Technical Report 19

Aquatic Environmental Sciences (AES) – Assessment of Ecological Effects

Aquatic
Environmental
Sciences

Assessment of Ecological Effects of the reclamation and extension to Wellington Airport

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1. Introduction

1.1 Background

Wellington International Airport Ltd (WIAL) presently operates with a single 1945 m Take-Off Runway Available (TORA) and 90 m Runway End Safety Areas (RESA) at each end of the runway. WIAL has undertaken detailed reviews of traveler demography and has assessed that with an extension of the runway to a minimum of 2300 m TORA this would enable Wellington Airport to handle most Code E aircraft types with sufficient load capacity to and from east Asian and western north American destinations.

WIAL is very aware of the potential effects on the environment associated with a reclamation for a runway extension and has commenced planning for this extension with the first phase being preparation of a number of assessment reports as part of its preparation of the various statutory applications for the project. As yet the final detailed design of the extension has not been confirmed but based on geotechnical work and consideration of options to the north and south a decision has been made to apply to reclaim land to the south into Lyall Bay to enable the project. The design may involve the installment of stone columns into the underlying sediments to support the structure and/or vibro-coring depending on further investigations (AECOM 2015), and will involve a rock dyke around the outside to protect the reclamation from wave activity, and then infilling of the reclamation with material suitable to sustain the heavy impact loads of aircraft.

An initial scoping investigation was carried out and a number of work streams identified which would involve further field work before a full AEE could be prepared. This work has now been completed and a description of the existing marine ecological environment has been prepared based on existing and new information (MacDiarmid et al. 2015). New work undertaken as part of this assessment has included:

- Deployment of moorings to gather information on currents, waves and physical characteristics of the water column (light, turbidity, temperature, salinity)
- Bathymetric surveys of Lyall Bay
- Surveys and assessments of sediments and contaminants
- Modelling of potential impacts on waves, currents and turbid plumes from construction and ongoing impacts of the reclamation.
- Surveys of soft-bottom and reef communities in Lyall Bay.
- Surveys of plankton communities in Lyall Bay
- Collation of information on use of Lyall Bay by birds and mammals.
- Collation of information and modeling of fish and fisheries resources in Lyall Bay.

1.2 Scope of This Report

This report provides an assessment of the potential ecological effects of the reclamation on the natural environment's marine ecology during construction of the reclamation and operation of the extended runway. The report provides in:

- Section 2 a summary of the physical environment based on work undertaken and reported by NIWA (DePree et al. 2015, Pritchard et al. 2015, Bell 2016).
- Section 3 a summary of the biological resources of Lyall Bay based on the full description provided by NIWA (MacDiarmid et al. 2015).

- Section 4 a description of the construction and reclamation operations.
- Section 5 an examination of the potential effects of the construction phase.
- Section 6 a look at the effects of the potential changes to physical characteristics on the biological communities.
- Section 7 assesses the potential effects on water quality, Section 8 and 9 the potential effects of suspended sediments and turbidity, and sedimentation on the aquatic ecology.
- Section 10 provides an assessment of the potential effects of noise and blasting.
- Sections 11 and 12 include recommendations on ways to avoid, minimise or mitigate potential effects and provide an outline of a monitoring programme.

2. The Physical Environment

2.1 Lyall Bay

Lyall Bay is a semi-circular, large open bay on the Wellington south coast. The Bay is situated between the rocky headlands of Te Raekaihu to the west and Hue te Taka (Moa Point) to the east. The Bay shoals progressively from about 28 m in outer Lyall Bay to shoreline with steep slopes rising to ridge lines close to the headlands. The Bay is very exposed and can be subject to strong southerly swells and large high energy waves. Waves up to 4.7 m were recorded during the mooring deployment in September/October 2014 at the southern end of the runway and up to 6.1 m at the entrance to Lyall Bay.

Land use in the catchment is predominantly residential with light industry/ commercial as well as the Wellington Airport. The Bay receives stormwater from the Lyall Bay catchment including the area around Wellington Airport and from the Moa Point Wastewater Treatment Plant. Secondary treated ultra-violet disinfected wastewater from this plant is discharged through a 1.87 km pipe to an outfall diffuser just beyond the entrance to Lyall Bay.

2.2 Soft sediments

Surveys of sediments on the eastern side of Lyall Bay found that the seabed in the vicinity of the proposed reclamation is dominated by moderate to well sorted fine sands (**Figure 1**), with low levels of silt and low organic content (<0.3% organic carbon) (MacDiarmid et al. 2015). A site close to the southern end of the present runway had increased levels of very fine pebbly-gravel and coarse sand (**Figure 2**).

2.3 Hydrodynamics

Results from a hydrodynamic mooring and modelling for Lyall Bay show that mean or residual circulation alone in Lyall Bay is very weak but there can be a clockwise eddy in the head of the Bay and a counter clockwise eddy in the middle of the Bay (Pritchard et al. 2015). Modelling with the extension in place showed that the extension would have negligible effect on the scale and flow direction of the two residual eddies outside the immediate near-filed zone close to the extension. Simulations of wind-driven forcing indicate a similar pattern of eddies are produced to the residual currents in southerly winds but would be greater in magnitude. Under northerly conditions flows along the eastern and western sides would be directed south with return northerly inflow through the centre. The extension would cause little change to the northerly flow pattern but would cause some reduction to southerly wind-driven circulation in the vicinity of the extension. The lee-effect of wind-driven southerly currents could result in some localised deposition in the SW and SE corner of the dyke walls but these are likely to remobilize during strong weather events.

2.4 Contaminants

Lyall Bay receives stormwater from 283 ha of fully developed urban catchment with stormwater contaminant loads discharged through a series of outfalls including Lyall Bay Beach, Moa Point and near the breakwater at the southern end of the runaway as well as the outer Bay receiving treated waste from the Moa Point wastewater treatment plant (Depree at al. 2015). Water quality however is considered to be very good and chemical contaminants are not considered to have a significant effect on marine organisms in the area. Because of the dynamic environment and moderate to well sorted fine sand sediments with low levels of mud (2-5%) contaminants in the surficial sediments are very low and uniformly distributed across the area. Contaminant levels are at least two orders of magnitude less than the ANZECC guidelines and thus mobilization of the sediments during construction is not expected to result in any significant increase in sediment contaminants.

2.5 Optical properties

An important aspect when assessing the potential effects of any reclamation is potential changes to optical properties of the water column i.e. the potential for increased turbidity and suspended sediment levels, reduced water clarity and changes to water colour. In order to describe the background environment in Lyall Bay a mooring was deployed in the middle of the entrance to the Bay for 5 weeks in the spring of 2014.

This mooring and its sensors provided a time-series of optical conditions with samples taken on several occasions during deployment for calibration and grab samples for optical properties. This snapshot showed that the waters were typical of clear water with a blue-green hue with more of browner colour during storm events due to sediment runoff. During the deployment reduced visibility (20-30m down to <1 m) and euphotic depth (40-50 m to <10 m) corresponded to storm events. The euphotic depth is the depth to which there is sufficient light for net photosynthesis of aquatic benthic and planktonic plants. Although limited to a snap-shot in time this time-series provides a realistic range of conditions likely to be experienced in Lyall Bay.

Full details of the measurements are provided in MacDiarmid et al. (2015) and Bell (2016). Total suspended sediment concentrations from water samples taken at the mooring site on several occasions varied from 0.46 to 2.9 mg/L, corresponding to an NTU[1] of 0.3 to 2.2 NTU and secchi disc depth 5 to 11.5 m. During the deployment of the buoy with continuous measurements Kd[1] varied from 0.09 to 0.61 m^{-1} (median 0.21 m^{-1}), TSS[1] 0.17 to 37.5 mg/L (median 1.7 mg/L for the 8 m sensor, 1.9 mg/L for bottom sensor at 16 m) and euphotic depth[11] 7.6 to 51.36 m (median 21.83 m). The maximum recorded at the top sensor (8 m depth) was 16.3 and at the bottom sensor (16 m depth) was 37.5 mg/L. Because of the instruments involved the synoptic survey was carried out during calm, clear conditions. This survey showed TSS concentrations of 0.5 mg/L at the mooring increasing to about 1 mg/L inshore.

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[1] NTU – Nephelometric Turbidity Units, Kd – measure of light attenuation with depth, TSS – total suspended solids, euphotic depth – the depth at which there is sufficient light for net plant growth.

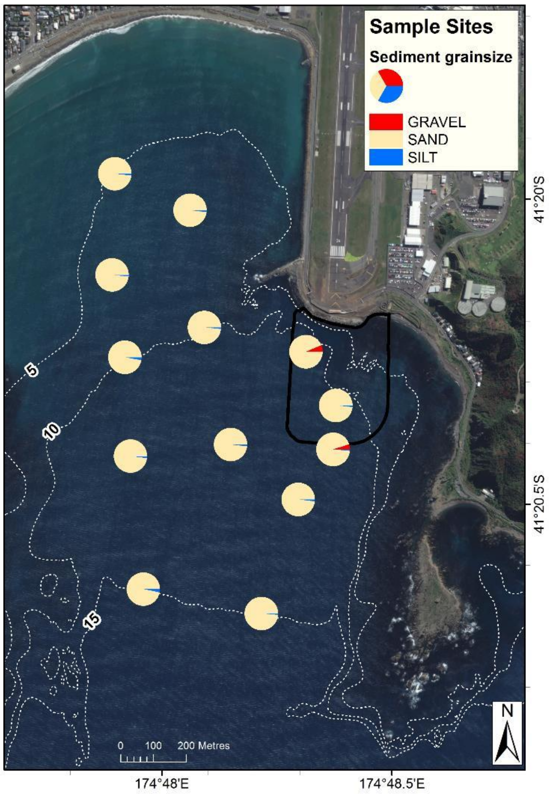


Figure 1: Surficial sediment grain size composition at sample sites in Lyall Bay. No muds were present. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines. (MacDiarmid et al. 2015).

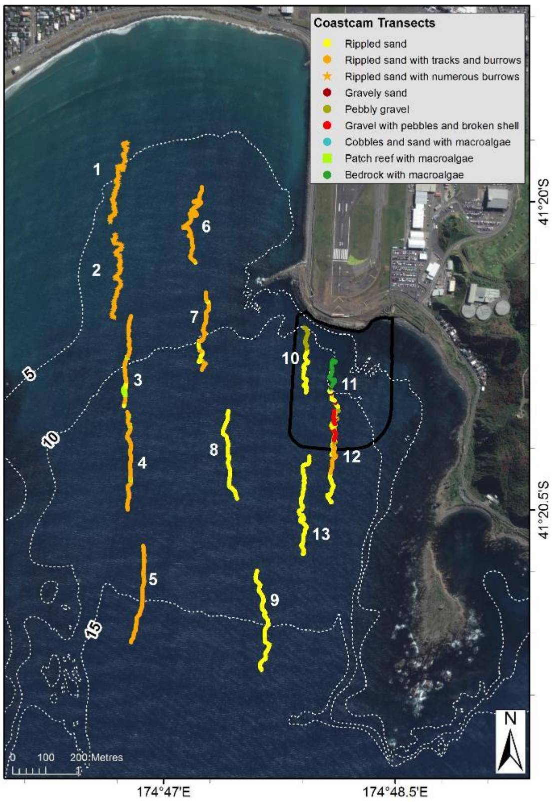


Figure 2: The distribution of habitat types along each seafloor imaging transect in Lyall Bay. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines. (MacDiarmid et al. 2015).

3. Biological resources

The biological resources and values of Lyall Bay and its coastline that may potentially be impacted by the construction of reclamation for a runway extension have been described in detail in a comprehensive report by NIWA (MacDiarmid et al. 2015). This report was based on existing information and new surveys of benthic biota, reef communities, and plankton as well as modelling and observations of fish, bird and mammal populations and their use of the Bay. For completeness the findings from those studies are summarised here.

3.1 Benthic Communities

As would be expected with a dynamic, exposed, highly mobile fine-sand dominated habitat the epifaunal communities (animals living on the surface) were very low in overall abundance and diversity (**Figure 3**) with only 34 individuals and 13 taxa captured. Shrimps (Malacostra) tended to dominate at sites close to the southern end of the runway and gastropods at other sites further out into the Bay (**Figure 4**). The presence of gravels at sites near the end of the existing runway appeared to provide greater opportunities for attachment for some taxa.

The macro-infauna that live in the sediment were also not very abundant (**Figure 5**) with densities half those typically encountered in similar environments in more sheltered harbours, due to the wave-exposed dynamic habitat. The low numbers will also be a consequence of low organic matter in the sediments as a result of low chemical and biological activity. The presence of large numbers of burrows belonging to ghost shrimps suggest these animals may comprise the bulk of the macro-infaunal biomass (MacDiarmid et al. 2015) and can burrow down to up to 65 cm.

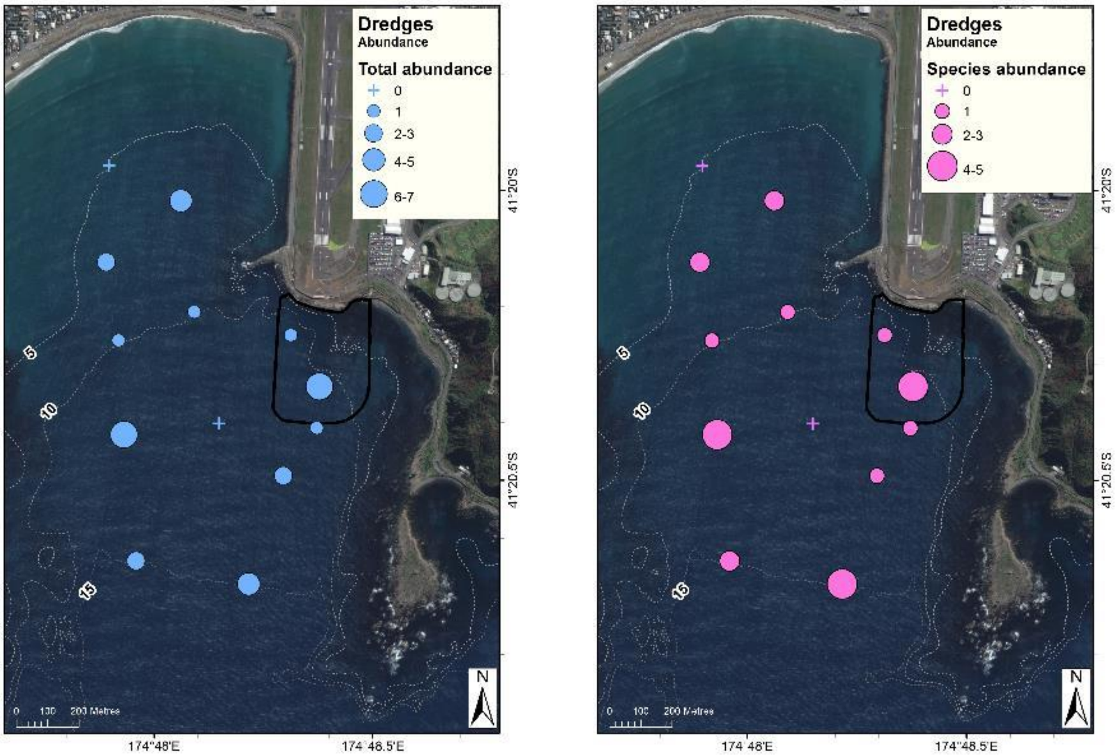


Figure 3: Total abundance (left panel) and number of species (right panel) of epibenthic fauna at 13 sites in Lyall Bay. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines. Sites where no epifauna was captured are indicated by crosses. (MacDiarmid et al. 2015).

