Interim Health New Zealand

Health Infrastructure Unit

Understanding and Improving the Seismic Resilience of Hospital Buildings

TECHNICAL REPORT

3 June 2022

kestrel group

Document Information

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Executive Summary

Background

An initial review of a sample of seismic assessments of key hospital buildings commissioned by various District Health Boards (DHBs) was undertaken for the Ministry of Health by Kestrel Group in 2019, and provided an input to the Ministry's June 2020 *Current State Assessment* report. That initial review of DHB seismic assessments highlighted the age and lack of consistency of some of the assessments, and that they typically covered only the primary structural elements. A further observation was that the critical aspect that affects the ability of hospital buildings to enable the delivery of acute services following an earthquake had not been assessed – namely, the adequacy of the seismic restraint of non-structural elements such as ceilings, partition walls, building services, pipe runs and heavy specialist medical equipment.

Kestrel Group was commissioned by the Ministry of Health's Health Infrastructure Unit (HIU) in March 2021 to build upon this previous work. This work included summarising the key seismic information the HIU currently holds on hospital buildings, and developing a framework for categorising the seismic risk of existing hospital buildings and enabling the prioritisation of mitigation work.

In addition, the HIU requested guidance to be developed on other aspects such as the interpretation of Importance Levels, approaches to evaluating non-structural elements and the components of seismic information that should be included in business cases, and recommendations for developing technical guidance for new and existing hospital buildings.

Overview of the Report

This report provides analysis, commentary and proposed guidance in three main areas:

Understanding the Current Seismic Risk Profile

A general background to the technical and regulatory aspects of seismic assessments is outlined in Section 3. An outline of what is currently known and not known in relation to the seismic risk profile and status of public hospital buildings across New Zealand is provided in Section 4.

Addressing Areas of Inconsistency and Uncertainty

A framework for more consistent presentation of seismic information in investment business cases is provided in Section 5. Guidance on how to interpret and apply Importance Level categorisations for hospital buildings is given in Section 6. A triage-based approach for evaluating the seismic vulnerability of non-structural components to tackle this significant information gap is proposed in Section 7.

A Structure for Consistent Management of Seismic Risk in Hospital Buildings

A framework for both categorising and prioritising the treatment of seismic risk is proposed in Section 8. This is further supported in Section 9 with recommendations for a *Seismic Policy* and a *Seismic Risk Management Strategy* for hospital buildings, and a process for preparing technical guidance for new and existing hospital buildings is outlined in Section 10.

Key observations from this work are outlined in Section 11, with the overall findings summarised in Section 12, along with 23 recommendations to enable a comprehensive and systematic approach to *understanding and improving the seismic resilience of hospital buildings*.

Key Findings and Observations

The key findings and observations are briefly summarised below, with corresponding references to the report sections where the issues are discussed in more detail.

Understanding the Current Seismic Risk Profile

1. ***A significant number of hospital buildings have not yet had seismic assessments undertaken or reported on*** (Section 4.2)

2. ***A number of key hospital buildings have low seismic ratings for life safety in rare earthquakes*** (Section 4.2)

3. ***There is considerable variation in the reliability of seismic information currently held on key hospital buildings*** (Section 4.3)

4. ***The post-earthquake functioning of hospital buildings is highly dependent on the performance of non-structural elements*** (Section 4.3)

Addressing Areas of Inconsistency and Uncertainty

5. ***More consistent use of seismic information is needed in investment business cases for hospital redevelopments*** (Section 5.2)

6. ***There is a need for a greater appreciation of the impact of seismic strengthening on clinical services*** (Section 5.3)

7. ***Clarity is required around the Importance Level categorisations that apply to the different functional uses of hospital buildings*** (Section 6)

8. ***A systematic approach to evaluating the seismic vulnerability of non-structural elements is required*** (Section 7)

A Structure for Consistent Management of Seismic Risk in Hospital Buildings

9. ***A risk categorisation of hospital buildings to reflect known levels of vulnerability and resilience is proposed*** (Section 8.3)

10. ***Prioritising the mitigation of seismic risk across New Zealand hospitals should take into account the wider consequences for the community of key buildings not being functional*** (Section 8.4)

11. ***Prioritising the mitigation of seismic risk across New Zealand hospitals needs to take account of current information gaps*** (Section 8.4)

12. ***A Seismic Policy is required to outline the expectations and requirements for hospital buildings, supported by a Seismic Risk Management Strategy to establish the basis and priorities for managing buildings with identified seismic vulnerabilities (Section 9.1)***

13. ***Seismic performance objectives and expectations for new and strengthened hospital buildings need clearer definition (Section 9.1)***

14. ***There is a need for national technical guidance for both the strengthening of existing and the design of new hospital facilities (Section 10)***

15. ***Hospital emergency plans should more clearly define the post-earthquake decision-making process relating to alternative facilities (Section 9.3)***

16. ***Specific Priority Response Agreements need to be formalised with engineers to ensure effective post-earthquake responses (Section 9.4)***

Summary and Recommendations

In summary, this report aims to create a framework and language that enables a clearer and more consistent understanding of the seismic vulnerability of public hospital buildings in New Zealand.

Much of this report focuses on buildings as individual structures, with the associated regulatory linkages. However, it is fundamental that a campus-wide approach to both buildings and infrastructure is adopted. Part of this involves understanding the difference between *meeting minimum building regulatory requirements* and *achieving the necessary levels of resilience across a hospital campus* (extending to regional and national levels, where necessary) to ensure the delivery of medical services to the community following major adverse events.

In many cases, currently low rating hospital buildings will need to continue to be used for some years until replacement facilities can be constructed. In most situations this is likely to be acceptable from a life safety risk perspective, provided that clear timelines and expectations are established, documented and managed. Buildings with potentially brittle failure mechanisms affecting the primary structure should however receive specific consideration. The expectation that a number of hospital buildings may not be usable immediately following a major earthquake requires a stronger focus on alternative facility identification and post-earthquake decision-making in hospital emergency plans.

Recommendations to enable a comprehensive and systematic approach to ***understanding and improving the seismic resilience of hospital buildings*** are grouped under seven themes in the following table.

The majority of these recommendations require adoption and implementation by Health New Zealand (Health NZ). Preparatory work can however be undertaken in several areas prior to the formation of Health NZ.

Theme		Recommendation
1. Update seismic information to address gaps and reliability issues	1.1	Update the status of current DHB seismic assessment information held by the HIU, with emphasis on clarifying the date and type of seismic assessments
	1.2	Review the seismic assessment information currently held to enable the reliability of the information to be taken into account
	1.3	The interpretation of the Importance Level definitions outlined in this report should be adopted by Health New Zealand to ensure that seismic ratings are based on the appropriate Importance Levels
	1.4	Provide tools such as briefing and report summary templates to support DHBs in obtaining additional seismic information
	1.5	Establish a process and programme for obtaining additional seismic information, giving priority to those IL4 buildings that have not had any seismic assessments to date
	1.6	Develop a plan and approach to obtain information on the seismic status of non-structural elements, giving priority to acute services buildings with high seismic ratings for primary structure
2. Prepare technical guidelines for designing new and assessing existing hospital buildings for Health New Zealand	2.1	Establish a specialist engineering panel (eg the Health Engineering Strategy Group) to prepare technical guidelines for designing new and assessing existing hospital buildings
	2.2	Establish seismic performance objectives for new and strengthened hospital buildings, covering both *life safety* and *building functionality*
	2.3	Confirm the scope and key elements of the technical guidance for practitioners required to support the *Seismic Policy* and *Seismic Risk Management Strategy*
	2.4	Develop a process for evaluating the seismic vulnerability of site-wide infrastructure that interfaces with both the building-based non-structural element evaluation processes and with external service providers
	2.5	Prepare a briefing template for consulting engineering practices undertaking seismic strengthening designs, and a template for summarising the strengthening scope and outcomes at the various stages of design

3. Establish a framework to enable the systematic categorisation of seismic vulnerabilities and identification of information gaps	3.1	Adopt the proposed risk categorisation to identify priority categories of hospital buildings for seismic upgrade or replacement, and where additional seismic information is required
	3.2	Extend the proposed risk categorisation to reflect overall hospital campus-wide seismic vulnerability
4. Develop a Seismic Policy and Seismic Risk Management Strategy for Health New Zealand	4.1	Develop a *Seismic Policy* to outline the expectations and requirements for new and strengthened hospital buildings and for managing buildings with identified seismic vulnerabilities
	4.2	Develop a *Seismic Risk Management Strategy* to implement the recommendations from this report in accordance with the requirements of the Seismic Policy
5. Actively progress seismic risk mitigation	5.1	Establish a seismic risk mitigation programme that utilises the seismic priority categories identified in this report and reflects overall campus-wide seismic vulnerability (including infrastructure) and the consequences for the community of key hospital buildings not being able to function following earthquakes
	5.2	Prepare guidance for how natural hazards and other risks should be addressed in hospital site-wide Master Planning
	5.3	Adopt the checklist proposed for seismic information to be included in business cases for the upgrades of existing hospital buildings
6. Ensure that hospital emergency plans provide greater emphasis and clarity around early post-earthquake decision-making	6.1	Update hospital emergency plans to provide greater clarity on early stage post-earthquake decision-making for key acute services functions
	6.2	Ensure that nominated alternative facilities have a reasonable level of seismic resilience and appropriate emergency backup infrastructure
7. Establish specific arrangements with engineers for post-earthquake response at each main hospital	7.1	Ensure that post-earthquake response arrangements for engineers are incorporated within hospital emergency plans
	7.2	Develop a common template for Priority Response Agreements with engineers for post-earthquake response
	7.3	Consider installing seismic instrumentation to key acute services buildings to provide information to support responding engineers and facilities managers with re-occupancy decisions

Contents

1. Introduction

1.1 Background

A number of public hospital buildings across New Zealand were constructed in eras that preceded the advent of modern seismic codes. Some more modern hospital buildings have also been found to contain design shortcomings that were highlighted by the Canterbury and Kaikoura earthquakes and more recent advances in engineering knowledge. Seismic assessments have been undertaken for the majority of hospital buildings over the past decade, but not all. Some key hospital buildings have been found to have low seismic ratings, with some receiving earthquake prone building notices from their local territorial authority.

Changes to the earthquake-prone buildings provisions of the Building Act[1] and the national seismic assessment guidelines in 2017 require assessments to include secondary structural and non-structural elements above a certain weight. In conjunction with the subsequent guidance on assessing concrete buildings issued in November 2018, including those with suspended precast concrete floor systems, this means that earlier assessments have a lower coverage and hence reliability than assessments carried out from 2019.

An initial review of a sample of seismic assessments of key hospital buildings commissioned by various District Health Boards was undertaken for the Ministry of Health by Kestrel Group in 2019, and provided an input to the Ministry's June 2020 *Current State Assessment* report. That work highlighted the age and lack of consistency of some of the assessments, and that they typically covered only the primary structural elements. The key observation from this review of DHB seismic assessments was that the critical aspect that will influence the ability of hospital buildings delivering acute services following an earthquake had not been assessed – namely the adequacy of the seismic restraint of non-structural elements such as ceilings, partition walls, building services, pipe runs and heavy specialist medical equipment.

1.2 Health System Reforms

During the course of this project, the Government announced the formation of a new Crown entity, Health New Zealand (Health NZ), on 1 July 2022. Health NZ will take over the planning and commissioning of services and the functions of the existing 20 District Health Boards to remove duplication and provide more effective national planning. As part of the transition to Health NZ, the Health Infrastructure Unit (HIU) and staff transferred to Interim Health New Zealand (iHNZ), on 1 March 2022. This report has been delivered to the HIU of iHNZ.

[1] Building (Earthquake-prone Buildings) Amendment Act 2016 which came into force on 1 July 2017

As well as informing the DHBs in the period leading up to the health reform system changes, the outputs from this work will inform the future management of seismic risk by Health NZ. Some references in this report to DHBs can be read interchangeably with Health NZ.

1.3 Scope of Project

Kestrel Group was commissioned by the Ministry of Health in March 2021 to provide input to the Ministry's Seismic Resilience Programme, building upon our previous work in 2019.

Specific outputs were sought in the following areas:

1. A summary of earthquake prone building requirements and the seismic assessment process as it applies to hospital facilities
2. A summary of the key information that the Ministry has obtained from the DHB seismic assessments
3. Outline of the seismic information components that should be included (or drawn upon) in a business case that is seeking funding for seismic work or campus redevelopment
4. Guidance on which operational areas of hospital facilities should be categorised as Importance Level 3 and 4
5. A recommended approach for evaluating the adequacy of seismic restraint and associated measures for non-structural elements
6. A framework for categorising the components of seismic risk associated with hospital facilities, and development of risk rating scales for these components
7. A prioritised strategy for addressing low rating/ high risk buildings, including the approach to gathering information that is not known or is incomplete
8. Outline of the purpose, scope and nature of technical guidance to the sector and designers that Health NZ can produce for DHBs for the design and assessment of hospital buildings, including briefing and reporting templates for seismic assessments.

The output from the above work elements are summarised in this report, along with recommendations for the implementation of project outputs.

While the main focus of this report is on existing public hospital buildings, the seismic performance expectations, objectives and criteria for new buildings represents a key point of reference for evaluating existing buildings. These objectives and criteria require better definition for new hospital buildings, and recommendations are made in this report for this to be accorded priority.

Also, while this project was primarily focused on hospital buildings, account was taken of the interface with hospital infrastructure systems, and the current work in relation to site-wide infrastructure risk management. The post-earthquake functionality of hospitals is inextricably linked to the performance of both the buildings and the services that are required to support key medical and surgical functions, and the effectiveness of emergency response planning. Recommendations are made for further integration of relevant activities.

A related point is the importance of making recommendations and decisions on seismic mitigation based on comprehensive site-wide master plans. Recommendations are made for national guidance on this aspect to be prepared.

This project focused on public hospital buildings, and did not include hospital buildings under private ownership.

This work was primarily undertaken during the period April to September 2021, and included review of and involvement with a sample of current building assessment projects with the Bay of Plenty, Hawke's Bay and Capital and Coast District Health Boards.

1.4 Purpose and Use of this Report

The primary purpose of this report is to inform Health NZ and key stakeholders of the state of information currently known about the seismic status of public hospital buildings.

Recommendations are also made to address key technical and process areas to enable the availability of more consistent seismic risk information for use in the prioritisation of risk reduction. While this report does not specifically address the seismic design of new hospital buildings, recommendations are made for the development of national technical guidance as a priority next step. These recommendations are presented for consideration by Health NZ, including how they would be implemented if supported.

While this report is likely to be of interest to design professionals working on hospital projects, it should be noted that the technical recommendations have not been formally adopted by iHNZ.

1.5 Overview and Structure of this Report

This report provides analysis, commentary and proposed guidance in three main areas:

Understanding the Current Seismic Risk Profile

A general background to the technical and regulatory aspects of seismic assessments is outlined in Section 3. An outline of what is currently known and not known in relation to the seismic risk profile and status of public hospital buildings across New Zealand is provided in Section 4.

Addressing Areas of Inconsistency and Uncertainty

A framework for more consistent presentation of seismic information in investment business cases is provided in Section 5. Guidance on how to address a common area of uncertainty relating to Importance Level categorisations for hospital buildings is given in Section 6. A triage-based approach to evaluating the seismic vulnerability of non-structural components in order to tackle this significant information gap is presented in Section 7.

A Structure for Consistent Management of Seismic Risk in Hospital Buildings

A framework for both categorising and prioritising the treatment of seismic risk is proposed in Section 8. This is further supported in Section 9 with recommendations for a *Seismic Policy* and *Seismic Risk Management Strategy* for hospital buildings, and a process for preparing technical guidance for new and existing hospital buildings is outlined in Section 10.

The key observations from this work are discussed in Section 11, followed by a summary in Section 12 with 23 recommendations to enable a comprehensive and systematic approach to *understanding and improving the seismic resilience of hospital buildings*.

1.6 Report Preparation and Review

This report was prepared by Kestrel Group, a consultancy specialising in the provision of strategic engineering and regulatory advice to government agencies, other national organisations and territorial authorities, in addition to emergency response planning and crisis management services.

Kestrel Group has worked for a number of organisations with buildings that have *special post-disaster functions* (ie. Importance Level 4 buildings), providing advice on how the regulatory requirements and design and assessment outputs align with their critical service delivery imperatives.

A draft of this report was reviewed by a group of engineers with experience in regulatory, technical and institutional matters, including the seismic assessment and design of hospital buildings (refer inside front cover). This review was undertaken through a workshop held on 2 November 2021.

The review group endorsed the report's principal findings and recommendations, and made a number of suggestions to add to the effectiveness of the recommendations, as briefly summarised below:

1. While the report focuses on existing buildings, the recommendations to clarify the performance expectations and criteria for the design of new hospital buildings should be addressed as a priority, as this provides the key point of reference for evaluating existing buildings.

2. The implications for the post - earthquake delivery of key medical services from buildings that are unlikely to be able to be functional need to be considered more specifically.
3. There is a need for more specific consideration of expected seismic performance at the campus level as part of both master planning and health emergency planning.
4. The prioritisation of seismic strengthening, re-purposing or replacement of specific buildings should place more emphasis on the overall operational vulnerability of the hospital campus to major earthquakes.
5. The prioritisation of seismic mitigation between regions should take into account the consequences for the population of a hospital being unable to deliver critical post-earthquake services.

A subsequent draft of this report was reviewed by the HIU and the Health Asset Management Improvement Forum (HAMI) Seismic Advisory Group, including a virtual workshop held on 22 November 2021.

Additional suggestions from the DHB representatives on the HAMI Seismic Advisory Group included:

6. Clarify which types of buildings are required to be assessed under the earthquake prone buildings legislation.
7. Note that other structures such as bridges and retaining walls that are not connected to buildings also need to be assessed as part of understanding site-wide infrastructure risk, even though not required under earthquake prone buildings legislation.
8. Clarify the Importance Level rating required for inpatient wards generally, and the extent to which certain medical services (eg renal) need to be included with IL4 categorisations.
9. Emphasise the many challenges in obtaining and verifying the seismic qualification of major plant and specialist medical equipment – particularly the uncertainty surrounding overseas testing standards and the long leads times for this testing.

The Building Performance and Engineering team within MBIE also undertook a review of the document from a building regulatory perspective. Recommendations were made to clarify the purpose and use of this document and the relationship between the technical proposals and the requirements of the New Zealand Building Code.

The suggestions and recommendations from these review stages have been incorporated in the final version of this report.

1.7 Key Terms

There are a number of key terms and concepts that are used throughput this report, including some that are either new or have come from international documents. They are briefly introduced below to assist readers.

Life safety – the exposure of people to injury or death from the failure of structural or non-structural elements or their connections during earthquakes

Element functionality – the ability of an individual element of a building to function and support the delivery of critical [medical] services to continue to be delivered following an earthquake or other hazard event

Building functionality – the ability to re-occupy a building after an earthquake and deliver critical [medical] functions following an earthquake or other hazard event

Serviceability Limit State 2 (SLS2) – the requirement for an Importance Level 4 structure to maintain operational continuity (ie. re-establish or continue operations) and perform adequately after 500 year earthquake shaking

Functional recovery – the maintenance or restoration of a building to safely and adequately support the basic intended functions associated with the pre-earthquake use or occupancy of a building

Non-structural Elements - an element within the building that is not considered to be part of either the primary or secondary structure (eg. ceilings and lights, partition walls, cladding, building services including lifts and pipe runs). This definition is extended further in Section 7.

Campus-wide Infrastructure – encompasses electrical infrastructure (substations, switchboards, site generators and distribution mains) and mechanical infrastructure (steam, heating and cooling pipes, heating and ventilating plant and ducting, water supply and storage, wastewater and stormwater pipes)

Low Damage Seismic Design - a new approach to building protection where designers and engineers design earthquake resilient buildings that not only preserve life but also minimise damage to the structure, fitout and contents, so the building can continue to be used following an earthquake or other hazard event

Special post-disaster function – the criteria for requiring a building to be categorised as Importance Level 4; for hospitals, the ability to provide emergency medical and surgical facilities to treat casualties from the disaster event

Further background information on relevant terminology, seismic hazard, and earthquake risk is provided in Appendix A.

2. The Wider Context: Challenges and Opportunities

There are many challenges in understanding and improving the seismic resilience of buildings generally. These begin with establishing the seismic vulnerability in engineering terms, and in conveying the wider risk considerations and the associated uncertainties across the aspects of both *life safety* and *continued functionality*. There are three key areas where industry awareness is changing and evolving in relation to the seismic risk posed by existing buildings, and this sets the wider context for the more specific question of seismic risk across the portfolio of hospital buildings.

Firstly, there is a growing awareness that a singular %NBS seismic rating only tells part of the story – both in terms of the potential range of outcomes that can be anticipated from different earthquakes, and that it only talks to life safety considerations. This is a key distinction for buildings with special post-disaster functions (IL4 buildings), where understanding the likely ability of the building to enable the key functions to continue is also fundamental. Currently however there is no nationally agreed approach for assessing the expected response of lighter non-structural elements that fall outside the scope of *secondary structural and non-structural elements* addressed within %NBS ratings.

Secondly, there is also growing awareness of the need to take a measured response to low seismic ratings. Low %NBS ratings provide a clear pointer to the presence and nature of seismic vulnerabilities, and to the need to address these within a reasonable timeframe. While some vulnerabilities are more significant than others, low %NBS ratings typically don't point to an immediacy of risk. This is especially the case for Importance Level 4 buildings where the rating is based on 2,500 year return period earthquake shaking. For perspective, the probability of an earthquake of this size occurring in a 5 year period is only 0.2%, or 0.4% in 10 years.

Particularly for hospital buildings, the significant impact of seismic strengthening on the delivery of medical services needs to be evaluated against the likelihood of a significant earthquake occurring over a time period of several years.

And thirdly, and perhaps more importantly, there is an increasing awareness of the need to place more focus on progressing seismic mitigation, rather than refining seismic assessments where the level of risk is already apparent and greater than levels that are generally regarded as being acceptable.

Industry knowledge and awareness is also changing in relation to providing seismic resilience in new buildings. There is a greater understanding of the need to do more than meet life safety requirements. Internationally, the concept of designing buildings with post-earthquake re-occupancy as a focus (*functional recovery)* are being developed to guide the development of seismic design codes. In New Zealand, similar thinking is evolving via a project by the New Zealand Society for Earthquake Engineering to identify the range of the performance expectations that different building user groups have for new buildings. Engineering New Zealand and the Structural Engineering Society are in the advanced stages of a project for MBIE that establishes more specific criteria for Low Damage Seismic Design (Tū Kahika: Building Resilience) that can be applied to buildings generally.

The Ministry of Education also requires that designers of new school buildings go beyond building code requirements to achieve more resilient outcomes to support community recovery objectives following a significant earthquake. A feature of the technical guidance for designers of school buildings is the definition of the performance requirements for non-structural elements as well as for the primary structure, and both qualitatively and quantitatively. There is a similar need for buildings with *special post-disaster functions*, including hospital buildings with acute services. There is currently only limited guidance on how to interpret and meet the serviceability limit state requirements for 500 year return period earthquakes (SLS2), noting that these requirements vary depending on the nature of the critical post-disaster functions.

