Using citizen data to understand earthquake impacts: Aotearoa New Zealand's earthquake Felt Reports

Tatiana Goded[1],
Marion L. Tan[2],
Julia S. Becker[2],
Nick Horspool[1],
Silvia Canessa[1],*
Rand Huso[1],
Jonathan Hanson[1],
David M. Johnston[2].

[1] GNS Science, Lower Hutt, New Zealand.

[2] Joint Centre for Disaster Research, Massey University, Wellington, New Zealand.

* Former GNS Science staff.

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Author correspondence:
Tatiana Goded
GNS Science
1 Fairway Drive
Avalon
Lower Hutt 5011
New Zealand.
Email: t.goded@gns.cri.nz

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Abstract

Aotearoa New Zealand's national seismic network, GeoNet, administers Felt Reports, including the Felt RAPID and Felt Detailed databases, which are being collected at present. NZ has a long tradition of using earthquake Felt Reports provided by the public to analyse the damage caused by moderate to large earthquakes. From traditional paper-based Felt Reports to current online reports (using the GeoNet website or a mobile app), researchers have been using such data to obtain a geographical distribution of the damage caused by an earthquake and to assess what actions people take during shaking. Felt Reports include questions on people's reactions, indoor and outdoor effects of earthquake shaking, building damage, and tsunami evacuation. The database of long online Felt Reports (Felt Classic between 2004 and 2016 and Felt Detailed from 2016 to the present) comprises over 930,000 reports from more than 30,000 earthquakes. Current research being carried out using this data includes: 1) updating of the NZ Ground Motion to Intensity Conversion Equation and Intensity Prediction Equation, 2) understanding human behaviour for earthquakes and related hazards such as tsunami, 3) developing a predictive model of human behaviour in earthquakes to estimate injuries and fatalities, and 4) improving public education. This paper summarises the history of NZ earthquake Felt Reports as well as the research currently being carried out using this data. Finally, we discuss how citizen science helps in the understanding of earthquake impacts and contributes to the aim of improving Aotearoa New Zealand's resilience to future events.

Keywords: *New Zealand, Felt Reports, citizen science, macroseismic intensity*

The term "citizen science" applies to the participation of the public in collection and analysis of data for scientific studies. It is sometimes referred to by other terms, including community science, participatory assessment, community-based monitoring, and volunteer monitoring (Shirk et al., 2012). Data contributed by the public is beneficial as it can fill gaps in data that arise from having limited technical networks (Fehri et al., 2020) and provide additional complementary information. Citizen science has often contributed to studies in biology and environmental science (Bonney et al., 2009), but has also been applied to other areas including natural hazard and climate change.

The public participate in earthquake science when they contribute to reporting, collecting, and analysing individual or community experiences of earthquakes (Allen, 2012). For example, an initiative involving citizen science in Aotearoa New Zealand (NZ) surveyed members of the public on how they responded and evacuated during the Kaikōura earthquake in 2016 (Blake et al., 2018). Using the results, the authors argued the need to enhance community capacity in responding appropriately to earthquake-related hazards. The public can also contribute through providing details of their experience of an earthquake through submitting *Felt Reports*. Felt Reports come in many forms, from historical paper-based Felt Reports to the more modern online questionnaires and thumbnail-based surveys. With modern technology, citizens can now rapidly contribute their near-real-time experience of earthquakes through web or app platforms. Examples of these rapid citizen-reporting platforms include the United States

Geological Survey's (USGS) *Did You Feel It?* (DYFI) system (Quitoriano & Wald, 2020), the European-Mediterranean Seismological Centre's LastQuake app (Steed et al., 2019), and GNS Science's GeoNet system (Lane et al., 2020). As platforms that collect Felt Reports from the public are crowdsourcing data, they can be considered a form of citizen science (Haklay, 2013).

In this paper, we focus on the Felt Reports submitted in NZ, in particular the long-form reports. First, to set the context, we discuss seismic intensity and Felt Reports, then Felt Reports as citizen science and their contributions to society. We then summarise past and present Felt Report initiatives in NZ. Finally, we discuss the current research trends in using Felt Reports and their benefits for understanding NZ earthquakes.

Seismic Intensity and Felt Reports

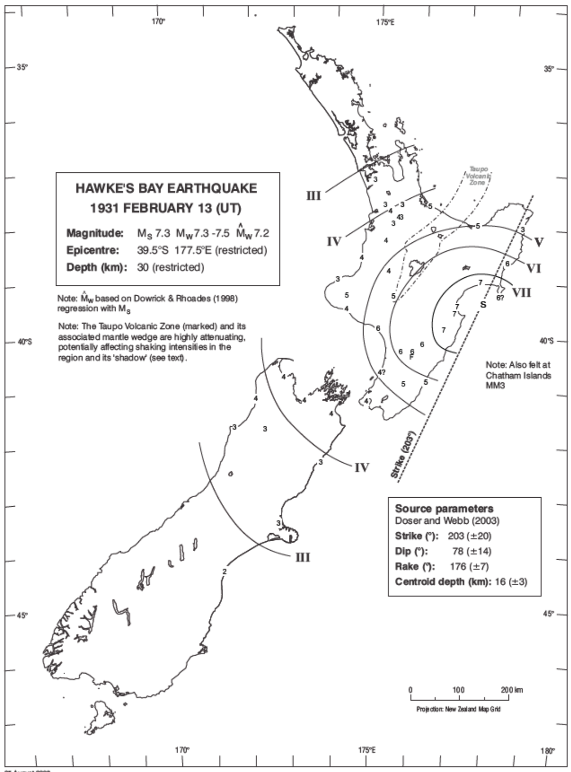
Seismic intensity has been traditionally used worldwide to quantify the extent of the damage caused by an earthquake. Intensities provide a simple representation of the complexity of the ground motion and the extent and nature of the damage (Wald et al., 1999a). When communicating about earthquakes, magnitude and macroseismic intensity can be commonly interchanged and misunderstood by the public (Celsi et al., 2005). Citizens' participation in Felt Reports helps educate the public on the difference between magnitude and macroseismic intensity (Celsi et al., 2005). An earthquake magnitude is a measure of the energy released by the earthquake, which is a unique value for each event. In comparison, earthquake intensity measures the level of shaking at any given location. A single earthquake event can therefore have a large range of intensities: higher intensities for locations closer to the epicentre and decreasing intensities as the epicentral distance increases. Intensities can also considerably vary depending on the soil conditions.

In the past, intensities were assigned after gathering data from fieldwork, an arduous task that could take weeks or months to be finalised. At present, Internet-based macroseismic surveys such as Felt Reports are the most popular means for the public to contribute, and substantial reports have become available from these worldwide. These Internet-based surveys have been implemented in the last 15 years by several international seismological institutions (see Goded et al., 2018). The most popular one is the USGS's DYFI project (Wald et al., 1999a) which is being used worldwide, with more than 5 million Felt Reports since 1999 (Quitoriano & Wald, 2020).

The measured intensity depends on people's perceptions of the severity of earthquake shaking, as well as the effects on objects and on the landscape, together with building damage. Intensity estimates have been provided with the use of macroseismic intensity scales. In NZ, the NZ version of the Modified Mercalli intensity scale (Dowrick, 1996; Dowrick et al., 2008) is currently used. This scale ranges from 1 to 11, in increasing order of shaking level (and thus damage; Dowrick et al., 2008). Macroseismic intensity has become an important metric for communicating hazard and risks (Becker et al., 2018, 2020), with the usefulness of intensity data widely acknowledged (e.g., Boatwright & Phillips, 2017; Hough, 2014; Quitoriano & Wald, 2020; Tosi et al., 2015; Wald et al., 2011; Worden et al., 2012). Intensity data are commonly communicated using maps (see Figure 1 for an example). An intensity map, based on accurate intensity estimations, could provide a good understanding of the geographical damage distribution following an earthquake. These maps help decision makers decide on intervention priorities. Intensity maps are also of great interest to the public, to understand which areas have been most affected and to guide their decision-making (Becker et al., 2019, 2020).

