Dunning Thornton consultants

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Dear Farzad

City to Sea Bridge – High Level seismic risk and mitigation review

The following memo summarises the work undertaken by Dunning Thornton for Wellington City Council (WCC) to review the seismic risks associate with the City to Sea Bridge. We have also provided options that could be considered to mitigate these risks. This review relates to the section of bridge over Jervois Quay, and the steps and sea wall on the lagoon side. It does not include the building or pedestrian accessible roof of the Capital E building.

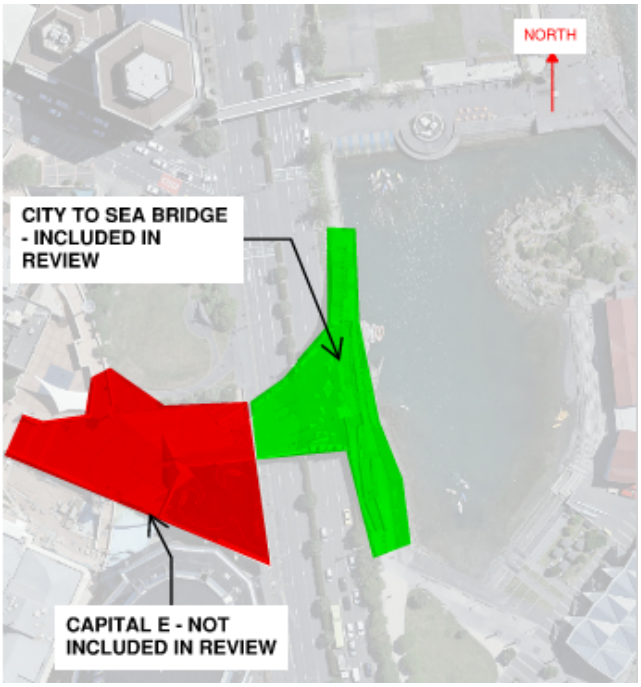


Figure 1 - Site Plan and Scope of Review

As an independent review we have only had access to select documentation provided by other consultants. This was followed up with a series of workshops with Aurecon (Structure), BECA (Structure & Geotech) and Tonkin & Taylor (Geotech). As an independent reviewer we have questioned some of the assumptions in the approaches taken by others. The approaches to managing risk outlined in our report are based on engineering principles, design standards

and guidance documents, however these are aways open to interpretation. We expect differences in opinion when dealing with complex issues and robust discussion is expected.

The following document should be considered in this context. Seismic Engineering and Risk Management are very complex concepts to deal with and subject to greater levels of uncertainty than most 'everyday' risks. These risks cannot be summarised easily, and good results rely on quality communication and collaboration.

Executive Summary

Dunning Thornton have carried out a high-level strategic review of the seismic risks associated with the City to Sea Bridge based on the documentation provided by WCC, and our own experience of risk assessment and mitigation.

This executive summary attempts to summarise both the actual risks associated with the City-to-Sea Bridge, and potential solutions (short-term, medium-term and long-term) to appropriately mitigate those risks, if there is a desire to retain it.

Risk Summary

a) **Life Safety Risk**
Kestrel Group identifies risk to people on and under the bridge. The Detailed Seismic Assessment (DSA) carried out by Hoffcon indicates that the critical vulnerabilities of the structure relate to geotechnical hazards, in particular ground movements enhanced by potential liquefaction. Risks dominated by geotechnical behaviour are generally more un-predictable than those associated with the building structure. The current assessment guidelines apply a 50% penalty to account for the type of behaviour noted in the engineering assessment report – ie potential structure failure following liquefaction induced lateral spread. This approach is currently under review to assess it is appropriate.

Life-safety risk for people on the bridge itself can also be considered as lower than in a building. Experience from Christchurch and other earthquakes suggests that people on the top floors of elevated structures (in effect with nothing to fall on them), face lower probability of death or severe injury.