The prospect of strong and prolonged shaking from a subduction zone earthquake emanating from the Hikurangi Trench also highlights the need for new hospital buildings in central New Zealand to be designed to be highly resilient. In conjunction with recent knowledge gained in relation to recurrence intervals of a rupture on the Alpine Fault, this reinforces the degree of priority that should be placed on the seismic upgrade of hospitals in regions of high seismicity.

Forthcoming changes to seismicity will affect central New Zealand and the east coast of the North Island. While any changes to the seismic loadings standard and the Building Code are unlikely to occur until 2023, new building designs and significant strengthening work in these areas should take this into account. What this means for the seismic ratings of existing buildings has yet to be determined, but the prospect of significant increases in design loadings in these areas is raising further questions about the appropriateness of assessing existing buildings directly against the requirements for new buildings.

The commentary in this report on the current levels of seismic vulnerability of hospital buildings and the recommendations to improve their resilience are set against the backdrop of these wider challenges and opportunities.

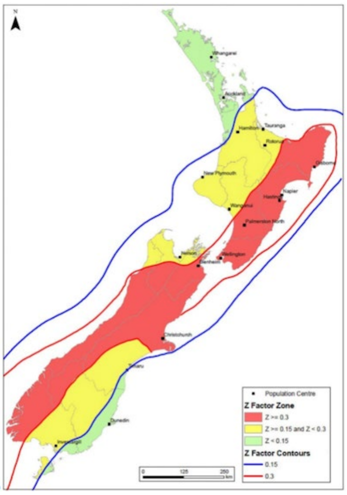
3. Background to Seismic Assessments

3.1 Earthquake Prone Building Requirements of the Building Act

Commercial and multi-storey residential buildings fall within the provisions of the earthquake-prone building, EPB, regulations that came into force in July 2017 with changes to the Building Act 2004 (the Act).

The seismic capacity of the building needs to be assessed against that of an equivalent new building at the same location. This provides a percentage rating contrasted against the new building standard, %NBS. Building Importance Levels (ILs) and the hazard factor for the location (Z) are important in the design of a new building (refer Section 4), and therefore in the assessment of existing buildings. Buildings falling below 34% NBS are required to be strengthened or removed over time.

The Act provides timeframes for assessment and strengthening or removal of buildings falling below the 34%NBS threshold. Timeframes vary depending on whether it is in a seismic risk area that is High (Z value greater than 0.3, red), Medium (Z between 0.15 and 0.3, yellow) or Low (Z less than 0.15, green), refer Figure 3.1 below. There is a lower likelihood of earthquakes in the Low risk area. Therefore, the time exposure to damage is lower and so the timeframes for both identification of EPBs and strengthening are longer.



Seismic risk area	TAs must identify potentially EPBs by:		Owners of EPBs must carry out seismic work within *(time from issue of EPB Notice)*	
	PRIORITY	OTHER	PRIORITY	OTHER
High	1 Jan 2020	1 July 2022	7.5 years	15 years
Medium	1 July 2022	1 July 2027	12.5 years	25 years
Low	n/a	1 July 2032	n/a	35 years

Figure 3.1: Seismic Hazard Areas for EPB Purposes and Corresponding Time Frames

The seismic hazard factors and corresponding risk area designation of New Zealand towns and cities are summarised by geographical location in Table 3.1 below.

Table 3.1: Hazard factors, Z, from NZS 1170.5, for typical NZ locations

Location, North Island	Hazard Factor, Z	Location, South Island	Hazard Factor, Z
Whangārei and north	0.10	Blenheim	0.33
Auckland/Manukau	0.13	Nelson	0.27
Hamilton	0.16	Greymouth	0.37
Tauranga	0.20	Hokitika	0.45
Whakatāne	0.30	Christchurch	0.30
Gisborne	0.36	Arthurs Pass	0.60
Rotorua	0.24	Ashburton	0.20
Taupō	0.28	Timaru	0.15
Taumarunui	0.21	Oamaru	0.13
New Plymouth	0.18	Queenstown	0.32
Hastings	0.39	Dunedin	0.13
Whanganui	0.25	Invercargill	0.17
Palmerston North	0.38	(green)	Low seismic risk area, EPB regs. Refer Section 3
Masterton	0.42	(yellow)	Medium seismic risk area
Wellington	0.40	(red)	High seismic risk area

Priority buildings have half the time to be identified and strengthened if found to be below the EPB threshold. Hospital buildings in High or Medium seismic risk areas that are likely to be needed to provide emergency services, including those providing essential ancillary services, are defined as priority buildings in the Act and therefore have the reduced timeframes for action[2]. Other hospital buildings on the same High or Medium risk area campus and all hospital buildings in Low risk areas have the longer timeframes.

MBIE's EPB Methodology[3] outlines three *Profile Categories* of buildings that are regarded as potentially earthquake prone and require engineering assessment. These categories are as follows:

- Profile Category A – unreinforced masonry buildings (unstrengthened or strengthened)
- Profile Category B – buildings of three or more storeys (or more than 12m in height) constructed prior to 1976
- Profile Category C – one or two storey concrete or steel buildings constructed prior to 1935

[2] Refer MBIE Guidance on Priority Buildings for further details on hospital facilities at: https://www.building.govt.nz/assets/Uploads/building-code-compliance/b-stability/b1-structure/epb-priority-buildings.pdf

[3] Methodology required under s 133AV of Building Act 2004, Refer https://www.building.govt.nz/building-code-compliance/b-stability/b1-structure/methodology-identify-earthquake-prone-buildings/

TAs must identify buildings in these categories within the time frames indicated in Figure 3.1.

Timber-framed buildings fall outside the Profile Categories and are not required to be assessed for regulatory purposes.

TAs can identify potentially earthquake prone buildings of any other construction type of form at any time, based on receipt of relevant specific information.

The overall process in relation to the assessment of potentially earthquake prone buildings is summarised in Figure 3.2 below.

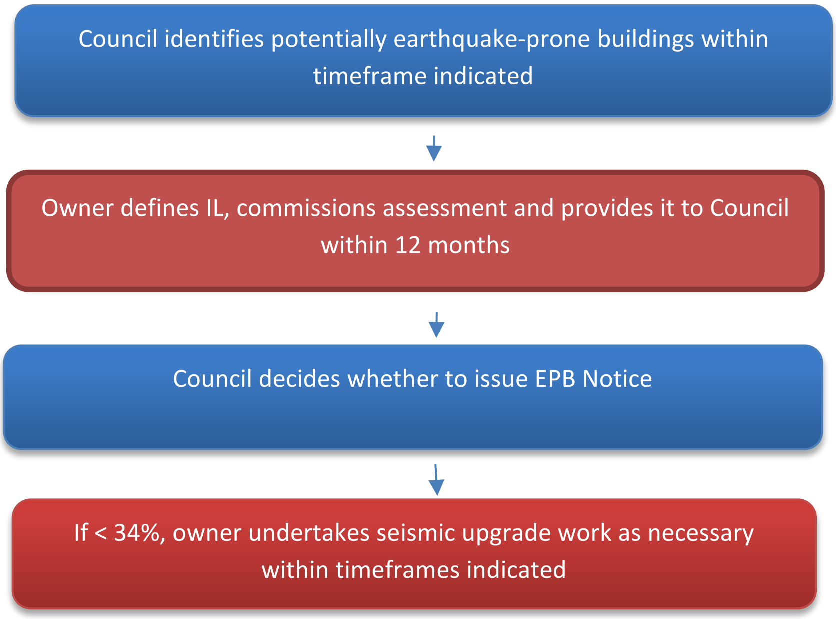


Figure 3.2: The EPB Assessment Process

EPB regulations and seismic assessment ratings only focus on life safety. People in and around buildings with a high seismic rating are much more likely to be protected in a large earthquake than those in a low rated building. However, buildings with high ratings may well be damaged, requiring considerable lost time for engineering assessment and repair, thereby affecting on-going operations.

3.2 Evolution of the National Seismic Assessment Guidelines

The EPB Methodology also specifies the scope, qualification, and form of engineering assessment required. It references the Engineering Assessment Guidelines[4] (the Guidelines) that provides engineers with assessment criteria and methods. The EPB Methodology recommends, in most cases, an Initial Seismic Assessment (ISA) be carried out as the first step of a Detailed Seismic Assessment (DSA). If the ISA only is to be used as the engineering assessment, the engineer must have a clear understanding of the structure and how it responds to earthquake, and be confident that further detailed investigation will not reveal any weaknesses that could lead to the building being close to or below the earthquake-prone threshold of 34% NBS. Unless the situation is clear cut, a DSA is often likely to be required.

Seismic assessments typically focus on primary structural elements. However the amendments to the earthquake-prone buildings provisions of the Building Act and the release of updated national seismic assessment guidelines in 2017 require engineering assessments to include heavy façade and internal non-structural elements. Few assessments undertaken prior to these 2017 amendments being released included these elements.

The November 2018 proposed update to the concrete buildings section[5] of the Engineering Assessment Guidelines provides a more comprehensive treatment of concrete elements (particularly precast concrete floors), and represents current best practice for use in seismic assessments.

3.3 Coverage of %NBS Ratings

The principal output from a seismic assessment is a rating of the building as a percentage of New Building Standard (%NBS). This only reflects the extent to which an existing building meets the minimum life safety requirements of an equivalent new building – ie the presence of *Significant Life Safety Hazards* affecting more than one person. In this respect the term 'New Building Standard' is somewhat misleading – it doesn't relate to the other provisions of the Building Code that address aspects such as functionality.

Assessments cover primary structural systems and secondary structural and heavy non-structural elements – ie. those weighing 25kg or 25kg/m^2or greater. Other non-structural elements to which damage or failure wouldn't give rise to life safety concerns are typically not addressed in seismic assessments. Damage to these non-structural elements can however directly affect the functionality of buildings with complex fitouts and equipment such as

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[4] MBIE, NZSEE, SESOC, NZGS & EQC *The Seismic Assessment of Existing Buildings: Technical Guidelines for Engineering Assessments.* July 2017 - refer http://www.eq-assess.org.nz

[5] MBIE, NZSEE, SESOC, NZGS & EQC *Concrete Buildings C5: Technical Proposal to Revise the Engineering Assessment Guidelines* November 2018

hospital facilities. It is necessary to understand how these elements are likely to perform during disaster events such as earthquakes in order to fully understand the consequences on medical services, and the periods of disruption that should be planned for.

Where they are included within a seismic assessment, the expected impacts on non-structural elements are typically not evaluated using an equivalent %NBS rating (although noting that some engineering practices do this). However, the nature and scale of impacts can be triaged into broad categories once the adequacy of the seismic restraints etc have been evaluated by experienced earthquake engineers (refer Section 7).

Seismic assessments also do not cover the 'contents' components of buildings, as in most cases they do not influence the seismic performance of the overall structure, nor give rise to a *Significant Life Safety Hazard* affecting more than one person. For particularly heavy items in the hospital context, it is a general expectation that there has been some form of specific engineering input associated with their installation. However, verification of this via documentation is not always available. For older installations, engineering reviews of these elements against current seismic loadings (Parts coefficients) are warranted, noting again that this considers *life safety* aspects of the overall unit, and not the ability of the internal components to continue to function.

3.4 Building Code Performance Requirements

The Building Code requires buildings to meet performance criteria for different levels of seismic shaking:

- In a reasonably frequent moderate earthquake that could occur at that location once in 25 years, there should be no significant structural damage (termed Serviceability Limit State, SLS1).
- In a rare major earthquake occupants and passers-by should be protected and egress maintained but there is likely to be significant structural damage (termed Ultimate Limit State, ULS). The building provides life-safety protection and allows people to escape but will not necessarily allow for business continuity. Modern design provides for building ductility, the ability of the building to move and deform in large earthquakes. Damage and spalling can occur in less critical elements such as beams but critical elements such as columns remain intact, so the building does not fail in a brittle, catastrophic manner. This may not be the case for older buildings (generally pre-1976), adding complication to the comparison of new and existing buildings.
- The ULS earthquake shaking intensity level varies with the importance level of the building, from a 1 in 500-year earthquake for a normal IL2 building to a 1 in 2,500-year earthquake for an IL4 building where a higher level of protection is required.

- IL4 buildings, those designated as being of high importance to the community for delivering *special post-disaster functions*, also need to meet continuing functionality criteria (SLS2), providing confidence that the building can continue to be used in the event of a 1 in 500-year earthquake. SLS2 criteria are however defined in only broad terms, and there is currently no specific guidance on their application for the different sectors that have IL4 buildings (Health, Police, Fire, Ambulance, Lifeline Utilities, Civil Defence Emergency Management).

These represent minimum requirements, and can always be specified to be exceeded if desired by building owners to meet their specific requirements.

Table 3.2 provides more detailed design performance criteria, and SLS2 requirements are discussed further on the following page and in Section 6.3.

An R-factor (earthquake return period) is used to define the difference in design capacity between the various levels of earthquake shaking. A 1 in 500-year earthquake has an R-factor of 1.0, whereas a 1 in 2,500-year earthquake, a much larger event, has an R-factor of 1.8.

Section 6.1 describes Importance Levels in further detail, and Table 3.2 below provides information on loadings multipliers (hazard factors).

Table 3.2: Design Cases and Corresponding Performance Requirements

Design case	**Performance Criteria**	**Earthquake shaking intensity and R-factor Building Importance Levels, ILs**			
		IL1	**IL2**	**IL3**	**IL4**
Life safety – Ultimate Limit State, ULS	Life safety, no collapse or rupture of structural elements Egress possible	1:100-year event R = 0.5	1:500-year event R = 1.0	1:1000-year event R = 1.3	1:2500-year event R = 1.8
Functionality – SLS2 (for IL4 structures only)	Maintain all elements for critical functions in operational state or returned to fully operational state within short timeframe (minutes to hours, not days)	Not Required	Not Required	Not Required	1:500-year event R = 1.0
'No damage' – Serviceability Limit State, SLS1	Avoid damage to structure and components that would prevent it from being used without repair	Not Required	1:25-year event R = 0.25	1:25-year event R = 0.25	1:25-year event R = 0.25

3.5 Considerations for Existing Buildings

It is important for assessments to take account of the geotechnical conditions that may not have been known or included at the time of original design. These include aspects such as liquefaction and other potential causes of land movement, as these can cause structural and services damage in 500-year ground shaking, and hence preclude use of the building.

Seismic assessments, as for new building designs, are based upon a 50-year *specified intended life*, which provides the linkage with the return periods and hence seismic coefficients used to establish the seismic demand from which the %NBS rating is derived. While it is possible that a reduced *specified intended life* can be used in situations where definite plans exist for demolition, giving rise to lower seismic demands and hence higher %NBS ratings, this is not recommended practice.

As already noted, SLS2 behaviour is typically not evaluated as part of seismic assessments, which focus on life safety, including heavy non-structural elements. In part this stems from the lack of specific definition of the SLS2 criteria in relation to hospital buildings. It is also difficult to evaluate the ability of an existing building to function following 500-year ground shaking given all the complexity of specialist services, etc. This can depend on many factors that are challenging for structural engineers to determine.

The Engineering Assessment Guidelines suggest (A3.1.2):

> *The serviceability required to provide confidence that an existing IL4 building will be able to maintain operational continuity (i.e. SLS2) may be satisfied by simply assessing behaviour at an appropriate level and using judgement to determine what the outcomes may be for usability.*

A possible method for evaluating the operational continuity aspect of non-structural components in existing hospital buildings that adopts this approach is outlined in Section 7.

A related point to note is that a building assessed as being (or strengthened to) 100%NBS (IL4) is not necessarily capable of performing at the same level as a new building with both the required strength and the ability to meet SLS2 requirements.

4. Seismic Assessments of Hospital Buildings: Current Situation

There are approximately 1,238 buildings across 125 hospital campuses that are currently owned and managed by the 20 District Health Boards.

There is also a significant number of privately-owned hospital buildings across New Zealand, but these are not included within the scope of this report.

4.1 Seismic Assessments Undertaken for District Health Boards

A review of a sample of DHB-commissioned seismic assessments in 2019 by Kestrel Group for the Ministry of Health highlighted the following points:

1. A number of the assessments pre-dated the amendments to the earthquake prone building provisions of the Building Act and the associated update of the national seismic assessment guidelines in 2017. This means that some earlier ratings may significantly reduce when heavier parts of the buildings are assessed.
2. More recent concerns about the behaviour of precast concrete floor systems and connections of precast elements in buildings in the 1985 to 2005 era have also yet to be considered for most buildings with these features.
3. Many of the interfaces between buildings are complex, and the interaction effects between different sections of adjacent buildings (and associated infrastructure) have typically not been established. In many situations, engineering assessments are based on simplifying assumptions that, while perhaps understandable to enable rational analysis, do not represent the physical situation that currently exists.
4. The ratings from the assessments essentially only address life safety aspects. They don't provide much insight into the levels of damage (and hence operational disruption) to primary and secondary structural elements to be expected at either moderate or major levels of earthquake shaking.
5. Even more importantly, non-structural elements have typically not been assessed. The seismic restraint and movement allowances associated with heavy partitions, suspended ceilings, pipework and plant need to be evaluated in order to understand the disruption potential, particularly in moderate earthquakes.
6. In many cases in the sample of assessments reviewed, it was considered that the buildings (including those categorised as IL4) should be assumed to be unusable for at least several weeks after a significant earthquake. Where the actual levels of damage to structural and non-structural elements had not been established, time would need to be allowed for engineering assessments and basic repairs to be undertaken – even for buildings with relatively high seismic ratings.

7. While the assignment of Importance Level categories for use in the assessments appeared generally reasonable, the appropriateness of their selection depends on how various buildings across a campus will be used in a post-disaster context.

4.2 Current Assessment Information

All DHBs have been pro-active in seeking to understand their seismic risk, and in having seismic assessments undertaken on their key buildings. Canterbury DHB, in particular, has had to look into its buildings very closely given the range of damage levels experienced across their portfolio in the Canterbury and Kaikōura earthquakes, and has looked at seismic risk in considerable detail.

The HIU database of seismic assessment results from the DHBs was compiled during 2019, and reported on in the Ministry's June 2020 *Current State Assessment* report[6]. Subsequent updates have recently been received from some DHBs. This information has only a high level of granularity, and it has not been possible to break this down in terms of building typologies. A further analysis by *assessment type* - IEP, ISA and DSA – and date also needs to be undertaken, but requires a full refresh of the information from all DHBs.

The current assessment outcomes are summarised below in aggregate under the headings of *assessment coverage* and *assessment outcomes,* based on DHB data held by the Ministry at December 2021.

Assessment coverage

The numbers of buildings for which seismic ratings across all DHBs are currently held by the HIU are indicated in Table 4.1 for each of the seismic hazard areas shown in Figure 3.1 and Table 3.1.

Table 4.1: Overall Buildings Assessed/ Not Assessed by Seismic Hazard Area

	High Seismic Hazard		**Medium Seismic Hazard**		**Low Seismic Hazard**		**Overall**	
	No.	%	No.	%	No.	%	No.	%
Assessment Rating Recorded	348	78%	254	60%	184	50%	786	63%
No Assessment Rating Recorded	100	22%	169	40%	183	50%	452	37%
Totals	**448**		**423**		**367**		**1238**	

[6] Ministry of Health *The National Asset Management Programme for District Health Boards - Report 1: The current-state assessment June 2020*

These figures indicate that %NBS ratings have been obtained for 63% of all hospital buildings, and that 37% have either yet to be assessed or the results have not been conveyed to the HIU. This is a slight improvement on the ratio as reported in the Ministry's June 2020 report. A much higher proportion of assessments have been undertaken in the High seismic hazard area (78%) than in the Low seismic hazard area (50%).

There are considered to be approximately 225 buildings nationally categorised as Importance Level 4, and results have been recorded for 185 of these (82%). The numbers of IL4 buildings for which seismic ratings across all DHBs are currently held by the HIU are indicated in Table 4.2 for each of the seismic hazard areas.

Table 4.2: IL4 Buildings Assessed/ Not Assessed by Seismic Hazard Area

	High Seismic Hazard		**Medium Seismic Hazard**		**Low Seismic Hazard**		**Overall**	
	No.	%	No.	%	No.	%	No.	%
Assessment Rating Recorded	65	82%	78	85%	42	78%	185	82%
No Assessment Rating Recorded	14	18%	14	15%	12	22%	40	18%
Totals	**79**		**92**		**54**		**225**	

Table 4.2 highlights that 40 IL4 buildings have yet to have assessment results recorded (18% of IL4 buildings). It is noted that the overall number of buildings regarded as IL4 may change once a more consistent approach to categorising IL3 and IL4 buildings is taken (refer Section 6).

Assessment outcomes

The seismic ratings currently held by the HIU from the DHBs are summarised in Table 4.3 by seismic grade for each of the seismic hazard areas.

Figure 4.1 shows the distribution of ratings in bar chart and pie chart format, including the buildings that have not been assessed.

Table 4.3: Seismic Ratings <u>for Assessed Buildings</u> by Hazard Area

Rating Grade	High Seismic Hazard		Medium Seismic Hazard		Low Seismic Hazard		Overall	
	No.	%	No.	%	No.	%	No.	%
A (>80%NBS)	135	39%	90	35%	86	47%	311	40%
B (67 to 80%NBS)	56	16%	27	11%	33	18%	116	15%
C (34 to 66%NBS)	121	35%	93	37%	42	23%	256	33%
D (20 to 33%NBS)	23	7%	30	12%	21	11%	74	9%
E (<20%NBS)	13	4%	14	6%	2	1%	29	4%
Totals	**348**		**254**		**184**		**786**	

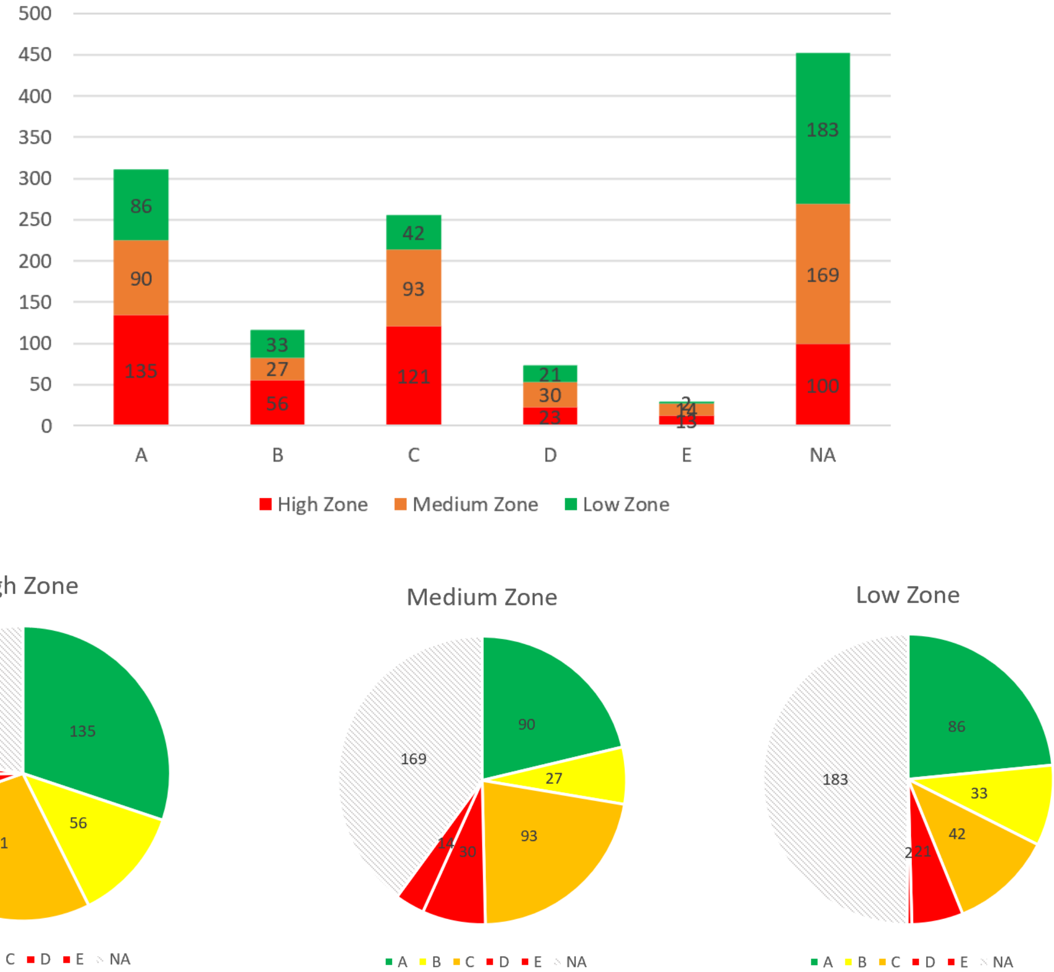

Figure 4.1: Seismic Ratings for All Buildings

Overall, just over a half (55%) of buildings that have been assessed have ratings above 67%NBS, one third are between 34% and 66%NBS and 13% are less than 34%NBS. These results are reasonably consistent across all seismic hazard areas.