Figure 1

Example of an Intensity/Isoseismal Map for New Zealand, corresponding to the Ms7.3 13/2/1931 Hawke's Bay Earthquake



Note. Figure from Downes and Dowrick (2014).

Seismic strong-motion coverage may be insufficient to provide comprehensive maps of shaking levels. For example, in NZ, there are approximately 325 strong-motion stations (SMS) distributed around the country. To provide an intensity measure of the shaking level following an earthquake, accurate values are estimated near the SMS (using a ground motion to intensity conversion equation, GMICE); however, far away from the SMS, intensities will be based on attenuation equations, increasing the uncertainty. Felt Reports thus have an immense value as they can be used to fill gaps, with institutions often receiving thousands of reports from citizens after large events. As an example, after the Mw7.0 4 September 2010 Darfield earthquake, GeoNet (NZ's national geological hazards monitoring service at GNS Science, http://www.geonet.org.nz/) received 7,564 Felt Reports within the *Felt Classic* database (described below). Thumbnail-based reports, where the public chooses from a set of cartoons depicting different levels of shaking intensity, are even more numerous and faster to receive; for example, around 58,000 were received for a recent event, a magnitude M7.3 earthquake in Te Araroa, off the East Coast, which occurred on 5 March 2021.

Intensities are not only used to produce shaking intensity maps. Intensity datasets derived from Felt Reports are used to develop the relationship between magnitude and intensity (used for historical earthquakes), between magnitude, source distance, and intensity (called intensity attenuation relations or intensity prediction equations, IPE), and between ground-motion data (e.g., acceleration or velocity) and intensities (GMICEs). These relationships are commonly used in hazard and risk tools such as ShakeMap (e.g., Horspool et al., 2015; Wald et al., 1999b) or RiskScape (King et al., 2009).

Felt Reports and Citizen Science

As well as the benefits from gathering shaking data itself, the contribution of such data has additional social benefits. Citizen science projects vary widely, with some projects designed and coordinated by scientists with citizens contributing passively or actively through data collection or analysis (e.g., crowdsourced projects with "citizens as sensors"; Haklay, 2013). For example, there are projects around the world where citizens collect weather data (e.g., rainfall, snow, hail) to send to their relevant meteorological agency (Shuttleworth, 2021). At the "extreme" end of citizen science, the citizens themselves can drive projects, and they are involved in the project design, data collection, and analysis (Haklay, 2013). An example comes from a project in the Congo which aimed to tackle illegal logging and improve environmental management (Stevens et al., 2014). A data collection tool for monitoring appropriate to the local context was developed by locals including Pygmy hunter-gatherers, other indigenous communities, and a local non-governmental organization. In between these two extremes, there are varying degrees of participation and collaboration between scientists and citizens, leading to a range of different types of projects (Bonney et al., 2009; Haklay, 2013; Shirk et al., 2012). Wherever the project sits within the spectrum, citizen science can play a role in creating new scientific outputs and outcomes.

In terms of typologies of citizen science, Felt Reports fall more toward the contributory and crowdsourcing definitions, whereby citizens act as sensors and participation is through contributing data. Citizens' participation in science, through Felt Reports, not only improves understanding of earthquakes, but it also provides understanding of human behaviour and social impacts. Casey et al. (2018) explained how DYFI provides emotional support to people who have just had a traumatic experience from feeling a large earthquake. Data from citizens also helps us to understand people's behaviour during earthquakes. For example, Goltz et al. (2020a) studied data from eight earthquakes around the world, including the M_w6.2 22nd of February 2011 Christchurch, NZ, earthquake. They concluded that flight from buildings is still a prevalent action during a damaging earthquake, even in countries such as NZ where the "drop, cover, and hold" action is recommended. Even though the NZ MMI scale (Dowrick, 1996; Dowrick et al., 2008) does include some public reactions at all intensity levels, it could still be greatly improved by adding more information based on social science studies on human behaviour following large events. As an example, at MMI 6 the scale mentions "people and animals alarmed" and at MMI 8 that "alarm may approach panic", with no description of a typical human response at those intensity levels. There is much room to understand public reactions and to improve communication of desirable response actions to hazards at different intensity levels (Dowrick, 1996; Dowrick et al., 2008).

Felt Reports also perform a role related to the sharing of knowledge on earthquakes (Hicks et al., 2019). The online Felt Report platforms often also allow for the rapid release of information to the public, and the data can be used to enhance earthquake detection and warning systems (Finazzi, 2020). Other benefits of engaging citizens in felt reporting include relationship building (emerging from engagement between trained scientists and citizens), capacity building of the public to collect and interpret data, assisting with helping people make sense of what has happened following earthquake events, and developing community resilience (Becker et al., 2019; Wein et al., 2016). People's engagement in earthquake science will ultimately improve their understanding of the phenomenon, and likely lead to them taking more notice of actions that help with earthquake preparedness, response, and recovery.

New Zealand Historical Felt Reports

The first recorded earthquakes are based on the rich Māori oral tradition, grounded in their extended occupation of Aotearoa NZ and utilisation of its natural resources (King et al., 2007). In the late 1860s, a network of human observers was set up by Sir James Hector (Nathan, 2015). Whenever a "Reporter Network" member experienced an earthquake, they posted an A5-sized survey form to the New Zealand Institute, founded in 1867 (now named the Royal Society of New Zealand – Te Aparangi). These early records are stored in James Hector's personal correspondence at Te Papa Tongarewa Museum (Wellington). These felt observations were later addressed to the New Zealand Geological Survey and, following its founding in 1926, to the NZ Government's Department of Scientific and Industrial Research (DSIR). The collection also includes collated letters, newspaper cuttings, and other first-hand, primary observations of earthquake intensity.

GNS Science is a Crown Research Institute (in existence since 1992) operating on behalf of the NZ government to deliver geoscience research and societal benefits across a wide range of themes, including natural hazards and risk. GNS Science can trace its lineage back to the NZ Geological Survey (founded in 1865) and maintains a collection of Felt Reports that are a unique historical record of NZ's earliest recorded earthquakes and destructive geohazard events. The Felt Report database is the only known collection of these original records in existence in NZ and is therefore extremely valuable due to our relatively short history of human occupation and by allowing the extension of the known earthquake catalogue to a pre-instrumental time with approximate epicentres and magnitudes. Derived epicentres and magnitudes from 1901 to 1993 have survived (Viskovic et al., 2020).

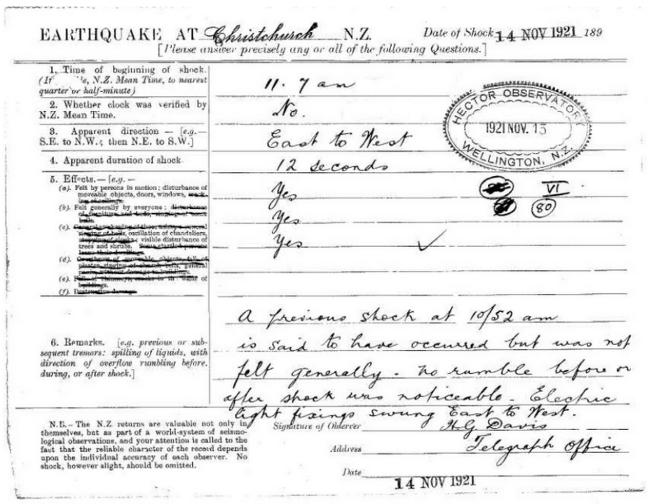
GNS Science holds over 87,000 unique historical paper-based Felt Report records from the 1870s to 1993, of which those from 1901 to 1932 have been digitally scanned (14,000 records). Unfortunately, the Felt Reports for the period of 1993 until 2004, when the Reporter Network was disbanded, are completely lost, both paper and digital copies (Viskovic et al., 2020). An example of an historical Felt Report is provided in Figure 2.

