SALT ECOLOGY

Kāpiti Whaitua

Review of estuary ecological condition and habitat vulnerability

Prepared for

Greater Wellington Regional Council

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Review of estuary ecological condition and habitat vulnerability

Prepared by

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for

Greater Wellington Regional Council

November 2019

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For the People
Mō ngā tāngata

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EXECUTIVE SUMMARY

In response to the National Policy Statement for Freshwater Management (NPSFM), Greater Wellington Regional Council (GWRC) has recently engaged in a community-led approach to provide advice and direction on how best to manage land and water to ensure that the future state of the regions streams, estuaries, beaches, rocky shores and waters meet the aspirations of those most closely connected with them. To support the Kāpiti Coast Whaitua process, Salt Ecology was commissioned by GWRC to re-assess the broad scale condition of nine Kāpiti Coast estuaries that had been previously assessed in 2007 and to evaluate any conspicuous changes in the pressures which may impact on coastal ecological values. The assessment of pressures draws extensively from existing information, supplemented with synoptic field assessments of the current ecological state of each estuary which were undertaken in January 2019. These field surveys were used to update broad scale maps of substrate, macroalgae, seagrass and salt marsh, and to collect point-in-time water quality data (e.g. chl-a measures) to support the calculation of NZ Estuary Trophic Index (ETI). The synoptic assessments are the main component described in the current report.

All nine estuaries are Shallow, Short Residence time Tidal River (and adjoining lagoon) Estuaries (SSRTREs). Seven are low flow SSRTREs (Waitohu, Mangaone, Pekapeka, Waimeha, Tikotu, Wharemauku, Whareroa). They are primarily small, shallow, narrow and occur where stream outlets to the coast are restricted or blocked completely by a sand or gravel barrier just short of the ocean. They are characterised by having little or no intertidal habitat or salt marsh, and water and sediments experience regular cycles of degradation and rejuvenation. Most of these estuaries have been heavily modified by past drainage and channelisation, with mouths opened artificially to reduce flood risks. In the two moderate and high flow SSRTREs (Waikānae, Ōtaki), freshwater flows dominate over tidal flows and flushing is relatively extensive because the mouth is nearly always open and river flow relatively large. In addition, tidal flats are large relative to the smaller SSRTREs, but not particularly broad or expansive. The presence of larger areas of salt marsh adds to their ecological value, particularly for birdlife, and the estuaries often support healthy fisheries, including whitebait. The presence of intertidal flats and intermittent stratification of these moderate and high flow SSRTREs may result in fine sediment deposition and the growth of nuisance macro- and micro-algae, requiring targeted management of catchment nutrient and sediment inputs.

The tables below summarise ecosystem and social/cultural values, current pressures, and condition ratings based on prior work and the further assessment of each estuary in January 2019.

VALUE RATINGS	Waitohu	Ōtaki	Mangaone	Peka Peka	Waimeha	Waikānae	Tikotu	Wharemakau	Whareroa
Ecosystem value	Mod	Mod	Low	V. Low	Low	V. High	V. Low	V. Low	Mod
Social/Cultural value	High	High	Mod	Low	V. Low	High	Low	Low	Mod
Restoration potential	High	High	Mod	Mod	Low	High	V. Low	V. Low	High
Current Overall Pressure	Mod	Mod	Mod	High	Low	Low	V. Low	Low	High
CONDITION RATINGS									
Intertidal soft mud extent (%)	0	14	0	0	0	6	0	0	0
Macroalgae (OMBT EQR)	1	1	1	1	1	1	1	1	1
Seagrass (decrease from baseline)	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Salt marsh (% of estuary)	3	0.2	0	0.3	0.33	19	0	0	0
Historical salt marsh (% remaining)	20	5	0	10	10	10	0	0	20
Densely vegetated 200m margin (%)	60	10	20	50	40	10	5	5	20
High Enrichment Conditions (ha, %)	0	0	0	0	0	0	0	0	0
NZ ETI Susceptibility Rating	Low	Low	V. High	Low	Low	V. High	Low	High	High
NZ ETI Score (Band)	0.26 (B)	0.29 (B)	0.3 (B)	0.36 (B)	0.51 (C)	0.62 (C)	0.56 (C)	0.51 (C)	0.48 (B)

Very Good	Good	Moderate	Poor

In general terms, the larger estuaries have the highest ecological, social/cultural value and restoration potential, primarily because they had greater biodiversity through the combined presence of salt marsh, relatively large intertidal flats and variable substrate types. In contrast, modification has been more pronounced in many of the smaller estuaries which have been heavily modified and have historically lost many of their more vulnerable features to development. Consequently, while they can be protected from ongoing degradation, restoration potential is largely limited to improving fish passage to upstream areas and planting terrestrial margin areas adjacent to the estuary. While improvements can always be made to enhance the values of these small estuaries, there is realistically now very limited scope for returning these highly modified systems to a more natural estuarine state.

Overall, very little change was observed in the estuaries from 2007 to 2019 which reflects the fact that most of these systems are already highly modified. Ongoing pressures include water quality deterioration, the presence of introduced weeds, catchment flow alterations (abstraction, diversion) and loss of wetlands, mouth constriction, and human disturbance of wildlife. Stream channelisation and salt marsh loss are ongoing pressures only in systems where these activities have not occurred.

The summary tables highlight that the estuaries with the highest ecological value, highest social/cultural value and highest restoration potential are the Waikānae, Waitohu, Ōtaki and Whareroa. These estuaries also have moderate to high pressures present. Consequently, it is recommended that they be prioritised for any targeted management and restoration work being undertaken or coordinated by GWRC on the Kāpiti coast. The following recommendations are made for consideration by GWRC:

- Undertake a repeat synoptic assessment of estuary condition and risk at 10 yearly intervals to maintain a high-level overview of estuary condition and change.
- Continue the management of identified pressures and high biodiversity values through existing programmes like the Key Native Ecosystem (KNE) plans, ensuring that specific estuary components have been identified and included appropriately.
- Where limitations in the risk framework criteria used previously have been identified, refine assessment criteria to enable a more objective assessment of risk to identified pressures.

1. INTRODUCTION

1.1 BACKGROUND

In response to the National Policy Statement for Freshwater Management (NPSFM), Greater Wellington Regional Council (GWRC) has recently engaged in a community-led, collaborative approach for managing land and water. Termed the Whaitua Implementation Programme (WIP) it is, or will be, undertaken in five sub-regions (whaitua) in the Greater Wellington region. It comprises a non-statutory community-led committee to provide advice and direction on how best to manage land and water to ensure that the future state of the regions streams, estuaries, beaches, rocky shores and waters meet the aspirations of those most closely connected with them. It brings together mana whenua, local communities, local authority officers and scientific experts to set objectives and limits, and identify strategies to address key issues.

Underpinning the whaitua process are a range of studies including beach, rocky shore and estuary assessments which evaluate the most common pressures affecting different ecological features; i.e. nutrient and fine sediment inputs, and provide guidance on their management. Previous coastal assessments have been undertaken on the Kāpiti coast [Ōtaki to Paekākāriki], southwest coast [Paekākāriki to Sinclair Head], south coast [Sinclair Head to Breaker Bay], Wellington Harbour [Breaker Bay to Baring Head], southeast coast [Baring Head to Cape Palliser], and Wairarapa coast [Cape Palliser to Ōwhanga] (e.g. Stevens et al. 2004, Stevens & Robertson 2006, Robertson & Stevens 2007a,b, Stevens 2013, 2018).

These coastal assessments in turn are supported by detailed coastal state of the environment (SOE) monitoring results for representative beaches, rocky shores and estuaries (e.g. Forrest & Stevens 2019b,c; Stevens 2018a,b; Stevens & O'Neill-Stevens 2017; Robertson & Stevens 2014, 2015; Stevens et al. 2004, 2006).

More recently, approaches have been developed in NZ to help assess susceptibility to specific pressures and evaluate the current state of the environment; e.g. Robertson at al. (2016a,b), Stevens & Robertson (2017), Townsend & Lohrer (2015). Consistent with the NPSFM, these approaches generally define four 'bands' of ecological condition (rated 'Very Good', 'Good', 'Moderate' and 'Poor') for a suite of key indicators, as well as combining multiple measures into integrated indices. These outputs allow current ecological state to be consistently assessed and provide guidance on the likely management effort needed to maintain or change current ecological condition.

While very useful as a way to communicate science information, any attempt to simplify complex ecological interactions to single metrics requires care in their use and interpretation. For example, an estuary with high nutrient and sediment inputs may be strongly flood-scoured and indicators of enrichment such as excessive macroalgal growth or muddiness may therefore not be apparent if regularly flushed out to sea. Thus the absence of enrichment symptoms may not mean an absence of potential problems. Similarly, a highly modified environment; e.g. a channelised estuary, may have already lost all of its sensitive salt marsh habitat and be significantly degraded as a result. Consequently, a measure of further salt marsh loss may show little or no change, poorly representing its actual state of already being significantly degraded.

Finally, the concept of 'death by a thousand cuts' is also important to consider in a regional context where multiple small ongoing losses can have disproportionately high overall consequences, especially within significantly modified systems. As such, the assessment approaches are best viewed as screening tools to highlight key pressures with priority placed on the protection of remaining ecological features from further degradation or loss, and the restoration of degraded or displaced habitat wherever possible.

1.2 PURPOSE AND SCOPE OF THIS REPORT

To support the Kāpiti Coast Whaitua process, Salt Ecology was commissioned by GWRC to assess any conspicuous changes over the past decade in the pressures which may impact on coastal ecological values, and to re-assess the broad scale condition of nine Kāpiti Coast estuaries (Fig 1) that had been previously assessed in 2007 (Robertson & Stevens 2007b).

The current work is not a comprehensive re-assessment of pressures and draws extensively from existing information for this part (e.g. Stevens & Robertson 2006, Robertson & Stevens 2007b, Stevens 2013, Todd et al. 2016). This information is supplemented with the results of synoptic field assessments undertaken in January 2019 of the current ecological state of each estuary. These were used to update broad scale maps of substrate, macroalgae, seagrass and salt marsh, and to collect point-in-time water quality data (e.g. chl-a measures) to support the calculation of NZ Estuary Trophic Index (ETI) (Robertson et al. 2016b, Zeldis et al. 2017). The synoptic assessments are the main component described in the current report (see Section 4). The report is limited to estu-

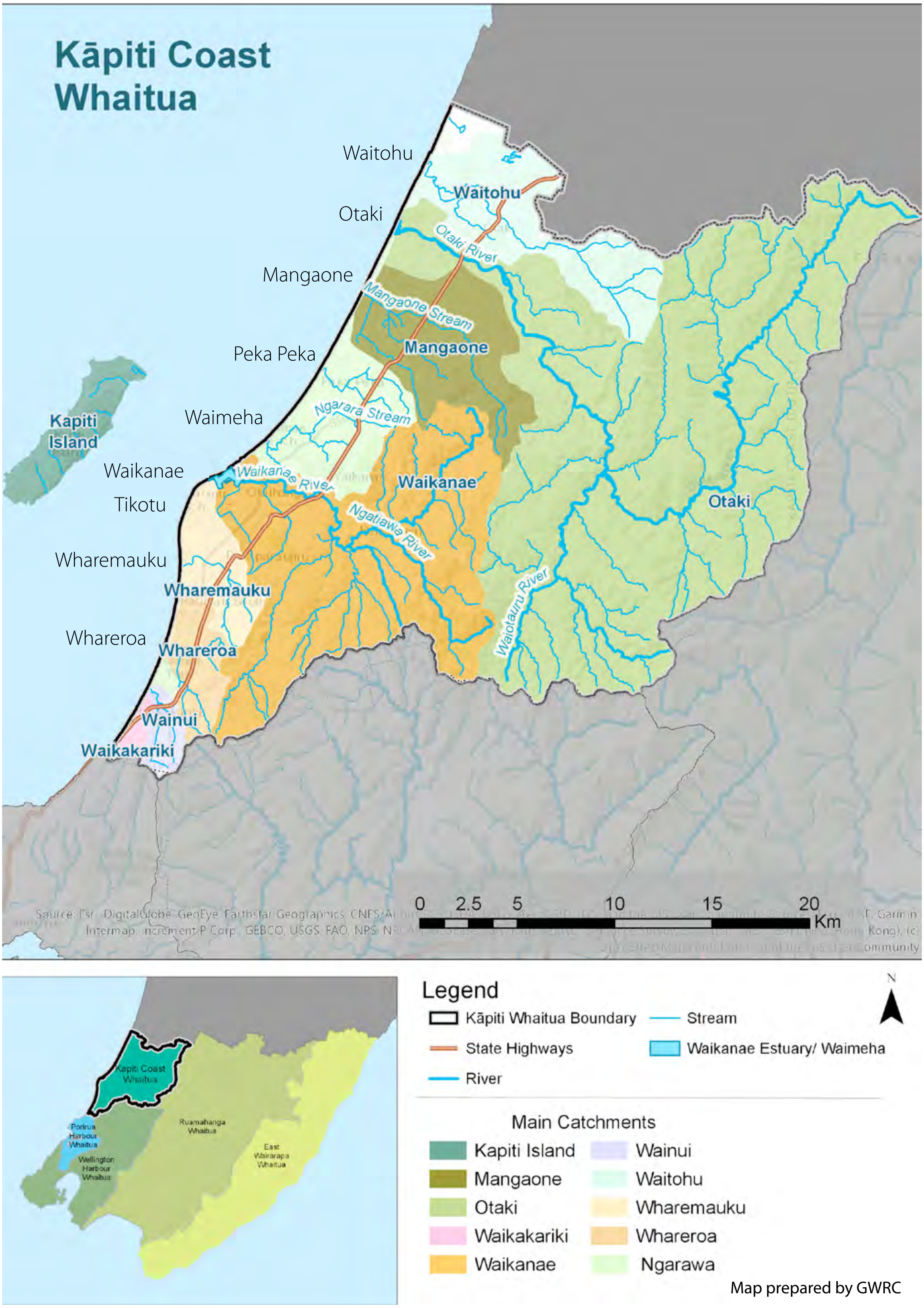


Fig. 1. Overview map showing the Kāpiti Coast Whaitua and location of estuaries assessed in the current report

arine and coastal areas below the high tide line so excludes coastal sand dunes, and does not address human health issues from disease risk or freshwater or coastal water quality. It is noted that GWRC will be establishing a coastal monitoring buoy to collect continuous water quality data for key indicators including chlorophyll-a, dissolved oxygen, turbidity, temperature, and salinity. Results from this data set will be reported on separately by GWRC in coming years.