The meiofauna community (animals retained on a 45um mesh) was dominated by nematodes (commonly known as roundworms), then Kinorynchs, a type of small marine worm, and tardigrades (microscopic animals often referred to as “water bears”). The abundance of Kinorynchs and tardigrades is probably related to their ability to withstand strong currents and preference for fine, clean sediments. These taxa are commonly found at other non-polluted sites.

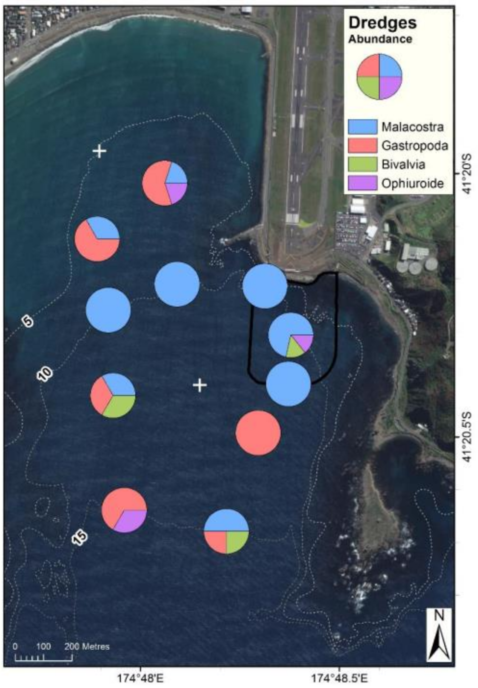


Figure 4: Composition of epibenthic fauna at 13 sites in Lyall Bay by broad taxonomic class. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines. Sites where no epifauna was captured are indicated by crosses. (MacDiarmid et al. 2015).

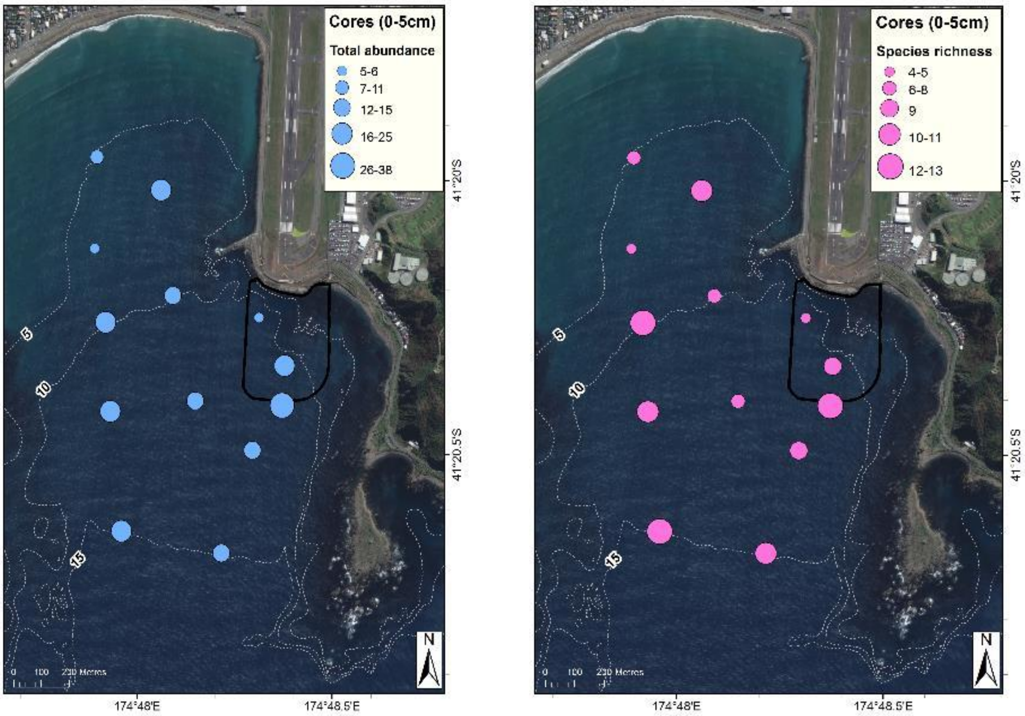


Figure 5: Total abundance (left panel) and number of species (right panel) of macro-infauna in the upper 5 cm of sediment at 13 sites in Lyall Bay. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines. (MacDiarmid et al. 2015)

3.2 Reef Communities

Rocky reef habitats are found all along the exposed southern Wellington coast supporting a rich and diverse community of brown, red and green macroalgae which in turn support a rich reef community of a range of fauna including gastropods, paua, kina and rock lobsters (MacDiarmid et al. 2015). The communities found on the reefs off the southern end of the runway are typical of those found along the Wellington coastline (**Figure 6**). Large strap-like canopy-forming macro-algal species (e.g. *Lessonia variegata* and *Macrocystis pyrifera*) were common in the sub-tidal parts of all transects, except the one directly off the end of the runway. Crusting and turfing red algae occurred intertidally along most transects except the one off the end of the runway. The transect off the end of the runway was dominated by fine-branched red algae.

Artificial substrates (e.g. Akmons) in the inter-tidal and sub-tidal zones along the edge of the runway (**Figures 7 and 8**) provide habitat for a range of species including green tubular “ulva” like algae and/or the red algae *Pyropia*. Broken rubble habitats (cobbles-gravel-sand) supported more red algae and bryozoans.

Small patch reefs (<2m^2) with macroalgae holdfasts of giant kelp (*Macrocystis pyrifera*) were also observed in the centre of Lyall Bay at depths of 10-13 m.

Sponges, bryozoans and ascidians were common in the subtidal zones along all reefs with sponges more common in the mid or lower parts of transects and acidians very common on reefs off the breakwater. Over 40 other species were found on the reefs at low densities. Barnacles were the most common taxa intertidally along with periwinkles and limpets while sea-urchins occurred subtidally. Paua and rock lobster were uncommon but paua were associated with both natural bedrock and artificial substrate. A range of invertebrate taxa were found on concrete structures in the intertidal zone including periwinkles, snails, limpets, chitons and barnacles (MacDiarmid et al. 2015). Barnacles and snails were more common on rougher surfaces and chitons on smooth surfaces.

During the first survey of reefs a “Bangiales” type filamentous algae and an undescribed red foliose macroalgae were found respectively on intertidal concrete substrate and subtidal rocks at the southern end of the runway. Subsequent additional surveys found no additional specimens of the filamentous Bangiales on boulders in the vicinity but more specimens were found at the extreme western end of Lyall Bay which genetic sequencing confirmed were the same as previous specimens found in the wider Wellington region. The subtidal foliose red algae was not found during additional searches along other parts of Wellington’s south coast but has been found on the Otago coastline.

3.3 Plankton

The phytoplankton community (microscopic algae in the plankton) was dominated by diatoms then dinoflagellates. Cell concentrations from the single sampling were very low with highest number of taxa and cell numbers found inshore in the middle of Lyall Bay. All species found are harmless and cosmopolitan, as would be expected from a well-flushed open bay.

The abundance of zooplankton (microscopic planktonic animals) was also highest in the inner and middle of Lyall Bay than around the edges. The community was dominated by copepods and the community was typical of inshore coastal waters.

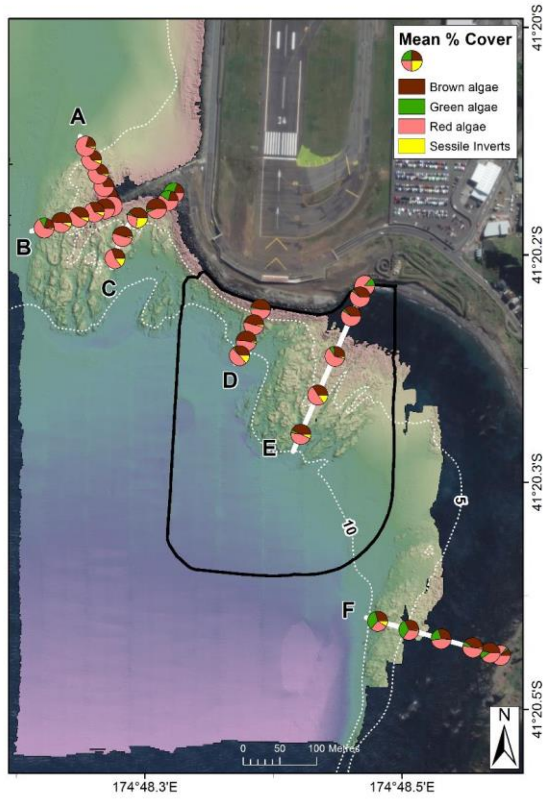


Figure 6: The percentage cover of brown, green and red algae, and encrusting sessile fauna in different zones on rocky reef transects A-F. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines. (MacDiarmid et al. 2015)

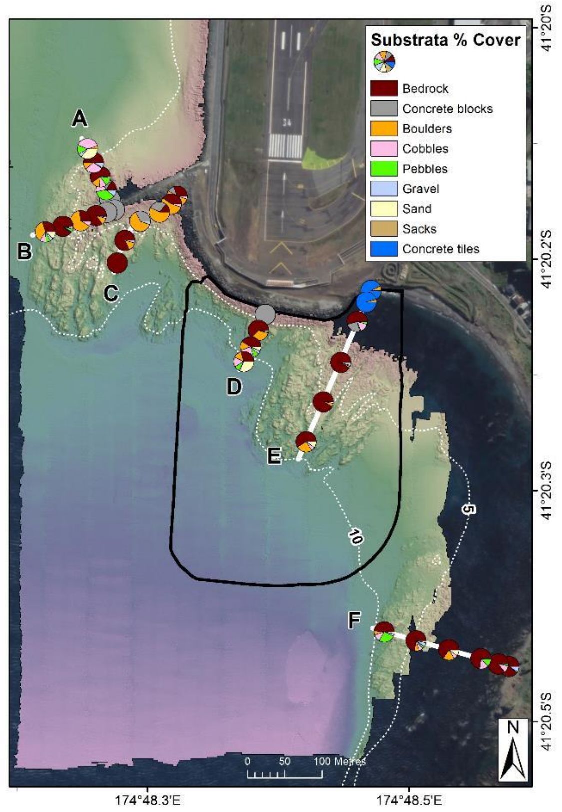


Figure 7: Substrate types encountered in different zones in rocky reef transects A-F. The proposed extension to the runway is outlined in black. Depth contours are indicated by white dashed lines. (MacDiarmid et al. 2015).

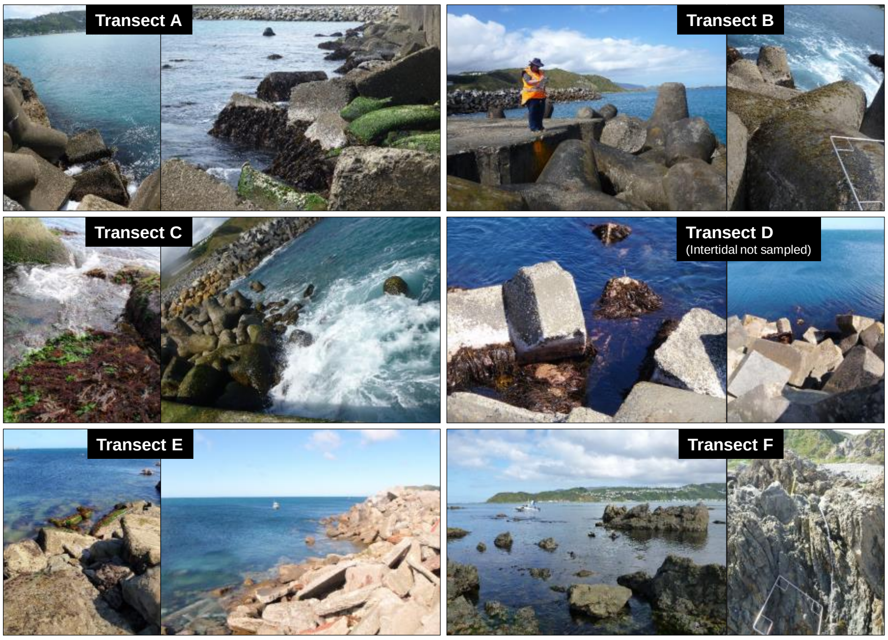


Figure 8: Still photos of rocky reef transects A-F showing the profile and substratum composition of the intertidal zones (MacDiarmid et al. 2015).

3.4 Birds and Mammals

New Zealand supports the most diverse seabird assemblage on earth with 161 species recorded (359 worldwide) including 95 which breed in New Zealand (MacDiarmid et al. 2015). Thirty-one taxa are classified as "threatened". The full list is provided in MacDiarmid et al. (2015). Compared with the large number of taxa that would use Cook Strait a much reduced assemblage would use Lyall Bay. This group is likely to comprise blue penguin (*Eudyptula minor*) which breeds along the south coast, fluttering shearwater (*Puffinus gavia*), gulls, terns, shags, reef (*Egretta sacra*) and white-faced (*Egretta novaehollandiae*) herons and variable oystercatcher (*Haematopus unicolor*). Blue penguins are likely to breed nearby at Moa Point but it is unlikely that any species would nest along the wall at the end of the runway.

Diversity among mammals is similarly high with 54 taxa recorded in New Zealand (43% of worldwide total), eight of which are "threatened". Based on the DoC cetacean sighting database killer whales (*Orcinus orca*) and common dolphins (*Delphinus delphis*) have been sighted in Lyall Bay and close to the southern end of the runway. Other species may occur close to the Harbour entrance but there is no evidence that Lyall Bay is particularly important for marine mammals and use is likely to be sporadic and transitory (MacDiarmid et al. 2015).

3.5 Fish populations

Lyall Bay has a moderately diverse fish community with 27 species of reef fish predicted to occur, none are nationally threatened (Smith et al. 2013). In order of increasing abundance these 27 species include blue dot triple fin, common conger eel, Yaldwyns's triplefin, leather jacket, sea perch, rock cod, scaly head triplefin, scarlet wrasse, variable triplefin, spectacled triplefin, red moki, butterfish, red-banded perch, yellow-black triplefin, banded triplefin, blue moki, marble fish, blue-eyed triplefin, common triplefin, common roughy, tarakihi, blue cod, banded wrasse, oblique-swimming triplefin, butterfly perch, and spotty (MacDiarmid et al. 2015). The most abundant species during dive surveys were spotties and banded wrasse which occurred on all transects and the number and type of species showed good agreement with the predicted distributions from models of distribution around the New Zealand coastline. Along with tarakihi and blue cod these species are common on reefs throughout Lyall Bay and the south coast.

Forty-four demersal species are predicted to occur in Lyall Bay but only 11 species are likely to be common. The 11 species likely to be commonly found in Lyall Bay are barracouta, blue cod, leatherjacket, lemon sole, red cod, spiny dogfish, spotty, silver warehou, tarakihi, common warehou, and witch. No species is confined to Lyall Bay and all species are ubiquitous throughout the region (MacDiarmid et al. 2015). It should be noted that the modelling of fish distributions and abundance is based on a very large and comprehensive data set of diver observations and trawl surveys.

