Before the Independent Commissioner Hearing Panel

Under	the Resource Management Act 1991 (**RMA**)
In the matter of	an application by **Dunedin City Council** to develop a landfill at Smooth Hill, Dunedin.

Statement of evidence of Mark Stirling

29 April 2022

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Qualifications and experience

1 My name is Mark Stirling. I am the Professor and Chair of Earthquake Science at the University of Otago and have a PhD in earthquake science.

2 I am a seismologist with a multidisciplinary background in geology and seismology, and specialise in the integration of geological, seismological and geodetic datasets for seismotectonic and seismic hazard modelling. I have led the development of the last three versions of the national seismic hazard model for New Zealand and have led research and field studies around the country including numerous studies in the Dunedin and wider Otago region.

3 I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note 2014. This evidence has been prepared in accordance with the code, and I agree to comply with it. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

Scope of evidence

4 I have been asked to respond to a number of submitters regarding the seismotectonic setting of the site. Submitters' comments are summarised below. I have also provided the latest information on the site setting to allow Samantha Webb to update her geotechnical analysis.

Submitters

5 The following submitters commented on the seismotectonic setting of the site including:

(a) Brighton Surf Lifesaving Club, R Aburn;

(b) Hutchinson;

(c) S & B Judd;

(d) Otokia Creek and Marsh Habitat Trust;

(e) Saddle Hill Community Board;

(f) K Schneider; and

(g) South Coast Neighbourhood Society Inc (SCNS).

6 In summary, submitters noted:

(a) the presence of the nearby Akatore Fault and the potential impact on the site;

(b) the need for a site-specific seismic hazard assessment; and

(c) the potential impact of fault rupture beneath the site on the landfill construction and linear integrity.

7 The following sections address these various submissions.

(a) Neotectonics and Seismic Hazard; and

(b) Regional neotectonics.

8 The site is located near the eastern edge of the deforming zone of the boundary of the Pacific and Australian plates. The principal element of the plate boundary is the Alpine Fault, which accommodates 60–70% of the transpressional (compressional and translational) motion across the plate boundary (e.g. Norris and Cooper 2001).

9 The remaining plate motion is primarily distributed to the east of the Alpine Fault, in a 200 km wide area which includes the entire Otago region (e.g. Norris 2004). Several mm/yr of the contractional plate motion is accommodated east of the Alpine Fault, leading to the development of the reverse fault-bounded ranges of the Otago Range and Basin region (Taylor-Silva et al. 2020).

10 The Otago faults tend to have lengths of about 40–80 km, and are usually steeply dipping where observed. They have vertically displaced Tertiary sediments and the underlying Waipounamu Erosion surface (Landis et al. 2008). This erosion surface is a sub-horizontal regional unconformity between Mesozoic basement schist and is overlain by diachronous Cretaceous to Tertiary marine, fluvial and lacustrine sediments (Landis et al. 2008).

Neotectonics of the Smooth Hill area

11 The Smooth Hill site is located within the easternmost uplifted range of the Otago Range and Basin region. The range is less than 10 km wide, and forms the hill country between the Taieri Basin and the Brighton coast. It is bounded to the northwest by the east dipping, active, Titri Fault, and to the southeast (and offshore) by the east dipping, active, Akatore Fault (Figure. 1).

12 The range has been uplifted and tilted southeast by the Titri Fault. The relatively smooth backslope of the range, including the Smooth Hill site, can be attributed to the Waipounamu erosion surface, which is a Cretaceous-age surface of low relief cut into the basement Haast Schist (Fig. 2). The site is underlain by a veneer of late Cretaceous Henley Breccia, which rests conformably on the erosion surface (Bishop et al. 1996).

13 The site is at close distances (less than 10 km) to both the Titri and Akatore Faults. The faults have been the foci of paleoseismic investigations in the last six years (Taylor Silva et al. 2020; Barrell et al. 2020). The Titri Fault has been shown to have produced two ground rupturing earthquakes in the last 42,000 years (Barrell et al. 2020), and the Akatore Fault has shown more pronounced activity. Specifically, the last three earthquake timings are as follows (Taylor-Silva et al. 2020):

(a) between 13,314 B.C. and 680 A.D. (antepenultimate event);

(b) between 737 and 960 A.D. (penultimate event); and

(c) between 1047 and 1278 A.D (most recent event).