2. OVERVIEW OF ASSESSMENT AND PRIORITISATION

Five high-level attributes are commonly used to define values, to assess how existing pressures may influence values, to define defensible approaches for the prioritisation of further monitoring or investigation, and to identify where management actions may be necessary as follows:

- **Values:** Natural values potentially at risk, partitioning different core values (ecological, economic, social, cultural) from each other as appropriate.
- **Pressures:** Natural and anthropogenic pressures on those values.
- **State:** Current condition with respect to qualitative or quantitative indicators of health or state measures
- **Susceptibility:** Vulnerability to future changes in state, with and without changes to pressures.
- **Management:** Potential to avoid emerging or impending problems, remediate degraded conditions, or restore to a more natural state.

For each of the estuaries and coastal sections in the Kāpiti Coast Whaitua, natural values, pressures, state and susceptibility have previously been defined and summarised (e.g. Stevens & Robertson 2006, Robertson & Stevens 2007b, Stevens 2013, Todd et al. 2016). The assessment of values and pressures in particular reflect judgements based on the expert opinion of the authors, with each report providing narrative criteria to indicate how attributes have been assessed. In the absence of a formal stakeholder consensus process, the results are used as a preliminary guide for ranking monitoring and management priorities relative to each other. These values are summarised in Section 4 for each of the estuaries assessed.

Based on the previous work outlined above, Table 1 provides an overview of the key pressures identified and which are likely to be encompassed within GWRC policy and management objectives. In general terms, the most common ecological pressures are excessive inputs of fine muds, nutrients, toxicants (e.g. stormwater, sewage or industrial discharges and spills), and habitat changes. The latter include habitat losses from reclamation, drainage, piping, land clearance and infrastructure, as well as effects related to climate change such as exacerbated coastal erosion from sea level rise and changing storm intensities. These pressures have variable influences depending on the specific receiving environments they occur in.

Table 1. Common pressures impacting on coastal ecological values

Fine Sediment
Nutrients/Eutrophication
Toxicants (Urban runoff, pesticides)
Coastal Erosion (Sea Level Rise)
Climate Change - pH, temp
Grazing of high value habitat
Freshwater abstraction
Reclamation/Drainage
Harvesting of living resources
Algal blooms
Seawalls, breakwaters etc
Biosecurity (introduced weeds/pests)
Vehicle damage
Loss of vegetated terrestrial margin
Animal/human disturbance of wildlife

In estuaries, catchment inputs of nutrients (eutrophication) and fine sediment (muddiness) remain two of the most significant pressures on ecological condition, recognising that direct habitat loss (e.g. reclamation and drainage) is much less prevalent than in the past due in part to most of the readily modifiable habitat already being lost, and to an increasing awareness of the high ecological value of estuaries.

Eutrophication is a process driven by nutrient enrichment of water and sediment that results in excessive primary production of macroalgae and/or phytoplankton. Fine sediment causes a variety of problems including smothering, altered grain size, reduced clarity, lowered sediment oxygenation and pore water exchange and, because of their strong affinity to adsorb to fine sediments, increased concentrations of nutrients and toxicants. The latter feature means the two issues of eutrophication and sediment muddiness are generally strongly interlinked, with ecological degradation exacerbated when they occur together (e.g. muddy, nutrient-rich sediments generally have increased organic matter, reduced sediment oxygenation, elevated toxic sulphide levels and increased concentrations of other toxicants such as metals).

The key ecological pressures to beaches include habitat loss from sea level rise, sea walls, erosion, vehicle use, human disturbance (including shellfish harvesting), and discharges (stormwater and sewage).

Rocky shores are most susceptible to human harvesting pressure and to longer term climate change influences such as sea level rise or ocean acidification, although reclamation, eutrophication or fine sediment can still be significant pressures. Marine biosecurity issues arising from invasions from pest plants and animals are common to beaches, rocky shores and estuaries.

For further detail on coastal pressures see Robertson and Stevens (2012) and Stevens and Robertson (2017). These reports include preliminary criteria to rate the presence of a pressure and the potential ecological impact associated with it, and from this, define appropriate monitoring indicators.

A range of monitoring indicators commonly used to determine current ecological state in response to key pressures is presented in Table 2, grouped under the broad issues commonly addressed by council policy.

In Section 3, the specific monitoring and assessment methods used for the current project are described.

Table 2. Dominant coastal issues and monitoring indicators commonly used to assess their influence

Issue	Monitoring indicator
Nutrients/Eutrophication	Chlorophyll-a in water
	Macroalgal growth
	Epiphyte abundance
	Dissolved oxygen in water
	Sediment oxygenation
	Nutrient concentrations
	Sediment organic carbon
	Seagrass/Macrophyte loss
	Benthic invertebrates
	Phytoplankton blooms
Fine sediment	Muddiness (extent)
	Sedimentation rate
	Sediment grain size
	Seagrass/Macrophyte loss
	Water clarity
	Benthic invertebrates
Toxicants	Heavy metals
	SVOCs
	Toxic marine algal blooms
Habitat change	Substrate composition
	Seagrass/Macrophytes
	Salt marsh extent
	Vegetated margin cover
	Catchment land use
	Birds
	Fish
	Invasive species
	Benthic invertebrates
	Harvestable shellfish
	Sea level

3. MONITORING METHODS

3.1 ESTUARY MONITORING

The National Estuary Monitoring Protocol (NEMP) (Robertson et al. 2002a,b,c) provides a standard approach for assessing the ecological health of estuaries in order to better understand human influences, and assess changes.

This protocol has been applied to many estuaries since 2001 and, in the years since, the approach has been refined. A recently developed extension has been the ETI. The ETI describes methods and provides screening guidance for assessing where estuaries of different types are positioned on a eutrophication (nutrient enrichment) gradient. It applies several NEMP metrics, alongside new assessment criteria, to the estuary as a whole (i.e. in a broad scale context), as well as at a site-specific level (i.e. in a fine scale context). In this report we use the original NEMP, the ETI and a range of additional metrics (e.g. Forrest & Stevens 2019a) for seagrass, macroalgae, and sedimentation, to assess current state.

3.2 ESTUARY EXTENT AND TYPE

The definition of estuary extent adopted for the current study is that used in the ETI (Robertson et al. 2016a), which defines an estuary as the area between the upper extent of saline intrusion (i.e. where ocean derived salts during average annual low flow are <0.5ppt) and seaward to a straight line between the outer headlands where the angle between the head of the estuary and the two outer headlands is <150°.

Included within such a definition are a range of different estuary types described in a comprehensive typology of NZ estuaries (Hume et al. 2016). This typology has been simplified in the ETI (see Robertson et al. 2016a) as follows:

(1) Shallow Intertidal Dominated Estuaries (SIDEs)

(2) Shallow, Short Residence time Tidal River (and adjoining lagoon) Estuaries (SSRTREs)

(3) Deeper Subtidal Dominated, longer residence time Estuaries (DSDEs).

Sub-types of SIDEs and SSRTREs are Intermittently Closed/Open Lake and Lagoon estuaries (ICOLLs) whose mouths close for variable periods.

In addition to theses broad categories, SSRTREs may be further divided into subcategories based on flow as follows.

Type 1 - Low-flow ($<1m^3.s^{-1}$)

Type 2 - Moderate-flow (≥ 1 to $<5m^3.s^{-1}$)

Type 3 - High-flow ($\geq 5m^3.s^{-1}$)

Each of the subcategory estuaries have variable susceptibilities to nutrients and sediments based on flushing and dilution capacity, those most susceptible to impacts having low flows and long periods of mouth closure, and those least susceptible being well flushed and remaining open. Common to all estuary types with constricted mouths or deep pools is the potential for areas to stratify, trapping denser seawater beneath more buoyant freshwater and allowing phytoplankton blooms to develop where flushing is restricted.

All nine estuaries are SSRTREs. Seven of these are low flow Type 1 SSRTREs (Waitohu, Mangaone, Pekapeka, Waimeha, Tikotu, Wharemauku, Whareroa). They are generally small, short, narrow and occur where stream outlets to the coast are restricted or blocked completely by a sand or gravel barrier just short of the ocean. In such estuaries, a small brackish lagoon may form on the stream side of the barrier, whose size, salinity and water quality varies depending on the duration of closure or degree of restriction, river flow and inflow water quality. The majority of these estuaries are perched at the top of the beach, with intermittent saline water intrusion extending only a few tens to hundred of metres upstream, or not at all. They are characterised by having little or no intertidal habitat or salt marsh, and water and sediments experience regular cycles of degradation and rejuvenation. When the mouth is restricted and stream flows are low, the estuary may experience symptoms of eutrophication and sedimentation (i.e. muddy, anoxic, black sulphide-rich sediments, algal blooms, low dissolved oxygen, high temperatures and low clarity). When the mouth is open or flows are high, the narrow estuary channel is flushed clean. Poor water quality conditions are a natural occurrence, but are exacerbated when sediment and nutrient loadings to the estuaries are elevated (e.g., in catchments with high erosion, intensive agriculture or urban development) or water flows are restricted; e.g. due to upstream abstraction, flap gates or weirs. In many cases the estuaries have been heavily modified by past drainage and channelisation, with mouths opened artificially to reduce flood risks.

In the moderate and high flow SSRTREs (Waikānae, Ōtaki), freshwater flows dominate over tidal flows and flushing is relatively extensive because the mouth is nearly always open and river flow relatively large. Tidal flats are large relative to the smaller ICOLL sub type SSRTREs, but not particularly broad or expansive. The presence of larger areas of salt marsh adds to their ecological value, particularly for birdlife, and the estuaries often support healthy fisheries, including whitebait.

3.3 HABITAT CLASSIFICATION AND MAPPING

Within each estuary, the NEMP was used for classifying and mapping intertidal estuarine habitats based on the dominant surface substrate and vegetation features present. Appendix 1 summarises the key NEMP classes (and extensions) used to define estuarine habitats. For example, substrate is classified as rock, boulder, cobble, and gravel, with sand and mud substrates divided into subcategories based on how much a person walking on the sediment sinks in. Vegetation is classified in broad structural classes (e.g. rush, sedge, herb, grass, reed, tussock) that are defined based on the dominant plant species present.

For the habitat classification mapping undertaken in the current study, ground truthing was undertaken by experienced scientists who walked the estuaries in January 2019 to map the spatial extent of dominant vegetation and substrate. In the field these habitat features were drawn onto laminated aerial photographs printed at a scale of 1:3000. The broad scale features were subsequently digitised into ArcMap 10.6 shapefiles using a Wacom Cintiq21UX drawing tablet, and combined with field notes and georeferenced photographs to produce habitat maps showing the dominant estuary features. The area (horizontal extent) of intertidal mud-dominated sediment is the primary indicator used in the current report to assess fine sediment issues, with macroalgal percent cover (see Section 3.5) used to assess nutrient enrichment.

3.4 SEDIMENT OXYGENATION

The assessment of visually apparent Redox Potential Discontinuity (aRPD) depth provides an easily measured, time integrated, and relatively stable measure of sediment oxygenation and the prevailing oxygenation conditions that infaunal communities are predominantly exposed to. It is a broad scale supporting indicator used in the ETI to help assess enrichment impacts on macrofauna and associated higher trophic communities including birds and fish.

As part of broad scale mapping, sediment aRPD was assessed in representative areas by digging into the underlying sediment with a hand trowel to identify whether there were any significant areas where sediment oxygenation was depleted close to the surface. Sediments were considered to have poor oxygenation if the aRPD was consistently <5mm deep and showed signs of organic enrichment indicated by a distinct colour change to grey or black in the sediments.

Examples of well oxygenated sandy sediment with aRPD >150mm (left) and poorly oxygenated muddy sediment with aRPD <5mm (right).

3.5 MACROALGAL ASSESSMENT

Opportunistic macroalgae are a primary symptom of estuary eutrophication. They are highly effective at utilising excess nitrogen, enabling them to out-compete other seaweed species and, at nuisance levels, can form mats on the estuary surface that adversely impact underlying sediments and fauna, other algae, fish, birds, seagrass, and salt marsh. Macroalgae that becomes detached can also accumulate and decay in subtidal areas and on shorelines causing oxygen depletion and nuisance odours and conditions. Certain types of macroalgae can also become entrained in sediments (i.e. grow within the sediment matrix) and establish persistent growths that trap fine sediment and lead to surface smothering of habitat. The greater the biomass, cover and extent of macroalgal entrainment, the greater the subsequent impacts.

The NEMP provides no guidance on the assessment of macroalgae beyond recording its presence when it is a dominant surface feature. Because opportunistic macroalgae is a primary indicator of nutrient enrichment in SIDEs and SSRTREs, the NZ ETI (Robertson et al. 2016b) adopted the use of the United Kingdom Water Framework Directive (WFD-UKTAG 2014) Opportunistic Macroalgal Blooming Tool (OMBT) for macroalgal assessment. The OMBT is a five part multi-metric index that provides a comprehensive measure of the combined influence of macroalgal growth and distribution in an estuary. It produces an overall Ecological Quality Rating (EQR) ranging from 0 (major disturbance) to 1 (minimally disturbed) and which rates estuarine condition in relation to macroalgal status within overall quality status threshold bands (bad, poor, good, moderate, high). The individual metrics that are used to calculate the EQR include

- Percent cover of opportunistic macroalgae throughout soft sediment habitat in an estuary - the spatial extent and density of algal cover providing an early warning of potential eutrophication issues.

