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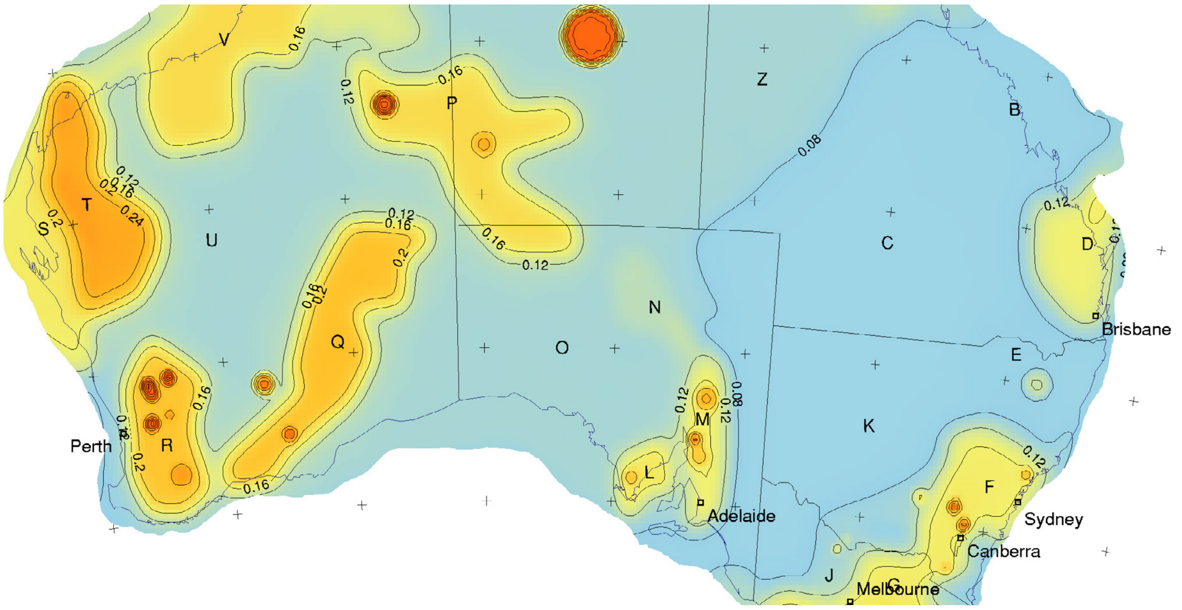

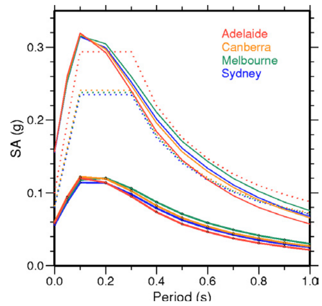

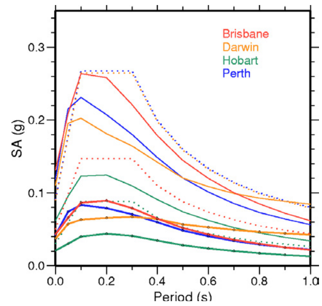

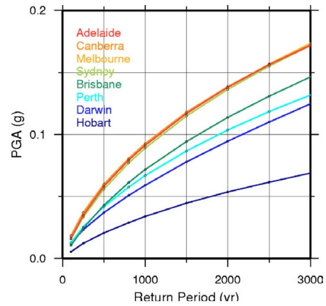

Record 2013/41 | **GeoCat** 77399

Atlas of Seismic Hazard Maps of Australia

Seismic hazard maps, hazard curves and hazard spectra

M. Leonard, D. Burbidge and M. Edwards

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GEOSCIENCE AUSTRALIA
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Contents

List of Figures

List of Tables

1 Introduction

1.1 Introduction to this Atlas of NSHM

In 2012 Geoscience Australia produced a National Seismic Hazard Map (NSHM) of Australia using the Probabilistic Seismic Hazard Assessment (PSHA) methodology. The technical details describing the process used to produce the NSHM are presented in the GA record, Burbidge ed. (2012). The primary product of the project was a single 500 year return period Peak Ground Acceleration (PGA) map. Readers interested in the underlying science used to produce the map are referred to the papers: Allen et al. 2006, Leonard 2008, Clark et al. 2011, Allen 2012, Allen et al. 2012, Burbidge et al. 2012, Clark et al. 2012, Leonard 2012, Leonard et al. 2012, Leonard et al. 2013-submitted.

At the 2012 Australian Earthquake Engineering Society meeting, where the NSHM was initially presented, there was a general acceptance that the reference hazard return period in the earthquake loading code should move from 500 years to 2500 years. Since the publication of the hazard map the authors have also received extensive feedback from various technical experts. A recurring theme was that a single 500 year return period PGA map was not adequate for many of the users of NSHM. For example, those in the mining industry are interested in much longer return periods with intervals of 10,000 years, even 100,000 years, being mentioned. A wider range of Pseudo Absolute Spectral Acceleration (SA) periods have also been requested, with professionals designing, building and managing large structures being primarily interested in SA periods of 1.0s or longer. In response to this feedback, it was decided to publish this atlas which contains a range of hazard maps with different return and spectral acceleration periods. It also contains hazard curves and hazard spectra for 34 locations across Australia.

In total, the hazard in this assessment has been calculated for 14 return periods (100 – 100,000 years) and 21 SA periods (0.0 – 5.0s), giving 294 hazard layers (maps) for 48,000 sites across Australia. The hazard maps, curves and spectra presented in this Atlas are effectively slices and lines extracted from this four dimensional data volume. Due to space limitation, only five of the possible 294 hazard maps and 34 of the tens of thousands of possible hazard curves and spectra are shown. These were selected to cover the main types of additional maps that have been requested since the NSHM was released and to cover a reasonable range of return periods, SA periods and locations. In this record, the probability factors (Kp) given in AS1170.4 are also compared to the equivalent curve from the hazard assessment for the eight capital cities. Finally, the hazard spectra for the capital cities and for some selected locations are compared to the spectra for site class B_e given in AS1170.4.

Modern ground motion prediction equations (GMPE) predict the maximum acceleration response of a 5% damped oscillator with a natural period of vibration equal to that of interest when subject to an earthquake of given magnitude, depth, distance and local bedrock condition (Reiter 1990 pg 100-106). Where acceleration response values are determined across a range of natural periods they lie on what is described as the acceleration response spectrum for the earthquake under consideration. These values are related to the spectra used in engineering design in that the spectral accelerations associated with the entire range of possible earthquake events are integrated into a generalised acceleration response spectrum in which each point on the spectrum has an equal annual likelihood of exceedence. The spectrum is generally smoother than that associated with an individual earthquake event and a single earthquake usually does not match the full spectrum as it is an integration of a range of earthquakes having varied ground motion frequency contents. In building regulations around the world this generalised design spectrum is defined in several ways. In the current Australian standard (AS1170.4, 2007) the PGA is defined to provide the zero period spectral acceleration value for a soft rock site. The balance of the acceleration spectrum “hangs” off this value using a set of period specific shape factors that are applied to the PGA value. The GMPE can provide a direct prediction of the shape factors for a soft rock site, though the codified values are often subject to some heuristic modifications to address design issues. The design demands for non-rock sites are also specified using alternate spectral shape factors that are applied to the same soft rock site PGA, which are developed from site response modelling with similar heuristic modifications. Finally, the site PGA value in the standard is factored for other annual likelihoods of exceedence which in turn proportionally adjusts the entire design spectrum.

1.2 Technical changes from GA Record 2012/71

To extend the Probabilistic Seismic Hazard Assessment (PSHA) to longer return and SA periods the modelling had to be modified slightly from that described in Burbidge (ed. 2012). For the NSHM the ground motions for the 500 year PGA map were calculated out to 100km for each synthetic earthquake. However for longer return and SA periods it was found that ground motions out to 600km still made a significant contribution to the probabilistic hazard. As several of the GMPEs used in the assessment were only defined out to 200 or 500km extrapolation was needed in order to use them out to 600km. Similarly, some extrapolation is needed to calculate the SA for periods longer than that specified for the equation in question (for example, the Allen (2012) equation is only specified up to 4.0s).

The requirement to calculate ground motion out to longer distances for a larger range of SA periods provided an opportunity to adjust some zone boundaries. First the western Southwest Seismic Zone (SWSZ) boundary was moved from approximately 35km east of the Darling Fault to approximately 5km east of it. This new position is now more consistent with the boundary between the Cratonic and Extended Stable Continental Regions (Leonard et al. 2012). This slightly increases the PGA hazard in Perth from 0.036g to 0.042g at a return period of 500 years. Second, the Flinders and Mt Lofty Ranges source zone was extended south by about 50km. This reduces the effect of the smoothing algorithm on the hazard in Adelaide and changes the PGA hazard in the Adelaide CBD from 0.06g to 0.08g at a return period of 500 years.

With these changes implemented, the two layers (one for which combined the Background, Regional and Offshore zones and one for the Local zones) were rerun. The return periods used were: 100, 250, 500, 800, 1000, 1500, 2000, 2500, 3000, 5000, 10000, 20000, 50000 and 100000 years. The SA periods used were 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2, 1.5, 1.7, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 and 5.0s. Note that a recurrence interval of 500 years is often called an annual frequency of exceedence of 1/500. Similarly a 500 year hazard map is also known as a map of hazard values with an annual probability of exceedence of 1/500. The recurrence interval is also known as the return period.

1.3 Major changes from AS1170.4-2007

The 2007 earthquake hazard map for the building code was a single 500 year PGA map, with a Probability Factor (Kp) applied to scale this to other recurrence intervals. The general trend of the maps shown in this atlas is that at a return period of 500 years the PGA hazard is generally lower than the hazard map in AS1170.4. In most capital cities the 500 year PGA hazard is around three quarters of the current hazard value in AS1170.4. However, at recurrence intervals of 2500 years or more the hazard is generally higher. The lower 500 year hazard is thought to be primarily the result of two factors. First, the selected GMPEs in the new assessment have a higher attenuation than those used in the late 1980's PSHAs which were used as the basis of the map in AS1170.4. Second, the adoption of local magnitude scales (M_L) from around 1990 have resulted in the lowering of the magnitudes of larger (>M_L4.0) earthquakes. This reduces the seismicity rate. The effect of these two factors on the hazard can be summarised by comparing the probability factor (Kp) for the eight capitals.

The Kp factor is calculated at a point by normalising the hazard by its value at a recurrence interval of 500 years. The Kp values calculated probabilistically here differ markedly from the Kp values given in AS1170.4 (Figure 1). Above 500 years, the calculated Kp curve continues to rise whereas the AS1170.4 Kp values flatten off. The differences in Kp between the capital cities appears to be primarily controlled by the b-value. A high b-value (e.g. 1.0 for Canberra and Adelaide) results in lower Kp values at longer recurrence intervals compared to mid-values (e.g. 0.9 for Melbourne, Perth and Sydney) or lower values (e.g. 0.75 for Brisbane and Hobart). The high M_{MAX} (the maximum magnitude used in the hazard modelling), of 9.3, used in the zones to the north of Australia is likely to be causing the rapidly increasing Kp curve for Darwin. The 500 year PGA hazard, presented here, is 75% of the AS1170.4 value for many Australian cities (i.e. Adelaide, Brisbane, Canberra, Melbourne, Sydney) whereas the 2500 year hazard value is 30% higher.

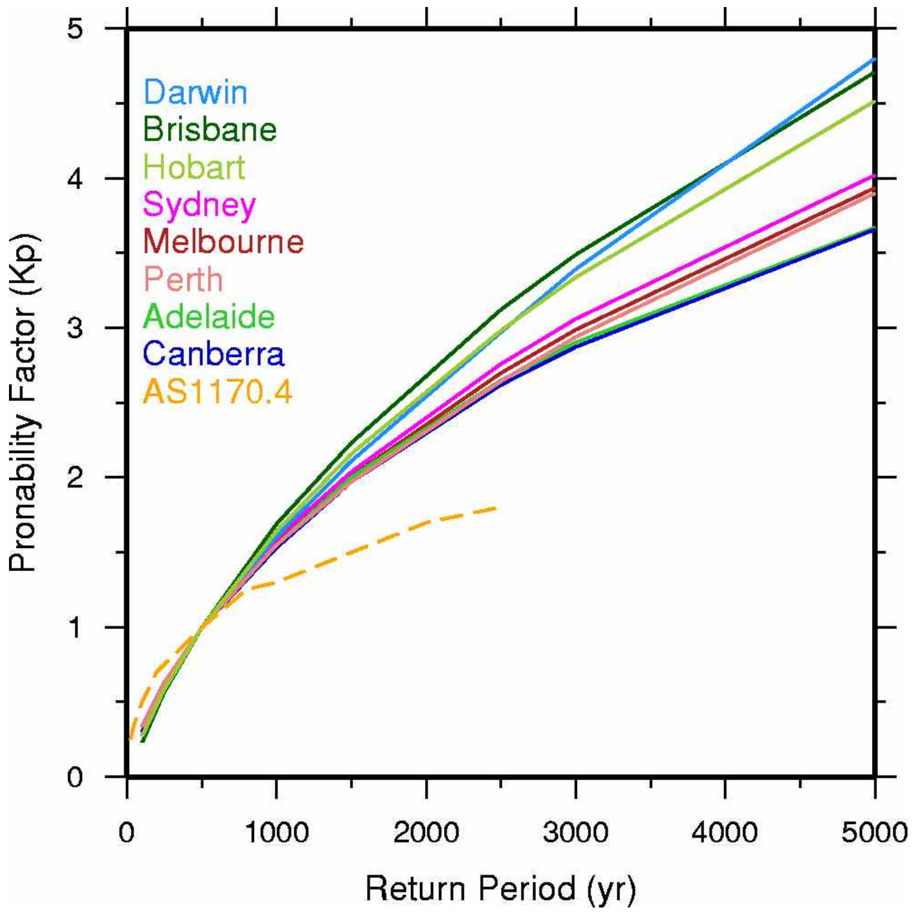


Figure 1 The probability factor (Kp) for the eight capital cities compared to the single Kp values in AS1170.4-2007 (orange dashed curve).

2 Comparison of PGA hazard curves for selected sites

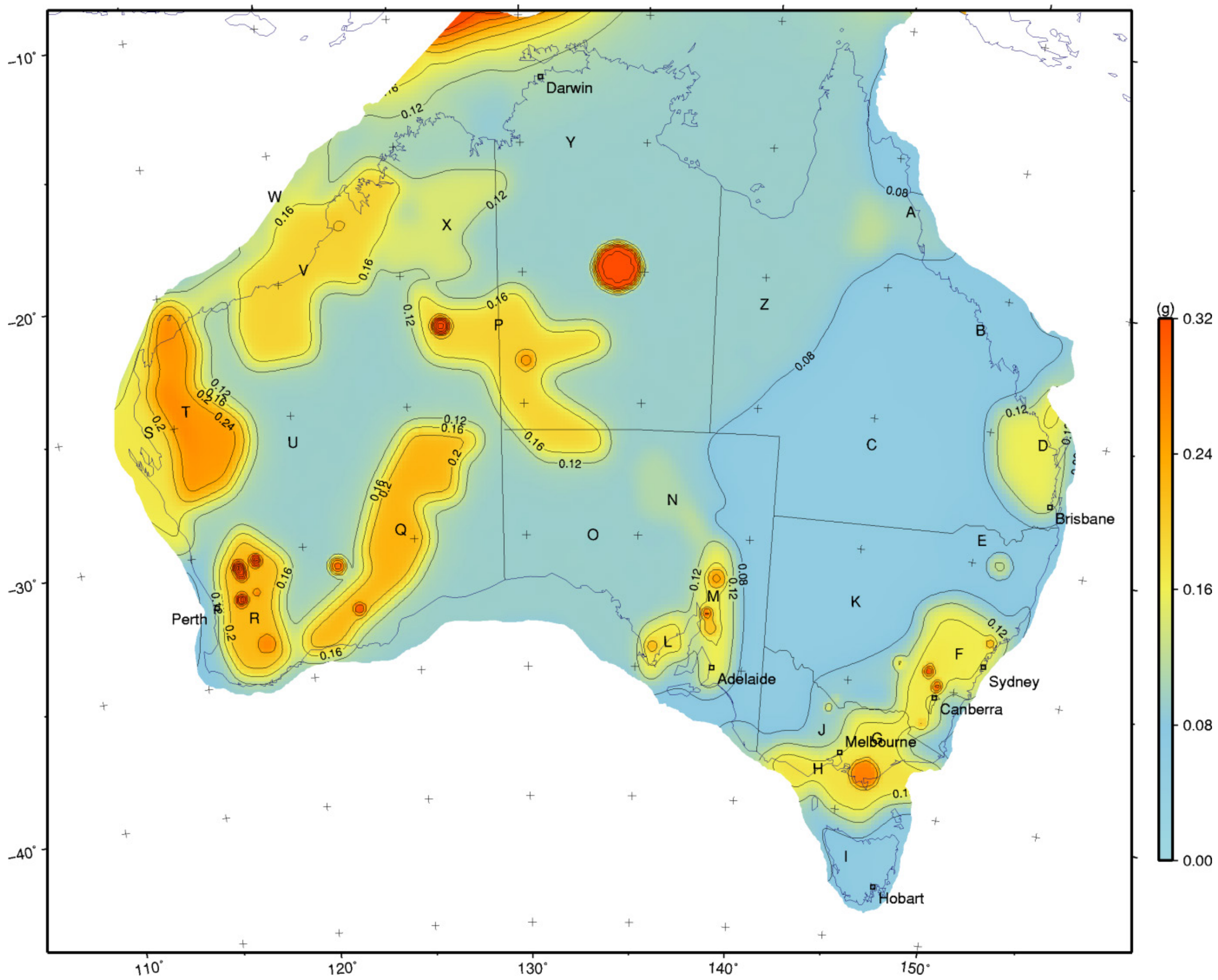


Figure 2 A map of the 0.0s (PGA) Spectral Acceleration (SA) with an annual probability of exceedence of 1/2500.