On this basis, it is our view, that in reality, the existing risk of death or injury is lower when compared to typical concrete buildings and infrastructure with a similar level of %NBS

b) **Risk of Key-Transport Route Blockage**
Kestrel Group have identified consequences arising from the potential traffic route blockage resulting from bridge collapse. It is our view that the likelihood of a City-to-Sea bridge collapse being the sole cause of blockage along the Quays is relatively low. In an event large enough to cause collapse of both bridge spans, other items of structure/infrastructure may also cause road blockage. These could include:

- Damage to road associated with Lagoon seawall failure and lateral spread - local

- Damage to link/feeder roads due to liquefaction settlements and/or slope failures – widespread
- Damage to road due to lateral spread of waterfront – widespread
- Damage to other adjacent structure causing closure of road – potentially wide spread.
- General Tsunami damage – widespread

We are also of the view that mitigation options are viable to counter the effects of road blockage resulting from potential bridge collapse which may be more cost-effective than full strengthening.

Finally on this matter, we would observe 'daily traffic flows' are unlikely to be an issue in the short-term aftermath of a major seismic event, and that demolition of the current bridge in the near future (with reinstatement of alternative pedestrian access) is far more likely to cause significant disruption to typical traffic flows and is not without its own risks.

c) Legislative Risk

As Kestrel Group have identified, bridges are not subject to the Earthquake Prone provisions within the Building Act. This means that there is no legal requirement to seismically strengthen the City-to-Sea bridge under earthquake prone building legislation.

Further, it is our interpretation of the relevant Standards that this footbridge would be more appropriately classified as IL2 rather than IL3. While the roof of Capital E appears to have been designed to support assembly in the Civic Square (especially the amphitheatre type stairs) it is not clear from the information we have been provided that the City to Sea bridge (small section over Jervois quay and down to Lagoon) is used for assembly during these type of events. Its main purpose appears to be transitional (ie short time period footbridge type use). By assigned a IL3 classification to the bridge, the %NBS score is reduced and the perceived risk is increased.

Potential Mitigation Strategies Summary

The below approach to risk management is based on reducing risks in the short-term and adding higher levels of structural resilience over a longer timeframe to reduce the impacts of the risk management approach. Some of these options are innovative, however we believe they should be reviewed considering the unique situation. Innovation always has its own risks and these would need to be reviewed and managed if these options are to be viable. The timeframes for each stage of this strategy would need to be considered in relation to the potential risks over time.

a) Short Term

- Paint stationary exclusion zones road markings beneath the bridge and 10m either side – NZTA standard keep clear cross-hatching (link)
- Install signs and/or motion-triggered warning lights to stop traffic in case of earthquake shaking.

b) Medium Term

- Minor superstructure strengthening to areas indicated in the Hoffcon report.
- Simple ground level ties to reduce the magnitude/likelihood of east-west foundation spreading in moderate earthquakes.

c) Longer Term

A long-term solution would involve addressing the potential liquefaction/lateral spreading risk. Conceptual solutions have been put forward by T&T and Beca. These can be summarised as follows (further detail, together with consequential effects, is included in our section 2):

- Partial infilling the lagoon to improve seawall stability
- Ground improvement beneath the bridge to remove liquefaction potential
- Buttressing the existing seawall, and eastern bridge foundations, to improve seawall stability.

We note that this long-term solution would provide risk mitigation beyond the bridge, providing protection to the road and nearby civic centre buildings and landscaping.

Each of the options have structural/geotechnical merit but, as currently proposed, they all would involve significant traffic disruption and or loss of some amenity in the case of partial lagoon infilling. It is our view that a buttressing option constructed entirely on the lagoon side of the seawall could be a feasible, and relatively cost-effective solution. In simple terms, it could involve new structure below the existing (and widened) pedestrian boardwalk, constructed largely from a barge within the lagoon. Subject to developed design and costing of alternatives, it is probable that the buttressing could be carried out without the need for drilled piling.

In our view the workshop process that has been carried out with the other engineering consultants has been of great value in reviewing assumptions and coming to a greater level of consensus on these complex issues with no simple answers.

Given the complexities and uncertainties around this structure, and similar complexities in communicating these issues, we would recommend a more collaborative process be undertaken with the stakeholders to enable discussion and provide further clarity and to help develop a more holistic based approach to manging these risks.