It was not able to be ascertained with clarity how many of the 103 buildings rating less than 34%NBS have received earthquake prone building notices and are included on MBIE's National EPB Register.

The currently held ratings are further broken down for IL 4 buildings for each of the seismic hazard areas in Table 4.4.

Table 4.4: Seismic Ratings for Assessed Importance Level 4 Buildings

	High Seismic Hazard		Medium Seismic Hazard		Low Seismic Hazard		Overall	
Rating Grade	No.	%	No.	%	No.	%	No.	%
A (>80%NBS)	25	38%	29	37%	23	55%	77	42%
B (67 to 80%NBS)	19	29%	10	13%	9	21%	38	21%
C (34 to 66%NBS)	15	23%	19	24%	5	12%	39	21%
D (20 to 33%NBS)	3	5%	15	19%	5	12%	23	12%
E (<20%NBS)	3	5%	5	6%	0	0%	8	4%
Totals	**65**		**78**		**42**		**185**	

Figure 4.2 shows the distribution of ratings for IL4 buildings in bar chart and pie chart format, including the buildings that have not been assessed.

It can be seen that almost two thirds (62%) of assessed IL4 buildings have ratings above 67%NBS, 21% are between 34% and 66%NBS and 16% are less than 34%NBS.

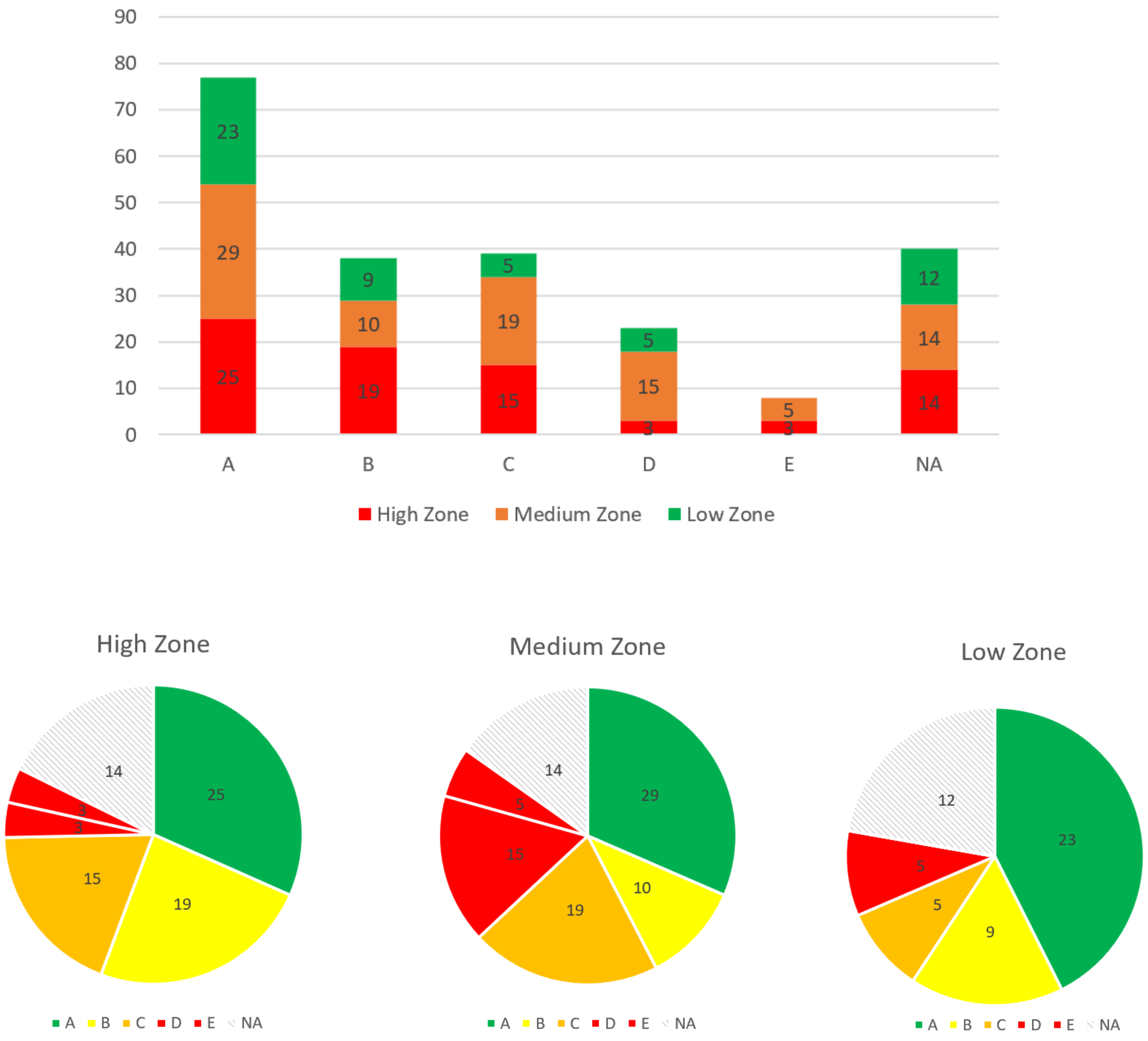

Figure 4.2: Seismic Ratings for IL4 Buildings

While there is a significant proportion of hospital buildings still to be assessed, it is considered that the distribution of ratings in Tables 4.2 and 4.4 can be taken as being a likely representation across the whole set of public hospital buildings, and the associated subset of IL4 buildings, respectively. This is based on the presumption that the remaining unassessed buildings are likely to be smaller and can be anticipated to be less seismically vulnerable buildings. Also, some of the currently listed buildings are being redeveloped at the Dunedin and Taranaki Base hospitals. This would suggest that the proportion of lower rating buildings is unlikely to increase above the level currently indicated.

The wider issue of the reliability of the current ratings is however explored further in the next sub-section.

4.3 Information Gaps and Inconsistencies

In addition to the buildings for which there appears to be no seismic assessment information, there are areas where the seismic assessments are not sufficiently robust or complete to enable a full understanding of the seismic vulnerability of firstly, the individual buildings, and secondly all buildings across the portfolio.

These areas relate to the reliability of the assessment information, inconsistency of Importance Levels used and lack of information on non-structural elements.

Reliability of information

Some of the seismic assessments held by DHBs are only qualitative ISAs, rather than the more comprehensive quantitative DSAs. Furthermore, some ISAs are as early as 2009 and only based on an IEP spreadsheet analysis without a comprehensive inspection and any supplementary calculations.

Also as noted in Section 3.2, few seismic assessments prior to the amendments to the earthquake prone buildings provisions of the Building Act and update of the national seismic assessment guidelines which took effect in July 2017 included heavy façade and internal non-structural elements. These elements often have lower scores due to the lack of strength and/ or inadequate movement allowance in their supporting connections, and this is leading to significant reductions in the overall ratings for some pre-1976 (and newer) buildings.

The presence of precast concrete floor systems is having a similar impact on the ratings buildings of more modern construction, many of which have not been subject to a seismic assessment or have only had an ISA.

Furthermore, some of the ratings supplied by the DHBs to the HIU don't have the corresponding dates of assessment and/ or form of assessment included.

Reflecting on the different levels of reliability associated with these different assessment types and eras, the following *reliability categories* are suggested for life safety ratings:

Table 4.4: Assessment Reliability Categories

Reliability Category	Reliability Expectation	Assessment Type and Date
REL1	High reliability	From post-July 2017 DSA
REL2	Reasonable reliability for primary structure	From post-July 2017 ISA/ pre-July 2017 DSA
REL3	Limited reliability	From pre-July 2017 ISA
REL4	Low reliability	From pre-2011 IEP
NI	None	No information

In addition, the following building categorisations are used to identify particular building typologies where revisitation is likely to be needed for various eras of previous assessment:

Typology A: 3 or more storeys pre-1976 (MBIE EPB Methodology Profile Category B). One particular area of focus is precast concrete cladding panels

Typology B: 2 or more storeys 1976 or later. Particular areas of focus are precast concrete floor systems and structural and cladding panels

Typology C: Other

This information is drawn together in Table 4.5 to indicate the likely need to revisit and refresh previous assessments or undertake new assessments.

A preliminary analysis of the data held by the HIU has highlighted significant gaps in information beyond the %NBS ratings. As indicated earlier, many buildings do not have either the dates of the assessment or the type of assessment indicated. This means that a full analysis that takes account of the reliability of the assessment information cannot be undertaken until the information from the DHBs is refreshed.

Table 4.5: Reliability of Seismic Assessment Information and Need to Revisit

Reliability Category	Assessment Type and Date	Reliability Expectation	Need to Revisit Previous Assessments
REL1	From post-July 2017 DSA	**High reliability**	Unlikely to need to revisit, unless the building contains precast flooring systems
REL2	From post-July 2017 ISA or pre-July 2017 DSA	**Reasonably reliable for primary structure**; but information on secondary structural and non-structural elements not necessarily included, unless specific calculations were undertaken	• Typology A - need to revisit for heavy partition walls/ ceiling or precast spandrel panels • Typology B - need to revisit for precast concrete floor systems and precast panel restraints • Typology C – probably adequate reliability
REL3	From pre-July 2017 ISA	**Limited reliability;** depending on typology and whether specific calculations were undertaken	ISAs won't have picked up either heavy elements or precast floor systems Prioritise Typology A and B for revisit (DSA likely)
REL4	From pre-2011 IEP	**Low reliability**	Prioritise Typology A and B for revisit (DSA likely)
NI	No information	NA	DSA likely to be required for most typologies

Lack of information on Non-structural Elements

As noted in earlier sections, the vulnerability of non-structural elements has only been systematically evaluated for a limited number of existing IL4 hospital buildings. This represents a significant gap in understanding the expected seismic performance of buildings that deliver critical functions on an everyday basis and are expected to continue to do so to an even greater extent following a major earthquake.

In order to effectively evaluate the ability of an existing hospital building to be able to *continue to function* following a significant earthquake, the likely performance of all non-structural elements needs to be evaluated.

Section 7 addresses this topic in further detail, and outlines a proposed triage approach that enables IL4 buildings with inadequate restraint of non-structural elements to be established relatively swiftly.

Lack of clarity on Importance Levels

Another area where the seismic assessments have a degree of inconsistency relates to the Importance Levels used for some buildings. Some buildings have been regarded as IL4 when IL3 would have been more appropriate, and vice versa.

Section 6.5 outlines a proposed interpretation of the current regulatory Importance Level definitions across the range of surgical and medical post-disaster functions, and for buildings with associated support functions. It is intended that the application of these IL category interpretations (once formally adopted by Health New Zealand) will enable more consistent outcomes for both design and assessment. They can be used as part of any revisitation of previous assessments for other reasons, or to enable the numerical adjustment of other assessments.

In summary, the HIU database of seismic assessment information compiled from the DHBs needs to be systematically updated to better inform investment decision-making.

Once the current database is further updated, a review of the reliability of the seismic ratings for IL4 buildings should be undertaken by the HIU, and a view formed as to which seismic assessments should be revisited, having due regard to building typology. This will result in a list of buildings that need to have full Detailed Seismic Assessments (including those not already assessed), and those for which a Targeted Seismic Assessment, focusing on particular features, will be sufficient.

A clear priority should be placed on having appropriate seismic assessments undertaken for those IL4 buildings that have not yet had any form of assessment.

5. Use of Seismic Information in Business Cases

5.1 Context

Business cases for the upgrades of individual hospital buildings or hospital campuses overall should draw upon appropriate *seismic information* as one of the key inputs. The focus of this information is on understanding the seismic vulnerability of existing hospital buildings and the likely consequences should earthquakes of varying levels occur in the regions of those hospitals. The cost implications of any seismic upgrades (including the impact of the work on other buildings and functions) also needs to be fully quantified.

There are essentially three aspects or stages associated with applying seismic information in the planning of hospital upgrades, summarised as follows:

1. Clear understanding of the current seismic status of key buildings, how they are likely to be affected by a significant earthquake, and the end date for any statutory requirement to strengthen or demolish the building
2. Establishing the scope of work involved in upgrading (or demolishing) buildings, including the impact of the physical work on day-to-day hospital operations
3. Having a clear view of the 'end state' of the completed structures, and their likely performance in a future major earthquake.

The wider context is conveying the consequence of key buildings not being functional following earthquake for firstly the hospital, and secondly the community. This underlines the importance of comprehensive Master Planning as the basis for establishing the scope and sequencing of mitigation work.

5.2 Basic Seismic Information Requirements

In overview, if seismic information is to be utilised for business cases, it should:

- Be based on a seismic assessment that reflects current national assessment guidance;
- Include the expected response of all elements that could adversely affect the ability of the building or buildings to operate;
- Include the potential impacts of and to adjacent and adjoining buildings; and
- Include the potential disruption to hospital functions

It is also important that the seismic information is interpreted appropriately from a risk perspective – that is to say, the potential physical and operational impacts are not either over-stated or under-stated.

Although the output focus of the seismic information relates to the response of the building, one of the key inputs is a good understanding of the likely performance of the ground and infrastructure in and around the building, and indeed across the whole site from appropriate geotechnical investigations.

Similarly, the extent to which tunnels, etc, for infrastructure essential for critical medical functions are separate from or integral with key buildings informs both the individual building perspective and the campus-wide perspective.

5.3 The Challenges in Implementing Strengthening in Operational Hospital Buildings

The impact of seismic strengthening activities on clinical services represents the biggest challenge in planning and undertaking strengthening work.

Seismic strengthening of primary structural elements typically involves highly intrusive work. The strengthening and/ or addition of concrete and steel elements involves breaking out of and drilling into concrete and welding of steel. New or additional foundations are also often required, with associated excavation. Usually it is not possible to have this work undertaken whilst highly sensitive hospital operating environments remain functioning.

While the upgrading or installation of seismic restraints can be a relatively straightforward process in office buildings, it is particularly complex in the hospital environment. Most of the key operational buildings have a plethora of services running in ceiling spaces and corridors. This typically requires the associated removal, relocation and replacement of equipment and fit-out items.

An additional challenge is posed by the presence of asbestos in older hospital buildings. In many situations where asbestos is known to be present, this effectively precludes internal strengthening.

Where hospitals have had buildability reviews of strengthening proposals undertaken by contractors, these have usually identified more operational impacts and challenges (and hence time and cost impact) than envisaged by the project teams. This raises questions around the practicality and viability of seismic strengthening in some situations.

There are corresponding challenges associated with the demolition of buildings within a functioning hospital campus.

To avoid these operational impacts requires the prior construction of alternative facilities (temporary or permanent), which in turn requires a robust and agreed master plan. This wider planning process would however be better informed by comprehensive seismic information on all affected buildings on the campus, as noted above.

This is an area which has received inconsistent treatment in the preparation of investment business cases, and requires more specific engagement with hospital operational personnel.

5.4 Recommended Elements of Seismic Information to Inform Business Cases

From the preceding sections, the following categories of seismic information elements that should inform upgrade business cases are suggested:

1. **Building context**
   - Interconnectedness and functional dependency
2. **Seismic status of current building**
   - Assessment information
     - Date of assessment (pre- or post- the 2017 legislation amendment and guidance update)
     - Basis of key parameters used, including Importance Level
   - Estimated impact of a major earthquake (ie. the problem statement)
3. **Strengthening objectives and impacts**
   - Investment objectives and outcomes of proposed upgrading
   - Scope and operational impacts of strengthening (or re-purposing or demolition)

Table 5.1 on the following page expands upon these information categories to indicate the various specific information elements within each.

Table 5.1: Information Categories and Elements for Business Cases

Information Category	Information Element
1. Building Context	
1.1 Interconnectedness and/ or functional dependency	Are key medical functions affected if there is no access to the building following an earthquake?
	Are other buildings and their functions directly impacted? (degree of physical interconnectedness)
	Extent to which the connections to infrastructure services have been taken into account.
2. Seismic Status of Current Building	
2.1 Assessment information	Current %NBS rating (life safety)
	If the rating is less than 34%NBS, has an earthquake prone building notice been issued? If so, what is the deadline for the completion of work?
	Summary of the vulnerability of non-structural elements • Life safety • Building functionality
2.2 Estimated impact of a major earthquake	Life safety risk
	Level of expected damage
	Likely *Building Functionality* status
	Impact on adjacent buildings/ functions
	Impact on hospital infrastructure/ underground services and services tunnels
3. Strengthening Objectives and Impacts	
3.1 Investment objectives and outcomes of proposed upgrading	%NBS (life safety)
	Building Functionality objectives
	Re-purpose to lower importance level
3.2 Scope and operational impacts of strengthening (or re-purposing or demolition)	Cost (to achieve different %NBS ratings)
	Time frames
	Operational disruption to building/ hospital (levels of service, alternative arrangements)

6. Applying Importance Level 4 Definitions to Hospital Buildings

6.1 Background to Importance Levels

The design of new buildings is based on an Importance Level category that depends on their intended use, and existing buildings have their seismic assessment rating derived from an IL based on the current use. The higher the IL the higher the seismic demand required, thereby providing increased protection for the most important buildings.

The underlying principle behind Importance Levels is the consequence of failure. Buildings are required to be designed for more extreme events where the failure would have higher consequences in terms of either the number of people directly physically affected or the community through loss of the functionality of the building. This results in higher load factors being applied for structural design purposes.

The consequence of failure consideration can also play out in terms of not requiring the higher categorisation if it can be shown that there would not be an overall loss of functionality to the community if the individual building was unusable. This situation would arise if for example there were equivalent facilities within the same town or city, and the loss of one would not affect the delivery of critical services to the community. This logic can be more readily applied to services that are provided via an integrated network with degrees of redundancy, such as lifeline utility networks, and is generally considered less applicable to major community response facilities such as hospitals where there can be a considerable distance to corresponding facilities.

Importance Levels appear in two separate places within the building regulatory system:

- For fire design purposes - in Building Code clause A3
- For structural design purposes - in the structural loadings standard AS/NZS1170 Part 0

Although fundamentally the same provisions, there is minor variation between the versions. The application of the provisions can also differ, and we understand that some Building Consent Authorities are interpreting ILs differently for fire than for structure. MBIE's 2015 Determination in relation to the importance levels used for the design of new facilities at Grey

Base Hospital[7] considered that the use of AS/NZS1170 for the purposes of Code clause B1 Structure to be distinct from the use of Clause A3 for Code clause C.

Table 6.1 provides descriptions of the different ILs for buildings with examples relevant to hospital campuses. A small storage shed would be IL1, an administration and office building would be IL2, a small hospital facility with less than 50 patients or a department not intended for post-disaster use would be IL3, and buildings for surgery or post-disaster medical emergency are designated as IL4.

Table 6.1: Building Importance Levels, from AS/NZS 1170.0

<table>
<tr><th>Importance Level</th><th>Consequences of failure</th><th>Description</th><th>Building Types</th><th>Examples</th><th>ULS Design multiplier R factor (refer Table 3.2)</th></tr>
<tr><td>IL1</td><td>Low</td><td>Low loss of life consequences, small or moderate economic or environmental</td><td>Minor structures</td><td>Very small isolated buildings less than 30 m^2 with low life safety hazard</td><td>0.5</td></tr>
<tr><td>IL2</td><td>Ordinary</td><td>Medium for loss of human life, or considerable economic, social or environmental</td><td>Normal structures</td><td>Administration buildings, car parks, residential houses</td><td>1.0</td></tr>
<tr><td>IL3</td><td rowspan="2">High</td><td rowspan="2">High consequence for loss of human life, or very great economic, social or environmental consequences</td><td>Major structures (affecting crowds)</td><td>Health care facilities with capacity of 50 or more resident patients but not having surgery or emergency treatment facilities
Emergency medical & other emergency facilities not designated as post-disaster</td><td>1.3</td></tr>
<tr><td>IL4</td><td>Structures with special post-disaster functions</td><td>Medical emergency or surgical facilities</td><td>1.8</td></tr>
</table>

It should be noted that while for consistency and convenience the same R-factor is used in NZS 1170.5 throughout the country as the ULS multiplier, the ratio of 2,500-year shaking to 500-year shaking in fact varies throughout the country. For example, the ratio in Dunedin (low seismic hazard) is larger than 1.8, whereas in Wellington (high seismic hazard) the true ratio is

[7] MBIE Determination 2015/059 *Regarding the building importance level of two proposed buildings at Grey Base Hospital at 146 High Street, Greymouth*

less than 1.8. More information on this (including more specific potential ratio changes) is likely to come out from the current update of the National Seismic Hazard Model.

The health-related IL provisions from Building Code clause A3 and AS/NZS1170 Part 0 for IL3 and IL4 buildings are shown in Table 6.2 following.

Table 6.2: Current Standard Importance Level 3 and 4 Provisions for Hospital Buildings

Importance Level	Category (‘Comment’)	Description (Building Code Clause A3)	Applicable Health Descriptors (AS/NZ1170.0 ‘Examples’)
IL3	Structures that as a whole may contain people in crowds or contexts of high value to the community or pose risks to people in crowds	*Buildings* of a higher level of societal benefit or importance, or with higher levels of risk-significant factors to *building* occupants. These *buildings* have increased performance requirements because they may house large numbers of people, vulnerable populations, or occupants with other risk factors, or fulfil a role of increased importance to the local community or to society in general.	Health care buildings with a capacity of 50 or more resident patients but not having surgery or emergency treatment services Emergency medical and other emergency facilities not designated as post-disaster
IL4	Structures with special post-disaster functions	*Buildings* that are essential to post-disaster recovery or associated with hazardous facilities.	Buildings and facilities with special post-disaster functions Medical emergency or surgical facilities Utilities or emergency supplies or installations required as backup for buildings and facilities of Importance Level 4 Buildings and facilities containing hazardous material capable of causing hazardous conditions that extend beyond the property boundaries Hospitals and other health care buildings having surgery or emergency treatment services *(Building Code Clause A3*)

As can be seen, ILs are described in only high-level terms. *Special post-disaster functions* is essentially only defined by examples, the listings of which are very brief, particularly with respect to health facilities. Furthermore, the key words highlighted in red such as *medical emergency*, *surgery*, and *emergency treatment services* are not defined. For example, *surgery* has a wider interpretation and application than just in the public hospital system.