The 2500 year return period SA 0.0s (PGA) hazard map is shown in Figure 2, along with the capital cities. The figure also shows 26 reference locations, from A to Z, which typify the hazard across the rest of the country. From this figure it can be seen that the four cities of Adelaide, Canberra, Melbourne and Sydney all have a similar hazard (≈0.16g) with Brisbane, Perth and Darwin being lower (≈0.12g) and Hobart being much lower (≈0.07g) at a recurrence interval of 2500 years. This difference between the cities is clearer in the hazard curves (Figure 3). The hazard in the CBDs of Adelaide, Canberra, Melbourne and Sydney are effectively identical (Figure 3a), while the hazard in Brisbane, Perth and Darwin is 25% lower. Hobart's hazard is significantly lower than for all the other capital cities. Due to their size and a gradient in the hazard, the hazard varies significantly across the cities of Adelaide, Brisbane, Melbourne, Perth and Sydney. The maximum hazard for the greater metropolitan areas covered by the capital cities (Figure 3b) shows a greater spread in values than for the CBDs.

The hazard for Melbourne and Sydney has increased and is now slightly higher than Adelaide and Canberra which still have effectively identical hazard curves. The hazard in Perth and Brisbane has increased to a similar level to that in Adelaide and Canberra. Darwin is lower and Hobart remains the lowest.

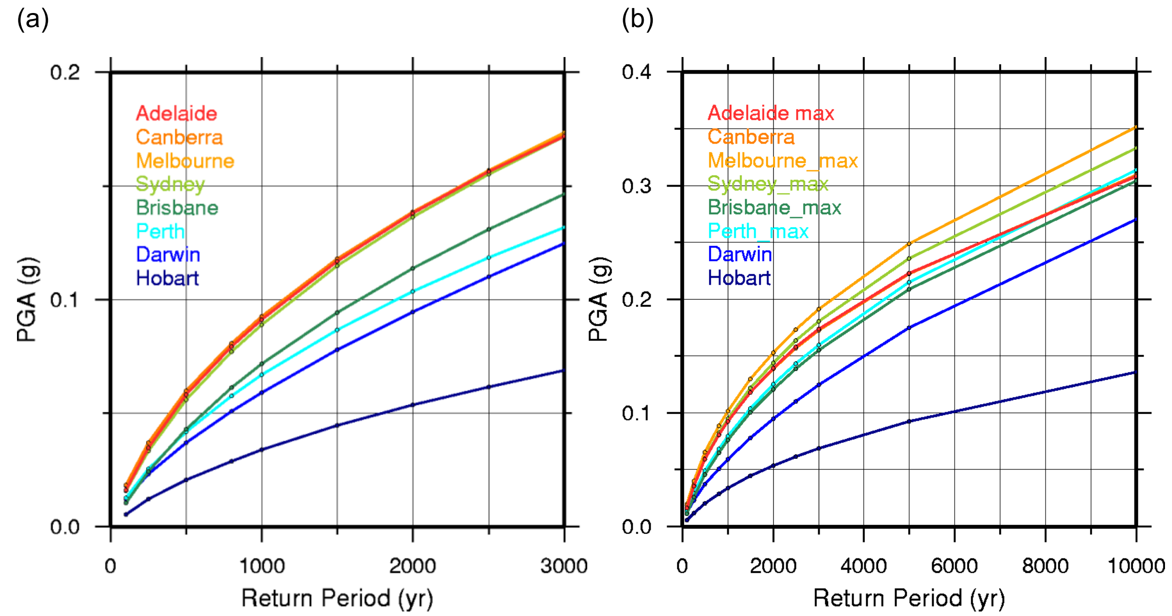


Figure 3 PGA hazard curves for the capital cities for (a) the CBD values or (b) the maximum values for the greater metropolitan area covered by the city. The hazard of the CBD of the four cities of Adelaide, Canberra, Melbourne and Sydney are effectively identical (Figure 3a), and that for Brisbane, Perth and Darwin hazard is 25% lower. The PGA hazard for Hobart is significantly lower than the other capital cities for all return periods.

The hazard curves for five locations D, K, T, V, Y (see Figure 2) and for Tennant Creek are shown in Figure 4. The six locations characterise the vast majority of seismic hazard in Australia. As the local layer has a lower M_{MAX} in the Tennant Creek zone than for the regional layers (i.e. 6.3 for Tennant Creek compared to 7.5 for zones which contain points D, K, T, V and Y) it might be expected that the Tennant Creek hazard would roll off more rapidly than the other locations. However this is not the case. This slower roll-off is thought to be due to the high variance in the ground motion prediction equations (GMPEs), particularly at distances less than 20km (Allen 2012). The high variance means that at long return periods the hazard is being dominated by the very high ground motions that are two standard deviations above the median. As a result, the hazard continues to rise quite steeply as a function of return period even for very long recurrence intervals.

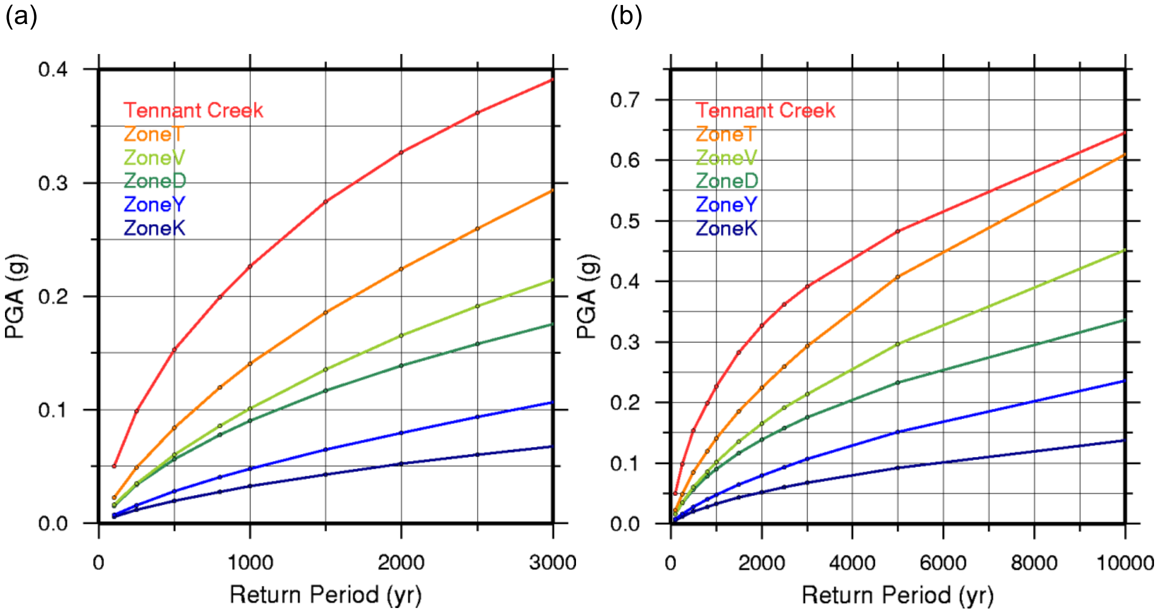


Figure 4 Hazard curves for a SA of 0.0s (PGA) at locations D, K, T, V, Y and Tennant Creek between 100 and (a) 3000 or (b) 10,000 years.

3 National Seismic Hazard Maps

Table 1 Details of the six national hazard maps presented in Figures 5 to 10.

Figure	Return Period (yr)	SA period (s)	GMPE distance (km)	Filter Width (km) regional	Filter Width (km) local	Filter Width (km) combined
5	500	0.0	100	120	60	60
6	500	0.0	600	180	30	60
7	2500	0.0	600	180	30	60
8	2500	0.3	600	180	30	60
9	2500	1.0	600	180	30	60
10	10000	1.0	600	180	30	60

This section shows the national hazard map for the six combinations of parameters shown in Table 1. They were chosen on the basis of the requests received by GA for maps with these recurrence intervals or SA periods and to ensure that this Atlas covers a reasonable range of values. For a detailed explanation of the meaning of the filter widths used (last three columns) see Burbidge et al. (2012). The maps are shown in Figures 5 to 10. The main difference between Figure 5 and 6 is the distance out to which the GMPEs are calculated for each event (100km and 600km respectively). Hence, Figure 5 shows the 500 year return period earthquake hazard purely from local earthquakes, while Figure 6 includes the hazard generated by earthquakes at regional distances as well. Figures 7 to 9 show the national hazard at a return interval of 2500 years for three different SA periods (all for 5% damping). All were calculated out to 600km. Figure 10 shows the hazard at a very long recurrence interval (10,000 years) for a long period of ground motion (1.0s), also at 5% damping.

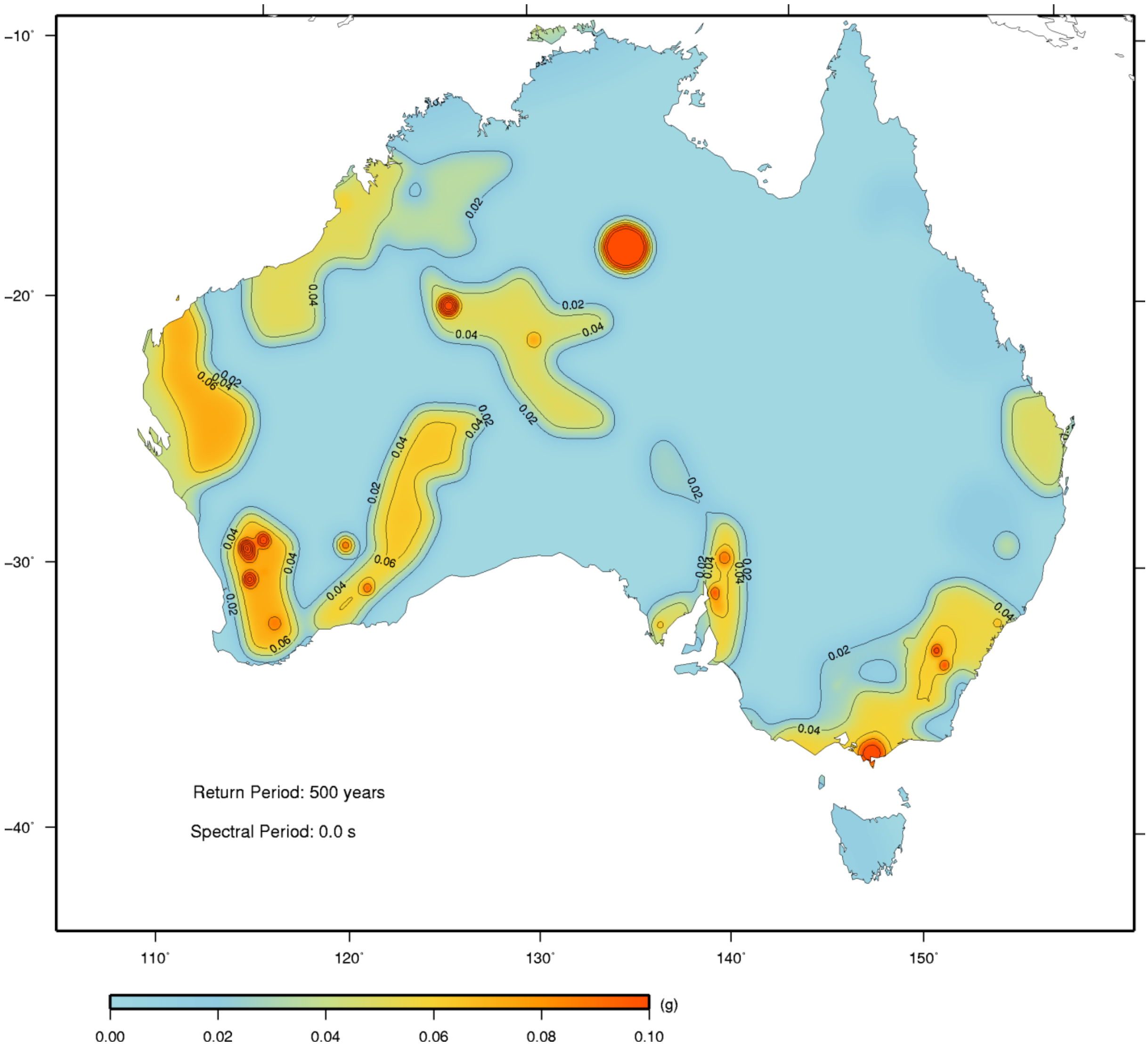


Figure 5 The national hazard map with an annual probability of exceedence of 1/500 at a RSA of 0.0s (PGA). Ground motions were calculated out to 100km only. This is the map released in Burbidge (ed. 2012).

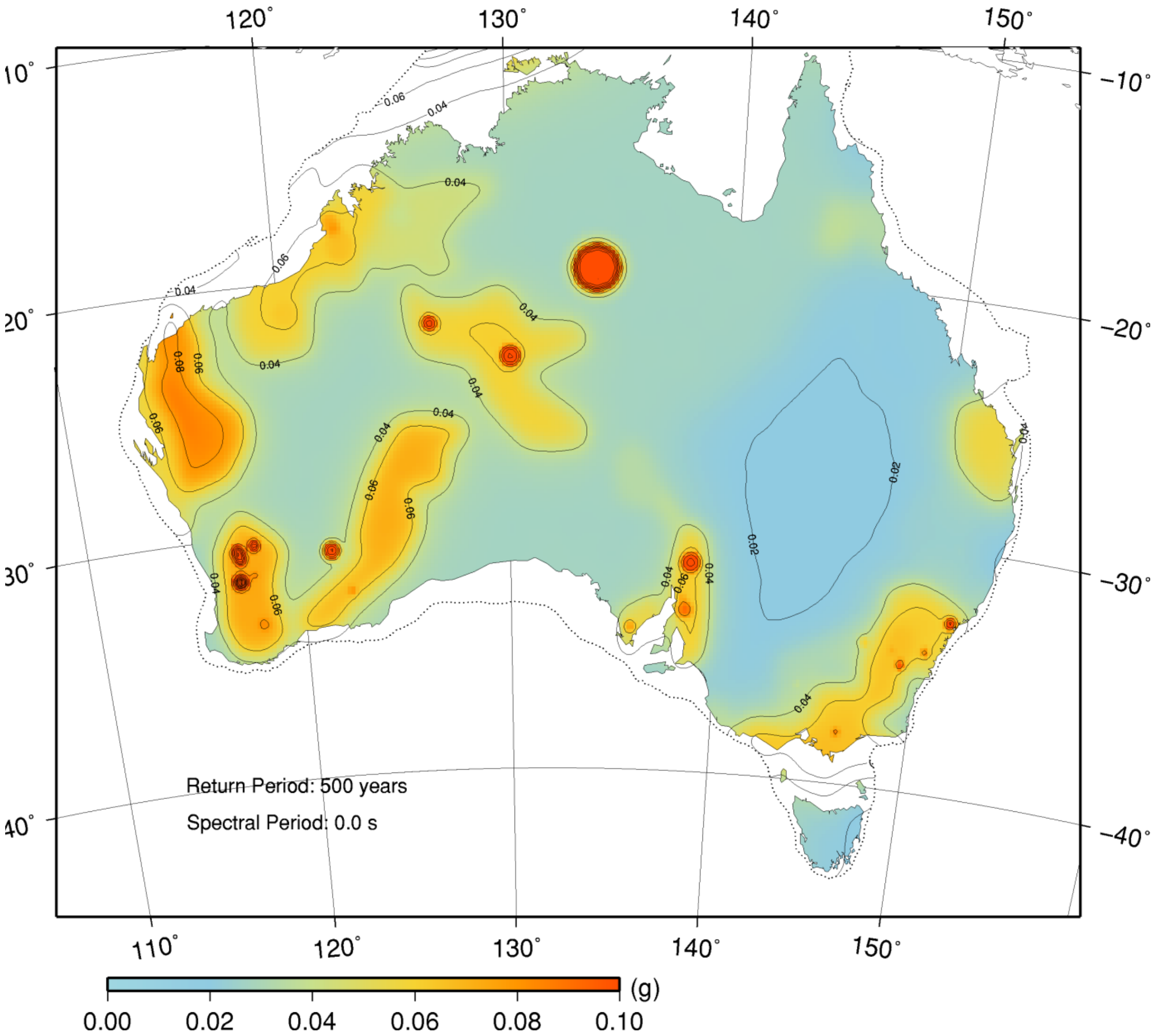


Figure 6 The national hazard map with an annual probability of exceedence of 1/500 at a SA of 0.0s (PGA). Ground motions were calculated out to 600km.