Appendices

1. Review of Current Documentation

We have been provided with the following documentation by WCC

- Tonkin and Taylor (T&T) – Desktop Geotechnical Seismic Assessment – 24.6. 2024
- Hoffcon – Detailed Seismic Assessment – 26.6.2024
- BECA – City to Sea Bridge Seismic Assessment Peer Review Summary – 27.6. 2024
- Kestral Group – Seismic Risk Evaluation – 8.2024
- Tonkin & Taylor – Seawall strengthening sketches – 3 pages

Our review has been carried out in parallel to the reviews by the consultants noted above and we have had no direct engagement with them.

All reporting to date has assumed the structure is Importance Level 3. This may have an impact on the perception of the overall risk of this structure and is explored in Section 2 and the Executive Summary

Based on the Hoffcon report the critical structural vulnerability of the bridge is the potential performance of the reinforced concrete piles and their pile head joints. There are two potential forms of ground movement associated with seismic induced liquefaction that may cause this poor performance.

1. Cyclic Displacement – The non-liquefied soils at the surface are displaced by the earthquake and push on the pile heads (moderate movement)
2. Lateral spread – The potential failure of the sea wall allows liquified soils to move towards the lagoon. (large movement)

It is unclear from the current documentation what assumptions have been made in the sea wall stability analysis, however we note that the Lagoon levels noted in T&T's strengthening sketches appear to show the case scenario at some of the deepest sections of the Lagoon, whereas the southern section of the lagoon is considerably more shallow.

There are two elements of the superstructure which are noted as having 45*%NBS* which appear to be independent of the geotechnical issues. Detail is not provided of the scale or potential strengthening of these elements. These may become critical if the geotechnical vulnerabilities are re-assessed or mitigated. Aside from these two elements the Hoffcon report notes that the majority of the bridge structure has a IL3 70*%NBS* or greater score (ie ~>90%NBS if IL2). Remediation of these local structural vulnerabilities is recommended under a medium-term retention plan.

2. Seismic Risks - Bridge

It has become common practice to discuss seismic risks in relation to *%NBS* based on a detailed seismic assessment of the structure in relation to the seismic assessment guidelines. It should be noted that *%NBS* is a crude measure for discussing seismic risks, particularly for non-typical structures with complex vulnerabilities, and especially those associated with the ground.

This can be compounded when enhanced importance levels are proposed.

Considerations in relation to these aspects of the current reporting are noted below:

Geotechnical Hazard Review

Dunning Thornton are specialist structural engineers and are not experienced in the highly analytical aspects of geotechnical engineering. The following commentary is based on our extensive experience designing structures on and adjacent to the Wellington Waterfront with Geotechnical Engineering input including: PWC Centre, Bell Gully Centre, Deloitte Building, BNZ Centre and involvement in the proposed Fale Malae.

Based on our review of the provided documentation the majority of the significant vulnerabilities to the bridge (<50%NBS.IL3) appear to be related to the potential for liquefaction induced ground movements to occur. As noted above these can be broken up into two types of movement – cyclic displacement and lateral spread.

We also understand that there is a review in progress of the geotechnical provisions of the seismic assessment guidelines. This includes a review of the “step-change’ provisions which have an impact on the current risk reporting. In our view it would be valuable to review the geotechnical risks accounting for these new guidelines as we understand they have been developed to better account for the high uncertainties associated with similar sites.

We also note that different site soil classes have been conservatively adopted for the assessment of geotechnical and structural components. This can be prudent when no clarifying information is available. However, if a more accurate estimation of %NBS is required there may be value in confirming this.

Importance Level Discussion & Review:

Our review of Importance levels only relates to the City of Sea Bridge (green in Figure 1) and not the Capital E building or its roof.

The use of importance levels within the Building Codes were intended to provide a higher level of risk mitigation for structures where the negative impacts of a standard level of performance may be disproportionate to that of a “normal” structure. In the case of the City to Sea bridge the assumption has been to use a IL3 designation due to the potential for crowds on the bridge (>300people). This means that the bridge performance is assessed against a larger and less likely event - a 1 in 1000 year event rather than a 1 in 500 year event for a ‘normal’ structure – which is an event that is 50% less likely to occur in a 50 year timeframe.