- Macroalgal biomass - providing a direct measure of macroalgal growth and enabling estimates of mean biomass to be made within areas affected by macroalgal growth, as well across the total estuary area.
- Extent of algal entrainment in sediment - highlighting where persistent macroalgal growths have established.

If an estuary supports <5% opportunistic macroalgal cover within the Available Intertidal Habitat (AIH), then the overall quality status is reported as 'high' with no further sampling required.

Using this approach for the nine Kāpiti estuaries, macroalgae patches were mapped to the nearest 10% using a 6-category percent cover rating scale as a guide to describe density (see Fig. 2). Within these percentage cover categories, representative patches of comparable macroalgal growth were identified and the biomass and the degree of macroalgal entrainment were measured.

Biomass was measured by collecting algae growing on the surface of the sediment from within a defined area (e.g. 25x25cm quadrat) and placing it in a sieve bag. The algae was then rinsed to remove sediment. Any non-algal material including stones, shells and large invertebrate fauna (e.g. crabs, shellfish) were also removed. Remaining algae were then hand squeezed until water stopped running, and the wet weight of algae was recorded to the nearest 10g using a 1kg Pesola light-line spring scale. Macroalgae were defined as entrained when growing >30mm deep within sediments. When sufficient representative patches had been measured to enable biomass to be reliably estimated, additional subjective biomass estimates were made following the OMBT method (WFD-UKTAG 2014). Macroalgal data were recorded electronically in templates that were custom-built using Fulcrumapp software (www.fulcrumapp.com). Pre-specified constraints on data entry (e.g. with respect to data type, minimum or maximum values) ensured that the risk of erroneous data recording was minimised. Each sampling record created in Fulcrum generated a GPS position, which was exported to Arcmap. Macrofauna OMBT scores were calculated using the WFD-UKTAG excel template.

3.6 SEAGRASS ASSESSMENT

Seagrass (*Zostera muelleri*) beds are important ecologically because they enhance primary production and nutrient cycling, stabilise sediments, elevate biodiversity, and provide nursery and feeding grounds for a range of invertebrates and fish. Though tolerant of a wide range of conditions, seagrass is vulnerable to fine sediments in the water column (reducing light), sediment smothering (burial), excessive nutrients (primarily secondary impacts from macroalgal smothering), and sediment quality (particularly if there is a lack of oxygen and production of sulphides).

The NEMP provides no guidance on the assessment of seagrass beyond recording its presence when it is a dominant surface feature. To improve on the present NEMP method, the mean percent cover of discrete seagrass patches was visually assessed to the nearest 10% based on the 6-category percent cover rating scale presented in Fig. 2.

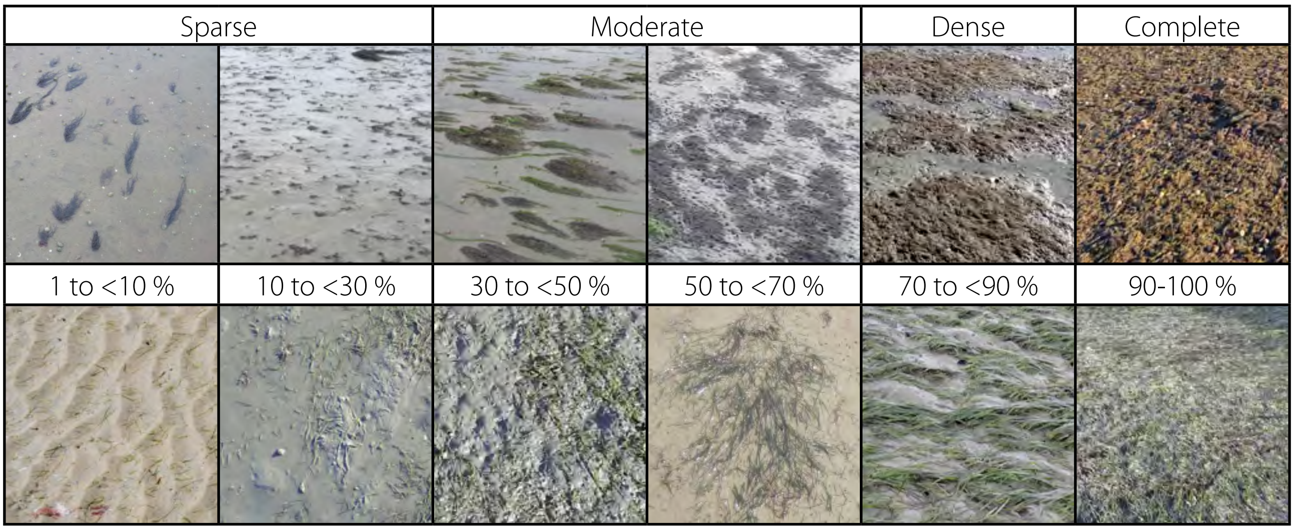


Fig. 2. Visual rating scale for percentage cover estimates. Macroalgae (top), seagrass (bottom).
Modified from FGDC (2012).

3.7 SALT MARSH ASSESSMENT

Salt marsh (vegetation able to tolerate saline conditions where terrestrial plants are unable to survive) is important as it is highly productive, naturally filters and assimilates sediment and nutrients, acts as a buffer that protects against introduced grasses and weeds, and provides an important habitat for a variety of species including fish and birds. Salt marsh generally has the most dense cover in the sheltered and more strongly freshwater influenced upper estuary, and relatively sparse cover in the lower (more exposed and saltwater dominated) parts of the estuary, with the lower limit of salt marsh growth restricted for most species to above the height of mean high water neap (MHWN) tide.

In this report two measures were used to assess salt marsh condition; i) intertidal extent (percent cover) and ii) current extent compared to historical extent. The latter was assessed using expert judgement based on the degree of modification of the estuaries.

3.8 SYNOPTIC WATER QUALITY MEASURES

Water quality measures were made *in situ* using a YSI Pro10 mulitmeter (pH/salinity/dissolved oxygen/temperature) and a Delrin Cyclops-7F fluorometer with chlorophyll optics and Databank datalogger. Water quality measurements were collected ~20cm below the water surface, and ~20cm above the sediment surface, with care taken not to disturb bottom sediments before sampling. Thermocline and halocline depths were recorded as the average depth of abrupt changes in temperature and salinity, respectively, recorded on the up- and down-cast meter deployments. A modified secchi method was used to estimate vertical water clarity. All data were recorded electronically in the field in templates that were custom-built using Fulcrumapp software (www.fulcrumapp.com).

Although subject to high spatial and temporal variation, water column measures provide a useful tool for the synoptic appraisal of ecological condition. Salinity measures provide a simple way for determining the upstream extent of the estuary and indicate where stable areas of saline water may be trapped, with phytoplankton potentially able to grow and bloom in the retained water. Waters that are high in phytoplankton typically reflect situations where nutrient supply is high and flushing is low. The nutrients facilitate rapid algal growth but when algal blooms crash and die, they deplete dissolved oxygen levels which can adversely impact both sediment-dwelling and water column communities, and are a primary cause of most fish kills.

The ETI provides criteria for assessing phytoplankton (an optional primary indicator of nutrient enrichment), and for 1-day instantaneous dissolved oxygen minima in the water column measured from representative areas (including likely worst-case conditions). Criteria for nutrient concentrations remain under development.

3.9 ASSESSMENT OF ESTUARY VALUES

Todd et al. (2016) recently assessed the ecological, economic, social and cultural values, and the significance, status and future management options of estuarine systems in the lower North Island/Te Ika-a-Māui using a defined set of criteria (see Appendix 2). The work complements an earlier ranking prepared by Stevens (2013) as part of regional oil spill response planning for GWRC which provides an overall ranking using a simple additive scoring method. The current report adopts the values and rankings determined in these previous assessments.

3.10 ASSESSMENT OF ESTUARY CONDITION AND TEMPORAL CHANGE

Because existing habitat maps exist for most of the coastline in the Kāpiti Coast Whaitua, and previous vulnerability assessments have been undertaken, the synoptic field assessments used in the current study sought primarily to identify whether there had been any significant changes to mapped habitat estuary features or obvious changes to the coastal stressors present.

Basic QA/QC was undertaken on existing GIS data where relevant to review previous classifications, check for duplicated or overlapping GIS polygons, validate typology and cross-check the calculation of areas or percentages. Where discrepancies were identified between GIS data and results presented in associated reports, underpinning GIS data were used to produce summary statistics.

The results are used to assess estuary condition in response to common stressors such as fine sediment inputs, nutrient enrichment or habitat loss. In addition to the authors' interpretation of the data, results are assessed within the context of established or developing estuarine health metrics ('condition ratings'), drawing on approaches from NZ and overseas (Table 3). These metrics assign different indicators to one of four 'health status' bands, colour-coded as shown in Table 3. Most condition ratings are sourced from the ETI (Robertson et al. 2016b).

As an integrated measure of the combined presence of indicators which may result in adverse ecological outcomes, the occurrence of 'High Enrichment Conditions' (HEC) was evaluated. HECs have sediments with elevated organic content (>1% TOC) and/or dense macroalgal cover (>50%), combined with an elevated mud content (≥25% mud) and low sediment oxygenation (<10mm) or water column oxygenation (<4mg/l). HECs are also referred to alternatively as 'Gross Nuisance Areas' (GNAs) in the ETI (Zeldis et al. 2017). Once HECs establish, they are generally difficult to reverse and are likely to cause significant adverse ecological impacts on sediment-dwelling animals.

3.11 SEDIMENT AND NUTRIENT SUSCEPTIBILITY

Because sediment and nutrients have been identified previously as key issues, estuarine pressure-state responses have been assessed primarily using Tools 1 and 2 of the ETI (Zeldis et al. 2017). Tool 1 provides an indication of susceptibility to these issues through the combined use of estuary physical characteristics and predicted responses to modelled nutrient and sediment loads. Tool 2 uses monitoring results (largely collected using the NEMP), and defined criteria to assess state across four condition bands.

Much of the data supporting the ETI is sourced from NIWA's CLUES model, including estimates of freshwater flow, and nitrogen (TN), phosphorus (TP) and suspended sediment (SS) loads for each estuary catchment. For further details on the CLUES framework see Semadeni-Davies et al. (2011, 2015), Elliot et al. (2016).

The CLUES Estuaries model does not yet include estimates for many of the smaller coastal estuaries found in NZ, and nutrient thresholds included in the ETI have only been developed for larger estuaries that are not ICOLLs. Consequently, additional guidance on susceptibility in the smaller ICOLL estuaries on the Kāpiti Coast has been based on total nitrogen areal load criteria [(mgN/d)/estuary area (m^2)] proposed by Robertson and Stevens (2016) as follows:

1. SSRTREs with long periods of mouth closure or restriction (months): Low susceptibility to eutrophication if areal TN load <35mg/m^2/d.
2. SSRTREs with short periods of mouth closure or restriction (days to weeks), or with extensive poorly flushed high value habitat; i.e. estuaries with long water column residence time: Low susceptibility to eutrophication if areal TN load <100-250mg/m^2/d.
3. SSRTREs with mouth always open or mouth generally open with short periods of mouth closure or restriction (days to weeks) and no significant areas of poorly flushed high value habitat; i.e. a well flushed water column: Low susceptibility to eutrophication if areal TN load <2000mg.m^2/d.

TN load estimates were derived using the NIWA CLUES model (Version 10.6, released Feb 2019 default setting using REC2 and LCBB4 (2012/2013) land cover).

In addition to the above, land cover sourced from the Landcare Research Land Cover Data Base (LCDB4

Table 3. Indicators used to assess results in the current report

Indicator	Unit	Very Good	Good	Moderate	Poor
Broad scale spatial indicators					
Mud extent[1]	% of estuary	< 1	1-5	> 5-15	> 15
Macroalgae (OMBT)[1]	EQR	≥ 0.8 - 1.0	≥ 0.6 - < 0.8	≥ 0.4 - < 0.6	0.0 - < 0.4
Seagrass[2]	% decrease from baseline	< 5	≥ 5-10	≥ 10-20	≥ 20
Salt marsh extent[2]	% of intertidal area	≥ 20	≥ 10-20	≥ 5-10	0-5
Historical salt marsh area[2]	% remaining	≥ 80-100	≥ 60-80	≥ 40-60	< 40
200m terrestrial margin[2]	% densely vegetated	≥ 80-100	≥ 50-80	≥ 25-50	< 25
High Enrichment Conditions (HEC)[1,3]	ha or % of estuary	< 0.5ha or < 1%	≥ 0.5-5ha or ≥ 1-5%	≥ 5-20ha or ≥ 5-10%	≥ 20ha or ≥ 10%
NZ ETI[1]	ETI score	0-0.25	>0.25-0.5	>0.5-0.75	>0.75-1.0
Sediment Quality					
Mud content[1]	%	< 5	5 to < 10	10 to < 25	≥ 25
aRPD depth[1]	mm	≥ 50	20 to < 50	10 to < 20	< 10

1. General indicator thresholds derived from the New Zealand Estuary Tropic Index, with adjustments for aRPD as described in FGDC (2012).

2. Subjective indicator thresholds derived from previous broad scale mapping assessments.

3. HEC termed GNA (Gross Nuisance Area) in the ETI, and referred to interchangeably elsewhere as GEZ (Gross Eutrophic Zones).

2012/13) has been summarised for each catchment as an indicator of the dominant terrestrial pressures (Fig 3).

3.12 PRESENTATION OF FINDINGS

The following section provides a high level summary for each estuary of the previously identified values, the key stressors present (drawing extensively from Robertson & Stevens 2007b and Todd et al. 2016), current state, and the extent of any significant conspicuous changes since 2007. Summaries, ordered geographically from north to south, include maps of the dominant substrate and vegetation cover and field photos of each estuary. Note that the map legend is standardised and not all items are necessarily present in all estuaries.

As a visual aid, the following colour bands have been applied to relative ratings of values and pressures.

