Revising Seismic Design Levels to Account for Time-Varying Hazard from the Canterbury Earthquake Sequence

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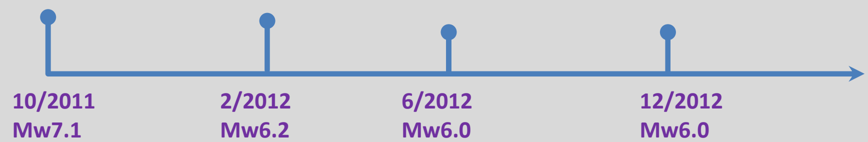
The On Going Canterbury Earthquake Sequence

10/2011	2/2012	6/2012	12/2012
Mw7.1	Mw6.2	Mw6.0	Mw6.0

- ***September 2010 Mw7.1*: ~ 40km from Christchurch, sparsely populated region, damage and liquefaction in Christchurch. Very early Saturday morning**
- ***February 2011 Mw6.2*: Directly under Christchurch. 1pm Tuesday. Significant damage (especially CBD), building collapse, strong liquefaction, >180 deaths**
- ***June 2011 Mw 6.0*: Directly under Christchurch. Weekday afternoon. Less damage, more strong liquefaction**
- ***December 2011 Mw 6.0:* slightly east from CBD. Strong liquefaction. Less damage.**

The On Going Canterbury Earthquake Sequence



Overall aftershock productivity is about average for NZ or global sequences

- **Consistent with expected number of aftershocks**

Temporal distribution is not necessarily average

- **large inter-event times for largest aftershocks**

Very strong ground shaking up to 2.2g

- **Exceeded current design levels**
- **Particularly strong in Sept/Feb/June**
- **Less so in December**
- **Directivity? High stress drop? As expected? Not clear!**

Why do we Need to Update the NSHM?

- **Christchurch is considered low to moderate hazard in the New Zealand National Seismic Hazard Model**
- **Building standards are based on the Z-factor**
- **Pre- sequence, Z=0.22 for Christchurch (Wellington, Z=0.4, highest in NZ=0.7)**

When considering clustering of earthquakes and time-dependent hazard, the Z-factor is expected to be considerably higher than 0.22.

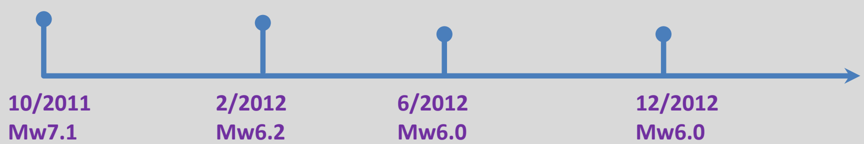
The Response: Probabilities of Future Events & ChCh Hazard

Three Phase Response:

Phase I: **September 2010+ Probability estimates of future earthquakes (on going)**

Phase II: **April 2011. Rapid (two weeks!!) update of the NZ NSHM for Christchurch considering future clustering including preliminary building standards update/ recommendations & liquefaction, rockfall, etc**

Phase III: **November 2011- Present. Slightly less rapid update and finalisation of building standards, etc**



Phases II & III

Post February 22nd Mw 6.2

Two Questions to be Addressed

***Question 1*: Is the existing NSHM source model appropriate for Canterbury?**

***Answer*: No.**

***Question 2*: Is the current McVerry et al (2006) GMPE correctly modelling ground motions for Canterbury?**

***Answer*: No. Significant debate remains about the correct way to do so & if/how to handle stress drop, directivity, basin effects, variability, etc**

The Update Procedure

Phase II – Prelim Update (NSHM & Building Design Standards):

