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Comparison of the 22 Sept 2021 Mw 5.9 Mansfield earthquake with large or damaging Australian earthquakes

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On 22 September 2021, a magnitude 5.9 earthquake occurred southeast of Mansfield in the Eastern Highlands of Victoria, approximately 130 km northeast of Melbourne. The purpose of this briefing is to compare this earthquake with large or damaging earthquakes that have previously occurred in Australia, to provide insight into the impacts from the Mansfield earthquake. Table 1 is a list of large or damaging Australian earthquakes ranked by magnitude, shown in Figure 1. This list uses the preferred magnitudes from Allen et al. (2018), which produced significant downward revisions in the magnitudes of many Australian earthquakes, with resulting changes in seismic hazard estimates described by Allen et al. (2020). The table includes all events of M 5.7 and larger that are not located far offshore, and smaller events that have caused significant damage and casualties.

The deaths, serious injuries and additional information in Table 1 are derived from PerilAUS, Risk Frontiers' database of impacts of natural hazards in Australia (in bold) and from Daniell and Love (2010) (non-bold). Where available, ICA (2021) normalised losses, which are derived by Risk Frontiers, are shown in bold, and normalised losses from Daniell and Love (2010) are shown in non-bold. In both cases, the normalised insurance sector losses, which are designed to estimate the costs if historical events were to impact current societal conditions, were estimated using the method of Crompton and McAneney (2008). We have not yet made estimates of the losses from the 2021 Mansfield earthquake, which is shown in bold in Table 1. Only eight Australian earthquakes in Table 1 have been larger than the Mansfield earthquake.

As indicated by the Epicentre Setting listed in Table 1 and the locations of the earthquakes shown in Figure 1, the earthquakes have occurred in a wide range of environments, ranging from urban to rural to remote to offshore. This has evidently had a major influence on the impacts that they have caused.

Table 1. *Magnitudes and losses from large or damaging earthquakes in Australia, ranked by magnitude.*

Location	M	Year	M	D	Long	Lat	H	Deaths	Serious Injuries	Norm. Loss $M	Epicentre Setting
Meeberrie, WA	6.83	1941	4	29	116.197	-26.791	25				Remote
Meckering, WA	6.58	1968	10	14	116.98	-31.62	10		5	**59.9**	Urban
Tennant Creek, NT	6.58	1988	1	22	133.854	-19.896	5			2.5	Remote
Simpson Desert, NT	6.52	1941	6	27	137.34	-25.95	0				Remote
Collier Bay, WA	6.2	1997	8	10	124.333	-16.159	20				Rural
Cadoux, WA	6.1	1979	6	2	117.104	-30.821	3			**41.5**	Urban
Petermann Ranges, NT	6.09	2016	5	20	129.832	-25.579	0				Remote
Tasman Sea, TAS	5.93	1892	1	26	149.5	-40.4	10				Offshore
Mansfield, VIC	**5.9**	**2021**	**9**	**22**	**146.363**	**-37.491**	**21.5**				**Rural**
Bundaberg Offshore, QLD	5.87	1918	6	6	152.5	-23.5	10			8.3	Offshore
Lake Tobin, WA	5.87	1970	3	24	126.673	-22.059	15				Remote
Bowen Offshore, QLD	5.84	2016	8	18	148.756	-19.821	10			**2.0**	Offshore
Northern Flinders, SA	5.79	1939	3	26	138.3	-31.1	0				Remote
Marryat Creek, SA	5.7	1986	3	30	132.734	-26.31	5			**5.8**	Remote
Beachport, SA	5.6	1897	5	10	139.75	-37.3	14		5	11.5	Offshore
Newcastle, NSW	5.42	1989	12	27	151.61	-32.952	10.5	**14**	30	**4244**	Urban
Warooka, SA	5.2	1902	9	19	138	-35	10	**2**		10.4	Urban
Picton, NSA	5.15	1973	3	9	150.34	-34.187	28.9			**99**	Urban
Boolara, VIC	4.93	1969	6	20	146.3	-38.47	19			**15**	Utban
Warrnambool, VIC	4.89	1903	7	14	142.533	-38.433	10			5.5	Urban
Adelaide, SA	4.79	1954	2	28	138.564	-35.033	4		**3**	152.5	Urban
Robertson, NSW	4.79	1961	5	22	150.606	-34.564	18.8			7.2	Urban
Ellalong, NSW	4.71	1994	8	6	151.292	-32.917	0.64			**156**	Urban
Kalgoorlie-Boulder, WA	4.16	2010	4	20	121.77	-30.745	10		**1**	**36**	Urban