The MBIE Determination for Grey Base Hospital considered that the examples in Table 3.2 of AS/NZS1170.0 should not be used in a strict and rigid manner without taking into account the intent and principles of the various ILs.

6.2 General Application of Importance Levels

ILs predominantly take effect as an input to the structural design process, with the corresponding provisions in Building Code clause A3 having a much narrower application through only one facet of fire design (spread of flame).

ILs for structural purposes are primarily used for the design of new buildings and in the seismic assessment of existing buildings. They are categorisations that the engineer selects in conjunction with the building owner. This requires detailed understanding of the use of the facility in post-disaster context as well as the day to day usage. Any building owner can always go beyond the minimum provisions of the Building Code and standards and self-select a higher category.

After the design or assessment work is completed, the building maintains that same IL categorisation. It is important to note that the IL is not a rating in itself, nor is it a designation. A change in the use of the building doesn't necessarily trigger a re-categorisation of the IL (or vice versa), as an engineering re-assessment is not always required. An owner can however re-categorise the IL of a building at any time, but this should ideally be linked to a structural design or assessment document.

For seismic risk purposes, the latest engineering assessment should always be used (but with a check of the appropriateness of the IL used).

A key provision in AS/NZS 1170 Part 0 is:

> *Structures that have multiple uses shall be assigned the highest importance level applicable for any of those uses. Where access to a structure is via a structure with a lower importance level, then the importance level of the access structure shall be designated the same as the structure itself.*

This means that the IL used for the overall building corresponds to the most critical function applying in the building. The only exception to this is where the section of the building that is required to be IL4 can be shown to not be physically affected by the behaviour of the other sections of the building under either serviceability or ultimate limit state loading. This is particularly important for large buildings, and also highlights the need to understand the extent to which sections of buildings may be structurally interconnected.

A related point is the need to understand the interdependency of critical services, particularly where these services are spread across a number of different buildings in a hospital campus.

6.3 Regulatory and Design Requirements for Importance Level 4 buildings

For the design of new IL 4 buildings, there are essentially two requirements that are to be met:

- Life Safety requirements – the primary structure and parts of the structure representing a hazard to human life inside and outside the building are designed to withstand a 1 in 2,500 year event without endangering the occupants (referred to within the engineering context as Ultimate Limit State, or ULS)
- Operational Continuity/ Building Functionality requirements – minimal damage to non-structural and structural elements, and hence the ability to establish or continue operations in a 1 in 500 year event (Serviceability Limit State 2, or SLS2)

SLS2 requirements for *Operational Continuity* are however only defined in general performance terms (‘*a fully operational state within an acceptably short time frame’*). Addressing this aspect for new buildings principally involves the specific design of seismic restraints of non-structural elements and the provision of seismic separation between elements where required in accordance with NZS1170 Part 5 Amendment 1, with a focus on:

- Heavy plant and equipment (including Lifts)
- Ceiling systems (suspended and fixed) and lighting and other overhead elements
- Partitions (especially around escape routes)
- Glazing elements (façade and internal)

The *Building Functionality* considerations beyond the structurally focused IL4 provisions are also not defined or codified for other design disciplines, including key aspects such as infrastructure services. The concept of ‘IL4’ is therefore interpreted and applied quite broadly as a proxy for resilience.

The Building Code establishes the minimum requirements in this area at a reasonably high level, noting that the post-disaster functionality requirements cannot practically be defined in detail to cover all critical facility situations. Agencies can however develop their own definitions, which may go beyond the minimum requirements of the Building Code.

For *existing buildings* whose post-disaster functionality requires them to also be categorised as IL4 structures, there are no specific regulatory requirements to be met – other than not being earthquake prone (ie. not less than 34%NBS) beyond the time frames defined in the Building Act. As with any building, IL3 and IL4 buildings rating less than 34%NBS can continue to be occupied. There is however the general expectation that the key buildings that deliver emergency medical services and surgical functions should be able to deliver those services following earthquakes generating up to 500 year return period shaking, unless hospital emergency plans state otherwise.

Part A of the Engineering Assessment Guidelines reflect this in its recommendation *that an IL4 building should either attain a 67%NBS (IL4) rating as a minimum and fully satisfy SLS2 requirements, or be re-designated*. There is no corresponding recommendation for IL3 buildings.

However, as established in Section 4, the current reality is that many critical operational hospital buildings are currently not capable of meeting these requirements – especially the operational continuity (SLS2) requirements – and so re-categorisation in itself will not necessarily address the situation. A clearer understanding of the post-earthquake implications of a building not meeting the SLS2 requirements nevertheless needs to be conveyed, including the fundamental requirement for suitable alternative arrangements to be established in the emergency response plans for the hospital.

Every building with a *special post-disaster function* (irrespective of their seismic rating) should have a nominated alternative facility (on or off-site). The planning process of exploring practical alternatives forms part of understanding the operational consequences of losing the use of the primary facility.

6.4 Interpreting Key Importance Level Definitions for Hospital Buildings

Interpreting the current IL definitions requires consideration of the meaning and application of firstly, the medical terms used in Building Code clause A3 and NZS1170.5, and secondly, the term *special post-disaster function*.

Medical Service Descriptors

Clarifying the hospital-related descriptors for Importance Levels 3 and 4 requires consideration of the pathway that patients traverse in a post-disaster situation. Utilising the key words in the current IL4 descriptors, this focuses on those requiring either *emergency medical* or *surgical* treatment, interventions and/or procedures. This includes clinical support services required to support care delivery.

Key health-specific definitions that support interpretation of the key terms used in the regulatory documents are suggested as follows:

Medical – treatment provided by medical specialty physicians

eg. Cardiology, Gastroenterology, Respiratory, Endocrine, etc.

Surgical – treatment provided by surgical specialty doctors

eg. General, Orthopaedic, Vascular, ENT, Ophthalmology, etc.

Acute – urgent, often lifesaving, medical or surgical treatment and/or intervention

Buildings with *Special Post-Disaster Functions*

The general intent of the enhanced requirements associated with IL4 provisions is to avoid the consequences of being unable to deliver key services or functions in response to a disaster.

This suggests a focus on emergency medical functions that are directly required by the circumstances of the event, as opposed to functions whose delivery would be made more difficult in the context of the event.

A strict interpretation of *special post-disaster [medical] functions* would therefore be to deal with the medical consequences of the disaster event – for example, dealing with the influx of serious physical injuries and medical trauma of those brought to the hospital (mass casualties comprising fractures, crush injuries, burns, inhalation of dust and harmful substances).

The requirement for a hospital to continue to deliver services to people *already in the hospital at the time of the disaster event* (in addition to the event-driven *special post-disaster functions)* can be regarded as more of a service continuity imperative that requires campus-wide resilience thinking and implementation across buildings, infrastructure and other operational aspects.

Part of this consideration relates to non-deferrable medical services and functions that cannot be readily displaced or relocated without endangering the health of patients, all at a time of very high surge demand. Inpatients with a range of medical conditions and mobility states will continue to need treatment prior to discharge or with no ability to be discharged.

The heightened difficulty of evacuating large numbers of mobility-impaired or service-dependent patients is another important consideration, and one that needs to be taken into account. The undesirability of having to relocate many of these people at a very challenging time if the ward buildings are damaged beyond a usable state strongly supports the ideal of having robust buildings to enable the delivery of these services to be maintained. This is however likely to require going beyond the scope of event-focused *special post-disaster* functions intended under the Building Code to ensure more appropriate campus-wide resilience.

In order to distinguish between meeting the minimum requirements of the Building Code for individual buildings and meeting the service delivery expectations of the wider hospital campus overall[8] (including site-wide infrastructure), the following definitions are proposed:

[8] As framed in the Civil Defence Emergency Management Act and National Health Emergency Plan.

- ***Special post-disaster function*** – for hospitals, having appropriate emergency medical and surgical facilities and arrangements to enable the treatment of casualties from the disaster event

- ***Post-disaster service continuity*** – the ability to continue to provide medical services to people already in the hospital at the time of the disaster event, which cannot practically be provided immediately elsewhere in the local community.

The associated key concept is that overall hospital disaster capability is a combination of:

i. the ability to provide emergency medical and surgical facilities to treat casualties from the disaster event (the *special post-disaster function*)

   and

ii. the ability to continue to provide medical services to people already in the hospital at the time of the disaster event (*post-disaster service continuity*)

This notional distinction is made only for the purpose of distinguishing between meeting the minimum requirements of the Building Code for individual buildings and wider hospital service continuity planning.

The following Table 6.3 expands upon this distinction between *special post-disaster function* and *post-disaster service continuity*.

With regard to Note 1, if the ability to transfer patients to other facilities is being depended on, there needs to be reasonable confidence that reliable transport arrangements can be made, and specific arrangements provided for in Health Emergency Plans.

Table 6.3: Distinguishing between special post-disaster functions and service continuity

	Overall Hospital Campus Post-Disaster Capability	
Objective	Meeting the event-driven demands for *emergency medical services* and *surgical facilities*	Continuing to provide medical services to people already in the hospital at the time of the disaster event
Operational Outcome	***Delivering special post-disaster functions***	***Maintaining post-disaster service continuity***
Scope for Initial Response	Dealing with casualties from the disaster event • focusing on the influx of serious physical injuries and medical trauma of those brought to the hospital (mass casualties comprising fractures, crush injuries, burns, inhalation of dust and harmful substances). • includes Maternity secondary delivery suites, due to the inability to transfer patients with event-generated emergency needs • excludes Renal care, as patients with crush injuries are likely to have other injuries requiring treatment in ICU	Sustaining hospital services required by current inpatients
Considerations	Takes account of • the ability to transport some patients to other centres for specialist services (Note 1) • the ability for Medical Assistance Teams to provide supplementary capacity and facilities for some functions (Note 2)	• May involve decanting people from inpatient wards if buildings are found to be damaged or infrastructure services are no longer available/ outside the ability of emergency backups to support (in addition to sending ambulatory outpatients home)
Additional Commentary	• Buildings housing these functions should be categorised for design and assessment purposes as Importance Level 4 structures • Note that IL4 categorisation does not in itself regulate the associated provision of backup infrastructure, etc	• Buildings housing medical functions outside those corresponding to IL4 would be regarded as IL3

Notes:

1. Including transfers to burns units; renal care (haemodialysis) units; neonatal intensive care units (NICU) and special care baby units (SCBU)
2. Domestic and international Medical Assistance Teams capable of arriving within 24 to 48 hours to operate mobile field hospital facilities with various levels of clinical equipment and daily patient capacities

6.5 Proposed Importance Level 4 Interpretation for Hospital Buildings

Drawing upon the definitions and concepts outlined above, it is proposed that buildings housing any of the following services or functions relating to *special post-disaster functions* should be categorised as IL4:

- **Key Clinical Areas** (including operating theatres, Emergency Department and Intensive Care Units, and associated ward capacity)
- **Critical Clinical Support Functions** (including radiology and laboratories)
- **Other Specialist Functions or Services**
- **Infrastructure and Supplies** (facilities providing services required for the above functions)

These have been added firstly as sub-categories into Table 6.4, and then expanded upon in Table 6.5. This listing is considered to be consistent with (and an elaboration of) the high-level definitions of IL4 currently within the Building Code and structural loadings standard in Table 6.1.

The entries in Table 6.4 reflect a generic expectation of the key post-disaster emergency medical or surgical services that a hospital would be expected to deliver in response to a disaster event. As indicated above, these may vary for some hospitals, depending on their specific emergency response plans.

It is acknowledged that medical models of care are evolving along with modes of delivery of the services, and that periodic re-evaluation of these categorisations is warranted.

Similarly, the extent to which *other health care buildings having surgery or emergency treatment services* (words from Building Code clause A3) either associated with a hospital campus or in the community would be expected to be utilised in a post-disaster situation will depend on both the hospital and regional Health Emergency Plans.

It is important to clarify that Tables 6.3 and 6.4 provide a re-interpretation of the current (but high-level) IL definitions – they are not re-definitions of the provisions in Building Code clause A3 and AS/NZS1170.0. It is however acknowledged that these additional interpretations could see some previous categorisations change, and this may affect some recently assessed and designed structures.

Table 6.4: Expanding on the Current Standard Importance Level Provisions for Hospital Buildings

Importance Level	Category ('Comment')	Description (Building Code Clause A3)	Applicable Health Descriptors (AS/NZ1170.0 'Examples')	Additional Hospital Interpretation
IL2	Normal structures and structures not in other importance levels	Buildings posing normal risk to human life or the environment, or a normal economic cost, should the building fail. These are typical residential, commercial and industrial buildings	Buildings not included in IL1, IL3 or IL4	Hospital buildings that contain: • Offices • Outpatient services
IL3	Structures that as a whole may contain people in crowds or contexts of high value to the community or pose risks to people in crowds	Buildings of a higher level of societal benefit or importance, or with higher levels of risk-significant factors to building occupants. These buildings have increased performance requirements because they may house large numbers of people, vulnerable populations, or occupants with other risk factors, or fulfil a role of increased importance to the local community or to society in general.	Health care buildings with a capacity of 50 or more resident patients but not having surgery or emergency treatment services Emergency medical and other emergency facilities not designated as post-disaster	Hospital buildings that contain other medical facilities, including inpatient wards
IL4	Structures with special post-disaster functions	Buildings that are essential to post-disaster recovery or associated with hazardous facilities.	Buildings and facilities with special post-disaster functions Medical emergency or surgical facilities Utilities or emergency supplies or installations required as backup for buildings and facilities of Importance Level 4 Buildings and facilities containing hazardous material capable of causing hazardous conditions that extend beyond the property boundaries Hospitals and other health care buildings having surgery or emergency treatment services (Building Code Clause A3)	Hospital buildings that contain: • *Key Clinical Operational Areas* and associated ward capacity (including operating theatres, Emergency Department and Intensive Care Units) • *Critical Clinical Support Functions* (including radiology and laboratories) • *Other Specialist Functions or Services* • *Infrastructure and Supplies* (facilities providing services used in the above functions)

Table 6.5: Expanded Categorisation of Importance Level 4 Buildings in Hospitals

Sub-category	Service or Function	Scope/ Comments
Key Clinical Operational Areas	Emergency Department	Including triage
	Operating Theatres	Surgical interventions
	Intensive Care Unit	Medical/ surgical
Critical Clinical Support Functions	Radiology	Medical imaging - X-ray, CT, MRI
	Pathology (Laboratories)	Biochemistry, haematology, blood bank and cross-match
	Sterilisation	CSSD (central sterilising services unit), or SSU (sterile services unit)
	Wards providing capacity to support post-disaster clinical operational facilities	Incl. capacity for positive and negative pressure environments, ventilators
Other Specialist Functions or Services	Maternity and neonatal - delivery suite birthing rooms (excludes primary)	Note the required linkages to adult ICU and/ or NICU (neonatal intensive care units (tertiary)) Also SCBU (special care babies' units) - likely to be in regional hospitals – with complex cases transferred out to a NICU
	Burns units	Middlemore, Waikato, Hutt and Burwood
	Paediatrics	High end paediatric specialist services provided at Starship (Auckland City Hospital campus)
	Spinal	Two units in the country at Middlemore (Otara) and Burwood
Infrastructure and Supplies	Water, wastewater, power, data and voice communications	Focus on central plant (boiler room/ energy centre) and reticulated (trunk) services (incl. fire sprinklers)
	Medical gases and steam	
	Heating, ventilation and air conditioning (HVAC)	
	Clinical supplies	Including Pharmacy (storage, not dispensing)
	Solid waste disposal	

As noted earlier, the requirements for infrastructure supporting IL4 buildings, and the associated post-disaster backup capabilities, are not currently defined in a standard or guidance. Concepts such as operating in 'island mode for X days' are often referred to. This is an area where further work and guidance is warranted in order to firstly, understand the additional building space that should be provided, and secondly, establish baseline service continuity requirements.

Table 6.4 indicates that IL3 facilities are defined somewhat by default – *Hospital buildings that contain other medical facilities* - that is, buildings that are not IL4 but sit above 'ordinary' buildings at IL2. That broad approach seems reasonable, given the preceding clarification of the definition of IL4 buildings for hospital facilities. Consideration should however be given as to whether further definition of IL3 buildings is warranted – that is, expanding upon *Emergency medical and other emergency facilities not designated as post-disaster*.

It is however important to note that from an engineering perspective, the difference in the design of new IL3 buildings will not necessarily differ greatly from the design of new IL4 buildings when the principles of *Low Damage Seismic Design* are applied. These principles typically require the building to be designed to have movement minimised in an intermediate level of loading. For IL3 structures, which are designed for 1,000 year return periods for life safety, an intermediate level of loading (ie. SLS2) could be for example 250 year return period earthquake shaking. This is only 25% less than the SLS2 earthquake loading required for IL4 structures.

This points to the broader need to define the performance requirements and corresponding engineering design criteria for both IL3 and IL4 buildings in hospitals, as noted earlier in Section 4. This aspect is commented on further in Section 10.

In summary, in determining whether a building should be categorised as IL3 or IL4 in accordance with the requirements of the Building Code, it is possible to distinguish between medical services that correspond to *special post-disaster functions* and those that relate to *post-disaster service continuity*. New and larger hospital blocks are tending to incorporate all acute services and support functions in the one building. However in certain parts of existing hospitals, it will not be possible to draw this distinction. Ward blocks are one such example – determining which parts are and aren't required to support emergency operations is unlikely to be practical. For medical services where there will be some direct event-driven need, the ability to transfer those patients to other specialist facilities at other regional or metropolitan hospitals also needs to be taken into account.

However the wider considerations of achieving more appropriate levels of hospital campus resilience would suggest that adopting ILs beyond code minimum requirements is more appropriate, particularly for new hospital buildings. Another important consideration is providing for future flexibility, and not wanting to limit the ability to convert part of a new IL3-designed building into operational facilities as a hospital changes its modes of operations in the future.

7. Evaluating Non-structural Elements

7.1 The Scope of Non-structural Elements

Non-structural elements can be broadly considered under the following categories:

1. Heavy elements, whose complete dislodgement or overturning can create a significant life safety hazard
   - eg. masonry partition walls, overhead elements, plant or specialist equipment, storage containers;
2. Elements whose movement and damage renders an area (or the whole building) unusable
   - eg. lifts, ceiling systems and light fittings; overtopping of water storage tanks, sprinkler pipe runs
3. Elements where movement can impact on the delivery of critical services, rendering an area (or whole building) unusable
   - eg. separation of partition walls affecting egress and positive and negative pressure compartmentation; fracture of oxygen and steam lines; pendant light fittings in operating theatres

As noted in Section 3, the amendments to the earthquake prone buildings provisions of the Building Act, the EPB methodology and the Engineering Assessment Guidelines in 2017 now require seismic assessments to include the evaluation of heavy non-structural elements (Category 1 above). These requirements however only address the heavier parts of buildings that could pose a significant life safety hazard – typically those weighing 25kg or 25kg/m^2.

There is however no universally established method in New Zealand for assessing the typically lighter non-structural components from Categories 2 and 3 above, whose movement or dislodgement could render a building unusable. This is particularly the case for hospitals with complex fitouts, where damage to some elements can occur in some cases under even moderate levels of earthquake shaking where they have not had engineering oversight during their installation.

These Category 2 and 3 non-structural components are common throughout hospital buildings and often form part of wider systems, in contrast to the heavier items from the first category that are typically in more discrete locations. It is therefore suggested that they be referred to as non-structural ***systems***, being a subset of the wider set of non-structural elements. This terminology also provides for a better linkage to and integration with campus-wide infrastructure (refer Section 7.7).

In addition, there are heavy medical equipment items such as scanners and radiology units that need to be considered from the perspectives of both life safety and continued functionality. As building ‘contents’, medical equipment is not usually included within engineering assessments. Furthermore, equipment of this type has the added complication of internal componentry that is sensitive to shaking. Large pendant light fittings in operating theatres are another example of building contents whose failure would give rise to both life safety and continued functionality concerns.

Similarly, other building contents such as furniture and shelving are generally not assessed by engineers but should be considered as part of business continuity and health and safety planning.

A visual representation of these items and their suggested inter-relationship is shown in Figure 7.1 below.

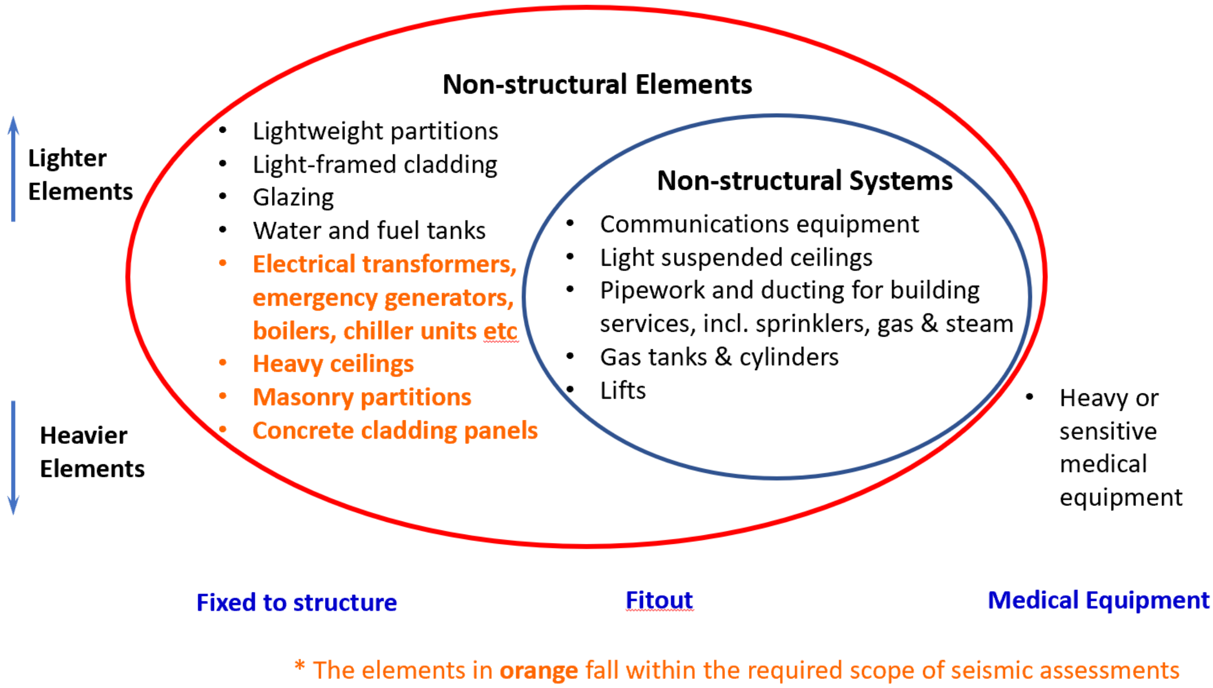

Figure 7.1: The Anatomy of Non-structural Elements in Hospital Buildings

For new IL4 hospital buildings, these elements and their restraints are all required to be designed to withstand 500 year shaking without causing loss of building functionality (the SLS2 requirement). As noted in the previous section, it is recommended that a similar requirement beyond minimum building code requirements be developed for IL3 hospital buildings, as is the case currently for school buildings.

