NZ TRANSPORT AGENCY
WAKA KOTAHI

Roads of national significance

Ara Tūhono – Pūhoi to Wellsford

FURTHER NORTH

Pūhoi to Warkworth

Marine Ecology Assessment Report

August 2013

Boffa Miskell

Pūhoi to Warkworth

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Glossary of abbreviations

Abbreviation	Definition
AEE	Assessment of Environmental Effects
ANZECC	Australian and New Zealand Environment Conservation Council
ARC	Auckland Regional Council (preceded the Auckland Council)
ASCV	Area of significant conservation value
CMA	Coastal marine area
CPA 1	Coastal Protection Area 1 (as defined in ARP:C)
CPA 2	Coastal Protection Area 2 (as defined in ARP:C)
Cu	Copper
DoC	Department of Conservation
dw	Dry weight
ERC	Environmental response criteria
GIS	Geographic information system
GPS	Global positioning system
HMW	High molecular weight
ISQG	Interim sediment quality guideline
MHWS	Mean high water springs
NIWA	National Institute of Water and Atmospheric Research
NZTA	NZ Transport Agency
OSNZ	Ornithological Society of New Zealand
PAHs	Polycyclic Aromatic Hydrocarbons
RoNS	Roads of National Significance
s.e.	Standard error
SH1	State Highway 1
TOC	Total organic carbon

Abbreviation	Definition
TPH	Total petroleum hydrocarbons
TSS	Total suspended solids
Zn	Zinc

Glossary of defined terms

Term	Definition
Auckland Council	The unitary authority that replaced eight councils in the Auckland Region as of 1 November 2010.
Benthic	Of, relating to, or occurring at the bottom of a body of water.
Construction Runoff	Any runoff, sediment laden or otherwise, that flows as a result of the construction related activities. Typically results from rain events.
Earthworks	The disturbance of land surfaces by blading, contouring, ripping, moving, removing, placing or replacing soil or earth, or by excavation, or by cutting or filling operations.
Epifauna	Any organism living on the surface of the ocean floor (both subtidal and intertidal).
Infauna	Any organism living with intertidal or subtidal benthic sediment.
Intertidal	Marine habitat that occurs between high tide and low tide that is not permanently submerged.
Macroalgae	Macroscopic and multicellular red, green and brown algae.
Motorway	Motorway means a motorway declared as such by the Governor-General in Council under section 138 of the PWA or under section 71 of the Government Roading Powers Act 1989.
Pier	Vertical support structure for a bridge.
Primary habitat	The habitat type in which a species spend most of its time, though is not necessarily limited to (may utilise other habitat types less frequently).
Project Area	From the Johnstone's Hill tunnels portals in the south to Kaipara Flats Road in the north.
Ria	Long narrow river inlet.
Sediment Control	Capturing sediment that has been eroded and entrained in overland flow before it enters the receiving environment.
Stormwater	Water that flows from impervious areas and completed areas of the motorway after the construction period.
Subtidal	Marine habitat that occurs below low tide and is always submerged.
Taxa	Types / groups of animals (e.g. species).
Terrigenous	Sediment derived from the erosion of rocks on land; that is, that are derived from terrestrial environments.

Term	Definition
Terrestrial	Land-based.
Turbidity	Turbidity is a measure of water clarity or murkiness of a waterbody.
Wetland	Vegetated stormwater treatment device designed to remove a range of contaminants, providing superior water quality treatment to wetponds with increased filtering and biological treatment performance.

Contents

1. Introduction

The purpose of this report is to identify the marine ecological values of the Project area, assess the actual and potential effects of the Project on those values and identify measures to avoid, remedy or mitigate the potential effects identified.

The Project is an extension of the existing SH1 from the Northern Gateway Toll Road (NGTR) at Johnstone's Hill tunnels to just north of Warkworth.

During construction of the Project treated runoff will discharge to streams and rivers that ultimately discharge to the Mahurangi Harbour and the Pūhoi Estuary. In addition, in order to bridge the Okahu Creek, piers will be constructed within the Coastal Marine Area (CMA).

During the operational phase of the Project, treated road runoff will ultimately be discharged to the Mahurangi Harbour and Pūhoi Estuary.

1.1 Purpose of report

This report forms part of a suite of technical reports prepared for the NZ Transport Agency's (NZTA's) Ara Tūhono Pūhoi to Wellsford Road of National Significance (RoNS), Pūhoi to Warkworth Section (the Project). Its purpose is to inform the Assessment of Environmental Effects (AEE) and to support the resource consent applications and Notices of Requirement for the Project.

The indicative alignment shown on the Project drawings has been developed through a series of multi-disciplinary specialist studies and refinement. A NZTA scheme assessment phase was completed in 2011, and further design changes have been adopted throughout the AEE assessment process for the Project in response to a range of construction and environmental considerations.

It is anticipated that the final alignment will be refined and confirmed at the detailed design stage through conditions and outline plans of works (OPW). For that reason, this assessment has addressed the actual and potential effects arising from the indicative alignment, and covers the proposed designation boundary area.

1.2 Project description

This Project description provides the context for this assessment. Sections 5 and 6 of the Assessment of Environment Effects (Volume 2) further describe the construction and operational aspects of the Project and should be relied upon as a full description of the Project.

The Project realigns the existing SH1 between the Northern Gateway Toll Road (NGTR) at the Johnstone's Hill tunnels and just north of Warkworth. The alignment will bypass Warkworth on the western side and tie into the existing SH1 north of Warkworth. It will be a total of 18.5 km in length. The upgrade will be a new four-lane dual carriageway road, designed and constructed to motorway standards and the NZTA RoNS standards.

1.3 Project features

Subject to further refinements at the detailed design stage, key features of the Project are:

- A four lane dual carriageway (two lanes in each direction with a median and barrier dividing oncoming lanes);
- A connection with the existing NGTR at the Project's southern extent;
- A half diamond interchange providing a northbound off-ramp at Pūhoi Road and a southbound on-ramp from existing SH1 just south of Pūhoi;
- A western bypass of Warkworth;
- A roundabout at the Project's northern extent, just south of Kaipara Flats Road to tie-in to the existing SH1 north of Warkworth and provide connections north to Wellsford and Whangarei;
- Construction of seven large viaducts, five bridges (largely underpasses or overpasses and one flood bridge), and 40 culverts in two drainage catchments: the Pūhoi River catchment and the Mahurangi River catchment;
- A predicted volume of earthworks being approximately 8M m^3 cut and 6.2M m^3 fill within a proposed designation area of approximately 189 ha earthworks;

The existing single northbound lane from Waiwera Viaduct and through the tunnel at Johnstone's Hill will be remarked to be two lanes. This design fully realises the design potential of the Johnstone's Hill tunnels.

The current southbound tie in from the existing SH1 to the Hibiscus Coast Highway will be remarked to provide two way traffic (northbound and southbound), maintaining an alternative route to the NGTR. The existing northbound tie in will be closed to public traffic as it will no longer be necessary.

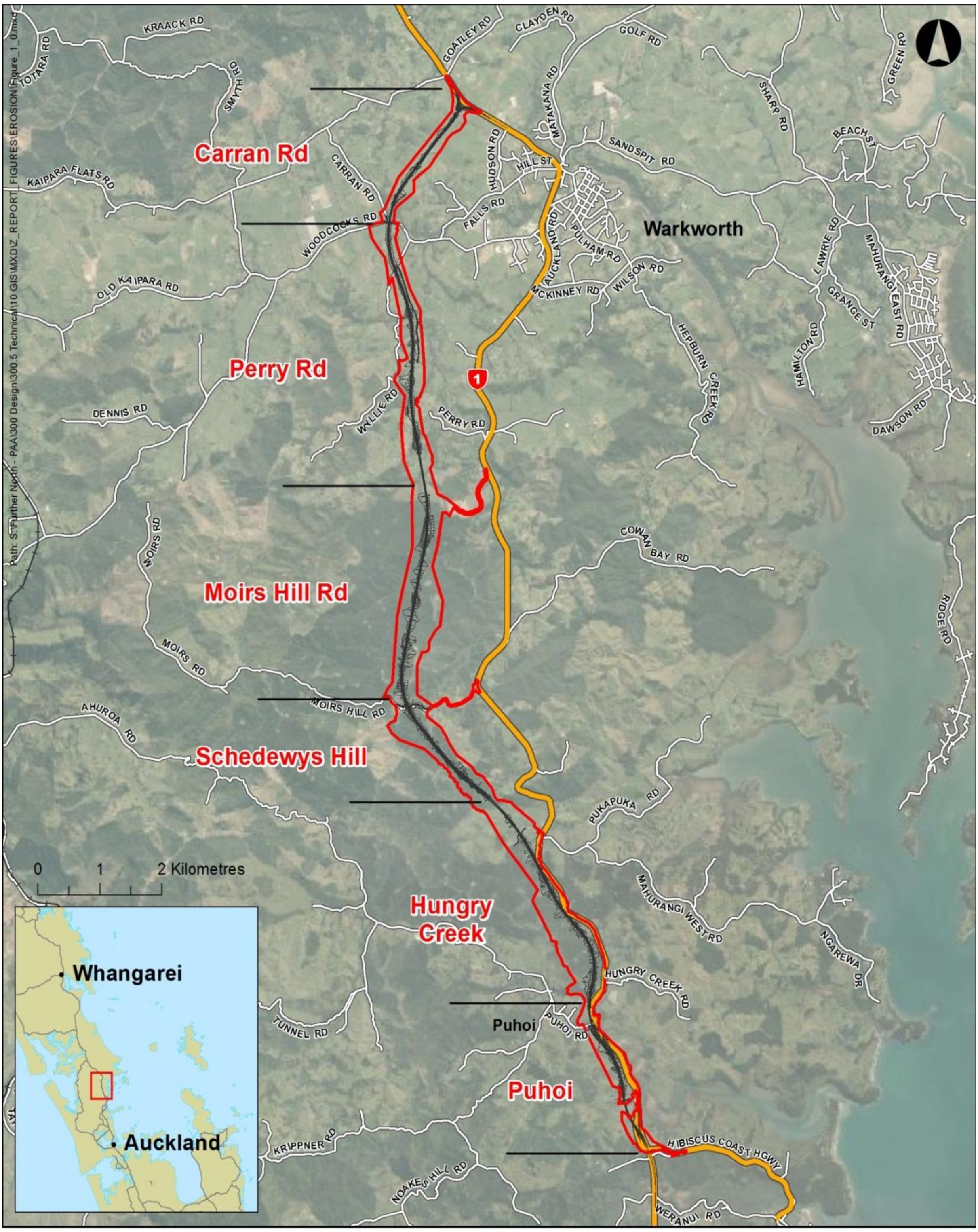
1.4 Interchanges and tie-in points

The Project includes one main interchange and two tie-in points to the existing SH1, namely:

- The Pūhoi Interchange;
- Southern tie-in where the alignment will connect with the existing NGTR; and
- Northern tie-in where the alignment will terminate at a roundabout providing a connection with the existing SH1, just south of Kaipara Flats Road north of Warkworth.

1.5 Route description by Sector

For assessment and communication purposes, the Project has been split into six sectors, as shown in Figure 1. Section 5.3 of the AEE describes these Sectors.



Proposed Designation Boundary

Indicative Alignment

Figure 1: Project sectors

1.6 Marine / estuary statutory and planning context

The Mahurangi Harbour and Pūhoi Estuary are located on the north east coast of the Auckland Region (Figure 2), within the Hauraki Gulf Marine Park.

1.6.1 Coastal protection areas

The Auckland Council Regional Plan: Coastal classifies important coastal marine areas into Coastal Protection Areas 1 (CPA1) and Coastal Protection Areas 2 (CPA2). CPA1 include those areas which, due to their physical form, scale or inherent values, are considered to be the most vulnerable to the adverse effects of inappropriate subdivision, use and development. These areas include regionally or nationally rare habitat types as well as the best examples of saltmarsh, mangroves and where coastal marine areas are identified as within significant ecotones in the Auckland Region. CPA2 are of regional, national or international significance but are more robust than CPA1 areas. CPA2 areas often include intertidal banks of the region's harbours and estuaries, which are key foraging grounds for wading birds (Auckland Coastal Plan).

The Mahurangi Harbour contains CPA1 and CPA2 areas (Auckland Coastal Plan, Map Series 1 – Sheet 37). The main body of the harbour is a CPA2 area (CPA76a, Schedule 2, Auckland Council Regional Plan: Coastal) and the mouth of the Mahurangi River, Dyers Creek, Hamiltons Landing and Te Kapa River, plus adjacent to the headland at Cudlip Point and Big Bay are recognised as CPA1 areas (CPA76b-o, Schedule 2, Auckland Council Regional Plan: Coastal) (see Figure 3 and section 1.3.1 below).

The Pūhoi Estuary includes both CPA 1 and 2 areas (CPA 75 c-i, Schedule 2, Auckland Council Regional Plan: Coastal). The upper reaches of the estuary and a small area in the lower reaches on the southern side of the estuary are classified as CPA1. The main body of the estuary is a CPA2 area (see Figure 3 and section 1.3.2 below).

Figure 2: Location map of Mahurangi Harbour and Pūhoi Estuary

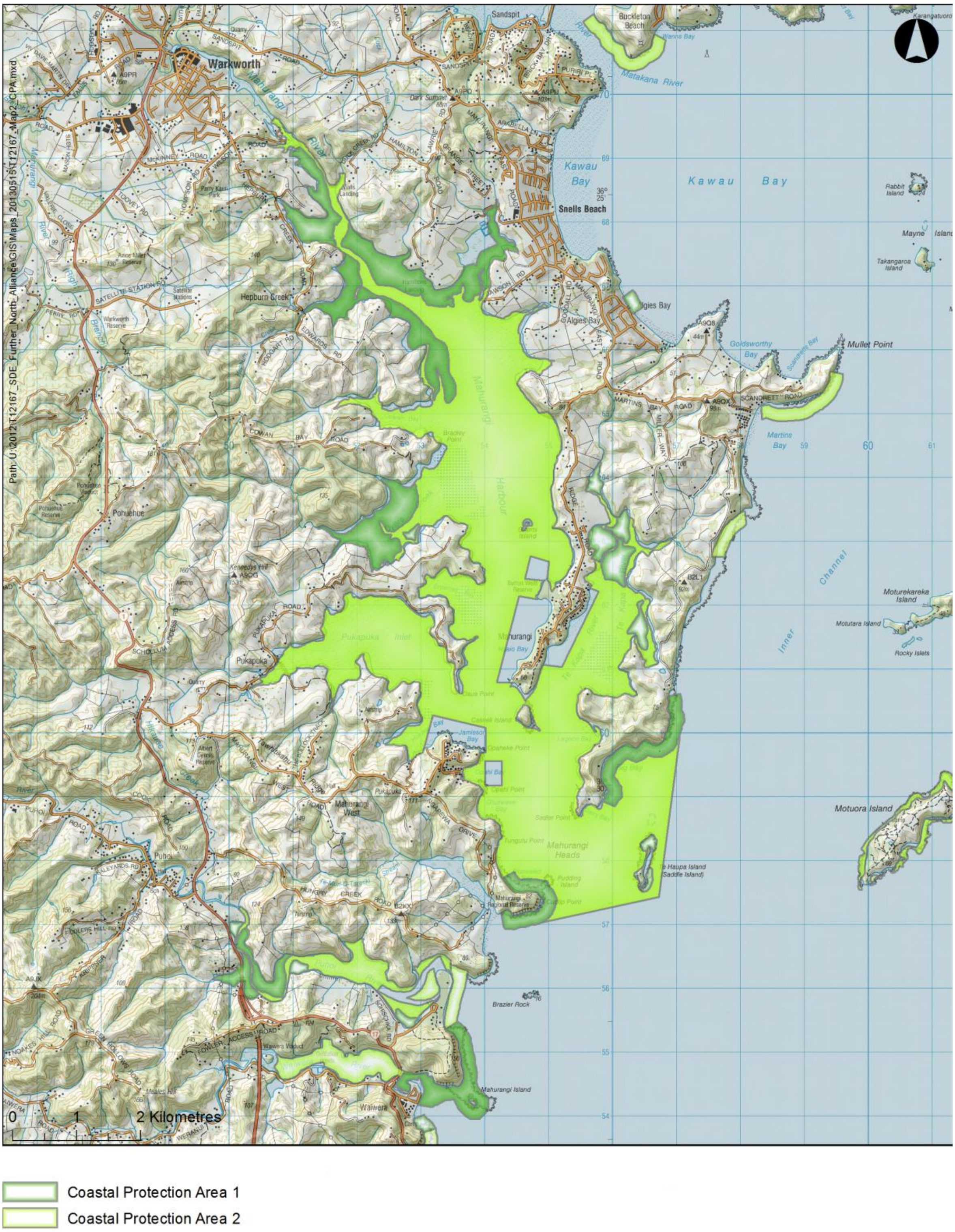


Figure 3: Coastal protection areas category 1 and 2 – Auckland Council

Schedule 2 of the Auckland Council Regional Plan: Coastal contains a description of the ecological values of the CPA1 and CPA2 areas identified in the Mahurangi Harbour and Pūhoi Estuary. The relevant sections of Schedule 2 have been extracted from the Plan and are contained in sections below.

(a) Mahurangi Harbour - CPA76 a-o

The Mahurangi Harbour is a classic example of a ria or drowned coastline. Within the harbour there are large areas of intertidal mud and sand. Outside of the mouth of the harbour there are a variety of more exposed shores ranging from broad rock platforms to small sandy beaches. This physical variety provides a similarly varied range of habitats for an assortment of animal and plant communities.

In the shelter of the harbour grow extensive areas of mangroves. Some of these areas are judged to be amongst the best in the district (76b-j, 76p). The saline vegetation provides high quality habitat for threatened secretive coastal fringe birds particularly where it abuts terrestrial vegetation which provides roosts for the birds and potential nesting sites.

There is a notable gradation from the mangroves into terrestrial vegetation. At Dyers Creek (76f) a large expanse of mangroves adjoins a highly diverse area of regenerating coastal kauri-tanekaha forest on lowland hills. In this more sheltered part of the harbour is found a small 'old hat' island (76o), Grants Island, so called because the broad intertidal rock platforms that surround the island look like the brim of a hat. This is one of the examples of an 'old hat' in New Zealand and as such is considered to be a landform of regional geological importance. The Department of Conservation has selected this inner harbour area as an Area of Significant Conservation Value (ASCV)[1]*.*

(b) Pūhoi Estuary - CPA75 c-j

The intertidal flats of the Pūhoi Estuary (75 c) are used as a feeding ground by a variety of wading birds, many of which use [the estuary] as a stepping stone in their travels. The saline vegetation areas in the Pūhoi estuary contain some of the best saltmarsh and mangrove in the district (75d-h).

These too are inhabited by a variety of secretive coastal fringe birds particularly where habitat quality is enhanced by the adjoining terrestrial vegetation which provides shelter for the birds and offers potential nesting sites. The Department of Conservation has selected the area as an ASCV[2]*.*

1.6.2 Other regional ecological values

As identified in the Auckland Coastal Plan, the Mahurangi Harbour and Pūhoi Estuary contain natural heritage wetlands (Figure 4), and protected natural wildlife areas (Figure 5). The coastal vegetation adjacent to the harbour and estuary contain areas of high conservation value (Figure 6)

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1 Department of Conservation, 1994. Areas of Significant Conservation Value, Auckland Conservancy. Department of Conservation.

2 ibid

and significant natural area with moderate-high values (some areas are proposed adjacent to the Pūhoi Estuary) (see Figure 7).

The Department of Conservation (DoC) has recognised almost the entire Mahurangi Harbour as an Area of Significant Conservation Value (ASCV 024). The harbour contains a diversity of coastal habitat zones including rocky shorelines, sandy beaches, extensive mudflats, mangroves, saltmarsh and adjacent coastal forest. The area is regionally important for the collection of oyster spat.

The Pūhoi Estuary is recognised by DoC (ASCV 115) as an unmodified habitat with extensive mangrove forests and saltmarsh (*Juncus krausii*) associations in the upper reaches and edges of the intertidal flats. In addition, the estuary supports a number of coastal bird species.

Natural Heritage Wetlands- Auckland Council

Natural Heritage Wetlands

Figure 4: Natural Heritage Wetlands – Auckland Council

Figure 5: Protected Natural Areas Wildlife – Auckland Council

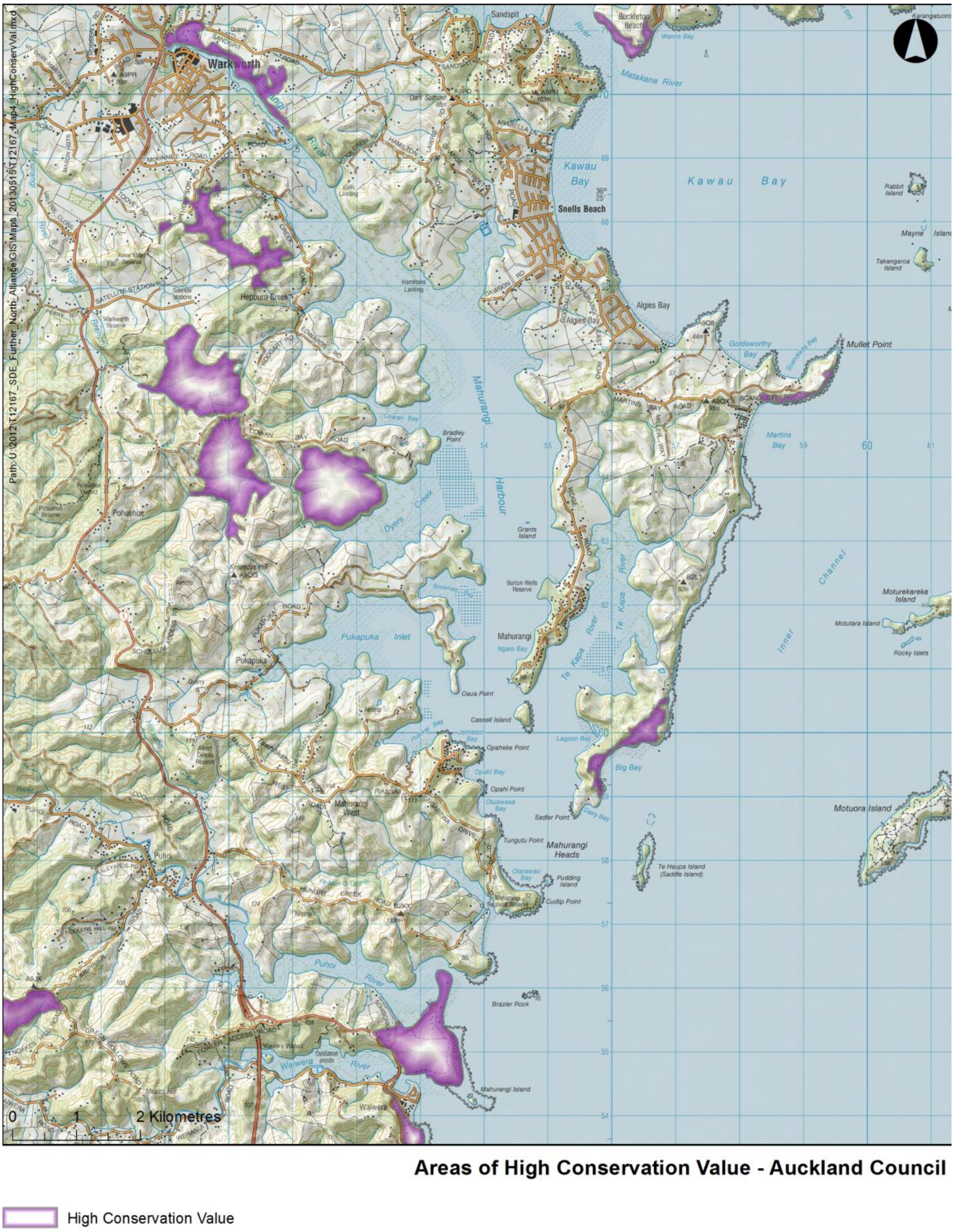


Figure 6: Areas of high conservation value – Auckland Council

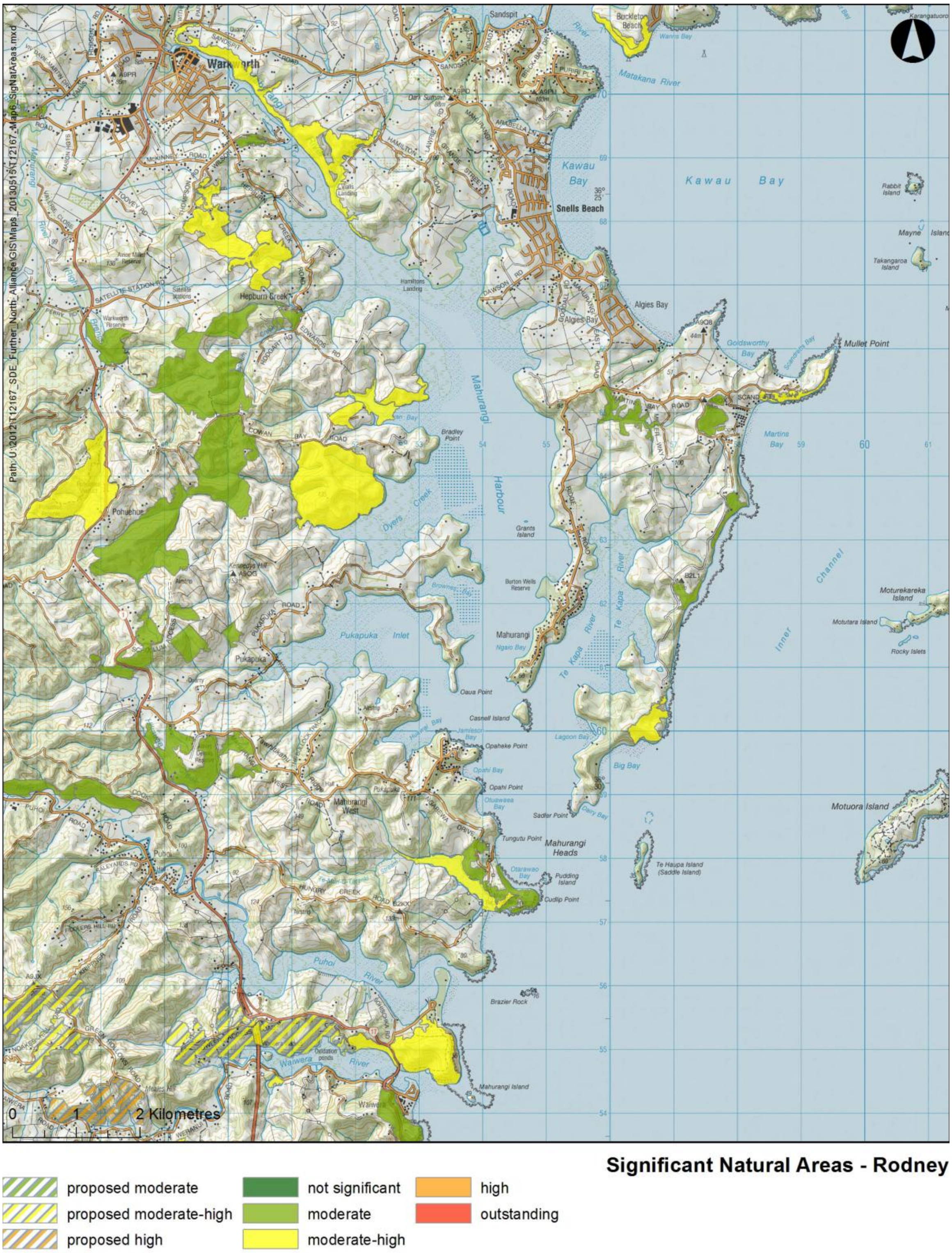


Figure 7: Significant natural areas – Rodney

1.6.3 Overview of potential effects

Potential adverse effects on the marine environment are primarily indirect, arising from the discharge of treated runoff during construction and operation. Figure 8 below shows the indicative alignment and the catchments involved. There will be direct discharge of treated runoff to the Pūhoi Estuary, and to the Mahurangi River. The Western Shore (upper), Pukapuka Inlet and Te Muri Beach catchments will not receive discharges from the Project. Our marine ecology data collation and field surveys have therefore focussed on the Pūhoi Estuary and the main central areas of the Mahurangi Harbour i.e. excluding the western and eastern inlets.

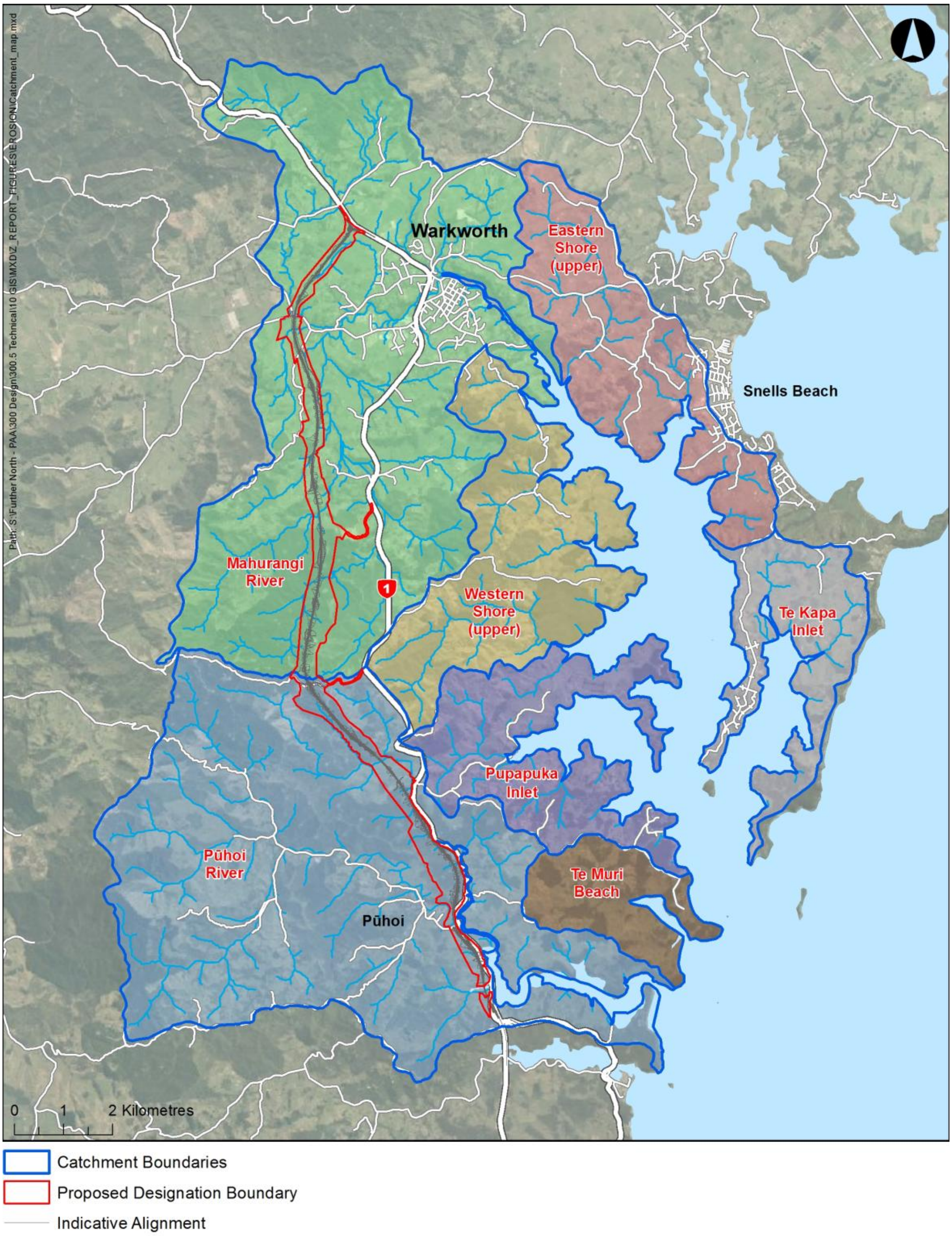


Figure 8: Proposed designation boundary, indicative alignment and catchment boundaries

During construction the likely effects on the marine environment are likely to be largely indirect, arising from the discharge of treated runoff from open earthworks areas. Discharges may cause elevated total suspended sediment (TSS) within the water column and deposition of terrigenous sediment (i.e. sediment from the land) on benthic habitats (i.e. the seabed). Deposited sediment and TSS may in turn adversely affect marine organisms through smothering and clogging of filter-feeding structures and gills. In addition, where structures such as piers are located within the CMA, there will be direct effects including permanent habitat loss and disturbance of habitat during construction.

During the operational phase the likely effects on the marine environment are likely to be indirect, arising from the discharge of treated stormwater from the road. The Project's stormwater system will be designed to remove 75% of TSS and associated contaminants, with the residual sediment and contaminants being discharged via streams and rivers to the marine environment (Operational Water Assessment Report). In addition to sediment, common stormwater contaminants include copper, lead, zinc and hydrocarbons, including polycyclic aromatic hydrocarbons (PAHs).

Cumulative effects of the Project on the marine ecological values present are likely to contribute to the ongoing sedimentation of Mahurangi Harbour and Pūhoi Estuary.

These effects are considered in sections 4 and 5 below.

2. Methodology

Our marine ecology assessment focused on those parts of the CMA within the Pūhoi Estuary and Mahurangi Harbour where there was the potential for adverse ecological effects due to the Project. Information on the marine ecological values within the Pūhoi Estuary and Mahurangi Harbour was collated from existing literature and supplemented with focused field surveys where sufficient information did not already exist in particular areas.

Our marine ecological value investigations included:

- Literature review of the existing marine ecological values;
- Benthic invertebrate infaunal and epifaunal surveys;
- Analysis of common stormwater contaminants in sediment; and
- Sediment grain size surveys.

This assessment draws together the marine ecological values, the potential construction-related effects (including sediment discharge, habitat disturbance and habitat loss), the potential operational-phase effects (primarily the discharge of treated stormwater) and potential cumulative effects on the marine environment.

We estimated the potential effects from construction sediment using a coastal processes model. Direct effects arising from construction activities (habitat loss and disturbance) were assessed from construction drawings and methodologies. Our assessment of operational phase stormwater discharges was informed by contaminant load modelling.

The significance of the Project's potential adverse effects is assessed using an assessment matrix that incorporates ecological value and effect magnitude.

2.1 Literature review

We conducted a thorough search of literature via internet search engines, Council websites, government websites, library catalogues and scientific journal websites. We reviewed and summarised the literature (both published and unpublished) in relation to the marine ecological values of Pūhoi Estuary and Mahurangi Harbour.

2.2 Field surveys

2.2.1 General habitat characterisation

Figure 2 above shows the general location of the Mahurangi Harbour (and embayments) and Pūhoi Estuary. We used aerial photography to manually delineate mangrove and mudflat habitat within the Pūhoi Estuary and Mahurangi Harbour. We validated the extent of mangrove habitat and mudflats in the field from kayaks. Geo-referenced images were also collected during this survey.

2.2.2 Benthic invertebrate community and sediment quality surveys

(a) Survey locations

We carried out infaunal and epifaunal invertebrate surveys, sediment grain size and sediment contaminant surveys at intertidal and subtidal sites within the Pūhoi Estuary (see IP1-6 and SP1-4 shown in Figure 9). Within the Mahurangi Harbour, we supplemented the existing recent intertidal and subtidal infaunal invertebrate community and sediment grain size data collected as part of Auckland Council's marine monitoring programme (Halliday & Cummings, 2012 and unpublished Auckland Council raw data from Halliday) with the collection of intertidal epifaunal invertebrate data as well as intertidal and subtidal sediment grain size and sediment contaminant data (see IM1a-9 and SM1-8 shown in Figure 10).

We considered that the sites surveyed on behalf of Auckland Council provided an appropriate general spatial coverage of Mahurangi Harbour and therefore we did not duplicate survey effort where this recent data existed. Once the harbour modelling outputs were available, we re-evaluated the distribution of existing ecological data and established additional survey sites in the upper reaches of the Mahurangi Harbour in order to form a robust basis for assessment of potential effects from construction and operation of the Project. We did not consider additional surveys were necessary in the various western and eastern arms of the harbour (including Cowan Bay, Dyers Creek and Pukapuka Inlet) as these arms do not receive discharges from their catchments and the harbour modelling results indicated that they were unlikely to be significantly adversely affected by discharges into the Mahurangi River from the Project.

Accordingly, we surveyed infaunal and epifaunal benthic invertebrates and sediment quality at a site immediately downstream of Warkworth township (IM0) and two sites in the upper reaches of the harbour at Vialls Landing (site IM1a and IM1b, located adjacent to the boat landing on the Hamilton property) in order to characterise the ecological values in these upper harbour areas.

In July 2013 we surveyed infaunal and epifaunal benthic invertebrates and sediment quality at three sites within the intertidal habitat in the Okahu Inlet at locations where piers are proposed to be located (survey sites IP0a-c).

We sampled benthic invertebrate communities and sediment quality at low tide between April and July 2013, as detailed in the following sections.

Survey site GPS co-ordinates in NZTM format are provided in Appendix A.

A summary of the benthic invertebrate community and sediment quality survey effort is provided in Table 1 below.

Table 1: Summary of marine surveys and existing data relied on for effects assessment

	Pūhoi Estuary	Mahurangi Harbour
Intertidal infaunal invertebrate survey	Seven sites (IP0-6) April-July 2013 (Further North).	Seven sites. HL, DC, MH, TK, JB, October 2011 (Halliday & Cummings 2012); CB, October 2012 (unpublished raw data provided by Auckland Council via Jane Halliday at NIWA); IM0, IM1a and IM1b, May-July 2013, Further North).
Intertidal epifaunal invertebrate survey	Seven sites (IP0-6) April-July 2013 (Further North).	Twelve sites (IM0-9) April-July 2013 (Further North).
Intertidal sediment size and contaminant	Seven sites (IP0-6) April-July 2013 (Further North).	Twelve sites (IM0-9) April-July 2013 (Further North).
Subtidal infaunal invertebrate survey	Seven sites (IP0-6) April-July 2013 (Further North).	Two sites (A, C), October 2012 (unpublished raw data provided by Auckland Council via Jane Halliday).
Subtidal sediment size and contaminant	Four sites (SP1-4) April 2013 (Further North).	Nine sites (SM1-9) April 2013 (Further North).
Intertidal oxidation reduction potential	Six sites (IP1-6) April 2013 (Further North).	Nine sites (IM2-9) April 2013 (Further North).

