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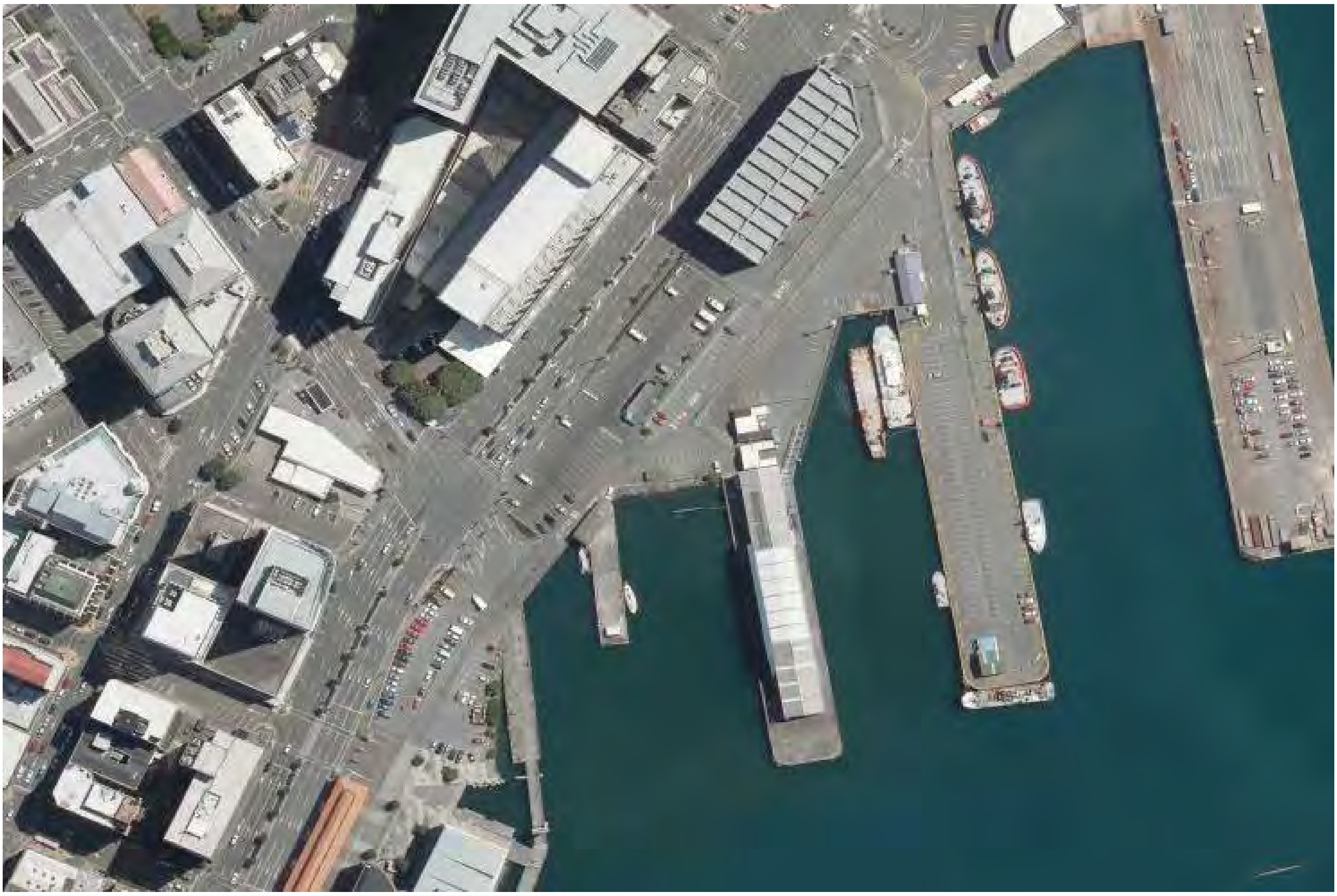
Report

Site 10 - Kumutoto - Natural Hazards Assessment

Prepared for Willis Bond & Co

Prepared by Beca Ltd (Beca)

22 October 2014



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A	Richard Sharpe	First draft	16/08/2014
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C	Rob Crosbie	Third Draft	16/10/ 2014
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Document Acceptance

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on behalf of	Beca Ltd		

Executive Summary

Beca Ltd (Beca) has been commissioned by Willis Bond & Co on behalf of the Site 10 Redevelopment Limited Partnership to provide an assessment of climate change/sea-level rise issues with respect to the currently proposed development of Kumutoto-Site 10 on the Wellington waterfront.

The datum used for all levels referenced is the “New City Datum” which is the same level as “Mean Sea Level” and “1953 Wellington Local Datum”.

The site and adjacent wharf are at a level of approximately 2.0 m above New City Datum (NCD).

