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PROBABILISTIC EARTHQUAKE RISK MAPS OF TASMANIA

Marion O. Michael-Leiba[1] and Brian A. Gaull[2]

1. Bureau of Mineral Resources, Canberra, ACT., Australia
2. Bureau of Mineral Resources, Mundaring, Western Australia

SUMMARY

New earthquake risk maps of Tasmania have been prepared depicting risk by contours of peak ground velocity, acceleration and intensity with a 10% probability of being exceeded in a 50 year period. The Cornell method was used. The maps are based on average site conditions, seismicity up to 1984, and take historical data into consideration. The highest risk land areas are Flinders and Cape Barren Islands which lie predominantly between the $0.6 m.s^{-2}$ and $1.2 m.s^{-2}$ contours. At Hobart and Launceston, the values are $0.21 m.s^{-2}$ and $0.29 m.s^{-2}$ respectively but site amplification takes place in some parts of Launceston.

INTRODUCTION

The first seismic risk map of Tasmania was that of Underwood (Ref.1). He produced contours of intensity at a 10-year return period based on 10.5 years of data. McCue (Ref.2) contoured the return periods of peak ground velocities of $50 mm.s^{-1}$ and $100 mm.s^{-1}$ for the Tasmanian region.

In this study, we have produced risk maps of Tasmania for the area 39-44°S, 142-150°E, using the Cornell methodology as described in Ref.3, and earthquake data from the BMR earthquake data file up to the end of 1984, and from Refs.4 and 5.

The magnitudes of historic events from Ref.5 are designated MI. MI is an approximation to the Richter magnitude, ML. It is determined (Ref.5) by comparing the more reliable isoseismal radii, measured from an isoseismal map of the earthquake, with the average southeastern Australian attenuation curves (Ref.6) for various magnitudes.

METHOD

Seismic risk estimation using the Cornell methodology requires the definition of earthquake source zones (each having its own magnitude-frequency recurrence relationship, mean focal depth, and maximum magnitude chosen to be the maximum observed magnitude + 0.5, then rounded to the nearest 0.5 magnitude unit (Ref.3)); background seismicity; and attenuation of strong ground motion. The computer program (Ref.3) uses the attenuation and recurrence relations to numerically integrate contributions from the source zones to evaluate probabilities of exceeding different levels of ground motion at a site.

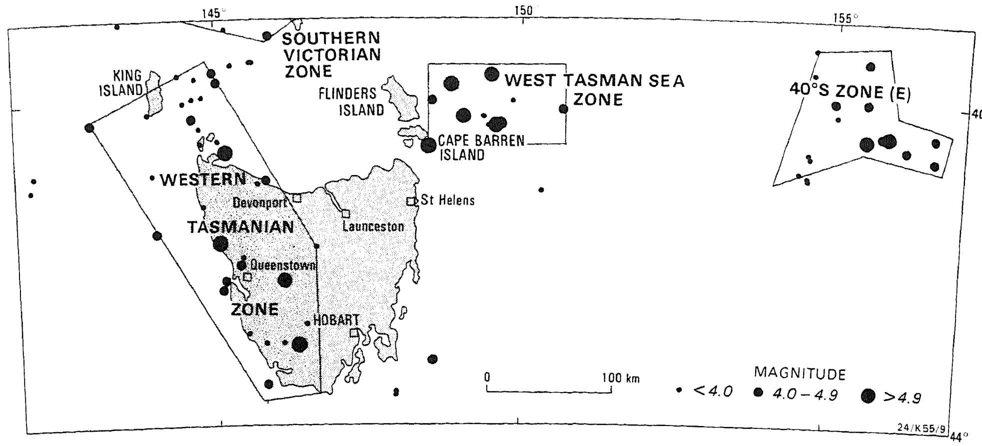

Fig. 1 Earthquake scource zones and epicentres in the Tasmanian region

The earthquake process was assumed to be Poissonian, so foreshocks and aftershocks were not used in determining the magnitude-frequency recurrence relationship.

Earthquake source zones were chosen primarily on the basis of the spatial distribution of magnitude ML≥4.0 earthquakes (Fig.1). Only events for which epicentres have been reliably determined are shown in this figure. The Western Tasmanian Zone and the West Tasman Sea Zone are the source zones most affecting the risk in the Tasmanian region.

In the Western Tasmanian Zone, instrumental magnitudes are available only back to 1958, so felt reports (Ref.5) were used to obtain data for numbers of magnitude MI≥5.0 and 5.5 events back to 1853. The magnitude-frequency recurrence relationship is -

logN=3.5-1.0ML

where N is the mean yearly number of earthquakes with Richter magnitudes ≥ML. This gives an average recurrence interval of about 30 years for a magnitude ML≥5.0 event, 90 years for a magnitude ML≥5.5 event, and 290 years for a magnitude ML≥6.0 earthquake. We chose a maximum magnitude of ML6.0 for this source zone. The largest earthquake occurred on 3 February 1880 and had a magnitude MI5.5 (Ref.5). It may have occurred on the Lake Edgar Fault which appears to have been recently active and the site of large earthquakes according to the field observations of Carey (Ref.7). In conformity with the rest of eastern Australia (Ref.6) and because we cannot do any better with hypocentral locations, 10 km was the depth used for earthquake risk calculations.

