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SRC's AUS8 Earthquake Recurrence Model

A product of 30 years of continuous improvements of earthquake hazard data, concepts and techniques

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Abstract

A seismic source model to estimate seismic hazard for Australia has been continually modified and updated as more information and better techniques become available. Since the last iteration was described in 2016, we have incorporated significant changes resulting in the current model, AUS8, namely: i) original magnitude values are now revised, using M_w magnitude conversion factors, prior to earthquake recurrence values being calculated; ii) activity rates have been updated using recent earthquake data leading to a refinement in the Gutenberg-Richter parameters, a- and b-values, for the magnitude frequency distributions; iii) the updated source model now includes, as independent seismic sources, all active and neotectonic faults within 70 km from the site as well as significant bedrock faults within 40 km that are favourably aligned with the current crustal stress regime, and also incorporate the episodicity of fault activity; iv) maximum magnitude (M_{max}) values assigned to a source zone were previously altered based on the number of active or neotectonic faults located within that zone, whereby all large earthquakes were assigned to the fault(s). This methodology is still used for zones nearby to the site under consideration, but for all zones beyond 70 km, any fault-related earthquake activity is included in the zone earthquake activity and the zone is assigned a M_{max} of M_w 7.3; v) source zone boundaries have been modified. These changes, combined, contribute towards improved earthquake hazard estimates within Australia.

Keywords: Seismic source model, seismic hazard, Australia.

1 Introduction

Seismic hazard assessments require ground motion models (GMMs) and seismic source models (SSMs) to characterise the hazard at a site. The Seismology Research Centre's (SRC) AUS8 model is an ongoing development of a SSM that was originally developed in the 1990's (Brown & Gibson, 2000; 2004) and is an evolution of the AUS4, AUS5, AUS6 and AUS7 methodology (Dimas et al., 2016). The model has been continually modified, reviewed and updated as more data, better techniques and an increased understanding of the nature of Australian seismicity have become available.

The AUS8 model divides Australia into zones based primarily on the spatial distribution of earthquakes, major geological boundaries (particularly neotectonics relating to Quaternary and Tertiary deformation) and geophysical data (particularly gravity and magnetic data). Within each zone, seismicity is assumed to be uniformly distributed throughout the zone at depths from 2 to 20 kilometres. Activity rates are assigned to each zone based on the Gutenberg-Richter seismicity recurrence equation (Gutenberg & Richter, 1944; 1956).

In this paper we describe the significant changes the SRC have made resulting in the current model, AUS8.

2 Magnitude Conversion & Activity Rates

For earlier versions of the AUS model, an equivalence was assumed between the magnitudes calculated for the original earthquake catalogue and the M_w values used by the various ground motion models. The AUS8 model now converts all magnitudes to M_w using the preferred National Seismic Hazard Assessment 2018 (NSHA18) M_L to M_w conversion factors (Allen et al., 2018) before computing the earthquake recurrence.

Figure 1 shows the catalogue data for each zone using magnitude-frequency plots. The Maximum Likelihood Estimation (MLE) and Least Squares (LSQ) methods are used to calculate activity rates. The MLE method is controlled mainly by the more numerous events at smaller magnitudes while the LSQ method treats each data point equally so is uniformly influenced by both large and small magnitude events. Both methods can be adversely affected by outliers. In order to minimise such impacts we generally exclude points on the magnitude-frequency plot that represent magnitudes with less than five events present in the catalogue when computing LSQ and MLE values. The activity rates from both methods are used in as separate equally weighted branches in a logic tree.

It can be seen that the N_0 and b-value are very different for before and after magnitude conversion. Similar to the NSHA18 results, we found that the conversion to M_w results in lowering the hazard estimated by AUS8 at most locations across Australia.