The wider coastal and Cook Strait area supports important and diverse commercial fisheries (see MacDiarmid et al. 2015 for full description of activity in the wider TAC area), but activity in Lyall Bay is likely to be limited to occasional set netting and potting at reefs at the entrance to the Bay targeting butterfish and rock lobsters respectively.

The main species targeted by recreational fishers along the Wellington south coast, including Lyall Bay, is blue cod followed by terakihi, kahawai, Jock Stewart, paua, rock lobster, butterfish and blue moki. The main method of fishing is rod and line from a boat but with little of this effort actually being targeted at Lyall Bay. No recreational diving or potting effort was recorded in Lyall Bay, however fishing from the shore, set netting, and hand gathering of paua and kina are likely to be popular, including around the reefs surveyed at the end of the runway.

4. Description of Reclamation Construction

The construction of the reclamation to extend the airport runway is designed to meet WIAL's requirements while minimizing the impact on the environment and interruption to the ongoing operations of the airport. The area of the reclamation to the south is approximately 10.82 ha (including toe). The design criteria is based on providing a minimum 2,300 m TORA and 90 m RESA. Further details of the proposed construction are provided in AECOM (2015).

It is not anticipated that the associated activities of construction, such as onshore staging, will impact directly on the marine ecology of Lyall Bay. Control of sediment runoff from the land-based activities will be dealt with separately as part of an Erosion and Sediment Control Plan to ensure runoff is minimised. Further measures are also outlined in the construction methodology report (AECOM 2015).

Construction of a reclamation in Lyall Bay is particularly challenging because of the dynamic high energy physical environment including intermittent, strong, and at times extreme wave activity. The construction methodology is still to be finalised but is outlined in AECOM 2015 and will consist of 3 general phases:

- Phase one - Stone columns may or may not be required. If they are then they are likely to be ~ 1m in diameter, driven 5-6 m deep into the seabed. Ground preparation may also involve vibro-coring depending on further investigations.
- Phase two – A rock dyke will be constructed most likely starting from shore and working outwards.
- Phase three - Reclamation in-fill with horizontal lifts across the area most likely starting at the existing beach and working southwards. The fill material will either be sandy marine sediments or alternatively a land-based fill from a nearby quarry and if marine based will most likely be delivered to the site by pipe or dredge. Otherwise it will arrive by land or barge. Once the filling operation is completed the fill will be stepped or sloped as required. Excess water will be discharged through a weir and outlet pipe as the reclamation is in-filled.

It is anticipated that weirs will be constructed for the dewatering discharge of sediment-laden water in the NW or SW corners. A more recent consideration is a weir in the centre of the rock dyke at the southern end of the reclamation. Details and schematics are provided in Bell (2016).

The construction is expected to take up to 3-4 years depending on the type of operations.

5. Effects of Construction

This section of the report examines effects of the construction phase of the project on marine ecology. This report only deals with effects of the actual construction and does not include associated activities such as dredging of material if that source is used.

The assessment of the effects of construction on the marine environment needs to be based on a good understanding of the biological resources present, the type of construction activity and sensitivities of the biological communities to those activities. The effects associated with construction of a reclamation are likely to be short-term and mostly associated with temporary disturbance of the seabed and production of turbid plumes from de-watering discharges, particularly if a fine-sediment fraction is present, which could impact beyond the reclamation area and near-field environment. The biological communities would be expected to eventually recover from these effects.

The longer term or permanent effects associated with the reclamation will be dealt with in the next section of this report (Section 6). The major impacts of construction are likely to be:

- Physical disturbance and loss of habitat
- Changes in water quality through the disturbance of the seabed and introduction of contaminants with the infill
- Increases in suspended sediments and turbidity of the water column during construction of the dyke and from dewatering discharges.

- Sedimentation of material in suspension.
- Release of contaminants, such as heavy metals, during disturbance of the seabed and potentially from the fill.
- Noise from drilling and blasting activities.

The evaluation of the environmental effects of activities such as a reclamation must take account of the severity, the short-term and long-term effects that may occur both at the site of construction (near-field) and the surrounding area (far-field). The IADC/ CEDA (1998) document provides a useful guide that illustrates the temporal and spatial scales in which various environmental effects of such activities might be realised. Near-field effects are simply defined as ‘phenomena occurring within the geographic bounds of the activity, or less than approximately 1 km from the activity’. For reclamations, near-field short-term effects include disturbance of the benthic habitat, loss of habitat and communities in the immediate area, increased turbidity, smothering of organisms nearby, reduced faunal densities/biomass and diversity, at least temporarily in the immediate area, reduced water quality and potential contamination and release of sediments during disturbance.

Generally, far-field effects, ‘occurring more than approximately 1 km from the activity', are not expected to be significant in the short or long-term but there can be dispersal of some fine sediments that can impact on biota in the near-field and changes to geomorphology and hydrodynamics at the bay scale. In the context of the runway extension we have assessed effects with-in and beyond 150 and 500 metres as these are potentially more relevant in this environment.

6. Physical Disturbance and Loss of Habitat

6.1 Overview

Creation of a rock dyke and infilling of the reclamation will result in complete loss of intertidal and subtidal habitat for an area of approximately 10.82 ha (including toe) and is one of the major impacts of the runway extension project. The habitat loss will include soft-bottom and reef habitats and most of the biota associated with these habitats will be lost.

6.2 Soft sediment benthic communities

Benthic communities in the area being reclaimed will be disturbed and most of them completely lost. The outer area that will be lost is predominantly rippled sand which provides habitat for a depauperate epifauna dominated by shrimp (*Tenagomysis* sp), bivalves and ophiuroids and a macrofauna consisting predominantly of amphipods, isopods and polychaete worms. The community is typical of the south Wellington coast and no rare or unique species or assemblages of special scientific or conservation interest are present.

Close inshore, within about 80 m of the end of the runway, is a gravely habitat with cobbles and pebbles with areas of bedrock, boulders and cobbles closer inshore (**Figure 9**). These habitats harbour canopy forming macroalgae such as the brown kelp *Ecklonia radiata*, and the brown algae *Carpophyllum maschalocarpa* and *Lessonia variegate.* There will be about 5.9 ha of this habitat lost with the reclamation but similar habitats will be present along much of the south Wellington coast.

To put this loss of soft-bottom habitat in context Lyall Bay has 189 ha of soft benthic habitat and thus 3% would be lost with the reclamation and considerably less for the south Wellington coast overall. The loss is therefore not considered to be significant.

Figure 9: Bedrock, boulder and macroalgae habitat with sand and gravel patches along site 12.

6.3 Reef communities

The rocky reef habitat in the area to be reclaimed consists of bedrock and concrete tiles and blocks close to the shoreline. These reefs are dominated by finely branched red and brown algae including the large kelps *Macrocystis*, *Ecklonia* and *Undaria* which support sponges, ascidians and bryozoan with low numbers of sea urchins. Like the soft-bottom habitat the rest of the community found on these reefs is typical of the south Wellington coast and no rare or unique species or assemblages are present. The undescribed red foliose algae in the family Kallyemeniacae found on a transect at the end of runway was not found elsewhere in further searches made along Wellington's south coast but sequencing indicated it is known from Otago Harbour. Additional specimens of filamentous 'Bangiales' were found at the extreme western end of Lyall Bay beach which sequencing revealed were the same as the original specimens collected on reefs at the end of the runway, and belong to an undescribed species of algae known as '*Bangia* BMW' which has been previously collected from the Wellington region.

The area of subtidal reef likely to be lost to the proposed reclamation activities (**Figure 10**) is about 5.0 ha. Most of this comprises natural bedrock but in the shallow subtidal a small proportion of reef is comprised of artificial substrates, mostly concrete blocks, concrete tiles and clay bricks (MacDiarmid et al. 2015). This area of subtidal reef comprises 5.0% of the 98.76 ha of subtidal rocky reefs in Lyall Bay (**Figure 11**) and 1.5% of 328 ha of the subtidal rocky reefs along Wellington's south coast from Sinclair Head to the point at the northern end of Breaker Bay (**Figure 12**).

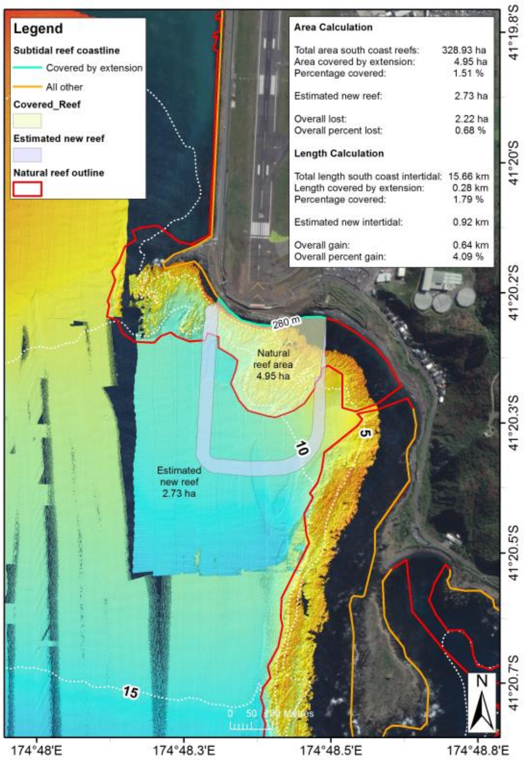
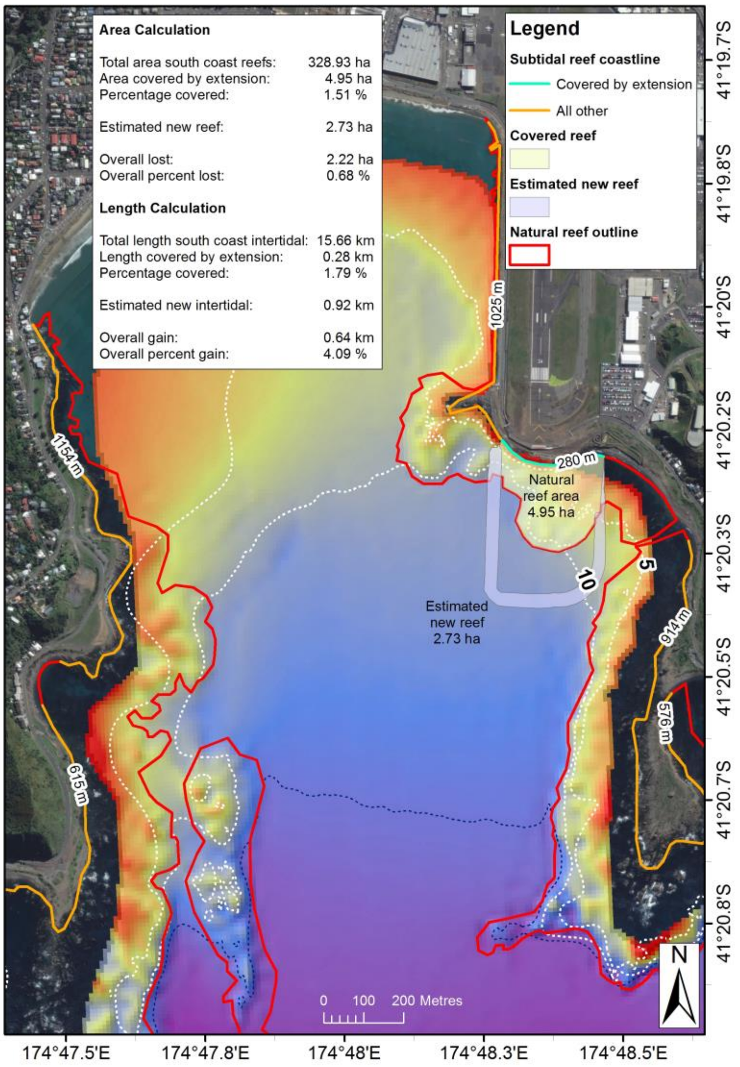


Figure 10: Map showing the area of reef in Lyall Bay lost to reclamation if the proposed runway extension proceeds.

The length of existing coastline boarded by intertidal rocky reef that will be buried during the runway construction will be 0.28 km, with much of it comprised of artificial substrates including accropods, concrete blocks, concrete tiles and clay bricks (MacDiarmid et al. 2015). This comprises 7% of the 4 km of coastline boarded by intertidal reefs in Lyall Bay and 2% of the 15.7 km of coastline boarded by rocky reefs along Wellington's south coast from Sinclair Head to the harbour entrance at Fort Dorset.

The proposed rock dyke will provide a subtidal reef area of approximately 2.7 ha along a length of about 0.92 km of coastline. The net loss of subtidal reef area to Lyall Bay and to Wellington's south coast will be 3% and 1% respectively. The net gain in coastline boarded by intertidal reef will be 0.6 km, a 16% increase for Lyall Bay and 4% increase for Wellington's south coast. The area and length of rocky reef that will be lost in terms of actual and net loss is considered to be no more than minor.



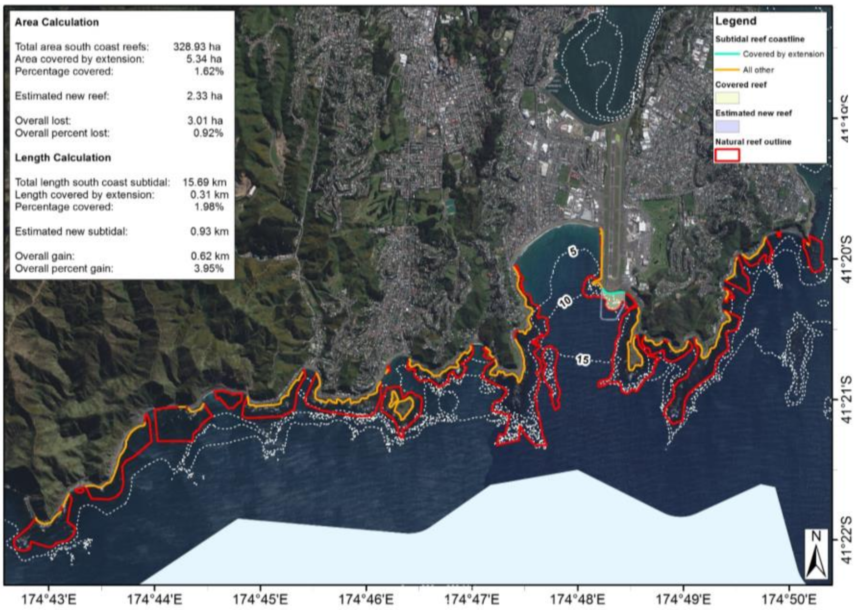
Area Calculation

Total area south coast reefs:	328.93 ha
Area covered by extension:	4.95 ha
Percentage covered:	1.51 %
Estimated new reef:	2.73 ha
Overall lost:	2.22 ha
Overall percent lost:	0.68 %

Length Calculation

Total length south coast intertidal:	15.66 km
Length covered by extension:	0.28 km
Percentage covered:	1.79 %
Estimated new intertidal:	0.92 km
Overall gain:	0.64 km
Overall percent gain:	4.09 %

Figure 11: Rocky reefs in Lyall Bay.



Area Calculation

Total area south coast reefs:	328.93 ha
Area covered by extension:	5.34 ha
Percentage covered:	1.62%
Estimated new reef:	2.33 ha
Overall lost:	3.01 ha
Overall percent lost:	0.92%

Length Calculation

Total length south coast subtidal:	15.69 km
Length covered by extension:	0.31 km
Percentage covered:	1.98%
Estimated new subtidal:	0.93 km
Overall gain:	0.62 km
Overall percent gain:	3.95%

Figure 12: Rocky reefs along Wellington's south coast.