Carey (Ref.7) catalogued 2 540 events felt in northeastern Tasmania during the period 1883 to 1886. The activity continued intermittently until 1892. Recent work (Ref.5) suggests that the three largest events (13 July 1884, 12 May 1885 and 26 January 1892) had magnitudes MI6.4, 6.8 and 6.9 respectively and that their epicentres are situated in the West Tasman Sea Zone. The events of 1884 and 1885 occurred during a period of almost continuous swarm activity and consequently are not necessarily independent. There were several periods with no felt reports in the years 1888-1891 so we considered the earthquake of 26 January 1892 to be an independent event. Hence, there are at least two independent magnitude MI≥6.5 events in the 131 years since 1853. The magnitude frequency recurrence relationship is

logN = 1.8 - 0.6 ML

suggesting that the return period for a magnitude ML6.0 event is about 70 years, for a magnitude ML6.5 earthquake, 140 years, and for a magnitude ML7.0 event, 290 years. The maximum magnitude for the West Tasman Sea Zone was taken to be 7.5 because of the magnitude MI6.5-7.0 events in the swarm. Reliable focal depths for the zone are non-existent, so a depth of 10km was chosen for the earthquake risk calculations.

The epicentres not included in the source zones are considered to be background seismicity. For the Tasmanian earthquake risk calculations, the mean eastern Australian background seismicity (Ref.6) was used.

As isoseismal maps have been published for only four Tasmanian earthquakes (Ref.8) for which instrumental magnitudes are available, we used the average southeastern Australian attenuation (Ref.6) for the earthquake risk assessment. The attenuation function is given by

$$I=3.9+1.5ML-1.7\ln R$$

where I is Modified Mercalli intensity, ML is Richter magnitude, and R is hypocentral distance in km.

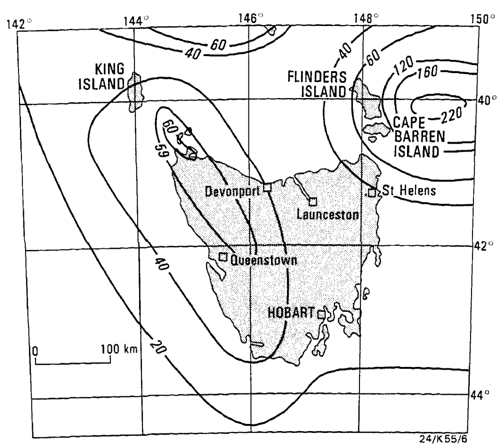

Fig. 2 Peak ground velocity (mm.s-1) with a 10% probability of being exceeded in a 50 year period.

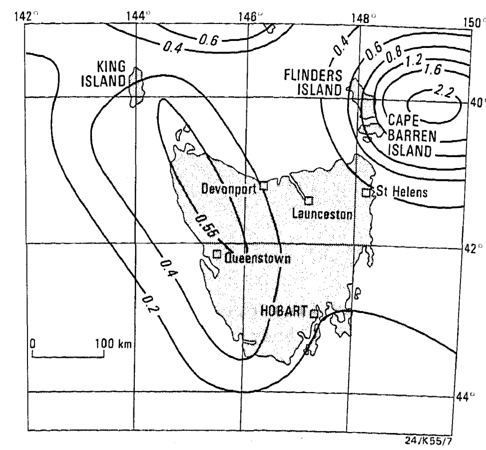

Fig. 3 Peak ground acceleration (m.s-2) with a 10% probability of being exceeded in a 50 year period.

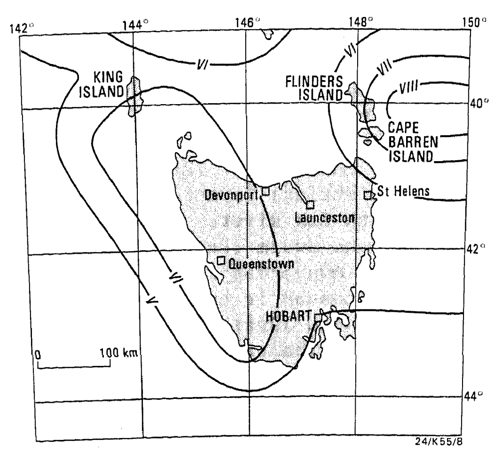

Fig. 4 Peak ground intensity (Modified Mercalli scale) with a 10% probability of being exceeded in a 50 year period.

RESULTS

Earthquake risk for the Tasmanian region was computed and plotted on a 0.25° grid near the source zones and a 0.5° grid elsewhere. The contours of peak ground velocity, peak ground acceleration, and Modified Mercalli intensity with a 10% probability of being exceeded in a 50 year period are shown in Fig.2,3 and 4. The risk computations assumed average site conditions. Because the effect of water on strong motion on the sea floor is unknown the offshore contours are dotted.

