REPORT

Tonkin+Taylor

Marine Ecological Effects Assessment

Beachlands South

Prepared for
Beachlands South Limited Partnership

Prepared by
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Glossary

Benthic	Of, relating to, or occurring at the bottom of a body of water or the depths of the ocean.
Best Practicable Option (BPO)	Defined in section 2(1) of the Resource Management Act 1991 (RMA), as: *"in relation to a discharge of a practicable contaminant or an emission of noise, means the best method for option preventing or minimising the adverse effects on the environment having regard, among other things, to —* *(a) the nature of the discharge or emission and the sensitivity of the receiving environment to adverse effects; and* *(b) the financial implications, and the effects on the environment, of that option when compared with other options; and* *(c) the current state of technical knowledge and the likelihood that the option can be successfully applied.*
BCM	A Biodiversity Compensation Model uses field data and science-based qualitative data (where required) to calculate whether NNL or NG is likely to be achieved by a compensation proposal. It takes into account the time lag between the biodiversity impact and gain, and adjusts for risks such as the risk of under-estimating losses or over-estimating gains and the likelihood of success of the proposed compensation actions.
Bioaccumulation	Gradual accumulation of substances, such as pesticides or other chemicals, in an organism. Occurs when an organism absorbs a substance at a rate faster than that at which the substance is lost or eliminated by catabolism and excretion.
Coastal Marine Area (CMA)	Defined in section 2(1) of the RMA, as: *"the foreshore, seabed, and coastal water, and the air space above the water—* *(a) of which the seaward boundary is the outer limits of the territorial sea:* *(b) of which the landward boundary is the line of mean high water springs, except that where that line crosses a river, the landward boundary at that point shall be whichever is the lesser of—* *(i) 1 kilometre upstream from the mouth of the river; or* *(ii) the point upstream that is calculated by multiplying the width of the river mouth by 5".*
Compensation	Compensation is any measure proposed or agreed to by the applicant for the purpose of ensuring positive effects on the environment to compensate for any adverse effects on the environment that will or may result from allowing the activity.
Council	Auckland Council.
Cumulative effects	Changes to the environment that are caused by an action in combination with other past, present and future human actions.
E-MBR	Enhanced Membrane Bioreactor.
Endemic	Only found in New Zealand.
Mean Low Water Springs	The average of each pair of successive low waters during that period of about 24 hours in each semi-lunation (approximately every 14 days), when the range of the tide is greatest.
Mean High Water Springs	The average of each pair of successive high waters during that period of about 24 hours in each semi-lunation (approximately every 14 days), when the range of the tide is greatest.

No Net Loss / Net Gain	The values that are adversely affected by an activity are addressed through compensation that seeks to achieve a No Net Loss (NNL) / Net Gain (NG) outcome as assessed using a qualitative biodiversity modelling tool.
Residual effect	Effects on biodiversity or ecological values that cannot be avoided, remedied or mitigated.
Significant Ecological Area (SEA)	Significant Ecological Areas (SEAs) are identified by the Auckland Council to maintain and protect indigenous biodiversity. These areas are recorded in the Auckland Unitary Plan (Operative in Part) (AUP) – Schedule 4.
Substrate	The material that rests at the bottom of a body of water.
Total suspended solids (TSS)	The total amount of particulate matter that is suspended in the water column, that are not dissolved, that can be trapped by a filter.
Turbidity	A measure of the clarity of water. Turbidity is the measurement of the amount of light scattered by suspended particulates present in the water when a light is shined through the water. The more total suspended particulates in the water, the murkier it can appear and the higher the turbidity.
Water column	Column of water from the surface of a sea, river or lake to the bottom sediment.
Zone of Influence (ZOI)	The areas/resources that may be affected by the biophysical changes caused by the proposal and associated activities.

Executive summary

Beachlands South Limited Partnership (BSLP) is seeking a Private Plan Change (PPC) to re-zone an area of currently rural and private property land in Beachlands to facilitate urban development of that area. The re-zoning is across multiple contiguous properties in Beachlands, Auckland.

The properties included in this PPC process and associated Beachlands South Structure Plan (herein 'Structure Plan') include the Formosa Golf Resort (approximately 170 ha), a farm at 620 Whitford-Maraetai Road (approximately 80 ha) and various smaller land parcels totalling 57 ha.

The PPC area is currently zoned Rural – Countryside Living under the Auckland Unitary Plan – Operative in Part (AUP-OP). Through the Structure Plan, the BSLP are seeking to rezone the land to a combination of Business (Mixed Use, Local Centre and Neighbourhood Centre), Open Spaces, Residential and Future Urban Zone (FUZ).

A key focus of the Structure Plan is to enable the urbanisation of the land whilst protecting and enhancing ecologically significant values. To this end, the proposed PPC area includes an Ecological Protected Area Network (EPAN) covering 88.7 hectares. This EPAN includes the most significant existing and potential ecological values, which will be protected from development and enhanced.

Initially it is proposed to 'Live Zone' the northern portion of the PPC area (the 170 ha Formosa Golf Course) via a plan change. It is also proposed to rezone the southern portion of the PPC area as FUZ. This FUZ will then be the subject of a further plan change application in due course.

Report scope and methods

BSLP has requested that Tonkin & Taylor Ltd (T+T) prepare a marine ecological effects assessment (this report) for the PPC. This report will sit alongside terrestrial, wetland and stream ecology assessment reports to inform the assessment of environmental effects of the project prepared to support the PPC application.

This report presents an assessment of marine ecological effects for the proposed PPC undertaken in general accordance with the Ecological Impact Assessment (EcIA) guidelines (vs.2) produced by the Environmental Institute of Australia and New Zealand (EIANZ, 2018). The work has included a desktop review of existing relevant ecological data, site surveys to provide quantitative data on marine habitats (benthic infauna and sediment contaminants), coastal saline vegetation and coastal birds in the Waikopua Creek and the wider Whitford Embayment. The EcIA guidelines ascribe an overall level of ecological effect (from **Very Low** to **Very High**) that is determined using a matrix based on ecological values and the magnitude of effect on these values.

Site description and values

The marine receiving environment is located adjacent to the Waikopua Creek and along the coastal margin to the west of the Formosa Golf Course at 110 Jack Lachlan Drive and the neighbouring property at 620 Whitford-Maraetai Road. The coastal area is part of the Hauraki Gulf Marine Park and comprises three distinct tidal creeks (Waikopua, Turanga and Maungamaungaroa Creeks) which are identified as being regionally and nationally significant (Schedule 4, Auckland Unitary Plan (AUP)).

Turanga Creek is the largest estuarine habitat (including mangrove shrubland ecosystems) in the Hunua Ecological District and provides a complex of intertidal mud, sand and shell flats. The intertidal banks are a rich feeding ground and important mid-tide roost for a variety of international migratory and New Zealand endemic wading birds including a number of threatened species. A large shellbank at the Waikopua Creek mouth is used as high tide roost by birds. Moderate numbers of wading birds roost on the shellbanks including godwit, South Island pied oystercatcher, whimbrel, reef heron, variable oystercatcher and banded dotterel. The length of coastline adjacent to the site is recognised as an extensive area of feeding habitat for wading birds.

Assessment of ecological effects

Our assessment of marine ecological effects is summarised in Table ES.1 and is based on an assessment of effects following efforts to avoid, remedy and mitigate effects from the proposed PPC. This includes site optimisation during the master-planning phase, construction staging, on-site water sensitive urban design, erosion and sediment control in line with best practice, and wastewater treated through a E-MBR system to achieve a high level of contaminant removal.

Residual ecological effects that are moderate or higher (after steps to avoid, remedy or mitigate effects) warrant further efforts to avoid, remedy, mitigate, offset or compensate for those effects unless otherwise accepted (for example, effects that may occur within a zone of reasonable mixing for discharges).

Table ES.1 summarises the ecological effects associated with the proposed PPC and concludes that the overall level of residual effects on the marine receiving environment are **Moderate** for effects on firm muddy sand flat / cockle shell covered flats, shellbank habitats, mangroves and coastal birds.

With reference to the EIANZ framework, further effects management to reduce the overall effects on habitats and coastal avifauna is warranted.

Table ES.1: Summary of ecological values, magnitude of effect and overall ecological effect on ecological values in the Beachlands South marine receiving environment

Habitat attribute / species	**Ecological value**	**Magnitude of residual effect on ecological values after measures to avoid, remedy or mitigate effects**	**Potential overall level of residual effect on ecological values**
Marine habitats	Seagrass - high	Low	Low
	Firm muddy sand flats / cockle shell covered flats – very high	Low	Moderate
	Shellbanks – very high	Low	Moderate
	Sandstone reef - high	Low	Low
	Soft gloopy mud – moderate	Negligible	Very Low
	Rock revetment - low	Negligible	Very Low
Fish	High	Low	Low
Coastal saline vegetation	Mangroves – moderate	Low	Low
	Saltmarsh and saltmeadow - high	Low	Low
Coastal birds	Waders – Low to Very high	Moderate	Very Low to High
	Water column feeders – Low to Very High	Negligible	Very Low to Low
	Generalist Feeders - Low to Very High	Negligible	Very Low to Low
	Coastal fringe and wetland species - High	Low	Low

Residual effects management

Preliminary compensation measures to address residual effects are outlined below and will be fine-tuned through the resource consenting phase and following monitoring and adaptive management. Potential compensation options include:

- Enhancement of coastal avifauna habitat. The Waikopua shellbanks adjacent to the PPC site are currently in a degraded state and on a decline trajectory due to encroachment of vegetation (i.e. pampas) that is compromising use of the shellbanks by avifauna as roosting habitat. Selective vegetation removal (mangroves and saline vegetation) and replanting of ground cover native species that introduce better line of sight will improve the quality of this habitat type both for roosting and nesting purposes.
- This measure is in line with approaches being taken in other areas i.e. Tāmaki Makaurau and Waiuku River / Manukau Harbour.
- Mangrove management. Selective removal of mangroves and ongoing maintenance of seedlings is proposed to maintain quality foraging habitat at the mouth of the Waikopua Creek. Without intervention it is likely that mangroves will continue to expand seawards in this location and compromise foraging habitat quality.
- The large coastal wetland near the middle of the PPC site currently comprises predominantly exotic vegetation and initially appears like a good enhancement opportunity. However, based on experience it is expected that there would be logistical, technical, resource and cost issues associated with its restoration and a low level of confidence in successful outcomes.

To address any residual effects, in addition to the measures proposed above, restoration and enhancement activities could also be undertaken at a broader embayment scale, this ideally would include roost enhancement of shellbanks close to Motukaraka Island or on the opposite side of the Whitford Embayment at Porterfield Road Esplanade Reserve.

Conclusion

In conclusion, our assessment is that most effects due to rezoning from the PPC, associated Land use change and subsequent development on marine habitats and values will be **Very Low** to **Low** provided the measures to avoid remedy or mitigate effects are implemented as set out in this report. However, our assessment also indicates that some residual (**Moderate** or higher) effects remain that should be offset or compensated, including residual effects on firm muddy sand flat / cockle shell covered flats, shellbank habitats and coastal birds due to effects associated with discharges and disturbance in the CMA.

Residual effects associated with the development of the Live Zone and the FUZ can be addressed through the proposed effects management measures and we consider that a NNL outcome for marine ecological values can be achieved.

Effects management outcomes for marine ecology will be achieved through the Auckland Wide provisions under the AUP and proposed precinct provisions developed for the proposed Beachlands South Precinct (as set out in the Planning Report that accompanies the PPC application) and through subsequent resource consent processes, including associated consent conditions, management plans and monitoring. Measures to manage residual effects include Biodiversity Compensation Modelling and associated monitoring to verify that expected ecological outcomes have been realised, and to guide adaptive management as required.

We therefore consider that adverse ecological effects on marine and coastal values due to the PPC and subsequent development can be adequately addressed through the effects management measures outlined in this report and as guided by the Auckland-wide and proposed precinct provisions.

1 Introduction

This Marine Ecological Effects Assessment report has been prepared to inform the Structure Plan and a proposed Private Plan Change (PPC) being sought by Beachlands South Limited Partnership (BSLP) across multiple contiguous properties in Beachlands, Auckland.

1.1 Overview

BSLP is seeking a PPC across multiple contiguous properties in Beachlands, Auckland (approximately 307 ha) to expand the existing Beachlands Maraetai coastal town.

The PPC area is bound by Jack Lachlan Drive to the north, the Pine Harbour Marina and ferry terminal directly to the northwest, a coastal edge and the coastal marine area (CMA) along the west, Whitford-Maraetai Road to the east and rural-residential properties to the south. The properties included in this PPC process and associated Beachlands South Structure Plan (herein 'Structure Plan') include the Formosa Golf Resort (approximately 170 ha), a farm at 620 Whitford-Maraetai Road (approximately 80 ha) and various smaller land parcels (see Table 1.1).

The PPC area is currently zoned Rural – Countryside Living under the AUP-OP. Through the Structure Plan, the BSLP are seeking to rezone the land to a combination of Business (Mixed Use, Local Centre and Neighbourhood Centre), Open Spaces, Residential and FUZ.

A key focus of the Structure Plan is to enable the urbanisation of the land whilst protecting and enhancing the significant ecological values. To this end, the proposed PPC area includes an Ecological Protected Area Network (EPAN) covering 88.7 hectares and including the most significant existing and potential ecological values, which will be protected from development and enhanced.

Table 1.1: Complete Structure Plan area (properties owned by BSLP shaded)

Address	Lot and DP number	Area (Hectares)
110 Jack Lachlan Drive Beachlands	LOT 2 DP 501271	170.475
620 Whitford-Maraetai Road	LOT 100 DP 504488	79.9444
770 Whitford-Maraetai Road	LOT 10 DP 54105	6.8665
758 Whitford-Maraetai Road	LOT 9 DP 54105	6.1403
746 Whitford-Maraetai Road	LOT 8 DP 54105	5.7996
740 Whitford-Maraetai Road	LOT 7 DP 54105	5.1448
732 Whitford-Maraetai Road	LOT 6 DP 54105	5.0939
722 Whitford-Maraetai Road	LOT 5 DP 54105	4.9227
712 Whitford-Maraetai Road	LOT 4 DP 54105	4.7518
702 Whitford-Maraetai Road	LOT 1 DP 208997	2.1341
692 Whitford-Maraetai Road	LOT 1 DP 197719	1.7747
682 Whitford-Maraetai Road	LOT 1 DP 187934	1.2583
680 Whitford-Maraetai Road	LOT 26 DP 504488	12.8125
Total		**307.1186**

Initially it is proposed to 'Live Zone' the proposed development footprint within the northern portion of the PPC area (the 170 ha Formosa Golf Course at 110 Jack Lachlan Drive, Beachlands) via a plan change. It is proposed to rezone the remaining development footprint within the southern portion of the PPC area as FUZ. This includes the proposed development footprint within the farm at 620 Whitford-Maraetai Road and various smaller land parcels. These FUZ areas will be the subject of a further plan change application in due course. The site location and proposed zoning is shown in Figure 1.1.

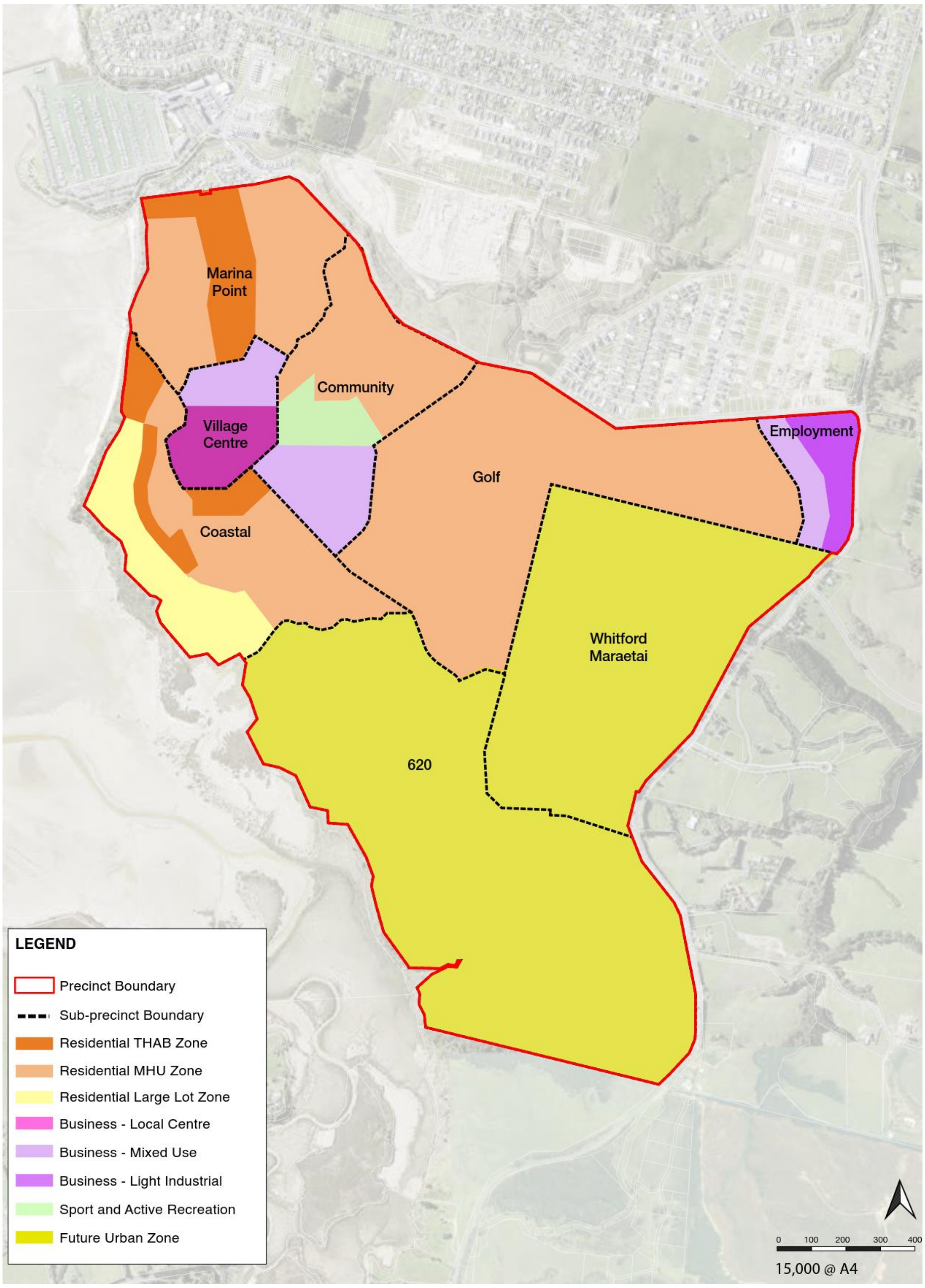

Figure 1.1: Beachlands South site location and proposed zoning

BSLP has commissioned a series of technical reports as part of the planning process for the Beachlands South Structure Plan and subsequent private plan change (the Project). This report assesses the potential effects of the Project on marine ecological values. It also provides recommendations to avoid, remedy or mitigate adverse effects within the structure plan and plan change area and matters to be considered in the development of potential precinct provisions over the plan change area to guide and manage future development activities.

1.2 Report scope

BSLP has requested that Tonkin & Taylor Ltd (T+T) prepare a marine ecological effects assessment (this report) to inform the Section 32 Assessment of Environmental Effects (AEE) that will support the Private Plan Change (PPC) application[1].

This ecology assessment focusses on the marine receiving environment of the site. This marine ecological effects assessment report includes:

- A description of the marine receiving environment;
- A summary of the desktop review of available marine ecological information related to the site;
- A summary of the methods and results of the field (coastal bird and benthic ecology) surveys conducted;
- A review of contaminant fate modelling with respect to potential effects on marine ecology;
- An assessment of effects on marine ecology associated with the land use change due to the proposed PPC and subsequent development, including construction phases, and effects management measures following EIANZ guidelines (Roper-Lindsay *et al*., 2018)
- Recommended measures to avoid, remedy or mitigate adverse effects on marine ecology; and
- Recommendations for addressing residual adverse effects on marine ecology that cannot be avoided, remedied or mitigated, through habitat creation, restoration and enhancement.

This Marine Ecological Effects Assessment sits within a suite of ecological assessment reports and associated information as set out below:

- Volume 1: Ecology Technical Reports
  - Ecological Assessment of Effects Report: Executive Overview
  - Terrestrial Ecology Effects Assessment
  - Wetland Ecology Effects Assessment
  - Stream Ecology Effects Assessment
  - Marine Ecology Effects Assessment (this report)
  - Biodiversity Compensation Modelling Report
- Volume 2: Appendices
  - Appendix A: Combined Ecology Tables and Figures
  - Appendix B: Terrestrial Ecology Tables and Figures
  - Appendix C: Wetland Ecology Tables and Figures
  - Appendix D: Stream Ecology Table and Figures
  - Appendix E: Marine Ecology Tables and Figures
  - Appendix F: Biodiversity Compensation Modelling Tables

[1] This work has been undertaken in accordance with our letter of engagement dated 11 December 2020.

1.3 Statutory context

The statutory and planning documents that provide the framework for this marine ecology effects assessment are detailed in the Section 32 Assessment of Environmental Effects and Section 32 Evaluation for the proposal. In brief, these include:

- Part 2 of the Resource Management Act 1991.
- The New Zealand Coastal Policy Statement 2010 (NZCPS), in particular:
  - Policy 3: The precautionary approach recognises the need to adopt a precautionary approach towards proposed activities whose effects on the coastal environment are uncertain, unknown, or little understood, but potentially significantly adverse.
  - Policy 11: Indigenous biodiversity. This Policy recognises the need to avoid adverse effects of activities on indigenous taxa that are listed as threatened or at risk indigenous in the New Zealand Threat Classification System lists, indigenous ecosystems and habitats.
  - Policy 15: Natural features and natural landscapes. This Policy recognises the needs to protect the natural features and natural landscapes (including seascapes) of the coastal environment from inappropriate subdivision, use and development.
  - Policy 19: Walking access. This Policy recognises the public expectation of and need for walking access to and along the coast that is practical, free of charge and safe for pedestrian use. A restriction is only imposed on public walking access to, along or adjacent to the CMA where such a restriction is necessary (amongst other things):
    - To protect threatened indigenous species; or
    - To protect dunes, estuaries and other sensitive natural areas or habitat.
  - Policy 22: Sedimentation. This Policy requires that subdivision, use, or development will not result in a significant increase in sedimentation in the CMA, or other coastal water.
  - Policy 23: Discharge of contaminants. This Policy recognises the need to manage discharges to water in the coastal environment, having particular regard to the sensitivity of the receiving environment and the nature of the contaminants to be discharged, and avoiding significant adverse effects on ecosystems and habitats after reasonable mixing.
- The Resource Management (National Environmental Standards for Freshwater) Regulations 2020 (NES-FW). Notably, the PPC proposal does not involve any activity prohibited by Regulation 53 of the NES-FW in relation to natural wetlands.
- The AUP-OP. In particular, Schedule 4 – Significant Ecological Areas – Marine which identifies 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 (SEA-M1) or areas that are of regional, national or international significance which do not warrant an SEA-M1 identification as they are generally more robust (SEA-M2).
- The Marine and Coastal Area (Takutai Moana) Act 2011.
- The Hauraki Gulf Marine Park Act 2000.

The following non-statutory documents are also relevant to this assessment:

- Roper-Lindsay, J., Fuller S.A., Hooson, S., Sanders, M.D., Ussher, G.T. (2018). Ecological impact assessment Guidelines (EcIAG). EIANZ guidelines for use in New Zealand: terrestrial and freshwater ecosystems. 2nd edition.
- Sea Change – Tai Timu Tai Pari – Hauraki Gulf Marine Spatial Plan.

- Maseyk, F., G.T. Ussher, G. Kessels, M. Christensen and M. Brown (2018). Biodiversity Offsetting under the Resource Management Act: A guidance document September 2018. Prepared for the Biodiversity Working Group on behalf of the BioManagers' Group.

2 Methods

Our approach to the assessment of marine ecological effects has comprised collation and desktop review of existing ecological data relevant to the site, and site-specific survey of the marine receiving environment including:

- High level habitat mapping.
- Visual inspection of epifauna.
- Collection of benthic infauna cores and sediment quality samples.
- Coastal bird surveys.

We have prepared an assessment of effects on marine ecology based on the known or likely ecological values in the receiving environment and the expected magnitude of effects on those values. We have used the Environment Institute of Australia and New Zealand (EIANZ) Ecological Impact Assessment Guidelines (EcIAG) (Roper-Lindsay *et al*., 2018) to frame our assessment of ecological effects.

Our assessment assesses potential direct effects of the PPC proposal on marine habitats, proposed stormwater discharges during construction and finished development stages and the point and / or diffuse source discharge of treated wastewater from a proposed on-site Wastewater Treatment Plant (WWTP). The assessment considers effects associated with the proposed Land use change within the Live Zone and FUZs.

A Biodiversity Compensation Model (BCM) will be used to assist in determining the type and magnitude of offsetting or compensation measures needed to address potential residual adverse effects that could not be avoided, remedied or mitigated (e.g. discharges to high value marine habitats).

