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NEW ZEALAND NATIONAL SEISMIC HAZARD MODEL 2022 REVISION AND NZSEE ADVISORY ON BUILDINGS

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BRIEFING NOTE 471 OCTOBER 11, 2022

The 2022 revision of the New Zealand National Seismic Hazard Model was released on 4 October 2022 (GNS, 2022). There are thirty scientific reports associated with the revised model. The main reports describe the Seismicity Rate Models (SRM) and the Ground Motion Models (GMCM). The SRM is based on a newly developed Community Fault Model. A web app allows users to get hazard curves and response spectra and the corresponding plots and tables for individual sites by inputting Lat, Long, Vs30, and AEP.

The SRM is based on a revised earthquake catalogue with Mw-consistent estimates of magnitudes. This has yielded a catalogue with significantly fewer earthquakes for a given Mw magnitude. In the case with NSHA18 in Australia, downward magnitude revisions caused a large reduction in the probabilistic seismic hazard. In contrast, despite the reduction in some magnitudes, the hazard level throughout New Zealand in NSHM2022 is about 50% higher than that of 2010 NSHM, and about twice higher in the main cities, due to other model changes.

The main causes of the increases in hazard, despite the reduction in some magnitudes, are the use of new ground motion models for subduction zones, which mainly affects the North Island, and the enhanced treatment of uncertainties in the seismicity rate and ground motion models. Consistent with global practice, the modification of ground motion levels by surficial geology is represented by V s30 , the time averaged shear wave of the upper 30m of the ground, in place of the geological categories that were used previously. The seismicity rate model includes multi-segment ruptures based in the UCERF model (ref)., providing for complex ruptures like that of the 2016 Kaikoura earthquake.

The 2010 and 2022 hazard maps for PGA for 1:475 AEP are shown in Figure 1, and the ratios of the 2022 to 2010 PGA's are shown in Figure 2 for AEP of 1:475 and 1:2,475 AEP. Countrywide, the hazard levels are about 50% higher on average than those for the 2010 model, but twice as high in the main cities.

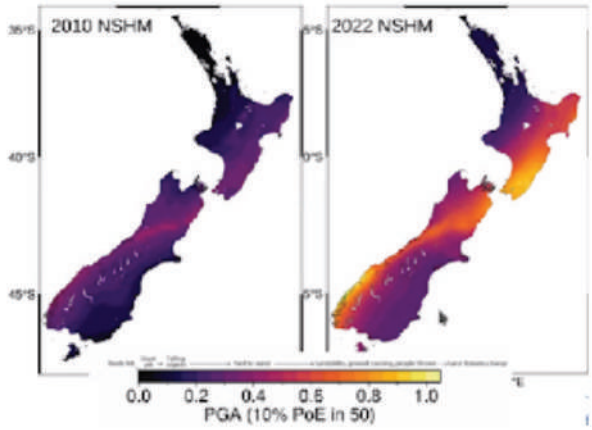

Figure 1. Comparison of peak ground acceleration for AEP of 1:475 in 2010 (left) and 2022 (right). Source: Modified from Gerstenberger et al., 2022.

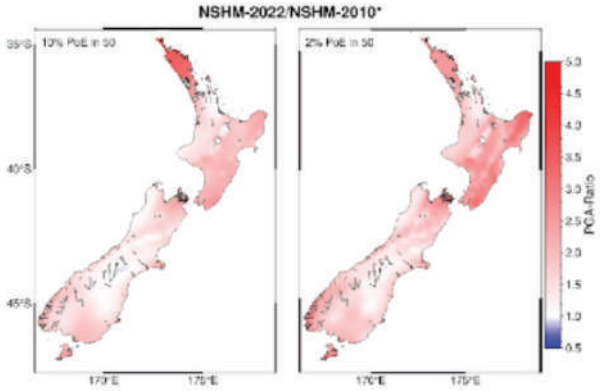

Figure 2. Ratio of 2022/2010 NSHM peak ground acceleration for AEP of 1:475 (left) and 1:2,475 (right). Source: Gerstenberger et al., 2022

There are strong spatial variations in the ratio of the 2022 to 2010 maps. Figure 3 shows changes in hazard curves in Auckland, Wellington, Christchurch, and Dunedin coming from varying one model component at a time: the Seismicity Rate Models (SRM, grey) and the Ground Motion Models (GMCM, orange line), as well as the 2010 and 2022 model curves. In Auckland and Wellington, the changes come mainly from the new ground motion models, whereas in Christchurch the contributions from the seismicity rate and ground motion models are similar, and in Dunedin the contributions from the seismicity rate dominate the changes.

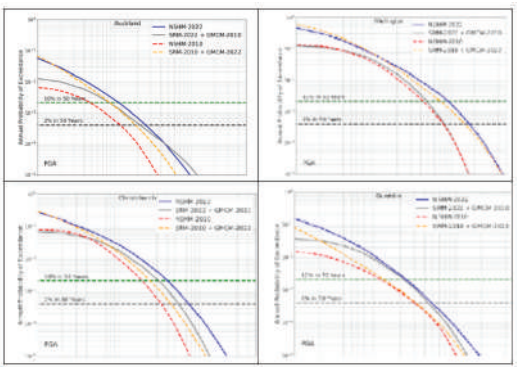

Figure 3. Changes in hazard curves in Auckland, Wellington, Christchurch and Dunedin coming from varying one model component at a time: the Seismicity Rate Models (SRM, grey line) and the Ground Motion Models (GMCM, orange line). Red and blue lines are the 2010 and 2022 models respectively. Source: Modified from Gerstenberger et al., 2022.