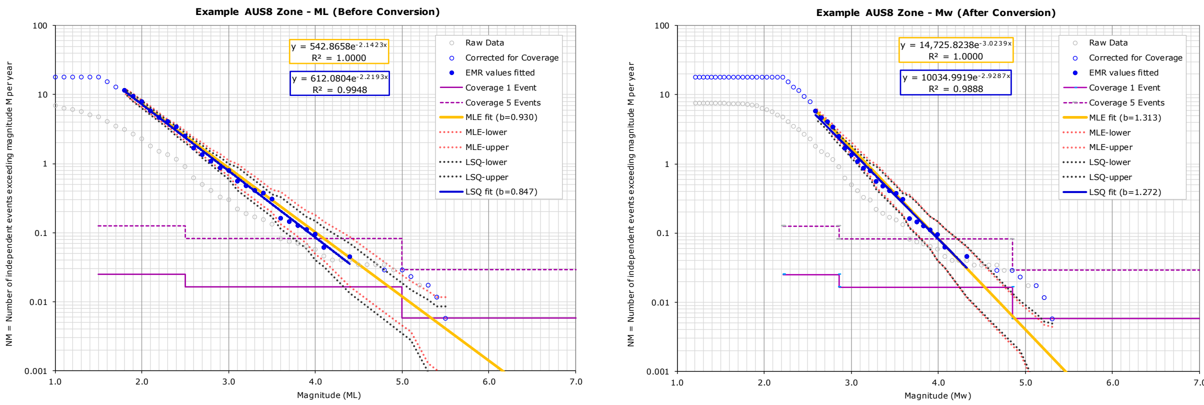

Figure 1. Comparison of earthquake magnitude recurrence plots before and after magnitude conversion.

3 Fault Inclusion

AUS8 now uses more rigorous guidelines on the inclusion or exclusion of faults in a study. Our current approach to site specific analyses is to include all active fault sources (known to have produced historical earthquakes or shown evidence of movement in the last 35,000 years (e.g. ICOLD, 2016; ANCOLD, 2019) and neotectonic fault sources (which show evidence of activity in the last 5-10 Myr (e.g., Dickinson et al., 2001; Sandiford, 2003; Hillis et al., 2008)) within a maximum horizontal distance of 70 km from the site. We consider that the seismic activity of a fault beyond 70 km from the site s adequately represented by including its seismicity in the area source zone (e.g., Somerville et al., 2017). In addition, we include significant bedrock fault sources (>15-25 km in length) that are favourably aligned with the current stress regime i.e., perpendicular or near-perpendicular to the maximum horizontal present-day crustal stress (S_{Hmax}) (e.g., Hillis and Reynolds, 2000; Rajabi et al., 2017) but otherwise do not show evidence of prior neotectonic movement, within a maximum horizontal distance of 40 km of the site (Ninis et al., 2018).

Neotectonic faults are sourced from the Australian Neotectonic Features Database (Clark, 2012, https://neotectonics.ga.gov.au/) as well as from any additional published and unpublished reports available to us. We also analyse lidar-derived elevation data to identify evidence for neotectonic features e.g., scarps. Neotectonic faults are assigned one of four Class Types – 'A' for Definite (including faults considered active); 'B' for Probable; 'C' for Possible; and 'D' for Unlikely – to indicate the level of confidence concerning the neotectonic evidence associated with the structure. The fault class types are weighted; A=1.0, B=0.8, C=0.6, and D between 0 and 0.5 depending on a range of factors. We apply previously determined slip rates to these faults (Clark, 2012, www.ga.gov.au/neotectonic-feature-distribution; Clark et al., 2016; updated in Allen et al., 2018;), or, if not quantified, we estimate a slip rate based on all available data. Bedrock faults are assigned a low uplift rate of 1 m/Myr (i.e. 0.001 mm/yr) and are weighted 0.5, meaning that they are assigned a 50% probability that they may experience activity.

