Ecological and environmental considerations for a civil project in New Zealand water

Koneski G[1] and Huteau J[1]
[1] Brian Perry Civil Limited, Wellington, New Zealand; gabrielak@fcc.co.nz

Abstract
New Zealand is a world hotspot for biodiversity with almost half of the world's cetaceans reported in our water. This paper presents the ecological, environmental and social commitments during a major piling project in Wellington, New Zealand. The project involves the maintenance and extension of the Seaview Wharf in Wellington, rated as one of the region's most critical assets. Construction activities include structural strengthening works and underwater piling (drilling and driving) to install 30m long piles. Permanent pile casings are driven into the seabed using a combination of vibrating and impact hammers. Piling noise is among the loudest underwater anthropogenic sounds and has been a serious threat to some marine mammal species such as the hector's dolphin. This construction project requires procedures that will reduce impacts on marine life and protect the Waiwhetu Aquifer, one of the key drinking water supply sources for the region.

This paper presents the company's journey to develop and establish ecological and environmental plans by working collaboratively with various partners such as research institutes, environmental consultants, Department of Conservation and local communities. The Seaview project was an opportunity to engage with these partners to deliver reliable records in a marine mammal observation zone. The implementation challenges and successes of mitigation measures are discussed, as well as results from the noise and water monitoring carried out to protect marine species. The acoustic monitoring was conducted during piling to assess background levels and the efficacity of a bubble curtain to mitigate piling noise. Those results were compared to thresholds for various marine species. The development of trigger values compared to monitoring results will be presented to assess groundwater leaking from the aquifer. Finally, this paper provides recommendations to improve current ecological and environmental management practices for future civil marine projects.

Keywords: piling, blue penguin, aquifer, mammals, monitoring

1. Introduction

Seaview Wharf, located south of Point Howard, Wellington, is managed, operated, and maintained by CentrePort Ltd. The Wharf is a critical lifeline and an important unloading facility for fuel and chemical tankers in the Lower North Island of New Zealand, serving approximately 20% of New Zealand's population. However, since the wharf was constructed in the 1970s, there has been a significant increase in tanker size, and international oil industry standards have become more rigorous, therefore the wharf necessitates upgrading. Impact pile-driving required for the construction of the wharf has been identified as a serious threat for marine mammal species (Thompson et al, 2013; Brandt et al, 2011). This paper presents the ecological considerations and mitigation measures necessary to ensure the wharf upgrade does not negatively impact the surrounding environment, including marine life in Wellington Harbour.

1.1 The Project

The wharf is a reinforced concrete and steel pile structure consisting of a 600m long approach wharf, a 100m long main wharf, and associated dolphins, trestles, walkways, and ancillary buildings (Figure 1).

CentrePort engaged Brian Perry Civil Ltd (BPC) as the contractor to renew the wharf and its supporting structures, be more resilient for future seismic hazard events, and make the wharf more suitable for the berthing of fuel ships, including meeting international fuel regulations.

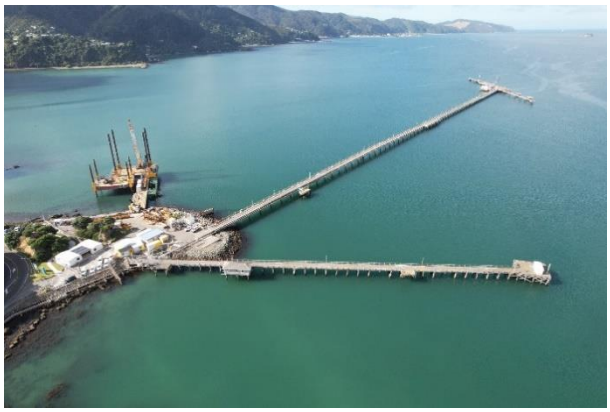

Figure 1. Aerial view of the Seaview Construction site

The key elements of the renewal work involve the repair of the lateral load resisting system of the wharf. The majority of the project required construction from barges; therefore, a site compound and a temporary staging platform were set up to serve the boats and barges.
The activities to complete the temporary staging involve installing 710 mm piles using both impact- and vibro-driving methods.

On the wharf structure, the works involve:

- removing piles by cutting them below seabed level and installing new 1500mm diameter reinforced concrete piles using a jack-up barge
- Construct new reinforced concrete pile caps and new fendering
- Installation of under-wharf gravity support system requiring the wharf to be jacked up, bearings installed and post tensioning works

The proposed upgrades will ensure that the wharf continues to serve as a crucial lifeline and an essential unloading facility for fuel and chemical tankers in the Lower North Island.

