Additional Waitemata Harbour Crossing

Coastal and Ecological Assessment

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1. Introduction

1.1 Background

The Additional Waitemata Harbour Crossing (AWHC) Project progresses the outcomes of previous studies undertaken which have examined the nature and form of an additional transport crossing of Auckland's Waitemata Harbour. In order to develop a business case for an AWHC the Project, work required for the business case has been split into three separate, concurrent work streams. The work presented in this assessment forms part of the contribution from Beca and AECOM who are providing engineering and planning services. The Engineering and Planning Services workstream involves a number of phases including:

Phase 1: Confirming objectives, principles, constraints and requirements.

Phase 2: Rapid narrowing of a long list of options to a short list of a bridge and tunnel options, defined for further detailed assessment.

Phase 3: Targeted design and assessment of up to three options to consider the relative merits of each option in terms of consent-ability or consenting risk, constructability and operational functionality.

Phase 4: Design and assessment of up to three options to understand the cost, effects, risks and benefits of each option as an input to the Business Case to recommend a preferred option.

The assessment of options carried out in Phase one and two for an AWHC has resulted in the identification of two options for final assessment. These options are referred to as Options T1 and B3.

This report has been prepared at the end of Phase 3 of the Engineering and Planning Services work stream. It provides and assessment of the relative merits of each short list option in terms of environmental issues (as it pertains to natural resources and construction of either option) and identifies areas of consenting risk. Ultimately, the work undertaken in this project will determine whether an additional harbour crossing should be "under the water" (tunnel), "over the water" (bridge) or a combination of both.

1.2 Phase 3 Options Assessment

As part of Phase 3 of the overall assessment of an AWHC options, this document prepared by Golder Associates (NZ) Limited (Golder) provides:

- An overview of the key elements of the natural environment within the Option T1 and B3 project areas.

- Identification and comparison of any key issues, constraints, opportunities and gaps to the implementation of either Option T1 or B3. This assessment covers both the construction and operational phases of the harbour crossing options.

- Identification of mitigation options that relate to the ecological/environmental impacts identified as arising from Options T1 or B3.

- Rough order costs associated with the development of mitigation for Options T1 or B3.

2. Harbour Crossings Options background

2.1 Introduction

The AWHC Options being considered in this assessment are Options T1 and B3. The key elements of the two options are:

- For the Bridge option B3, a road bridge (three lanes each way) from the Victoria Park Tunnel to the existing Onewa interchange in Shoal Bay. Two rail tunnels are bored (one track in each tunnel) and connect Gaunt Street (underground station) in Auckland City in the south to Akoranga Busway Station on the North Shore.

- For the Tunnel option T1, the option consists of two bored tunnels for road (three lanes in each tunnel) and two bored tunnels for rail (one track in each tunnel). The road tunnels connect to the existing motorway network in the vicinity of Onewa Road interchange in the north and the Central Motorway Junction (CMJ) in the south. The rail tunnel option is as above.

- For both Options, the existing Auckland Harbour Bridge is retained and used for general traffic, pedestrians, cyclists and bus public transport. Figure 2.1 illustrates the key elements of Option T1 and Figure 2.2 the key elements of Option B3.

2.2 Key Project Elements

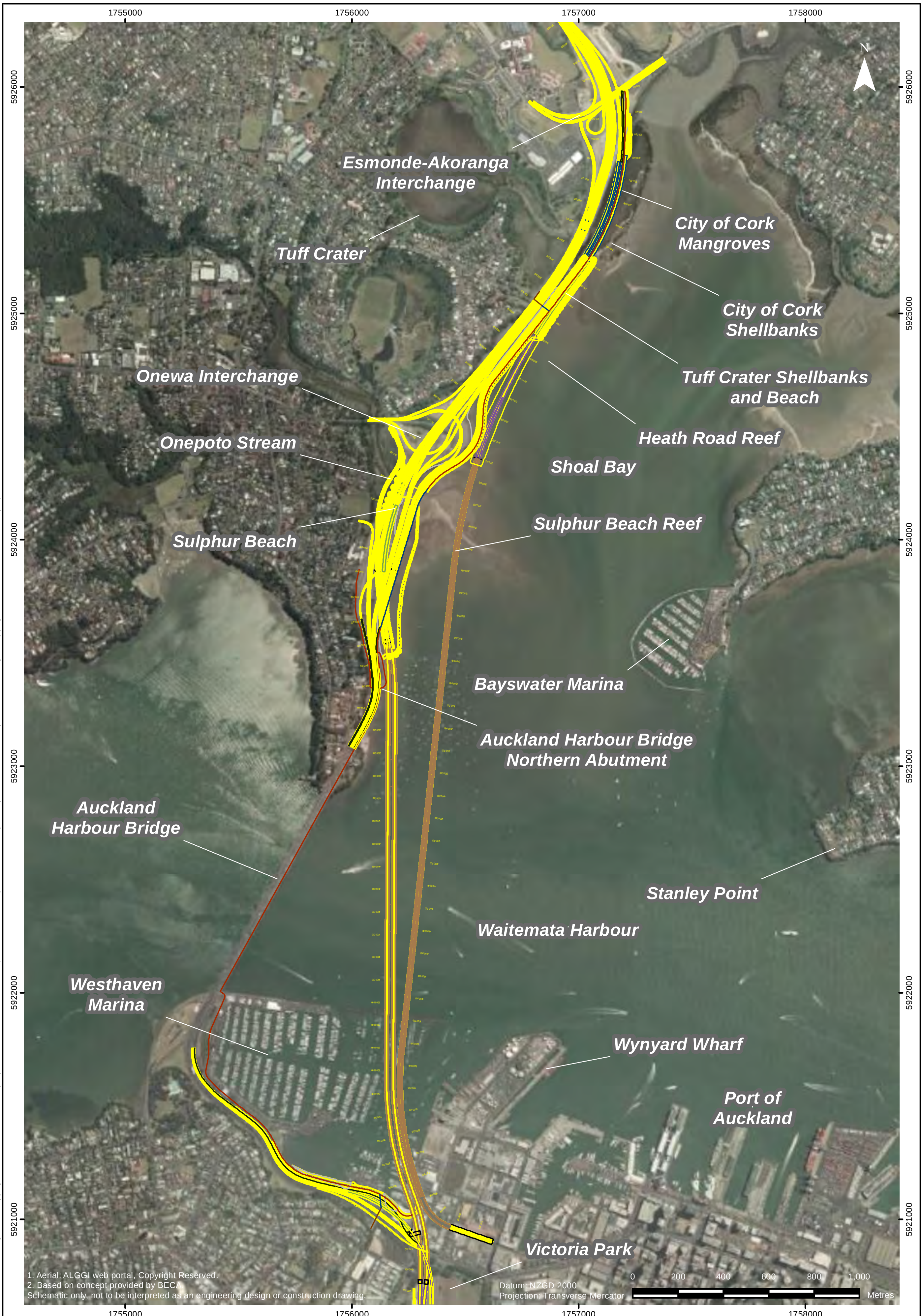
2.2.1 Road Tunnel (Option T1)

The road tunnel option T1 has the following features:

- Road tunnels are 15.5 m outer diameter (OD), 0.8 km trench, 0.55 km cut and cover, 3.65 km bored for each tunnel.

- Road tunnels emerge into reclamations in the northern sector between the existing Harbour Bridge and Onewa Rd interchange. Road mainline continues north at grade. The road tunnel is some 50 m below sea level across the harbour.

- At the southern end, road tunnels emerge in Victoria Park and continue south in cut and cover and trench to the central motorway junction.



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TITLE ADDITIONAL WAITEMATA HARBOUR CROSSING - OPTION T1.

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2.2.2 Rail Tunnel (Options T1 and B3)

The rail tunnel (for both options T1 and B3) has the following features:

- Two rail tunnels are bored (one track in each tunnel) and connect to Akoranga Busway Station in the north and Gaunt Street (underground station) in the south.
- The rail tunnels are 6.9 m OD, 0.4 km trench, 0.6 km cut and cover, 3.5 km bored for each tunnel.
- The rail tunnels emerge into reclamations in the northern sector. Following the tunnel, rail is elevated on bridge structures to Esmonde Road.
- As for road tunnels, the rail tunnels are some 50 m below sea level across the harbour.
- Rail tunnels are 30 m below ground level at Gaunt Street station.

2.2.3 Road Bridge (option B3)

The road bridge option (B3) has the following features:

- The road bridge is three lanes each way and connects to the existing motorway network in the vicinity of Onewa Road Interchange in the north and the CMJ in the south. The bridge south approach will pass over the motorway and continue north bound through Victoria Park Tunnel to the CMJ. The south bound connection to CMJ will be a new cut and cover tunnel east of Victoria Park Tunnel.
- Bridge 41 m clearance over the navigation channel.
- Bridge main span 250 m to maintain navigation clearance. Approach spans 75 m.
- Bridge south approach viaduct clearance 30 m over Westhaven Marina entrance to 10 m over Westhaven Drive.

2.2.4 Reclamations

- There are a number of reclamations associated with Options T1 and B3.
- The T1 option requires a reclamation in the corner of Westhaven Marina adjacent to Orams marine.
- Options T 1 and B3 require a reclamation between the existing Harbour Bridge and Onewa Stream.
- Options T 1 and B3 require a reclamation between the Onewa interchange and a point prior to the pedestrian over-bridge.
- The reclamations are required in the northern sector for road and rail tunnel cut and cover sections. Ground treatment and construction staging are required.

3. Physical Environment and Coastal Processes

3.1 Introduction

The proposed project intersects the coastal and marine environment between Shoal Bay on the north east side of the lower Waitemata Harbour and the Westhaven Marina on the south side of the Harbour entrance channel. The project involves reclamation and bridge structures within the coastal marine area (CMA) on the Southern, City side of the Harbour (to widen Westhaven Drive) and on the northern side of the Harbour to widen the AWHC approaches between Sulphur Beach and the Esmonde Road interchange. This section summarises:

- Studies undertaken to date and the dominant coastal processes occurring within the project area.
- Information on the physical nature of those marine environments as it relates to those processes.
- Reclamation changes that have occurred in Shoal Bay.

3.2 Place Names

There are a number of key locations referred to in this assessment that are often referred to be different names. The key locations which are shown on Figures 2.1 and 2.2 and referred to in the assessment are:

- Tuff Crater (sometimes referred to as Tank Farm) which is a volcanic explosion crater located south of Esmonde Rd. The crater was created by a series of eruptions approximately 20,000 to 140,000 years ago. Originally a freshwater lake, it later became a tidal lagoon when the sea levels rose after the last ice age. Tuff Crater is mostly in its natural state, though some parts of the tuff ring were quarried and the name Tank Farm stems from the fuel storage tanks located there during World War II.
- Onepoto Lagoon is located to the south of Tuff crater. The crater has been reclaimed. Onepoto Stream discharges via a tidal mangrove estuary south of the Onewa Rd interchange.
- Sulphur Beach is typically referred to as the small beach immediately south of outlet of the Onepoto Stream mouth.
- Sulphur Beach reef is the section of intertidal shore from the abutments of the harbour Bridge north to Stafford Rd. The beach was the location of sulphur works which opened in 1878 and processed sulphur ore from Whale Island.
- Heath Rd reef is located off Heath Avenue. This area is located between the Onewa Rd interchange and the outlet from Tuff Crater.

3.3 Coastal Studies

Relatively few direct studies of coastal processes have been conducted in the project area. CCNZ (2001) provide a description of the historical development, coastal processes, sediments, and geomorphology on the west side of Shoal Bay based on a desktop analysis and field investigation with focus on the reclamation area proposed for the North Shore Busway. Sinclair Knight Merz (SKM, 2009) summarised the study by CCNZ (2001) in their overview of coastal and marine hydrology. It should be noted that the CCNZ assessment was focused on the northern and western areas of Shoal Bay (albeit the most sensitive from an ecological perspective) and obtained very limited process measurements of water levels and current during two, one-day deployments of a single point gauge that was deployed near the Exmouth Road footbridge. Although the measurements may represent typical (non-storm) conditions near the footbridge in one of the proposed reclamation areas, they do not represent the conditions generally for areas proposed for reclamation in the final AWHC options being considered, or which might be impacted as a result. The limited temporal span and spatial context of the measurements is also of concern. The CCNZ report did not document sediments, processes or morphological conditions south of the Onewa Interchange.

NIWA has constructed and validated the Regional Harbour Model of the Waitemata Harbour to predict tidal currents and water levels (Ramsay et al. 2009) and several other regional models have been developed (e.g., BECA, 2009). Regional descriptions of the Waitemata Harbour geology and sediments are available from several sources (e.g., BECA, 1995, 1997). No additional modelling studies (relating to sediment transport etc.) that have been conducted in Shoal Bay have been identified for any other studies since the construction of Bayswater Marina.

3.4 Harbour Coastal Environment

With an opening to the sea and fresh water entering from a river or streams (as is the case in Shoal Bay), the main processes within the estuary relate to water circulation, mixing, and locally-generated wind waves. As one proceeds up-estuary from the mouth, the salinity generally decreases progressively from pure sea water to brackish water, and finally to the fresh water of streams.

The Waitemata Harbour is classified as a well-mixed estuary owing to the dominance of tidal processes over river and creek discharge, and the relatively large width to depth ratio of the estuary. Turbulence generated by the tidal currents and waves result in mixing of salt and fresh water such that the majority of the estuary is vertically unstratified most of the time. However, large horizontal gradients in salinity may exist depending on precipitation and these may have implications for transport and settlement of fine silts and clay-sized particles.

The spring tidal range in the Waitemata Harbour is 2.9 m while the neap range is 1.75 m (BECA, 2009). Important to the consideration of engineering projects in estuaries such as an AWHC (particularly those involving reclamation) is the tidal prism, representing the total volume of water entering due to the tides, essentially being the product of the tidal range and the surface area of the estuary.

For the Waitemata Harbour the prism for the mean range has been estimated as 216.1 x 106 m3 (NIWA Estuary Environment Classification Database). No estimates of the prism at Shoal Bay were readily available in published documents (e.g., as a part of the earlier AWHC studies). The information will need to be obtained to undertake any final assessment of effects.

Mangroves are established within and seaward of the Tank Farm and City of Cork Tuff Craters and the northern portions of Shoal Bay. There are no significant mangroves to the south of City of Cork Beach which may be an indication of greater hydrodynamic exposure (SKM, 2009) and/or substrate conditions.

Short-period wind generated waves and currents are the primary processes responsible for sediment entrainment and transport on estuarine intertidal flats such as those found in Shoal Bay, however, a detailed understanding of the way these processes control estuarine sediment transport involving a mixture of grain sizes and density has been lacking and no integrated studies or measurements in Shoal Bay have so far been undertaken.

Recent progress in terms of understanding physical processes in New Zealand estuaries has been made through a series of process-based studies which have involved detailed measurements as well as modelling of fluid-sediment interactions (e.g., Green et al. 1997, 1999; Osborne & Boak, 1999; Green & MacDonald, 2001; Green & Coco, 2007). Patterns of estuarine sediment transport are complex and often subtle because tidal currents and wave-induced sediment re-suspension patterns operate largely independent of each other. Furthermore, sediment suspension processes generally become progressively decoupled from both waves and tidal currents towards the upper margins of the tidal flat and modes of silt, sand, gravel and shell hash transport are markedly different in different process regimes of the estuary. It may therefore be difficult to ascertain the potential impacts of the project without additional process studies including modelling.

In Shoal Bay, as in other relatively sheltered estuaries, waves vary systematically in response to changes in fetch, wind speed, and wind direction. Fetch lengths in turn are associated with the submergence and emergence of intertidal flats during the rise and fall of the tide. For a given wind speed, growth in fetch on a rising tide causes growth in wave height and period (Dolphin, 2003; CCNZ, 2001). Variation in the near-bed velocities and bed shear stress responsible for entraining the mixture of sediments that occurs in estuaries such as the Waitemata Harbour and in particular Shoal Bay, result from different combinations of wave height, period, water depth, as well as ambient mean currents driven by the tide, wind, and runoff of precipitation, as well as variations in bed roughness.

Wind speeds (in the general Shoal Bay area) most commonly lie in the 2 – 7 m/s range (51%), with stronger winds infrequent with 10 m/s equalled or exceeded 2.9% of the time. Most winds in the project area originate from the west, the southwest, or northeast, with relatively few winds from the southeast, north, or south (Ramsay et al. 2009). No detailed records of the wind-wave climate for Shoal Bay are readily available at this time and the only direct measurements consist of two, one-day deployments of a single point current meter and wave gauge by CCNZ (2001). CCNZ (2001) present results of a wind-wave hindcast based on the ACES v1.07 approach and conclude that wave heights range between 0.01 m up to 0.41 with periods ranging from 0.25 s to 2.3 s. More than 75% of the waves are less than 0.05 m in height and waves are greater than 0.2 m for 1.5% of the time while waves larger than 0.25 m occur for only 0.2% of the time. However, CCNZ's wave study predicted hindcast waves at a point near the Exmouth Road footbridge and south of Tuff Crater Creek outlet, which is towards the northern end of Shoal Bay (based on the fetch lengths and angles presented in

Table 3 (CCNZ 2001). This location is not representative of the proposed reclamation area to the south of Onewa Road. The latter location has a fetch of at least 2.5 km to the northeast (considerably larger than the fetch of 0.36 km used by CCNZ) and a fetch of 6 km to the southeast and is considerably more exposed to wave action and potentially also tidal currents (Figure 3.1).

Information on the coastal environment provided in Beca (2010) provides a conservative estimate of the 2-year wave height of 1.0 m with period of 3.2 sec for a wind speed of 35 knots.

At greater depths, the influence of waves is diminished as a result of limited penetration of short period wave orbital motions through the water column. In shallow water, or when the wave period is longer, orbital penetration is greater and larger bed orbital speeds result (Dolphin, 2003; Green et al. 1999). The small and short period wind waves which are common on a daily basis in most estuaries (including Shoal Bay) are extremely effective in suspending both sand and silt in shallow water. As a result, silt concentrations are typically highest in the edge of the estuarine water body known as the turbid fringe (Green et al. 1997) and this is reflected in the suspended particulate concentrations that have been measured in Shoal Bay in a variety of studies and monitoring programmes over the last 20 years. Therefore, despite the relatively benign wave climate in Shoal Bay, the potential for regular and frequent wind wave induced re-suspension and transport of fine silts and muds (see Section 4.4.4) is substantial and should not be overlooked in the context of the proposed alternatives.

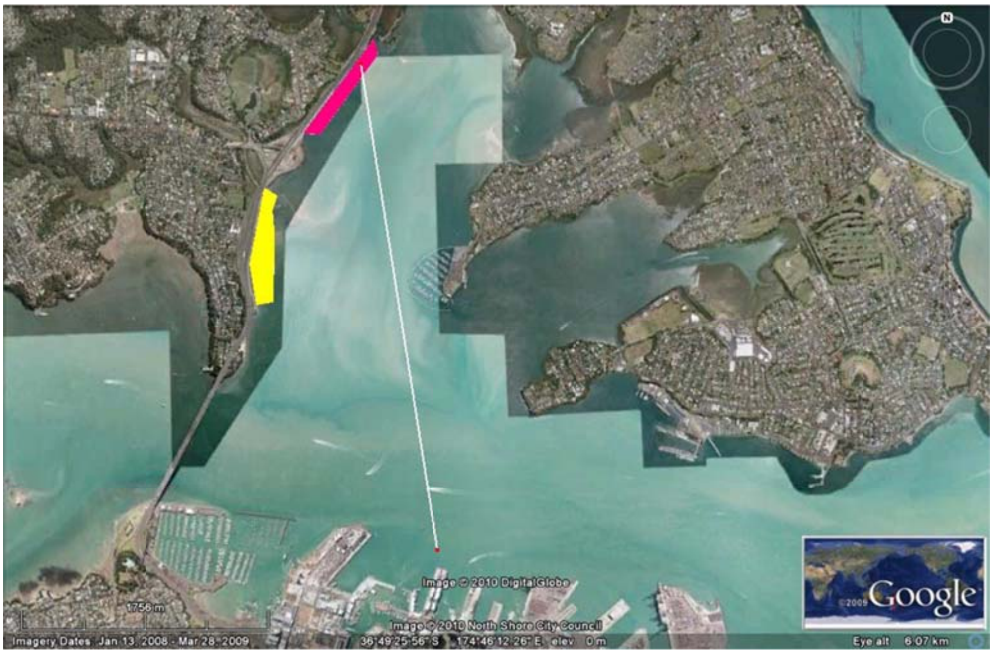


Figure 3.1: Key reclamation areas and line of greatest fetch

Notes: The yellow area is the approximate location of the reclamation required for the T1 and B3 Options. The magenta area is the approximate location of the reclamations and structures associated with the road and rail viaducts to Akoranga Station. The white line is the approximate position of the line of maximum fetch in Table 3 of CCNZ (3.75 km at about 170 deg).

Enhanced settling and onshore directed wave orbital asymmetry encourage silt and sand deposition on the upper inter-tidal flats. Mud (silt and clay) suspensions in particular may be advected both landward and seaward by net currents (wave, tidal, and wind). Wave processes are modulated spatially and temporally across inter-tidal and shallow sub-tidal areas by the rise and fall of the tide and a maximum in wave forcing typically occurs in the middle reaches of the flats (e.g., Green & Coco, 2007). Water level fluctuations are also the dominant control on tidal currents which may enhance offshore transport as tidal flats and channels drain during a falling tide (Dolphin, 2003).

Spatial patterns in processes typically align with sedimentary and geomorphic features and such associations have been previously noted in Shoal Bay (e.g., CCNZ, 2001). Silts being more abundant near channel margins where the shear stress induced by waves is generally less than the critical threshold for sand. The inter-tidal region is typically broad and flat and is a potential depositional area for both sand and silt with an increase in the percentage of sand and broken shell, which typically form ridges towards the edge of tidal inundation (e.g., Gregory & Thomson, 1973). Wave asymmetry at high water levels encourages landward migration and stranding of shell hash and sand as does a systematic asymmetry in suspended silt concentration (Green & Coco, 2007). Sand transport and concentration generally increases within channels. CCNZ (2001) have interpreted a net transport of sediment in Shoal Bay to the north based on the increase in sediment volume northward in the Bay, and the migration trends of shell banks determined from aerial photo analysis.

Estuarine creek channels (e.g., Onepoto Stream, Tuff Crater Creek, Hillcrest Creek) which dissect the tidal flats focus drainage from the inter-tidal sand flats. Exchanges of silt between the tidal creek bed and the upper and mid-flats occurs continuously in fair-weather (no wave) conditions and is controlled by the elevation of the flat with respect to the creek bed (e.g., Green & Coco, 2007). Green & Coco (2007) showed that rainfall in the watershed does not fundamentally alter the way an inter-tidal flat and channel interact, but it does increase silt loads, which in turn increases the amount of silt exchanged with the upper flat. Tidal creeks which dissect the sand flats carry silty sediment from either upland soil erosion or mobilisation of estuarine mud deposits in the upper reaches of the creeks (e.g., the basin known as Tuff Crater or Hillcrest Creek at the north end of Shoal Bay). In general, currents in tidal creeks and sub-tidal channels are stronger than on the flats and may exceed the critical thresholds for silt, fine sand and shell during portions of the tidal cycle. Deeply incised channel beds may therefore be characterised by a surface armour of relatively coarse sand, gravel, and shell hash. The presence of fine sediments and activity of benthic organisms may contribute to cohesive properties in the sand, silt, and muds in this environment.