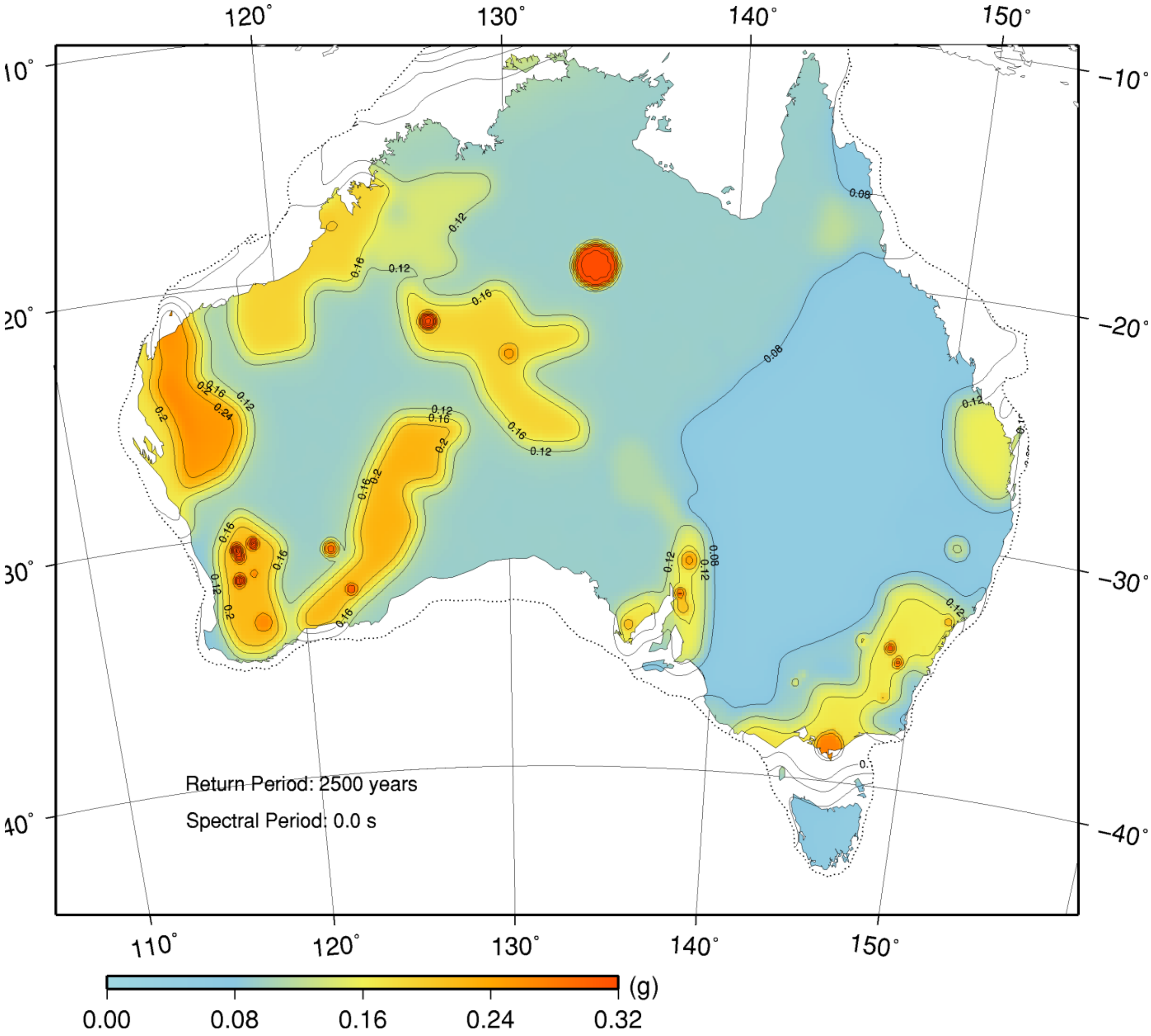


Figure 7 The national hazard map with an annual probability of exceedence of 1/2500 at a SA of 0.0s (PGA).

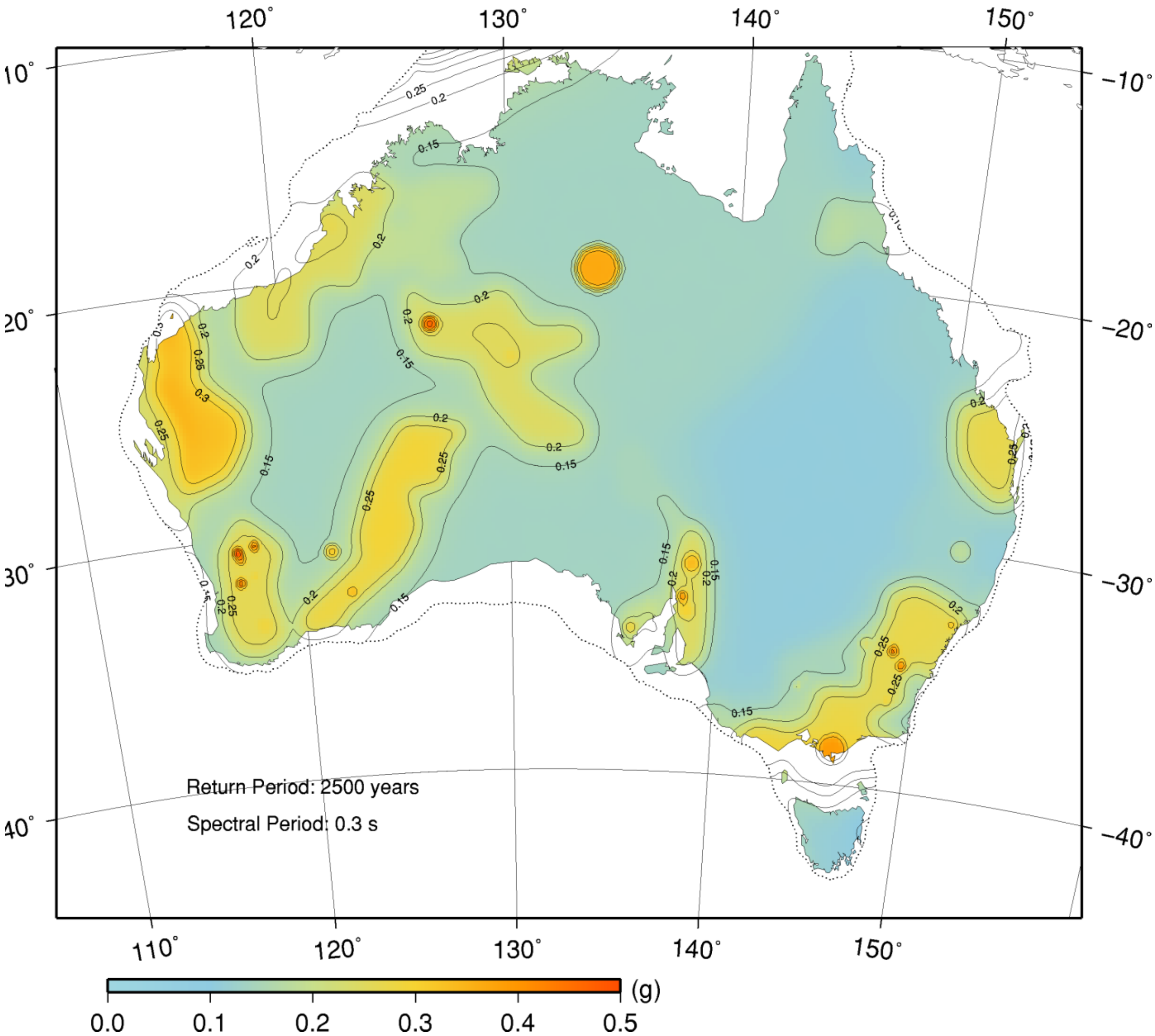


Figure 8 The national hazard map with an annual probability of exceedence of 1/2500 at a SA of 0.3s.

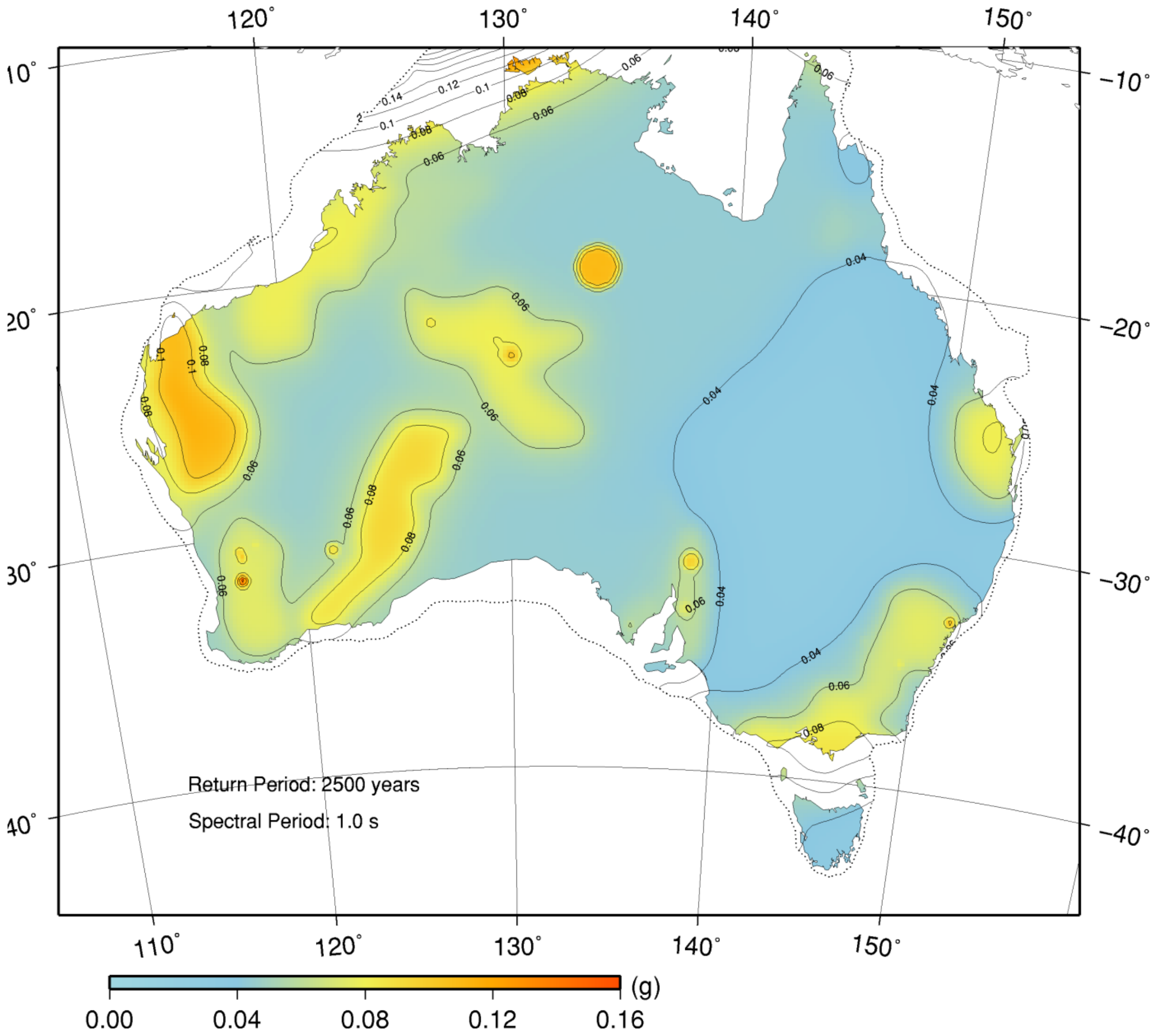


Figure 9 The national hazard map with an annual probability of exceedence of 1/2500 at a SA of 1.0s.

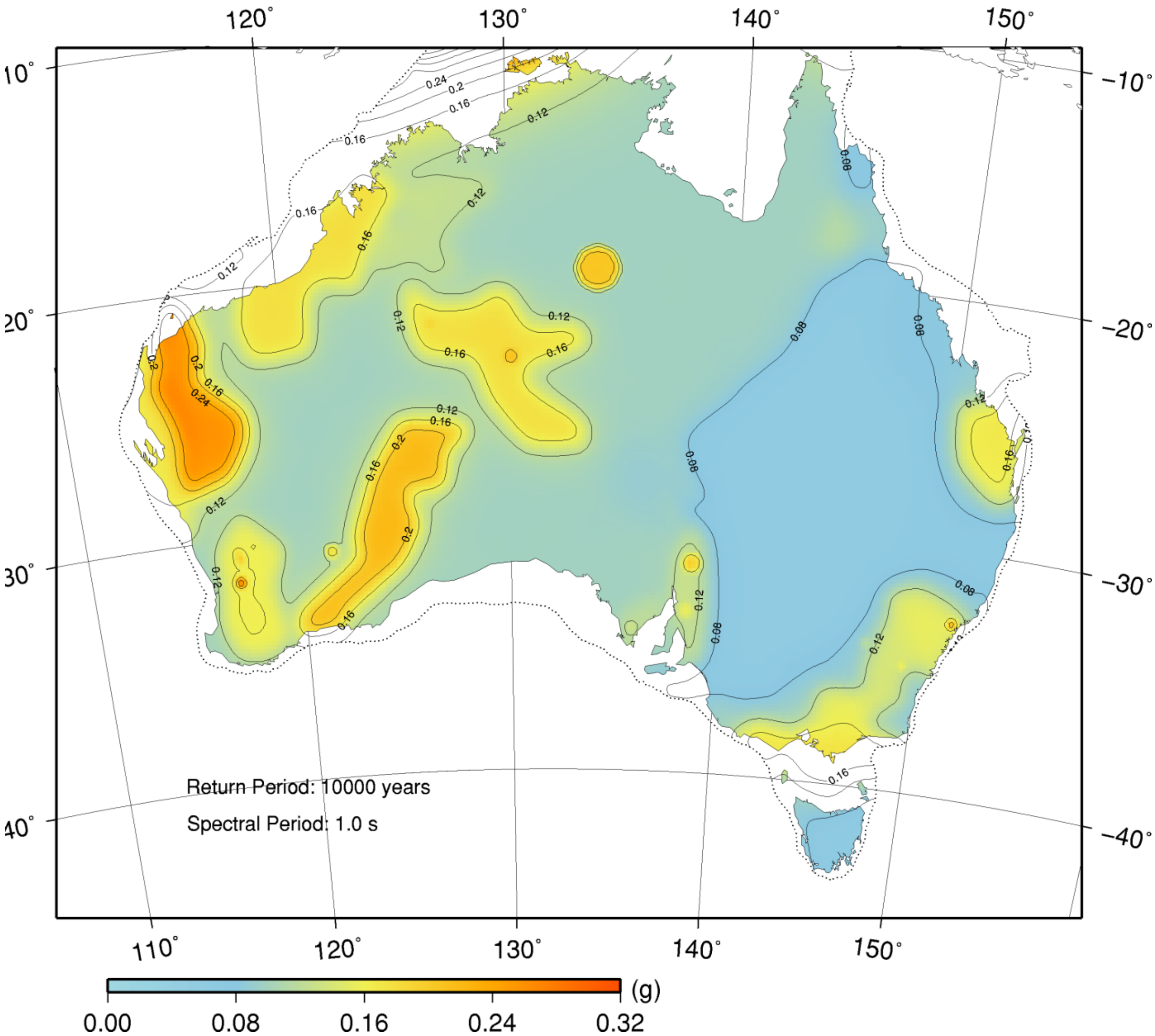


Figure 10 The national hazard map with an annual probability of exceedence of 1/10000 at a SA of 1.0s.

4 Regional Seismic Hazard Maps

Figures 11 to 20 show the PGA hazard maps for recurrence intervals of 500 and 2500 years on a region by region basis. Also shown on each map are the cities and towns listed in Table 3.2 of AS1170.4.

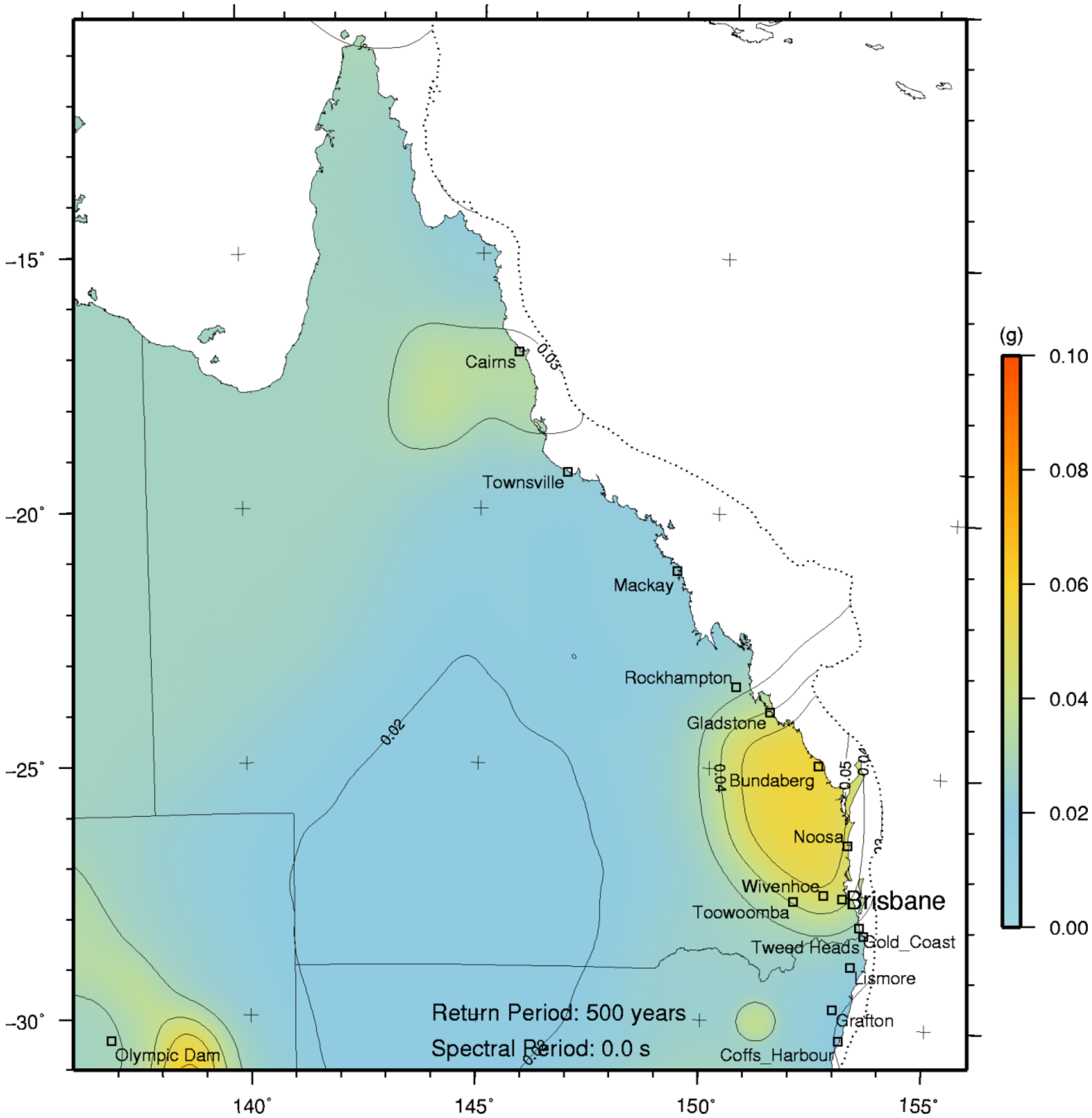


Figure 11 The hazard map of Queensland with an annual probability of exceedence of 1/500 at a SA period of 0.0s (PGA).

