Seaview Wharf: risk-based thinking underpins the future

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ABSTRACT

Wellington's Seaview Wharf, constructed in circa 1975, is a critical asset in the Lower North Island fuel supply system. Recent annual fuel supply for the region has exceeded 1 Million tonnes, and there is currently no credible alternative supply solution.

One aspect of Holmes' partnership with CentrePort is a renewal process currently underway for Seaview Wharf. This is based on understanding risk to systematically improve resilience and operational outcomes, targeted to critical aspects of fuel supply and distribution.

A risk assessment was completed not just for the Seaview Wharf structure, but with consideration of wider fuel supply system components. This demonstrated that a traditional approach to seismic retrofit of the wharf alone would not be an effective strategy to truly enhance the resilience of the supply system. The assessment adopted a range of communication methods to describe and prioritise activities to incrementally decrease the operational risks presented by the built infrastructure.

In parallel with the fuel industry's proposal to renew the fuel distribution pipeline, CentrePort's largest current infrastructure work item is a targeted wharf structure renewal project. The design philosophy has risk management at its core. It draws on numerous international codes and guidance documents, plus requirements of key stakeholders. The design focuses on operability at various design limit states; enhancing collective understanding of performance so that resilience efforts can be targeted in an affordable way. This approach is critical to the ability over the long term to affordably indemnify significant assets, such as Seaview Wharf, given current insurance market conditions.

This paper will discuss the risk assessment and design issues associated with renewal work on an operational marine fuel terminal.

1 INTRODUCTION

CentrePort Limited (CPL) is a private company owned by W R C Holdings Limited (Wellington Regional Council) and MWRC Holdings Limited (Horizons Regional Council). CPL runs the commercial port operations in Wellington Harbour and beyond, servicing Central New Zealand. Seaview Wharf is a CPL-owned marine fuel terminal located in the north eastern corner of Wellington Harbour. Refer to Figure 1.

The Civil Defence Emergency Management Act (CDEMA) identifies CentrePort as a 'lifelines utility', with Seaview Wharf as a 'lifelines facility', as it is part of the distribution system for petroleum products. While the CDEMA states that a lifeline facility must perform some degree of post-disaster function, it also permits CPL to determine an appropriate level of service and obliges them as a lifelines utility to manage the risks associated with their facility.

The terminal typically receives different petrochemical products including diesel and petrol. Recent annual supply of these products through Seaview Wharf has exceeded 1 Million tonnes. Chemical products are also infrequently handled at this terminal. It serves as the primary fuel supply point for the lower North Island and is a critical backup fuel supply point for other parts of the North Island.

Seaview Wharf was originally constructed circa 1975. At the landward end there is a small reclamation with rock revetment, and security to serve 'port of first arrival' functions. The Approach Wharf structure extends from here approximately 600 m south to the wharf head, consisting of the Main Wharf and dolphin structures. Generally, the structures comprise of prestressed concrete decking, reinforced concrete pile caps and steel H piles. The piles are driven through soft marine sediment of varying thickness into an outcrop of greywacke rock.

Pipelines owned by the fuel industry extend from the wharf head along the sides of the Approach Wharf. On the landward side, this pipeline follows the coastline north to the storage facilities in Seaview. The fuel industry is currently engaged in works to upgrade at least one of these pipelines. Other pipelines and services along the Approach Wharf include potable water, a high voltage electric supply, telecommunications and a chemical transfer pipeline.

Figure 1: General aerial view of Seaview Wharf looking north-east

Operational demands on the terminal have increased significantly throughout the life of the structure, with a current maximum ship size of 60,000 DWT and length of 185 m. The concrete components of the wharf structure have deteriorated to varying degrees over time, though have been partially protected by an impressed current cathodic protection (ICCP) system. Damage induced by the 2016 Kaikoura Earthquake was widespread, especially to the connections between deck elements and raker piles.

A renewal project is currently underway to not only target known structural damage and condition-related issues, but to improve the overall resilience and operational processes of the fuel supply system. The business case for this project highlighted that:

- there is no credible alternative to marine-based fuel delivery into the city. Options such as road-based transport would overwhelm key transport links and lead to negative environmental outcomes.
- new, replacement infrastructure to support fossil fuel delivery is costly and insensitive to the needs of a sustainable future.
- it is feasible to target renewals work to existing infrastructure to offer an improved level of performance for a 30-year horizon.