Very Low	Low	Moderate	High	Very High

The majority of the background information and data used to assess each estuary is appended as follows:

Appendix 1. Broad scale habitat classification definitions

Appendix 2. Criteria for assessing estuary values

Appendix 3. ETI Scoring criteria

Appendix 4. ETI Tool 1 Input data

Appendix 5. ETI susceptibility and scores

Appendix 6. Summary of water quality data collected in January 2019

Appendix 7. Dominant catchment land cover (LCDB4 2012/13).

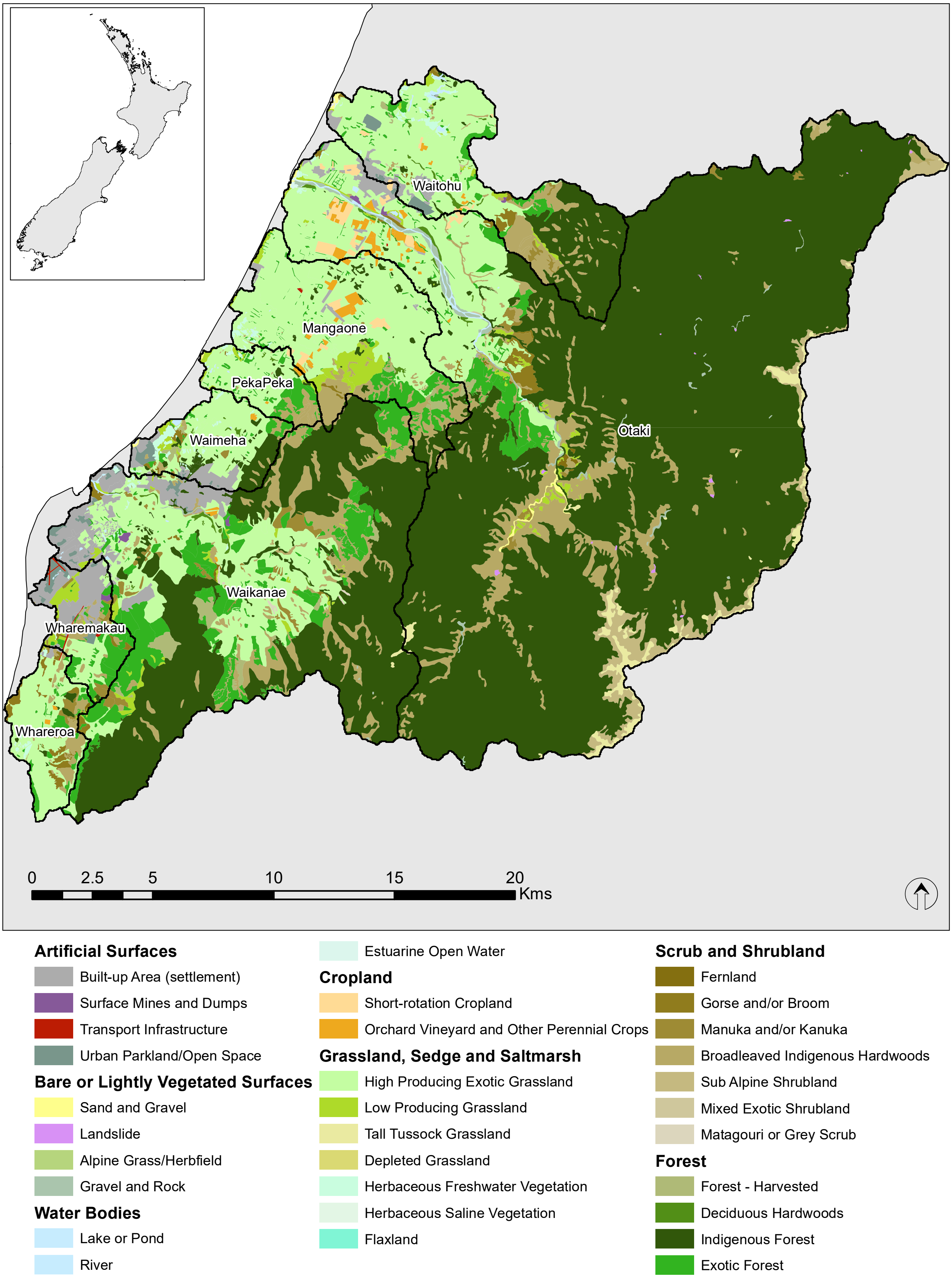


Fig. 3. Map showing estuary catchments and dominant land cover (LCDB4 2012/13). A tabulated summary for each catchment is presented in Appendix 7.

4. RESULTS

4.1 WAITOHU ESTUARY

General description

Waitohu Estuary is a relatively small (11ha) tidal river mouth estuary located just north of the Ōtaki River. The estuary is shallow (mean depth <0.5m) and has two distinct sections. The upper estuary is relatively deep (>1.5m) and confined within stable steep-sided river banks with no appreciable intertidal habitat. Near the coast the channel is much shallower (~0.25m) and its location varies widely as it meanders 500-800m over the beach, intermittently creating a shallow lagoon on the upper beach to the north of the estuary. The mouth can occasionally block for short periods as a consequence of coastal sand accretion. Salinity is commonly low due to limited tidal inflow, with estuary water generally clear but humic stained. Sediments are sand-dominated and well oxygenated, but muddier in the upper stream channel.

Human Uses and Values

The estuary is seasonally popular for whitebaiting, swimming, and walking with recreational fishing, picnickers, motorbikers, 4WDs and quad bikes common on the open coast.

Ecological Values

The estuary provides important habitat for a variety of shorebirds, waders and waterfowl and thirteen migratory native freshwater fish have been found in the catchment, including ten species that are listed as 'At Risk: Declining' (shortfin eel, brown mudfish, longfin eel, giant kōkopu, shortjaw kōkopu, kōaro, inanga, redfin bully, torrrentfish and lamprey; Allibone et al. 2010).

It is likely to support a relatively impoverished estuarine sediment dwelling community due to the strong freshwater influence and riverine nature of the estuary.

An area of approximately 2ha of residual salt marsh is present on both banks near the upper tidal extent. These areas are dominated by a mix of sea rush, salt marsh ribbonwood and tall fescue, with additional native species being planted as part of active riparian restoration initiatives. Due to channelisation and drainage, these areas are likely to be only infrequently inundated with freshwater; i.e. during floods.

The middle estuary is flanked by high introduced marram dunes with small pockets of native sand-binding pingao and spinifex fenced for protection.

SUMMARY INFORMATION	
Estuary area (Ha)	11.2
% Intertidal	86
Dominant estuary substrate	Sand
Mean length (m)	1000
Mean depth (m)	0.3
Mouth opening regime (closure period)	ICOLL, days
Macroalgae (Ha density >50% cover)	0
Seagrass (Ha density >50% cover)	0
Salt marsh (Ha)	0.31
Catchment area (Ha)	4842
Dominant catchment land cover	High Producing Exotic Grassland
Catchment geology	Greywacke, Alluvium, Peat
Mean freshwater flow (m^3/s)	0.96
Catchment nitrogen load (TN/yr)	48.1
Catchment phosphorus load (T/Pyr)	3.1
Catchment sediment load (KT/yr)	4.5
N areal load in estuary ($mg/m^2/d$)	1176
P areal load in estuary ($mg/m^2/d$)	75

VALUES	RATING
Ecosystem	Moderate
Social/Cultural	High
Restoration Potential	High
Overall Value Rating	High

PRESSURES	
Reduced estuary habitat diversity, water quality and dune condition	
Variable cycles of low to high water quality linked to mouth constriction	
Artificial openings	
Vehicle impacts	
Introduced weeds and pest animals	
Catchment flow alterations (abstraction, diversion)	
Current Pressure Rating	Moderate

CONDITION RATINGS	SCORE/RATING
Intertidal soft mud extent (%)	0
Macroalgae (OMBT EQR)	1
Seagrass (decrease from baseline)	< 5
Salt marsh (% of estuary)	3
Historical salt marsh (% remaining)	20
Densely vegetated 200m margin (%)	60
High Enrichment Conditions (ha, %)	0
NZ ETI Susceptibility Rating	Low
NZ ETI Score (Band)	0.26 (B)

Salt marsh
- Apodasmia similis (Jointed wirerush)
- Ficinia (Isolepis) nodosa (Knobby clubrush)
- Schoenoplectus pungens (Three-square)
- Selliera radicans (Remuremu)

Dominant Substrate
- Boulder field man-made
- Firm muddy sand
- Firm sand
- Gravel field
- Soft mud
- Water
- Water Quality Measure Jan 2019

Fig. 4. Aerial photo showing Waitohu Estuary features and location of spot water quality measurements

River channel cutting through firm sands at the top of the beach

Sand dune and raised banks in the confined upper estuary channel

Three square (foreground) and pingao (background) in the middle estuary

Three square with rushland in the distance in the old river channel in the northeast arm

Clean well oxygenated sands dominate the estuary

Native *Spinifex* and introduced tree lupin in front of the lower estuary

Meandering channel in the lower estuary

Multiple tyre tracks along the estuary channel edge

Salt marsh generally transitions from a narrow margin of three square, to a mix of jointed wire rush, flax, sea rush and raupō at the terrestrial edge. An extensive bed of salt marsh dominated by three square is present in a residual channel area to the north, although there is a strong terrestrial influence developing here due to limited inundation with saline water. Beyond the thin marginal band of estuarine vegetation is grazed pasture.

GWRC has identified Waitohu Estuary as a site with high biodiversity values under the Key Native Ecosystem (KNE) programme. The KNE Plan for Waitohu Coast and Wetlands 2017-2020 (http://www.gw.govt.nz/assets/council-publications/Waitohu-Coast-and-Wetlands-KNE-Plan-2017-20.pdf) provides detailed information about the site's values, threats to those values, and actions that will be carried out to protect and restore the site.

Pressures

Because the estuary is small and dominated by freshwater inputs, its quality is expected to be similar to that of the stream for much of the time. Water quality is monitored at Norfolk Crescent (GWRC site RS04) and consistently scores 'poor' (Perrie 2007, 2008, 2009; Perrie & Cockeram 2010; Perrie et al. 2012; Morar & Perrie 2013, Keenan & Morar 2015). This is likely related to 44% of the catchment being high producing grassland, predominantly dairy farming.

Estimated nitrogen loads (the major driver of eutrophication) are below thresholds where major problems are expected, however when the mouth becomes constricted or blocked, the estuary is more susceptible to eutrophication (e.g. nuisance algal blooms, low dissolved oxygen and enriched sediments), and may become muddier with reduced water clarity.

Pest species present include common weeds (blackberry, tree lupin, pampas grass, pine trees) and wild rabbits and hares are a significant problem.

Historically the mouth opening has been artificially managed to minimise water quality deterioration, dune erosion and flood risk. A consequence of such management is that it prevents the natural development of stable lagoon areas behind the dunes, which reduces habitat diversity, limits salt marsh development, and restricts the capacity of the estuary to naturally assimilate sediments and nutrients.

Dune management to stabilise the mouth, minimising extent of earth moving associated with mouth opening, and land use monitoring is therefore recommended as a means of identifying potential threats to the values of this estuary.

Overall Condition

There have been no significant conspicuous changes to estuary condition since the 2007 survey.

Waitohu Estuary has moderate ecological value including relatively extensive salt marsh habitat which has been lost from many of the smaller estuaries on the Kāpiti Coast. It has low eutrophication susceptibility from nutrient inputs and showed no signs of excessive nutrient enrichment in January 2019.

Current pressures on the estuary are moderate and are predominantly a consequence of catchment influences (flow restrictions, flooding, poor water quality), although vehicle use and managed mouth openings also cause ecological impacts.

Human use and interest in the estuary is high and supported by active community restoration initiatives with pest and weed control and riparian planting of the estuary fringes and dune. There is good potential for ongoing habitat restoration at this site.

4.2 ŌTAKI ESTUARY

General description

Ōtaki Estuary is a moderate sized (19ha) estuary at the mouth of the Ōtaki River. The estuary is dominated by river flows and is well-flushed with a series of braided channels. The location of the mouth varies widely as it meanders 500-800m over the beach, intermittently creating shallow backwaters behind the upper beach berm. The mouth can very occasionally block for short periods as a consequence of coastal accretion. To the north where the flood gate controlled Rangiuru and Ngātoko streams enter the estuary there is a relatively extensive mud flat with small areas of rushland and relatively extensive riparian plantings. Salinity is low due to limited tidal inflow, with estuary water fluctuating between clear and turbid depending on river flow. Water quality is generally high, reflecting the dominance of indigenous forest cover in the catchment (74%). Sediments in the main river are gravel and cobble-dominated and well oxygenated but provide little opportunity for salt marsh to establish.

Human Uses and Values

The estuary is seasonally popular for whitebaiting, walking, with recreational fishing, picnickers, surfers, swimmers, motorbikers, 4WDs and quad bikes common on the open coast.

Ecological Values

Due to the coarse and mobile nature of the bed, low habitat diversity, scarcity of salt marsh, salinity fluctuations and strong water currents, estuarine productivity and biodiversity is expected to be low. However, it provides important habitat for a variety of shorebirds, waders and waterfowl. Ten migratory native freshwater fish species have been found in the catchment, including seven species that are listed as 'At Risk: Declining' (longfin eel, giant kōkopu, shortjaw kōkopu, kōaro, inanga, redfin bully and torrentfish; Allibone et al. 2010). Taylor & Kelly (2001) recorded inanga in the northern lagoon.