6.4 Birds and mammals

In the context of the use of Lyall Bay and the area at the end of the runway, extending the runway to the south will temporarily (for the time of construction) disturb both seabirds and marine mammals, and will cause localised displacement of animals to adjacent areas or potentially result in animals moving further afield out of the Lyall Bay – Moa Point area altogether. The ‘zone of disturbance’ for marine mammals and seabirds that forage within the water column (blue penguin and shags) could extend beyond the immediate vicinity of any construction through noise generated as part of the construction process - the spatial extent of any ‘noise disturbance’ would depend upon the frequencies and the magnitude of sounds generated.

It is also possible that any breeding blue penguins near to the construction zone could be disturbed to the extent that breeding is deferred, abandoned or breeding birds move to areas away from the construction zone. Again, these effects would be mostly temporary, although any displaced breeding birds may not return to the area even on completion of runway construction, and their progeny may take several years to recruit to the breeding population and occupy areas formerly used by breeding birds. Although a relatively small number of blue penguins could be affected as described above, these effects would be insignificant at a ‘Wellington population’ level.

Similarly, any marine mammals, including killer whales and common dolphins that have been sighted close to the airport, will likely be displaced from the area of proposed construction. As noted in MacDiarmid et al. (2015), there is no evidence to suggest that the marine zone immediately to the south of the airport is particularly important for marine mammals. So while exclusion from the proposed area of construction will be permanent, this area is almost certainly negligible in comparison to the full extent over which marine mammals range.

6.5 Fish

The loss of reef habitat has been discussed above and is not considered to be more than minor in the context of Lyall Bay and the wider south coast of Wellington. In addition there will be a 250 m exclusion zone around the construction zone for the period it takes for the runway to be extended. This is not likely to affect any commercial fisheries as none operate within this distance of the present southern end of the runway (MacDiarmid et al. 2015). However, some recreational and customary fishing activities will be affected. The main recreational fishing activity that takes place in Lyall Bay is rod and line fishing from the shore (Bell and Associates 2000) and hand gathering of kina and paua along the affected shore (MacDiarmid et al. 2015). The existing breakwater is frequently used by recreational fishers targeting kahawai (Rob Stewart, NIWA personal observation) so it is likely that this activity and hand gathering will be most affected by a temporary exclusion zone.

Emigration from surrounding habitats to the rock dyke is potentially high for a range of species including spotties, blue cod, goatfish, leather jacket, and tarakihi, which also occur in the demersal soft sediment habitats in Lyall Bay. For reef obligate species such as many of the triplefins, hiwihiwi, red moki, marblefish, and butterfish, development of populations on the rock dyke will be principally from settlement of post-larvae, and their subsequent survival and growth to mature sizes. This will take a number of years and will be dependent on the establishment of suitable algal beds for herbivorous species such as butterfish, and invertebrate populations for predatory species such as red moki.

As emigration from other reefs is highly unlikely, the development of fishable paua populations on the rock dyke will be principally from settlement of post-larvae, and their subsequent survival and growth to legal sizes. This may take 10 or more years (Sainsbury 1982, McShane and Naylor 1995). However, it is possible to hasten this process by enhancing the population on the rock dyke by ‘out-planting’ juveniles raised in captivity from locally sourced parents (e.g. Tong et al. 1987, Roberts et al. 2007) (also see mitigation below).

As emigration from other reefs is highly unlikely the development of fishable kina populations on the rock dyke will be principally from settlement of post-larvae, and their subsequent survival and growth to mature sizes. As settlement of kina is highest in coralline turf, successful settlement may depend on this settlement habitat to develop initially. Kina settlement on reefs is seasonal (summer) and highly variable in magnitude among years (see review in Andrew 1988), so it could take several years before successful recruitment of juvenile kina on the rock dyke occurs. The growth of kina is highly variable and can sometimes be negative, with highest growth occurring at sites where macro-algal are readily available to graze (Andrew 1988). Thus, development of adult kina populations with gonads attractive to recreational and customary fishers may take several additional years, depending on the establishment of canopy forming macro-algal beds on the rock dyke.

Rock lobsters are large and mobile and can move long distances across open seafloor habitats (MacDiarmid et al 2012) thus their emigration from other reefs in Lyall Bay to the rock dyke is highly likely to occur soon after construction is completed. The provision of suitable sized holes on the accropodes for puerulus larvae and small juveniles should help initiate recovery of rock lobster populations in the area. Rock lobsters are predators of a wide range of benthic invertebrates so growth of resident lobsters on the rock dyke may be slow until suitable prey populations establish.

Summary – Physical disturbance and loss of habitat

The loss of habitat within the footprint of the reclamation during construction is unavoidable.

The area of soft (sand and gravel) habitats likely to be permanently lost to the reclamation is approximately 5.9 ha, representing only 3% of the area of soft sediments in Lyall Bay which is not considered to be significant.

The area of subtidal reef likely to be lost to the proposed reclamation activities is about 5.3 ha. This comprises 5% of the 99 ha of subtidal rocky reefs in Lyall Bay and 1.5% of 328 ha of the subtidal rocky reefs along Wellington’s south coast from Sinclair Head to the point at the northern end of Breaker Bay.

The length of existing coastline boarded by intertidal rocky reef that will be buried during the runway construction will be 0.28 km, with much of it comprised of artificial substrates including accropods, concrete blocks, concrete tiles and clay bricks. This comprises 7% of the 4 km of coastline boarded by intertidal reefs in Lyall Bay and 2% of the 15.7 km of coastline boarded by rocky reefs along Wellington’s south coast.

However the proposed rock dyke will provide a reef area of approximately 2.7 ha along a length of about 920 m of coastline. The net loss of subtidal reef area to Lyall Bay and to Wellington’s south coast will be 3% and 1% respectively. The net gain in coastline boarded by intertidal reef will be 0.6 km, a 16% increase for Lyall Bay and 4% increase for Wellington’s south coast. The loss of area or length of reef habitat in terms of actual or net loss is considered to be no more than minor.

No rare or unique species or assemblages will be lost and the communities are typical of the south Wellington coast. The only species of significance found was an undescribed red algae which is known from other parts of New Zealand and may be more widespread but hasn’t been recorded. Some of the reef communities that would be lost in the immediate vicinity would be at least partially offset by the development of rock wall communities around the reclamation.

There is the possibility that a few penguins may be displaced but this represents a very small part of the “Wellington population”. Most shore and seabirds and marine mammals will forage over a large area and there is no evidence that this area is particularly important.

A 250 m exclusion zone around the construction zone will be in place for the period it takes for the runway to be extended. This is not likely to affect any commercial fisheries as none operate within this distance of the present southern end of the runway. However, some recreational and customary fishing activities will be affected on a temporary basis.

Post-construction recovery of specific reef groups will vary. Emigration from surrounding habitats to the rock dyke is potentially high for a range of fish species which also occur in the demersal soft sediment habitats in Lyall Bay. For reef obligate species development of populations on the rock dyke will be principally from settlement of post-larvae, and their subsequent survival and growth to mature sizes. This will take a number of years.

As emigration from other reefs is highly unlikely, the development of fishable paua and kina populations on the rock dyke will be principally from settlement of post-larvae, and their subsequent survival and growth to legal sizes. This may take 10 or more years for paua. However, it possible to hasten this process by enhancing the population on the rock dyke by ‘out-planting’ juvenile paua raised in captivity from locally sourced parents.

Rock lobsters are large and mobile and can move long distances across open seafloor habitats thus their emigration from other reefs in Lyall Bay to the rock dyke is highly likely to occur soon after construction is completed. The provision of suitable sized holes on the accropodes for puerulus larvae and small juveniles should help initiate recovery of rock lobster populations in the area.

7. Water quality and contaminants

Contaminants released from benthic sediments during reclamation could potentially bioaccumulate and become concentrated in species at the top of the food chain (large benthic fauna like cockles and eventually large fishes, birds, marine mammals) potentially ultimately affecting human health if contaminants were at high enough levels.

The sediments in the area to be reclaimed are very low in contaminants (Depree et al. 2015), low in organic content and particulate nitrogen, and are likely to be very low in other nutrients. Contaminant concentrations are at least two orders of magnitude lower than default ANZECC values (Depree et al. 2015). As the contaminant levels are low and evenly distributed across the study, including the area to be reclaimed, then the risk of adverse effects from disturbance of the seabed is negligible. Full details of the contaminant studies are provided in Depree et al. (2015).

Nutrients are necessary for the growth of primary producers (e.g., phytoplankton and aquatic plants), but excess nutrients can cause algal blooms and periphyton growths. There is no evidence of organically enriched sediments in Lyall Bay. Any nutrients or contaminants that were disturbed would quickly be diluted and flushed out of the Bay.

Summary – Water quality

Sediments that may be disturbed by construction of the reclamation are very low in contaminants, organic material or nutrients. The risk from mobilization of contaminants or nutrients is negligible.

8. Suspended Sediments and Turbidity

8.1 Introduction

Disturbance of the seabed, infilling and dewatering discharge for reclamations results in the release of fine sediments into the water column which can result in impacts on plankton and fish in the water column, benthic biota and reduced light levels which can impact on benthic and pelagic algae and other plants. Most sediment particles will be transported away into deeper water but some may settle, at least temporarily, on the seabed or along rocky shores (including the cove to the east of the runway) before being resuspended and dispersed.

The potential direct effects of suspended sediments include:

- Reduced water clarity and changes in colour.
- Increases in suspended sediments and turbidity in the water column.

- Impacts on physiological processes of benthic fauna, such as feeding, respiration.

Indirect effects include:

- Reduced primary production by benthic and planktonic algae and macroalgae.
- Reduced clarity for visual feeders such as birds and some fish.
- Effects on fish and birds through reduced prey and food resources.

The impact on suspended sediment and turbidity of constructing a reclamation will largely depend on the nature of the material to be used for in-filling (sediment type, degree of organic enrichment, presence of contaminants) and the characteristics of the area being reclaimed (sediment type, accumulative or dispersive areas for sediment). While the latter characteristics are well described from surveys undertaken for WIAL the exact nature of the in-fill material is not yet available.

The dispersal footprint has been modelled based on discharges from the three possible weir sites, one in the north-west corner of the reclamation site, one in the south-west corner and one in the middle of the southern end of the rock dyke (see Figure 6-1 in Bell 2016). As there is no information available yet on the particular characteristics of the in-fill material the effects described below are based on the changes above the background. The modelling has used an infill dewatering concentration of 1 kg/sec and 2 kg/sec of source material, discharged continuously and assumes all the material is medium silt (grain size 15 um) which represents the fraction most likely to generate plumes. Details of the approach for modelling turbidity plumes and dispersion are given in Pritchard et al. (2015) and Bell (2016) but essentially are based on advection and turbulent diffusion due to small-scale turbulent mixing and currents and particle settling velocities using standard equations. Resuspension was not included as it is considered the relatively frequent storms and southerly waves and swells would result in a ubiquitous turbidity throughout the Bay from a number of sources.

Model simulations for each of the weir locations provide a composite envelope of the maximum total suspended sediment above background concentrations (TSS) at any time over a 30-day simulation. The modelling provides maps of the potential plumes resulting from 1 and 2 kg/sec of source material and calm, southerly and northerly winds occurring over the modelled period. The threshold for the plume maps was set at 3 mg/L as the level that TSS is likely to be ecologically meaningful.

The maximum predicted TSS in the near-field (~ 150 m from the weir) is 13-15 mg/L, 13-14 mg/L and 11-13 mg/L for the NW, SW and S discharge sites respectively and a 1 kg/sec discharge rate. The maximum predicted TSS with a discharge of 2 kg/sec is 32-34 mg/L, 21-22 mg/L and 22-23 mg/L for the NW, SW and S discharge sites respectively (Bell 2016). Thus we would expect the discharge from the NW location to have the most effect on inner Lyall Bay but with a maximum of < 3 mg/L and 6-8 mg/L for discharges of 1 and 2 kg/sec respectively. A discharge from the southern end of the rock dyke would have a negligible effect in inner Lyall Bay but would generate higher levels close to Moa Point Beach and associated rocky reefs with highest values during calm conditions and lowest during southerly wind events.

Summary – Suspended sediments

The construction of a reclamation will result in release of fine sediments which can impact on biota through reduced light levels affecting primary producers, changes in water clarity and colour, changes to feeding and physiological processes of benthic and pelagic animals and the flow-on effects to higher levels in the food web such as birds and fish.

The dispersal footprint has been modelled based on a dewatering rate of 1 kg/s and 2 kg/s. It is predicted that TSS could be up to a maximum of 15 mg/L within 150 m of the discharge points for 1 kg/sec and up to a maximum of 34 mg/L for 2 kg/sec. Concentrations of 15 mg/l or less during construction would have no more than a minor impact on biota in the nearby rocky reefs and effects if they were to occur would be temporary. For most of Lyall Bay TSS would be <3 mg/L and <8 mg/L for discharge rates of 1 and 2 kg/sec respectively.

8.2 Benthic communities

Increases in suspended sediments and turbidity are associated with most reclamation activities as a result of physical disturbance of the seabed, release of sediment/water mix during in-filling and subsequent resuspension of settled sediments during periods of high wave activity. Increased levels of suspended sediments and turbidity will impact on benthic communities through direct physical effects and indirectly through changes to water clarity and light availability.

In assessing the effects of suspended sediments in the area to be reclaimed there are a number of considerations. The most obvious one is the resulting plume of water/fine sediment mix that will be released during the installation of stone columns, border dyke and infilling with material which often contains fine sediments. Material that settles out on the seabed nearby can also subsequently be resuspended. The degree of resuspension of sediments from reclamation depends on the type of sediments being used for infill, methods of infilling, hydrodynamic characteristics, geomorphology, and weather conditions but as discussed above this is likely to be ubiquitous across the Bay because of the exposure to periodic strong waves and swells.

Direct physical effects of suspended sediments on benthic fauna include clogging of gills, and impairment of respiration and feeding via filtration. Suspension feeding animals such as some polychaete worms, cockles, and mussels can be vulnerable to high sediment levels and persistent high turbidities can result in changes in assemblages from dominance by suspension feeding taxa to ones dominated by deposit feeders (eg. some polychaete worms, gastropod snails). Impacts of increased turbidity are likely to be greatest in low energy areas where water exchange and wave action are limited. In the case of the Wellington Airport extension the small cove to the east could be such an area, at least for a short period before the next major wind and wave event.

There is a large body of work available from overseas and some work in New Zealand on the effects of high TSS levels at which condition and suspension feeding processes of benthic animals are potentially impacted. Most of the experiments have been on mussels and the cockle *Austrovenus stutchburyi* and have found that some species actually benefit from small amounts of suspended sediments. In the case of the cockle, Hewitt and Norkko (2007) found they benefitted at suspended sediment concentrations up to 400 mg/L and even higher in field observations, before condition started to decline. Persistent high levels and very high levels of suspended sediments dominated by clays for more than a week in that case however, were found to have a significant impact. Other taxa which have been shown to show some adverse effects when exposed to concentrations above 80 mg/L for several days to a few weeks include some deposit feeding polychaetes, heart urchins (Nicholls et al. 2003) and pipis (Hewitt et al. 2001). Some taxa are more robust and show more resilience, for example, the wedge shell (*Macomona liliana*) only showed effects when exposed to concentrations over 300 mg/l after 9 days and the snail *Zeacumantus lutulentus* showed no response up to 750 mg/L after 14 days (Nicholls et al. 2003).