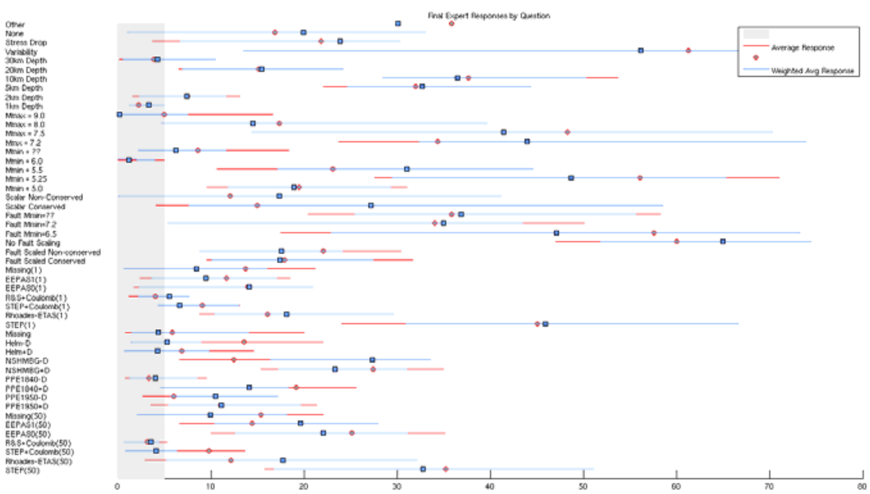
- **Update procedure was largely GNS based**
- **Source model update based on earlier work for NZ Earthquake Commission & previous published research**
- **Ad-hoc committee including external engineers for deciding on "engineering parameters" in the model (Engineering Advisory Group)**
- **External review**
- **Preliminary update out in May 2011 (Z=0.3)**

The Update Procedure

Phase III - Final Update (NSHM & Building Design Standards):

- **International and NZ feedback from NZ Royal Commission Review on building collapse (on going)**
- **November 2011: International expert panel (12 experts)**
  - **convened to weigh options presented by (mostly) GNS and external scientists**
  - **Not a consensus procedure. Based on Cooke (1996) & individual experts were given weights.**
  - **Capturing uncertainty was important**
- **March 2012: Additional international panel (5 experts)**
  - **GMPE: Bradley (2010) & McVerry (2006)**
  - **Liquefaction thresholds published in building codes**
- **Z-factor, etc., forthcoming**

Expert Elicitation Results

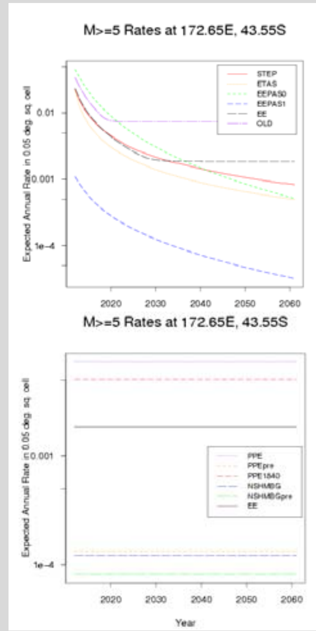


Updating the Source Models: An Ensemble Model

An Ensemble model of 3 components:

- ***Short-term clustering***
  - **STEP & ETAS (aftershocks)**
- ***Medium-term clustering***
  - **EEPAS (decadal scale)**
- ***Long-term smoothed seismicity***
  - **PPE, NSHM (Gaussian), Helmstetter**

Top: Time-dependent clustering models
Bottom: Time-independent Poisson models



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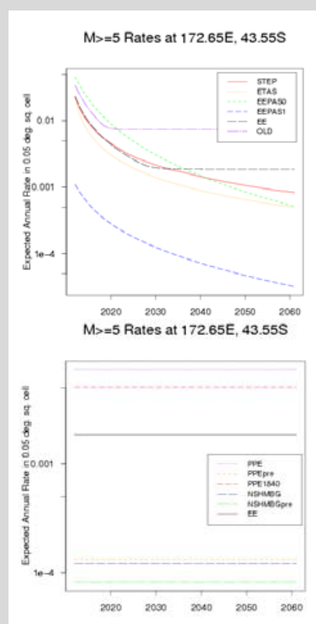
ChCh seismicity expected to remain above pre-2010 levels for more than 50 years