Intertidal salt marsh is scarce (0.02ha) although areas of residual salt marsh are present on both banks near the upper tidal extent. These are dominated by introduced grasses and common freshwater tolerant species including raupō, three square, bachelor's button, slender clubrush, shore primrose, remuremu and mudwort, and small areas of wīwī. The northern side of the river in particular has had significant effort put into replanting with native species. Due to channelisation and drainage, these areas are likely to be only

SUMMARY INFORMATION	
Estuary area (Ha)	19
% Intertidal	66
Dominant estuary substrate	Sand
Mean length (m)	800
Mean depth (m)	3.0
Mouth opening regime (closure period)	ICOLL, days
Macroalgae (Ha density >50% cover)	0
Seagrass (Ha density >50% cover)	0
Salt marsh (Ha)	0.02
Catchment area (Ha)	35763
Dominant catchment land cover	Indigenous Forest
Catchment geology	Greywacke, Alluvium
Mean freshwater flow (m^3/s)	30.77
Catchment nitrogen load (TN/yr)	277.0
Catchment phosphorus load (T/Pyr)	67.9
Catchment sediment load (KT/yr)	128.7
N areal load in estuary ($mg/m^2/d$)	3994
P areal load in estuary ($mg/m^2/d$)	980

VALUES	RATING
Ecosystem	Moderate
Social/Cultural	High
Restoration Potential	High
Overall Value Rating	High

PRESSURES	
Water quality deterioration	
Stream channelisation and floodgates	
Intensive lowland land use	
Vehicle impacts	
Introduced weeds and pest animals	
Catchment flow alterations (abstraction, diversion)	
River channel and flood management	
Current Pressure Rating	Moderate

CONDITION RATINGS	SCORE/RATING
Intertidal soft mud extent (%)	14
Macroalgae (OMBT EQR)	1
Seagrass (decrease from baseline)	< 5
Salt marsh (% of estuary)	0.2
Historical salt marsh (% remaining)	5
Densely vegetated 200m margin (%)	10
High Enrichment Conditions (ha, %)	0
NZ ETI Susceptibility Rating	Low
NZ ETI Score (Band)	0.29 (B)

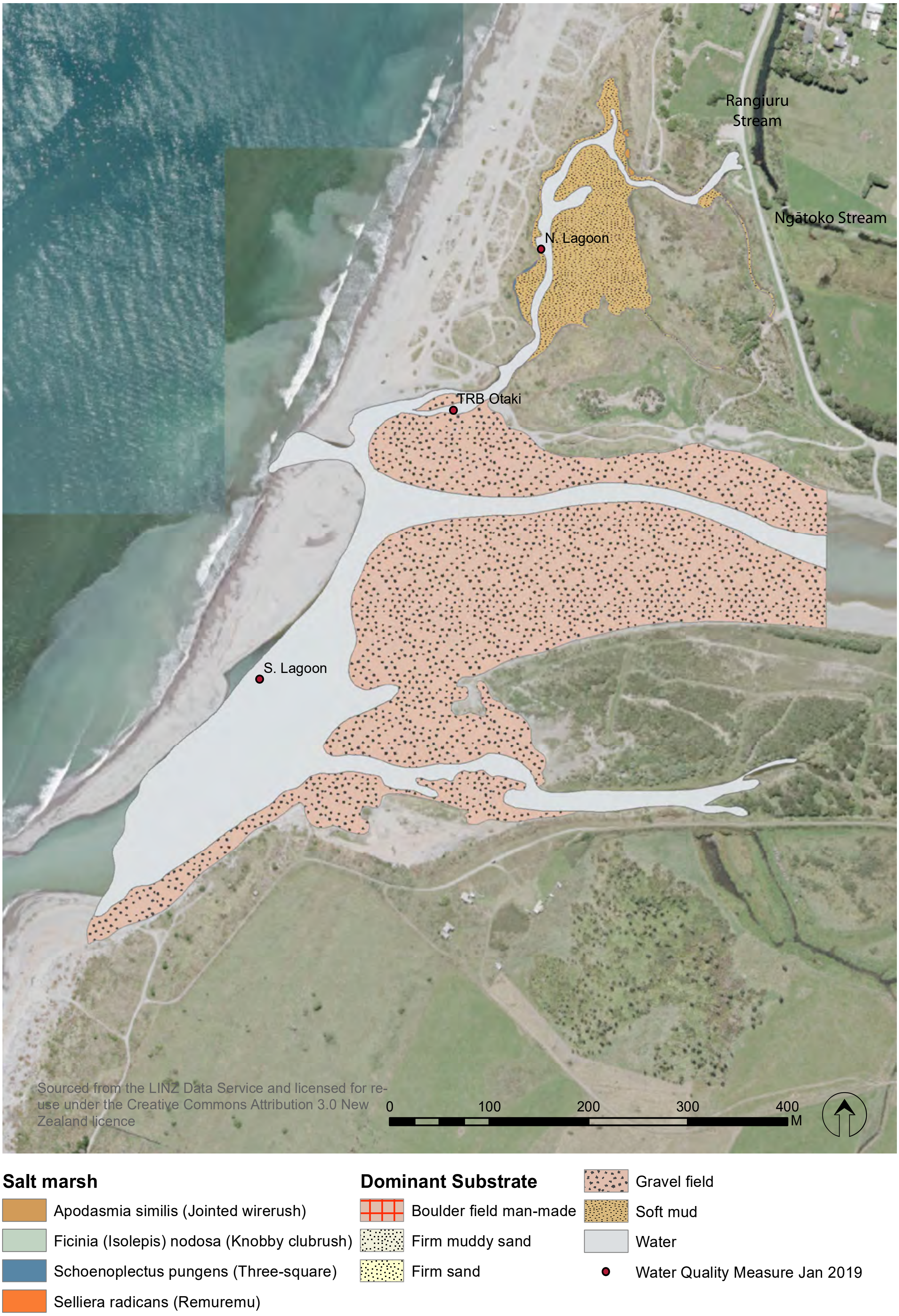


Fig. 5. Aerial photo showing Ōtaki Estuary features and location of spot water quality measurements

Estuary entrance cutting through gravel at the top of the beach

Stream channel exiting the northern lagoon into the main river

Unvegetated cobble and gravel habitat dominates the estuary

Driftwood and cobbles on the dynamic coastal margin of the estuary

Steep cobble habitat around the southern edge of the estuary

Flow control gates on the streams entering the northern lagoon

Algal film growing on cobble

Flax and grass dominated habitat surrounding the northern lagoon infrequently inundated with freshwater; i.e. during floods with salt water inundation very unlikely.

The beach edge of the estuary is sparsely covered with introduced marram grass, iceplant and knobby clubrush. Small pockets of native sand-binding pingao and spinifex are also present while the surrounding margin vegetation is dominated by gorse and flax scrub and grassland.

Because the estuary is moderately large and dominated by freshwater inputs, its quality is expected to be similar to that of the river for much of the time. Generally, water quality is high in the Ōtaki, rated as 'good'-'excellent' according to the monitoring site at the river mouth (GWRC site RSO6; Perrie 2007, 2008, 2009; Perrie & Cockeram 2010; Perrie et al. 2012; Morar & Perrie 2013; Keenan & Morar 2015), although there is no monitoring of the Rangiuru Stream which drains into the northern lagoon.

GWRC has identified Ōtaki Estuary as a site with high biodiversity values under the Key Native Ecosystem (KNE) programme. The KNE Plan for Ōtaki Coast 2015-2018 (http://www.gw.govt.nz/assets/council-publications/Key-Native-Ecosystem-Plan-for-Otaki-Coast-2015-2018.pdf) provides detailed information about the site's values, threats to those values, and actions that will be carried out to protect and restore the site.

Pressures

Strong flushing of the estuary means the major pressures evident are weed invasion of margins, and flood control gates on drains/streams entering the estuary area. Pest species present include common weeds (blackberry, tree lupin, pampas grass, gorse) and there was evidence of significant numbers of wild rabbits and hares. Stoats and ferrets are also present.

Eutrophication or sedimentation pressures are low with estimated nitrogen loads (the major driver of eutrophication) well below thresholds where major problems are expected.

Flood control measures are extensive with stopbank construction along ca 4km of both banks of the lower river.

Overall Condition

There have been no significant conspicuous changes to estuary condition since the 2007 survey.

Ōtaki Estuary has moderate ecological value primarily bird and fish habitat, although the latter is constrained by flood control measures and tidal gates. Estuarine biodiversity is relatively low due to the low diversity of substrate types and limited presence of salt marsh. It has low eutrophication susceptibility from nutrient inputs and showed no signs of excessive nutrient enrichment in January 2019.

Current pressures on the estuary are moderate and are predominantly a consequence of flood control measures, terrestrial weed invasion, and vehicle use.

Human use and interest in the estuary is high and supported by active community restoration initiatives with pest and weed control and riparian planting of the northern estuary fringes. There is good potential for ongoing habitat restoration at this site.

4.3 MANGAONE ESTUARY

General description

Mangaone Estuary is a small (0.4ha) estuary ca 6.5km south of the Ōtaki River mouth. It is stream dominated and is well-flushed when open, but the mouth frequently blocks and is artificially opened under GWRC regional coastal plan rules to mitigate the risk of flooding. Under un-managed conditions the mouth meanders ca 500m along the beach with a narrow and shallow shore-parallel lagoon developing at times, and a deeper pool (1-2m) present where the streamway reaches the coast. The upper beach and estuary sediments are predominantly cobble and gravel with an intermittent and variable cover of sand.

The upper estuary is highly modified with the stream mouth diverted in the 1950's, the banks channelised, and the estuary margins drained for pasture. There are small residual areas of salt marsh vegetation (dominated by wīwī, ōioi and flax) present in front of the settlement of Te Horo, but these are no longer connected to the estuary.

Salinity is low due to limited tidal inflow. Predicted nutrient concentrations in estuary are very high, and water quality is frequently low, reflecting the dominance of high producing exotic grassland in the catchment (60%). At the time of sampling, sediments in the main river were gravel and cobble-dominated and well oxygenated.

Human Uses and Values

The estuary is directly adjacent to the settlement of Te Horo and provides a well-used beach vehicle access point. It seasonally popular for walking, recreational fishing, picnickers, surfers, swimmers, and motorbikers, 4WDs and quad bikes are common on the open coast. Some whitebaiting is likely.

Ecological Values

The Mangaone Stream, estuary and wetland are included in the GWRC Key Native Ecosystem (KNE) Plan for the Ōtaki Coast. This document notes that stream is largely modified and degraded but the Mangaone Restoration Group have been active in planting its banks with native species such as mānuka, taupata, koromiko, coastal tree daisy and cabbage tree from the early 2000s.

Due to the coarse and mobile nature of the estuary bed, low habitat diversity, scarcity of salt marsh, salinity fluctuations and channelisation of the upper streamway, estuarine productivity and biodiversity is low. The loss of salt marsh has allowed for a vari-

SUMMARY INFORMATION	
Estuary area (Ha)	0.4
% Intertidal	50
Dominant estuary substrate	Sand
Mean length (m)	250
Mean depth (m)	0.1
Mouth opening regime (closure period)	ICOLL, days
Macroalgae (Ha density >50% cover)	0
Seagrass (Ha density >50% cover)	0
Salt marsh (Ha)	0
Catchment area (Ha)	4770
Dominant catchment land cover	High Producing Exotic Grassland
Catchment geology	Greywacke, Alluvium, Sand
Mean freshwater flow (m^3/s)	0.84
Catchment nitrogen load (TN/yr)	46.0
Catchment phosphorus load (T/Pyr)	3.6
Catchment sediment load (KT/yr)	3.0
N areal load in estuary ($mg/m^2/d$)	31511
P areal load in estuary ($mg/m^2/d$)	2459

VALUES	RATING
Ecosystem	Low
Social/Cultural	Moderate
Restoration Potential	Moderate
Overall Value Rating	Moderate

PRESSURES
Stream channelisation and salt marsh drainage
Intensive lowland land use
Water quality deterioration
Vehicle impacts
Introduced weeds
Catchment flow alterations (abstraction, diversion)
Mechanical mouth opening and flood management
Current Pressure Rating: Moderate

CONDITION RATINGS	SCORE/RATING
Intertidal soft mud extent (%)	0
Macroalgae (OMBT EQR)	1
Seagrass (decrease from baseline)	< 5
Salt marsh (% of estuary)	0
Historical salt marsh (% remaining)	0
Densely vegetated 200m margin (%)	20
High Enrichment Conditions (ha, %)	0
NZ ETI Susceptibility Rating	Very High
NZ ETI Score (Band)	0.3 (B)

Salt marsh

- Apodasmia similis (Jointed wirerush)
- Ficinia (Isolepis) nodosa (Knobby clubrush)
- Schoenoplectus pungens (Three-square)
- Selliera radicans (Remuremu)

Dominant Substrate

- Boulder field man-made
- Firm muddy sand
- Firm sand
- Gravel field
- Soft mud
- Water
- Water Quality Measure Jan 2019

Fig. 6. Aerial photo showing Mangaone Estuary features and location of spot water quality measurements

Estuary entrance cutting through gravel and sand at the top of the beach

Stream channel immediately upstream of the estuary

Sand is common on the lower beach in contrast to cobble and gravel which dominates in the estuary

Shallow pool in the upper estuary. Wind blown sand overlies cobble

Extensive driftwood washed to the upper beach south of the estuary entrance

Middle estuary where the stream channel flows parallel to the shore before discharging across the beach

Freshwater pool at the top of the estuary

Residual salt marsh now drained and cut off from the estuary ety of weeds to establish, including reed sweetgrass, oxygen weed and cape pondweed, with small patches of raupō and flax the only native species obvious.

The estuary and adjacent coast provide important habitat for a variety of shorebirds, waders and waterfowl. Six migratory native freshwater fish species have been reported from the wider catchment, including seven species that are listed as 'At Risk: Declining' (longfin eel, shortjaw kōkopu, kōaro, inanga, redfin bully (GWRC KNE Plan for the Ōtaki Coast).

GWRC water quality data indicate clarity is relatively poor, with elevated fine sediment deposition, with nutrient concentrations rated 'good' (Band B).

Pressures

The major pressures evident are weed invasion of margins, and a natural cycle of low to high water quality as the degree of mouth restriction varies. Pest species present include common weeds (blackberry, tree lupin, pampas grass, gorse, introduced grasses). Eutrophication and fine sediment pressures are slightly elevated, commensurate with the dominant land cover of the catchment being pastoral grazing, but due to regular flushing of the estuary significant eutrophication symptoms do not appear to be present.