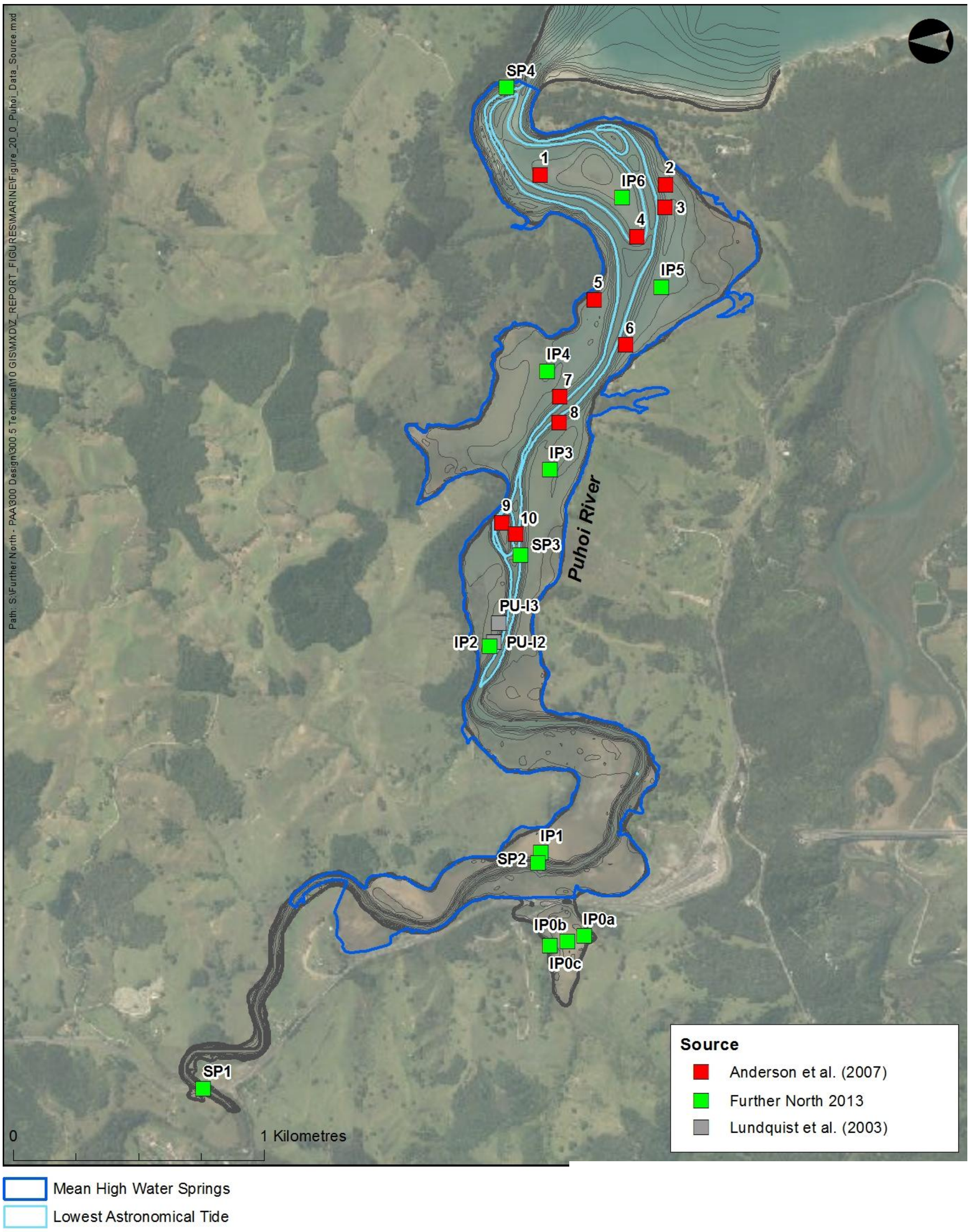


Figure 9: Pūhoi Estuary sampling locations

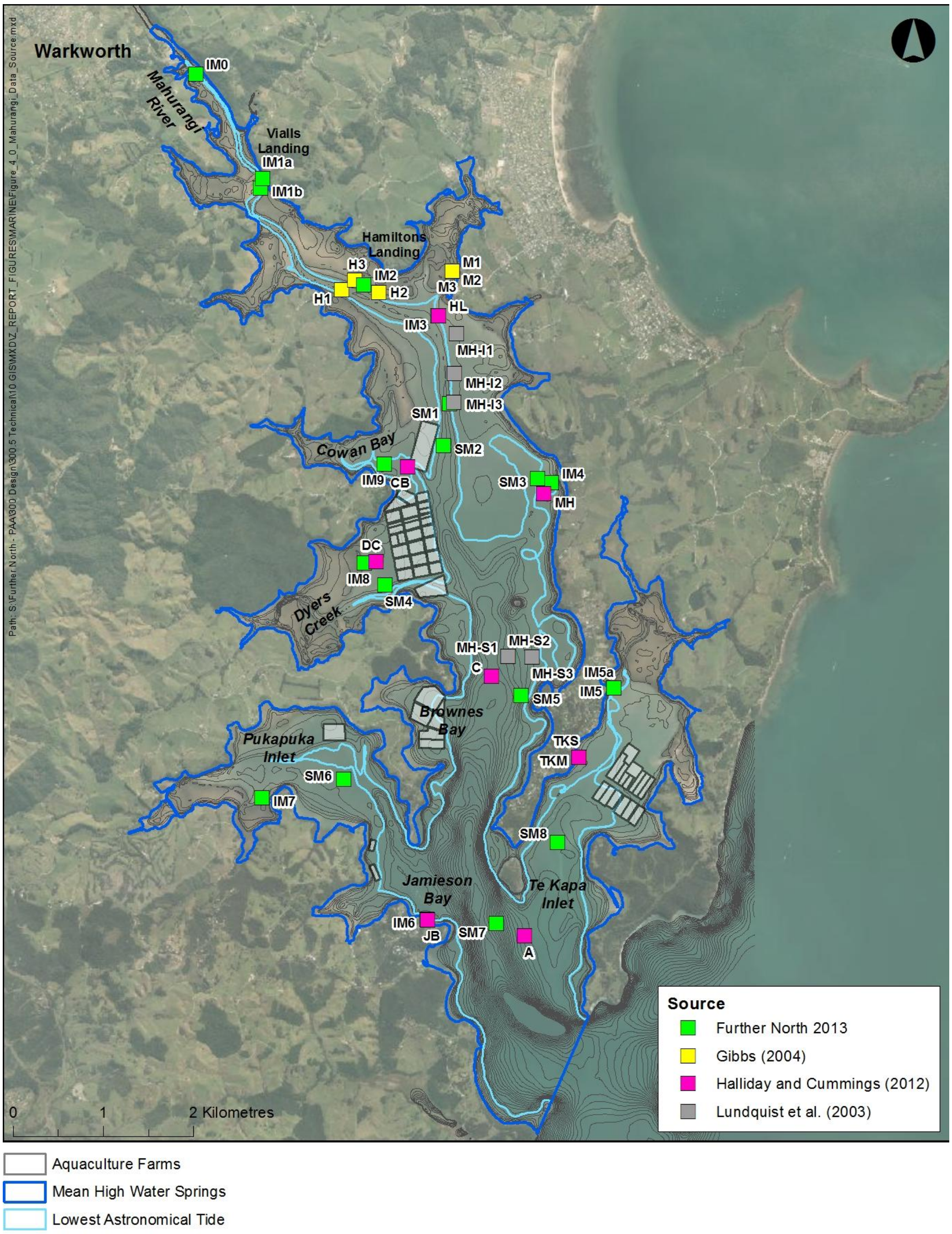


Figure 10: Mahurangi Harbour sampling locations

(b) Infaunal invertebrate community

We based our sampling methodology on Lundquist et al. (2003) and Swales et al. (2002). At each intertidal sampling location within the Pūhoi Estuary, five randomly placed replicate cores were collected within a circular area (10 m radius). We used a PVC tube (13 cm diameter and 15 cm deep) to collect sediment cores. Cores were transferred to heavy duty zip lock bags and stored on ice. Each sample was subsequently sieved in seawater through a 0.5 mm mesh sieve and the retained material was placed into a jar and preserved with 70% ethanol (with 2% glyoxal) in seawater. Samples were then sent to Cawthron Institute for extraction and identification of invertebrates.

Subtidal infaunal sample collection was conducted for Further North, under the direction of our marine experts, by eCoast Ltd in both the Pūhoi Estuary and Mahurangi Harbour. eCoast Ltd collected five replicate surficial (at or near the surface) sediment samples at each site using a 500ml scoop (two per sample, corresponding to a similar volume of sediment to that collected for the intertidal invertebrate survey). Samples were sieved at the water's edge through 0.5mm mesh sieve. All living organisms retained in the sieve were placed in jars, preserved as above, and couriered to the Cawthron Institute for analysis.

Average total abundance of individuals, average number of taxa (species richness) and average Shannon-Wiener Diversity Index[3] have been calculated and graphically presented for each intertidal and subtidal site surveyed as part of this Project and surveys undertaken through Auckland Council's routine monitoring sites in the Mahurangi Harbour (Halliday & Cummings 2012). In addition, the average proportion of each main taxa group at each site represented as a pie chart, with the size of the pie representing the average total abundance of organisms at each site, have been plotted using GIS on aerial photography of the Pūhoi Estuary and Mahurangi Harbour.

Multi-dimension scaling plots (MDS) are used to place samples on a map in two dimensions in such a way that the rank order of the distances between samples on the map exactly agrees with the rank order of the matching similarities. Simply stated, samples that are located closely together on the two dimensional map have greater similarities in their invertebrate assemblage than those that are more distant from each other. MDS plots of invertebrate assemblages were created using the multivariate statistical software package, PRIMER-6[4]. Data were transformed using square root transformation (in order to weight the contributions of common and rare species in the multivariate representation) and a Bray-Curtis similarity matrix was created prior to each MDS analysis (see Clarke & Warwick, 2001 for a detailed explanation of MDS, transformations and similarity matrices).

(c) Epifaunal communities

Epifaunal communities were surveyed at each intertidal sampling site of Pūhoi Estuary and Mahurangi Harbour. At each site, three 0.25m^2 quadrats were randomly positioned in previously undisturbed areas. Epifaunal invertebrates and macroalgae on the sediment surface were identified and recorded, and crab burrows were counted as a relative indicator of mud crab populations. Raw epifaunal data is presented in Appendix B.

Epifaunal invertebrate and macroalgae data are described qualitatively.

[3] Shannon-Wiener Diversity takes into account both number of taxa and evenness (i.e. the spread of individuals across individual taxa). Communities with a large number of species that are evenly distributed are the most diverse and communities with few species that are dominated by one species are the least diverse.

[4] Clarke, K.R., Warwick, R.M., 2001. Change in marine communities: an approach to statistical analysis and interpretation. 2nd Edition, PRIMER-E: Plymouth.

(d) Oxidation reduction potential

The oxidation reduction potential (ORP) reflects the level of oxygenation in marine sediments, which influences the ability of the sediment to support marine life. The ORP was measured in surface sediment in previously undisturbed sediment at intertidal survey sites in both the Pūhoi Estuary and the Mahurangi in the field using a YSI handheld multiparameter meter.

Sediment cores were also collected and photographed. The depth of the surface oxygenated sediment above anoxic sediment was measured. Images of the cores and raw ORP data are presented in Appendix B.

Data are described qualitatively and comparisons made among sites.

(e) Sediment samples

At each intertidal survey site within both the Pūhoi Estuary and the Mahurangi Harbour, a surface sediment sample (top 1-2 cm) was collected for sediment grain size and stormwater contaminant analyses. Sediment was collected from undisturbed areas adjacent to the location of each of the five core samples within the Pūhoi Estuary and from undisturbed areas at each intertidal GPS location within the Mahurangi Harbour. Sediment was combined to form a composite sample for each site. Clean sample collection procedures were followed (i.e. gloves were worn and clean instruments used to collect samples at each site).

At each subtidal site approximately 500 ml of surficial sediment was collected for stormwater contaminant concentration and grain size.

Sediment samples were sent on ice to Hill Laboratories where they were analysed for the concentration of contaminants commonly detected in urban stormwater and road runoff (i.e. copper, lead, zinc, high molecular weight polycyclic aromatic hydrocarbons (HMW-PAHs)) in both total sediment and in the <63µm fraction. The <63µm fraction represents the silt and clay proportion of the sediment, based on the Wentworth scale. The concentrations of HMW-PAHs were normalised to 1% total organic carbon (TOC). Contaminant concentrations were compared against relevant biological threshold guidelines (i.e. ANZECC Interim Sediment Quality Guidelines (ISQG) and Auckland Council's Environmental Response Criteria (ERC)).

Total sediment was also analysed for sediment grain size by Hill Laboratories using a graduated wet sieve technique.

2.3 Harbour model

The Project team has modelled baseline sediment movement into Mahurangi Harbour and Pūhoi Estuary and the potential increase in sediment discharged to these waterways as a result of open earthworks during a short- (5 year) and long-term (10 year) construction period (see Section 3.3, Coastal Processes Modelling Report).

A detailed description of the development and results of the coastal modelling scenarios is contained in the report *Pūhoi to Warkworth Coastal Processes Modelling*, Further North Alliance, 2013, and the modelling report *Pūhoi – Warkworth Coastal Modelling and Field Data Collection*, eCoast, 2013. A brief summary of the scenarios modelled and the model construction is as follows:

The models of the Mahurangi and the Pūhoi estuaries were used to explore all permutations of the following conditions:

- Sediment loads and flows predicted in the 10 year and 50 year return period rain events;
- Calm and ENE winds; and
- Existing situation, events under the 'long' construction and 'short' construction.

In total, this amounted to 24 scenarios model runs.

The following modelling parameters were developed based on the analysis of rainfall events in the affected catchments and the requirements for similar projects:

- Mean tidal range was modelled for the sediment input events;
- Peak flows during the rain events have a 5-6 hour duration – mid-tide up to full and back to mid-tide;
- One particle size was modelled (combined silt/clay), with the size fraction being provided by the GLEAMS modelling team at NIWA. NIWA undertook analysis of the sediment along the indicative alignment and compared it with data they have collected previously. Based on this analysis, NIWA's suggested particle size distribution (NIWA, April 2013) for catchment sediment loads was:
    - Clay (<3.9 µm) 26%;
    - Silt (3.9 – 63.0 µm) 56%;
    - Sand (63.0 µm – 2mm) 18%; and
- Wind speed of 9m/s was used with ENE wind event modelling; and
- The seabed deposition threshold was 10mm.

In the model, flocculation, and therefore fall velocity, increases with increasing TSS concentration. The relationship used was: $W_{50}=kC_M^m$

Where w_{50} is the settling velocity and C_M is the suspended sediment concentration. k and m are empirically derived constants and values of k=0.001 and m=1 were used as recommended by Whitehouse et al (2000). This relationship is independent of grain size, but rather assumes that fall velocity is governed by flocculation. The particle size distribution was reflected in the bulk density estimation. An upper limit was placed on the fall velocity to inhibit unreasonably high settling rates in release cells and cells neighbouring the release cells. The effect of varying the fall velocity upper limit was assessed by eCoast in the sensitivity analysis as was variations in bulk density and settling velocity. In each of these cases there was little variation in the extents and depths of deposition in the estuaries. The model has been validated against observed data collected as part of this project and against measured data in Western Port, Aus (sea grass investigations). Furthermore the model results for the Mahurangi estuary matched closely the locations of historical deposition from model results as investigated for Auckland Council by Swales et al (2009).

The closely matched hydrodynamic calibration, the little variation observed in the sensitivity analysis and the agreement with locations of historical deposition in the estuaries, combine to give a high level of confidence that the model results can be used for a comparative assessment of impacts associated with the additional sediment that could be generated by the Project.

The harbour model domains were chosen to contain both the Pūhoi Estuary and Mahurangi Harbour in their entirety. The open ocean boundaries were chosen to be close to the estuary mouths while not infringing on the ebb tidal jets. In the Mahurangi model the upper extent of the model was chosen so that it contained the Mahurangi River up river as far as the Warkworth Weir which is where the tidal influence of the Mahurangi Harbour ends. The Pūhoi River does not have a weir and so is tidal at the river boundary, but the river boundary was chosen so that it did not interfere with water travelling up river from the Pūhoi Estuary. The upriver boundary was also chosen so that it contained the location where currents, sea level and turbidity measurements were made during the field data collection programme as these data were used to provide modelled river boundary conditions (Dougal Greer, eCoast Ltd, pers. com.).

The Coastal Processes Modelling Report describes the development of the harbour model (section 3.5 and section 4). In summary, background sediment inputs were developed using a Basins New Zealand model, which was run for 50 years of rainfall data. Sediment load rating curves for the catchments that discharge to the Mahurangi Harbour and Pūhoi Estuary were developed and used to estimate the baseline load of sediment. NIWA developed a GLEAMS model to assess the additional sediment that would be generated during construction of the Project, with erosion and sediment control devices in place (see Construction Water Management and Assessment Report). The background sediment load was added to the construction sediment load, assuming there was no loss of sediment to the freshwater environment. Representative inflow hydrographs for the major streams and rivers for the 10 year and 50 year ARI rainfall event were based on observed data from the flow gauge at Warkworth.

eCoast Ltd collected hydrodynamic data in the field in order to build the harbour model. In addition to the stream and river inflows during rainfall events, the models were driven by sea level boundaries on the open coast extracted from the Hauraki Gulf model. Hydrodynamic calibration of the model was undertaken using measured data for this Project. A cohesive sediment transport model was used for simulating the deposition and re-suspension of sediment.

Hydrodynamic modelling provides predictions of concentration of total suspended sediment and depth of sediment deposition likely to occur throughout the harbour and estuary under a range of rainfall events and wind environments, with robust erosion and sediment control measures operating (Construction Water Assessment Report).

The rainfall events modelled that we have used in our assessment of effects on the marine ecological values included a 10 year (10 year ARI) and 50 year (50 year ARI). Each rainfall event was modelled under calm wind conditions and the prevailing east-north-easterly wind condition, as wind has a strong influence on where in the harbour sediment is ultimately deposited. A 10 year ARI rainfall event has a 39% chance of occurring at least once during the 5 year (short-term) construction period, and a 63% chance of occurring during the 10 year (long-term) construction period. A 50 year ARI rainfall event has a 10% chance of occurring at least once during the short construction period and an 18% chance of occurring during the long construction period (Table 11, Coastal Processes Modelling Report).

The patterns of sediment deposition and total suspended sediment (TSS) vary among catchments depending on many factors, including the underlying geology, soil, slope, land-use, and the proximity of the discharge point to the harbour/estuary taking into account mixing.

The harbour model outputs are separated into intertidal and subtidal. The Mahurangi Harbour is estimated to cover approximately 2526ha including both intertidal and subtidal habitat, whereas the Pūhoi Estuary covers approximately 173ha intertidal and subtidal habitat.

2.4 Assessment criteria

2.4.1 Ecological value

In New Zealand, regional or national guidelines or criteria for the assessment of marine ecological values have not been developed to date. The following approach to the assessment of marine ecological value (including species richness and diversity) has been used and accepted in previous Board of Inquiry hearings.[5]

Marine ecological values are described in this report as being low, medium or high.

Table 2 lists the characteristics we have used to guide the assessment of the ecological values of parts of the marine environment within the Project area. Due to the lack of assessment criteria and guidelines consideration of low, moderate and high benthic invertebrate species richness and diversity is based on expert judgment and experience[6].

5 See evidence of Dr De Luca in Board of Inquiry Hearings for NZTA Projects: Waterview Connection, Transmission Gully, and Mackays to Peka Peka.

6 ibid

Table 2: Characteristics of estuarine sites with low, medium and high ecological values

Ecological Value	Characteristics
LOW	• Benthic invertebrate community degraded with low species richness, diversity and abundance. • Benthic invertebrate community dominated by organic enrichment tolerant and mud tolerant organisms with few/no sensitive taxa present. • Marine sediments dominated by silt and clay grain sizes. • Surface sediment predominantly anoxic (lacking oxygen). • Elevated contaminant concentrations in surface sediment, above ISQG-high or ARC-red effects threshold concentrations[7]. • Invasive, opportunistic and disturbance tolerant species dominant. • Estuarine vegetation provides minimal/limited habitat for native fauna. • Habitat highly modified.
MEDIUM	• Benthic invertebrate community typically has moderate species richness, diversity and abundance. • Benthic invertebrate community has both (organic enrichment and mud) tolerant and sensitive taxa present. • Marine sediments typically comprise less than 50-70% silt and clay grain sizes. • Shallow depth of oxygenated surface sediment. • Contaminant concentrations in surface sediment generally below ISQG-high or ARC-red effects threshold concentrations. • Few invasive opportunistic and disturbance tolerant species present. • Estuarine vegetation provides moderate habitat for native fauna. • Habitat modification limited.
HIGH	• Benthic invertebrate community typically has high diversity, species richness and abundance. • Benthic invertebrate community contains many taxa that are sensitive to organic enrichment and mud. • Marine sediments typically comprise <50% smaller grain sizes. • Surface sediment oxygenated. • Contaminant concentrations in surface sediment rarely exceed low effects threshold concentrations. • Invasive opportunistic and disturbance tolerant species largely absent. • Estuarine vegetation provides significant habitat for native fauna. • Habitat largely unmodified.

7 ANZECC (2000) Interim Sediment Quality Guideline (ISQG) High contaminant threshold concentrations or Auckland Regional Council's Environmental Response Criteria Red contaminant threshold concentrations (Auckland Regional Council, 2004).

2.4.2 Magnitude of ecological effect

We assess the magnitude of ecological effects using the following criteria[8]:

Table 3: Criteria for describing effect magnitude

Magnitude	Description
Very High	Total loss or very major alteration to key elements/ features of the baseline conditions such that the post development character/ composition/ attributes will be fundamentally changed and may be lost from the site altogether.
High	Major loss or major alteration to key elements/ features of the baseline (pre-development) conditions such that post development character/ composition/ attributes will be fundamentally changed.
Moderate	Loss or alteration to one or more key elements/features of the baseline conditions such that post development character/composition/attributes of baseline will be partially changed.
Low	Minor shift away from baseline conditions. Change arising from the loss/alteration will be discernible but underlying character/composition/attributes of baseline condition will be similar to pre-development circumstances/patterns.
Negligible	Very slight change from baseline condition. Change barely distinguishable, approximating to the "no change" situation.

2.4.3 Significance of ecological effects

We then assess the significance of ecological effects using ecological value (determined in Table 2) and effect magnitude (above) as shown in the following matrix:

Table 4: Matrix combining magnitude and value for determining the significance of ecological impacts

SIGNIFICANCE		Ecological &/or Conservation Value			
		Very High	**High**	**Medium**	**Low**
Magnitude	**Very High**	Very High	Very High	High	Moderate
Magnitude	**High**	Very High	Very High	Moderate	Low
Magnitude	**Moderate**	Very High	High	Low	Very Low
Magnitude	**Low**	Moderate	Moderate	Low	Very low
Magnitude	**Negligible**	Low	Low	Very Low	Very Low

8 Regini, K. (2002). *Draft Guidelines for Ecological Evaluation and Impact Assessment*. Institute of Ecology and Environmental Management (IEEM).

3. Existing marine ecological values

Mahurangi Harbour

The Mahurangi Harbour is a drowned river valley, with vast intertidal flats and subtidal areas present in its middle to lower reaches. The harbour contains CPA1 and CPA2 areas, in addition to being recognised by DoC as an ASCV. Dense mangrove stands fringe the tidal flats of the upper estuary and side embayments. Seagrass patches have been noted in the middle to lower reaches. Estuarine vegetation provides significant habitat for native fish, birds and invertebrates.

The water quality of the harbour has been ranked as excellent by Auckland Council. The concentration of common stormwater contaminants in surface sediment is typically below effects thresholds and the proportion of silt and clay is rarely greater than 50%. ORP measurements indicate oxygenated surface sediment.

Benthic invertebrate community species diversity and richness is moderate to high in middle and lower reaches of the harbour. Benthic invertebrate diversity is low in the upper harbour (upstream of Hamiltons Landing). A large range of fish and birds use the harbour, including several threatened bird taxa.

The harbour has been modified through the establishment of intertidal oyster farms within various embayments.

We consider the Mahurangi Harbour to have moderate to high marine ecological values in the middle and lower reaches, and low to moderate marine ecological values in the upper reaches.

Pūhoi Estuary

The Pūhoi Estuary is a mature, highly infilled, tidal lagoon with extensive intertidal flats fringed by dense mangrove stands and saltmarsh that provide important habitat for indigenous birds and fish. The estuary contains CPA1 and CPA2 areas, and is recognised by DoC as an ASCV. A sand barrier has reduced the mouth to a narrow channel. The estuary has high sedimentation rates with deposition occurring in the upper reaches of the estuary.

As far as we are aware water quality surveys have not previously been undertaken in the Pūhoi Estuary; however, during our field surveys we noted water clarity was high. The concentration of common stormwater contaminants in surface sediment do not exceed effects thresholds and the proportion of silt and clay is typically less than 50%. Surface sediment, as evidenced by ORP measurements, is oxygenated.

The diversity, richness and abundance of benthic invertebrates in subtidal and upper estuary intertidal sites are low and dominated by tolerant organisms (e.g. oligochaete worms). The benthic invertebrate assemblage at sites in the middle and lower reaches of the estuary has moderate diversity and abundance.

Habitat modification in the Pūhoi Estuary is typically low, although SH1 has created a partial barrier between Okahu Inlet and the main body of the Pūhoi Estuary.

The Okahu Inlet has a moderate diversity and abundance of organisms on the open mudflat area, but a low diversity and high abundance of organisms adjacent to the incised low tide channel on the northern side of the Inlet. In addition, the mudflats of the Okahu Inlet support a population of adult mud snails that are notable for their size and abundance. Mud snails are an important cultural harvest species.

Overall, we consider the marine ecological values of the main body of the Pūhoi Estuary to be moderate in the middle to lower reaches, and low in the upper reaches. Ecological values within the Okahu Inlet are assessed as moderate.

3.1 Mahurangi Harbour

3.1.1 Physical description

The Mahurangi Harbour is located within the Rodney Ward of Auckland Council and encompasses an area of approximately 24km^2 (Swales et al., 1997) (Figure 2). The harbour has a tidal volume of approximately 45M m^3 (Auckland Council, 2012b). The harbour has extensive intertidal mudflats/sandflats (1610ha) and 916ha of subtidal habitat (Coastal Processes Modelling Report).

The Mahurangi Harbour is a drowned valley with advanced infilling, vast intertidal flats and subtidal areas present in its middle to lower reaches. Dense mangrove stands fringe the tidal flats of the upper reaches of the main body of the harbour and inlets (Lundquist et al., 2003; Swales et al., 1997). The upper harbour has a defined narrow and shallow tidal creek (1-2m deep at low tide), that runs for 6.4km from the town of Warkworth to Hamiltons Landing, near Dawson's Creek.

The lower harbour, from Hamiltons Landing to the harbour mouth, is largely subtidal, with numerous shallow embayments and inlets along the east and west of the harbour. The mouth of the harbour is wide and deep (>20 m) enabling a high degree of flushing with coastal waters (Swales et al., 1997). Currents in the harbour are primarily driven by tidal cycle. While ocean swell can enter the Mahurangi Harbour through the mouth, predominantly the waves in the inner harbour are wind driven.

3.1.2 Land and harbour use

Historical deforestation and pastoral land-use within the catchment has led to high sedimentation in the harbour, which has resulted in an increase in the extent of intertidal flats and alterations to the benthic invertebrate communities (ARC, 2010).

A number of intertidal oyster[9] farms are located within various embayments of the Mahurangi Harbour, covering approximately 110.8ha of intertidal habitat (i.e. 7% of the total intertidal area). Commercial oyster spat is primarily gathered each year in February, with juvenile oysters on-grown to harvestable size over approximately a 12 month period. In 2009/2010 many oyster farms in the Mahurangi Harbour suffered significant stock mortality due to a viral infection. Oyster farm

9 The introduced Pacific oyster, *Crassostrea gigas*, is farmed intertidally on wooden racks.

operators are required by New Zealand Safety Authority regulations to routinely monitor seawater and oyster flesh quality for the presence and concentration of faecal indicator bacteria, in addition to weekly monitoring for the presence of toxic phytoplankton in ambient seawater (Jim Dollimore, pers. comm.).

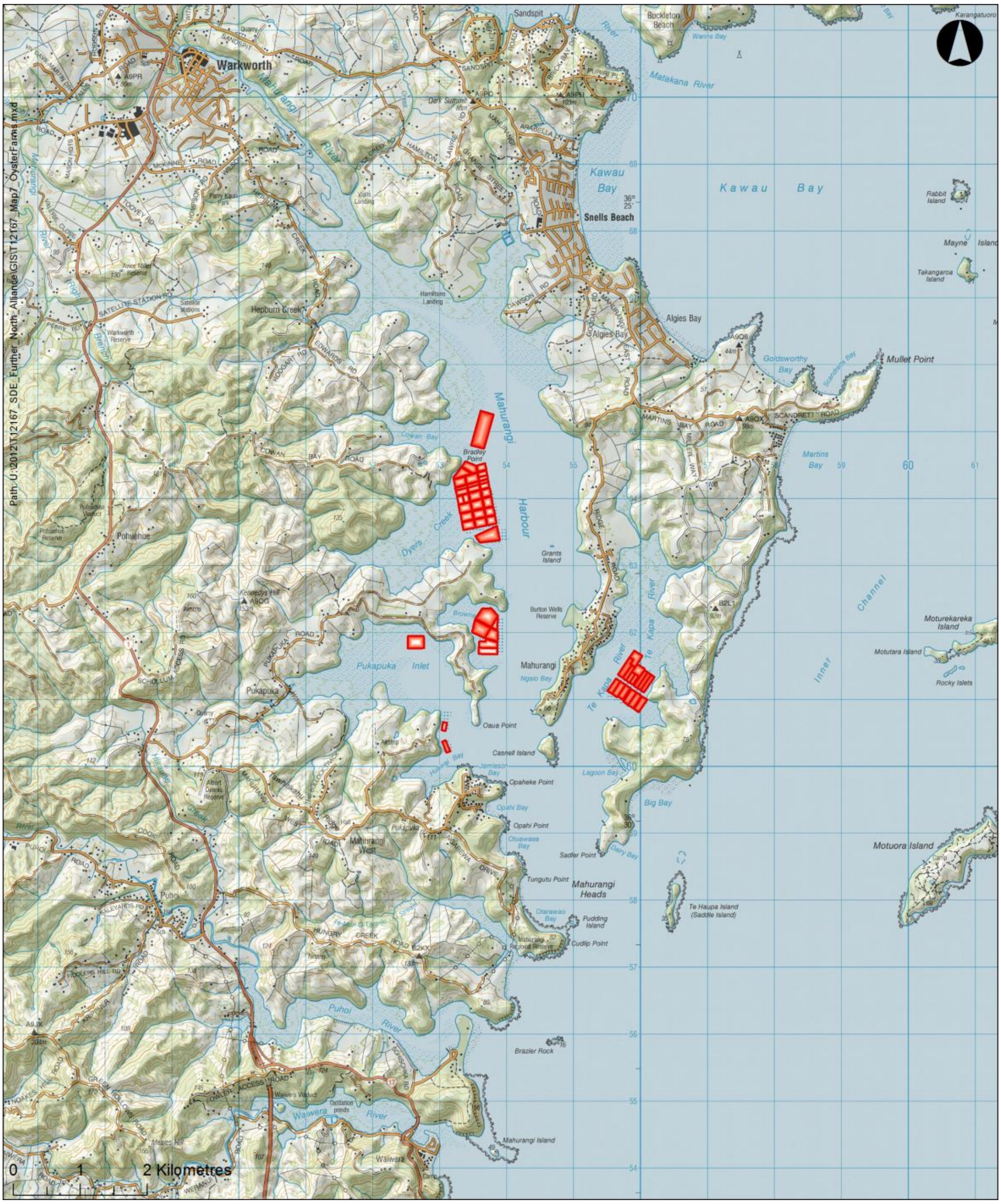


Figure 11: Oyster farm locations

Rainfall criteria established by New Zealand Food Safety Authority determine when harvesting oysters is not permitted (i.e. for number of days following certain size rainfall events harvesting is not permitted). The rainfall threshold and number of days of closure for the Mahurangi Harbour are more stringent in the upper harbour areas compared to lower reaches. For example, oyster harvesting must cease for five days in Cowan Bay and four days in Dyers Creek if 10-15 mm of rain occurs within a 24 hour period. In comparison, harvest restrictions in the Pukapuka Inlet and Te Kapa Inlet only occur following more than 25mm rainfall within a 24 hour period[10]. The purpose of the harvesting closures is to ensure oysters have time to depurate potential microbiological pathogens (primarily through the production of pseudo-faeces) discharged to the harbour during rainfall that they may have ingested during filter-feeding.

The Mahurangi Harbour catchment is a popular tourist and recreational area. Being located close to Auckland it receives numerous visitors (ARC, 2010). Recreational uses of the Mahurangi Harbour include boating, fishing and water sports such as kayaking (Swales et al., 1997).

Extensive ecological surveys, carried out mainly by the Auckland Council, have been completed in Mahurangi Harbour over the past two decades. As such, a wealth of information on the existing physical and biological environment is available, which is summarised in the following sections.

3.1.3 Water quality

Water quality monitoring undertaken by Auckland Council in the Mahurangi Harbour indicates that the estuary has good to excellent water quality with most parameters being below guidelines (Auckland Council, 2012b; Section 4.4 Construction Water Assessment Report). However, dissolved reactive phosphorus was elevated at the Dawson's Creek monitoring site, as was ammoniacal nitrogen, nitrate and nitrite. The concentration of TSS was detected above aquaculture guideline values at the Dawson's Creek site, whereas TSS was within guideline values at a site located at Mahurangi heads (ibid). Auckland Council (2012b) rated the estuary as having excellent water quality overall.

3.1.4 Sediment grain size

(a) Literature review

Sediment grain size distribution relates to both the benthic invertebrate community composition and the concentration of contaminants in sediment. Typically, harbours/estuaries with a high proportion of silt and clay have corresponding high concentrations of contaminants in the <63µm fraction, as contaminants bind to small organic particles. With respect to benthic invertebrate communities, sediment with a high proportion of silt and clay is usually characterised by a tolerant and less diverse suite of organisms.

Halliday & Cummings (2012) report sediment grain size data collected between 1994 and 2011 for Auckland Council at intertidal and subtidal sites in the Mahurangi Harbour. The location of their survey sites are shown in Figure 10 and the percent sediment composition for each site surveyed in 2011 is presented below in Figure 12 and Figure 13. Fine sand dominates the sediment grain size distribution at intertidal sites, with Dawsons Creek having the highest average percent

10 New Zealand Food Safety, Harvesting criteria for Mahurangi Harbour Growing Area 301 as at 01/08/2011.

composition of fine sediments (89%) and Hamiltons Landing the lowest (57%) (Figure 13). Within the intertidal sites surveyed by Halliday & Cummings (2012), silt and clay comprises between 15% (at Mid Harbour) and 42% (at Hamiltons Landing) of the total sediment composition. Coarser sediments, including medium sand, coarse sand and gravel/shell hash form a small component of the sediment composition at intertidal sites (0.5-6%).

Appendix C contains historic sediment grain size data from 1995 to 2011 for all Halliday & Cummings (2012) sites apart of Dyers Creek where data is only available from 2005 to 2011. Inter-annual variability in sediment grain size composition within the intertidal sites indicates relatively stable proportions over time, the exception being in 1995 and 1996 when a higher proportion of medium sand grain size was present at most sites. Jamieson Bay has the greatest inter-annual variation in grain size composition, with medium sand varying between 5% and 65% over the 17 year survey period. The proportion of silt and clay does not show a clear trend of increasing over time (Appendix C).

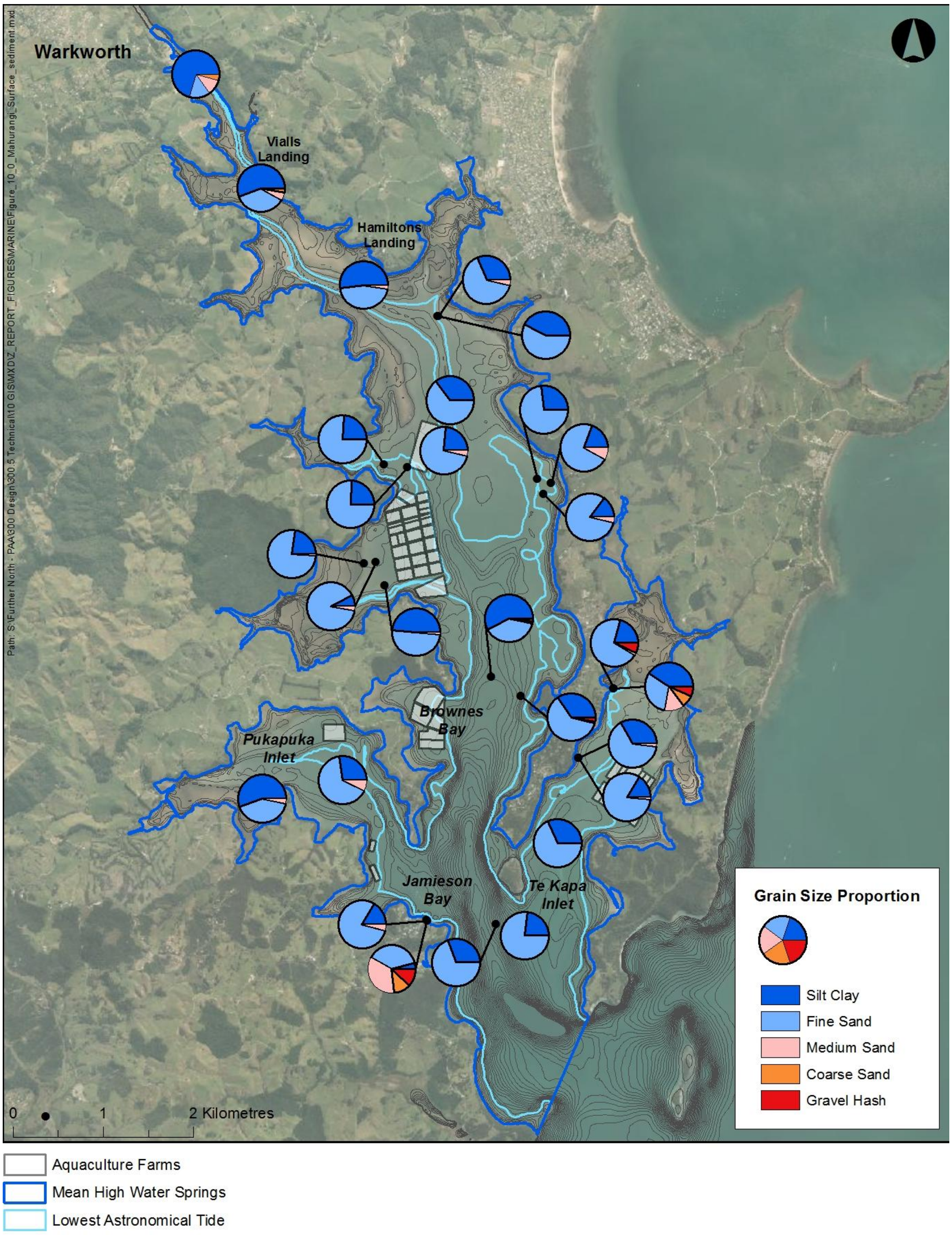


Figure 12: Mahurangi surface sediment grain size proportion

Subtidal site C, located towards the centre of the subtidal habitat, had a higher proportion (approximately 58%) of silt and clay compared to subtidal site A and the intertidal sites. The grain size distribution at subtidal site A was similar to the intertidal sites surveyed (Figure 13).