The most abundant epibenthic taxa within 2-300 m of the discharge points in the case of the reclamation at the southern end of the Wellington runway are mysid shrimps which swarm just above the seafloor, followed by the olive shell *Amalda australis* and bivalves. The infauna is dominated by polychaete worms such as *Paraonella*, amphipods and isopods.

Based on data from the optical mooring deployed at the entrance to Lyall Bay from 4th September to the 8th October suspended sediment concentrations ranged from 0.2 to 40 mg/L, corresponding to a euphotic depth of 51 to 8 m (MacDiarmid et al. 2015). During the deployment there were several periods when TSS was over 5 mg/L for 2-3 days with peaks over 10 mg/L. The synoptic survey at 11 sites in the Bay showed that at the time (relatively calm conditions) the TSS was ~0.5 mg/L in the centre of the Bay and 1.0 mg/L close to shore including a site just off the southern end of the runway. Although only a snap-shot in time the range of TSS concentrations recorded during the mooring deployment are likely to be representative of what would be experienced in the eastern end of Lyall Bay. Most benthic communities are adapted to episodic periods of high turbidity and the predicted maximum increases in TSS beyond 150 m from the discharge is likely to be up to 15 mg/L for a discharge of 1 kg/sec and 34 mg/L for 2 kg/sec which would be very unlikely to cause any significant effect on the benthic soft-bottom biota present as these are maximum levels and levels would be considerably lower most of the time.

Effects, if they were to occur from suspended and settled sediments outside the reclamation footprint, would also be temporary and the populations would recover on a time scale of months to a few years. Early successional stage taxa like some polychaete worms will recover within weeks to months while larger taxa may take a few years. In the case of a large dredging programme by Ports of Auckland the benthic community had recovered within 3 years to a community indistinguishable from the surrounding area (Ports of Auckland 2001).

Increased suspended sediments will cause decreases in water clarity and the availability of light for phytoplankton in the water column, and for benthic plants on the seabed including macroalgae and microphytobenthos (benthic microalgae like diatoms). The most sensitive communities to the indirect impacts of the construction of a reclamation or similar activities are seagrass beds but these are not present in the region of the Wellington airport extension. The most significant impacts of increased turbidity will be restricted to the immediate area around the reclamation. The attenuation coefficient or Kd quantifies the rate at which light is attenuated as a result of all absorbing and scattering components of the water column. The Kds measured in Lyall Bay ranged from 0.15 to 0.18 m^{-1}. The Kd at the mooring site varied from 0.09 to 0.61 m^{-1} over the deployment. The relatively low turbidity levels predicted from modelling of the turbid plume are unlikely to have a significant effect on benthic biota, which already experience levels up to 40 mg/L corresponding to a Kd of 0.61 m^{-1}. The predicted plume TSS concentrations up to 15 mg/L (for 1 kg/sec discharge) at 150 m from the weir during the construction period will be temporary and will be rapidly diluted and dispersed during the next storm or strong wind event. The area potentially impacted is in water depths <15 m and the euphotic depth (depth at which there is sufficient light for net photosynthesis) in the Bay has a median of 22 m thus it is highly unlikely that reduced light levels would impact on benthic plants beyond what they would experience naturally.

In terms of TSS limits the recent Port of Melbourne and Port of Otago dredging programmes (Port of Melbourne 2008, James et al. 2009) assessed levels that could impact on various communities. These assessments concluded that the following levels, based on a 2 week moving average with higher levels based on a 6 hourly average, would protect various communities:

- 15-35 NTU (Nephelometric turbidity units) above background levels for benthic invertebrates. This was based on a 1:1 relationship between TSS and NTU.

- 35 NTU or 50 mg/L to prevent impacts on a *Pyura* sea tulip species.

- 70 NTU above background for fish.

The TSS concentrations predicted from modelling indicate that these levels would not be reached but they could serve as the basis for limits for the discharge points.

8.3 Reef communities

The coastline along the Wellington south coast has extensive areas of rocky shore and reefs supporting benthic algal and kelp beds which are a very important habitat for a range of invertebrates (including the likes of kina and paua) and fish.

Increased suspended sediment concentrations can lead to lower water clarity which in turn can impact on photosynthesis and growth of aquatic plants. The kelp *Macrosystis pyrifera* has a “recruitment window” when light and temperature requirements are met and allow the establishment of sporophytes. Recruitment of *Macrocystis* has been observed along the coastline near Pleasant River, near Otago Harbour through spring and summer months following thinning of the canopy during winter storms (Fyfe 2000).

Reef communities in the vicinity of the reclamation would be subject to the same level of increased TSS from the reclamation as the benthic community. The reef communities within 200-300 m of the discharge points contain a mixed algal assemblage of brown and red algae, including large kelp beds. These communities in turn support a varied faunal community dominated by sponges, ascidians and bryozoans.

There has been little work on the TSS concentrations that would impact on the types of reef communities found in eastern Lyall Bay but the discussion of light levels affected for benthic biota would also apply to the reef communities. Most reef communities are resilient to short periods of high turbidity. Development of oyster eggs was found to be impacted at suspended sediments concentrations of 188 mg/l of silt and larvae at 750 mg/l of silt (Clarke and Wilber 2000). Similarly Hawkins et al. (1999) found the filtering rate for the Green-shell mussel, *Perna canaliculus,* did not start decreasing until suspended sediments levels were above 1000 mg/l.

Concerns have been raised elsewhere that even small amounts of suspended sediment reaching rocky reefs could impact on survival of grazing for more sensitive taxa. Small grazing and suspension-feeding invertebrates found on rocky reefs are an important trophic link between primary producers and fish with kelp often being the main habitat. In addition to being indirectly impacted by decreased light levels for plant growth these communities can be impacted directly by clogging of feeding apparatus or smothering of food resources such as epiphytes. Epifaunal abundance, biomass and productivity were found to be 50% lower at turbid sites (up to 16 mg/l) than "cleaner" sites (undetectable to 7 mg/l) off the Whitianga harbour (Schwarz et al. 2006). Using a range of natural concentrations Schwarz et al. (2006) found a drop-off in mussel and oyster condition at suspended sediment concentrations over 26 mg/l and sponges at over 15 mg/l. TSS concentrations around the reefs in Lyall Bay, including those close to the reclamation, could experience over 40 mg/L during storm events, although normal levels are likely to be < 1 mg/L. Sustained levels of over 15 mg/L would be confined to within 150 m of the discharge during construction and for a discharge from the NW corner and for the higher 2 kg/sec discharge. The plume would be rapidly dispersed and diluted during storms and strong wind events.

Short duration exposure to high sediment loads has been found to cause larval mortality in the sea urchin or kina (*Evechinus chloroticus*) and paua (*Haliotis iris*) (Phillips and Shima (2006). The sediment used in these experiments had a large fraction of clay and with turbidity considerably higher (18-74 mg/l) than those predicted to occur as a result of the construction of the reclamation.

In terms of recovery, if they were to be impacted, then recolonization would start within weeks. Surveys following the construction of a small reclamation in Napier provide valuable insights to recovery (Barter & Keeley 2002). Fast growing algae were evident within weeks and within 6 months turf-forming and encrusting corraline red algae became established and larger macroalgae were establishing within 12 months. Within 2-3 years the hard substrate communities would be expected to be indistinguishable from existing communities. These rates also provide us with some indication of how quickly reef-like communities would develop on the artificial border-dyke wall. The rock dyke will create reefs in slightly deeper water but the community that would colonise the rock walls would be expected to be similar to the existing community. Inclusion of additional microhabitats has been included in the suggested mitigation.

8.4 Plankton

As discussed above as the overflow material is released during infilling and sediments are disturbed during pile driving there will be an increase in turbidity and development of a turbid plume as sediments are suspended in the water column and are dispersed with the currents. Some of the material that reaches the seabed may subsequently be re-suspended into the water column under certain hydrodynamic conditions but this is likely to rapidly disperse offshore in this exposed coastal environment.

Although coastal plankton communities are subject to episodic turbid events as a result of increased runoff and riverine input, elevated suspended sediment concentrations as a result of the construction of the reclamation could potentially impact on both phytoplankton and zooplankton. As discussed earlier for benthic plants lower water clarity can mean less light reaching the water column reducing photosynthetic capacity. Primary production in offshore areas, including the greater part of Lyall Bay, is predominantly associated with phytoplankton in the water column.

Many benthic species and most fish have a larval phase which is critical for dispersion and recruitment. These larval stages, along with permanent zooplankton (mostly copepods) and crustaceans, are generally adapted to episodic high levels of suspended sediments that occur in estuaries and harbours and along New Zealand's coastline. Experiments over a two week period with different zooplankton showed that mortality was high at levels over 10,000 mg/L but generally studies have not shown any significant impact at the levels experienced from activities such as dredging (Clarke & Wilbur 2000). Many larval stages are only in the plankton for short periods and other groups have short life cycles which mean recovery can be relatively quick (less than a year) depending on the time of year and source of larvae.

Turbidity associated with construction of the reclamation could reduce light penetration in the immediate vicinity with potential temporary effects on phytoplankton and zooplankton. The predicted suspended sediment concentrations are up to a maximum of 15 mg/L above background within 150 m of the discharge points (for discharge rate of 1 kg/sec) and are predicted to be considerably less up to 500 m from the discharge points. To put this into context, recent measurements of background levels in Lyall Bay varied from 0.17-37.5 mg/L with the highest concentration during a storm event.

Suspension and filter-feeding zooplankton can be affected by clogging of feeding apparatus. As discussed above TSS concentrations are predicted to reach a maximum of 15 mg/L above background (35 mg/L for discharge of 2 kg/sec) within 150 m of the site, which is well below the level that is known to have a significant impact on zooplankton communities, fish eggs and larvae (>500 mg/L, Wilber and Clarke 2001). Any impact, if it was to occur would be short-term as zooplankton are short-lived (days to months) so recovery would be relatively rapid through recruitment and advection from other areas.

Generally the impacts on planktonic communities are expected to be negligible and only for the duration of the construction.

8.5 Birds

The area to the east of the proposed reclamation, and Moa Point more generally, is likely to support a small number of breeding blue penguins. A number of other species may occur in the area at times including fluttering shearwater, gulls, terns, shags, reef and white-faced herons and variable oystercatcher.

The effects of increased TSS concentrations during construction of a reclamation in Lyall Bay could potentially impact on birds through:

(1) Changes to the invertebrate community as a food source, during construction of the reclamation;

(2) Increased turbidity levels around the reclamation affecting visual feeding.

Changes to invertebrate community

The level of any impact on species through the reduction in feeding resource will depend on the type of food required and the proportion of area lost. As discussed above the invertebrate community is not predicted to be significantly impacted by the increased sedimentation except in the footprint of the reclamation and immediate vicinity of the discharge and thus we would not expect more than a minor effect on food resources for birds in the vicinity of the reclamation.

Increased turbidity levels

Construction of the reclamation could potentially have some short-term temporary effects on birds in the vicinity of the reclamation. However, as described earlier for disturbance birds are likely to avoid areas of high suspended sediment levels if they were to occur. This could potentially cause localized displacement to adjacent areas or further afield out of Lyall Bay – Moa Point area. The area impacted compared with their foraging areas will be negligible and only affect a very small percentage of the “Wellington populations”.

Modelling indicates that the concentrations of suspended sediments in surface waters are likely to be less than 15 mg/L above background close to the reclamation (maximum of 35 mg/L if 2 kg/sec used) and considerably smaller further away. The threshold set by Port of Melbourne to protect terns and gannets was 25 mg/L or 17 NTU thus the levels likely to be encountered by any birds foraging during the construction would be unlikely to have any significant impact on the birds.

8.6 Mammals

Fur seals with easy access to deep water in Cook Strait forage offshore on lanternfish as well as hoki (Dix 1993). Consequently, because of the ability of these seals to forage over such a large area, potential impacts due to construction of a reclamation, if they were to occur, will be minimal.

The common dolphin (*Delphinus delphis*) and Orca (*Orcinus orca*) have been observed in Lyall Bay on some occasions, close to the south of the airport runway but are likely to forage over large areas of the Bay and southern coast.

Some sightings of the Southern Right whale (*Eubalaena australiis*) off the Wellington coast have been made close to shore in the vicinity of Lyall Bay and the harbour entrance. Direct impact on whales from construction of a reclamation is highly unlikely as they can avoid areas of activity and there are guidelines to avoid impacts.

8.7 Fish

Suspended sediments can interfere with gas exchange in fishes as well as causing gill abrasion and clogging of gills at high concentrations but fish will avoid high suspended sediment concentrations by moving into unaffected or less affected areas. Waves and currents will disperse material that settles in these areas so any impacts on fish communities and fishers in these areas are likely to be very localised and short term.

Although there may be some very localised increase in turbidity, fish and rock lobsters are well adapted to avoid potential threats and typically, move away from any disturbance or high turbidity levels (some may actually be attracted) in their vicinity. They are likely to avoid high suspended sediment levels that occur during construction activity. Fish can be expected to return to the general area as soon as construction finishes. The area which will be lost with the reclamation is minimal compared with the wider Bay and the mobility of fish means that they can move away from these areas.

Appleby and Scarratt (1989) summarised a number of studies that have assessed the effects of suspended sediments on fish. Most fish eggs and larvae do not show a significant effect until concentrations get above 500 mg/L and adult fish can tolerate at least 2000 mg/L for extended periods before mortality occurs. The only study conducted to date on the effect of suspended sediment concentrations (SSC) on a New Zealand marine fish species is Lowe (2013). She examined these effects in relation to juvenile snapper (*Pagus auratus*) and reviewed the available international literature on the relationship between SSC and fish survival, sub-lethal effects and behaviour. Through a series of laboratory experiments, Lowe (2013) demonstrated that although SSC in the range 43-261 mg/L is unlikely to cause high mortality in juvenile snapper, prolonged exposure to SSC greater than about 170 mg/L can result in adverse growth and developmental effects from physiological stress (e.g. respiratory distress/disease).

Lowe (2013) also examined juvenile snapper from seven north-eastern estuaries and found that fish condition decreased, and gill damage increased as SSC increased from 4-37 mg/L. Lethal SSC thresholds have not been conducted on any New Zealand marine fish; the only local fish data are for freshwater species not normally occurring in areas of high SSC. For these fish, lethal SSC levels were at or above 1000 mg/L (Rowe et al. 2009) and may be indicative of the sensitivity of offshore species not normally encountering high SSC. Many New Zealand marine fish species occur in the sometimes turbid near-shore waters of the Wellingtons southern coast, indicating they must have a degree of tolerance to moderately elevated SSC.

Overseas studies show that some overseas pelagic fish species have the ability to swim away from areas of elevated SSC (e.g., Johnson and Widish 1981, Newcombe and Jensen 1996). In the Port of Melbourne assessment it was suggested that maximum values of 100 mg/L of SS and 70 NTU were necessary to protect fish eggs and larvae.

In the case of the proposed reclamation in Lyall Bay predicted concentrations are substantially below these levels so any effects, if they were to occur, would be negligible.

Summary – effects of suspended sediments

Physical disturbance of the sea bed, release of sediment/water mix during the construction of the reclamation and subsequent resuspension of settled sediments will result in increases in suspended sediments and lower water clarity. The predicted maximum increase in TSS in the turbid plumes is expected to be up to a maximum of 15 mg/L based on a medium silt source of 1 kg/sec and 34 mg/L for 2 kg/sec discharge with the highest levels being for discharge from a weir in the NW of the rock dyke. These levels would be confined to within a few hundred meters of the discharge point and would be unlikely to have more than a minor effect on the benthic biota in the region.