2.1 Description of ecological characteristics and values

2.1.1 Desktop assessment

A desktop assessment was undertaken to compile information and data relating to the ecology of the marine receiving environment and the surrounding area. This included the following key sources of information and additional references therein. A full list of information sources is provided in the References section below (Section 9):

- Auckland Council, Geomaps viewer – Significant Ecological Areas layer.
- Retrolens, an online portal for historical aerial imagery.
- Auckland East Coast Estuarine Monitoring Programme: Summary of key changes 2015-2018 (Hewitt and Carter, 2020)
- Coastal and Estuarine Water Quality: 2020 Annual Data Report (Ingley, 2020).
- Auckland Council Regional Sediment Contaminant Monitoring Programme (RSCMP): States and trends 2004-2019 (Mills and Allen, 2021).
- National Aquatic Biodiversity Information System (http://www.nabis.govt.nz/) (Data retrieved 13/07/2021).
- E-bird, an open-source citizen science bird observation platform.

2.1.2 Habitat mapping

The habitats present within the intertidal area were classified based on a site walkover and the descriptions presented in the 'Intertidal and subtidal biota and habitats of the central Waitemata

Harbour' (Hayward *et al*., 1999). Subtidal seagrass extent was delineated where possible based on aerial photography and a drone survey of the Plan Change area undertaken for this project by T+T. The locations and relative extent of the different habitats present are presented in at Figure 2 in Volume 2: Appendix E.

2.1.3 Benthic ecology survey

2.1.3.1 Site selection

A marine ecological survey was carried out at eight sites within the low-mid tide area around Turanga Creek in the Waikopua Estuary (Refer to Volume 2: Appendix A; Figure 2 and Table 2.1 below). Site locations were selected to be representative of the receiving environments potentially affected by the PPC and subsequent development. This included potential sediment settling sites within both the low and mid intertidal zone located near identified discharge points from the site (stream outlets). Sites were also selected to complement known Auckland Council study sites within the estuary.

All sites were sampled between 24 and 26 February 2020. Sites were accessed by foot within two hours either side of low tide.

Table 2.1: Location of benthic ecology and sediment survey sites, location within the tidal zone and coordinates.

Site	Location in tidal zone	Coordinates (WGS84)	
		Latitude	Longitude
Site 1	Mid-intertidal	-36.891977	174.986112
Site 2	Low-intertidal	-36.891939	174.984181
Site 3	Mid-intertidal	-36.896092	174.985219
Site 4	Low-intertidal	-36.896015	174.984018
Site 5	Low-intertidal	-36.900821	174.982364
Site 6	Mid-intertidal	-36.901207	174.984746
Site 7	Mid-intertidal	-36.90626	174.989673
Site 8	Low-intertidal	-36.907461	174.991266

2.1.3.2 Sediment quality

A single composite sediment sample was collected at each of Sites 1 - 8. Composite samples[2] were taken from the top 2 cm of sediment; for most settling zones the top 2 cm contains sediments deposited over a 0.2 - 7 year period and therefore targets more recently deposited contaminants (TP168, 2004).

Samples were sent to RJ Hill Laboratories for analysis. Analyses included particle size distribution, concentrations of zinc, copper and lead (total fractions), and Chlorophyll *a*.

Metal results were compared against the Auckland Council Environmental Response Criteria (ERC) "traffic light" system as described in TP168 (ARC, 2004). This reporting system is more conservative than the trigger values provided in the Australian and New Zealand Water Quality Guidelines (ANZWQG, 2018). Auckland Council considers that ANZWQG trigger values are too permissive for the

[2] Five sub-samples taken from an area approximately 100 m^2

Auckland Region and has modified them (Mills and Allen, 2021)[3]. This is based on evidence from the Benthic Health Model of ecological effects even within the ERC 'Green' band.

The ANZWQG Sediment Quality Guidelines (SQG) are also provided in Table 2.2 below for reference. The sediment Default Guideline Values (DGVs) indicate the concentration below which there is a low risk of unacceptable effects occurring. The Guideline Values – High (GV-High) provide an indication of concentrations at which you might already expect to observe toxicity-related adverse effects. As such, the GV-High value should only be used as an indicator of potential high-level toxicity problems, not as a guideline value to ensure protection of ecosystems (ANZWQG SQG, 2018).

Table 2.2: SQG concentrations according to Auckland Council ERC and ANZWQG (2018) Default Guideline Value and Guideline Value – High.

Contaminant	Unit	Auckland Council ERC			DGV	GV-High
		Green	Amber (TEL)	Red (ERL)		
Copper	mg/kg dry weight	<19	19-34	>34	65	270
Lead	mg/kg dry weight	<30	30-50	>50	50	220
Zinc	mg/kg dry weight	<124	124-150	>150	200	410

2.1.3.3 Epifauna

Five 0.25 m² quadrats were surveyed at each site. Quadrats were photographed and all live species present on the sediment surface within the quadrat were identified and recorded. The placement of the quadrats within the site was random.

2.1.3.4 Infauna

A total of 40 (5 per site) benthic core samples were collected to characterise existing benthic infauna communities. Sample locations are presented in Volume 2: Appendix A; Figure 2 and described in Table 2.1 above.

Sites were sampled along a 50 m transect running south to north, with one benthic infauna core collected randomly at 0 - 10, 10 - 20, 20 - 30, 30 - 40 and 40 - 50 m along the transect. The exceptions to this alignment were Sites 7 and 8, where the transect was run parallel to the sub-tidal channel of the Waikopua Creek. This alternative alignment was used to limit variability in results due to sampling from different elevations in the low tidal to mid tidal zones.

Samples were collected using a 0.013 m^2 corer pushed into the surface sediments to a depth of approximately 15 cm. The recovered core material was then sieved using a 0.5 mm mesh sieve and the remaining contents preserved with 99 % ethanol for invertebrate identification. Samples were sent to Biolive Invertebrate Identification Services (Nelson) where they were processed and all organisms present identified and counted. The Shannon Weiner Diversity and Shannon Weiner Evenness index values were calculated and reported for each sample.

The Shannon Weiner Diversity and evenness indices are commonly used to describe community complexity and equitability of distribution, where the diversity value (H) ranges between 0 (indicating low community complexity) and 4 (indicating high complexity); whilst the evenness value (E) ranges from 0 (highly irregular distribution) to 1 (all counts are equal).

[3] This is consistent with the ANZWQG (2018) philosophy of developing trigger values appropriate to local conditions.

2.1.4 Coastal avifauna

Coastal birds were assessed through desktop assessments and field assessments. Field assessments included the deployment of Automatic Bird Recorders (ARDs) in the coastal marine environment, and site-specific coastal bird surveys undertaken in March, April and May 2021.

2.1.4.1 Automatic Bird Recorders

Two Automatic Bird Recorders (ARDs) were deployed in coastal wetland areas (Refer to the Wetland Ecological Effects assessment, Volume 2: Appendix C; Wetland Values) in December 2020. ARD01 was deployed on early successional terrestrial vegetation adjacent to a brackish wetland and in close proximity to the coastal fringe, while ARD02 was deployed deep in saltmarsh vegetation. ARDs were set to record between one and a half hours before sunrise to two and a half hours after sunrise, and between one hour before sunset to three hours after sunset.

ARD01 recorded from 18 December to 25 December 2020, while ARD02 recorded from 18 December to 21 December 2020 (before running out of battery). A total of 80 hours (59.5 hours and 20.5 hours per recorder, respectively) of spectrogram data was analysed in the programme Raven (v. 2.0.1) to identify any terrestrial, coastal and wetland bird species.

2.1.4.2 Coastal avifauna field surveys

Coastal avifauna field assessments were undertaken on the 5, 22, 23 and 24 March, 19 April, and 13 May 2021, for a total of three low tide to high tide surveys and three high tide to low tide surveys (refer Table 2.3 below). High tide to low tide surveys commenced approximately one hour after high tide, while low tide surveys commenced at low tide time (refer to Table 2.3 below).

Surveys were focussed across two intertidal zones, North Beach and South Beach (refer to Volume 2: Appendix E; Figures 3a to 3f) and conducted over a four-hour period divided into four one-hour sub-surveys.

All wetland and coastal birds heard or seen during each sub-survey were identified and mapped spatially onto an iPad using Collector for ArcGIS, noting species, abundance and behaviour. Individual birds were mapped using points, and discrete flocks of greater than 20 individuals of the same species were mapped via polygons. The maximum number of birds and species identified in each sub-survey was recorded. Both bird behaviour and their location were recorded as first identified by the observer. Birds flying high overhead, and not actively foraging or utilising the focal area were excluded from counts.

Bird behaviours were recorded in the following categories:

- Feeding in the intertidal habitat.
- Feeding in or over the water.
- Resting in the intertidal habitat.
- Resting on the water.
- Resting/roosting on land.

Coastal bird surveys were undertaken using a Kowa Prominar 88 mm with 25 - 60 x eyepiece Spotting Scope attached to a Celestron Trailseeker Tripod. A TruPulse 200 laser rangefinder was used to calibrate distance estimates to each bird. The spotting location of each survey is shown in Volume 2: Appendix E; Figures 3a to 3f.

All bird records were analysed and mapped in ArcGIS Pro (v 2.7.3). Bird flocks mapped in the field via polygons (i.e. flocks > 20 birds) were randomly distributed as points within the polygon boundaries.

Table 2.3: Details of coastal bird surveys undertaken at North Beach and South Beach, south of Pine Harbour Marine in Waikopua Creek (Refer to Volume 2: Appendix E; Figures 3a – 3f)

Survey no.	Date	Site*	Survey start time	Low tide time	Tide movement
1	5 March 2021	S	14:52	06:27	High to low
2	22 March 2021	N	08:00	08:00	Low to high
3	23 March 2021	S	09:00	09:00	Low to high
4	24 March 2021	N	10:00	10:00	Low to high
5	19 April 2021	S	13:03	05:41	High to low
6	13 May 2021	N	09:15	01:53	High to low

Note:
N = North Beach
S = South Beach

Avifauna species use all or some of the terrestrial, coastal marine and inland wetland environments present at different times. Assessment of effects for avifauna which are found in multiple habitat types are assessed as per the following habitats in which they most commonly use (or were identified using during surveys):

- Marine Ecological Assessment (this report): southern black-backed gull, black shag, black swan, white-faced heron, pied stilt, Canada goose, little black shag, little shag.
- Terrestrial Ecological Assessment Report: welcome swallow, swamp harrier, spur-winged plover, sacred kingfisher.
- Wetland Ecological Assessment Report: grey teal, mallard, Australasian shoveler, grey duck, grey duck x mallard hybrid, New Zealand scaup, white-faced heron, Australian coot, New Zealand dabchick, pūkeko, paradise shelduck.

All avifauna identified during coastal bird surveys are specified in this report, however assessment of effects on avifauna predominantly found in terrestrial or inland wetland habitats are outlined in the terrestrial or inland wetland assessment of effects reports respectively.

2.2 Assessment of ecological effects

An assessment of effects on marine ecology (Section 5) was carried out on the basis of the information above and the details of the details of the PPC. Our assessment covers the effects of the Land use change, and associated effects including stormwater and wastewater discharges and disturbance.

Our assessment of ecological effects follows the framework outlined in the Ecological Impact Assessment Guidelines (EcIAG) (Roper-Lindsay *et al*., 2018). These guidelines provide a systematic, consistent and transparent framework for undertaking assessments of effects, while also providing for professional judgement and flexibility where appropriate. Whilst these guidelines are designed for freshwater and terrestrial systems, we have broadly followed a version of the guidelines for marine systems developed by Boffa Miskell[4], and modified those further to apply to the current application.

[4] The characteristics of marine and estuarine sites with 'Negligible' to 'Very High' ecological values were originally developed by Dr Sharon De Luca, Boffa Miskell Ltd, then modified further here to provide a transparent approach that can be replicated. The characteristics have been accepted by decision-makers in Environment Court and Board of Inquiry hearings, including a number of NZTA projects (Transmission Gully, MacKays to Peka, Ara Tūhono Project Puhoi to Warkworth and Warkworth to Wellsford Sections). Table 2 in Appendix B of this report is based on the approach taken in

As outlined in the following sections, the guidelines have been used to determine:

- Step 1: 'Ecological value' (Volume 2: Appendix A; Table 2 and Table 8) of the site.
- Step 2: The 'Magnitude of Effect' on the environment (Volume 2: Appendix A; Table 4).
- Step 3: The overall 'Level of Effect' after recommended efforts have been taken to further avoid, remedy or mitigate for effects (Volume 2: Appendix A; Table 6).

2.2.1 Step one: Assigning ecological value

Ecological species values were assigned on a scale of **negligible** to **very high** based on species and habitat values using criteria in the EcIAG adapted for marine environments (see Volume 2: Appendix A; Table 2).

Ecological habitat values are assigned a level on a scale of **negligible, low, moderate, high or very high** based on assessing the value of marine habitats identified against criteria set out in Volume 2: Appendix A; Table 8.

2.2.2 Step two: Assessing the magnitude of effects

The 'Magnitude of Effect' is a measure of the extent or scale of the effect of an activity and the degree of change that it will cause after measures to avoid, remedy or mitigate for effects have been applied.

The 'Magnitude of Effect' after efforts to avoid, remedy or mitigate for effects, was assigned on a scale of 'Positive' to 'Very High' (Volume 2: Appendix A; Table 6) and was generally assessed in terms of:

- Spatial scale of the effect.
- The relative permanence of the effect.
- The intensity of the effect within the impact footprint.
- Timing of the effect in respect of key ecological factors.
- Level of confidence in understanding the expected effect.

2.2.3 Step three: Assessing the level of effects

An overall 'Level of Effect' on each value (after efforts to avoid, remedy or mitigate for effects) was identified for each activity or habitat/fauna type using a matrix approach. This approach combines the ecological values (described in Section 2.2.1 above) with the magnitude of effects (Section 2.2.2 above) resulting from the activity (Volume 2: Appendix A; Table 8).

The matrix describes an overall 'Level of Effect', after efforts to avoid, remedy or mitigate effects, on a scale from 'Net Gain' to 'Very High'. The 'Level of Effect' is then used to guide the extent and nature of measures to demonstrably offset and/or compensate for these residual effects.

It is considered necessary to address any 'Level of Effect' assessed as being 'Moderate' or higher through offsetting or compensation measures. However, any 'Level of Effect' deemed to be 'Very High' (if applicable) may not comply with the 'Limits of offsetting' principle[5] and therefore cannot be offset.

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these projects, and has been further developed with additional available indices to improve its use for the current consent applications.

[5] Limits to offsetting: Many biodiversity values cannot be offset and if they are adversely affected then they will be permanently lost. These situations include where: i) residual adverse effects cannot be offset because of the irreplaceability or vulnerability of the indigenous biodiversity affected ii) there are no technically feasible or socially

2.3 Determining residual effects management requirements

Determining the type and magnitude of marine habitat and enhancement measures to address residual effects associated with the proposed PPC that cannot be avoided, remedied or mitigated will be guided by the application of a Biodiversity Compensation Model (BCM) (Baber et al. 2021*a*,*b,c*) (see the Biodiversity Compensation Modelling Report). These models provide additional objective transparency, process and justification for the overall compensation package (Baber *et al*. 2021). In summary, BCMs:

- Provide guidance on addressing all residual adverse effects associated with a project for which impacts or gains cannot feasibly be measured or quantified with adequate precision and for which residual effects management is deemed appropriate when assessed against the 'limits to offsetting' principle.
- Serve as a decision support tool that provides additional transparency and rigour to the process of addressing residual adverse effects on biodiversity through compensation measures at proposed habitat restoration/enhancement site(s).
- Provide guidance on whether Net Gain (NG) outcomes are expected to be achieved for specified biodiversity values. Expected NG outcomes are sought, rather than No Net Loss (NNL) outcomes, to provide more confidence that NNL will actually be achieved.
- Operate at the 'as close to offset as possible' end of the compensation continuum. This is termed 'biodiversity compensation' in the Draft NPS-IB.
- Operate across the full spectrum and scale of project optioneering and plan change or consent applications.
- Can be later used to verify offsetting based on real data that is collected after the commencement of habitat restoration and enhancement activities at proposed offset/compensation sites.

acceptable options by which to secure gains within acceptable timeframes iii) effects on indigenous biodiversity are uncertain, unknown or little understood, but potential effects are significantly adverse. In these situations, an offset would be inappropriate. This principle reflects a standard of acceptability for offsetting and a proposed offset must provide an assessment of these limits that supports its success (Draft National Policy Statement for Indigenous Biodiversity, 2019).

3 Water Quality and Sedimentation Modelling Summary

Water quality and sedimentation modelling has been undertaken to identify potential effects associated with the Structure Plan and Plan Change during three (consecutive) stages of planned land development, being existing (baseline), during construction and following completion of the development (including the FUZ) (T+T, 2022).

To inform model inputs, ecological effects thresholds were used in the study[6], including:

- Deposition of sediment in the immediate aftermath of single events (Gibbs and Hewitt ,2004):
  - 20 mm thick, remaining for longer than five days.
  - 5 mm thick, remaining for longer than 10 days.
- Long-term (yearly to decadal) accumulation of sediment: 2 mm sediment accumulation per year above the natural annual sedimentation rate, which has been adopted by Australian and New Zealand Water Quality Guidelines (ANZECC, 2018) as a Default Guideline Value (DGV) for sedimentation.
- Metal (zinc and copper) accumulation in the surface mixed layer of the bed sediments, reported against the Auckland Council Environmental Response Criteria (ERC) "traffic light" system as described in TP168 (ARC, 2004).

The modelling report identifies five (5) main streams (labelled as A through E, north to south; refer to Figure 3.1) which discharge to the CMA from the site (T+T, 2022). Each stream proportionally contributes a discharge of sediment and contaminants to the marine receiving environment. Streams A, B and C are receiving environments for works within the Live Zone, and Streams C, D and E are receiving environments for works within the FUZ.

[6] These ecological effects thresholds are discussed in more detail in Section 5.2 Assessment of ecological effects

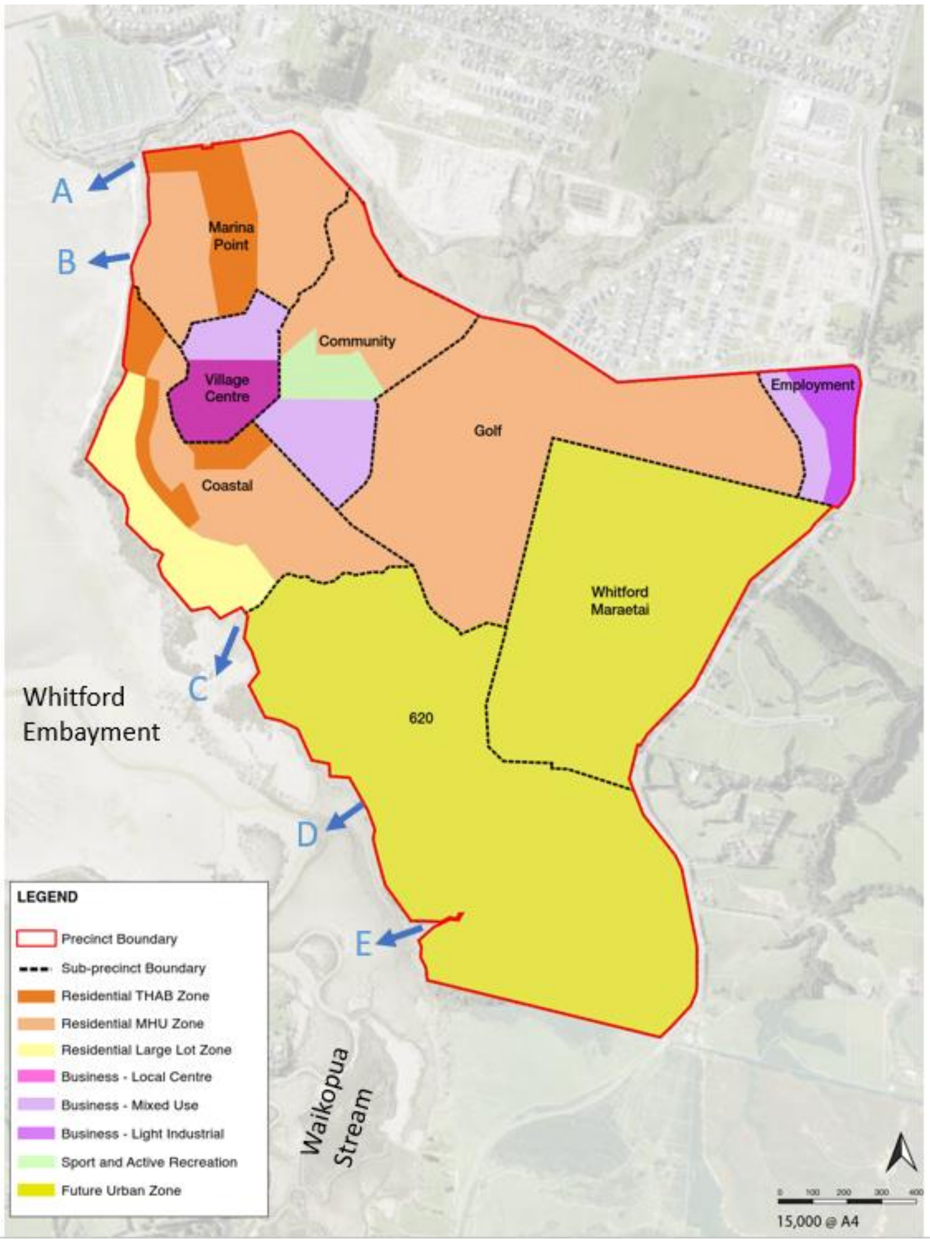

Figure 3.1: Location map of the existing site, with development extent outlined and stream discharge points A – E labelled.

The model further considers the probability of occurrence of a range of weather 'events', based on a 10-year development period, being:

- The 2-year ARI (Average Recurrence Interval) rainfall event (likely to occur five times within a 10-year development period);
- The 10-year ARI rainfall event (likely to occur once within a 10-year development period); and
- The 100-year ARI rainfall event (10% chance of occurrence within a 10-year development period).

For further details regarding model inputs, refer to the Water Quality and Sedimentation Modelling Report (T+T, 2022). Model outputs have been used to inform the ecological effects assessment in Section 5.

3.1 Model outputs

The modelled outputs cover two main stages of the overall development: the period during which earthworks will be conducted, and post-earthworks / construction, when the landscape is "developed".

3.1.1 During earthworks

During the earthworks phase, which includes certain levels of stormwater treatment, sediment runoff from the site will increase compared to sediment runoff from the existing landscape. The predicted increases are:

- 1 to 3 times for the 95^{th} percentile rainfall event (approximately heaviest rainfall event expected annually).
- 2 to 3 times for the 2-year ARI.
- 3 to 5 times for the 10-year ARI.
- 5 to 10 times for the 100-year ARI.

Modelling shows predicted sediment deposition thickness and the area over which deposition occurs to be particularly influenced by tidal range (spring/neap), and the stage of tide during which peak sediment discharge occurs for a rainfall event.

For the 100-year ARI event, the 20 mm threshold persisting from more than 5 days was exceeded only over areas less than 0.1 ha. The 5 mm threshold was exceeded over greater areas and persisted for more than 10 days (in the order of 3 to 4 ha in the upper intertidal area under a worst-case scenario).

For sediment discharged from streams A and B in a 100-year ARI event, worse case deposition occurred under spring tide conditions. A peak discharge over high tide had the potential for approximately 3 ha coverage of 5 mm or more in the upper intertidal area. Approximately 1 ha was similarly affected within the lower intertidal area at other times. No appreciable areas with more than 5 mm deposition were noted under neap-tide conditions. Winds that typically follow rainstorms are expected to gradually remove a portion of deposited material within 10 days, redistributing it within subtidal areas of the wider embayment.

For sediment discharged from streams C, D and E in a 100-year ARI event, largest deposition areas with more than 5 mm occurred over up to 3.5 ha under neap tide conditions, when tidal currents were higher (ebb/flood) enabling a greater spread of discharge material. At high tide, reduced currents enabled a more focused deposition in the upper inter-tidal vicinity of the discharge points resulting in comparably smaller areas exceeding the 5 mm threshold.

Sediment deposited in the vicinity of Waikopua Stream, where it is sheltered from winds and waves, is likely to remain in place. However, under neap tidal flow conditions, no appreciable areas with more than 5 mm of deposited sediment remained after 10 days.

A 2 - 3 times increase in sediment is predicted during construction for more frequent events such as 2-year ARI. Noting existing rates of sedimentation are as high as 3 mm/year, the potential exists for more than 2 mm of accumulated sediment above existing background rates during the construction period (taken indicatively as 10 years) in the vicinity of discharges C,D,E. These streams discharge to existing predominantly silty and muddy environments. Potential 2 -3 time increases in TSS over the relatively short duration of construction need to be considered in context with long term reductions in TSS by 64 % in its developed form.

3.1.2 Developed landscape

For the developed landscape, annual TSS (Total Suspended Solids, measured in tonnes) load is predicted to reduce by 64 % compared with loads under the existing landscape. Copper and zinc will accumulate, but metal concentrations within the surface mixed layer are predicted by the model to remain below the ERC amber threshold (19 mg/kg and 124 mg/kg for copper and zinc, respectively).