The proposed building has a ground floor level of 2.50 m above NCD and a basement level 1.1 m below NCD.

The average (measured/observed) mean sea level is currently about 0.170 m above the datum.

A design life for the Normal Importance building is assumed to be 50 years for mitigation of risks from natural hazards (in accordance with the New Zealand Building Code).

For predicted sea-level rise from climate change, it is suggested that a 100-year life be considered for impacts as this is a realistic estimate of the development’s economic life.

Published contributions on sea-level rise to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Climate Change 2013: The Physical Science Basis) predict a mean sea-level rise of about one metre above present levels in 100 years.

If a one metre sea-level rise over 100 years is considered (which would require a six-fold increase in the long-term average rate of sea-level rise over the past 100 years), then in combination of other effects it is possible but unlikely that the site itself will be inundated. There is a low likelihood of the ground floor of the proposed building being inundated on occasions in the second 50-year period of the building’s life under extreme sea-level events in combination with sea-level rise.

However, it should be noted that the inundation that affects the site and the proposed building will also affect much of Waterloo Quay and the CBD to the west of the site to the same extent.

Latest predictions for a tsunami height consistent with a probability of exceedance used for life-safety design for earthquakes would inundate the proposed building to about the first (elevated) floor level.

For both sea-level height and tsunami inundation, the same levels of inundation could be expected to the west of the site to Lambton Quay.

The proposed base isolation system for the superstructure provides a pragmatic possibility for the superstructure to be lifted in the future if the predictions of sea-level rise from climate change are realised. The basement could be protected by additional bunding, or other protective mechanisms.

Contents

Appendix

1 Introduction

Beca Ltd (Beca) has been commissioned by Willis Bond & Co of behalf of the Site 10 Redevelopment Limited Partnership to provide an assessment of climate change/sea-level rise issues with respect to the currently proposed development of Kumutoto-Site 10 on the Wellington waterfront.

The proposed development as described to us is a five-storey base-isolated building on an underground basement as described in Athfield Architects Limited's drawings P0.01-03 &10 and P3.01-02, Dunning Thornton Consultants' drawings P-H01-03 show historical seawall and fill information, and P-S20-02 Rev C shows a typical cross-section of the proposed structure.

It is appropriate to look at the same time at the possible impacts of long-term sea-level rise, storm surge, wave height and tsunami.

While our scope of work does not cover the stability of the foundation soils in an earthquake, it is appropriate to relate the tolerable impacts of the sea-related hazards to those currently accepted for earthquake.

We have considered whether the proposed project has particular vulnerabilities to each of these hazards, and assessed whether there is a need for the risk to be mitigated to appropriate levels.

2 Data Sources

2.1 The Building

The footprint of the proposed building is described on the architect's drawings which also show the ground floor level as 2.50 m with respect to the New City Datum (NCD), and the basement level was 1.1 m below NCD.

"New City Datum", "Mean Sea Level", and "1953 Wellington Local Datum" have the same datum.

The average (measured/observed) mean sea level is currently about 0.170 m above the datum.

The Wellington Standard Port Zero Datum, referenced by New Zealand Tide Tables, is 0.915 m below the New City Datum.

The existing ground and wharf structures on the seaward side of the site are generally 2.0 m to 2.6 m above NCD, with some localised areas adjacent Waterloo Quay around 1.9 m above NCD. Figure 1 (below) indicates the relationship between these and the proposed building.

While the ground surrounding the building is reclamation fill placed between 1893 and 1970, the proposed building is to be founded on firmer material below the original sea bed.

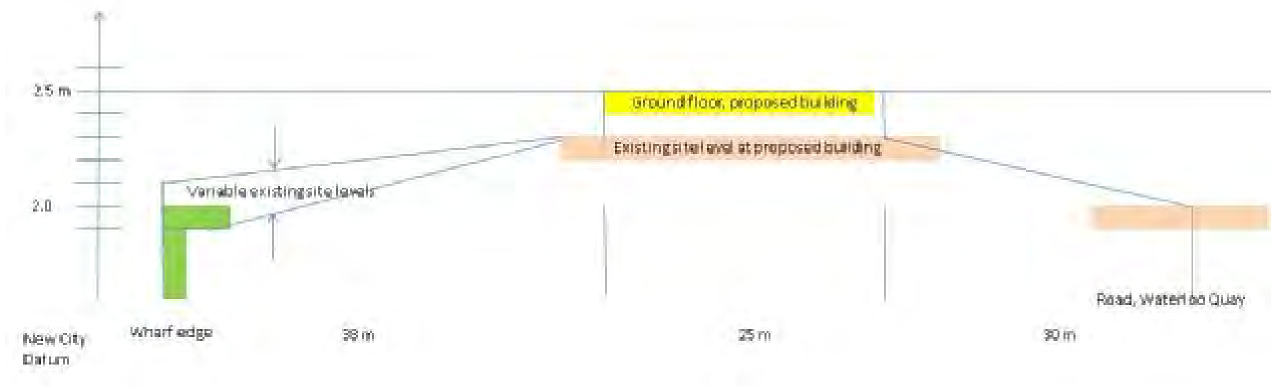


Figure 1: North-south cross-section through the centre of the site

2.2 Acceptable Risk

New Zealand Standard AS/NZS 1170.0 (Tables 3.1 and 3.2) [1] provides an authoritative guide as to acceptable probabilities of exceedance of design events for life-safety. This Standard is a Compliance Document (Verification Method) under the New Zealand Building Code [2].

