Recent work in the New Zealand NSHM: Programme review and Kaikoura earthquake hazard model revisions

Outline

• Government led review of NSHM programme structure, etc.

• Development of a time-dependent seismic hazard model for Kaikoura

• The Alpine Fault

• Optimal NSHM for building design standards
Review of NSHM Programme

• New Zealand government has never funded a NSHM Programme

• Minimal investment into seismic hazard modelling. Budgets have ranged from 0-100K USD/year

• Not coordinated with building standards reviews (e.g., current standard based on 2002 model)
Review of NSHM Programme

- 2016-2017 Review of NSHM “Programme” by Ministry of Business Innovation and Employment (MBIE)
- Norm Abrahamson, Tom Jordan, Kevin Coppersmith, Ned Field, Jonathan Stewart

Key Points:
- Adequate funding (e.g., 3 FTE for operations, more for science)
- Transparency (i.e., easy for others to obtain/reproduce results)
- Uncertainties

Business case being prepared by MBIE for developing a long-term NSHM Programme
Time-dependent hazard: capturing uncertainty in PSHA through multiple models

- **Canterbury Seismic Hazard Model (CSHM),** Mw7.1  2010+
- **Kaikoura Seismic Hazard Model (KSHM),** Mw7.8  2016+
- Our overriding philosophy: **No single source model** alone provides the best estimate of hazard

- Used for: revision of design standards, road/rail networks, insurance, design projects, etc

- Multiple source models covering
  - Different time-scales
  - Different input data sets
  - Different input date set time-windows (e.g, 1840-Present is a different model than 1900-Present)
  - Different philosophies
  - Different physical ideas
  - etc
Ground accelerations: Wellington

Class D: 1 in 500 year design spectra

BNZ building location
Te Papa location
Average (Class D)
Rock site (Class B)

Semmens et al. 2010.
Combining Multiple Models: A Hybrid Source Model

A hybrid source model of three components covering different time frames and information: informed by CSEP-style test results, constructed by statistical optimisation & expert judgement

<table>
<thead>
<tr>
<th>Short-term</th>
<th>Medium-term</th>
<th>Long-term</th>
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<tr>
<td>days to years</td>
<td>years-decades</td>
<td>decades</td>
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<td>STEP</td>
<td>EEPAS1</td>
<td>Multiple smoothed seismicity &amp; hybrids (e.g., strain rate)</td>
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<td>ETAS</td>
<td>EEPAS0</td>
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1 day to 100-year forecasts

Variability in short & medium term rate at one location

- Total forecast is the maximum rate in any space-time-magnitude bin between the short-term rate and the medium-term rate

- The total rate is not allowed to drop below long-term rate

- Standard PSHA combination with time-dependent fault source model

Variability in long term rate At one location
Includes different smoothed seismicity models, plus a hybrid based on strain rate

**Strain Rate Hybrid**

Smoothed Seismicity X Shear Strain Rate
Optimised and tested retrospectively

*Very skillful model in testing!*

Has some similar features to a fault based model but emphasises areas not in fault or smoothed seismicity models (e.g., Wellington Region)
KSHM Fault-based model component

Time dependent probabilities added to many significant faults in the region

- Based on a combination of Log-normal, Weibull and BPT models
- Hope Fault (various segments), Kekurangau Fault, Awatere, Fault, ...
- **Hope Fault** with a current hazard rate of 1/180 years dominates the long-term hazard calculations
- **Hikurangi Subduction Interface Logic Tree**
  1) Model 1: *Impossible* to Rupture South of Cook Strait
  2) Model 2: Can rupture to Kaikoura
  3) 0.5 Weight to each
     (little impact on hazard → 10,000 years)

KSHM, SA(1.0), 2% Probability of exceedance in 100 years
   (design criteria for bridges, road/rail)
Uncertainty in GMPE

**NSHM** Uses a single GMPE (McVerry), or in more recent work McVerry et al. (2006) + Bradley (2013)

**KSHM** based on Van Houtte (2017) and Mak et al. (in revision):

**Crustal Logic Tree:** Group 1 received higher weights
- **Group 2:** Chiou & Youngs (2014), Bradley (2013), McVerry (2006)

**Subduction Logic Tree:** equal weights

KSHM Logic Tree estimates significantly higher hazard for the KSHM region than NSHM GMPEs (not true for all of NZ)

KSHM estimates higher hazard almost everywhere (despite some fault CPs decreasing)

**Ratio of KSHM/NSHM**
2% in 100 years SA(1.0s)
Mandated retrofitting to unreinforced masonry

Ratio of increase in probability of exceeding ground shaking equivalent to 33% New Building Standard:

Hazard for September 5th to Dec 5th, 2017
-compared to-
Pre-Kaikoura Hazard

Using hybrid time-dependent forecast model, combining 6 models

Short-term hazard increases of up to 10x

Retrofit time for unreinforced masonry facades and parapets reduced to 1-year (government cost share) from 10-years +
Tools for immediate building inspection and response: Relative increase in hazard compared to pre-Kaikoura

For shaking to exceed Design Standard than before the main shock in a 30-day period.

10-20 times more likely

Large uncertainty in ground motion prediction also included

Unique obs in main shock
The Alpine Fault: A time-dependent model

• Plate boundary on the South Island

• One of the largest hazards in NZ

• A significant amount of paleo date from trenching and lake deposits

• A record of more than 20 events

• What is the best representation of future AF earthquakes?
• Can we isolate it from the system?
• Are current time-dependent models appropriate – data suggests strong periodicity?
• How well do we understand the uncertainties?
• What is the appropriate magnitude range?
• How well can we constrain rupture locations?
Japan & New Zealand End-Member Approaches to Seismic Hazard Design Factors

**Japan** Seismic Hazard Zoning Factor Z
3-4 Zones

(Ishiyama, 2012. Fig 3)

**New Zealand** Seismic Hazard Z-Factor
NZS1170.5 (2004)
Spatially continuous ~0.1-~0.8
Mean hazard from on Stirling, 2002)

Different methods
Many design standards around the world are (mostly) based on mean hazard. How can increased epistemic uncertainty be allowed for in design when a only a single metric is used?

Auckland’s hazard is necessarily lower than Wellington, but the uncertainty is necessarily higher. How should that be transferred to end-uses (e.g., design standard)?

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**Design Standards Must be Risk based (Most are NOT!)**

Need to move beyond mean hazard to capture the risk (this needs to be done with hazard modellers)

Requires optimising the hazard models (e.g, spatial resolution) in risk space to allow for better accounting of epistemic uncertainties and better represent current state of knowledge of hazard and risk to practical applications. This will likely reduce the spatial precision in the hazard forecast.
Thank you.