4 Marine Ecology Characteristics and Values

4.1 General marine environment

Jack Lachlan Esplanade Reserve is located adjacent to the Waikopua Creek and along the coastal margin to the west of the Formosa Golf Course at 110 Jack Lachlan Drive and the neighbouring property at 620 Whitford-Maraetai Road. The coastal area is part of the Hauraki Gulf Marine Park and comprises three distinct tidal creeks (Waikopua, Turanga and Maungamaungaroa Creeks) which are identified as being regionally and nationally significant (refer to Figure 4.1 below). The Waikopua Creek is nearest the site (refer to Photograph 4.1 below). The three tidal creeks discharge into the Whitford embayment, a drowned valley estuary, which is approximately 11.1 km^2, with a mean tidal range of 2.4 m and a catchment area of 61 km^2 (Thrush *et al*., 2003).

Four Significant Ecological Areas - Marine (SEA-M) are recognised by the AUP. These include, SEA-M2-43a, SEA-M1-43c, SEA-M1-43w4 and SEA-M2-43w1 (refer to Table 4.4 and Volume 2: Appendix A; Figure 1).

Turanga Creek is the largest estuarine habitat (including mangrove shrubland ecosystems), in the Hunua Ecological District and provides a complex of intertidal mud, sand and shell flats. The intertidal banks are a very rich feeding ground and important mid-tide roost for a variety of international migratory and New Zealand endemic wading birds including a number of threatened species. A large shellbank at the Waikopua Creek mouth is used as high tide roost by birds. Moderate numbers of wading birds roost on the shellbanks including godwit, South Island pied oystercatcher, whimbrel, reef heron, variable oystercatcher and banded dotterel. The length of coastline adjacent to the site is recognised as an extensive area of feeding habitat for wading birds.

A number of sites within Waikopua estuary have been monitored for sediment quality and benthic health by Auckland Council since August 2004. Originally 10 sites were monitored annually, which was reduced to four sites in 2014 to enable sites to be sampled six-monthly. Waikopua estuary monitoring sites have displayed trends consistent with increased sedimentation since monitoring began including increased percentages of very fine sands/mud and decreasing number of taxa identified in fauna samples.

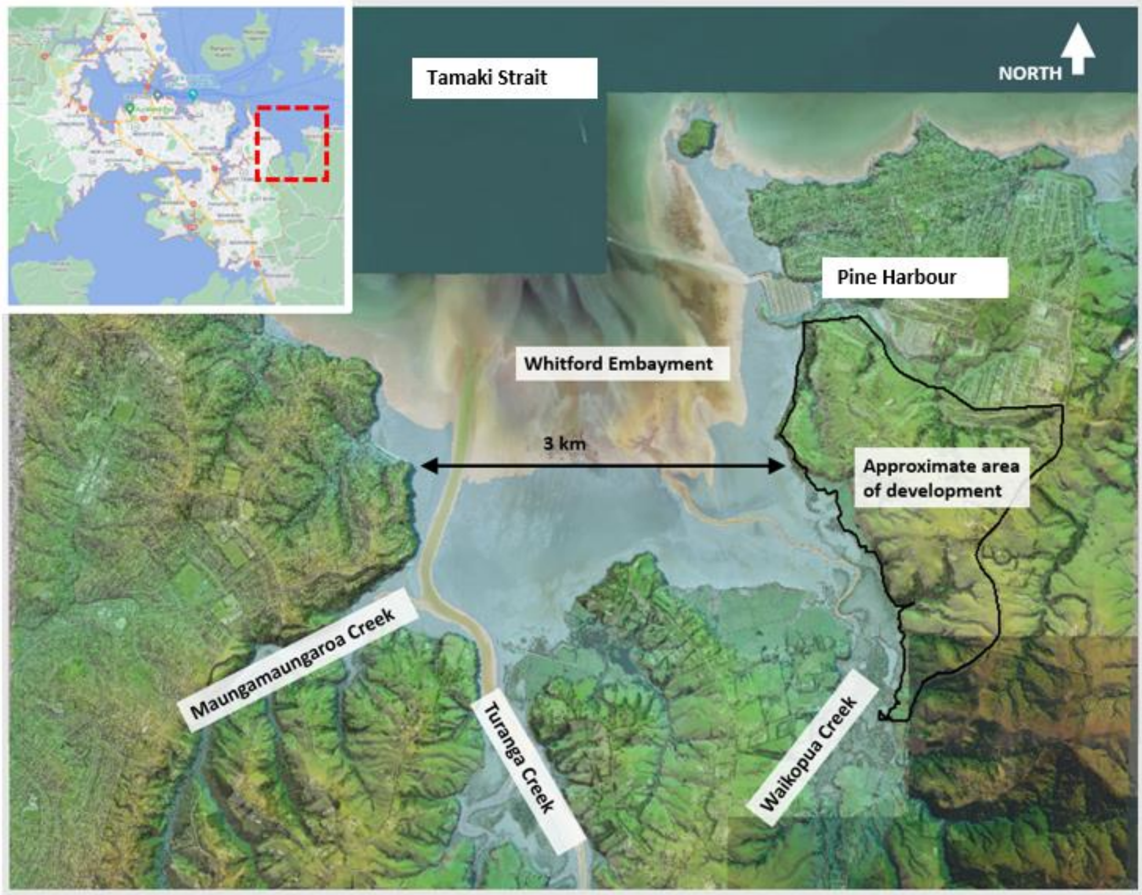

Figure 4.1: Map of the Whitford Embayment

Photograph 4.1: Coastal Marine Area (CMA) adjacent to the site and facing south. Waitemata sandstone reef habitat in foreground, high tide beach along the coastal margin and intertidal flats towards the sub-tidal.

4.2 Habitat mapping

The habitats and species observed within the areas surrounding the project footprint during the site walkover and intertidal surveys are described in Sections 4.2.1 to 4.2.8 below and locations are mapped in Volume 2: Appendix A; Figure 2.

4.2.1 Subtidal channel

The Waikopua Creek subtidal channel ranges from approximately 5 m in width at the Mean High Water Spring (MHWS) to approximately 30 m at the mean low water spring (MLWS). While no quantitative data was collected within the sub-tidal channel, the sediments are likely to support a low diversity biota comprising polychaetes, oligochaetes, amphipods and mud crabs as is typical of these habitats (Hayward *et al*., 1999). The subtidal channel is an important migration pathway for fish and provides some foraging habitat for birds feeding in the water column.

4.2.2 Seagrass beds

Approximately 78.1 ha of intertidal and subtidal seagrass beds are present within the zone of influence within Waikopua estuary. Seagrass cover within the intertidal zone is not continuous but is present in patches across the mid-low intertidal areas, as observed during site survey and from aerial imagery.

Substrate around seagrass beds tends to be softer than surrounding areas due to the accumulation of fine sand and silt amongst the root systems. The most common organisms found in seagrass beds are crustaceans including mud crabs (*Helice crassa*, *Hemigrapsus crenulatus* and *Macrophthalmus hirtipes*) and shrimps, as well as small snails and sometimes bubble shells (e.g. *Haminoea zelandiae*). Infauna living beneath seagrass beds are typically wedge shells (*Macomona liliana*) and cockles (*Austrovenus stutchburyi*).

The extent of seagrass beds in Auckland and nationwide have rapidly declined since and continue to be threatened due to anthropogenic impacts such as sedimentation influencing water clarity and quality.

Locally, a 2009 NIWA study concluded that 'seagrass habitat is absent from the Whitford Embayment' (NIWA, 2009). While it can be difficult to determine seagrass extent from aerials alone[7], more recent aerials captured in 2017 and 2021 indicate an increase in the cover of seagrass habitat in the embayment, indicating that this habitat type is currently in a period of recovery.

4.2.3 Firm muddy sand / cockle covered sandflats

Firm muddy fine sand flats are common in the Auckland region and are highly productive. Sand flats support high diversity of intertidal organisms dependent on tidal level, including bivalves (i.e. shellfish), gastropods and polychaete worms (Hayward *et al*., 1999).

A large proportion of the intertidal area in the Waikopua estuary consists of firm muddy sand flats; 112.2 ha of firm muddy sand flats was mapped in the immediate marine receiving environment adjacent to the site[8]. Sites 1 - 6 were located in firm muddy sand flat habitat.

4.2.4 Shellbanks

Cockle shell banks are created by the accumulation of dead cockle shells carried landward on incoming tides. Typically, shell banks found between mid and high tide levels are inhabited by few, if

[7] Dependent on image quality and the stage of the tidal cycle during which imagery is captured.
[8] Noting that this area does not include firm muddy sand flats for the entire Whitford Embayment.

any species, however they can support chitons, limpets and snails (Hayward *et al*., 1999). If clear of vegetation, they can also provide important roosting habitat for coastal birds.

Two large shell banks (the Waikopua shellbanks) (0.8 ha) are located at the Waikopua Creek mouth, adjacent to the site and are classified as an SEA-M1 (refer to Figure 4.2). Currently the shell banks include low-lying salt tolerant species, such as glasswort, oioi, ribbonwood, and sea rush (wiwi). However, non-native species including needle grass and pampas were also observed growing on the shell banks. Young mangrove trees are also encroaching on the shell banks in several locations.

Additional shell banks are present within the Whitford embayment, including north of the site near Motukaraka Island and at Porterfield Road Esplanade Reserve at the mouth of Turanga Creek.

Figure 4.2: Left photo shows cockle shell bank with overlying vegetation (mix of native and exotic species). Right photo shows sandstone reef, including encrusting oysters.

4.2.5 Sandstone reef

Sand and siltstone belonging to the Waitemata Group are often referred to as Waitemata sandstone. A large area (7.06 ha) of sandstone reef habitat is present underneath sandstone cliffs in the upper intertidal zone, immediately adjacent to the western boundary of the site.

Sandstone reefs generally support a diverse species assemblage including sea snails, seaweeds, sponges, crabs and shrimps, bivalves, polychaete worms, amphipods, chitons, echinoderms, sea squirts, barnacles, anemones and fish. Within sandstone reefs, there are distinct tidal zonation patterns, with species such as periwinkles (*Nodillittorina antipodum*) observed at the high tide mark, and seaweeds and sponges inhabiting the lower intertidal zone.

Qualitative observations while at the site included identification of the encrusting rock oyster (*Saccostrea glomerata*), whelks (*Cominella sp*), barnacles, chitons, top shells, anemones and horn snails (*Zeacumantus sp*).

4.2.6 Mangroves

Mangrove forests in New Zealand are characterised by a single species (*Avicennia marina*). In the vicinity of the site, young mangrove trees and seedlings were observed around the shellbanks, with larger, mature trees located further up the Waikopua Creek. Smaller stature mangroves were also observed adjacent to the rock revetment alongside the Pine Harbour marina.

Sediment characteristics found within mangrove forest habitats typically support high densities of mud crabs (*Helice crassa*), mud snails (*Amphibola crenata*), horn shells (*Zeacumantus lutulentus*) and top shells (*Diloma subrostrata*). An area of approximately 45.9 ha of mangrove vegetation has been mapped in the immediate marine receiving environment of the site, and as shown in Volume 2: Appendix E.

Based on historical aerial imagery, it is apparent that there has been approximately 2.6 ha of additional mangrove growth seawards from the Waikopua Creek since the early 1960s (see Figure 4.3 below for spatial extent).

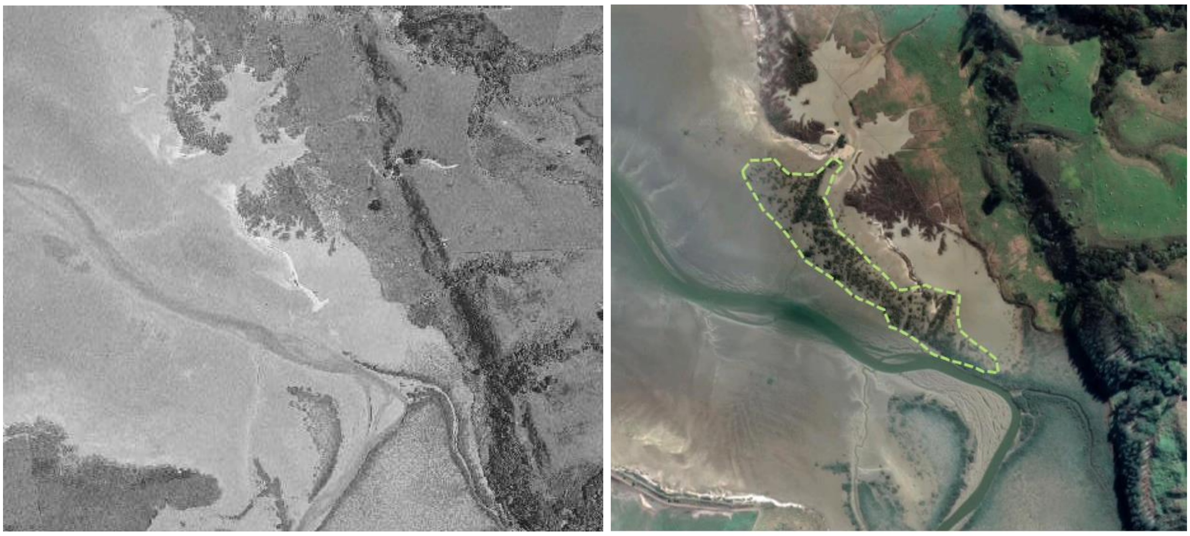

Figure 4.3: Left photo shows mangrove extent in 1961. Right photo shows current day extent of mangroves and mangrove expansion in Waikopua Creek (delineated in green polygon).

4.2.7 Saltmarsh and saltmeadow

Saltmarsh and salt meadow habitats generally span high tide fringes and consist of a variety of rushes and sedges (saltmarsh) as well as common salt meadow species including glasswort, sea primrose and bachelor's button. Biota that typically inhabit saltmarsh and salt meadow habitats include mud crabs (*Helice crassa*) and mud snails (*Amphibola crentata* and *Potamopyrgus estuarinus*).

A range of saltmarsh and salt meadow habitat was present in patches close to the high tide level, and adjacent to terrestrial vegetation. Saline vegetation located behind shellbanks at the coastal wetland site also comprised a number of exotic species including pampas (*Cortaderia selloana*).

4.2.8 Soft gloopy mud

Soft gloopy mud habitat is typically found in the upper arms of estuaries. Fauna diversity is relatively low within intertidal soft gloopy mud habitats due to the shallow redox later; species inhabiting these areas are typically limited to mud crabs (*Helice crassa*) and mud snails (*Amphibola crenata*). Soft gloopy mud habitats originate as a result of increased sediment inputs from upstream, typically related to earthworks, erosion, intensive Land uses (such as horticulture) or vegetation clearance.

This habitat type was identified adjacent to the Waikopua Creek sub-tidal channel towards the southern extent of the site.

4.2.9 Rock revetment

A rock revetment wall runs the length of northern section of Jack Lachlan Drive Esplanade, near Pine Harbour Marina. Rock revetment structures can support a range of encrusting species, depending on tidal influence. Pacific encrusting oysters were observed on the lower extents of the rock revetment.

4.3 Water quality

There are no Auckland Council water quality monitoring sites in Waikopua Creek or the wider Whitford embayment. We reviewed results for the Auckland Council estuarine monitoring site at the mouth of the Wairoa River (in the Tamaki Strait). This is the closest monitoring location to the site and is located around the coastline to the east (approximately 20 km), with a similar catchment Land use to Waikopua Creek (predominantly rural).

With regards to water quality index categories used by Auckland Council, water quality at the Wairoa River estuarine sampling site is within the 'fair' range, meaning that water quality is usually protected but occasionally threatened or impaired (Ingley, 2020). Scores within this range suggest that there is some departure from natural or desirable water quality conditions. Water Quality Index scores have decreased at the Wairoa River site, from 90.3 ('good') for 2014-2016 data to 69.0 ('fair') for 2017-2019 data. The decline has mainly been associated with increases in ammoniacal nitrogen, chlorophyll *a* and total oxidised nitrogen exceedances.

Water quality results from the Wairoa River estuarine monitoring site in 2019 are presented and compared against Auckland Council Estuary Guidelines for the Auckland region in Table 4.1 below.

While there is no available water quality data for the Whitford embayment, the results from the Wairoa River can be used as an indicator of the potential water quality in the embayment, noting however that the results should be viewed with a level of conservatism (i.e. the actual water quality could be better or worse).

Table 4.1: Minimum, median and maximum water quality results taken between January 2019 and December 2019 at Wairoa River monitoring site and Auckland Council Estuary water quality guidelines

Water Quality Parameter	Wairoa River estuarine monitoring site			Auckland Council Estuary Guideline
	Minimum	Median	Maximum	
Dissolved oxygen (%)	92.1	97.4	101.5	90-110
Turbidity (NTU)	2.8	4.5	56	<10
Chlorophyll a (mg/L)[1]	0.0005	0.0019	0.0071	<0.0031
Soluble reactive phosphorus (mg/L)	0.008	0.016	0.021	<0.021
Nitrite N (mg/L)[1]	0.0005	-	0.0025	-
Nitrate N (mg/L)[1]	0.0005	-	0.320	-
Nitrite + Nitrate (mg/L)	-	-	-	<0.029
Ammoniacal nitrogen (mg/L)	0.01	0.014	0.0470	<0.015
TKN (mg/L)	0.138	0.169	0.520	-
Total nitrogen	0.138	0.178	0.84	-
Total phosphorus (mg/L)	0.021	0.032	0.076	-
Suspended sediment	6	17.2	50	-
Electrical conductivity	43.15	49.5	53.15	-
Salinity	27.76	32.36	35.11	-
pH	7.96	8.12	8.31	-
Temperature	12.9	17.2	23	-

1 - More than 50 % of samples were below laboratory detection limit

4.4 Sediment quality

4.4.1 Total recoverable copper, lead and zinc

Heavy metals (including total recoverable copper, lead and zinc) are common stormwater contaminants and have the potential to be toxic to aquatic organisms. Stormwater contaminants also tend to increase with development and increases in impervious surfaces. Total recoverable copper, lead and zinc concentrations in sediment samples were low across all sites and all fell well below the Auckland Council ERC green threshold (refer Figure 4.4 below).

Total recoverable copper concentrations ranged from 1.1 to 2.74 mg/kg dry weight, the lowest concentration was recorded at Site 3 and highest at Site 8. Total recoverable lead concentrations ranged from 2.17 to 5.03 mg/kg dry weight, the lowest concentration was recorded at Site 3 and highest at Site 8. Total recoverable zinc concentrations ranged from 12.5 to 19 mg/kg dry weight, the lowest concentration was recorded at Site 3 and highest at Site 8.

Overall, the receiving environment has good sediment quality with regards to heavy metal contaminants. Site 8 has the highest concentrations of total recoverable copper, lead and zinc, this is likely as it is closest to the Waikopua Creek channel which carries land derived contaminants to the coast.

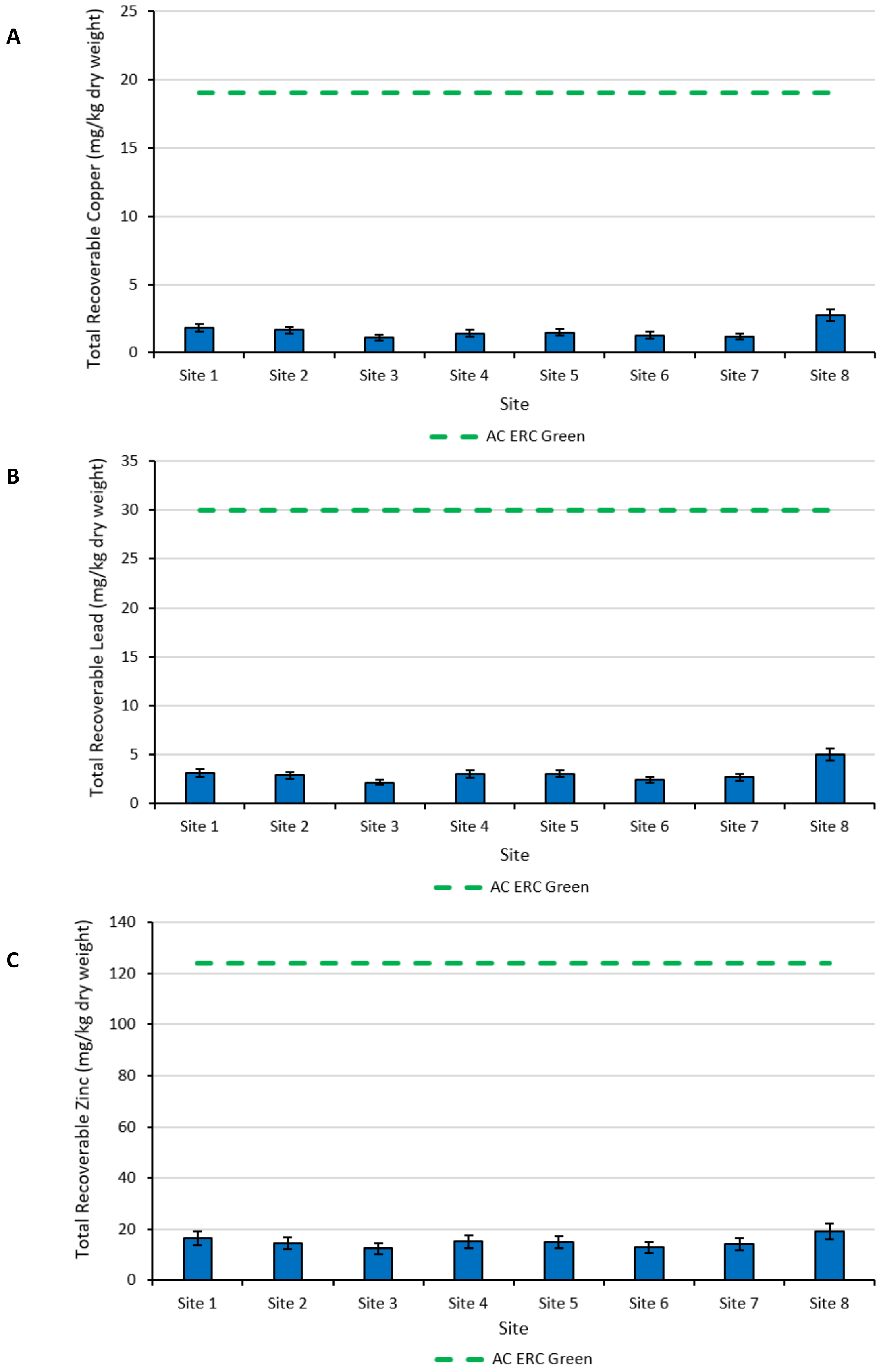

Figure 4.4: Total recoverable copper (A), lead (B) and zinc (C) in sediment samples collected at Sites 1 - 8 in the Waikopua estuary in February 2021. Error bars display the uncertainty values provided by the processing laboratory. Green dashed line indicates Auckland Council ERC green threshold.

4.4.2 Chlorophyll *a* and Pheophytin *a*

Elevated concentrations of chlorophyll *a* can reflect an increase in nutrient loads and increasing trends can indicate eutrophication of aquatic ecosystems. Pheophytin *a* is sampled alongside chlorophyll *a* as it is a common degradation product of, and can interfere with the determination of, chlorophyll *a*.

Chlorophyll *a* and pheophytin *a* concentrations varied across Sites 1 - 8 (refer Figure 4.5 below). Generally, Chlorophyll *a* and pheophytin *a* concentrations were well correlated. The greatest chlorophyl *a* and pheophytin *a* concentrations were recorded at Site 8 (10.7 and 6.5 mg/kg respectively). Site 3 recorded the lowest chlorophyll *a* and pheophytin *a* concentrations (4.4 and 2.4 mg/kg respectively).

Sites 5 – 8 have higher Chlorophyll *a* concentrations than Sites 2 – 4 which are situated to the east of the embayment, this may be because Sites 5 – 8 are closer to the Waikopua Creek channel and more affected by nutrient enriched discharges. Site 1 also has slightly higher Chlorophyll *a* concentrations than Sites 2 – 4 which may be because it is near another discharge channel of an unnamed stream.

Chlorophyll *a* concentrations measured at Auckland Council sites are similar to those recorded at the eight sites established for this Project.