Due to the episodicity of earthquake recurrence on Australian faults, whereby through time faults show evidence of periods of heightened activity alternating with periods of quiescence (e.g. Crone et al., 1997; Clark et al., 2008; Clark et al., 2012; Clark et al., 2017), there is a large amount of uncertainty regarding whether the measured uplift rate represents the present or future uplift rates. To allow for this, we follow the approach of Stirling et al. (2011) whereby factors of 0.1, 1 and 10 have been applied to the uplift rate of a given fault, to estimate uplift during a quiescent phase (x 0.1 the average uplift rate), the average uplift rate (x 1), and uplift during an active phase (x 10 of uplift rate), respectively. To represent the probability of the fault being in each of these phases, these rates are then weighted by 0.18 for the quiescent phase, 0.8 for the average uplift rate and 0.02 for the active phase (Figure 2).

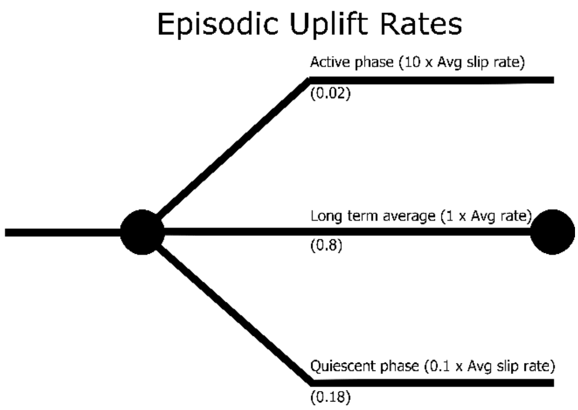

Figure 2. Logic tree for the treatment of fault episodicity.

4 Maximum Considered Magnitude

In the early versions of the AUS model the M_{max} value of M_w 7.5 was assigned to the all areal source zones whether they had faults or not. However, for later iterations of the AUS model, we assigned the M_{max} based on the amount of faults in the zone, regardless of how close that zone was to the site. In the current version AUS8, we assigned the M_{max} based on our confidence on the number of faults within the zone for nearby zones but for distant zones without faults in the model we now revert to a M_{max} value of Mw 7.3 (Figure 3). This approach is taken as a method of primarily modelling small to moderate events using area zone sources while modelling the largest events using fault sources. Faults sources are modelled using a truncated exponential approach. In summary:

- For a nearby area or host zone where all significant faults are thought to have been identified, a lower M_{max} of M_w 6.4 is assigned to that zone.
- For a nearby area or host zone where no faults have been identified a higher M_{max} of M_w 7.3 is assigned to that zone.
- For a nearby area or host zone with some identified and modelled faults, an intermediate M_{max} of M_w 6.8 is assigned to that zone.
- For distant area zones (beyond 70 km) we model any fault-related earthquake activity together with the zone earthquake activity using the area zone earthquake recurrence values and a M_{max} of M_w 7.3.