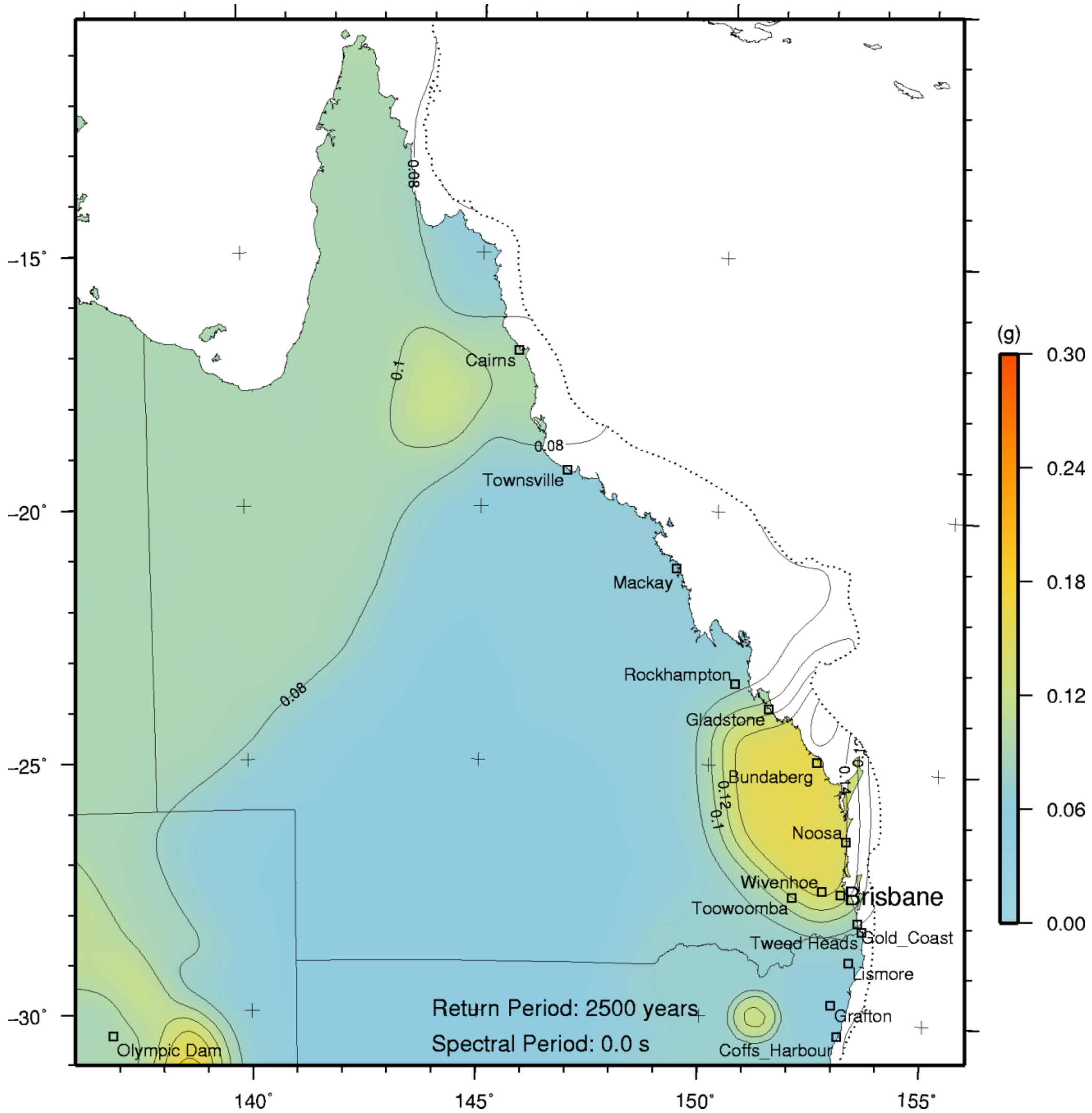


Figure 12 The hazard map of Queensland with an annual probability of exceedence of 1/2500 at a SA period of 0.0s (PGA).

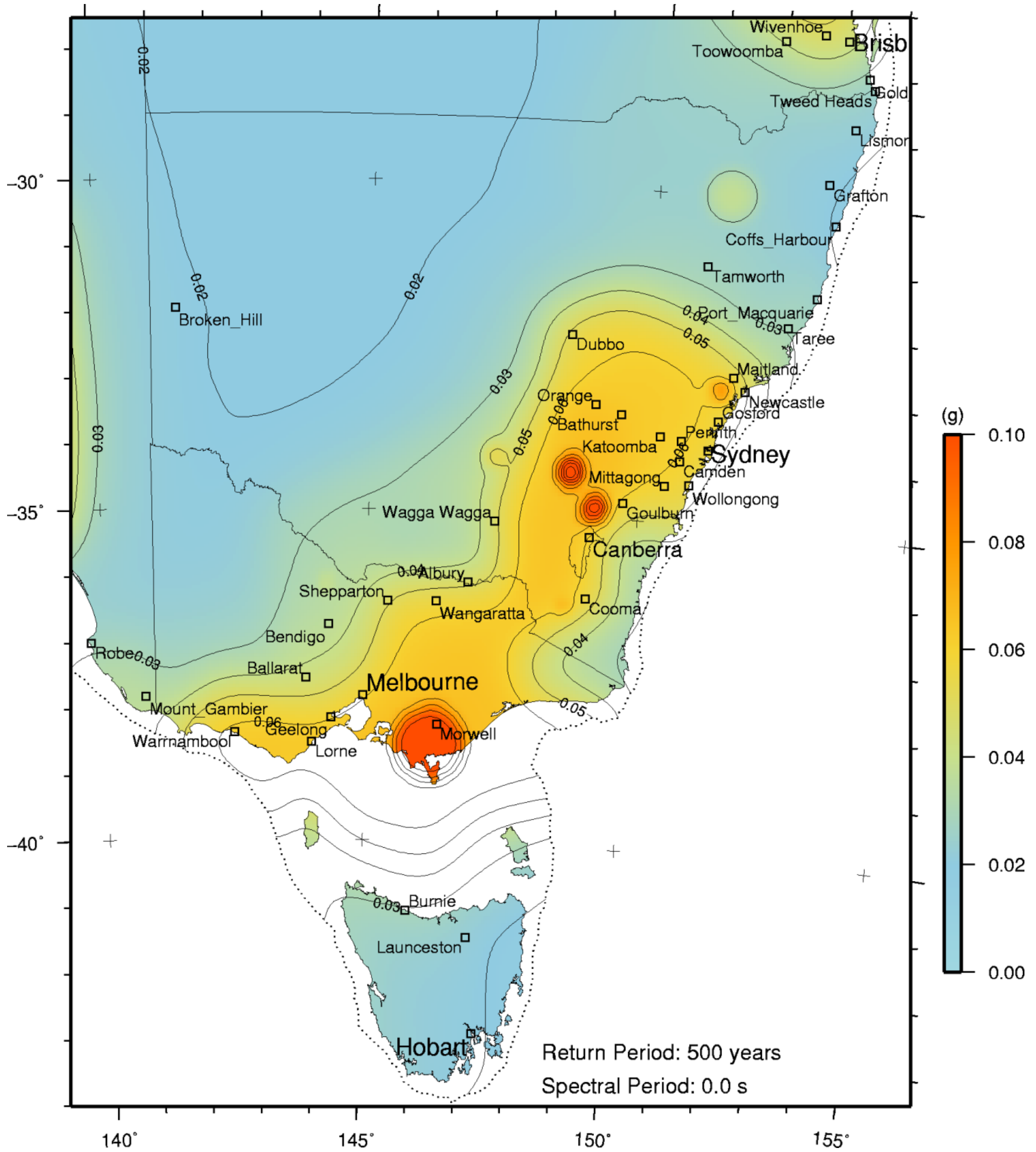


Figure 13 The hazard map of NSW, Victoria and Tasmania with an annual probability of exceedence of 1/500 at a SA period of 0.0s (PGA).

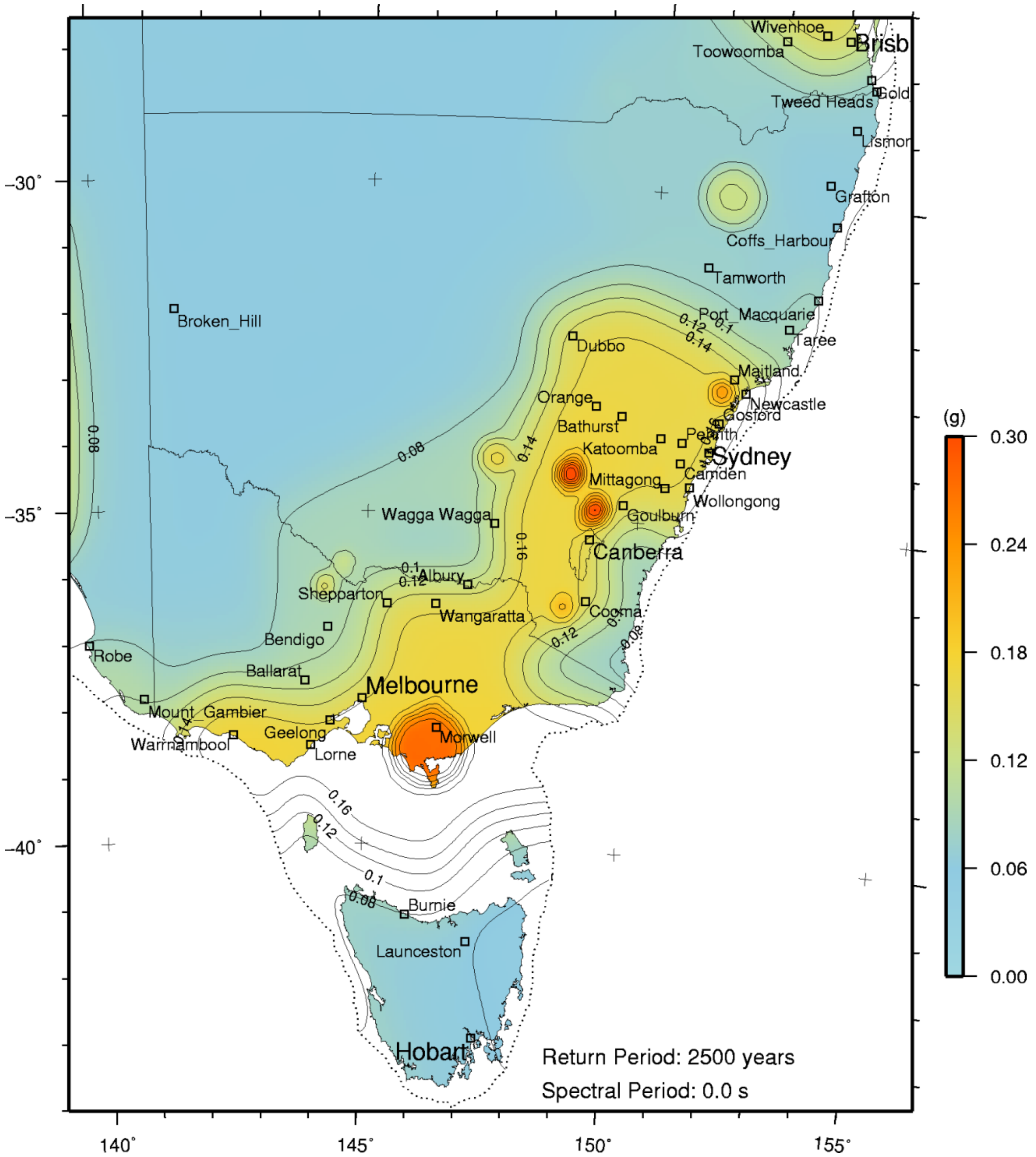


Figure 14 The hazard map of NSW, Victoria and Tasmania with an annual probability of exceedence of 1/2500 at a SA period of 0.0s (PGA).

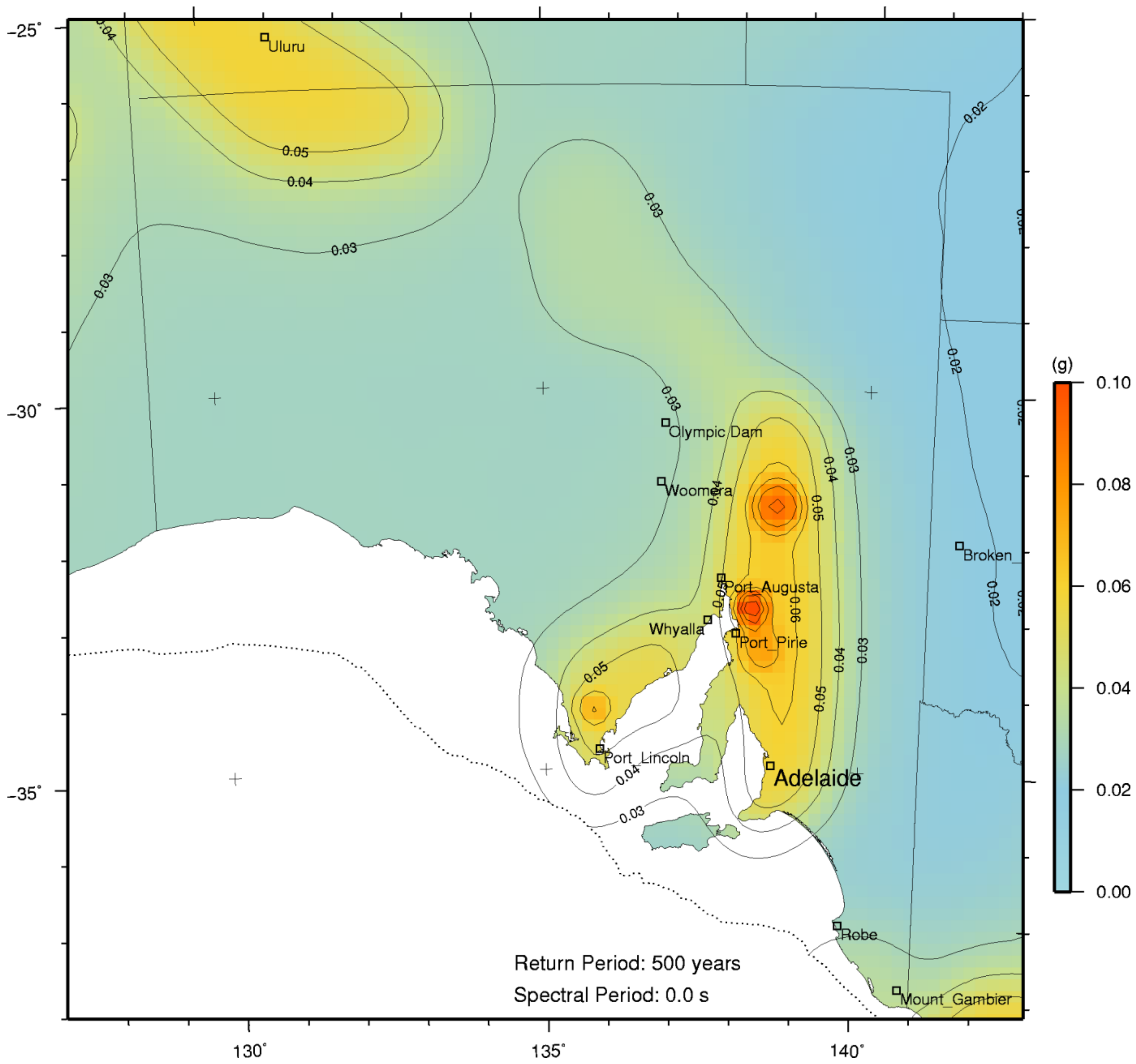


Figure 15 The hazard map of South Australia with an annual probability of exceedence of 1/500 at a SA period of 0.0s (PGA).

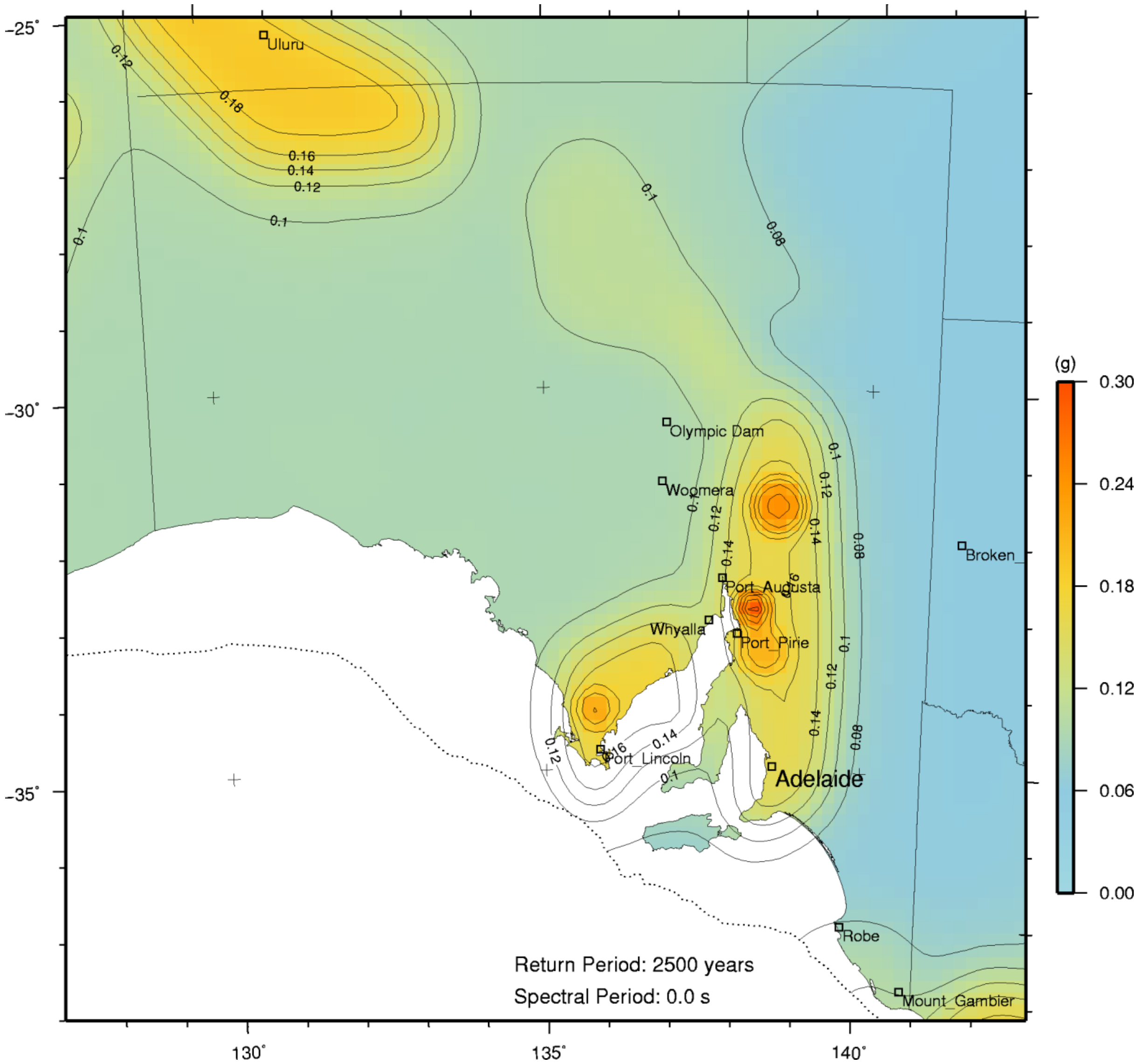


Figure 16 The hazard map of South Australia with an annual probability of exceedence of 1/2500 at a SA period of 0.0s (PGA).