New Zealand Online Felt Reports (Felt RAPID, Felt Classic, and Felt Detailed)

From 2004, GeoNet has had three types of online questionnaires: *Felt Classic* (FC: GNS Science, 2004), *Felt Detailed* (FD: GNS Science, 2016), and *Felt RAPID* (FR: GNS Science, 2015). FC and FD are long questionnaires of around 40 questions each. FD succeeded FC, while FR is an independent survey. FC questionnaires were operative between October 2004 and August 2016. During this period, GeoNet received more than 856,000 Felt Reports from the catalogue of 267,478 different earthquakes during that period. The FC questionnaire was similar to the traditional version that had been used for the decades prior to 2004 (e.g., Downes & Dowrick, 2014). From August 2016, two different surveys have been conducted via the GeoNet website: FD and FR.

FD (provided in Appendix 1) is GeoNet's newest questionnaire, with similar questions and answers to FC plus some additional questions related to tsunami evacuation and social science. FD consists of 40 questions divided into 10 sections: 1) General questions on the earthquake, 2) Earthquake experience, 3) Earthquake effects, 4) Building information, 5) Building damage effects, 6) Neighbourhood effects, 7) Tsunami evacuation, 8) Tsunami information, 9) Information about earthquakes, and 10) Demographic information (see

Figure 2
Example of a Paper Felt Report Corresponding to a Christchurch Earthquake from 1921


EARTHQUAKE AT Christchurch N.Z. Date of Shock 14 NOV 1921 189
[Please answer precisely any or all of the following Questions.]

1. Time of beginning of shock. (If [illegible], N.Z. Mean Time, to nearest quarter or half-minute) — 11. 7 am
2. Whether clock was verified by N.Z. Mean Time. — No.
3. Apparent direction — [e.g.—S.E. to N.W.; then N.E. to S.W.] — East to West
4. Apparent duration of shock — 12 seconds
5. Effects.—[e.g.—
(a). Felt by persons in motion; disturbance of moveable objects, doors, windows, ~~cracking of ceilings~~. — Yes
(b). Felt generally by everyone; ~~disturbance of furniture and beds, ringing of some bells~~. — Yes
(c). ~~General awakening of those asleep, general ringing of bells~~, oscillation of chandeliers, ~~stopping of clocks~~; visible disturbance of trees and shrubs. ~~Some startled persons leave their dwellings~~. — Yes ✓
(d). [illegible]
(e). [illegible]
(f). [illegible]

HECTOR OBSERVATORY 1921 NOV. 15 WELLINGTON, N.Z.
VI
80

6. Remarks. [e.g. previous or subsequent tremors: spilling of liquids, with direction of overflow rumbling before, during, or after shock.] — A previous shock at 10/52 am is said to have occurred but was not felt generally. No rumble before or after shock was noticeable. Electric light fixings swung East to West.

N.B.—The N.Z. returns are valuable not only in themselves, but as part of a world-system of seismological observations, and your attention is called to the fact that the reliable character of the record depends upon the individual accuracy of each observer. No shock, however slight, should be omitted.

Signature of Observer H.G. Davis
Address Telegraph Office
Date 14 NOV 1921

Appendix 1 for the complete FD questionnaire). The FD questionnaire also has a considerable number of extra questions compared to the USGS DYFI survey, including: 1) more detailed options around people's behaviour (see further discussion in the human behaviour section below), 2) questions around the type of building, 3) questions around damage effects in the neighbourhood, and 4) questions around potential tsunami evacuation. FD currently has 12,160 Felt Reports from a total of 98,667 catalogued earthquakes (up to 14 September 2020).

Table 1
Correspondence Between Felt RAPID and MMI Assignments

Felt RAPID description	MMI level
Weak shaking	3
Light shaking	4
Moderate shaking	5
Strong shaking	6
Severe shaking	7
Extreme shaking	>=8

FR (Table 1 and Appendix 2) is a questionnaire available on Internet-capable and mobile devices where the person contributing their response chooses from a set of six cartoons (each corresponding to a different intensity level; Appendix 2) depicting their experience of the earthquake (GNS Science, 2015). The purpose of FR is to obtain quick and numerous responses from the public using a simplified questionnaire. Research on the use of FR data for science is currently in progress, with the aim to obtain quick intensity maps using the fast and numerous FR data available minutes after an earthquake. FR has gathered more than 1,158,000 reports since it started on 18th May 2016 (with earthquakes generating FR reports occurring every day). Data from FR reports is mainly used by the media and GeoNet as a public communication tool. Reports from FC and FD questionnaires have been used since their development to assign MMI intensities (Coppola et al., 2010; Goded et al., 2014, 2017a,b, 2018, 2019) using the NZ MMI scale (Dowrick, 1996; Dowrick et al., 2008).

Both FC and FD questionnaires are similar to the traditional version that had been used for the decades prior to 2004 (e.g., Downes & Dowrick, 2014). FR directly assigns one intensity level to each chosen cartoon. Levels go from MMI 3 to a maximum of 8. Both FD and FR are limited to no greater than intensity 8, as above that level, further detailed information of the building damage is required (see more details below).

The Mw7.8 2016 Kaikōura earthquake occurred when GeoNet was adapting the method to assign intensities from FC to the new FD surveys. FD was created as a faster and easier way to fill in questionnaires than FC. Between August and November 2016 there was only the FR questionnaire on GeoNet's website, during which the East Cape (2/9/2016, M7.2) and Kaikōura earthquakes occurred. Members of the public stated that they were disappointed about not having the "long reports" available on GeoNet's website (C. Little, GeoNet, personal communication), showing their willingness to fill in seismic surveys and collaborate in science research. FD reports were released on GeoNet's website shortly after the two events to collect data for those specific events; since a few days after the Kaikōura event, FD has been permanently available on GeoNet's website.

This meant that fewer long-form Felt Reports were received for the Kaikōura event (just above 3,500) than for the smaller Mw6.5 21/7/2013 Cook Strait and Mw6.6 16/8/2013 Lake Grassmere events in a nearby region, with around 5,500 reports each. A reason for this lower number of reports could be due to the switch from FC to FD questionnaires, the inexistence of the FD questionnaire on GeoNet website at the time of the earthquake (it appeared in GeoNet news some hours after the event), and the lack of awareness from the public of the new surveys when the earthquake occurred.

MMI Scale, Community Intensities, and ShakeMaps

This citizen science-derived data is used to estimate the macroseismic intensity at different locations. With this information, shaking intensity maps are produced of the geographical damage distribution from a damaging event, used by decision makers and end users. In this section, we will describe NZ's MMI scale and two types of intensity maps derived from Felt Report data: community maps and ShakeMapNZ maps. The next section will describe the use of these intensity data to update two equations commonly used in the engineering community to assess seismic hazard and risk: the GMICE and the IPE.