Hence making best use of current assets is essential. Key stakeholders for the project are numerous, and consultation is ongoing as design develops. Because the wharf is part of a much wider functional system, the project requires a more holistic, collaborative approach than would traditionally be undertaken for structural repair and renewals.

2 DATA GATHERING

2.1 Risk assessment

A series of workshops were held in 2017 capturing input from CPL and key suppliers around likelihood and consequences of various scenarios impacting fuel supply operations at Seaview. This process proved useful in canvasing a wide range of opinions across the operational, maintenance, compliance, technical performance, and commercial aspects of fuel transfer at the site. These scenarios and risks were summarised alongside outputs from a qualitative seismic risk assessment on the wharf structure itself.

The structural seismic risk assessment considered expected failure mechanisms of key interfaces and estimated the damage that would occur during different events. Return periods that aligned with codified requirements were selected. However, the focus was firmly on the consequential impacts of structural performance, rather than checking levels of compliance by percentage or other means. High level technical predictions were compared to observations made following earthquakes in 2013 and 2016 (Seddon / Grassmere, Kaikoura).

The resulting register summarised risks to not only the built infrastructure where mitigation measures could be enacted by CPL, but also to the wider fuel supply system. The most critical risks were identified to be posed by, in no particular order:

- Tsunami damage to the structure and/or fuel pipeline
- Stray vehicle (from local road) or vessel (from an adjacent marina) causing damage to the pipeline
- Seismic event causing damage to the petrochemical storage facilities
- Differential deformation of structures and services at structural interfaces
- Structural overload or condition-related failure of wharf-mounted structures (fenders, light poles, walkways, buildings…) where collapse precludes operations
- Structural overload to wharf resulting in damage which restricts access and thus precludes operations.

Some of the most critical risks to system performance are outside of CPL's control. This presented a useful context at this early stage and served as a catalyst for much broader thinking than would typically be undertaken by an asset owner looking to renew their structure. Clearly, if CPL undertook renewal work in isolation, then numerous other risks to this fuel supply lifeline would still remain. As an example, while a new wharf may be able to sustain a 2500-year return period event, the lifeline would not function if pipelines ruptured and transport links were severed. Thus, a more holistic approach was sought from the beginning.

The intent of this was that the resilience of the fuel supply system could most efficiently be improved by a range of mitigation measures – hard and soft – rather than the seismic retrofit of the wharf alone. From this point, the data gathering phase progressed based on two different paths – based on what was under CPL's control and what was not.

2.2 External engagement

Following the above, the findings of the risk assessment work were communicated by CPL to various external stakeholders. This included face to face discussions with civil defence groups and representatives of the fuel industry. Through this process, a breadth of mutual understanding was ensured as different entities progressed their own work related to the fuel supply system.

2.3 Internal engagement

Of the risk items that CPL could influence, many were founded on an item's condition. The risk exposure is based on level of use, and the presence of age-related deterioration or loading-induced damage. For these items, further work was required to define the current status.

2.3.1 Deterioration of wharf structure

The Seaview Wharf structure is located in an exposed marine environment with very high atmospheric corrosivity. It is around fifty years old, and so can be expected to suffer a level of deterioration. A condition assessment was undertaken by Holmes and WSP in 2018, to confirm that existing live load limits were appropriate and to inform the upcoming renewals work.

In general, the assessment found that the condition of many reinforced concrete elements was degraded. In particular, simply supported deck units on the Approach and Main Wharf were identified as primary load path elements which were typically degraded. Impressed current cathodic protection (ICCP) systems, where installed and currently operational, were generally found to be effective at managing the risk of atmospheric corrosion. This meant that many other wharf deck members were suffering more localised, rather than wholesale, levels of deterioration.