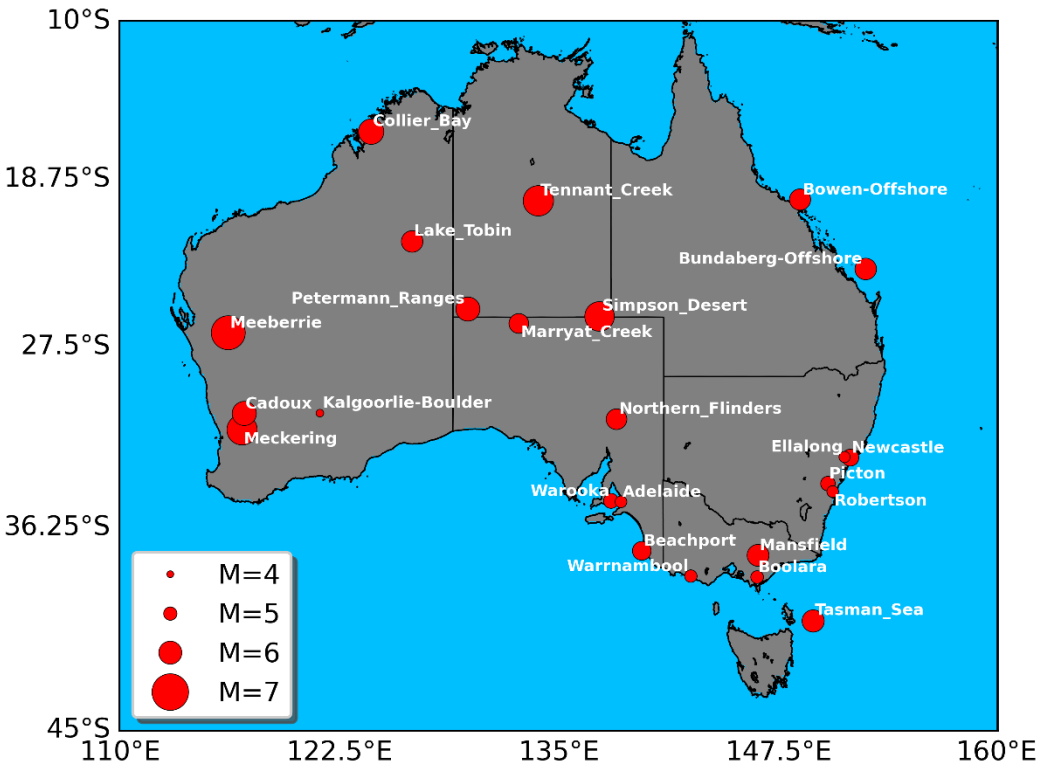


Figure 1. *Large or damaging earthquakes in Australia listed in Table 1.*

Most historical earthquake damage in Australia has come from small nearby events

The ranking of earthquakes by magnitude in Table 1 indicates that, along with the earthquake magnitude and the seismic capacity of the affected buildings, the distance of the earthquake from built-up areas is a primary factor that determines earthquake losses. Among all eight of the Australian earthquakes having magnitudes larger than 5.9 (the magnitude of the Mansfield earthquake), six occurred in remote, rural or offshore locations and produced no significant damage; the same is true of the next five largest earthquakes smaller than the Mansfield earthquake, which lie in the magnitude range of 5.7 to 5.9. Of the 14 largest earthquakes in Table 1, the only two that are known to have caused significant damage, the 1968 Meckering and 1979 Cadoux earthquakes, both occurred in populated regions.