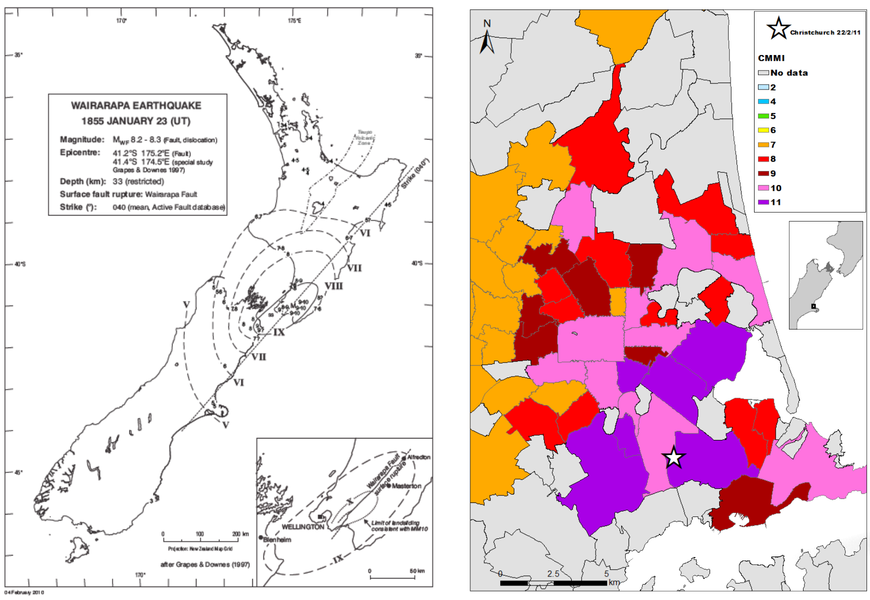
New Zealand's MMI scale. A macroseismic scale, used for high damage events, provides a set of descriptions of the effects of earthquakes on people, buildings, non-structural components, and the environment, together with a list of vulnerability classes and damage grade descriptors for different types of buildings. A macroseismic scale can therefore be used to assess the level of shaking intensity generated by an earthquake at different locations, providing a geographical distribution of the potential damage. Maps of this damage distribution (or intensity maps) are used by emergency responders following a damaging event to establish intervention priorities (e.g., Potter et al., 2020). There are different ways of producing these intensity maps: directly by assigning intensities from Felt Reports using a macroseismic scale (as for the community intensity maps described below) or using additional types of data (like peak ground acceleration (PGA) from ground motion stations) converted to intensities by using several equations (GMICE, IPE, and ground motion prediction equations (GMPE)). An example for this type of maps is ShakeMap (Wald et al., 1999b), now adapted to NZ (ShakeMapNZ; Horspool et al., 2015, in prep.)

Community intensities. Intensities are a measure of the earthquake's shaking intensity at a regional scale, and they should be provided within a specific region. In NZ, intensities have been estimated in three different ways:

- Generating contours of decreasing intensity at locations further from the epicentre. These are called isoseismal maps. These maps were traditionally generated for historical earthquakes. See Figure 3 (left) for an example.
- Per location, by using a group of Felt Reports in a specific town/city, providing intensity maps, traditionally from historical reports in combination with isoseismal maps.
- Community intensity maps, where intensities are provided for either a suburb in urban areas, or a town for rural areas. Alternatively, our team is also producing maps of intensity within grid cells (at 0.02 degrees spacing) and within circles at different distances from the SMSs. The latter database is used to update NZ's GMICE (Moratalla et al., 2020) and IPE equations. See Figure 3 (right) for an example.

Figure 3

Example of an Intensity/Isoseismal Map for New Zealand, Corresponding to the Mw8.2-8.3 23/2/1855 Wairarapa earthquake and a Community Intensity Map, Corresponding to the Mw6.2 22/2/2011 Christchurch Earthquake



Note. Left: Figure from Downes and Dowrick (2014). Right: Figure from Goded et al. (2019).

Currently, community MM intensities (or CMMI) are assigned using a method developed for NZ by Goded et al. (2018) and improved in Moratalla et al. (2020). Automatic intensity evaluations can be made through two different approaches: regression-based or expert-based (Musson & Cecic, 2012; Tosi et al., 2015). A regression-based approach obtains results through a regression between the automatic scores and the "postal traditional" intensities (assigned manually by a seismologist using paper or online surveys, to be distinguished from the "traditional intensities", which are assigned on site) to align with past datasets. However, these will refer to assignments from paper/online questionnaires, and not from field studies. An example is the USGS DYFI method (Atkinson & Wald, 2007; Mak & Schorlemmer, 2016; Wald et al., 1999a, 2011). The expert-based approach follows the specifications of a macroseismic scale and assigns a set of scores using the experience of an expert panel. This method has the advantage that it can be implemented in a short timeframe and several methods can be used to calibrate it, such as the use of GMICE (see Gerstenberger et al., 2007 for NZ data), systems like ShakeMap (Wald et al., 1999b) and the recently developed ShakeMapNZ (Horspool et al., 2015), and traditional macroseismic surveys where intensities are assigned to a community by a seismologist. "Traditional" (on site) and "postal traditional" (through questionnaires) assignments are very scarce nowadays due to being quite time-consuming and costly, hence the need for new methods to obtain intensity information.

The method to obtain CMMI values in NZ (Goded et al., 2018; Moratalla et al., 2020) uses an expert-based approach developed by the Italian Geophysics and Vulcanology Institute (Instituto Nazionale de Geofisica e Vulcanologia, INGV; Sbarra et al., 2010; Tosi et al., 2015), and adapted to GeoNet's online questionnaires and the NZ version of the MMI scale. The method used to assign CMMI is based on a score distribution for each answer to the questions in the survey. The score distribution has been chosen through an expert panel with experience using the NZ MMI scale. The intensities derived from this score distribution are first normalized then weighted by the corresponding MMI level. All the weighted scores per Felt Report are then added, and the CMMI corresponds to the mean of all the added weighted scores corresponding to all the reports in that community (suburb/town), to obtain a CMMI for each community with five or more Felt Reports (Moratalla et al., 2020). CMMI values assigned as explained above are limited to no greater than intensity 8. In NZ, at MMI 8 and above, buildings can suffer considerable damage and the assignment of intensity values involves an engineering study of the building's damage level and building type (Coppola et al., 2010). This limitation for high intensity levels is well known and has been noted in previous studies (e.g., Dewey et al., 2002; Wald et al., 1999a, 2011).

The method to obtain CMMI values can be summarised with the following steps (Goded et al., 2018; Moratalla et al., 2020):

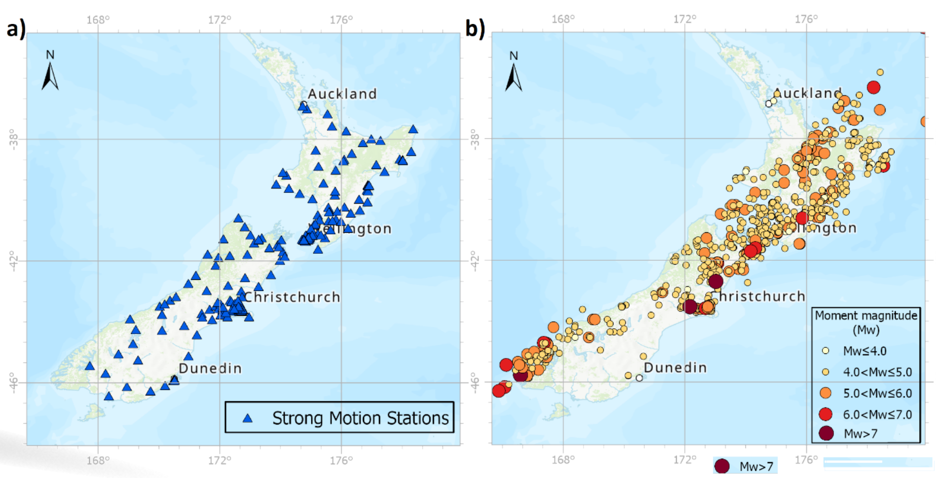
- A score system was developed to assign scores to each element of the matrix of answers and intensities. A score was assigned to each answer amongst all the intensity values, creating an intensity distribution for each answer to the questionnaire. Weights have also been used for the questions, similar to the DYFI data from USGS (Wald et al., 1999a).
- The score distribution of MMI per community is obtained by adding, for each intensity level, all the scores from all the reports belonging to that community. Scores are then normalized with respect to the sum of all the scores per report.
- Each normalized score per Felt Report is then weighted by the corresponding MMI level. All the weighted scores per Felt Report are then added.
- The CMMI corresponds to the mean of all the added weighted scores corresponding to all the reports in that community (suburb/town). A CMMI is only obtained in communities with five or more Felt Reports.