3.5 Reclamation in Shoal Bay and the Waitemata Harbour

Shoal Bay has undergone significant changes since European arrival in the Waitemata Harbour. Figure 3.2 provides a comparison of Shoal Bay as described by Chapman & Ronaldson (1958) with the current shoreline. The significant changes that have occurred in Shoal Bay have been associated with:

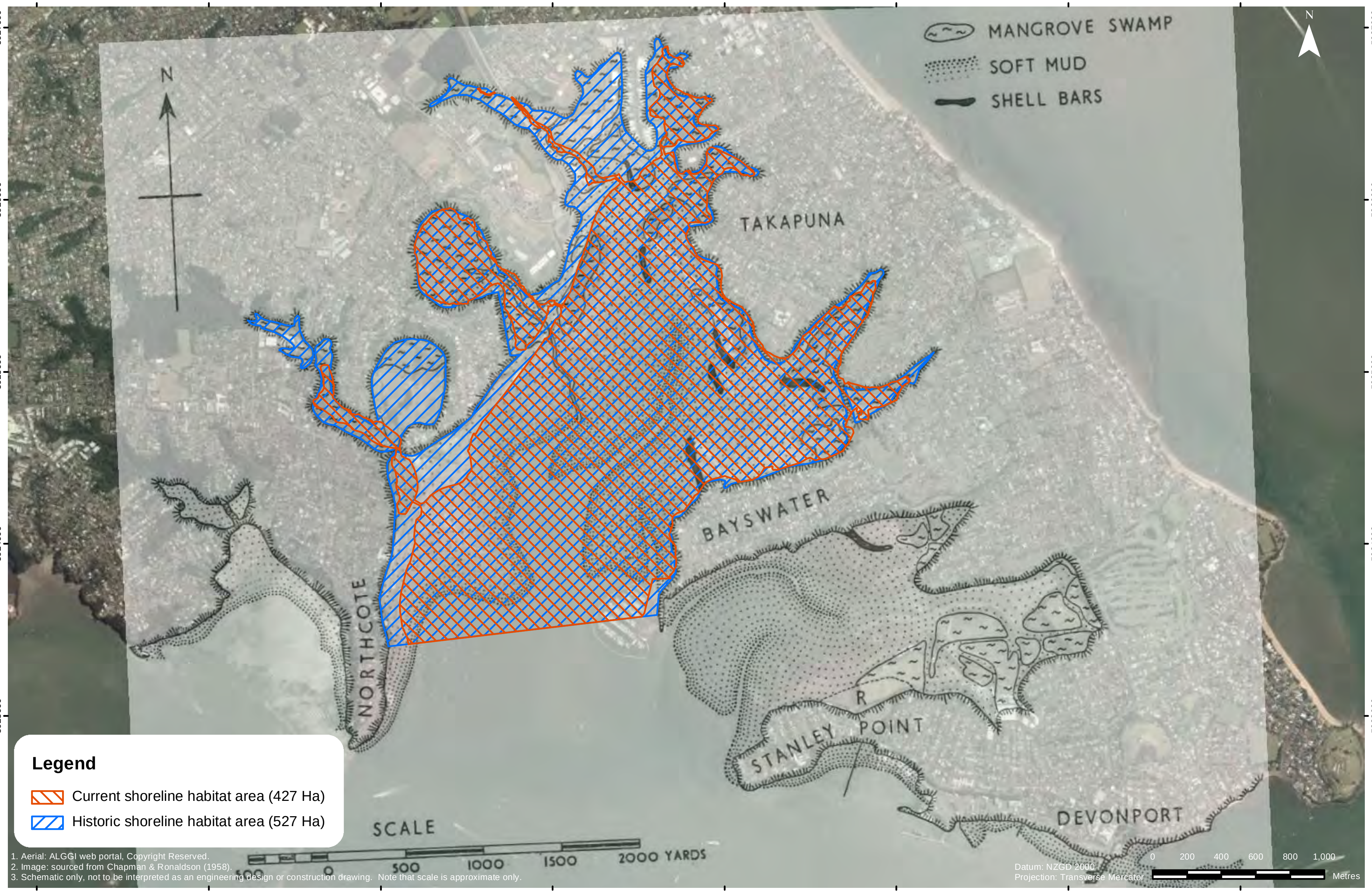
- The construction of the Harbour Bridge, State highway and Onewa interchange.
- The infilling of the upper part of Shoal Bay as part of the development of the North Shore City Council Barrys Point Reserve.

- The additional reclamation required for the construction of the North Shore busway in 2008.

Changes in the area of Shoal Bay result in tidal prism changes and the change in the width of the Bay have the potential to result in changes in tidal velocities.

These developments resulted in the loss of 19% of the area of Shoal Bay (historic area 527 ha, current area 427 ha) (Figure 3.2).

The developments to date have resulted in the mouth of Shoal Bay (a line drawn between O'Neills Pt at Bayswater and the shore south of Onepoto Stream) reducing by 200 m with the construction of the motorway and the Bayswater marina. This resulted in a reduction in the width of the mouth of the Bay by 11%. The construction of the bus-way resulted in a further reduction of about 20 m in the width (about 0.6%) of the shoreline from Onewa to Esmonde Rd.



1. Aerial: ALGGI web portal, Copyright Reserved.
2. Image: sourced from Chapman & Ronaldson (1958).
3. Schematic only, not to be interpreted as an engineering design or construction drawing. Note that scale is approximate only.

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TITLE COMPARISON OF CURRENT AND HISTORIC MARINE HABITAT AREAS.

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3.6 Summary

The primary coastal process forcing mechanisms of relevance to the proposed alternatives include tidal hydraulics, wind-generated waves, and freshwater inputs from a number of creeks, all of which are modulated on longer time scales by long term water level shifts including storm surges, tsunamis, and sea level changes,

In spite of relatively small fetch lengths which do not typically align with dominant wind directions in Shoal Bay, there is a significant potential for regular and frequent re-suspension and transport of fine silts and muds as a result of wind-wave processes. Fine sediments in suspension in the turbid fringe remain in suspension to be acted on by currents induced by freshwater inflows and tides which serve to redistribute fine sediment within Shoal Bay.

Shoal Bay has undergone significant changes since European arrival in the Waitemata Harbour in terms of changes to the inter-tidal and sub-tidal areas (affecting tidal prism) and to the width of the entrance to the Bay, both of which have potential to alter tidal velocities and sediment transport. Although, the system has potentially reached an equilibrium with respect to these changes, the proposed project will contribute to additional changes in tidal prism and cross-section change across the Bay.

4. Ecological Resources

4.1 Introduction

This section of the options assessment provides a description of the existing natural resources within the footprint of Options T1 and B3. The following sections describe:

- Terrestrial ecology (but not Scheduled trees as these have been adequately documented in SKM (2010).
- Coastal ecology including intertidal and sub-tidal marine vegetation and faunal ecology.
- Birds.
- Reptiles.

4.2 Terrestrial Ecology

Terrestrial vegetation within the proposed AWHC Option T1 and B3 Options footprint includes a small portion of the coastal escarpment between Tuff Crater and the Onewa interchange, aesthetic and stormwater management plantings in and around the Onewa Interchange flyovers and grassed playing fields and amenity trees within Victoria Park and environs.

4.2.1 Victoria Park and Viaduct

The proposed AWHC footprint for Options T1 and B3 (for cut and cover trenches and bridge approaches and motorway adjustments), encompasses an area of exotic amenity trees including London plane (*Planatus acerifolia*), Queensland box (*Trisania conferta*), monkey apple (*Acmena smithii*) and ornamental pines (Pinus sp.). A copse of planted native vegetation is also within the footprint, comprising flax (Phormium tenax), cabbage trees (Cordyline australis), Coprosma cultivars and single specimens of karaka (*Corynocarpus laevitagus*), kahikatea (*Dacrycarpus dacrydioides*), kauri (Agathis australis) and akeake (*Dodonaea viscosa*). In addition, a number of trees in the vicinity may be affected by the wider construction footprint in the vicinity of the cut-and-cover tunnels. Some of the trees to be removed are large specimens and include two scheduled trees (protected in the ACC District Plan), although some of these specimens may have already been removed as part of the Victoria Park Tunnel development.

4.2.2 Shoal Bay

Remnant forest vegetation on the coastal escarpment between Tuff Crater and the Onewa interchange comprises mixed native and exotic trees and shrubs. Pohutukawa (*Metrosideros* excels) dominates the canopy, interspersed with karaka, totara (*Podocarpus totara*), and puriri (*Vitex lucens*). Kawakawa (*Macropiper excelsum*), *Coprosma macrocarpa,* karamu (*Coprosma robusta*), mapou (*Myrsine* australis) and hoheria (*Hoheria* populnea) are also present. Invasive exotics (Chinese privet (*Ligustrum sinense*), monkey apple (*Syzygium smithii*), bamboo (*Bambusa multiplex*), jasmine (*Jasminum polyanthum*), smilax (*Asparagus asparagoides*), Japanese honeysuckle (*Lonicera japonica*), wandering jew (*Tradescantia fluminensis*), *Elaeagnus*, giant reed (*Arundo donax*), kahili ginger (*Hedychium gardnerianum*), *Impatiens* sp., Japanese spindleberry (*Euonymus japonicas*) and moth plant (*Araujia sericifera*) etc.) are common throughout the understorey.
This coastal forest is significant as a remnant of the forest that once flanked the western shores of Shoal Bay, and as a linkage between the bush remnants of Tuff Crater and Onepoto Lagoon. Development of an AWHC is likely to result in the loss of a number of mature pohutukawa and karaka trees, along with kohekohe (*Dysoxylum spectabile*), mahoe (*Melicytus ramiflorus*), houpara (*Psedopanax lessonii*) and puriri trees. However, the majority of indigenous vegetation on the escarpment will be retained.

4.3 Intertidal Vegetation

4.3.1 Victoria Park and Viaduct and Westhaven Marina

There is no intertidal vegetation of any note associated with the City end of the AWHC Option T1 tunnel location or B3 bridge crossing location (apart from algae on man-made shores and jetty structures within Westhaven Marina).

4.3.2 Shoal Bay

There is a range of habitat associated with the areas encompassed by the Shoal Bay side of the AWHC T1 and B3 Options. These have been described and the location of the key vegetation components mapped in BML

(2009). Supplementary observations of vegetation along the western side of Shoal Bay from the Auckland Harbour Bridge to the Esmonde Rd interchange were made on 25 August and 6 September 2010. The broad habitat and vegetation communities as have been described previously include:

- Mangroves.
- Saltmarsh.
- Saltmeadow.
- Freshwater influenced saltmeadow/marsh.
- Shell banks.
- Roadside.

The saline communities of Shoal Bay are described as "outstanding" (e.g., Auckland Regional Plan: Coastal) and contain examples of mangrove, saltmarsh, salt meadow and shell bank vegetation communities. The Auckland Regional Air, Land and Water Plan, identifies sites of regional, national or international significance due to their ecological, landform or geological values as Coastal Protection Areas (CPA). Coastal Protection Areas 1 include those areas which, due to their physical form, scale or inherent values, are considered to be the most vulnerable to any adverse effects of inappropriate subdivision, use and development. These areas include regionally or nationally rare habitat types, such as saline herbfields, as well as the best examples of saltmarshes and mangroves in the Auckland Region. Coastal Protection Areas 2 are generally more robust, but still require more protection than that accorded under a general management area as their physical form or inherent values make it more difficult to avoid, remedy or mitigate any adverse effects on the environment of which they form part. Coastal Protection Areas 2 include areas of mangroves which are of regional importance because of their size and degree of intactness, and small areas of rare or uncommon coastal vegetation such as saltmarshes growing in association with mangroves. The whole of Shoal Bay is identified as CPA 2, while some specific features within Shoal Bay (such as shell banks) are identified as CPA 1.

The key elements of the Shoal Bay vegetation within the Option T1 and B3 corridor are the salt marsh and shell bank communities which have been identified as the best in North Shore City. Some examples of the nature of these communities are shown in Figures 4.1 and 4.2 and the distribution of these communities is shown on Figures 4.3, 4.4 and 4.5.

4.3.2.1 Mangroves

Mangrove (*Avicennia marina* subsp. *australasica*) communities occupy 140.3 ha of Shoal Bay, in sheltered areas around the coastal margin. Mangroves are the most significant community in Shoal Bay and range in stature depending on location, exposure and tide. Approximately 8.1 ha of mangroves are present between the seaward margin of the northern motorway and the leeward edge of the "City of Cork" shell banks (Figure 4.1). Mangroves range in stature from 0.5 m throughout much of the main thicket by the Esmonde Rd interchange (Figure 4.1), to 3 m tall in the sheltered area immediately adjacent to the motorway embankment. A thin strip of mangroves extends along the foreshore adjacent to the motorway south of the Tuff Crater lagoon outlet along the City of Cork Beach, and mangroves are also present at the northern end of Sulphur Beach. The basin of Tuff Crater encompasses 25.9 ha, and is almost entirely vegetated in mangroves.

Figure 4.1: Short stature mangrove vegetation south of the Esmonde Road motorway interchange

4.3.2.2 Saltmarsh

The saltmarsh communities in Shoal Bay are identified as the best examples of their type in the North Shore District and are thus of particular ecological significance. Local patches of salt marsh (predominantly salt marsh ribbonwood (*Plagianthus divaricatus*), sea rush (*Juncus kraussii* var.*australiensis*) jointed wire rush (*Apodasmia similis*) and coastal immortality grass (*Austrostipa stipoides*) occur in places on the landward margin of mangroves, where periodic inundation by high spring tides occurs.

4.3.2.3 Salt meadow

Small areas of salt meadow comprising *Selliera radicans,* bachelors button (*Cotula coronopifolia*), shore pimpernel (*Samolus repens*), sea blite (*Suaeda novae-zelandiae*) and glasswort (*Sarcocornia quinquefolia*) are also present in along the landward margins of mudflats. Brackish wetland containing marsh clubrush (*Bolboschoenus fluviatilis*), raupo (*Typha orientalis*) and tussock swamp twig rush (*Baumea juncea*) occur at the mouths of watercourses entering Shoal Bay.

4.3.2.4 Shell-banks

Shell banks located adjacent to the seaward margin of the northern motorway (informally named "City of Cork Beach") are sparsely vegetated with patches of *Austrostipa stipoides, Sarcocornia quinquefolia* (glasswort*), Plagianthus divaricatus* and *Suaeda novae-zelandiae* (sea blite) (Figure 4.2), along with a variety of hardy exotic species including *Cortaderia selloana* (pampas grass) and *Elytrigia repens* (couch grass). These shell banks are zoned as Coastal Protection Area 1. The western-most shell bank of this group is situated within the footprint of the rail viaduct.

Figure 4.2: Typical shell bank community vegetation including Austrostipa stipoides, mangrove, glasswort and sea blite

A mixture of mangrove, saltmarsh and salt meadow vegetation is present on Sulphur Beach, a small sandy beach at the mouth of Onepoto Lagoon.

4.3.2.5 Roadside

Weedy roadside pasture on the motorway verge comprises lotus (*Lotus pedunculatus*), dock (*Rumex spp.*), white clover (*Trifolium repens*), red clover (*Trifolium pratense*), buffalo grass (*Stenotaphrum secundatum*), kikuyu (*Pennisetum clandestinum*), *Elytrigia repens*, *Geranium* spp., mouse ear chickweed (*Cerastium fontanum*), sow thistle (*Sonchus olearaceous*), vetch (*Vicia sativa*), black nightshade (*Solanum nigrum*) and broad-leaved plantain (*Plantago major*). Karo (*Pittosporum crassifolium*) and pohutukawa shrubs are dotted throughout the rank grass verge.

4.4 Intertidal Marine Fauna

4.4.1 Victoria Park and Viaduct and Westhaven Marina

There is no intertidal fauna of any note associated with the City end of the AWHC Option T1 tunnel location or B3 bridge crossing location (apart from fauna growing on and inhabiting man-made shores and jetty structures within Westhaven Marina).

4.4.2 Shoal Bay – studies to date

The marine intertidal environment of Shoal Bay has been previously described in a number of older studies (Bioresearches 1990, Kingett Mitchell 1995), which have provided broad-scale details of the habitats types occurring along the western coastline of the bay. These surveys have varied in terms of their scale, the detail provided, the types of information collected and the overall outcomes sought from the surveys.

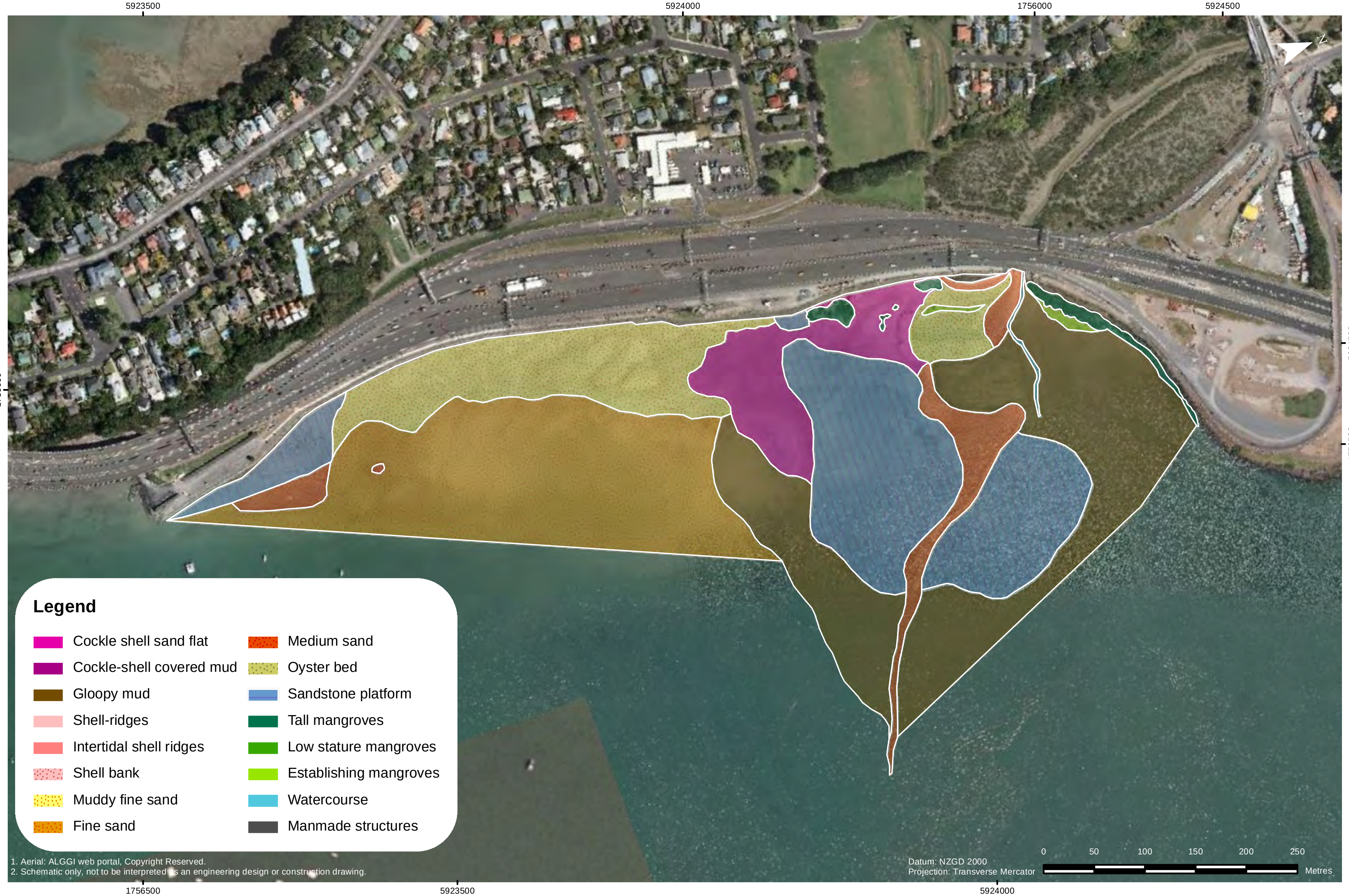
The most recent marine intertidal investigations undertaken in relation to Shoal Bay have included:

- Examination of marine benthic communities along the western shoreline between the mouth of Tuff Crater and Sulphur Beach (BML 2001).
- Mapping of intertidal and subtidal habitats undertaken by Kingett Mitchell (2003).
- The assessment of the intertidal area to the immediate north of the Onewa Interchange (BML 2007).
- The area between the northern abutment of the Auckland Harbour Bridge (BML 2009).

Kingett Mitchell (2003) mapped the broad-scale distribution of marine substrates and faunal communities throughout the harbour (Figure 4.5). Specifically, the subtidal area of Shoal Bay was identified as predominantly firm fine sand – muddy fine sand flats or soft gloopy mud. The marine habitats closer to the western shoreline of the bay, and in the vicinity of proposed AWHC works, also included smaller patches of shell bank, cockle-shell covered sand flat, shell bank vegetation, mangrove, and sandstone reefs, and some man-made substrates. Changes in sediment textures generally relate to differing water movement and sediment deposition, and in turn the nature and distribution of these substrates provide a significant influence on the nature of intertidal and subtidal ecological community composition.

4.4.3 Shoal Bay – habitat overview

Shoal Bay is considered to have excellent ecotone sequences from mangrove forests to saltmarsh vegetation, to intertidal marine habitats (BML 2009). The predominant marine fauna community inhabiting the mangroves of Shoal Bay (i.e., City of Cork, Tuff Crater mangrove stands) is typical of mangrove habitats throughout New Zealand, and was considered to have a lower diversity than the invertebrate communities found in surrounding bare mudflats and sandflats (BML 2009). There was a small, gradual decline in the abundance of major taxa (molluscs, isopods, amphipods) from north to south along the western shoreline. This pattern in abundance was thought to be attributed to changes in sediment types from sandy through to more muddy sediments along this gradient (BML 2009).



Golder Associates

TITLE MARINE HABITATS SULPHUR BEACH.

OCTOBER 2010

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4.3

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Golder Associates

TITLE MARINE HABITATS CITY OF CORK BEACH AND TUFF CRATER MOUTH.