The proposed development is classed as a Normal structure Importance-wise, and by default has a Design Life of 50 years. Design events for life-safety for earthquake and wind for such a structure are those that will be exceeded on average at least once every 500 years. For snow, the corresponding return period is 150 years. A 500-year return period corresponds approximately to a 10 % probability of exceedance in the 50-year Design Life [1]. This return period can be considered an appropriate reference for design for life-safety from other rare natural hazards such as tsunami, storm surge and seiching.

Section E1.2 of Clause E1-Surface Water of Schedule 1 of the New Zealand Building Regulations 1992 states the functional requirement that “Buildings and sitework shall be constructed in a way that protects people and other property from the adverse effects of surface water.”

Section E1.3.1 has the general performance requirement that “surface water resulting from an event having a 10 % probability of occurring annually and which is collected or concentrated by buildings or sitework shall be disposed of in a way that avoids the likelihood of damage or nuisance to other property.” (Return Period for 10 % probability of exceedance in 1 year is 10 years).

Section E1.3.2, which does not apply to commercial buildings, states that “Surface water, resulting from an event having a 2 % probability of occurring annually, shall not enter buildings.” (Return Period for 2 % probability of exceedance in 1 year is 50 years).

The Intergovernmental Panel on Climate Change [8] believes that sea levels will rise with time. There are no central government statutory provisions in New Zealand specifically addressing the time period for which sea-level rise must be considered for the design of a particular building.

Policy 25 (Subdivision, use and development in areas of coastal hazard risk) of the New Zealand Coastal Policy Statement 2010 [10] addresses “areas potentially affected by coastal hazards over at least the next 100 years”. While the Design Life of a building is set at 50 years, it seems reasonable to consider sea-level rise be considered over a period of 100 years consistent with the New Zealand Coastal Policy Statement. The average of the current predictions for Mean Sea Level in 100 years’ time then becomes the basis for this assessment.

The Ministry for the Environment's *Coastal Hazards and Climate Change: A Guidance Manual for Local Government in New Zealand* (2nd Edition, 2008) [9], based on the IPCC Fourth Assessment Report [6], recommended for planning and decision timeframes out to 2090-2099 that:

1. A base value sea-level rise of 0.5 m relative to the 1980-1999 average should be used, along with:
2. An assessment of the potential consequences from a range of possible higher sea-level rises (particularly where impacts are likely to have high consequence or where additional future adaption options are limited). The Guidance Manual states that, at the very least, all assessments should consider the consequences of a mean sea-level rise of at least 0.8 m relative to the 1980-1999 average.

The Ministry for the Environment has yet to update their guidance following release of the IPCC's Fifth Assessment Report [8].

The Wellington City Council has released in October 2014 a report *Sea Level Rise Options Analysis* [12] which recognises that a sea level rise of 1 m over the next 100 years is considered likely.

2.3 Earthquake

Hazard: The seismic hazard is high in the Wellington region. New Zealand is considered to have a state-of-the-art model of seismic hazard and, for practical purposes, an up-to-date version of this underpins the New Zealand Loadings Standard [1]. This Standard also includes a methodology for calculating the greater shaking levels when the site is close to active faults such as the Wellington Fault. An associated hazard is the potential for the liquefaction of foundation soils in strong earthquake shaking.

Vulnerability: The location and nature of the proposed development.

Mitigation: The structural engineer is proposing a solution that:

- Provides a foundation down to suitable depths beneath the seabed to bear the loads of the development
- Uses tension piles to enhance the resistance to overturning of the superstructure
- Base isolates the superstructure at ground level.

Ground treatment works proposed by Dunning Thornton Consultants Ltd and Tonkin and Taylor Ltd are intended to mitigate the risk of liquefaction and lateral spreading on the site.

Compliance with the requirements of the Building Code should result in this proposed structure having a similar risk of earthquake damage to any other similar new structures now being built anywhere in New Zealand.

3 Tsunami

Hazard: The Institute of Geological and Nuclear Sciences Ltd's (GNS Science) 2005 review of New Zealand's exposure to tsunami has been recently updated (August 2013) by them [3]. This can confidently be considered to represent the best knowledge on this hazard with respect to the waterfront in Wellington.