Data quality procedures include elimination of duplicated Felt Reports from the same address, elimination of reports with insufficient information, and correction of misspelt addresses (Goded et al., 2018). Community intensities using this method have been calculated for the complete set of GeoNet FC data (2004-August 2016) and FD data until the end of September 2020, comprising a total of 607,301 Felt Reports from 7,265 earthquakes. The New Zealand Strong-Motion Database (SMDB; Van Houtte et al., 2017), corresponding to 276 NZ earthquakes with magnitudes 3.5-7.8 and 4-185 kilometre depths, has been used to include strong-motion data (e.g., PGA and Peak Ground Velocity, PGV) from the SMS in the CMMI database. The resulting database of intensity and strong-motion data for the 2004 to September 2020 period is the first of its kind in NZ. The database contains 174,214 CMMI values for communities with five or more Felt Reports. The earthquakes in the database in this study are shown in Figure 4. This figure includes the SMSs with records from the database.

It should be noted that no uncertainty estimates have been obtained yet for the CMMI values. Working on uncertainties will be part of future improvements to this method. However, comparison with traditional intensity evaluations (analysed manually by a seismologist) was carried out for three moderate-to-large earthquakes in NZ: M_w 7.1 4/9/10 Darfield (7,564 reports, 317 communities), M_w 6.2 20/1/2014 Eketahuna (10,885 reports, 331 communities), and M_w 7.8 14/11/16 Kaikōura (3,509 reports, 164 communities) earthquakes. Results indicate matching CMMI values for 68% in the case of the Kaikōura and Eketahuna earthquakes, with around

Figure 4

Geographical Distribution of Earthquakes from the 2004-September 2020 CMMI Database



Note. Figure 4a shows strong motion stations marked as triangles. The CMMI database (4b) corresponds to the intensity data around the SMSs used to develop the most recent NZ GMICE (Moratalla et al., 2020).

20 to 25% of communities at one MMI level lower using FD than traditional assignment. The Darfield earthquake had 43% matching and 54% one MMI level lower when using FD CMMI assignments. Thus, an uncertainty of around 1 MMI level is expected for the CMMI method.

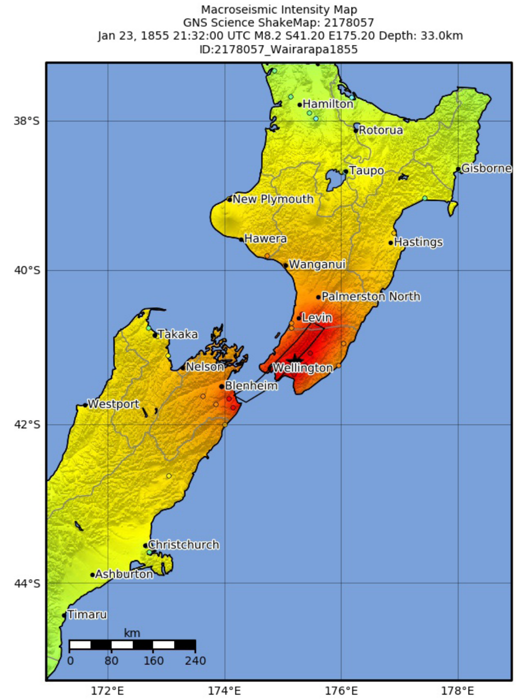
ShakeMaps. The CMMI intensities derived from FC and FD Felt Reports have also been used to produce intensity and strong motion maps using ShakeMap. ShakeMap was developed by the USGS following the devastating 1994 Northridge Earthquake to rapidly map areas of potentially damaging shaking following an earthquake (Wald, 1999b). In the past 16 years, many seismic network operators have adopted and calibrated the ShakeMap software for their region, including Italy (Michelini et al., 2008) and Canada (Kaka & Atkinson, 2005).

The strength of ShakeMap is not in the map itself, but how observed data in the form of strong or weak ground motions and macroseismic intensity data are combined with ground motion prediction equations to produce estimates of ground shaking in several ground motion intensity types (Worden et al., 2012). This allows decision makers to move from using magnitude and location as an indicator of an earthquake's severity to using the spatial distribution of shaking intensity (Wald et al., 1999b).

ShakeMap integrates data with ground motion prediction models to estimate ground motions and their uncertainties in areas without instrumentation. The data comprises observed instrumental ground motions from seismic recording stations and felt report data from the public. ShakeMap produces maps of gridded shaking intensity in the form of PGA, PGV, response spectral acceleration (0.3s, 1s, 3s), and macroseismic intensity. ShakeMapNZ is the ShakeMap system adapted to NZ. It was developed in 2015 (Horspool et al., 2015) and has been automatically generating shakemaps until recently. Since May 2019, a new version of ShakeMapNZ has been installed, using the latest version 4 developed at USGS, based on Python Programming Language (Worden et al., 2020); however, at present this version is only manually generated. It is intended to be run automatically and be open to the public again in the near future.

Recently, the first ShakeMapNZ atlas of past earthquakes in NZ has been created, with a total of 61 earthquakes, comprising four paleoearthquakes, 10 large historical events, and 47 earthquakes from the instrumental period (1968-2019), with magnitudes 6.0+ (Horspool et al., in prep). An example is provided in Figure 5, corresponding to the M8.2 Wairarapa earthquake on 23/1/1855.

Figure 5
ShakeMapNZ Intensity Map Corresponding to the M8.2 23/1/1855 Wairarapa Earthquake



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.04	0.24	1.36	4.31	10.5	18.8	33.8	60.6	>109
PGV(cm/s)	<0.02	0.1	0.86	3.52	11.7	21.4	39	71	>129
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Moratalla et al. (2020) Version 2: Processed 2020-07-28T02:20:20Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter ▭ Rupture

Note. Figure from Horspool et al. (in prep).

Updating New Zealand's GMICE And IPE Equations

The existence of the large CMMI and SMDB has given us the opportunity to update two equations for NZ: The GMICE and the IPE.

A new GMICE for New Zealand. NZ's GMICE has recently been updated (Moratalla et al., 2020). Previously, this GMICE was from Gerstenberger et al. (2007), in which DYFI data (Wald et al., 1999a) from the Western US was combined with nearly 6,500 points recorded for NZ to develop PGV to intensity conversion equations. The NZ relationships were based only on PGV and lacked high intensity MMI data. They were developed prior to a large dataset resulting from the Canterbury 2010-2011 and Kaikōura 2016 earthquake sequences. Two main factors provided us with the opportunity to update NZ's GMICE: 1) recent publication of NZ's SMDB (Van Houtte et al., 2017), in which strong-motion data corresponding to 276 NZ earthquakes (including Darfield Mw 7.1, 4/9/2010, Christchurch Mw 6.2, 22/2/2011, and Kaikōura Mw 7.8, 14/11/2016) have been filtered and analysed individually according to the specific features of each record (instead of using GeoNet's automatic filtering system), thus considerably improving its quality; and 2) recent development of a method to obtain MMI at a community (suburb/town) level using GeoNet's online Felt Reports, together with the generation of the first database of community intensities for GeoNet's FC and FD online Felt Reports (Goded et al., 2018), as explained above.