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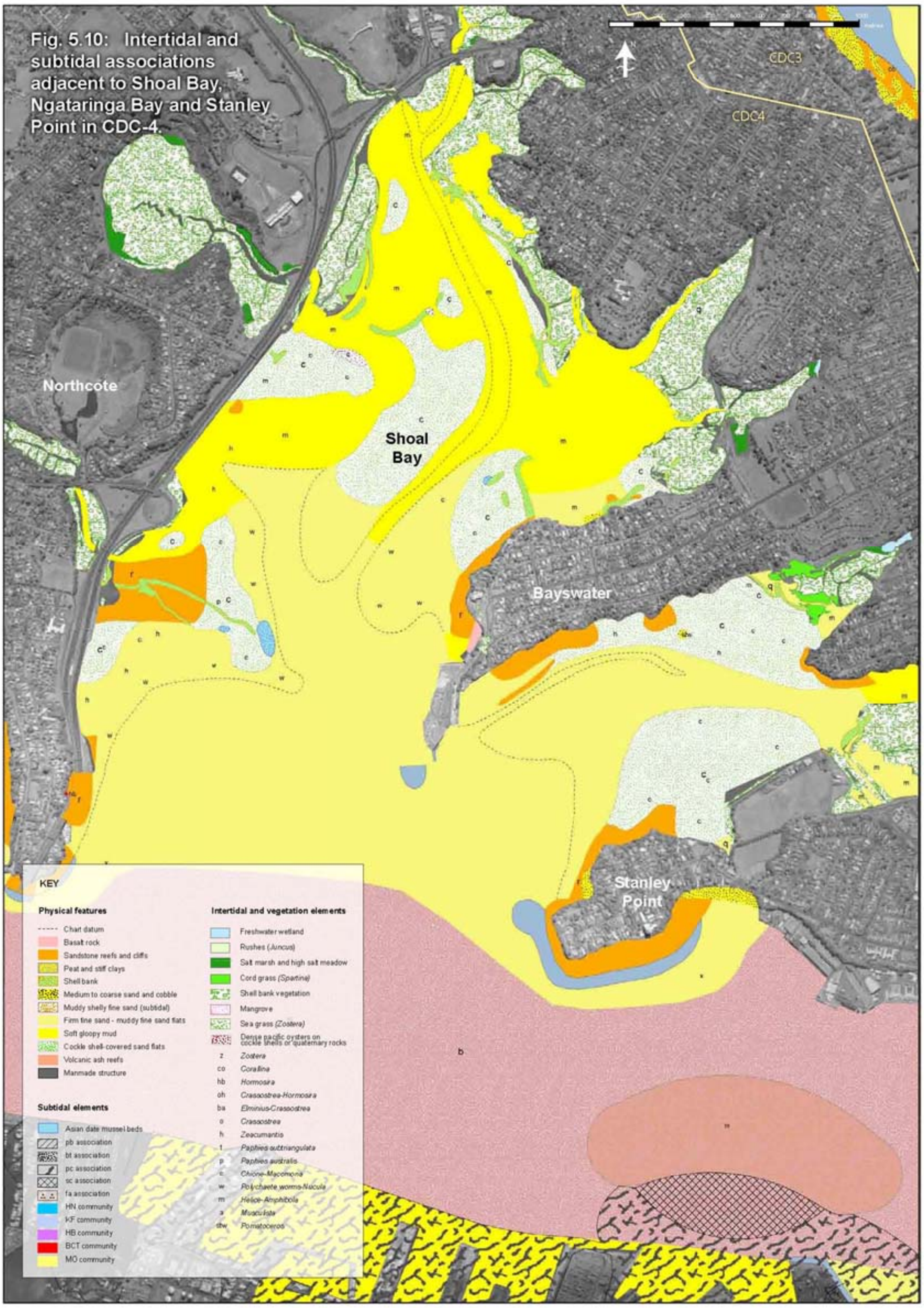


Figure 4.5: Shoal Bay habitats (Figure 5.10 from KIngett Mitchell 2003a)

Although habitat descriptions have been provided in studies undertaken to date, as part of the current AWHC Options assessment, additional habitat mapping was undertaken to allow the relationship between proposed works and structures to be assessed more precisely. This was undertaken through examination of aerial photographs and habitat walk-over surveys aimed at examining as much area as possible during the low tide period on 25 August and 7 September 2010. The habitat boundaries were recorded in the field using handheld GPS and then mapped onto low level aerials. Habitats in the marine environment were predominantly selected on the basis of substrate type, followed by an examination of these substrates for dominant flora and epifauna. No quantitative sampling of infauna was undertaken, however some qualitative investigations of the infauna was made to aid in the identification of visually dominant marine taxa. As mangrove and saltmarsh habitats are dominated and best categorised by their floral elements, marine habitat mapping typically extended outwards from these zones. Notes of faunal elements from these vegetation zones were taken however to aid in the descriptions.

A description of the marine classification categories follows. The distribution of these habitat types are presented in Figure 4.3 for the area south of the Onewa Interchange and Figure 4.4 for the area near the City of Cork mangroves.

4.4.4 Shoal Bay habitats

4.4.4.1 Very soft gloopy mud

This habitat type was the dominant substrate over the much of the western side of Shoal Bay (Figure 4.6 top). The muddy substrate was often very deep and soft, making it hard to traverse on foot during low tide. This habitat type generally occurred along the banks of water courses entering Shoal Bay. Pacific oysters (*C. gigas*) were common throughout this habitat, occurring as lone individuals or in denser groups of several individuals (very dense aggregations were designated as their own classification of oyster bed habitat). The only other fauna associated with the very soft substrate were the burrows associated with various crustaceans, particularly the common mud crab (*A. crassa*), with their high abundance indicated by the sediment surface often being heavily pocked with their burrows (Figure 4.6 top right). Small numbers of cockles (*Austrovenus stutchburyii*) and mud shells (*A. crenata*) were also seen, often associated with oyster clumps.

4.4.4.2 Oyster bed

The sediment characteristic of this habitat consisted of soft to very soft gloopy mud. The introduced Pacific oyster (C. *gigas*) is well-known to inhabit soft muddy substrates and does so extensively within Shoal Bay (Figure 4.6 bottom left). Pacific oysters formed dense, extensive clusters within the soft mud (Figure 4.6 bottom right), often forming raised mounts as the colonies trapped fine sediment within their shell matrix.

After initially settling on shell material or other debris on the surface, the oysters grow vertically in an elongated shape outwards from the substrate. The anterior margin of the shell remains above the sediment-water interface, allowing the oyster to filter feed.

4.4.4.3 Medium sand

The medium sands that characterised this habitat were well sorted and generally devoid of epifauna. This habitat was found in association with the sandstone reef at the AHB Northern Abutment and through the centre of the reef at Sulphur Beach (Figure 4.7). The epifauna was relatively limited with only mud whelk (*C. glandiformis*) seen on the days of survey.

Figure 4.6: Very gloopy mud habitat (top left) that had relatively high abundance of mud crabs as indicated by their burrow holes (top right); and oyster bed habitat (bottom left) that was formed by clumps of Pacific oyster (bottom right)

4.4.4.4 Fine sand – muddy fine sand

The substrates of this habitat consisted of firm fine muddy sands in which shell fragments were relatively common (Figure 4.7). Small surface ripples formed throughout this habitat and indicate that the area is subjected to moderate tidal currents. The faunal components of this habitat included scattered clusters of Pacific oysters (*C. gigas*) and Neptune's necklace (*H. banksii*), the algae *Codium fragile*, a mudflat top shell (*D. subrostrata)*), mud snail (*A. crenata*), cat's eye snail (*T. smaragdus*) and cockles. This habitat covered the majority of the area between the two exposed sandstone reefs at Sulphur Beach.

These habitats make up a mosaic of sand flats and mud flats that support the same epifauna, with the habitat landward being muddier than that seaward. Large pieces of gravel and cobble were also present on this habitat on which barnacles and rock oysters inhabited. This gravel could originate from the seawall constructed adjacent to the motorway.

Figure 4.7: Fine – muddy fine sand (top) showing subtle change from fine sand to muddy fine sand(top right); and cockle-shell covered mud/sand (bottom) extending south from Tuff Crater (bottom right).

4.4.4.5 Cockle-shell covered mud

The areas of shelly mud identified during the survey was characterised by soft, fine sandy mud covered in dead shell fragments consisting mainly of dead cockle fragments, but not at the density seen on shell banks (Figure 4.7). Live cockles were common in the upper layer of the substrate with mud crabs (*H. crassa)* and low numbers of horn shells (*Z. lutulentus*) also present. This habitat was extensive, covering a large proportion of the marine habitat south of Tuff Crater.

4.4.4.6 Cockle-shell covered sand flat

The substrates of this habitat consisted of firm fine sands in which cockle-shell fragments were common (Figure 4.8). The faunal components of this habitat were similar to that of fine sand – muddy fine sand and included scattered clusters of Pacific oysters (*C. gigas*) and Neptune's necklace(*H. banksii*), the algae *Codium fragile*.

Figure 4.8: Cockle-shell covered sand flat change from sandstone reef (left), and small mangrove seedlings (right).

4.4.4.7 Sandstone reef

Hard packed reefs of basement rock were exposed amongst the predominately soft shore habitat in patches throughout the study area were most often present in the Sulphur Beach area (Figure 4.9). Occasionally this substrate formed a reef/mudflat mosaic and was covered by a thin layer of fine sandy mud and/or small pieces of rubble from nearby man-made structures. The dominant macrofaunal taxa present on the hard substrates (i.e., natural rocky shore, mudstone reefs and artificial hard shores) included typical intertidal taxa such as barnacles (*Austrominius modestus*, *Chamaesipho columna*), oysters, chitons (*Chiton glaucus, C. pelliserpentis*), gastropods, little black mussels (*Limnoperna pulex*), periwinkles (*Austrolittorina antipodum, Littorina unifasciata*) and limpets (*Cellana ornata*).

The sandstone reefs adjacent to the AHB northern abutment were dominated by the presence of Neptune's necklace (*Hormosira banksii*), while the large reef at Sulphur Beach supported large numbers of oysters (*S. glomerata, C. gigas*). Cat's eye snails (*T. smaragdus*), whelks (*C. adspersa, C. maculosa*), cockles (*A. stutchburyi*), sea slugs (*Onchidella* sp.) and mud crabs (*H. crassa, M. hirtipes*) were also present on the reefs in low numbers.

BML (2009) described this habitat as mudstone reef and found additional common marine species in this area including limpets, chitons, amphipods and tubeworms, an anemone species (*Anthopleura aureoradiata*), a half crab species (*Petrolisthes elongates*), the big-handed crab (*Heterosis rotundifrons*), seaweeds (*Codium tomentosoides, Colpomenia peregrina, Scytosiphon lomentaria*) and encrusting algae (*Corallina officinalis*). In addition, BML (2009) described the area of sandstone reef at Sulphur beach as a series of linear reefs that are intermixed with sand/shell/mud habitat between individual outcrops. This is consistent with what was observed at Sulphur beach, and to a lesser extent at the AHB northern abutment.

The area of sandstone at the Heath Road Reef has been described by BML (2009) as not having any directly associated soft sediment components which has lead to a low diversity dominated by oysters. Although there was a distinctive lack of soft sediments, diversity on this reef was comparable with that of the larger sandstone reef found at Sulphur Beach.

Figure 4.9: Sandstone reef habitat in Shoal Bay.

4.4.4.8 Shell ridges

Shell ridges were present at both the City of Cork and Tuff Crater (Figure 4.10). These habitats were comprised of high numbers of shell fragments and large numbers of dead cockle and nutshells (*Nucula* sp.). Some ridges are frequently inundated by the tide, whilst others are only inundated by 'king' tide conditions (BML, 2009). The majority of the City of Cork shell ridges are clear of spring high tides and consequently appear to be devoid of marine invertebrate fauna. However a number of coastal plants were present on these ridges (terrestrial flora is discussed in Section 4.3).

The shell ridges present at the City of Cork have an artificial influence. Parts of the shell ridges were enlarged to provide alternative breeding habitat for shorebirds that were displaced by the construction of the Northern Busway (BML, 2009). This work involved the addition of shell material and the placement of small cloth fences to hold the additional shells in place and reduce erosion.

Shell ridges at Tuff Crater, and those at City of Cork that are inundated by the tides were composed of large numbers of dead cockle and nutshells (*Nucula* sp.). A small number of live cockles and the occasional cat's eye were found inhabiting the ridges. These ridges often graded to shell bank and subsequently mangrove forest landward, and cockle-shell covered mud or fine gloopy mud seaward.

4.4.4.9 Shell bank

Shell bank habitats consisted of open sand-mud substrate with a thick layer of shell creating a surface that was solid and easy to walk on (Figure 4.10 bottom). This habitat was associated with shell ridges (Figure 4.10 top), often forming a transition zone between the shell ridges and soft gloopy mud. Dead cockles and nutshells created the surface layer (Figure 4.10 bottom right), with a small number of live cockles present. A low number of mud crabs were also observed. BML (2009) identified the shell bank as the area of greatest abundance for shellfish (i.e., cockles), which provides a food resource for birds, fish and rays. The size of the cockles in this area is, however, smaller than those commonly taken as a recreational fishery.

Figure 4.10: Shell ridges (top) forming a transition zone between soft gloop mud habitat and shell bank (top right; and shell bank habitat (bottom) with cockle gravel material (bottom right).

4.4.4.10 Establishing mangroves

Mangrove seedlings and pneumatophores often extended out several metres seaward from the mature plants, particularly when close to a water course (Figure 4.11). The substrate within this habitat was a soft, gloopy mud that was pocked with holes from gastropods. The marine fauna within this habitat was abundant with high numbers of cat's eye snails (*T. smaragdus*) and horn shells (*Z. lutulentus*). Cat's eye snails in this habitat were larger than those in the other habitat types, with some specimens up to 5 cm in width. Cockles, mud crabs, and small clusters of Pacific oysters were present in lower numbers. Barnacles (*A. modestus*) were present on mangrove seedlings.

4.4.4.11 Tall mangroves

The mangrove communities were dominated by the mud snail (*Amphibola crenata*), horn shells (*Zeacumatus lutulentus*) and, to a lesser degree, cat's eye snails (*T. smaragdus*), mud crabs (*Austrohelice crassa, Macrophthalmus hirtipes*) and Pacific oysters (*C. gigas*). The substrates in which the mangroves occurred were predominately very soft mud, often anoxic. The marine epifauna found within the mangroves was consistent with those found in a previous study by BML (2009).

Figure 4.11: Tall mangrove habitat (top) with soft gloopy mud (top right); and establishing mangrove pneumatophores (bottom) extending out from tall mangroves (bottom right).

4.4.4.12 Low stature mangroves

Low stature mangroves were situated adjacent to the City of Cork shell bank (Figure 4.12). The epifaunal communities were dominated by the mud-flat top shell (*D. subrostrata)* with smaller numbers of mud snail (*A. crenata*), horn shells (*Z. lutulentus*), cat's eye snails (*T. smaragdus*), common spotted top (*M. aethiops)* and Pacific oysters (*C. gigas*). There was a distinct lack of pock marks from gastropods in comparison to the other mangrove based habitats.

4.4.5 Summary

The marine fauna of the soft sediments is dominated by common and widespread invertebrate species such as mud crabs and snails, but there have been no rare species recorded in this area. Cockles (*Austrovenus stutchburyi*) and nut shells (*Nucula* sp.) were the most common bivalves found in intertidal sediments, while the most conspicuous polychaete worms included species from nereid, spionid and capitellid families. All other fauna were recorded in relatively low abundance and had a patchy distribution. Although noted as present, there were no significant populations of edible shellfish were recorded in this area of Shoal Bay. The soft sediment communities recorded along the coastline between Sulphur Bay and the northern abutment of the Auckland Harbour Bridge (AHB) had slightly lower diversity than the shore further to the north (BML 2009). This community consisted largely of gastropods, bivalves, polychaete worms (nereid, spionid and capitellid families), isopods and amphipods. Other less abundant taxa included crabs, anemones, other worms (nematodes, sipunculids, oligochaetes, chaetognaths), mysid shrimps, cumaceans, ostracods, copepods, barnacles, and red and green algae.

Figure 4.12: Low stature mangrove habitat (top) with high numbers of mud-flat top shell (top right); and medium sand habitat (bottom) extending through the reef at Sulphur Beach (bottom right).

4.5 Subtidal Ecology

4.5.1 Benthic soft sediment communities

The subtidal area of Waitemata Harbour that could potentially be affected by the current AWHC design includes the seafloor above driven tunnels and areas of seabed in bridge pile locations. These tunnels would run from the northern portals at the Onewa Interchange (rail tunnel) and AHB abutment (road tunnel) in a south-easterly direction beneath the mooring area north of Westhaven Marina and under Pier 21 to the southern portal at Wynyard Quarter. Investigation of subtidal fauna and flora have generally included the wider expanse of Waitemata Harbour rather than this specific corridor. More specifically, the subtidal benthic communities within the wider harbour area were investigated by Hayward et al. (1997) for comparison to previous investigations undertaken in the 1930s.

4.5.2 Westhaven Marina

Westhaven Marina sediment fauna has been examined in the past as part of America's Cup studies (Bioresearches 1989). It is likely that sediment quality and degree of disturbance is higher in the south east section of the marina in and around the commercial working areas of the marina.

The soft substrate in the vicinity of Wynyard Quarter is largely fine particulate matter that is often disturbed by vessel movement through the area. There is consequently a relatively low abundance and diversity of marine invertebrate taxa in this area. The taxa that typically dominate this environment include polychaete worms (i.e., *Cossura* sp., *Sthenolepis laevis*), bivalves (particularly the exotic species *T. lubrica*), and burrowing amphipods (i.e., *Paraphoxus* sp.). Westhaven Marina is situated immediately west of the main commercial port area and covers more than a kilometre of coastline in additional man-made structures. The Port of Auckland operates in an area adjacent to Wynyard Quarter. The fauna and flora found within the vicinity of the Port of Auckland facilities including a site in Westhaven were described as part of a baseline survey for non-indigenous marine species (Inglis et al. 2006).

4.5.3 Waitemata Harbour

Hayward et al. (1997) identified eight species associations throughout the Waitemata Harbour, four of which were more predominant than the other minor taxa groupings. Benthic communities were named for the most dominant taxa and the main associations included: *Theora-Nucula-Macropthalamus*, *Maoricolpus-Ruditapes-Tawera-Limaria*, *Maoricolpus-Limaria-Nucula*, and *Limaria-Ruditapes-Tawera* associations. Overall, these species were found throughout the subtidal regions of Waitemata Harbour, with only their relative abundance and the association with other taxa changing between community types. Subtidal benthic species associations were likely influenced by changing sediment types within the harbour, which ranged from shell gravel, fine sand and muddy substrates (Hayward et al. 1997). The assemblages included species that are not native to New Zealand and have arrived in the country since 1930, including the bivalves *Limaria orientalis*, *Theora lubrica*, and the Asian date mussel *Musculista senhousia*. Further work was also undertaken in 2005 as part of deepening the port approaches. Information presented in Kingett Mitchell (2001) included sites in the lower harbour that provide useful information on communities that occur in the tunnel corridor. They concluded, however, that there was a lack of information to make quantitative assessments of the changes that may have occurred with the development of the Port of Auckland.

More recently, Cummings et al. (2002) reported on a study designed to define the benthic ecological values of the area's intertidal and subtidal habitats. Based on information on the distribution and densities of taxa postulated as being sensitive to long term habitat change (e.g., the bivalve *Paphies australis*), they provided a qualitative assessment of the potential effect on benthic communities to long-term habitat change, and identified specific ecologically important areas of the upper Waitemata Harbour. They found the intertidal and subtidal benthic communities in the area to be generally in good condition, and although the sediment organic content was notably high in some areas that communities at these sites did not show characteristics of highly organically enriched areas.

Hard substrate encrusting fauna has been described by Morton and Miller (1968) and was considered to be typical of such environments. The generalised pattern of species from hightide to lowtide levels on the piles was: barnacles (*A. modestus, C. columna*), little black mussel (*L. pulex*), Pacific oyster (*C. gigas*), tubeworm (*Pomatoceros caeruleus*), bryozoan (*Watersipora cucullata*), green lipped mussel (*P. canaliculus*) and a sea squirt (*Microcosmus kura*). Species tolerant of low light levels are found beneath the wharf structures (e.g., sponge species such as *Cliona celata*, *Microciona coccinea*, *Tethya aurantia*).

4.5.4 Rocky subtidal habitat

At this stage there is no information that indicates whether there are any subtidal reefs located within the northern section of the road tunnel corridor or in the alignment of the trenched portals.

4.6 Coastal Ornithology Resources

4.6.1 Westhaven Marina

The southern side of the Waitemata Harbour including Westhaven Marina contains no natural habitat of any significance to birds, although a range of man-made roosts are used for resting. The southern component of the Options (the start of the tunnels through Westhaven Marina) does not impinge on any bird resources or habitat. The Waitemata Harbour between Westhaven and Shoal Bay is utilised by a range of seabirds but no significant species or intensity of uses are involved that would pose constraints. As such, the remainder of this preliminary assessment focuses on the Shoal Bay environment.

4.6.2 Shoal Bay

The coastal zone within the project area on the north side of the Harbour above the Harbour Bridge contains significant roosting, foraging and nesting habitats for shorebirds and other coastal birds. At least 26 bird species are known to use habitats within Shoal Bay (BML 2009), half of which are threatened under the Department of Conservation Threat Classification System (Miskelly et al. 2008). Although habitats within Shoal Bay are important for a range of shorebirds including the nationally vulnerable wrybill, the area is probably best known for its breeding population of NZ dotterel that nest on the shell banks adjacent to the highway and at the Esmonde Rd Interchange. NZ dotterel are only present in Shoal bay during the August-February breeding season with the exception of the pair at Sulphur Beach which is resident year round, making that site unique. The number of pairs of NZ dotterel breeding in Shoal Bay has increased since records began in 1997 from a single pair to up to eight pairs. The species can now be considered part of the natural character of the coastline in this area. Nesting success for this species is higher than the national average and contributes disproportionately higher to the national population due to increased protection from predators and human disturbance afforded by the existing motorway.

To the north, Shoal Bay is characterised by extensive shell banks and intertidal sand and mud flats. The latter substrates support a diverse range of marine invertebrates and are important foraging habitats for a range of indigenous avifauna while the shell banks provide roost habitat for shorebirds including three Nationally Vulnerable species (Miskelly et al. 2008), the wrybill, northern NZ dotterel and Caspian tern. The Naturally Uncommon little shag species (Miskelly et al. 2008) has also been recorded from habitats associated with Shoal Bay (BML 2009) and given its use of salt marsh and mangrove habitats (Heather & Robertson 1996), may also be present in mangroves and salt marsh associated with the Tank Farm wetlands.
The key habitats for shorebirds present in the project area north of the Harbour Bridge and are discussed below.

4.6.2.1 City of Cork Shellbanks

Zoned CPA1 the City of Cork shell banks comprise 5 shell ridges that provide nesting and roosting habitat for shorebirds. The availability of nesting habitat for northern NZ dotterel has been successfully increased as part of mitigation for disturbance and habitat loss associated with NZTA's North Shore Busway/Esmonde Interchange Project. The created shell banks have benefitted other shorebird species including variable oystercatcher and Caspian tern, both of which in addition to northern NZ dotterel successfully nest on the constructed shell banks. Other species using the shell banks include the international migrant bar-tailed godwit, internal migrants wrybill and pied oystercatcher and resident variable oystercatcher, pied stilt and Caspian tern. As such, the constructed shell banks are an important resource for threatened avifauna and have become a functional part of the natural ecosystem.

4.6.2.2 Esmonde Interchange

Up to 4 pairs of NZ dotterel have attempted to nest in a single season in this inland area. Although breeding success is variable, 3 fledglings were successfully fledged in the 2007-08 season (BML 2008).

4.6.2.3 Tuff Crater Shellbanks

These shell banks are located immediately south of the City of Cork shell banks. Some are attached to the existing rock edge of the Northern Busway. Others are just offshore and inundated at high tide. No records of shorebird breeding exist for the area, perhaps due to their close proximity to the motorway and being at the same level (BML 2008). The area is also little used as a roost.

4.6.2.4 Heath Road Reef

This small reef is one of only a few rocky reefs exposed by the receding tide. Northern NZ dotterel and variable oystercatcher have been observed foraging on the reef as it emerges from the receding tide (BML 2008). It should be noted, that this is actually a reef near Heath Avenue (north of the Onewa interchange), but for the purposes of consistency we refer to the Heath Road Reef as per BML (2009).

4.6.2.5 Onewa Interchange

Both NZ dotterel and variable oystercatcher have historically bred at the northern end of the site. Although absent from the site outside of the breeding area, the high site fidelity shown by both species renders the site likely to be used into the future.