In order to effectively evaluate the ability of an existing hospital building to be able to *continue to function* following a significant earthquake, the likely performance of all non-structural elements and key medical equipment should ideally be evaluated.

7.2 Previous NZ Health Sector Approaches

Where assessments of non-structural elements have been undertaken, these have typically focused on compliance with NZS4219:2009 *Seismic Performance of Engineering Systems in Buildings*[9]. However certain elements such as fire sprinkler pipework, lifts and suspended ceilings are excluded from the scope of this standard, which is general in nature in terms of the buildings to which it applies. There are also many challenges associated with establishing compliance of existing installations with a standard, and this point is discussed further later in this section.

Some seismic assessments have also ascribed %NBS ratings for secondary structural and non-structural elements under SLS2 (500 year return period) loading. The basis for this calculation is unclear, noting also that typically it only pertains to a small proportion of non-structural elements in the buildings.

In 2019, as part of their work developing framework for rating the seismic resilience of hospital buildings for the National Asset Management Plan[10], Beca included a component for Operational Continuity. This framework drew upon structural seismic assessments, and in the absence of any information about the non-structural elements was only able to broadly separate newer IL4 buildings where attention had been paid to low damage in the design (eg. the use of base isolation and the likely restraint of non-structural elements) from other buildings.

This index-based framework anticipated the future development of an assessment methodology to consider non-structural continuity aspects, and a system for rating them relative to the standard required for a fully compliant new IL4 building.

7.3 Relevant Overseas Approaches

California has had various programmes to reduce seismic risk following earthquakes in 1971 (San Fernando) and 1994 (Northridge) that caused significant damage to hospital facilities. Specific legislation aimed at protecting acute care patients and enabling the provision of post-earthquake medical care was created in 1972, and has been influencing seismic risk reduction across California's public and private hospitals since. An area of focus has been on non-structural elements.

[9] Standards New Zealand NZS4219:2009 *Seismic Performance of Engineering Systems in Buildings*

[10] NAMP Methodology for Rating Seismic Resilience *Beca September 2019*

The Office of Statewide Health Planning and Development (OSHPD) (now Department of Health Care Access and Information, HCAI) was established in the 1970s for the State of California. Senate Bill 1953, established a 2008 deadline (subsequently relaxed) for ensuring the life safety of acute care facilities during seismic events, as well as a 2030 deadline for retrofitting to a level that would enable them to be fully operational following an earthquake. Structural Performance Categories and Non-structural Performance Categories for state and private hospitals were defined on a 1 to 5 basis, and are publicly reported on each year.

ASCE 41

The principal document used as the basis by engineers in the US for seismic assessments is the American Society of Civil Engineers document ASCE 41 – *Seismic Evaluation and Retrofit of Existing Buildings*. This defines a sophisticated tiered process for assessing the likely performance of both structural systems and non-structural elements of any building, enabling both qualitative and quantitative approaches.

ASCE 41 defines performance levels for non-structural elements as follows:

- A Operational
- B Position Retention
- C Life Safety
- D Hazards Reduced

Position Retention is defined as *may or may not be damaged to the extent that they are not able to immediately function, but are secured in place so that damage caused by falling, toppling or breaking of utility connections is avoided.* This performance level is required to be achieved in order for a facility to meet the *Immediate Occupancy* criteria.

Assessments are required to report the status as *Compliant*, *Non-compliant*, *Not Applicable* or *Unknown*.

FEMA E-74

The US FEMA document E-74 *Reducing the Risks of Non-structural Earthquake Damage – A Practical Guide*[11] (January 2011) provides guidance for assessing non-structural elements in buildings. This guidance is aimed at a non-engineering audience (eg. facilities managers), and is not specific to hospital facilities.

[11] FEMA E-74 *Reducing the Risks of Non-structural Earthquake Damage – A Practical Guide* January 2011

The FEMA document structures the assessment of non-structural elements under the following areas:

- **Life safety**
- **Functional loss** (focusing on the seismic restraint of building services, etc)
- **Property loss** (focusing on equipment)

FEMA E-74 contains comprehensive standard inventory and risk assessment checklists and tables, and these provide a good base for this work. However it also takes a compliance approach, requiring the assessing person (be they engineer or facilities manager) to rate each element/ aspect as *Complying*, *Non-complying* or *Not Applicable*. The use of compliance language is considered unhelpful in the context of seismic assessment of existing buildings generally, and particularly for non-structural elements, as it implies an absolute statement or a Yes/No outcome.

This latter challenge is best illustrated in relation to assessing the effectiveness of the anchorages of existing seismic restraints. Evaluating the adequacy and effectiveness of the anchor bolts cast or drilled into concrete primary structure and masonry walls, etc is highly problematic. The seismic loads required for new (fully compliant) fixings to resist have increased significantly in recent years, and the corresponding allowable capacities for drilled-in anchors have reduced to cover worst-case situations for design purposes. Very few existing anchorages are likely to achieve full compliance with the standards set for the design of new anchors to meet the Building Code.

Establishing compliance of seismic restraints and associated fixings therefore represents a high bar, and is extremely difficult to ascertain from what is generally perceived as needing to be a reasonably rapid qualitative assessment.

Other adjustments to the characterisation of impacts and language used in FEMA E-74 that would be required for use in a New Zealand context include:

- The *Life Safety* category focuses on egress pathways, whereas clearly life safety issues can arise in any parts of the buildings from heavy elements.
- The distinction between *Functional Loss* and *Property Loss* is not necessarily appropriate, as all the impacts highlighted under Property Loss would clearly lead to a Functional Loss situation.

7.4 The Nature of Damage to Non-structural Elements in Previous Earthquakes

Reports and analysis of damage to non-structural elements from previous earthquakes provide some insights into which components have the greatest vulnerability to damage, and hence impact on hospital operations.

An analysis of hospital damage reports from the Loma Prieta earthquake that affected the San Francisco Bay Area in 1989 highlighted that certain hospital components exhibited a high incidence of damage[12]. These included:

- Emergency generators
- Elevators
- Communications systems
- Bulk oxygen tanks
- Furniture, fixtures and supplies

An analysis of the impact of the 2010 Chilean earthquake on the functions of the public hospital system in the Bío-Bío Province in the Maule, Chile earthquake of February 2010[13] also highlighted the nature of damage to non-structural elements when significant structural damage hasn't occurred.

While only one of the seven hospitals in the affected region sustained structural damage, most suffered non-structural damage, and damage to utility services. Most hospitals reported damage to their suspended ceilings, cracking of the plaster over brick walls, and partition damage. The collapse of ceilings and associated light fixtures and mechanical grilles discomfited occupants and caused unsanitary conditions that led to many evacuations. A few hospitals also had moderate water damage from pipe failures. Most buildings that required evacuation also lost use of elevators due to either a lack of power or failure of the counterweight rails.

A further interesting observation is that no evidence was observed of structural damage in any of the one-storey hospitals of the Bío-Bío province built after the 1960 earthquake.

Damage to Christchurch Hospital buildings in the February 2011 earthquake has also been well-recorded. A paper by McIntosh et al[14] noted that the effects of damage to non-structural building components and equipment and wider lifeline utility and supply chain disruption were far more disruptive to the functioning of the hospital than the generally minor structural damage observed to the buildings. The non-structural damage included the failure of many components such as windows, non-load bearing ceilings, partition walls, floor coverings, medical equipment and other building contents.

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[12] William T Holmes *The Background and History of the Seismic Hospital Program in California* Proceedings of Workshop on Seismic Design and Retrofitting of Hospitals in Seismic Areas, Florence, Italy, 1999

[13] Judith Mitrani-Reiser et al *A Functional Loss Assessment of a Hospital System in the Bío-Bío Province* EERI Earthquake Spectra, Volume 28, June 2012

[14] J.K. McIntosh et al *The Impact of the 22nd February 2011 Earthquake on Christchurch Hospital,* NZSEE Conference 2012

This paper observed that the failures of suspended ceilings, particularly the heavier plaster tiles with inadequate bracing, proved to be one of the most disruptive non-structural failures at Christchurch Hospital. These tiles are also life safety hazards, hence the subsequent requirement for them to be included in seismic assessments. Many light fittings in these locations became dislodged and had to be replaced alongside ceiling tiles. The majority of pumps and chiller units in rooftop plantrooms jumped off their mounts due to the strong shaking, even though their restraints were understood to have been specifically designed.

The most functionally significant non-structural damage was to roof-top water tanks and roof coverings in one building. The consequent ingress of water into the top two floors of the building caused the immediate evacuation of five medical wards. The associated unavailability of the lifts due to the activation of the seismic switches and failure of the stairwell emergency lighting made this evacuation operation very challenging.

Each of these observations needs to be calibrated against the level of earthquake shaking that the hospital buildings received. They do however send a signal as to which elements have the potential to cause greater problems in moderate to significant levels of earthquake shaking, and hence where priority of effort should be placed in evaluating the effectiveness of seismic restraint and movement allowance for non-structural components in hospital buildings.

Emphasis should be placed on heavier elements such as key plant (especially emergency generators), bulk gas storage tanks, water storage tanks, heavy suspended ceiling systems and lifts. While other non-structural components such as lighter ceilings and lights, partitions and pipe runs also have the potential to disrupt hospital functions, in some situations it may be appropriate to evaluate the adequacy of their restraints etc in a second phase after the more vulnerable items are inspected.

7.5 Proposed Approach for Hospital Buildings

As has been noted earlier, there is currently a general lack of information on the seismic vulnerability of non-structural elements within hospital buildings in New Zealand. However, it is necessary to balance the time and resources required to obtain better information about this vulnerability against the need to progress the seismic mitigation of buildings where issues with primary structural systems have already been established.

A higher-level screening of non-structural elements which is based on a qualitative evaluation that avoids using a compliance approach is considered as being the best approach to gather ‘big picture’ information as rapidly and efficiently as possible. Furthermore, the initial emphasis for gathering this information should be placed on buildings with favourable %NBS ratings, as these buildings are currently less likely to have seismic strengthening undertaken – and they may erroneously be considered to represent a low seismic risk.

Taking these considerations into account, it is proposed that a triage-based approach is adopted where the vulnerability of non-structural elements are evaluated under each of the three areas of ***Element restraint***, ***Element movement capacity*** and ***Internal capability*** *of specialised equipment*.

For each of these areas it is proposed that the vulnerability of elements in hospital buildings be categorised in relation to the likelihood of the building to be able to continue to function, *building functionality*, following earthquake shaking as follows:

CF_{likely} : ***Likely to enable continued functionality in major earthquake shaking***

This would correspond to the reasonable expectation of satisfactory performance of the element in a 500-year level of shaking (indicative rather than absolute), noting also the implied duration of strong shaking.

Note: 500-year shaking is the level of earthquake loading used for SLS2 in the design of new IL4 buildings.

$CF_{uncertain}$: ***Likely to enable continued functionality in minor earthquake shaking*** (ie.earthquakes having a greater frequency of occurring) but unlikely to be adequate in *major* earthquake shaking.

For assessment purposes, the minor earthquake would be indicative of around 100-year level of shaking.

$CF_{unlikely}$: ***Unlikely to enable continued functionality in minor earthquake shaking***

NI : ***No information*** – generally the current situation for most buildings, or

NA : ***Not assessed***

The overall focus of the ratings is on the impact on the *continued functionality of the building* – ie having due regard to the critical medical services delivered within the building. In many cases, movement and/ or failure of the component or service will directly impact on the functionality of the building – but not always.

The vulnerabilities of non-structural systems and elements that could affect the functionality of the buildings can be evaluated under the headings of ***Element restraint*** and ***Element movement capacity***.

The outcomes by element can expressed under each of the above categories together with a rating assessment in accordance with Table 7.1 following. The corresponding CF rating (CF_{likely}, $CF_{uncertain}$ or $CF_{unlikely}$) is then assigned based on the lowest of the three ratings, as appropriate.

Table 7.1: Vulnerability Ratings by Element Type

A. Element restraint

Rating	Category	Description
1	CF_{likely}	Appears well restrained, likely to enable continued functionality in major (~ 500 year) earthquake shaking
2	$CF_{uncertain}$	Some restraint (partial) but unlikely to be adequate in major earthquake shaking but likely to enable continued functionality in minor (~ 100 year) earthquake shaking
3	$CF_{unlikely}$	No restraint apparent, unlikely to enable continued functionality in minor earthquake shaking
NI	NI	No information currently available

B. Element movement capacity

Rating	Category	Description
1	CF_{likely}	Adequate movement available or not an issue, likely to enable continued functionality in major (~ 500 year) earthquake shaking
2	$CF_{uncertain}$	Some movement available but unlikely to be adequate in major earthquake shaking but likely to enable continued functionality in minor (~ 100 year) earthquake shaking
3	$CF_{unlikely}$	No ability to move apparent, unlikely to enable continued functionality in minor (~ 100 year) earthquake shaking
NI	NI	No information currently available

C. Internal capability of adequately restrained equipment to withstand shaking *(applies to specialised equipment)*

Rating	Category	Description
1	CF_{likely}	Equipment has seismic qualification (or is considered 'rugged' and qualification therefore unnecessary), likely to provide continued functionality in major (~ 500 year) earthquake shaking
2	$CF_{uncertain}$	Uncertain
3	$CF_{unlikely}$	Inadequate
NI	NI	No information currently available

Undertaking assessments of non-structural elements

The recommended process for assessing non-structural elements is outlined in Section 7.6 and a template is provided in Appendix B. Assessors need to have suitable expertise and experience in order to know what to look for. An engineer who is not familiar with restraint design may note some restraint and assess that the item is suitably restrained, when it is in fact unlikely or uncertain to provide continued functionality. As examples, tek-screws or rivets holding a restraining bracket to a wall of a duct may have minimal tensile capacity, and insufficient concrete edge distances for anchor connections will not provide reliable restraint.

The consequences associated with elements not being adequately restrained or having adequate movement capacity needs to be taken into account. For example, having heavier pipework laterally restrained but not the cable trays is far better than the reverse situation.

It is also important to consider the effects of the relative movement at building junctions on service pipes that can cross these junctions. It is clear that base-isolated buildings are likely to sustain significantly less non-structural damage. However, checking movement capability across the isolation plane is necessary, as this has not always been adequately provided.

The assessing engineer needs to undertake the evaluation in close association with hospital facilities management personnel in order to appreciate the consequences of poor local performance of services.

Seismic qualification of equipment – internal capability

For *specialised equipment,* the ***Internal capability*** should be considered. Evaluation of the external restraint of this equipment is however the first step. When assessing equipment, check whether it has a seismic qualification. If not readily available, an internet search may assist. The website of the California Department of Health Care Access and Information (HCAI), formerly OSHPD, is a good place to start - refer: https://hcai.ca.gov/construction-finance/preapproval-programs/oshpd-special-seismic-certification-preapproval-osp/.

This will apply particularly to specialist medical equipment. The engineer will need to have regard to the stiffness of the structure and likely accelerations, checking whether OSHPD certifies the equipment to this level of shaking.

Some items will not require qualification as they are considered ‘rugged’. Details about the rugged equipment and components listed by OSHPD include such things as: valves (not in cast iron housings, except for ductile cast iron); pneumatic operators; hydraulic operators; motors and motor operators; horizontal and vertical pumps (including vacuum pumps); air compressors; sterilisers; blanket warmers; anaesthesia power columns, ceiling or wall mounted; refrigerators and freezers; microwave ovens for patient service; film illuminators; lift cabs; underground tanks.

7.6 Process for Categorising Element Functionality of Non-structural Systems Within Buildings

The following steps represent a methodology to categorise *element functionality*:

Likelihood of earthquake

i. Consider first the likelihood of an earthquake occurring at the hospital site by progressively analysing all buildings in High Seismic Risk Areas, then buildings in Medium Seismic Risk Areas, followed by those in Low Seismic Risk Areas, noting the discussion of risk exposure and population consequences in Section 8.

Continued functionality vulnerability of non-structural systems within buildings

ii. Build the inventory of non-structural components within IL4 hospital buildings. The table in Appendix B provides a template for the different non-structural systems that are likely to be present.

iii. Determine the locations in the building where the failure of that element would affect critical hospital operations. Hospital operational staff/facilities management personnel need to be engaged to assist in undertaking this exercise as they will have the expertise to understand what services are particularly important to maintain the hospital in a functional state, particularly in a post-earthquake environment. Priority should be given to elements where secondary effects of failure are serious, such as release of water or hazardous materials such as toxins or chemicals. The Assessment Template in Appendix B provides a column to indicate critical elements.

    Judgement will be required, as some non-structural systems may not seem critical to continuing functionality. However significant cracking of partitions or localised failure of suspended ceilings may result in the perception of the building being unsafe and therefore requiring engineering inspection before re-occupation, which may take some time. Additionally, cracking or distortion of partitions and door and other services penetrations can be an issue for positive and negative pressure patient care.

iv. Prioritise locations within the IL4 building that will be essential for the building continuing to function: main lobbies, operating theatres, and means of escape pathways

v. List the infrastructure systems essential to support critical functions. This will include essential infrastructure services (power, water, etc) located within the building, often above suspended ceilings.

vi. Qualitatively assess the type of elements and systems essential to continued functionality of the building, depending on its function(s) (eg. emergency, operating theatre, intensive care, mental health services, in-patient, administration, infrastructure services) for restraint, movement capacity and internal capability as appropriate (note the section on seismic qualification of equipment on the previous page).

vii. Assign element ratings on ***restraint***, ***movement capacity*** and ***internal capability*** to withstand shaking. Use ratings of CF_{likely}, $CF_{uncertain}$, $CF_{unlikely}$, and then assign the CF rating corresponding to the lowest of the three ratings, as appropriate. Where there is no information assign NI, or if the element is not assessed, enter NA.

The networked distribution of critical infrastructure services should be addressed separately as they will require assessment from the source to the building (refer Section 7.7).

viii. Reconsider the consequences to building functionality of any poorly rated non-structural elements or systems in liaison with hospital facility management personnel.

ix. List and assign ratings to all critical infrastructure services within the building (beyond the point of entry and separate to campus-wide reticulation lines).

Overall building functionality rating

x. The worst rating for these critical non-structural systems in priority locations across each building will become the overall *building functionality* rating, as the failure of any of these will prevent the building from continuing to function.

The recording of non-structural element vulnerability in the inventory should also make reference to the likely degree of difficulty of undertaking the relevant mitigation measure(s) for those elements – ie. ***relatively straightforward***, ***complex*** or ***impossible without relocating or re-installing the element***.

The approach outlined above is considered to provide a balance between the desirability of having a comprehensive understanding of the vulnerability of non-structural elements in each IL4 hospital building and the need to ascertain information in a highly complex operating environment in the most efficient way possible across a national portfolio of buildings. It may therefore not be suitable as a general approach for individually-owned buildings where it is both practical and desirable to have a finer-grained assessment that is more closely aligned with the SLS2 design requirements for new buildings.

It is recommended that the technical aspects of this proposed approach be discussed further as part of the development of national technical guidance (refer Section 10).

7.7 Assessing the Vulnerability of Campus-wide Infrastructure

The distribution networks of essential infrastructure services such as power, water and gas supply, fire protection systems, medical gas and steam supply and heating and air conditioning run throughout the hospital campus. These run between and beneath buildings, often via tunnels and basement undercroft spaces. In order to capture the overall network vulnerability, the evaluation of restraint and movement capacity of these distribution systems across the hospital campus needs to be carried out as a separate process by close inspection from source (eg. boiler room/ energy centre) to the point of entry into the furthest building, rather than inspecting them building by building and risking sections being overlooked.

This campus-wide evaluation should follow the approach outlined earlier in this section for building *functionality*, with the results being summarised in a similar way.

Where the reticulation lines run beneath buildings, the *life safety* ratings should reflect those of the building from this section; where housed in tunnels, the life safety ratings should be separately assessed.

For tunnels close to or below the water table and/ or in areas of potentially liquefiable ground, the criticality and adequacy of waterproofing of junctions and penetrations should be specifically evaluated.

As part of ensuring the hospital has a good understanding of the vulnerability of external infrastructure supply feeds, there should be engagement with local water, power and gas suppliers about the vulnerabilities of their networks, particularly in the proximity of the hospital. These conversations could be held on a one-to-one basis with utility suppliers or could be facilitated by the regional Lifeline Utility Groups. Understanding the nature and extent of external infrastructure outages provides one of the points of linkage with the hospital's business continuity and emergency response plans.

8. A Framework for the Categorisation and Prioritisation of Seismic Risk

8.1 Framework Objective and Scope

As part of this project, a framework was developed to enable the HIU to categorise the seismic risk of hospital buildings and prioritise seismic strengthening (or re-purposing or decommissioning).

This framework sets out a basis for categorising current seismic information held by District Health Boards.

The work undertaken by the Canterbury DHB following the Canterbury Earthquakes in developing a prioritisation framework for their building investment programme is also acknowledged. This work looked at resilience from a wider perspective than conventional seismic assessment ratings, including functional performance (building criticality)[15]. This process also regarded retrofit as just one part of the risk management process, and that accepting the risk (the 'do nothing' option) was a valid short-term option. This work has provided useful insights into the framework that we have proposed for the Ministry. A key point of difference in context between the Canterbury DHB and other regions is that in triaging investment across their sites, the Canterbury DHB framework was able to draw upon a reasonably comprehensive and consistent set of post-earthquake damage and seismic assessment information.

A basis for prioritising future actions is also proposed, with recommended priorities for firstly, risk mitigation and secondly, obtaining further seismic information where required before decisions can be made on mitigation prioritisation.

The framework:

- Draws upon the identified seismic vulnerabilities of hospital buildings, and reflects general performance expectations from both *life safety* and *building functionality* perspectives; and
- Is consistent with other risk and asset management considerations in relation to hospital buildings

[15] Resilient Organisations *Canterbury District Health Board Earthquake Buildings Programme of Works Prioritisation Framework* August 2017

The framework does not explicitly include consideration of:

- The seismic restraint of general contents (furniture, smaller equipment)
- Land or other external hazards affecting building use
- Health and safety obligations under the Health & Safety at Work Act

Meeting the requirements of the earthquake-prone buildings provisions of the Building Act as summarised in Section 3.1 underpins the prioritisation framework.

8.2 Functional Considerations

In developing a framework for categorising the seismic risk of existing buildings, the general objective is to be able to characterise the relative vulnerability and resilience with respect to an equivalent new structure.

This characterisation can be expressed in terms of the continuum from *high vulnerability/ low resilience* to *low vulnerability/ high resilience.* Where a building sits on this continuum should take into account both *life safety* and *building functionality* aspects.