2. Site Location

Seaview Wharf is situated within the Hutt Valley Aquifer Protection Zone, and as such, any activities conducted within this area must be executed with techniques that prioritise the safeguarding of the underlying aquitard.

The location of Seaview Wharf within Wellington Harbour has significant ecological importance. The harbour provides a natural habitat for nationally endangered bottlenose dolphins, killer whales, and the nationally vulnerable Hector's dolphins, contributing to their overall resilience (Childerhouse, 2020). The coastal margin of the project site, specifically the crevices within the loose rip-rap above mean high water springs (MHWS), also offers valuable nesting and moulting habitat for the Little Blue Penguin (kororā).

Therefore, it is important to consider the ecological system around Seaview Wharf and take necessary measures to ensure the conservation of the diverse marine life that calls this area home. Any activities undertaken within this location must be approached with a keen awareness of the potential impact on the surrounding environment and must prioritise the protection of these vulnerable species and their habitats.

3. Preconstruction strategy

3.1 Engineering Aspects

Marine construction sites can have a significant impact on the marine environment, but there are several ecological improvements that can be implemented to minimise this impact. At the Seaview Wharf Project, the items below have been considered and implemented:

- Best practices for minimising underwater noise pollution, such as using quiet construction techniques or scheduling construction during times of low marine animal activity to avoid disturbing marine animals and habitats
- Implementing erosion and sediment control measures, such as silt socks around the cesspit to protect nearby water.
- Implementing spill prevention and response plans, such as containment booms and skimmers, to prevent and respond to oil spills or other hazardous material spills that could harm marine life. Marine spill kits are kept in the site office and on the barges

By properly implementing these actions and other ecological improvements, marine construction sites can minimise their environmental impact and contribute to a more sustainable future.

3.2 Environmental and ecological aspects

The Resource Management Act 1991 (RMA) is the main piece of legislation that sets out how we should manage our environment in New Zealand and to ensure activities such as pilling civil projects won't damage our communities, air, water, soil and ecosystems. Councils set rules and requirements to manage activities through regional policy statements, plans and resource consents. Civil construction project such as piling has the potential to negatively impacts the environment when not properly managed, contravene sections of the RMA and therefore resource consents were required before carrying out construction activities. CentrePort Limited successfully applied to Greater Wellington Regional Council for coastal permits to facilitate the repairs, replacement and partial rebuild of Seaview Wharf and associated structures. The resource consent provided mandatory conditions to manage and mitigate negative effects on the environment.

At the start of the project and before carrying out any construction activities, the BPC team assessed the risks for each planned activities by using BPC environmental risk matrix, a compulsory step for any new project. Some of the key challenges for the Wharf construction were:

- Vulnerability of the Waiwhetu aquifer during pilling and drilling
- Water quality of the Wellington harbour during soft mud disposal
- Underwater noise and its effect on marine life when driving the casing into the seafloor

The environmental risk matrix assessment permitted to review consent requirements and developed additional controls to protect the harbour's natural environment (Table 1). Consent requirements included the production and implementation of the following plans to manage our construction activities:

- Construction Management and Monitoring Plan (CMMP)
- Environmental and Sustainability Management Plan (ESMP)
- Blue Penguin Management Plan (BPMP)
- Marine Mammal Management Plan (MMMP)

- Construction Noise Management Plan (CNMP)

Table 1. Comparison of the main environmental controls provided by resource consent and various management plans

Item	Resource Consent	Management Plans
Aquifer Protection	- Drill an exploratory bore hole to capture ground conditions	- Conductivity monitoring during casing installation and drilling activities
Underwater noise	- Measure underwater noise to mitigate any environmental effects	- Install a bubble curtain to reduce our impacts for all casing work
Little Blue Penguin (LBP)	- LBP monitoring - Mitigation measures to protect LBP	- Install a steel mesh - Preconstruction survey and relocation
Mammal	- Establish marine mammal observation zones	- Involve community groups including training
Water Quality	- Sediment plume observation - Ph treatment	- Electrical conductivity monitoring during casing installation and drilling activities