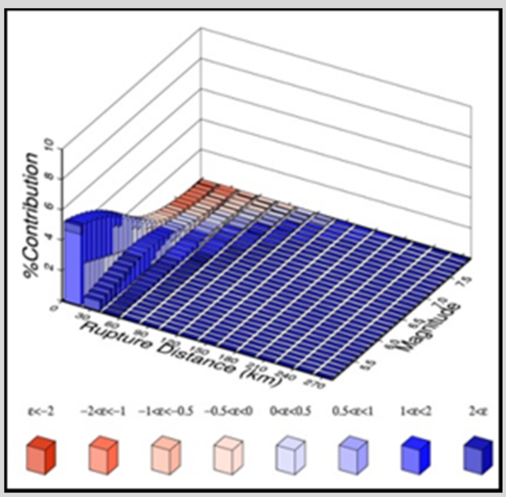
Ground Motion Prediction: Model Combination

Fundamental seismological questions remain about observations. Disagreement among the community.

- **Only Bradley and McVerry GMPE considered (at this point)**
- **Different weightings M > 5.5 & M < 5.5 (small events are important)**
- **Bradley model is dominant at both small and large M**
- **Both models include an option with increased variability to match that seen across NGA models in California**
- **McVerry has additional option for increased stress drop scaling (Boore & Atkinson)**

Deaggregation

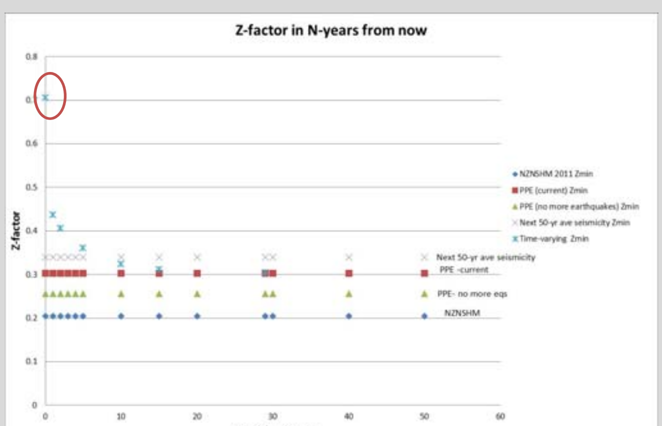
- Relative contribution of sources to 10% probability of exceedance of SA(0.5s) for a Christchurch site
- Epsilon is the number of standard deviations on the ground motion.
- Dominated by near and small magnitudes (M<6)
- Large epsilon
- Not a typical deagg!
- Appropriate selection of Mmin is critical



Mmin

- Fig showing difference of something based on different Mmin

Decrease of Z-factor in Time



Equivalent Z-factor (50yr) based on the yearly expected number of events (shown with x)

Key Points

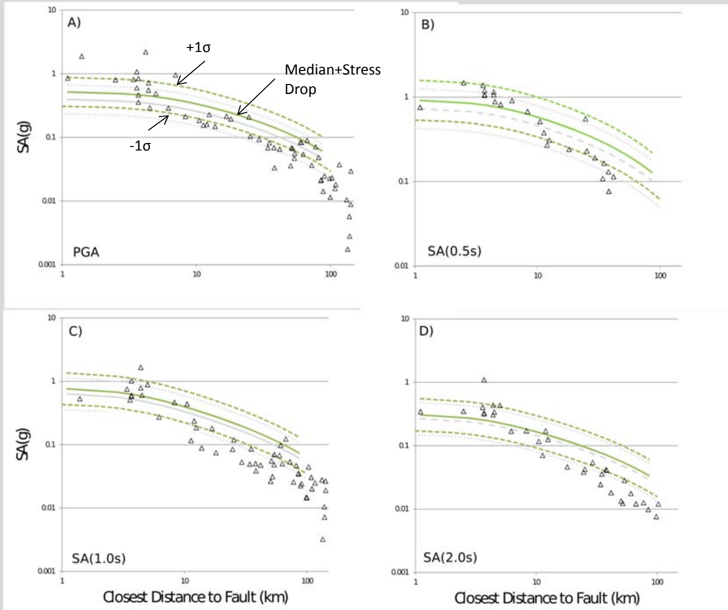
- Prelim Z-factor increased from 0.22 to 0.3. Final expected to be about the same.
- 1/25 year rates for liquefaction are PGA=0.13g
- Estimated hazard is dominated by small events
- Appropriate selection of Mmin for each engineering application is critical (large effect on estimated hazard)
- Start time for hazard parameter estimates is important. Shifting start times by 1-year can decrease estimates significantly