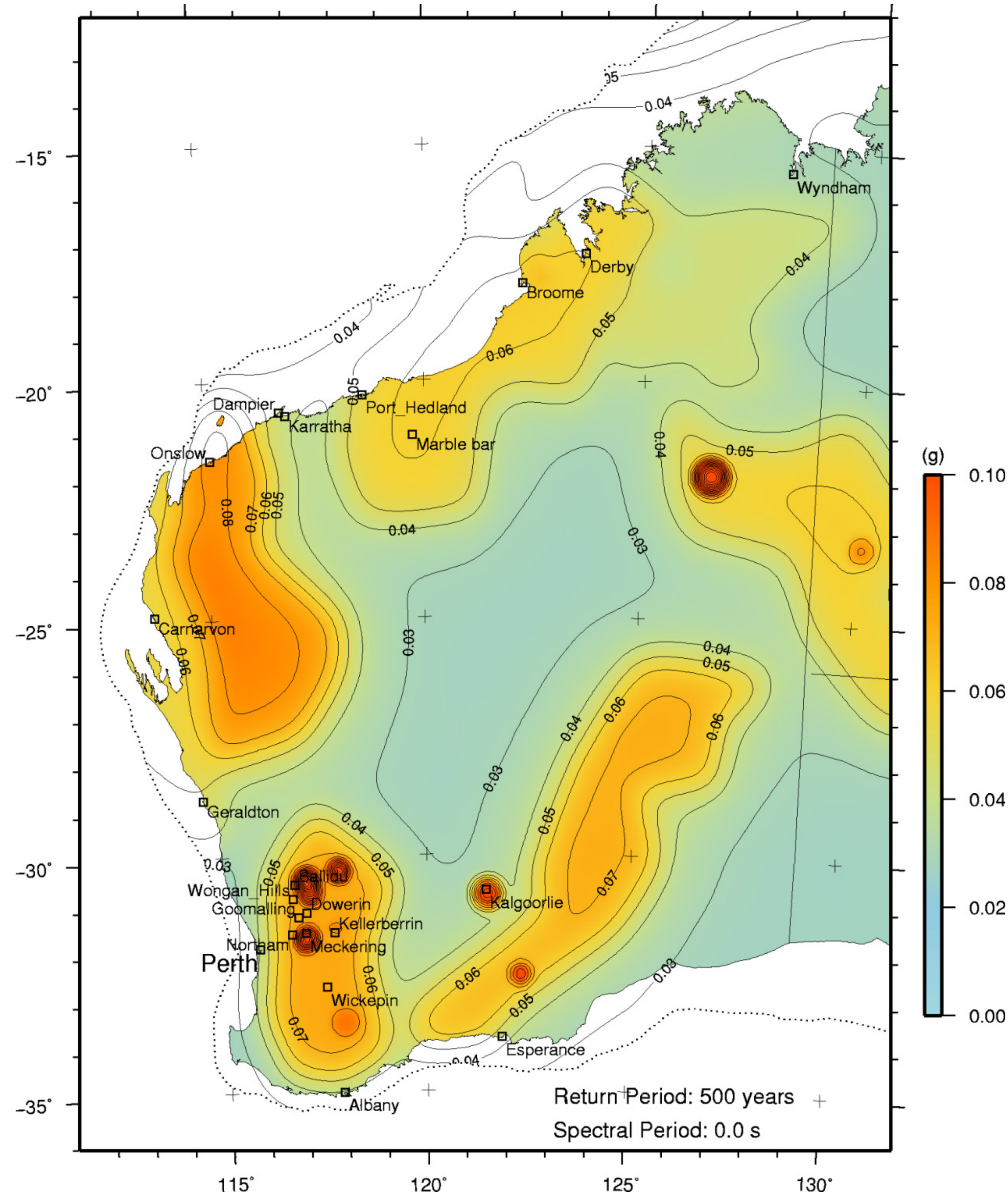


Figure 17 The hazard map of Western Australia with an annual probability of exceedence of 1/500 at a SA period of 0.0s (PGA).

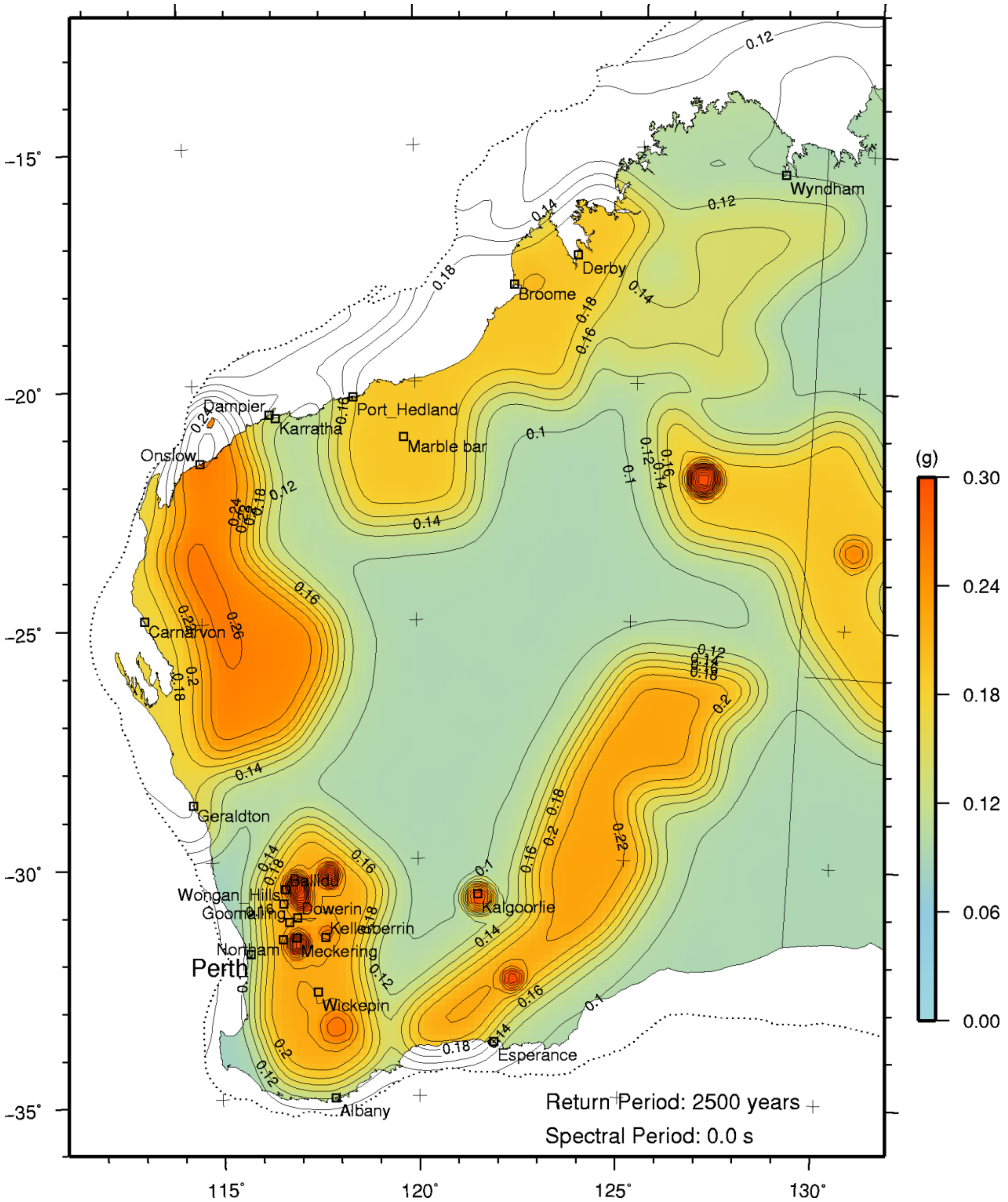


Figure 18 The hazard map of Western Australia with an annual probability of exceedence of 1/2500 at a SA period of 0.0s (PGA).

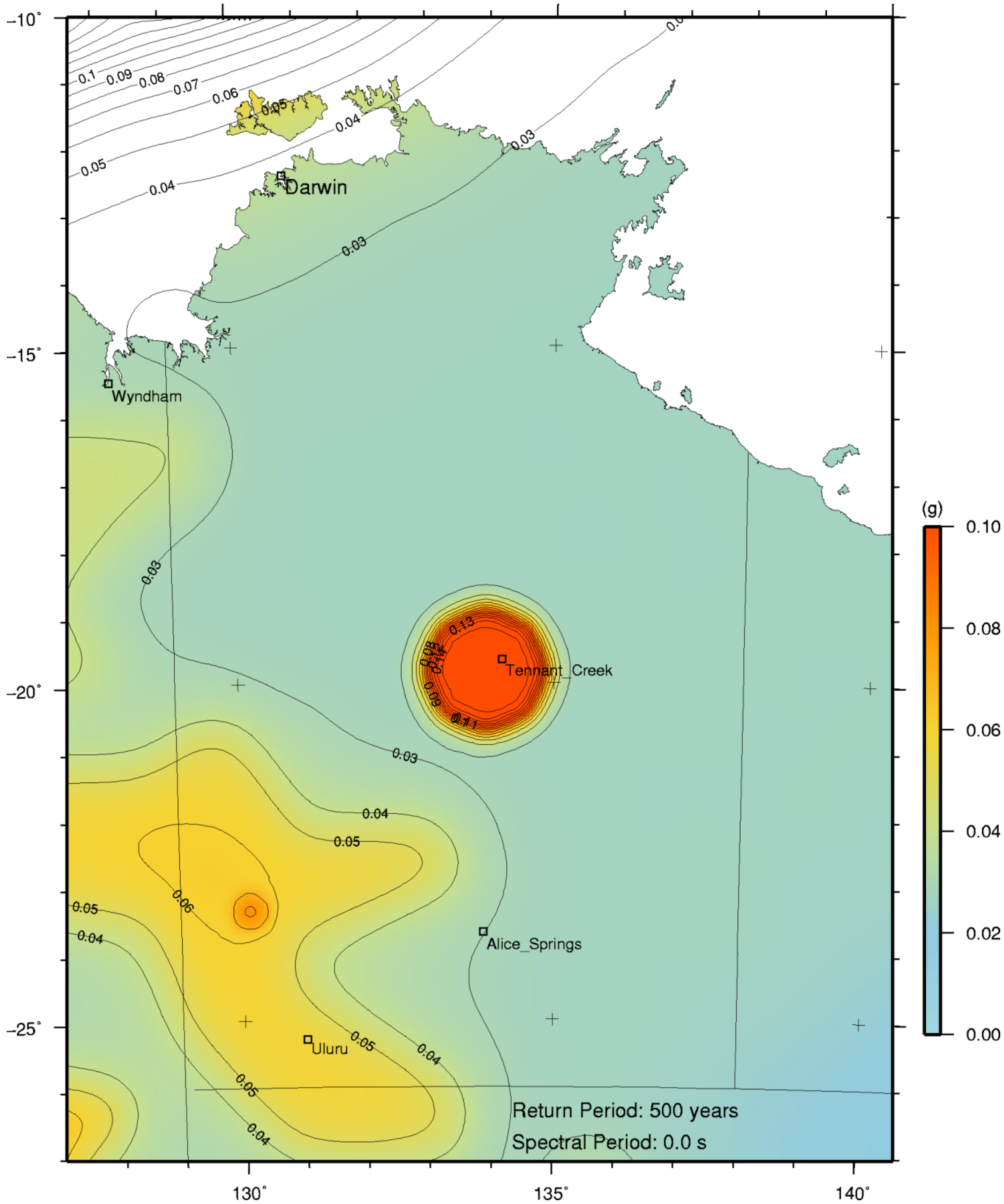


Figure 19 The hazard map of the Northern Territory with an annual probability of exceedence of 1/500 at a SA period of 0.0s (PGA).

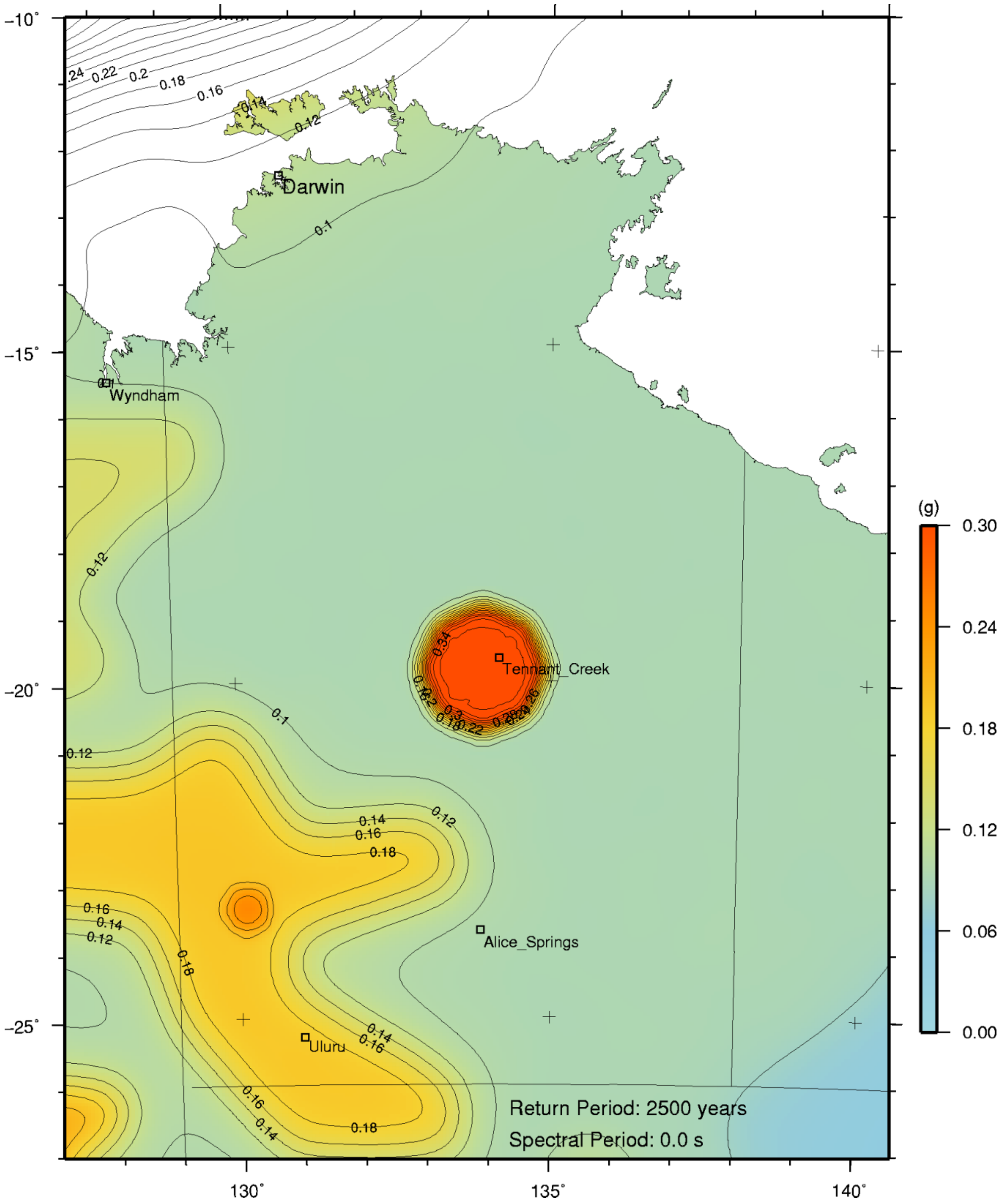


Figure 20 The hazard map of the Northern Territory with an annual probability of exceedence of 1/2500 at a SA period of 0.0s (PGA).

5 Hazard Curves

This section presents the hazard curves for the eight capital cities and for 26 characteristic sites. These 34 locations encompass the range of hazard levels typically observed across Australia. The locations of these points are shown with respect to the source zones and the hazard map in Figure 21 and Figure 22 respectively. The hazard for the eight capital cities are shown in Figure 23 and for the 26 characteristic sites in Figure 24.