3.2.1 Aquifer Protection

The Seaview Wharf is located on a bedrock high in the north-eastern part of Wellington Harbour, within the Hutt Valley Aquifer zone. The Waiwhetu Aquifer, a major source of drinking water for the region, is a confined artesian gravel aquifer extending out below the harbour. There are a series of freshwater springs discharging from this aquifer near the mouth of the Hutt River and a small cluster of springs is also present approximately 50-60 m west of the main wharf. The protection of this aquifer is critical and proposed management approaches included groundwater level and electrical conductivity monitoring. Field measurements of the water electrical conductivity was proposed as a proxy for salinity as the readings can be taken instantly and provide a good approximation for salinity. This will permit to detect of any anomalies such as freshwater egress from new piles. However, the geological model suggests that it is unlikely that the Waiwhetu Aquifer extends under the main or approach wharfs, but due to its proximity from construction site, a precautionary approach offered the best protection.

3.2.2 Marine Life Protection

The MMMP has been developed alongside the CNMP and BPMP to provide details of the management and mitigation of activities that have the potential to impact marine life. The species identified as potentially occurring in the vicinity of Seaview Wharf are little blue penguin (*Eudyptula minor*), common dolphin (*Delphinus delphis*), bottle nose dolphin (*Tursiops truncatus*), New Zealand fur seal (*Arctocephalus forsteri*), Hector's dolphin (*Cephalorhynchus hectori*), southern right whale (*Eubalaena australis*), humpback wale (*Megaptera novaeangliae*), dusky dolphin (*Lagenorhynchus obscurus)* and killer whale (*Orcinus orca*). Acoustic modelling predicted underwater noise levels from the proposed piling works and permitted to calculate marine mammal observation zones (MMOZ). The effects of anthropogenic underwater noise on marine mammals were assessed using the guidance document provided by the US Department of National Oceanic and Atmospheric Administration (NOAA, 2018). Ambient noise levels higher than 80 dB had the potential to affect penguin behaviours and thus mitigation plans were developed.

Pile-driving activities within water are estimated to lead to permanent threshold shift (PTS; permanent physiological hearing damage) levels that may occur up to 750 m from the noise source for species such as Hector's dolphins (185 and 198 dB $SEL_{cum(24h)\ (mf)}$ for impact and vibratory piling respectively). Therefore, validation of the actual noise levels was necessary. Pile-driving activities within water were expected to reach temporary threshold shift (TTS; temporary physiological hearing damage) levels. The estimated spatial zone as a radius from the pile driving impact site over which TTS may occur is approximately 3,500 m from the source for whales (a low-frequency hearing cetacean) and approximately 2,400 m for Hector's dolphins (a high-frequency cetacean) but confined to less than 220 m from the source for all other species. The acoustic model conducted by Marshall Day Acoustics predicted that the use of a burble curtain can reduced the TTS and PTS zones to 750m and 120 m respectively (Arden, 2021).

4. Environmental and ecological protection during construction

4.1 Little Blue Penguin Protection

The BPMP was prepared to recommend actions to avoid potential adverse effects on penguins, provide recommendations when penguins are encountered during the construction period and details how penguins will be monitored throughout the construction period.

Prior to commencing construction works, a penguin mesh was installed to safeguard the Little Blue Penguin nesting and moulting habitat. Surveys were conducted throughout the installation process to ensure the mesh's efficacy in providing adequate protection.

During the non-breeding season, tight mesh fabric was placed from the top to the bottom of the rock revetment to stop LBP from using potential nesting/moulting habitat along the revetment. This process was supervised and directed by a suitable qualified person with a DOC certified conservation dog (Figure 2).

Figure 2. *Protection mesh and DOC workers to protect the LBP*

The BPC team has also built penguin housing in case penguins reach the construction site in need of a place to rest. Penguin housing was checked weekly by the team, and relocation was conducted as required. This was an opportunity to raise environmental awareness within the team and have everyone involved in this environmental initiative.

To further improve the protection of the penguins, the site crew conducts daily inspections of the mesh, carefully documenting their findings. These inspections are crucial in identifying any potential issues or damages that may have occurred to the mesh, allowing for prompt action to be taken to rectify any concerns and prevent potential harm to the penguins. The diligent and consistent inspection process ensures that the penguin mesh remains functional and effective in safeguarding the Little Blue Penguins' habitat during the construction works.