In contrast, all of the earthquakes with magnitudes less than 5.7 in Table 1 caused damage. This is by design because they were selected for that reason; to include all earthquakes would make the table unmanageably large. There are many other earthquakes in the magnitude range of 4.7 to 5.7 that are not listed because they did not cause significant damage. Earthquake frequencies are distributed on a logarithmic scale, so there are approximately ten times as many magnitude 5 earthquakes and one hundred times as many magnitude 4 earthquakes as there are magnitude 6 earthquakes.

These smaller earthquakes have historically caused more damage in Australia than larger earthquakes because they are more numerous, and they have occurred in populated areas. Just two small earthquakes, the 1989 Mw 5.42 Newcastle and the neighbouring 1994 Mw 4.71 Ellalong earthquake, have caused about 90% of all earthquake losses in Australia. This is notable because Table 1 lists 15 earthquakes larger than the Newcastle earthquake, whose magnitude was only 5.42.

The importance of proximity to earthquakes was vividly brought home to the residents of Christchurch, New Zealand during the 2010-2011 Canterbury earthquake sequence (Figure 2). The 4 September 2010 Mw 7.1 Darfield earthquake (the mainshock on the Greendale fault; Risk Frontiers Briefing Note 222) was located on the western outskirts of the city and caused the kinds of damage that New Zealand earthquake engineers expected for an event of that size, with an estimated insured loss of $NZ 6,623M. However, the 22 February Mw 6.2 Christchurch earthquake (Risk Frontiers Briefing Notes 214, 215 and 216) occurred on a previously unidentified fault directly below the CBD, and its ground motions were greatly amplified by a combination of rupture directivity and basin resonance effects. This earthquake caused damage that lay far beyond the expectations of New Zealand earthquake engineers, with an estimated insured loss of $NZ 19,868M. These losses were estimated by partitioning the total estimated insured losses of $NZ33,114M obtained by McAneney et al. (2021) assuming that these two events caused 20% and 60% of the total losses respectively, roughly consistent with King et al. (2014).

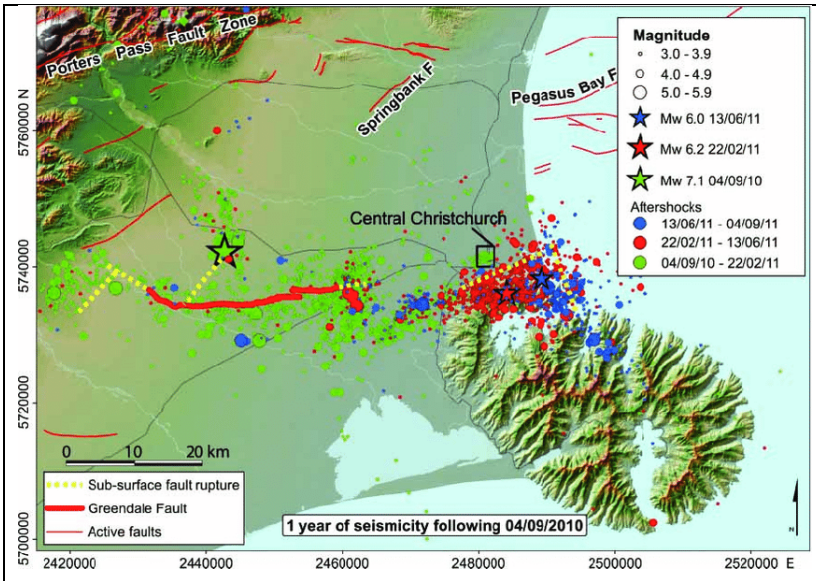


Figure 2. *Locations of the 2010 – 2011 Canterbury earthquake sequence, showing the location of the 4 September 2020 Mw 7.1 mainshock on the Greendale fault, which is the 30 km long roughly east-west red line west of Christchurch, and the 22 February 2011 aftershock, shown by the 10 km long yellow dotted line striking ENE just south of the CBD, shown by a green square. The epicentres of these events are shown by the green and red stars respectively. Source: GNS Science.*

The 1918 Bundaberg and 2016 Bowen earthquakes are most comparable to the Mansfield earthquake

The shakemap of the 2021 Mansfield earthquake shown in Figure 3 indicates that it generated MMI intensity IV out to a radius of about 200 km. From Table 1, it appears that the most comparable events to the Mansfield event are the events off Bundaberg in 1918 and Bowen in 2016, because they had similar magnitudes and were similarly distant from the affected towns. Their shakemaps and descriptions of damage are shown in Figure 4, and their estimated normalised losses are $8.3M and $2.0M respectively. These are quite low losses, and are almost certainly lower than the losses that will come from the Mansfield earthquake. This would be expected because there is a much larger population in the region around Mansfield than in the regions affected by the Bundaberg and Bowen earthquakes.