The GNS report estimates that a tsunami will reach a height of 6.2 m (50 percentile) above the sea level at the time in the inner harbour area every 500 years on average. This is 1.3 m higher than predicted in the 2005 review, and the 16 and 84 percentile heights are 5.3 and 7.1 m, respectively. This estimate takes into account tsunami from all sources, and a majority of the hazard comes (probabilistically) from near-shore sources.

There is no certainty in how a tsunami of this height will manifest itself in the Lambton Harbour area. It could be expected that the narrowness of the harbour entrance will have a choke effect which would lead to a very rapid, swirling tide change over a number of minutes rather than a near vertical wave front. Nevertheless, it suggests that all of the central business district to the west of the proposed building would be inundated.

The inundation may peak for only a short time. The swirling waters may turn cars and boats into battering rams. Warnings (some hours) of a far-source event are now available through international monitoring systems, and these warnings are expected to be publicly made. Tsunami originating from near-shore events are likely to occur with a warning time of less than one hour (most less than 30 minutes), and it is most likely that the earthquake triggering such a tsunami would be felt in Wellington.

While GNS Science's update has looked at the effect of a tsunami generated by the impact of asteroids and comets (bolides), it was considered that such tsunami are too rare to be included in their probabilistic model.

Vulnerability: A tsunami with a 500-year return period height has a probability of occurrence that is reasonable when designing for safety (see section on Acceptable Risk above). An inundation of 6.1 m above New City Datum would inundate completely the ground floor of the proposed building to around the first-floor level for a short period of time. The underground carpark would inevitably be completely flooded. Extensive damage to the non-structural items ('fit-out') in the ground floor of the building would be expected.

The horizontal loads on the wharf and building structure from this rapid inundation are likely to be significantly less than the similar loads associated with a 500-year return period design earthquake. The structural integrity of the building is unlikely to be affected unless it takes a direct hit from debris such as a boat as big as a commercial fishing vessel, tug or harbour ferry. Damage to non-structural elements would be comparable to the earthquake event considered above. People unable to move to a higher level in the building, or inland, would be at risk of drowning.

The site, together with the area of the Central Business District (CBD) to the west as far as Lambton Quay, lies within the Wellington City Council's Orange tsunami evacuation zone. Tsunami evacuation zones are indicative only, and identify areas that Council would evacuate to protect residents for different-sized tsunami during official warnings and evacuations. They are not inundation zones. The official warning will come from Wellington Regional Emergency Management Office (WREMO).

Mitigation: We understand that the ground floor of the building will not have apartments where people might be resident 24 hours a day. It is likely that secondary structures on the ground floor of the building will fail before they can impose significant loadings on the primary structure. The moving of all ground floor staff and patrons to upper levels will mitigate the risk to human life. There are few mitigation options for the underground car park. However, there are unlikely to be many people at risk at the time, particularly if there has been a warning. The risk to occupants from this design-level tsunami is therefore unlikely to be any greater than that which would apply to other waterfront properties in the Wellington CBD.

The probability of inundation of the site from a smaller tsunami is, of course, higher than that from the design-level one. For such tsunami, it may be possible to provide landscaping or other features in the future, if considered desirable, to form a barrier or first line of defence to the impact of debris on the structure.

4 Climate Change

Hazard: A 2002 NIWA report [4] to the Wellington Regional Council predicted an increase in sea level of 1.7 mm/year due to climate change. Over a 100-year economical life, this corresponds to a net increase in mean sea level of 170 mm.

Working Group 1 of the Intergovernmental Panel on Climate Change (IPCC) [8] has published Climate Change 2013: The Physical Science Basis. Sea Level Change is discussed in Chapter 13. The projections of global mean sea-level rise during the 21st century are larger than in the Fourth Assessment Report (AR4).

There is a great deal of uncertainty in the projections across the four models considered by the working group. The Executive Summary of Chapter 13 reports the 5 and 95 percentiles in Table 1 below.

Table 1 - Projections of Sea-Level Rise (m) in 21st Century

Model	5 percentile	95 percentile	Mean (m)
RCP2.6	0.26	0.55	0.41
RCP4.5	0.32	0.63	0.48
RCP6.0	0.33	0.63	0.48
RCP8.5	0.45	0.85	0.65

There are other potential additional contributions cited which, if they occur, are unlikely to exceed "several tenths of a metre".

No specific information is given in this report for New Zealand or for Wellington. The Executive Summary states that "It is very likely that in the 21st century and beyond, sea level change will have a strong regional pattern, with some places experiencing significant deviations of local and regional sea level change from the global mean change." It also states "About 70% of the global coastlines are projected to experience a relative sea level change within 20% of the global mean sea level change."