Decreases in water clarity can impact on benthic plants, including ecologically important kelp beds and algal mats. Impacts are likely to be short-term (less than one year) and most plants and associated animals are resilient or can recover through recolonisation or recruitment.

Increases in TSSwith a maximum of less than 15 mg/L (1 kg/sec discharge) would be confined to within 150 m of the discharge points and would not be expected to have an impact on the reef communities nearby. Increases in TSS and turbidity, if they were to occur outside 150 m, would be temporary, localised and separating out the effects of the discharge from other sources of turbidity would be difficult.

Plankton communities are relatively resilient to increases in turbidity with significant impacts only likely at concentrations over 500 mg/L. Effects, if they were to occur, would be negligible, very localised and temporary.

Release of suspended sediments during construction of reclamations can impact on birdlife either directly through impacts on foraging capability or indirectly through effects on food resources. The ability of visual feeding birds to detect their prey is unlikely to be impacted at the low TSS levels predicted.

The construction is unlikely to interrupt or affect the foraging of birds that feed in this area and immediate vicinity. Any effects, if they were to occur would be temporary and impact on a very small percentage of their foraging area or the “Wellington” shorebird community.

Common dolphins, Orca and occasionally Southern Right whales have been observed in Lyall Bay and nearby. These species all forage over large areas and depths greater than 20m and thus will not be impacted by the TSS effects of construction of the reclamation.

Fish are well adapted to avoid potential threats and typically swim away from any high levels of turbidity. Some of the invertebrates that fish feed on will be lost or impacted in the immediate vicinity by higher levels of suspended sediments but these effects will be very localised and likely to be negligible.

The effects of suspended sediments have been studied for one New Zealand fish species, snapper. Prolonged exposure to SSC greater than about 170 mg/L can result in adverse growth and developmental effects from physiological stress (e.g. respiratory distress/disease). Lethal suspended sediment thresholds have not been conducted on any New Zealand marine fish but lethal levels for freshwater fish are at or above 1000 mg/L.

Fish eggs, larvae and adults can tolerate much higher concentrations of TSS than those predicted to occur from the reclamation construction. Waves and currents will disperse material that settles in these areas so any impacts on fish communities and fishers in these areas are likely to be very localised and short term.

9. Sedimentation

9.1 Introduction

The potential direct effects of sedimentation include smothering of benthic communities and reduced growth and grazing of invertebrates. Indirect effects include reduced food availability for grazing invertebrates, fish and birds.

Sedimentation has not been modelled as it is expected that storm, wave and swell events will rapidly disperse any material that sediments out. The only area that could show localized deposition are in the SW and SE corners of the dyke and the corner of the cove closet to the east of the proposed extension but in the longer term most of this material would be expected to be remobilised and dispersed. The changes would be limited to small sand/gravel cover over the bedrock and reefs in this corner.

9.2 Benthic communities

Coastal benthic communities are adapted to episodic and extreme events including sediment transport, erosion and deposition. When sediments settle out in the vicinity of a reclamation, they can smother benthic organisms and depending on the amount of sediment settling, can change the sediment characteristics and community structure and in extreme cases cause mortality of fauna and flora. Small and recently settled life-stages of many species are especially vulnerable to smothering, as are organisms that must maintain contact with the sediment-water interface.

The habitats found in Lyall Bay in the region of the reclamation, have very low faunal abundance, and are dominated by suspension (eg bivalves) and deposit feeders (polychaete worms). Settling of fine silts in the Bay is unlikely because of exposure to strong waves, tidal movement and currents. Any accumulations would quickly be flushed out of the Bay and dispersed over a wide area in deeper water during the next strong wind or storm event.

Shrimps have been shown to survive up to 9 cm of deposition (Norkko et al. 1999) while many crab species on the other hand actually show a strong preference for finer silt/mud habitats and are less sensitive.

Deposits of up to 3-7 mm can have a negative effect on microphytes and, although responses vary, repeated additions of 3 mm over several months can have a cumulative effect at these levels of deposition (Gibbs and Hewitt 2004). Such accumulations are very unlikely to occur as a result of the reclamation.

Exposed coastlines are subject to dynamic and high energy events and thus the communities are resilient to episodic periods of higher sedimentation. Even if there were unexpected high levels of sedimentation recovery of sediment properties and benthic communities will only take a few months for opportunistic species like many polychaete worms, and several months for larger taxa like some gastropod molluscs. This would also apply to the cove area in the immediate vicinity to the east of the reclamation where the present communities are mostly short-lived and fast growing taxa that are regularly impacted by sediment movement during storms. Impacts will also be mitigated through the mitigation measures outlined in Section 11 of this report.

9.3 Reef communities

In general the deleterious direct impacts of sedimentation on macroalgae and rocky shore communities are associated with settlement, recruitment, growth and survival and indirect effects of loss of photosynthetic capacity with a film of a few millimetres of sediment potentially reducing photosynthesis of plants. While most established alga can survive burial for short periods attachment of germlings can be impacted by a light dusting of sediment while relatively heavy settlement (2 mm) can prevent attachment altogether (Schiel et al. 2006). The southern coast of Wellington is highly dynamic and exposed to significant wave events thus the rocky shore communities are able to tolerate extreme events and are unlikely to be impacted by short-periods of sedimentation, if they were to occur. Limpets and some gastropods are also very effective at moving sediment around so that they can access the algae below (Schiel et al. 2006).

We are not aware of any guidelines or broad generalisations about levels of sediment that macroalgae can tolerate but some open coast species of macroalgae can survive extended periods of burial with cycles of beach building and erosion. For example, the open coast species of *Gracilaria* can be buried for days/weeks and photosynthetic capacity can re-activate once the plants are uncovered through scouring and wave activity. Some intertidal algae can remain intact after 3 months of burial but growth is inhibited, while others do not survive burial under thick sediments for a month (D’Antonio 1986). Coralline crusts were found to be unaffected by burial in sand for a few months but there was significant mortality of the sea lettuce *Ulva*. Recruitment for macroalgae taxa such as *Macrocystis* relies on adequate light reaching the seabed. Fyfe (2000) observed recruitment of *Macrocystis* in spring and summer months following substantial thinning over winter thus spring and summer is likely to be a critical period for recruitment. Overall impacts on macroalgae from sedimentation are likely to be very low, if at all, and will be very localised and short-term if they did occur.

9.4 Birds and fish

Settled sediments could potentially adversely affect rocky habitats of importance to birds and fish along the Lyall Bay shoreline if significant sedimentation was to occur as a result of the construction of the reclamation. There are a few rocky areas around Moa Point and the eastern side of end of the runway that are important for rock lobster and along with paua are collected by recreational divers. As discussed above any sedimentation that did occur would be very localised and short-term and would be dispersed by tidal movement, the next strong wind or storm event.

Summary – Sedimentation

When sediments settle out they can smother benthic animals and plants causing reduced growth and changes to community structure and in extreme cases mortality. Exposed coastlines are subject to dynamic and high energy events and thus the communities are resilient to episodic periods of higher sedimentation.

Settlement of fine material can smother algal mats and kelp beds but they can generally survive up to 2-3 cm of sediment. The area where the reclamation is located and vicinity are very exposed to strong waves and swells so any material settling out would be rapidly remobilized. Benthic communities found in Lyall Bay are very resilient to such events.

Sedimentation can smother reef communities and reduce growth, grazing and recruitment. The Lyall Bay environment is subject to regular strong winds and to storm events which will prevent significant sedimentation and disperse material that may settle temporarily. Overall impacts on reef animals and macroalgae from sedimentation, if it did occur, are likely to be very localized, short-term and negligible.

Sedimentation of sediments can have direct and indirect effects on birds and fish. Sedimentation as a result of the construction of the reclamation is predicted to be very low and if it did occur would be negligible, very localised and short-term.

10. Noise and Blasting

The installation of stone columns and/or vibro-coring in the seabed and reclamation area to support the rock dyke and runway fill material has the potential to generate underwater noise (URS 2015). This underwater noise potentially could affect some fish species that produce and are receptive to sound. There may be the potential for impacts on some aquatic animals, particularly fish and mammals. Animals with swim bladders (many fish and marine mammals) and other sensitive organs can be impacted by sudden pressure waves causing rupture and possible mortality. Some fish species are more susceptible than others, with those living on the bottom often not having swim bladders and thus being less susceptible.

Recent New Zealand based research has described vocalisations and hearing in several New Zealand fish species. Ghazali (2011) describes vocalisations in red gurnard (*Chelidonichthys kumu*) and bigeye (*Pempheris adspersa*). Red gurnard produce vocalisations exceeding 60 dB over a frequency range of 100-500 Hz, while peak sound output by bigeye is over the frequency range of 100-400 Hz.

The sensitivity of red gurnard to sound has not been described but presumably they are sensitive to the same frequency range as they produce. Radford et al. (2013) describe the hearing mechanism in bigeye and determined they detected sound up to 1000 Hz but were most sensitive at lower frequencies (100–400 Hz). Caiger et al. (2013) found hapuka (*Polyprion oxygeneios*) hearing ability increased with age to reach a bandwidth of 100–1000 Hz and with greatest sensitivity to 100-600 Hz one year after hatching. Caiger et al. (2012) found juvenile (about 55 mm fork length) snapper (*Pagrus auratus*) had bandwidths of auditory sensitivity ranging from 100 to 2000 Hz but were most sensitive to lower frequencies (100–400 Hz). However, exposure of juvenile snapper to a noisy underwater environment (120 dB re 1 μPa) for two weeks decreased sensitivity to the lower frequencies by up to 10 dB re 1 μPa. Recovery of sensitivity was not investigated.

This range of 100-1000 Hz is typical for fish and overlaps with the frequency range likely to be produced by construction operations. As the attenuation of sound underwater is slow (about 0.02 dB per km for frequencies of 500 Hz in 10°C seawater), it is reasonable to expect some masking of individual fish calls in the vicinity of the construction area.

However, given that the principal sound producing fish in the project area (red gurnard) is uncommon in Lyall Bay, mobile and is widely distributed (MacDiarmid et al. 2015), the effects of underwater sound produced during stone column construction and/or vibro-coring on the gurnard population along Wellington’s south coast are likely to be negligible.

Similarly marine mammals within 100m could be impacted. Dolphins and occasionally whales are observed in Lyall Bay and may be disrupted temporarily by the construction of the reclamation. Direct impact on whales from construction of the reclamation is highly unlikely but many mammals rely on sound for navigation/feeding and have sensitive hearing apparatus. These animals are large enough to swim away from bothersome background dredging noises, but sudden high-decibel blasts could harm them if they were in close proximity.

Surveys before and after blasting by Port Otago Ltd at the Beach Street Wharf, Port Chalmers were carried out in 1993 (Stewart 1993). The presence and effects on marine mammals, shags, penguins, fish and shellfish were monitored over the three months of operation and concluded that the blasting appeared to have had little effect on the marine fauna and flora except in the immediate vicinity. Marine bird life appeared to be totally unaffected and no marine mammals were seen in the vicinity during blasting.

The main effects on birds during the construction of the reclamation would be excess noise, lights and the appearance of large machinery. These effects and potential impacts on mammals if they were to occur, can be mitigated with appropriate shading of lights. Birds in Lyall Bay are already acclimatised to regular boat and aircraft movement and human activity.

Summary – Noise and pile driving

Birds and mammals can be impacted by high levels of noise and lights during construction.

The potential installation of stone columns in underlying sediments and/or vibro-coring to support the rock dyke and runway fill material is likely to generate underwater noise. The effects of this underwater noise on sensitive fish species that produce and are receptive to sound are likely to be negligible.

Birds and mammals are already used to a noisy environment in this area and can also move away and thus are unlikely to be significantly impacted. Any effects, if they did occur, would be short-term and very localised.

11. Recommendations for avoiding, remedying or mitigating effects

Suspended sediments

There are a number of best practice guidelines available to avoid and mitigate impacts of activities such as construction of reclamations. The major mitigation measures required are for treatment of the dewatering discharge and ensuring construction operations minimise the risk of adverse effects on birds and mammals.

Best practice with sediment-ladened water discharges include booms to prevent spread of surface plumes of particulate material and if the TSS concentrations in the discharge is predicted to be high then settling ponds or geotextile screens can be used to ensure the discharge meets certain standards. It is expected that a construction plan will be developed which will include measures to minimise discharge of turbid water, meet best practice and guidelines in the operative Wellington Regional Coastal Plan which require no conspicuous change to water clarity or colour. Some further mitigation measures are provided in the Construction Report (AECOM 2015).

In terms of standards for receiving waters there is no definitive guideline although Regional Coastal Plans often have conditions depending on the classification of coastal waters including that water clarity in receiving waters should not reduce by >50% outside a mixing zone. For slightly to moderately-disturbed systems the relevant ANZECC (2000) criterion is that clarity should not reduce below the 80th percentile of reference levels. As discussed earlier, recent cases for the Port of Melbourne and Port of Otago dredging programmes established levels to avoid significant impacts on benthic environments. In those cases 35 NTU or 50 mg/L was used as a guideline and would be relevant as a limit in the case of the airport extension with 150m as a mixing zone. The operative Wellington Regional Plan has a water quality guideline referring to no conspicuous change to water clarity or colour after reasonable mixing which will need to be incorporated in the sediment management plan.

Rock wall construction

It is widely recognised that structural complexity influences the biological community associated with a habitat. The international literature suggests that habitat features that will increase biodiversity in the intertidal zone include rock pools, crevices, and shaded overhangs, as well as a variety of smooth and pitted surfaces. There has been less research on design features that increase the biodiversity in subtidal zones with respect to micro-habitats, although it is well known that larval propagules can select for surface roughness/texture and colour. NIWA have investigated the current state of the literature on rock wall construction to enhance biodiversity and potential options for the construction. Full details are provided in **Appendix One** and summarised here. The options are provided for consideration by WIAL.

The addition of roughened/pitted surfaces on 50% of each accropod would increase the range of microhabitats available for colonising marine algae and invertebrates, while the inclusion of five shallow (100 mm deep, 250 mm wide, 1000 mm long) indented prisms along the arm of each accropod (the five indented prisms to be spaced equally around the circumference of each arm) would increase the possibility of at least one forming a rock pool no matter what the final orientation of each accropod. The indented prisms on the underside of accropods would provide suitable cavities for wind and sun intolerant groups such as anemones, while indented prisms on the sides of each arm would form suitable crevices for chitons and snails.

It is recommended that one 1 m^3 concrete block with a truncated conical shaped hole (400 mm diameter at the top, 200 mm diameter at the bottom and 400 mm deep) is inserted in the top layer of the secondary armour every 10 m around the perimeter of the rock dyke somewhere between MLS and MHS tide levels. This will add about 85 large rock pools to the intertidal zone with large concomitant increases in biodiversity in this zone.

To accommodate newly settled lobsters from 10-35 mm CL concrete accropods could incorporate holes of three sizes; small (15 mm diameter by 45 mm deep), medium (25 mm diameter by 75 mm deep), and large (40 mm diameter, 120 mm deep). Each 1 m^2 of accropod surface would have a minimum of 1 hole of each size (i.e. 3 holes in total).