4.6.2.6 Sulphur Beach

Sulphur Beach, zoned CPA1, is one of the more important shorebird habitats in Shoal Bay. This is in part due to the beach being the habitat of the only year round resident pair of NZ dotterel. Having nested on the beach since the mid 1990's, this pair is unusual in that it regularly fledges two broods each summer as opposed to the single brood for other pairs in the bay. Between 1997 and 2008 the pair has produced 14 fledglings (BML 2009) and their high productivity may be due to the high quality of resources available or as a function of their residence, starting their first clutch early and enabling a second clutch to be completed in the same season. Both possibilities probably reflect the quality of the habitat available at the beach. The success of NZ dotterel breeding at this site demonstrates the ability for the species to withstand significant levels of traffic disturbance and still remain reproductively successful. In addition to the NZ dotterel, two pairs of variable oystercatcher also successfully nest on the beach and it functions as a high tide roost for a range of other shorebirds including wrybill.

4.6.2.7 Sulphur Beach Reef

Also zoned CPA1, the reef is the largest rock reef in Shoal Bay and one of the largest in the Waitemata Harbour. It is one of the first reefs to be exposed by the receding tide and it used by at least NZ dotterel and wrybill.

4.6.2.8 Intertidal Area between Onewa Interchange and AHB Northern Abutment

This area is zoned CPA2 and supports very few mangroves. Although the mudflats provide shorebird foraging habitat use of them is relatively low, probably reflecting the abundance of foraging habitat elsewhere in Shoal Bay.

4.6.3 Summary

Key habitats for nationally threatened bird species are situated within Shoal Bay within and near the AWHC construction envelope. The intertidal and supratidal area provides critical habitat for nesting, roosting and feeding for shore birds.

4.7 Coastal Reptile Resources

Terrestrial habitats available to reptiles within the proposed AWHC footprint are limited and of poor-moderate quality. Lizards typically inhabit areas that provide both refuge and suitably humid and warm microhabitats, including dense vegetation (e.g., thick grass, pampas and epiphytes), leaf litter and rock piles surrounded by adequate ground cover (Habgood 2003, Peace 2004, Porter 1987).

Habitat within the Victoria Park and Viaduct area is restricted to exotic amenity trees, a small grove of planted native vegetation and grassed playing fields. These environments are generally unsuitable as lizard habitat due to the extent of disturbance in the surrounding area and the lack of adequate ground cover. As such, the remainder of this assessment focuses on potential reptile resources in the Shoal Bay environment.

Five lizard species, comprised of two families, Gekkonidae (*Hoplodactylus granulatus* and *Naultinus elegans elegans*) and Scincidae (*Oligosoma aeneum*, *O. ornata* and *Lampropholis delicata*) have been recorded within five kilometers of Shoal Bay (DoC 2009).

Native coastal vegetation between Tuff Crater and the Onewa Interchange may provide limited habitat for arboreal geckos and terrestrial skinks, particularly as it provides a link to the bush remnants of Tuff Crater Reserve. However, it is likely that any remaining remnant lizard populations would be of low density, and impacted by predators.

Roadside pasture vegetation, including rank kikuyu grass and scattered exotic pampas may provide lizard habitat on the grassy verge and seawall between the saltmarsh and the Northern Motorway. Two skink species, copper skink and rainbow skink (*Oligosoma aeneum* and *Lampropholis delicata* respectively) are relatively common in grassy exposed habitats, and copper skinks in particular may occur close to the high tide mark in coastal habitats. Copper skinks are widely distributed throughout Auckland and are not listed as threatened (Hitchmough et al. 2007), but are absolutely protected under the Wildlife Act (1953). Rainbow skinks are an exotic species, recently listed as an unwanted organism (DoC 2010) that is widespread and common throughout the Auckland Region (Peace 2004). Given the level of disturbance along the roadside, it is likely that lizard populations would be of low density.
There are no species of New Zealand reptiles that occupy coastal mudflat or sandy beach habitat of this type on the mainland. No species of reptiles have been identified utilising those areas of supra-tidal habitat such as shell banks in Shoal Bay. Most of these areas of habitat are not connected to the man-made shoreline that runs alongside the edge of State-Highway 1.

4.8 Coastal Insect Resources

Habitats that are of interest in relation to insect fauna are the high tide salt marsh, meadow and shell banks. No information has been sighted providing data on the terrestrial and supratidal invertebrate (insect) fauna of areas within the T1 and B3 corridors.

Te Ngahere (2009) provides listings of invertebrates (e.g., moths) identified in the vegetation around Tuff crater. Although this area is not specifically within the Options corridor it provides an indication of the types of species that may be present in vegetation close to the corridor.

4.9 Other Coastal Resources

4.9.1 Fisheries

There is minimal current information on the fish populations occurring specifically within Waitemata Harbour. The north east coast of the North Island falls under Fisheries Management Area 1, which encompasses fisheries for finfish and shellfish (NZ Fisheries Info site, http://fs.fish.govt.nz). Information presented for commercially fished populations includes the extended Hauraki Gulf and wider fisheries management area.

A variety of fisheries resources are to be expected within Shoal Bay. The shallow intertidal flats, harbouring rich invertebrate populations, provide ideal feeding habitats for a variety of flatfish (e.g., yellowbelly flounder, *Rhombosolea leporina*, snapper, *Pagrus auratus*). Although Larcombe (1973) reported that little is known of the fish in the area, several common harbour species are caught by line fishing. These include snapper (*Pagrus auratus*), kahawai (*Arripis trutta*), yellow-eyed mullet (*Aldrichetta forsteri*), and koheru (*Decapterus koheru*).

Early reports such as Kingett Mitchell (1988) identified fish to be found in the Shoal Bay area. A fauna of some 24 species was noted. Fish species commonly inhabiting other areas of the Waitemata Harbour have been documented (Briggs 1980, Roper et al. 1994). A variety of other species have been identified, including anchovy (*Engraulis australis*), common sole (*Peltorhamphus novaezelandiae*), eagle ray (*Myliobatus tenuicaudatus*), grey mullet (*Mugil cephalus*), jack mackerel (*Trachurus declivis*), paketi (*Pseudolabrus celidotus*), parore (G*irella tricuspidata*), sand flounder (*Rhombosolea plebeia*), school shark (*Galeorhinus australis*), and smoothhound (*Mustelus lenticulatus*).

Kingett Mitchell (1988) commented on recreational fishing activity (e.g., flounder fishing and boat fishing in deeper water off Shoal Bay) and shellfish collection within Shoal Bay (possibly cockles and oysters on accessible parts of the western shore e.g., near the Exmouth overbridge). No recent information has been sighted as part of the AWHC studies.

4.9.2 Marine mammals and reptiles

There is a lack of recent information on the distribution of marine mammals within the Waitemata Harbour. However, a recent sighting of an orca pod (*Orcinus orca*) off St Heliers Bay indicates that cetaceans currently visit the harbour area (see http://tvnz.co.nz/national-news/pod-orca-visit-waitemata-harbour-2801959). Bottlenose (*Tursiops truncates*) and common dolphins (*Delphinus delphis*) have been reported as common within the harbour (BML 2009). Other marine mammals occasionally sighted within the harbour include dusky dolphin (*Lagenorhynchus obscurus*), spotted dolphin (*Stenella attenuate*), killer whale (*Orcinus orca*), humpback whales (*Megaptera novaeangliae*) and Bryde's whale (*Balaenoptera edeni*) (BML 2009).

Knowledge of marine reptile use of the Waitemata Harbour is similarly limited, although the Department of Conservation Herpetofauna Database (DoC 2009) includes six records of sea turtles observed within the Waitemata Harbour since1984. Three species of sea turtle have been recorded, including *Dermochelys coriacea* (Leathery turtle), *Caretta caretta* (Loggerhead turtle), and *Chelonia mydas* (Green turtle). Sea turtles are described as regular or occasional visitors to New Zealand, as they are seldom sighted, although it is likely that many go unnoticed, or are not reported (Gill & Whitaker 1994, Jewell 2008)).

4.10 Areas of Conservation Significance

The entire project area north of the Harbour Bridge is listed as either CPA1 or CPA2 in the ARC Coastal Map Series (Series 1 – Sheet 29) (CPA1 = high ecological value; CPA2 = slightly less but significant ecological value). There are no CPA classifications in the project area south of the Harbour Bridge. The significance of Shoal Bay and its associated habitats is reflected in local body plans and policies. Most of Shoal Bay and Sulphur Beach are identified as CPA2 with small inclusions of CPA1. The Tank Farm Explosion Crater is listed as CPA1. With the exclusion of the latter, the Department of Conservation recognises Shoal Bay as an Area of Significant Conservation Value (Auckland Regional Plan: Coastal) and the North Shore City Council recognises that area as a site of ecological significance. Shoal Bay and the Tank Farm explosion crater are listed in Appendix 2 of the Auckland Regional Policy Statement as sites of ecological significance, with the latter cited as being of regional significance.

Shoal Bay contains examples of ecotone sequences from mangrove forests, to salt marsh communities through to intertidal marine habitats which are relatively rare in the Waitemata Harbour. Supplementary survey work in Shoal Bay has shown that no flora, fauna or reptiles occur in the Shoal Bay area of conservation significance, other than the nationally threatened birds described in Section 4.6.

5. Environmental Quality

5.1 Introduction

The two key areas of environmental quality that will interface with the proposed works are:

- Sediment quality (as it relates principally to construction effects, via disturbance and possible disposal).
- Water quality (as it related to construction and operational activities).

5.2 Sediment Quality

5.2.1 Westhaven Marina

Sediment quality in the general mooring area of Westhaven Marina was described by Bioresearches (1989). Seabed sediments along the T1 and B3 alignment within Westhaven Marina are located within the commercial areas of Westhaven Marina and areas with a significant history of vessel maintenance activity. Sediment quality data is also available in the Port Management area from Wynyard Wharf to the Fergusson Container Terminal (characterised at least every five years since 1988 (Golder KIngett Mitchell, 2007)), however, these surveys do not include Westhaven Marina. Although published sediment quality data is not available within this area of the Marina, it is considered likely that sediment contamination will be present, such that should sediments in the landward portion of the tunnel corridor need to be disturbed in any way, then sediment quality surveys will be required. The quality from those surveys will determine how those sediments are managed.

5.2.2 Waitemata Harbour

Sediment quality information for the Harbour Channel close to the proposed T1 and B3 tunnel routes is available and likely to be representative of the quality of surficial sediments from outside of Westhaven Marina across the mouth of Shoal Bay.

Sediment quality data is also available from work associated with the dredging of the Rangitoto Channel and port wharf approaches. Kingett Mitchell (2001) reported data for a series of sediment samples collected seaward of the Port in the approaches to the Fergusson Container terminal. This data is likely to be representative of sediments in the main channel of the Harbour.

5.2.3 Shoal Bay

A range of sediment quality information has been collected with Shoal Bay over the years. This information is summarised in part by BML (2009) and also earlier information was reviewed by Kingett Mitchell (2003b). Sediment quality within the main body of Shoal Bay (in terms of trace elements and organic contaminants such as PAHs) appears good. Results for sediment samples collected in tidal creeks entering Shoal Bay (Onewa, Hillcrest etc.) is poorer (Kingett Mitchell 2003b).

5.3 Water Quality

The closest long term ARC water quality monitoring station to Shoal Bay is located at Chelsea Wharf up harbour from The Harbour Bridge. Water quality information in Shoal Bay has been summarised by Kingett Mitchell (2003b). For the key elements of water quality relevant to the AWHC study, that review indicated:

- Suspended solids concentrations within Shoal Bay have been found to be dependent on water depth and wave conditions with particulate concentrations becoming high under certain conditions.
- Water clarity can be very poor in shallow intertidal areas when wind causes small waves to disturb sediment surfaces.
- Water clarity in Harbour waters can range from very poor to good depending on water depth, weather and sea state.
- Beca (2010) provides a summary of suspended solids data in the lower Waitemata Harbour.

6. Options Comparison

6.1 Introduction

This section of the report provides a comparative assessment of Options T1 and B3. This comparative assessment examines the key elements of the two options and examines the environmental issues and concerns that might arise from the construction and subsequently the operation of the two options. The assessment uses the resource information presented in the previous sections.

6.2 Project Elements

6.2.1 Key elements

The key project elements relevant to this assessment are illustrated on Figures 6.1, 6.2, 6.3 and 6.4 on the following pages.

- Figures 6.1 and 6.2 illustrate the location of key structures for the tunnel option T1 and bridge option B3 in the southern section of the project area (Westhaven Marina).
- Figures 6.3 and 6.4 illustrate the location of key structures for the tunnel option T1 and bridge option B3 in the northern Section of the project area (Onewa interchange north to Akoranga Station).

- The key structural elements relevant to this assessment are:
- Portals for tunnels for both options.
- Location of permanent and temporary reclamations for both options.
- Location of new seawalls for both options.
- Location of viaduct road and rail sections in the northern section of both options.
- Location of replacement road bridges in the northern section for both options.
- Location of bridge piles for the new harbour bridge in option B3.

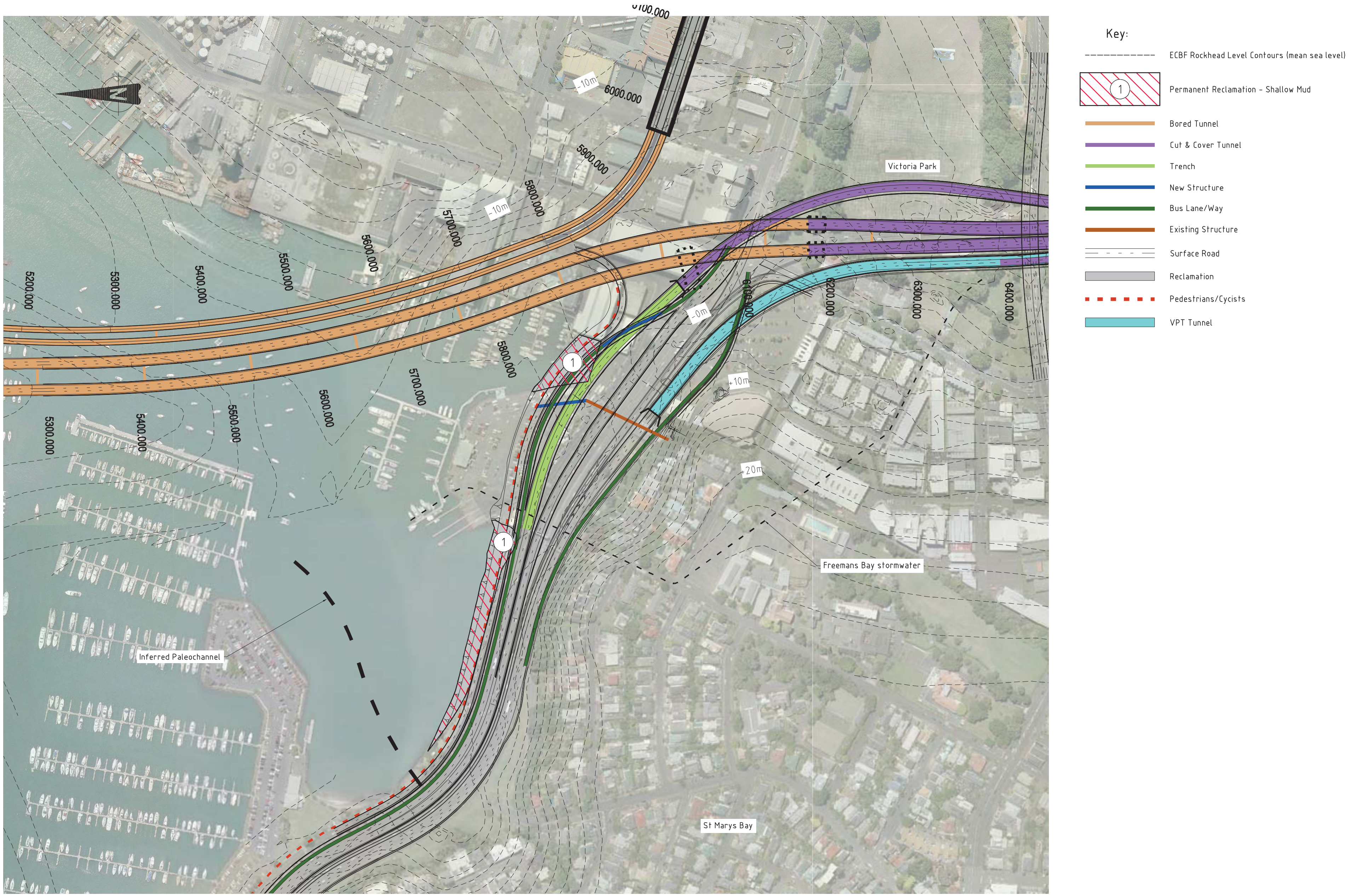
The figures specifically detail the location of reclamations as these are particularly important in relation to a number of environmental impacts described in this section.

6.2.2 Structures in the marine environment

6.2.2.1 Southern section

There are no specific structures associated with the tunnel Option T1 in the southern section of the project. The rail tunnel remains as a bored tunnel to its termination at the proposed Gaunt Street Station, at a depth of 30m.

For Option B3, the approach spans of the bridge will be 75 m apart and the main span will be 250 m long for navigation. The spans will be supported on concrete piers.



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1. Drawing produced and supplied by AECOM. Drawing Number: 60157303-GE-016, Rev B

Golder Associates

TITLE LOCATION OF STRUCTURES AND RECLAMATIONS OPTION T1 SOUTHERN SECTION.

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PROJECT 1078202101

6.1

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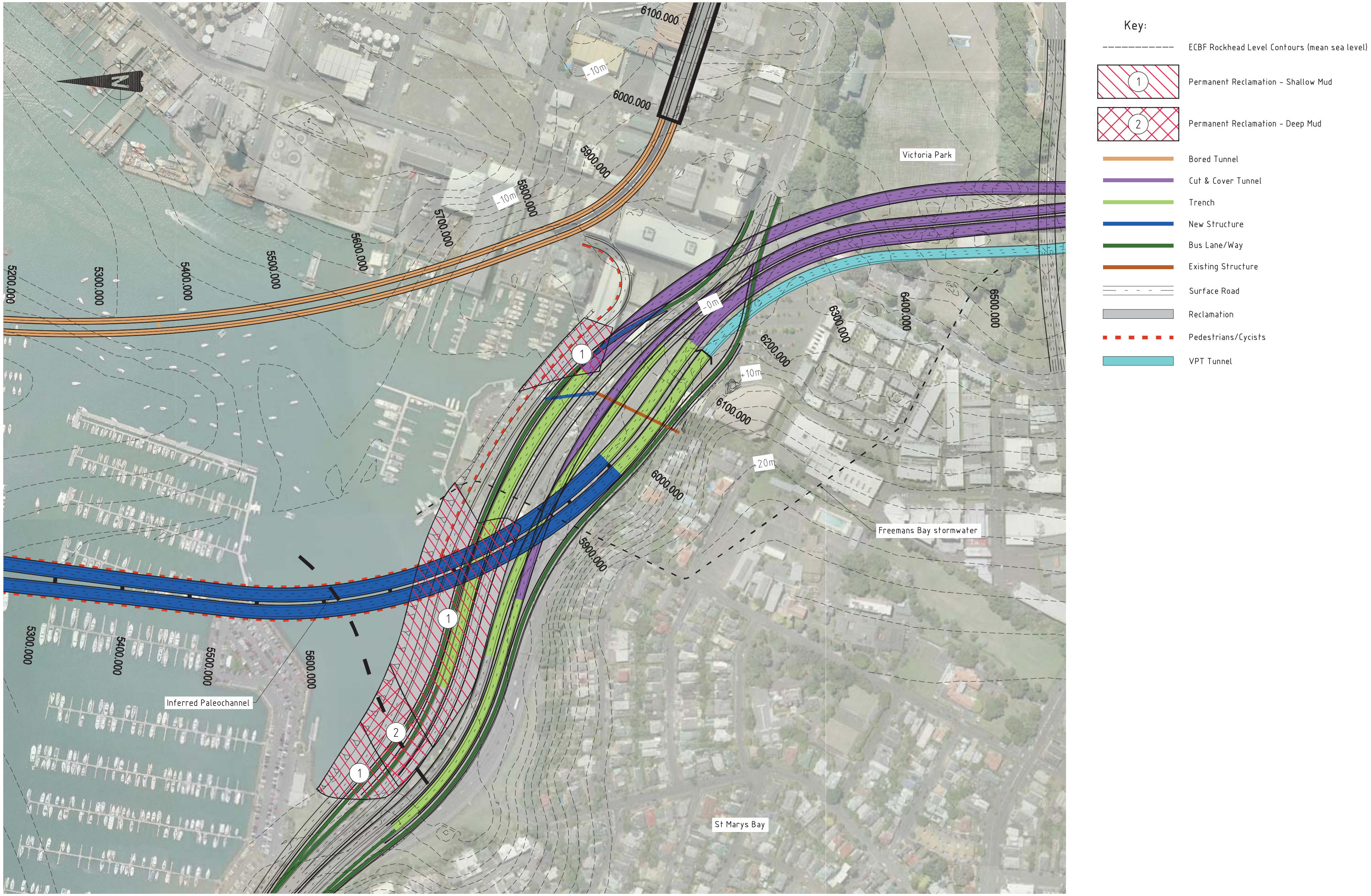

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1. Drawing produced and supplied by AECOM. Drawing Number: 60157303-GE-017, Rev B

Golder Associates

TITLE LOCATION OF STRUCTURES AND RECLAMATIONS OPTION B3 SOUTHERN SECTION.