Vulnerability: The proposed ground floor level of the building is 2.5 m above Mean Sea Level, and 0.54 m higher than the highest astronomical tide plus an allowance of one metre sea-level rise over the next 100 years.

Mitigation: In our view, it would be prudent for the designers to allow for a one-metre increase in mean sea level over the economic life of the building – it being an upper bound on the mean which is considered unlikely, based on the above IPCC information, but which is conceivable. In effect, this one metre could be considered as the maximum mean of the projections of the four models in Table 1 (above) plus "several tenths". This could be allowed for at the beginning of the building's life. However, in order to reach a one metre sea-level rise in the next one hundred years, a six-fold increase in the long-term average rate of sea-level rise (over the past 100 years) is required commencing now. IPCC's assessments for the next 100 years do not support such an extreme acceleration in the rate of sea-level rise. Given that degree of uncertainty, a means of adjusting the height of the superstructure during its life, if required, would be a pragmatic method of mitigating this risk. This would be relatively simple to allow for, given that it is currently proposed to base-isolate the building.

5 Storm Surge

Hazard: The 2002 NIWA report [4] also suggests that the worst-case scenario of a storm surge coinciding with high tide would result in a 1.7 m increase from Mean Sea Level (WVD-53, NCD). This scenario has a 100-year return period, and would result from a weather event of the same size as the cyclone of 1936. Another specific study carried out by Beca in 1993 [5] for the Queens Wharf carpark development considers the tidal 500-year return period as 1.1 m above the New City Datum (see Figure A.1 in Appendix).

Vulnerability: The proposed ground-floor level is 2.5 m above Mean Sea Level. This is at least one metre above the tide+storm surge prediction. If this level were, however, reached with a superimposed wave motion, some damage might occur to ground-floor coverings and other non-structural items. The basement might be flooded. Because of the sheltered position of the adjacent sea, such damage is however, unlikely to occur.

Mitigation: These height increases will occur relatively gradually, and could be expected to trigger natural responses from occupants that would ensure their safety. No specific mitigation methods are, in our view, warranted.

6 Wave Height

The position of Lambton Harbour with respect to the open sea means that it is almost certainly unaffected by deep-sea swells, and the waves along the shore beside the CBD are generated by wind over relatively very small distances within the harbour. Because of the sheltering effect of the wharves and reclaimed land to the North/North East and the short fetch to the south (see Figure 2 below), the maximum wave height expected to reach the wharf adjacent to the site is small. For the purposes of this assessment, a half-amplitude of 0.3 m (max.) has been assumed. This is approximately half the open-water estimate used by NIWA [11]. This height superimposed on a 100-year storm surge event, see above, will still be below the general level of the site.

Figure 2: Lambton Harbour – short fetches

7 Tide Levels

There are twice-daily (diurnal), monthly and longer periodic changes to sea level (tides). These include seasonal fluctuations; the El Nino Southern Oscillation and the Interdecadal Pacific Oscillation. Some of these cycles have periods of many years [4]. These are explained in some detail in www.linz.govt.nz/hydro/tidal-info/tidal-intro.

These changing tide levels are a baseline for other superimposed changes to sea level such as arise (upwards and downwards) from storm surge, tsunami and waves.

Hazard: The highest astronomical tide level expected at Queen's Wharf (not allowing for sea-level change arising from climate change) over 100 years is 0.9 metres above Mean Sea Level [4].

This maximum is about 0.2 – 0.3 metres higher than would be expected on average over a shorter period of a few years [5]. The NIWA report [4] notes that only 11 % of high tides recorded have exceeded the Mean High Water Perigean-Spring tide level of 0.75 m, and that that level may be a more pragmatic level to work with than the lower Mean High Water Springs (0.62 m).

Vulnerability: We understand that, in its current state, Site 10 and the adjacent wharf have a minimum freeboard of about 2.0 m above Mean Sea Level. The proposed building's ground-floor level is 0.5 m higher than this. Tidal changes in sea level alone will not cause overtopping of the wharf or flooding of the ground floor of the proposed building.

Mitigation: It would be normal for a basement of a structure close to the water's edge to be designed to resist building uplift or water ingress from fluctuations in groundwater levels that may accompany tidal changes.

8 Combination of Effects

The likely maximum height of actual sea level allowing for current predictions of maximum tide (over 100 years), surge and wave height in 2014 is 1.7 + 0.3 = 2.0 m. At this level, the land between the site and the water's edge, but not the ground floor of the proposed building, would be on the brink of being inundated.

It is unlikely, however, that the maximum wave height, surge and tide levels will coincide. This is discussed in a report undertaken by NIWA for the Queens Wharf area in 2009 [11] for open-sea wave heights. Their joint probability model suggests that the combination height for a 100-years average return period is 1.6 m (open sea) (see Figure A.2 in Appendix).