4.2 Monitoring of underwater noises and mammal protection

The comparison of root mean square (RMS) logarithmic average levels of piling noise with and without the burble curtain are presented in Figure 3. The results showed a decrease in noise levels at higher frequencies (>120Hz) for both vibration (-33dB max at 200Hz) and impact piling (-45dB at 8kHz). The bubble curtain reduction was higher than other studies reporting a reduction of ~15dB (Verfuß & Jülich 2012, Koschinski & Lüdemann 2013). During impact pilling, a noise reduction to ambient levels were reached at 6300 Hz and demonstrated the efficacy and ecological implications to deploy a burble curtain. At frequency lower than 120Hz, the efficacy of the bubble curtain decreased with no significant noise reduction observed. The measured levels in the present study were lower than the PTS and TTS NOAA underwater noise guidelines.

The underwater noise levels at 90m and 350m distances from the piling were compared using regression calculations. The results showed that the noise levels were similar at the different monitoring locations (correlation coefficient of 0.86 and 0.91 for bubble curtain on and off respectively) and demonstrated that noise can travel long distances underwater, potentially blanketing large areas. The reduction of noise level at the source (e.g. bubble curtain) is therefore fundamental to managing the impacts of underwater noise that can adversely affect marine animals in a variety of ways such as hearing injury, altering behaviour, and driving species away from areas of habitat (Leunissen & Dawson 2018).

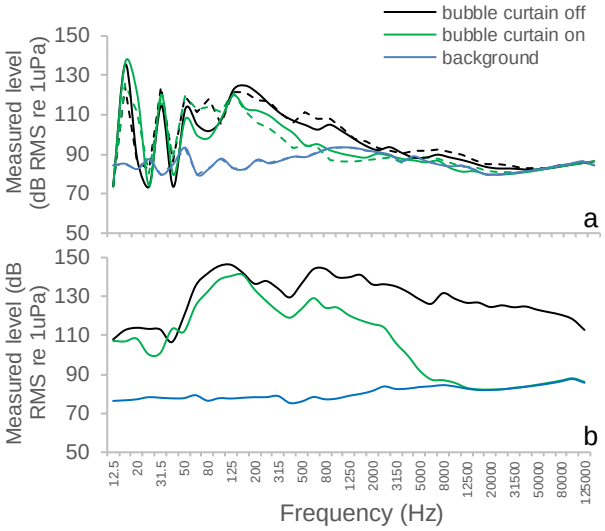

Figure 3*. Comparison of RMS logarithmic average levels (dB RMS re 1uPa) of background and piling noise recorded at 10m depth with and without a bubble curtain. (a) full and dash line at 90m and 350m distance respectively during vibro piling. (b) at 90 m distance during impact piling*

Noise reductions for each species group were calculated based on the NOAA weighting curves. The following single-strike sound exposure level reductions were achieved:

- High-frequency cetaceans (hectors dolphin): 35 dB
- Mid-frequency cetaceans (orca, common dolphin, dusky dolphin, bottlenose dolphin): 32 dB
- Low-frequency cetaceans (baleen whales): 7 dB
- Otariid pinnipeds (fur seals): 19 dB

This finding permitted refining the observation area to 200m when the bubble curtain mitigation is applied. The marine survey to verify that marine life is not being adversely affected was an opportunity to involve and provide a Department of Conservation marine mammal observer course to a local community group (Rotary Club). MMOs observation flowcharts was developed to guide the observers and provide clear guidance for the records and follow up actions when mammals were observed in the area. If any mammals were observed within and around the survey area, all piling activities ceased immediately until the animals vacated the area.

4.2.1 Water Quality Turbidity

Visual clarity and sedimentation caused by barge washdown are a concern during piling activities. If there are any spills, the procedures outlined in the

CMMP will be followed which requires work to stop if a sediment plume larger than 15m is detected at the water surface. To address this issue, BPC proposed to to dispose the sediment directly on the seafloor using an empty casing on an angle, resting on the side of the working platform and socketed into the soft seabed material (Figure 4). This mitigates the increase in turbidity caused by the disposal of fine sediment in the water column. Visual sediment plume monitoring was conducted during the disposal of sediment to ensure proper implementation of this mitigation measure.