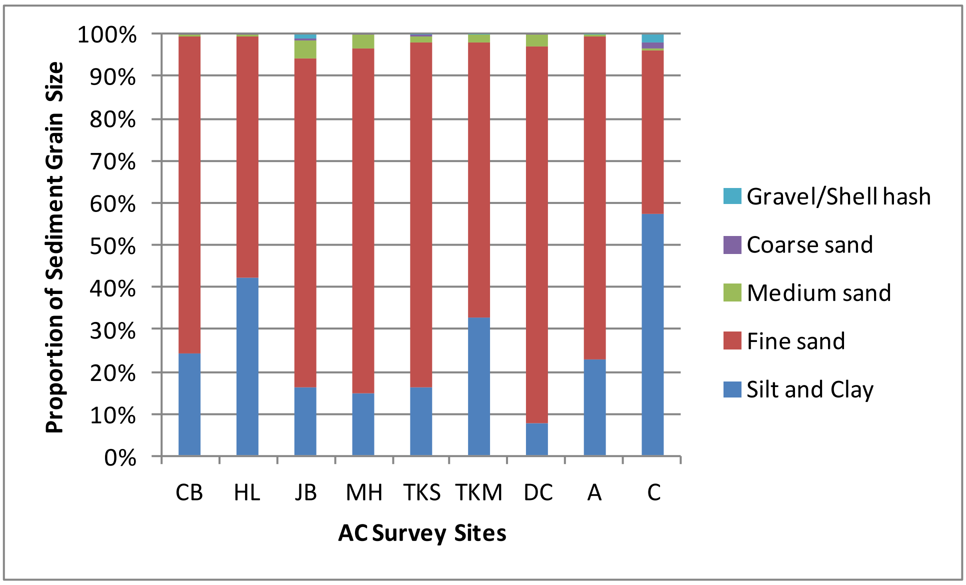


Figure 13: Mahurangi Harbour surface sediment grain size composition (Halliday & Cummings, 2012)

Where freshwater meets denser saltwater, vertical circulation patterns are created, which churn up sediments and lead to higher sedimentation in upper reaches of the harbour compared to middle and lower reaches of the harbour where freshwater inflow has less influence. This higher sedimentation is clearly seen at Hamiltons Landing, which Swales et al. (2002) state is an area of high turbidity and has been an area of rapid sedimentation over 150 years. In the upper harbour the dense mangrove stands also influence the deposition of sediment (Swales et al., 1997).

Swales et al. (1997) calculated historic accretion rates for the Harbour between 1905 and 1975. In the lower harbour the accretion rate was estimated at 10 mm/year, while in the middle reaches, near Hamiltons Landing, the sediment accretion rate was much higher at 40 mm/year. Near the harbour mouth there has been relatively little accretion, most likely due to flushing and tidal exchange.

(b) 2013 Field results

Intertidal sediment grain size distribution obtained from the 2013 survey was similar to that reported in Halliday & Cummings (2012), with silt and clay ranging between approximately 20-55%. However, in the 2013 study, sites IM0, IM1a, IM1b and IM2 located in the upper harbour had greater than 50% silt and clay, as did site IM7, which is located within sheltered Pukapuka Inlet. Site IM0 located immediately downstream of Warkworth township had greater than 80% silt and clay. There is a clear trend of upper harbour sites being characterised by a higher proportion of silt and clay sediment grain size (Figure 14).

The 2013 proportion of silt and clay at subtidal sites was similar to those detected by Halliday & Cummings (2012), with the highest proportion (approximately 48%) at site SM4 which is located on the eastern side of the mid-harbour (Figure 14).

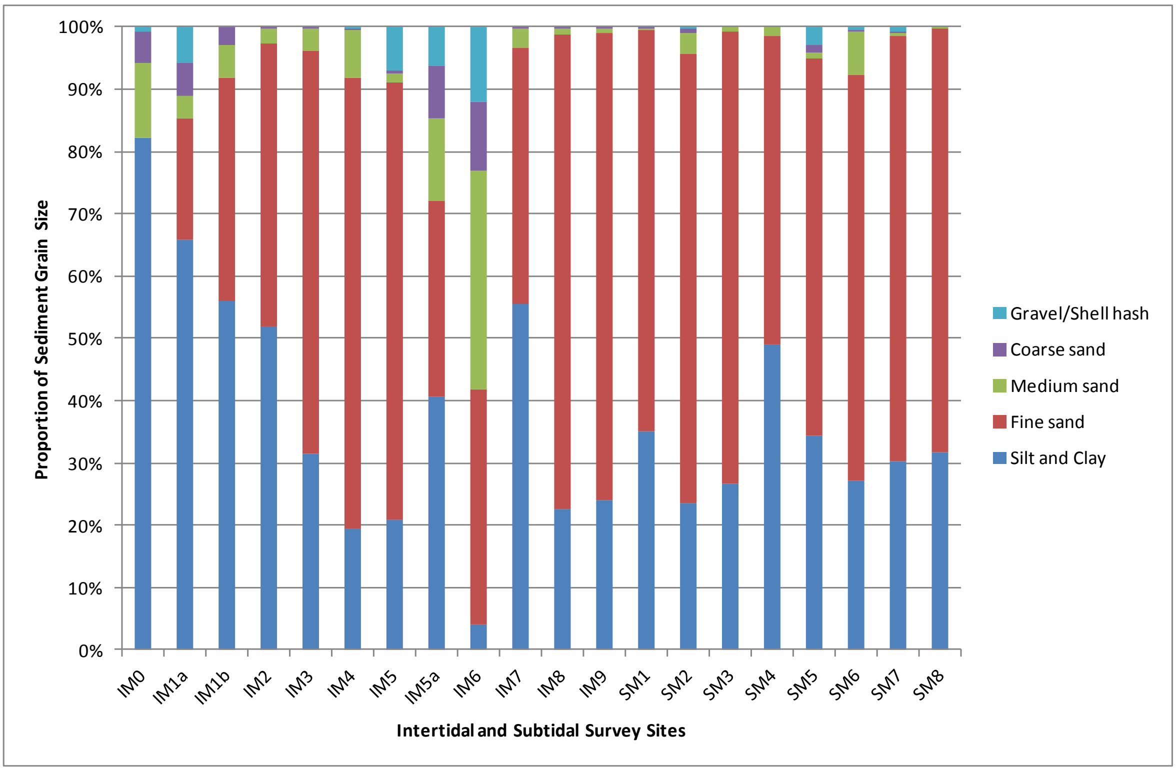


Figure 14: Proportion of sediment grain size distribution in surface sediment from intertidal (IM) and subtidal (SM) survey sites within Mahurangi Harbour

3.1.5 Sediment contaminants

Table 5 below presents the Auckland Council's Environmental Response Criteria (ERC) thresholds and the ANZECC (2000) ISQG low value, which enable the assessment of the environmental quality of coastal marine areas in relation to stormwater discharges (Auckland Regional Council, 2004). Green indicates low concentrations of contaminants that are unlikely to cause adverse effects on biology, amber indicates that there is the potential for adverse effects on biology, and red indicates likely effects on biology.

ANZECC ISQG were adopted from Long et al. (1995) and the NOAA[11] sediment quality values which are based on laboratory toxicity tests and field data. These data suggest that if a sediment contaminant is detected between the ISQG-low threshold and the ISQG-high threshold it is possible that adverse effects could occur. Concentrations above the ISQG-high threshold suggest probable adverse effects. However, if a sediment quality threshold is not exceeded there is no surety that adverse ecological effects will not occur. The Auckland Council ERC thresholds are based on the ANZECC ISQG, plus additional currently available guidelines, which is consistent with development of trigger values associated with local conditions (Auckland Regional Council, 2004). The ERC amber thresholds are set relatively low in order to enable time for a response and further investigation before ecological effects are likely to occur (ERC Red and ISQG-low threshold concentrations).

[11] National Oceanic and Atmospheric Administration, United States of America.

Table 5: Ecological effects contaminant concentration thresholds for marine sediment

Contaminant (mg/kg dry weight)	AC ERC Green	AC ERC Amber	AC ERC Red	ISQG-Low
Copper	<19	19-34	>34	65
Lead	<30	30-50	>50	50
Zinc	<124	124-150	>150	200
HMW PAHs	<0.66	0.66-1.74	>1.74	1.7

(a) Literature review

Recent intertidal sediment quality monitoring data from the Mahurangi (Halliday & Cummings, 2012) and that of a previous study by Gibbs (2004) indicated that copper, lead, zinc and HMW-PAHs were below effects thresholds at all sites. The concentration of metals in the <63µm fraction was higher than in the >500µm fraction at all sites and for all contaminants where data is available. Sediment analysed from Jamieson Bay in 2013 indicated a concentration of HMW-PAHs approaching the ERC amber threshold (Table 6).

(b) Benthic sediment associated with oyster farms

Intertidal oyster farms can alter benthic sediment characteristics and sediment quality. In environments near oyster farms, benthic sediment becomes dominated by silt and clay grain sizes, is organically enriched and can become anoxic. Beneath the farm growing racks live oysters, shell litter and farm debris can accumulate, which can in turn provide habitat for encrusting and associated mobile organisms. Changes in the topography of the benthic habitat can occur due to accumulation of shell and debris and through erosion or accretion beneath and between farm structures. Physical disturbance from vessel movements and farm workers walking around the structures can also disturb benthic sediment and affect benthic invertebrate organisms. Oyster racks constructed from treated timber have the potential to leach contaminants into the surrounding water and sediment. However, these effects on benthic sediments are typically localised to beneath the farms and/or within tens of metres from the farms (Keeley et al., 2009).

Table 6: Intertidal sediment contaminant concentrations in Mahurangi Harbour (Halliday & Cummings, 2012; and Gibbs 2004)

Contaminant (mg/kg dw)	Sediment Fraction	Cowan Bay (CB)	Dawsons Creek (DC)	Jamieson Bay (JB)	Hamiltons Landing (HL)	Mid Harbour (MH)	Te Kapa (TK)	H3 (Mudflat)	M3 (Mangrove)
Copper	**>500µm**	3.0	<2.0	6.0	5.3	3.3	5.7	13.5	14.6
	<63 µm	6.7	8.0	15.9	8.3	7.8	6.6	No data	No data
Lead	**>500µm**	**3.5**	**1.8**	**6.0**	**5.3**	**3.5**	**4.5**	**8.03**	**8.98**
	<63 µm	6.2	6.2	11.1	7.5	7.3	5.5	No data	No data
Zinc	**>500µm**	30.0	15.3	39.0	30.3	31.3	35.3	51.8	57.1
	<63 µm	37	39.3	51.7	42.3	40.0	37.7	No data	No data
HMW PAHs	**>500µm**	No data	No data	0.53	0.08	No data	No data	No data	No data

(c) 2013 Field survey

The concentration of metals and HMW-PAHs detected in the 2013 field survey in intertidal surface sediment was low at most sites, both in the total sediment[12] and the <63µm fraction[13]. Copper was detected in the 63µm fraction in the amber ERC range at Vialls Landing (IM1a) and Jamiesons Bay (IM6), and above both the ERC red and the ISQG-Low thresholds in total sediment at Vialls Landing (IM1a) (Table 7). There is a large boat mooring area adjacent to Jamiesons Bay and at Vialls Landing boats are currently and were historically stored and hauled out. It is likely that there is widespread copper contamination in estuarine sediment, particularly in the upper reaches, of the Mahurangi Harbour from anti-fouling of boat hulls arising from the historic and current boat related activities. The concentration of copper was close to the AC ERC amber threshold at IM1b located in the upper harbour and, to a lesser extent, site IM5a located within mangrove habitat in the Te Kapa Inlet. At most of the other intertidal sites, the concentration was less than half the amber threshold. These results (excluding data from site IM1a) are similar to those of Halliday & Cummings (2012), whilst we recognise that different grain size fractions were analysed.

Table 7: Intertidal surface sediment contaminant concentrations in Mahurangi Harbour

Contaminant (mg/kg dw)	Sediment Fraction	IM0	IM1a	IM1b	IM2	IM3	IM4	IM5	IM5a	IM6	IM7	IM8	IM9
Copper	**Total**	25	108	18.5	8.8	6.3	5.0	5.9	15.8	6.0	6.2	3.6	4.0
	<63 µm	18.4	25.5	18.6	13.3	13.7	11.2	13.3	14.1	24.0	9.3	12.1	11.7
Lead	**Total**	9.9	10.8	8.5	5.8	5.6	3.5	4.1	7.5	5.9	5.0	3.2	3.2
	<63 µm	72	10.2	10.0	9.1	8.3	8.1	9.7	8.5	18.7	7.5	7.8	9.6
Zinc	**Total**	84	93	59	38	31	34	35	52	32	32	21	24
	<63 µm	72	63.5	66	56	56	54	61	56	47	47	51	52
HMW PAHs	**Total**	0.006	0.015	0.012	0.019	0.021	0.016	0.006	0.006	0.538	0.029	0.014	0.013
	<63 µm	0.003	0.017	0.013	0.012	0.014	0.015	0.012	0.012	0.015	0.011	0.016	0.012

The concentration of metals and HMW-PAHs at the subtidal sites that were surveyed was below the ERC amber threshold at all sites, in both total sediment and <63µm fraction (Table 8). These results are consistent with Halliday & Cummings (2012).

12 Sediment sample as received by laboratory. Metals: total recoverable digestion nitric/hydrochloric acid digestion. ICP-MS, trace level. US EPA 200.2; PAHs: Sonication extraction, SPE cleanup, GC-MS SIM analysis US EPA 8270C.

13 Sediment sample wet sieved through <63µm sieve. Metals: nitric/hydrochloric acid digestion. ICP-MS, trace, US EPA 200.2; PAHs: Sonication extraction, SPE cleanup, GC-MS SIM analysis US EPA 8270C.

Table 8: Subtidal surface sediment contaminant concentrations in Mahurangi Harbour

Contaminant (mg/kg dw)	Sediment Fraction	SM1	SM2	SM3	SM4	SM5	SM6	SM7	SM8
Copper	**Total**	5.1	5.8	3.5	7.4	6.1	5.3	5.6	4.8
	<63 µm	10.7	12.0	9.4	10.7	11.4	11.4	11.3	10.7
Lead	**Total**	5.1	4.1	3.3	6.5	5.1	3.4	4.6	3.2
	<63 µm	8.3	7.3	7.1	8.6	7.4	7.8	8.9	7.6
Zinc	**Total**	42	28	27	42	44	33	36	31
	<63 µm	49	46	40	47	45	48	53	45
HMW PAHs	**Total**	0.030	0.017	0.035	0.043	0.008	0.012	0.009	0.015
	<63 µm	0.015	0.015	0.020	0.015	0.012	0.013	0.025	0.031

(d) Oxidation reduction potential

The average ORP detected in surface sediment at intertidal sites in the Mahurangi Harbour was 460 mV, indicating oxygenated sediment (Gray, 1981)[14]. The range of ORP was 386.6 to 478.1.

3.1.6 Saline vegetation

The mangroves in Mahurangi Harbour are an important habitat for a variety of fauna (Auckland Regional Council, 1999). Dense stands of mangroves fringe the tidal creek of the Mahurangi upper estuary as well as the upper reaches of its inlets including Te Kapa and Pukapuka, and Dyers Creek (Lundquist et al., 2003; Cummings, 2007; Swales et al., 1997). Some areas of mangroves in the harbour are recognised as being the best in the district based on the Department of Conservation's survey of Areas of Significant Conservation Value in the Auckland Region (Auckland Council Regional Coastal Plan, 2004, Department of Conservation, 1994). The saline vegetation provides high quality habitat for threatened coastal fringe birds (e.g. banded rail) particularly where it abuts terrestrial vegetation which provides roosts for the birds and potential nesting sites (DoC, 1994). Mangroves are typically taller in stature adjacent to low tide channels and at coastal margins with central intertidal mudflats colonised by shorter less dense mangroves.

Areas of seagrass are likely to provide habitat for juvenile fish (including snapper, *Pagurus auratus*) and benthic invertebrates (Inglis 2003; Morrison & Francis 2001 in Turner and Schwarz 2006). Seagrass has been identified in a number of inlets in the middle to lower reaches of Mahurangi Harbour where turbidity and sedimentation are lower, and water clarity is greatest. Two patches of seagrass were recorded in Dyers Creek in 2007, with the largest patch being approximately 50m^2. A number of other patches of seagrass have been observed a few hundred metres to the north of

[14] Gray (1981) states that in intertidal sediments the usual range of ORP can be >400 mV in oxygenated sediment and down to approximately -250 mV in anoxic sediment.

Dyers Creek, near Cowan Bay (Cummings, 2007). Auckland Council reports that seagrass is present intertidally within Pukapuka Inlet, Hauwai Bay and Te Kapa Inlet (Auckland Council, 2012b). Usmar (2010) noted during subtidal surveys of snapper in Mahurangi Harbour that there is little subtidal seagrass present. The patches of seagrass observed by Auckland Council, Cummings (2007) and Usmar (2010) have not been mapped, they have only been observed in the middle to lower reaches of the Harbour, which is consistent with greater water clarity in these areas.

Seagrass meadows are naturally temporally variable in their colour and size. Cummings (2007) detected lower seagrass health, density and abundance in July 2006 compared to October 2006 at sites within the Mahurangi Harbour. The observed differences are most likely due to differing light conditions and nutrient availability (Turner and Schwarz, 2006). Seagrass is sensitive to reduced light penetration, which reduces photosynthesis and therefore growth. In addition, seagrass is sensitive to sediment deposition, which can smother the plant and also reduce or inhibit photosynthesis.

There is little information in the literature regarding the distribution of saltmarsh and macroalgae in the harbour. No macroalgae was recorded during epifaunal surveys on intertidal flats within the Mahurangi Harbour, although Neptune's necklace (*Hormosira banksii*) was present throughout the lower reaches of the harbour within intertidal rocky habitats.

3.1.7 Benthic marine invertebrates

The Auckland Council has been conducting surveys of the benthic macrofaunal communities at six intertidal sites and two subtidal sites in Mahurangi Harbour since 1994 (Figure 10 and Figure 15). The survey strategy has developed over time and a range of intertidal and subtidal taxa have been identified as being the most important to monitor for presence, abundance and community structure (Halliday & Cummings, 2012). The most recent data for each site[15] has been analysed and are presented in Figure 15 to Figure 22 and discussed below.

Polychaete worms and bivalves dominated the community composition at the majority of intertidal and subtidal sites surveyed (Figure 15). Oligochaetes were more dominant at subtidal site C and at the intertidal sites furthest up the harbour (IM0 and IM1). Bivalves were more abundant at Dyers Creek, comprising mostly cockles and nut shell. Gastropods were a minor feature at all sites, but were most abundant at Hamiltons Landing where mud snails were more prevalent. The larger proportion of "other" taxa at Jamiesom Bay predominantly comprised a shrimp-like crustacean (order tanaidacea). Subtidal sites (A and C) had a similar range of taxa compared to the intertidal sites (Figure 15).

[15] Sites DC, HL, JB, MH and TK were surveyed in October 2011; whereas sites CB, A and C were most recently surveyed in October 2012. IM0 and IM1 were surveyed in May-July 2013.

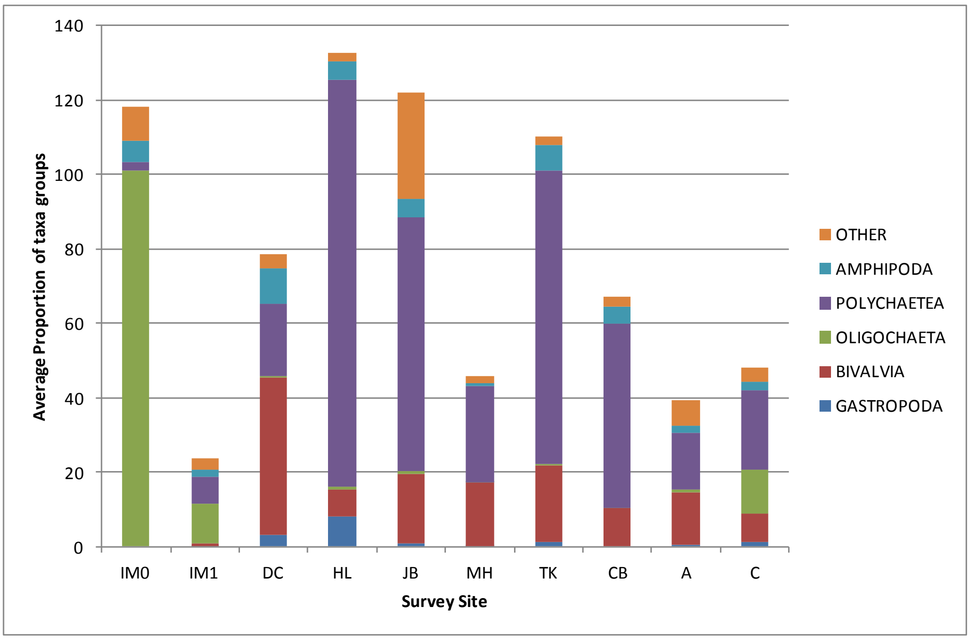


Figure 15: Average proportion of main benthic infaunal taxa groups per core sample at each survey site

The abundance of main taxa groupings has also been mapped (Figure 16). The size of the pie chart reflects average total abundance at each site, with the average proportion of each taxa group shown as different coloured segments. Figure 16 clearly shows the dominance of polychaete worms (many species of which are tolerant of disturbance and high proportions of silt and clay) and lower abundance of bivalves and gastropods (many species of which are sensitive to disturbance and cannot tolerate high proportions of silt and clay) in the upper harbour areas and side arms of the harbour (Appendix D). The upper harbour site (IM1) adjacent to Vialls Landing has a low abundance of organisms and different composition to most of the other sites (oligochaete and polychaete worms are the dominant benthic invertebrate groups), which is typical of highly sedimented upper estuary habitats. Site IM0 located downstream of Warkworth township had the highest abundance of oligochaete worms, in addition to numerous other tolerant taxa including amphipods, mud crab, and several species of tolerant polychaete worms. Appendix D provides a description of the tolerance and sensitivity of benthic invertebrate species detected (where research data exists).

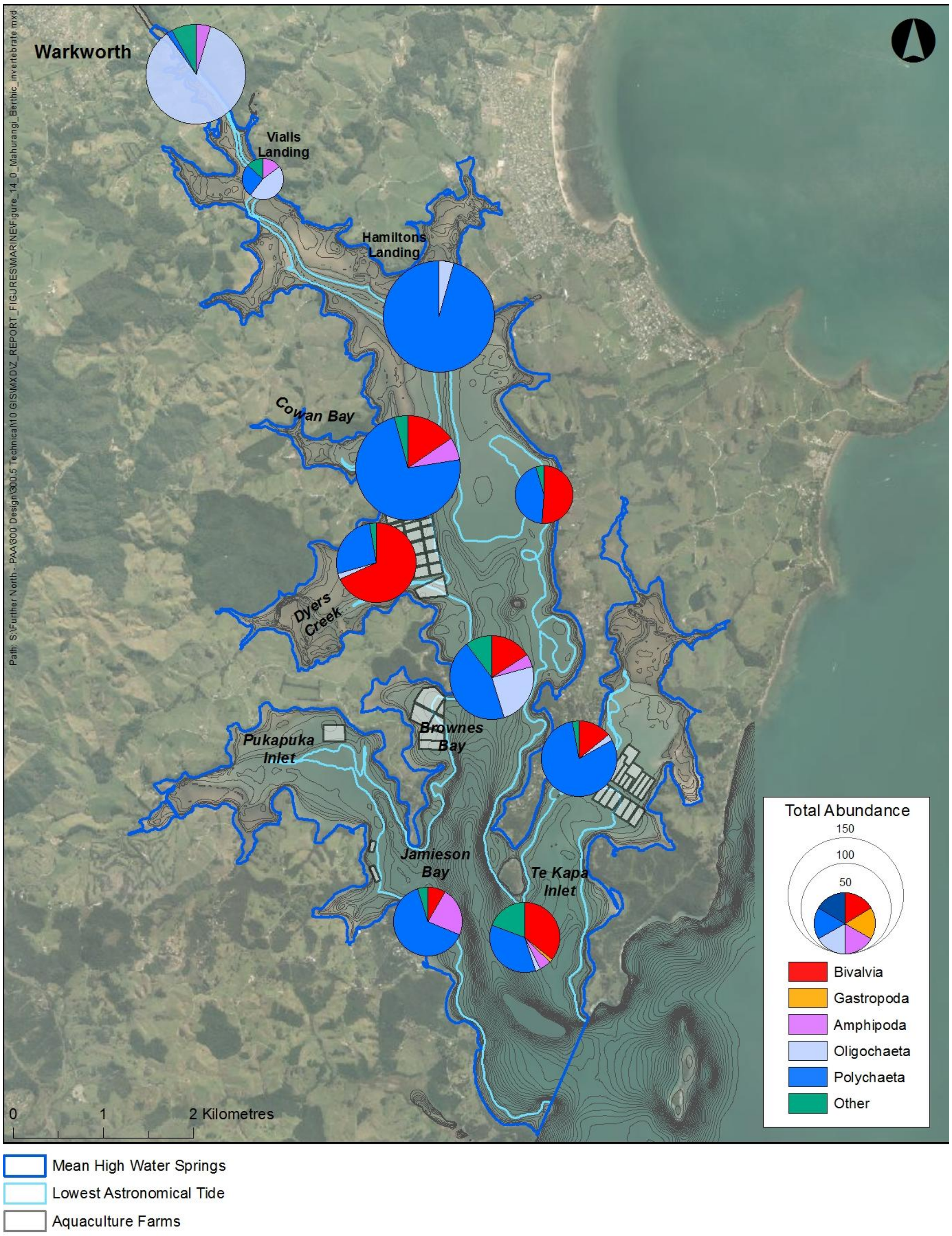


Figure 16: Mahurangi Benthic invertebrate community composition

Of the common recreational and cultural harvest species, cockles and mud snail were present in harvestable densities at some sites. A high abundance of cockles was detected at the Dyers Creek and Te Kapa survey sites, where low numbers of cockles were present at Hamiltons Landing, Cowan Bay and Jamieson Bay. Mud snails were present in high abundance at Hamilton Landing only and pipi were rarely detected at any site surveyed.

The average number of taxa was highest at Jamieson Bay (JB) (approximately 25 taxa per sample), located near the mouth of the harbour, and lowest at sites IM0 and IM11 (approximately 5-7 taxa per sample), located in the upper reaches of the harbour (Figure 17). The number of taxa in samples from intertidal sites in the mid to lower parts of the harbour (excluding JB) was approximately between 12 and 16, whereas subtidal sites had slightly higher number of taxa (approximately 17) (Figure 17).

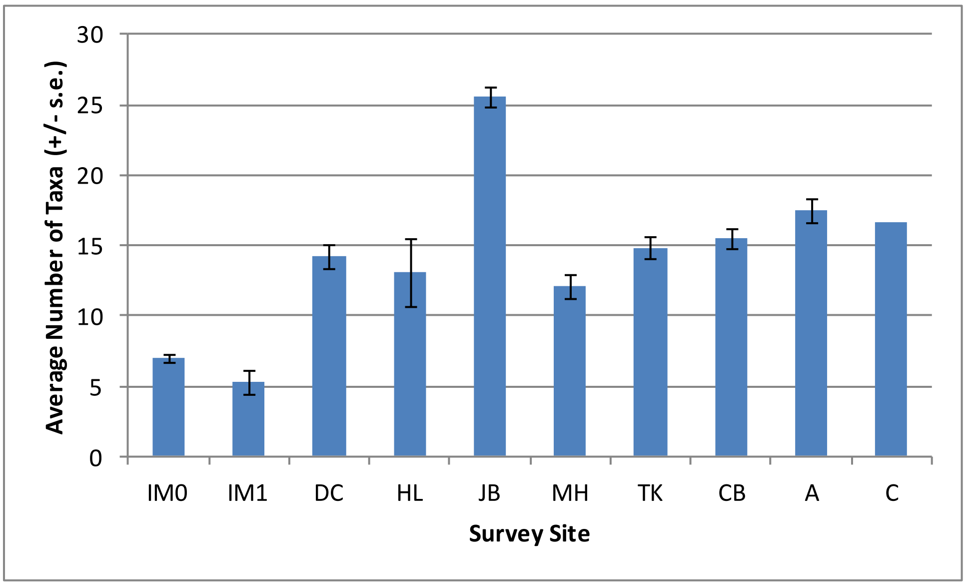


Figure 17: Average number of benthic infaunal taxa per core sample at each survey site

The average abundance of benthic infauna was highest at Hamiltons Landing (approximately 130), Jamieson Bay and IM0 (approximately 120), and Te Kapa (approximately 110). Lowest abundance was detected at the upper harbour site IM1 (a little over 20 individuals per sample), the Mid Harbour site (approximately 45) and the two subtidal sites (approximately 40 and 50) (Figure 18). The high abundance at site IM0 located downstream of Warkworth township was primarily due to the high numbers of oligochaete worms detected comprising between 80-90% of organisms detected in each replicate core collected.

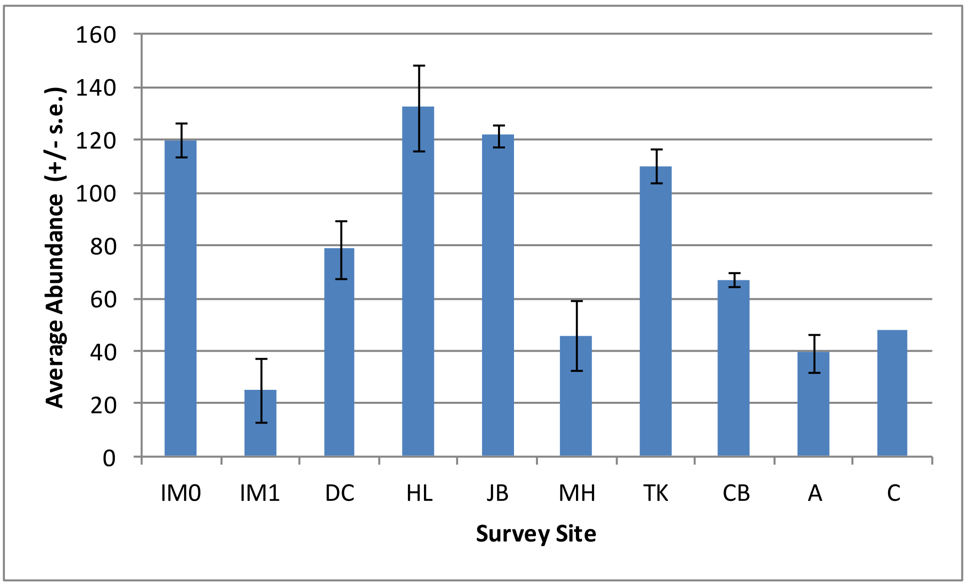


Figure 18: Average number of benthic infauna per core sample at each survey site

The Shannon-Wiener diversity index was lowest at site IM0 (approximately 0.6) followed by IM1 and Hamiltons Landing (approximately 1.3). The diversity index at the remaining intertidal and subtidal sites ranged between approximately 1.9 and 2.6, indicating moderate to high species diversity (Figure 19). Clearly the three sites located in the upper harbour area have the lowest Shannon-Wiener diversity, with all three sites below 1.5.

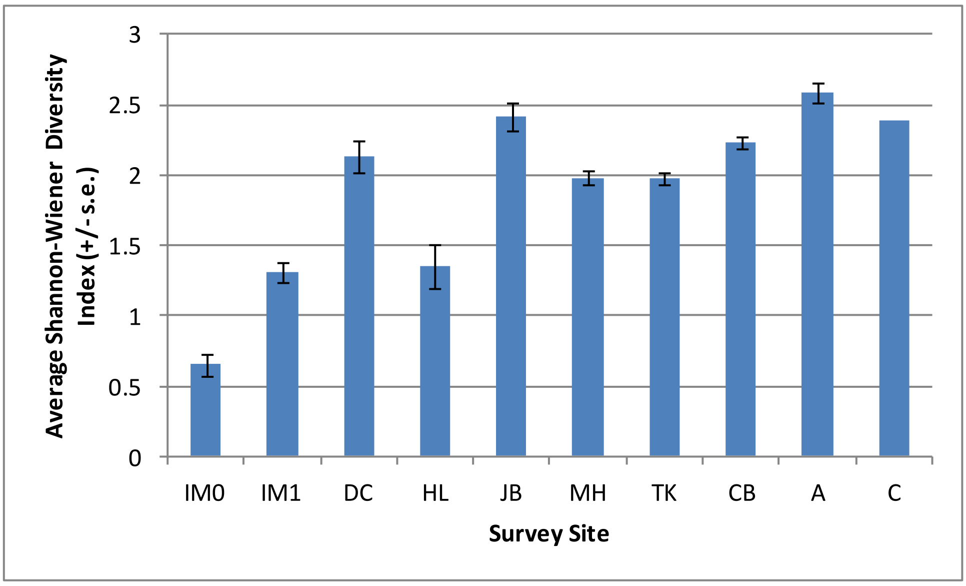


Figure 19: Average Shannon-Wiener diversity index per core sample at each survey site

Lundquist et al. (2003) calculated Shannon-Wiener diversity indices for the benthic invertebrate communities in intertidal and subtidal sites within various estuaries in the Auckland Region. The authors reported moderate diversity within the Mahurangi Harbour, although the diversity index tended to be lower in intertidal areas (approximately 1.0-1.3) compared to subtidal areas (approximately 1.4-1.7). The diversity indices shown in Figure 19 above are generally higher than that reported by Lundquist et al. (2003).

The following five species detected by Halliday & Cummings (2012) in Mahurangi Harbour are considered to be sensitive to increased suspended sediment concentration: the bivalve species *Macomona liliana*, *Austrovenus stutchburyi*, and *Nucula hartvigiana*, the gastropod *Notoacmea scapha* and the polychaete *Scoloplos cylindrifer* (Auckland Council, 2012b). Swales et al. (1997) reported increasing sedimentation at Hamiltons Landing and Halliday & Cummings (2012) noted large changes in the abundance of taxa at that site. Halliday & Cummings (2012) attributed the decrease in abundance of the more sensitive species to the sediment at the site being largely muddy and the faunal communities potentially being at their 'threshold' for survival. The authors also noted increases in stress-tolerant or sediment tolerant species such as the polychaete worms *Cossura consimilis* and *Aricidea* sp. at Hamiltons Landing.

Overall, Halliday and Cummings (2012) concluded that the long-term trends in macrofaunal populations and communities at both intertidal and subtidal sites remained relatively similar in the period 1994 to 2011.

The MDS plot of intertidal and subtidal benthic invertebrate community composition data shows a clear difference in assemblage between the subtidal sites (A and C), the upper harbour site (IM0 and IM1) and the remaining intertidal sites. In addition, the MDS plot suggests that the two subtidal sites have somewhat different assemblages to each other, in addition to differences between some of the intertidal sites surveyed (Figure 20).

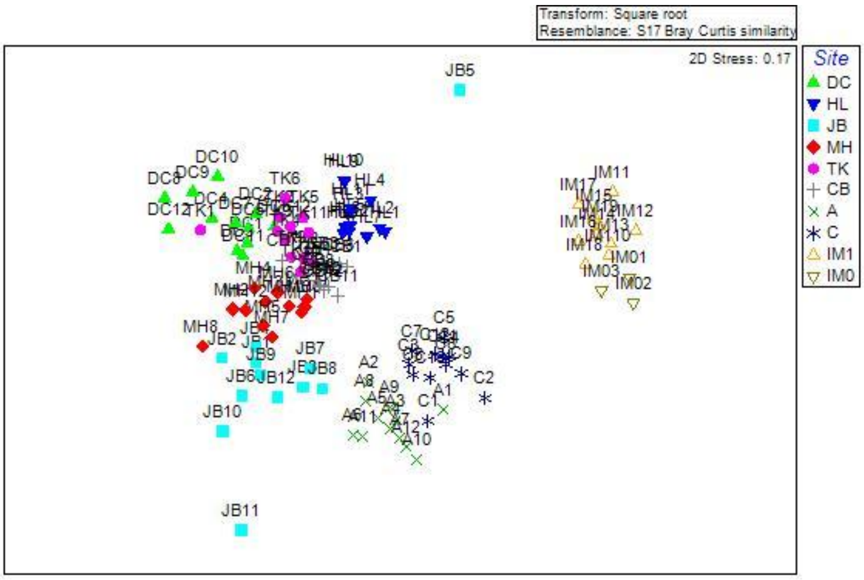


Figure 20: MDS plot of intertidal and subtidal community composition[16]

Figure 21 is an MDS plot of the intertidal community composition within Mahurangi Harbour (excluding site IM0 and IM1 which Figure 19 shows clearly has a different composition to the other intertidal sites). This figure shows that the variability within each site, indicated by the tight clustering of replicate samples, is relatively low (apart from Jamieson Bay and Mid Harbour to a lesser extent). The separation between sites indicates different community composition, with Jamieson Bay's assemblage being the most different to the other sites. The invertebrate community at Te Kapa and Cowan Bay is relatively similar, shown by the overlapping of some samples. Hamilton Landing has low within site variability (i.e. tightly clustered data points) and is distinct to the other sites. Sites on the left of the plot are upper harbour sites, grading to mid harbour and sites in the lower reaches on the right hand side of the plot (Figure 21).

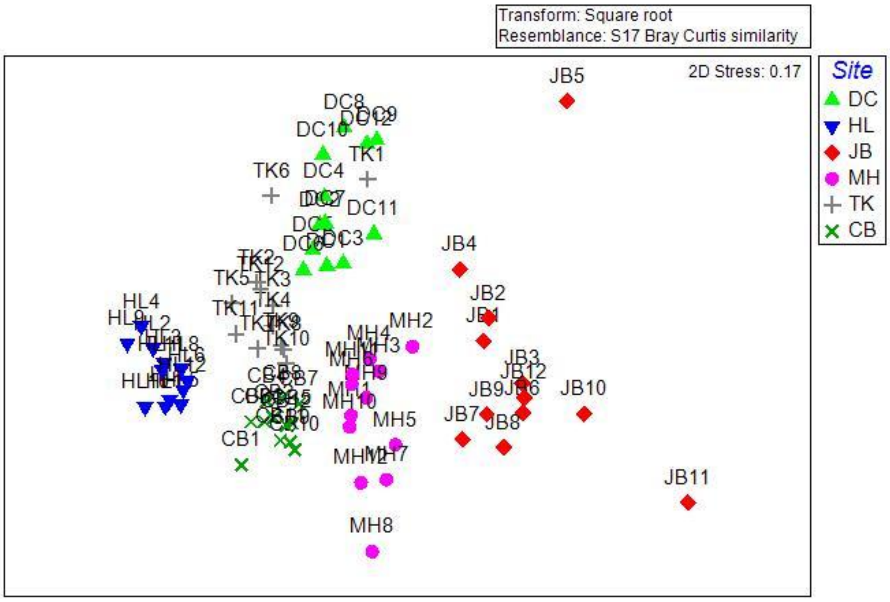


Figure 21: MDS plot of intertidal benthic invertebrate assemblages (excluding IM0)[17]

Analysis of the middle to upper harbour sites only shows that all sites have different assemblages, with Cowans Bay being more similar to Mid Harbour and Hamiltons Landing than Dyers Creek. Hamiltons Landing and Cowan Bay, the upper-most sites in Figure 21, have low within site variability in community composition, and are relatively distinct from the sites lower down the harbour (Figure 22). The trend from top right to bottom left on the MDS plot reflects the spatial location i.e. MH is located lowest, with DC and CB higher up in the harbour, and Hamilton's Landing the upper most site.

[16] Empty cores excluded from analyses.

[17] Empty cores excluded from analyses.