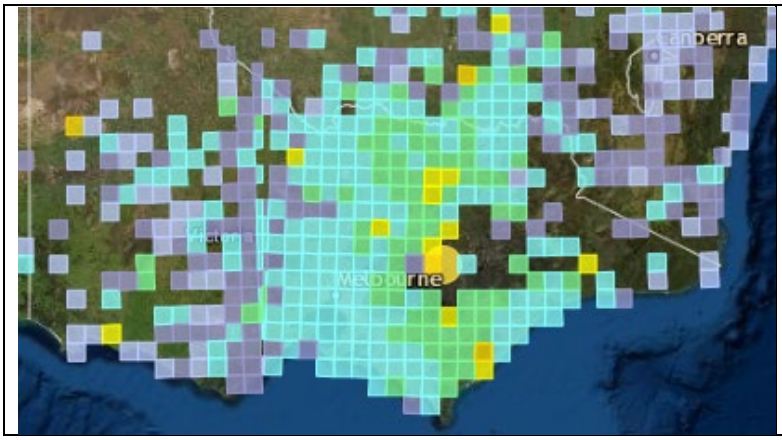
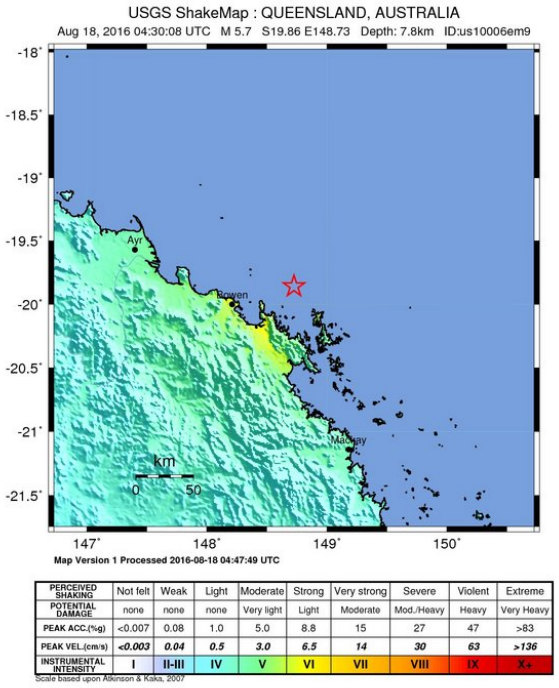


Figure 3. *Shakemap of the 22 Sept 2021 Mw 6.9 Mansfield earthquake. The epicentre is a yellow circle that is partly obscured and the pixels outline the coast. Source: Geoscience Australia.*



A magnitude 5.87 earthquake occurred about 100 km off the central Queensland coast. It was felt over an area in excess of 300,000 km² extending from Mackay to Grafton (NSW) and west to Charleville. Some damage occurred in Rockhampton and Bundaberg where a maximum intensity of MM VI was reported. Over 100 towns reported felt effects associated with the earthquake. Daniell and Love (2010) estimated normalised losses of $8.3M.

A magnitude 5.84 earthquake occurred about 30 km off the coast and about 50 km from Bowen, followed by 22 aftershocks during the next 3 days. It triggered evacuations of buildings in Cairns and Townsville but there were no reports of serious injuries or damage. Precautionary shutdowns of airports and rail infrastructure were carried out. Very little damage was reported to contents, no significant structural damage was reported, and normalised estimated loss is $2M. .

Figure 4. *Shakemaps and descriptions of the 1918 Bundaberg (left) and 2016 Bowen (right) earthquakes.*

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