Life safety is broadly characterised by seismic ratings. However as indicated in previous sections, there is no established metric for *building functionality*. The concept of post-earthquake functionality can however assist in broadly characterising the operational impacts of a significant earthquake. The following three *building functionality states* can be articulated:

- **Functional** – *no damage or minor damage that doesn't affect operations*
- **Functional within 24 hours** - *damage requires engineering assessment and/ or clean up or minor repairs*
- **Not Functional for more than 24 hours -** *damage or other impacts require engineering assessment and/or repairs that will take a period of time*

These functionality states are shown indicatively in Figure 8.1, overlaid on the Resilience/ Vulnerability continuum.

This figure also reflects the uncertainty associated with assessment and design, which is important to represent when 500-year categorisations are a composite of several components. This representation conveys that even a new fully complying IL4 structure might not be able to be used for critical functions immediately following 500-year earthquake shaking for various unforeseen reasons. Conversely, even a building assessed as being highly vulnerable may receive only minor damage in a significant earthquake, and would therefore be functional. It also reflects that seismic assessments of existing buildings endeavour to portray the *probable* or *expected* outcome in an earthquake, and they should represent neither an upper or lower bound scenario. This is important to bear in mind with respect to non-structural components.

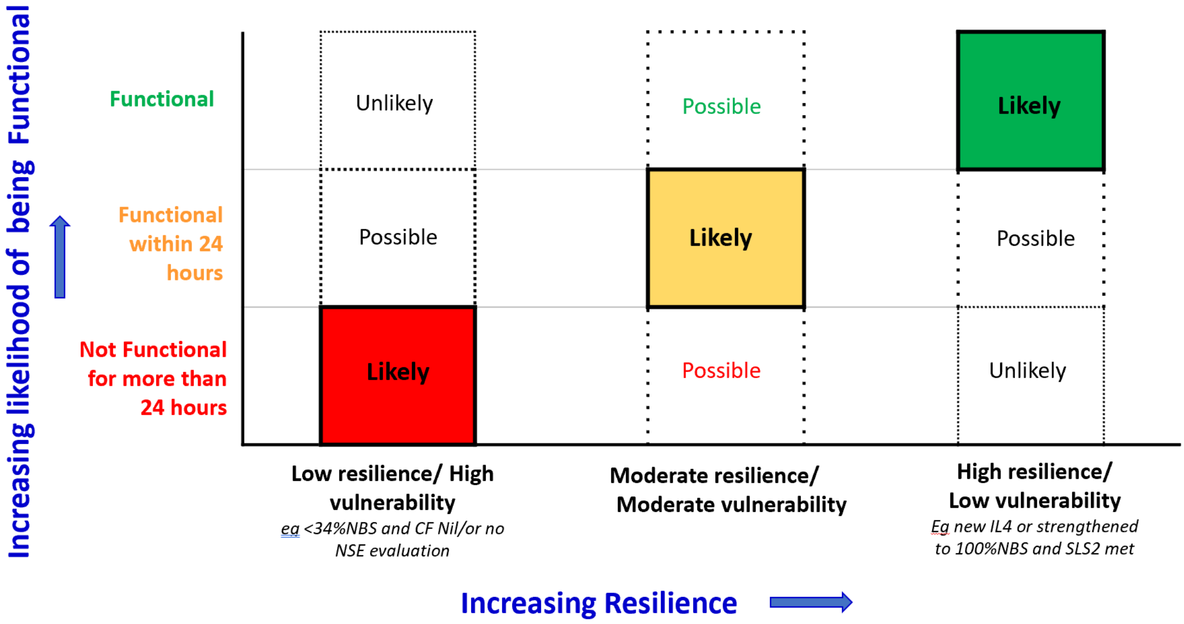

Figure 8.1: The Continuum of Vulnerability to Resilience (focusing on a 500 year earthquake)

Seismic resilience has been defined as the ability of a system to reduce the chances of a shock, to absorb such a shock if it occurs and to recover quickly after a shock. This concept is scalable and can be applied at both community level and individual facility or building level. The seismic resilience of acute care facilities has previously been explored by Bruneau and Reinhorn[16], and *Functional Recovery* is the subject of current international research, including by QuakeCoRE, the New Zealand Centre for Earthquake Resilience, Te Hiranga Rū.

The interruption to the functionality of a building following an earthquake (or other event) can be represented in a plot of *Functionality (or Service Level)* against *Time*.

Figure 8.2 indicates conceptually the effects of losing different degrees of functionality as a result of increasing damage. In the first case (green line), there is only a small reduction in functionality, with the ability for hospital operations to continue without interruption. In the the second case (red line), there is a more significant loss in functionality which results in the building no longer being functional (or usable). Depending on the degree of damage and loss of function, the building may not be functional for a short or long period of time.

[16] M Bruneau and A Reinhorn *Exploring the Concept of Seismic Resilience for Acute Care Facilities* EERI Earthquake Spectra, Volume 23, No. 1, pages 41–62, February 2007

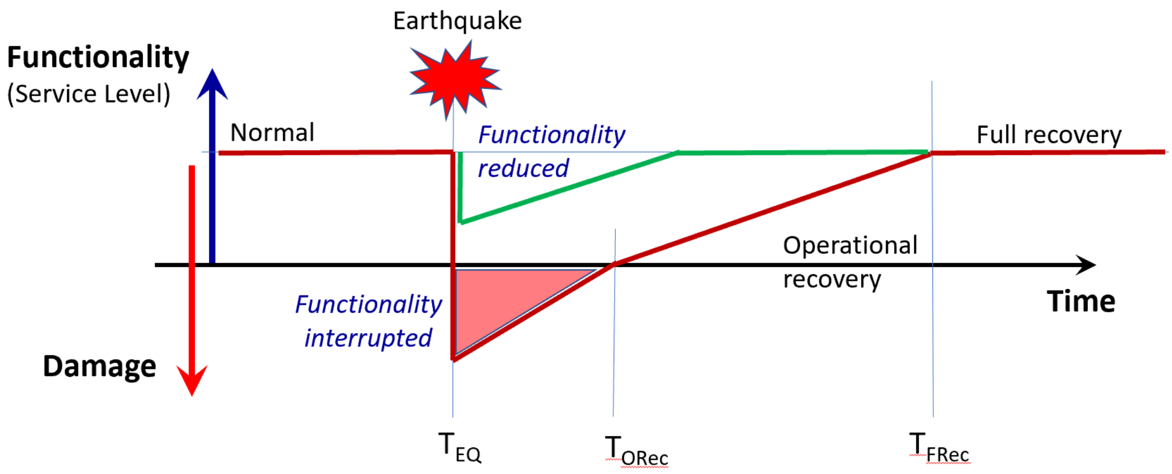

Figure 8.2: Functional impacts of earthquakes

This representation can also be used to convey in general terms the expected performance of a new operational facility that fully complies with the IL4 SLS2 requirements, and existing IL4 buildings with different expected losses of functionality. Figure 8.3 shows the expectation that a new IL4 building will continue to remain operational, and be able to be restored to full functionality within a relatively short period of time. Also shown is an existing building that does not meet the equivalent SLS2 requirements that correspond to *operational recovery* and would therefore not be functional for a period of time.

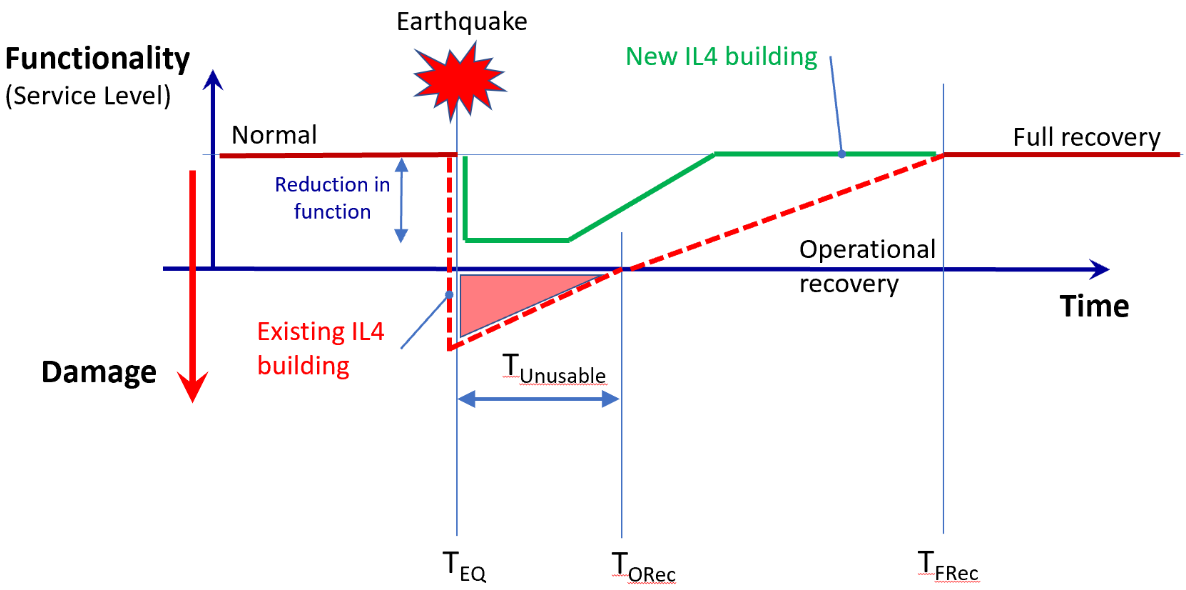

Figure 8.3: The difference in functional impacts of earthquakes on new and existing IL4 buildings

Understanding how long a building is likely to be unable to function and hence deliver critical services for and what governs this is are key assessment objectives, particularly in relation to non-structural elements. Achieving continued operational functionality (or at least minimising the length of time that a building is unusable for) represents the seismic upgrading objective for IL4 buildings in relation to SLS2 requirements.

8.3 Risk Categorisation

The proposed risk categorisation framework draws upon both *life safety* and *building functionality* inputs.

For *life safety*, the risk rating is based on current known information from seismic assessments.

For *building functionality*, the *element functionality* ratings for non-structural elements as outlined in the previous section are used. *Element functionality* is from the evaluation of lighter non-structural systems and elements. It is acknowledged that vulnerability ratings for non-structural systems have currently yet to be set for any hospital building.

The lowest rating element dictates the overall *building functionality* (with reference to Table 8.1).

The separately derived *life safety* and *building functionality* ratings can then be used to determine overall risk categories on a 1 to 5 scale, summarised in Table 8.1 below, with the corresponding qualitative levels of building resilience indicated.

Table 8.1: Overall Building Risk Categories

Risk Category	Overall Resilience
RC1	High Resilience
RC2	Resilient
RC3	Some Vulnerabilities
RC4	Vulnerable
RC5	High Vulnerability
Not Established	Not Known

Risk Category 1 (RC1) corresponds to a fully complying new IL4 building, which is broadly assumed to be any building designed from 2015 onwards.

Risk Category 2 (RC2) covers buildings that are rated at or above 67%NBS (IL4) <u>and</u> considered likely to meet SLS2 requirements for 500 year earthquake shaking.

The risk categories can also be used to reflect where buildings sit on the 'vulnerability to resilience' continuum, as indicated in Figure 8.1 previously.

Figure 8.4 below indicates how these risk categories are determined from the constituent *life safety* and *building functionality* ratings.

Figure 8.4: Risk Categorisation

>67%NBS(IL4)

SLS2 met

Building Functionality	No assessment results	Grade E <20%NBS	Grade D 20 to 34%NBS	Grade C 34 to 66%NBS	Grades A & B ≥67%NBS	New IL4 building
Likely					RC2	RC1
Uncertain		RC5	RC4	RC3	RC3	
Unlikely		RC5	RC4	RC4	RC4	
Not known		(RC5)	(RC4)	(RC4)	(RC4)	

Seismic Assessment (Life Safety) Rating

The reliability of the seismic assessments as discussed and defined in Section 4 is not explicitly included in this table, given the current incompleteness of the seismic information held by HIU. It is however suggested that only ratings that come from assessments from after July 2017 and are above 67%NBS can be included as *Resilient* (ie. risk category RC2), unless reviewed and confirmed as covering relevant Secondary Structural and Non-Structural elements (or not needing to).

It is noted that risk categories RC4 and RC5 can be further divided into *overall primary structure* and *local element,* to convey a quick sense of the nature and extent of the seismic vulnerabilities.

8.4 Prioritisation of Seismic Strengthening and Obtaining Additional Information

From the risk categories identified in the previous sub-section, indicative priorities for physical risk mitigation and obtaining missing or additional seismic information can be derived.

Again, the current limitations of the set of seismic information held by the HIU limits the extent to which these risk categories can be applied. The refreshing of this information to reflect additional and updated seismic assessments obtained by the DHBs over the past two years, along with relevant redevelopment decisions made for specific buildings during this period, is the highest overall priority action.

Seismic Mitigation

The corresponding mitigation priorities can be derived at the *risk category* level. Figure 8.5 below suggests that priority is given to buildings that sit within Risk Categories 4 and 5 (highlighted in the yellow shaded cells). Further prioritisation according to seismic hazard would see this work focusing on buildings in High Seismic hazard areas, then Medium, then Low.

Figure 8.5: Recommended Seismic Mitigation and Information Prioritisation (based on current information)

>67%NBS(IL4)

Building Functionality	No assessment results	Grade E <20%NBS	Grade D 20 to 34%NBS	Grade C 34 to 66%NBS	Grades A & B ≥67%NBS	New IL4 building
Likely					**RC2**	**RC1**
Uncertain		**RC5**	**RC4**	**RC3**	**RC3**	
Unlikely		**RC5**	**RC4**	**RC4**	**RC4**	
Not known		**(RC5)**	**(RC4)**	**(RC4)**	**(RC4)**	

SLS2 met

Seismic Assessment (Life Safety) Rating

For buildings that are already in the *Vulnerable* and *High Vulnerability* risk categories (RC4 and RC5), it is suggested that the assessment reliability category does not necessarily need to be considered further. This is because firstly, obtaining additional information in these cases is typically highly unlikely to improve the vulnerability categorisation, and secondly, more information will be obtained as part of developing the concepts for seismic strengthening (or other actions).

This ensures that the focus for these buildings is on treating the risk rather than introducing a further step of seeking additional information that is unlikely to change the recommendation to mitigate. Buildings in these risk categories should however be subject to an engineering risk review as part of confirming the suitability to continue to be used in the short-term/ interim period prior to strengthening, re-purposing or decommissioning (refer Section 9.2).

In some situations where there are concerns about the seismic performance of specific non-structural elements, there may be some relatively straightforward fixes for discrete items that have been identified to be undertaken that would give a much higher level of confidence regarding both life safety and building functionality. These should be enabled via a different planning filter taking a 'bang for buck' approach.

Wider Considerations

These risk categories and associated priorities focus on the expected performance of the building rather than the criticality of the medical service(s) within the building, beyond the Importance Levels assigned having due regard to the emergency plans for the campus. There are therefore two wider considerations involving the consequences for the population of a hospital being unable to deliver critical post-earthquake services that should be taken into account.

Firstly, taking a campus-level perspective that takes into account both the criticality of the medical services and the likely overall level of performance (vulnerability) of the campus (including infrastructure) in a major earthquake. This underlines the importance of comprehensive site-wide Master Planning as a basis for establishing the scope and sequencing of mitigation work. This should also extend to regional analysis in situations where there is more than one hospital in a region, reflecting the way a number of DHBs are undertaking more integrated planning.

Specific guidance on how seismic risk should be fed into the early stages of site-wide master planning should be developed in order to foster national consistency.

Secondly, consideration should also be given to comparing the seismic vulnerabilities and populations affected between different regions. This would enable the wider dimension of *population consequence* to be taken into account alongside *event likelihood* and *building vulnerability* to provide a more comprehensive modelling and evaluation of overall risk, alongside other factors such as climate change considerations. This may lead to different mitigation priorities in some regions than those based purely on seismic hazard aspects.

Development of this further national level risk filter is beyond the scope of this current study, but is strongly encouraged.

Obtaining Additional Seismic Information

In parallel to the risk mitigation priorities indicated above, the priority for obtaining additional information is for the seismic assessment of unassessed IL4 buildings, followed by unassessed IL2 and IL3 buildings. Higher level reviews of earlier seismic assessments of lower reliability (eg Reliability Categories REL1 or REL2) should also be undertaken to identify which of these assessments need to be updated for issues such as heavy cladding or precast concrete floor systems.

It is recommended that this information be sought irrespective of their hazard area, but with an obvious sub-priority of High and Medium Seismic Hazard Areas. For buildings where seismic assessments have yet to be undertaken, priority should be given to those of heavier construction – ie. more than one storey with concrete floors and wall panels. Strategic engineering input would enable the identification of buildings of lighter weight low rise construction that are unlikely to require seismic assessment.

Overall Priority

In summary, the initial focus for prioritising the planning of seismic risk mitigation is recommended to be on buildings in Risk Categories RC4 and RC5, commencing with those in High Seismic hazard areas, then Medium, then Low. However specific mitigation projects need to be validated as part of site-wide master planning, with careful consideration of practicality and buildability in relation to the ongoing delivery of clinical functions. This should also involve further consideration of regional population and potential national impacts as an additional risk consequence filter in order to better establish national priorities.

The priority for obtaining additional information should be on buildings involved in current campus master planning processes. Having seismic assessments undertaken on the IL4 buildings that have yet to be assessed should also be a clear priority action.

An additional baseline priority is to ensure that the earthquake prone buildings requirements of the Building Act are being met. This involves firstly, providing seismic assessments for all buildings identified by TA as potentially earthquake prone within 12 months of receiving notification, and secondly, strengthening, re-purposing or demolishing those buildings issued with an EPB notice within the EPB notice timeframe.

As part of refreshing DHB seismic assessment information, a national list of hospital buildings that are current posted on MBIE’s national EPB Register as being earthquake prone and the corresponding notice expiry dates should be obtained, and actively maintained.

9. Addressing Current Seismic Risk in Existing Hospital Buildings

This section outlines four areas to enhance the management of current seismic risk in existing hospital buildings. These areas acknowledge that seismic risk exists, and it will take a considerable period of time before it can be reduced to a more acceptable level across the whole portfolio. In the meantime, decisions about continuing to occupy seismically vulnerable buildings will be required, and there is also a need to be prepared to mobilise a rapid technical response to the earthquakes that will occur.

9.1 Developing a Seismic Policy and Seismic Risk Management Strategy for Hospital Buildings

The development and implementation of an overarching *Seismic Policy* document with an accompanying *Seismic Risk Management Strategy* across all hospital buildings is seen as a key mechanism of achieving a more consistent and effective treatment of seismic risk across existing hospital buildings. Together these documents would also guide the design of new hospital facilities.

A *Seismic Policy* is a document that provides for a consistent approach across buildings in large and complex property portfolios, covering aspects such as:

- How buildings are categorised in relation to seismic risk, and the priority categories for seismic strengthening, re-purposing or removal
- Importance Level categorisations relevant to the organisation
- Seismic assessment requirements (eg. the type of seismic assessment required for different types of buildings, and where they are not required)
- Seismic design and strengthening objectives (with specific linkages to the engineering design guidance outlined in Section 10)
- Linkages with capital asset management plans and risk management approaches
- Decision-making in relation to the continued occupancy of Earthquake Prone Buildings and those rating less than 34%NBS.
- Requirements for future property commitments (eg. seismic requirements if entering a new building acquisition or lease)

As well as providing a framework including relevant ‘rules’ for operational decision-making, a national policy will provide a reference point for consistent and risk-aligned funding decisions.

A *Seismic Risk Management Strategy* is a document that sets the direction for seismic work by outlining the implementation response to the *Seismic Policy*, providing actionable steps to actively reduce earthquake risk across hospital buildings through short, medium and long-term priority actions. As for the risk prioritisation framework, meeting the requirements of the Building Act would be a basic requirement of the Seismic Policy and Seismic Risk Management Strategy.

Site-specific *Seismic Risk Management Plans* (akin to the current Asbestos Risk Management Plans) could then follow, providing the key linkage with site-wide infrastructure.

It is recommended that Health New Zealand to have a Seismic Policy, supported by a Seismic Risk Management Strategy, in place prior to taking over responsibility for the management of buildings currently owned by the individual DHBs.

9.2 Risk-based Approach to the Continued Occupancy of Low Rating Buildings

As highlighted in Section 4, there are currently 103 hospital buildings known to have ratings less than 34%NBS, 31 of which are IL4 buildings. It is understood that essentially all of these buildings are currently being occupied.

While we have not had the opportunity to explore the historical decision-making processes involved, it is clear that a consistent (and conscious) decision around continued occupancy is required in future situations. Moreover, part of a more optimal sequencing of hospital upgrades will involve reviewing and accepting current risk levels in low-rating buildings in the interim period before master planning can be completed and relocations can occur ahead of strengthening work or replacement commencing.

The first point to appreciate is that earthquake-prone building provisions of the Building Act do not preclude the continued use and occupancy of buildings with an earthquake-prone designation until the expiry of the date on the EPB notice.

The second point is that WorkSafe have stated that they will not enforce a higher standard of health and safety under the Health and Safety at Work Act 2015 for a Person Conducting Business or Undertaking (PCBU) who owns or occupies an earthquake-prone building and is meeting the earthquake performance requirements of the Building Act 2004.

Current practice amongst other national agencies is to have their independent engineering risk advisers undertake a specific review of the engineering assessment to evaluate the actual nature of the seismic vulnerabilities, the risk exposure factors that apply to the various occupants, and take into account the likely intended overall period of occupancy prior to strengthening commencing and/ or the building no longer being used. This review typically generates a specific risk assessment to inform decision-making and communication with user groups. This risk assessment identifies any applicable short-term risk mitigation measures and makes recommendations about continued occupancy.

Emerging practice is to have this decision-making process defined and contained within an organisation's seismic risk policy, as noted in the previous sub-section.

There are no specific recommendations or criteria as to the period of time that buildings with low seismic ratings should continue to be occupied prior to strengthening or decanting. It is nevertheless important to have a documented plan with anticipated timelines agreed to by all parties involved, backed by a specific engineering risk assessment, and monitored annually.

A recent BRANZ-led research report[17] reviewed current practice by city and district councils as asset owners in making occupancy decisions for low-rating buildings, and contains a decision-making framework which encompasses all relevant risk considerations, taking account of both the likelihood and consequence components associated with earthquakes.

9.3 Identification of Alternative Facilities and Associated Arrangements

All key operational facilities need a specifically designated alternative facility or arrangements. While this principle applies irrespective of whether a building is near-new and purpose designed or an older structure, it is clearly more important to have specific alternative arrangements in place for older and/ or lower rating buildings.

We have reviewed a sample of DHB hospital emergency plans as part of this project. From those reviewed, some alternative buildings nominated within Business Continuity Plans for acute services had low seismic ratings, with associated question-marks about their likely usability after a significant earthquake. It was also not always apparent that appropriate levels of backup infrastructure are available at the indicated alternative locations. A key consideration here is emergency power, which may require a wider coverage than is currently the case for some hospitals.

Any decision to continue to deliver services in a damaged building or evacuate to an alternative facility is a significant one. It is suggested that this decision-making process be given specific consideration and greater clarity and prominence in the Major Incident Plans, along with the key steps involved in quickly activating alternate facilities for key functions. Having timely post-earthquake engineering assessments is a key component of this, and the necessary pre-arrangements to enable this are expanded upon in the next sub-section.