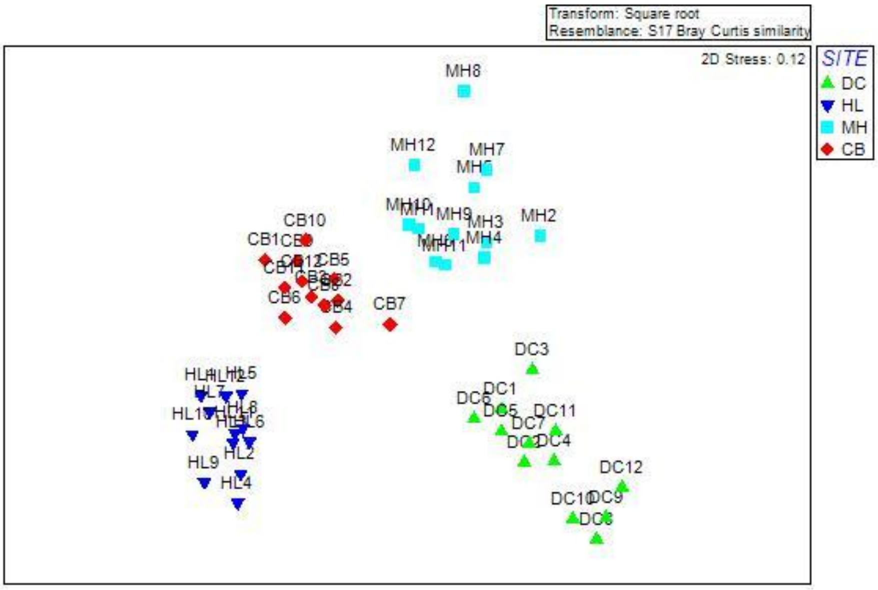


Figure 22: MDS of intertidal middle to upper harbour sites

Based on data from the uppermost reaches of other estuaries in the Auckland Region, the invertebrate community at the uppermost sites within the Mahurangi Harbour (i.e. above those surveyed by Halliday & Cummings (2012)) is expected to have low species diversity, comprising primarily small opportunistic species that are highly disturbance/stress tolerant.

The bivalve *Nucula hartvigiana* and polychaete *Cossura consimilis* are the most common and dominant fauna within the intertidal sites. At subtidal sites two bivalve species are common (*Arthritica bifurca* and *Theora lubrica)* (Halliday and Cummings 2012).

Lundquist et al. (2003) found that polychaete species (*Cossura* sp., *Aricidea* sp. and *Heteromastus filiformis*) as well as the bivalve *Nucula hartvigiana* were the most abundant species at intertidal sites. These authors detected a greater diversity of taxa at the three subtidal sites. Subtidal invertebrate community composition was found to be dominated by the bivalves *Theora lubrica* and *Arthritica bifurca*, *Cirratulidae* sp., and polychaetes *Labiosthenolepis laevis* and *Aricidea* sp. These findings are comparable to the recent results of Halliday and Cummings (2012).

The horse mussel, *Atrina zelandica*, has been a feature of the subtidal macrofaunal community in previous surveys (Halliday & Cummings, 2012; Cummings et al., 1994), but is in decline. No new horse mussel beds were detected in the 2011 survey (Halliday and Cummings, 2012; Cummings, 2007). Recent surveys carried out in 2013 in the Mahurangi Harbour did not reveal any newly recruited horse mussels and confirmed that the previously high density patches were becoming sparse as the single cohort of adult mussels naturally ages (Lohrer, D., pers. comm.).

Morrison and Carbines (2006) observed large dense beds of scallops (*Pecten novaezealandiae*) in subtidal areas within the lower harbour of Mahurangi Harbour during their fish survey. Scallops were not detected in the subtidal samples reported by Halliday & Cummings (2012) nor were they observed during subtidal sediment sample collection for the current Project. However, scallop beds may still be present within other subtidal areas within the harbour.

(a) 2013 Field results

The dominant epifaunal taxa present was mud crab, as evidenced by the presence of crab burrows. The average number of crab burrows per $0.25m^2$ quadrat was 44.3. Cockles and pipi were present at sites IM5a (upper Te Kapa) and IM6 (Jamison Bay), whereas mud whelk were present at site IM8 (Dyers Creek).

3.1.8 Fish

Morrison and Carbines (2006) report the diversity of fish in Mahurangi Harbour as modest, with a small number of common estuarine species accounting for over 90% of total fish numbers. The most common species detected include exquisite gobies (*Favonigobius exquisitus*), snapper (*Pagrus auratus*), yellow-eyed mullet (*Aldrichetta forsteri*), anchovy (*Engraulis australis*), jack mackerel (*Trachurus novaezelandiae*), red mullet (*Upeneichthys lineatus*) and mottled triple-fin (*Grahamina capito*). Parore (*Girella tricuspidata*), spotted dogfish (*Mustelus lenticulatus*), eagle ray (*Myliobatus tenuicaudatus*) and hammerhead shark (*Sphyrna zygaena*) were also detected (Morrison and Carbines, 2006).

Other species that may be periodically present in Mahurangi Harbour include flounder (*Rhombosolea plebeia*), sole (*Peltorhamphus latus*), kahawai (*Arripis trutta*), trevally (*Pseudocaranx dentex*), red cod (*Pseudophycis bachus*), short-tailed stingray (*Dasyastis brevicaudatus*), long-tailed stingray (*D. thetid*), short finned (*Anguilla australis*) and long finned eels (*A. dieffenbachii*), and inanga (*Galaxias maculatus*) (NIWA, 2013a; Francis et al., 2011; Morrisey et al., 2007; Thrush et al., 1991). Longfin[18] eel, shortfin eel and inanga were detected in streams and rivers that discharge into the Mahurangi Harbour (see Freshwater Ecological Assessment Report) and are also likely to use parts of the harbour at various times of the year during migration and spawning periods.

During field surveys for the current Project, fish species observed (not surveyed) in the lower reaches of the harbour near Scott's Landing and the mouth of Pukapuka Inlet included snapper, mullet and kahawai.

The Mahurangi Harbour has a large population (166,000 ± 28,000 s.e.) of snapper in a common size range (Morrison and Carbines, 2006). Juvenile snapper were frequently found adjacent to horse mussel beds, which have been previously identified predominantly in the middle to lower subtidal regions of the harbour. Juvenile snapper feed mainly on copepods, shrimp and polychaete worms, while adults consume brachyuran crabs, shrimps, bivalves, polychaete worms and hermit crabs, and occasionally harder shelled molluscs and bivalves (Usmar, 2009). During the benthic invertebrate and sediment quality field surveys carried out for the current Project a stingray and an eagle ray were observed. Though no targeted survey has been undertaken, it is expected that stingrays may utilise the extensive intertidal flats within the Mahurangi Harbour as a feeding ground during high tide (Thrush et al., 1994).

[18] Threat status of longfin eel is Declining (Allibone et al., 2010).

3.1.9 Cetaceans

Surveys of cetaceans in Mahurangi Harbour were not carried out as part of this Project. However, a variety of species are known to occur in the coastal waters of the north-eastern coast of the North Island.

Dolphins that may occasionally be observed within or near Mahurangi Harbour include common short-beaked (*Delphinus delphis*) and long-beaked (*D. capensis*) dolphin, bottlenose dolphin (*Tursiops truncates*) and dusky dolphin (*Lagenorhynchus obscurus*) (Suisted and Neale, 2004; Stockin and Visser, 2005).

In February 2013, a pod of 10 to 15 killer whales (*Orcinus orca)* in Mahurangi Harbour was observed by the Project's marine ecology field team. Killer whales may use the harbour as a transitory habitat for feeding or resting. They forage for prey (primarily rays, sharks, and fin-fish) in shallow estuarine areas, including harbours and bays (Visser, 1999, 2000, 2007), such as Mahurangi Harbour.

While there have been no published records of whales in or near the Mahurangi Harbour, the main whale species that migrate along the east coast of the North Island include the southern sperm whale (*Physeter macrocephalus*) and humpback whale (*Megaptera novaeangliae*) (Te Ara, 2013). In addition, the Nationally Critical Bryde's whale (*Balaenoptera edeni*) is known to be present in near shore coastal waters within the Hauraki Gulf (Suisted and Neale, 2004).

3.1.10 Avifauna

Avifauna is discussed in this report in the context of the marine environment being used as foraging and roosting habitat. Ecological values of, and effects on, avifauna is assessed in more detail within the Terrestrial Ecology Assessment Report. Mahurangi Harbour (including associated coastal vegetation) provides breeding, feeding and roosting habitat for a number of avifauna species. The estuary is part of network of regionally important, moderate size, east coast estuaries that provide important habitat for wildlife, such as banded rail, Caspian tern, Australasian bittern, NZ dabchick, variable oystercatcher, and North Island fernbird (Green, 1990; Bell, 1986; cited within DoC, 1994).

Data from the 1999-2004 Ornithological Society of New Zealand's (OSNZ) atlas survey (Robertson et al. 2007) was collated from the two 10km x 10km grid squares (266, 652; 266, 653) which encompass the Mahurangi Harbour and surrounding area. Information regarding the primary habitat used by each of the species recorded was obtained from Heather & Robertson (2000), along with each species' New Zealand threat status according to Miskelly et al. (2008).

Table 9 below shows that a total of 73 avifauna species were recorded within the 200km^2 area of the two grid squares. Of those species, coastal and/or estuarine environments are the primary habitat (dark green square) for 14 species, while a further 16 species may also use these habitats less frequently (light green squares). For the majority of these species, the Mahurangi Harbour is likely to form a part of a wider network of coastal and estuarine habitats that they use depending on the time of year and tidal sequence.

Ten of the 14 species recorded for which the coastal/estuarine environment is their primary habitat, are classified by Miskelly et al. (2008) as At Risk or Threatened (highlighted in bold Table 9).

Table 9: Habitat and threat status of avifauna detected within and near the Mahurangi Harbour (Darker green cells indicate primary habitat)

SPECIES	CONSERVATION STATUS[19]		HABITAT							
			Native forest	Exotic Forest	Scrub / shrubland	Farmland / open country	Freshwater / wetlands	Coastal / Estuary	Urban/Residential	Oceanic
Banded dotterel	**Endemic**	**Nationally Vulnerable [RR]**								
Banded rail	**Endemic**	**Naturally Uncommon[DP]**								
Black-backed gull	Native	Not Threatened[SO]								
Caspian tern	**Native**	**Nationally Vulnerable[SO]**								
Eastern bar-tailed godwit	Native	Migrant[SO]								
Lesser knot	Native	Migrant[SO]								
Northern NZ dotterel	**Endemic**	**Nationally Vulnerable[CD]**								
Red-billed gull	**Native**	**Nationally Vulnerable**								
Reef heron	**Native**	**Nationally Vulnerable[SO St]**								
Royal spoonbill	**Native**	**Naturally Uncommon[Inc RR SO Sp]**								
Variable oystercatcher	**Endemic**	**Recovering**								
White-faced heron	Native	Not Threatened[SO]								
White-fronted tern	**Native**	**Declining[DP]**								
Wrybill	**Endemic**	**Nationally Vulnerable[RR]**								
Fantail	Native	Not Threatened								
Kereru	Endemic	Not Threatened[CD Inc]								
Morepork	Native	Not Threatened								
North Island kaka	Endemic	Nationally Vulnerable[CD PD RF]								
Pied tomtit	**Endemic**	**Not Threatened**								
Shining cuckoo	Native	Not Threatened[DP]								
Tui	Endemic	Not Threatened[OL St]								
Blackbird	Introduced	Introduced & Naturalised[SO]								
Brown quail	Introduced	Introduced & Naturalised[SO]								
California quail	Introduced	Introduced & Naturalised[SO]								
Eastern rosella	Introduced	Introduced & Naturalised[SO]								
Grey warbler	**Endemic**	**Not Threatened**								
Kookaburra	Introduced	Introduced & Naturalised[SO RR]								
Pheasant	Introduced	Introduced & Naturalised[SO]								
Silvereye	Native	Not Threatened[SO]								
Australasian harrier	Native	Not Threatened[SO]								

19 Miskelly et al. (2008) with qualifiers: SO -Secure Overseas; Sp - Sparse; TO - Threatened Overseas; De - Declining; Inc - Increasing; RR -Range Restricted; DP -Data Poor; EF - Extreme Fluctuations; CD - Conservation Dependent; St - Stable.

SPECIES	CONSERVATION STATUS[19]		HABITAT							
			Native forest	Exotic Forest	Scrub / shrubland	Farmland / open country	Freshwater / wetlands	Coastal / Estuary	Urban/Residential	Oceanic
Australian magpie	Introduced	Introduced & Naturalised[SO]								
Chaffinch	Introduced	Introduced & Naturalised[SO]								
Dunnock	Introduced	Introduced & Naturalised[SO]								
Goldfinch	Introduced	Introduced & Naturalised[SO]								
Greenfinch	Introduced	Introduced & Naturalised[SO]								
NZ pipit	Native	Declining								
Redpoll	Introduced	Introduced & Naturalised[SO]								
Skylark	Introduced	Introduced & Naturalised[SO]								
Song thrush	Introduced	Introduced & Naturalised[SO]								
Spur-winged plover	Native	Not Threatened[SO]								
Starling	Introduced	Introduced & Naturalised[SO]								
Welcome swallow	Native	Not Threatened[Inc SO]								
Wild turkey	Introduced	Introduced and Naturalised[SO]								
Yellowhammer	Introduced	Introduced & Naturalised[SO]								
Australasian bittern	Native	Nationally Endangered[Sp TO]								
Black shag	Native	Naturally Uncommon[SO Sp]								
Black swan	Native	Not Threatened[SO]								
Black-billed gull	Endemic	Nationally Endangered[De]								
Feral goose	Introduced	Introduced & Naturalised[SO]								
Grey duck	Native	Nationally Critical								
Kingfisher	Native	Not Threatened								
Little black shag	Native	Naturally Uncommon[RR]								
Little shag	Native	Naturally Uncommon[Inc]								
Mallard	Introduced	Introduced & Naturalised[SO]								
North Island fernbird	Endemic	Declining[RR St]								
NZ pied oystercatcher	Endemic	Declining								
Paradise shelduck	Endemic	Not Threatened								
Pied shag	Endemic	Nationally Vulnerable								
Pied stilt	Native	Declining[SO]								
Pukeko	Native	Not Threatened[Inc SO]								
Shoveler	Native	Not Threatened								
Spotless crake	Native	Relict								
House sparrow	Introduced	Introduced & Naturalised[SO]								
Myna	Introduced	Introduced & Naturalised[SO]								
Rock pigeon	Introduced	Introduced & Naturalised[SO]								
Spotted dove	Introduced	Introduced & Naturalised[SO]								
Australasian gannet	Native	Not Threatened[De Inc SO]								
Blue penguin (northern)	Native	Declining[DP EF]								
Buller's shearwater	Endemic	Naturally Uncommon[OL St]								
Cook's petrel	Endemic	Relict[Inc RR]								

SPECIES	CONSERVATION STATUS[19]		HABITAT							
			Native forest	Exotic Forest	Scrub / shrubland	Farmland / open country	Freshwater / wetlands	Coastal / Estuary	Urban/Residential	Oceanic
Flesh-footed shearwater	Native	Declining[RR TO]								
Fluttering shearwater	Endemic	Relict[RR]								

Table 10 below details the diet and habitat use of the avifauna species for which the coastal and estuarine areas are the primary habitat. Those that feed on marine/estuarine invertebrates include banded dotterel, banded rail, Eastern bar-tailed godwit, lesser knot, Northern NZ dotterel, red-billed gull, reef heron, royal spoonbill, variable oystercatcher and wrybill. Other species listed below feed on marine fish (Heather & Robertson, 2000).

Table 10: The diet and habitat use of the avifaunal species identified in Table 9 above as having coast/estuary as their primary habitat

SPECIES	DIET	HABITAT USE (Heather & Robertson, 2000)
Banded dotterel	Marine invertebrates and freshwater insects and their larvae. In wet pastures they eat earthworms.	Occupy wide range of habitats; estuaries, sandy beaches, stream mouths, coastal lakes, ponds, salt marshes, coastal farmland, airports and ploughed fields. Mostly found in South Island but during December flocks up to several hundred can be found around NZ coast.
Banded rail	Diet unknown but presumably invertebrates such as snails, worms and insects (Heather & Robertson 2000).	Saltmarsh, mangroves and, less often, freshwater swamps.
Black-backed gull	Opportunist.	Ranges widely.
Caspian tern	Carnivorous; almost entirely fish (Higgins & Davis 1996).	Breeds widely; in NZ colonies on isolated sandspits and shellbanks of coast and harbours; some pairs on riverbeds or lake shores. Feeds inshore waters, up rivers and over coastal lakes.
Eastern bar-tailed godwit	Diet is mainly polychaete worms and molluscs found in soft mud. Also dig out crabs from sandy burrows or in eelgrass beds (Heather & Robertson 2000). Battley (2013) notes that they feed on small cockles, pipi, nut shells and small snails.	Arrives NZ mid-Sept and depart March-April. Can be found throughout NZ in estuaries with broad intertidal mudflats and sandflats, harbours, sandy coasts and inlets.

SPECIES	DIET	HABITAT USE (Heather & Robertson, 2000)
Lesser knot	Omnivorous: worms, bivalves, gastropods, crustaceans and echinoderms (Higgins & Davis 1996). Diet is mainly small (5-15 mm) thin-shelled bivalves *Myodora*, *Tellina* and *Nucula* with other thicker-shelled molluscs (e.g. cockle *Austrovenus*) and gastropods which are swallowed whole (Heather & Robertson 2000).	Breeds in Arctic. Summer in NZ estuaries. Favours northern and western estuaries.
Northern NZ dotterel	Feed on a wide range of marine invertebrates; particularly sandhoppers. When feeding on mudflats they eat crabs (Heather & Robertson 2000)	Generally restricted to beaches, river mouths and estuaries of northern NZ. Few individuals have been recorded on west coast southern NI.
Red-billed gull	During breeding season feed mainly in inshore waters on planktonic euphausiid, although some other marine inverts, small fish, terrestrial insects and earthworms also taken. Autumn and winter diet more varied including offal, refuse, marine inverts, fish and shellfish.	Common in coastal waters, beaches and estuaries.
Reef heron	Diet is mainly small fish, including eels and flounder; also crabs and molluscs (Heather & Robertson 2000).	Rocky coasts, mangrove estuaries, tidal streams.
Royal spoonbill	Feed on invertebrates and fish along with frogs (Moon 2002). Feed mostly in tidal mudflats or around the margins of shallow lakes.	Distributed throughout NZ mainland when not breeding. Located on tidal mudflats, muddy estuaries and sometimes on margins of freshwater lakes.
Variable oystercatcher	Diet is mainly molluscs (especially bivalves), worms and crabs, also other small invertebrates and occasionally small fish (Heather & Robertson 2000).	Mudflats, estuaries and beaches. Widely distributed throughout NZ.
White-faced heron	Diet is fish, frogs and tadpoles, aquatic and pasture insects, spiders, earthworms and mice (Heather & Robertson 2000).	Common throughout NZ in lowland areas. Occupy mudflats, estuaries, rocky shores, harbours, lagoons, lake margins, riverbeds, farms and parks.
White-fronted tern	Mainly small surface-shoaling fish (Heather & Robertson 2000).	Breeds NZ coast mainland. Favours coastal waters and harbours. Roosts on shellbanks or sandspits.
Wrybill	Mainly aquatic invertebrates; also fish (Marchant & Higgins 1993).	Breeds shingle riverbeds. Winter flocks in northern estuaries.

While no targeted avifauna surveys were undertaken as part of this marine ecology assessment[20], a number of species were observed while undertaking other field investigations, including:

- Australasian gannet (*Morus serrator*)

[20] See Terrestrial Ecology Assessment Report for field survey data.

- Eastern bar-tailed godwit (*Limosa lapponica baueri*)
- Kingfisher (*Todiramphus sanctus vagans*)
- North Island fantail (*Rhipidura fuliginosa placabilis*)
- New Zealand pied oystercatcher (*Haematopus finschi*)
- Pied stilt (*Himantopus h. leucocephalus*)
- Red-billed gull (*Larus novaehollandiae scopulinus*)
- Southern black-backed gull (*Larus d. dominicanus*)
- Variable oystercatcher (*Haematopus unicolor*)
- White-faced heron (*Ardea novaehollandiae*)

3.2 Pūhoi Estuary

The Pūhoi River catchment has a total area of approximately 53km^2 and is situated south of the Mahurangi Harbour, within the northern Auckland Council Rodney Ward (RDC 2010, Swales et al. 2002). The catchment extends from the mouth of the Pūhoi Estuary, east to Mahurangi West Road, north towards Moirs Hill, west out towards Monowai Road and south along the Hibiscus Coast Highway (Figure 8).

The Pūhoi Estuary contains CPA1 and CPA2 areas. The intertidal flats of the Pūhoi Estuary are used as a feeding ground by a variety of wading birds and the saltmarsh and mangrove vegetation is recognised as some of the best in the district (Auckland Council Regional Coastal Plan, 2004). DoC has listed the estuary as an Area of Significant Conservation Value (ASCV 115) with regional significance, primarily because of the unmodified nature of the habitat, the number of coastal bird species that use the estuary and the areas of mangrove forest (primarily in the upper reaches) and saltmarsh (DoC, 1994; RDC, 2010).

Approximately 158ha of the estuary is intertidal habitat and 15ha subtidal habitat. The estuary is characterised as a highly infilled tidal lagoon with narrow drainage channels intersecting the extensive intertidal sand and mud flats (Figure 2) (Swales et al., 2002; Lundquist et al., 2003). Whilst a sand barrier at the estuary mouth inhibits ocean waves entering the estuary, wind is still likely to generate waves (Swales et al., 2002; Lundquist et al., 2003). Transportation and deposition of sediment is influenced both by the tidal cycle and hydrodynamics. In Pūhoi Estuary, during low tides, the narrow channels act like rivers transporting suspended sediments seawards. Therefore, during low tide, sediment can bypass the upper intertidal flats and be carried to the lower reaches of the estuary or out into the coastal environment. During a rising high tide, suspended sediment can be transported to, and deposited on, intertidal flats.

The Pūhoi Estuary has a high tide surface area of 1.7km^2 and a tidal volume of 2.7M m^3 (approximately 6% of the tidal volume of the Mahurangi Estuary). The tidal cycle enables flushing and exchange between the estuary and sea (Lundquist et al., 2003; Swales et al., 2002). However, the upper reaches of the estuary have a lower inundation time and low tidal current, in comparison to the lower reaches near the estuary mouth (Swales et al., 2002). Figure 9 indicates the survey sites of the previous researchers in addition to those surveyed for the current Project.

Freshwater streams and tributaries in the Pūhoi catchment are described in the Freshwater Ecology Assessment Report. The streams draining pastoral land have little riparian vegetation, while the edges of the creeks running through forestry lands are heavily fringed with overgrown weeds and scrub. All waterways have low flow and many are intermittent watercourses. The baseline flow of freshwater from the Pūhoi River to the estuary is low (Swales et al., 2002).

The indicative alignment traverses the Okahu Creek with a viaduct. The adjacent intertidal area consists of open mudflat with a narrow, patchy fringe of manuka and maritime vegetation around its grazed-through upper fringes. The lower areas are vegetated with grazed oioi (*Apodasmia similis*), maritime rush (*Juncus krausii*), and mangroves. Mud crabs and large mud snails (*Amphibola crenata*) are present on the mudflats (Bioresearches, 2011).

There is a paucity of existing information on the ecological values of the Pūhoi Estuary. In order to characterise the marine ecological values for the current Project, we conducted intertidal and subtidal benthic invertebrate community and sediment quality surveys.

3.2.1 Water quality

(a) Literature review

Prior to commencement of this Project, there was no available marine water quality data for the Pūhoi Estuary. Based on the data collected for the Project, water quality appears to be similar between the Mahurangi River and the Pūhoi River (Section 3.6, Construction Water Management and Assessment Report). During field surveys conducted at high tide as part of the current Project water clarity was noted to be high.

Swales et al. (2002) state that turbidity is likely to be low in the lower reaches of the estuary where there is a greater exchange of water, but elevated near the intertidal mudflats where wind driven waves and tides may resuspend sediment (Swales et al., 2002).

3.2.2 Sediment grain size

(a) Literature review

Estuarine sediment characteristics vary depending on the tidal regime, predominant hydrodynamics and inputs from the surrounding catchment. Lundquist et al. (2003) described the grain size distribution of intertidal mudflat sediment within the upper reaches of the Pūhoi Estuary as similar to the Mahurangi Estuary, comprising predominantly fine silt and very fine sand, with mud content between 5 to 20%. The Pūhoi Estuary was found to have the highest sedimentation rates, and highest proportion of sand in intertidal sediments compared with other east coast estuaries in the Auckland Region (Swales et al., 2002).

(b) 2013 Field results

The proportion of silt and clay in surface sediment is highest at the upper harbour intertidal (IP0 62% and IP1 50%) and subtidal (SP1 48% and SP2 57%) sites. Sites located in the middle reaches of the harbour were dominated by fine sand (approximately 70-80%), with approximately 20% silt and clay. Sites located towards the mouth of the estuary had approximately 10% silt and clay. Sediment collected at subtidal site SP4, at the mouth of the estuary, was characterised by a range of grain sizes with approximately 30% fine sand, 40% medium sand, 15% coarse sand and 15% gravel (Figure 23).

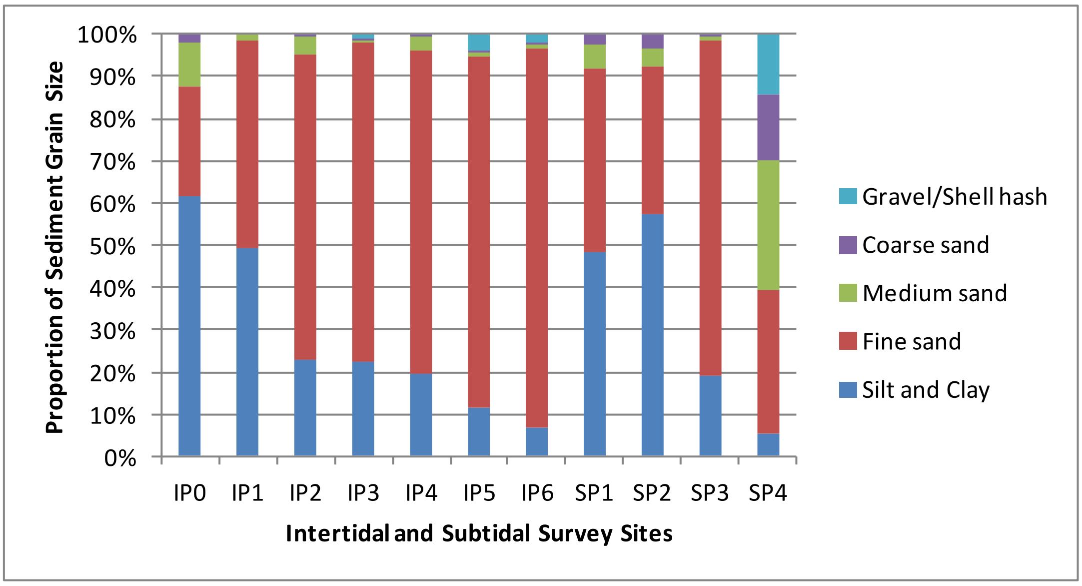


Figure 23: Proportion of sediment grain size distribution in surface sediment at intertidal and subtidal survey sites within Pūhoi Estuary

Figure 24 shows the 2013 grain size data spatially within the Pūhoi Estuary. The proportion of silt and clay increases greatly with increased distance upstream, with upper estuary sites comprising around 50% silt and clay.

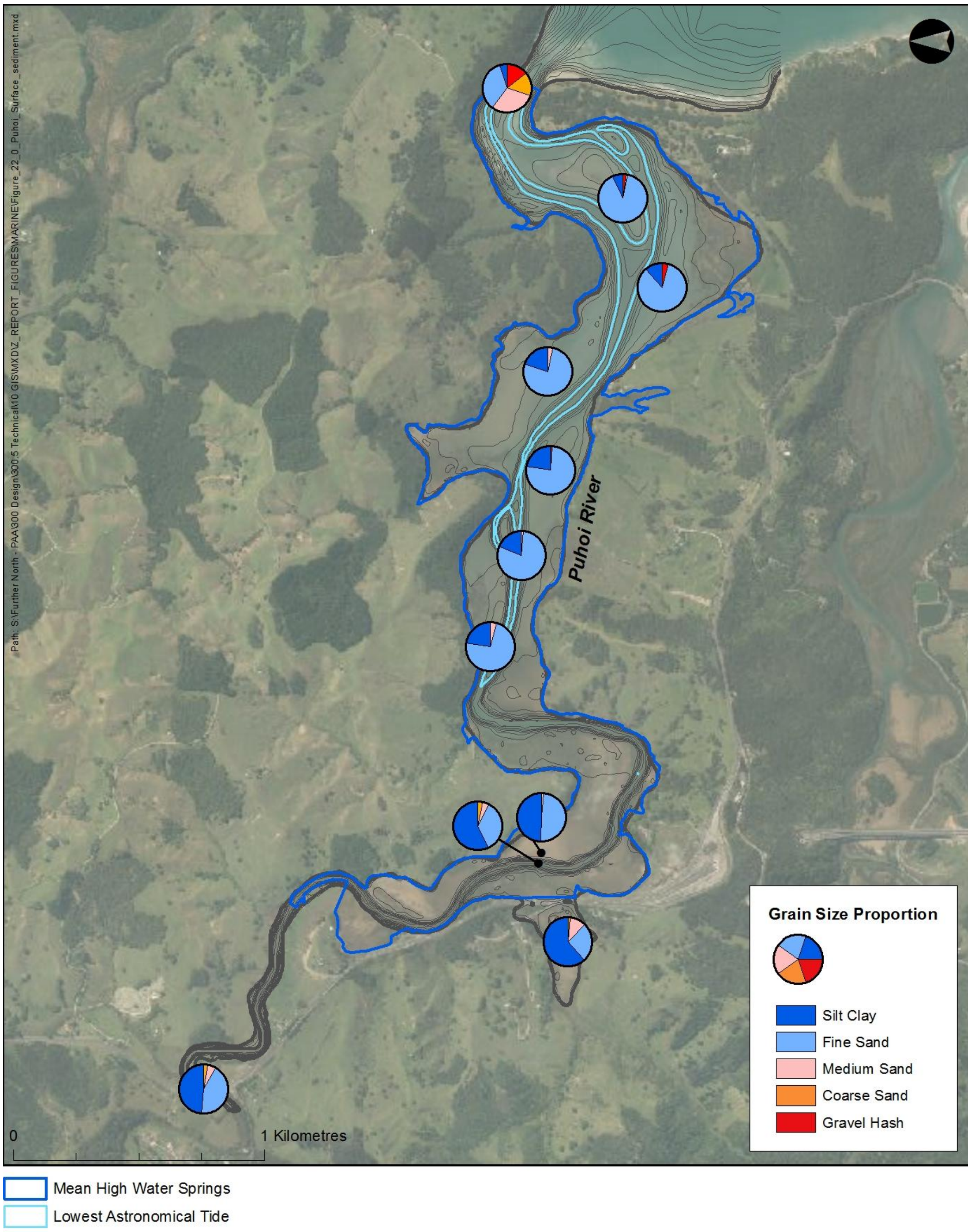


Figure 24: Pūhoi surface sediment grain size proportion

3.2.3 Sediment contaminants

(a) Literature review

Auckland Council undertook sediment quality surveys at three sites within the Pūhoi Estuary in 2010. The concentrations of copper, lead, zinc and PAHs detected at all three sites were within the respective ERC green range for each contaminant (Auckland Council, 2012a).

(b) 2013 Field results

Further sediment quality surveys within Pūhoi Estuary were carried out for the current Project in order to better understand the spatial variation in sediment grain size and contaminant concentrations. Samples were collected from six intertidal sites (IP1-6) and four subtidal sites (SP1-4) (Figure 9).

The concentration of common stormwater contaminants in both intertidal (Table 11) and subtidal (Table 12) surface sediment was below thresholds in both total sediment and in the <63µm fraction.

Table 11: Intertidal surface sediment contaminant concentrations in Pūhoi Estuary

Contaminant (mg/kg d.w.)	Sediment Fraction	IP0	IP1	IP2	IP3	IP4	IP5	IP6
Copper	**Total**	13.1	8.8	7.0	5.4	4.7	4.1	3.7
	<63µm	10.1	13.6	13.8	10.3	11.9	12.5	11.7
Lead	**Total**	6.1	4.6	3.9	3.4	3.3	3.4	2.5
	<63µm	5.8	4.7	5.6	5.4	6.4	7.0	6.5
Zinc	**Total**	39	30	30	28	27	28	26
	<63µm	30	42	47	40	46	50	50
HMW PAHs	**Total**	0.007	0.015	0.019	0.019	0.021	0.009	0.011
	<63µm	0.003	0.014	0.012	0.015	0.011	0.012	0.008

Table 12: Subtidal surface sediment contaminant concentrations in Pūhoi Estuary

Contaminant (mg/kg d.w.)	Sediment Fraction	SP1	SP2	SP3	SP4
Copper	**Total**	15.9	16.0	6.5	3.6
	<63µm	18	19.6	15.4	15.2
Lead	**Total**	6.7	6.4	3.6	1.9
	<63µm	8.2	8.4	6.9	6.8

Contaminant (mg/kg d.w.)	Sediment Fraction	SP1	SP2	SP3	SP4
Zinc	Total	49	48	30	24
	<63µm	52	56	50	43
HMW PAHs	Total	0.038	0.023	0.430	0.021
	<63µm	0.100	0.010	0.012	NA[21]

(c) Oxidation Reduction Potential

The average ORP detected in May 2013 in surface sediment at intertidal sites in the Pūhoi Estuary was 480 mV (ranging from 421.4 to 492.4 mV), indicating oxygenated sediment (Gray, 1981)[22].

3.2.4 Saline vegetation

(a) Literature review

The former Auckland Regional Council (1999) described the mangrove and saltmarsh vegetation areas of Pūhoi Estuary to be substantial and some of the best in the Rodney ecological district. In addition, the Department of Conservation has identified the estuary as an Area of Significant Conservation Value (ASCV 115) primarily because of the unmodified nature of the habitat, the number of coastal bird species that use the estuary and the areas of mangrove forest (primarily in the upper reaches) and saltmarsh (DoC, 1994).

In the upper reaches of the estuary, where the intertidal flats are relatively high and expansive, dense mangrove stands are present, continuing up into the Pūhoi River (Swales et al., 2002). Tall mangroves fringe the low tide channel and the coastal fringe, with less dense, shorter stature mangroves in central areas. Large areas of saltmarsh habitat are present in the middle reaches of the estuary. The lower reaches of the estuary are dominated by extensive intertidal flats fringed by mangroves (*Avicennia marina* var*. australasica*) and patches of saltmarsh.

Seagrass was not observed within the Pūhoi Estuary during our surveys.

3.2.5 Benthic marine invertebrates

(a) Literature review

Anderson et al. (2007) conducted surveys of benthic invertebrates in the Pūhoi Estuary from 2002 to 2007 at 10 sites (see Figure 9) to monitor temporal trends in benthic ecology and associated sediment characteristics. The most dominant taxa across the Pūhoi were corophidae amphipods, the polychaete worm *Capitella* spp., oligochaete worms and pipi (*Paphies australis*). Average species richness was high at all sites surveyed, though no upper estuary sites were included in the survey. Average species richness (i.e. number of taxa) was slightly higher (i.e. 25 taxa) towards the central part of the estuary at sites 4, 5, 6 and 7. These regions were characterised as sandy intertidal flats with some mud. Lower species richness (i.e. 17 taxa) was detected further up the

21 Insufficient <63um fraction of the sediment sample was available for this analysis.

22 Gray (1981) states that in intertidal sediments the usual range of ORP can be >400 mV in oxygenated sediment and down to approximately -250 mV in anoxic sediment.

estuary at sites 9 and 10. Higher variability in community composition was detected at sites in the middle reaches of the estuary compared to sites close to the mouth of the estuary (Anderson et al., 2007).

The Lundquist et al. (2003) survey of intertidal and subtidal sites within various estuaries in the Auckland Region recorded low benthic invertebrate diversity and richness within Pūhoi Estuary compared to other intertidal estuarine sites surveyed along the east coast. These surveys were limited to three sites in close proximity to one another (Figure 9). The average number of taxa detected in core samples was less than 3, whereas the average number of individuals in samples collected at other estuaries by Lundquist et al. (2003) varied between approximately 11 and 38. In total, 11 taxa were observed in the Pūhoi samples, with oligochaete worms, *Paracorophium excavatum* (amphipod) and *Helice crassa* (mud crab) dominating the community composition.

Low average Shannon-Wiener diversity index was detected in intertidal areas within the Pūhoi Estuary (approximately 0.5-0.7). Lundquist et al. (2003) summarised the invertebrate community as having low species diversity, consisting primarily of small opportunistic species that were highly disturbance/stress tolerant. The community composition was described as characteristic of upper estuary mudflats with low inundation time and low tidal current within a mature estuary.

Analyses carried out by Anderson et al. (2007) of the influence of rainfall and dry events on temporal variability in benthic invertebrate community structure found that season was more important in determining variation in community composition than rainfall. Their investigation did not detect any measureable effect of rainfall events on marine benthic invertebrate communities. In addition, the spatial variation in benthic invertebrate community composition was explained best by the mud content of sediment (Anderson et al., 2007).

Further detailed investigations of pipi (*Paphies australis*) and cockle (*Austrovenus stutchburyi*) populations were conducted by Anderson et al. (2007). The density of cockles was found to be stable over time. Juvenile cockles were the most dominant size class and seasonal patterns in their abundance were identified. Pipi populations and size classes were temporally stable.

(b) 2013 Field results

In 2013, surveys of seven intertidal and four subtidal sites within the Pūhoi Estuary revealed a low abundance of organisms at all sites apart from IP5 located on the open intertidal mudflats adjacent to Schischka Road and site IP0a located adjacent to the low tide channel within the Okahu Inlet (Figure 25). Due to the large difference in abundance at the three sub-sites within Okahu Inlet (IP0a-c), we have shown them separately in the graphs below. Intertidal sites IP3-IP5 were dominated by bivalves and polychaete worms, whereas IP0-2 contained predominantly oligochaete worms and amphipods, and site IP6 was dominated by bivalves and amphipods. Only one taxa was detected at site IP1, located in the upper reaches of the estuary (Figure 25).

Subtidal sites had a lower average abundance of organisms than intertidal sites IP2-IP6, with no organisms detected at subtidal site SP1 and one individual detected on average at site SP2. Bivalves and polychaete worms dominated the community at sites SP3 and SP4 (Figure 25).

Cockles of a harvestable size were present at intertidal sites IP3-6. The average density of cockles (all size classes) per core at these sites was between 1 and 18. We detected pipi in low abundance at subtidal site SP4, and a very low abundance mud snail within the estuary.

Upper estuary sites (IP0b, IP0c, IP1, SP1 and SP2) are characterised by a depauperate community (i.e. low abundance and diversity) of tolerant and /or opportunistic species e.g. oligochaete worms. Site IP0a has different habitat characteristics compared to IP0b and IP0c, which are located on the extensive mudflats of the Okahu Inlet. IP0a is located on the banks of the deeply incised low tide channel, where freshwater flows dominate. The most abundant organisms at IP0a were oligochaete worms and amphipods of the Corophiidae family, which are both known for their tolerance of a range of salinity and high sedimentation.

