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Michael Fowler Centre - Life Safety Considerations

Dear Peter,

1 OCCUPANCY DECISIONS

We are providing this letter at WCC's request to aid in decision-making around continued occupancy of the Michael Fowler Centre (MFC). We have previously provided WCC our Detailed Seismic Assessment (DSA) of the building, along with conceptual strengthening solutions and possible interim temporary mitigation measures. Please refer to sections 2 and 3 below for further information on the outcomes of the DSA.

Decisions on occupancy of the MFC should be made using the process laid out in the MBIE document "Seismic Risk Guidance for Buildings" ("MBIE Seismic Risk Guidance"). The information presented in this letter is a part of that process but doesn't form a complete picture. Before making a decision on occupancy, several aspects need to be considered, as described in that document and below.

1.1 Comparative Risks

While a low %NBS rating does indicate a heightened life safety risk in the event that an earthquake occurs, it does not mean that the building is imminently dangerous. There is no legal requirement to close a building based solely on a low %NBS rating; there is a requirement to manage the risk of the building and take steps to improve it. WorkSafe have provided some guidance around occupying an earthquake-prone building in their document "Dealing with earthquake-related health and safety risks".

Compared to most business-as-usual risks, earthquakes are low probability. The annual fatality risk for a user of a regular (IL2) building that is just earthquake prone (i.e., has a 33%NBS_{IL2} rating) is estimated at 1 in 100,000. To help put that in context, flying in an aeroplane has an estimated annual fatality risk of approximately 1 in 700,000 and driving a car in New Zealand is estimated to carry a fatality risk of 1 in 20,000. Workers in New Zealand are estimated on average to have an annual fatality risk of 1 in 20,000 from accidents in the workplace.

Buildings such as the MFC are assigned a higher importance level (IL3 instead of IL2), because of the large number of occupants that may be exposed to risk at any one time. Because the %NBS rating is related to the importance level, this means that an IL3 building with the same rating as an IL2 building actually has a lower likelihood of damage. The MBIE Seismic Risk Guidance document suggests that short term occupancy decisions can be made on the basis that the building is an IL2 building, rather than IL3. This is because the difference between importance levels is the return period of the earthquake required to be considered. On a short timescale (e.g., the time after a building is determined to be Earthquake Prone but before the building is strengthened), the focus should be on life safety risk in the near term: that is considering earthquakes that are more frequent and hence smaller, and the reduced chance of a larger earthquake occurring over that shorter time period. Converting IL3 scores to IL2 scores is a convenient (albeit not entirely accurate) proxy for accounting for this shorter time period. IL3 scores can be converted to equivalent IL2 scores by multiplying by a factor of 1.3. For the MFC, the score conversions are:

Table 1. Conversion between IL3 and IL2

IL3 score	Equivalent IL2 score
20%NBS_{IL3}	26%NBS_{IL2}
25%NBS_{IL3}	33%NBS_{IL2}
30%NBS_{IL3}	39%NBS_{IL2}

It can also be relevant to consider the aggregate risk of occupying a building over a reduced timeframe. Assessments are, for consistency, all made against the same benchmark (50 year) building life. However, the aggregate risk of occupying an earthquake-prone building for a shorter time may be no greater. For example, occupying the MFC at 20%NBS_{IL3} over a five-year time period has approximately twice the risk of an equivalent new IL3 building over its 50-year design life (noting that this is still a very low risk) [1]. A 20%NBS_{IL3} rating corresponds to earthquake shaking with a 30-year return period (a new IL3 building would be designed for a 1000-year return period).

In practical terms, this could mean that, subject to understanding and accepting the possible consequence of failure, occupying a building over a shortened timeframe while strengthening plans are developed and/or alternative facilities are identified and brought on-stream, can be a viable risk management approach.

1.2 Ongoing risk

Seismic risk cannot be eliminated. Even if a building is vacated, staff and building users will be exposed to seismic risk in their homes and other buildings.

While planning seismic remediation work, risk to staff and other building users can be mitigated through emergency planning and training as well as restraining plant, services and contents within the building. Temporary mitigation measures can be instituted where appropriate to reduce life safety risk. These can be structural, such as the ones noted in our memo of 24 March 2023, or they could be operational or management mitigations, such as restricting access to areas of the building or relocating staff that might otherwise occupy the building for longer durations (e.g., a full 40hr+ working week).

When making decisions on occupancy, impact to the community should also be considered, as well as the context of the status of strengthening works to other buildings with similar functions (e.g., the Wellington Town Hall, the Opera House, etc). A risk management plan could be put into place that accounts for strengthening priorities, the availability of alternative venues, and the wider consequence of any closure

[1] This comparison uses the current NZS1170.5 probability curves and does not consider any research used to update the National Seismic Hazard Model in 2022. This relationship may or may not hold with the updated understanding of the local hazard.

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decisions on the community. Communication with building users is also a key component of managing earthquake risk, and this is covered in some detail in the MBIE Seismic Risk Guidance document.