Ground motion hazards

14 An earthquake on the Titri or Akatore faults would produce strong ground motions at the site. The site is less than 10 km from the two faults, which can be regarded as "near field" in the context of ground motions. Ground motion models (GMMs, formerly known as ground motion prediction equations and attenuation relations) show that ground motions decrease with increasing distance from source to site, but the maximum motions generally show little change over distances of less than about 10 km. What this means is that in the context of ground motions the strength of shaking will be just as strong at 10 km distance as at zero distance. For Akatore Fault earthquakes the strength of shaking from the latest GMMs can be estimated at about 0.5 g (median estimate) and about 0.8 g (median + 1 sigma). Titri Fault earthquakes would be expected to produce about 0.6 g (median) and about 1 g (median + 1 sigma). The units 'g' are units of acceleration, in that 1 g = 10 metres per second squared.

15 These estimates are based on an ensemble of the latest GMMs, and assume typical rock ground conditions for the site (Vs30=760 m/s). The estimates also assume approximate fault-to-site distances of 5km for the Akatore Fault, and 2 km for the Titri Fault. The difference in ground motions for the two faults is due to the site being in the hanging wall of the Titri Fault (i.e. the fault dip is in the direction of the site), and also through being closer to that fault. Hanging wall sites have been shown to experience consistently

higher motions than footwall sites (e.g. Abrahamson and Somerville, 1996). Therefore, in the context of scenario (deterministic) hazards, the Titri Fault is the more hazardous of the two faults.

16 In the context of probabilistic seismic hazard, the Akatore Fault will be the most hazardous active fault for the site. The occurrence of three ground rupturing earthquakes in latest Quaternary times on the fault means that the recurrence interval (average time between earthquakes) is less than 5000 years. This is considerably shorter than the typical recurrence intervals for Otago faults, which are in the range of 10 – 20,000 years (e.g. Griffin et al. 2022).

17 Based on my evidence Samantha Webb has assumed that the Akatore Fault will be the most hazardous fault for the site, and has used the Akatore scenario median peak ground acceleration (PGA) of 0.5 g to illustrate the levels of shaking that could be produced by the fault. However, only a comprehensive probabilistic seismic hazard analysis (PSHA) will determine the hazard at the site with any degree of confidence, together with the relative contributions to hazard from the individual faults. I therefore agree with the draft conditions of consent, which require a PSHA to be conducted for the site as part of the detail design process. I am confident that the PSHA will show the Akatore Fault to be the dominant contributor to seismic hazard at hazard levels greater than that of the 10% in 50 years (475 year return period) level used in the NZ Loadings Standard ("the Code").

Fault displacement hazards

18 I note one of the submitters expressed concern about fault displacement occurring beneath the landfill site, and can address this concern in a straightforward way. First, no known active faults are mapped through the footprint of the site. The Titri and Akatore faults lie approximately 5 km to the northwest and southeast of the site, respectively. While the possibility exists that unknown, potentially active faults might be present at the site, the lack of any observable vertical displacement of the low relief, Cretaceous-age Waipounamu erosion surface across the site is not supportive of that possibility (Fig. 2). This means that no appreciable displacement has occurred in the vicinity of the site in over 65 million years. In my opinion the likelihood of direct fault displacement at the site must be extremely low.