Before 2018, it was common to regard the hazard level in Auckland as being comparable to that in Australian capital cities.

However, with the approximate halving of that hazard level in Australia for an AEP of 1:475 and a more than doubling of the equivalent hazard level in Auckland, that parity no longer exists. Fortuitously, the new probabilistic hazard level in Auckland for an AEP of 1:475 is now about equal to the deterministic code minimum value of 0.13g, which had been conservatively adopted because the 2010 probabilistic value of about 0.05%g was considered to be too low for code purposes. The deterministic code minimum was based on a magnitude 6.5 normal faulting occurring at a distance of 20 km.

IMPACT ON SEISMIC RISK TO BUILDINGS

The impacts of these changes in seismic hazard levels for the design of new buildings have been anticipated in an Advisory prepared by a group of organisations led by NZSEE (2022); see also MBIE (2022), whose guidance is excerpted as follows; comments on the three statements highlighted by this writer in bold are provided following the excerpts:

MBIE have initiated a Seismic Risk Working Programme (SRWP) to review the Building Code compliance documents used for structural design, and how well they meet our Building Code objectives and society's expectations of seismic performance. New research and lessons from recent earthquakes on the design and performance of buildings will inform this work, as well as the new NSHM information. After an assessment of risk settings in the context of this new information, changes may be recommended to building design practices, and the way design actions are established from hazard models. Building Code Verification Method updates related to this work are planned in two stages, the first in late 2023 and the second in late 2025.

Following the principles in this guidance will lead to improved seismic performance of buildings, even whilst continuing to use the seismic design loadings specified in NZS 1170.5. This guidance applies to new building design, and the new components of alterations and seismic retrofit work. It is not intended to apply to the assessment of existing buildings. The recommendations within this advisory generally extend beyond the minimum requirements of the current Building Code compliance documents and are therefore non-mandatory.

Past earthquakes have shown that significant failures generally do not arise simply because the shaking intensity was greater than expected. Instead, failures typically eventuate in poorly configured structures featuring issues such as poor or missing load paths, vulnerable details, and irregular configurations. Consequently, dependable structural performance is better achieved by avoiding such issues than by simply seeking to increase the strength of a structure in response to hazard uncertainty.

Better certainty of performance is achieved by scheming structures so that they behave in a controlled, reliable manner during earthquakes—even when subjected to shaking that is more intense than anticipated. This approach manages the actual risk holistically, rather than just the hazard (loads) specifically.

Key focusses in achieving these outcomes include:

- ***Regularity, clear load paths***
- ***Ensuring redundancy of load paths***
- ***Capacity design (and controlled inelastic behaviour)***
- ***Robust detailing that ensures ductile response, avoids strength loss, and suppresses brittle failure***
- ***Providing tying between elements and deformation compatibility in all parts of the system, especially vertical load carrying elements***
- ***Considering soil/structure interaction, managing, or avoiding the consequences of the ground changing during and after shaking***
- ***Avoiding excessive flexibility and softening with displacement***
- ***Avoiding limited displacement capacity in a system or detail, before a significant and rapid change to undesirable behaviour occurs***

New Zealand's performance-based Building Code framework enables adoption of a virtually unlimited range of structural forms. However, while all buildings must achieve a specified minimum level of performance, the robustness and reserve capacity of different structural forms varies greatly. Some structures deliver significantly higher reliability than others, and in turn will deliver significantly lower risks of collapse, injury or death or expected losses when subjected to stronger than expected shaking. This mostly comes about from an ability to retain strength under inelastic deformation—whether that be lateral strength, or sustained ability of an element or construction detail to carry gravity loads.

Promoting the use of such systems is more likely to result in better risk and performance outcomes than simply increasing design actions. It is also more likely to result in a building being assessed more favourably in the future against a different hazard setting—as the overarching purpose of existing building assessment is after-all to assess risk.

Although the Advisory states that "it is not intended to apply to the assessment of existing buildings," it provides a list of eight deficiencies that, if known to be present in a structure, could be used to assess the capacity of the structure to withstand damage. Following the Canterbury earthquake sequence, extensive work was done in the assessment of residual capacity, which is the capacity of a structure that has been already damaged by an earthquake to withstand another earthquake.

The Advisory also refers to "reserve capacity", which is the capacity of a building to withstand ground motions that exceed the design level. Residual capacity comes from conservative assumptions that are present in the existing building code and that are made in the design process. The Advisory may prompt research into the assessment of reserve capacity of existing buildings.

The Advisory states that "Promoting the use of such systems is more likely to result in better risk and performance outcomes than simply increasing design actions." This is the underlying "philosophy" behind MBIE's approach to addressing the challenge posed by NSHM22. This seems consistent with the kinds of damage that have occurred to large buildings in recent , which have been more attributable to flaws in existing building code procedures and their implementation in design than to the ground motion levels per se, although large exceedances of code design levels did occur in both Christchurch and Wellington.

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ABOUT THE AUTHOR/S

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Paul is Chief Geoscientist at Risk Frontiers. He has a PhD in Geophysics, and has 45 years experience as an engineering seismologist, including 15 years with Risk Frontiers. He has had first hand experience of damaging earthquakes in California, Japan, Taiwan and New Zealand. He works with Valentina Koschatzky in the development of QuakeAUS and QuakeNZ.