If one metre of sea-level rise were to occur in the latter half of the proposed building's economical life, it is possible but unlikely that a combination of maximum tide, maximum surge and maximum wave height would lead to inundation of the ground floor of the proposed building for a few hours. Well before this would occur, the same effect would presumably be causing some longer-duration inundation of the general waterfront area, and the occasional flooding of Waterloo Quay and the CBD if no mitigation had been undertaken prior to the event.

Figure 3 below summarises the fluctuations in sea level considered with respect to the levels of the existing site and the proposed buildings.

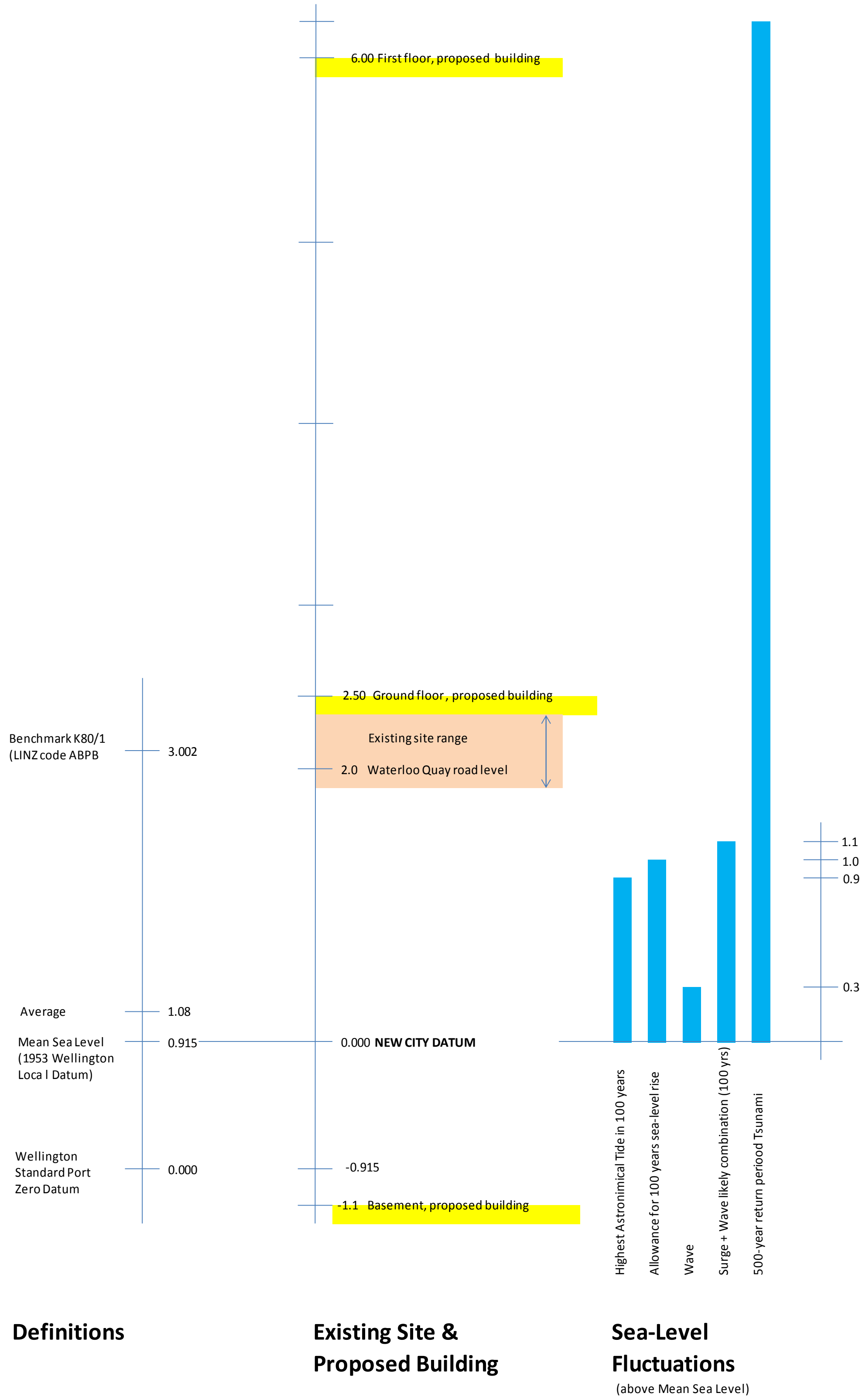


Figure 3: Summary of sea, existing site and proposed building levels (m)

9 Conclusions

If predictions of sea-level rise from climate change are not considered, the maximum sea level plus wave height predictions for the 100-year economic life of the proposed building do not suggest any significant threat to it.