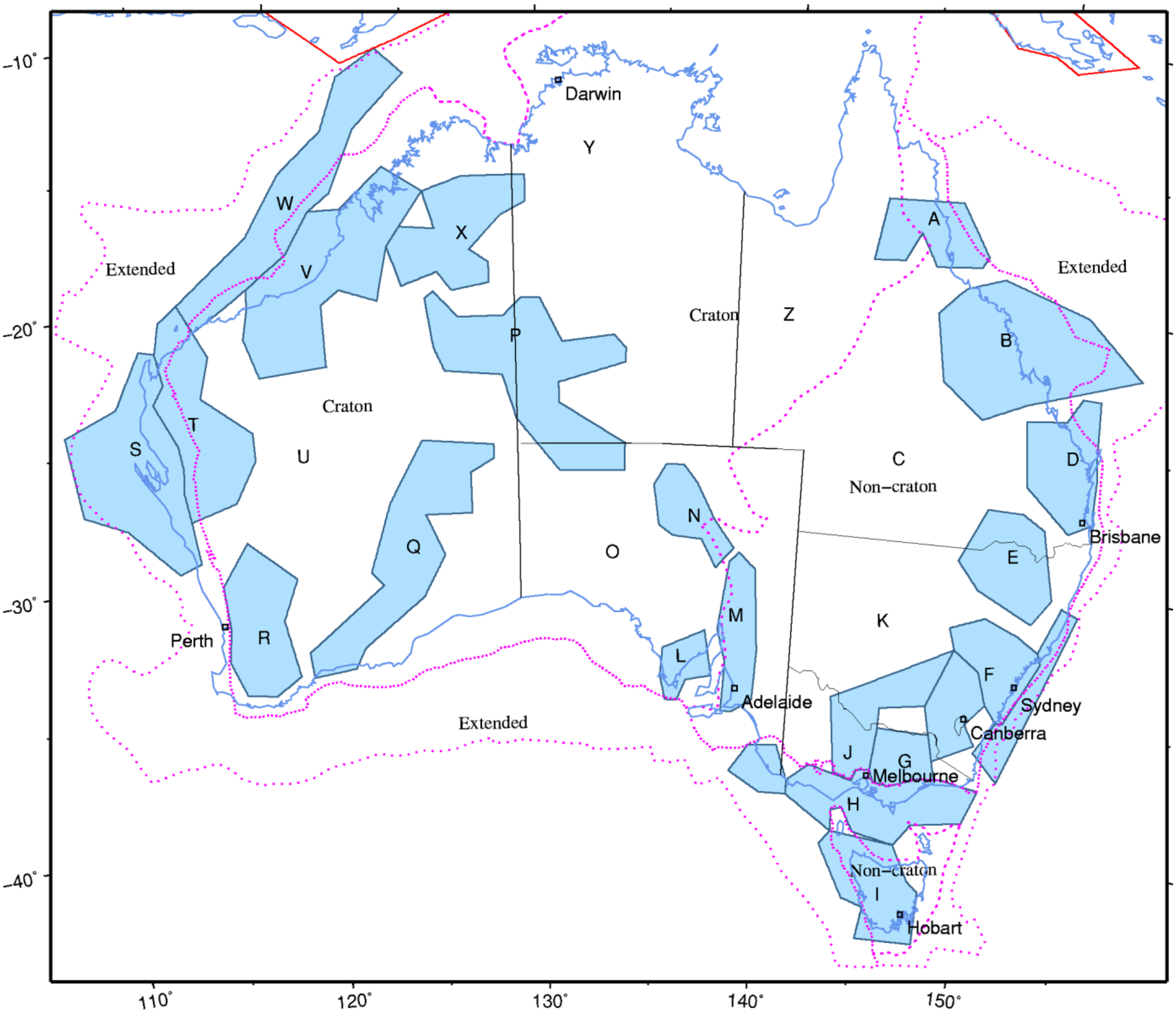


Figure 21 The source zones with the 26 locations and eight capital cities for which hazard curves and spectra shown in Figures 23 and 24 are calculated.

Where there is a strong gradient of the hazard, such as the boundaries of the source zones centred on locations Q, R and T, it is difficult to take a hazard curve from one location and apply it to another. Elsewhere for locations, with low gradient of the hazard, which have a similar 2500 year PGA hazard value, the hazard curves tend to be very similar for all other recurrence intervals. For example, Canberra and Melbourne are both within the same, non-Cratonic, background zone, they both have a 2500 PGA hazard of 0.016-0.17g and all their curves are very similar. The same applies to other locations in the same background zone like F and H. Similarly, locations which are all with the Cratonic crust, like locations P, V and S, all have similar curves. However Brisbane and location X, which are in different background zones, have a similar 2500 year PGA hazard but are quite different at other recurrence intervals.

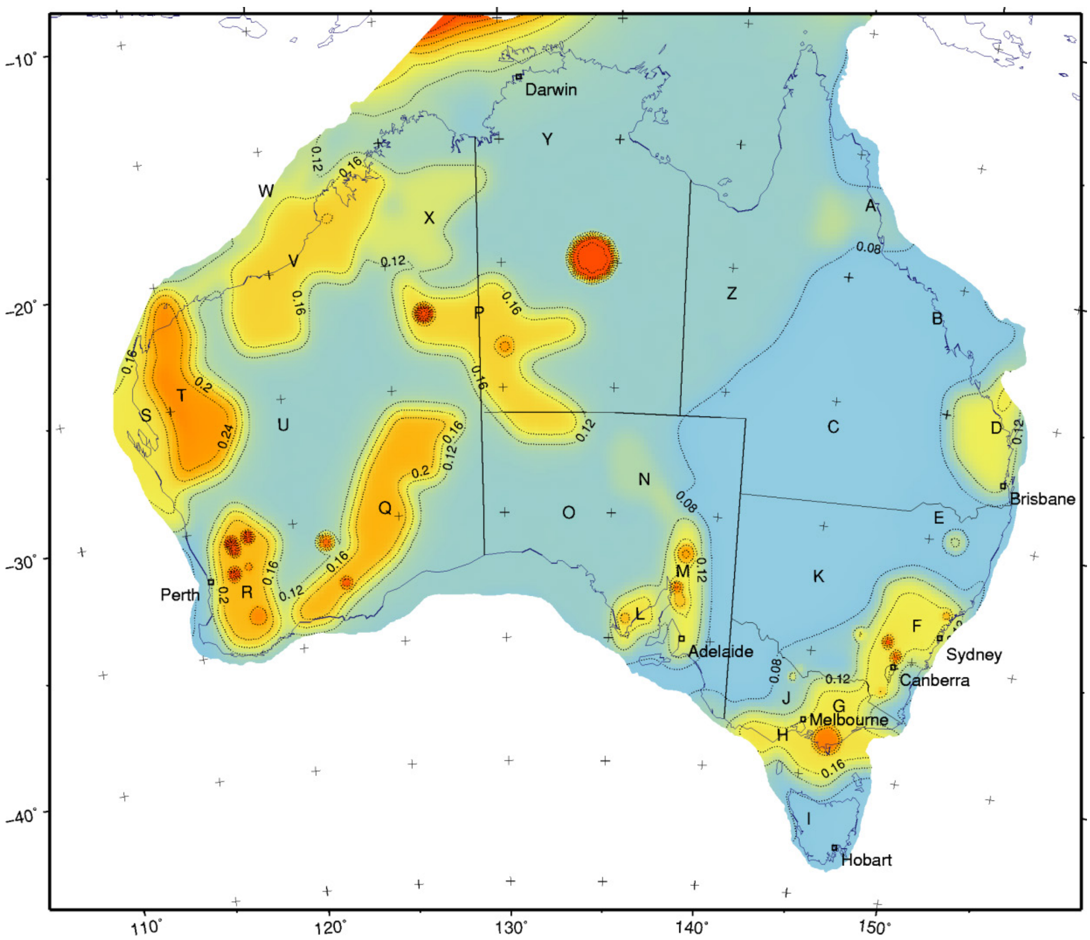
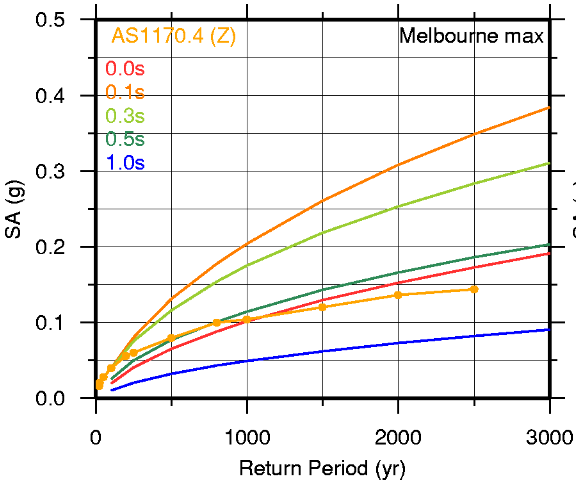
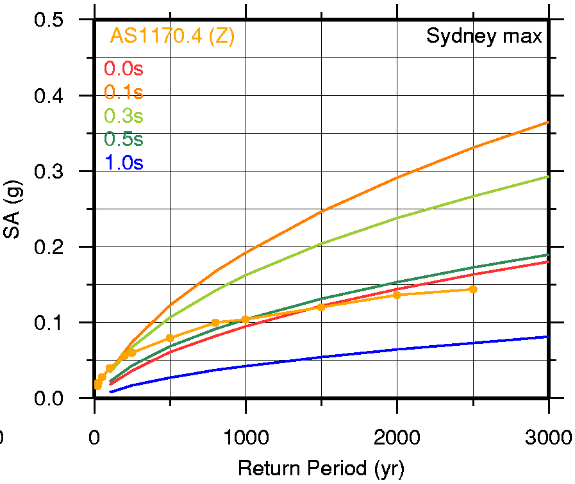


Figure 22 The hazard map, with an annual probability of exceedence of 1/2500, with the 26 locations and eight capital cities for which hazard curves in Figures 23 and 24 are calculated.

(a)


AS1170.4 (Z)
Melbourne max
0.0s
0.1s
0.3s
0.5s
1.0s
SA (g)
0.0
0.1
0.2
0.3
0.4
0.5
0
1000
2000
3000
Return Period (yr)

(b)


AS1170.4 (Z)
Sydney max
0.0s
0.1s
0.3s
0.5s
1.0s
SA (g)
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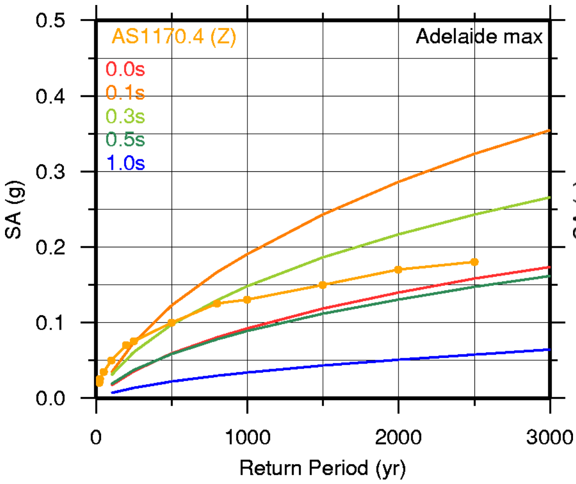
0.1
0.2
0.3
0.4
0.5
0
1000
2000
3000
Return Period (yr)

(c)


AS1170.4 (Z)
Adelaide max
0.0s
0.1s
0.3s
0.5s
1.0s
SA (g)
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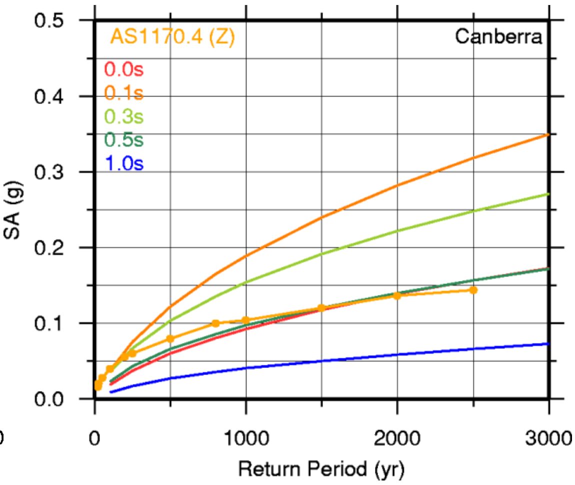
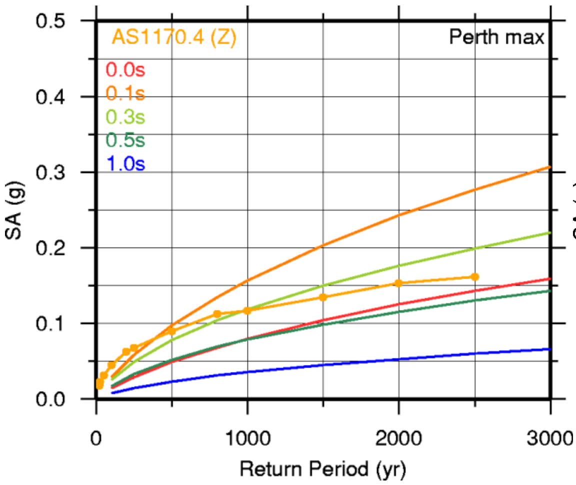
0.1
0.2
0.3
0.4
0.5
0
1000
2000
3000
Return Period (yr)

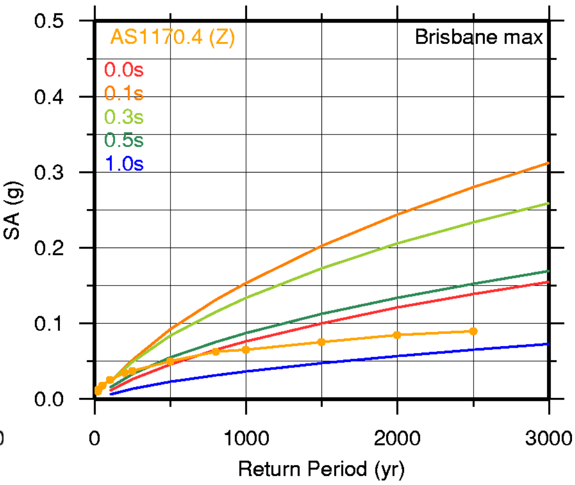
(d)


AS1170.4 (Z)
Canberra
0.0s
0.1s
0.3s
0.5s
1.0s
SA (g)
0.0
0.1
0.2
0.3
0.4
0.5
0
1000
2000
3000
Return Period (yr)

(e)


AS1170.4 (Z)
Perth max
0.0s
0.1s
0.3s
0.5s
1.0s
SA (g)
0.0
0.1
0.2
0.3
0.4
0.5
0
1000
2000
3000
Return Period (yr)

(f)


AS1170.4 (Z)
Brisbane max
0.0s
0.1s
0.3s
0.5s
1.0s
SA (g)
0.0
0.1
0.2
0.3
0.4
0.5
0
1000
2000
3000
Return Period (yr)

(g) (h)