In the new GMICE, Felt Reports were regrouped into circles at 500 metres, 1,000 metres, and 2,000 metres from the SMSs. The CMMIbySMS values mentioned in this paper refer to the community intensity data used to develop the GMICE, where communities are circles around the SMSs. The distance of 1000m was chosen as the optimal distance to have sufficient Felt Reports in the community and sufficiently similar soil characteristics between an SMS and the locations of associated Felt Reports. The intensity database contains 67,572 Felt Reports from 917 earthquakes, with magnitudes 3.5-8.1, and 1,797 recordings from 247 NZ SMSs, with hypocentral distances of 5-345 kilometres. Only SMSs with three or more responses were used to calculate CMMIbySMS.

As a first step towards obtaining a new GMICE for NZ, the CMMI data were converted to traditional intensities, similarly to what was done within the DYFI programme between their Community Weighted Sum and their Community Decimal intensity using data from the Northridge earthquake (Wald et al., 1999a). Traditional MMI (MMItrad) data were available in the database for three main earthquakes that occurred in the last 10 years: M_w7.8 Kaikōura 2016, M_w 7.1 Darfield 2010, and M_w 6.2 Eketahuna 2014. Moratalla et al. (2020) compared these MMItrad data with CMMI data, also available for these three earthquakes, and derived a relationship based on 767 data pairs. Once all the CMMI data were converted to traditional MMI values, the data were compared to data from other regions. It was observed that previous underestimations (below MMI 4) and overestimations (above MMI 6) of data were corrected when using traditional MMI values.

The new GMICE was created using Total Least Squares linear regression, also known as Deming regression (Deming, 1943) or orthogonal regression, to fit the logPGM-MMItrad (PGM: Peak Ground Motion) data pairs and develop the GMICE for NZ. More details on this GMICE can be found in Moratalla et al. (2020).

A new IPE for New Zealand. Using the recent CMMI database, a new IPE (or intensity attenuation model) is currently being developed for NZ. The previous intensity attenuation model for NZ, from 2005 (Dowrick & Rhoades, 2005), used intensities from 89 earthquakes between 1855 and 1998, based on isoseismal data. Development of the new IPE is currently underway, so no results are available yet.

Understanding Human Behaviour

In recent FD Felt Report surveys (from 2016 to present), additional questions have been included that relate to people's actions during earthquake shaking and following the earthquake regarding tsunami evacuation. These questions are similar to the behavioural response questions used in studies by Lindell et al. (2016), Goltz et al. (2020b), and Vinnell et al. (2020). Analysis of these behavioural questions is useful for tracking longitudinal changes in response during and after earthquakes. This can be used to understand the efficacy of educational campaigns such as the ShakeOut earthquake drill and tsunami hīkoi (McBride et al., 2019), for updating and improving the MMI scale over time, and to develop casualty and evacuation models that attempt to predict human behaviour as outlined in the following section.

Predictive Model of Human Behaviour in Earthquakes

Recent studies investigating human casualties during earthquakes and tsunami have revealed that human behaviour plays an important role in the determination of injuries and deaths (Horspool et al., 2020; Johnston et al., 2014). To improve existing earthquake and tsunami casualty models, human behaviour needs to be included. Data on human behaviour during earthquake shaking and tsunami evacuation collected by Felt Reports is valuable for better understanding human behaviour and developing predictive models. Felt Report data from the past 4 years covers a range of earthquake shaking intensities (MMI 3 to MMI 9), times of day, seasons, contextual settings (e.g., at home, at work, on the street), and geographic regions, allowing robust statistical analysis to determine key variables that drive human behaviour during and following earthquakes.

Table 2 shows the behavioural response question currently in the FD survey and the corresponding question in the DYFI survey (Goltz et al., 2020a; Quitoriano & Wald, 2020). FD has a larger variety of behavioural answers than the current DYFI. The answer "Moved to doorway" is currently not in FD but is planned to be included in a future version of the survey. FD has the same responses as Lindell et al. (2016) to retain consistency in survey responses and analysis in NZ. Research in progress is using regression models to

Table 2
Questions on Behavioural Response for the NZ Felt Detailed and the USGS Did You Feel It? Surveys

	Felt Detailed (GeoNet)	Did You Feel It? (USGS)
Question	"What was your first response while the earthquake was shaking?"	"How did you respond?
Response	Continued what I was doing before	Not specified
	Stopped what I was doing but stayed where I was	Took no action
	Dropped, covered under a sturdy piece of furniture (e.g., table or desk), and held on to it	Moved to doorway
	Tried to protect other people nearby	Dropped and covered
	Tried to protect property nearby (e.g., prevent things from falling)	Ran outside
	Immediately left the building I was in	Other (please specify)
	Continued driving	
	Stopped driving and pulled over to the side of the road	
	Not applicable	
	Other (please explain)	

assess statistical relationships between these variables and demographic factors.

Improving Public Education

The information gained from Felt Reports is also useful for targeting educational initiatives to improve resilience to earthquakes. For example, we know that most buildings in NZ are designed to remain standing during strong shaking, so public education focuses primarily on earthquake mitigation (e.g., retrofitting buildings, securing loose items) and preparedness activities (e.g., household, work, and community preparedness). In terms of responses to shaking, people are asked to drop, cover, and hold to avoid injury (McBride et al., 2019), and if located near the coast, evacuate inland or to higher ground after feeling a long duration or strong earthquake. Despite such best practice advice, Felt Reports for the 2016 Kaikōura earthquake indicate that only 18.2% of participants undertook the recommended drop, cover, and hold action upon feeling shaking, which shows a continuing need to focus on promoting these actions via public education initiatives such as the ShakeOut earthquake drill (Vinnell et al., 2020). Likewise, Horspool et al. (2020) highlight that 8% of injuries during the Kaikōura earthquake occurred when people were struck by unsecured contents, suggesting that education programmes need to continue to advocate earthquake mitigation and preparedness actions. Finally, the time an earthquake occurs might impact the responses received. For example, the Kaikōura earthquake occurred at midnight, when people were most likely asleep, even though many of them were awakened by the event.

In terms of future work, there is an opportunity to analyse the current FD questions in more detail, such as those related to tsunami evacuation, to inform public education. Additional questions could also be included to gain a better understanding of people's actions. As an example, asking why individuals might *not* drop, cover, and hold would further guide the development of targeted information encouraging people to take appropriate protective action. Additionally, the Felt Reports provide a comprehensive data set over a long period of time, from which the impact of education on people's behaviour can be evaluated longitudinally, and education programmes adjusted accordingly.

Conclusions and Future Work

Earthquake Felt Reports are a constructive way for the public to contribute to science. Thanks to such contributions, scientists can better understand the geographical distribution of damage following earthquake shaking, and consequently are better able to inform decision makers and first responders on priority interventions. Even if instrumental-based parameters such as magnitude and PGA are commonly used in the science and engineering community, the use of intensity data based on Felt Report information is still considered important for two main purposes: 1) to be able to compare damage caused by modern and historical earthquakes, and 2) to fill in gaps where modern instruments are scarce. Citizen science via Felt Reports plays a key role in providing detailed shaking maps that can be used by first responders and the public. Additionally, Felt Reports contribute to a better understanding of how the physical environment behaves during shaking and how humans respond, for which the data can be fed into updating both physical and social (e.g., injury) models. Self-reflection from the public when filling out a questionnaire also helps people to understand the impacts of earthquakes. Whether the mechanism be updated data and models or self-reflection by participants, improved understandings can help with developing preparedness for future earthquakes and can be used to target appropriate educational interventions.