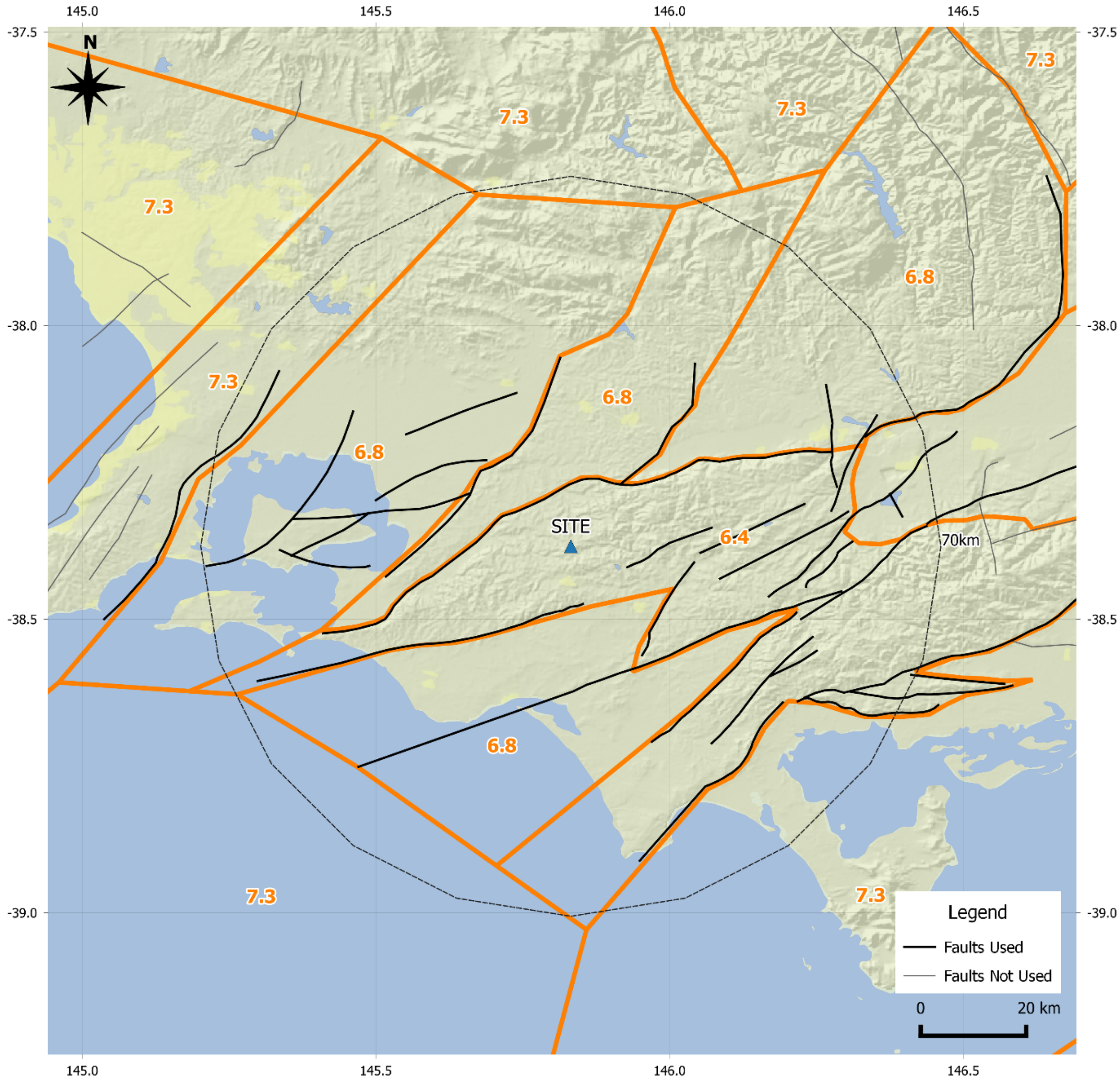

Figure 3. Mmax (Mw) values for AUS8 zones surrounding a site. Zones are depicted by polygons in orange, while the faults are given by black lines. Estimated Mmax are annotated for each zone.

5 Zone Boundary Changes

There have been some major changes to the source zones in AUS8 since the first iteration of the AUS model (Brown & Gibson, 2000; 2004). Most significantly, boundaries have changed so that four zones no longer meet at the one point as this likely does not represent what is generally observed in natural geological settings. Figure 4 shows a quadruple join in the previous AUS7 model (purple lines) and the current updated AUS8 model (orange dashed lines) where these four zones no longer meet. There are no longer any quadruple joins in the current AUS8 model.