The current design of the sub-tidal parts of the rock dyke provides for a range of crevices, overhangs, flat open surfaces and dark shaded surfaces suitable for a wide range of reef fish and invertebrates, including juvenile and adult kina and paua.

The 0.5 m filter bed where the rock dyke meets the seabed is sufficiently stable (and of suitable material – i.e. stable hard substrate) for the attachment and growth of macroalgae in order to reduce sediment scour around the rock dyke.

Generally, blue penguins respond well to the provision of artificial nesting opportunities. However, the exposed nature of the site and proposed construction of the runway extension, and in particular the characteristics of the primary and secondary armour layers (see URS 2015a), may provide little opportunity for the inclusion of artificial nesting boxes for blue penguins, nor for any planting of native coastal plant species to further increase the attractiveness of artificial nest boxes. However, this should be incorporated if there are suitable locations and it is feasible.

The proposed construction may provide nesting sites for penguins without the need for artificial nest boxes, especially on the more sheltered eastern side of the runway extension. Penguins may be able to navigate through gaps and spaces in the primary armour and locate suitable sites for nesting within voids in the secondary armour, a 2.2 m thick layer of relatively large rocks and boulders, above high water levels and sheltered from storm waves and swells.

Other measures

Other measures to minimise the impact of the construction of the reclamation, some of which are included in the Construction Report (AECOM 2015) include:

- Use of clean fill low in silts, marine sands would be the best infill material.
- Shading of lights during construction to minimise risk of bird attraction and strikes
- Stopping construction activities if marine mammals are observed nearby – as per best practice guidelines.
- Field collection of mobile macro-invertebrates (e.g. paua, kina, large gastropods, starfish, etc.) from reefs destined for burial, holding these for the construction period in sea water facilities on land, and their later transfer to new reef surfaces once the construction is completed, could help to mitigate the effects of the destruction of rocky reefs and their resident populations within the construction zone and speed up the repopulation of the rock dyke.

12. Monitoring

A full Environmental Monitoring Plan (EMP) will be developed. It is recommended that the following monitoring be included in the EMP:

- Monitoring of turbidity at a compliance site and a control site during the reclamation to ensure that the TSS in the discharge plume is less than 25 mg/L beyond 150 m when the control site is <15 mg/L and a maximum of 10 mg/L above levels at the control site.

- Monitoring of the extent of the plume ring construction to confirm that levels and extent are as predicted.

- Surveys of the reef and benthic environment three years after construction is completed to confirm that recolonization is occurring as predicted.

- Monitoring of the rock walls to demonstrate the success of the mitigation measures for design of the rock wall to enhance biological communities.

13. Acknowledgements

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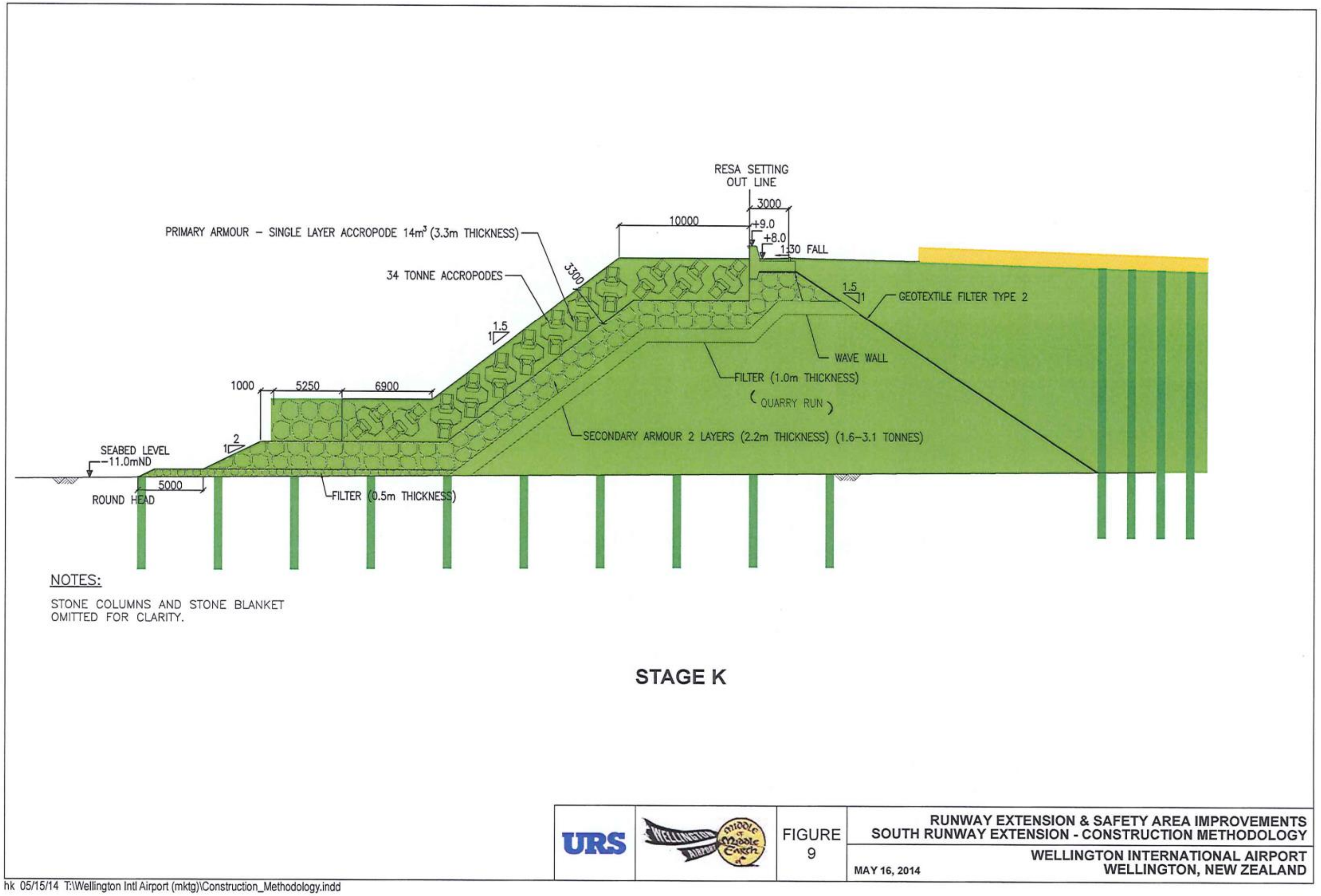
Appendix 1. Construction details (from AECOM)



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Appendix 2. Enhancing the ecological value of the rock dyke for rocky reef species –Jennifer Beaumont, NIWA

1.0 Literature review

The development of breakwaters, sea walls and other man-made structures along coastlines is increasing worldwide to sustain commercial, residential and tourist activities as well as for protection from coastal erosion and sea level rise (Moschella et al 2005, Bulleri and Chapman 2010, Linley et al 2007). With so much change in the coastal zone with the potential to remove or disturb natural habitats, it is important to consider habitat provision and biological productivity when designing new structures.

In order to consider the ecological value of the proposed rock dyke at Wellington Airport, it is useful to consider the rock dyke as an artificial reef. Artificial reefs have been defined as a “submerged structure placed on the seabed deliberately to mimic some characteristics of natural reefs” (Jensen 1997). A reef can be defined as “submarine, or exposed at low tide, rocky substrates and biogenic concretions, which arise from the seafloor in the sublittoral zone but may extend into the littoral zone where there is an uninterrupted zonation of plant and animal communities. These reefs generally support a zonation of benthic communities of algae and animal species including concretions, encrustations and corallogenic concretions” (Davies et al. 2001). The south coast of Wellington, and some of the coastline within Lyall Bay, has natural rocky reefs that extend from the intertidal into the subtidal environments. These reefs provide habitat for a number of marine species, as detailed in a recent report (MacDiarmid et al 2015). Some of this rocky reef habitat will be buried during the construction of the runway extension. Other nearby rocky reefs may experience indirect disturbance due to construction (e.g. increased sedimentation).

1.1 Ecological functioning of reefs

There are many reasons why reefs can support diverse biological communities. The surface of a reef can provide a hard substratum suitable for the larvae and propagules of many epibiotic species to settle, mature and reproduce (Barnes & Hughes 1999). The habitat complexity offered by many reefs can provide mobile species with living space (Tait 1981), a means of escape from predators (Hixon & Beets 1993) and opportunity for nest building and the deposition of eggs (Moring & Nicholson 1994). The sessile and mobile reef-dwelling flora and fauna provide a readily available food source for many marine consumers (Johnson et al. 1994). Physical factors could also be important; reefs with high vertical relief can provide shelter from strong currents. Altered water currents around reefs can cause flocculation of plankton which is beneficial for suspension feeders (Bohnsack & Sutherland 1985), as well as localised effects on salinity and water temperature as the bottom waters are pushed up with currents moving over the obstruction (Lin & Su 1994). These cooler waters mix with the warmer waters above and this has been shown to attract gatherings of animals such as fish (Lin & Su 1994) perhaps in response to the flocculation of plankton resulting in increased food availability. All of these factors have been shown to contribute towards the success of natural reefs in supporting biologically diverse communities, and may also apply to artificial reefs (Bohnsack & Sutherland 1985).

There is much debate about whether artificial structures can support biological communities that are comparable to communities inhabiting natural reefs (e.g. Beaumont 2006, Carr and Hixon 1997, McGuinness 1989). However, the surface of a reef, or any hard substratum in the marine environment, becomes colonised when the planktonic propagules of sessile organisms, which include many marine invertebrates and plants, settle from the water column and attach to a suitable substratum (Barnes & Hughes 1999). The life-cycle of a typical sessile marine invertebrate is shown in Figure 1.

The settlement of these planktonic propagules is a complex process involving physical, chemical and biological cues, and fouling propagules have been shown to demonstrate the ability to select surface characteristics that will enhance their chances of survival (Crisp 1974, Richmond & Seed 1991, Morgan 2001, Brown et al. 2003). These include biological cues in the form of biofilms (Hurlbut 1991, Todd & Keough 1994, Wieczorek et al. 1995, Brown et al. 2001) as well as surface roughness/texture (Walters & Wethey 1996, Brown et al. 2003, Brown 2005) and colour (James & Underwood 1994). For example, barnacles have been shown to have a preference for dimples on settlement plates which perhaps reduces susceptibility to predation (Miller & Carefoot 1989). James and Underwood (1994) found spirorbids to select dark coloured boulders in preference to light coloured boulders and suggested this may be a result of negative phototactic behaviour immediately before settlement.

With so many environmental factors known to affect settlement it is not surprising that substrate has been shown to be an important factor in the development of epifaunal assemblages (see work by Keough & Downes 1982, Keough & Downes 1986, Walters & Wethey 1996, Glasby 2000, Brown 2005).

Many studies have investigated the effects of substratum orientation on epifaunal recruitment (e.g. Todd & Turner 1986, Glasby 2000, Glasby & Connell 2001, Maughan 2001) and, as a result, it is well known that the underside of horizontal surfaces support the most diverse assemblages, possibly as a result of low siltation rates (Todd & Turner 1986, Turner & Todd 1993). Topside horizontal surfaces, on the other hand, are prone to heavy siltation thereby reducing the availability of primary substratum for larval attachment and reducing epifaunal recruitment (Todd & Turner 1986, Maughan 2001)

Note that while these processes greatly influence the settlement of planktonic propagules to any substrata they can only affect settlement once the propagule has arrived at the settlement site. It has, thus, been suggested that the supply of larvae to an area is the critical first step in determining the structure of epibiotic assemblages, a concept termed supply-side ecology (Lewin 1986, Underwood & Keough 2001).

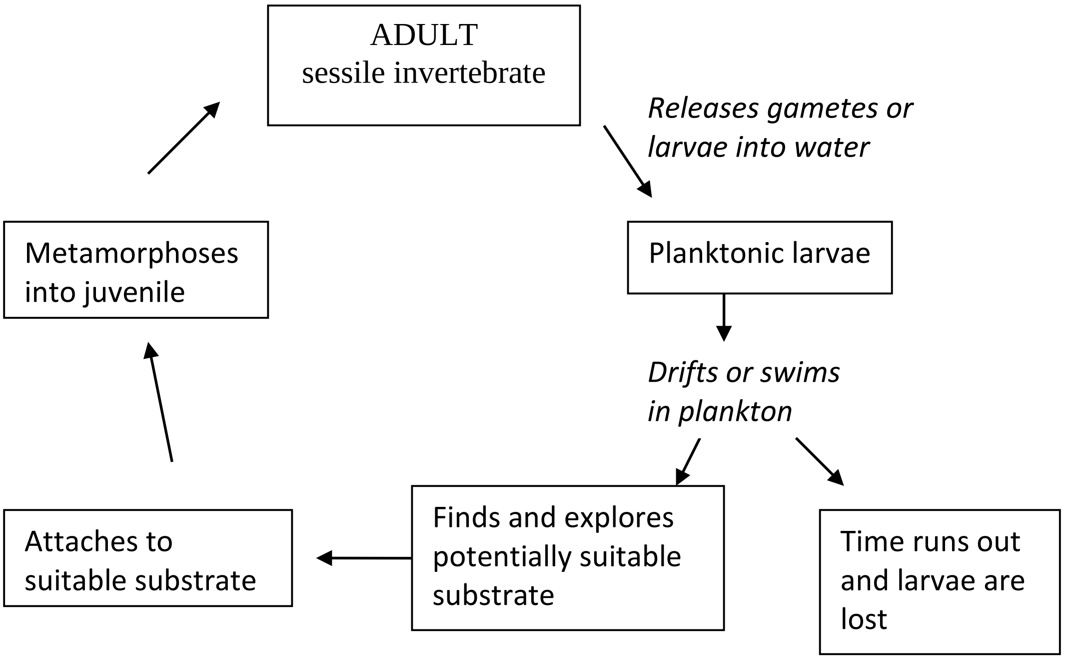

Figure 1. Life-cycle of a typical sessile marine invertebrate (adapted from Beaumont 2006).

While planktonic dispersal, as described above, is the main source of connectivity between hard substrates in the marine environment, the immigration of adult and juvenile individuals from nearby hard substrates or reefs can also occur. In the case of the extension to the Wellington runway, this could include natural reefs within Lyall Bay and along the South Coast of Wellington, as well as the existing seawall for the airstrip (depending on disturbance during construction). Recent surveys of the reefs within Lyall Bay suggest a relatively sparse invertebrate fauna (MacDiarmid et al 2015).

1.2 Habitat complexity and biodiversity

It is widely recognised that structural complexity influences the biological community associated with a habitat (e.g. Bohnsack & Sutherland 1985, Todd & Turner 1986, Barkai & Branch 1988, Sebens 1991, Potts & Hulbert 1994, Guichard & Bourget 1998, Svane & Peterson 2001, Bradshaw et al. 2003) and that the physical design of artificial structures can have major consequences at multiple trophic levels (Daffron et al 2015). Increased habitat complexity, especially with respect to provision and size of refuge holes, has been shown to increase the species richness, abundance and biomass of fish assemblages on artificial reefs (Hixon and Beets 1993, Carr and Hixon 1997, Danner et al 1994, Gratwicke and Speight 2005, Charbonnel et al 2002). It is not only true of fish populations. A study on an artificial reef complex in Scotland showed that artificial reef modules made from structurally complex blocks (concrete blocks with voids) supported a 1.6 times greater standing crop of epifaunal biomass than reef modules made from the same number of reef blocks, but using blocks without voids. (Beaumont 2006).