All assessments to date have applied this assumption, including in the reporting of %NBS. To be clear this approach to reporting under the assessment guidelines is correct, if the ‘building’ is designated as IL3, however, to an outside party without in depth knowledge of the seismic assessment process this has the potential to give the false impression of the absolute risks around the structure. Other buildings or structures with the same %NBS as the bridge, but which are categorised with a different Importance Level will not represent the same level of absolute risk. This can add complexities to decision making when trying to assess life-safety hazards with regard to continued occupancy in the short-term. This is why the MBIE Seismic risk guidance for buildings recommends that IL2 levels be used for these decisions:

Making occupancy decisions on importance level (IL) three and four buildings

Some buildings are built to withstand larger earthquakes than others. A building is given an importance level (1-5) based on occupancy, its post-disaster function and potential environmental consequences of failure. Buildings with higher importance levels are designed to withstand larger, less frequent earthquakes. Most buildings are importance level 2 (IL2). For all buildings, regardless of importance level, short-term occupancy decisions should focus on life safety risk in the near term: that is considering earthquakes that are more frequent and hence smaller. Therefore, it is more appropriate for occupancy decisions for IL3 and IL4 buildings to be based on the design earthquake for an IL2 building, that is a 1 in 500-year event. Further consideration of risk in high occupancy buildings is factored into the decision guidance in Part B.

Figure 2 - Extract from MBIE - Seismic Risk Guidance for Buildings

There is limited commentary in the documentation we have reviewed to date around the decision to require the seismic review of the bridge structure be carried out to Importance Level 3. It generally appears that that this has been adopted due the provisions around the congregation of crowds greater than 300 people on this structure. While the roof of Capital E appears to have been functionally designed to support assembly in the Civic Square (especially the amphitheatre type stairs) it is not clear from the information we have been provided that the City to Sea bridge (small section over Jervois quay and down to Lagoon) is used for assembly during these type of events. Its main purpose appears to be transitional (ie short time period footbridge type use).

This risk differs from that of most IL3 designated buildings such as concert halls, sports arenas, and convention centres where significant crowds may be expected to be accommodated regularly for multiple hours.

A more comprehensive review of the Importance Level requirements could be carried out following a similar approach to that used in a Determination to better establish the minimum code requirements for this structure.

3. Seismic Risk - Roadway

Where seismic risks relate to a road that extends beyond the potential impact area of the structure a more wide ranging assessment may be required to establish the critical risks to this piece of infrastructure ie where do the risks associated with the structure under review lie within the total risks to the road.

We will discuss these aspects of the seismic risk to the road below:

- Damage to Bridge leading to closure or road - local
- Collapse of Bridge leading to closure of road - local
- Damage to Road associated with Lagoon seawall failure and lateral spread - local
- Damage to road due to liquefaction settlements – widespread
- Damage to road due to lateral spread of waterfront – widespread
- Damage to other adjacent structure causing closure of road – potentially widespread.
- General Tsunami damage - widespread

The above risks should be reviewed in relation minimum desired road use requirements following varying levels of seismic events to assess the critical risks, and where practical

strategies put in place to mitigate them. A critical aspect of the above, if demolition of the bridge is to be considered, are there seismic scenarios where the bridge would be damaged (causing road closure) but the road would remain in operable condition? If all scenarios causing damage to the bridge are the result of lateral spread due to sea wall failure the road would need remediation works regardless of the bridges presence.

4. Risk Management / Mitigation Options

The following options could be considered as part of a seismic risk mitigation strategy for the City to Sea bride and associated infrastructure. These options should be considered not only within the context of the risks associated with the bridge, but within a wider context - for example what additional costs/benefits may these options have beyond the bridge site. These may include funding that could be provided to manage greater risks elsewhere, or the consideration of benefits of certain mitigation techniques that could reduce risks beyond the bridge, such as lateral spread mitigation to the road and Civic Centre precinct associated with a replacement / strengthening of the sea wall. A short, medium and long term strategy could be developed to manage the risks associated with the bridge. The time frames for these different strategies could be assessed accounting for the level of risk over time and available resources. An initial draft outline of such a plan is noted below for discussion. Input from stakeholders and other technical parties (engineering, emergency management etc) would be required to develop this further if this approach were to be adopted.

Short Term

- Paint stationary exclusion zones road markings beneath the bridge and 10m either side.
- Install signs and/or motion-triggered warning lights to stop traffic in case of earthquake shaking.