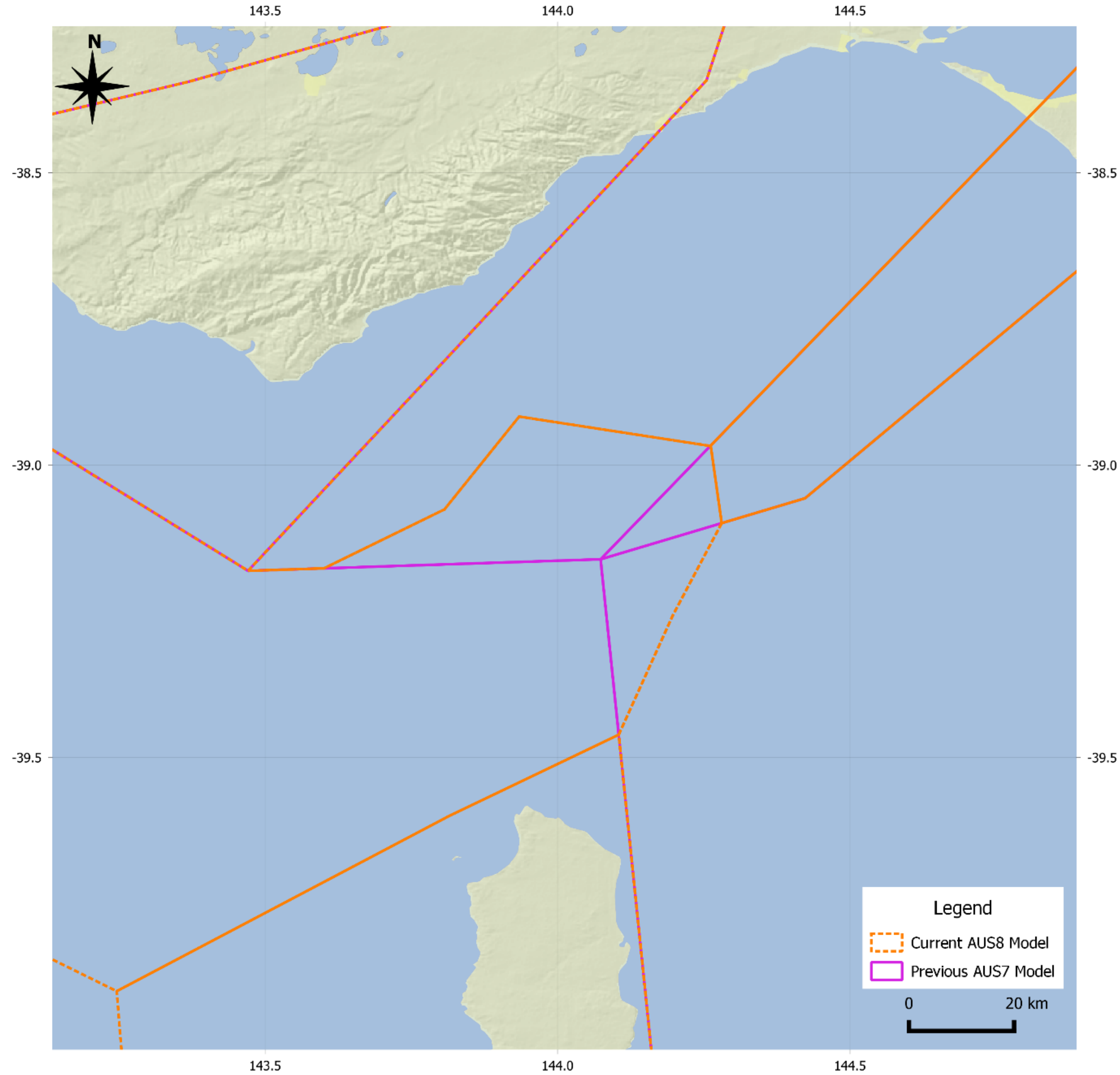

Figure 4. AUS model boundary changes. Current zones are depicted by polygons in orange, previous zones are depicted by polygons in purple.

As additional earthquakes have been recorded since the last iteration of the AUS model, some area source boundaries have changed in consideration of these events.

6 Summary

The AUS8 model is an Australian seismic source model that the SRC continues to develop and iteratively improve. It divides Australia into zones based primarily on seismicity and major geological boundaries and activity rates are calculated for each zone. Multiple changes have been made over the years with the most significant changes to the latest iteration outlined in this paper.

7 Future Updates

We are currently reviewing the AUS8 model and any major changes will be included in future updates. Possible updates include using an improved M_w conversion equation and revision of M_{max} individually assigned to each zone considering possible larger magnitudes as high as M_w 7.5.

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