NZ has a long tradition of using Felt Report information provided by the public to analyse earthquake damage. From historical paper-based Felt Reports to the more modern Internet-based questionnaires and thumbnail-based surveys, NZ has gathered a large amount of Felt Report information. Uses of Felt Reports include analysis of human post-event responses, shaking intensity maps, rapid shaking maps (e.g., ShakeMapNZ), or development and improvement of equations such as GMICE or IPE. NZ Felt Report-based research has burgeoned in recent years, with an increasing number of studies taking advantage of the large number of Felt Reports following moderate-to-large events, including the 2010-2011 Canterbury earthquake sentence and the Mw 7.8 2016 Kaikōura earthquake.

This paper summarises the most recent research carried out in NZ using Felt Report data, from citizen science to the update of equations and development of community intensity maps and ShakeMapNZ. There is still considerable work to be carried out, including:

- Analysis of intensity data derived from FR thumbnail-based surveys, comparing them with the more detailed FC and FD questionnaires. Preliminary analysis has been carried out for more than 4 months of data (mid-November 2020 to early April 2021), corresponding to 1,683 Felt Reports with both intensities assigned from FD and FR data (from a total of 103 earthquakes), using an updated FD questionnaire which also includes the FR question, thus comparing the MMI derived from FD and FR corresponding to the same respondent. Preliminary results show around 50% of reports with matching intensities, with a tendency of FR to underestimate the MMI compared to FD by one MMI level (28%) or more (6%).
- Testing the use of the quick and numerous FR responses for the release of quick ShakeMaps following a damaging event.
- Improvement of the current FD questionnaire (see Appendix 1), including reducing the number of questions, improving questions related to social science, and updating the code. A major improvement is for the public to be able to choose their address from a drop-down list, as currently the public fills it in manually, leading to a considerable number of unusable misspelt addresses. Another improvement is to automatically store the earthquake ID corresponding to the event felt by the responder, as currently the responder needs to fill it in manually.
- Updating the current GMICE to include other parameters such as spectral acceleration at different periods.
- Updating NZ's prediction equation.
- Inclusion of shaking intensity maps as a product delivered by GeoNet.
- Development of an automated system for providing shaking layers (such as ShakeMapNZ) minutes after a damaging event in NZ, using Felt Report information (FR and FD) automatically fed in as input parameters.

Data and Resources

The availability of the data used in this project is as follows:

- Original Felt Reports are stored at GNS Science in cardboard boxes and manila folders, grouped based on earthquake date. Due to privacy concerns all original Felt Reports are deemed confidential and unable to be shared with the public. Plans are currently underway to make records public where there is no risk of identifying individuals involved (Viskovic et al., 2020). Published research products derived from the historical Felt Report database exist and are available for researchers (e.g., Downes & Dowrick, 2014).
- Historical reports are currently stored by GNS Science and not available to the public.
- FR data is publicly available through GeoNet's website and the dataset metadata available from the GNS Dataset Catalogue (GNS Science, 2015). They can be downloaded from http://api.geonet.org.nz/intensity?type=reported&publicID=2016p858000, changing the last digits to the needed public ID. The link provided corresponds to the 2016 M_w 7.8 Kaikoura earthquake. More information on GeoNet felt report data can be found at https://www.geonet.org.nz/data/types/felt
- FC and FD data are not publicly available. They can only be used for research purposes if the research team has obtained ethical approval. The use of FC and FD data for research purposes in this project has been approved as a low-risk project by the Massey University Human Ethics Committee. However, the metadata for both datasets are available from the GNS Dataset Catalogue (GNS Science, 2004 for FC and GNS Science, 2016 for FD).
- The CMMI database for FC and FD is undergoing further testing and is not publicly available. Once the database has undergone further testing, work towards making it publicly available will be considered.
- The NZ SMDB has been used in this study to include strong-motion data in the CMMI database. This database is publicly available through the GeoNet website: https://www.geonet.org.nz/data/supplementary/nzsmdb

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Appendices

Appendix 1:
GeoNet's "Felt Detailed" online questionnaire

Stars mark the questions used to assign a community Modified Mercalli intensity (CMMI)

Reference	Question	Answers
Section 1: General questions		
1*	Details of this earthquake	Public ID Earthquake date Earthquake time (NZST) Earthquake location Magnitude
2*	What was the address of the location where you were when the earthquake occurred?	Street number Street name Suburb Town/City/Locality
3*	At the time of the earthquake were you	Indoors Outdoors In a stopped vehicle In a moving vehicle Not applicable Other (please specify)
4*	What were you doing when the earthquake occurred?	Sitting / Lying Standing Walking/Running Sleeping and was woken up Travelling in a vehicle Not applicable Other (please specify)
5	Did you feel the earthquake?	Yes No
Section 2: Your experience of the earthquake		
6	How long did the earthquake feel (in seconds)?	Open answer
7*	How would you best describe the shaking?	Heard, but not felt Gentle, hardly recognised as an earthquake (like light trucks passing) A jolt or mild, but unmistakably an earthquake (like heavy traffic passing) Moderate Strong, powerful Violent, severe Other (please specify)
8	What was your first response while the earthquake was shaking?	Continued what I was doing before Stopped what I was doing but stayed where I was Dropped, covered under a sturdy piece of furniture (e.g., table or desk), and held on to it Tried to protect other people nearby Tried to protect property nearby (e.g., prevent things from falling) Immediately left the building I was in Continued driving Stopped driving and pulled over to the side of the road Not applicable Other (please explain)
9	What was your reaction?	No reaction Very little reaction Excited but not alarmed A bit frightened Very frightened Extremely frightened Don't know/Not applicable Other (please specify)

Section 3: Earthquake effects within your building		
10*	Did objects such as glasses, dishes, ornaments or other small shelf items rattle, topple over or fall off shelves?	No Rattled slightly Rattled loudly A few toppled or fell off Many toppled or fell off Nearly everything toppled or fell off No shelves with unrestrained objects Don't know/Not applicable
11	Were cupboard or appliance doors thrown open?	No Yes Yes, and contents were ejected Don't Know / Not applicable
12*	Did any items of furniture, appliances (TV, fridge, filing cabinet, computer, microwave) or machinery slide (not just sway) or topple over?	No Yes, slid a little Yes, slid a lot Yes, toppled over Don't know/Not applicable
13*	Did any items of furniture, appliances (TV, fridge, filing cabinet, computer, microwave) or machinery slide (not just sway) or topple over?	Response options: No Yes, slid a little (less than 5cm) Yes, slid a lot (more than 5cm) Yes, toppled over Don't know/Not applicable Items: TV, Computer, Microwave, Fridge, Filing cabinet, Oven, Light machinery, Heavy machinery
14	Check which services failed, if any:	No services failed Water Electricity Gas Telephone Sewerage Elevators Sprinklers Internet connection Other (please specify)

Section 4: Your building		
15	What was the built environment?	Residential Business/Industrial Rural Don't Know / Not applicable
16	Please select the type of building or structure	Family home or flat Low-rise building (e.g. offices, supermarket, church, theatre or warehouse) Multi-storey building I was outside Other (please specify)
17	If you were in a multi-storey building, what floor were you on?	
18	If you were in a multi-storey building, what is the total number of storeys?	
19	When was the building constructed?	Before 1940 Between 1940 and 1960 Between 1960 and 1980 Between 1980 and 1990 After 1990 Don't know/Not applicable
20*	Choose the main building material for the exterior walls that experienced the damage:	Wood Stucco (cement) Brick/stone veneer Concrete block Solid brick Sheet material (fibre cement board, plywood) Don't know/Not applicable Other (please specify)
21	The ground is mainly...	Level or nearly level Steeply sloping/hilly Don't know/Not applicable
22	What is the main type of ground under the building?	Peat/Soil Rock Clay Fill Sand River gravels Don't know/Not applicable
23	Choose the structural style of the building foundations	Unbraced piles Braced piles Perimeter only concrete Concrete slab on ground Raised concrete slab Pole house Don't know/Not applicable Other (please specify)