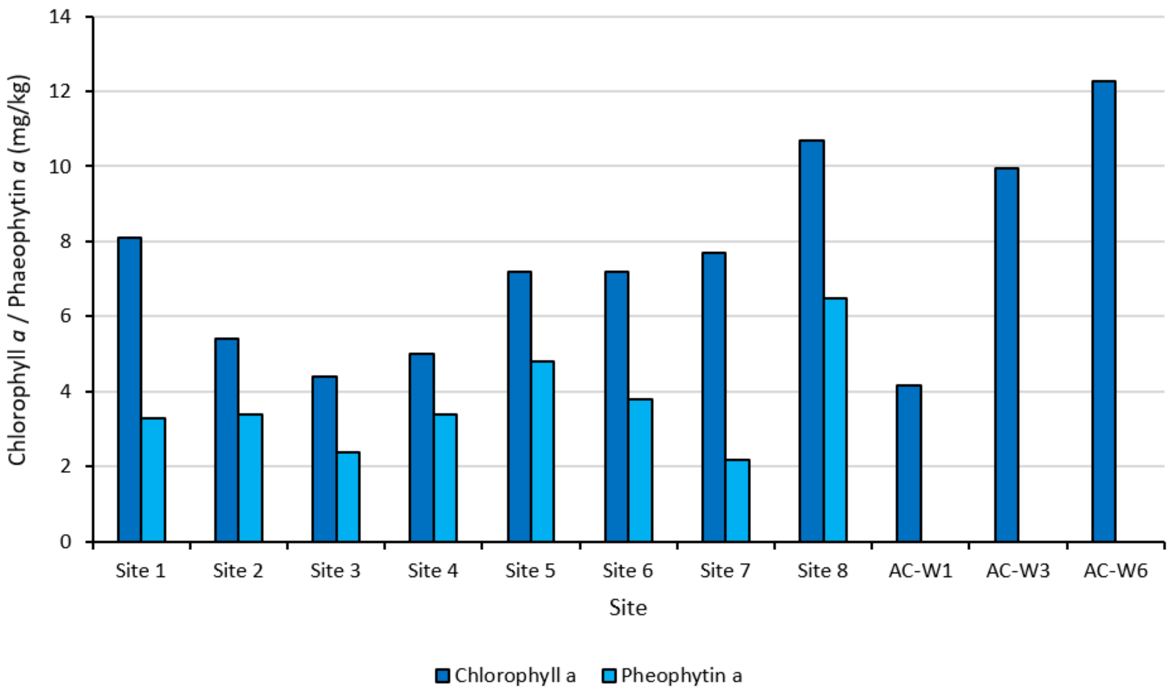

Figure 4.5: Chlorophyll a and Pheophytin a concentrations in sediment samples collected at Sites 1 - 8 in the Waikopua estuary in February 2021, alongside Auckland Council Waikopua estuary sites (sampled May 2019).

4.4.3 Sediment particle size

Sediment particle size analysis conducted on samples from Sites 1 - 8 is presented in Figure 4.6 below. Data for samples collected from Auckland Council sites is presented in Figure 4.7 below but utilises slightly different size classes. As silt and clay particles are combined for Auckland Council data, there is less information provided about the particle size distribution below 63 µm. However, for Sites 1 - 8 we can differentiate between the proportions of clay, very fine silt, fine silt, medium silt and coarse silt.

Sediment particle size distribution differed slightly from Site 1 - 8 (refer Figure 4.6 below). Sediment samples at all sites were predominately sand (66.2 - 97.4 %) with smaller proportions of silt (2.05 – 24.89 %) and clay (0.6 – 8.89 %). Site 8 had the smallest proportion of sand while Site 3 had the greatest proportion of sand. Following further size class divisions the sand portion was predominantly fine (28.5 – 59.8 %) and very fine (29.2 – 53.6 %) sands. Sites 1 and 2 appear to have similar sediment composition, as do Sites 4, 5 and 6. The proportion of clay present in sediment samples was low (< 3.5 %) for all sites except Site 8.

Auckland Council Waikopua estuary sites show similar particle size distributions to Sites 1 - 8, with all samples predominately sand (refer Figure 4.7 below). Sites Waikopua 3 and Waikopua 6 were dominated by very fine sands (51.4 – 55.8 %) while Waikopua 1 was dominated by fine sand (83.0 %). Waikopua 6 had the greatest proportion of muds (< 63 µm), followed by Waikopua 3 and Waikopua 1.

The results show that the sites to the north of the embayment (Site 1 and 2) comprise coarser material that transitions towards greater proportions of fine material (clay and silt) present at sites near the Waikopua Creek channel. The higher proportions of fine material at sites near the channel may be due to land derived sediment reaching the coast.

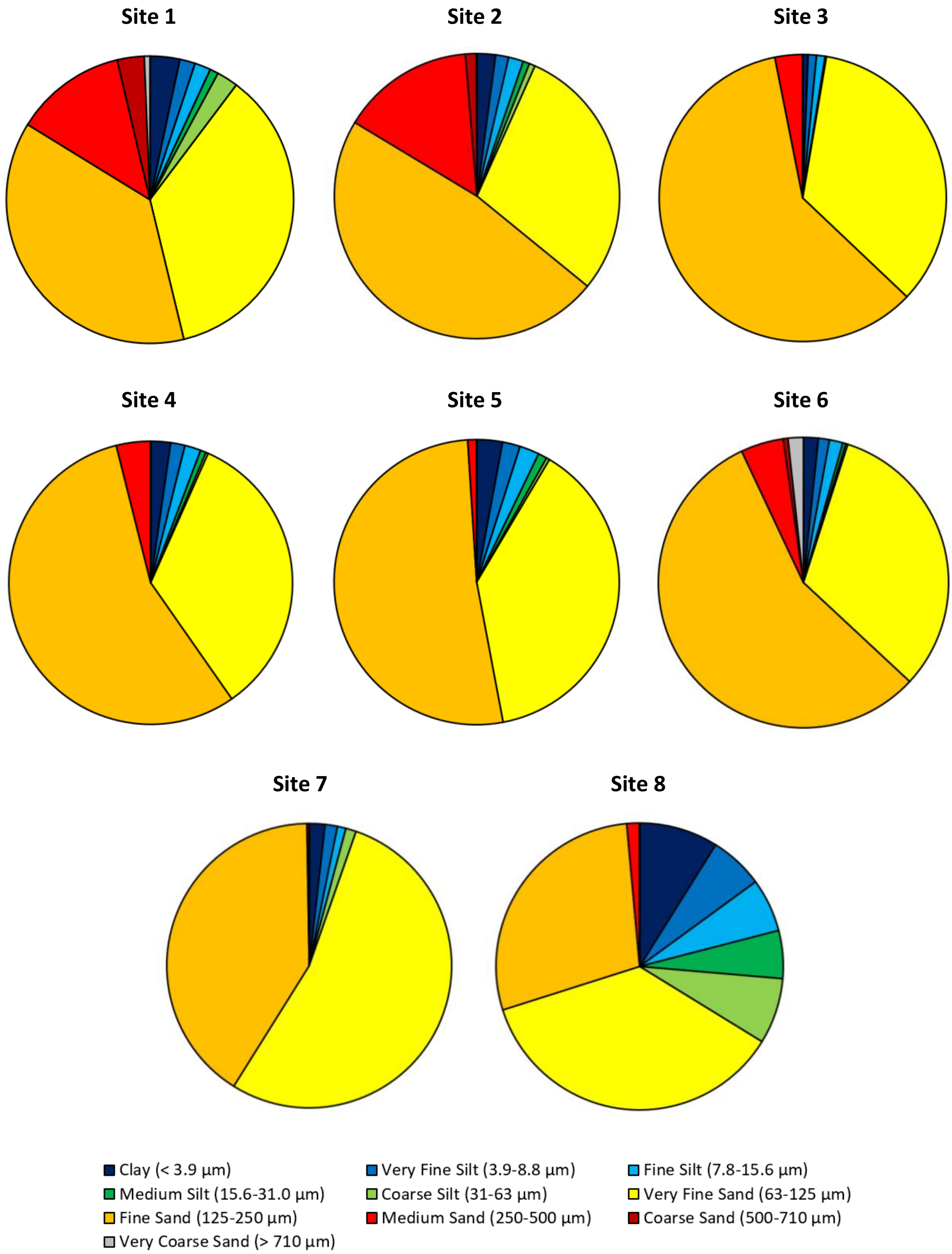

Figure 4.6: Pie charts showing percentage of sediment within each grain size class for sediment samples collected at Sites 1-8 in February 2021.

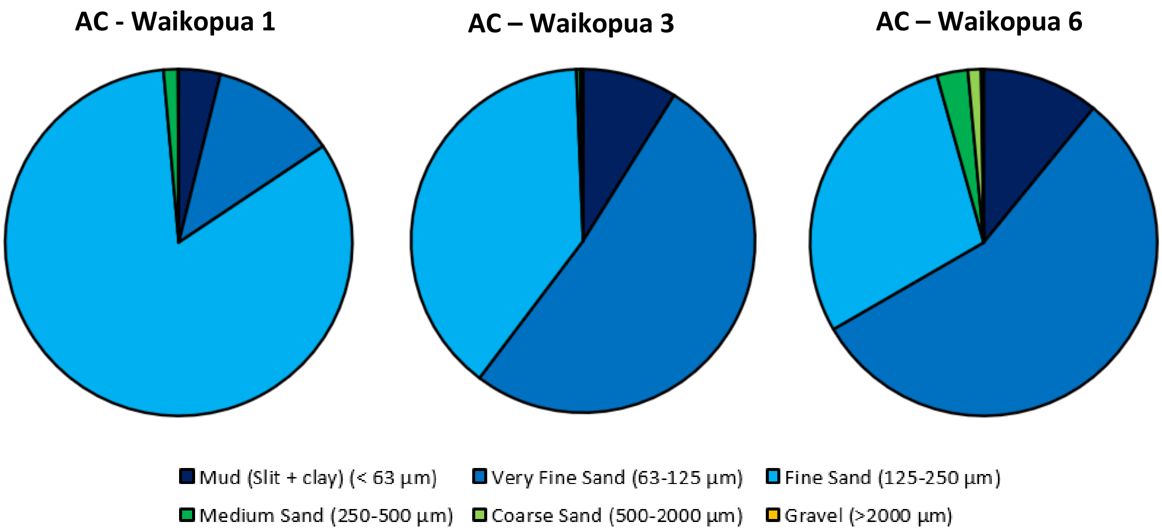

Figure 4.7: Pie charts shows percentage of sediment within each grain size class for sediment samples collected at Auckland Council Waikopua estuary (sampled May 2019). Note: size classes used vary from the classes used for Sites 1-8 above.

4.5 Benthic ecology

4.5.1 Benthic epifauna and epiflora

Key summary metrics calculated on the observed benthic epifauna show some variation between sites (refer Figure 4.8 below). The mean number of individuals observed within epifauna quadrats ranged from 6.0 at Site 7 to 58.4 at Site 8. Site 8 is heavily influenced by the large number of biopores observed (which is used as a proxy for mud crabs). The mean number of taxa observed within epifauna quadrats ranged from 1.6 at Site 8 to 6.6 at Site 6. Sites 1 to 5 appear similar (ranging from 4.2 to 5.4). Site 5 has the most within-site variability, with variation at least 30 % greater than all remaining sites (Standard deviation = 2.49). The mean Shannon Weiner Diversity Index ranged from 0.05 at Site 8 to 1.44 at Site 3 and the mean Shannon Weiner Evenness Index ranged from 0.05 at Site 8 to 0.90 at Sites 4 and 5.

There was little spatial variation in the number of taxa and diversity measured at Sites 1 – 5. Number of taxa and diversity scores at Sites 7 and 8 were lower, and this is likely due to the higher mud (clay and silt) content closer to the Waikopua Creek channel which is unsuitable for a number of the epifauna species present at other locations.

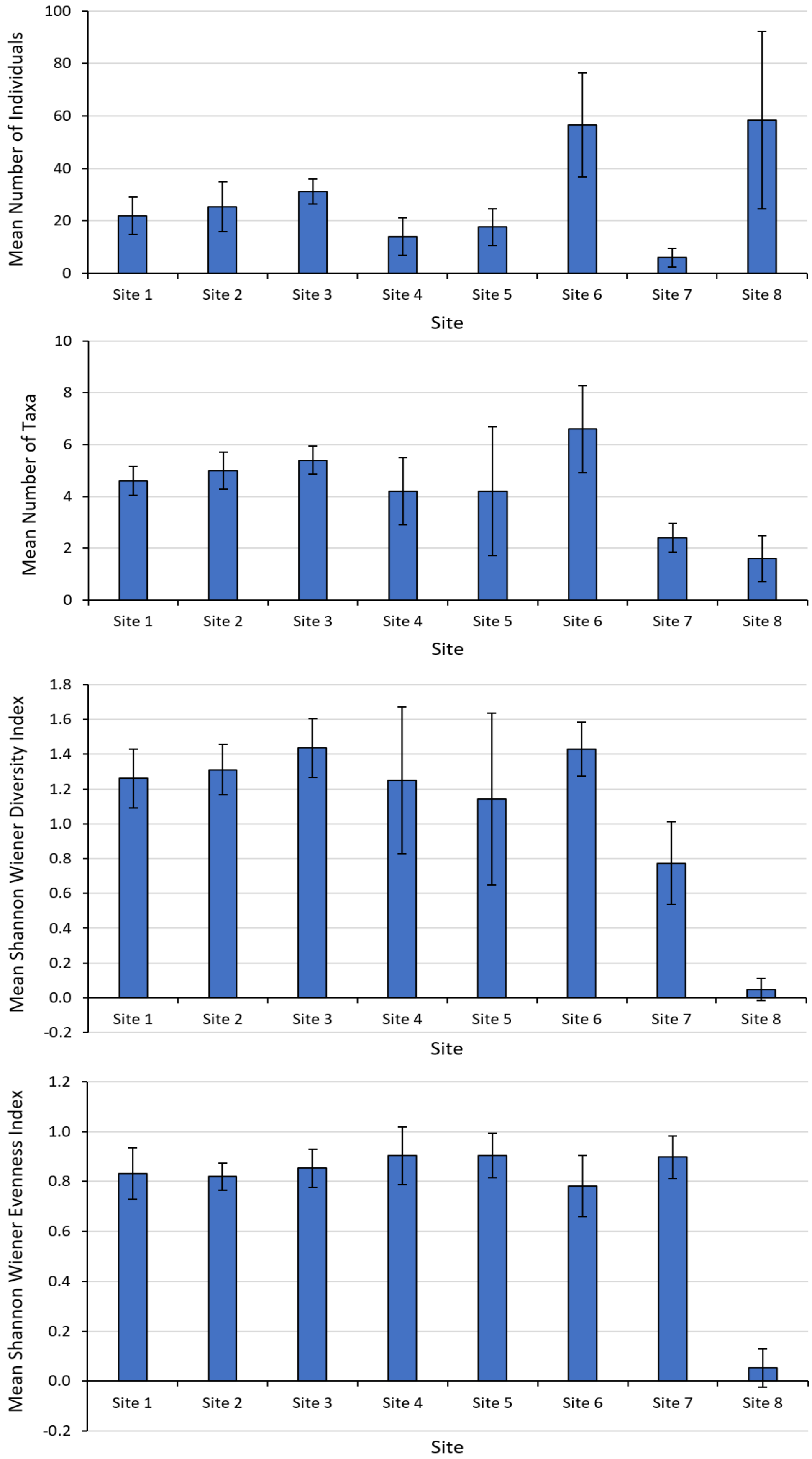

Figure 4.8: Summary graphs (mean number of individuals, mean number of taxa, mean Shannon Weiner Diversity and mean Shannon Weiner Evenness scores) for benthic epifauna species observed in sampling quadrats at Sites 1 - 8 in the Waikopua estuary in February 2021.

Observed epifauna species composition varied between sites (refer Figure 4.9 below). The most commonly observed species included barnacle (*Elminius modestus*), top shell (*Diloma subrostrate*), limpet (*Notoacmea helmsi),* horn shell (*Zeacumantus lutulentus*) and whelk (*Cominella glandiformis*).

Site 8 was dominated by biopores, which are considered a proxy measure for mud crabs (*Helice crassa*). Mud crabs were only observed at Sites 3 and 8, however biopores were noted at all sites except Sites 1 and 7. Tube worm (*Spirobranchus carinferus*) and chiton (*Chiton glaucus*) were only observed at Site 6.

None of the species observed are considered 'Threatened' or 'At Risk' in the threat classification of marine invertebrates, however this threat classification does not assess all species observed (Freeman *et al.,* 2014)[9].

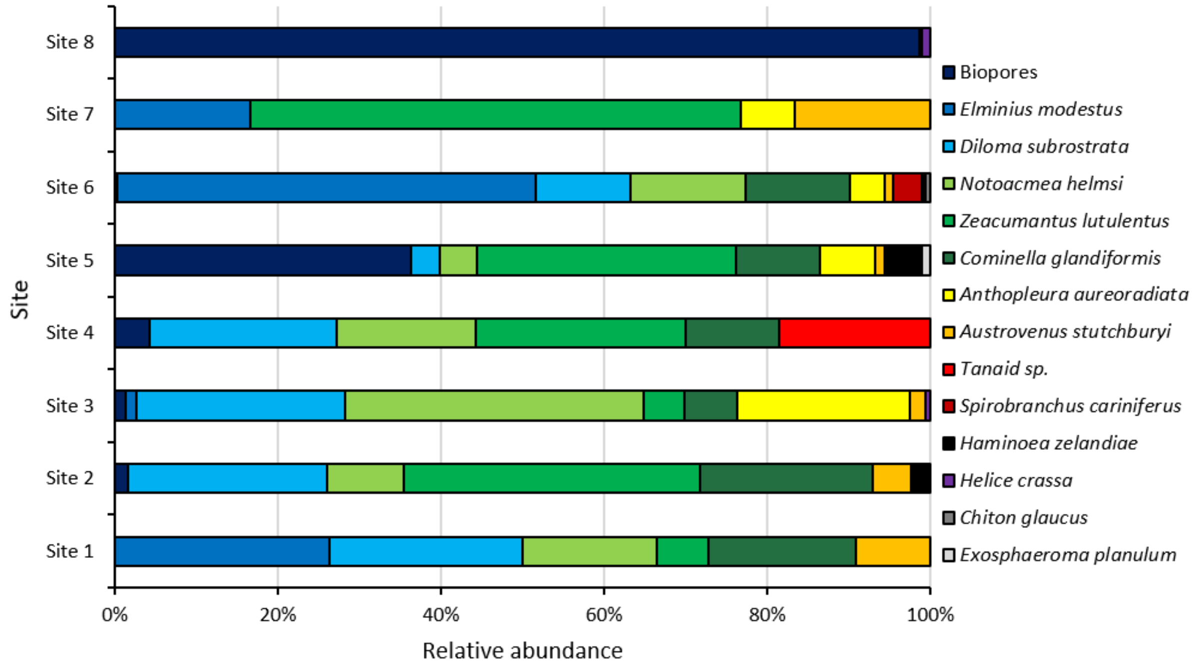

Figure 4.9: Relative abundance of benthic epifauna species observed in sampling quadrats at Sites 1 - 8 in the Waikopua estuary in February 2021.

4.5.1.1 Seagrass cover

Seagrass (*Zostera muelleri*) was observed at a number of sites, including within surveyed quadrats. The average percentage cover of seagrass varied across sites and is presented in Table 4.2 below. Some areas of high seagrass cover was observed at Site 4 (quadrats ranged from 0 – 85 %), some moderate seagrass cover was observed at Site 3 (0 – 55 %) and relatively low cover observed at Site 5 (0 – 15 %).

Zostera muelleri is classified as 'At Risk – Declining' under the New Zealand Threat Classification System (NZTCS) and is impacted in urban and semi-urban receiving environments due to anthropogenic inputs, including sediment and nutrients, with extensive distribution decline recorded in recent years (De Lange *et al*., 2017; Matheson *et al*., 2011).

[9] This threat classification includes <95 % of marine invertebrates in New Zealand.

Table 4.2: Average seagrass cover within surveyed quadrants at Sites 1 – 8 in the Waikopua estuary in February 2021.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Mean seagrass cover (%)	0	0	12	17	3	0	0	0

4.5.2 Benthic infauna

Key summary metrics calculated on the benthic infauna assemblages show variation between sites (refer Figure 4.10 below):

- The mean number of individuals in infauna samples ranged from 24 at Site 8 to 340 at Site 6. The three Auckland Council sites within Waikopua estuary (AC – W1, AC – W2 and AC – W3) fit within this range (97 – 110).
- The mean number of taxa in infauna samples ranged from 6 at Site 8 to 23 at Site 6. The three Auckland Council sites with Waikopua estuary fit within this range (15 – 20).
- The mean Shannon Weiner Diversity Index ranges from 1.3 at Site 8 to 2.4 at Site 4. Auckland Council Site 1 (AC – W1) and 3 (AC – W3) lie within this range (2.4 and 1.9, respectively). Auckland Council Site 6 (AC – W6) lies outside this range with a Shannon Weiner Diversity Index of 0.3 which is considerably lower than any of the 8 sites sampled in February 2021.
- The mean Shannon Weiner Evenness Index ranges from 0.6 at Site 6 to 0.8 at Site 4. Similar to the Diversity Index, the Evenness Index at Auckland Council Site 6 is much lower than all other sites (0.08).

There was little spatial variation in the number of taxa and diversity measured at Sites 1 – 6. The number of taxa and diversity scores at Sites 7 and 8 were comparatively much lower than Sites 1- 6, and this is likely due to the higher proportion of fine sediment (clay and silt) closer to the Waikopua Creek channel which is unsuitable for a number of infauna species.

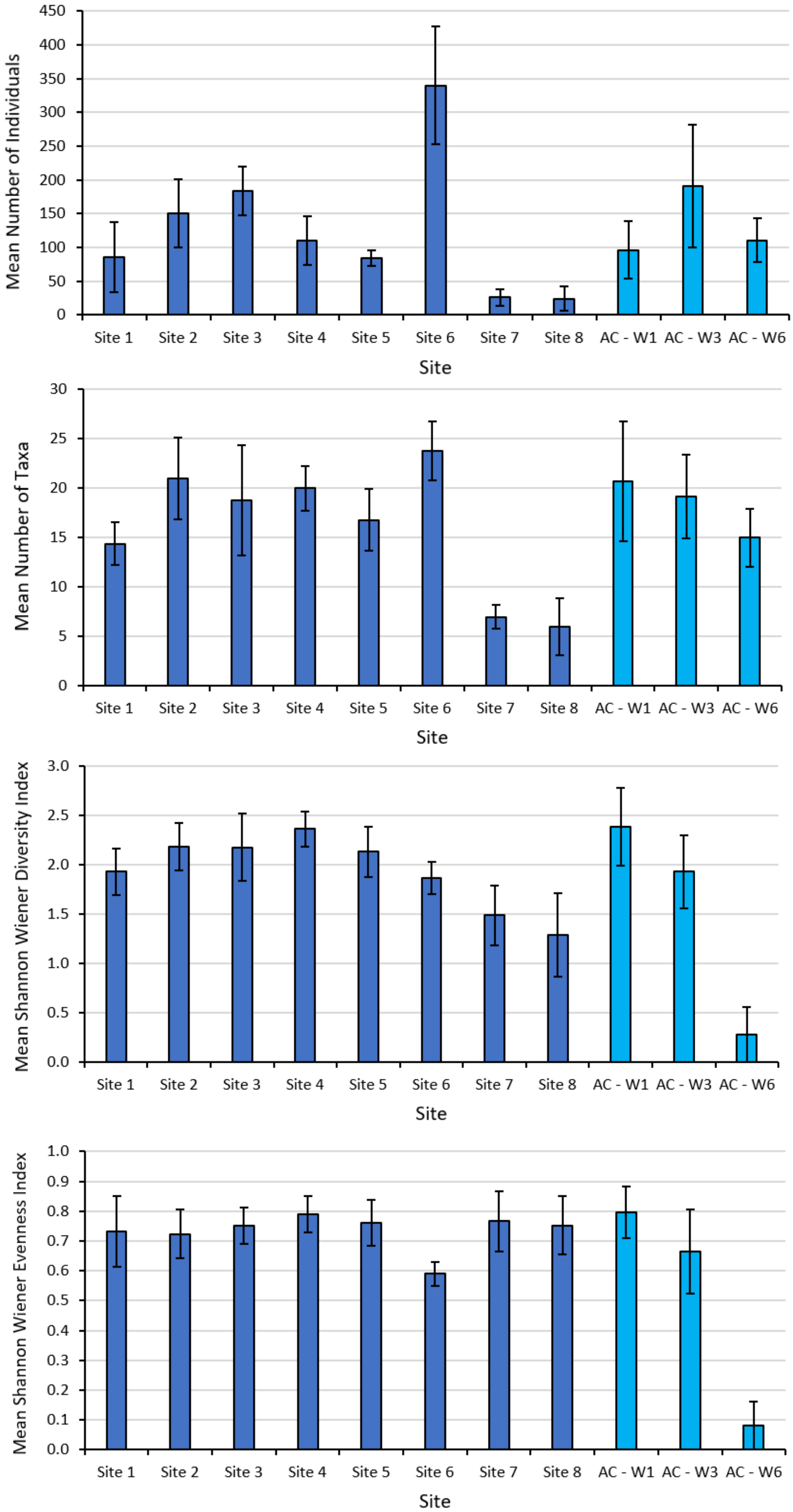

Figure 4.10: Summary graphs (mean number of individuals, mean number of taxa, mean Shannon Weiner Diversity and mean Shannon Weiner Evenness scores) for benthic infauna samples collected from Sites 1-8 in the Waikopua estuary in February 2021, alongside Auckland Council Waikopua estuary sites (sampled May 2019).

Species composition varied between sites (refer Figure 4.11 below). The dominant group at Sites 1 – 6 were polychaetea (35.6 – 59.7 %), bivalvia at Site 7 (58.0 %) and oligochaeta at Site 8 (50.8 %). The highest proportion of gastropods were found at Sites 2 and 3. The highest proportion of decapoda taxa were found at Site 8. Auckland Council sites were similar in composition to the eight sites surveyed for this Project, with polychaetea dominating Site 1 (AC – W1) and Site 3 (AC – W3). Site 6 (AC – W6) was dominated by amphipoda taxa which was influenced by a high presence of *Melita awa*.

Relative abundance of different taxa groups appears similar across Sites 1 – 6. Sites 7 and 8 show some differences with high relative abundance of oligochaeta taxa (worms) at Site 8 and high relative abundance of bivalvia at Site 7, however there are low number of taxa present at these sites.