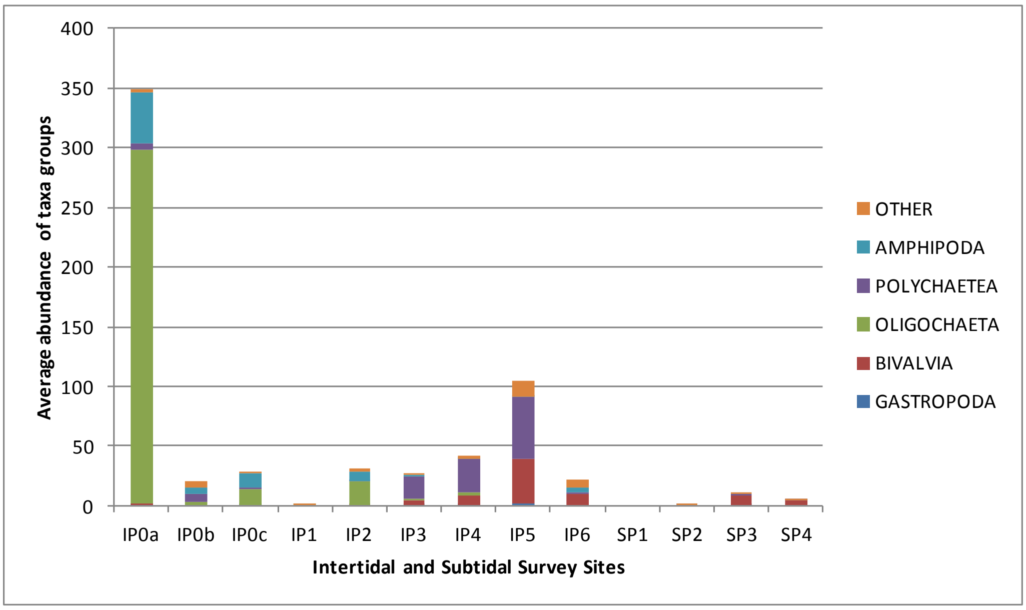


Figure 25: Average abundance of main taxa groups at intertidal and subtidal sites surveyed in Pūhoi Estuary

The abundance of main taxa groupings has also been mapped (Figure 26). The size of the pie chart reflects average total abundance at each site, with the average proportion of each taxa group shown as different coloured segments. Figure 26 clearly shows the dominance of oligochaete worms, amphipods and polychaete worms and lack of bivalves and gastropods in the upper harbour areas where sediment grain size is dominated by silt and clay. Many species of polychaete and oligochaete worms are known to be disturbance tolerant and typically inhabit mudflats with a high proportion of silt and clay, whereas many bivalve and gastropod species are sensitive to disturbance and cannot tolerate high proportions of silt and clay (see Appendix C). Although very difficult to detect in Figure 26 due to their small size (and therefore very low abundance), both a subtidal and intertidal survey site exist adjacent to the Okahu Creek inlet. The benthic community at both these sites is depauperate, with only two isopods detected at the intertidal site and several snapping shrimp detected at the subtidal site.

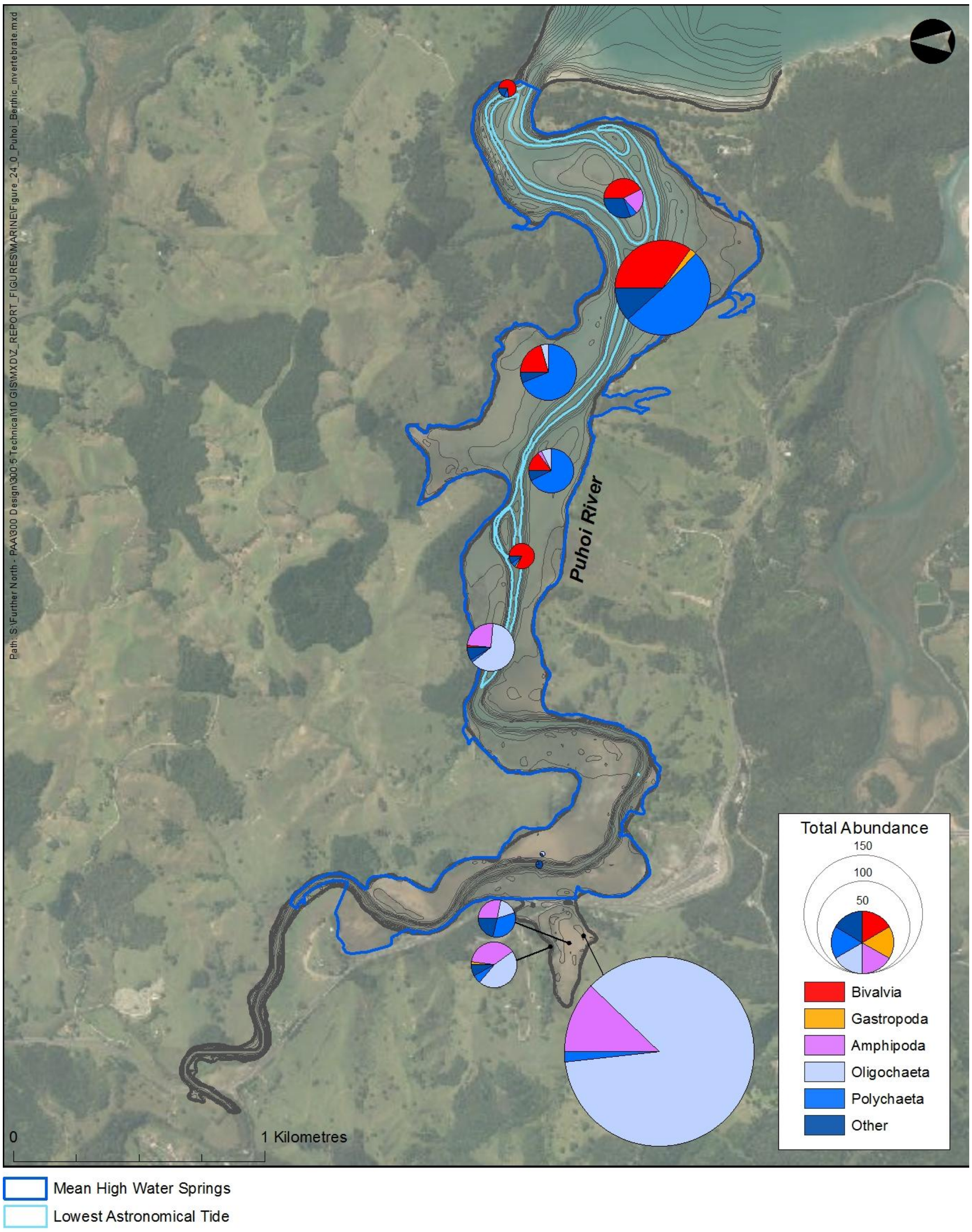


Figure 26: Pūhoi Benthic invertebrate community composition

The average number of taxa detected varied between 1 and 17 at intertidal sites, lower than that detected by Anderson et al. (2007). Greater than ten taxa were detected at sites IP3-5 located in the middle reaches of the estuary, whereas less than ten taxa were detected at in the upper reaches (IP0-IP2) and near the mouth of the estuary (IP6) (Figure 27). The greatest average species richness (6) detected for a subtidal site was detected at SP3 in the middle reaches (Figure

27). We did not detect any taxa at subtidal site SP1 and we only detected one organism in one replicate at site SP2.

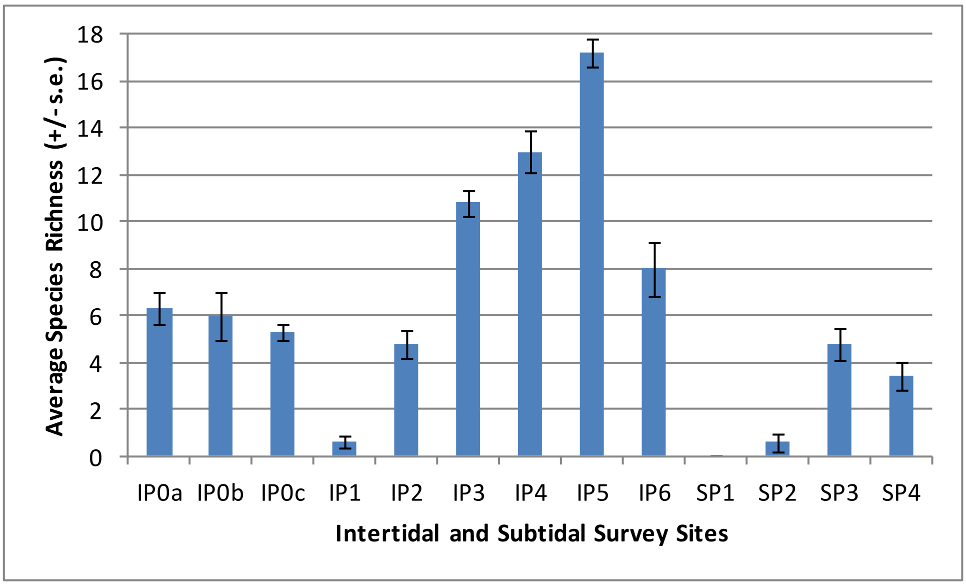


Figure 27: Average species richness (number of species) at intertidal and subtidal sites surveyed in the Pūhoi Estuary

The Shannon-Wiener diversity index revealed a high diversity at intertidal sites IP3-6 and moderate at IP2. Only oligochaete worms were detected at site IP1, hence the diversity is zero. We detected moderate diversity within the sites on the mudflats within Okahu Inlet (IP0b and IP0c), whereas we detected low diversity at the site adjacent to the low tide channel at Okahu Estuary (IP0a). The low diversity at IP0a reflects the numerical dominance of 1-2 species at this site. Shannon-Wiener diversity at the subtidal was very low at site SP2 and moderate at SP3 and SP4 (approximately 1.4 and 1.1 respectively) (Figure 28). No organisms were detected at site SP1.

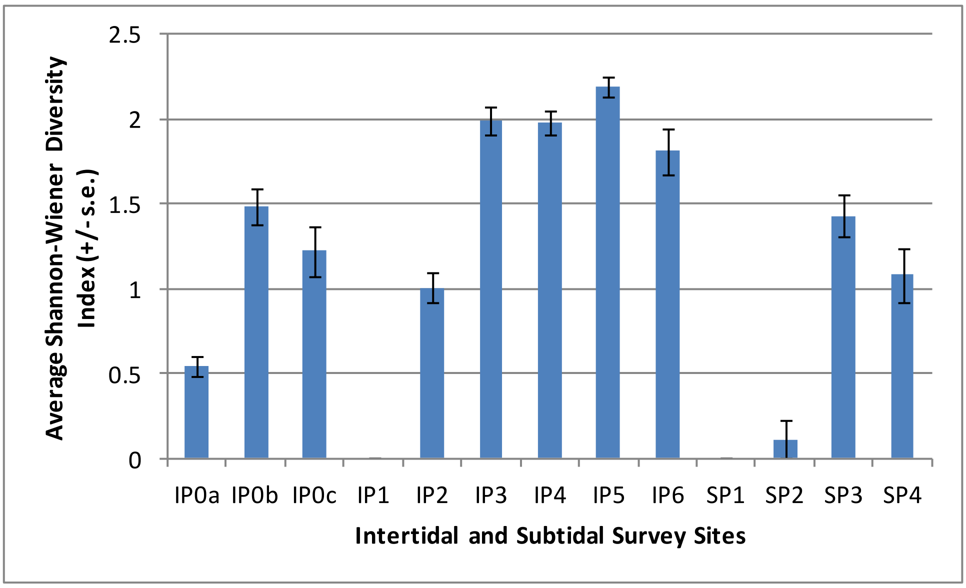


Figure 28: Average Shannon-Wiener diversity index at intertidal and subtidal sites surveyed in the Pūhoi Estuary

The dominant epifaunal taxa present at intertidal survey sites was mud crab, as evidenced by the presence of crab burrows. The average number of crab burrows per $0.25m^2$ quadrat across all sites surveyed in April 2013 was 27.2. Cockles were present at sites located in the lower reaches of the estuary (i.e. IP5 and IP6). In addition, modest barnacle and horn shell were present at site IP5.

The MDS plot of the intertidal and subtidal invertebrate assemblages[23] in the Pūhoi Estuary show a clear separation between the middle estuary sites (IP3, IP4 and IP5), upper estuary sites (IP0 and IP2) and sites located in the middle to lower reaches of the estuary. The invertebrate community composition at site IP6 was more similar to that of subtidal sites SP3 and SP4 than the other intertidal sites (IP3-5). The composition of the community at sites IP3-5 was similar, indicated by the relatively tight clustering of the replicates. Site IP0a was clearly separated from IP0b and IP0c as expected from the data shown in Figure 25 above (Figure 29).

[23] Excluding samples from IP1, SP1 and SP2 as they were clearly outliers and different to all other samples. This is primarily due to many replicate core samples containing little or no organisms.

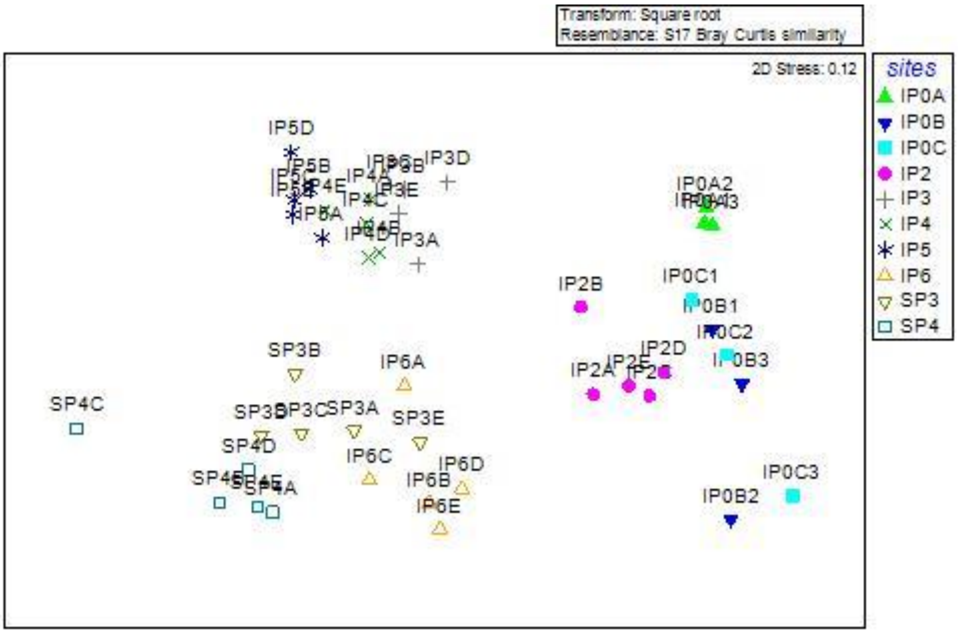


Figure 29: MDS plot of intertidal invertebrate assemblages[24]

3.2.6 Fish

While marine fish species and distribution has not been intensively studied in the Pūhoi Estuary, it can be inferred from surveys in estuaries nearby on the basis of the dominant habitat types that are present.

The Pūhoi Estuary contains large mangrove stands and therefore likely provides habitat for fish species when inundated at high tide. Morrisey et al. (2007) found that the typical fish species that use mangrove habitats included sand and yellow-belly flounder (*Rhombosolea plebeia* and *R. leporina*) and snapper (*Pagrus auratus*). Flounder were observed by the field team when carrying out the benthic invertebrate and sediment quality surveys for this Project.

In 2005, NIWA conducted fish surveys in mangrove and seagrass habitats of Auckland's east coast estuaries, including the Mahurangi Harbour but excluding the Pūhoi Estuary. Across all estuaries surveyed, yellow-eyed mullet (*Aldrichetta forsteri*) were found to be the most abundant fish in addition to juvenile short-finned eels. Other juvenile fish commonly detected by NIWA in east coast estuaries included parore and grey mullet (NIWA, 2013a; b). It is likely that these species are also present within the Pūhoi Estuary at various times.

Francis et al. (2011) estimated fish richness, occurrence and abundance from intertidal estuaries on the north and south islands of New Zealand. The study found that estuaries in the far north of New Zealand had the highest species richness, which was positively correlated with estuary area

24 Empty cores were excluded from the analyses.

and area of intertidal habitat. The most abundant species caught included yellow-eye mullet, smelt (*Retropinna retropinna*), anchovy (*Engraulis australis*), NZ sprat (*Sprattus muelleri*), estuarine triplefin (*Grahamina nigripenne*) and exquisite goby (*Favonigobius exquisitus*).

During the benthic invertebrate and sediment quality field surveys carried out for the current Project a stingray was observed in the Pūhoi Estuary. Though no targeted surveys of rays have been conducted, it is expected that stingrays may use the extensive intertidal flats in the Pūhoi Estuary as a feeding ground during the high tide (Thrush et al., 1994).

3.2.7 Cetaceans

Whales, dolphins and porpoises have not been recorded within the Pūhoi Estuary, nor is it likely they would venture into this estuary, as the shallow nature of the estuary with extensive, high intertidal flats and a narrow main channel limits access of cetaceans into the estuary.

3.2.8 Avifauna

A search of the available literature has not revealed any dedicated surveys of avifauna undertaken within the Pūhoi Estuary. The former Auckland Regional Council (1999) observed that wading birds use the saline vegetation as nesting, roosting and foraging habitat. The area supports a diverse range of coastal bird species. Threatened species recorded in the estuary include banded rail, North Island fernbird, New Zealand dotterel and Caspian tern. Other bird species that use the estuary include little black shag, white-faced heron, pied shag, harrier, kingfisher and pied stilt. In addition, the intertidal flats provide foraging habitat for a variety of wading and migratory birds (DoC, 1994). Whilst Pūhoi Estuary is not recognised as a significant nesting or feeding habitat for migratory birds, it is considered a potential transitory habitat (Auckland Regional Council, 1999; Dowding and Moore, 2006).

Data from the 1999-2004 Ornithological Society of New Zealand's (OSNZ) atlas survey (Robertson et al. 2007) was collated from the 10km x 10km grid squares (266, 651) which encompass the Pūhoi Estuary and surrounding area. Information regarding the primary habitat used by each of the species recorded was obtained from Heather & Robertson (2000), along with each species' New Zealand threat status according to Miskelly et al. (2008)[25].

A total of 74 avifauna species were recorded within the 100km^2 grid square area. Of those species, coastal and/or estuarine environments are the primary habitat (dark green square) for 13 species, while a further 19 species may also use these habitats less frequently (light green squares). For the majority of these species, the Pūhoi Estuary is likely to form a part of a wider network of coastal and estuarine habitats that they use depending on the time of year and tidal sequence. Nine of the 13 species recorded for which the coastal/estuarine environment is their primary habitat, are classified by Miskelly et al. (2008) as At Risk or Threatened.

Avifauna recorded in Pūhoi Estuary is similar to that recorded in Mahurangi Harbour. Of those that use the coast/estuary as their primary habitat, royal spoonbill were detected in the vicinity of the Mahurangi Harbour, but not in the Pūhoi Estuary. Avifauna detected in the Pūhoi Estuary area which were not detected in the Mahurangi Harbour are shown in Table 13 below.

25 Avifauna have been assessed in detail within the Terrestrial Ecology Assessment Report.

Table 13: Habitat and threat status of avifauna detected within and near the Pūhoi Estuary, additional to those species covered in Table 9

SPECIES	CONSERVATION STATUS[1]		HABITAT							
			Native forest	Exotic Forest	Scrub / shrubland	Farmland / open country	Freshwater / wetlands	Coastal / Estuary	Urban/Residential	Oceanic
North Island robin	Endemic	Not Threatened[St]								
Canada goose	Introduced	Introduced & Naturalised[SO]								
Australasian little grebe	Coloniser	Coloniser[SO]								
Grey teal	Native	Not Threatened[Inc SO]								
Marsh crake	Native	Relict[DP SO]								
NZ dabchick	Endemic	Nationally Vulnerable								
Scaup	Endemic	Not Threatened[Inc]								

Table 10 provides details regarding diet and habitat use of those species that utilise coastal and estuarine areas as their primary habitat. Those that feed on marine/estuarine invertebrates include banded dotterel, banded rail, Eastern bar-tailed godwit, less knot, Northern NZ dotterel, red-billed gull, reef heron, variable oystercatcher and wrybill. Other species listed in Table 10 feed on marine fish (Heather & Robertson, 2000).

While no targeted avifauna surveys were undertaken for this marine ecology assessment, a number of species were observed within the Pūhoi Estuary while undertaking other field investigations, including: NZ kingfisher, black shag, pied stilt, variable oystercatcher, Caspian tern and red-billed gull[26].

3.3 Assessment of existing ecological values

Our assessment of ecological value for the Mahurangi and Pūhoi marine environments is based on Tables 15 and 16 below, which detail some of the common characteristics of these environments under different ecological value categories. Whilst recognising that invertebrate communities and sediment quality within estuaries are often variable, both spatially and temporally, we have assessed the values using all of the data we describe above, guided by the characteristics in Table 2. This process involves condensing a large volume of data into single descriptors. It should be noted that more information is available regarding the Mahurangi Harbour compared to the Pūhoi Estuary; this may have some influence on the data, for example, greater sampling effort typically results in the detection of more species.

The characteristics that applied to each of the waterways have been extracted from Table 2 and are listed below (Table 14 and Table 15):

[26] See the Terrestrial Ecology Assessment Report

Table 14: Marine ecological values of Mahurangi Harbour

ECOLOGICAL VALUE	CHARACTERISTIC
LOW	• Low benthic invertebrate community species diversity and richness in the upper reaches of the harbour. • Silt and clay comprise approximately 50% of sediment in the upper harbour areas. • Concentration of copper in sediment in the upper reaches of the Harbour above ISQG-low and ERC red thresholds.
MEDIUM	• Moderate to high benthic invertebrate community species diversity, richness and abundance in middle to lower parts of the harbour. • Silt and clay rarely greater than 50% in the middle and lower parts of the harbour.
HIGH	• Contaminant concentrations in surface sediment rarely exceed ISQG-low or ERC-amber thresholds throughout the middle to lower reaches of the harbour. • Surface sediment oxygenated. • Estuarine vegetation provides significant habitat for native fauna. • Habitat modification low (apart from presence of oyster farms).

Table 15: Marine ecological values of the Pūhoi Estuary

ECOLOGICAL VALUE	CHARACTERISTIC
LOW	• Low diversity, richness and abundance of benthic invertebrates at subtidal and upper estuary intertidal sites.
MEDIUM	• Moderate diversity, richness and abundance benthic invertebrate assemblage and middle and lower reaches of the estuary. • Silt and clay rarely greater than 50%.
HIGH	• Contaminant concentrations in surface sediment do not exceed ISQG-low or ERC-amber thresholds. • Surface sediment oxygenated. • Estuarine vegetation provides significant habitat for native fauna. • Habitat modification low.

The overall ecological values of the Mahurangi Harbour and the Pūhoi Estuary are relatively similar, based on the criteria in Table 2. They both have generally low contaminant concentrations in sediment, oxygenated surface sediment, generally less than 50% silt and clay in surface sediment, significant estuarine vegetation providing habitat for native fauna, and low habitat modification. Pūhoi Estuary has lower ecological values than the Mahurangi Harbour relating to a greater spatial variability in benthic invertebrate community composition. Conversely, Mahurangi Harbour has greater habitat modification due to the presence of the oyster farms. Marine ecological values are lower in the upper reaches of both the Pūhoi Estuary, and, to a lesser extent, the Mahurangi Harbour, primarily due to a low diversity of benthic invertebrate assemblages in these areas. Due to the large differences in benthic invertebrate community composition between the upper reaches and that of the middle and lower reaches of both waterways, we have divided the assessment of ecological value into these two areas. The overall marine ecological values of the Pūhoi Estuary are assessed as medium in the middle to lower reaches, and low in the upper reaches. The Mahurangi Harbour marine ecological values are considered to be medium to high in the middle to lower reaches, and low to medium in the upper reaches.

4. Assessment of effects – construction activities

Construction of the Project has the potential to adversely affect marine ecological values through:

- The discharge of runoff from open earthworks areas to marine environments;
- Permanent habitat loss;
- Temporary habitat loss; and
- Temporary habitat disturbance.

Sediment generated from open earthworks areas during rainfall events that will be treated and then discharged to the Mahurangi Harbour and Pūhoi Estuary has been modelled. The concentration of TSS and the area and depth of deposited sediment under the 10 year and 50 year rainfall event with both calm and ENE wind conditions have been calculated and mapped for two potential construction scenarios (a five year and a 10 year programme).

TSS will reduce to concentrations significantly below effects thresholds within approximately three days in all scenarios modelled within both the Mahurangi Harbour and the Pūhoi Estuary. Therefore, we conclude that the effect of suspended sediments on benthic invertebrates (including farmed oysters), saltmarsh, seagrass and marine/estuarine habitat values is negligible.

Deposition of sediment in both the Mahurangi Harbour and the Pūhoi Estuary in a 10 year average return interval (ARI) rainfall event, under both the short- and long-term construction scenarios, results in a relatively small increase in area of harbour predicted to receive sediment (three days following the rainfall event) at the biological thresholds considered (the 5-10mm threshold is used as an indicator of potential adverse effects on sensitive taxa and the >10mm threshold is an indicator of potential effects on benthic communities). . Accordingly, we consider, the 10 year ARI events to have adverse effects of low to very low significance.

In the 50 year ARI rainfall event in Mahurangi Harbour, adverse effects of medium significance may occur on marine ecological values in the short-term construction scenario, compared to effects of low significance in the long-term construction scenario. The Mahurangi Harbour already receives a large volume of sediment during rainfall events. In the short-term construction scenario, the area receiving >5-10mm of sediment increases from an existing baseline of approximately 90ha to 110ha in the 'with Project' scenario; the area receiving >10mm increases from an existing baseline of approximately 40ha, to around 44ha in the 'with Project' scenario. In both cases, sediment is primarily deposited in the upper reaches of the harbour (i.e. upstream of Hamiltons Landing).

We consider effects on oyster farms from the deposition of Project-related sediment to be negligible.

In the 50 year ARI rainfall event in the Pūhoi Estuary, deposition of sediment due to the Project occurring in the short-term construction scenario results in a diffuse pattern of deposition throughout the estuary, which is not confined to the upper reaches as it is in the Mahurangi Harbour. As there are sensitive organisms throughout the middle and lower reaches of the estuary, the potential adverse effects of the diffuse deposition in addition to the existing baseline deposition are considered to be of medium significance. Deposition >5-10mm increases from 30ha (calm) and 40ha (ENE) in the existing baseline to 35ha and 45ha in the 'with Project' scenario respectively. Deposition greater than 10mm also increases from 50ha in the baseline to 55ha in the 'with Project' scenario.

Permanent and temporary habitat loss, in additional to temporary habitat disturbance associated with the construction of piers within the Okahu Inlet are considered to have negligible adverse effects due to the small areas affected and the lower ecological values present in those areas.

4.1 Sediment discharge from open earthworks to the Mahurangi Harbour and Pūhoi Estuary

4.1.1 Background

Treated construction-related water from the Project will be discharged to rivers and streams that ultimately discharge to the Mahurangi Harbour and Pūhoi Estuary. Sediment associated with construction water discharges has the potential to adversely affect benthic intertidal and subtidal marine flora and fauna.

The effect of the discharge of sediment on marine organisms and habitats relates to both suspended sediment and deposited sediment. Effects on organisms are a factor of volume of sediment (concentration of suspended sediment and depth of deposited sediment) and duration of exposure. The significance of these effects also depends on the nature and values of the existing receiving environment.

High loads of suspended sediments can have negative effects on the physiological condition of filter feeding taxa, such as horse mussel (which are sensitive to elevated suspended sediment), and areas of higher sediment deposition will most likely exclude colonisation of, or remove, these species. Marine taxa have differing sensitivities to suspended sediment concentration and duration of exposure. Thus, our approach to the assessment of effects of suspended sediment has first been to gain an understanding from the modelling outputs of the area affected by suspended sediment at biological effects threshold concentrations and duration of exposure. We then determined whether the areas affected are likely to contain organisms that are sensitive to suspended sediment.

Research undertaken by Hewitt et al. (2001), Ellis et al. (2002) and Nicholls et al. (2003) on the tolerance of marine invertebrates to TSS has primarily been laboratory-based due to the difficulties in manipulating the concentration of TSS in the field. Laboratory trials have shown measureable adverse effects on marine organisms at a range of TSS concentrations and a range of extended periods. Of the organisms upon which research has been carried out, those that are known to be present within the Mahurangi Harbour and Pūhoi Estuary are listed in Table 16 below. Research indicates that sensitive organisms (e.g. horse mussel, pipi and a tubeworm) suffer sublethal effects after three or more days exposure to TSS concentrations around 75-80 mg/kg (Table 16).

Table 16: Laboratory trial results of the effect of TSS on marine invertebrates that are present in Mahurangi Harbour and Pūhoi Estuary

Species	Effect detected	TSS concentration and duration of exposure at which effects were measured	Reference	Mahurangi Harbour	Pūhoi Estuary
Pipi - (*Paphies australis*)	Reduced condition	75 g/m³ (exposure >13 days)	Hewitt et al., 2001	Uncommon	Uncommon
Horse mussel - (*Atrina zealandica*)	Reduced condition	80 g/m³ (exposure >3 days)	Ellis et al., 2002	Uncommon	Uncommon
Tubeworm - (*Boccardia sp.*)	Reduced feeding rate	80 g/m³ (exposure >9 days)	Nicholls et al., 2003	Common	Uncommon
Wedge shell - (*Macomona liliana*)	Reduced survival	300 g/m³ (exposure >9 days)	Nicholls et al., 2003	Common	Common
Cockle - (*Austrovenus stutchburyi*)	Reduced condition	400 g/m³ (exposure >7 days)	Hewitt et al., 2001	Common	Common

The current published scientific research indicates that the deposition of fine grain sediment derived from the land at a depth of greater than 5 mm on top of muddy benthic sediment has adverse effects on small, less mobile marine invertebrates (Nicholls et al., 2009). Thicker deposits of fine grain sediment affect an increasing number of species, with most bivalves and gastropods affected at 5-10mm deposition. Layers greater than 30 mm significantly affect most organisms that inhabit muddy sediment which in turn affects food supply for fish and birds that utilise the marine habitat. Adverse effects are also experienced at shallower depths of fine sediment deposition when the receiving environment sediment is coarse grained. For instance, mud deposited on coarser grained sediment such as sand has effects at shallower depths of deposition compared to mud deposited on mud (Lohrer et al., 2006).

With respect to the duration of sediment deposition remaining in place, the literature suggests that most marine invertebrates can tolerate the deposition of sediment for up to three days by isolating themselves from environmental stressors (e.g. bivalves close their valves, other invertebrate cease feeding and may burrow) (Nicholls et al., 2009). Many organisms are able to slow their metabolism and temporarily reduce their reliance on oxygen by changing their metabolic pathway from aerobic to anaerobic during this time. If the sediment deposition persists for longer than three days, sublethal and lethal effects begin to occur in the most sensitive taxa. Less sensitive organisms may tolerate sediment deposition for a longer period before adverse effects begin to occur (Lohrer et al., 2006). Our assessment has therefore evaluated the depth of sediment deposition at three days following the peak of the rainfall events modelled, in order to capture effects on the most sensitive species from a sedimentation event.

The movement of large bivalves (wedge shell and cockles), crabs and burrowing shrimp helps to break up the deposited sediment and assist with sediment removal (Nicholls et al., 2009).

Many marine invertebrates are considered to be susceptible to the discharge of sediment, as most taxa have limited mobility, whereas fish can move to areas that are less affected. The marine invertebrate communities present in the Mahurangi Harbour and Pūhoi Estuary include both sensitive and tolerant taxa. However, the upper reaches of both bodies of water are characterised by tolerant, opportunistic organisms that prefer high proportions of silt and clay in benthic sediment, whereas the middle and lower reaches are characterised by a more diverse community containing sensitive organisms that are intolerant of high proportions of silt and clay.

In the Mahurangi Harbour and Pūhoi Estuary, sediments tend to be coarser in the middle to lower reaches of the waterways, with fine sediment dominating in the upper estuary and upper harbour areas. Therefore, we anticipate that adverse effects may be experienced by marine organisms inhabiting middle to lower sections of the two waterways at shallower depths of sediment deposition compared to organisms inhabiting the upper harbour habitats characterised by a higher proportion of silt and clay. In our assessment, however, we have considered those areas of harbour/estuary that receive sediment during various rainfall events that pushes the total deposition in an event to 5-10mm and to greater than 10mm. We consider that individual sensitive marine organisms may be adversely affected at 5-10mm deposition (both intertidally and subtidally), and a large number of species may be adversely affected at greater than 10mm deposition (i.e. community level effects may occur). It may be that the organisms inhabiting the muddy upper estuary and upper harbour areas are able to tolerate greater depths of deposition. However, in order to be conservative, we have used the same effects thresholds across the entire benthic habitat of both the Mahurangi Harbour and Pūhoi Estuary.

Seagrass is known to occur intertidally in middle to lower reaches of the Mahurangi Harbour, but has not been detected in the Pūhoi Estuary. While there is little information available regarding the tolerance of seagrass to increased sedimentation and suspended sediment directly, reduced light and smothering is known to result in the degradation of seagrass beds. Turner & Swart (2006) note that increased suspended sediment reduces photosynthesis and growth in seagrass. Therefore, there is the potential for adverse effects on seagrass patches if they were located in the upper Mahurangi Harbour areas (i.e. north of Hamiltons Landing) from sedimentation and turbidity.

Saltmarsh and mangroves naturally trap sediment as they attenuate hydrodynamic energy. Increased sediment elevation can stimulate plant growth because the inundation duration is shortened and the newly deposited sediment may contain nutrients. However, germling stages can be smothered by sediment deposition. During large rainfall events, storm surge can cause erosion of saltmarsh, with resilience depending on the relationship between vegetation composition and sediment dynamics (Bouma et al., 2007). Whilst it is not clear from the existing scientific literature what depth of sediment deposition can be tolerated by saltmarsh communities in New Zealand, saltmarsh in many harbours and estuaries survive despite high sediment loads.

4.1.2 Aquaculture

Increases in sediment runoff into an estuary can impact the viability of oyster farms (Swales et al. 1997).

Oysters filter suspended particulate matter (algae and sediment) from the water column through filter feeding. Sediment and other inorganic particles are rejected through the production of pseudofaeces. The farmed Pacific oyster naturally occurs in turbid waters and farms are located throughout northern New Zealand in estuaries characterised by elevated TSS and sediment deposition during rainfall events. Locating oyster racks above the sea floor reduces sediment deposition on farmed oysters.

Increases in sediment can affect oysters through fouling their filter-feeding apparatus, which then requires a shift in their energy investment away for important physiological activities, such as growth, towards removing the material (i.e. depuration). The potential impact of the Project on oysters from sedimentation will depend on the timing, duration and intensity of the disturbance event, but could lead to a reduction in condition and health (Gonda-King et al., 2010).

4.1.3 Harbour model results

(a) Mahurangi Harbour

Modelling of peak TSS patterns during a 10 year ARI and 50 year ARI rainfall event under baseline conditions (i.e. without the Project) show that there are high concentrations of suspended sediment (i.e. up to approximately 500 g/m^3) in the upper reaches of the harbour following the low tide channels (Figure 9, Coastal Processes Modelling Report). Higher concentrations of TSS occur when the rainfall events are modelled with ENE wind due to wave-induced re-suspension of sediment (Figure 10, Coastal Processes Modelling Report).

Modelling of the short-term (5 year) construction period showed that TSS is markedly reduced at just one day post the peak of a 50 year ARI event with ENE wind, and there are only very small areas in the upper reaches of the harbour of low concentration TSS (i.e. <100 g/m^3) (below that likely to cause adverse effects) at three days post the peak of the rainfall event (Figure 11, Coastal Processes Modelling Report). We have observed that the baseline water clarity in the upper reaches of the Mahurangi Harbour is low and only organisms that can tolerate low light penetration and elevated sediment concentrations inhabit these upper harbour areas (e.g. seagrass is highly unlikely to survive upstream of Hamiltons Landing).

The TSS generated by the 10 year ARI events modelled was significantly less than the 50 year ARI and at three days post the peak of the rainfall event TSS was negligible.

Due to the low TSS concentration, short duration of exposure primarily in the upper harbour habitat (i.e. upstream of Hamiltons Landing), and organisms in the upper harbour area being tolerant of sediment and low light penetration, the risk to ecological values from the 50 year ARI rainfall event is low. Based on the model of the worst storm event (i.e. 50 year ARI with ENE wind during 5 year construction period), we consider the potential adverse effects on marine organisms, including sensitive taxa of invertebrates and seagrass, arising from TSS from the discharge of sediment from open Project earthworks in rainfall events 50 year ARI and smaller to be negligible (Table 17).

We consider the increase in TSS concentration above baseline in the Mahurangi Harbour resulting from the Project in a 50 year ARI rainfall event with ENE wind would have negligible adverse effects on farmed oysters due to the relatively small increase in TSS and the short duration of elevated TSS.

(b) Pūhoi Estuary

Modelling of baseline TSS in the Pūhoi Estuary during a 10 year ARI and 50 year ARI rainfall event, with calm and ENE wind, indicated that high concentrations of sediment occur throughout the estuary (Figure 17, Coastal Processes Modelling Report). Wind made little difference to the concentration and distribution of TSS within the estuary. Assessment of the worst storm event (50 year ARI with calm wind during a short construction period) revealed that TSS rapidly dissipates, with the concentration below 50 g/m^3 at three days post the peak of the rainfall event (Coastal Processes Modelling Report). TSS is elevated throughout the estuary and a wide range of taxa (including more sensitive species such as pipi) may be exposed.

However, based on the existing effects threshold data, the modelling indicates that the exposure period and concentration is unlikely to cause adverse effects on marine organisms. Therefore, due to the concentration at three days post the peak of the rainfall being below effects thresholds for those taxa that data exists for, we consider TSS due to the Project will have negligible adverse effects on marine ecological values in the Pūhoi Estuary (Table 17).

(c) Exposed nearshore coastal habitat

Suspended sediments that are flushed from the Pūhoi Estuary and Mahurangi Harbour to the open coast during the 10 or 50 year event are considered by Mead et al. (2011) to be unlikely to settle and accumulate in the exposed nearshore habitats for extended periods due to re-suspension and distribution into deeper waters. The discharge of Project-related sediment to near-shore habitats outside of the Pūhoi Estuary and Mahurangi Harbour during 10 and 50 year rainfall events during construction is likely to have negligible adverse effects on marine ecological values as sediment will be re-distributed, and diluted over a large area. These exposed coastal areas are characterised as high energy environments that will disperse sediment.

Table 17: Significance of effect of TSS during a 50 year ARI rainfall event during short construction period

Marine Habitat	Ecological Value	Assessment of Impact Magnitude	Assessment of Impact Significance
Mahurangi Harbour			
Middle and Lower	High	Negligible	Very Low
Upper	Medium	Negligible	Very Low
Pūhoi Estuary			
Middle and Lower	Medium	Negligible	Very Low
Upper	Low	Negligible	Very Low

We conclude that in all scenarios modelled within both the Mahurangi Harbour and the Pūhoi Estuary, the effect of suspended sediments on benthic invertebrates (including farmed oysters), estuarine vegetation and marine/estuarine habitat values is negligible.