Figure 2 - Visible deterioration of deck unit soffit

Chloride ingress tests were completed, which indicated that corrosion had likely commenced, to some degree, on all prestressed strands in the deck units. As a more direct way to understand this risk, exploratory breakouts were completed on selected 'poor condition' deck units. These indicated that where spalling was present, the underlying strands had typically lost their entire section (refer Figure 2) at some locations. They also indicated that for all deck units, several competent prestress strands remained. This outcome informed updated load rating calculations and validated the decision by CPL to reduce the service load and vehicle speed along the Approach Wharf.

2.3.2 Deterioration of wharf furniture

Further to the structure itself, attachments to the wharf have been in service for many decades and are in varying states of repair.

Some of the highest risks identified in the assessment process related to the ongoing use of operational furniture which had been in place at time of construction. This included fenders, light poles and walkways amongst other items. As a result, and with the knowledge that relatively little effort would be required to address some big risk items, information was collated on known defects and redundant structures at the site.

2.3.3 Earthquake damage

On Monday 14th November 2016, Wellington experienced the effects of a magnitude M7.8 earthquake (with epicentre near Culverden) at 12:02am. Inspections carried out by Holmes and others revealed damage due to this seismic event. This included cracking, permanent residual displacement, impact damage at interfaces and pull-out failure at raker pile connections amongst other things.

On the basis of the damage assessment, no earthquake damage-related occupancy or usage restrictions have been recommended or implemented. The damage has, however, resulted in a loss of resilience, because of durability risks, and the reduction of stiffness and residual capacity in the seismic load resisting system.

3 RENEWALS PROJECT

The data gathering exercise identified risks and developed options to improve the resilience of the fuel supply system in response to these. One of the first actions was to simply start work on known condition-related replacement of wharf furniture. In many cases this was simply a like-for-like replacement exercise. In the case of fenders, for example, this was a delivery project with formal design and construction phases delivered by industry alongside CPL. This action addressed several risks in quick time without the delay which would occur if they were incorporated into a wider renewals project.

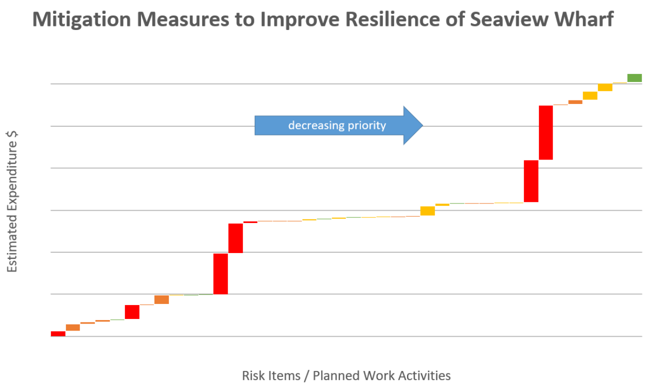

Figure 3 - Cost chart for prioritised risk items

The remainder of risk items were prioritised and, through engagement with various parties, formalised into a suite of works. Refer Figure 3 for one of the tools used to communicate the risk items and mitigation cost estimates to internal stakeholders as part of the prioritisation process. At this point, there remained a heavy reliance on face to face discussion around charts such as this to allow the views of various experts to be balanced as the project took shape.

Other contributors to the fuel supply system were similarly progressing actions under their own control, such as the fuel industry pipeline renewal project. A collegial approach has been maintained, with regular interface discussions to understand reliance of certain infrastructure upon others prior to project delivery.

3.1 Objectives

Resilience is a critical objective at the core of the CPL business model and culture as the port embraces regeneration. It is an overarching requirement for the Seaview Wharf Renewals Project.

Supporting that, and informed by internal and external stakeholder consultations, the specific objectives underpinning a successful project outcome are to:

- provide at least a minimum level of compliance and service to the fuel industry to 2050 or beyond
- reduce the risk and improve the safety of all wharf users during all aspects of the project, including design, construction, operation, maintenance, and eventual decommissioning
- strive to achieve conformance with industry-driven guidance documentation
- ensure proactive collaboration between the project team and the stakeholders
- explore opportunities to protect and enhance the local environment.

Successful delivery of the above will mean that port operational staff are better equipped to safely respond to planned and unexpected events on site, built infrastructure is less likely to suffer damage, operations are more likely to continue after a significant loading event, and the delivery team's relationships with stakeholders are enhanced for the short and long term. These outcomes are all aligned with resilience for people, infrastructure and business.