None of the species identified are considered 'Threatened' or 'At Risk' in the threat classification of marine invertebrates, however this threat classification does not assess all species observed (Freeman *et al.,* 2013).

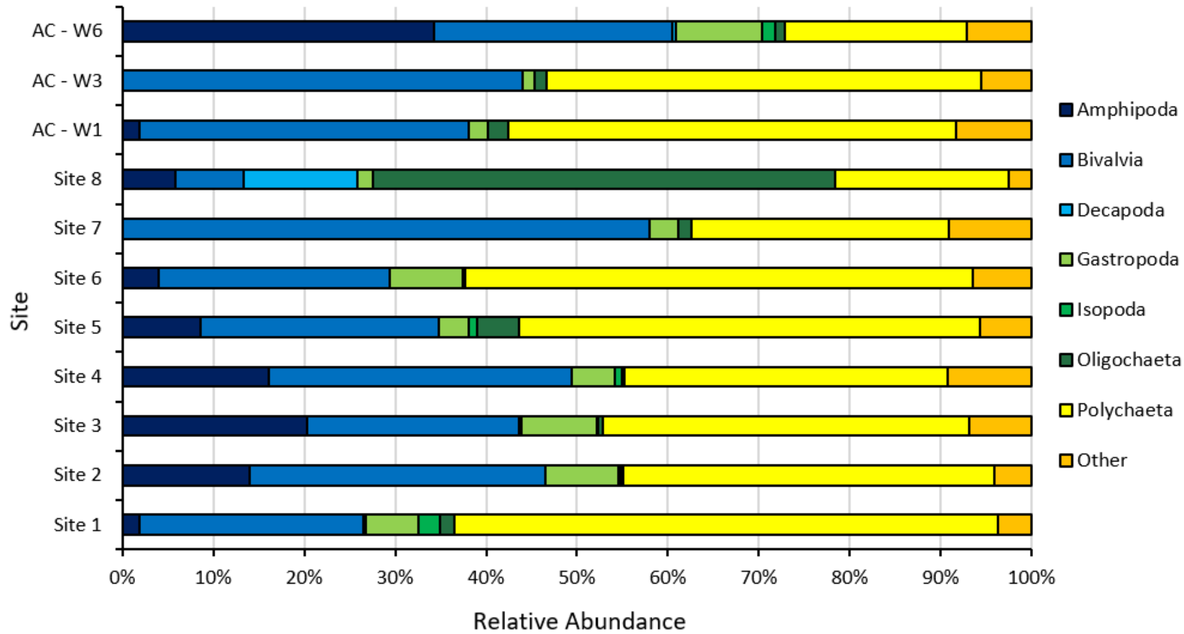

Figure 4.11: Relative abundance of benthic infauna species (grouped by scientific order) in samples collected from Sites 1 -8 in the Waikopua estuary in February 2021, alongside Auckland Council Waikopua estuary sites (sampled May 2019).

The non-metric multidimensional scaling (nMDS) plot below (refer Figure 4.12 below) shows the similarities in benthic community composition across the eight sites sampled within the Waikopua estuary. The nMDS plot of benthic infauna community composition presents the degree of similarity between sites, the closer the points are in ordination space (i.e. on the nMDS plot) the more similar the community composition is. Consequently, it is expected that the 5 replicate samples taken at each site would be close to each other on the nMDS plot.

The stress value associated with this plot is 0.103. Stress values less than 0.20 provide a useful picture from which benthic community composition can be interpreted. Therefore, the nMDS plot presented in Figure 4.12 below shows a good interpretation of the similarity and dissimilarity in benthic community composition at the eight sites.

Results from the nMDS plot indicate that the community composition at Sites 7 and Site 8 are dissimilar to the remaining sites. This reinforces the results from the summary statistics that Site 7 and 8 had lower number of taxa and diversity. Site 8 appears to have the greatest within-site variation, followed by Site 1. Sites 2 and 3 appear to be quite similar, with a considerable about of overlap between these two sites. Sites 1 and 5 also show some overlap implying relatively similar community composition.

The overlap seen in the nMDS indicates the similarities of benthic community, and this is likely linked to the sediment characteristics present at each site, with overlapping sites sharing similar heavy metal concentrations, chlorophyll *a* concentrations and grain size distributions.

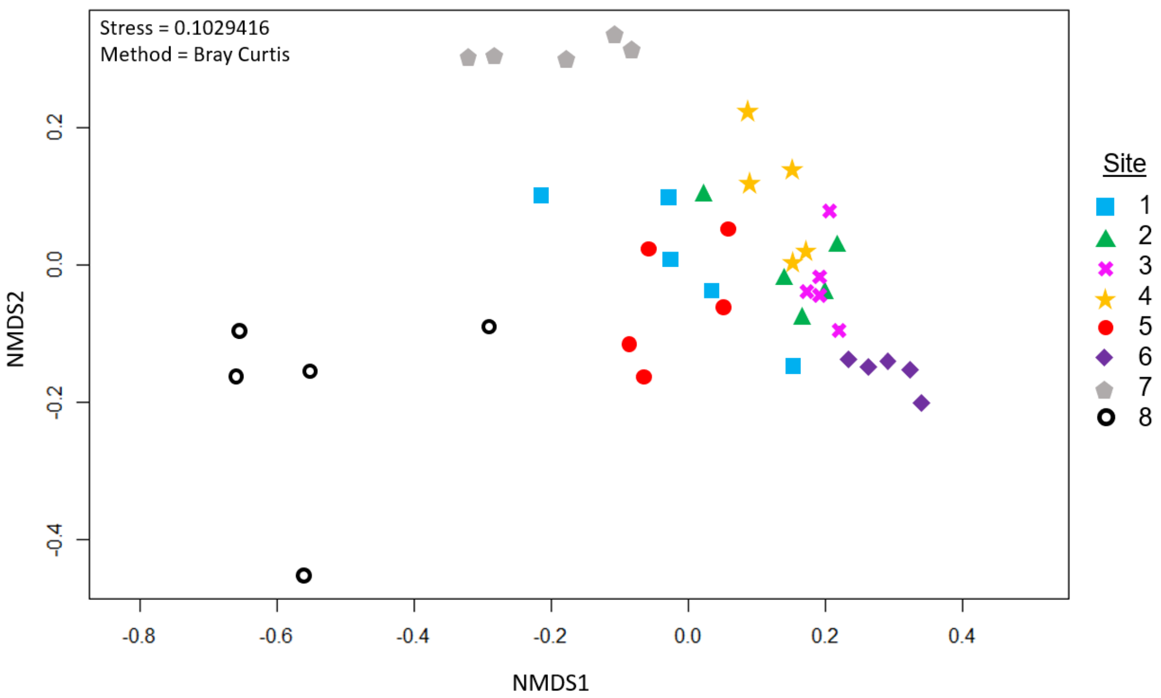

Figure 4.12: Non-metric multidimensional scaling (nMDS) plot of benthic infauna samples collected from Sites 1-8 in the Waikopua estuary in February 2021.

4.5.3 Benthic Health Model

Auckland council utilise the Benthic Health Model (BHM) to classify its intertidal/marine monitoring sites according to relative ecosystem health. This is based on a site's community composition and the predicted response to stormwater contamination. The BHM facilitates recognition of temporal trends in ecosystem health at sites that are routinely monitored. The combined BHM score, which combines scores from metals, mud and Traits Based Index (TBI), ranges from 0.2 ('Excellent') to 1.0 ('Poor').

Waikopua Sites 1, 3 and 6 show relatively stable BHM scores from 2015 to 2019, and generally indicates 'Good' (0.4) to 'Fair' (0.6) ecosystem health (refer Figure 4.13 below). The highest scores (since 2015) were based on 2019 data suggesting that ecosystem health at Waikopua estuary sites is slightly decreasing. Waikopua Site 9 was monitored annually from 2015 to 2017, the three years of BHM data show a considerable improvement in BHM score.

It is likely that the eight sites sampled for this Project would also indicate 'Good' to 'Fair' ecosystem health based on the proximity of these sites to the Auckland Council sites, and the similarities observed with regards to the sediment quality (Section 4.4) and infauna (Section 4.5.2) data.

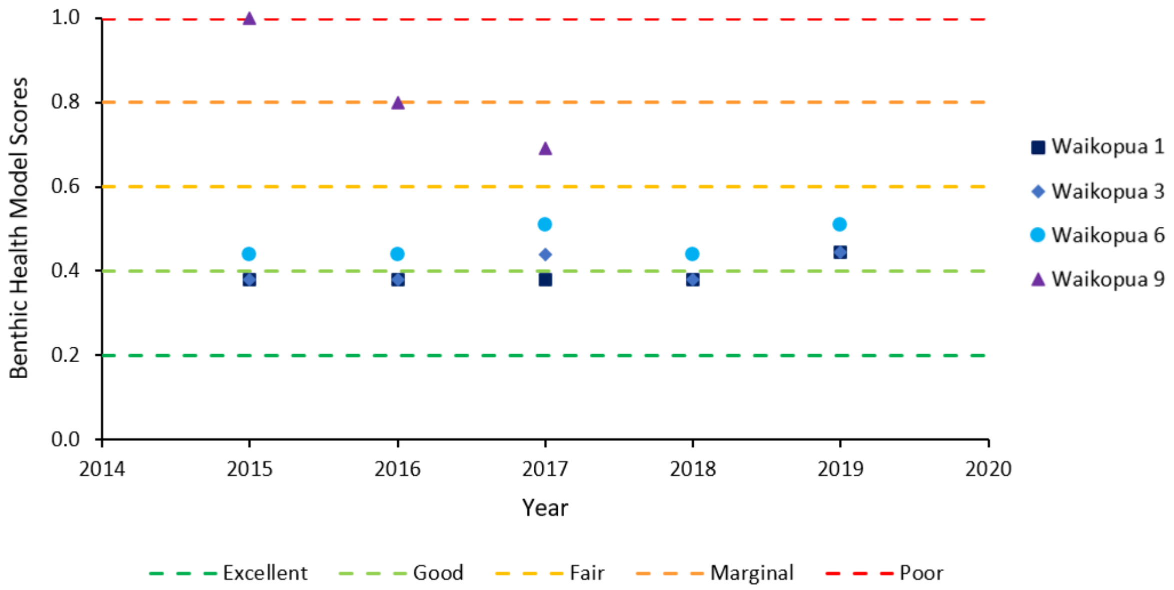

Figure 4.13: BHM scores over time for Auckland Council Waikopua estuary monitoring sites.

4.6 Shellfish

A 2001 study of shellfish in the Whitford embayment by NIWA identified that the dominant suspension feeder in the embayment was the cockle (*Austrovenus stutchburyi*). Dense beds of pipi were also located, with juvenile pipis found in several areas. Extensive numbers of juveniles of the wedge shell (*Macomona liliana*) were also widely distributed throughout the intertidal area. Low numbers and small specimens of suspension-feeding species were observed subtidally (Hewitt *et al*., 2001).

4.6.1 Cockle size distribution

Cockles were found at all eight sites at varying densities (refer Figure 4.14 below). At most sites the greatest numbers of cockles were juveniles (< 10 mm), especially at Site 6 where 241 of 260 cockles were < 10 mm. This suggests that Site 6 lies within a juvenile settlement zone. Large adults > 20 mm were only identified at Sites 3, 6 and 8. Only one adult cockle (>10 mm) was found at both Sites 5 and 8. The attractive edible size for cockles is 25 mm (ARC, 1992). Only five cockles of attractive edible size were recorded at the monitored sites, two were found at Site 3 and three found at Site 6. A total of 16 cockles were recorded within the 20 - 30 mm size class at the three Auckland Council sites; we are unable to determine if these are 25 mm or greater, however some may be of attractive edible size.

The low numbers of adult cockles suggests that the Waikopua estuary does not currently provide a significant shellfish/recreational resource however the presence of juvenile cockles suggests successful settlement of larvae and good spat survival. Suspension feeders such as *A. stutchburyi* tend to be more abundant in sediments with a larger grain size and have been shown to be most abundant in sediments of below 12 % mud in two separate studies (Thrush *et al* 2003, Anderson 2008).

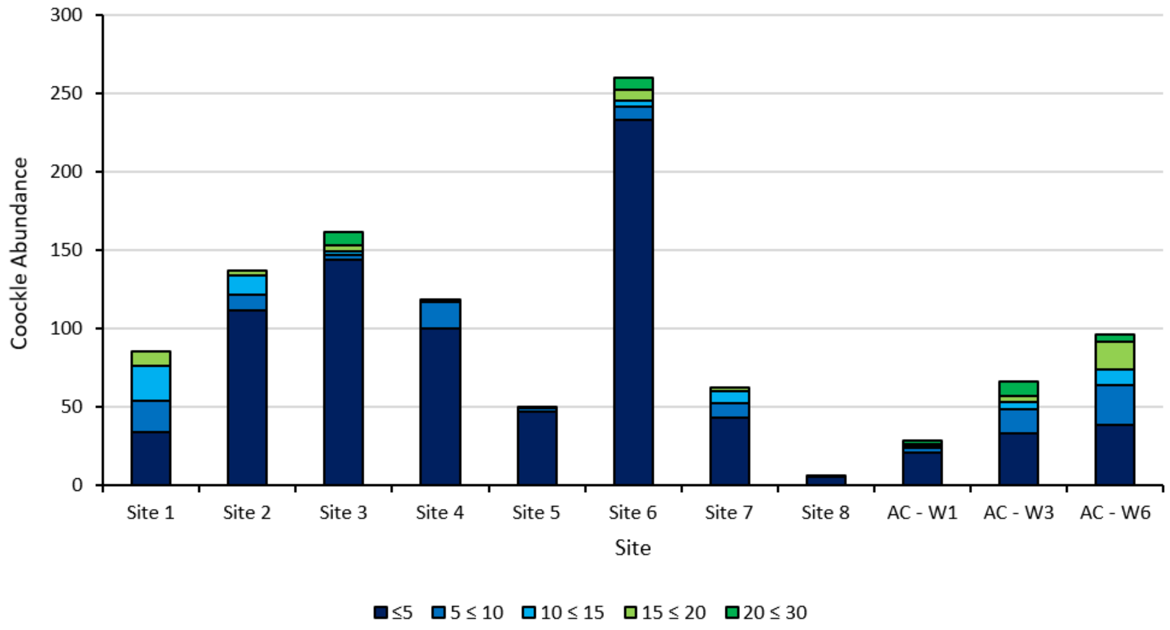

Figure 4.14: Total cockle abundance identified in infauna samples collected from Sites 1-8 in the Waikopua estuary in February 2021, alongside Auckland Council Waikopua estuary sites (sampled May 2019).

4.6.2 Pipi size distribution

Pipi (*Paphies australis*) were identified in benthic infauna cores taken from Sites 1 and 2. Sixteen pipi were found at Site 1 and one pipi was found at Site 2. The pipi ranged in size from 17 – 28 mm, therefore no juvenile pipi were identified at our sampling sites. No pipi were identified at any of the three Auckland Council sites within Waikopua estuary. No pipi found are of attractive edible size (45 mm).

4.7 Fish

The Whitford embayment, including Waikopua, Mangemangeroa and Turanga Creeks provide important habitat for fish species, including shelter and nursery grounds. The Whitford embayment is within the normal range of a number of marine species, these are presented in Table 4.3 below (NABIS, 2021).

The Whitford embayment is a hotspot for the hammerhead shark (*Sphyrna zygaena*) and yellow belly flounder (*Rhombosolea leporina*). The Whitford embayment is also a hotspot for juvenile yellow-eyed mullet (*Aldrichetta forsteri*). The wider Hauraki Gulf (2 km from the site) is a hotspot for thresher sharks (*Alopias vulpinus*) and spawning hotspot for blue mackerel (*Scomber australasicus*) and horse mackerel (*Trachurus novaezelandiae*).

White pointer sharks (*Carcharodon carcharias*) also known as great white sharks utilise the Whitford embayment and are Threatened – Nationally Endangered (Duffy *et al*., 2016).

The three creeks (Waikopua, Mangemangeroa and Turanga) also provide a pathway for migrating freshwater fish that are migrating either upstream to freshwater catchments, or downstream for spawning purposes.

Table 4.3: Fish likely to be present in Waikopua Creek and within the Whitford embayment based on species annual normal range distributions from the National Aquatic Biodiversity Information System (NABIS) (Data retrieved 13/07/2021)

Common name	Maori name[1]	Scientific name	NZ threat status[2]	International threat status (IUCN)[3]
Hammerhead shark	Mangoopare	*Sphyrna zygaena*	Not Threatened	Vulnerable
Yellow Belly Flounder	Patiki-totara	*Rhombosolea leporina*	-	Unknown
Barracouta	Mangaa, Makaa	*Thyrsites atun*	-	Unknown
Blue cod	Raawaru, Pakirikiri, Patutuki	*Parapercis colias*	-	Least Concern
Blue Mackerel	Tawatawa	*Scomber australasicus*	-	Least concern
Frostfish	Hikau, Paara, Taharangi	*Lepidopus caudatus*	-	Unknown
Garfish	Ihe, Takeke	*Hyporhamphus ihi*	-	Unknown
Horse Mackerel	Haature, Hauture	*Trachurus novaezelandiae*	-	Least Concern
John dory	pukeru	*Zeus faber*	-	Data deficient
Kingfish	Kuparu	*Seriola lalandi*	-	Unknown
Koheru	Koheru, Hature	*Decapterus koheru*	-	Least Concern
Porae	Pōrae	*Nemadactylus douglasii*	-	Unknown
Red gurnard	Kumu, Kumukumu	*Chelidonichthys kumu*	-	Unknown
Silver Warehou	-	*Seriolella punctata*	-	Unknown
Spotted stargazer	Kourepoua	*Genyagnus monopterygius*	-	Least Concern
Sprats	Kuupae	*Sprattus muelleri*	-	Least Concern
Turbot	Patiki	*Colistium nudipinnis*	-	Unknown
White pointer shark	Mangō ururoa	*Carcharodon carcharias*	Threatened–Nationally Endangered	Vulnerable
Yellow-eyed mullet	Aua, Awa, Matakawhiti	*Aldrichetta forsteri*	-	Least Concern
Thresher shark	Mangō ripi	*Alopias vulpinus*	Not Threatened	Vulnerable

1 Maori names sourced from https://www.mpi.govt.nz/dmsdocument/194/direct

2 NZTCS - https://www.doc.govt.nz/documents/science-and-technical/nztcs23entire.pdf

3 Threat Status - IUCN list status of threatened species for shards, rays and bony fishes (https://www.iucnredlist.org/)

4.8 Coastal birds

4.8.1 Coastal bird habitat

Coastal bird habitat in the vicinity of the Plan Change area comprised of a matrix of shellbanks, intertidal mud and sand flats, saltmarsh and saltmeadow, seagrass beds and mangroves (as described in Section 4.2.6). Furthermore, the AUP identifies a number of SEA-Ms in the vicinity of the Plan Change area, and overlaying these coastal bird habitat areas (refer to Table 4.4 and Volume 2: Appendix E; Figure 2 for spatial extent). These SEA-Ms delineate key marine features including intertidal banks, a very rich feeding ground and important mid tide roost for many hundreds of a variety of international migratory and New Zealand endemic wading birds, and shellbanks that provide high tide roosting habitat.

The coastal area is part of the Hauraki Gulf Marine Park and comprises three distinct tidal creeks (being Waikopua, Turanga and Mangemangeroa Creeks) which are identified as being regionally and nationally significant.

Table 4.4: SEA-Ms[10] in site vicinity

SEA-M ID	Proximity to site	Description
M2-43a	Surrounds site	Three distinct tidal creeks (Maungamaungaroa, Turanga, and Waikopua) flowing into one large bay, within which a complex of intertidal mud, sand, and shell flats have accumulated. This physical variety provides a similarly varied range of habitats for an assortment of animal and plant communities. The intertidal banks are a very rich feeding ground and important mid tide roost for many hundreds of a variety of international migratory and New Zealand endemic wading birds including a number of threatened species. Turanga Creek is the largest estuarine habitat, including mangrove shrubland ecosystems, in the Hunua Ecological District. The Department of Conservation has selected this area as an Area of Significant Conservation Value (ASCV).
M2-43w1 (see 43a)	Surrounds site	Wading bird habitat - extensive areas of feeding habitat for waders along this coastline.
M1-43w3 (see 43e)	~500 m from site to the west	
M1-43w4	Adjacent to site / coastal wetland	
M1-43b	~ 1 km from site to the north	<u>Shellbanks</u> - Large shellbanks at various locations at creek mouths (43c, 43f), behind the beach (43e), or near Motukaraka Island (43b) are used (or have been used in the past) as high tide roosts by these birds and a variety of other coastal bird species. Moderate numbers of wading birds roost on the shellbanks including godwit, SIPO, whimbrel, reef heron, variable oystercatcher and banded dotterel. The Department of Conservation has selected this area as an ASCV.
M1-43c	Adjacent to site / coastal wetland	
M1-43e	~500 m from site to the west	
M1-43d	~900 m to south of site up Waikopua Creek	Contains the best areas of mangrove/oioi rushland and marsh ribbonwood/sea rush rushland in the Hunua Ecological District.

[10] Auckland Unitary Plan – Operative in Part, Schedule 4 Significant Ecological Areas – Marine Schedule.

Turanga Creek is the largest estuarine habitat (including mangrove shrubland ecosystems) in the Hunua Ecological District and provides a complex of intertidal mud, sand and shell flats. The intertidal banks are a very rich feeding ground and important mid-tide roost for a variety of international migratory and New Zealand endemic wading birds including a number of threatened species. A large shellbank at the Waikopua Creek mouth is used as high tide roost by birds. Moderate numbers of wading birds roost on the shellbanks including godwit, South Island pied oystercatcher, whimbrel, reef heron, variable oystercatcher and banded dotterel. The length of coastline adjacent to the site is recognised as an extensive area of feeding habitat for wading birds.

4.8.2 Coastal bird survey results

Coastal birds comprise both seabirds (birds that spend most of their time on open ocean waters and come to shore only to breed) and waders (birds that spend much of their time near bodies of water for foraging and roosting). Site specific coastal bird surveys were conducted in February and March 2021.

A diverse assemblage of coastal birds feed and roost at the North and South beaches (Appendix E; Figures 3a - 3f), including 'Nationally Threatened' and 'At Risk' species (refer Table 4.5 below). During high tide, some species were observed roosting on the sandbars at the South beach, including banded dotterels, Caspian tern, New Zealand dotterel, spur-winged plover, Canada geese, and black-backed gull.

During lower tides, coastal birds were observed feeding intertidally, feeding over the water, and resting on the water or intertidally. The following is noted with regard to 'Threatened' and 'At Risk' species observed during site surveys:

- Caspian terns (Threatened – Nationally Vulnerable) were observed in every survey at the South and North beaches. Caspian terns were observed feeding over water, roosting on the sandbars, and resting in the inter-tidal zone. The maximum number of Caspian terns observed at any one time was two.
- Banded dotterels (At Risk - Declining) were observed at the South beach on survey days 5 and 23 March 2021 in flocks of up to 42 individuals, both feeding intertidally and roosting on the sandbars.
- Lesser knots (At Risk - Declining) were predominantly observed foraging during low tides at South Beach in high numbers (maximum count of 320 individuals observed during 23 March 2021, sub-survey 1).
- Bar-tailed godwits (At Risk - Declining) were predominantly observed foraging during low tides, with a maximum count during any one survey of 33 individuals (23 March 2021, sub-survey 2). Bar-tailed godwits were most frequently observed feeding at the South beach.
- New Zealand dotterels (Threatened – Nationally Increasing) were observed at both the North and South beaches on 5 March, 22 March, 23 March and 5 May 2021, with the maximum number observed at any one time being 14 individuals (South Beach, 5 March 2021, sub-survey 3). New Zealand dotterels were most commonly observed feeding in the intertidal zone.
- South Island pied oystercatchers (At Risk – Declining) were abundant across all surveys, with a maximum count of 138 during any one survey (South Beach, 23 March 2021, sub-survey 4). South Island pied oystercatchers were generally observed distributed across the exposed intertidal areas feeding.
- Variable oystercatchers (At Risk – Recovering) were observed in all surveys, with a maximum abundance in any one sub-survey of 15 (South Beach, 13 May 2021, sub-survey 4).

- A single royal spoonbill (At Risk – Naturally Uncommon) was observed on 13 May 2021 feeding at North Beach.
- Pied shags (At Risk – Recovering) were observed in four of the six surveys at both South and North beaches feeding in the water, or roosting on wooden seamarks in the estuary.

In addition to the above observations, a large flock of black-backed gulls (Not Threatened) of more than 300 individuals were frequently observed roosting and feeding in the intertidal zone outside of the survey boundaries to the south of South Beach (Volume 2: Appendix E; Figures 3a - 3f).

Seasonal changes to coastal avifauna are associated with the movements of overseas migrant species that arrive in September and depart for the northern Hemisphere in about March; NZ migrants leave for (mainly) the South Island in about August and return from January. As such, a number of migratory species, e.g. lesser knots were absent from later surveys.