There is the potential for forest harvesting (9% of the catchment) to impact on the estuary if mitigation measures are not adequate.

Vehicle access and mechanical mouth opening regularly disturb localised parts of the foreshore.

Overall Condition

There have been no significant conspicuous changes to estuary condition since the 2007 survey.

Although Mangagone Estuary is included within the GWRC KNE Plan for the wider Ōtaki coast, its flood-prone nature and past modification, regular mouth closures (which cause water quality to be highly variable) and coarse sediment types mean estuarine biodiversity is relatively low. Despite these limitations, it supports limited salt marsh, provides bird and fish habitat, and has low eutrophication susceptibility from nutrient inputs. The estuary showed no signs of excessive nutrient enrichment in January 2019.

Current pressures on the estuary are moderate and predominantly arise from flood control measures, terrestrial weed invasion, and vehicle use.

Human use and interest in the estuary is moderate-high and supported by active community restoration initiatives with pest and weed control and riparian planting of the estuary fringes. There is good potential for ongoing habitat restoration at this site.

4.4 PEKA PEKA ESTUARY

General description

Peke Peka Estuary is a small (2.2ha) estuary located ca halfway between Mangaone Estuary in the north and Waimeha Estuary in the south where the Kukutauaki Stream (also known as Hadfields Stream) enters the beach through a gap in the coastal dune system.

The estuary is narrow (ca 5m) and shallow (0.1m) and stream-dominated with a low flow. The stream mouth meanders ca 300m along the beach creating a wide delta with a relatively stable fulcrum centred ca 90m inland from the dune toe. Salinity in the upper estuary is low due to limited tidal inflow while the coastal delta has a small freshwater influence because of the low stream flow.

The upper streamway is narrow and confined. It passes through grass-dominated marram and spinifex dunes with much of the surrounding land developed and modified for grazing. Low density residential housing is established in the back dune areas.

The mouth occasionally blocks as a result of coastal sand accretion, but is unlikely to remain closed for prolonged periods. Waves also wash into the upper estuary at times depositing large volumes of driftwood.

Human Uses and Values

Recreational use of the estuary is relatively low. Several tracks run through the dune systems providing foot access, and vehicles regularly drive along the coast. The beach attracts a moderate number of seasonal swimmers, picnickers and recreational fishers.

Ecological Values

The stream, estuary and dune system are included in the GWRC Key Native Ecosystem (KNE) Plan for the Peka Peka Coast, although little specific detail is provided on the estuary. Across the KNE site shorebirds including Caspian tern, red-billed gull, South Island oystercatcher, pied stilt, black backed gull, white-fronted tern, banded dotterel and variable oystercatcher have all been observed. The estuary is known to support longfin eel, shortfin eel, banded kokupu and inanga and is likely to be important for other migratory fish species.

Due to the perched nature of the estuary on the upper beach, and its mobile flow path, it is likely to support only a limited sediment dwelling animal community. Apart from a small patch of three square, salt marsh is not present, and the in-stream plant community is dominated by a variety of invasive weed species

SUMMARY INFORMATION	
Estuary area (Ha)	2.2
% Intertidal	95
Dominant estuary substrate	Sand
Mean length (m)	200
Mean depth (m)	0.1
Mouth opening regime (closure period)	ICOLL, days
Macroalgae (Ha density >50% cover)	0
Seagrass (Ha density >50% cover)	0
Salt marsh (Ha)	0.006
Catchment area (Ha)	1081
Dominant catchment land cover	High Producing Exotic Grassland
Catchment geology	Sand, Greywacke, Loess, Peat
Mean freshwater flow (m^3/s)	0.21
Catchment nitrogen load (TN/yr)	6.2
Catchment phosphorus load (T/Pyr)	0.7
Catchment sediment load (KT/yr)	1.3
N areal load in estuary ($mg/m^2/d$)	773
P areal load in estuary ($mg/m^2/d$)	91

VALUES	RATING
Ecosystem	Low
Social/Cultural	Low
Restoration Potential	Moderate
Overall Value Rating	Low

PRESSURES	
Stream channelisation and salt marsh loss	
Intensive lowland land use	
Water quality deterioration	
Vehicle impacts	
Introduced weeds	
Catchment flow alterations (abstraction, diversion) and loss of wetlands	
Current Pressure Rating	Moderate

CONDITION RATINGS	SCORE/RATING
Intertidal soft mud extent (%)	0
Macroalgae (OMBT EQR)	1
Seagrass (decrease from baseline)	< 5
Salt marsh (% of estuary)	0.3
Historical salt marsh (% remaining)	10
Densely vegetated 200m margin (%)	50
High Enrichment Conditions (ha, %)	0
NZ ETI Susceptibility Rating	Low
NZ ETI Score (Band)	0.36 (B)

Salt marsh
- Apodasmia similis (Jointed wirerush)
- Ficinia (Isolepis) nodosa (Knobby clubrush)
- Schoenoplectus pungens (Three-square)
- Selliera radicans (Remuremu)

Dominant Substrate
- Boulder field man-made
- Firm muddy sand
- Firm sand
- Gravel field
- Soft mud
- Water
- Water Quality Measure Jan 2019

Fig. 7. Aerial photo showing Peka Peka Estuary features and location of spot water quality measurements


Estuary entrance meandering through sand at the top of the beach


Stream channel running parallel to the base of the dune


Estuary channel cutting through sand and driftwood on the upper beach


Shallow pool in the upper estuary


Sand dominated substrate was present throughout the estuary


Terrestrial grass dominated margins of the upper estuary


Well oxygenated sandy sediments with a thin layer of brown organic matter on the surface


Freshwater weed species in the upper estuary

including reed sweetgrass and Mercer grass, which form mats along the estuarine margin. Oxygen weed in the stream is particularly problematic as it is an aggressive coloniser and difficult to control.

The terrestrial margin cover was relatively dense and comprised primarily marram grass and spinifex, blackberry, great bindweed, monkey musk, tree lupin, gorse, tall fescue and marram grass are all common in the margin areas.

GWRC does not measure water quality in the stream but spot measurements indicated it was well oxygenated, although tannin stained. Chl-a, an indicator of phytoplankton growth, was slightly elevated (4-5µg/L).

Pressures

The major pressures evident are weed invasion of margins, and a natural cycle of low to high water quality due to mouth restriction.

Eutrophication and fine sediment inputs are slightly elevated, commensurate with the dominant land cover of the catchment being pastoral grazing (59%), but significant eutrophication and fine sediment symptoms do not appear to be present.

Vehicle access is likely to have a localised impact on parts of the foreshore.

There is the potential for forest harvesting (20% of the catchment) to impact on the estuary if mitigation measures are not adequate.

Overall Condition

There have been no significant conspicuous changes to estuary condition since the 2007 survey.

Peka Peka Estuary is relatively undeveloped compared to many of the other estuaries on the Kāpiti Coast, but still has a high degree of modification and is in a moderate state overall.

It has relatively low ecological value primarily due to its variable flow path across the beach, and likely regular mouth closures which cause water quality to be highly variable. It provides reasonable bird and fish habitat, although estuarine biodiversity is relatively low due to limited salt marsh and high weed presence. It has moderate eutrophication susceptibility from nutrient inputs but showed no signs of excessive enrichment in January 2019.

Current pressures on the estuary are moderate and are predominantly a consequence of terrestrial weed invasion, catchment modification (particularly drainage and flow restrictions), and vehicle use.

Human use and interest in the estuary is moderate- and community restoration initiatives are being undertaken in the wider area, but not in the estuary itself. There is good potential for habitat restoration at this site through the clearance of aquatic and terrestrial pest species, and replanting of the estuary margins with native species already present, such as wīwī, clubrush, flax and toetoe.

4.5 WAIMEHA ESTUARY

General description

The Waimeha (also known as the Ngārara) Estuary is a small (3.6ha) estuary located immediately north of Waikanae. The estuary entrance was artificially created in the 1920's when the streamway that used to run parallel to the beach through many of the small dune lakes was diverted to the coast.

It is now fed by the spring-fed Waimeha Stream from the south and the spring-fed Ngārara Stream from east. These streams combine ca 250m from the coast and discharge through a gap in the dune system after which the unconstrained mouth meanders ca 400m along the beach over a wide delta that occasionally blocks.

The upper estuary is highly modified, channelised and bordered by houses and parkland. It is narrow (ca 5m wide) and relatively shallow (0.8m deep) in the upper reaches, but becomes wider (10m) and shallower (0.2m) once it reaches the beach front. Sediments are dominated by sands with little indication of anoxic conditions, and water is clear but humic stained.

Waves wash into the upper estuary at times depositing large volumes of driftwood.

Human Uses and Values

Recreational use of the estuary is relatively high. Several tracks run through the dune systems providing foot access, and vehicles regularly drive along the coast. The beach attracts a relatively high number of walkers, seasonal swimmers, picnickers and recreational fishers, and is very popular for whitebaiting.

Ecological Values

Ecologically, habitat diversity is low, given the highly modified upstream channels and the absence of tidal flats, lack of salt marsh vegetation, the regularly modified beach channel and the high incidence of weeds. The beach front supports a variety of bird species and the catchment includes large freshwater wetland areas which provide good habitat for native fish. Nine migratory native freshwater fish species have been found in the catchment, including four species that are listed as 'At Risk: Declining' (longfin eel, giant kōkopu, inanga and redfin bully; Allibone et al. 2010). Inanga spawning has been reliably reported (Todd et al. 2016).

Due to the perched nature of the estuary on the upper beach, and its mobile flow path, it is likely to support only a limited sediment dwelling animal community. Apart from a very small patch of three

SUMMARY INFORMATION	
Estuary area (Ha)	3.6
% Intertidal	84
Dominant estuary substrate	Sand
Mean length (m)	625
Mean depth (m)	0.3
Mouth opening regime (closure period)	ICOLL, days
Macroalgae (Ha density >50% cover)	0
Seagrass (Ha density >50% cover)	0
Salt marsh (Ha)	0.01
Catchment area (Ha)	1754
Dominant catchment land cover	High Producing Exotic Grassland
Catchment geology	Sand, Urban, Greywacke, Peat
Mean freshwater flow (m^3/s)	0.33
Catchment nitrogen load (TN/yr)	25.2
Catchment phosphorus load (T/Pyr)	4.8
Catchment sediment load (KT/yr)	1.5
N areal load in estuary ($mg/m^2/d$)	1920
P areal load in estuary ($mg/m^2/d$)	367

VALUES	RATING
Ecosystem	Low
Social/Cultural	Low
Restoration Potential	Moderate
Overall Value Rating	Low

PRESSURES
Stream channelisation and salt marsh loss
Intensive lowland land use
Water quality deterioration
Introduced weeds
Catchment flow alterations (abstraction, diversion) and loss of wetlands
Mouth constriction and managed openings
Current Pressure Rating: Low

CONDITION RATINGS	SCORE/RATING
Intertidal soft mud extent (%)	0
Macroalgae (OMBT EQR)	1
Seagrass (decrease from baseline)	< 5
Salt marsh (% of estuary)	0.33
Historical salt marsh (% remaining)	10
Densely vegetated 200m margin (%)	40
High Enrichment Conditions (ha, %)	0
NZ ETI Susceptibility Rating	Low
NZ ETI Score (Band)	0.51 (C)

Fig. 8. Aerial photo showing Waimeha Estuary features and location of spot water quality measurements


Estuary passing through dunes at the upper beach


Stream channel heading upstream from the coastal dune system


Densely covered dune systems flank both sides of the estuary entrance


Shallow and narrow channel passing over the top of the beach


Channelised upper estuary with highly modified margins


Terrestrial grass dominated margins of the upper estuary


Well oxygenated sandy sediments with a thin layer of brown organic matter on the surface in the upper estuary


Raupō growing in the clear waters of the upper estuary

square and bachelors button, salt marsh is not present, and the in-stream plant community is dominated by a variety of invasive weed species including blackberry, ice plant, gorse, pampas and lupin along the estuarine margin. Buffalo grass and Parrot's feather have also become established.

The moderate rating for dense 200m terrestrial margin cover predominantly reflects the inclusion of vegetated coastal dune systems. Native spinifex is common in the dunes, although introduced species (marram grass, tree lupin) dominate.

Chl-a, an indicator of phytoplankton growth, was slightly elevated in the Ngarara Stream (6µg/L).

Pressures

The major pressures evident are weed invasion of margins, and a natural cycle of low to high water quality due to mouth restriction.

Eutrophication and fine sediment inputs are elevated, commensurate with the dominant land cover of the catchment being pastoral grazing (48%) and urban (11%), but significant eutrophication and fine sediment symptoms do not appear to be present.

Vehicle access is likely to have a localised impact on parts of the lower foreshore, as is managed opening of the estuary mouth.

Overall Condition

There have been no significant conspicuous changes to estuary condition since the 2007 survey.

Waimeha Estuary is significantly modified and in a relatively poor state overall.

It has relatively low ecological value primarily due to its variable flow path across the beach, and likely regular mouth closures which cause water quality to be highly variable. It provides reasonable bird and fish habitat, although estuarine biodiversity is low due to limited salt marsh and high weed presence. It has moderate eutrophication susceptibility from nutrient inputs but showed no signs of excessive enrichment in January 2019.

Current pressures on the estuary are low and are predominantly a consequence of terrestrial weed invasion, catchment modification (particularly drainage and flow restrictions), and nutrient inputs.

Human use and interest in the estuary is moderate and community restoration initiatives are being undertaken in the wider area. There is very good potential for further habitat restoration at this site through the clearance of aquatic and terrestrial pest species, and replanting of the estuary margins with native species.