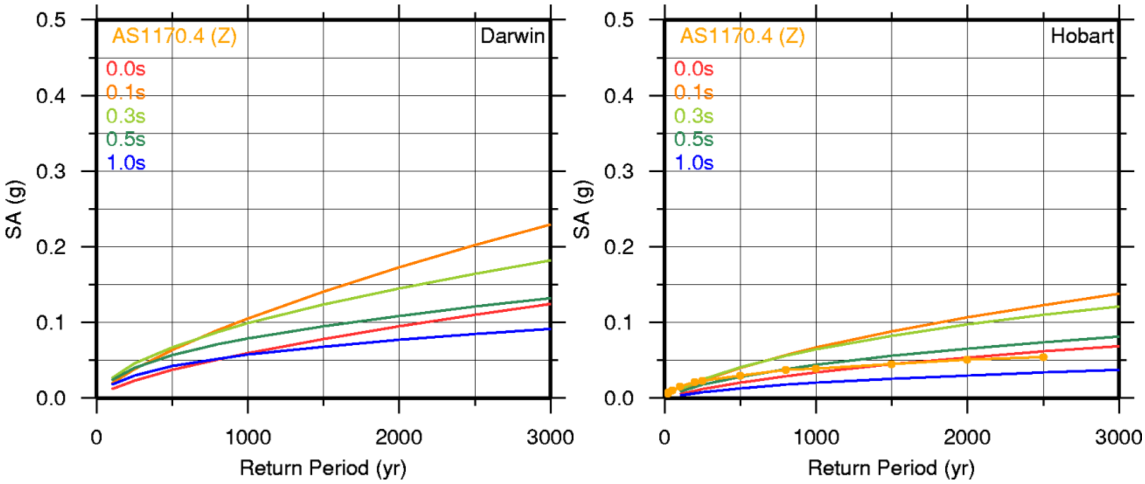
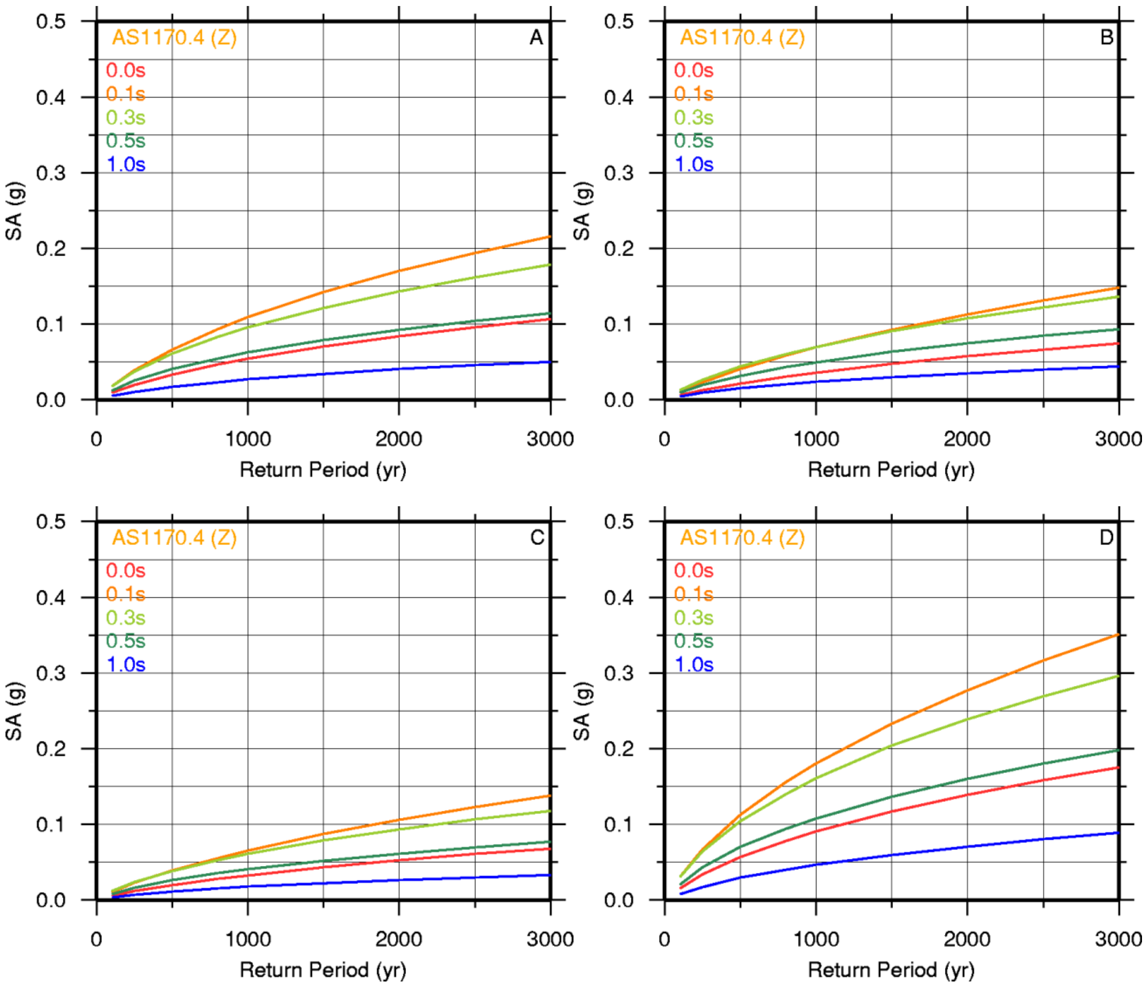
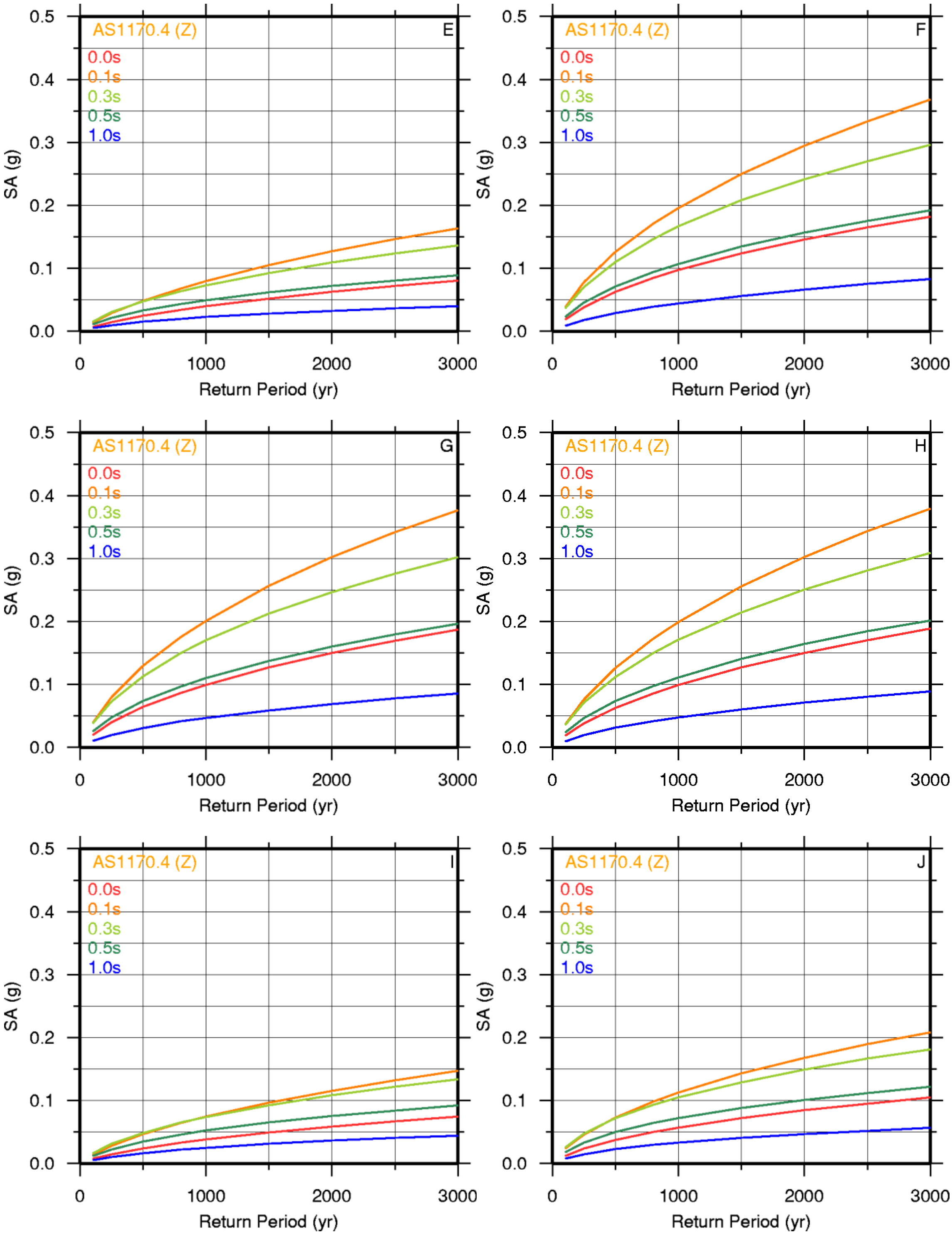
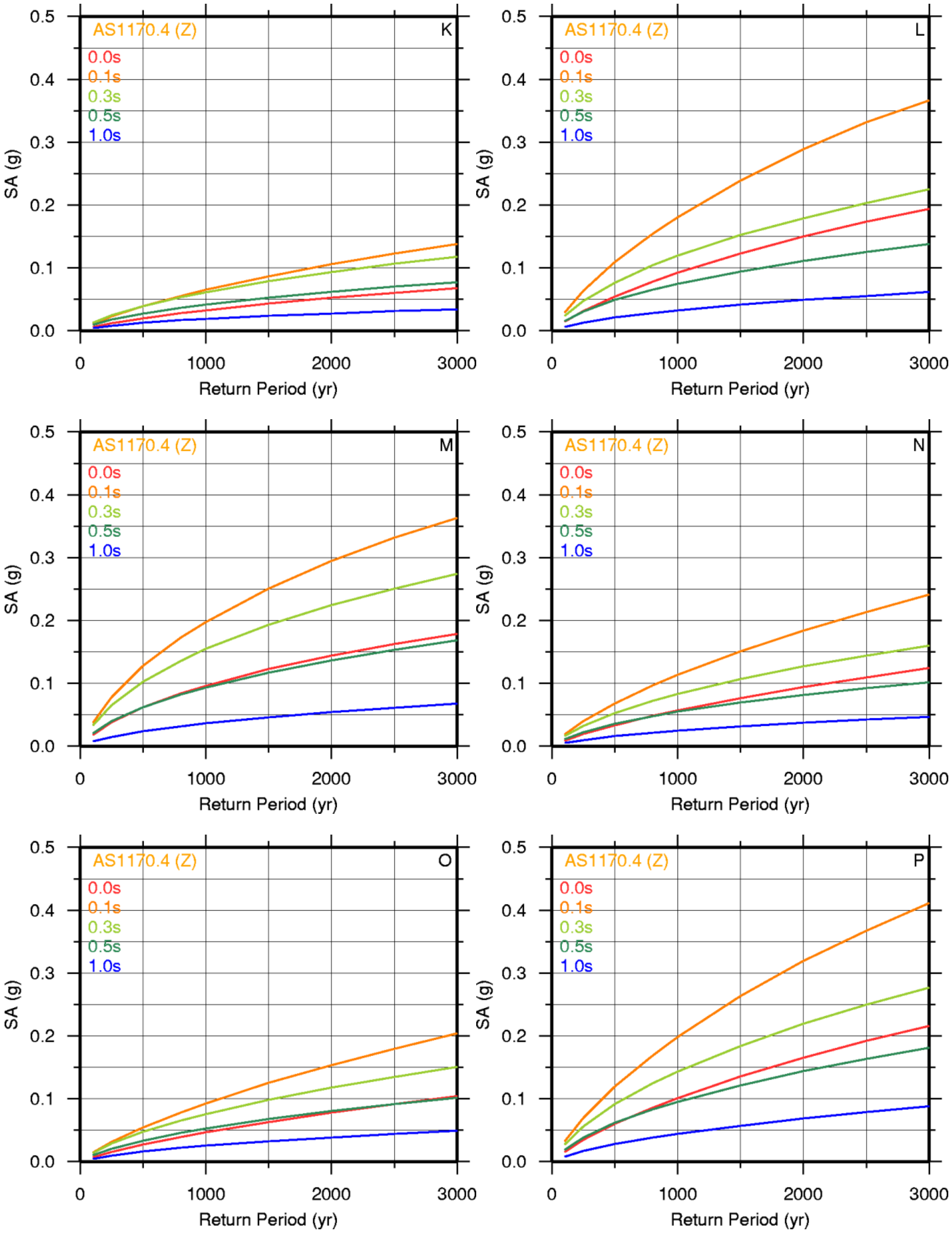
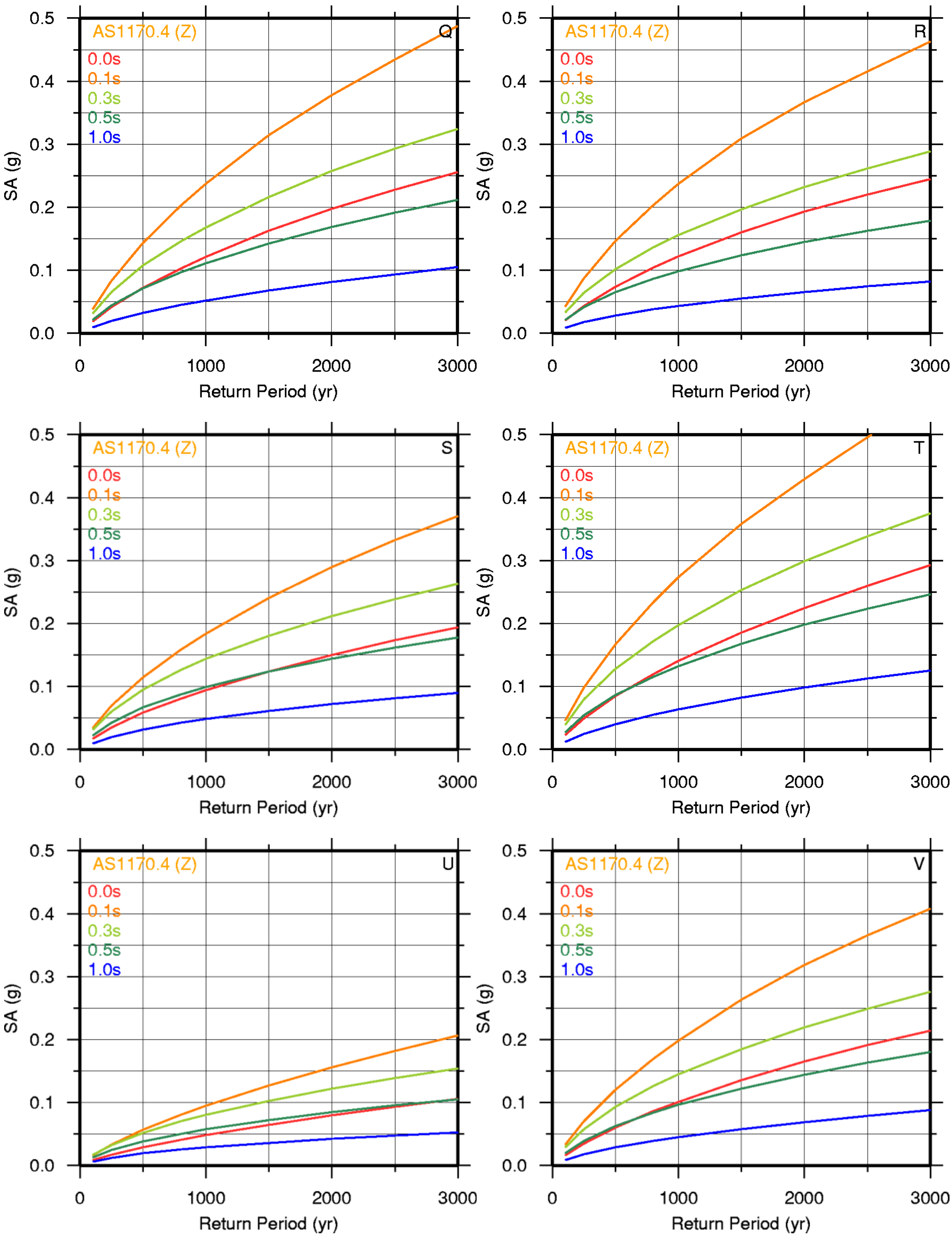


Figure 23 The hazard curves for the eight capital cities. All the SA curves were calculated at 5% damping




AS1170.4 (Z)
E
F
G
H
I
J
0.0s
0.1s
0.3s
0.5s
1.0s
SA (g)
0.0
0.1
0.2
0.3
0.4
0.5
0
1000
2000
3000
Return Period (yr)


AS1170.4 (Z)
0.0s
0.1s
0.3s
0.5s
1.0s
K
L
M
N
O
P
SA (g)
Return Period (yr)
0.0
0.1
0.2
0.3
0.4
0.5
0
1000
2000
3000


AS1170.4 (Z)
0.0s
0.1s
0.3s
0.5s
1.0s
Q
R
S
T
U
V
SA (g)
Return Period (yr)
0.0
0.1
0.2
0.3
0.4
0.5
0
1000
2000
3000

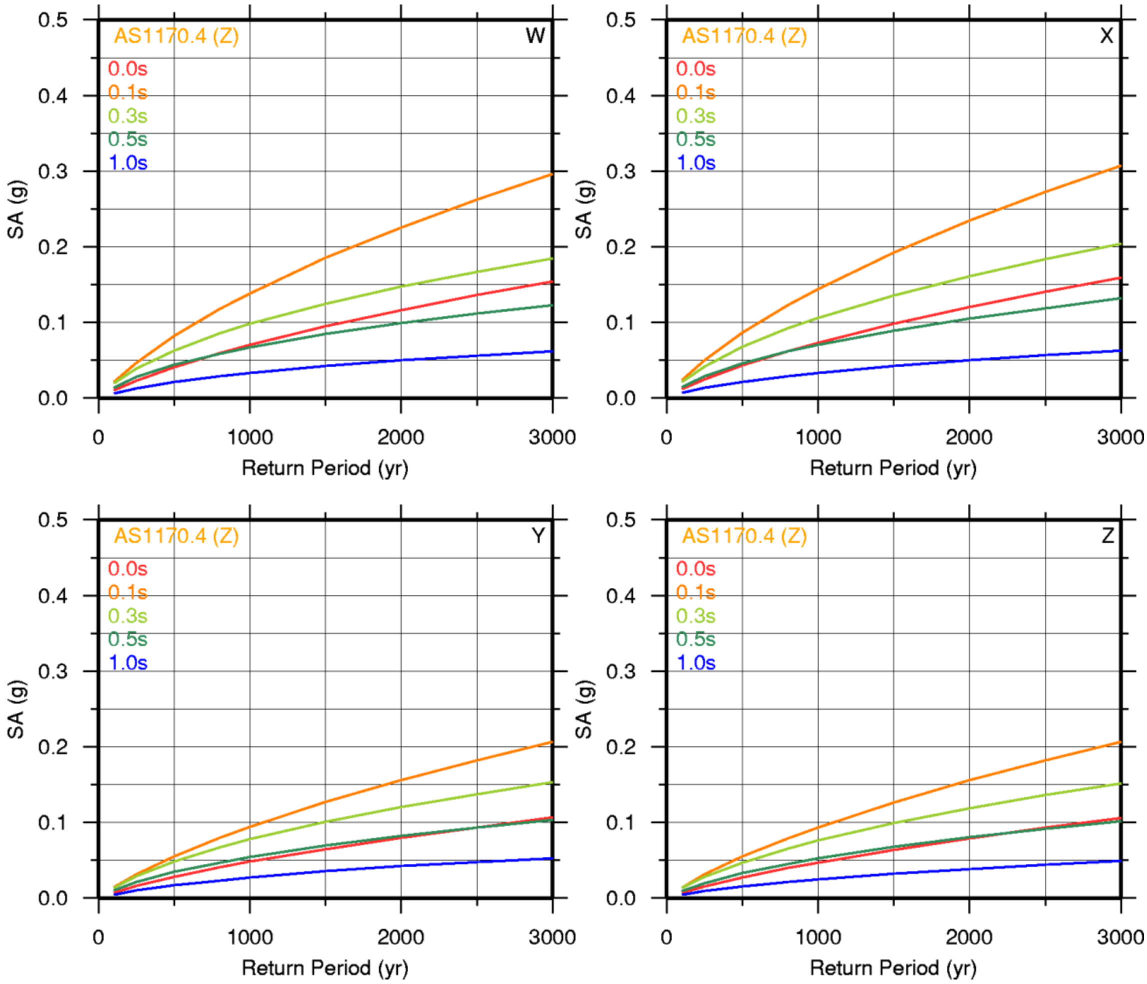


Figure 24 The hazard curves for the 26 locations A – Z shown in Figures 21 and 22. All the SA curves were calculated at 5% damping.