Desktop assessment also identified the following coastal birds that may intermittently use the site but were not observed during surveys:

- Reef heron (Threatened – Nationally Endangered)[11] has been identified at Motukaraka Island, 1.5 km north of North beach. Reef herons preferentially use rocky habitats for feeding, and may intermittently feed on reef areas of the South beach.
- A single observation of a Black-billed gull[12] (At Risk - Declining) has been recorded at North Beach.
- A number of species have been recorded at Potts Lane Coastal Wetland 2.7 km west of South Beach[13] including:
  - A single record of a shore plover (Threatened – Nationally Critical), wrybill (Threatened – Nationally Increasing), white-fronted tern (At Risk - Declining) and Australasian gannet (Not Threatened);
  - 14 recordings of little black shag (At Risk – Naturally Uncommon); and
  - 2 recordings of black shag (At Risk – Relict).
- Migrants Pacific golden plover, ruddy turnstone, red-necked stint, and vagrant great knot have also been observed across various eBird hotspots and iNaturalist observations in proximity to the site and have been included in this assessment.

A banded rail (At Risk – Declining) call was heard in the brackish wetland behind the viewing location at North beach on 24 March 2021. Banded rails were also identified through spectrogram analysis of ARDs. Banded rail call date and timings are presented in Table 4.5.

Table 4.5: Banded rail calls identified during spectrogram analysis of ARDs deployed in the coastal marine environment.

Call no.	Date	Time	ARD number (see Volume 2: Appendix B; Wetland Bird Habitats, Wetland ecological effects assessment for locations)
1	18 December 2020	05:05	2
2	21 December 2020	07:52	1
3	24 December 2020	07:03	1

[11] iNaturalist (2019). Pacific Reef Heron observation. Accessed on 5 July 2021 from https://www.inaturalist.org/observations/33110545
[12] eBird (2021). Beachlands--Mudflats south of Formosa Golf Course. Black-billed gull. Accessed on 5 July 2021 from https://ebird.org/hotspot/L13909038
[13] eBird (2021). Potts Lane Coastal Wetlands. Accessed on 5 July 2021 from https://ebird.org/hotspot/L3057858

Call no.	Date	Time	ARD number (see Volume 2: Appendix B; Wetland Bird Habitats, Wetland ecological effects assessment for locations)
4	24 December 2020	07:08	1
5	25 December 2020	06:09	1
6	25 December 2020	06:19	1

The proportional utilisation of the habitats at North and South beach for At Risk and Threatened bird species (as first observed for each individual bird) are presented in Figure 4.15 below. All species were observed feeding and resting in the coastal zone. Caspian terns, pied shags and red-billed gulls were observed feeding on or over the water. Other species were usually observed feeding or resting intertidally, with variable oystercatcher, South Island pied oystercatcher, royal spoonbill lesser knot and bar-tailed godwits frequently feeding intertidally, and New Zealand dotterels and banded dotterels frequently using the intertidal zones for resting.

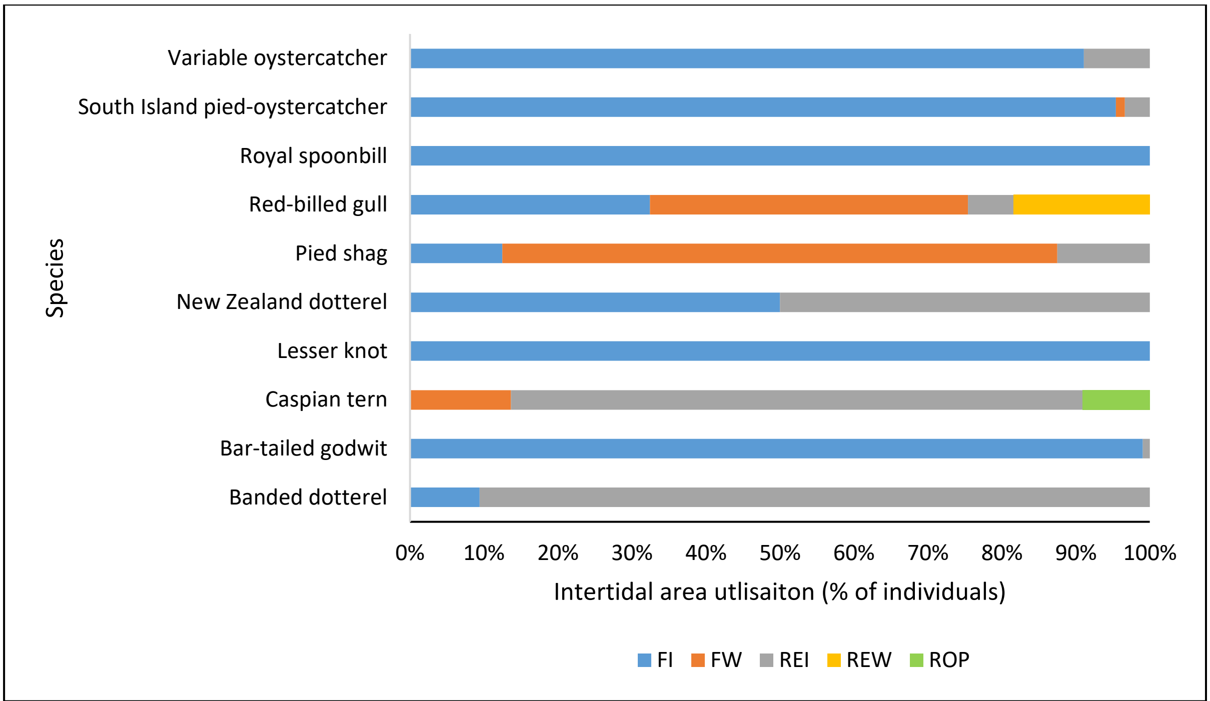

Figure 4.15: Nationally At-Risk or Threatened species and their intertidal utilisation as a % of total counts within a species group. FI = feeding intertidally, FW = feeding over water, REI = resting intertidally, REW = resting on water, ROP = roosting on land.

5 Ecological Effects Assessment

This section presents an assessment of the actual and potential effects of the proposed PPC on the marine receiving environment as follows:

- Section 5.1:
  - An overview of the potential PPC effects on the marine receiving environment.
  - An outline of proposed measures to avoid, remedy or mitigate effects of the Plan Change on marine ecology.
  - A description of the defined Zone of Influence (ZOI).
- Section 5.2:
  - An ecological values assessment within the marine receiving environment based on the ecological characteristics and values described in Section 4 above.
  - An assessment of the magnitude of effects on ecology from the proposed PPC and the overall level of ecological effect. This is based on an assessment of magnitude of effect following proposed mitigation and is an assessment of residual ecological effects following initial mitigation.

5.1 Potential Plan Change effects

The PPC proposes to re-zone current coastal land, being the Formosa Golf Course and the rural-residential property at 620 Whitford-Maraetai Road. Ultimately, the Project will incorporate residential living (4,500 housing unit equivalents – including the land to be zoned FUZ in the PPC), with associated transport networks, green space and additional commercial developments.

Wastewater from the development will be treated on-site at a proposed wastewater treatment plant (WWTP). Discharges from WWTP typically contain elevated levels of microbes, nutrients, BOD_5 and heavy metals[14].

GWE has developed the concept design for on-site reticulation and wastewater treatment to service the proposed development (GWE, 2022). The options assessment identified an Enhanced Membrane Bioreactor (E-MBR) WWTP as the most suitable option to treat wastewater based on anticipated quantities and quality of influent and required effluent quality.

The potential effects on marine ecology associated with the proposed PPC and subsequent change in Land use include:

- Improved access to the coastal environment and the coastal walkway will result in increased levels of disturbance to significant and / or sensitive habitats.
- Increased disturbance to coastal avifauna due to increased presence of people, pets (dogs and cats) and pest animals.
- Increased suspended sediment due to construction related discharges and stormwater contaminants due to discharges that have the potential to impact on marine, invertebrates, birds and fish.
- Increased sedimentation (suspended and deposited) which can impact on benthic habitat quality, invertebrates (including shellfish), birds and can result in increased mangrove encroachment.

[14] Noting that elevated heavy metals from wastewater treatment systems is dependent on the Land use of the catchment being serviced; industrial catchments are more likely to contribute heavy metal loads to wastewater treatment systems via trade waste.

- Wastewater point and / or diffuse source discharges to the CMA are a potential ecological risk due to contaminant impacts on marine ecology and shellfish resources. Potential wastewater discharge effects include:
  - Nutrient enrichment and direct and indirect effects on benthic communities (and flow on effects within the food web leading to fish and birds).
  - Deteriorating water quality (nutrients, microbial, heavy metals and emerging organic contaminants).
  - Potential for nuisance plant growths, including shoreline plants, macroalgae and phytoplankton.
  - Development of anoxic conditions through oxygen depletion, sulphide-rich sediments and poor health of the benthic habitat which have flow-on effects to higher levels in the food web.

5.1.1 Proposed mitigation measures

Efforts to avoid or mitigate the potential for adverse ecological effects associated with the change in Land use activities enabled by the PPC were undertaken though the optioneering and master planning phase of the project and have included refining the configuration of the Project and the PPC provisions. These measures are detailed in the Planning report and section 32 analysis that supports the PPC and include, for example, the locating of the indicative coastal walkway to be outside the CMA.

Further, adverse effects associated with the proposed PPC are avoided, remedied or mitigated through:

- Implementation of Erosion and Sediment Control (ESC) during construction phases on site, as outlined in the ESC Plan (HG, 2021). Construction will be staged over several earthworks seasons with open earthworks limited within sub-catchments.
- Stormwater treatment on site in line with GD01 and as outlined in the draft stormwater management plan.
- Proposed measures to manage coastal bird disturbance effects including:
  - Designing the coastal walkway alignment to avoid sensitive coastal areas.
  - Proposed inclusion of signage and dog restrictions to limit disturbance to coastal birds.
  - Inclusion of specific dog parks on the site to mitigate for the need to exclude dogs from the coastal marine environment, including the beaches, shellbanks and inter-tidal sand flats.
  - A ban on cats in coastal properties to minimise the risk of predation on coastal birds while nesting or roosting.
  - Ongoing intensive mammalian predator control along coastal buffer vegetation to reduce predation pressure on roosting and nesting coastal birds, including banded rail, variable oystercatchers and dotterel, with targets based on best practice pest management.
  - Coastal buffer enrichment planting to minimise disturbance and provide additional protective habitat (e.g. dense flax plantings to further protect nesting birds from humans or unleashed dogs).

  Some or all of the measures outlined above will be refined further at the resource consenting phase.
- Inclusion of an E-MBR WWTP that provides a high level of treatment for wastewater outputs. Table 5.1 below outlines the anticipated effluent concentrations and treatment efficiencies.

Treated effluent concentrations are the product of several key units in the wastewater treatment process, including UV disinfection to removal faecal coliform bacteria and chemical dosing to aid dentifrication and phosphorus removal prior to discharge (GWE, 2021). We note that no information is available on potential concentrations of Emerging Organic Contaminants (EOCs)[15].

Table 5.1: PPC anticipated effluent quality requirements. Extract from GWE, 2021.

Parameter	Raw combined influent	Treated effluent	Removal %
5-Day Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	320	10	97%
Total Suspended Solids (TSS)	380	10	97%
Total Nitrogen (TN)	65	5	92%
Total Phosphorus (TP)	40	2	95%

Table TN – All concentrations in mg/L

GWE further outline a range of disposal options for treated wastewater from the E-MBR. Options for disposal are described briefly as follows, noting a combination of options may be implemented and scaled to the staging of future development.

1 Land disposal to FUZ land.

2 Land disposal to the golf course and/or to FUZ land if the golf course is saturated.

3 Tertiary polishing wetland at the head of the western catchment gully with subsequent discharge into the existing constructed wetland and permanent stream sections of the western catchment, and subsequently to the marine environment (Outlet B on Figure 3.1).

Land disposal options 1 and 2 above would include areas draining to the Eastern, Southern and 620 Catchment streams. Disposal would be to ground and would avoid issues associated with direct discharges to the CMA, although there may be some potential for nutrients to enter the CMA diffusely.

Depending on the option selected for wastewater disposal from the E-MBR, some monitoring may be required in the coastal receiving environment of the Site. Monitoring requirements should be determined during the resource consenting phase and following further detailed design of disposal options. Monitoring may be necessary to ensure effects on marine ecological values are mitigated to the extent practicable, with residual effects to be addressed if required.

5.1.2 Zone of Influence

The EIANZ EcIA framework (Roper-Lindsay *et al*., 2018) refers to a Zone of Influence (ZOI), defined as "the areas / resources that may be affected by the biophysical changes caused by the proposed project and associated activities". In this case the ZOI refers to all estuarine and marine water bodies and environments (including intertidal sand and mud flats, coastal saline vegetation, and shellbanks) that could be potentially impacted by the development enabled by the proposed PPC.

The ZOI should also be viewed in the context of the type of effect, as follows:

[15] The effects on marine life from EOCs is an emerging area of science, and there is global concern that the presence of EOCs in the environment may lead to adverse effects on ecological health (Stewart *et al*., 2016). Despite an increase in international studies, there is still a paucity of information on EOCs in the New Zealand receiving environment.

- For disturbance related effects, the ZOI is likely to encompass a larger area of intertidal habitats, shellbanks and coastal saline vegetation, being more accessible by people and animals.
- For stormwater and sediment related effects, the ZOI is likely to be concentrated around point source discharge points, being streams A to E as shown in Figure 3.1. The size of the ZOI is further dependent on the ARI events that occur during the 10-year construction period, with a smaller ZOI associated with a 95th percentile rainfall event, and the largest possible ZOI associated with a 100-year ARI rainfall event.
- For wastewater related effects, the ZOI relates to the area and resources that will be impacted as a result of the wastewater discharge. The ZOI in this context is dependent on the disposal option selected.

5.2 Assessment of ecological effects

The assessment of ecological effects is undertaken following the implementation of measures to avoid, remedy and mitigation effects as outlined in 5.1.1above.

5.2.1 Marine habitats

5.2.1.1 Marine habitat values

In the context of this assessment, marine habitats refer to those identified by habitat mapping (Section 4.2 above), comprising firm sand and cockle shell covered sandflats, intertidal and sub-tidal seagrass beds, sandstone reefs, shellbanks, soft gloopy mud and artificial rock revetment. Mangroves and saltmarsh vegetation are assessed separately as 'coastal saline vegetation' in Section 5.2.3 below. Table 5.2 below outlines the key marine habitat types mapped in the marine receiving environment, associated characteristics and ecological value in line with Volume 2: Appendix A; Table 1 and Table 6, which assign value to species and habitats respectively.

Table 5.2: Marine habitat types mapped in the marine receiving environment, characteristics and associated ecological value

Marine habitat	Characteristics	Value
Seagrass beds (intertidal and sub-tidal)	Seagrass beds are recognised as a highly valuable coastal ecosystem based on the numerous ecosystem services they provide. Seagrass can improve stability of the seabed and reduce erosion as well as improving water quality by trapping sediment within the leaves (Matheson *et al.*, 2009). Seagrass beds enhance local habitat and biodiversity as they provide additional three-dimensional structure and food sources (Morrison *et al*., 2014). Oxygen production from seagrass beds is beneficial for other marine fauna and encourages nutrient cycling (Matheson et al., 2009). Numerous fish species have been observed utilising seagrass beds for feeding and nursery functions (Hayward et al., 1999). Seagrass is classified 'At Risk – declining' under the NZTCS due to anthropogenic stressors (deLange *et al*., 2017; Matheson *et al.,* 2011).	High
Firm muddy sand flats / cockle shell covered flats	This habitat type is highly productive as evidenced by the high diversity and abundance of organisms. The high number of juvenile cockles also indicate a settlement zone at Site 6, with a small number of pipi located at Sites 1 and 2.	Very high

Marine habitat	Characteristics	Value
	The predominant sediment types typically comprise < 25% silt and clay grain sizes, and sediment contaminant concentrations are significantly below ISQG-low and AC ERC-Orange effects threshold concentrations. This habitat type is common in the Auckland region. The importance of this habitat is recognised in the classification of the area as an SEA-M2 (foraging ground for wading birds; AUP, Schedule 4). Firm muddy sand flats / cockle shell covered flats provide habitat for seven 'Threatened' and one 'Endangered' coastal bird species.	
Shellbanks	Regionally, a large number of shellbanks adjacent to shorelines have, in recent years, become overgrown with mangroves or invasive species (i.e. pampas grass), inhibiting their use as roost sites for coastal bird species. Although currently impacted due to the presence of exotic species, the potential future value of these shellbanks is likely to be high or very high if restored. These shellbanks currently provide nesting habitat for New Zealand dotterel, an 'At Risk – declining' species, and potential nesting habitat for Variable Oystercatcher, an 'At Risk – recovering' species. The importance of this habitat is recognised in the classification of the area as an SEA-M1 (43c and 43w4). In general M1 SEAs are 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 (AUP, Schedule 4)	Very high
Sandstone reef	Sandstone reefs support a high diversity and abundance of organisms and provide a hard substrate for encrusting organisms such as the native New Zealand rock oyster. Although locally common, sandstone reefs in the Waitemata, Tamaki and inner Hauraki Gulf are increasingly impacted by terrigenous sediment inputs that smother the reefs or are alternatively colonised by the non-native Pacific oyster. Largely unmodified sandstone reefs are therefore uncommon locally. The importance of this habitat is recognised in the classification of the area as an SEA-M2 (foraging ground for wading birds; AUP, Schedule 4).	High
Soft gloopy mud	This habitat type is typically found in tidal creek environments, close to terrigenous sediment inputs. It is a natural habitat type, which has increased in extent in recent years due to increased inputs of fine sediment from land-based activities (Hayward et al., 1999). Higher mud content (clay and silt particle sizes) contribute to more degraded benthic invertebrate communities, as evidenced by the lower taxa and diversity scores at Sites 7 and 8. This habitat type is located within an SEA-M2 (AUP, Schedule 4).	Moderate
Rock revetment	Rock revetments in the Auckland region are comprised of predominantly basalt rock type, and typically support low species diversity and abundance. It is a highly modified habitat type.	Low

5.2.1.2 Magnitude and overall effect on marine habitats

The proposed PPC and associated Land use change has the potential to increase sediment loadings and stormwater contaminants to the marine receiving environment. Our assessment on the magnitude of effect on marine habitats relies on contaminant modelling that assumes mitigations outlined in Section 5.1.1 are in place, such as erosion and sediment controls and stormwater management.

With reference to sedimentation modelling (T+T, 2022), the predicted level and spatial scale of effect during the construction phase increases with the associated size of rainfall event, with sedimentation primarily concentrated around stream discharge points A to E (refer to Figure 3.1 and Appendix E of the Water Quality and Sedimentation Modelling Report (T+T, 2022)):

- Figures 9 - 13 to 9 - 20 of Appendix E (T+T, 2022), spatially represent modelled sediment deposition during a 100-year ARI. There is a low likelihood (10 % chance) of a 100-year ARI rainfall event occurring during the 10-year construction period. The model outputs identify that there is a spatial variability and variability in depth of sediment deposition depending on the tidal stage and spring versus neap tides.

  For the 100-year ARI event, the 20 mm threshold persisting for more than 5 days was exceeded only over areas less than 0.1 ha. The 5 mm threshold was exceeded over greater areas and persisted for more than 10 days. For sediment discharged from streams A and B, the worst-case scenario for sediment deposition occurred under spring tide conditions, with the potential for an area approximately 3 ha covered with 5 mm of more in the upper intertidal area

  The modelling report predicts that winds following rainstorm events will gradually remove a portion of deposited material within 10 days, redistributing it within subtidal areas of the wider embayment.
- Figures 9 - 21 to 9 - 28 of Appendix E (T+T, 2022) spatially represent modelled sediment deposition during a 10-year ARI. This event is expected to occur once during the 10-year construction period.

  The spatial extent of sediment deposition of 5 mm or more, occurring for more than ten days is significantly reduced when compared to the 100-year ARI, covering an area of <0.1 ha (discharged from streams A and B) and 0.4 ha (discharged from streams C, D and E) in the worst-case scenario.
- Figures 9 - 29 to 9 - 36 of Appendix E (T+T, 2022) spatially represent modelled sediment deposition during a 2-year ARI. This event is expected to occur several times during the construction period.

  Under some tidal scenarios, small areas (< 0.1 ha) are predicted to experience sediment deposition of 5 mm of more, occurring for more than ten days in the vicinity of stream discharge A, D and E.

Following construction and considering a developed landscape, TSS inputs from the Site are predicted to reduce by 64 % compared to loads under the existing landscape. Stormwater contaminants copper and zinc are expected to accumulate, however will remain below the ERC amber threshold and levels of ecological concern.

Treated wastewater discharges may also contribute to increased loadings of nitrogen and phosphorus which can cause eutrophication in estuaries. Increases in TSS, microbial pathogens, heavy metals, and EOCs are also associated with wastewater discharges, however it is noted that these effects are significantly lower in scale compared with those expected as a result of nutrient enrichment.

The E-MBR provides a high level of treatment for wastewater outputs; contaminants and removal efficiencies are provided in Table 5.1 above. The polishing and disposal options, as discussed in Section 5.1.1 and in the GWE report (2022), will determine the location and magnitude of effect on marine habitats. Land disposal options are likely to result in negligible effects in the CMA based on discharges being to ground. Disposal to a polishing pond and the permanent stream in the western catchment will produce a point source discharge to the CMA at the stream B discharge point (refer Figure 3.1). The magnitude of effect from this discharge option should be assessed in the context of additional treatment efficiencies and potential contaminant concentrations prior to discharge to the CMA at resource consent stage.

Nutrient enrichment, including increases in algal and shoreline plant growths, organic loadings and enrichments, eutrophication and altered benthic habitat structure and functioning are the primary concern associated with discharge of treated wastewater to the marine receiving environment. A response to increased nutrient concentrations and loads will vary seasonally with less risk of adverse effects during autumn and winter, and greater risk because of warmer temperatures and higher light levels in spring and summer (James *et al*., 2016).

5.2.1.2.1 Seagrass

Seagrass in the Whitford embayment has the potential to be impacted by an increase in TSS, metal contaminants and nutrient enrichment associated with changes in Land use on the Site. The run-off of nutrients and sediments into estuarine and coastal areas as a result of human activities on land is considered to represent the greatest threat to seagrasses worldwide (Hemminga and Duarte 2000; Coles *et al*. 2003; Green and Short 2003; Walker 2003):

- **Nutrients**. Many seagrasses respond favourably to low or moderate nitrogen or phosphorus enrichment (Turner and Schwarz, 2006). However, excessive nitrogen loading in the water column can inhibit seagrass growth and survival. For example, increases in nutrient loading can promote the growth of phytoplankton, epiphytic algae and bottom-living and free-floating macroalgae, all of which can contribute to light reduction to seagrass beds and inhibit seagrass growth (Turner and Schwarz, 2006).
- **Sediment**. Seagrasses depend directly on sediment for nutrients and anchorage, therefore seagrass distribution and abundance is strongly related to sediment characteristics. However, chronic increases in suspended sediments lead to increased turbidity, limiting light availability for photosynthesis (Turner and Schwarz, 2006); the response of seagrasses to light deprivation depends on the intensity and duration. In extreme cases, excessive sediment loads may result in the smothering and burial of seagrass.

  Most seagrasses can survive moderate inundations of sediment, with mortality occurring beyond a given threshold of sediment accretion (Duarte et al. 1997; Vermaat et al. 1997; Manzanera et al. 1998)
- **Contaminants**. A review of management and conservation for seagrass indicated that there is little or no information about the effects of toxic compounds on the growth and survival of seagrass in New Zealand estuarine and coastal areas. Limited information from overseas studies indicate that contaminants, including heavy metals, are all potentially harmful (Turner and Schwarz, 2006). Existing sediment metal contaminants in the Waikopua Creek sediments indicate that existing sediment contaminants are all well below the ARC ERC Green criteria.

Modelled outputs indicate that sediment deposition is largely concentrated around stream discharge points, with the effect lessening with distance from the point source discharge. For the 10-year ARI (i.e. the worst case scenario that is expected to occur during construction), a small proportion of seagrass in the vicinity of stream discharge point A could experience sediment deposition > 5 mm, however the model predicts that this effect will be short in duration (< five days). Intertidal and subtidal seagrass may be impacted to a lesser degree by subsequent resuspension and movement of sediment towards the subtidal area of Whitford Embayment. In the long term (i.e. post construction) effects on seagrass from sediment deposition and suspension are likely to lessen compared to the current situation given the predicted 64 % reduction in sediment (compared to the existing levels) arriving in the CMA from the Site.

Potential nutrient loading in the CMA and associated effects on seagrass habitats is dependent on the wastewater disposal option, which will be confirmed at consent stage. Options for disposal have been outlined in Section 5.1.1. Disposal to land options are likely to have a negligible effect on seagrass habitats, with disposal largely to groundwater and / or evapotranspiration. A potential discharge to polishing ponds and the permanent stream in the western catchment will create a point source discharge to the CMA at the stream B discharge location. It is expected that during the resource consenting phase, further work and detailed design will be required to understand potential nutrient loading effects, however, we expect that these effects can be appropriately managed.

While nutrients, sediment and contaminants have separate effects on seagrass that could be tolerated on an individual basis, collectively they are a stressor that is expected to have an at least **Low** magnitude of effect on seagrass. With reference to Volume 2: Appendix A and the **High** value of seagrass, this equates to an overall **Low** level of effect. This level of effect is dependent on further work being undertaken during the resource consenting phase.