4.6 WAIKĀNAE ESTUARY

General description

The Waikanae Estuary is a moderately large (37ha) and long (1.5km) estuary located at the mouth of the Waikanae River. The confined upper estuary is dominated by cobble and gravel substrate but, where intertidal flats begin to establish, muddy sands settle and accumulate, while closer to the coast, stronger tidal flushing sees a transition to marine sands. These three substrate types reflect the main zones of the estuary - the relatively shallow and wide tidal beach section of the lower estuary where the mouth migrates over the beach front, the deep and channelised middle estuary where denser seawater can become trapped under more buoyant freshwater, and the shallower river-dominated upper estuary where tidal influences are relatively small.

Waikanae was the only estuary monitored in 2019 that was stratified, with a layer of freshwater 0.6-1.0m recorded above high salinity (29-32ppt) seawater. In the main bend of the river the bottom waters had high chl-a (16µg/L) concentrations indicating the presence of a phytoplankton bloom. This is reflected in the ETI score of 0.62, the highest recorded for the estuaries surveyed.

The estuary has undergone significant modification in the past with flood protection works and stopbanks, and the construction of control gates to create the Waimanu Lagoon, turning the once intertidal estuary arm into an artificially controlled lake. Managed opening of the mouth has also occurred in the past.

Human Uses and Values

Recreational use of the estuary is high. It is a local focal point for conservation, boating, birdwatching, swimming, picnickers, walking, whitebaiting and recreational fishing. Urban developments now surround the estuary and river margins.

Ecological Values

Ecologically, habitat diversity is relatively high with a range of different substrate types, but compromised somewhat by the modified channels that restrict the extent of tidal flats and salt marsh vegetation in the upper estuary, and drainage that has increased the presence of terrestrial weeds.

Notwithstanding, there are extensive areas of salt marsh (6.7ha), and more expansive areas of coastal wetland and duneland adjacent to that, much of it included in, and protected by, a DOC-administered scientific reserve to the south of the estuary. The salt marsh in the upper estuary reaches is listed as a

SUMMARY INFORMATION	
Estuary area (Ha)	37
% Intertidal	82
Dominant estuary substrate	Sand
Mean length (m)	1500
Mean depth (m)	1.9
Mouth opening regime (closure period)	ICOLL, days
Macroalgae (Ha density >50% cover)	0.5
Seagrass (Ha density >50% cover)	0
Salt marsh (Ha)	5.7
Catchment area (Ha)	15275
Dominant catchment land cover	Indigenous Forest
Catchment geology	Greywacke, Loess, Alluvium
Mean freshwater flow (m^3/s)	4.64
Catchment nitrogen load (TN/yr)	78.2
Catchment phosphorus load (T/Pyr)	14.0
Catchment sediment load (KT/yr)	21.0
N areal load in estuary ($mg/m^2/d$)	579
P areal load in estuary ($mg/m^2/d$)	104

VALUES	RATING
Ecosystem	Very High
Social/Cultural	High
Restoration Potential	High
Overall Value Rating	Very High

PRESSURES
Stream channelisation and salt marsh loss
Water quality deterioration and wastewater inputs
Introduced weeds
Catchment flow alterations (abstraction, diversion) and loss of wetlands
Mouth constriction and managed openings
Human disturbance of wildlife
Current Pressure Rating: Moderate

CONDITION RATINGS	SCORE/RATING
Intertidal soft mud extent (%)	6
Macroalgae (OMBT EQR)	1
Seagrass (decrease from baseline)	< 5
Salt marsh (% of estuary)	19
Historical salt marsh (% remaining)	10
Densely vegetated 200m margin (%)	10
High Enrichment Conditions (ha, %)	0
NZ ETI Susceptibility Rating	Very High
NZ ETI Score (Band)	0.62 (C)

Dominant Habitat

- Apodasmia similis (Jointed wirerush)
- Juncus kraussii (Searush)
- Isolepis cernua (Slender clubrush)
- Schoenoplectus pungens (Three-square)
- Selliera radicans (Remuremu)
- Boulder field man-made
- Cobble field
- Firm mud/sand
- Firm sand
- Soft mud
- Water
- Water Quality Measure Jan 2019

Fig. 9. Aerial photo showing Waikanae Estuary features and location of spot water quality measurements

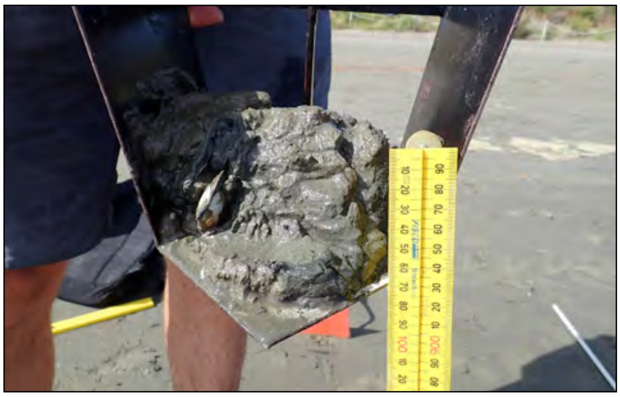
Upper estuary just before the river enters the main part of the beach

Stream channel heading downstream from the main bend in the river

Muddy tidal flats in the upper estuary

Readily disturbed fine sediments in the otherwise clear waters of the upper estuary

Muddy sands over anoxic organically-enriched muds from the channel in the upper estuary



Well oxygenated sands and shellfish from the middle estuary

Nuisance macroalgal growths near the Waimanu Lagoon flood control gate

Ruppia (Horses' mane weed) growing in Waimanu Lagoon (visible due to the lagoon being drained)

Priority One Recommended Area for Protection (No. 5) by Ravine (1992).

Fourteen migratory native freshwater fish species have been found in the catchment, nine of which are listed as 'At Risk: Declining' (longfin eel, giant kōkopu, shortjaw kōkopu, kōaro, inanga, redfin bully, bluegill bully, torrentfish and lamprey; Allibone et al. 2010). Inanga are historically known to have spawned in the upper tidal reaches.

Abundant marine invertebrate animals are found in the sediments of the mudflats including gastropod snails, paddle crabs, polychaete worms and amphipods. These are major food sources for wading birds and the estuary arguably attracts a greater number of birds than any other place in the Wellington region.

The estuarine site is an important nesting site for banded dotterel, dabchick, pūkeko, and variable oystercatchers, and an important roosting and feeding area for migrants including wrybills, South Island pied oystercatchers, and bar-tailed godwits. Several species, including the black shag and pied shag, have permanent roosts in the scientific reserve, while small numbers of brown teal, dabchick and scaup have been noted regularly.

Waimanu Lagoon supports extensive beds of the native seagrass Horses' mane weed.

The moderate rating for dense 200m terrestrial margin cover predominantly reflects the vegetated coastal dune systems. Native spinifex is common in the dunes, although it remains dominated by introduced species

Pressures

The major pressures evident are weed invasion of margins, human disturbance to wildlife, channelisation of estuary edges, vehicle use on the lower estuary and foreshore, and sediment deposition in the upper estuary.

Localised nuisance macroalgal growths and occasional phytoplankton blooms have been recorded consistently in Waikanae Estuary for several years; e.g. Stevens and Robertson (2015), indicating pressure from nutrient inputs. The macroalgal growths comprise small areas of sea lettuce near the Waimanu Lagoon outflow with a biomass of 1500g/m^2 (wet weight), which is at the threshold where adverse ecological effects start to occur.

This is not unexpected given the high risk rating for the estuary calculated using Tool 1 of the ETI, with mouth constriction and stratification likely to increase the expression of problems by trapping and accumulating nutrients. This is also likely to be exacerbated by the input of tertiary treated wastewater discharge (via the Mazengarb Drain).

Sediment inputs are also relatively high, averaging ca 17.5mm/year for the past decade in the upper estuary flats (Stevens 2019).

Overall Condition

There have been no significant conspicuous changes to estuary condition since the 2007 survey.

Waikanae Estuary is significantly modified and in a moderate state overall, with Stevens and Robertson (2015) reporting a slight decline in quality between 2010 and 2015 with respect to nutrient enrichment.

However, it has high ecological value due to its habitat diversity, and is a significant site for birds, fish and wetland and estuarine plants.

It has very high eutrophication susceptibility from nutrient inputs and showed localised signs of excessive enrichment in January 2019, consistent with that measured in previous years.

Current pressures on the estuary are moderate and predominantly a consequence of terrestrial weed invasion, catchment modification (particularly drainage and flow restrictions), and sediment and nutrient inputs to the upper estuary.

Human use and interest in the estuary is high and community restoration initiatives are being undertaken in the wider area by the Waikanae Estuary Care Group. There is very good potential for further habitat restoration at this site through the clearance of aquatic and terrestrial pest species, and replanting of the estuary margins with native species.

4.7 TIKOTU ESTUARY

General description

Tikotu Estuary, located at Paraparaumu, is very small (0.4ha), short (150m) narrow (3-5m wide) and shallow (<0.1m). It has no readily definable catchment of any significance, and is not included with the CLUES network of streams for modelling catchment sediment and nutrient inputs.

The confined upper estuary is highly modified, channelised and bounded by vertical wooden walls, piped, and surrounded by introduced grasses and weeds. The estuary discharge point is perched high on the beach and the unconfined low tide mouth meanders ca 50-100m across the beach carving a small but variable channel.

The mouth occasionally blocks as a result of beach accretion and mechanical opening of the mouth has occurred in the past.

Human Uses and Values

Recreational use of the estuary is low. It has walking access linked to the wider urban developments of the area. The beach near the lower estuary is heavily used by vehicles and is the departure point for boat tours to Kāpiti Island.

Ecological Values

Ecologically, habitat diversity is low and significantly compromised by the modified channels that restrict the extent of tidal flats in the upper estuary. There is no remaining salt marsh vegetation. Some fishery value is present with an eel observed during sampling in 2019. There is extensive dune restoration work being undertaken near the estuary mouth.

Pressures

The major pressures evident are weed invasion of margins, channelisation of estuary edges, and vehicle use on the lower estuary and foreshore. Slightly elevated (4-5µg/L) chl-a concentrations indicate a potential for phytoplankton blooms under low flow conditions where flushing is limited.

Overall Condition

There have been no significant conspicuous changes to estuary condition since the 2007 survey. Tikotu Estuary is a very small, significantly modified estuary in a moderate to poor state overall. There is limited capacity to undertake restoration within the estuary because of its channelisation, but good potential for habitat restoration by replanting the estuary margins with native species.

SUMMARY INFORMATION	
Estuary area (Ha)	0.4
% Intertidal	80
Dominant estuary substrate	Sand
Mean length (m)	150
Mean depth (m)	0.1
Mouth opening regime (closure period)	ICOLL, days
Macroalgae (Ha density >50% cover)	0
Seagrass (Ha density >50% cover)	0
Salt marsh (Ha)	0
Catchment area (Ha)	0
Dominant catchment land cover	Built-up Area (settlement)
Catchment geology	Urban, Sand
Mean freshwater flow (m^3/s)	0.004
Catchment nitrogen load (TN/yr)	na
Catchment phosphorus load (T/Pyr)	na
Catchment sediment load (KT/yr)	na
N areal load in estuary ($mg/m^2/d$)	na
P areal load in estuary ($mg/m^2/d$)	na

VALUES	RATING
Ecosystem	Very Low
Social/Cultural	Low
Restoration Potential	Very Low
Overall Value Rating	Very Low

PRESSURES	
Stream channelisation, piping, and salt marsh loss	
Water quality deterioration	
Introduced weeds	
Catchment flow alterations (abstraction, diversion) and loss of wetlands	
Mouth constriction and managed openings	
Low flows	
Current Pressure Rating	Low

CONDITION RATINGS	SCORE/RATING
Intertidal soft mud extent (%)	0
Macroalgae (OMBT EQR)	1
Seagrass (decrease from baseline)	< 5
Salt marsh (% of estuary)	0
Historical salt marsh (% remaining)	0
Densely vegetated 200m margin (%)	5
High Enrichment Conditions (ha, %)	0
NZ ETI Susceptibility Rating	Low
NZ ETI Score (Band)	0.56 (C)

Fig. 10. Aerial photo showing Tikotu Estuary features and location of spot water quality measurements


Upper estuary just before the stream enters the main part of the beach


Stream channel looking upstream from the beach

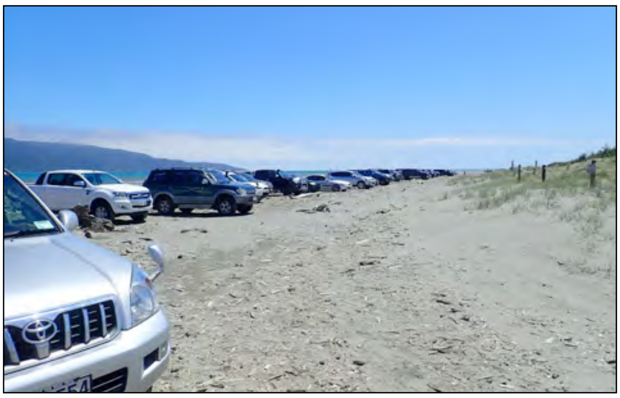

Shallow tidal flats in the upper estuary


Channelised and freshwater weed dominated upper estuary


Thin algal mats growing in the channel at the top of the beach


Measuring water quality in the upper estuary


Well oxygenated sandy sediment in the lower estuary


Extensive vehicle presence at the upper beach margin

4.8 WHAREMAKU ESTUARY

General description

The Wharemakau Estuary is small (0.55ha) short (250m), narrow (3-5m wide), shallow (<0.1m) and confined within a highly modified, channelised estuary margin. Much of the lower estuary has been reclaimed and is now bounded by vertical wooden or concrete walls, with no remaining salt marsh. The estuary discharge point is perched high on the beach and the unconfined low tide mouth meanders ca 50-100m across the beach carving a small but variable channel. Upstream, large concrete culverts and flap gates greatly limit any available ecological habitat.

Human Uses and Values

Recreational use of the estuary is moderate. The beach is the main local focal point for swimming, picnickers and walking, although the estuary is used for contact recreation. Urban developments surround the estuary and river margins.