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[17] BRANZ study report SR463 *Managing Earthquake-prone Council Buildings: Balancing Life Safety Risks and Community Costs* (November 2021)

9.4 Technical Arrangements for Post-earthquake Response

Hospital facilities are critical facilities for communities in any recovery from large earthquakes. It is essential that specific arrangements are in place with engineering consultants to respond to any earthquake event as required. Utilisation of seismic instrumentation to inform responding engineers and assist their decision-making is another key element of post-earthquake technical arrangements.

Priority Response Agreements with Engineers

The Canterbury and Kaikoura earthquakes have demonstrated the many immediate demands for assistance from structural and geotechnical engineers. Many DHBs (along with Territorial Authorities and Lifeline Utilities) have well-established relationships with consulting engineering practices for the supply of a range of professional engineering services. Some of these agreements include provision for post-disaster response, but where this aspect is included, it is typically only at the practice level rather than with individual engineers, and without specific expectations and arrangements being included.

The optimum form of agreement with an engineering practice is referred to as a *Priority Response Agreement*. This agreement defines the expectations and arrangements for those who own and operate operational facilities (hence the reference to Priority), and the engineers who will be carrying out the post-earthquake assessment.

The engineers engaged with Priority Response Agreements should ideally be those who have already assessed most of the acute services buildings on the hospital campus. They will therefore have knowledge of the building structural system, the materials used, whether the buildings have any critical structural weaknesses to target their initial inspections on, and how vulnerable the buildings might be to various levels of seismic shaking. They should be more aware of building elements and where to look for possible damage compared with another engineer unfamiliar with the building and who may not have access to plans and specifications, providing for a much more timely and effective initial assessment.

While the key elements of a Priority Response Agreement were developed by the New Zealand Society for Earthquake Engineering in 2005, each agreement needs to be customised to meet the agency's requirements, and there is no template as such.

The key philosophies that should underpin a Priority Response Agreement are:

- A clear commitment on the part of the consultant to respond as quickly as they are able to the facility, and ahead of other client commitments;
- Acknowledgement by the operational agency or building owner that it is a 'best endeavours' agreement, but that it is backed up by the consultancy with more than one listed engineer who is reasonably confident of being able to attend the site following a major event;

- The engineers are familiar with the building (either as designers or having undertaken a seismic assessment of the building or reviewed a recent assessment); and
- The engineers have prepared a specific post-earthquake assessment plan – essentially a method statement for the process they will follow, covering how they will respond, how they will physically evaluate the building (including where they may wish to expose structural elements), and all relevant contact details. This typically requires annual 'readiness' to ensure the currency of the arrangements, and the response arrangements for the engineers should be formally linked to the hospital emergency response plans.

This latter aspect and the active engagement with the DHB represent a particularly important 'readiness outcome' focus of a Priority Response Agreement. We are aware of the extent to which the Facilities Management team at Hawke's Bay DHB engage with their contracted response engineers, including familiarisation sessions on how the Territorial Authority-led Rapid Building Assessment process operates, and consider this to be a good practice model.

It will also be important for the DHB or their engineers to liaise with the TA responding to an earthquake to provide them with hospital building assessment status updates. Building management is an important aspect of TA obligations following a declared emergency. The TA may have initiated area-wide rapid assessments of buildings as a public safety measure, and will want to know which buildings have already been assessed by owners. A TA Rapid Building Assessment initiative involves volunteer engineers who assess buildings for damage and place placards on them stating whether they can continue to be occupied (White – can be used, Yellow – restricted access, Red – entry prohibited). The DHB engineers need to be trained and registered with the TA to be able to post these placards, as part of the more comprehensive assessments they will be undertaking for the DHB.

Seismic Instrumentation

The principal objective of having seismic instrumentation installed in a building is to reduce the time taken by engineers to evaluate the response of the structure to significant earthquake shaking, hence hastening re-occupancy decisions.

In the first instance the responding engineer is looking for and reacting to signs of damage to both structural and non-structural elements throughout the building. Decisions to re-occupy can be most challenging in situations where the visible damage to primary structure is minor (with or without appreciable non-structural damage). Having appropriate seismic instrumentation installed informs the engineer on aspects like the proportion of design loading that the building has actually experienced, and in some cases the amount of structural movement that has occurred. This information can support the damage observations, and give the engineer confidence in making re-occupancy recommendations – or information to support a decision not to re-occupy the building.

There is a range of seismic instrumentation systems that are currently available from a variety of vendors. Selection of the appropriate instrumentation technology needs to be undertaken carefully in conjunction with response objectives and arrangements – highlighting again the key linkage with the Emergency Response Plans - and the contracted engineers.

Where the building is instrumented, the engineer must understand the nature of the output from the instrumentation, and be able to utilise the information. This forms part of the required preparatory work referred to in the previous sub-section.

Certain forms of seismic instrumentation are linked with an App that provides high-level summary information about the level of shaking that the building has experienced. In addition to assisting engineers to decide whether or not to respond to minor to moderate earthquakes, Facilities Managers and others within the hospital organisation can directly access this information to better inform aspects of their initial response, and also in relation to subsequent aftershocks.

10. Design Guidance for New and Strengthened Hospital Buildings

10.1 Scope of Guidance Required

The review of a range of seismic assessments of hospital buildings in 2019 and 2021 has identified the desirability of national technical guidance to establish a more unified approach to both seismic assessment and the design of new buildings. A common framework for the briefing of consultants was also recommended in 2019, and a draft template produced.

The particular area of greatest need for agreed guidance relates to the seismic performance objectives for both the structural and non-structural elements, with a focus on continued functionality in 500 year (and more frequent) earthquake shaking. In addition to this strategic direction setting, other aspects such as a common basis for the selection of key design parameters (including Importance Level categories) can follow.

This is a priority activity with respect to further seismic assessments as well as for the protection of forthcoming new building investment.

The required scope of the engineering design guidance envisaged for hospital buildings is broadly:

1. The design of new buildings
2. The alteration/ extension/ upgrade of existing buildings
3. The assessment of existing buildings

10.2 Key Area of Need: Protecting Non-structural Elements and Medical Equipment

The key feature of hospital facilities that is not covered in either Building Code provisions or structural design standards and codes of practice relates to the protection of non-structural elements and specialist medical equipment from damage in earthquakes. As discussed in Section 7, there are particular sensitivities associated with hospital equipment and operating environments with respect to building movement in earthquakes that need to be taken account of in both the design and assessment process.

Following the Canterbury and Kaikoura earthquakes of the past decade, greater attention is being paid to the principles and details associated with low damage seismic design, with new national guidance from MBIE on this topic expected to be released later this year.

However, while this will represent a significant advance for design generally, there is a number of specific considerations in relation to hospital facilities that require additional design guidance. In essence, this guidance would seek to achieve two objectives – firstly, clarifying what is required in key areas for hospital buildings to meet the current Building Code requirements (including meeting SLS2 requirements) and secondly, for those areas where Health New Zealand would like to see buildings that house key medical services exceed minimum code requirements, what additional requirements should designers meet for wider post-disaster service continuity purposes.

A particular area where guidance is needed is in relation to the forthcoming increases in seismicity, which is likely to affect lower and east coast regions of the North Island, and the top of the South Island. While the likely increases affect primary and secondary structural elements, the effect on non-structural elements also needs to be taken into consideration.

10.3 Use of the Ministry of Education's Design Guidance as a Model

An appropriate model for design guidance from other sectors which addresses the above two objectives is the Ministry of Education's *Structural and Geotechnical Requirements* document, which was updated in 2020.

The Ministry of Education's full suite of design guidance documents encompasses other discipline areas such as architecture, along with specific areas such as acoustics and weathertightness.

There are notable differences in the construction profile of school buildings and hospital buildings. More than 90% of the Ministry of Education's portfolio is timber-framed construction of one and two storeys, and the majority of new construction is also one and two storeys in height, although typically of a heavier commercial construction type.

The Ministry of Education also owns almost all property in state-owned schools, whereas the DHBs currently own hospital property. The change in ownership arrangements as a result of the creation of Health New Zealand will however align the ownership models.

A further point of difference is that the nature of school activities allows non-disruptive damage to generally be accommodated, provided it can be readily repaired during school holiday breaks. This is in contrast to key hospital facilities that must be able to function and deliver critical services immediately after earthquakes. This point relates to the difference between Importance Level 2 and 3 buildings in schools and IL4 buildings in hospitals. The added complexity of the IL4 building requirement for hospital buildings to ensure *continued functionality* in 500 year return period earthquake shaking requires additional and new material to address this.

Key elements relevant to counterpart technical guidance for hospital campuses and buildings include:

Master Planning

While master planning in hospitals appears to be a relatively well-developed field of practice, the particular engineering aspect that is often overlooked is having appropriate campus-wide geotechnical information at each stage of planning.

Engineering Design and Architectural Detailing

Seismic performance requirements articulated in general terms for *minor*, *significant* and *major* earthquake shaking, along with corresponding design loadings for the intermediate *significant* earthquake shaking

More detailed performance requirements (both qualitative and quantitative) are provided for structural and non-structural elements to ensure the design focuses on minimising non-structural damage, in order to provide confidence that the functions within the building can continue to be delivered.

The Ministry of Education's *Structural and Geotechnical Requirements* focuses on limiting damage to within repairable levels, whereas technical guidance for hospitals needs to focus on limiting damage to ensure *continued functionality*.

Design Review

With respect to design review, the Ministry of Education has implemented a structured and multi-disciplinary design review process that focuses on the review and acceptance of designs at both the *concept* and *preliminary design* stages. These reviews are separate from the regulatory reviews undertaken at the completion of the design for building consent purposes.

10.4 Recommendations for the Development Process

It is considered that the Ministry of Education's *Structural and Geotechnical Requirements* document represents a good base model for adaption by Health NZ into technical guidelines for hospital buildings. The MoE document has been endorsed by MBIE, who are supportive of other sectors producing similar forms of technical guidance to clarify where their requirements may exceed the requirements of the Building Code.

This document was developed by the MoE's *Engineering Strategy Group*, which comprises five leading structural and geotechnical practitioners from different engineering practices that worked together to produce a consensus document. Having different practices involved provides a high level of pan-industry ownership of the document, reducing the potential for professional disagreements in its application.

A similar process is recommended for Health NZ to follow. There are budget and time-frame implications to be considered, noting that the process of development of guidance and achieving consensus in technically complex areas typically involves work over a period of time.

10.5 Templates for Briefing and Summarising Design Outcomes

In order to ensure the designs of new buildings and strengthening work are approached and delivered in a consistent way and in accordance with the technical requirements outlined above, a briefing template for consulting engineering practices should be developed.

A corresponding template that summarises the strengthening scope and outcomes at the various stages of design (concept design, preliminary design and detailed design) consistently should also be developed. A sample template developed previously in 2019 is included in Appendix C.

11. Key Observations

Hospital buildings, particularly those with clinical and associated functions, are extremely complex facilities with many points of vulnerability to earthquake shaking. There are many challenges in firstly, understanding the nature and extent of the vulnerabilities, and secondly, to summarise and convey them.

Our review of the current situation for hospital buildings with respect to seismic risk and formulation of a strategy to address these risks has highlighted several key observations. These are outlined below, along with associated discussion, organised under the following headings:

- *Understanding the Current Seismic Risk Profile;*
- *Addressing Areas of Inconsistency and Uncertainty;* and
- *A Structure for Consistent Management of Seismic Risk in Hospital Buildings*.

Understanding the Current Seismic Risk Profile

Key Observation 1:

A significant number of hospital buildings have not yet had seismic assessments undertaken or reported on

The majority (63%) of public hospital buildings throughout New Zealand have had seismic assessments commissioned by the respective District Health Boards reported to the HIU. However more than a third of all hospital buildings have yet to have an assessment undertaken, including 40 buildings currently categorised as IL4.

Key Observation 2:

A number of key hospital buildings have low seismic ratings for life safety in rare earthquakes

Of those buildings that have been assessed, a number have been found to have low %NBS ratings. Of all hospital buildings for which assessments have been reported, 103 (13%) currently rate less than 34%NBS. For IL4 buildings, 31 (16%) are rated less than 34%NBS. It is unclear how many of the buildings rating less than 34%NBS have been determined by territorial authorities to be earthquake prone.

While the low seismic ratings in themselves sound somewhat alarming, the exposure of hospital staff, visitors and patients to the extremely strong ground shaking associated with 1 in 2,500 year return period earthquakes used in Importance Level 4 buildings is actually relatively low. The risk to occupants needs to be viewed alongside that for a 500 year return period earthquakes as used for general usage buildings.

Also of concern is that new shortcomings that shortcomings in relatively modern public hospital buildings (ie. constructed since 2000) are continuing to emerge from new seismic assessments. These are buildings that until recently had been thought to represent a low seismic risk, but learnings from the Canterbury and Kaikōura earthquakes have highlighted areas of vulnerability in aspects of modern construction.

Key Observation 3:

There is considerable variation in the reliability of seismic information currently held on key hospital buildings

A number of seismic assessments obtained by DHBs are somewhat dated, preceding the new earthquake prone buildings legislation and national technical guidance that took effect in 2017. Some assessments were also only qualitative Initial Seismic Assessments, rather than quantitative Detailed Seismic Assessments.

The amendments to the earthquake prone buildings provisions of the Building Act and the updated national seismic assessment guidelines in 2017 now require engineering assessments to include heavy façade and internal non-structural elements. Few assessments prior to these amendments included these elements. A number of earlier assessments with higher ratings are therefore likely to be reduced for some buildings with heavy parts.

Reliability categories are therefore proposed to enable a more transparent understanding of the usefulness of the seismic ratings for life safety obtained by the DHBs.

As noted above, very few assessments have had non-structural elements included within their scope. This further reduces the overall knowledge of the state of vulnerability (or resilience) of current hospital buildings.

Key Observation 4:

The post-earthquake functioning of hospital buildings is highly dependent on the performance of non-structural elements

A key area of operational vulnerability of existing hospital facilities during and following earthquake relates to non-structural elements such as ceiling systems, fire sprinkler pipes, pipe runs for medical gases and steam and specialist medical equipment. Where these elements are not adequately restrained or separated, damage in earthquakes can be considerable, with associated impacts on functionality in addition to life safety concerns.

Seismic ratings for buildings essentially only address life safety considerations, and do not provide information on the likely ability of a building or facility to continue to function following a significant earthquake. A further consideration is that this vulnerability to non-structural damage can be independent of how well the primary structure performs.

Furthermore, very few of the seismic assessments referred to above have included an evaluation of the adequacy of the restraints to or movement allowance for non-structural elements. For hospital buildings where this aspect has been given engineering consideration, the level of seismic restraint provided has typically fallen well short of compliance with current code requirements. There is however currently no agreed approach for evaluating the adequacy of the seismic restraints and associated provisions for non-structural elements in existing hospital buildings delivering acute medical services.

Operational Continuity (or maintaining Building Functionality) is a key regulatory requirement of new buildings with special post-disaster functions, but it is not an explicit requirement for existing critical facilities. The general expectation nevertheless remains. The lack of information on the seismic vulnerability of these components restricts the understanding of the *building functionality* (post-earthquake usability) of a building. This in turn further reduces the overall knowledge of the state of vulnerability (or resilience) of current hospital buildings.

The likelihood of having a key hospital facility rendered unusable due to the failure of these elements appears quite high for many buildings. It is therefore concluded that a number of hospital buildings will not be able to support an effective medical emergency response following a major earthquake (500 year return period) due to the likely damage to these items.

Addressing Areas of Inconsistency and Uncertainty

Key Observation 5:

More consistent use of seismic information is needed in investment business cases for hospital redevelopments

A review of recent investment business cases has highlighted inconsistent and incomplete use of seismic information. This information should:

- Be based on a seismic assessment that reflects current national assessment guidance;
- Include the expected response of all elements that could adversely affect the ability of the building or buildings to operate;
- Include the potential impacts of and to adjacent and adjoining buildings; and
- Include the potential disruption to hospital services

A framework for more consistent use of seismic information in business cases is proposed.

Key Observation 6:

There is a need for a greater appreciation of the impact of seismic strengthening on clinical services

The biggest challenge in planning and undertaking seismic strengthening work in existing operational buildings is the impact on clinical services, as it typically involves highly intrusive activities.

Seismic strengthening of primary structural elements typically involves highly intrusive activities. The strengthening and/ or addition of concrete and steel elements involves breaking out of and drilling into concrete and welding of steel. New or additional foundations are also often required, with associated excavation. Usually it is not possible to have this work undertaken whilst highly sensitive hospital operating environments remain functioning.

While the upgrading or installation of seismic restraints can be a relatively straightforward process in office buildings, it is particularly complex in the hospital environment. Most of the key operational buildings have a plethora of services running in ceiling spaces and corridors. This typically requires the associated removal, relocation and replacement of equipment and fit-out items.

Hospitals that have had buildability reviews of strengthening proposals undertaken by contractors usually identify greater operational impacts and challenges (and hence time and cost impact) than envisaged by the project teams. This raises fundamental questions around the practicality and viability of seismic strengthening for buildings housing acute services.

There are corresponding challenges associated with the demolition of buildings within a functioning hospital campus.

To avoid these operational impacts requires the prior construction of alternative facilities (temporary or permanent), which in turn requires a robust and agreed Site Master Plan. This wider planning process would however be better informed by comprehensive seismic information on all affected buildings on the campus, as noted above.

The acceptance of current increased risk levels in low-rating buildings in the interim period before relocations etc can occur ahead of strengthening or replacement commencing is an important consideration in the sequencing of strengthening and redevelopment work.

This is an area which has received inconsistent treatment in the preparation of investment business cases, and requires more specific engagement with hospital operational personnel.

Key Observation 7:

Clarity is required around the Importance Level categorisations that apply to the different functional uses of hospital buildings

There has also been a lack of consistency in the way that Importance Level classifications have been applied to hospital buildings for both assessment and design purposes across the DHB network. A clarification of those hospital buildings that warrant classification as Importance Level 4 structures to address this information void is proposed.

It is important to realise that the focus of importance levels is primarily on deriving the structural parameters for individual buildings. They do not in themselves inform the wider need and requirement for campus-wide resilience.

Key Observation 8:

A systematic approach to evaluating the seismic vulnerability of non-structural elements is required

The significant information gap in relation to understanding the seismic vulnerability of non-structural elements has already been commented on.

There is a vast array of non-structural elements in hospitals, and the failure of any one of these has the potential to render a building and its associated services unusable following a significant earthquake. Observations from recent earthquakes in New Zealand and overseas has highlighted that certain heavier components such as emergency generators, elevators (lifts), water storage and bulk oxygen tanks and suspended ceilings are more prone to damage or failure.

As with evaluating the seismic performance of buildings generally, it is considered important not to place undue emphasis on assessing absolute compliance with standards for new construction. The status of the fixings of seismic restraints is extremely difficult to ascertain, and so establishing and achieving full compliance represents a very high bar.

We propose that a higher level review of non-structural elements be used, based on a qualitative evaluation that avoids using a compliance approach to gather 'big picture' information as rapidly and efficiently as possible. This triage-based approach suggests non-structural elements be evaluated under each of the three areas of ***Element restraint***, ***Element movement capacity*** and ***Internal capability of specialised equipment***, with vulnerability categorised in relation to the likelihood of *functionality* of the building to be affected under levels of earthquake shaking consistent with the design of new IL4 buildings.

A Structure for Consistent Management of Seismic Risk in Hospital Buildings

Key Observation 9:

A risk categorisation of hospital buildings to reflect known levels of seismic vulnerability and resilience is proposed

A framework is proposed for categorising individual hospital buildings into five risk categories that indicates the likelihood of post-earthquake *building functionality*. These risk categories are derived from the key inputs of *life safety* (%NBS) ratings and *building functionality* ratings.

A further cycle of refreshing the assessment information currently held by DHBs is necessary before these categories can be initially populated and reported on, and then monitored. It should however be emphasised that the effectiveness of these categories is quite limited in the absence of information on non-structural components.

The proposed risk categories can be used as a basis for prioritising the concurrent activities of seismic mitigation and obtaining further information where little exists.

Key Observation 10:

Prioritising the mitigation of seismic risk across New Zealand hospitals should take into account the wider consequences for the population of buildings not being functional

From a building perspective, it is suggested that initial priority be given to Importance Level 4 buildings in Risk Categories 4 and 5.

However, an additional component of risk that should be taken into account when prioritising mitigation involves the consequences for the affected community of the potential poor performance of hospital buildings and associated infrastructure. The scope and sequencing of mitigation work should be based on comprehensive campus-wide Master Planning informed by a vulnerability assessment of site-wide infrastructure (including external network vulnerabilities), with reference to the relevant local, regional and national Health Emergency Plans.

This can also extend to regional analysis in situations where there is more than one hospital in a region. Consideration should then be given to comparing the building vulnerabilities and populations affected <u>between</u> different regions. This may lead to different national mitigation priorities than those based purely on seismic hazard and risk aspects.

Key Observation 11:

Prioritising the mitigation of seismic risk across New Zealand hospitals needs to take account of current information gaps

Progress needs to be made to mitigate seismic risk for hospital buildings that pose significant risks to life safety and continued functionality. There is nevertheless a need to balance getting physical risk reduction underway with the need for more information in some areas, given the knowledge gaps highlighted above.

It would clearly be desirable to have a more complete picture of the full extent of seismic vulnerability across the whole portfolio on which to base future mitigation planning on. However in many cases the key seismic vulnerabilities are already clearly identified, with any additional items able to be picked up during the design of the strengthening work. Similarly, the typically invasive nature of most strengthening measures will require the need for significant making good of non-structural and fit-out items, and this provides the best opportunity for ensuring that appropriate levels of seismic restraint are provided to non-structural elements. In many cases, the planning for strengthening work would therefore not necessarily need to wait for a separate prior assessment of the current levels of seismic restraint.

It is considered that both the physical mitigation of risk and the gathering of additional seismic information need to be progressed in parallel, and this project proposes a risk prioritisation framework that reflects this. The commencement of much-needed seismic mitigation work in some buildings should not be held back while further information is gathered.

In the prioritisation and planning of seismic upgrade work, it is important to acknowledge that seismic risk is only one consideration, alongside a range of clinical and asset management considerations. Addressing the seismic vulnerability of hospital buildings must always have due regard to other needs, opportunities and constraints.

Key Observation 12:

A Seismic Policy is required to outline the expectations and requirements for hospital buildings, supported by a Seismic Risk Management Strategy to establish the basis and priorities for managing buildings with identified seismic vulnerabilities

Currently, each DHB makes decisions in relation to managing seismic risk that respond to aspects such as their own situation, professional advice and the availability of operational and capital funding.

To create a systematic risk management basis for implementing this work, the development of a *Seismic Policy* (seismic performance objectives and expectations) and a

Seismic Risk Management Strategy (implementation approach and priorities) that is integrated with asset management and infrastructure risk management approaches is recommended. Site-specific Seismic Risk Management Plans (akin to the current Asbestos Risk Management Plans) could then follow, providing the key linkage with campus infrastructure.

A comprehensive seismic policy, supported by a seismic risk management strategy outlining implementation pathways, would provide a clear basis for Health New Zealand as it takes over the hospital portfolio.