Medium Term

- Minor superstructure strengthening to areas indicated in the Hoffcon report.
- Simple ground level ties to reduce the magnitude/likelihood of east-west foundation spreading in moderate earthquakes.

Longer Term

- A long-term solution would involve addressing the potential liquefaction/lateral spreading risk to the bridge, road and nearby buildings in Civic Square. This would likely require the strengthening of the existing retaining wall.

5. Seawall Strengthening

There are multiple options available to strengthen the existing lagoon seawall. For any of the seawall strengthening options the main risks appear to relate to the construction complexities (site constraint/access) and resource consenting/environmental risks. These include:

- Building over and in water – temporary platforms required and the high water content of spoil needs to be managed
- Building on or adjacent to major roadway

- Access to the site and impacts on current uses
- Impact on water quality and management of groundwater / seawater disposal
- Potential contamination

Consideration should also be given to the extent of the seawall works, as a greater extent of works may come at a proportionally lower cost, and provide risk mitigation to a larger extent of roadway and buildings in the civic centre.

Given the construction challenges, and highly specialised techniques likely required to carry out a seawall strengthening project it is our view that if this option was to be pursued WCC should consider non-traditional procurement options. With a suitable performance specification including environmental requirements and sufficient geotechnical information, a specialist civil contractor and their engineering support may be able to develop a construction methodology that is cheaper / less risky / faster etc then a traditional procurement process.

Review of Current Seawall Strengthening Options

A number of these are presented in the consultant reports to date. We provide high level comments on these options below, noting our experience as structural engineers but with significant experience on liquefiable and laterally spreading sites. Due to time constraints the considerations/risks below cannot be considered exhaustive.

If any strengthening options are to be considered we would recommend a comprehensive design risk / constructability workshop be carried out.

T&T Sketches - Option 1 – Dredge and Infill Lagoon

This scheme appears to require the dredging of the lagoon and replacement of these soils with competent fills. Consideration should be given to:

- The current ground levels in the lagoon as they vary greatly (the lagoon being quite shallow to the south). This may impact dredging volumes.
- The founding/underpinning of other structures around the lagoon which may be undermined by the dredging.
- Extensive silt management likely required
- Costs / practicality of removal of spoil (contamination, high water content) and transportation of fill to site
- Removes lateral spread risk, unclear how this would deal with cyclic movement
- Significant benefits of risk reduction to roadway and surrounding structures and land.

T&T Sketches - Option 2 – New Palisade wall – RC Bored Piles

This scheme appears to require the construction of a new Palisade wall consisting of conventional bored piles. Consideration should be given to:

- Temporary works and access for piling rigs and handling cranes
- All piles will require temporary or permanent casings
- Costs / practicality of removal of spoil (contamination, high water content)
- Removes lateral spread risk, unclear how this deals with cyclic movement

- Benefits of risk reduction to roadway if extended full length of lagoon plus additional to avoid lateral spread at North / south end.
- Impact on existing landscaping

T&T Sketches - Option 3 – CFA/Jetgrout Cell walls

This scheme appears to require the construction of a cellular wall structure in the roadway consisting of CFA and jet grouted piles. Consideration should be given to:

- Requires closing road for construction period
- Access under bridge restricted
- Doesn't appear to restrain sea wall or bridge piles directly adjacent to seawall
- Mitigates lateral spread and cyclic movement
- Costs / practicality of removal of spoil (contamination, high water content)

BECA Memo – Deadman + Ground Improvement

- Similar to T&T option 3 but suggests using ground improvement / cell wall to restrain seawall providing restraint to piles adjacent to seawall.