6 Hazard Spectra

This section presents the hazard spectra for the eight capital cities (Figures 25 and 26) locations D, K, T, V, Y and Tennant Creek (Figure 27). Again, all the SA curves are for 5% damping. The shape of the hazard spectra falls into two classes. Those located in the Cratonic crust of Australia all have a peak at 0.1s (e.g. Perth, locations T, V, Y & Tennant Creek). Those in the non- Cratonic crust of Australia have a peak at 0.2s (e.g. Canberra, Melbourne, Sydney, locations D and K). This is likely to be mostly due to the different GMPEs used in Cratonic and non-Cratonic crust zones. Adelaide, despite being located in non-Cratonic crust, has a hazard spectra similar to the locations in Cratonic zones. This is probably because Adelaide is surrounded by Cratonic crust zones and the hazard in the city is therefore driven by earthquakes in those zones. The spectrum for Darwin is different. It contains relatively more long period energy than the other cities due to the large M_{MAX} in the very active off shore source zones to the north of Australia.

The difference between the Cratonic and non-Cratonic spectra is minor and small relative to the uncertainties in the spectra. This is typified by comparing locations D and V and locations K and Y in Figure 27. Given the overall similarity, the spectral shape of Sydney, which is almost identical to Melbourne, could be used for almost all of Australia. The main exceptions to this being Darwin and the Timor Sea which have a much higher hazard spectra at the longer SA periods.

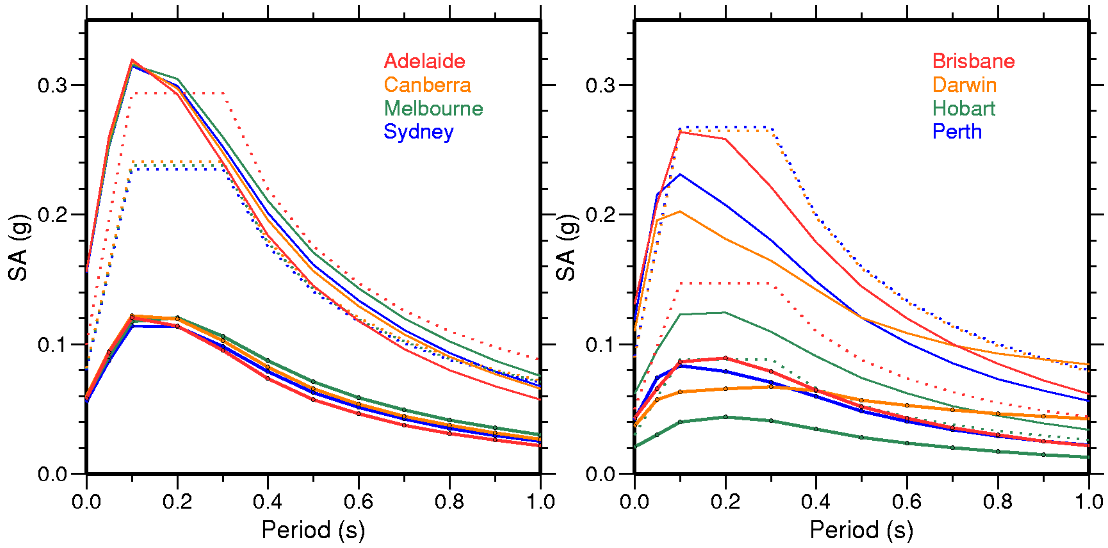


Figure 25 The 500 year (thick solid lines), 2500 year (thin solid lines), and AS1170.4 500 year (dotted lines), return period hazard spectra for the capital cities, out to 1.0s.

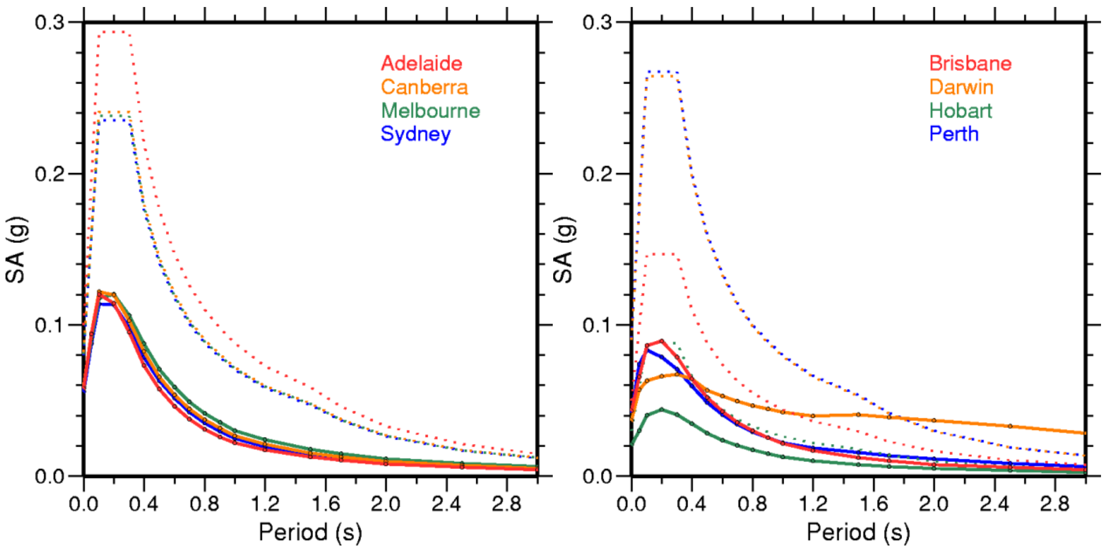


Figure 26 The 500 year return period hazard spectra for the capital cities, out to 3.0s. The dotted lines are the AS1170.4 500 year return period hazard spectra.

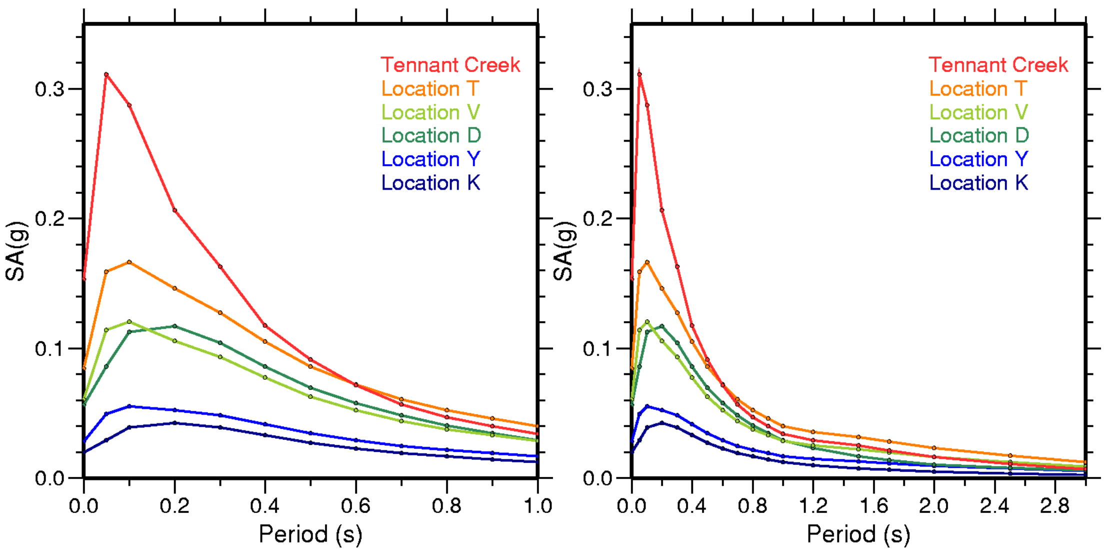


Figure 27 The 500 year return period hazard spectra for the locations D, K, T, V, Y and Tennant Creek, out to 1.0s and 5.0s. The location D spectrum is very similar to that of Melbourne's.

7 PGA Hazard Values

This section presents the 0.0s SA hazard value at 500 and 2500 year return periods for the 110 specific Australian locations. Table 3 gives the hazard values for the 8 capital cities. Table 3 gives the hazard values for the 76 cities and towns shown in Figures 11 to 20 (Table 3) and Table 4 for the 26 locations shown in Figures 21 and 22

Table 2 The 0.0 s SA (PGA) hazard value at 500 and 2500 year recurrence interval for the capital cities of Australia. For the larger cities two values are given; one in the CBD and one for the largest value in the greater metropolitan area of the city.

Location	Long.	Lat.	500 yr (g)	2500 yr (g)	Location	Long.	Lat.	500 yr (g)	2500 yr (g)
Adelaide	138.6	-34.93	0.0581	0.1562	Adelaide max	138.7	-34.75	0.0591	0.1580
Brisbane	153.02	-27.47	0.0430	0.1310	Brisbane max	153.0	-27.29	0.0457	0.1389
Melbourne	144.96	-37.81	0.0588	0.1568	Melbourne max	145.5	-38.07	0.0654	0.1731
Perth	115.86	-31.95	0.0418	0.1184	Perth max	116.03	-31.89	0.0488	0.1431
Sydney	151.2	-33.86	0.0560	0.1553	Sydney max	150.74	-33.59	0.0606	0.1636
Canberra	149.13	-35.3	0.0598	0.1567	Darwin	130.83	-12.45	0.0370	0.1100
Hobart	147.33	-42.88	0.0205	0.0617					

Table 3 The 0.0 s SA (PGA) hazard value at 500 and 2500 year recurrence intervals for the cities and towns shown in Figures 11 to 20.

Location	Long.	Lat.	500 yr. (g)	2500 yr. (g)	Location	Long.	Lat.	500 yr. (g)	2500 yr. (g)
Albany	117.88	-35.02	0.0394	0.1193	Marble	119.75	-21.16	0.0607	0.1922
Albury	146.9	-36.06	0.0479	0.1260	Meckering	117.01	-31.63	0.1518	0.3798
Alice Springs	133.88	-23.7	0.0301	0.0965	Mittagong	150.45	-34.45	0.0583	0.1597
Ballarat	143.86	-37.56	0.0436	0.1114	Morwell	146.4	-38.23	0.1049	0.2708
Ballidu	116.76	-30.6	0.1052	0.2683	Mount Gambier	140.78	-37.83	0.0355	0.0991
Bathurst	149.58	-33.41	0.0637	0.1670	Newcastle	151.78	-32.93	0.0510	0.1454
Bendigo	144.28	-36.75	0.0368	0.0945	Noosa	153.08	-26.4	0.0481	0.1402
Broken Hill	141.46	-31.96	0.0205	0.0612	Northam	116.66	-31.65	0.0783	0.2245
Broome	122.23	-17.95	0.0611	0.1930	Olympic Dam	136.88	-30.45	0.0290	0.0930
Bundaberg	152.35	-24.86	0.0563	0.1581	Onslow	115.11	-21.64	0.0817	0.2603
Burnie	145.9	-41.05	0.0294	0.0797	Orange	149.1	-33.28	0.0639	0.1677
Cairns	145.76	-16.91	0.0324	0.0944	Port Augusta	137.76	-32.48	0.0494	0.1374
Camden	150.7	-34.06	0.0595	0.1624	Port Hedland	118.61	-20.31	0.0540	0.1761

Location	Long.	Lat.	500 yr. (g)	2500 yr. (g)	Location	Long.	Lat.	500 yr. (g)	2500 yr. (g)
Carnarvon	113.66	-24.88	0.0565	0.1714	Port Lincoln	135.86	-34.73	0.0509	0.1669
Coffs Harbour	153.11	-30.3	0.0195	0.0627	Port Macquarie	152.91	-31.43	0.0252	0.0798
Cooma	149.13	-36.23	0.0551	0.1476	Port Pirie	138.01	-33.2	0.0594	0.1627
Dampier	116.71	-20.66	0.0454	0.1377	Robe	139.76	-37.01	0.0282	0.0823
Derby	123.63	-17.31	0.0600	0.1919	Rockhampton	150.5	-23.38	0.0278	0.0756
Dowerin	117.03	-31.2	0.0739	0.2208	Shepparton	145.4	-36.38	0.0486	0.1346
Dubbo	148.6	-32.25	0.0514	0.1457	Tamworth	150.93	-31.08	0.0275	0.0753
Esperance	121.88	-33.86	0.0444	0.1395	Taree	152.45	-31.91	0.0295	0.0861
Geelong	144.35	-38.15	0.0594	0.1595	Tennant Creek	134.18	-19.65	0.1531	0.3620
Geraldton	114.61	-28.78	0.0484	0.1603	Toowoomba	151.95	-27.56	0.0410	0.1193
Gladstone	151.25	-23.85	0.0407	0.1112	Townsville	146.8	-19.26	0.0233	0.0678
Gold Coast	153.43	-28.02	0.0281	0.0816	Tweed	153.54	-28.18	0.0256	0.0750
Goomalling	116.83	-31.3	0.0722	0.2177	Uluru	131.01	-25.28	0.0572	0.1867
Gosford	151.35	-33.41	0.0567	0.1570	Wagga Wagga	147.35	-35.13	0.0477	0.1243
Goulburn	149.71	-34.75	0.0585	0.1527	Wangaratta	146.31	-36.36	0.0552	0.1511
Grafton	152.93	-29.68	0.0207	0.0636	Penrith	150.7	-33.75	0.0604	0.1633
Kalgoorlie	121.46	-30.75	0.1114	0.2959	Warrnambool	142.48	-38.38	0.0610	0.1719
Karratha	116.85	-20.73	0.0433	0.1293	Whyalla	137.56	-33.03	0.0452	0.1287
Katoomba	150.31	-33.71	0.0615	0.1641	Wickepin	117.5	-32.78	0.0735	0.2199
Kellerberrin	117.71	-31.63	0.0804	0.2524	Wivenhoe	152.61	-27.41	0.0475	0.1440
Launceston	147.13	-41.43	0.0225	0.0626	Wollongong	150.9	-34.41	0.0554	0.1551
Lismore	153.28	-28.81	0.0228	0.0676	Wongan Hills	116.71	-30.9	0.0729	0.2169
Lorne	143.98	-38.53	0.0629	0.1709	Woomera	136.82	-31.22	0.0292	0.0929
Mackay	149.16	-21.15	0.0214	0.0664	Wyndham	128.11	-15.48	0.0315	0.1000
Maitland	151.55	-32.73	0.0549	0.1584	York	116.76	-31.88	0.0977	0.2679

Table 4 The 0.0s SA (PGA) hazard value at 500 and 2500 year recurrence intervals for the locations shown in Figure 21 and 22.

Location	Long.	Lat.	500 yr. (g)	2500 yr. (g)	Location	Long.	Lat.	500 yr. (g)	2500 yr. (g)
A	145.6	-17	0.0330	0.0959	N	136.5	-28.6	0.0334	0.1094
B	149	-21.2	0.0213	0.0664	O	133	-30	0.0271	0.0915
C	145	-26	0.0196	0.0606	P	129	-22	0.0599	0.1919
D	152.3	-25.2	0.0565	0.1580	Q	124.4	-29.6	0.0719	0.2274
E	150.3	-29.1	0.0245	0.0719	R	117.5	-32.5	0.0736	0.2198
F	150	-33.5	0.0625	0.1652	S	113.9	-25	0.0581	0.1734
J	144	-37	0.0372	0.0952	T	115.6	-24.4	0.0843	0.2596
G	146.7	-37.1	0.0640	0.1693	U	120	-26	0.0287	0.0929
H	144	-38.5	0.0627	0.1704	V	121.1	-19.5	0.0605	0.1911
I	145.8	-41.8	0.0241	0.0670	W	120.2	-16.6	0.0407	0.1361
K	145	-32	0.0198	0.0605	X	127	-18.1	0.0431	0.1408
L	136.5	-34	0.0544	0.1734	Y	132	-15	0.0280	0.0935
M	138.5	-32.2	0.0620	0.1625	Z	140	-21	0.0272	0.0928

8 Erratum to GA record 2012/71

After the publication of the GA record 2012/71, the following issues were identified in the report. They are listed here for reference and should be read in conjunction with the GA record itself.

1. Page 2, Figure 2 caption. The line "…10% chance of being exceeded per annum" should be "..10% chance of being exceeded per 50 years".
2. Page 28. The sentence beginning "After the stakeholder workshop in February 2012…" should read as follows:
    a. "After the stakeholder workshop in 2012, where 0.6 was considered too low, the acceptable range of b-values was modified to a range of 0.69 to 1.1 for the regional and background layer and 0.82 to 1.15 for the hotspot layer."
3. Page 41. Table 11 caption. The sentence "…$A_{5.5}$ is the number of earthquakes per 1,0 00 years per 10,000 km^2" should be "…$A_{3.5}$ is the number of earthquakes per 1,000 years per 10,000 km^2".
4. Page 42 and 43. Tables 12 and 13. The column labelled "M_C" should read "Models for M_C".
5. Page 42. Table 12. There was a change in the model numbers between the draft and final documents of the report and the wrong version of the model numbers were used in the Table 12. MC models 5, 9 & 91 in Table 12 are the listed in Table 4 as MC model 1. MC model 7 in Table 12 is listed MC model 2 in Table 4. MC model 102 in Table 12 is missing from Table 4. It is a single corner model which is complete above M5.0 since 1963. MC model 103 in Table 12 is complete above M5 from 1995.
6. Page 43. The following sentence should be added to the caption. "$A_{3.5}$ is the number of earthquakes above M3.5 per year in the zone".
7. Page 55. Dot point 6. It should read as follows: "Ground motions were calculated out to a distance of 100 km for each earthquake".
8. Page 57. Figure 35 caption. The sentence "…with a 300 km Gaussian spatial filter…" should read "…with a 240 km Gaussian spatial filter".
9. Page 60, Figure 38 caption. The sentence "A 240 km Gaussian spatial filter…" should be "A 120 km Gaussian spatial filter…"
10. Page 104, Figure E 3 caption. "…based on the centroid of each zone in Figure 2" should be """…based on the centroid of each zone in Figure E 2".

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