Key Points

- Updates done under very tight time frames
  - Considerations for how to do such work should be in place ahead of time
  - Such changes to building standards likely only necessary in low-moderate hazard regions
- Time-dependence is new to most of the community
  - Communication is challenging
  - May require better understanding of PSHA assumptions and modelling by end-users than time-independent hazard
- Building design standards are created in time-independent space. Is this appropriate for time-dependent hazard? e.g., 2 exceedances in first 5 yrs of 50 years may not be the same as 2 exceedances anywhere in 50 years

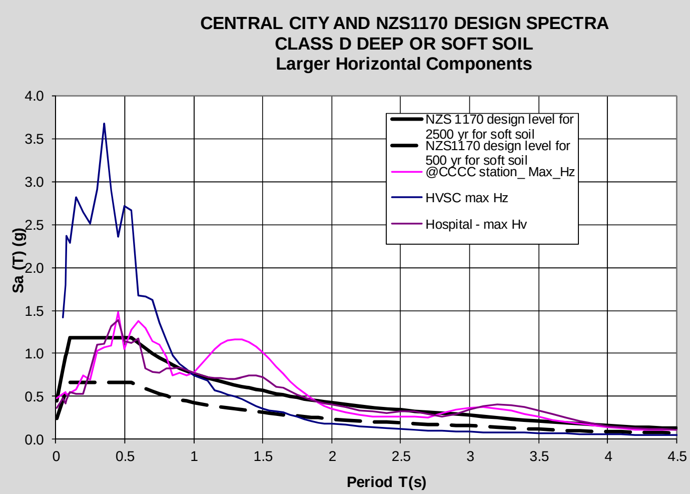
Thank You

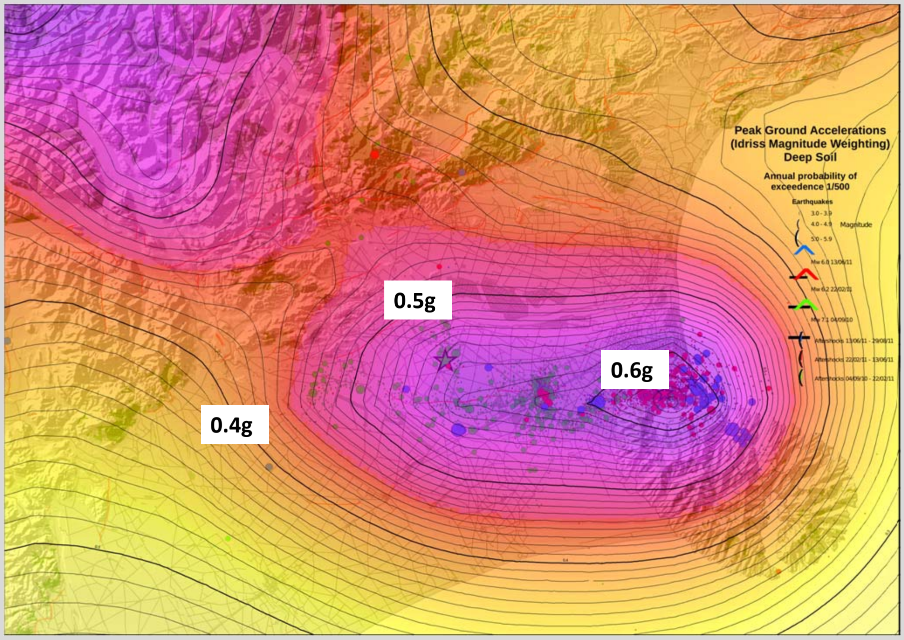
February 22nd Mw 6.2: McVerry Predicted vs. observed ground motions



Green lines are McVerry Predictions + Boore & Atkinson Stress Drop Scaling

Comparison of Feb Ground Shaking to Building Standards





PGA with 10% Probability of Exceedance in 50 years for Class D deep soils