If a one-metre sea-level rise over 100 years is considered (which would require a six-fold increase in the long-term average rate of sea level rise over the past 100 years), then in combination of other effects it is possible but unlikely that the site itself will be inundated. There is a low likelihood of the ground floor of the proposed building being inundated on occasions in the second 50-year period of the building’s life under extreme sea-level events in combination with sea-level rise.

However, it should be noted that the inundation that affects the site and the proposed building will also affect much of Waterloo Quay and the CBD to the west of the site to the same extent.

The site and building are exposed to damaging tsunami. Similarly, buildings and infrastructure to the west of the site will be affected to much the same extent.

The proposed foundation of the building is of a form that would make the raising of the whole building a relatively easy matter if some predictions of climate change-induced sea-level rise are realised.

References

[1] AS/NZS 1170.0:2002: Structural Design Actions, Part 0: General principles. Standards New Zealand.

[2] New Zealand Building Code.

[3] Institute of Geological & Nuclear Sciences Ltd (2013): Review of Tsunami Hazard in New Zealand. GNS Science Consultancy Report 2013/131.

[4]NIWA (2002): Meteorological Hazards and the Potential Impacts of Climate Change in the Wellington Region. Wellington Regional Council Report No. WRC/RP-T-02/16.

[5] Beca (1993): Queens Wharf Development Tide Levels and Foundations. Prepared for Lambton Harbour Management Ltd by Beca Carter Hollings & Ferner Ltd, April 1993.

[6] IPCC (2007): Intergovernmental Panel on Climate Change Report, Report AR4 WG1, Table SPM3, April 2007.

[7] Coastal Hazards and Climate Change, 2nd Edition, July 2008.

[8] IPCC (2013): Working Group 1 Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change: Climate Change 2013: The Physical Science Basis.

[9] The Ministry for the Environment (2008): Coastal Hazards and Climate Change: A Guidance Manual for Local Government in New Zealand (2nd Edition).

[10] New Zealand Coastal Policy Statement 2010, Department of Conservation, Wellington.

[11] Expected sea level variation at Queens Wharf sites, prepared for Wellington Waterfront Ltd., NIWA Client Report WLG2009-28, April 2009.

[12] Sea Level Rise Options Analysis, Report prepared for the Wellington City Council by Tonkin & Taylor Ltd., June, 2013.