(d) Deposited Sediment – Potential Adverse Effects

The modification of estuarine habitats from sedimentation above effects threshold levels can reduce ecological heterogeneity. Benthic sandflat and mudflat taxa have differing sensitivities to the deposition of terrigenous sediment. Different life stages of single taxa can also have differing sensitivity to deposited sediment. Thus, deposition of terrigenous sediment can result in a shift towards tolerant organisms dominating the invertebrate community composition. For example, oligochaete worms, mud crab (*Helice crassa*) and the amphipod *Paracorophium excavatum* are known to prefer mud habitats comprising 95-100% mud grain sizes, whereas cockles, and the gastropods *Cominella glandiformis* and *Diloma subrostrata* prefer 5-10% mud (Appendix E; Gibbs & Hewitt, 2004).

The tolerance of taxa detected in the Mahurangi Harbour and Pūhoi Estuary (where data exists) referred to in Appendix D summarises the findings of numerous scientific papers on the relationships between organisms and mud. Therefore, the large body of scientific literature on this topic is not discussed in detail separately in this report.

In general, deposited fine sediment, both in the intertidal and shallow subtidal habitats, is likely to persist in the short-term, but will be eroded over time and broken up by the movement of water and wind, and bioturbation activity of benthic organisms.

Spatial and temporal changes in benthic invertebrate distribution are often associated with disturbance events, such as elevated TSS and high sedimentation loads from floods and heavy rain storms into adjoining estuaries. Such events have the potential to smother or remove benthic fauna from these areas. However, faunal recolonisation and recovery may occur after the disturbance event. Thrush et al. (1996) studied the recovery of a benthic invertebrate community in a sandflat habitat over a 9 month period by experimentally removing the fauna. They found that initially there was a slow recovery rate. The species that showed signs of fast recovery included a capitellid polychaete and phoxocephalid amphipod. Areas of larger scale disturbances took longer to recover than smaller scale disturbances. After the field period (9 months) disturbed plots still had significantly lower numbers of taxa compared to undisturbed plots (Thrush et al. 1996). The Thrush study has shown that recolonisation of disturbed areas is scale-dependent and depends largely on the extent, duration and frequency of the disturbance events.

Therefore, over time, benthic invertebrates will recolonise areas of deposited sediment through natural processes of succession i.e. opportunistic, short-lived, tolerant species will colonise areas initially, followed by larger more sensitive organisms in the longer term. Deposited fine sediment (from the Project and other more significant sources) will, in the medium and long-term, be redistributed within the Mahurangi Harbour and Pūhoi Estuary, with a proportion of sediment discharged out to the open coast.

Our approach to the assessment of effects of sedimentation has been to first gain an understanding from the modelling outputs of the area affected by sediment deposition at biological effects threshold depths (5-10mm and >10mm) and duration of exposure, and then determine from the maps produced (Appendix A and C, Coastal Processes Modelling Report) whether the areas predicted to receive sediment are sensitive to deposition. In our assessment, we have used conservative sediment depth thresholds as our triggers. The 5-10mm threshold is used as an indicator of potential adverse effects on sensitive taxa and the >10mm threshold is an indicator of potential effects on benthic communities. We have assessed the effects of sediment deposition at three days, because based on the existing literature that is when adverse effects on organisms can begin to occur (primarily sub-lethal effects on sensitive benthic organisms).

Mahurangi Harbour

Under baseline conditions (i.e. without the Project), the Mahurangi Harbour receives a large volume of sediment during rainfall events (Tables 8 and 9, Coastal Processes Modelling Report). The hydrodynamic modelling of various storm events indicates that in the short–term (5 year) construction scenario there is likely to be approximately a 1.1% and 6.0% increase in the area of benthic habitat receiving sediment deposition above threshold concentrations three days after the peak of a 10 year ARI and 50 year ARI rainfall event respectively. Deposition occurs predominantly within the upper harbour areas, with deepest deposition in intertidal habitats, particularly on the mangrove fringes (Figure 12, Coastal Processes Modelling Report, attached in Appendix E). An ENE wind results in larger areas of deep deposits (10-50mm and >50mm) in the upper reaches of the harbour and less deep deposits in western intertidal habitats (Figure 13, Coastal Processes Modelling Report, attached in Appendix E).

Pūhoi Estuary

Baseline sediment deposits throughout the Pūhoi Estuary following 10 year ARI and 50 year ARI rainfall events. The areas of greatest deposition are downstream intertidal areas and adjacent to the mouth of the estuary (Figure 19, Coastal Processes Modelling Report, attached in Appendix E). The prevailing ENE wind does not alter the pattern of deposition greatly (Figure 20, Coastal Processes Modelling Report, attached in Appendix E).

(e) Summary of Modelled Sediment Deposition Thresholds

Table 18 and Table 19 summarise the range of modelled scenarios of sediment deposition during 10 and 50 year rainfall events and at the time of peak earthworks.

Mahurangi Harbour

Table 18: Net areas subject to exceedences of the 5mm and 10mm thresholds 3 days following the rainfall/sediment event in Mahurangi Harbour

Rainfall Event /Wind Environment	Net Area Sediment Deposition (ha)	Further North Map Reference[27]	Description of Potential Sediment Deposition
Short Construction Period Mahurangi 10 year ARI			
	5-10 mm		
Calm	3.1	Appendix A DEPO-10	Under existing baseline 19.7ha is affected, 19ha of which is intertidal. With Project, an additional 2.8ha of intertidal and 0.3ha of subtidal habitat is affected i.e. 0.1% of the benthic habitat of the harbour. Additional sediment deposits in upper harbour areas on the landward edges of the mangrove intertidal habitat.
ENE	5.0	Appendix A DEPO-12	Under existing baseline 20.9ha is affected, 19ha of which is intertidal. With Project, an additional 4.5ha of intertidal and 0.5ha of subtidal habitat is affected i.e. 0.2% of the benthic habitat of the harbour. Additional sediment deposits in the upper harbour area on landward edge of the mangrove intertidal habitat.
	>10 mm		
Calm	0.8	Appendix A DEPO-10	Under existing baseline 4.6ha is affected, 4.5ha of which is intertidal. With Project, an additional 0.7ha of intertidal and 0.1ha of subtidal habitat is affected. Additional sediment deposits in the upper harbour area on landward edge of the mangrove intertidal habitat.
ENE	1.1	Appendix A DEPO-12	Under existing baseline 5.4ha is affected, 5.2ha of which is intertidal. With Project, an additional 1.0ha of intertidal and 0.1ha of subtidal habitat is affected. Additional sediment deposits in the upper harbour area on landward edge of the mangrove intertidal habitat.
Short Construction Period Mahurangi 50 year ARI			
	5-10 mm		
Calm	20.5	Appendix A DEPO-14	Under existing baseline 90.5ha is affected, 80.2ha of which is intertidal. With Project, an additional 16.9ha of intertidal and 3.6ha of subtidal habitat is affected i.e. 0.8% of the benthic habitat of the harbour. Additional sediment deposits in the upper harbour on the landward edge of the intertidal habitat and adjacent to the low tide channel (to as approximately Hamiltons Landing) where existing deposition is high within mangrove habitat.

[27] The full suite of sediment deposition plans are contained with the Coastal Processes Modelling Report.

Rainfall Event /Wind Environment	Net Area Sediment Deposition (ha)	Further North Map Reference[27]	Description of Potential Sediment Deposition
ENE	22.6	Appendix A DEPO-16	Under existing baseline 90.7ha is affected, 75.8ha of which is intertidal. With Project, an additional 17.6ha of intertidal and 5.0ha of subtidal habitat is affected i.e. 0.9% of the benthic habitat of the harbour. Additional sediment deposits in the upper harbour on the landward edge of the intertidal habitat and adjacent to the low tide channel (north of Hamiltons Landing) where existing deposition is high within mangrove habitat.
	>10 mm		
Calm	3.6	Appendix A DEPO-14	Under existing baseline 40.2ha is affected, 38.4ha of which is intertidal. With Project, an additional 4.9ha of intertidal and 0.3ha of subtidal habitat is affected i.e. 0.2% of the benthic habitat of the harbour. Additional sediment deposits in the upper harbour on the landward edge of the intertidal habitat and adjacent to the low tide channel (to as approximately Hamiltons Landing) where existing deposition is high within mangrove habitat.
ENE	5.0	Appendix A DEPO-16	Under existing baseline 37.5ha is affected, 33ha of which is intertidal. With Project, an additional 5.0ha of intertidal and 0.7ha of subtidal habitat is affected i.e. 0.2% of the benthic habitat of the harbour. Additional sediment deposits in the upper harbour on the landward edge of the intertidal habitat and adjacent to the low tide channel (north of Hamiltons Landing) where existing deposition is high within mangrove habitat.
Long Construction Period Mahurangi 10 year ARI			
	5-10 mm		
Calm	1.0	Appendix A DEPO-18	Under existing baseline 19.7ha is affected, 18.9ha of which is intertidal. With Project, an additional 0.9ha of intertidal and 0.1ha of subtidal habitat is affected. Additional sediment deposits on the landward edge of the narrow upper harbour intertidal area, north of Vialls Landing.
ENE	1.8	Appendix A DEPO-20	Under existing baseline 20.9ha is affected, 19.0ha of which is intertidal. With Project, an additional 1.6ha of intertidal and 0.2ha of subtidal habitat is affected. Additional sediment deposits on the landward edge of the narrow upper harbour intertidal area (more on the eastern side), north of Vialls Landing.
	>10 mm		
Calm	0.3	Appendix A DEPO-18	Under existing baseline 4.6ha is affected, 4.5ha of which is intertidal. With Project, an additional 0.3ha of intertidal habitat is affected. Additional sediment deposits on the landward edge of the narrow upper harbour intertidal area, north of Vialls Landing.
ENE	0.3	Appendix A DEPO-20	Under existing baseline 5.4ha is affected, 5.2ha of which is intertidal. With Project, an additional 0.3ha of intertidal habitat is affected. Additional sediment deposits on the landward edge of the narrow upper harbour intertidal area, north of Vialls Landing.

Rainfall Event /Wind Environment	Net Area Sediment Deposition (ha)	Further North Map Reference[27]	Description of Potential Sediment Deposition
Long Construction Period Mahurangi 50 year ARI			
	5-10 mm		
Calm	7.4	Appendix A DEPO-22	Under existing baseline 90.5ha is affected, 80.2ha of which is intertidal. With Project, an additional 6.5ha of intertidal and 0.9ha of subtidal habitat is affected i.e. 0.3% of the benthic habitat of the harbour. Additional sediment deposits on the landward edge of the narrow upper harbour intertidal area, north of Vialls Landing.
ENE	9.7	Appendix A DEPO-24	Under existing baseline 90.7ha is affected, 75.8ha of which is intertidal. With Project, an additional 8.7ha of intertidal and 1.0ha of subtidal habitat is affected i.e. 0.4% of the benthic habitat of the harbour. Additional sediment deposits on the landward edge of the narrow upper harbour intertidal area, north of Vialls Landing.
	>10 mm		
Calm	1.7	Appendix A DEPO-22	Under existing baseline 40.2ha is affected, 38.4ha of which is intertidal. With Project, an additional 1.6ha of intertidal and 0.1ha of subtidal habitat is affected. Additional sediment deposits on the landward edge of the narrow upper harbour intertidal area, north of Vialls Landing.
ENE	2.3	Appendix A DEPO-24	Under existing baseline 37.5ha is affected, 33ha of which is intertidal. With Project, an additional 1.7ha of intertidal and 0.6ha of subtidal habitat is affected. Additional sediment deposits on the landward edge of the narrow upper harbour intertidal area, north of Vialls Landing.

Pūhoi Estuary

Table 19: Net areas subject to exceedences of the 5mm and 10mm thresholds 3 days following the rainfall/sediment event in Pūhoi Estuary

Rainfall Event /Wind Environment	Net Area Sediment Deposition (ha)	Further North Map Reference[28]	Description of Potential Sediment Deposition
Short Construction Period Pūhoi 10 year ARI			
	5-10 mm		
Calm	3.1	Appendix C DEPO-10	Under existing baseline 26.9ha is affected, 22.2ha of which is intertidal. With Project, an additional 3.6ha of intertidal and 0.6ha of subtidal habitat is affected i.e. 2.4 % of the benthic habitat of the estuary. Diffuse areas of deposition adjacent to low tide channel in upper parts of the estuary and on the sheltered bends where baseline deposition high in the middle to lower reaches.
ENE	5.0	Appendix C DEPO-12	Under existing baseline 28.2ha is affected, 21.9ha of which is intertidal. With Project, an additional 3.1ha of intertidal and 0.4ha of subtidal habitat is affected i.e. 2.0% of the benthic habitat of the estuary. Diffuse areas of deposition adjacent to low tide channel and on landward edge of intertidal habitat in upper parts of the estuary and on the sheltered bends where baseline deposition high in the middle to lower reaches.
	>10 mm		
Calm	0.8	Appendix C DEPO-10	Under existing baseline 10.3ha is affected, 9.0ha of which is intertidal. With Project, an additional 1.5ha of intertidal and 0.4ha of subtidal habitat is affected i.e. 1.1% of the benthic habitat of the estuary. Diffuse areas of deposition adjacent to low tide channel in upper parts of the estuary and on the sheltered bends where baseline deposition high in the middle to lower reaches.
ENE	1.1	Appendix C DEPO-12	Under existing baseline 13.0ha is affected, 10.7ha of which is intertidal. With Project, an additional 1.7ha of intertidal and 0.6ha of subtidal habitat is affected i.e. 1.3% of the benthic habitat of the estuary. Diffuse areas of deposition adjacent to low tide channel in upper parts of the estuary and on the sheltered bends where baseline deposition high in the middle to lower reaches.
Short Construction Period Pūhoi 50 year ARI			
	5-10 mm		
Calm	4.5	Appendix C DEPO-14	Under existing baseline 30.9ha is affected, 28.3ha of which is intertidal. With Project, an additional 4.2ha of intertidal and 0.3ha of subtidal habitat is affected i.e. 2.6% of the benthic habitat of the estuary. Deposition largely in upper estuary on sheltered bends and in the lower reaches within and areas of high baseline deposition.

28 The full suite of sediment deposition plans are contained with the Coastal Processes Modelling Report.

Rainfall Event /Wind Environment	Net Area Sediment Deposition (ha)	Further North Map Reference[28]	Description of Potential Sediment Deposition
ENE	5.2	Appendix C DEPO-16	Under existing baseline 39.3ha is affected, 36.0ha of which is intertidal. With Project, an additional 4.4ha of intertidal and 0.8ha of subtidal habitat is affected i.e. 3.0% of the benthic habitat of the harbour. Deposition largely in upper estuary on sheltered bends and in the lower reaches within and areas of high baseline deposition.
	>10 mm		
Calm	3.7	Appendix C DEPO-14	Under existing baseline 49.3ha is affected, 40.5ha of which is intertidal. With Project, an additional 3.4ha of intertidal and 0.3ha of subtidal habitat is affected i.e. 2.1% of the benthic habitat of the estuary. Deposition largely in upper estuary on sheltered bends and in the lower reaches within and areas of high baseline deposition.
ENE	5.2	Appendix C DEPO-16	Under existing baseline 46.6ha is affected, 36.7ha of which is intertidal. With Project, an additional 4.4ha of intertidal and 0.8ha of subtidal habitat is affected i.e. 3.0% of the benthic habitat of the harbour. Deposition largely in upper estuary on sheltered bends and in the lower reaches within and areas of high baseline deposition.
Long Construction Period Pūhoi 10 year ARI			
	5-10 mm		
Calm	1.9	Appendix C DEPO-18	Under existing baseline 26.9ha is affected, 22.2ha of which is intertidal. With Project, an additional 1.7ha of intertidal and 0.2ha of subtidal habitat is affected. Very small diffuse areas of deposition on landward edges of the intertidal habitat.
ENE	1.4	Appendix C DEPO-20	Under existing baseline 28.2ha is affected, 21.9ha of which is intertidal. With Project, an additional 1.3ha of intertidal and 0.2ha of subtidal habitat is affected. Very small diffuse areas of deposition on landward edges of the intertidal habitat.
	>10 mm		
Calm	0.7	Appendix C DEPO-18	Under existing baseline 10.3ha is affected, 9.0ha of which is intertidal. With Project, an additional 0.6ha of intertidal and 0.1ha of subtidal habitat is affected. Very small diffuse areas of deposition on landward edges of the intertidal habitat.
ENE	1.0	Appendix C DEPO-20	Under existing baseline 13.0ha is affected, 10.7ha of which is intertidal. With Project, an additional 0.8ha of intertidal and 0.3ha of subtidal habitat is affected. Very small diffuse areas of deposition on landward edges of the intertidal habitat.

Rainfall Event /Wind Environment	Net Area Sediment Deposition (ha)	Further North Map Reference[29]	Description of Potential Sediment Deposition
Long Construction Period Mahurangi 50 year ARI			
	5-10 mm		
Calm	2.2	Appendix C DEPO-22	Under existing baseline 30.9ha is affected, 28.3ha of which is intertidal. With Project, an additional 2.0ha of intertidal and 0.2ha of subtidal habitat is affected i.e. 1.3% of the benthic habitat of the estuary. Additional sediment deposits within areas of high baseline deposition.
ENE	2.7	Appendix C DEPO-24	Under existing baseline 39.3ha is affected, 36.0ha of which is intertidal. With Project, an additional 2.6ha of intertidal and 0.1ha of subtidal habitat is affected i.e. 1.6% of the benthic habitat of the harbour. Additional sediment deposits within areas of high baseline deposition.
	>10 mm		
Calm	2.0	Appendix C DEPO-22	Under existing baseline 49.3ha is affected, 40.5ha of which is intertidal. With Project, an additional 1.8ha of intertidal and 0.2ha of subtidal habitat is affected i.e. 1.1% of the benthic habitat of the estuary. Additional sediment deposits within areas of high baseline deposition.
ENE	2.6	Appendix C DEPO-24	Under existing baseline 46.6ha is affected, 36.7ha of which is intertidal. With Project, an additional 2.3ha of intertidal and 0.3ha of subtidal habitat is affected i.e. 1.5% of the benthic habitat of the harbour. Additional sediment deposits within areas of high baseline deposition.

[29] The full suite of sediment deposition plans are contained with the Coastal Processes Modelling Report.

(f) Significance of Modelled Deposition

Table 20-Table 27 provide an analysis of the significance of effect, based on the ecological values present and the magnitude of the potential impact of sediment deposition.

10 Year ARI Rainfall Event

Table 20-Table 23 indicate that for the 10 year rainfall events under both the short- and long-term construction scenarios, we consider the resultant increased area of harbour that is predicted to receive sediment (three days following the rainfall event) at the thresholds considered (i.e. 5-10 mm and >10 mm) to have adverse effects of low to very low significance. This conclusion is due to the deposition areas being small, occurring almost entirely in the upper reaches of both waterways where the background deposition of sediment is high, the ambient proportion of silt and clay in benthic sediment being high and the biological community comprising predominantly tolerant and opportunistic organisms.

Table 20: Significance of sediment deposition during construction in a 10 yr event (calm wind conditions) and short construction period

Marine Habitat	Ecological Value[30]	Assessment of Effect Magnitude	Assessment of Effect Significance
Mahurangi Harbour			
Middle and Lower	High	Negligible	Low
Upper	Medium	Moderate	Low
Pūhoi Estuary			
Middle and Lower	Medium	Low	Low
Upper	Low	Low	Very Low

Table 21: Significance of sediment deposition during construction in a 10 yr event (ENE wind conditions) and short construction period

Marine Habitat	Ecological Value	Assessment of Effect Magnitude	Assessment of Effect Significance
Mahurangi Harbour			
Middle and Lower	High	Very Low	Low
Upper	Medium	Moderate	Low

[30] In order to be conservative, the higher ecological value has been used within Mahurangi Harbour i.e. in the middle to lower reaches of the harbour where the values have been assessed as moderate to high, the high value is used.

Marine Habitat	Ecological Value	Assessment of Effect Magnitude	Assessment of Effect Significance
Pūhoi Estuary			
Middle and Lower	Medium	Low	Low
Upper	Low	Low	Very Low

Table 22: Significance of sediment deposition during construction in a 10 yr event (calm wind conditions) and long construction period

Marine Habitat	Ecological Value	Assessment of Effect Magnitude	Assessment of Effect Significance
Mahurangi Harbour			
Middle and Lower	High	Negligible	Low
Upper	Medium	Negligible	Very Low
Pūhoi Estuary			
Middle and Lower	Medium	Negligible	Very Low
Upper	Low	Negligible	Very Low

Table 23: Significance of sediment deposition during construction in a 10 yr event (ENE wind conditions) and long construction period

Marine Habitat	Ecological Value	Assessment of Effect Magnitude	Assessment of Effect Significance
Mahurangi Harbour			
Middle and Lower	High	Negligible	Low
Upper	Medium	Negligible	Very Low
Pūhoi Estuary			
Middle and Lower	Medium	Negligible	Very Low
Upper	Low	Negligible	Very Low

50 Year ARI Rainfall Event

In the 50 year rainfall event in Mahurangi Harbour, adverse effects on marine ecological values of medium significance may occur in the short-term construction scenario, and of low to very low significance in the long-term construction scenario (Table 24 -Table 27). In the short-term construction scenario, the area receiving >5-10mm increases from an existing baseline of approximately 90ha to 110ha, and the area receiving >10mm increases from an existing baseline of approximately 40ha to around 44ha (Table 24 and Table 25). Sediment is primarily deposited in the upper reaches of the harbour. Sediment deposition >5-10mm deep has the potential to adversely affect sensitive benthic invertebrates, which are largely present in the middle to lower reaches of the harbour i.e. outside the primary area of sediment deposition. Sediment deposition >10mm can affect benthic community composition (including sensitive and tolerant organisms) and under the 50 year short construction scenario, the area affected increases by approximately 10%.

Smothering of benthic invertebrates by deep sediment causes mortality and sublethal effects, which over a large area, has the potential to adversely affect the foraging habitat of birds and fish. The 50 year short construction event in the Mahurangi Harbour coinciding with peak earthworks has the potential to smother an additional 24ha of benthic habitat, which is less than 1% of the entire harbour. Whilst the potential loss of benthic invertebrate assemblages over 24ha is in itself an adverse effect of moderate significance, given the large area of remaining foraging habitat, we consider that effects on birds and fish specifically would be negligible.

Deposition of sediment in the Pūhoi Estuary due to the Project arising from the 50 year rainfall event occurring in the short-term construction scenario results in a diffuse pattern of deposition throughout the estuary, not confined to the upper reaches as in the Mahurangi Harbour. Deposition >5-10mm increases from 30ha (calm) and 40ha (ENE) in the existing baseline to 35 and 45ha respectively. Deposition greater than 10mm also increases in area by 5ha from 50ha in the baseline to 55ha in the 'with Project' scenario. As there are sensitive organisms throughout the middle and lower reaches of the estuary, we consider the potential adverse effects of the diffuse deposition in addition to the existing baseline deposition on benthic invertebrate assemblages to be of medium significance (Table 24 and Table 25).

The additional 10ha of benthic habitat that may be adversely affected if a 50 year ARI rainfall event coincides with peak open earthworks comprises 5.8% of the Pūhoi Estuary, whereas the baseline sediment deposited (i.e. without the Project) comprises 52% of the estuary. We consider that the additional 5.8% of potential habitat is insignificant in terms of loss of foraging habitat for birds and fish given the high baseline deposition. In addition, there is abundant available foraging habitat in adjacent estuaries and harbours that could be used instead. We conclude that the Project's potential adverse effects specifically on the foraging habitat of birds and fish due to sediment deposition from a 50 year ARI event in the Pūhoi Estuary are negligible.

The modelling indicates that additional deposition arising from Project earthworks does not deposit within or near to the existing oyster farms. However, farms located in the upper harbour are affected by baseline sediment deposition in a 50 year rainfall event, and to a much lesser extent, in a 10 year event with calm wind (Figures 13 and 14, Coastal Processes Modelling Report). We consider effects on oyster farms from the deposition of Project related sediment to be negligible.

Table 24: Significance of sediment deposition during construction in a 50 yr event (calm wind conditions) and short construction period

Marine Habitat	Ecological Value	Assessment of Impact Magnitude	Assessment of Impact Significance
Mahurangi Harbour			
Middle and Lower	High	Negligible	Low
Upper	Medium	High	Moderate
Pūhoi Estuary			
Middle and Lower	Medium	Moderate	Moderate
Upper	Low	Low	Very Low

Table 25: Significance of sediment deposition during construction in a 50 yr event (ENE wind conditions) and short construction period

Marine Habitat	Ecological Value	Assessment of Impact Magnitude	Assessment of Impact Significance
Mahurangi Harbour			
Middle and Lower	High	Negligible	Low
Upper	Medium	High	Moderate
Pūhoi Estuary			
Middle and Lower	Medium	Moderate	Moderate
Upper	Low	Low	Very Low

Table 26: Significance of sediment deposition during construction in a 50 yr event (calm wind conditions) and long construction period

Marine Habitat	Ecological Value	Assessment of Impact Magnitude	Assessment of Impact Significance
Mahurangi Harbour			
Middle and Lower	High	Negligible	Very Low
Upper	Medium	Moderate	Low

Pūhoi Estuary			
Middle and Lower	Medium	Low	Low
Upper	Low	Low	Very Low

Table 27: Significance of sediment deposition during construction in a 50 yr event (ENE wind conditions) and long construction period

Marine Habitat	Ecological Value	Assessment of Impact Magnitude	Assessment of Impact Significance
Mahurangi Harbour			
Middle and Lower	High	Negligible	Very Low
Upper	Medium	Moderate	Low
Pūhoi Estuary			
Middle and Lower	Medium	Low	Low
Upper	Low	Low	Very Low

In summary, the following modelled events are assessed as potentially causing significant adverse effects on marine ecological values of a moderate scale:

- 50 year ARI rain event in ENE wind conditions during a short-term (five year) Project construction period; and
- 50 year ARI rain event in calm wind conditions during a short-term (five year) Project construction period.

The 50 year ARI rainfall event has a 10% probability of occurring at least once during the five year construction period (see Table 11, Coastal Processes Modelling Report). Whilst the likelihood of this occurring during the peak earthworks period is considered to be unusual according to the NZTA's Risk Management Process Manual (2004) (Table 11, Coastal Processes Modelling Report), the consequences of the events on small areas of the Mahurangi Harbour and Pūhoi Estuary are considered to have medium ecological significance, causing adverse effects on marine ecological values in the short-term.

(g) The Project's contribution to long-term sedimentation of the harbour and estuary

Project-related sediment arising from open earthworks during a range of rainfall events will discharge to the Mahurangi Harbour and Pūhoi Estuary and contribute (along with other activities) to long-term sedimentation. This contribution to sedimentation of the waterways is a cumulative effect.

The total additional sediment deposition in both the Mahurangi Harbour and the Pūhoi Estuary has been extrapolated using USLE over the five year construction period (see Table 34, Section 7.7.2, Construction Water Management and Assessment Report). Only sediment potentially arising from the five year construction period, not the 10 year construction period, has been calculated for this part of the assessment because the five year construction period is the worst case i.e. has the largest areas of earthworks open. Consideration of sediment deposition from the five year construction period enables a conservative estimate of the cumulative effect.

An additional 7767 tonnes of sediment is likely to deposit within the Mahurangi Harbour due to the Project over the five year construction period, and an additional 6307 tonnes may deposit within the Pūhoi Estuary. This represents a 13% increase in the Mahurangi Harbour and a 7% increase in the Puhoi Estuary (Table 34, Construction Water Management and Assessment Report). Of this, it is estimated that 80% of the sediment discharged to the Mahurangi Harbour will be deposited, whereas 70% will deposit within the Puhoi Estuary. It is estimated that where deposition occurs in the Mahurangi Harbour the depth of deposition due to the Project over the five year construction period will be 5mm (Construction Water Assessment Report). In the Puhoi Estuary the average deposition depth due to the Project is estimated to be 2mm (Construction Water Assessment Report). In addition, residual sediment contained in operational phase stormwater discharges to the waterways will, to a lesser degree, contribute to sedimentation in the long-term (see Section 5 below).

Anthropogenic changes to the Mahurangi and Pūhoi catchments, e.g. the clearing of native forest for pasture, have increased the rate of natural infilling of the Mahurangi Harbour and Pūhoi Estuary. The additional Project-related sediment also accelerates the natural coastal process of infilling over the five year construction period and has a small contribution to reducing the tidal prism within the waterways. The significance of the Project's cumulative effect on sediment, with respect to effects on marine ecological values, is assessed as negligible as the increased rate of sedimentation due to the Project is temporary (i.e. 5 years), and is small compared to the high baseline of natural sedimentation and sedimentation from other human-induced activities within the catchments.

4.2 Permanent habitat loss and temporary habitat disturbance from pier construction

Construction of a viaduct across the Okahu Estuary (which discharges into the Pūhoi Estuary) necessitates the permanent location of piers in the CMA (see Drawing number ES-071 and ES-072).

The current design for the Okahu Viaduct comprises two separate bridges that in combination are 524m long, eight span, concrete box girder viaduct, with up to 14 piers. Each pier will be constructed on a reinforced concrete pad foundation. Beneath each pad foundation will be four reinforced concrete bored piles. Eight piers will be located within the coastal flats of the Okahu Estuary. Construction of pad foundations for four of the piers will be below MHWS. Any viaduct design with a similar number of piers in a similar location would have similar effects to those assessed below.

The potential construction sequence for the Okahu Viaduct is detailed in section 6.1.7 of Construction Water Assessment Report and is summarised with respect to effects on the CMA as follows:

- An access track will be constructed from the Billings Road side of the estuary, at low tide, down the coastal bank and across the Okahu Estuary mudflat in stages as required to construct the next set of piers;
- The access track will comprise a geotextile membrane placed directly onto the mudflat, on top of which a geogrid material will be placed, on top of which certified clean hard fill will be carefully deposited and compacted to form a stable access track on which construction plant and machinery can track across;
- The geotextile membrane will be laid flat on the mudflat over an area of approximately 1,820m^2. Placement of the geogrid material and clean hard fill is expected to cause the track to depress into the mudflat drawing the geotextile membrane edges inwards. Once formed, the access track will cover a reduced area (approximately 910m^2) due to the depression into the mudflat;
- A dirty water diversion (DWD) will be formed to receive construction runoff from the access track. The DWD will discharge stormwater runoff from the works via a decanting earth bund into the estuary;
- Access to the foundation construction areas will require a crossing of the open channel to the north of the Okahu Estuary. Crossing the low tide channel will require the placement of a bailey bridge;
- A sheet pile cofferdam will be constructed around the extent of the excavation works to provide a dry working environment;
- Material will be excavated from within the coffer dam prior to construction of the concrete bored piles. Excavated material will be removed from site and transported to one of the identified spoil sites associated with the Project;
- Water from the excavation will be pumped to either a container impoundment system (CIS) or a decanting earth bund (DEB) which will be located above MHWS to the north of the estuary;
- Once piles are in place, a concrete pad foundation and piers will be constructed with the placement of steel reinforcement and *in-situ* concrete being poured;
- Water from within the coffer dam will be pumped to a container impoundment system or chemically treated decanting earth bund above the MHWS;
- After construction of the viaduct is complete the sheet piles and access tracks will be removed; and
- The depression in the mudflat following removal of the access track will be allowed to infill naturally over time.

4.2.1 Potential effects on marine ecological values

Actual and potential effects on marine ecological values relate to permanent habitat loss, temporary habitat loss, habitat disturbance and the discharge of construction related runoff.

(a) Permanent habitat loss

Permanent habitat loss within the CMA will arise from the area occupied by the six concrete pad foundations that are to be placed within the upper estuary intertidal habitat for the Okahu Viaduct. The area of occupation is anticipated to be approximately 70m^2, which represents approximately 0.0004% of the intertidal habitat within the Pūhoi Estuary. The marine ecological values within the Okahu Estuary are medium but the area involved is negligible in the wider context of the Pūhoi Estuary. We assess the significance of the impact as low (Table 28).

(b) Temporary habitat loss

Temporary habitat loss arising from occupation of the CMA by the access track, bailey bridge, and area disturbed around the permanent occupation area involves an area of approximately 2,000m^2 i.e. 0.13% of the intertidal habitat within the Pūhoi Estuary. The benthic sediment (and associated organisms) beneath the access track will be compacted and smothered. It is anticipated that all biota beneath the access track will die and the sediment will become increasingly anoxic. In order to avoid mortality of many of the large adult mud snails that are abundant on the mudflat within the Okahu Inlet, we recommend that immediately ahead of laying the geotextile membrane the adult mud snails within the access track footprint are collected and placed outside of the construction area. Moving the adult snails will avoid loss of adult reproductive stock and also protect this important cultural harvest species.

Once the access track is removed, biological process will, over a period of several years, restore the area affected. Sediment will move into the area of depression and short-lived, opportunistic and tolerant benthic organisms will initially begin to colonise the area. Through physical coastal processes and biological processes (e.g. bioturbation), oxygen will be reintroduced to the sediment enabling the colonisation of less sensitive species over time. It is anticipated that the benthic invertebrate community composition will be restored within approximately five years. We assess the significance of the impact as low due to the small area involved, the translocation of the mud snails proposed and the expected recovery of the ecological values of the area in the longer term.

(c) Temporary habitat disturbance

The coastal vegetation at the mouth of the Okahu Inlet is characterised as medium ecological value comprising a narrow fringe of saline wetland with oioi and mangroves and exotic pines. Further upstream within the Okahu Inlet there are larger areas of wetland vegetation comprising raupo, giant umbrella sedge and rushes that provide high quality native wading bird habitat (Section 4.1.3, Terrestrial Vegetation Assessment Report). We consider the potential effect on fauna from disturbance and habitat loss arising from the removal of coastal and terrestrial vegetation (over an area of 2,250m^2) in order to construct the access track to be negligible given the small area involved and the presence of higher value habitat upstream available for use by avifauna. However, we recommend that removal of estuarine vegetation is not carried out during peak bird breeding season, which is between October and February.

During construction of the access track, piers and the viaduct itself, there will be ongoing disturbance to the coastal environment e.g. noise, vibration, movement of vehicles and people. The foraging and movement of some marine organisms and wading birds may be affected by these activities e.g. crabs may remain within their burrows at times instead of foraging for food. However, the disturbance activities are temporary and are unlikely to occur constantly throughout a 24 hour period. Therefore, organisms will not be completely inhibited from foraging and moving. We anticipate that the biological condition of organisms is unlikely to be adversely affected. Therefore, whilst some organisms may be temporarily affected at times, the significance of temporary habitat disturbance on marine ecological values is considered to be very low.

(d) Discharge of construction run-off

The Construction Water Assessment Report details the likely erosion and sediment control measures that will be established during construction of the Okahu Viaduct. These measures have been designed to ensure that significant adverse effects on ecological values are avoided and any discharges to the marine environment are treated to a robust and acceptable level (Section 6.1.7 Construction Water Assessment Report). Therefore, we consider the impact of runoff to the marine environment during construction of the Okahu Viaduct to be very low.

(e) Shading

The height of the viaduct above the Okahu Estuary is approximately 27-28m (see Drawing S-021), with the combined width of the two separate bridges being 25.7m. The structure will cast a shadow on the estuary at various times of the day, but given the height proposed, light under the structure will not be limited and adverse effects on the ability of estuarine plants to photosynthesise and thrive are considered to be negligible.

Table 28: Assessment of significance of effect arising from the construction of piers within the Okahu Inlet.

Activity	Ecological Value	Assessment of Impact Magnitude	Assessment of Impact Significance
Permanent habitat loss	Medium	Low	Low
Temporary habitat loss	Medium	Low	Low
Habitat disturbance	Medium	Negligible	Very Low
Discharge of construction related runoff	Medium	Negligible	Very Low
Shading	Medium	Negligible	Very Low

4.2.2 Discharge of contaminants to Mahurangi Harbour and Pūhoi Estuary

There is a risk of discharge of a range of contaminants from the construction sites to streams and ultimately the Mahurangi Harbour and Pūhoi Estuary. The potential contaminants include fuel, lubricants, cement, oil etc. This risk can be avoided through implementation of appropriate construction management systems (Construction Water Assessment Report).

For example, the Construction Water Assessment Report describes the treatment that will be provided for cement contaminated water in order to achieve an appropriate pH prior to discharge to the receiving environment.

We consider the potential adverse effects on marine ecological values from the discharge of contaminants from construction sites can be avoided and we therefore assess them as having negligible impact.

5. Assessment of effects – operational phase

Operational phase stormwater discharges will be to the Pūhoi River and the Mahurangi River. Constructed wetlands will primarily be used to treat operational phase stormwater from the new alignment prior to discharge to aquatic environments. Wetlands will be designed to remove 75% of suspended solids and associated contaminants. It is anticipated that any residual sediment and associated contaminants will largely be distributed within the upper estuary and upper harbour areas due to their low energy depositional characteristics.

The contaminant load model calculations indicate that of the remaining common stormwater contaminants in the treated discharges the greatest percentage increase above the baseline contaminant concentrations is in zinc discharged to the Pūhoi Estuary (i.e. 12%). The baseline load of zinc discharged to the Pūhoi Estuary is low due to the non-urban land-use in the catchment. Therefore, the small increase in load of zinc in the 'with Project' contaminant load model calculations (i.e. less than 5kg per year) is a relatively large percentage increase. An assessment of the proportion of the load of zinc that is likely to be retained within the Pūhoi Estuary and the physical and biological processes that will re-distribute and dilute the contaminant within the estuary leads us to consider that the potential adverse effects of the increased zinc load on the marine ecological values present within the estuary will be low.

There are no significant increases in stormwater contaminants within operational phase discharges to the Mahurangi Harbour, therefore we consider potential adverse effects to be negligible.

Although operational phase stormwater discharges from the Project will contain low contaminant loads, there is the potential for these discharges to add to the long-term accumulation of common stormwater contaminants within marine sediments in both the Mahurangi Harbour and Pūhoi Estuary.

5.1 Discharge of treated operational phase stormwater

Constructed wetlands are the preferred stormwater treatment for the Project and will be designed in accordance with TP10 guidelines. Water quality treatment is proposed for all new impervious areas. Gross litter, floatables and 75% of total suspended solids (on a long-term average annual basis) and associated contaminants will be removed (Section 3.1, Operational Water Assessment Report).

The discharge of treated stormwater will contribute in the long-term to the accumulation of stormwater contaminants in marine sediments. As with any stormwater discharge, there may be cumulative effects in the long-term arising from the residual contaminants contained in the treated discharge accumulating in the marine sediments. The contaminant accumulation rate, in marine sediments, depends on the hydrodynamic environment (i.e. sheltered or high energy) and the ratio of sediment to contaminants discharged (i.e. the dilution of the contaminants within sediment).

5.1.1 Contaminant Load Model

A contaminant load model was used to assess the change in TSS, Zn, Cu and TPH due to the Project based on traffic volumes in 2031. Both baseline and 'with Project' contaminant loads were calculated for the Pūhoi and Mahurangi River catchments.

The low background loads of Zn, Cu and TPH in the Pūhoi River catchment reflect the current lack of urban development. The model predicts minimal change to contaminants except for Zn which is predicted to increase by 12% (approximately 4 kg/yr). The increase in Zn is primarily because the Pūhoi section of motorway is predicted to have the highest number of vehicles per day in 2031 (8, Operational Water Quality Assessment Report).

In the model, there is negligible change in the contaminant loads in the Mahurangi River catchment as a result of the Project, with the largest increase being a 1.3% (approximately 6 kg/yr) increase in zinc (Table 26, Operational Water Quality Assessment Report). Minor improvements in the load of TPH and TSS are predicted as traffic transfers from roads where there is minimal stormwater treatment to the new motorway where stormwater treatment is provided (Section 8.3, Operational Water Quality Assessment Report).