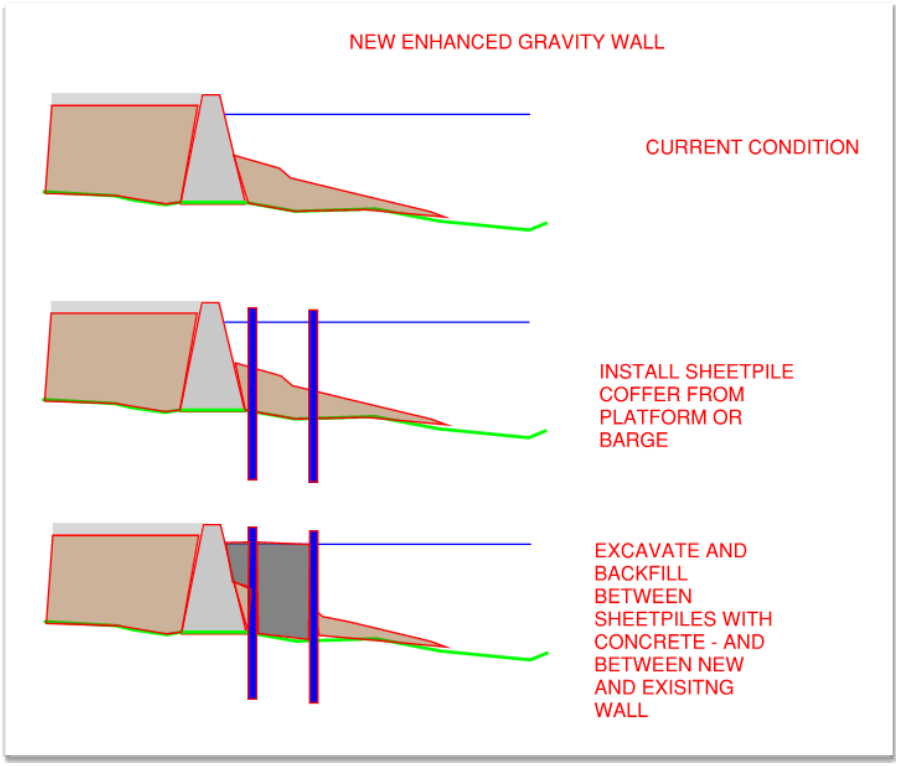
Alternative Seawall Strengthening Option

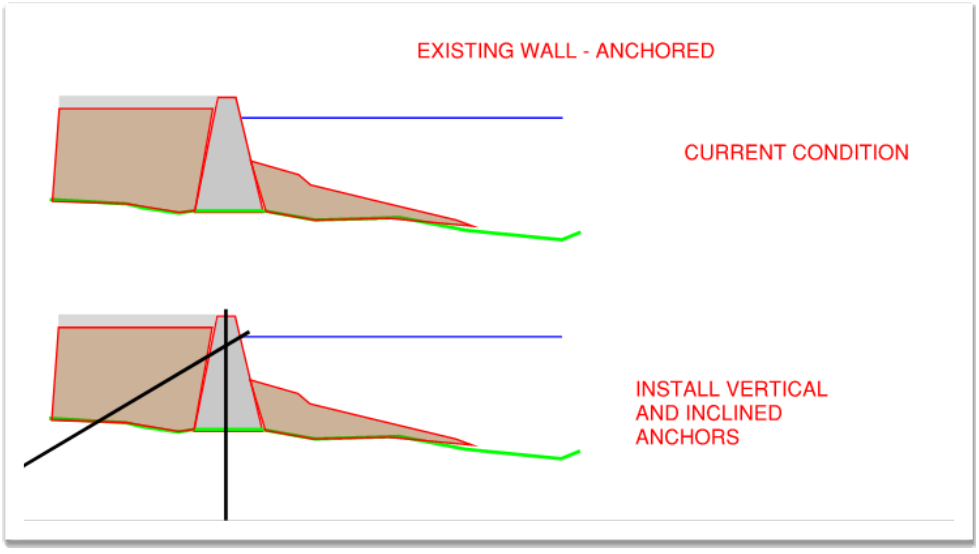
We have workshopped an option internally that may be considered within the current seawall replacement thinking and takes measures to mitigate the complexities noted above.