Appendix

Tidal Statistics and Wave-Tide Combinations for Lambton Harbour

Appendix – Beca 1993 [5] Tidal Statistics for Lambton Harbour

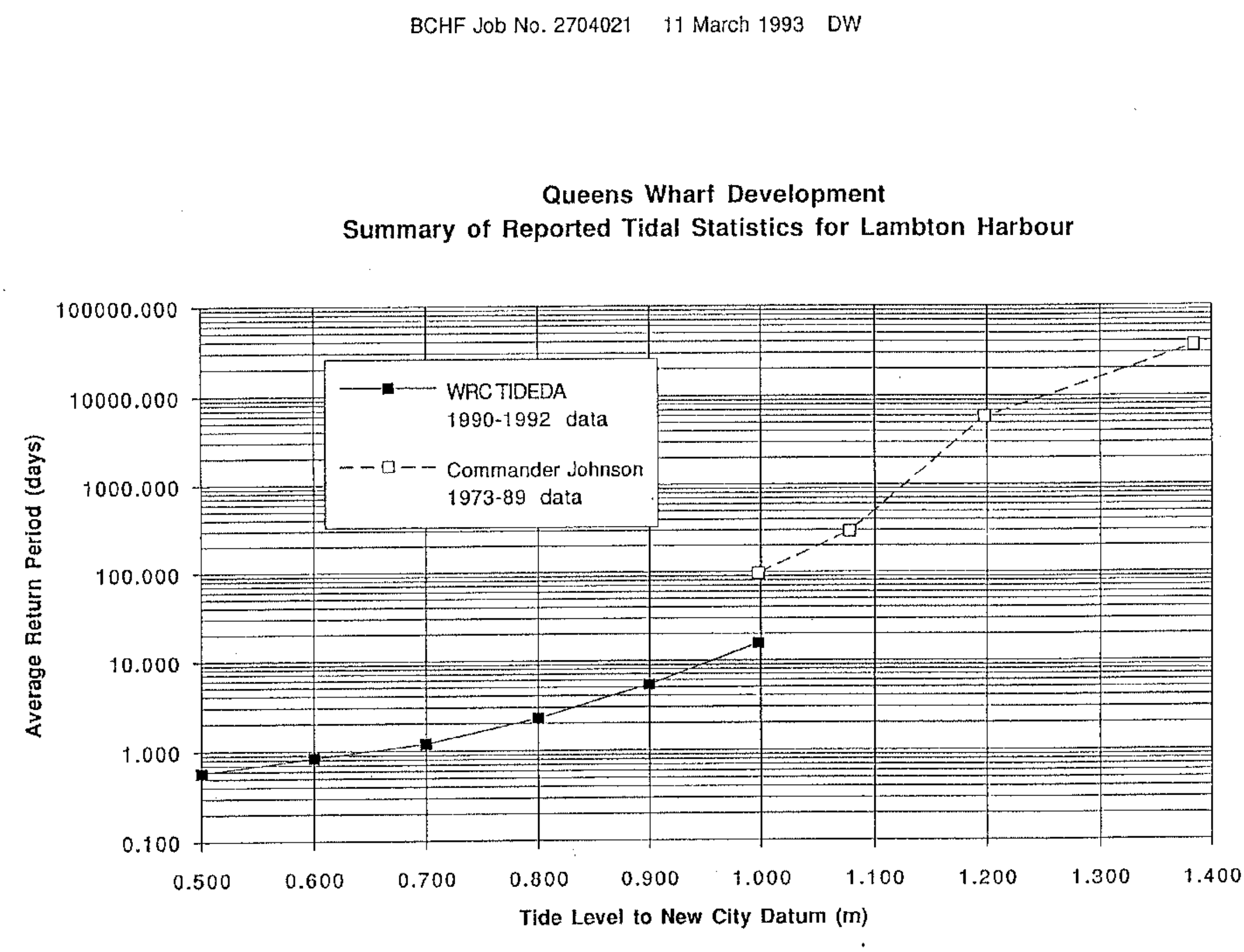
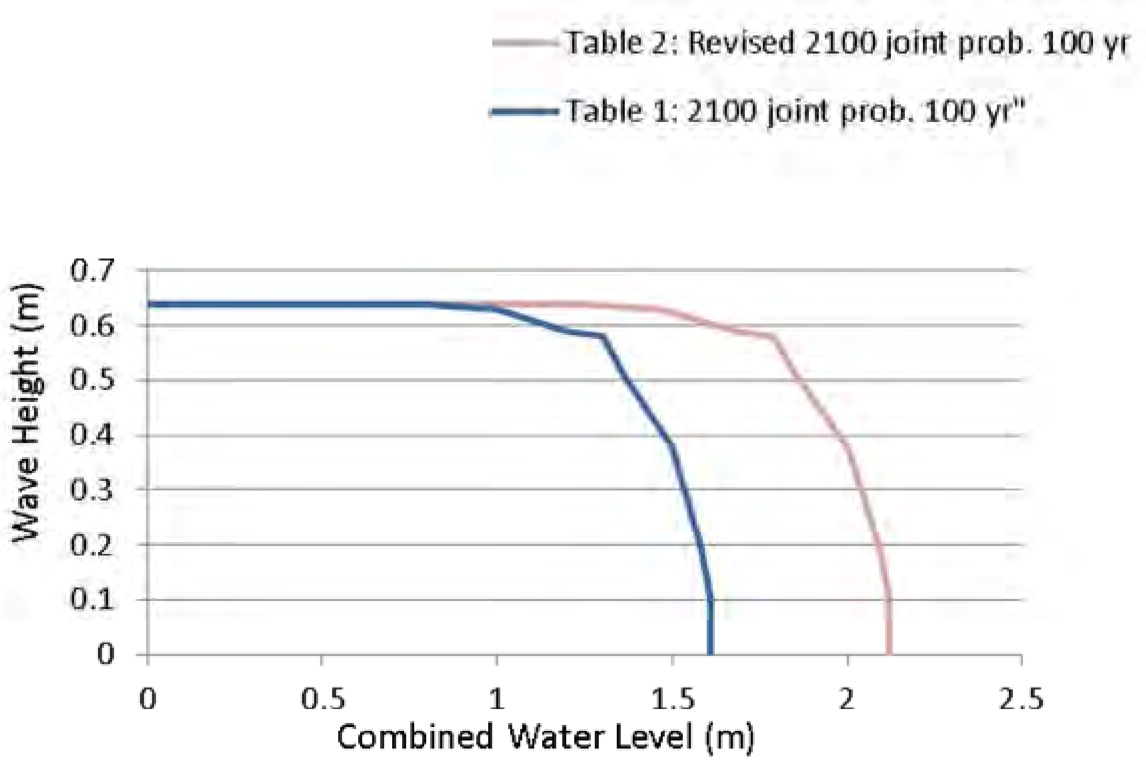


Figure A.1

Appendix – NIWA 2009 [11] Joint Probability



Plot of NIWA 2009 [11] Tables 1 and 2 showing joint probability recurrence interval wave (offshore) and water levels (metres above present-day Mean Sea Level) for Queens Wharf for a 100-year return period. Table 2 includes an allowance of 0.8 m sea-level rise by 2100 and the latest storm tide calculations in 2009.

Figure A.2