3.2 Management of key risks

3.2.1 General

There are various risks and challenges to mitigate or solve to deliver success in all aspects of the project. Throughout the development of design, effort was lent to key priorities including operational, compliance, environmental, and safety matters. Items of particular relevance follow.

- Health and Safety. Essential to the construction phase and to the long-term use of the facility. It is critical that renewals are designed with the safety of users in mind. Even in advance of early contractor engagement, the design team sought advice from construction experts, and developed and demonstrated construction methods to fit the site constraints and the need for ongoing operation during construction.
- Environmental issues, including aquifer effects, ecological impacts, fuel spills and sea level rise. Boffa Miskell spent much of 2020 on ecological data gathering and environmental management proposals. The design team have also modelled subsurface conditions in 3D and engaged with experienced contractors.
- User requirements and levels of service impact design criteria and underpin stakeholder engagement and advocacy. Importantly, the operability of the wharf during construction, and then in typical and post-earthquake situations, needs to be assured. Numerous non-structural performance elements are critical for designers to understand in order to achieve this.
- Existing structural condition. This contributes to the urgency of renewals action, safety of personnel working on the wharf, and construction methodology. Understanding existing condition also contributes to efficiency of renewal options, as one piece of work may address multiple known risks.

3.2.2 Seismic design criteria

For marine structures, there is no New Zealand specific method for the determination of seismic actions cited in the Building Code. The concrete material standard (NZS 3101) instead references the British BS 6349 suite of documents. However, this document is not appropriate for the determination of seismic loading in high-risk seismic regions such as New Zealand. To compensate, BS 6349 references European standard BS EN 1998 and American standard ASCE 61 for seismic design. BS EN 1998 relies on national annexes for seismic loading guidance, for which there is none relevant to NZ.

For this project, the Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS) and American Society of Civil Engineers – Seismic Design of Piers and Wharves (ASCE 61-14) guidance documentation are deemed appropriate for the determination of seismic loading. This is because these documents are developed by a first-world country (similar community expectations) for high-risk seismic regions, are recognised by CPL's stakeholders as an appropriate design method, and are referenced through a demonstrable series of links in New Zealand's building regulations.

Return periods used for the determination of seismic loading using NZS 1170.5 are matched to selected seismic performance criteria within the ASCE 61 guidance document, which are summarised below.

- "Operational" case (minor/no damage) under a 1 / 50 annual probability of exceedance event
- "Repairable and operable" case (controlled inelastic damage, repairable within months) under a 1 / 500 annual probability of exceedance event
- "Collapse avoidance" case (extensive damage not preventing egress) under a 1 / 1500 annual probability of exceedance event.

3.2.3 Geotechnical design criteria

Some geotechnical data was available at the outset of the design process. Two historic boreholes aligned with dolphins at the wharf head, and current qualitative information was available from divers working at the site. The original wharf construction drawings also contained some information on seabed level at the time of construction.

Generally, this indicated that bedrock was overlain by 0-3 m of seabed sediment at the Main Wharf, and that it was overlain by ten or more metres of seabed sediment along the length of the Approach Wharf. A site specific seismic hazard study is yet to commence, but will be undertaken once further specific geotechnical investigation data on the soft seabed sediments is obtained.

In order to progress design in lieu of a site specific hazard study, other available data was reviewed. Original 1970s pile driving records were processed by reviewing set measurements recorded during the driving of around 300 piles. This information was incorporated as data at appropriate depths in a 3D model. The model thus gave an indication of planes of transition in seabed sediments quality. Bathymetric survey data from NIWA was overlaid with and correlated against the construction-phase seabed profiles. The correlation indicated the seabed level had remained constant to within about a metre in most locations, thus offering confidence in the original construction-phase data.

The resulting three-dimensional model assisted in the project team's knowledge of unseen elements and estimation of likely seismic demands. It also assisted immeasurably in engagement activity with both internal port personnel and external stakeholders. Refer to Figure 4 for a section through the model along the Approach Wharf.