5.2.1.2.2 Firm muddy sand flats / cockle shell covered flats

Potential effects associated with the PPC on firm muddy sand flats and cockle shell covered flat habitats include those associated with increased sediment (suspended and settled), stormwater contaminants and nutrient enrichment.

The current health of this habitat is considered to be ‘good’ or ‘fair’ with reference to BHM scores associated with Auckland Council monitoring (Waikopua 1, 3, 6 and 9 sites) and sediment quality testing conducted as part of this study. Benthic survey results also indicate that certain areas of the marine receiving environment are settling zones for juvenile cockles. Feeding, growth rates and condition of shellfish can be impacted by discharges to the marine environment, and in particular effects on shellfish can be more severe on juvenile populations (NIWA, 2020).

Gibbs and Hewitt (2004) undertook a synthesis on research studies considering the effects of sedimentation on macrofaunal communities (as reference in the sedimentation modelling (T+T, 2022) and Section 3 above. The study identified that:

1. In general, the thicker the layer of mud, the more animals will be killed and the longer recovery will take. This will affect both the number of species and the number of animals within each species, however some species are more sensitive than others.
2. If mud that has been washed down a stream to one of the tributary estuaries or the embayment and results in a mud layer greater than 20 mm thick, remaining for longer than five days, then all the resident animals in that area (with the exception of mobile crabs and shrimp) will be killed due to lack of oxygen.
3. A mud thickness of around 5 mm, persisting for longer than 10 days, will reduce the number of animals and the number of species, thereby changing the structure of the animal community.
4. Frequent deposition of mud < 5 mm may have long-term impacts that can change the animal communities.

NIWA undertook a 2001 study to investigate the potential effects from urban development on the marine receiving environment in the Whitford embayment, in particular, effects of suspended sediment concentrations on feeding, growth rates and condition of suspension-feeding shellfish living in the benthic environment. The outcomes from the study suggest that cockles initially benefit from extra food available in high suspended sediment concentrations, although not where suspended sediment concentration are terrigenous clays recently arrived in the marine receiving environment. Concentrations of >400 mg/L persisting for 14 days adversely impact cockle condition.

Field experiments on pipis also indicated that pipi received some benefit from increased sediment concentrations, however high concentrations occurring more frequently than 25% of the time decreased condition. Finally, field growth rates of juvenile cockles and *Macomona*, and condition and reproductive status of adult pipi and cockles at some sites were adversely affected by suspended sediment concentrations currently (i.e. circa 2001) occurring in the Whitford embayment.

With reference to modelled outputs, during a 10-year ARI event (i.e. the worst case event expected to occur during construction), small areas of sediment deposition > 5mm and occurring for more than ten days are anticipated. Depending on the tidal stage and neap versus spring discharge, this occurs to a greater or lesser degree at all stream discharge points A to E with impacted areas ranging from <0.1 ha to 0.4 ha. When considered in the context of guidance on effects associated with sediment deposition and the likely benthic fauna community associated with firm muddy sand flat habitats, it is likely that adverse effects on community compositions would occur within those areas.

During a 100-year ARI event (i.e. the event with a 10 % chance of occurring during construction), the spatial extent of sediment deposition on firm muddy sand flats significantly increases, with the 20 mm threshold persisting for more than five days over an area of 0.1 ha; it is expected that benthic communities (with the exception of crabs and shrimps) would be killed due to lack of oxygen within this area. Sediment deposition of 5 mm that persists for more than ten days is also observed at all stream discharge points A to E; effects within these areas include adverse impacts on benthic community structure, with a reduction in species diversity and abundance.

As previously mentioned, in the long term (i.e. post construction) effects on firm muddy sand flats and associated benthic fauna from sediment deposition and suspension are likely to lessen given the predicted 64 % reduction in sediment arriving in the CMA from the Site.

Copper, lead and zinc are well-known stormwater contaminants, particularly in urban runoff that can be toxic at relatively low concentrations (Williamson *et al*., 2017). With reference to stormwater modelling, at 50 and 100 years following full development of the Site (Live Zone and FUZ) metal concentrations are predicted to remain below the ERC amber threshold, therefore benthic fauna communities are not expected to be adversely impacted by stormwater contaminants.

Potential nutrient loading in the CMA and associated effects on firm muddy sand flats / cockle shell covered habitats is dependent on the wastewater disposal option, which will be confirmed at consent stage. Options for disposal have been outlined in Section 5.1.1. Disposal to land options are likely to have a negligible effect on these habitats, with disposal largely to groundwater and / or evapotranspiration. A potential discharge to polishing ponds and the permanent stream in the western catchment will create a point source discharge to the CMA at the stream B discharge location. It is expected that during the resource consenting phase, further work and detailed design will be required to understand potential nutrient loading effects, however, we expect that these effects can be appropriately managed.

While nutrients, sediment and contaminants have separate effects on this habitat type that could be tolerated on an individual basis, collectively they are a stressor that is likely to have a **Low** magnitude of effect on this habitat. The magnitude of effect takes into account the spatial scale (based on model outputs and habitat types), permanence of effect (i.e. effects from sedimentation are higher during construction and then significantly reduced in the developed scenario when compared to the existing situation), and the likelihood of various ARI events during the construction period.

With reference to Volume 2: Appendix A and the **Very High** value of firm muddy sand flat / cockle shell covered flat habitat, this equates to an overall **Moderate** level of effect. This level of effect is dependent on further work being undertaken during the resource consenting phase.

5.2.1.2.3 Shellbanks

The proposed PPC has the potential to impact on Waikopua shellbanks through increased disturbance to roosting and nesting coastal birds through public access and an increase in pest animals associated with urban areas.

Although the shellbank habitat is located above the level of mean high water, and is therefore not directly impacted by discharges, there are potential knock-on effects associated with effects on benthic ecology and shellfish located in the wider embayment, the shells of which contribute directly to the replenishment of the Waikopua shellbank.

With reference to Volume 2: Appendix A, effects on the Waikopua shellbank habitats are expected to be **Low**, where a discernible loss or alteration would be observed over time. With reference to Volume 2: Appendix A and the **Very High** value of shellbank habitat, this equates to an overall **Moderate** level of effect.

5.2.1.2.4 Sandstone reef

Potential effects associated with the proposed PPC on sandstone reef habitats are similar to those identified for firm muddy sand flats / cockle shell covered flats, being increased sediment (suspended and settled), stormwater contaminants and nutrient enrichment.

A variety of benthic epifauna and macroalgae are located in this habitat, with individual sensitivities to TSS and deposited sediment, contaminants and nutrients.

With reference to the modelled sediment deposition outputs and the location of stream discharge points, sandstone reef habitat is most likely to be impacted by discharges from streams A and B during the construction period. Under a 10-year ARI scenario, small areas of sediment deposition > 5mm and occurring for more than ten days are anticipated, with sediment expected to be gradually mobilised, resuspended and transported outside the Whitford Embayment following further wind and wave action (refer to Figure 5-1 in the water quality and sedimentation modelling report (T+T, 2022)).

As with seagrass habitats and firm muddy sand flats / cockle shell covered flats, further work is expected during the resource consenting phase to understand potential nutrient loading effects, however, we expect that these effects can be appropriately managed.

While nutrients, sediment and contaminants have separate effects on this habitat that could be tolerated on an individual basis, collectively they are a stressor that is likely to have a **Low** magnitude of effect on this habitat. As with firm muddy sand flat habitats, this magnitude of effect takes into account the spatial scale (based on model outputs and habitat types), permanence of effect (i.e. effects from sedimentation are higher during construction and then significantly reduced in the developed scenario when compared to the existing situation), and the likelihood of various ARI events during the construction period.

With reference to Volume 2: Appendix A and the **High** value of firm muddy sand flat / cockle shell covered flat habitat, this equates to an overall **Low** level of effect. This level of effect is dependent on further work being undertaken during the resource consenting phase.

5.2.1.2.5 Soft gloopy mud

Suspended sediment discharges can decrease water clarity, smother estuarine sediments (and associated flora and fauna), increase ‘muddiness’ and accelerate estuarine infilling and shallowing (Williamson *et al*., 2017).

Increased sediment and contaminant inputs to the marine receiving environment associated with the proposed PPC have the potential to accelerate this process and contribute to increased ‘muddiness’, particularly in locations in the upper Waikopua Creek where the habitat already comprises soft gloopy mud. This habitat type in general comprises organisms that are tolerant of disturbed environments.

Currently there are no operational TSS criteria for Auckland (ANZWQG or ERC), however a recent recommendation of 2 mm of sediment accumulation per year (above natural background annual average sedimentation rate) has been adopted by ANZWQG (2018) as a default guideline value (DGV) for sedimentation (Townsend and Lohrer, 2015). This value (2 mm / year) can be applied where catchment loads and sediment deposition models are available.

As noted in the model outputs, a 2 - 3 times increase in sediment during construction is expected for more frequent events such as the 2-year ARI. The model further notes that existing rates of sedimentation is as high as 3 mm/year, therefore the potential exists for more than 2 mm of accumulated sediment above existing background rates during the construction period (taken indicatively as 10 years) in the vicinity of discharges C,D,E which predominantly discharge to soft gloopy mud (and mangrove vegetation) habitats.

This figure should also be considered within the context of long-term effects; the model predicts long term reductions in TSS by 64 % from the current situation. Therefore in the long term it is predicted that sedimentation effects in the receiving environment associated with the site will lessen.

With reference to the EIANZ framework (Volume 2: Appendix A), it is likely that there will a **Negligible** magnitude of effect on this habitat type. The magnitude of effect is determined based on the level of confidence in the effect (associated with a reasonably frequent ARI event) and the short-term impacts versus the longer-term improvements in sediment discharges to soft gloopy mud habitats. With reference to Volume 2: Appendix A and the **Moderate** value of soft gloopy mud habitat, this equates to an overall **Very low** level of effect.

5.2.1.2.6 Rock revetment

Rock revetments comprise a small area of the marine receiving environment (approximately 2,600 m^2) and due to the scarcity of marine organisms inhabiting this habitat type, are unlikely to be adversely impacted by any of the potential effects associated with the PPC.

The magnitude of effect on rock revetment habitat as a result of the proposed Plan Change would be **Negligible**. With reference to Volume 2: Appendix A and the **Low** value of rock revetment habitat, this equates to an overall **Very Low** level of effect.

5.2.2 Fish

5.2.2.1 Fish values

Based on the potential high diversity and abundance of fish species, and the habitat available within Waikopua Creek and the wider Whitford embayment, the values in the marine receiving environment are considered **high** for fish.

5.2.2.2 Magnitude and overall effect on fish

Potential adverse effects on fish species and values in the marine receiving environment include effects on food resources and risk of predation, avoidance and displacement due to reductions in water clarity and other water and sediment quality related parameters including accumulation of contaminants in the flesh of fish (Lowe *et al.*, 2015).

Rays in particular feed primarily on benthic bony fishes and invertebrates such as molluscs, worms and crustaceans, by repeatedly inhaling sediments and water through the mouth and venting this out through gill slits, an excavatory feeding mechanism which has a bioturbation effect (Cadwallader, 2020). Speckled sole and other flatfish also feed directly on the benthos. In this regard, any adverse impacts on benthic fauna assemblages are likely to impact available food resources for fish, and contaminants could be passed on up the food chain and carried outside the immediate marine receiving environment when fish move away.

The Waikopua Creek is also likely to provide a migration pathway for diadromous fish species[16] that are either migrating upstream to freshwater habitats or downstream for spawning.

The effects on fish from the proposed Plan Change are linked to water quality, including increases in TSS during the construction period, contaminants bound to sediments and increased nutrient loadings that can impact benthic invertebrate and macroalgal communities, with subsequent flow on effects for fish.

An effect with a higher degree of uncertainty is the potential for high concentrations of EOCs in wastewater discharge from the proposed E-MBR. The potential impacts of EOCs on marine life include reduced feeding rates, survival, binding of mussels to rock surfaces, changes to spawning behaviour and immune response and biochemical markers (Gaw *et al*., 2014). While some attenuation of EOCs will likely occur in the coastal wetland system, it is acknowledged that literature on the removal efficiencies of EOCs in wetlands in an evolving area of research. Further work is expected during the resource consenting phase to understand potential wastewater associated effects, including those associated with EOCs, however, we expect that these effects can be appropriately managed.

When considering the magnitude of effect on fish, the following is noted:

- Based on an overall low magnitude of effect on benthic communities, it is likely that there will also be some effect on fish species that feed directly on the benthos.
- Effects associated with sediment suspension, such as reduced foraging ability, are likely to be measurable during peak sediment discharges from the Site, with effects lessening over time following completion of construction.
- Effects associated with metal contaminants are not expected to adversely impact fish communities, based on predicted low zinc and copper concentrations in marine sediments.

It is considered that there is a potential **Low** magnitude of effect on fish within the ZOI of stream discharge points; based on the **High** ecological value of fish this equates to an overall **Low** level of ecological effect on fish. This level of effect is dependent on further work being undertaken during the resource consenting phase.

[16] Fish species that live in both freshwater and marine environments for a portion of their life cycle.

5.2.3 Coastal saline vegetation

5.2.3.1 Coastal saline vegetation values

Coastal saline vegetation values have been separated based on the two vegetation types identified during intertidal habitat mapping; mangroves and saltmarsh.

Areas dominated by mangroves are classified with a regional IUCN threat status of Least Concern and are locally and nationally common. However, mangroves provide important habitat for species such as banded rail (*Gallirallus philippensis*) with a threat classification of 'At Risk – Declining'. Mangroves are widespread in the Auckland region, and are widespread in the upper Waikopua, Turanga and Mangemangeroa Creeks. Mangroves are considered to be of **Moderate** ecological value.

The saltmarsh meadow habitat consisting of herbfields within a mosaic of sea rush is one of the variants of mangrove forest and scrub ecosystem classified by Singers *et al.*, (2017) with a regional IUCN threat status of Least Concern. However, coastal turfs are an historically rare ecosystem (Williams *et al*., 2007). Saltmarsh meadows provide foraging and nesting habitat for indigenous fauna including banded rail and other shore birds. Considering this, the areas of saltmarsh are considered of **High** ecological value.

5.2.3.2 Magnitude and overall effect on coastal saline vegetation

The proposed PPC, and associated change in Land use, has the potential to adversely impact coastal saline vegetation. Adverse effects might include the degradation of vegetation communities through a loss of species richness, overall extent, or habitat quality:

- **Saltmarsh**. Saltmarsh wetlands are effective sinks for metal contaminants and the concentration of heavy metals is unlikely to cause adverse effects for salt marsh communities (Williams *et al.*, 1994). Salt marsh communities are also predicted to be relatively resilient to sedimentation effects and can be used to remove sediment loads (Thomsen *et al.*, 2009). Nonetheless, few studies have assessed the effects of pollutants on salt marsh communities and there may be effects.

  In addition to the potential effects from discharges, it is possible that there would be low levels of trampling and disturbance by people accessing the foreshore, notwithstanding efforts to direct foot traffic away from these areas.

  On this basis, the magnitude of effect on saltmarsh vegetation is expected to be **Low**. With reference to a high ecological value and Volume 2: Appendix A, this equates to an overall **Low** ecological effect.
- **Mangroves**. With regards to effects on mangrove habitats, mangroves are tolerant to a wide range of environmental conditions and accumulate heavy metals, buffering the wider environment from pollutants (Bastakoti et al., 2018). However, any increases in sediment or nutrient loading as a result of the proposed change in Land use (construction and operation, and including the proposed E-MBR discharge) is likely to further enhance / accelerate mangrove growth in the Whitford embayment area, thereby altering the rate at which mangrove habitat would expand under natural circumstances (i.e. with no anthropogenic influences). In other areas of New Zealand, mangrove expansion has been attributed to catchment Land use inputs, including increased fine sediments and nutrients (Morrisey *et al*., 2007; Swales *et al*., 2007).

  Mangrove expansion in the Waikopua Creek is best shown in Figure 4.3, which identifies additional mangrove growth from 1961 to the present day, with an area of approximately 26,000 m^2 of additional mangrove growth. Mangrove encroachment can occur at the expense of other habitat types, such as intertidal feeding grounds and high-tide roosts, as has been observed elsewhere in the Auckland region (i.e. the Waipipi roost and Pollok Spit in the Manukau Harbour).

With reference to the model outputs, it is evident that during the ten-year construction period, sediment accumulation around the Waikopua Creek mangrove habitat is likely to exceed 2 mm / year above existing background rates, thereby potentially exacerbating mangrove expansion in this area. In the longer term however, the effect associated with sediment deposition and mangrove expansion would significantly reduce, based on a 64 % reduction is sediment discharges from the Site under the developed scenario (Live Zone and FUZ).

The impact on mangroves associated with additional nutrient loads to the CMA will be dependent on the wastewater disposal option selected. This option will be refined during the resource consenting phase however we expect that these effects can be appropriately managed.

In the context of the EIANZ framework, and with reference to Volume 2: Appendix A, this would constitute a **Low** magnitude of effect. This magnitude of effect considers that while the Waikopua Creek mangrove habitat would be impacted in the short term (ten years), effects on mangrove vegetation (i.e. accelerated encroachment of mangroves) would lessen over the longer term. With reference to a high ecological value, this equates to an overall **Low** ecological effect. This level of effect is dependent on further work being undertaken during the resource consenting phase.

5.2.4 Coastal birds

5.2.4.1 Coastal bird values

Following the EIANZ framework, the species and habitat in the vicinity of the site are considered to have a **Very high** ecological value, based on the presence of ‘Threatened’ species in the ZOI either permanently or seasonally.

Coastal bird values ranged from Negligible (introduced species), to Very High (Nationally Threatened species) as presented in Table 5.3 below. Very High value birds observed during surveys included Caspian tern and New Zealand dotterel, and High value birds observed during surveys included banded dotterel, bar-tailed godwit, red-billed gull, South Island pied oystercatcher, white-fronted tern and banded rail.

Other potential Very High value species at the site include reef heron, shore plover and wrybill. Great knots have also been considered as having a Very High ecological value as their IUCN global threat status is Endangered.

Table 5.3 also denotes the four broad ‘functional groups’ that are characterised based on the predominant use of habitat at the site and that may be affected differently by activities from the PPC; these coastal bird functional groups include:

- ‘**Waders**’ such as godwits or oystercatchers, which predominately feed on benthic marine fauna within the inter-tidal mud/sand flats. Some waders also utilise shellbank habitat adjacent to the Site for nesting.
- ‘**Water column feeders’** such as shags or terns, that predominately forage on fish or other marine organisms within the water column when the inter-tidal habitat is inundated.
- ‘**Generalist feeders**’, such as seagulls and herons that forage (herons) or scavenge (seagulls) on both benthic marine fauna and fish can be found within the inter-tidal habitat at all or most tidal cycles.

- '**Coastal fringe and wetland species'**, e.g. banded rail that forage and nest within mangrove forest and salt marsh vegetation.

Table 5.3: Native coastal bird threat status, functional group and ecological value (with reference to Volume 2: Appendix E; Table 1)

Common name	Species name	Threat status (NZTCS, 2017)	Function group	Ecological value
Shore plover	*Thinornis novaeseelandiae*	Threatened – Nationally Critical	Wader	Very high
Reef heron	*Egretta sacra*	Threatened – Nationally Endangered	Generalist	Very high
New Zealand dotterel	*Charadrius obscurus*	Threatened – Nationally Increasing	Wader	Very high
Caspian tern	*Hydroprogne caspia*	Threatened – Nationally Vulnerable	Water-column feeder	Very high
Wrybill	*Anarhynchus frontalis*	Threatened – Nationally Increasing	Wader	Very high
Great knot	*Calidris tenuirostris*	Vagrant (IUCN classification of 'Endangered)	Wader	Very high
Black-billed gull	*Larus bulleri*	At Risk - Declining	Generalist	High
Banded dotterel	*Charadrius bicinctus*	At Risk – Declining	Wader	High
Banded rail	*Gallirallus philippensis*	At Risk – Declining	Coastal fringe and wetland	High
Bar-tailed godwit	*Limosa lapponica*	At risk – Declining	Wader	High
Lesser knot	*Calidrus canutus*	At Risk – Declining	Wader	High
Red-billed gull	*Larus novaeholandiae*	At risk – Declining	Generalist	High
South Island pied oystercatcher	*Haematopus finschi*	At risk – Declining	Wader	High
White-fronted tern	*Sterna striata*	At risk – Declining	Water-column feeder	High
Black shag	*Phalacrocorax carbo*	At risk – Relict	Water-column feeder	Moderate
Royal spoonbill	*Platalea regia*	At risk – Naturally Uncommon	Wader	Moderate
Little black shag	*Phalacrocorax sulcirostris*	At risk – Naturally Uncommon	Water-column feeder	Moderate
Little shag	*Phalacrocorax melanoleucos*	At Risk - Relict	Water-column feeder	Moderate
Pied shag	*Phalacrocorax varius*	At risk – Recovering	Water-column feeder	Moderate

Common name	Species name	Threat status (NZTCS, 2017)	Function group	Ecological value
Variable oystercatcher	*Haematopus unicolor*	At risk – Recovering	Wader	Moderate
Red-necked stint	*Calidris ruficollis*	Migrant (IUCN classification of Near Threatened)	Wader	Moderate
Australasian gannet	*Morus serrator*	Not threatened	Water-column feeder	Low
Black-backed gull	*Larus dominicanus*	Not threatened	Generalist	Low
Little shag	*Phalacrocorax melanoleucos*	Not threatened	Water-column feeder	Low
Pied stilt	*Himantopus*	Not threatened	Wader	Low
White-faced heron	*Egretta novaehollandiae*	Not threatened	Generalist	Low
Black swan	*Cygnus atratus*	Not Threatened	Generalist	Low
Ruddy turnstone	*Arenaria interpres*	Migrant (IUCN classification of Near Threatened)	Wader	Low
Pacific golden plover	*Pluvialis fulva*	Migrant (IUCN threat classification of Least Concern)	Wader	Low

5.2.4.2 Magnitude and overall effect on coastal birds

The magnitude of effects on ecological values is assessed based on the extent, intensity, duration and timing of effects associated with the PPC. Potential effects on coastal avifauna values are set out below and in turn the magnitude of effects on each of these values are assessed after efforts to avoid, remedy or mitigate effects (as outlined in Section 5.1.1 below).

In general, the threats to coastal avifauna values are centred around urbanisation and associated adverse effects, including disturbance, an increase in potential for predation by domestic cats and dogs, sedimentation and associated mangrove spread, contamination and lighting. In isolation, each effect can appear negligible in nature, however this assessment takes into account the cumulative impact of these effects on coastal avifauna values.

In addition, some of these effects are likely to occur only during the construction phase of the project, while others are expected to continue on a permanent basis.

Disturbance at high tide roosting sites and on foraging grounds can have adverse effects on birds through a reduction in time spent foraging or roosting. The threat of disturbance can result in increased 'vigilance behaviour' to visually monitor a perceived threat, walking/running away from a perceived threat, or taking flight (Weston et al. 2012; Lilleyman et al. 2016). The distance at which a bird species will take flight is termed the Flight Initiation Distance (FID) and is variable depending on the bird species and the life stage. A larger FID is also expected where dogs are off the leash in the CMA. For coastal avifauna, responding to disturbance and perceived threats exacts a cost in terms of energy expenditure that can be significant.

Excessive levels of disturbance can also result in the functional loss of otherwise suitable foraging or roosting habitat through avoidance behaviour. A New Zealand study also found that New Zealand dotterel (*C.obscurus*) exhibited a greater avoidance response to humans and dogs while nesting, and remained off their nests for longer as a result (Lord *et al*., 2001). New Zealand dotterels nest currently at the Waikopua shellbanks.

Based on modelled outputs, erosion and sediment control practices (and construction staging) and water sensitive urban design, it is considered that effects from sedimentation (suspended or settled) are likely to have some impact on foraging quality for coastal birds. Increased inputs of sediment (during the construction phase) and nutrients to the marine receiving environment also have the potential to exacerbate mangrove growth and further encroachment into both important foraging habitat and the Waikopua shellbanks.

Urbanisation is also generally accompanied by an increase in pest animals (i.e. rats and cats) which poses a predation risk to roosting and nesting birds. Urban areas are also associated with a higher ambient level of artificial lighting, however coastal vegetation currently acts as a buffer that is likely to mitigate this potential effect.

The magnitude of effects from the PPC have been assessed based on the functional group of coastal bird species, as follows:

- **Waders**. Wading bird species largely inhabit shorelines where they hunt for small animals (mostly invertebrates) that sustain them during the mid and low tidal stages. Waders also utilise high tide sites for roosting, at which point they rest and preen. During the high tide, they are susceptible to general public access at high tide beaches and roost sites, an effect that is likely to occur more frequently with access to the CMA adjacent to an urbanised site. Waders, such as dotterel and variable oystercatchers, that nest on shellbanks and high tide beaches are also susceptible to increased predation from pests associated with urbanisation. Pest control is currently proposed for terrestrial ecological areas on the site, with additional pest control targeted along the coastal edge to provide a buffer and level of protection to wading species that nest above MHWS.

  A 2021 synthesis review on the effects of sediment on foraging birds in intertidal and nearshore habitats in Aotearoa New Zealand provides some further context to sedimentation impacts on food resources that waders rely on (Lukies et al., 2021). While the authors acknowledge that literature on this topic is scant, they do provide case studies and examples from international studies that add weight to the argument that impacts on benthic community health (abundance and diversity) can adversely impact the ability of an area to support foraging shorebirds (Jackson et al., 2020).