5.1.2 Marine Sediment Quality

Currently, stormwater contaminants in surface sediment are below biological effects thresholds in both the Mahurangi Harbour (apart from copper at upper harbour site IM0 (Vialls Landing) and adjacent to the Jamiesons Bay mooring area) and Pūhoi Estuary (see Sections 3.1.5 and 3.2.3 above). Operational stormwater discharges will have negligible effect on the concentration of copper in either waterway.

Based on the contaminant load modelling and the runoff data of Moores et al. (2009, cited in Operational Water Quality Assessment Report), approximately 2.9 kg/yr of the 4.2 kg/yr of zinc that will be discharged in the operational phase of the Project to the Pūhoi Estuary will be retained within the estuary, with the remainder flushed from the estuary over a period of 4-5 tidal cycles (Coastal Processes Modelling Report). The volume of zinc retained within the estuary will be mixed with deposited sediment and further diluted and redistributed within upper harbour areas over time through physical (wave action and tidal exchange) and biological (bioturbation) processes. Changes in sediment quality within the Pūhoi Estuary due to the retained proportion of the annual zinc load are expected to be minor, given the small load predicted and anticipated dilution and redistribution. All other common stormwater contaminants discharged to the Pūhoi Estuary and Mahurangi Harbour are anticipated to be in low concentrations.

The Motorway Runoff Report states that the predicted zinc load in the Mahurangi River comprises 0.3% of the TSS load. Similarly, the predicted zinc load in the Pūhoi River comprises 0.04% of the TSS load. Both estuaries are predicted to retain similar proportions of incoming sediment loads and have similar flushing times. Neither the Mahurangi nor Pūhoi have elevated concentrations of zinc in sediment in the existing situation. The predicted increases in zinc load and stormwater concentrations in both estuaries will result in only minor changes in zinc concentrations in sediment in those parts of the estuaries where contaminants sourced from road run off are likely to deposit.

The predicted increase in copper in both the stormwater concentrations at the River mouths and the contaminants loads predicted to be discharged to the estuaries, is very small. The predicted increases in copper load in both estuaries will result in only minor changes in copper concentrations in sediment in those parts of the estuaries where contaminants sourced from road run off are likely to deposit.

Accordingly, we expect that any long-term change in sediment quality as a result of the Project will be small to negligible in the estuarine receiving environments and therefore will have negligible effects on marine ecological values (Table 29).

Table 29: Assessment of impact significance of the discharge of treated stormwater

	Ecological Value	Assessment of Impact Magnitude	Assessment of Impact Significance
Upper Mahurangi Harbour	Low	Negligible	Very Low
Upper Pūhoi Estuary	Low	Low	Very Low

6. Avoidance and mitigation

Avoidance and mitigation measures for potential adverse effects during construction include:

- Erosion and sediment control designed to regional guidelines and standards.
- Staging of works and establishment of maximum open earth worked area to reduce risk.
- Risk management plan for storm event monitoring and response.

If a large storm such as the 50 year ARI occurs during the Project's peak earthworks period options for remedial measures or mitigation will be limited and offset mitigation measures may need to be established.

During the operational phase of the Project, the treatment of stormwater to remove 75% TSS and associated contaminants will be sufficient to avoid significant adverse effects on the receiving environment.

Mitigation proposed for each of the identified potential indirect and direct effects of construction of the Project, and the potential effects during the operational phase is shown in Table 30 below. All potential effects identified can be directly mitigated, other than the potential deposition of sediment following large (50 year ARI) storm events. We consider that design of erosion and sediment control device and treatment to regional guidelines and standards is appropriate and sufficient for this Project in order to avoid significant adverse effects on the receiving environment during construction (excluding the unlikely 50 ARI rainfall event). We further consider that treatment of operational phase stormwater to remove 75% TSS and associated contaminants is appropriate and sufficient for this Project in order to avoid significant adverse effects on the receiving environment.

It is very difficult to mitigate the deposition of sediment in marine environments. Thus, the focus throughout this Project has been on avoidance of the discharge of sediment to the harbour. However, if as a result of a large rainfall event (e.g. 50 year event), sediment deposition within the Mahurangi Harbour and/or Pūhoi Estuary occurs at a depth and duration that is likely to cause adverse effects, the options for remedial measures or mitigation are limited. Removal of the deposited sediment is difficult without causing additional and potentially greater adverse effects. Natural coastal physical and biological processes can remediate areas of terrigenous sediment deposition in relatively short times (e.g. within a few years).

Potential adverse effects from the Project relating to the two 50 year ARI storms identified are small compared to the baseline deposition, but if one of these events occurs and significant adverse effects on ecological values are detected, offset mitigation for the short-term loss of ecological values, activity and functioning would be appropriate. We recommend that, if required, potential offset mitigation measures are developed in consultation with the appropriate stakeholders and should reflect existing strategies and plans for improvement of the ecological values of the Mahurangi Harbour and Pūhoi Estuary. It is important that the offset mitigation proposed has direct benefit to the marine environment affected. Offset mitigation could include the treatment of other discharges entering the marine environment, revegetation of coastal margins, weed and pest control or the retirement of steep land from grazing.

Table 30: Proposed mitigation for effects on marine ecological values.

INDIRECT EFFECTS ON ESTUARIES & HARBOURS – CONSTRUCTION SEDIMENTATION			
Description	**Predicted Impact**	**Proposed Mitigation**	**Significance of Residual Impact after mitigation**
10 Year Rainfall Event during construction			
Mahurangi Harbour	• Sediment deposition on intertidal and subtidal benthic habitats in the upper harbour.	• Erosion and sediment control designed to regional guidelines and standards. • Staging of works and establishment of maximum open earth worked area to reduce risk. • Risk management plan for storm event monitoring and response.	**Low**
Pūhoi Estuary	• Sediment deposition on intertidal and subtidal benthic habitats throughout the estuary.		**Low**
50 Year Rainfall Event during construction			
Mahurangi Harbour	• Sediment deposition on intertidal and subtidal benthic habitats in the upper harbour.	• Erosion and sediment control designed to regional guidelines and standards. • Staging of works and establishment of maximum open earth worked area to reduce risk. • Risk management plan for storm event monitoring and response. • Offset mitigation measures may need to be established if a large rainfall event, such as the 50 year ARI, occurs during peak earthworks period and adverse effects on marine ecological values are detected as a result of Project-related sediment.	**Moderate**
Pūhoi Estuary	• Sediment deposition on intertidal and subtidal benthic habitats throughout the estuary.		**Moderate**
Contribution to long-term sedimentation of the harbour			
Mahurangi Harbour	• Reduction in the tidal prism and shallowing of the harbour due to sedimentation.	• Erosion and sediment control designed to regional guidelines and standards. • Staging of works and establishment of maximum open earth worked area to reduce risk. • Risk management plan for storm event monitoring and response.	**Low**
Pūhoi Estuary	• As above		**Low**
DIRECT EFFECTS ON ESTUARIES & HARBOURS – CONSTRUCTION OF PIERS WITHIN THE CMA			
Description	**Predicted Impact**	**Proposed Mitigation**	**Significance of Residual Impact after mitigation**
Pūhoi Estuary	• Permanent and temporary habitat loss. • Temporary habitat disturbance.	• Erosion and sediment control designed to regional guidelines and standards. • Risk management plan for storm event monitoring and response.	**Very Low**

POTENTIAL OPERATIONAL IMPACT – DISCHARGE OF OPERATIONAL PHASE STORMWATER			
Description	**Predicted Impact**	**Proposed Mitigation**	**Significance of Residual Impact after mitigation**
Mahurangi Harbour	• Discharge of residual sediment and associated contaminants in road runoff to the upper harbour which has low existing contaminant concentrations sediment and an invertebrate community largely comprising tolerant organisms in upper harbour.	• Stormwater treatment wetlands and proprietary devices to meet targeted removal rates of 75% TSS and associated contaminants.	**Low**
Pūhoi Estuary	• Discharge of residual sediment and associated contaminants in road runoff to the upper estuary which has low existing contaminant concentrations sediment and an invertebrate community largely comprising tolerant organisms in upper estuary.	• Stormwater treatment wetlands and proprietary devices to meet targeted removal rates of 75% TSS and associated contaminants.	**Low**

7. Recommended monitoring

Monitoring of marine ecological values (and freshwater ecological values) is integrated with, and form an essential part of, the erosion and sediment control Continuous Improvement Monitoring Programme. Both routine monitoring and triggered monitoring is required to confirm the conclusions drawn in this assessment.

We recommend that routine (6 monthly) surveys of benthic invertebrate community composition and sediment quality be carried out pre-, during and post-construction within the Pūhoi Estuary and Mahurangi Harbour.

Additionally, triggered monitoring may be required if rainfall event thresholds are exceeded, if a contaminant spill occurs or if there appears to be degradation of the marine receiving environment.

Monitoring of marine ecological values (and freshwater ecological values) are integrated with, and form an essential part of, the erosion and sediment control Continuous Improvement Monitoring Programme (Section 8, Construction Water Management and Assessment Report).

Monitoring of sediment deposition and marine ecological values both spatially and temporally through routine and triggered event based data collection will be required in order to confirm the conclusions drawn in the assessment of effects. Monitoring will focus on the areas that may receive sediment deposition in the various rainfall events identified, but will also include reference sites.

7.1 Routine monitoring

The routine monitoring experimental design and intertidal and subtidal survey site locations[31] within the Pūhoi Estuary and Mahurangi Harbour will be developed at a later date but will include as a minimum:

- 6-monthly benthic invertebrate and sediment quality surveys to be carried out pre-construction (at least four surveys prior to construction), during construction and post-construction (at least four surveys prior to construction);
- Given the high natural spatial and temporal variability in benthic invertebrate community composition, the experimental design should ensure that the number of replicate infaunal benthic invertebrate samples collected at each survey site has the statistical power to support detection of a 50% change in community composition; and
- Surface sediment quality surveys should include analysis of copper, lead, zinc, TOC and HMW-PAHs in both total sediment and the <63µm fraction, plus grain size analysis of the total sediment sample.

[31] The same survey sites will be used throughout the monitoring programme.

7.2 Triggered monitoring

In addition to routine monitoring, triggered monitoring of marine ecological values may be required if one of the following events occurs during construction:

- Greater than 25mm of rainfall over any a 24 hour period;
- Greater than 15mm of rainfall with an hour period;
- Spillage/accident reports that cause a discharge of sediment or contaminants to the aquatic environment; or
- Obvious degradation of the receiving environment immediately downstream of the sediment retention ponds such as accumulation of sediment, conspicuous oil/grease, scums/foams, floatable matter, fish kills, discolouration of water or significantly increased growth of nuisance algae.

7.2.1 Level one monitoring and management response to trigger events

Within a 48 hour period of any of the above listed trigger events, the erosion and sediment control management will be investigated to determine whether there has been a discharge from the devices. If there has been a discharge the receiving environments will be investigated.

The key determination of this initial response is:

- To determine if any earthworks sediment is deposited within the coastal environment and if so the extent of such deposition.

In the event of a Level One Response the consent holder will:

- Inspect the earthworks site, all erosion and sediment controls and associated management procedures to identify any problems or activities likely to have contributed to increased sediment discharge to the receiving environment; and
- Take manual samples of discharges as necessary; and
- Remedy any identified problems, and implement any further controls on activities that are likely to contribute increased sediment discharge.

7.2.2 Level two marine monitoring and management response

If freshly deposited potentially earthworks derived sediment is detected in the level one monitoring, sediment deposition depth will be measured by cutting a vertical face through the deposit with a rule. If at the time of the first inspection (i.e. within 48hrs), earthworks derived sediment from the Project (determined by duration of discharges from the erosion and sediment control devices) has been deposited to a depth ≥3mm over a continuous area of $1000m^2$ (or greater), or a discontinuous area of $1000m^2$ within an area of $3000m^2$, the triggered sediment depth and extent monitoring above shall be repeated three days after the first triggered inspection.

These triggers have successfully been used in monitoring the effects of earthworks at other sites in the Auckland Region (e.g. Long Bay).

If the average deposition depth exceeds the above criteria at three days after the first inspection, an ecological survey shall be triggered and will be undertaken within a further 48 hours.

8. Conclusions

The marine ecological values within the Pūhoi Estuary are considered to be low in the upper reaches and moderate in the middle and lower reaches, whereas values in the Mahurangi Harbour are moderate to low in the upper reaches and high to moderate in the middle and lower reaches.

Potential effects of the Project on the marine ecological values may occur from the discharge of construction phase sediment, construction of piers within the CMA and the discharge of operational phase stormwater.

The only potentially significant effect to marine ecological values within both the Pūhoi Estuary and the Mahurangi Harbour from the Project is the occurrence of a large rainfall event (e.g. 50 year ARI) during peak open earthworks.

We have assessed smaller rainfall events, permanent and temporary loss of benthic habitat, temporary disturbance of benthic habitat and the discharge of operational phase stormwater as having insignificant adverse effects on marine ecological values.

The contribution of the Project to the long-term sedimentation of the Mahurangi Harbour and Pūhoi Estuary is a cumulative effect, but we assess it as having low significance.

We propose both routine and triggered monitoring of benthic invertebrates and sediment quality.

Offset mitigation that has direct benefit to the marine environment (e.g. planting of coastal margins, retirement of steep land from grazing etc.) may be required if a large rainfall event (50 year ARI) occurs during peak open earthworks, which results in significant adverse effects on marine ecological values from large areas of sediment deposition as predicted by the harbour model.

9. References

Allibone, R., David, B., Hitchmough, R., Jellyman, D., Ling, N., Ravenscroft, P., and Waters, J., 2010. Conservation status of New Zealand freshwater fish, 2009. New Zealand Journal of Marine and Freshwater Research, 44:271-287.

Anderson, M.J., Pawley, M.D.M., Ford, R.B., and Williams C.L., 2007. Temporal variation in benthic estuarine assemblages of the Auckland Region, prepared by UniServices for Auckland Regional Council Technical Publication No.348.

ANZECC, 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australia.

Auckland Council, 2012a. State of Auckland Marine Report Card: Warkworth/Wellsford Coast reporting area. Auckland Regional Council.

Auckland Council, 2012b. State of Auckland Marine Report Card: Mahurangi Harbour reporting area. Auckland Regional Council.

Auckland Council Regional Coastal Plan, 2004. Auckland Council.

Auckland Regional Council (ARC), 2010. Mahurangi Action Plan: A strategic plan for the catchment 2010-2030. Auckland Regional Council.

Auckland Regional Council, 2004. Blueprint for monitoring urban receiving environments. TP 168 revised edition August 2004. Auckland Regional Council.

Auckland Regional Council, 1999. Auckland Regional Policy Statement. Auckland Regional Council.

Battley, P., 2013. Shorebird research in New Zealand and the East-Asian Australasian Flyway, viewed at http://www.nzshorebirds.com/ on 08/03/2013.

Bell, B.D., 1986. The Conservation Status of NZ Wildlife. NZ Wildlife Service Occasional Publication No. 12.

Bioresearches, 2011. Pūhoi to Wellsford Project: Assessment of Terrestrial and Aquatic Ecological Effects: Pūhoi to Warkworth. Prepared for Sinclair Knight Merz Limited and New Zealand Transport Agency.

Bouma, T.J., Van Duren, L.A., Temmerman, S., Claverie, T., Blanco-Garcia, A., Ysebaert, T.J., Herman, P.M.J., 2007. Spatial flow and sedimentation patterns within patches of epibenthic structures. Continental Shelf Research, 27(8): 1020-1045.

Cummings, V.J., 2007. Mahurangi Estuary Ecological Monitoring Programme – report on data collected from July 1994 to January 2007. NIWA Client Report ARC07207, prepared for Auckland Regional Council.

Cummings, V.J., Thrush, S.F., Pridmore, R.D., and Hewitt, J.E., 1994. Mahurangi Harbour Soft Sediment Communities: Predicting and Assessing the Effects of Harbour and Catchment Development, prepared by the National Institute of Water and Atmosphere for Auckland Regional Council. Auckland Regional Council TR2009/040.

Department of Conservation, 1994. Areas of Significant Conservation Value. Department of Conservation, Auckland Conservancy.

Department of Conservation, 2013. Dolphins in New Zealand waters, viewed at

Dowding, J.E., and Moore, S.J., 2006. Habitat networks of indigenous shorebirds in New Zealand, prepared for New Zealand Department of Conservation.

Ellis. J., Cummings, V., Hewitt, J., Thrush, S., and Norkko, A., 2002. Determining effects of suspended sediment on condition of a suspension feeding bivalve (*Atrina zelandica*): results of a survey, a laboratory experiment and a field transplant experiment. Journal of Experimental Marine Biology and Ecology, 267:147– 174.

Forrest, B.M., Elmetri, I., and Clark, K., 2007. Review of the Ecological Effects of Intertidal Oyster Aquaculture. Cawthron Report No. 1275, prepared for Northland Regional Council.

Forrest, B.M., 1991. Oyster farm impacts on the benthic environment: A study in Mahurangi Harbour. Master of Science, University of Auckland.

Francis, M.P., Morrison, M.A., Leathwick, J., and Walsh, C., 2011. Predicting patterns of richness, occurrence and abundance of small fish in New Zealand estuaries. Marine and Freshwater Research, 62:1327-1341.

Gibbs, M., 2004. Relating terrigenous sediment deposition in Mahurangi Harbour to specific land-use in the catchment: a pilot study. NIWA Client Report HAM2004-111, prepared for Auckland Regional Council.

Gibbs, M. & Hewitt, J., 2004. Effects of sedimentation on macrofaunal communities: a synthesis of research studies for ARC. Auckland Council Technical Publication 264, Auckland Council.

Gonda-King, L.M., Keppel, A.G., Kuschner, M.A., Rodkey, C.N., 2010. The relation of sedimentation to growth rate in the Eastern oyster (*Crassostrea virginica*). St Mary's College of Maryland, St. Mary's City.

Gray, J., 1981. The ecology of marine sediments: An introduction to the structure and function of benthic communities. Press Syndicate of the University of Cambridge, Cambridge, pp 189.

Green, C., 1990. Fauna Wetland Habitat Sheets. Unpublished Report, Department of Conservation, Auckland.

Halliday, J., Cummiongs, V., 2012. Mahurangi Estuary Ecological Monitoring Programme: Report on Data Collected from July 1994 to January 2011. Prepared by NIWA for Auckland Council. Auckland Council Technical Report 2012/003.

Harper S., Moores J., Elliott S. (2013). Pūhoi - Warkworth Road of National Significance: Estimates of Construction Sediment Loads. Prepared by NIWA for the Further North Alliance.

Heather, B.D., and Robertson, H.A., 2000. The Field Guide to the Birds of New Zealand. Penguin Books, Rosedale.

Hewitt, J., Hatton, S., Safi, K., Cragg, R., 2001. Effects of suspended sediment levels on suspension feeding shellfish in the Whitford embayment. Prepared for Auckland Regional Council. NIWA Client Report ARC00205.

Higgins, P.J. & S.J.J.F. Davies (eds) 1996. Handbook of Australian, New Zealand and Antarctic Birds. Volume 3: Snipe to Pigeons. Oxford University Press, Melbourne.

Keeley, N., Forrest, B., Hopkins, G., Gillespie, P., Clement, D., Webb, S., Knight, B., Gardner, J., 2009. Sustainable Aquaculture in New Zealand: Review of the Ecological Effects of Farming Shellfish and other Non-finfish Species. Prepared for the Ministry of Fisheries, Cawthron Report No. 1476.

Lohrer, A.M., Thrush, S.F., Lundquist, C.J., Vopel, K., Hewitt, J., Nicholls, P.E., 2006. Deposition of terrigenous sediment on subtidal marine macrobenthos: response of two contrasting community types. Marine Ecology Progress Series, 307, 115-125.

Long, E.R., MacDonald, D.D., Smith S.L., Clader E.D., 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environmental Management 19, 81-97.

Lundquist, C.J., Vopel, K., Thrush, S.F., and Swales, A., 2003. Evidence for the physical effects of catchment sediment runoff preserved in estuarine sediments: Phase III macrofaunal communities. Technical publication 222, NIWA Project ARC03202, prepared for Auckland Regional Council.

Marchant, S., and Higgins, P.J. (eds) 1993. Handbook of Australian, New Zealand and Antarctic Birds. Volume 2: Raptors to Lapwings. Oxford University Press, Melbourne.

Mead, S. T., D. J. Phillips, and T. Haggitt, 2011. Development of a GIS to Determine the Vulnerability of Regionally Significant Marine Receiving Environments to Land-Use Impacts. Proceedings of the 20th Australasian Coasts and Ports Conference, Perth, Australia, 27-30 September 2011.

Miskelly, C.M., Dowding, J.E., Elliot, G.P., Hitchmough, R.A., Powlesland, R.G., Robertson, H.A., Sagar, P.M., Scofield, R.P. & Taylor, G.A. (2008). Conservation status of New Zealand birds, 2008. Notornis 55: 117-1350.

Moores, J., Pattinson, P., Hyde, C., 2009. Enhancing the control of contaminants from New Zealand's roads: results of a road runoff sampling programme. New Zealand Transport Agency research report, 395.

Morrisey, D., Beard, C., Morrison, M., Craggs, R., and Lowe, M., 2007. The New Zealand Mangrove: Review of the Current State of Knowledge. NIWA Client Report: HAM2007-052, prepared for Auckland Regional Council.

Morrison, M., and Carbines, G., 2006. Estimating the abundance and size structure of an estuarine population of the sparid Pagrus auratus, using a towed camera during nocturnal periods of inactivity, and comparisons with conventional sampling techniques. Fisheries Research, 82:150–161.

Nicholls, P., Hewitt, J., Halliday, J., 2009. Effects of suspended sediment concentrations on suspension and deposit feeding marine macrofauna. Prepared by NIWA for Auckland Regional Council. Auckland Regional Council Technical Report 2009/117.

Nicholls, P., Hewitt, J., Halliday, J., 2003. Effects of suspended sediment concentrations on suspension and deposit feeding marine macrofauna. Prepared for Auckland Regional Council. Auckland Regional Council Technical Report No. 211.

NIWA, 2013a. Update on NIWA survey of fish communities in mangroves and seagrass meadows, viewed at http://www.niwa.co.nz/publications/wa/vol13-no2-june-2005/4-fish-survey on 8/03/2013.

NIWA, 2013b. Yellow-eye mullet, viewed at http://www.niwa.co.nz/freshwater-and-estuaries/nzffd/NIWA-fish-atlas/fish-species/yelloweyed_mullet on 11/03/2013.

Regini, K. (2002). *Draft Guidelines for Ecological Evaluation and Impact Assessment*. Institute of Ecology and Environmental Management (IEEM).

Robertson, C.J.R., Hyvönen, P., Fraser, M.J., Pickard, C.R., 2007. Atlas of Bird Distribution in New Zealand 1999-2004. The Ornithological Society of New Zealand Inc., Wellington.

Rodney District Council (RDC), 2010. Pūhoi Structure Plan, Rodney District Council.

Stockin, K.A., and Visser, I.N., 2005. Anomalously Pigmented Common Dolphins (*Delphinus* sp.) off Northern New Zealand, Aquatic Mammals, 31:43-51.

Suisted, R., and Neale, D., 2004. Department of Conservation Marine Mammal Action Plan for 2005–2010, Department of Conservation.

Swales, A., Hume, T.M., McGlone, M.S., Pilvio, R., Ovenden, R., Zviguina, N., Hatton, S., Nicholls, P., Budd, R., Hewitt, J., Pickmere, S., and Costley, K., 2002. Evidence for the physical effects of catchment sediment runoff preserved in estuarine sediments: Phase II (field study). NIWA Client Report ARC01272, prepared for Auckland Regional Council.

Swales, A., Hume, T.M., Oldman, J.W., and Green, M.O., 1997. Sedimentation history and recent human impacts. NIWA Project ARC60201, prepared for Auckland Regional Council.

Swales, A., Hume, T. M, Oldman, J. W., Green, M. O, 2009. Mahurangi Estuary: Sedimentation History and Recent Human Impacts. Prepared by NIWA for Auckland Regional Council. Auckland Regional Council Document TP2009/061.Thrush, S.F., Whitlatch, R.B., Pridmore, R.D., Hewitt, J.E., Cummings, V.J., and Wilkinson, M.R., 1996. Scale-dependent recolonisation: The role of sediment stability in a dynamic sandflat habitat. Ecology, 77:2472-2487.

Thrush, S.F., Pridmore, R.D., Hewitt, J.E., and Cummings, V.J., 1994. The importance of predators on a sandflat: interplay between seasonal changes in prey densities and predator effects. Marine Ecology Progress Series, 107: 211-222.

Thrush, S.F., Pridmore, R.D., Hewitt, J.E., and Cummings, V.J., 1991. Impact of ray feeding disturbances on sandflat macrobenthos: Do communities dominated by polychaetes or shellfish respond differently? Marine Ecology Progress Series, 69:245-252.

Turner, S., and Schwarz, A.M., 2006. Management and conservation of seagrass in New Zealand: an introduction, prepared for New Zealand Department of Conservation.

Usmar, N.R., 2009. Ontogeny and ecology of snapper (*Pagrus auratus*) in an estuary, the Mahurangi Harbour. PhD thesis, The University of Auckland.

Visser, I.N., 2007. Killer whales in New Zealand waters: Status and distribution with comments on foraging. Orca Research Trust, viewed at http://www.orcaresearch.org/wp-content/uploads/2011/08/Visser-2007-Killer-whales-in-NZ-waters-SC-59-SM19.pdf on 07/03/2013.

Visser, I.N., 2000. Orca (*Orcinus orca*) in New Zealand waters. PhD dissertation, School of Environmental and Marine Science, University of Auckland.

Visser, I.N., 1999. A summary of interactions between orca (*Orcinus orca*) and other cetaceans in New Zealand waters. New Zealand Natural Sciences, 24:101-112.

Whitehouse R., Soulsby R., Roberts W., Mitchener H., 2000. Dynamics of Estuarine Muds. Thomas Telford, London.

Appendix A. Further North field survey site co-ordinates[32]

Mahurangi		
1M0	1751108	5969160
IM1a	1751874	5967933
IM1b	1751830	5967896
IM2	1752970	5966822
IM3	1753793	5966474
IM4	1755050	5964624
IM5	1755746	5962342
IM5a	1755746	5962342
IM6	1753674	5959778
IM7	1751841	5961127
IM8	1752977	5963733
IM9	1753198	5964832
SM1	1753126	5966581
SM2	1753925	5965498
SM3	1753853	5965035
SM4	1754899	5964673
SM5	1753205	5963487
SM6	1754717	5962265
SM7	1752748	5961333
SM8	1754440	5959734

[32] With reference to the site codes used, "I" indicates Intertidal survey sites,"S" indicates subtidal survey sites, "M" indicates Mahurangi and "P" indicates Pūhoi.

Pūhoi		
IP0a	1750061	5956082
IP0b	1750039	5956149
IP0c	1750022	5956218
IP1	1750394	5956254
IP2	1751216	5956458
IP3	1751918	5956218
IP4	1752312	5956229
IP5	1752647	5955773
IP6	1753003	5955930
SP1	1749453	5957600
SP2	1750352	5956265
SP3	1751579	5956334
SP4	1753442	5956391

Appendix B. Intertidal habitat plates and epifaunal data

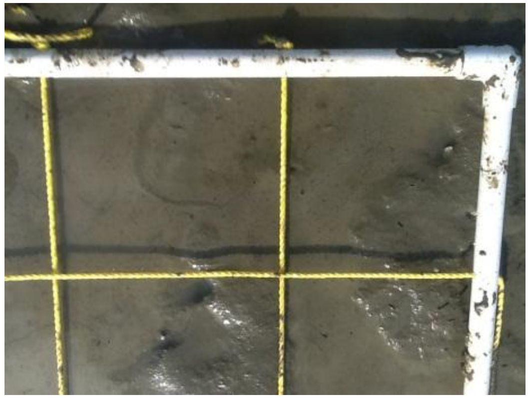
Site	Typical Intertidal Habitat	Quadrat	Data
Mahurangi (IM0)			• Av. No. Crab Burrows – 71.7 • Macroalgae - nil • Macrofauna – nil
Mahurangi (IM1)			• Av. No. Crab Burrows - 37.7 • Macroalgae - nil • Macrofauna – nil

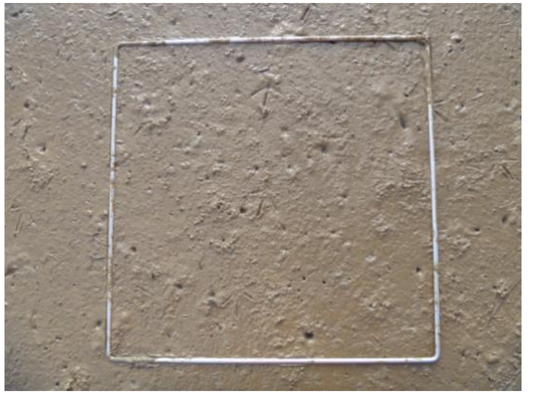
Site	Typical Intertidal Habitat	Quadrat	Data
Mahurangi (IM2)			• Av. No. Crab Burrows - 72.7 • Macroalgae - nil • Macrofauna – nil • Redox (ORP) – 460
Mahurangi (IM3)			• Av. No. Crab Burrows - 41.3 • Macroalgae - nil • Macrofauna - nil • Redox (ORP) – 478.1

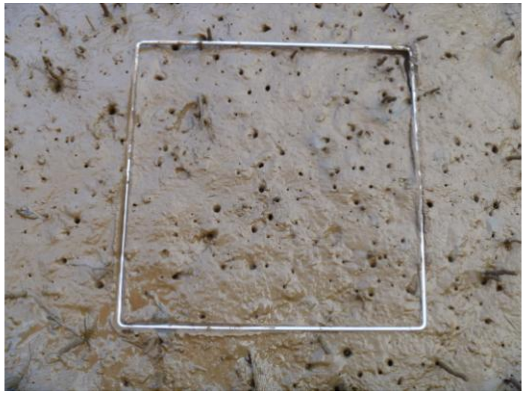
Site	Typical Intertidal Habitat	Quadrat	Data
Mahurangi (IM4)		Photograph not available	• Av. No. Crab Burrows - 44.7 • Macroalgae - nil • Macrofauna - nil • Redox (ORP) – 444.6
Mahurangi (IM5)		No quadrats taken (replaced with site M5a)	• Redox (ORP) – 470.1

Site	Typical Intertidal Habitat	Quadrat	Data
Mahurangi (IM5a)		Photograph not available	• Av. No. Crab Burrows– 79 • Macroalgae - nil • Macrofauna - 7 • Redox (ORP) – 469.3 • 5 x *Austrovenus stutchburyi* • 1 x *Paphies australis* • 1 x *Diloma subrostrata*
Mahurangi (IM6)		Photograph not available	• Av. No. Crab Burrows – 0.3 • Macroalgae - nil • Macrofauna - 4 • Redox (ORP) - 475 • 2 x *Austrovenus stutchburyi* • 1 x *Paphies australis* • 1 x *Diloma subrostrata*

Site	Typical Intertidal Habitat	Quadrat	Data
Mahurangi (IM7)			• Av. No. Crab Burrows – 24 • Macroalgae – nil • Macrofauna – nil • Redox (ORP) – 464.6
Mahurangi (IM8			• Av. No. Crab Burrows –31.3 • Macroalgae – nil • Macrofauna – 3 • Redox (ORP) – 477.6 • 2 x *Cominella glandiformis* • 1 x *Elminius modestus*

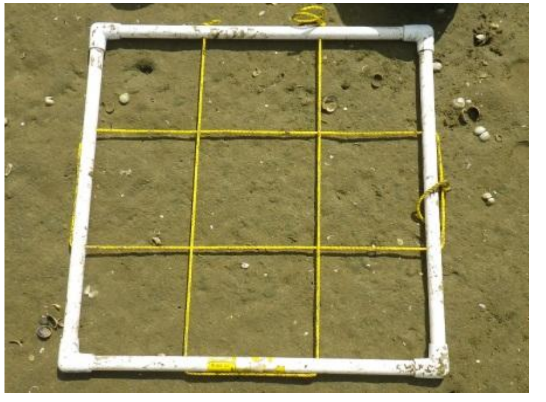
Site	Typical Intertidal Habitat	Quadrat	Data
Mahurangi (IM9)			• Av. No. Crab Burrows – 267.7 • Macroalgae – nil • Macrofauna – nil • Redox (ORP) – 477.7

Site	Typical Intertidal Habitat	Quadrat	Data
Pūhoi (IP0a)			• Av. No. Crab burrows – 14 • Macroalgae – nil • Macrofauna – nil
Pūhoi (IP0b)			• Av. No. Crab burrows – 10.3 • Macroalgae – nil • Macrofauna – nil • *Amphibola crenata* (mud snail) – Av. No. 2.7

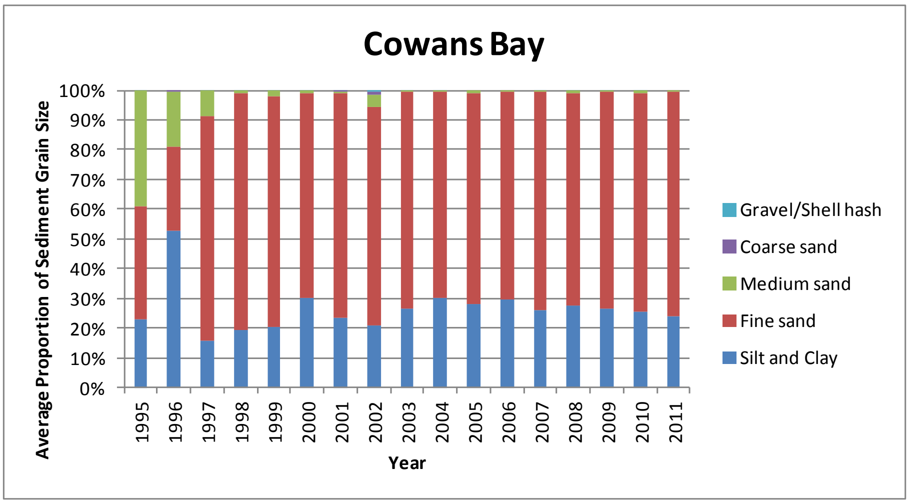
Site	Typical Intertidal Habitat	Quadrat	Data
Pūhoi (IP0c)			• Av. No. Crab burrows – 39 • Macroalgae – nil • Macrofauna – nil
Pūhoi (IP1)		Photograph not available	• Av. No. Crab burrows – 27 • Macroalgae – nil • Macrofauna – nil • Redox (ORP) – 492.4

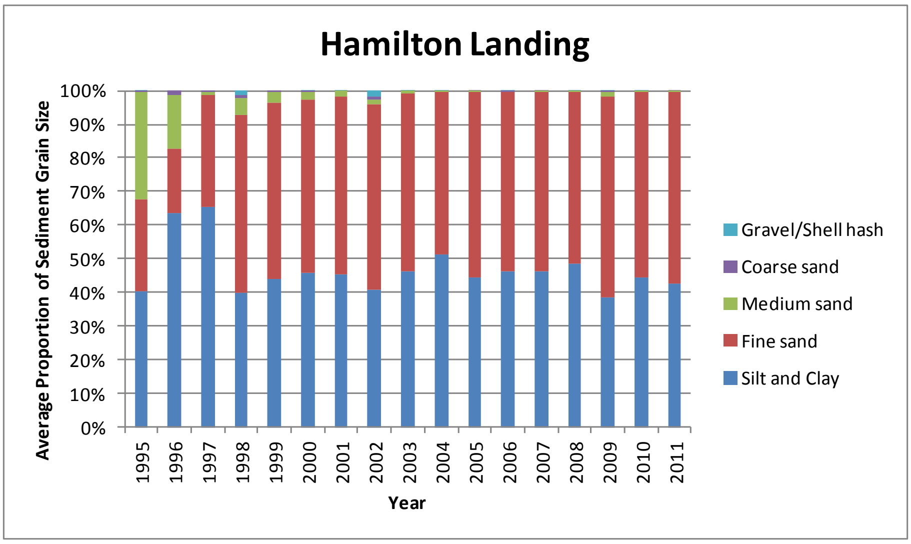
Site	Typical Intertidal Habitat	Quadrat	Data
Pūhoi (IP2)		Photograph not available	• Av. No. Crab burrows – 65 • Macroalgae – nil • Macrofauna – 9 • Redox (ORP) – 490.4 • 9 x *Helice crassa*
Pūhoi (IP3)			• Av. No. Crab burrows – 5.7 • Macroalgae – nil • Macrofauna – 1 • Redox (ORP) – 491 • 1 x *Cominella glandiformis*

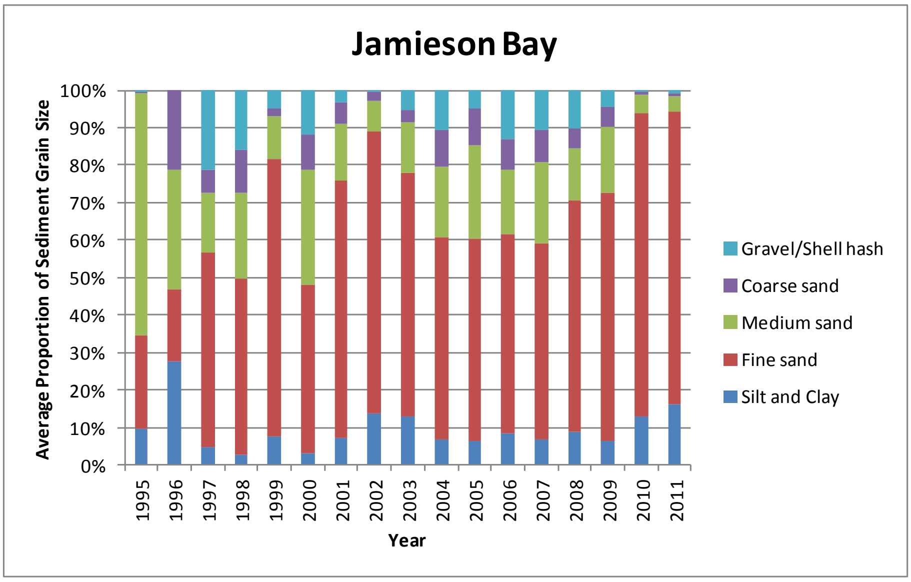
Site	Typical Intertidal Habitat	Quadrat	Data
Pūhoi (IP4)			• Av. No. Crab burrows – 11 • Macroalgae – nil • Macrofauna – 3 • Redox (ORP) – 488.7 • 2 x *Zeacumantus lutulentus* • 1 x *Cominella glandiformis*
Pūhoi (IP5)			• Av. No. Crab burrows – 18 • Macroalgae – nil • Macrofauna – 176 • Redox (ORP) – 489.1 • 158 x *Elminius modestus* • 16 x *Austrovenus stutchburyi* • 2 x *Zeacumantus lutulentus*

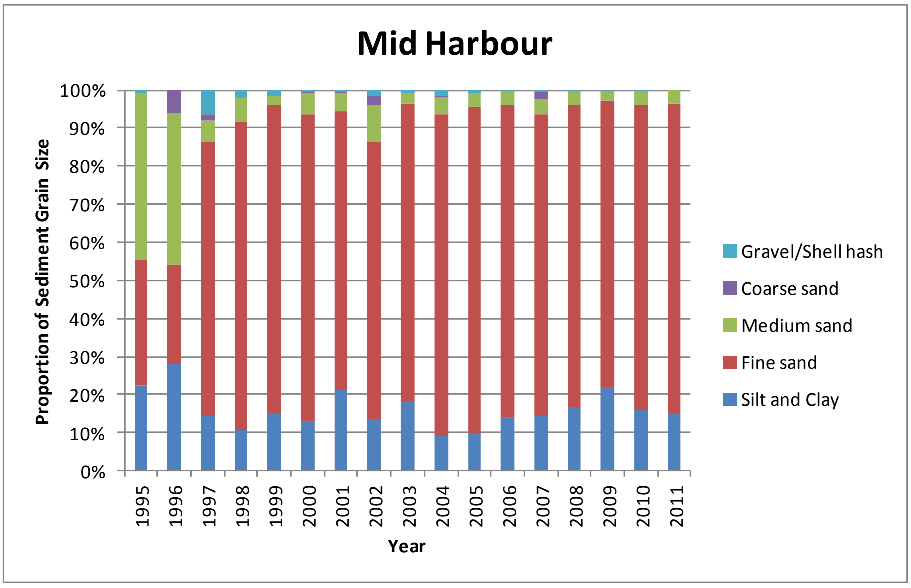
Site	Typical Intertidal Habitat	Quadrat	Data
Pūhoi (IP6)			• Av. No. Crab burrows – 36.7 • Macroalgae – nil • Macrofauna – 11 • Redox (ORP) – 421.4 • 10 x *Austrovenus stutchburyi* • 1 x *Helice crassa*

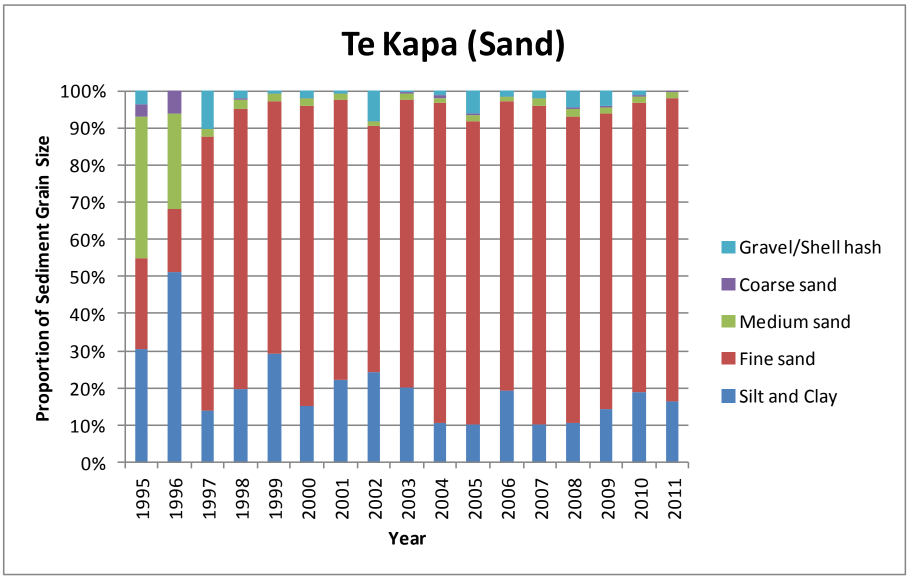
Appendix C. Annual sediment grain size composition at AC survey sites in Mahurangi Harbour.