Beaumont (2006) suggested that productivity of a reef is likely to be related to surface area which, in turn, is driven by the complexity of the reef and the scales of complexity (Figure 2).

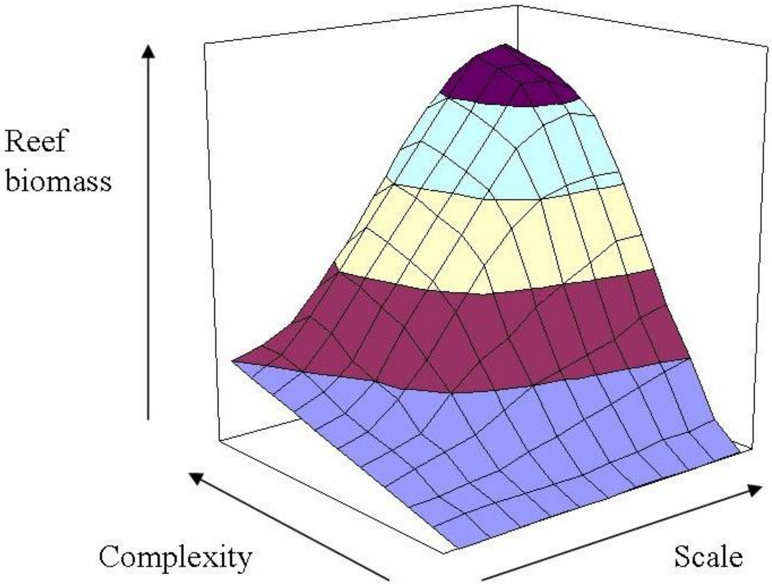

Figure 2 Proposed relationship between complexity, scale and reef biomass (taken from Beaumont 2006)

Linley et al (2007) suggested that man-made structures with complex shapes are likely to offer a greater range of localised hydrographic conditions with subsequent potentially beneficial effects for biodiversity. Habitat complexity has also been shown to be important in the intertidal zone, where multiple studies have shown features such as crevices and shaded overhangs as well as a variety of smooth and pitted surfaces have also been shown to increase diversity (Chapman and Underwood 2011, Martins et al 2010, Moreira et al. 2007, Moschella et al 2005, Firth et al 2014b).

1.3 Habitat requirements of key species

1.3.1 Paua

Paua (*Haliotis iris*) are herbivorous grazers of microscopic and macro-algae with the size of the algae grazed increasing with paua size. Paua occur reefs in Lyall Bay and are prized recreational and customary fishery species (MacDiarmid et al. 2015).

In a study along Wellington’s south coast, Aguirre and McNaught (2012) found that associations between paua abundance and the size of the boulders, as well as associations between abalone abundance and the surface area of the interstitial spaces between boulders, differ among ontogenetic stages of paua. Small individuals preferred smaller boulders while adults preferred large boulders. For all stages, abundance was positively associated with crustose coralline algae cover, but negatively associated with articulated coralline algae cover. The relationship between canopy algae and adult abundance was positive, whereas for early juveniles, late juveniles and subadults, the relationship was weakly negative. Last, Aguirre and

McNaught (2012) found that the association between the cover of understorey algae and abundance was negative for all ontogenetic stages.

Habitat complexity also mediates predation of juvenile paua by starfish. In a series of laboratory experiments Aguirre and McNaught (2013) demonstrated that predation of juvenile paua by starfish (*Astrostole scabra, Coscinasterias calamaria,* and *Pateriella regularis*) was lowest in habitats with the greatest structural complexity.

1.3.2 Kina

Kina, *Evechinus chloroticus*, occur reefs in Lyall Bay and is a prized customary fishery species (MacDiarmid et al. 2015). They are herbivorous grazers of microscopic and macro-algae occurring on shallow rocky reefs, cobbled areas, and, to a lesser extent, on sandy-muddy substrates (Andrew 1988). Kina are also found within the rocky intertidal zone, particularly in rock pools (Dix 1970). Small juvenile kina settle in coralline turf microhabitat and are crevice bound until they reach a test diameter of about 40 mm while larger kina occur on open surfaces (Andrew and MacDiarmid 1991).

Kina density is positively correlated with that of several molluscan herbivores (Andrew 1988) but may be negatively correlated with paua densities at least on scales from 1- 25 m2 (Andrew and MacDiarmid 1999). Wing (personal comment in Barker 2007) observed that peak abundances of kina and paua on rocky reefs overlap in depth distribution in southern New Zealand, but are generally negatively correlated with each other on the 2m^2 quadrat scale.

1.3.3 Reef fish

At least 19 species of reef fish are likely to be encountered on rocky reefs in Lyall Bay and more than 23 species along Wellington’s south coast (MacDiarmid et al. 2015). The abundance of reef fish depends on the type of habitat that develops. Abundances or frequencies of species such as leather jackets (*Meuschenia scaber*), butterfish (*Odax pullus*), jack mackerel (*Trachurus novaezelandiae*), and scarlett wrasse (*Pseudolabrus miles*), are greatest in kelp forest habitat, while species such as spotties (*Notolabrus celidotus*), banded wrasse (*Notolabrus fucicola*), and hiwihiwi (*Chironemus marmoratus*), are more common in areas of crustose and turfing coralline algae with few macro-algae (Anderson and Millar 2004). Other species, including goat fish (*Upeneichthys porosus*), sweep (*Scorpis lineolatus*) and red moki (*Cheilodactylus spectabilis*), show no strong consistent effects of these two differing habitats (Anderson and Millar 2004).

1.3.4 Rock lobsters

Red rock lobsters, *Jasus edwardsii*, are common on reefs along Wellington’s south coast and support valuable recreational and commercial fisheries (Gardner 2008, see section 3. in MacDiarmid et al. 2015). They are present, albeit in low numbers, on the reefs that will be buried under the proposed run extension (MacDiarmid et al. 2015). Rock lobsters settle on reefs as small pueruli a few grams in weight and can grow to 2 kg or more. Their shelter requirements likewise change considerably as they grow (Edmunds 1996). From first settlement to about 35 mm carapace length (CL) most lobsters occupy single entrance horizontal holes that scale with body size and are deeper than their height or width. Lobsters larger than this occupy ledges and gaps between boulders over a wide variety of dimensions but often are about as deep as they are wide and have two or more openings (Edmunds 1996, Butler et al. 1999, Booth and Ayers 2005) (Table 1). Gabites (1990) found that shelter width was the most important variable in explaining the numbers of larger juvenile and adult rock lobsters occupying shelters. In undisturbed groups, lobsters are usually oriented side-by-side across shelter entrances rather than behind other lobsters.

Table 1: Dimensions of shelters utilised by two size classes of red rock lobster *Jasus edwardsii* (from Edmunds 1996).

	Shelter dimensions	
Shelter aspect	**Lobsters <35 mm CL**	**Lobsters >35 mm CL**
Width (mm)	14-100	70-2000
Height (mm)	12-50	40-800
Depth (mm)	35-150	70-840
Shelter openings	91% entrance only	62% >2 openings
Width-height shape	52% rectangular	53% rectangular

Newly settled lobsters are typically solitary (MacDiarmid 1994, Butler et al 1999) and so many appropriately sized holes are required to accommodate this size class of lobster. Lobsters larger than about 35 mm CL are gregarious for most of the year so typically fewer larger shelters are required to accommodate larger size classes of lobsters (MacDiarmid 1994, Butler et al. 1999). Large shelters can be occupied by up to 100 lobsters (MacDiarmid 1994).

Artificial reefs have been deployed in Canada, Israel, the USA and the UK specifically for lobster habitat with some success (Jensen & Collins 1997). Jensen and Collins (1997) found their reef to be a suitable long term habitat for *Homarus gammarus*, supporting individuals from all stages of the benthic life cycle, including berried females. Similarly, artificial tyre reefs in Israel have provided new and suitable habitat for the colonisation of the slipper lobster, *Scyllarides latus* (Latrielle) (Spanier et al. 1988) and in Florida concrete blocks have enhanced the survival and local retention of the juvenile Caribbean spiny lobster, *Panulirus argus* (Latrielle) (Herrnkind et al. 1997). Studies have shown that many species of lobster are dependent on available crevices in their early life stages and that appropriately designed artificial shelters could enhance the survival and local production of these species (e.g. Spanier et al. 1988, Wahle & Steneck 1991, Herrnkind et al. 1997, Jensen & Collins 1997).

1.4 Designs that enhance biodiversity

The international literature suggest that habitat features increasing biodiversity in the intertidal zone include rock pools, crevices, and shaded overhangs, as well as a variety of smooth and pitted surfaces (Bulleri and Chapmen 2010, Moschella et al 2005, Moreira et al. 2007, Chapman and Blockley 2009, Chapman and Underwood 2011, Martins et al 2010, Browne and Chapman 2011, Firth et al. 2013, Firth et al. 2014a and b, Dafforn et al. 2015). For example, in Sydney, Browne and Chapman (2011) added concrete flower pots attached to seawalls to create artificial rock pools and found an increase of 64% in the number of species inhabiting the seawalls where rock pools were present. Chapman and Blockley (2009) also took advantage of the re-building of a seawall in Sydney to create rock pools by omitting some of the building blocks. Water was retained in the rock pools with a small lip on the outside edge. Their study showed that the presence of rock pools greatly increased the number of algae and animals that lived on the seawalls. Still in Sydney, Moreira et al (2007) showed an increase in the abundance and survival of chitons in the intertidal zone through the introduction of crevices in rock walls.

In the Azores archipelago in the Atlantic Ocean, Martins et al (2010) showed that the introduction of pits on artificial substrates in the intertidal zone increased the number of limpets and decreased the mortality of limpets.

There has been less research on design features that increase the biodiversity in subtidal zones with respect to micro-habitats, although it is well known that larval propagules can select for surface roughness/texture (Walters & Wethey 1996, Brown et al. 2003, Brown 2005) and colour (James & Underwood 1994). Studies on artificial reefs have shown a positive relationship between habitat complexity and epifaunal biomass (Beaumont 2006) and fish abundances (Hixon and Beets 1993, Carr and Hixon 1997, Danner et al 1994, Gratwicke and Speight 2005, Charbonnel et al 2002).

Research into the effects of offshore wind farms on the receiving environment has shown that changes in hydrodynamic conditions around these structures at the structure-sediment interface can induce sediment scour. This is particularly true in shallow, high energy areas and the resulting scour can be problematic to both marine life and the structural integrity of the wind farm structures. In order to minimise scour, the offshore wind farm industry use ether rock armouring (similar to that proposed by Wellington Airport) and/or anchored polypropylene fronds. These fronds are designed to mimic the sediment-trapping properties of seaweed beds. These anchored polypropylene fronds measure 1 – 1.5 m in height and are secured in concrete to form “mattresses” that emulate seaweed (Linley et al 2007). In addition to sediment stabilisation, it has been suggested that the exposed ends of the fronds can serve to attract fish.

2.0 Proposed design features to enhance biodiversity

2.1 Intertidal zone

Inspection of the latest rock dyke design indicates that crevices and shaded overhangs will be a common feature in the intertidal zone due to the combination of secondary rock armour and primary armour provided by the 34 t accropodes (AECOM 2015). Although not clearly stated in the present specifications, the accropodes are likely to have a smooth concrete surface and rock pools will be absent in the intertidal zone along the rock dyke. The addition of roughened/pitted surfaces on 50% of each accropod would increase the range of microhabitats available for colonising marine algae and invertebrates, while the inclusion of five shallow (100 mm deep, 250 mm wide, 1000 mm long) indented prisms along the arm of each accropod (the five indented prisms to be spaced equally around the circumference of each arm) would increase the possibility of at least one forming a rock pool no matter what the final orientation of each accropod. The indented prisms on the underside of accropods would provide suitable cavities for wind and sun intolerant groups such as anemones, while indented prisms on the sides of each arm would form suitable crevices for chitons and snails.

In addition, we recommend inserting one 1 m^3 concrete block with a truncated conical shaped hole (400 mm diameter at the top, 200 mm diameter at the bottom and 400 mm deep) in the top layer of the secondary armour every 10 m around the perimeter of the rock dyke somewhere between MLS and MHS tide levels. This will add about 85 large rock pools to the intertidal zone with large concomitant increases in biodiversity in this zone.

2.2 Subtidal zone

2.2.3 Rock lobsters

To accommodate newly settled lobsters from 10-35 mm CL we propose that the concrete accropods incorporate holes of three sizes; small (15 mm diameter by 45 mm deep), medium (25 mm diameter by 75 mm deep), and large (40 mm diameter, 120 mm deep). We suggest that each 1 m^2 of accropod surface has a minimum of 1 hole of each size (i.e. 3 holes in total).

The current design of the secondary rock armour should provide greatly increased shelter availability for larger juvenile and adult lobsters than presently available on the native and artificial reef structures that will be buried by the proposed extension of the runway. The area of subtidal reef reef that will be buried is about 5.3 ha and only a small proportion of this has holes, boulders and crevices suitable for rock lobsters. The proposed rock dyke will have approximately 2.3 ha of subtidal extent but will be comprised of rocks along its entire length.

2.2.4 Paua, kina and reef fish

The current design of the sub-tidal parts of the rock dyke provides for a range of crevices, overhangs, flat open surfaces and dark shaded surfaces suitable for a wide range of reef fish and invertebrates, including juvenile and adult kina and paua. However, the habitat will be augmented through the provision of additional nooky and crannies in the form of the prism-shaped indents and holes in the accropods as described for the intertidal habitat and for lobsters above.

2.2.5 Macroalgae

We recommend that the 0.5 m filter bed where the rock dyke meets the seabed is sufficiently stable (and of suitable material – i.e. stable hard substrate) for the attachment and growth of macroalgae in order to reduce sediment scour around the rock dyke. The use of artificial scour protectors (i.e. artificial turf or seagrass) for the first year after construction until natural algal beds develop could also be considered.

2.3 Enhancing the ecological value of the rock dyke for blue penguins

Generally, blue penguins *Eudyptula minor* respond well to the provision of artificial nesting opportunities. Indeed, there is evidence to suggest that in some cases penguins prefer artificial nest boxes over natural nesting sites and that reproductive output is greater for pairs using nest boxes compared to other sites (e.g. Perriman & McKinlay 1995, Houston 1999).

However, the proposed construction of the runway extension, and in particular the characteristics of the primary and secondary armour layers (see URS 2015), appear to provide little opportunity for the inclusion of artificial nesting boxes for blue penguins, nor for any planting of native coastal plant species to further increase the attractiveness of artificial nest boxes.

Specifically, the primary armour of a 3.3 m thick layer of accropodes will not provide a surface onto which artificial nest boxes could be placed, even on the 10 m wide horizontal section adjoining the wave wall – the spaces and gaps characteristic of ‘inter-locking’ accropodes are simply too large.

The proposed construction may provide nesting sites for penguins without the need for artificial nest boxes, especially on the more sheltered eastern side of the runway extension. Penguins may be able to navigate through gaps and spaces in the primary armour and locate suitable sites for nesting within voids in the secondary armour, a 2.2 m thick layer of relatively large rocks and boulders, above high water levels and sheltered from storm waves and swells. The proposed secondary armour is not dissimilar to the rock wall extending around the perimeter of Greta Point, in which blue penguins regularly breed, albeit in very small numbers (perhaps one or two pairs per year), and the proposed extension may provide nesting opportunities for a similarly small number of blue penguins.

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