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6.2

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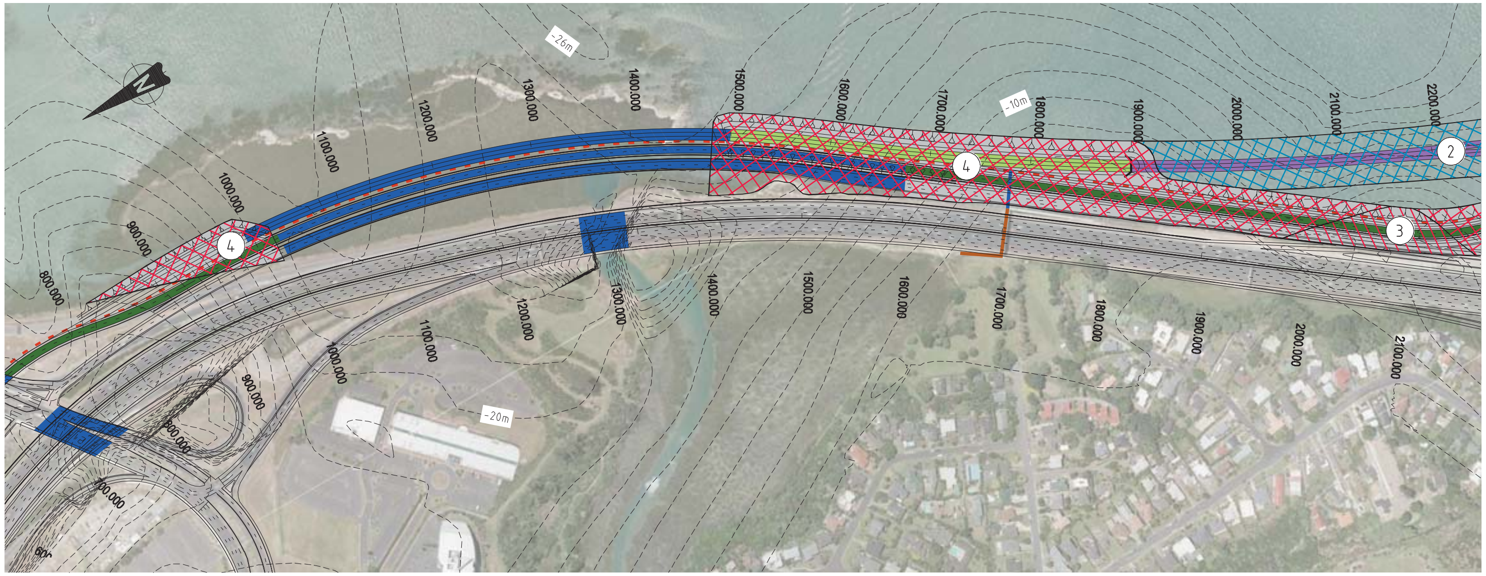

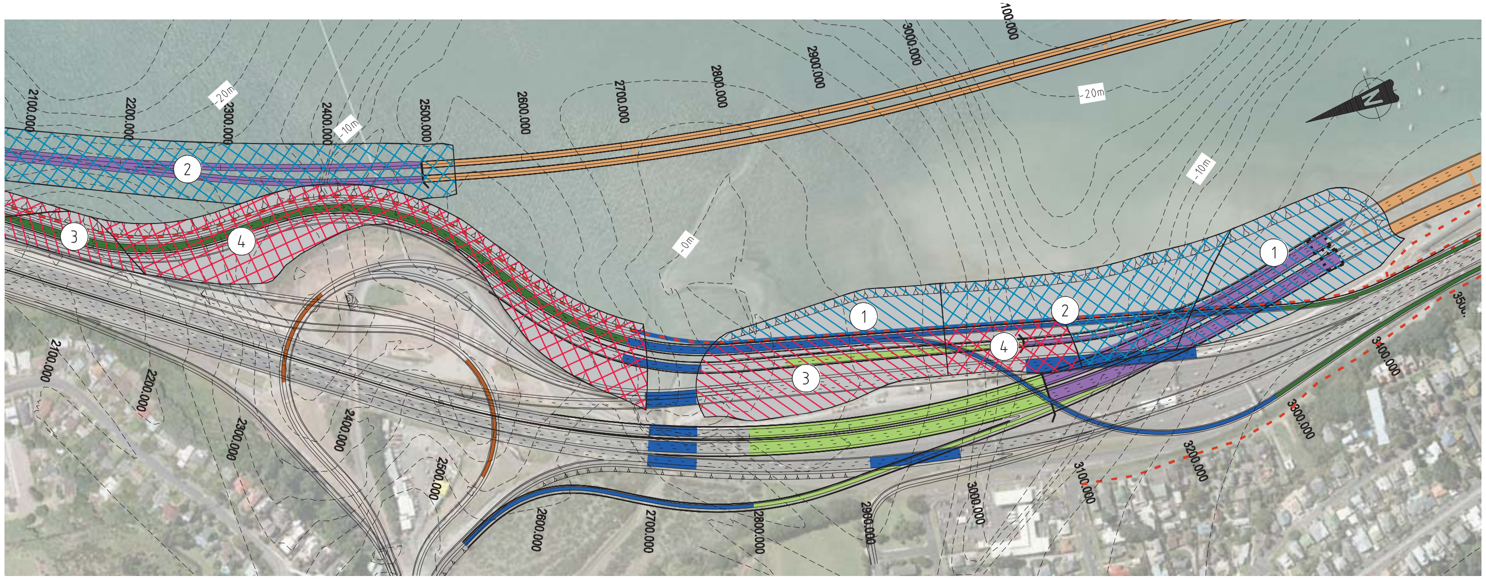

Notes:

1. For details of reclamation treatments see drawing 60157303-GE-020-Reclamation Typical Sections.
2. It is intended that temporary reclamation areas shall be reinstated to seabed/mudflats following completion of construction.

Key:

- ECBF Rockhead Level Contours (mean sea level)
- 1 Temporary Reclamation - Shallow Mud
- 2 Temporary Reclamation - Deep Mud
- 3 Permanent Reclamation - Shallow Mud
- 4 Permanent Reclamation - Deep Mud
- Bored Tunnel
- Cut & Cover Tunnel
- Trench
- New Structure
- Bus Lane/Way
- Existing Structure
- Surface Road
- Reclamation
- Pedestrians/Cycists

Scale 1:2500 A1, 1:5000 A3

1. Drawing produced and supplied by AECOM. Drawing Number: 60157303-GE-014, Rev B

Golder Associates

TITLE **LOCATION OF STRUCTURES AND RECLAMATIONS OPTION T1 NORTHERN SECTION.**

OCTOBER 2010

PROJECT 1078202101

6.3

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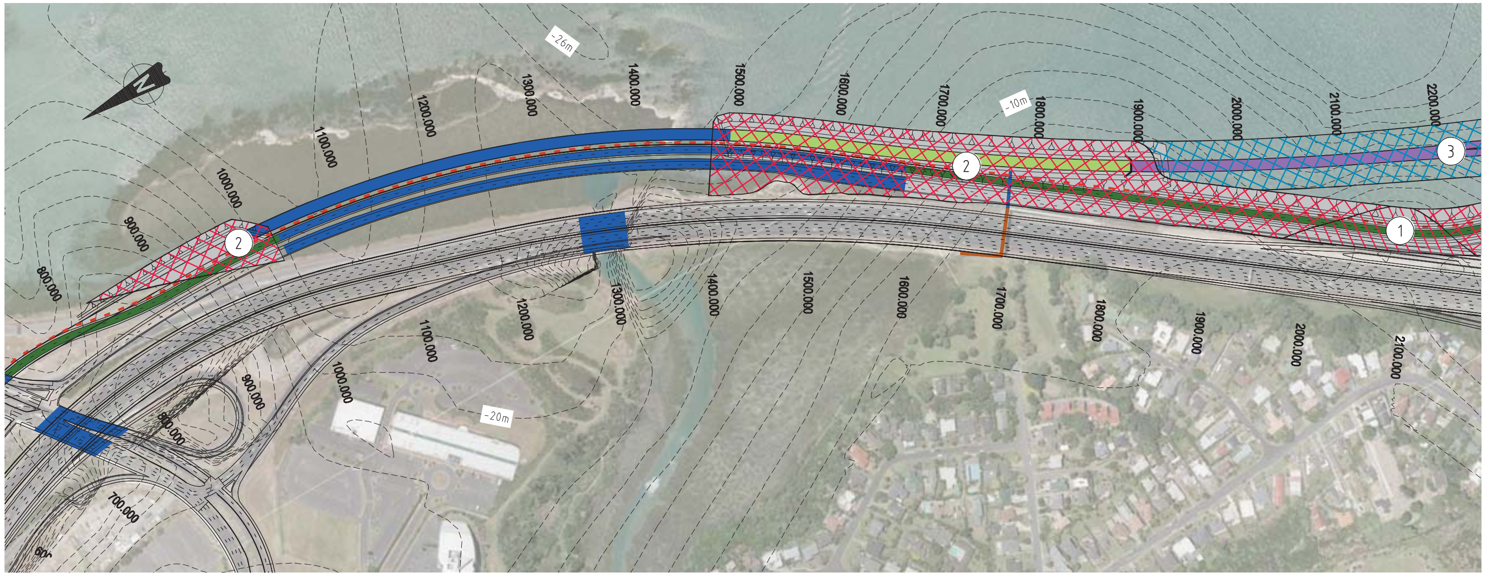

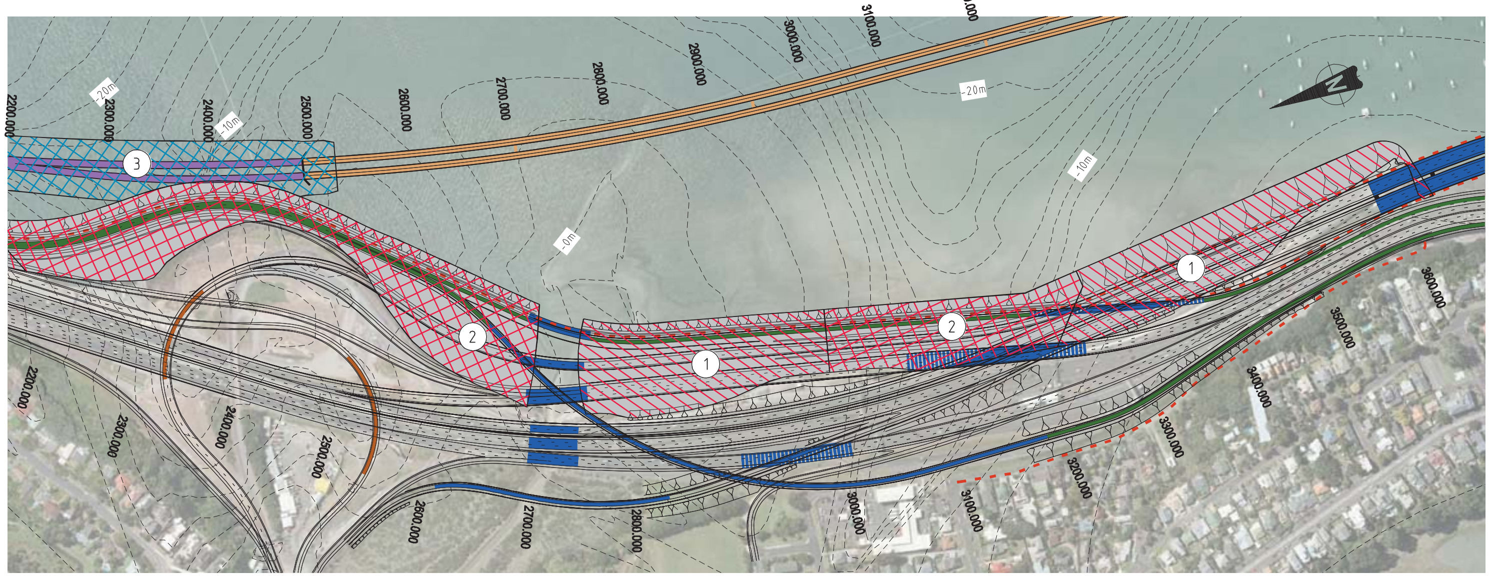

Notes:

1. For details of reclamation treatments see drawing 60157303-GE-020-Reclamation Typical Sections.
2. It is intended that temporary reclamation areas shall be reinstated to seabed/mudflats following completion of construction.

Key:

- ECBF Rockhead Level Contours (mean sea level)
- 1 Permanent Reclamation - Shallow Mud
- 2 Permanent Reclamation - Deep Mud
- 3 Temporary Reclamation - Deep Mud
- Bored Tunnel
- Cut & Cover Tunnel
- Trench
- New Structure
- Bus Lane/Way
- Existing Structure
- Surface Road
- Reclamation
- Pedestrians/Cycists

Scale 1:2500 A1, 1:5000 A3

1. Drawing produced and supplied by AECOM. Drawing Number: 60157303-GE-015, Rev C

Golder Associates

TITLE LOCATION OF STRUCTURES AND RECLAMATIONS OPTION B3 NORTHERN SECTION.

OCTOBER 2010

PROJECT 1078202101

6.4

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6.2.2.2 Northern section

The works proposed for Options T1 and B3 require a number of structures. These are summarised in Table 6.1.

Table 6.1: Key coastal structures in northern section

Options	Structures
Common to T1 and B3	Two parallel viaducts located east of the Tank Farm volcano, each approximately 650 m long, for the two lane Busway and the two lane Esmonde Road southbound on-ramp; A third viaduct for rail in the same section (refer Figures 6.3, 6.4).
	Seawall – about 2.4 km long; proposed to be constructed from mudcrete and lined with armour stone. Work will require prior ground improvement.
Option T1	A 50 m long four lane bridge over the Onepoto Stream carrying southbound traffic to the existing Auckland Harbour Bridge (Figure 6.3).
	An 80 m long two lane bridge carrying the on-ramp to the tunnel across Onepoto Stream (Figure 6.3).
	A 300 m long two lane Busway viaduct, with provision for pedestrians and cyclists, over the Onepoto Stream that branches to the two single lane Busway viaducts. (Figure 6.3).
	Two single lane Busway viaducts connecting with the existing Auckland Harbour Bridge, each approximately 350 m long and bridging over the proposed SH1; the south bound structure includes provision for pedestrians and cyclists.
Option B3	Bridge piles with span spacing of 75 m.

6.2.3 Reclamations

6.2.3.1 Southern section

The project requires permanent reclamation within Westhaven Marina adjacent to existing Westhaven Drive. Option T1 requires about 17,000 m^2 of reclamation in a narrow band alongside Westhaven Drive as shown in Figure 4.12.

Option B3 requires a greater area of reclamation compared to Option T1. As shown in Figure 6.1, two distinct areas of reclamation are required, totalling about 28,000 m^2. The larger area is required principally to reconfigure the existing motorway around the new bridge approaches. Table 6.2 provides a summary of all the key reclamations associated with the Options T1 and B3 in northern section of the AWHC project.

6.2.3.2 Northern section

Figures 6.3 and 6.4 show the location of reclamations for Options T1 and B3. The following points relating to the reclamations should be noted:

- Reclamations required for rail in Options T1 and B3 may be constructed later as the date for rail construction is confirmed. This includes part of reclamation area 2 and all of area 6.
- Reclamation area 6 required for the construction of the northern section of the rail between the bored tunnel and the portal will be temporary.
- All other reclamations for Option B3 are permanent (Figure 6.4).
- Reclamations 9, 10 which are seaward of reclamations 7 and 8 (landward shallow reclamation south of the Onepoto Stream mouth) are temporary.

Table 6.2: Northern section reclamations status and areas

	Location (Chainage Figures 6.3, 6.4)	Status	Option T1 North m²	Option B3 North m²
1	800–1,000	Permanent	5,743	5,743
2	1,500–1,800	Permanent	33,142	33,142
3	1,800–2,000	Permanent	6,600	6,600
4	2,000–2,200	Permanent	5,005	5,005
5	2,200–2,700	Permanent	31,217	35,924
6	1,900–2,500	Temporary	35,000	35,000
7	2,800–3,000	Permanent	16,055	20,009
8	3,000–3,100	Permanent	6,168	15,187
9	2,800–3,000	Temporary	7,401	

	Location (Chainage Figures 6.3, 6.4)	Status	Option T1 North m2	Option B3 North m2
		Permanent		14,015
10	3,000-3,300	Temporary	18,623	
11	3,300-3,500	Temporary	18,760	
	Total	Temporary	79,784	35,000
	Total	Permanent	103,930	135,625

Note: Green shaded cells are temporary reclamations.

6.3 Coastal Processes

6.3.1 Concerns

In evaluating and comparing the potential environmental impacts of options T1 and B3 on coastal processes, consideration was given to the following:

- The effects of reclamations on tidal cross-sections in the Waitemata Harbour and Shoal Bay.
- The effects of new structures (e.g., reclamations) on local tidal flow, freshwater inflows, and associated physical processes (e.g., wave reflection, tidal currents, sediment sorting, and changes to local sediment supply within reclaimed inter-tidal areas, etc.).
- The effects of structures such as piers and piles on local seabed scour.

Table 6.3 provides an overview of the assessed levels of concern relating to coastal processes as described in the following sections.

6.3.2 Southern section

Option T1 results in no changes to coastal processes in the southern section of the project corridor.
Option B3 requires:

- Shoreline changes within Westhaven Marina (refer Figure 6.5).
- Construction of bridge piers through Westhaven Marina. Based on 75 m pile spacings, 10 sets of piers/piles are likely to be constructed from St Marys Bay to The outer limit of the Marina.

The implications of these changes are identified as:

- The small area of reclamation within Westhaven Reclamation will result in minor additional losses of tidal cross section within the lower Waitemata Harbour. However, as the Marina is only a small part of the Harbour tidal cross-section the changes are very small (<< 1% of the total cross-section in this area).
- The total footprint from bridge pile construction is expected to be small and not likely to result in significant effects to either hydrodynamics or sediment dynamics. Some local disturbance to tidal circulation patterns may occur around piles but is not expected to result in scour in this area
- Both the reclamation and bridge piles will result in a small decrease in the total volume of water within Westhaven Marina. It is not expected that the changes will result in any substantial changes in marina flushing characteristics.

6.3.3 Central section

Option T1 results in no changes to coastal processes in the central section of the project corridor.
Option B3 requires construction of bridge piers from Westhaven Marina across to the northern end of the bridge at Sulphur Beach. Based on 75 m pile spacings with a central span of 250 m this requires about 15 sets of piles to be constructed. The construction of the bridge piles will:

- Result in a small change in the Harbour cross section between Northcote Pt and Westhaven Marina. The cross section of the piles is expected to be about 5 m resulting in a cross-sectional change of about 75 m. The change will result in a small change in tidal current velocity in the bridge vicinity but this change will be localised as the cross section change occurs for a very narrow section of harbour.
- Result in some scour in the immediate vicinity of each pile. This, however, is considered to be no worse than will have occurred around the base of the piers on the current bridge and would be expected to reach an equilibrium within a few years after construction and would not be expected to extend significantly beyond 1-2 bridge pier diameters on either side of the bridge.

6.3.4 Northern section

The two options result in a reclamations (refer Figures 6.3, 6.4) along Sulphur Beach. The reclamations required for Option T1 and Option B3 would result in permanent reductions in the area of Shoal Bay of 2.3% and 3.1%, respectively.

The reclamations for both options extend into Shoal Bay resulting in a further decrease in the width of the mouth of Shoal Bay. As described in Section 3.5, historical changes have resulted in the width of the Bay decreasing by 200 m. Option B3 and Option T1 (assuming the reclamation is not de-claimed) result in further width losses of about 75-100 m. This amounts to a change in the historical width from 11% to 13%.

In the northern section, the following points are noted in relation to effects on coastal processes involving both water and sediment transport:

- The options will permanently remove a portion of the upper inter-tidal zone of Shoal Bay that is currently occupied by natural low sloping inter-tidal sand and mud flat which transitions to sand and shell beach ridge (supra-tidal in some areas). This may have implications for sediment supply (sand

and shell hash) to landward areas and the interchange/equilibrium of sediments on the upper intertidal flats located both seaward and to the north – if net transport is to the north this will cut off some supply.

- As noted above, reclamation will result in additional losses to the tidal prism in areas which are currently backed by rip-rap – potentially leading to overall loss of beaches in this area as a result of presence of deeper water at edge of rip-rap introduces the possibility of larger waves/stronger currents at new shoreline. This may enhance scour reduced stability of existing seabed in those areas. This may influence availability of marine sediment in this area – interchange with channels and offshore and potentially interchange with sediments to the north in the Bay.
- Bridge piers are to be constructed across the mouth of the Tank Farm Tuff Crater and Onepoto Stream and from City of Cork Beach to Esmonde Road reclamation. Localised scour around piers can be managed by rip-rap scour protection. It is considered unlikely to be significant effects resulting from bridge piers to either hydrodynamics or sediment dynamics
- Shoal bay is a complex area of sediment depositional and erosional areas and these vary depending upon tidal height and freshwater inflows. Loss of area within Shoal Bay will require that the overall sediment budget equilibrate to the new area by depositing the sediment elsewhere within the bay or exporting it on the tide. Some areas where bed sediment is coarse (e.g., shell banks) are unlikely to be affected by changes in local sediment budgets. It is expected that effects will be complex and difficult to assess without modelling verified by measurements. The scale of changes will require calculation of the sediment flux in the areas being reclaimed.
- Areas behind shell banks appear to be sinks for fine sediment and net northward trends suggest fines will re-distribute to the north and will interchange with channels and mudflats; net affects difficult to assess without measurements and modelling.
- Confirming that there will be no affects from the proposed reclamations on sediment budget/regime will require an estimate of the expected change. Given the extent of the reclamation south of Onewa Interchange and local depths of water, it's possible that there might be some detectable changes to wave climate and tidal hydraulics which would have flow on to sediment transport and sediment budget. Overall, any changes that did occur would be expected to be a subtle change to sediment dynamics which may occur over relatively long time scales (e.g., decades).
- Previous study referenced in earlier assessments (e.g. CCNZ, 2001) did not consider areas south of the Onewa Interchange. Reclamations will occupy area of intertidal beaches and flats as well as stream deltaic deposits at Tank Farm Tuff Crater Creek outlet and at the Onepoto Stream outlet. As a result, the streams will no longer be able to deposit load in current locations, therefore deltas will be displaced seaward into deeper water. Role of such deltaic sediment (especially Onepoto Stream) has so far not been considered in beach stability and alongshore sediment supply to the north.

In relation to sea-level rise and its interaction with proposed structures and coastal processes in Shoal Bay, the following should be noted:

- Sea level rise projections will expose reclaimed areas to higher risk of flooding and overtopping. As such, sea level rise projections will encourage migration and dynamic response of shorelines and will increase the tidal prism. However, fixed structures will not be allow a dynamic shift in shoreline position, therefore effect must be balanced elsewhere – likely resulting in more intense migration response at other locations which are not fixed. This puts pressure on the remaining "natural" areas of shoreline which have been diminished by previous reclamations in the harbour.

- The current nature of Shoal Bay (i.e., fixed hard shores along much of the western shore) precludes roll-back to adapt, therefore effects will need to be managed (as noted in previous assessment e.g., SKM 2009). However, it should be acknowledged that reclamation effectively diminishes the ability of the system to accommodate increases in sea level to any extent.

In addition, the following two points should be noted:

- The small reclamation proposed at the northern end of the busway and rail line prior to Esmonde Rd protrudes into the drainage channel that allows tidal movement between Shoal Bay and the mangroves in the lee of the Tuff Crater shell-banks. If the reclamation requires the drainage channel to move, the changed channel location may result in local readjustment to tidal banks and mudflats and possibly the northern end of the shell banks. This may require further assessment of local hydrology to confirm potential effects. This is noted in Section 7.
- The reclamation to the south of the Tuff Crater lagoon outlet abuts the drainage channel from the lagoon. The close proximity of the reclamation edge may affect the ebb-tide flow from the lagoon and reduce the spread of flow across it delta. The inability of the discharge from the lagoon to flow south within its delta may result in the discharge pushing north slightly. This may potentially disturb and reshape shell banks adjacent to the delta. Woodroffe (1985) reported on the tidal flux in Tuff crater and it was noted that the ebb tide discharge may as measured in 1981-1982 be as high as 6-8 m^3/s at times.

6.3.5 Overview and risks

Overall, the comparison of Options T1 and B3 has shown that there are no environmental risks associated with the southern and central section of the project for Option T1 and the risks associated with Option B3 which involve reclamation and bridge pile construction within Westhaven Marina and in the central section of the project are considered to be minor.

In the northern section of the project corridor both Options T1 and B3 result in significant changes to the physical nature of the western shore of Shoal Bay. The principal changes arise from the construction of temporary and permanent reclamations. In all cases the reclamations result in the loss of further shore-line and sand/mud flat. The effects on coastal processes and sedimentation regime resulting from Options T1 and B3 are likely to be broadly similar in nature and magnitude; there are relatively small differences in the total areas of reclamation required for the two options. Option B3 results in slightly more permanent reclamation while the total short-term reclamation associated with Option T1 is slightly larger than for Option B3.
The assessment has identified a number of broad concerns that will require additional investigation to resolve. These include:

- Further definition of changes in tidal prism, tidal flows, and wind-wave process interactions in Shoal Bay.
- Evaluation of potential changes in Shoal Bay sediment budgets arising from reclamations.

A number of mitigation opportunities have been identified that may offset some of the identified concerns. These are discussed in Section 7.

Table 6.3 provides an overview of the assessed levels of concern relating to coastal processes as described in the following sections. The effects and implications are discussed below in Sections 6.3.2 through 6.3.5.