Key Observation 13:

Seismic performance objectives and expectations for new and strengthened hospital buildings need clearer definition

New IL4 buildings are specifically designed to achieve both *life safety* and *building functionality* objectives. Although the life safety objectives for new IL4 buildings in rare (2,500 year return period) earthquakes are clear, the corresponding objectives for the arguably more important *building functionality* in major (500 year return period) earthquakes are much less clearly defined, particularly for hospital buildings delivering acute medical services.

The corresponding objectives, expectations and requirements for <u>existing</u> IL4 buildings are also not defined. The objective of a building being usable following a 500 year return period earthquake doesn't correspond to a 'no damage' requirement, but the reality is damage or disruption to even small elements of many hospital facilities can be sufficient to make the building unusable.

Having performance objectives defined for new buildings is actually a key input for the assessment of into existing buildings, as it sets the scene for understanding how the likely response of the building will impact on key medical functions. This is therefore a priority activity with respect to further seismic assessments as well as for the protection of forthcoming new building investment.

Key Observation 14:

There is a need for national technical guidance for both the strengthening of existing and the design of new hospital facilities

There is currently no specific guidance in New Zealand for achieving the *operational continuity* objective for IL4 buildings generally. Furthermore, there is no specific guidance for design practitioners for either new or existing hospital buildings where they are upgraded.

In the education sector, the Ministry of Education has produced specific guidance for those involved in the design of new school buildings and the assessment of existing buildings. Entitled *Structural and Geotechnical Requirements*, this guidance highlights areas where the Ministry requires structural and geotechnical engineers to go beyond the minimum requirements of the Building Code. This document was the first New Zealand document to define specific design parameters aimed at limiting damage from earthquakes to defined repairability limits, covering both primary structure and non-structural elements.

The general scope and form of the Ministry of Education's technical guidance is provides a useful reference framework for the corresponding guidance for hospital buildings, particularly the approach to low damage design. However the different operational context of hospital buildings warrants specifically written technical guidance. The added complexity of the IL4 building requirement for hospital buildings to ensure *continued functionality* in 500 year return period earthquake shaking also requires additional and new material to address this.

National technical guidance for both the strengthening of existing and the design of new hospital facilities (across all importance levels) is therefore required.

A small panel of leading engineers with appropriate experience in the engineering design and seismic assessment of hospital buildings should be established to develop this guidance. This group should also review and refine the approach to evaluating non-structural elements proposed in this report.

Key Observation 15:

Hospital emergency plans should more clearly define the post-earthquake decision-making process relating to alternative facilities

Given the observation that there is a high likelihood of having key facilities rendered unusable due to damage to non-structural elements in earthquakes, hospital emergency plans must clearly outline the post-earthquake decision-making and implementation process. This should include nominated alternative facilities with reasonable degrees of resilience and appropriate backup infrastructure.

It is important to acknowledge that there are no absolutes. Even for new IL4 buildings there is always the possibility that some local damage occurs that renders the building unusable for a period of time.

A decision to continue to deliver services in a damaged building or evacuate to an alternative facility is a significant one that needs to take into account a number of clinical and functional considerations and compromises.

A national decision-making framework to address this in a consistent way could be developed by Health NZ.

Key Observation 16:

Specific Priority Response Agreements need to be formalised with engineers to ensure effective post-earthquake responses

As part of hospital emergency planning, it is essential that specific arrangements are in place with engineering consultants to respond to any earthquake event as required.

While most DHBs have well-established relationships with consulting engineering practices for the supply of a range of professional engineering services, their engagement agreements typically don't include specific provision for post-disaster response. Where this aspect is included, it is typically only at the practice level rather than with individual engineers, and with specific expectations and arrangements only rarely addressed.

The specific response expectations and mechanisms need to be clearly mapped out, including outline inspection plans and the nature of initial reporting. This typically requires annual 'readiness' to ensure the currency of the arrangements, and the response arrangements for the engineers should be integrated within hospital emergency response plans.

The option of having seismic instrumentation installed in hospital buildings should also be considered. This could reduce the time taken by engineers to evaluate the response of the structure to significant earthquake shaking, hence hastening re-occupancy decisions.

12. Summary and Recommendations

More information is needed to fully understand the extent of the seismic vulnerability of public hospital buildings in New Zealand, particularly for those with Importance Level 4 functions. However, notwithstanding the overall incompleteness of seismic information currently held, there is a need to actively progress seismic risk mitigation in public hospital buildings.

In accordance with the brief, much of this report focuses on buildings as individual structures, and the associated regulatory linkages. It is however fundamental that a campus-wide approach to both buildings and infrastructure is adopted. Part of this involves understanding the difference between *meeting minimum building regulatory requirements* and *achieving the necessary levels of resilience across a hospital campus* (extending to regional and national levels, where necessary) to ensure the delivery of emergency medical services to the community following major adverse events.

In many cases, currently low rating hospital buildings will need to continue to be used for some years until replacement facilities can be constructed. In most situations this is likely to be acceptable from a life safety risk perspective, provided that clear timelines and expectations are established, documented and managed. Buildings with potentially brittle failure mechanisms affecting the primary structure should however receive specific consideration. The expectation that a number of hospital buildings may not be usable immediately following a major earthquake requires a stronger focus on alternative facility identification and post-earthquake decision-making in hospital emergency plans.

We provide 23 recommendations in the table on the following pages grouped under the following key themes:

1. Update seismic information to address gaps and reliability issues
2. Prepare technical guidelines for designing new and assessing existing hospital buildings for Health New Zealand
3. Establish a framework to enable the systematic categorisation of seismic vulnerabilities and identification of information gaps
4. Develop a Seismic Policy and Seismic Risk Management Strategy for Health New Zealand
5. Actively progress seismic risk mitigation
6. Ensure that hospital emergency plans provide greater emphasis and clarity around early post-earthquake decision-making
7. Establish specific arrangements with engineers for post-earthquake response at each main hospital

The overall aim of the recommendations is to enable a comprehensive and systematic approach to ***understanding and improving the seismic resilience of hospital buildings***.

The majority of these recommendations require adoption and implementation by Health NZ. Preparatory work can however be undertaken in several areas prior to the formation of Health NZ.

Theme		Recommendation
1. Update seismic information to address gaps and reliability issues	1.1	Update the status of current DHB seismic assessment information held by the HIU, with emphasis on clarifying the date and type of seismic assessments
	1.2	Re-analyse the seismic assessment information to enable the reliability of the information to be taken into account
	1.3	The interpretation of the Importance Level definitions outlined in this report should be adopted by the Ministry of Health/ Health New Zealand to ensure that seismic ratings are based on the appropriate Importance Levels
	1.4	Provide tools such as briefing and report summary templates to support DHBs in obtaining additional seismic information
	1.5	Establish a process and programme for obtaining additional seismic information, giving priority to those IL4 buildings that have not had any seismic assessments to date
	1.6	Develop a plan and approach to obtain information on the seismic status of non-structural elements, giving priority to acute services buildings with high seismic ratings for primary structure
2. Prepare technical guidelines for designing new and assessing existing hospital buildings for Health New Zealand	2.1	Establish a specialist engineering panel (eg the Health Engineering Strategy Group) to prepare technical guidelines for designing new and assessing existing hospital buildings
	2.2	Establish seismic performance objectives for new and strengthened hospital buildings, covering both *life safety* and *building functionality*
	2.3	Confirm the scope and key elements of the technical guidance for practitioners required to support the *Seismic Policy* and *Seismic Risk Strategy*
	2.4	Develop a process for evaluating the seismic vulnerability of site-wide infrastructure that interfaces with both the building-based non-structural element evaluation processes and with external service providers
	2.5	Prepare a briefing template for consulting engineering practices undertaking seismic strengthening designs, and a template for summarising the strengthening scope and outcomes at the various stages of design

3. Establish a framework to enable the systematic categorisation of seismic vulnerabilities and identification of information gaps	3.1	Adopt the proposed risk categorisation to identify priority categories of hospital buildings for seismic upgrade or replacement, and where additional seismic information is required
	3.2	Extend the proposed risk categorisation to reflect overall campus-wide seismic vulnerability
4. Develop a Seismic Policy and Seismic Risk Management Strategy for Health New Zealand	4.1	Develop a *Seismic Policy* to outline the expectations and requirements for new and strengthened hospital buildings and for managing buildings with identified seismic vulnerabilities
	4.2	Develop a *Seismic Risk Management Strategy* to implement the recommendations from this report in accordance with the requirements of the Seismic Policy
5. Actively progress seismic risk mitigation	5.1	Establish a seismic risk mitigation programme that utilises the seismic priority categories identified in this report and reflects overall campus-wide seismic vulnerability (including infrastructure) and the consequences for the community of key hospital buildings not being able to function following earthquakes
	5.2	Prepare guidance for how natural hazards and other risks should be addressed in hospital Site-wide Master Planning
	5.3	Adopt the checklist proposed for seismic information to be included in business cases for the upgrades of existing hospital buildings
6. Ensure that hospital emergency plans provide greater emphasis and clarity around early post-earthquake decision-making	6.1	Update hospital emergency plans to provide greater clarity on early stage post-earthquake decision-making for key acute services functions
	6.2	Ensure that nominated alternative facilities have a reasonable level of seismic resilience and appropriate emergency backup infrastructure
7. Establish specific arrangements with engineers for post-earthquake response at each main hospital	7.1	Ensure that post-earthquake response arrangements for engineers are incorporated within hospital emergency plans
	7.2	Develop a common template for Priority Response Agreements with engineers for post-earthquake response
	7.3	Consider installing seismic instrumentation to key acute services buildings to provide information to support responding engineers and facilities managers with re-occupancy decisions

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Appendix A: Terminology, Seismic Hazard and Earthquake Risk

A1: Terminology

EPB - Earthquake-Prone Building

A legally defined category which describes a building that has been assessed as likely to have its ultimate capacity exceeded in moderate earthquake shaking (which is defined in the regulations as being one third of the size of the shaking that a new building would be designed for on that site).

ERB - Earthquake Risk Building

A general description developed by the New Zealand Society for Earthquake Engineering for buildings that are rated as being less that 67%NBS – i.e. representing more than twice the risk of a new building.

***%NBS* - New Building Standard**

New Building Standard (NBS) is intended to reflect the expected seismic performance of a building relative to the minimum life safety standard for a similar new building on the same site required by the New Zealand Building Code as at 1 July 2017.

An indication of the size of earthquake that a building could theoretically withstand if it had a %NBS rating of less than 100% is provided in the following table:

IL Rating	**30% NBS**	**50% NBS**	**75% NBS**	**100% NBS**
IL4 Building	≈ 100 year return period	≈ 400 year return period	≈ 1000 year return period	2500 year return period
IL3 Building	≈ 75 year return period	≈ 200 year return period	≈ 500 year return period	1000 year return period
IL2 Building	≈ 40 year return period	≈ 100 year return period	≈ 250 year return period	500 year return period

ISA - Initial Seismic Assessment

The recommended first qualitative step in the overall assessment process (including the Initial Evaluation Procedure, IEP). An ISA provides a broad indication of the likely level of seismic performance of a building.

IEP - Initial Evaluation Procedure

The principal engineering tool for carrying out an Initial Seismic Assessment.

DSA - Detailed Seismic Assessment

A quantitative assessment and report by structural engineers, with appropriate geotechnical engineering input. It involves calculations and typically also involves structural computer modelling.

DDE - Detailed Damage Evaluation (previously referred to as Detailed Engineering Evaluation)

This evaluation is only undertaken in a post-earthquake (recovery) context. It encompasses both qualitative and quantitative approaches.

SW and CSW - Structural Weakness, Critical Structural Weakness

A Structural Weakness is any weakness in the building structure that could potentially influence its performance at any level of earthquake shaking. One of the outcomes of an ISA is to identify potentially Critical Structural Weaknesses, and a DSA evaluates these to determine the governing Critical Structural Weakness. These may be rated as *insignificant*, *significant* or *severe*.

A2: Seismic Hazard

The seismic hazard factor, Z, is specified in the New Zealand Standard, NZS 1170.5 and is derived from the GNS National Seismic Hazard Model that considers the NZ earthquake record, known fault characteristics and allows for uncertainty.

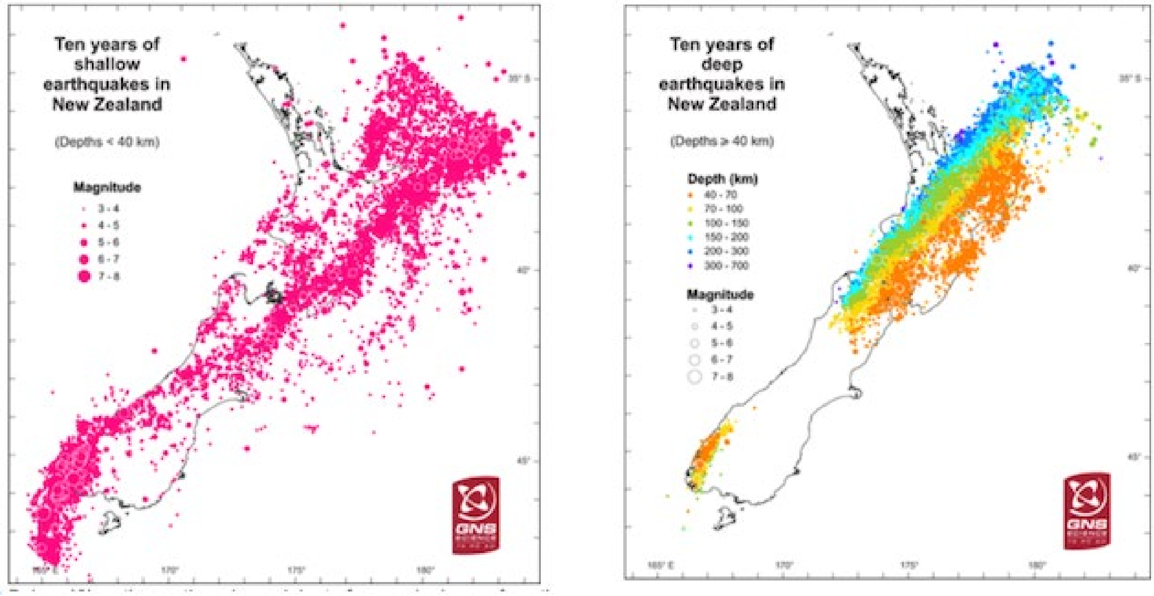

Figure A1: Recent earthquake activity (GNS)

Figure A2: New Zealand Faults (GNS Active faults database)

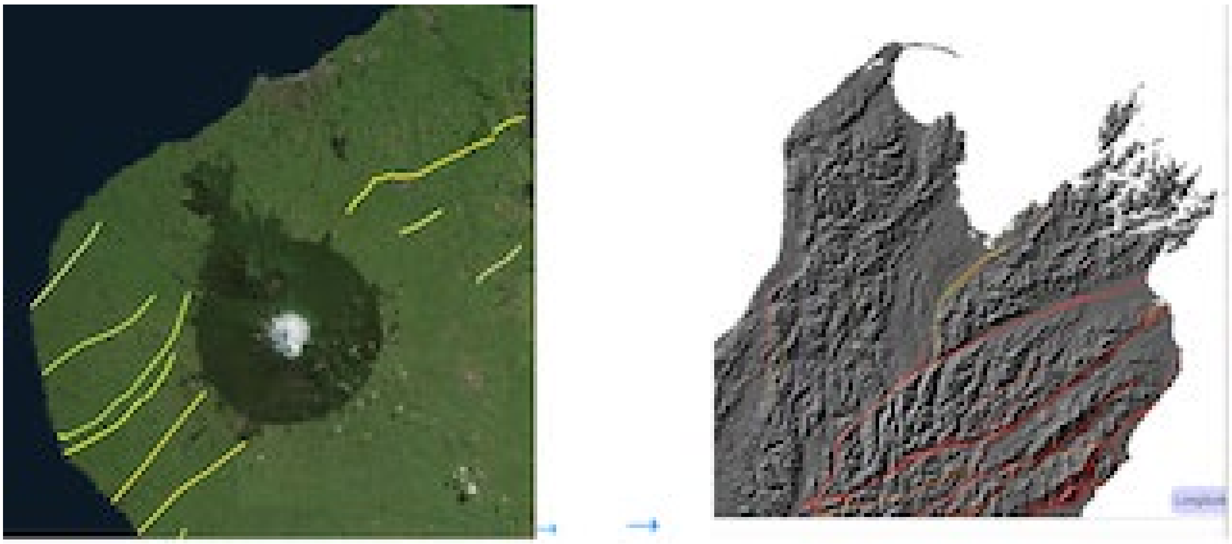

Figure A3: Comparison of known active faults between Taranaki and Nelson (GNS Active fault database)

Note: Nelson, with a hazard factor of 0.27 lies directly on the Waimea-Flaxmore fault system and is within 40 km of the Wairoa-Alpine fault extension. New Plymouth, with a hazard factor of 0.18 is approximately 20 km from the Inglewood fault and 30 km from the Cape Egmont fault, both low slip and long return period faults.

A3: Earthquake Risk

Each earthquake is unique and will impact structures differently. Earthquake risk (both life safety and damage) will depend on a number of factors, including: the likelihood of an earthquake occurring; the intensity, duration and pattern of shaking (dependent on factors such as distance from the earthquake source, fault characteristics, the direction of rupture, the magnitude of the earthquake, geomorphology, the type of ground the structure is situated on and the ground the earthquake waves have travelled through); the structural capacity of the structures and their components and services; the design assumptions made as to how the structures (ductility/flexibility) will respond in an earthquake; and whether there are any structural weaknesses.

Existing Building Risk

Table A3.1 below, from the Seismic Assessment Guidelines, provides the approximate relative seismic risk to occupants or to neighbouring buildings relative to the building that meets the minimum performance standard required by the New Zealand Building Code. The risk descriptions can be considered to be relative life safety risks if a large earthquake occurs.

Table A3.1: Assessment outcomes (potential building status)

Percentage of New Building Standard *(%NBS)*	Alpha rating	Approx. risk relative to a new building	Life-safety risk description
>100	A+	Less than or comparable to	Low risk
80-100	A	1-2 times greater	Low risk
67-79	B	2-5 times greater	Low to Medium risk
34-66	C	5-10 times greater	Medium risk
20 to <34	D	10-25 times greater	High risk
<20	E	25 times greater	Very high risk

Appendix B: Template for Inventory and Assessment of Non-Structural Components

Template for Inventory and Assessment of Non-Structural Components (IL4 Buildings only)

Building Name and Campus ID: ____________________

Non Structural Component	Applicability (tick rows that will affect continuing functionality) ✓	Location within building (identify locations within building where element failure would affect critical hospital operations)	Element Functionality (not applicable for shaded cells)				Building Functionality (worst of the three) CF_{likely}, $CF_{uncertain}$ or $CF_{unlikely}$	Comments
			Non-structural restraint 1, 2, 3	Non-structural movement detailing 1, 2, 3	Internal capability 1, 2, 3	Review of Consequences		
Heavy Non-structural elements (should be identified in post July 2017 Detailed Seismic Assessments)								
Emergency generator								
Chillers								
Boilers, furnaces, pumps								
Air handler units								
Transformers								
Batteries, battery rack								
Fuel tanks								
Structurally supported tanks and vessels								
Lift, cables, counterweights, guiderails								
Escalator								
Heat pumps/heat exchangers								

Non Structural Component	Applicability (tick rows that will affect continuing functionality) ✓	Location within building (identify locations within building where element failure would affect critical hospital operations)	Element Functionality (not applicable for shaded cells)				Building Functionality (worst of the three) CF_{likely}, $CF_{uncertain}$ or $CF_{unlikely}$	Comments
			Non-structural restraint 1, 2, 3	Non-structural movement detailing 1, 2, 3	Internal capability 1, 2, 3	Review of Consequences		
Concrete cladding panels								
Heavy light fixtures								
Heavy ceilings (panels >10kg)								
Masonry partitions								
Non-structural systems with established vulnerabilities								
Hazardous storage								
Fuel tanks								
Compressed gas cylinders (O_2, CO_2, NH_3, etc)								
Specialist medical gas equipment								
Fluid Piping								
Control panels, motor controls, switchgear								
Distribution panels								
Large computer and comms equip (speakers, monitors)								

Non Structural Component	Applicability (tick rows that will affect continuing functionality) ✓	Location within building (identify locations within building where element failure would affect critical hospital operations)	Element Functionality (not applicable for shaded cells)				Building Functionality (worst of the three) CF_{likely}, $CF_{uncertain}$ or $CF_{unlikely}$	Comments
			Non-structural restraint 1, 2, 3	Non-structural movement detailing 1, 2, 3	Internal capability 1, 2, 3	Review of Consequences		
Other Non-structural systems - services								
Fans/blowers/filters								
Air compressors								
Vents, flues								
Suspended fire protection piping, sprinklers & risers								
Motor, controls								
Cabling								
Electrical raceways, cable trays								
Antennae								
Suspended ductwork								
Air diffusers								
Solar panels								
Suspended equipment								

Non Structural Component	**Applicability** (tick rows that will affect continuing functionality) ✓	**Location within building** (identify locations within building where element failure would affect critical hospital operations)	**Element Functionality** (not applicable for shaded cells)				**Building Functionality** (worst of the three) CF_{likely}, $CF_{uncertain}$ or $CF_{unlikely}$	**Comments**
			Non-structural restraint 1, 2, 3	**Non-structural movement detailing 1, 2, 3**	**Internal capability 1, 2, 3**	**Review of Consequences**		
Other Non-structural elements								
Glazed exterior (rigid glazing frames)								
Interior partitions (light)								
Light-framed cladding								
Suspended ceilings (light)								
Pendant light fixtures								
Computer access floors								
Exterior lighting								
Contents								
Conveyor								
Storage racks								
Hazardous storage								
Specialised medical equipment (list)								

Appendix C: Sample Template for Summarising Seismic Assessments

Executive Summary

This report presents the results of a seismic assessment completed for the following building for the XXX District Health Board. The report provides an assessment of the building's %NBS rating, highlights the key seismic risk features and includes outline recommendations for improvements to mitigate potential risks.

The table below presents a summary of the assessment findings.

Hospital	
Building or Block Name/ Ref	
Gross Floor Area (m^2)	
No. of Storeys	
Year of Design (approx.)	
Construction Type and Materials	
Is Building Interconnected?	
Building or Block Function	Surgery or emergency treatment services – Yes/ No:
	Health care buildings with a capacity of 50 or more residents and without surgery or emergency treatment services – Yes/ No:
	Office/ Accommodation/ Other – Yes/ No:
Importance Level	
Sub-soil Classification	
Key Geotech Considerations	
Date Building Inspected	
Extent of Inspections	
Assessment Type	Initial - Yes/ No:
	Detailed - Yes/ No:
Scope of Assessment	Secondary Structural Elements included:
	Non-Structural Elements included – list:
Date of Assessment	
Assessed Overall Ductility Capacity	
%NBS Rating	
List specific Critical Structural Weaknesses and Significant Life Safety Hazards	
Further Investigation/ Assessment Required	
Summary of Strengthening Recommendations	

[*Add any other relevant comments to assist in the understanding of the scope and outcomes of the assessment*

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