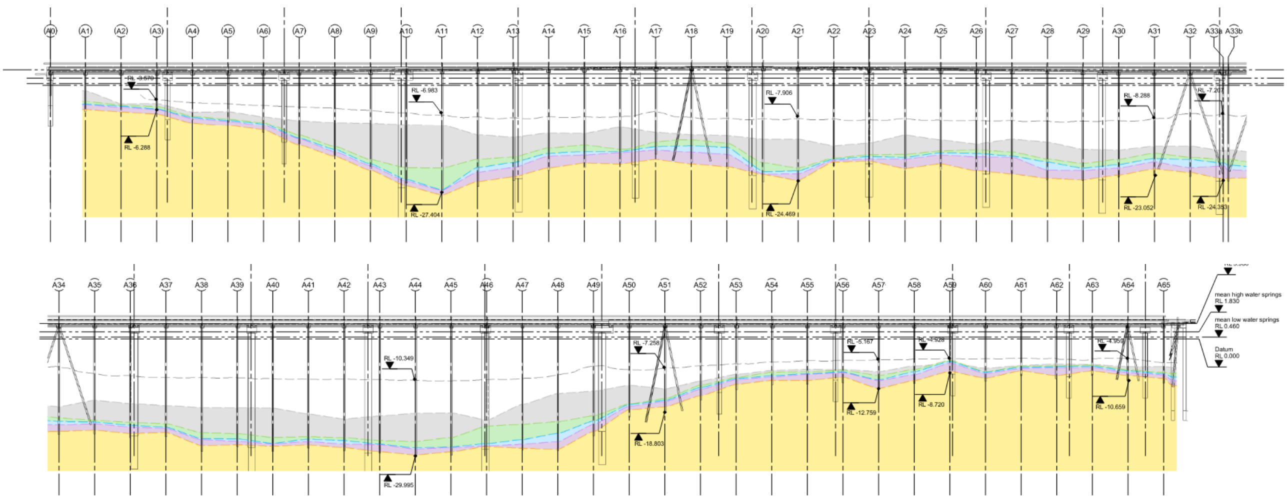

Figure 4: Approach Wharf long section including 3D geotechnical and seabed model data

3.2.4 Ship to fender interface

The renewed wharf would have different fender systems to the original – offering a more state of the art solution. This change represents an improvement in performance, but also a risk since it is a change in the contact interface of ship to fender from that used for the past 50 years.

The 3D model initially developed for the ground and existing structure was further developed to capture new design proposals and ship hull profiles. This provided acceptable impact angles and contact areas for key design scenarios.

3.2.5 Stakeholder engagement

Communication with different audiences – both technical and non-technical – was identified as an important aspect of design at an early stage. The technical model discussed above was further developed to facilitate discussions between the design team and a range of other parties. The model was used for still images and animations which greatly enhanced the design team's ability to describe and inspire people about the proposed renewals. Refer to Figure 5 for an extract from this model which is currently being developed for other communications media.