2 DETAILED SEISMIC ASSESSMENT

A DSA under the framework of the *Seismic Assessment of Existing Buildings Technical Guidelines* ("the Guidelines") is a means for engineers to assess and describe the performance of buildings under various seismic events. From the Guidelines:

> *These guidelines focus the assessment on life safety issues as the primary objective. This means that the earthquake scores or rating are based primarily on life safety considerations rather than damage to the building or its contents unless this might lead to damage to adjacent property. … There are two general forms of life safety hazard to consider; when the ultimate capacity of the building, a section of the building or a primary structural element is exceeded to the extent that a significant life safety issue arises, or when a falling secondary structural or non-structural (SSNS) building element poses a significant life safety hazard.*

Each individual structural member of a building is assessed for the level of earthquake shaking that creates a significant life safety hazard (a significant life safety hazard is an unavoidable danger that a number of people are exposed to). This level of shaking is then related to a benchmark percentage of New Building Standard (%NBS), which is that member's seismic score. The lowest score determines the seismic rating of a building (also reported in %NBS).

A DSA does not necessarily consider the exceedance of a structural member's design capacity as sufficient to create a life safety hazard; the member must fail in a manner to plausibly endanger people's lives before it is considered a life safety hazard. For example, a structural member could fail but still be held in place by other parts of the building, which would restrain it from falling; it would not be considered a life safety hazard in this case. The manner of failure is also reflected in its score; a member which has the ability to deform in a reliable manner (ductile) can withstand higher levels of shaking than a member which fails in a sudden manner (brittle).

%NBS results should be considered in the context of the Guidelines and are an index or relative rating compared to an equivalent new building on that site. It is not a predictor of building performance in any given earthquake. For example, the 2016 Kaikoura earthquake had a peak ground acceleration that corresponded to 40%NBS_{IL3} (52%NBS_{IL2}), and many buildings that were assessed below that threshold had little to no damage in that event, including the MFC.

3 RESULTS OF THE DSA

The MFC is made up of four distinct structures: the Auditorium, the Renouf Foyer, and two Independent Staircase Structures. The overall rating of the MFC is 20%NBS_{IL3}, governed by the following elements:

- the sloping transfer diaphragm below the Level 2 seating in the Auditorium (referred to as Level 1/2),
- the diaphragm chord tie across the promenade at Level 2 of the Auditorium,
- the diaphragm over the double-tee flooring at Level 2 in the lobby area of the Auditorium,
- the diaphragm over the double-tee flooring at Level 4 around the promenades of the Auditorium,
- the roof diaphragm of the Auditorium, and,
- the Level 2 diaphragm in the Renouf Foyer.

There are also localised elements with a similar seismic score (<34%NBS_{IL3}) identified in the following locations:

- the wall panels at the upper precast portion of the bay walls,

- the precast concrete cladding infill panels between the upper precast portion of the bay walls,
- the roof trusses of the Auditorium,
- the promenade roofs and facades around the building,
- the catwalk structure in the Auditorium, and,
- the wall reflectors in the Auditorium.

We have excerpted the results of the DSA in part in section 4 below, with some additional commentary on the consequence of failure. Please refer to the Holmes DSA for more detailed information.

The Guidelines provide some descriptive guidance on the life safety risk of a building based on its rating, see Figure 1 below. Note that these risks are relative to a new building, and the likelihood of a given earthquake is still very small. Using this table, the Holmes DSA concluded that the Michael Fowler Centre has an approximate risk of 10-25 times greater than that of a new building, or expressed in another way, has an estimated 1 in 40,000 to 1 in 100,000 annual fatality rate.

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

Figure 1. Table A3.1 from the Guidelines

4 APPLYING A CONSEQUENCE LENS

We have excerpted the elements from the DSA with scores less than $34\%NBS_{IL3}$ and added some commentary on the nature of the vulnerability in Table 2 below. This table is a synthesis of information from various reports previously presented (DSA Table ES-1, DSA Appendix A).

In this table, we have noted the locations affected by various vulnerable elements. We have provided a template for WCC to fill in information about the number of people who occupy these areas, the frequency with which they occupy it, and the duration of that occupancy. This data is critical for understanding the exposure to the risk described in the table below and in the DSA. We understand that this data is being gathered by WCC, and we're happy to help synthesise that data with ours to aid in future decision-making processes.

Please refer to our memo of 24 March 2023, which describes possible temporary structural mitigation measures, noting that most of the low hanging fruit has already been addressed through previous interventions over the years. Some of this temporary work could be eventually integrated with future strengthening work if so desired. Non-structural mitigation measures should also be considered.