Section 5: Damage caused by the earthquake to your building		
24*	Was there any damage to…?	Hot water cylinder: *No damage* *Leaked* *Fell over* *Don't Know / Not applicable* Chimneys *No damage* *Horizontally cracked or loose bricks dislodged* *Twisted or broken at roofline* *Fallen from roofline* *Fallen from base* *Don't Know / Not applicable* Elevated water tanks *No damage* *Shifted/leaking* *Twisted and/or brought down* *Don't Know / Not applicable* Entire building *No damage* *Hairline cracks* *Wide cracks* *Segments of walls bulged* *Building lightly distorted* *Building severely distorted* *Segments of walls collapsed* *Some walls totally collapsed* *Don't know/Not applicable*
25*	What other damage occurred? Check all that apply, if any	Some domestic wood-framed windows cracked Some glass fallen out of domestic wood-framed windows Some domestic aluminium-framed windows cracked Some glass fallen out of domestic aluminium-framed windows Some large shop windows cracked Some glass fallen out of large shop windows Hairline cracks in interior walls Cracks around window/door openings in interior walls Major cracks in interior walls Suspended ceilings damaged Masonry or concrete roof tiles dislodged Masonry or concrete roof tiles fallen
26	What do you believe caused the building damage?	Earthquake shaking Landslide Ground cracking or other ground damage A combination of the above Don't know/Not applicable

Section 6: Earthquake effects in your neighbourhood		
27	Are you aware of any effects in your neighbourhood?	Yes No
28*	Did any of the following effects occur? (Tick all that apply)	No visible effects Cracks on dry and level ground Cracks on permanently wet ground Ground cracks on hillsides Ground cracks on ridge tops Landslides or rockfalls from natural slopes Landslides or rockfalls from cut slopes Boulders dislodged Ground slumping of road edges Ground slumping on river banks Ground slumping on hillsides Building damage from landslides or slumps Considerable water splashed over the sides of rivers, lakes or estuaries Considerable water splashed over the sides of swimming pools Water or sand thrown from holes or cracks in the ground, or a lake/river bed Unusual sea level changes within one hour of the earthquake Tsunami Trees and bushes were shaken strongly and some branches/trees broken

Section 7: Tsunami evacuation		
29	If you felt the earthquake, did you think it could trigger a tsunami?	Yes No Unsure Not applicable
30	Did you evacuate?	Yes, I went inland Yes, I went inland and uphill Yes, I climbed up a tree or similar Yes, I went to the upper floor of a building No, I did not evacuate Not applicable Other action (please specify)

Section 8: Earthquake -Tsunami information		
31	When you evacuated, did you…?	Evacuate immediately after the earthquake Look for information to help decide whether or not to evacuate Wait for an official tsunami warning Wait to be told to evacuate Evacuate because you saw others evacuating
32	How many minutes after the earthquake did you evacuate?	
33	What was the main reason you decided to return after you initially evacuated?	When I felt it was safe (after seeing evidence that there was no danger) After discussing with others When I saw others returning After a reasonable time When I received an official 'All Clear' message Other (please specify)
34	How long were you evacuated for?	<1 hour 1-2 hours 3-6 hours 7-12 hours >12 hours Other (please specify)

Section 9: Information about earthquakes		
35	What items of information about earthquakes are the most valuable for you? (Tick all that apply)	General details about what has happened in an earthquake (magnitude, depth, location, shaking intensity, cumulative felt reports about the specific earthquakes) Earthquake forecasts about what might happen in future (e.g., projected numbers of future earthquakes, probabilities of occurrence in the future) Magnitudes of earthquakes Shaking intensities of earthquakes (MM) Peak ground acceleration (PGA) of specific earthquakes Impacts of earthquakes (e.g., damage, loss) None of the above Other (please specify)
36	When you talk to family/friends/ neighbours about the earthquakes, what do you most talk about? (Please specify)	
37	The tone and information provided by GeoNet is: (Tick one answer on each line) a. Too scientific. Can't understand it. b. Too general. Not enough specifics. c. Just right. In the middle	Strongly agree Agree Neutral Disagree Strongly disagree

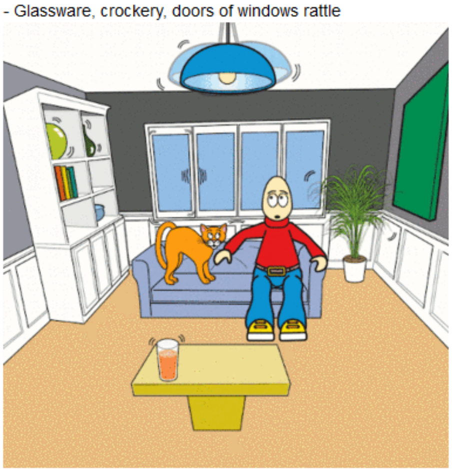
Section 10: Demographic Information		
38	Age: year of birth	
39	Gender	Male Female Gender diverse Prefer not to disclose
40	Final comments	

Appendix 2: GeoNet's "Felt RAPID" questionnaire

Choose the shaking that best describes your experience.

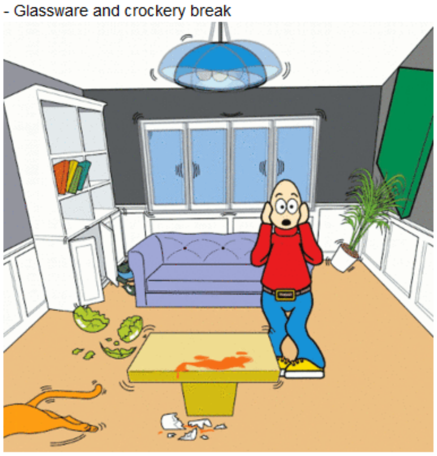
Weak Shaking
- Vibration similar to a light truck driving past
- Hanging objects may swing slightly

Light Shaking
- Vibration similar to heavy traffic passing, or a sharp jolt
- A light sleeper may be awakened
- Walls may creak
- Glassware, crockery, doors of windows rattle

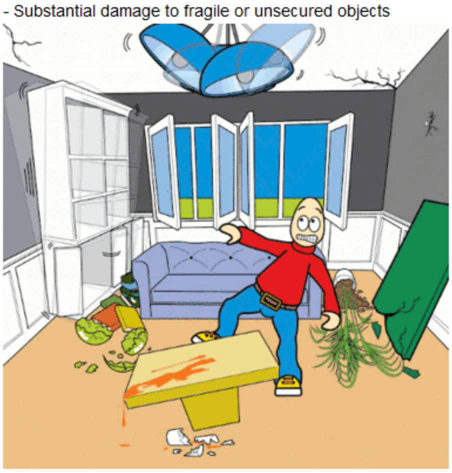


Moderate Shaking
- Most sleepers are awakened
- Pictures knock against the wall
- Open doors may swing open and shut
- Some glassware and crockery may break

Strong Shaking
- Walking is difficult
- Furniture and appliances may move on smooth surfaces
- Objects fall from walls or shelves
- Appliances move on bench or table tops
- Glassware and crockery break



Severe Shaking
- Standing is difficult
- Furniture and appliances are shifted
- Cracks in walls or ceilings may occur
- Substantial damage to fragile or unsecured objects



Extreme shaking
- Buildings are damaged or destroyed.