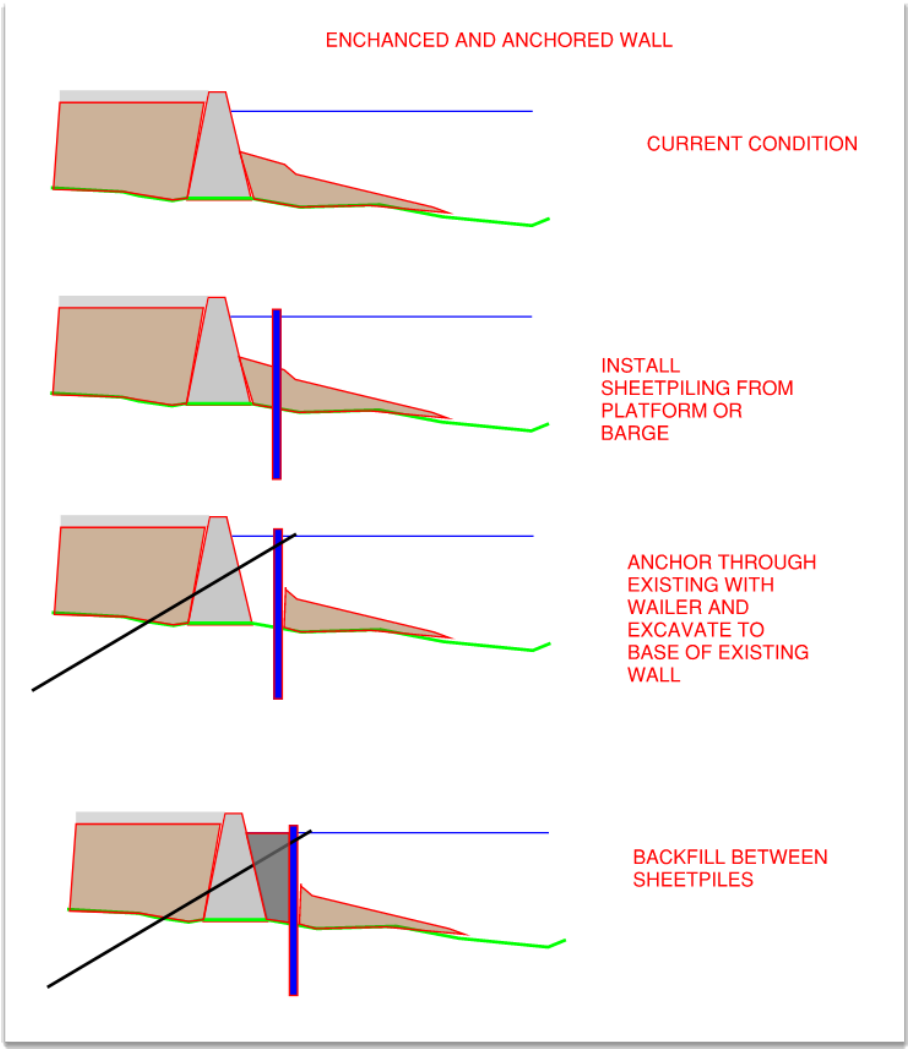
Sheetpiled Cofferdam Buttress –

1. Install a sheetpiled coffer dam in front of the existing seawall and into the non-liquified layers. Sheetpiling can be installed using digger mounted equipment and may be able to be installed from a barge avoiding significant temporary platforms. The sheetpiling provides cutoff to the lagoon, greatly reducing the potential for contamination entering from the following works.
2. Dredge / Vacuum excavate between the sheetpiled walls
3. Place reinforced concrete between walls.
4. Backfill between new and existing seawall with competent fill.

Basic sketches of this option are noted below, including some sub-options. These are all based on using small machinery (diggers, micropiles) rather than large piling rigs etc that will require considerable temporary platforms or may impact the road use. These are all based on a strengthening of the full wall extent, these options provide could provide risk-mitigation value to road and civic square building and landscape protection regardless of what options are taken forward with the Bridge.


NEW ENHANCED GRAVITY WALL
CURRENT CONDITION
INSTALL SHEETPILE COFFER FROM PLATFORM OR BARGE
EXCAVATE AND BACKFILL BETWEEN SHEETPILES WITH CONCRETE - AND BETWEEN NEW AND EXISITNG WALL


EXISTING WALL - ANCHORED
CURRENT CONDITION
INSTALL VERTICAL AND INCLINED ANCHORS



This report has been prepared for Wellington City Council to communicate potential seismic risks and mitigation strategies related to the City to Sea Bridge and the underlying road. It shall not be used by others or for alternate purposes without the approval of Dunning Thornton.