Table 2. Description of vulnerabilities and their consequences

Building	Building Element	$\%NBS_{IL3}$	Physical Consequences / Modes of Failure	Zone Affected	Approx. Number of People Affected	Frequency of occupancy	Duration of occupancy
Auditorium	Sloping transfer diaphragm at Level 1/2	15 – 20	Diaphragms are used to distribute loads and hold the vertical structure together. Here, they are expected to deteriorate when subjected to large and prolonged earthquake shaking, leading to unpredictable behaviour and possible loss of lateral support of the auditorium walls, which could potentially lead to them falling, along with structure they support such as parts of the roof and floors,	Auditorium (internal and external)			
Auditorium	Level 2 promenade diaphragm	20	Diaphragms are used to distribute loads and hold the vertical structure together. Here, they are expected to deteriorate when subjected to large and prolonged earthquake shaking, leading to unpredictable behaviour and possible loss of lateral support of the auditorium walls, which could potentially lead to them falling, along with structure they support such as parts of the roof and floors,	Auditorium (internal and external)			
Auditorium	Double-tee flooring at Level 2 in the lobby area	25	Diaphragms are used to distribute loads and hold the vertical structure together. Here, they are expected to deteriorate, leading to unpredictable behaviour, which could allow the structure to spread apart, potentially leading to the precast floor units losing their seating and falling inside the building.	Lobby area at Ground and Level 2			
Auditorium	Roof diaphragm	20 – 30	Diaphragms are used to distribute loads and hold the vertical structure together. Here, the roof diaphragm is expected to deteriorate, leading to unpredictable behaviour, which could lead to: ▪ Buckling the top chords of the roof trusses, potentially leading to loss of gravity support by the roof trusses and falling inside the building. ▪ Failure of the connection between the roof trusses and the perimeter wall, potentially leading to the roof	Auditorium (internal and external)			

Building	Building Element	%NBS$_{IL3}$	Physical Consequences / Modes of Failure	Zone Affected	Approx. Number of People Affected	Frequency of occupancy	Duration of occupancy
			trusses losing their seating and falling inside the building. ▪ Cracks forming in the diaphragm, allowing the trusses to separate and potentially leading to precast roof units losing their seating and falling inside the building. ▪ Redistribution of seismic loads to the perimeter buttress walls leading to loss of integrity of the walls which could potentially lead to them falling, along with structure they support such as parts of the roof and floors				
Auditorium	Roof trusses	25	Roof trusses are locked into walls, leading to excessive forces in the truss members and overloading them. This could lead to the outermost parts of the trusses separating, potentially leading to perimeter precast roof units losing their seating and falling inside the building.	Auditorium (internal perimeter, near the front and back)			
Auditorium	Level 4 wedge-shaped diaphragm of promenade floor and stepped seating	25	Diaphragms are used to distribute loads and hold the vertical structure together. Here, they are expected to deteriorate, leading to unpredictable behaviour, which could allow the structure to spread apart, potentially leading to some precast floor units losing their seating and falling inside the building.	Lobby area at Level 2 and Level 4			
Auditorium	Bay walls (upper precast wall panels)	25	Wall panels are overloaded, leading to cracking and spalling of the concrete section which could potentially lead to them falling, along with structure they support such as parts of the roof.	Auditorium (internal and external)			
Renouf Foyer	Level 2 diaphragm	25	Diaphragms are used to distribute loads and hold the vertical structure together. Here, they are expected to deteriorate, leading to unpredictable behaviour, which could allow the structure to spread apart, potentially	Renouf Foyer Ground (drive aisle) and Level 2			

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Building	Building Element	%NBS$_{IL3}$	Physical Consequences / Modes of Failure	Zone Affected	Approx. Number of People Affected	Frequency of occupancy	Duration of occupancy
			leading to some precast floor units losing their seating and falling inside the building.				
Auditorium (non-structural)	Catwalks structures	20-30	Bracing members and connections to wall are overloaded, potentially leading the catwalk to fall into the Auditorium.	Area directly beneath the catwalk structure in the Auditorium			
Auditorium (non-structural)	Wall reflectors	20	Bracing members and connections to wall are overloaded, potentially leading to the reflector falling.	Areas directly beneath wall reflectors in the Auditorium			
Auditorium (non-structural)	Promenade roof & façade system	25	Façade system is overloaded, leading to glazing panels falling.	Areas adjacent to façade			
Auditorium (non-structural)	Precast infill panels between the upper precast portion of the bay walls	25	Precast panels are locked into walls, potentially leading to overloading of bolted connections and the panels falling.	Perimeter of Auditorium (internal and external)			

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5 NEXT STEPS

We encourage WCC to carefully step through the process laid out in the MBIE Seismic Risk Guidance. Remaining steps include understanding the exposure to the vulnerable elements of building (further to the information presented above), evaluating how long remediation may take (based on Holmes Concept Strengthening), identifying the overall life safety risk, and understanding the consequences of building closure. Once these have been understood, a strategy to manage the risk can be identified. We suggest that this strategy should be couched within a broader risk management framework and set of strategic objectives that the MFC can be referenced against, and is consistent with.

We are happy to contribute to workshops discussing the merits of various strategies, and can also assist with collation and presentation of data related to the occupancy. We understand WCC are liaising with Dave Brunsdon at Kestrel Group, and we are happy to collaborate with him to help WCC make an appropriate decision on the next steps at the MFC.

Yours sincerely,

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