The land areas subject to the highest risk are Flinders and Cape Barren Islands which lie adjacent to the West Tasman Sea Zone and are predominantly between the 60mm.s^{-1}/0.6m.s^{-2} and 120mm.s^{-1}/1.2m.s^{-2} contours in Fig. 2 and 3.

The second highest risk land area is that part of western and northwestern Tasmania within the 59 mm.s^{-1}/0.55ms^{-2} contour in Figures 2 and 3. It is estimated that at Queenstown there is a 10% chance that the ground motion will exceed 58 mm.s^{-1} or 0.54 m.s^{-2} during a 50 year period. This corresponds to an intensity of MMVI-VII, which is the threshold at which damage can occur.

At Devonport, just outside the Western Tasmanian source zone, there is a 10% probability that ground motion will exceed 33 mm.s^{-1} or 0.31 m.s^{-2} (intensity MMV-VI) during a 50 year period. At Hobart, the corresponding figures are 23 mm.s^{-1} or 0.21 m.s^{-2} (intensity MMIV-V); and at Launceston 30mm.s^{-1} or 0.29 m.s^{-2} (intensity MMIV-V), well below the damage threshold.

DISCUSSION

The earthquake risk calculations indicate that the 100 year intensities at Queenstown and Flinders Island should be MMV-VI, while at Devonport, Launceston, and Hobart they should be MMIV-V. These results are reasonably consistent with the macroseismic data available for the period 1885 to 1984.

However, Launceston experienced intensity MMIV in 1900, 1948 and twice in 1887 (Ref.4), MMV in 1946 (Ref.4), MMIV-VII in 1885 and MMV-VII in 1892 (Ref.5). For seven out of eight earthquakes for which isoseismal maps were drawn, and which were felt in Launceston during the period 1859-1964 (Refs. 5 and 8), the maximum intensity experienced there was greater than that expected for an average site by one to two intensity units. For six out of eight events, even the mean intensity at Launceston was about one intensity unit greater than that for an "average site". Consequently the ground motion in some parts of Launceston appears to be underestimated by the risk maps. This is because the risk calculations assume average site conditions and there appears to be a local site effect in parts of Launceston, particularly the area (including the central business district) immediately south and southeast of the junction of the Tamar and North Esk Rivers. Minor damage occurred in this area during the 1883-1892 earthquake swarm (Ref.5). Also a magnitude ML5.7 event on 14 September 1946, 200 km away, was felt in Launceston with intensity MMV (Ref.4). This is because Launceston is built on a complex north northwest-trending Tertiary graben (in Jurassic dolerite) in which Tertiary lake sediments have been deposited. The area in which the maximum intensities were experienced during the swarm is underlain by up to 200m of Tertiary clays. Because of the complex nature of the graben, their thickness varies from an estimated 200m to zero where dolerite crops out in City Park at the eastern extremity of the area (P. Stephenson, Tasmanian Mines Department, personal communication). The estimated effect of this amplification in the lake sediments of the city is to increase the contours from about 30mm.s^{-1} and

$0.29 m.s^{-2}$ to about $60 mm.s^{-1}$ and $0.60 m.s^{-2}$. This should be taken into consideration in seismic zoning in those parts of Launceston underlain by the Tertiary lake sediments.

An uncertain parameter in the Western Tasmanian Zone is the maximum magnitude. The largest event in this region in historic times was a magnitude MI5.5 earthquake, and we used magnitude ML6.0 for our risk assessment. McCue (Ref.2) deduced an upper bound of magnitude ML6.5 for the Type III extreme value distribution for southeastern Australia. If this were taken to be the maximum magnitude for western Tasmania, then the risk at Queenstown, Devonport and Hobart would be increased by up to 10%.

Another uncertainty is the attenuation of strong ground motion. We have used an average southeastern Australian attenuation (Ref.6). Strong motion data need to be collected for the Tasmanian region to define the attenuation in this area.

A third uncertainty in the estimation of Tasmanian earthquake risk is caused by lack of instrumental information on the locations and magnitudes of earthquakes which occurred prior to the establishment of the Tasmanian seismic net. The first station was not opened until 1957 (Ref.7). There were few or no instruments to locate events accurately before this, or to determine their magnitudes. Some errors and omissions in existing catalogues have been corrected for this study, but more research into the magnitudes and epicentres of early earthquakes needs to be done.

CONCLUSIONS

The highest risk land areas are Flinders and Cape Barren Islands (which lie predominately between the $60 mm.s^{-1}/0.6 m.s^{-2}$ and $120 mm.s^{-1}/1.2 m.s^{-2}$ contours) followed by the northern part of western Tasmania ($59 mm.s^{-1}/0.55 m.s^{-2}$).

The chief contributors to uncertainty in the estimation of earthquake risk are uncertainties in early earthquake locations and magnitudes, and in strong ground motion attenuation.

We recommend that special attention be given to the microzoning of Launceston because of site effects.

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