References

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Figures

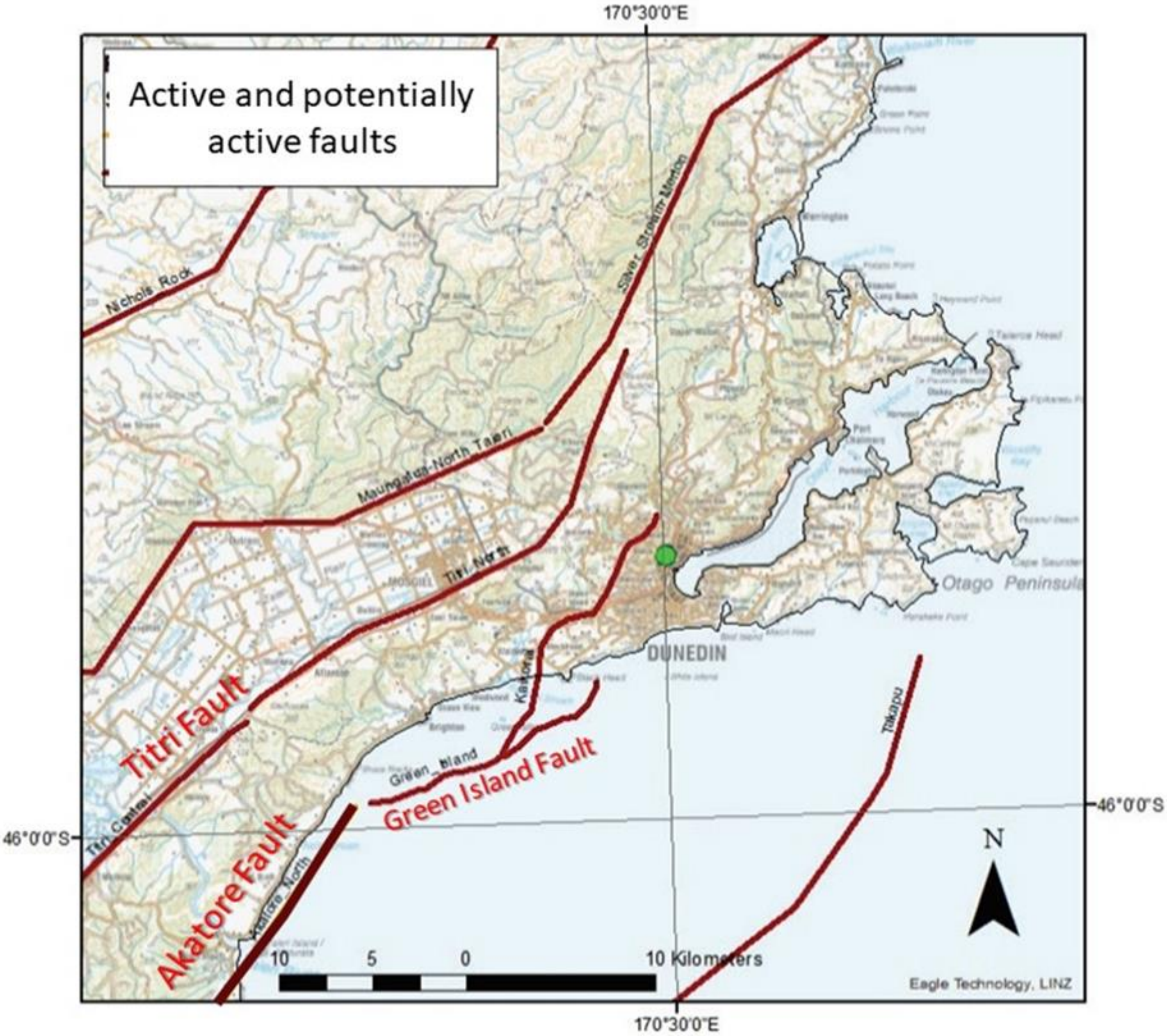

Figure 1: Active and potentially active faults of the Dunedin area. The Titri and Akatore Faults are clearly labelled, and the possible Green Island Fault extension to the latter is also labelled. The map is adapted from Fig. E1 of Villamor et al (2015).

Figure 2: View southwest from Signal Hill Dunedin, showing the gently sloping Waipounamu Erosion Surface in the vicinity of the Smooth Hill site. Also shown is the clear vertical displacement of the surface at the location of the Akatore Fault.

Mark Stirling

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