Table 6.3: Option issues comparison – coastal processes

Project section		Option T1		Option B3	
		Rail tunnel	Road tunnel	Rail tunnel	Road bridge
St Marys Bay		None	None	None	None
Westhaven marina		None	None	None	Very minor
Harbour channel		None	None	None	Minor
Northern section	Bridge to Onewa	None	Moderate	None	Moderate-major
	Onewa to Tuff crater	Minor-moderate	Minor-moderate	Minor-moderate	Minor-moderate
	Tuff Crater to Esmonde	Minor-moderate	Minor-moderate	Minor-moderate	Minor-moderate

6.4 Terrestrial Ecology

6.4.1 Concerns

In evaluating and comparing the potential environmental impacts of options T1 and B3, consideration was given to the following:

- Presence of native plant communities.
- Presence of rare or threatened plant species.
- Presence of specific amenity trees.
- The presence of habitat utilised by reptiles

6.4.2 Southern section

As described in Section 4.2, there are a range of natural and planted terrestrial vegetation resources in the landward southern section of the project corridor. These include amenity trees and the coastal escarpment vegetation in St. Marys Bay alongside the SH-1 approaches to the current Harbour Bridge.

No specific assessment of amenity trees located in proximity of Victoria Park has been conducted as a part of the current assessment. The escarpment vegetation in St Marys Bay includes a number of pohutakawa. The interaction of these trees with current motorway modifications as a part of the Victoria Park Tunnel project development will have already have been assessed. Following confirmation of specific motorway lane realignments as a part of this project, a site specific assessment of potential effects on trees will be needed.

At this stage, the overall issues associated with likely works in the Southern section of the project are considered to be only very minor to minor for the bridge option.

6.4.3 Northern section

In the northern section Options T1 or B3 do not impinge on any significant terrestrial vegetation resources as there are few additions to the roading network between the current bridge and Esmonde Rd where works require disturbance of current motorway edges. The new structures between the Onewa Rd off-ramp and the northbound motorway will result in minor disturbance of road side grass. No disturbance of the escarpment between the Onewa Rd and Tuff Crater is expected.

Terrestrial ecology is 'limited' in the sense that there is a lack of significant natural/native habitat associated with the areas along the Shoal Bay shoreline. The nature of what remains is constrained by its scale (predominantly small patches) and its quality.

There is also a lack of information regarding terrestrial resources as to whether they contain any faunal resources of note. BML (2009) identified utilisation of terrestrial habitat by birds – predominantly introduced. An examination of all reports prepared to date as part of the project leading up to this assessment indicates that there has been no consideration of insects and reptiles in the work carried out to date in relation to supratidal maritime resources and terrestrial resources that may be impacted by any of the previously assessed options – this is considered to be a minor omission in the decision making process.

Examination of available habitat for lizards and the potential species that might be present in areas that might be impacted by either Option T1 or B3 did not identify any concerns (refer Section 4.7).

Overall, it is considered that there are no significant differences between Options T1 and B3 in relation to their effects on terrestrial-vegetation resources above the high tide mark and true terrestrial resources (plants and reptiles).

6.4.4 Overview and risks

Overall, the environmental risks associated with the southern section of the project are considered minor and manageable.

In the northern section of the project corridor there are few locations where definite interaction with terrestrial resources will occur. Most environments where works are proposed for both Options B3 and T1 are already developed and built-upon. No significant risks have been identified due to the lack of terrestrial resources of note. This has been taken into account in mitigation recommendations (Section 7).

Table 6.4 provides an overview of the assessed levels of concern relating to terrestrial (vegetation ecology) as described in the preceding sections.

Table 6.4: Option issues comparison – terrestrial resources

Project section		Option T1		Option B3	
		Rail tunnels	Road tunnel	Rail tunnel	Road bridge
Victoria Park		None	None	None	Very minor
St Marys Bay		None	None	None	Minor?
Westhaven marina		None	None	None	None
Central Harbour channel section		None	None	None	None
Northern section	shoreline	None	None	None	None
	landside	None	None	None	None

Note: Minor? – on the basis of some further disturbance of vegetation inland on motorway.

6.5 Intertidal Ecology

6.5.1 Concerns

In evaluating and comparing the potential environmental impacts of options T1 and B3, consideration was given to the following:

- Presence of inter-tidal plant communities especially communities such as salt marsh and shell bank.
- Presence of rare or threatened plant species.
- Presence of unusual or rare habitat in Shoal Bay or the region.
- Areas of habitat used as a resource by bird species.

6.5.2 Southern section

No intertidal areas of note have been identified in the southern part of the project corridor. No intertidal habitat will be affected by the T1 Option as the tunnels pass below ground from the City across the harbour.

Option B3 results in modifications to the shoreline within Westhaven Marina. The level of disturbance will be significant but the habitat, fauna and flora is not considered to be of any significant ecological value. The habitat supports a range of common and resilient fauna all of which will colonise new surfaces when the new shoreline is formed.

6.5.3 Northern section

The relationship of structures in Options T1 and B3 to the location of inter-tidal marine habitats is shown in Figures 6.5 (Tunnel – Bridge to Onewa interchange), Figure 6.6 (Bridge – Bridge to Onewa interchange) and Figure 6.7 (Tunnel and Bridge Options – Onewa interchange to Esmonde Rd). From an examination of these figures the key features of Options T1 and B3 are as follows:

6.5.3.1 Bridge Option B3

- Construction of permanent reclamation covering 49,211 m^2 from Harbour Bridge abutments to Onepoto Stream outlet.

6.5.3.2 Tunnel Option T1

- Construction of permanent reclamation covering 22,223 m^2 and temporary reclamation totalling 44,784 m^2 and from Harbour Bridge abutments to Onepoto Stream outlet.

6.5.3.3 Bridge Option B3 and Tunnel Option T1

- Piled structure across Onepoto Stream estuary resulting in disturbance to mangroves.
- Construction of multiple bridges across mouth of Onepoto Stream.
- Temporary reclamation north of Onewa Interchange for rail tunnel approach to rail tunnel portal.
- Construction of a permanent reclamation for the rail tunnel portal and trench (tunnel to viaduct grade).
- Widening of shoreline (permanent reclamation) to accommodate busway around Onewa interchange.
- Construction of piled viaducts from south of the mouth of Tuff Crater Lagoon outlet to Esmonde Rd.
- Construction of a small permanent reclamation at the terminus of the viaducts at Esmonde Rd.

Options T1 and B3 result in the loss or disturbance of similar types of habitat. The key differences between the options relate to the amount of habitat lost through reclamation in Shoal Bay south of Onepoto Stream.

The key matters arising in relation to intertidal habitat loss and disturbance are as follows:

- Loss of the shell bank at Sulphur Beach.

- Burial of part of the hard habitat associated with Sulphur Beach reef. The rocky reef and mudflat mosaic present in Sulphur Beach is the largest rocky reef in Shoal Bay, and provides intricate microhabitats in the form of crevices, overhangs and rock pools for the correspondingly diverse epifaunal assemblages. The loss of these reefs would reduce the diversity of structural habitat within Shoal Bay.
- The Heath Road reef is small but presents foraging habitat to shorebirds when exposed at low tide.
- Effects of the north end of the permanent reclamation for busway and rail south of the Tuff Crater lagoon outlet on shell bank habitat north of the Tuff crater outlet. As noted in the earlier section on coastal processes, further evaluation of the effects of changes in the hydraulics of the Onepoto outlet flows during flood and ebb tide is required to ensure that any flow restriction arising from the presence of the hard reclamation does not result in the outlet affecting the southern tip of the shell banks.
- Effects of the permanent reclamation for the rail and road viaduct prior to Esmonde Rd on tidal flows in the short mangroves behind the shell banks. As noted in the earlier section on coastal processes, further evaluation of the effects of change in shoreline physical structures on tidal water movement is required to ensure that the changes do not have adverse effects on the shell banks close by.

6.5.4 Overview and risks

Overall, the environmental risks associated with the southern section of the project are considered minor and manageable. In those areas of temporary and permanent reclamation other than noted above (general shoreline reclamation, temporary rail reclamation, permanent and temporary road related reclamations), the benthic invertebrate communities are typical of similar environments throughout the wider Waitemata Harbour and elsewhere along New Zealand's coastline. However, these assemblages provide feeding grounds for shorebirds, and the rocky reefs (i.e., Heath Road and Sulphur Beach reefs) are some of the very few, natural, hard substrates within Shoal Bay.

Work carried out to-date (e.g., BML 2009 and previous reports) has identified a number of risks of different scales associated with works in the intertidal environment.

- Removal of limited habitats (e.g., intertidal hard substrates) resulting is loss of natural habitat complexity and corresponding biological diversity.
- Removal of locally representative habitats, e.g., Sulphur Beach rocky reef and mudflat mosaic.
- Disturbance of intertidal habitat through use of temporary reclamations. It is also likely that temporary reclamations may alter the physical characteristics of intertidal area (e.g., through compaction) reducing likelihood of full restoration.
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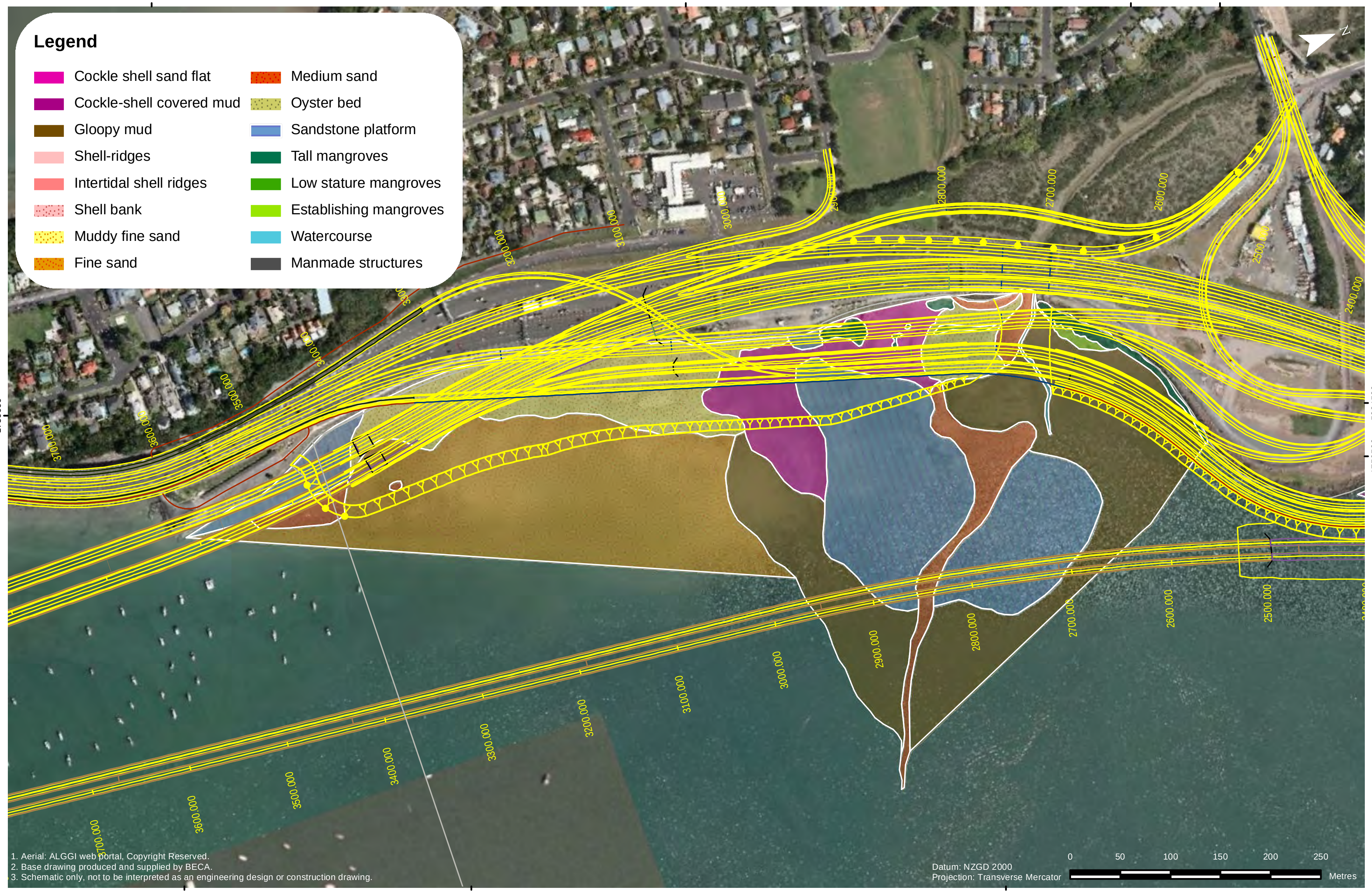

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TITLE MARINE HABITATS SULPHUR BEACH: TUNNEL OPTION 1.4 - T1.

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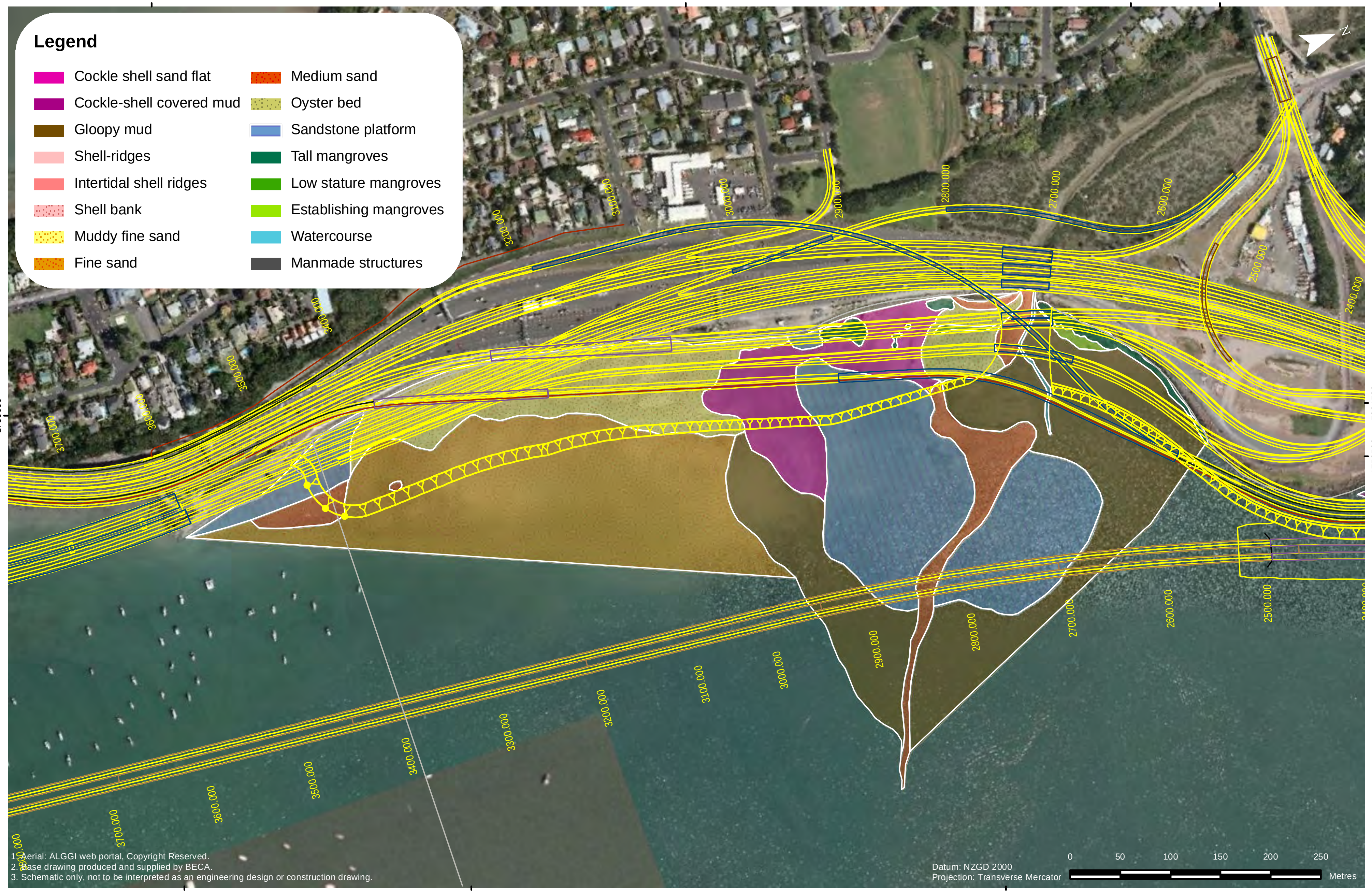

1. Aerial: ALGGI web portal, Copyright Reserved.
2. Base drawing produced and supplied by BECA.
3. Schematic only, not to be interpreted as an engineering design or construction drawing.

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TITLE MARINE HABITATS SULPHUR BEACH: BRIDGE OPTION 4.3 - B3.

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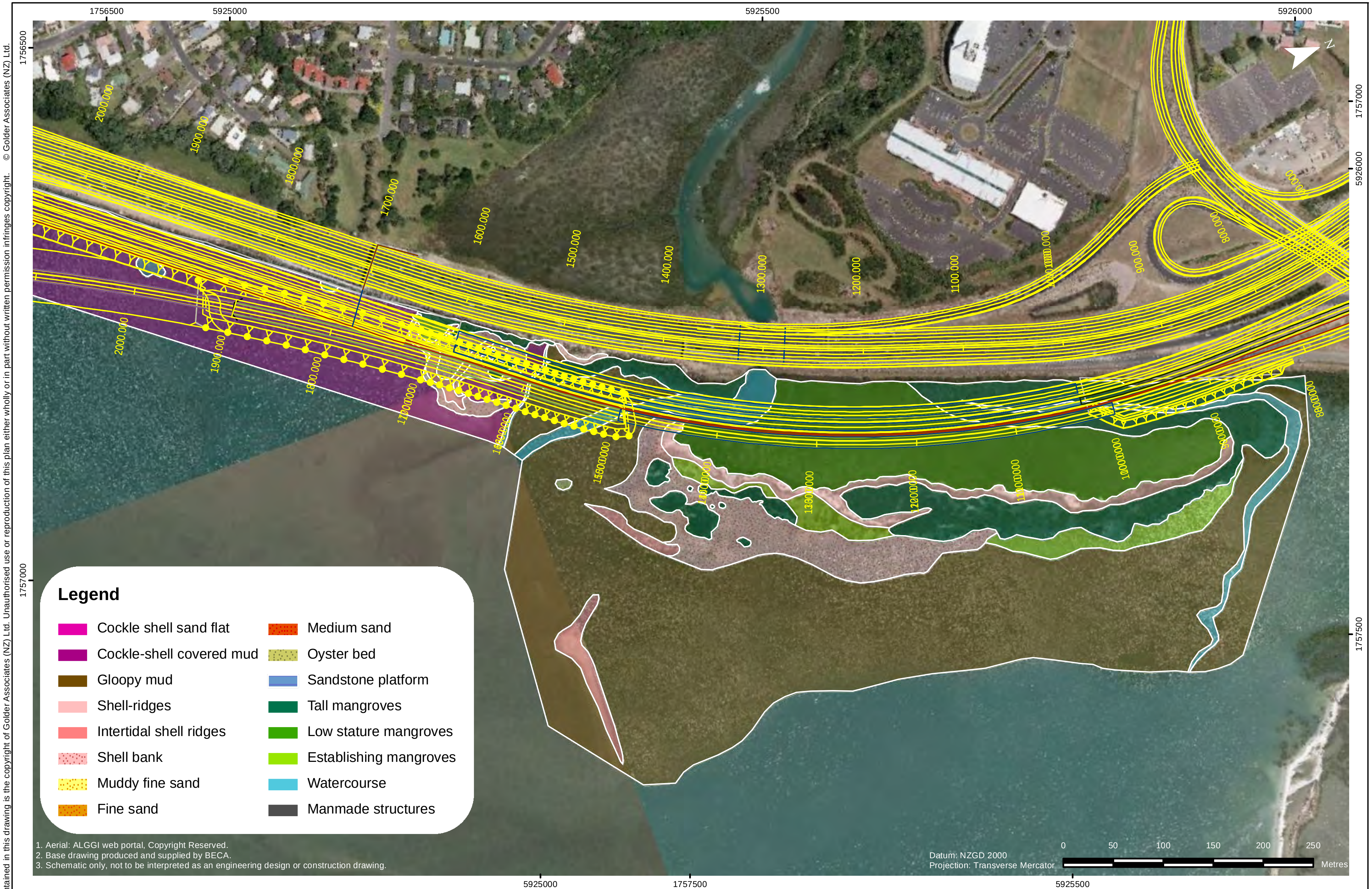

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TITLE

MARINE HABITATS CITY OF CORK BEACH AND TUFF CRATER MOUTH: TUNNEL OPTION 1.4 - T1 AND BRIDGE OPTION 4.3 - B3.

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Table 6.5 provides an overview of the assessed levels of concern relating to inter-tidal ecology as described in the previous sections.

Table 6.5: Option issues comparison – intertidal ecology

Project section		Option T1		Option B3	
		Rail tunnel	Road tunnel	Rail tunnel	Road bridge
St Marys Bay		None	None	None	None
Westhaven marina		None	None	None	Very minor
Harbour channel		None	None	None	None
Northern section	Bridge to Onewa	None	Moderate-major	Minor	Moderate-major
	Onewa to Tuff crater	Minor-moderate	Minor-moderate	Minor-moderate	Minor-moderate
	Tuff Crater to Esmonde	Minor-moderate	Minor-moderate	Minor-moderate	Minor-moderate

6.6 Subtidal Ecology

6.6.1 Concerns

In evaluating and comparing the potential environmental impacts of options T1 and B3, consideration was given to the following:

- Subtidal habitat to be lost by the options.
- Effects of works on sub tidal habitats along the option routes.
- Effects on specific biota such as marine mammals and marine reptiles.
-

6.6.2 Southern section

Option T1 results in no disturbance or effects in the sub tidal as the tunnels pass under the harbour and result in no disturbance to the southern section of the option corridor.

Option B3 results in some disturbance. This disturbance arises from the construction of the bridge piers from the approaches in St Marys Bay into Westhaven Marina. Each pier will have a footprint from drilling and construction. Loss of habitat is considered minor given the nature of habitat within Westhaven marina.

6.6.3 Central harbour section

Option T1 results in no disturbance or effects in the sub tidal as the tunnels pass under the harbour and result in no disturbance to the southern section of the option corridor.

From Westhaven Marina across to Sulphur beach, Option B3 requires a sequence of bridge piers to be constructed. This will involve drilling and removal of sand and shell from the seabed along with underlying Waitemata series sandstone. Habitat loss is expected to be relatively minor and no sub tidal habitats of note are known in the area based on seabed sampling and habitat mapping undertaken in the lower Waitemata Harbour (e.g., Hayward et al. (1997), refer Section 5).

Some sub tidal reef habitat is known from the lower Waitemata Harbour (e.g., near Bayswater Marina at O'Neills Point). For completeness, the location of any sub tidal Waitemata Series outcrops within the corridor (between the outside of Westhaven Marina and Sulphur Beach) for Option B3 should be identified if this option is selected.

The sub-tidal environment within the central harbour channel is also used by a variety of transient marine mammals and reptiles. There is limited current knowledge of the marine mammals and reptiles that visit the harbour; however a range of mitigation options are available to manage the effects on transient populations of dolphins, whales and sea turtles should they enter the construction zone. The constraint associated with limited data for marine mammal and marine reptile populations is considered to be minor if additional data can be obtained and mitigation options are further investigated if Option B3 is selected.