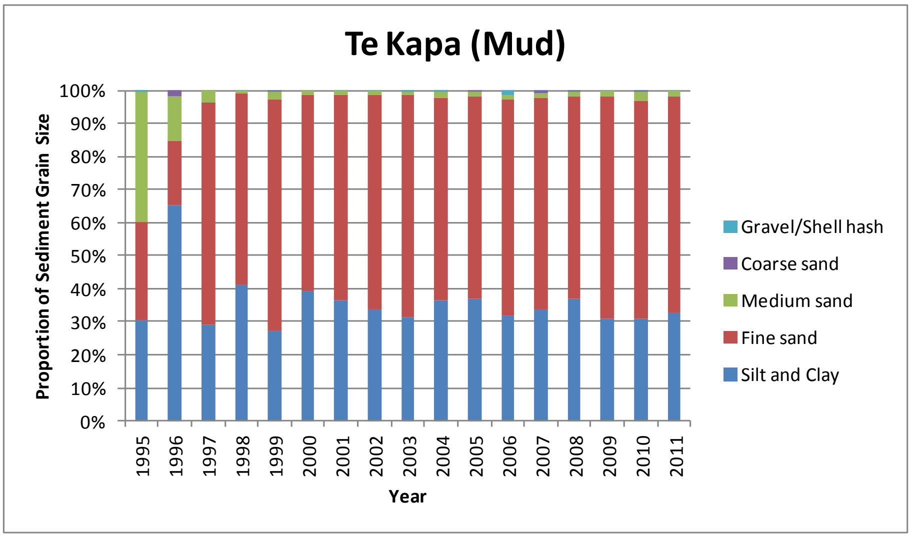


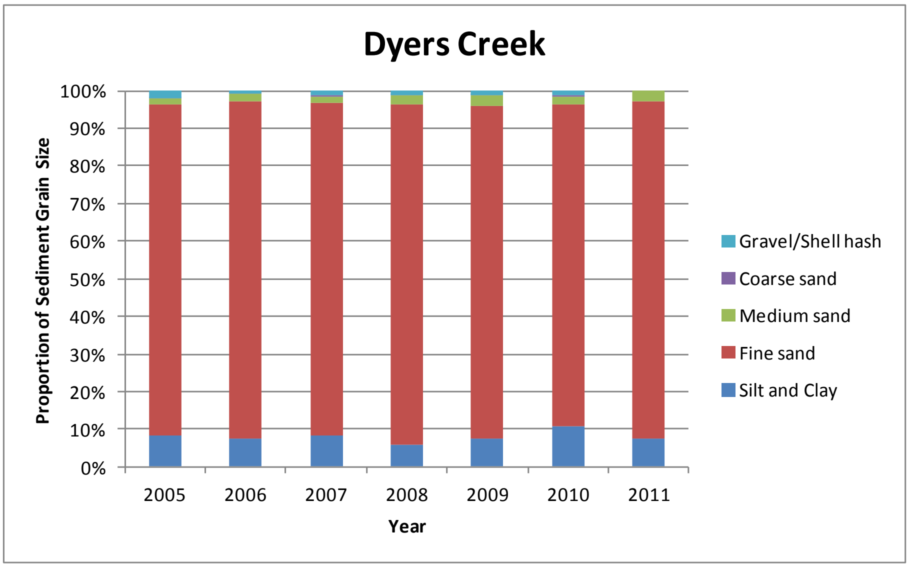


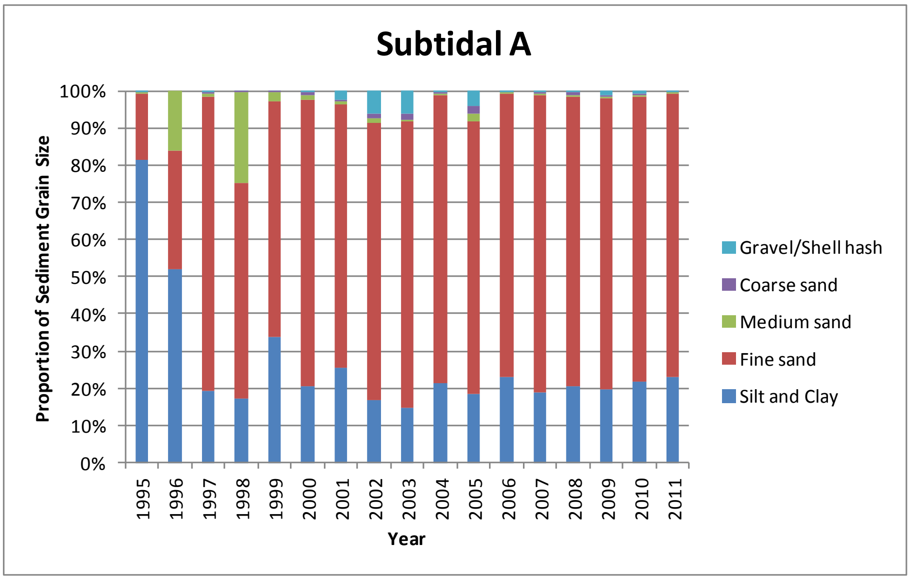

Jamieson Bay
Average Proportion of Sediment Grain Size
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year
Gravel/Shell hash
Coarse sand
Medium sand
Fine sand
Silt and Clay

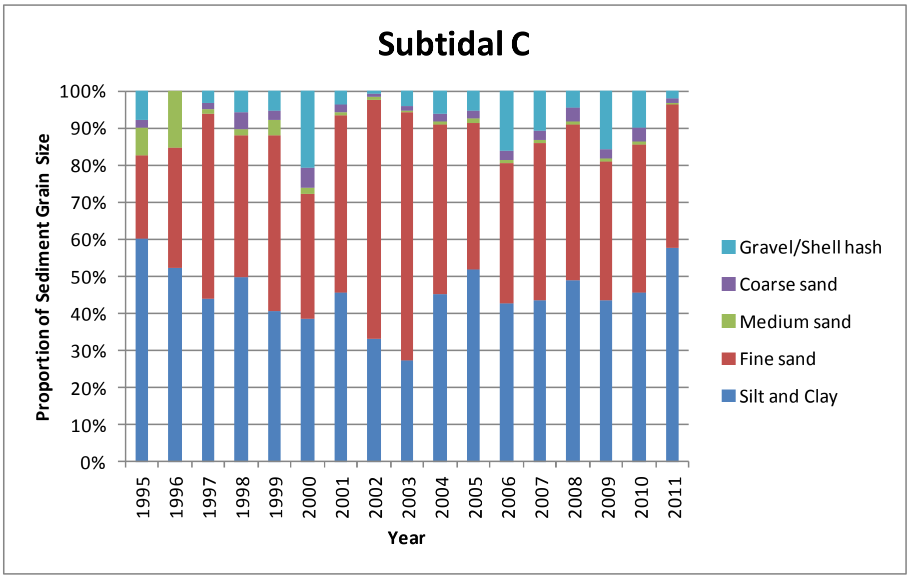

Mid Harbour
Proportion of Sediment Grain Size
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year
Gravel/Shell hash
Coarse sand
Medium sand
Fine sand
Silt and Clay


Te Kapa (Sand)
Proportion of Sediment Grain Size
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year
Gravel/Shell hash
Coarse sand
Medium sand
Fine sand
Silt and Clay


Te Kapa (Mud)
Proportion of Sediment Grain Size
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year
Gravel/Shell hash
Coarse sand
Medium sand
Fine sand
Silt and Clay


Dyers Creek
Proportion of Sediment Grain Size
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2005
2006
2007
2008
2009
2010
2011
Year
Gravel/Shell hash
Coarse sand
Medium sand
Fine sand
Silt and Clay


Subtidal A
Proportion of Sediment Grain Size
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year
Gravel/Shell hash
Coarse sand
Medium sand
Fine sand
Silt and Clay


Subtidal C
Proportion of Sediment Grain Size
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year
Gravel/Shell hash
Coarse sand
Medium sand
Fine sand
Silt and Clay

Appendix D. Invertebrate sensitivity characteristics

Sources: Gibbs & Hewitt (2004), Robertson & Stephens (2009) and Nicholls et al. (2009)

Tolerance Scales: enrichment (based on Borja et al., 2000) and mud (based on Gibbs & Hewitt, 2004; Norkko et al., 2001) and on author's own experience

		Tolerance to organic enrichment	Tolerance to mud	Present in Mahurangi Harbour	Present in Pūhoi Estuary	Details
Anemone	*Edwardsia sp.*	**Indifferent**	NA	Yes	Yes	A tiny elongate anemone adapted for burrowing; colour very variable, usually 16 tentacles but up to 24, pale buff or orange in colour. Fairly common throughout New Zealand. Prefers sandy sediments with low-moderate mud. Intolerant of anoxic conditions.
Ribbon worm	*Nemertea sp.*	**Tolerant**	**Prefers some mud**	Yes	Yes	Ribbon or Proboscis Worms, mostly solitary, predatory, free-living animals. Intolerant of anoxic conditions. Optimum mud range 55-60%, but distribution between 0-95%.
Polychaete worm	*Aglaophamus macroura*	**Indifferent**	NA	Yes	No	A large, long-lived (five years or more) intertidal and subtidal nephtyid that prefers a sandier, rather than muddier substrate. Feeding type is carnivorous. Significant avoidance behaviour by other species. Feeds on *Heteromastus filiformis*, *Orbinia papillosa* and *Scoloplos cylindrifer* etc.
	Armandia maculata	**Sensitive**	NA	Yes	No	Common subsurface deposit-feeding/herbivore. Belongs to Family Dpheliidae. Found intertidally as well as subtidal in bays and sheltered beaches. Prefers fine sand to sandy mud at low water. Does not live in a tube. Depth range: 0-1,000m. A good coloniser and explorer. Pollution and mud intolerant.
	Boccardia (Paraboccardia)	**Sensitive**	**Sand preference**	Yes	No	Small surface deposit and suspension feeding spionids. Prefers low-moderate mud content but found in a wide range of sand/mud. It lives in flexible tubes constructed of fine sediment grains, and can form dense mats on the sediment surface. Prefers sandy

		Tolerance to organic enrichment	Tolerance to mud	Present in Mahurangi Harbour	Present in Pūhoi Estuary	Details
	syrtis and acus					sediment to muddy. Very sensitive to organic enrichment and usually present under unenriched conditions. When in dense beds, the community tends to encourage build-up of muds. Intolerant of elevated TSS for more than six days. Sensitive to sediment deposition. Optimum range 10-15% mud, distribution 0-50% mud.
	Cirratulidae sp.	**Opportunistic**	**Sand preference**	Yes	No	Subsurface deposit feeder that prefers sands. Small sized, tolerant of slight unbalanced situations. Optimum range 10-15% mud, distribution range 5-70% mud.
	Capitella capitata	**Opportunistica nd Anoxia Tolerant**	**Prefers some mud but not high stoneage**	Yes	No	A blood red capitellid polychaete which is very pollution tolerant. Common in suphide rich anoxic sediments. Optimum range 10-15% or 20-40% mud, distribution range 0-95% mud, based on *Heteromastus filiformis*.
	Glyceridae	**Indifferent**	**Prefers some mud but not high percentage**	Yes	No	Glyceridae (blood worms) are predators and scavengers. They are typically large, and are highly mobile throughout the sediment down to depths of 15 cm. They are distinguished by having four jaws on a long eversible pharynx. Intolerant of anoxic conditions. Often present in muddy conditions. Intolerant of low salinity.
	Goniada sp.	**Indifferent**	**Prefers some mud but not high percentage**	Yes	No	Slender burrowing predators (of other smaller polychaetes) with proboscis tip with two ornamented fangs. The goniadids are often smaller, more slender worms than the glycerids. The small goniadid *Glycinde dorsalis* occurs low on the shore in fine sand in estuaries. Optimum mud range 50-55%, distribution range 0-60% mud.
	Hesionidae sp.	**Indifferent**	NA	Yes	No	Fragile active surface-dwelling predators somewhat intermediate in appearance between nereidids and syllids. The New Zealand species are little known.
	Heteromastus filiformis	**Opportunistic**	**Prefers some mud but not high percentage**	Yes	Yes	Small sized capitellid polychaete. A sub-surface, deposit-feeder that lives throughout the sediment to depths of 15cm, and prefers a sandy-muddy substrate. Despite being a capitellid, *Heteromastus* is not opportunistic and does not show a preference for areas of high organic enrichment as other members of this polychaete group do. Relatively tolerant of sedimentation and not very mobile. Optimum range 10-15% or 20-40% mud, distribution range 0-95% mud.

		Tolerance to organic enrichment	Tolerance to mud	Present in Mahurangi Harbour	Present in Pūhoi Estuary	Details
	Nicon aestuariensis	**Tolerant**	**Prefers mud**	Yes	Yes	A nereid (ragworm) that is tolerant of freshwater and is a surface deposit-feeding omnivore. Prefers to live in moderate to high mud content sediments. Optimum range 55-60% or 35-55% mud, distribution range 0-100% mud.
	Orbinia papillosa	**Sensitive**	**Prefers sand**	Yes	Yes	Long, slender, sand-dwelling unselective deposit-feeders which are without head appendages. Found in fine and very fine sands (occasionally mud), and can be uncommon. Pollution and mud intolerant. Sensitive to time and depth of deposition. Optimum range 5-10% mud, distribution range 0-40% mud.
	Pectinaria australis	**Sensitive**	NA	Yes	Yes	Subsurface deposit-feeding herbivore. Lives in a cemented sand grain cone-shaped tube. Feeds head down with tube tip near surface. Prefers fine sands to muddy sands. Mid tide to coastal shallows. Belongs to Family *Pectinariidae*. Often present in NZ estuaries. Density may increase around sources of organic pollution and eelgrass beds. Intolerant of anoxic conditions.
	Phyllodocidae	**Indifferent**	NA	Yes	No	The phyllodocids are a colour family of long, slender, and very active carnivorous worms characteristically possessing enlarged dorsal and ventral cirri which are often flattened and leaf-like (paddleworms). They are common intertidally and in shallow waters.
	Scolecolepides benhami	**Tolerant**	**Strong mud preference**	Yes	Yes	A surface deposit feeder. Is rarely absent in sandy/mud estuaries, often occurring in a dense zone high on the shore, although large adults tend to occur further down towards low water mark. Prefers low-moderate mud content (<50% mud). A close relative, the larger *Scolecolepides freemani* occurs upstream in some rivers, usually in sticky mud in near freshwater conditions. Optimum range 25-30% mud, distribution range 0-60% mud.
	Scoloplos (Scoloplos) cylindrifer	**Sensitive**	**Prefers sand**	Yes	Yes	Belongs to Family *Orbiniidae* which are thread-like burrowers without head appendages. Common in intertidal sands of estuaries. Long, slender, sand dwelling unselective deposit feeders. Optimum range 0-5% mud, distribution range 0-60% mud.

		Tolerance to organic enrichment	Tolerance to mud	Present in Mahurangi Harbour	Present in Pūhoi Estuary	Details
	Sphaerosyllis sp.	**Indifferent**	**Prefers sand**	Yes	Yes	Belongs to Family *Orbiniidae* which are delicate and colourful predators. Very common, often hidden amongst epifauna. Small and delicate in appearance. Prefers sandy sediments. Optimum range 25-30% mud, distribution range 0-40% mud.
	Syllidae	**Indifferent**	**Prefers sand**	Yes	No	Belongs to Family *Syllidae*. Delicate and colourful predators. Very common, often hidden amongst epifauna. Small size and delicate in appearance. Prefers mud/sand sediment. Optimum range 25-30% mud, distribution range 0-40%.
	Terebellidae sp.	**Indifferent**	NA	Yes	No	Large tube or crevice dwellers with a confusion of constantly active head tentacles and a few pairs of anterior gills.
Oligochaete worm	*Oligochaete sp.*	NA	**Strong mud preference**	Yes	Yes	Segmented worms - deposit feeders. Classified as very pollution tolerant by AMBI (Borja et al. 2000) but a review of literature suggests that there are some less tolerant species. Many oligochaete species prefer sand and then mud. Tolerant of depth of sedimentation and time exposed. Optimum range 95-100% mud, distribution range 0-100% mud.
Gastropod	*Chiton glaucus*	**Indifferent**	NA	Yes	No	The green chiton, is a marine polyplacophoran mollusc in the Family *Chitonidae*, the typical chitons. It is the most common chiton species in NZ. The shell, consisting of eight valves surrounded by a girdle, is fairly large, up to 55mm in length.
	Cominella glandiformis	NA	**Strong sand preference**	Yes	Yes	Endemic to NZ. A carnivore living on surface of sand and mud tidal flats. Has an acute sense of smell, being able to detect food up to 30m away, even when the tide is out. Intolerant of anoxic surface muds. Optimum range 5-10% mud, distribution 0-10% mud.
	Notoacmaea helmsi	NA	**Strong sand preference**	Yes	No	Endemic to NZ. Small limpet attached to stones and shells in intertidal zone. Intolerant of anoxic surface muds. Optimum range 0-5% mud, distribution range 0-10% mud.
Bivalve	*Arthritica sp.*	**Tolerant**	**Prefers mud but not high**	Yes	Yes	A small sedentary deposit feeding bivalve, preferring a moderate mud content. Lives greater than 2cm deep in the muds. Optimum range 55-60% or 20-40% mud,

		Tolerance to organic enrichment	Tolerance to mud	Present in Mahurangi Harbour	Present in Pūhoi Estuary	Details
			percentage			distribution range 0-70% mud.
	Austrovenus stutchburyi	NA	**Prefers sand**	Yes	Yes	The cockle is a suspension feeding bivalve with a short siphon - lives a few centimetres from sediment surface at mid-low water situations. Can live in both mud and sand but is sensitive to increasing mud - prefers low mud content. Rarely found below the RPD layer. Has average mobility. Is sensitive to depth of sediment deposited. Can be considered to have average overall tolerance to sedimentation. Prefers sand with some mud (optimum range 5-10% mud or 0-10% mud), distribution range 0-85% mud.
	Macomona liliana	NA	**Prefers sand**	Yes	Yes	A surface deposit feeding wedge shell. This species lives at depths of 5-10cm in the sediment and uses a long inhalant siphon to feed on surface deposits and/or particles in the water column. Rarely found beneath the RPD layer. Prefers a sandy substrate. Has moderate mobility, and has average tolerance to depth and duration of sediment deposition. Prefers sand with some mud (optimum range 0-5% mud), distribution range 0-40% mud.
	Nucula hartvigiana	**Tolerant**	**Prefers sand**	Yes	Yes	The nut clam of the Family *Nuculidae*, is endemic to NZ. It is found intertidally and in shallow water, especially in *Zostera* sea grass flats. It is often found together with the New Zealand cockle, *Austrovenus stutchburyi*, but is not as abundant showing a preference for mud. Like *Arthritica* this species feeds on organic particles within the sediment. Not very mobile. Intolerant of depth and duration of sediment deposition. Optimum range 0-5% mud, distribution range 0-60% mud.
	Paphies australis	NA	**Strong sand preference as adult. Sand or mud as juvenile**	Yes	Yes	This pipi is endemic to NZ. Pipi are tolerant of moderate wave action, and commonly inhabit coarse shell sand substrata in bays and at the mouths of estuaries where silt has been removed by waves and currents. They have a broad tidal range, occurring intertidally and subtidally in high-current harbour channels to water depths of at least 7m. Prefer sandy substrates. Highly mobile suspension feeders. Intolerant of depth of sediment deposition. Adults optimum range 0-5% mud, distribution 0-5% mud. Juveniles often found in muddier sediment.

		Tolerance to organic enrichment	Tolerance to mud	Present in Mahurangi Harbour	Present in Pūhoi Estuary	Details
Cumacea	*Colurostylis lemurum*	NA	**Prefers sand**	Yes	No	A cumacean and semi-pelagic detritus feeder. Some species of cumacea can survival in brackish water. Most species live only one year or less, and reproduce twice in their lifetime. Cumaceans feed mainly on microorganisms and organic material from the sediment. Species that live in the mud filter their food, while species that live in sand browse individual grains of sand. Optimum range 0-5% mud, distribution range 0-60% mud.
Decapod	*Austsrohelice crassa*	NA	**Strong mud preference**	Yes	Yes	Surface deposit feeder and predator/scavenger. Prefers a muddy substrate, is very mobile and tolerant of sedimentation. Overall considered relatively insensitive. Optimum range 95-100% mud, distribution range 5-100% mud.
Mysid shrimp	*Mysidacea sp.*	**Indifferent**	NA	Yes	No	Mysidacea is a group of small, shrimp-like creatures. They are sometimes referred to as opossum shrimps. Wherever mysids occur, whether in salt or fresh water, they are often very abundant and form an important part of the normal diet of many fishes.
Amphipod	*Paracorophium sp.*	**Indifferent**	**Strong mud preference**	No	Yes	A tube-dwelling corophioid amphipod. Two species in NZ, *P. excavatum* and *P. lucasi*. Both are endemic to NZ. *P. lucasi* occurs on both sides of the North Island, but also in the Nelson area. *P. excavatum* has been found mainly in east coast habitats of both the South and North Islands. Sensitive to metals. Also very strong mud preference. Optimum range 95-100% mud, distribution range 40-100% mud. Often present in estuaries with regularly low salinity conditions.
	Phoxocephalidae sp.	**Sensitive**		Yes	Yes	A family of amphipods.

Appendix E. Harbour modelling plans (from Coastal Process Modelling Report).

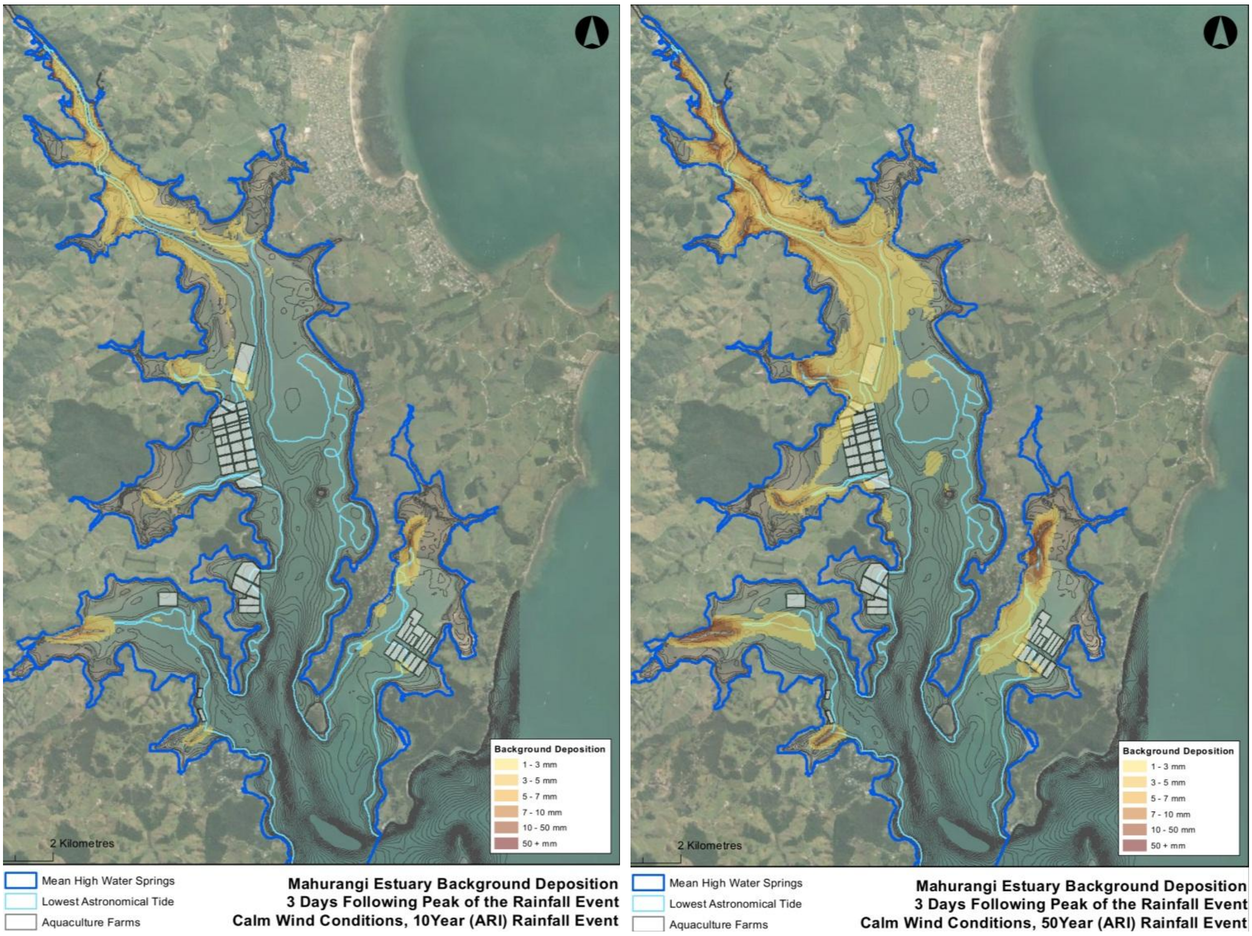


Figure 12: Background deposition in the Mahurangi Estuary in the 10 and 50 year sediment load scenarios

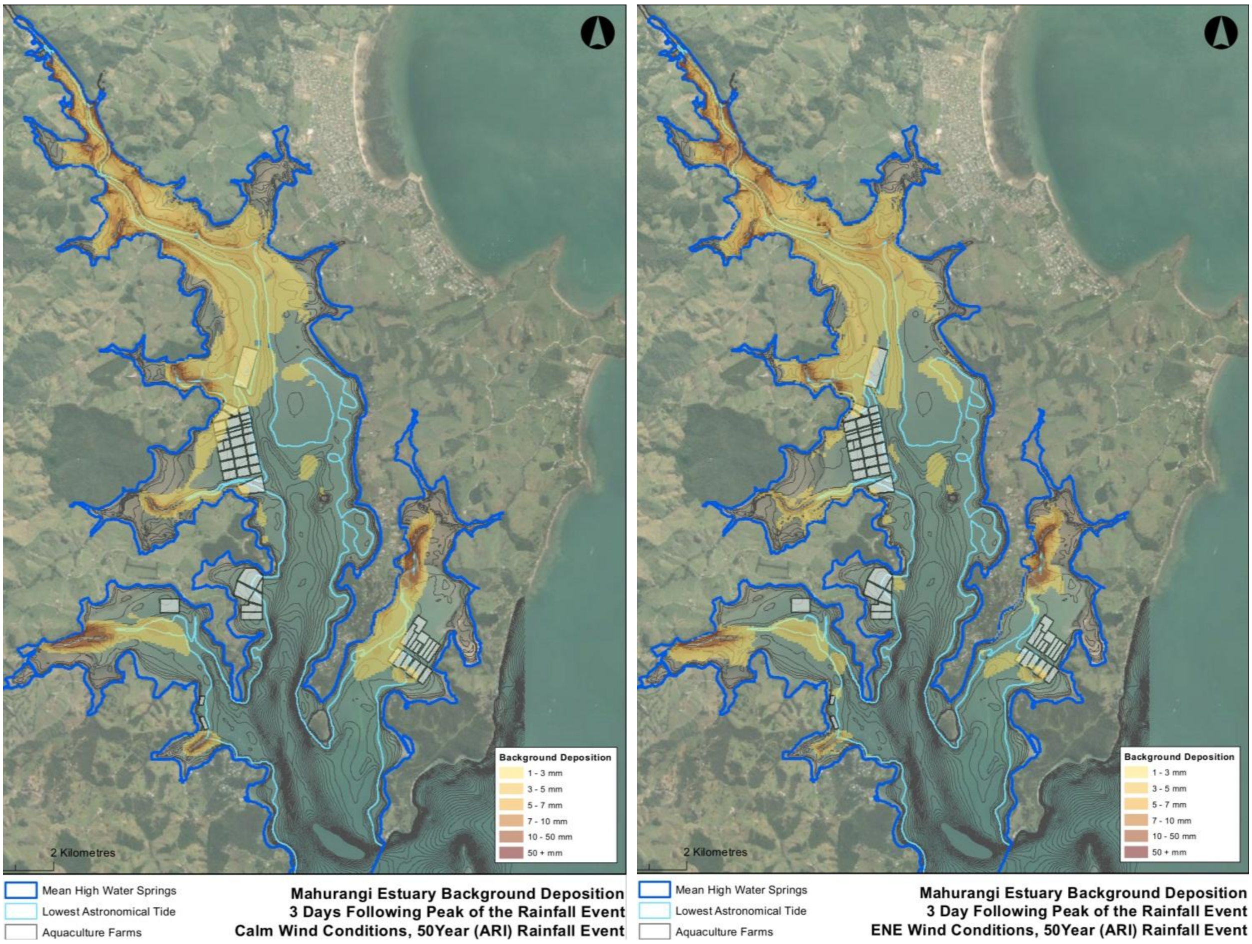


Figure 13: Background deposition in the Mahurangi Estuary in the 50 year sediment load scenario under calm and ENE wind conditions

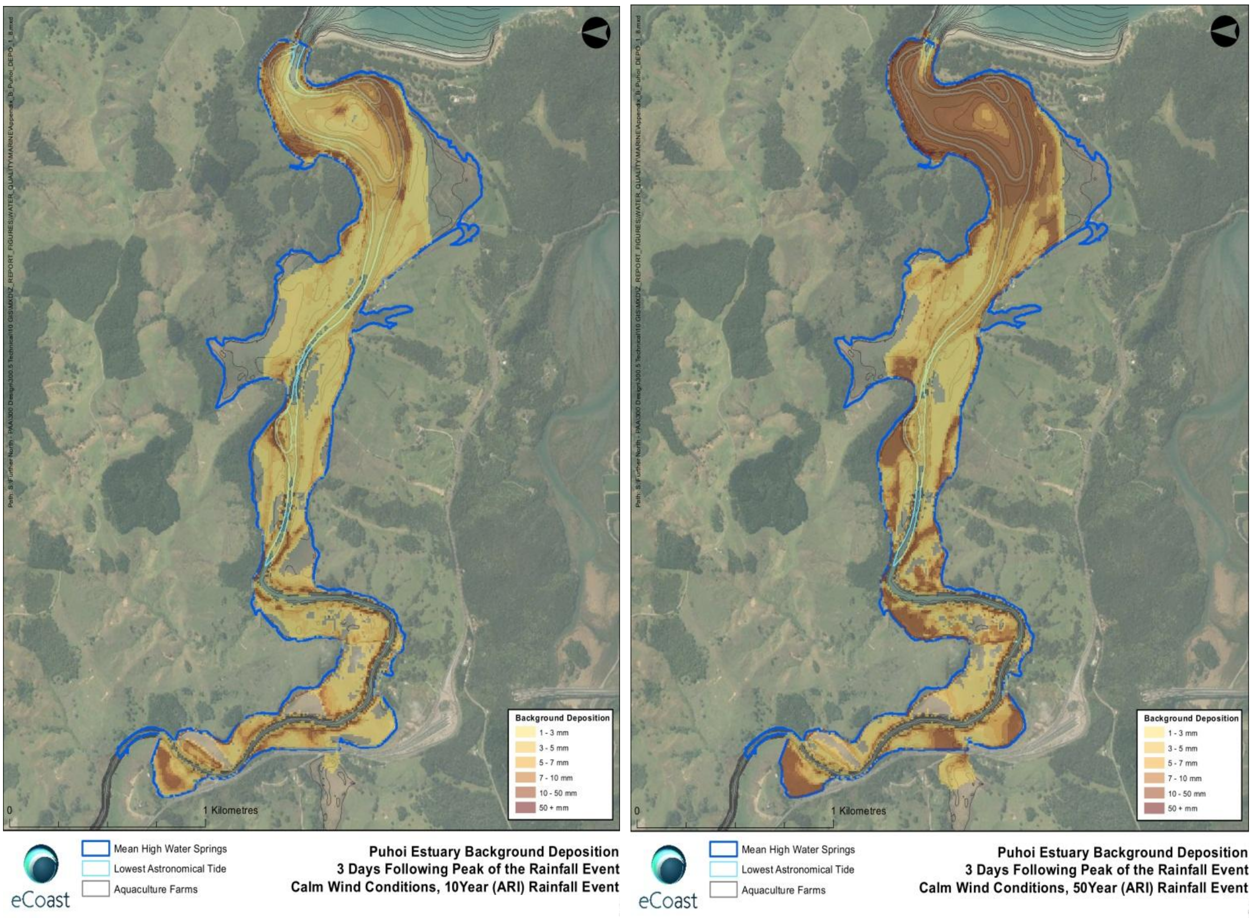


Figure 19: Background deposition in the Pūhoi Estuary in the 10 and 50 year sediment load scenarios

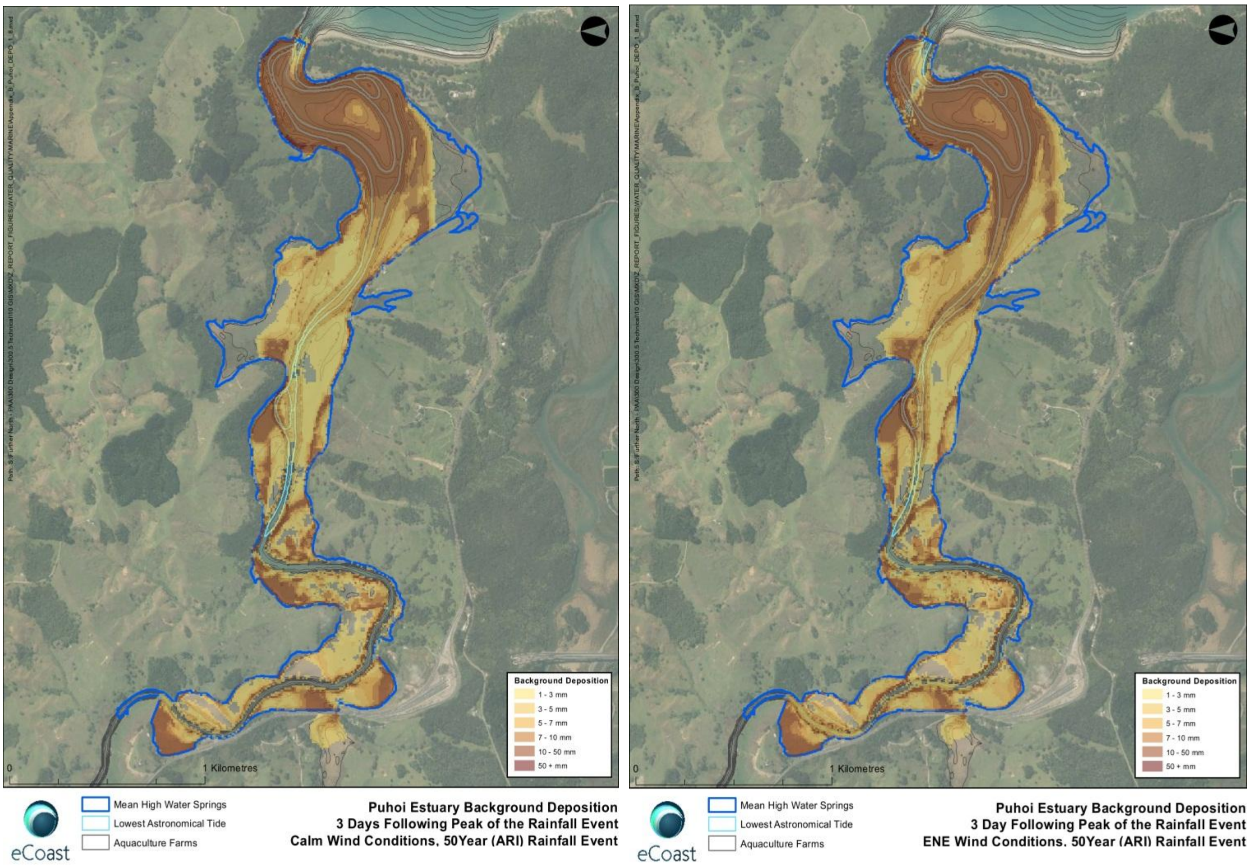


Figure 20: Background deposition in the Pūhoi Estuary in the 50 year sediment load scenario under calm and ENE wind conditions