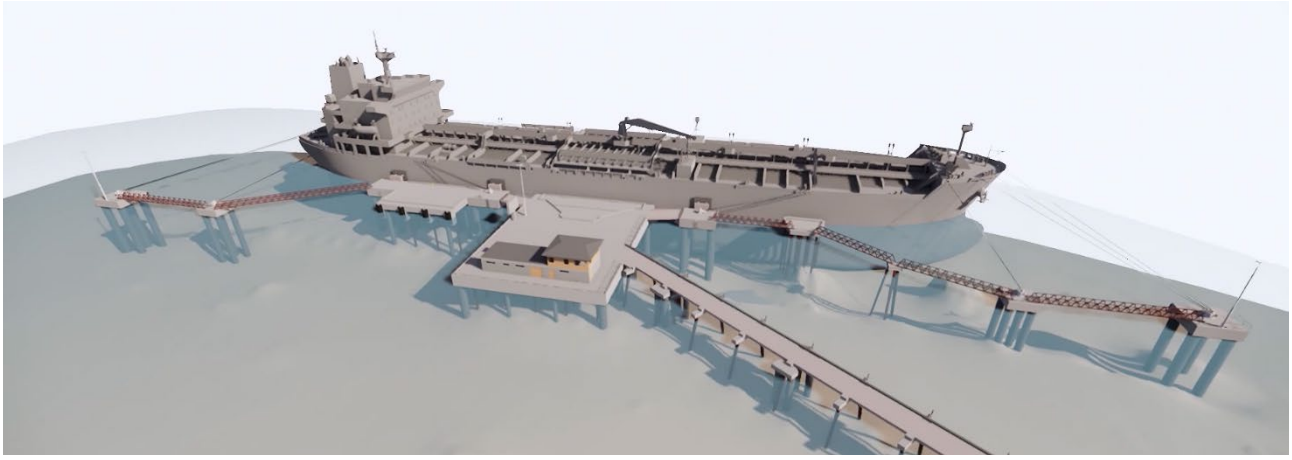

Figure 5: Screenshot from a fly-through showing the wharf head after construction completion

4 DESIGN PROPOSALS

In a general sense, the renewal project seeks to demolish redundant structure and upgrade the remainder. Redundant elements require maintenance, which carries cost and a need to expose personnel to a hazardous work site. If these same elements are known to perform poorly in seismic or operational events, then all the more reason to remove them from the structural system. Piles will be cut below seabed rather than extracted, to mitigate any risk to the aquifer.

The footprint of wharf that remains will be made more regular than the L-shaped wharf is at present. Regularity offers better assurance of theoretical behaviour being realised in practice. The existing raker piles will be removed, and the wharf will be supplemented by post tensioning with new bored pile / pile cap frames. New dolphins will be constructed, with a layout to better suit current design recommendations for marine oil terminals. Double or triple quick release hooks will be installed to better fit with current industry mooring recommendations. New walkways will also be constructed to suit the dolphin layout.

The existing lateral load resisting system of the Approach Wharf is insufficient to satisfy the design criteria. New pile and pile cap frames will supplement existing structure, and the degraded and earthquake-damaged superstructure will be repaired or replaced. Replacement with lightweight deck will reduce seismic load demands, and this will be pursued in more detail in upcoming stages of design. Repairs at the landward end may be extended to include a thrust block for the upgraded fuel industry pipeline.

A range of other operational-related elements are also being addressed to enhance safety and compliance. The team are also considering resilience of services. Increased movement allowances will be provided at structural interfaces, and electrical systems at the wharf head will be upgraded with more robust trunking or ducting. Self-sufficiency is being considered, as a contained wharf head with its own power, communication and water offers a change with respect to ongoing operations in the event that the Approach Wharf is damaged. Other aspects of wharf head services remain to be investigated further before current options are confirmed.

5 ASSET MANAGEMENT AND OPERATION

For asset owners in an increasingly challenging operating environment, a sound understanding of what is truly important to ongoing operability is essential. In this example, commercial success is reliant upon a customer who transfers fossil fuels. This is an industry fighting the tide of public sentiment and looking to transform as technology advances. This contributes to a limited timeframe for returns on infrastructure investment.

Earthquakes in New Zealand over the past decade have raised not just public awareness of seismic risk, but also that of insurers. As the cost of insurance for private citizens increases, so does the cost for businesses that own costly assets. Again, with understanding of risk profiles rather than just compliance regimes, an asset owner will be best equipped to decide how to invest. The balance, in many instances, may well be shifting away from insuring against seismic events towards investing in resilience improvements to better enable a business to operate despite these events.

6 CONCLUSIONS

The following has been concluded:

- Extensive data gathering during the initial stages of a project, especially a risk assessment and stakeholder consultation, is critical in the development of a solution for an entire system. Without a breadth of thought, significant resource can be spent ineffectively on improving a part which relies on other elements to perform.
- A risk management focus can comply with legislation for a structural design project. To do so, operational objectives need to be understood and then correlated against structural performance requirements which can be measured by calculation.
- A risk-based approach to project definition can enhance understanding of how assets function, and what the biggest risks to performance actually are. Public sentiment or political mood can stir interest or anxiety about certain aspects of performance which may be less relevant than many other factors for certain structures.
- Different communication strategies need to be employed to suit the wide range of stakeholders involved in a complex project on a large system. In many cases, face to face discussion around simple media is very effective. In other cases, for example where spatial awareness is critical, 3D, 4D and more advanced modelling can be of more benefit in demonstrating a proposal or idea.