6.6.4 Northern section

The tunnels associated with Options T1 and B3 result in no disturbance or effects in the sub tidal as the tunnels pass under the harbour and arise in intertidal environments.

6.6.5 Overview and risks

The assessment of Options T1 and B3 has confirmed that the only Option where any sub-tidal environmental considerations are required is Option B3. In summary:

- Adverse effects on marine mammal and reptile populations during construction (i.e., vibrations, noise) due to lack of mitigation, resulting in distressed animals and impacts on population abundance.

- The potential removal of limited habitats (e.g., sub tidal reefs) (subject to confirmation) resulting is loss of natural habitat complexity and corresponding biological diversity.

Overall, at this stage, sub tidal ecology is not seen as a constraint to the selection of either option T1 or B3. Option 2C.

Table 6.6 provides an overview of the assessed levels of concern relating to sub tidal ecology as described in the previous sections.

Table 6.6: Option issues comparison – sub tidal ecology

Project section	Option T1	Option B3	
	Road and rail tunnels	Rail tunnel	Road bridge
St Marys Bay	None	None	None
Westhaven marina	None	None	Very minor
Harbour channel	None	None	Minor
Northern section	None	None	None

6.7 Coastal Ornithology Resources

6.7.1 Concerns

In evaluating and comparing the potential environmental impacts of options T1 and B3 on birds, consideration was given to the following:

- The utilisation of habitat in Shoal Bay by coastal bird species (e.g., foraging, roosting) and in particular by bird species of conservation significance.
- The presence of nesting, breeding bird species in particular by species of conservation significance.
- The level of disturbance that might occur during construction.
- The level of disturbance that might occur during operation of new roads and structures.

6.7.2 Southern and central section

There are no aspects of Options T1 or B3 that are considered to result in undue effects on the utilisation of the southern part of the project corridor by birds.

It is recognised that the central section of the project corridor is utilised by a variety of seabirds, however, the use is not considered to be constrained by construction (tunnel boring, construction noise and vibration) or operation (noise, lighting etc.) as most bird utilisation of the area is for individual bird roosting or feeding.

6.7.3 Northern section

In the northern section concerns relate mainly to the potential for disturbance effects, primarily to nesting NZ dotterel. However, in relation to operational effects, the significance is not expected to be more than minor as NZ dotterel currently nest successfully in close proximity to high volumes of traffic and appear habituated to this type of disturbance. Construction related disturbance is likely to be an effect greater than minor but can be avoided or managed in a similar manner as for the Busway project. This is discussed further in the section on mitigation that follows.

6.7.3.1 Sulphur Beach

The small 2,200 m^2 Sulphur Beach located adjacent to the mouth of Onepoto Stream will be completely lost to reclamation based on the current recommended works for Options T1 and B3. The beach is one of the most important habitats in Shoal Bay for nesting and roosting shorebirds and is the habitat for the only pair of year round resident NZ dotterels in Shoal Bay. This pair is unusual in that it frequently raised two broods per year and since 1997 has successfully fledged a disproportionately high proportion (37% or 14 chicks) of the NZ dotterels produced in Shoal Bay. The loss of this habitat represents a significant adverse effect on NZ dotterel and the other birds (2 pairs variable oystercatcher) nesting on the beach.

Disturbance related effects during the operational phase of the project can be minimised during the design of mitigation for loss of habitat so that they are of a less than adverse level (refer Section 7).

6.7.3.2 Sulphur Beach Reef

A proportion of the Sulphur Beach reef will be lost under reclamation. The estimated area of about 4.7% or 2,600 m^2 of the reef lost is a relatively small proportion of the available foraging habitat associated with the reef and indeed the Shoal Bay wider area and is not expected to be of an adverse level. However, opportunities exist to contribute additively to create nesting habitat and predator management as part of an overall mitigation package. Such mitigation would be of more benefit to shorebirds because their local populations are more likely limited by nest site availability and predation than by foraging habitat and food resources (refer Section 7).

6.7.3.3 Intertidal Area between Onewa Interchange and AHB Northern Abutment

About 5 ha of intertidal habitat will be permanently lost to reclamation and construction associated reclamation and bridges with Option B3 near Onepoto Lagoon. The loss is similar in Option T1 but a proportion is identified as temporary reclamation.

A strip along the entire intertidal coastal edge between the Onewa Interchange and AHB northern abutment will be lost. Given the magnitude of loss and the high quality of foraging habitat the effect is considered to be more than minor in magnitude.

Opportunities exist to create substantial new nesting habitat for NZ dotterel and other shorebirds along the entire area lost to reclamation as well as predator management, given the high magnitude of impact. As for Sulphur Reef, the benefits of creating additional nesting habitat would be physically more feasible and outweigh benefits associated with efforts to improve existing foraging habitat (refer Section 7).

Effects during the operation phase are likely to be minor given the spatial distance between the likely location of created habitat and traffic and other sources of disturbance. With respect to the latter, access to this area by pedestrians and dogs should be prohibited to avoid nest abandonment or mortality to eggs and nestlings. The fine detail of such mitigation should be developed in a shorebird mitigation plan and overseen by a shorebird technical working group similar to that adopted for the Busway project (refer Section 7).

6.7.3.4 Onewa Interchange

The northern portion of this interchange has been successfully used by a pair each of NZ dotterel and variable oystercatcher. No habitat will be lost during the construction of a trench and elevated structures. Impacts are construction related and similar to that described for the Esmonde Interchange. Similarly, they can be avoided or managed in the same manner and are expected to be of short term only. The effects of the elevated structure during the operational phase are unclear and it is possible that the birds may discontinue nesting in the area. However, given current successful breeding here and at the Esmonde Interchange there is more than a low probability that they will continue to breed successfully after construction is complete. Notwithstanding this, potential effects can be avoided or managed in a similar manner as descried for the Esmonde Interchange.

6.7.3.5 Intertidal Area between City of Cork shell banks and Onewa interchange

In addition to the construction of elevated structures over the intertidal area and associated ground disturbance, there will be a permanent loss of some intertidal foraging habitat for shorebirds. The magnitude of this loss is less than adverse given the availability of the substantial area of intertidal habitat available in Shoal Bay and the wider area. Mitigation opportunities include the creation of roosting or nesting habitat either in-situ or elsewhere within the Shoal Bay area in a similar manner as successfully done for the Busway project (refer Section 7).

6.7.3.6 City of Cork shellbanks

No direct loss of shell bank habitat will occur as a result of construction. As such, there will be no direct effects to the habitat for NZ dotterel or other shorebirds that use the shell banks for either nesting or roosting. Potential effects relate to the presence of an elevated structure (bridge) over the south western portion of the shell banks. Although NZ dotterel and other shorebirds continue to nest successfully adjacent to traffic disturbance within the Shoal Bay area it is possible that the presence of an elevated structure over this portion of the shell banks will results in shorebirds avoiding the area in favour of similar habitat adjacent to but away from the structure. However, there are no records of shorebirds nesting in the area over which the elevated structure would be built (BML 2009) and they rarely roost there. Consequently, the long term effects are likely to be low.

Indirect effects include construction related disturbance to birds nesting or roosting nearby and traffic related disturbance during the operation phase. Disturbance associated with the operational phase of the project is likely to be of little consequence given the ability of the species present to withstand existing levels of disturbance associated with the high traffic volumes of the motorway and the Busway. Overall the disturbance effects are likely to be more than minor during the construction phase.

However, these can be avoided if construction occurs outside the breeding season or managed in a similar way to those for the Esmonde Interchange described below.

6.7.3.7 City of Cork mangroves

Most of the mangrove habitat will be avoided by the project. However, permanent reclamation at the northern end and along the western margin adjacent to the motorway will remove a small of the existing mangroves. Additionally, two substantial elevated bridges will traverse most of the mangroves. Any changes to mangrove habitat in this area is not considered to be an adverse effect on NZ dotterel or other shorebirds that do not use mangroves.

6.7.3.8 Esmonde Interchange

Up to 3 pairs of NZ dotterel have nested in the wider area of the interchange but the dotterel's habit of shifting the location of their nests each year makes it difficult to accurately assess potential effects in terms of their explicit spatial context. Potential effects relate primarily to construction disturbance as no potential nesting habitat will be lost.

Construction related impacts could be avoided by avoiding construction activity during the breeding season. If construction must occur during the breeding season, then measures similar to those adopted during the Busway construction could be applied. These include measures to dissuade the birds from nesting in the area with the use of flame sticks, hawk kites and the use of shade cloth to partition the environment in a manner that the birds avoid it. If NZ dotterels do nest in the area provisions for Auckland Zoo to incubate eggs and release reared juveniles should be made. This will require permits from the Department of Conservation and due consideration of other construction activities prior to their release at Shoal Bay. Given their ability to successfully breed at this site despite their exposure to high levels of traffic disturbance and predators, the birds would be expected to return in the next breeding season after construction is completed. Opportunities exist to incorporate predator control at the site to increase the productivity of birds once there. Overall, the effects to NZ dotterel at this site can be either avoided or managed to below an adverse level.

6.7.3.9 Tuff Crater shell banks

The Tuff Crater shell banks and associated beach will be permanently lost due to reclamation adjacent to the existing motorway. The loss of this bird habitat is less than an adverse effect because there are no records of shorebirds nesting there and it is only infrequently used as a high tide roost, possibly due to its elevated position being on a similar plane to the motorway. Notwithstanding this, opportunities exist to mitigate the loss of habitat and improve the availability of nesting and roosting habitat elsewhere in Shoal Bay through the construction of additional shell banks in a similar approach as for the Busway project.

6.7.3.10 Heath Road reef

The Heath Road Reef will be permanently lost under 600 m^2 of reclamation. Although this reef is small, it is one of the first to be exposed by the receding tide and is used as foraging habitat by some shorebirds, including NZ dotterel. Although the loss of the reef will reduce the diversity of structural habitat within Shoal Bay, its importance as a source of food resources for shorebirds is low when compared to the abundance of food within the intertidal area forming the primary foraging habitat. Overall, although the reef will be lost, the effect on shorebirds will be less than adverse.

6.7.4 Overview and risks

Several risks to coastal avifauna relate to construction related disturbance, operational phase disturbance and long term effects of habitat loss and its mitigation. These include:

- Disturbance cannot be avoided by constructing outside the breeding season.
- If construction occurs inside breeding season, dissuading NZ dotterel from breeding in construction areas does not work.
- Mortality of eggs and chicks transferred to a rearing facility results in reduced productivity.
- Some or all birds abandon the site permanently.
- Resident pair of NZ dotterel at Sulphur Beach does not use created habitat and abandons Shoal Bay.
- Created habitat does not recruit enough birds to offset losses associated with habitat loss.
- Reduced productivity of NZ dotterel and other shorebirds.
- Cumulative effects of disturbance are greater than anticipated and some or all birds abandon the site permanently.

Table 6.7 provides an overview of the assessed levels of concern relating to birds as described in the previous sections.

Table 6.7: Option issues comparison birds

Project section		Option T1		Option B3	
		Rail tunnel	Road tunnel	Rail tunnel	Road bridge
Westhaven Marina		None	None	None	Very minor
Harbour channel		None	None	None	Minor
Northern Section	Bridge to Onewa	None	Moderate-major	None	Moderate-major
	Onewa to Tuff crater	Minor	Minor	Minor	Minor
	Tuff Crater to Esmonde	Minor-moderate	Minor-moderate	Minor-moderate	Minor-moderate

6.8 Effects on Environmental Quality

6.8.1 Introduction

Options T1 and B3 require significant construction work to be undertaken. Although, these works require significant in-ground works and materials management, none of the construction works are considered new (i.e., have been undertaken previously on projects in New Zealand) and the potential effects in each option and construction/works components are considered manageable. For completeness this section provides an overview of potential environmental issues to provide sufficient information to compare the relative environmental risks associated with either of the two options (as they relate to water and sediment quality).

6.8.2 Tunnels

Tunnel construction has two key components that determine environmental effects. These are:

- Management and disposal of materials generated during the tunnel construction.
- Construction of the cut and cover sections of road and rail tunnels in the northern section of the options corridor.

Option T1 and B3 both have identical rail tunnel options. As such the environmental/management issues associated with the options are the same for both options. At this stage of tunnel design it is assumed that all material is transported to an off-site disposal site/fill location. This also assumes that materials excavated during tunnelling are able to be handled and transported by truck and that no significant on-site materials management is required.

If stockpiling of excavated material is required prior to transport, storage areas will need storm water management and collected storm water will need to meet discharge quality limits.

Virtually all of the material excavated by the bored tunnels will be natural Waitemata Series materials (sandstones and siltstones). The exception will be the first stage of tunnelling in the Southern Section of the project Corridor. When the final portal location is selected, consideration of contaminated materials management will be required as the land within the Portal footprint will be within the CBD. This is not likely to differ to materials management for the Victoria Park tunnel.
Waitemata Series materials have been examined previously following drilling in the harbour. POAL (2006) reported on the nature and quality of shallow Waitemata series materials that were to be excavated as part of the deepening of the Rangitoto Channel.

All northern portals of the rail and road tunnels in Shoal Bay require a cut and cover section to link the surface with the bored tunnels. The key elements of this work are likely to be:

- Construction of temporary seawalls to create a dry working area.
- Construction of tunnel walls.
- Excavation of tunnel followed by cover of tunnel.
- Removal of temporary reclamation if the declamation option is selected.

The key issues in the tunnel portal work areas are:

- Management of excavated sediment and Waitemata Series materials.
- Management of storm water and infiltration.
- Management of tunnel equipment/demobilisation.

Overall, the environmental issues associated with the tunnel component of the options are similar between the Options (Options T1 requires road tunnel construction and both options require future rail tunnel construction). It is assumed that all materials excavated from the tunnels will be transported to an approved disposal site. As such, materials management/storm water management will only require assessment if material excavated from the tunnels require temporary stockpiling. If they do, storm water management would fall under the same management plan as reclamation storm water control.

6.8.3 Bridge and viaduct construction

Option B3 requires significant construction works for the new bridge in the southern and central sections of the project corridor. The bulk of the works are associated with the approach ramps at the north and south end of the bridge. The key over water construction issues associated with the project that have the potential to influence water quality are:

- Construction of bridge piers and material management from drilling.
- Overhead works associated with deck construction.
- Stormwater management during construction.

Methods for stormwater management associated with the approaches and during all aspects of construction will be undertaken as set out in a purpose written storm water management plan. This plan will utilise all best practice methods for storm water management as set out in Auckland Regional Council storm water management manuals. By utilising a source based control approach, it would be expected that general works will not result in adverse water quality effects (e.g., changes in water clarity).
Drilling and construction of bridge piles will require a specific assessment when final methodology is identified. However following identification of methods, specific management controls can be utilised to minimise local environmental impacts (e.g., using caissons, concrete management). As bridge piles are typically built in sequence, effects are local and the scale managed.

Option T1 and B3 In the northern section require similar construction works for the viaduct section between the rail tunnel portal and Esmonde Rd and the busway viaduct for both options. The busway viaduct will be constructed first followed by the rail viaduct following the decision to construct the rail component of the project. The works for the viaducts will be carried out in an intertidal area of uniformly low mangroves. IF the viaduct is constructed end to end in sequence without the need for local reclamation, then the scale of impacts will be minor in relation to potential water quality disturbance. The issues to be considered will be essentially the same for both options and will include:

- Disturbance with local water clarity changes during piling.
- Materials and fuel and oil management during construction.

Works will result in local ground disturbance but the works footprint associated with pile construction is expected to be relatively small.

6.8.4 Reclamation

Options T1 and B3 require significant reclamation works. A small area of reclamation is required alongside Westhaven Drive in the Southern part of the project corridor. On a relative scale, these are minor compared to reclamation within Shoal Bay. The Shoal Bay reclamations construction requires sequencing to minimise exposure of unconsolidated reclamation materials to tidal action. Bund construction can accommodate filters and sufficient protection to minimise loss of finer sediments.
Key elements of the anticipated works are:

- Placement of bund materials, temporary works sheet piles/walls.
- Placement of temporary and permanent reclamation contents (assessed for suitability).

- Management of storm water generated on reclamation surfaces.
- Suspended sediment generation during declamations.

The key issues associated with the various areas of works related principally to off-site loss of sediment both in terms of changes in water clarity and smothering of adjacent off site sediments.

Table 6.8 provides a summary of the levels of concern as they relate to water quality for Options T1 and B3. As the assessment demonstrated that in most cases the environmental risks/effects arising from either option in the southern or central sections of the project corridor were 'none' or minor, the summary relates to the northern section of the study corridor from Sulphur Beach to Esmonde Rd.

Table 6.8 Option issues comparison – water quality

Project section		Option T1		Option B3	
		Rail tunnel	**Road tunnel**	**Rail tunnel**	**Road bridge**
Westhaven Marina		None	None	None	Reclamation and piles Minor
Harbour channel		None	None	None	Piles Minor
Northern Section	Bridge to Onewa	None	Tunnel portal, reclamation Major	None	Approach reclamation Major
	Onewa to Tuff crater	Reclamation and portal construction Moderate-major	Reclamation	Reclamation and portal construction Moderate-major	Reclamation Minor
	Tuff Crater to Esmonde	Viaduct construction, reclamation Minor-moderate	Viaduct construction, reclamation Minor-moderate	Viaduct construction. reclamation Minor-moderate	Viaduct construction, reclamation Minor-moderate

6.9 Comparative Summary

Table 6.98 provides a summary of the key outcomes from this comparison of the various environmental risks associated with Options T1 and B3.

As the assessment demonstrated that in most cases the environmental risks/effects arising from either option in the southern or central sections of the project corridor were ‘none’ or minor, the summary relates to the northern section of the study corridor from Sulphur Beach to Esmonde Rd.

Table 6.9: Comparative summary of environmental risks associated with Options T1 and B3

	Option T1	Option B3
Coastal processes	Moderate	Moderate-major
Terrestrial vegetation	None	None
Intertidal ecology	Moderate-major	Moderate-major
Subtidal ecology	None	None
Ornithology resources	Moderate-major	Moderate-major
Environmental (water) quality	Moderate major	Moderate major

7. Identification of mitigation opportunities

7.1 Introduction

This section of the options assessment examines the issues that have been identified in relation to Options T1 and B3 and discusses potential mitigation options under each of the key assessment topics described in sections 5 and 6.

Mitigation is identified in two groups. First, mitigation considered and recommended as necessary to ensure the consentabilty of the project and second, mitigation which is considered would assist in improving the consentability of the project.

7.2 Coastal Processes

7.2.1 Background

As described in earlier sections, the Waitemata Harbour and Shoal Bay are highly modified environments. Substantial physical changes to shorelines have already resulted in significant changes to coastal processes. There have, however, been few studies of the degree of change that allow a clear understanding of what might constitute further acceptable change, what the cumulative and net effects of proposed actions might be, and therefore what mitigation may be required in relation to further change.

Potential changes in various aspects of coastal processes has been identified as a key area of environmental concern although the potential risk has not as yet been clearly identified. In a number of cases, the need for specific study/modelling was identified as a need to resolve or qualify particular issues. Table 7.1 provides a summary of coastal processes issues and potential mitigation. In many of the mitigation comments, coastal processes mitigation needs to be inter-linked with other ecological mitigation.

The overall differences between Options T1 and B3 is considered to be relatively small, and in general the risks and opportunities for mitigation can be considered similar in the context of coastal processes.

Table 7.1: Coastal processes mitigation

Constraint (Anticipated Consequences)	Opportunity to Mitigate	Risk that consequences can't be mitigated
Harbour channel		
Bridge piers occupy additional channel area; locally enhanced scour	Mitigate by alignment with existing AHB; monitor and implement scour protection at piers as needed	Low
Reclamation: Sulphur beach to Onewa Interchange		
Changes in nearshore bathymetry resulting in increase in depth at the shoreline and potential for larger waves and an increase in time that waves and water levels intersect the shoreline resulting in potential for changes to local sediment transport regime including enhanced scour; local beach stability may be compromised	Incorporate shaping and contouring to minimise scour and reflection effects. Use rip-rap revetment to reduce reflection. Scour potential can be mitigated by placement of scour protection. New beaches may need to be constructed with sediment control structures and nourished to compensate changes in sediment dynamics	Low to moderate
Reduction in tidal prism may result in minor changes to local tidal hydraulics with alterations in sediment transport regime	As above	As above; rising sea level may decrease chances of success and reduce

Constraint (Anticipated Consequences)	Opportunity to Mitigate	Risk that consequences can't be mitigated
leading to enhanced local scour and changes in the sediment supply to areas to the north as well as loss of beach stability		opportunity to maintain beaches and creek delta in this portion of Shoal Bay; implications of changes in delta to sediment dynamics and supply unknown at this time.
Modification to shoreline position in vicinity of Onepoto Creek mouth resulting in loss of accommodation space for creek delta and displacement of delta offshore	Confirm that Onepoto creek mouth crossings can be accommodated in wider setting.	Uncertain.
Alteration to shoreline orientation and reflection regime resulting in change to local wave climate	Incorporate shaping, contouring, and use of rip-rap to reduce reflection; compensating nourishment may also be required.	Low
Direct loss of inter-tidal area and sediment supply in reclaimed areas	Compensate losses in sediment supply with nourishment.	Low
Reclamation: Onewa Interchange to City of Cork Beach.		
North of Onewa interchange to Exmouth footbridge the area is backed by existing rip-rap which intersects MHWS and is fronted by inter-tidal flats. Reclamation will result in additional losses of tidal prism and reduced sediment supply	Changes to prism will not likely have any significant effects in this area although cumulative effects together with Sulphur Beach reclamation may have subtle effects elsewhere as described above. Compensate losses in sediment supply with nourishment.	Low (for local effects)
Reclamation will result in additional losses of tidal prism in areas which are currently backed by rip-rap at the waters edge – potentially leading to an overall loss potential to maintain shell ridge/mangrove habitat in this area	Construction of new beaches and shell banks. As above for reclamation	Low to moderate; rising sea level may decrease chances of success and reduce opportunity to maintain beaches and shell banks in this area of Shoal Bay in the long term
Altered drainage pattern from Tuff Crater, affecting delta/shell banks.	Look to redesign adjacent reclamation by moving south.	Low.
Reclamation: Esmonde Road Interchange		
Direct loss of inter-tidal area and sediment	Mitigate with additional sediment	Low

Constraint (Anticipated Consequences)	Opportunity to Mitigate	Risk that consequences can't be mitigated
supply in reclaimed areas	supply; As above for reclamation	
Effects on tidal drainage patterns.	Look to redesign, add minimum number of additional piles to viaduct section to remove from inter-tidal.	Low.

7.2.2 Mitigation

It is evident that a number of physical issues associated with coastal processes can be mitigated.

- Prior to works in any area with shell/shell hash resources, harvest existing beach and shell sediments for re-use in bank re-nourishment and artificial beach placements.
- Assess potential for new beaches construction as a part of new reclamation frontage.
- Ensure that in locations where reclamation impinges on deeper water (e.g., at Sulphur Beach), reclamation edge design shape can be smoothed and slopes designed to minimise scour and reflection effects and through use of rip-rap revetment which is non-reflective. Overall, it is expected that the use of rip-rap will be able to manage wave reflection issues; however, scour may still be an issue if currents increase; also artificial beaches proposed as mitigation in this area may be unstable without sediment control structures included such as groins this may have further potential to disrupt sediment balance/budget in the Bay – alternatives would need to be evaluated in design stages.
- Proposed mitigation of sediment supply should be possible with construction of new beaches but will need careful design considerations because depth regimes in several reclamation areas on western side of estuary will have been modified. Effects will require long term to manifest.