  Waders that feed on benthic invertebrates can also be impacted through bioaccumulation of contaminants, including sediment, EOCs pathogens and heavy metals. EOCs concentrations in the proposed E-MBR discharge are currently unknown, therefore this potential risk should be treated with a level of conservatism.

  On balance, the magnitude of effect on wading bird species as a result of the proposed Plan Change is **Moderate**. This magnitude of effect considers the permanence of effects and the likelihood of each effect occurring. The ecological value of wading bird species ranged from **Low** to **Very High**. Based on a **Moderate** magnitude of effect, this equates to an overall **Very Low** to **High** ecological effect on wading birds.
- **Water column feeders**. Increased suspended sediment concentrations in the water column can adversely impact the foraging ability of birds (i.e. shags and terns) that feed in the water column at or near the water surface; this is where effects from increased suspended sediment are more noticeable (and more pronounced due to stratification of the water column). This effect is further supported by the previously mentioned literature review by Lukies et al. (2021), with increased turbidity contributing to a decline in feeding efficiency for visual foragers.

Based on the modelled outputs, the potential magnitude of effect from TSS is expected to be negligible, therefore limited impacts on water column feeders (over and above existing sediment inputs from the catchment) are expected. Water column feeders generally have large home ranges relative to the ZOI and can relocate when feeding conditions are unfavourable.

The ecological value of water column feeders ranged from **Low** to **Very High**. Based on a **Negligible** magnitude of effect, this equates to an overall **Very low** to **Low** ecological effect on water column feeders.

- **Generalist feeders**. Many of the threats associated with the proposed Land use change as described for waders will also apply to generalist feeders, such as gulls. However, these coastal bird species are not dependent on the marine receiving environment to the same degree as they can rest on the water and their breeding sites are not located within the ZOI[17].

  The ecological value of generalist feeders ranged from **Low** to **Very High**. Based on a **Negligible** magnitude of effect, this equates to an overall **Very Low** to **Low** ecological effect on water column feeders.

- **Coastal fringe and wetland species**. Potential effects on coastal vegetation that provide habitat for cryptic birds (such as banded rail) are likely to be **Low** to **Moderate** for saltmarsh and mangroves respectively (as outlined in Section 5.2.3).

  However increased disturbance associated with humans and dogs in the CMA, and associated pest species such as cats and rats, have the potential to predate on coastal fringe species, such as the banded rail, that are known to nest in saltmarsh habitats.

  Pest control is currently proposed for terrestrial ecological areas on the Site, with additional pest control targeted along the coastal edge to provide a buffer and level of protection to coastal fringe bird species that nest in saltmarsh vegetation.

  The ecological value of the coastal fringe and wetland species is **High**. Based on a **Low** magnitude of effect, this equates to an overall **Low** ecological effect on coastal fringe species.

5.3 Overall level of effects summary

Residual ecological effects that are moderate or higher warrant further efforts to avoid, remedy or mitigate and offset and compensate where required. Table 5.4 below summarises the ecological effects associated with the proposed PPC and concludes that the overall level of residual effects on the marine receiving environment are **Moderate** for effects on firm muddy sand flat / cockle shell covered flats, shellbank habitats and coastal birds.

With reference to the EIANZ framework, further effects management to reduce the overall effects on habitats and coastal avifauna is warranted; refer to Section 6 below.

[17] Black-billed gulls nest predominantly on sparsely vegetated gravels on inland river beds in the South Island. While red-billed gulls do nest in the North Island, there are no known nesting sites in the marine receiving environment surrounding the Site.

Table 5.4: Summary of ecological values, magnitude of effect and overall ecological effects on ecological values in Beachlands marine receiving environment

Habitat attribute / species	**Ecological value**	**Magnitude of residual effect on ecological values after measures to avoid, remedy or mitigate effects**	**Potential overall level of residual effect on ecological values**
Marine habitats	Seagrass - high	Low	Low
	Firm muddy sand flats / cockle shell covered flats – very high	Low	Moderate
	Shellbanks – very high	Low	Moderate
	Sandstone reef - high	Low	Low
	Soft gloopy mud – moderate	Negligible	Very Low
	Rock revetment - low	Negligible	Very Low
Fish	High	Low	Low
Coastal saline vegetation	Mangroves – moderate	Low	Low
	Saltmarsh and saltmeadow - high	Low	Low
Coastal birds	Waders – Low to Very high	Moderate	Very Low to High
	Water column feeders – Low to Very High	Negligible	Very Low to Low
	Generalist Feeders - Low to Very High	Negligible	Very Low to Low
	Coastal fringe and wetland species - High	Low	Low

6 Proposed Residual Effects Management Measures

As outlined in Section 5.3 above, our assessment of effects on marine ecological values concludes that there are residual effects (i.e. effects identified as **Moderate** and above) on firm muddy sand flat / cockle shell covered flats and shellbank habitats and coastal birds.

With reference to the EIANZ framework, further effects management to reduce the overall effects on habitats and coastal avifauna is required to ensure NNL in biodiversity values.

This PPC seeks to achieve NNL outcomes for marine biodiversity within five years through the type and magnitude of restoration and habitat enhancement actions proposed. Accordingly, this section sets out:

- An overview of residual effects management, i.e. offsetting and compensation (Section 6.1).
- The overall approach for addressing the residual effects on marine ecological values that cannot be avoided, remedied or mitigated (Section 6.2).
- The proposed habitat restoration or enhancement measures that will be undertaken for the purpose of addressing residual effects on marine ecological values (Section 6.3).

6.1 Residual effects management principles

Management of residual effects after efforts to avoid, remedy or mitigate impacts fall to offsetting or compensation. As defined in Baber et al., (2021) and Quinn et al. (2021):

> *"A biodiversity offset is a 'measurable conservation outcome' that meets certain principles and balances adverse residual effects, to a No Net Loss (NNL) or preferably Net Gain (NG) standard. While offsetting requires a measurable outcome that has been quantified through a robust and transparent process, biodiversity compensation does not necessarily need to be quantified and measurable. However, compensation measures under the principles of biodiversity compensation (as described below) are intended to achieve No Net Loss or preferably Net Gain outcomes where possible."*

Key biodiversity offsetting principles as set out in Appendix 3 of the draft National Policy Statement for Indigenous Biodiversity (draft NPS-IB, November 2019) include the principles of:

- NNL or preferably NG outcomes.
- Adherence to the effects management hierarchy. Offset should only be contemplated after steps to avoid, remedy, or mitigate adverse effects have sequentially been exhausted, and thus applies only to residual biodiversity impacts. Compensation, as the least certain and most risky management of effects, should be considered as a last resort.
- Ecological Equivalence, meaning the degree to which the biodiversity gain attributable to an offset is balanced with the biodiversity losses and therefore whether the exchange achieves NNL.
- Additionality, meaning the gains in biodiversity must be above and beyond gains that would have occurred anyway in the absence of the offset or compensation.
- Long-term outcomes (preferably in perpetuity).
- Landscape context, whereby the biodiversity offset or compensations considers the landscape context of both the impact site and the offset site.

- Science and matauranga Māori, whereby the design and implementation of a biodiversity offset must be a documented process informed by science, including an appropriate consideration of matauranga Māori[18].

Similarly, key biodiversity compensation principles are outlined in Appendix 4 of the draft NPS-IB. These biodiversity compensation principles generally follow the above offsetting principles, with the most notable difference relating to the scale of biodiversity compensation. Instead of the NNL or preferably NG outcome required by offsetting, compensation requires the indigenous biodiversity values lost through the activity to be addressed by positive effects to indigenous biodiversity that are proportionate to the adverse effects.

6.2 Proposed approach to residual effects management

The proposed residual effects management approach seeks to achieve NNL outcomes within ten years of commencement of compensation actions for the residual effects on indigenous marine biodiversity values.

Currently, our understanding of potential residual effects is based on outputs from predictive models (for effects on sand flats and shell banks) and literature of disturbance-based effects on coastal birds. The approach to residual effects management will broadly seek to first monitor actual effects, and concurrently implement compensation actions that will have a clear and direct benefit to marine biodiversity values. Further monitoring of effects and adaptive management will direct the approach for further compensation actions if Biodiversity Compensation Modelling suggests that there is a NL of biodiversity.

Preliminary ecological compensation options are outlined in Section 6.3 and will be developed further and fine-tuned during the resource consenting phase and subsequently following monitoring and adaptive management as development proceeds.

The proposed habitat restoration and enhancement options are all forms of compensation and do not strictly meet the definition of offsetting. This is due to the nature of residual effects and their management, which do not readily lend themselves to accounting for gains and losses with the necessary degree of confidence to constitute an offset (Baber *et al*., 2021). Specifically:

- The benefits associated with the proposed habitat enhancement constitute like-for-like effects management in a broad sense, but do not constitute an 'apples-for-apples' scenario for the purpose of biodiversity offset modelling. Adverse effects on marine biodiversity values will be addressed through positive effects on marine biodiversity values.
- There are potential (albeit low level) effects on biodiversity values that are difficult to detect or monitor, and for which the response to offsetting or compensation measures may be slow or uncertain (e.g. bird-roost enhancements).

Although biodiversity compensation does not require the same numerical rigour as offsetting, it is generally recognised that ecological outcomes are improved where offset principles are applied as a guideline when designing compensation packages.

The type and magnitude of proposed compensation measures will be guided by the application of a BCM (Baber *et al*., 2021).

[18] This principle will be addressed primarily in the Cultural Impact Assessment and integrated into the residual effects management approach. Similarly, other inter-related principles and disciplines, e.g., stormwater management and landscape design will be built into the overall residual effects management package for ecology.

6.3 Preliminary marine ecological compensation options

Preliminary compensation options are outlined below and will be fine-tuned following monitoring and through the resource consenting phase based on specific development activities at that time:

1 Enhancement of coastal avifauna habitat. The Waikopua shellbanks adjacent to the site are currently in a degraded state and on a declining trajectory. This is due to encroachment by invasive weeds (e.g. pampas) that is preventing the use of some parts of the shellbank for roosting or nesting, and proliferation of mangroves immediately surrounding the shellbanks which inhibits suitability for roosting and nesting birds by compromising line of site.

To this end, selective vegetation removal (mangroves and saline vegetation) and replanting of ground cover native species that introduce better line of sight will improve the quality of this habitat type both for roosting and nesting purposes.

This measure is in line with approaches being taken in other areas i.e. Tāmaki Makaurau, Waiuku River and the wider Manukau Harbour. The carrying capacity of intertidal areas for shorebirds is linked to the proximity of good high tide roosts, with proximity to foraging grounds being one of the most important factors affecting roost choice by shorebirds (Jackson, 2017). Improvements to the Waikopua shellbank roost site are therefore likely to also improve the utility of the intertidal foraging grounds by coastal bird species.

5 Mangrove management. Selective removal of mangroves and ongoing maintenance of seedlings is proposed to maintain quality foraging habitat at the mouth of the Waikopua Creek. Without intervention it is likely that mangroves will continue to expand seawards in this location, compromising foraging habitat quality and impinging on other habitats.

6 The large coastal wetland near the middle of the site currently comprises predominantly exotic vegetation and initially appears like a good enhancement opportunity. Based on experience it is expected that there would be logistical, technical, resource and cost issues associated with its restoration and we have a low level of confidence in successful outcomes.

To adequately address residual effects, in addition to the preliminary measures proposed above, restoration and enhancement activities could also be undertaken at a broader embayment scale. This ideally would include roost enhancement of shellbanks close to Motukaraka Island or on the opposite side of the Whitford Embayment at Porterfield Road Esplanade Reserve.

In conclusion, we consider it likely that all residual effects associated with a change in Land use activities can be adequately addressed through implementation of compensation measures and following Biodiversity Compensation Modelling. Associated monitoring to verify that expected ecological outcomes have been realised and to guide adaptive management, will further ensure NNL for marine ecological values.

7 Conclusion

In conclusion, our assessment is that most effects due to rezoning from the PPC, associated Land use change and subsequent development on marine habitats and values will be **Very Low** to **Low** provided the measures to avoid remedy or mitigate effects are implemented as set out in this report. However, our assessment also indicates that some residual (**Moderate** or higher) effects remain that should be offset or compensated, including residual effects on firm muddy sand flat / cockle shell covered flats, shellbank habitats and coastal birds due to effects associated with discharges and disturbance in the CMA.

Residual effects associated with the development of the Live Zone and the FUZ can be addressed through the proposed effects management measures and we consider that a NNL outcome for marine ecological values can be achieved.

Effects management outcomes for marine ecology will be achieved through the Auckland Wide provisions under the AUP and proposed precinct provisions developed for the proposed Beachlands South Precinct (as set out in the Planning Report that accompanies the PPC application) and through subsequent resource consent processes, including associated consent conditions, management plans and monitoring. Measures to manage residual effects include Biodiversity Compensation Modelling and associated monitoring to verify that expected ecological outcomes have been realised, and to guide adaptive management as required.

We therefore consider that adverse ecological effects on marine and coastal values due to the PPC and subsequent development can be adequately addressed through the effects management measures outlined in this report and as guided by the Auckland-wide and proposed precinct provisions.

8 Applicability

This report has been prepared for the exclusive use of our client Beachlands South Limited Partnership, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that our client, BSLP, will submit this report as part of an application for a Plan Change that Auckland Council as the regulatory authority will use this report for the purpose of assessing that application.

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9 References

Anderson, M J (2008) Animal-sediment relationships re-visited: Characterising species' distributions along an environmental gradient using canonical analysis and quantile regression splines. Journal of Experimental Marine Biology and Ecology 366(1–2): 16–27.

Auckland Regional Council (2004). *Blueprint for monitoring urban receiving environments*. Auckland Regional Council Technical Publication No 168, Auckland.

Auckland Regional Council (1992). Embargoed shellfish resources report.

Australian and New Zealand Environmental and Conservation Council (ANZECC) (2018) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZWQG), Volume 1, The Guidelines.

Baber, M, Dickson, J, Quinn, J, Markham, J, Ussher, G, Heggie-Gracie, S, and Jackson, S (2021). A Biodiversity Compensation Model for New Zealand – A User Guide (Version 1). Prepared by Tonkin & Taylor Limited. Project number 1017287.0000P

Bastakoti, U., Robertson, J., & Alfaro, A. C. (2018). Spatial variation of heavy metals in sediments within a temperate mangrove ecosystem in northern New Zealand. Marine pollution bulletin, 135, 790-800.

Belliss, S., Shepherd, J. D., Newsome, P., & Dymond, J. (2017). An analysis of wetland loss between 2001/02 and 2015/16. Landcare research contract report.

Cadwallader, H.F. (2020) The ecology of ray species in an urbanised estuary; seasonality, habitat use and pollutant exposure in Tauranga Harbour. PhD thesis, University of Waikato

Coles, R.; McKenzie, L.; Campbell, S. 2003: The seagrasses of eastern Australia. Pp. 119–133 in Green, E.P.; Short, F.T. (Eds): World atlas of seagrasses. University of California Press, Berkeley, California.

De Lange, P. J., Rolfe, J. R., Barkla, J. W., Courtney, S. P., Champion, P. D., Perrie, L. R., Beadel, S. M., Ford, K. A., Breitwieser, I., Schönberger, I., Hindmarsh-Walls, R., Heenan, P. B. & Ladley, K. (2017). Conservation status of New Zealand indigenous vascular plants. New Zealand Threat Classification Series 22. 82 p.

Duarte, C.M.; Terrados, J.; Agawin, N.S.R.; Fortes, M.D.; Bach, S.; Kenworthy, J.W. 1997: Response of a mixed Philippine seagrass meadow to experimental burial. Marine Ecology Progress Series 147: 285–294.

Duffy, C., Francis, M., Dunn, M., Finucci, B., Ford, R., Hitchmough, R. and Rolfe, J. (2016). *Conservation status of New Zealand chondrichthyans (chimaeras, sharks and rays), 2016*. Department of Conservation.

Freeman, D., Schnabel, K. E., Marshall, B., Gordon, D. P., Wing, S., Tracey, D. M., Hitchmough, R. (2014). *Conservation status of New Zealand marine invertebrates, 2013*. Department of Conservation.

Gaw, S., Thomas, K., Hutchinson, T.H., (2016) Pharmaceuticals in the marine environment. In: Hester, R., Harrison, R. (Eds*.), Issues in Environmental Science and Technology No 41 Pharmaceuticals in the Environment*. The Royal Society of Chemistry.

Gibbs, M., & Hewitt, J. (2004). Effects of sedimentation on macrofaunal communities: a synthesis of research studies for ARC. NIWA Client Report: HAM2004-060

Green, E.P.; Short, F.T. (Eds) 2003: World atlas of seagrasses. University of California Press, Berkeley, California. 324 p.

GWE (March 2022). Beachlands South - Reticulation and WWTP Concept Design V3.

Harrison Grierson (2021) Erosion and Sediment Control Plan

Hayward, B.W., Morley, M.S., Stephenson, A.B., Blom, W.M., Grenfell, H.R., Prasad, R., Rogan, D., Thompson, F., Cheetham, J. and Webb, M., 1999. Intertidal and subtidal biota and habitats of the central Waitemata Harbour. Auckland Regional Council Technical Publication, 127, p.40.

Hemminga, M.A.; Duarte, C.M. 2000: Seagrass ecology. Cambridge University Press, United Kingdom. 298 p.

Hewitt, J.E., Hatton, S., Safi, K. and Craggs, R (2001) Effects of suspended sediment levels on suspension-feeding shellfish in the Whitford Embayment. ARC Technical Publication 159

Hewitt, J.E., Lohrer, D., Townsend, M. (2012). Health of Estuarine Soft-sediment Habitats: continued testing and refinement of State of the Environment indicators. Prepared by NIWA for Auckland Regional Council. Auckland Council Technical Report, 2012/012.

Hewitt, J.E., Carter, K.R. (2020). Auckland east coast estuarine monitoring programme: summary of key changes 2015-2018. Prepared by NIWA for Auckland Regional Council. Auckland Council Technical Report, 2020/011

Ingley, R (2020). Coastal and estuarine water quality: 2019 annual data report. Auckland Council technical report, TR2020/016

Jackson, M. V., Fuller, R. A., Gan, X., Li, J., Mao, D., Melville, D. S., . . . Choi, C.-Y. (2021). Dual threat of tidal flat loss and invasive Spartina alterniflora endanger important shorebird habitat in coastal mainland China. Journal of environmental management, 278, 111549.

James, M., Stewart, M., Phillips, N., and Cook, J. (2016) Assessment of Ecological Effects on the receiving environment from the discharge of treated wastewater from a combined Clarks Beach, Waiuku and Kingseat WWTP. Prepared for Watercare Services Ltd

Lilleyman, A., Franklin, D. C., Szabo, J. K., & Lawes, M. . J. (2016). Behavioural responses of migratory shorebirds to disturbance at a high-tide roost. Emu, 116(2), 111–118.

Lord, Andrea & Waas, Joseph & Innes, John & Whittingham, Mark. (2001). Effects of Human Approaches to Nests of Northern New Zealand Dotterels. Biological Conservation. 98. 233-240.

Lovelock, C. E., Feller, I. C., Ellis, J., Schwarz, A. M., Hancock, N., Nichols, P., & Sorrell, B. (2007). Mangrove growth in New Zealand estuaries: the role of nutrient enrichment at sites with contrasting rates of sedimentation. *Oecologia*, *153*(3), 633-641.

Lowe, M.L., Morrison, M.A., Taylor, R.B. (2015) Harmful effects of sediment-induced turbidity on juvenile fish in estuaries. *Marine Ecology Progress Series*. Vol.539 241-254

Lukies, K.A., Gaskin, C.P. and Whitehead, E.A (2021) The effects of sediment on birds foraging in intertidal and nearshore habitats in Aotearoa New Zealand: A literature review and recommendations for future work. Prepared for the Department of Conservation by the Northern New Zealand Seabird Trust, Auckland. 77 p.

Manzanera, M.; Pérez, M.; Romero, J. 1998: Seagrass mortality due to oversedimentation: an experimental approach. Journal of Coastal Conservation 4: 67–70.

Matheson, F.; Dos Santos, V.; Inglis, G.; Pilditch, C.; Reed, J.; Morrison, M.; Lundquist, C.; Van Houte-Howes, K.; Hailes, S.; Hewitt, J. (2009). New Zealand seagrass – General Information Guide NIWA Information Series No. 72

Matheson, Fleur & Lundquist, Carolyn & Gemmill, Chrissen & Pilditch, Conrad. (2011). New Zealand seagrass – More threatened than IUCN review indicates. Biological Conservation - BIOL CONSERV. 144. 10.1016/j.biocon.2011.08.020.

Mills, G., Allen, H. (2021). Marine Sediment Contaminant State and Trends in Tamaki Makaurau / Auckland 2004-2019. State of the Environment Reporting. Auckland Council Technical Report, TR2021/10

Morrisey, D., Beard, C., Morrison, M., Craggs, R. and Lowe, M., 2007. The New Zealand mangrove: review of the current state of knowledge. Auckland Regional Council Technical Publication, 325, p.162.

Morisson, M.A., Lowe, M. L., Grant, C. M., Smith, P. J., Carbines, G., Reed, J., Bury, S. J. and Brown, J. (2014). Seagrass Meadows as Biodiversity and Productivity Hotspots. New Zealand Aquatic Environment and Biodiversity Report No 137

National Aquatic Biodiversity Information System (NABIS). Retrieved from: http://www.nabis.govt.nz/ (Data retrieved 13/07/2021).

NIWA (2009) Biodiversity of intertidal soft-sediment habitats in the Auckland Region. NIWA client report HAM2009-097, prepared for Department of Conservation

Robertson, H.A., Baird, K., Dowding, J.E., Elliott, G.P., Hitchmough, R.A., Miskelly, C.M., McArthur, N., O'Donnell, C.F.J., Sagar, P.M., Scofield, P and Taylor, G.A. (2017). *Conservation status of New Zealand birds, 2016*. Department of Conservation.

Roper-Lindsay, J., Fuller, S.A., Hooson, S., Sanders, M.D., and Ussher, G.T. (2018). Ecological Impact Assessment. EIANZ guidelines for use in New Zealand: terrestrial and freshwater ecosystems. 2nd edition.

Singers, N., Osborne, B., Lovegrove, T., Jamieson, A.; Boow, J.; Sawyer, J., Hill, K., Andrews, J., Hill, S., Webb, C. (2017). Indigenous terrestrial and wetland ecosystems of Auckland. Edited by Jane Conner, Auckland Council.

Swales, A., Bentley, S.J., Lovelock, C. and Bell, R.G., 2007. Sediment processes and mangrove-habitat expansion on a rapidly-prograding muddy coast, New Zealand. In Coastal Sediments' 07 (pp. 1441-1454).

Thomsen, M. S., Adam, P., & Silliman, B. R. (2009). Anthropogenic threats to Australasian coastal salt marshes. *Human Impacts on Salt Marshes: A Global Perspective*, 361-90

Thompson D.R., Dowding J.E. (1999) Site-specific heavy metal concentrations in blood of South Island pied oystercatchers Haematopus ostralegus finschi from the Auckland region, New Zealand. Marine Pollution Bulletin 38:202 –206

Thrush, S F; Hewitt, J.E; Norkko, A; Nicholls, P E; Funnell, G A; Ellis, J I (2003) Habitat change in estuaries: predicting broad-scale responses of intertidal macrofauna to sediment mud content. Marine Ecology-Progress Series 263: 101–112.

Tonkin + Taylor (2022). Beachlands South Structure Plan Change – Water Quality and Sedimentation Modelling Report. Prepared for Beachlands South Limited Partnership. Issued as DRAFT January 2022.

Townsend, M. and Lohrer, D. (2015) ANZECC Guidance for Estuary Sedimentation. Prepared for Ministry for the Environment, September 2015

Vermaat, J.E.; Agawin, N.S.R.; Fortes, M.D.; Uri, J.S.; Duarte, C.M.; Marbà, N.; Enríquez, S.; Van Vierssen, W. 1997: The capacity of seagrasses to survive increased turbidity and siltation: the significance of growth form and light use. Ambio 25: 499–504.

Walker, D.I. 2003: The seagrasses of Western Australia. Pp. 109–118 in Green, E.P.; Short, F.T. (Eds): World atlas of seagrasses. University of California Press, Berkeley, California.

Weston, M. A., McLeod, E. M., Blumstein, D. T., & Guay, P.-J. (2012). A review of flight-initiation distances and their application to managing disturbance to Australian birds. Emu-Austral Ornithology, 112(4), 269–286

Williams, T. P., Bubb, J. M., & Lester, J. N. (1994). Metal accumulation within salt marsh environments: a review. *Marine pollution bulletin*, *28*(5), 277-290.

Williams, P. A., Wiser, S., Clarkson, B., & Stanley, M. C. (2007). New Zealand's historically rare terrestrial ecosystems set in a physical and physiognomic framework. New Zealand Journal of Ecology, 119-128

Williamson, R. B., Hickey, C. W and Robertson, B. M (2017). Preliminary assessment of limits and guidelines available for classifying Auckland coastal waters. Prepared by Diffuse Sources, NIWA and Wriggle Coastal Management for Auckland Council. Auckland Council technical report, TR2017/035

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