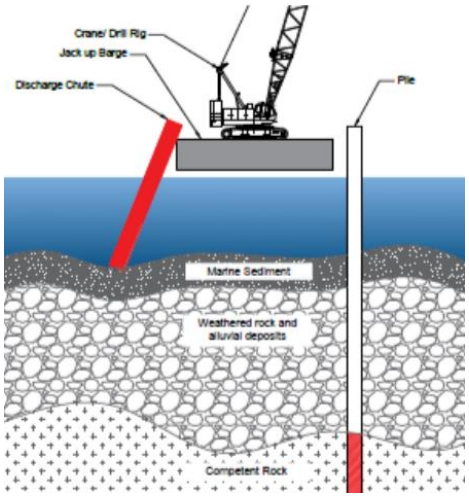

Figure 4. *Position of the empty casing on the side of barge*

4.2.2 Aquifer Protection

In addition to groundwater monitoring, a method using conductivity sensors has been developed to detect small leaks that may not be perceptible in the monitoring bores. Two conductivity sensors (Digital C4E sensor, Aqualabo) were simultaneously deployed at the bottom of the water column near the drilling activity. Conductivity levels are continuously measured and recorded to permit real-time management during piling operations (Figure 5).

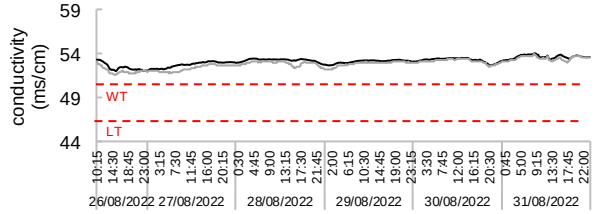

Figure 5*. Comparison of the conductivity levels (ms/cm) measured with two different probes during piling activity. WT: Warning Treshold; LT: Low Treashold*

A warning threshold and low threshold limit were established at 50 ms/cm and 46 ms/cm respectively. The warming threshold permitted to send an alarm to the team when the conductivity decreased below 50 ms/cm and was followed by a technician conducting real-time monitoring. When the conductivity dropped below the low threshold limit, piling activities were stopped until investigation was completed.

5. Conclusion and recommendation

Civil projects such as concrete piling in the marine space have the potential to negatively impact the environment when not properly managed. This project was an opportunity to implement and test new controls to protect the marine environment, such as deploying a burble curtain to decrease acoustic noise, conductivity monitoring to identify any freshwater leaks from the aquifer, and surveying marine mammals and birds. The comparison of noise levels with and without the bubble curtain showed a notable reduction. Overall, the Marine Mammal observation zone was minimized to 10m, rendering the presence of MMO unnecessary.

Besides further technical development of bubble curtains, it will be important to investigate their mode of action under different conditions and describe influencing parameters on the sound mitigation, especially for lower frequency.

The direct measurements of turbidity in the water column will permit to better understand the effects of soil disposal in the water column especially during calm weather. Direct observation can be supported by deploying remotely operated underwater vehicles that can be used for wharf structural inspection and ecological survey before and during construction.

Little blue penguins are sensitive to underwater noise, and it would be of interest to further explore any impacts on this species. A continuous running acoustic monitoring network could be deployed to establish baseline presence and behaviours of the marine mammals and compare records with the measurements during and after the piling.

6. References

Arden, S (2021). Seaview renewal works construction noise management plan. Rp 001 r02 20210175 SA. 25p

Brandt M, Diederichs A, Betke K, Nehls G (2011). Responses of harbour porpoises topile driving at the Horns Rev II offshore wind farm in the Danish North Sea. Mar.Ecol. Prog. Ser. 421, 205–216

Childerhouse S (2020). Marine mammals in Wellington Harbour. Prepared for CentrePort Ltd. Cawthron Report No. 3536. 18 p

Koschinski S, Lüdemann K (2013). Development of Noise Mitigation Measures in Offshore Wind Farm Construction 2013. Vilm, Germany

National Oceanic and Atmospheric Administration- NOAA (2018). Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing. p.178.

Leunissen E, Dawson S (2018). Underwater noise levels of pile-driving in a New Zealand harbour, and the potential impacts on endangered Hector's dolphins. Marine Pollution Bulletin 135 (2018) 195–204

Thompson P, Hastie G, Nedwell J, Barham R, Brookes K, Cordes L, Bailey H, McLean N (2013). Framework for assessing impacts of pile-driving noise from offshore wind farm construction on a harbour seal population. Environ. Impact

Verfuß T (2012) Noise Mitigation Measures & Low-noise Foundation Concepts – State of the Art.