7.3 Terrestrial Vegetation

7.3.1 Background

The Waitemata Harbour coastal environment is characteristic of a highly modified natural system post-human settlement, as is much of the Auckland Conservancy (Lindsay et al. 2009). Within the Tamaki Ecological District, coastal ecosystems are prioritised for protection (Lindsay et al. 2009). Coastal ecosystems play an important role in buffering land based activities and enhancing water quality and soil conservation.

There are a number ecological/public reserves in close proximity to the northern corridor of an AWHC. These reserves provide linkage opportunities which would contribute to wildlife corridors and buffer existing natural areas. Barrys Point Reserve is mainly on reclaimed land that was once a tidal marsh (Wakatete Inlet). Tuff Crater Reserve is situated on the western edge of the northern motorway between the Onewa and Esmonde Rd interchanges (Figure 7.1). The management plan for Tuff Crater reserve seeks to guide the restoration of the area to a natural, functioning and self-sustaining indigenous ecosystem representative of similar ecosystems in the Auckland region (Te Ngahere 2009). Only 2% of coastal forest remains from its original pre-human extent, and often these remnants are only thin coastal strips (Lindsay et al. 2009). Coastal forest therefore presents an ideal ecosystem type for restoration as a part of mitigation for changes that have occurred as a part of the long-term development of SH-1.

7.3.2 Mitigation

The extent of indigenous coastal vegetation is much reduced both on the North Shore and throughout New Zealand, due to its history of clearance, disturbance, and degradation by introduced weeds. The requirement to mitigate the effects of an AWHC development on coastal ecosystems presents opportunities to restore/enhance coastal vegetation in the vicinity of the project area. Figure 7.1 identifies key areas that would benefit from such restoration and enhancement. These areas are:

- The marginal corridor around Tuff Crater lagoon that forms part of the Tuff Crater Lagoon.
- The coastal escarpment between Onewa Rd and the Exmouth Rd over-bridge.
- Coastal scrub and wetland in Onepoto Domain.
- Coastal scrub adjacent to the lower (estuarine) reaches of Waiurutoa Stream.

Further mitigation relating to intertidal and coastal vegetation is considered in the following section.

Restoration of approximately 8 ha of remnant coastal forest, scrub and saltmarsh around the margin of Tuff crater is the North Shore branch of Forest & Bird's main conservation project. This initiative could be supported as part of the overall AWHS mitigation package, and extended to include improvement of the ecological values of coastal forest, scrub and saltmarsh remnants at Onepoto Domain (approximately 10 ha), coastal scrub around the lower reaches of Waiurutoa Stream (approximately 4 ha), and up to 2 ha of forested coastal escarpment north of Onewa Rd that links these sites to Tuff Crater.

Recommendations for restoration management for these areas would be generally consistent with those set out in Forest & Bird's restoration plan for Tuff Crater (Te Ngahere 2009). Te Ngahere (2009) sets out a wide range of information including suitable species lists for Tuff crater restoration as the restoration is an active programme. Conceptually the extended restoration plan would require the following:

- Confirmation of current work programmes and progress to date.
- Confirmation of resourcing constraints for Forest & Bird's Tuff Crater restoration.
- Identification of specific planting and weed management issues for the additional sites, along with any constraints to undertaking restoration works due to land ownership, Council plans for reserve sites, etc.

7.3.3 Anticipated costs

- Costs of undertaking restoration and enhancement planting can vary widely depending on the initial condition of the site, but a conservative cost of up to $120,000 per ha is estimated for weed control, planting and maintenance over 3 years.

7.4 Intertidal and Coastal Vegetation

7.4.1 Background

Historically, Sulphur Beach and the City of Cork beach were once sandy beaches, frequently used by holiday makers and for recreation purposes. Urbanisation of Auckland's North Shore and construction of transport links have resulted in significant shoreline changes both physically and ecologically.

In Shoal Bay, mangroves are now the predominant estuarine vegetation community occurring as a primary succession of recent intertidal mudflats. The current mangrove population in the main part of Shoal Bay has established since the construction of the Auckland Harbour Bridge and Northern motorway in 1959. It is estimated the oldest trees are approximately 50 years old. Chapman & Ronaldson (1958) described the mangroves of Shoal Bay and suggested that mangroves did not cover the central area of either Tuff Crater or the adjacent Onepoto Basin in the 1950s. Woodroffe (1982) indicated that aerial photographs of the area, available since 1940, show that considerable extension of vegetation has occurred to the west of the crater since the construction of the motorway (1958-1959).

Golder Associates

TITLE LOCATION OF TERRESTRIAL ENHANCEMENT CORRIDOR.

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Mangroves perform a vital role in coastal processes through consolidation of sediment, altering erosion dynamics, impeding flow rates and raising the shore bed. Consequently, mangroves facilitate succession of communities such as salt marshes. Over hundreds of years, the sucessional trajectory for mangrove and salt marsh vegetation in the absence of disturbance or sea level change is development into true terrestrial scrub.

7.4.2 Mitigation

The establishment of reclamations along western Shoal Bay provides an opportunity to re-establish some element of natural features that have been progressively encroached upon due to coastal development in the Waitemata Harbour (such as shell banks, saltmarsh and coastal scrub). This may include restoring some elements of natural ecotonal succession from mangroves to saltmarsh and woody terrestrial vegetation. The coastal margin of Shoal Bay has some capacity to restore itself naturally if disturbance is minimised and initial succession stage is appropriately restored. However this seldom is allowed to occur in coastal environments that have been engineered for development. Mangroves and saltmarsh communities will colonise shallow intertidal zones with a gentle intertidal gradient. If reclaimed land can be modified or partially declaimed after construction to re-create shallow shorelines with a degree of buffering against tidal scour, and an appropriate substrate is established, mangroves and salt marsh/meadow communities are likely to colonise such areas. Alternatively, such vegetation can be actively restored. The success of such restoration is largely dependent on the substrate composition after declamation, and the right combination of tide, elevation and salinity (Laegdsgaard 2006), hence detailed planning will be required in order to ensure a good outcome.

Mitigation of the loss of coastal vegetation and encroachment into the intertidal environment as a result of an AWHC development is considered necessary to meet Resource Management Act requirements. The following intertidal/coastal vegetation restoration options are the preferred approach to:

- Recreation of coastal beach habitat in conjunction with development of bird roosts and NZ Dotterel breeding sites (refer below).
- Establishment of intertidal and high tide coastal vegetation on reclamations with either the T1 or B3 Options.

“Temporary” reclamations provide the most potential for creation of intertidal/ coastal vegetation and habitat (provided they are not declaimed), due to both their size and location on the seaward margin of the development. Option T1 provides approximately 9.5 ha of suitable reclamation area, while Option B3 provides 3.5 ha of reclamation area.

- Restoration work would require development of a detailed restoration plan once more details of the form and substrate of reclamations are available. Generally, the intent of restoration would be to create a mosaic of habitats, including saltmarsh and saltmeadow, coastal shrublands, and areas of shellbank / beach habitat with coastal tussock grasslands.
- Conceptually development would require the following:
- Identification of shoreline shape, physical characteristics.
- Identification of materials requirements for beaches.

- Confirmation of planting requirements for high tide beach areas.
- Identification of shoreline materials re-placement (altering reclamation height etc).
- Surface re-working to create subsurface suitable for rooting.
- Identification of soil requirements.
- Confirmation of planting plan and species placement.
- Development of a maintenance and weed management plan.
- Identification/confirmation of accessibility / education opportunities.

7.4.3 Anticipated costs

- At this stage, costs of revegetating coastal and intertidal habitats are estimated at $90,000 per ha. This estimate covers planting only, as the requirements for establishing the substrate are not sufficiently well-known.
- The planting will comprise a range of species as set out in Table 7.2.

Table 7.2: Plant species suitable for restoration of high tide area and coastal forest in reclamation areas

Common name	Latin name
High tide species	
Oioi	*Apodasmia similis*
Coastal immortality grass	*Austrostipa stipoides*
Sea rush	*Juncus kraussii* var. *australiensis*
Salt marsh ribbonwood	*Plagianthus divaricatus*
Shore pimpernel	*Samolus repens* var. *repens*
Glasswort	*Sarcocornia quinqueflora* subsp. *quinqueflora*
Selliera	*Selliera radicans*
Coastal forest	
Rengarenga	*Arthropodium cirratum*

Coastal astelia	*Astelia banksii*
Taupata	*Coprosma repens*
Ti kouka/cabbage tree	*Cordyline australis*
Pohutukawa	*Metrosideros excelsa*
Ngaio	*Myoporum laetum*
Karo	*Pittosporum crassifolium*
Flax	*Phormium tenax*

7.5 Coastal Birds

7.5.1 Background

Coastal birds in Shoal Bay are one of the key ecological features of the Bay. The assessment of effects of Options T1 and B3 have indicated that the effects fall into two key areas. These are:

- The loss of NZ dotterel nesting site at Sulphur Beach.
- Potential disturbance or loss of foraging and roosting areas in Shoal Bay especially in the vicinity of Sulphur Beach.

7.5.2 Mitigation

Mitigation opportunities for the adverse effects include creation of significant areas of new nesting habitat and predator control to increase nest success and over all shorebird productivity. It is recommended that the effects are addressed in the development of a Shorebird Mitigation Plan and creation of a Shorebird Technical Group to oversee its implementation.

Shell banks were added to/re-created as mitigation from the northern busway extension to provide nesting habitat for NZ dotterels. Substrate was laid and replanted with local plant species. Mitigation comparable to this is a further opportunity for vegetation rehabilitation in Shoal Bay, however should be performed in conjunction with mangrove, salt marsh and coastal scrub rehabilitation.

The loss of Sulphur Beach presents a mitigation opportunity to significantly replace and add beyond the existing level, to the availability of nesting habitat in Shoal Bay. Preferably, this should occur as close to the current location of the beach while taking into consideration potential disturbance. Because the magnitude of effect is considered high, the quanta of habitat created should be greater than that currently available to the extent that the area can support more than a single pair of NZ dotterel. In doing this, due consideration of coastal processes and their effect on the long-term viability of created habitat should be provided for as well as the timing of shell bank construction in relation to the ecology of NZ dotterels in particular.

The location of such mitigation for Sulphur Beach and other areas lost, due to construction, should be investigated as part of a separate feasibility study with recommendations made in a shorebird mitigation plan to a shorebird technical working group similar to that adopted for the Busway project. In addition to the above, opportunities exist to enhance shorebird breeding success across the area within Shoal Bay as appropriate for the level of impact associated with the loss of Sulphur Beach.

7.5.3 Roost and habitat enhancement for shorebirds

- Any mitigation concept for shorebirds will need to be developed in conjunction with coastal processes mitigation and intertidal and coastal habitat/vegetation mitigation relating in particular to reclamation redevelopment. The key elements of the mitigation are:
- Identification of locations suitable for inter-tidal roosts.
- Identification of suitable locations and construction needs for NZ dotterel shell bank nesting sites.
- Ensuring new roost construction takes into account sea-level rise.

7.5.4 Anticipated costs

- Enhancement work relating to NZ Dotterel habitat and nest site protection etc was carried out for the North Shore Busway development. The costs that were associated with the NZ Dotterel enhancement programme provide an indication of potential costs. Given the experience of the work undertaken to date it is considered that the costs associated with enhancement works carried out for the busway will be lower than previous costs. Costs are dependent on final location of shoreline habitat changes/dotterel management locations.

7.6 Inter-tidal Ecology

- No specific mitigation needs were identified in relation to inter-tidal benthic ecology. A number of inter-tidal areas that will be buried by permanent and temporary reclamations are part of inter-tidal areas used by foraging coastal waders.
- The declamation concept for temporary reclamations will return those areas to intertidal habitat. The temporary reclamations will be constructed over soft sediments and over Waitemata materials that outcrop in the Sulphur Beach reef.
- Declamation where reclamation has been built over Sulphur Beach reef should aim to return the surface to the underlying reef profile with minimal disturbance.
- Declamation where the reclamation has been built on soft sediment, where the sediment was strengthened by re-working (creating mudcrete), will require over dredging to allow the sediment surface to reform with sufficient depth to allow infaunal communities to re-establish.

7.7 Water Quality

- As the project will include significant ground disturbance and sediment/materials management as a result of reclamation construction, tunnel portal construction, pile construction etc, mitigation for potential water quality affects will be identified through the preparation of storm water and construction management plans.
- Management Plans are a key approach to identifying strategies and methods appropriate to a particular project to offset/manage particular potential effects.
- There are a wide variety of management techniques that are able to be utilised to manage storm water runoff from construction areas and intertidal and subtidal sediment and seabed disturbance. These techniques are likely to include but are not limited to:
- Use of silt fences between works and intertidal areas.
- Use of geotextile and other ground covers for areas of potential erosion and sediment loss.
- Minimising exposed areas of materials in stockpiles.
- Use of storm water treatment devices to manage quality of site/works storm water.
- Managing water disposal from tunnel works.
- Managing timing of inter-tidal work and vehicle movement in inter-tidal areas.

8. Summary and conclusions

This assessment has been prepared to describe the natural environment within the corridors of Options T1 (comprising road and rail tunnels) and B3 (Rail tunnel and road bridge), the two final options being considered for an AWHC. The assessment considers the coastal and ecological effects and benefits of the two options being considered. The assessment compares the two options and provides a relative comparison of the anticipated effects of each. For each option, mitigation is examined and the minimum mitigation recommended to allow the final selected option to be consentable is identified. Where additional mitigation is also identified that may enhance the consentability of the selected option, that mitigation is described. Preliminary cost estimates for components of identified mitigation are presented.

The assessment of Options T1 and B3 has indicated that there are no significant ecological and environmental differences for works that would be associated with the southern side of the Waitemata Harbour. The coastal marine areas that are affected by Options T1 and B3 lie within Westhaven Marina.

Both options involve reclamation along the Westhaven Drive margin of the marina and Option B3 involves works associated with the construction of the approaches to and piles for the harbour bridge. Although significant works are required for the bridge option the environmental differences between the two options are not considered to be significant.

In the central part of the project corridor, Option T1 has no physical or ecological effects on the Harbour. Option B3 involves construction of a rail tunnel and like Option T1 direct effects are not evident. The bridge construction associated with Option B3 requires construction of piles and general construction works above Harbour waters. Although the bridge pile construction is a significant task, the work is unlikely to have significant effects on Harbour seabed or water quality. Although environmental issues requiring consideration can be identified in relation to the bridge component of Option B3, the issues are manageable and are not considered to result in a significant weighting to the road tunnel in terms of harbour environmental issues.

In the northern section of the project corridor which is located within Shoal Bay, the T1 and B3 Options have a number of essentially common elements. These are:

- Both have a bored tunnel that requires a temporary reclamation to bridge the gap between the drilled tunnel and surface portal. The reclamation is used to construct the intermediate trenched section (most of which is covered and buried).
- Both Options have rail and road options with essentially identical structure and reclamation requirements in the section north of the Onewa interchange to Esmonde Rd.
- The Option T1 road tunnel and Option B3 northern approaches to the bridge require reclamation in the area from Onewa interchange and the southern end of Sulphur Beach.

The key environmental issues and differences between the options for the northern project corridor were examined and compared for key physical processes and ecology. The key matters identified and the conclusions reached are as follows:

8.1 Coastal processes

Shoal Bay has been significantly impacted over a period of 100 years by development. Most of this development (reclamation) has occurred in the last 60 years. The two options result in further reclamation into Shoal Bay with both options affecting the effective width of the Bay. The declamation associated with Option T1 will potentially reduce the physical presence of the reclamation in that Option and make the reclamation effect similar in both options.

Both options will cause re-adjustments in the sediment supply and inter-tidal sediment budgets within Shoal Bay.

Both options result in the loss of key features such as the small shell beach developed at Sulphur Beach.

Mitigation has been recommended to enhance the naturalness of any man-made shorelines created as a part of the project. This includes re-creating pocket beaches (to create habitat) and shell banks where physical conditions allow.

8.2 Inter-tidal ecology

Shoal Bay has lost all of its natural inter-tidal shoreline north of the current Harbour Bridge. The shore is currently artificial along this entire length. Intertidal vegetation has readjusted principally through the development of mangroves in areas north of Onepoto Stream.

Both Options T1 and B3 result in the loss of soft and hard-shore intertidal habitat at Sulphur Beach with declamation in Option T1 potentially reducing this effect. Declamation may result in some changes to morphology of hard surfaces through construction damage.

Both options result in loss of shell bank at Sulphur Beach and in the current design there may be some impacts on shell-bank habitat near Tuff Crater outlet mouth. The identified concerns at Tuff Crater mouth are likely correctable through minor design changes.

Overall, the assessment of potential impacts and concerns rated inter-tidal ecological effects as moderate to major for the road tunnel and road bridge components of Options T1 and B3. This level of concern related to the project section south of Onepoto Stream. For both options, the effects and concerns were similar (rated minor-moderate) north of Onepoto as the footprint and works for both options were very similar.

Recommended mitigation for the loss and disturbance to inter-tidal ecology includes:

- The creation of pockets of intertidal vegetation where tidal level and physical conditions allow.
- The creation of new beach and shellbank habitat along the seaward edge of the reclamations for Options T1 and B3 south of Onepoto Stream.
- The development of coastal vegetation communities on temporary reclamations if they are not declaimed.

8.3 Terrestrial vegetation and ecology

Options T1 and B3 result in little effect on true terrestrial vegetation in Shoal Bay. However, as there are few remnants of natural vegetation alongside the motorway corridor, opportunities for restoration and enhancement planting are identified in areas of coastal vegetation remnants between Stafford Rd and Esmonde Rd. This planting would support and add to the work that Forest & Bird is already undertaking around Tuff Crater Lagoon. Restoration and enhancement of coastal terrestrial vegetation is identified as additional mitigation that would enhance the consentability of the project, and/or which may be a more viable mitigation alternative in the event that restoration of intertidal habitat on reclamations proves to be problematic.

8.4 Ornithological resources

Shoal Bay supports a range of coastal bird species and in particular provides habitat for NZ dotterel which breed along the shore within the project footprint. NZ Dotterel habitats were managed through the construction of the busway with no significant adverse effects on the existing population arising.

Options T1 and B3 will result in the loss of tidal foraging areas in Shoal Bay especially in the area directly seaward of Sulphur Beach. The extent of loss is greater for the T1 option if the area if the temporary reclamation is not declaimed. Following declamation in the T1 option, the nett areas lost in the T1 and B3 options are generally similar.

The assessment of overall issues rated the two Options similar in scale of concerns with the effects in the bridge to Onepoto Stream section rated Moderate to major and the northern section from Tuff Crater outlet to Esmonde Rd as Minor to moderate in scale.

Mitigation is considered necessary to compensate for the loss of NZ dotterel habitat and nest sites along with loss of inter-tidal foraging areas and roost areas. This mitigation falls into the same package as that for coastal processes and inter-tidal ecology along the seaward edge of the reclamation south of Onepoto Stream with the addition of specific areas suitable to allow multiple NZ dotterel nest sites.

NZ dotterel roost site management will need to take into account sea-level rise.

8.5 Environmental (water) quality

Many of the construction activities associated with both the T1 and B3 options will require management plans to ensure storm water and water management (e.g., during tunnel construction) do not result in water quality effects when discharged/disposed. Specific management will also be required in all areas of intertidal / subtidal sediment disturbance.

Management techniques are available to deal with storm water quality and other discharges. Tools and management approaches can be defined in management plans prior to works being undertaken.

Given the similarity of works in both the T1 and B3 options and the likely similarity of mitigation available for both options, there are no specific differences between the anticipated effects that might arise from the two options.

8.6 Option effects comparison

The assessment of Options T1 and B3 has shown that in the southern and central parts of the project corridor (City across the harbour channel to the foot of the current bridge) there are no significant differences between the two options in terms of environmental issues that would affect the Option selection process (even considering the significant construction works associated with the B3 option). As such the environmental issues that potentially influence the selection of either the T1 or B3 option lie in the northern section of the project corridor within Shoal Bay. As the rail tunnel component of the two options is identical it does not influence the overall assessment of the options. As such, the summary in Table 8.1 below related to the road component of the T1 and B3 options. The information in Table 8.1 identifies the effects prior to mitigation. In this context declamation is not specifically considered as mitigation as the activity may have effects itself.

Table 8.1: Comparative summary of environmental risks associated with Options T1 and B3

Environment component	Options T1 - Road tunnel	Option B3 - Road Bridge
Terrestrial ecology	No effect	No effect
Coastal processes	Moderate (with declamation)	Moderate-major
	Moderate-major (without declamation)	
Inter-tidal ecology	Moderate-major	Moderate-major
Ornithological resources	Moderate-major	Moderate-major

8.7 Mitigation overview

The key elements of mitigation identified in this assessment are summarised in Table 8.2.

Table 8.2: Summary of mitigation recommendations associated with Options T1 and B3

Area of mitigation	Location	Nature of recommended mitigation
Terrestrial ecology	Onepoto to Esmonde Rd	Restoration and enhancement of areas of remnant coastal vegetation.
Coastal processes	Onepoto to Esmonde Rd Beach	Creation of natural shoreline to areas of reclamation
	Sulphur Beach	Creation of natural shoreline, development of new pocket beaches and shell banks.
Inter-tidal ecology	Sulphur Beach	Creation of intertidal habitat pockets, shell bank vegetation and coastal shrubland and forest where reclamation allows.

Area of mitigation	Location	Nature of recommended mitigation
Ornithological resources	Sulphur Beach	Creation of new NZ dotterel habitat/nest sites
		Creation of coastal bird roosts

8.8 Options assessment overview

The assessment of Options T1 and B3 has shown that virtually all of the environmental concerns arising from the implementation of either option occur in Shoal Bay. Shoal Bay has been subject to previous roading related effects resulting on two occasions in an increase in the amount of reclaimed land in the bay.

The two options have very similar footprints in the corridor from Sulphur Beach through to Esmonde Rd. The most significant effects are considered to occur in the southern section in Sulphur Beach up to Onepoto Stream and the Onewa interchange. Option T1 has a larger reclamation footprint than Option B3 but it is proposed to declaim a major portion of the seaward part of the T1 reclamation. This would reduce the T1 Sulphur Beach reclamation to less than the B3 option. Consideration has been given to potentially keeping the T1 reclamation (i.e., not declaiming the reclamation) and using the temporary reclamation to develop coastal habitat as a part of recommended mitigation.

A number of mitigation recommendations have been made that all contribute to improving the naturalness of the motorway edge in Shoal Bay. The mitigation includes coastal edge shaping, creation of intertidal and high tide habitat, bird roosts and NZ dotterel nest sites and coastal shrubland/forest.

Overall, it is considered that there is little difference between Options T1 and B3 in terms of their effect on the Shoal bay environment. Both will have effects to the physical and ecological character of the Bay. However, it is considered that this can be mitigated through a suitable environmental enhancement mitigation package.

9. Abbreviations

ACC	Auckland City Council
ACES	
AHB	Auckland Harbour Bridge
ARC	Auckland Regional Council
AWHC	Additional Waitemata Harbour Crossing Project
AECOM	Architecture, Engineering, Consulting, Operations and Management
BECA	Beca Carter Hollings & Ferner Limited.
BML	Boffa Miskell Limited
CCNZ	Coastal Consultants New Zealand Limited
CMA	Coastal Marine Area
CMJ	Central Motorway Junction
CPA	Coastal Protection Areas
NIWA	National Institute of Water and Atmosphere
NZTA	New Zealand Transport Agency
OD	Outer diameter
PAH	Polycyclic Aromatic Hydrocarbon
POAL	Ports of Auckland LImited
SH-1	State Highway 1
SKM	Sinclair Knight Merz

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