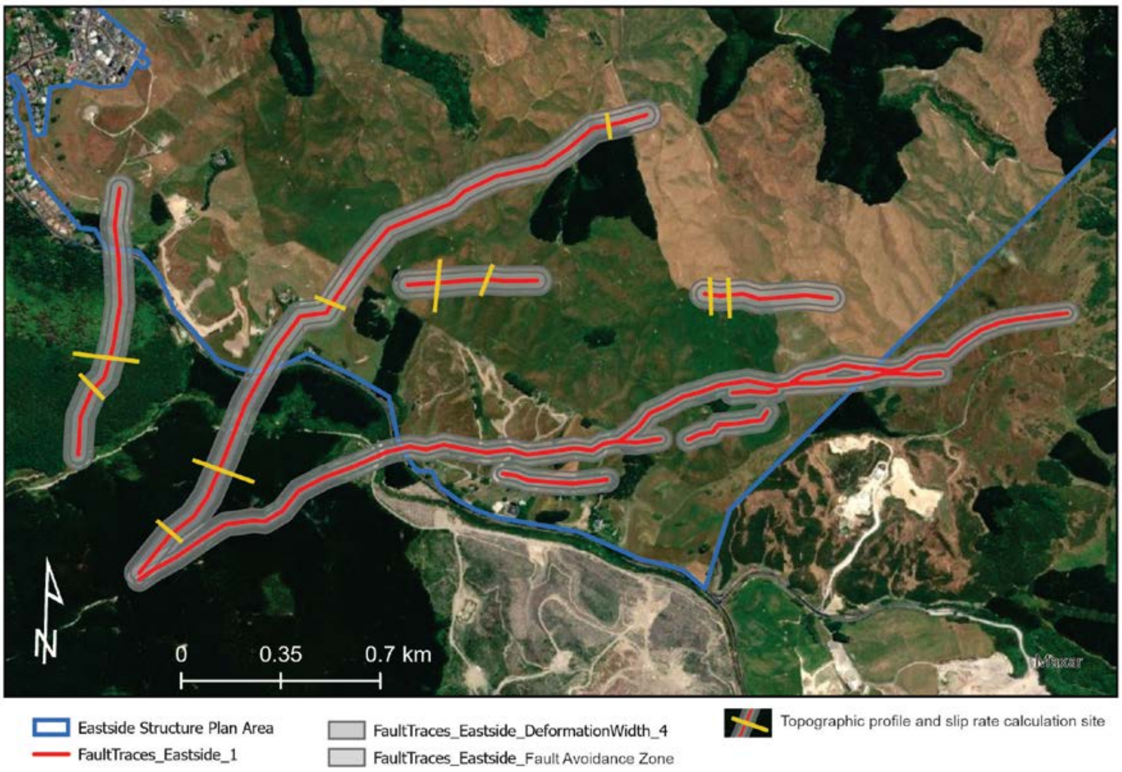

Figure A1.2 Locations of topographic profiles used to calculate fault slip rates.