Ecological Values

Ecologically, habitat diversity is low and significantly compromised by the modified channels that restrict the extent of tidal flats in the upper estuary. It is likely that the estuary provides access for migratory fish species, although obvious barriers exist further upstream.

Pressures

The major pressures evident are weed invasion of margins, human disturbance to wildlife, channelisation of estuary edges and vehicle use on the lower estuary and foreshore. The relatively small estuary size, combined with catchment land use comprising urban (30%), high producing pasture (17%) and exotic forestry (22%) means potential nutrient and sediment inputs are relatively high and slightly elevated (5-6µg/L) chl-a concentrations in Jan. 2019 indicate a potential for phytoplankton blooms under low flow conditions. However, as the estuary is so heavily modified and channelised, flushing is likely to prevent any significant problems from persisting.

Overall Condition

There have been no significant conspicuous changes to estuary condition since the 2007 survey. Wharemakau Estuary is a small, significantly modified estuary in a moderate to poor state overall. There is limited capacity to undertake restoration within the estuary because of its channelisation, but good potential for habitat restoration by replanting the estuary margins with native species.

SUMMARY INFORMATION	
Estuary area (Ha)	0.55
% Intertidal	65
Dominant estuary substrate	Sand
Mean length (m)	250
Mean depth (m)	0.1
Mouth opening regime (closure period)	ICOLL, days
Macroalgae (Ha density >50% cover)	0
Seagrass (Ha density >50% cover)	0
Salt marsh (Ha)	0
Catchment area (Ha)	1424
Dominant catchment land cover	Built-up Area (settlement)
Catchment geology	Greywacke, Loess, Peat, Urban
Mean freshwater flow (m^3/s)	0.28
Catchment nitrogen load (TN/yr)	8.1
Catchment phosphorus load (T/Pyr)	1.0
Catchment sediment load (KT/yr)	1.4
N areal load in estuary ($mg/m^2/d$)	4043
P areal load in estuary ($mg/m^2/d$)	486

VALUES	RATING
Ecosystem	Very Low
Social/Cultural	Low
Restoration Potential	Very Low
Overall Value Rating	Moderate

PRESSURES
Stream channelisation and salt marsh loss
Water quality deterioration
Introduced weeds
Catchment flow alterations (abstraction, diversion) and loss of wetlands
Mouth constriction and managed openings
Human disturbance of wildlife

Current Pressure Rating	Low

CONDITION RATINGS	SCORE/RATING
Intertidal soft mud extent (%)	0
Macroalgae (OMBT EQR)	1
Seagrass (decrease from baseline)	< 5
Salt marsh (% of estuary)	0
Historical salt marsh (% remaining)	0
Densely vegetated 200m margin (%)	5
High Enrichment Conditions (ha, %)	0
NZ ETI Susceptibility Rating	High
NZ ETI Score (Band)	0.51 (C)

Salt marsh

- Apodasmia similis (Jointed wirerush)
- Ficinia (Isolepis) nodosa (Knobby clubrush)
- Schoenoplectus pungens (Three-square)
- Selliera radicans (Remuremu)

Dominant Substrate

- Boulder field man-made
- Firm muddy sand
- Firm sand
- Gravel field
- Soft mud
- Water
- Water Quality Measure Jan 2019

Fig. 11. Aerial photo showing Wharemaku Estuary features and location of spot water quality measurements

Lower estuary crossing the beach

Channelised middle estuary

Channelised middle estuary looking towards the mouth

Stormwater flapgate in the upper estuary

Channelised middle estuary looking towards the mouth

Hanging stormwater pipe in the middle estuary

Clean well oxygenated sands in the middle estuary

Channelised upper estuary

4.9 WHAREROA ESTUARY

General description

The Whareroa Estuary is a small (0.9ha) estuary located at Whareroa Beach in Queen Elizabeth Park. The upper estuary is narrow (2-5m wide) and confined within steep sided and slumping earth banks, although the subtidal substrate remains predominantly sandy. The middle estuary is wider and the banks less steep, with two small sections of Gabian baskets installed to protect the stream banks near the bridge. Water depths in the middle and upper estuary are 0.5-0.8m deep respectively. The lower estuary is significantly wider (30-50m), flatter and shallower (0.1m deep); the meandering channel creating a relatively wide delta. An old wooden training wall is present on the true left bank to protect the adjacent carpark. This entire estuary area is wave swept at times and large accumulations of driftwood are intermittently present.

No salt marsh remains within the estuary, although there are vegetated dunes either side of the lower estuary with a range of species including flax (the dominant cover), tall fescue, tree lupin, South African ice plant, and marram grass.

Human Uses and Values

Recreational use of the estuary is moderate. It is the starting point for several walks in the park and gives access to the beach for swimming and fishing. It is seasonally popular for whitebaiting.

Ecological Values

The stream, estuary and dune system are included in the GWRC Key Native Ecosystem (KNE) Plan for Queen Elizabeth Park, although little specific detail is provided on the estuary. Ecologically, habitat diversity is low with substrate types limited to sand and a small area of gravel and shell. Channelisation of the streamway restricts the extent of salt marsh vegetation in the upper estuary, and drainage has increased the presence of terrestrial weeds.

Nine migratory native freshwater fish species have been found in the catchment, including six species that are listed as 'At Risk: Declining' (longfin eel, giant kōkopu, kōaro, inanga, redfin bully and lamprey; Allibone et al. 2010).

The estuary is likely to be well used by shorebirds.

Pressures

The major pressures evident are weed invasion of margins, human disturbance to wildlife, channelisation of estuary edges, and catchment sediment and

SUMMARY INFORMATION	
Estuary area (Ha)	0.9
% Intertidal	81
Dominant estuary substrate	Sand
Mean length (m)	350
Mean depth (m)	0.1
Mouth opening regime (closure period)	ICOLL, days
Macroalgae (Ha density >50% cover)	0
Seagrass (Ha density >50% cover)	0
Salt marsh (Ha)	0
Catchment area (Ha)	1566
Dominant catchment land cover	High Producing Exotic Grassland
Catchment geology	Greywacke, Loess, Peat, Sand
Mean freshwater flow (m^3/s)	0.366
Catchment nitrogen load (TN/yr)	8.9
Catchment phosphorus load (T/Pyr)	2.5
Catchment sediment load (KT/yr)	3.1
N areal load in estuary ($mg/m^2/d$)	2699
P areal load in estuary ($mg/m^2/d$)	748

VALUES	RATING
Ecosystem	Moderate
Social/Cultural	Moderate
Restoration Potential	High
Overall Value Rating	Moderate

PRESSURES	
Stream channelisation and salt marsh loss	
Water quality deterioration	
Introduced weeds	
Catchment flow alterations (abstraction, diversion) and loss of wetlands	
Mouth constriction	
Human disturbance of wildlife	
Current Pressure Rating	High

CONDITION RATINGS	SCORE/RATING
Intertidal soft mud extent (%)	0
Macroalgae (OMBT EQR)	1
Seagrass (decrease from baseline)	< 5
Salt marsh (% of estuary)	0
Historical salt marsh (% remaining)	20
Densely vegetated 200m margin (%)	20
High Enrichment Conditions (ha, %)	0
NZ ETI Susceptibility Rating	High
NZ ETI Score (Band)	0.48 (B)

Fig. 12. Aerial photo showing Whareroa Estuary features and location of spot water quality measurements

Estuary just before the river enters the main part of the beach

Stream channel heading downstream from the bridge over the river

Muddy tidal flats in the upper estuary

Tannin stained waters flowing from the middle estuary

Channel flowing past an old sea wall on the true left bank

Grassland dominated upper estuary margins

Well oxygenated sandy sediments from the bridge

Well oxygenated sandy sediments with a light brown organic cover in the upper estuary nutrient inputs. Although the regional park gives the impression of a relatively natural catchment, both nutrient and sediment loads are relatively high, reflecting a 60% land cover of high producing exotic grassland (much of it on drained wetlands), and 9% exotic forest. There have likely been some additional impacts associated with the significant earthworks associated with the Mckays Crossing road development in recent years. The retirement of some pastoral land to regenerating forest will reduce land use pressures in the future.

No nuisance macroalgal growths were observed, but slightly elevated (5-6µg/L) chl-a concentrations in Jan. 2019 indicate a potential for phytoplankton blooms under low flow conditions.

Overall Condition

There have been no significant conspicuous changes to estuary condition since the 2007 survey.

Whareroa Estuary is in a moderate state overall as a consequence of past modification. It has limited habitat diversity, but remains an important site for birds, fish and wetland plants.

It has high eutrophication susceptibility from nutrient inputs but was showing no signs of significant enrichment in January 2019

Current pressures on the estuary are high and are predominantly a consequence of terrestrial weed invasion, catchment modification (particularly drainage and flow restrictions), and nutrient inputs.

Human use and interest in the estuary is moderate and community restoration initiatives are being undertaken in the wider area. There is very good potential for further habitat restoration at this site through the clearance of aquatic and terrestrial pest species, and replanting of the estuary margins with native species, and through allowing pastoral land in the catchment to regenerate to native forest.

5. SYNOPSIS

For each of the nine estuaries assessed, ecosystem and social/cultural values have been previously derived (Robertson & Stevens 2007, Stevens 2013, Todd et al. 2016) and are summarised in Table 4 along with a subjective appraisal of current pressure. Condition ratings based on the assessment of each estuary in January 2019 are summarised in Table 5.

Overall, very little change was observed in the estuaries from 2007 to 2019 which reflects the fact that most of these systems are already highly modified and have historically lost many of their more vulnerable features to development. Ongoing pressures include water quality deterioration, the presence of introduced weeds, catchment flow alterations (abstraction, diversion) and loss of wetlands, mouth constriction, and human disturbance of wildlife. Stream channelisation and salt marsh loss are ongoing pressures only in systems where these activities have not occurred.

In general terms, the larger estuaries have the highest ecological values because they had greater biodiversity through the combined presence of salt marsh, relatively large intertidal flats and variable substrate types. This is primarily because historical modification has not been as pronounced as in many of the smaller estuaries which have been heavily modified through channelisation and reclamation. This is also reflected in their current ratings of social and cultural value, and for restoration potential and current overall pressure.

For example, the highly modified Tikotu and Wharemakau estuaries have no remaining salt marsh and, immediately upstream of the beach, comprise

Table 4. Summary ratings of values, restoration potential and current pressures for nine Kāpiti Coast estuaries assessed in 2019

VALUE RATINGS	Waitohu	Ōtaki	Mangaone	Peka Peka	Waimeha	Waikānae	Tikotu	Wharemakau	Whareroa
Ecosystem value	Mod	Mod	Low	V. Low	Low	V. High	V. Low	V. Low	Mod
Social/Cultural value	High	High	Mod	Low	V. Low	High	Low	Low	Mod
Restoration potential	High	High	Mod	Mod	Low	High	V. Low	V. Low	High
Current Overall Pressure	Mod	Mod	Mod	High	Low	Low	V. Low	Low	High

Table 5. Summary criteria and condition ratings for selected ecological indicators for nine Kāpiti Coast estuaries assessed in 2019

CONDITION RATINGS	Waitohu	Ōtaki	Mangaone	Peka Peka	Waimeha	Waikānae	Tikotu	Wharemakau	Whareroa
Intertidal soft mud extent (%)	0	14	0	0	0	6	0	0	0
Macroalgae (OMBT EQR)	1	1	1	1	1	1	1	1	1
Seagrass (decrease from baseline)	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Salt marsh (% of estuary)	3	0.2	0	0.3	0.33	19	0	0	0
Historical salt marsh (% remaining)	20	5	0	10	10	10	0	0	20
Densely vegetated 200m margin (%)	60	10	20	50	40	10	5	5	20
High Enrichment Conditions (ha, %)	0	0	0	0	0	0	0	0	0
NZ ETI Susceptibility Rating	Low	Low	V. High	Low	Low	V. High	Low	High	High
NZ ETI Score (Band)	0.26 (B)	0.29 (B)	0.3 (B)	0.36 (B)	0.51 (C)	0.62 (C)	0.56 (C)	0.51 (C)	0.48 (B)

Very Good	Good	Moderate	Poor

steep-sided reinforced channels that quickly enter underground piping. They are generally well-flushed and unstratified so are not subjected to significant phytoplankton or macroalgal blooms or fine sediment build-up. The high degree of past modification and low biodiversity means current pressures are unlikely to significantly change estuary ecosystem quality, while past reclamation and channelisation means restoration potential is largely limited to improving fish passage to upstream areas and planting terrestrial margin areas adjacent to the estuary. While improvements can always be made to enhance the values of these small estuaries, there is realistically now very limited scope for returning these systems to a more natural estuarine state.

In contrast, Peka Peka and Mangaone estuaries, which are similar types of estuary but less modified, are more susceptible to ongoing pressure from terrestrial development and land use inputs, and also have a significantly greater potential for restoration due to less permanent modification of the estuary margins. Effort directed at preventing further difficult to reverse changes (e.g. channelization and infilling) will have significant long term gains, and provide future opportunities for enhancing the interface between the estuary and the surrounding terrestrial areas.

The larger estuaries (e.g. Waikānae, Waitohu and Ōtaki), despite extensive modification, have retained many important ecological features including relatively large areas of salt marsh and densely vegetated terrestrial margin habitat. The potential to protect and enhance this habitat through restoration efforts is also relatively high. In addition, due to the episodic presence of stratification, combined with elevated nutrient and sediment inputs in some; i.e. Waikānae, these estuaries can be susceptible to eutrophication and fine sediment related problems and therefore management of these inputs in the wider catchment is also a key component of any estuary management.

The relatively small to negligible changes in estuary condition from 2007 to 2019 indicates that current policy is holding the line in terms of protecting against significant degradation. However, there are considerable opportunities evident to enhance and protect each estuary. It is recommended that estuaries be prioritised based primarily on their ecological value, and restoration and enhancement plans be developed for each, with the focus on maintaining healthy ecological functioning and resilience, taking into account likely changes expected in response to both sea level rise and climate change. A focus on protecting ecological functioning is expected to also maintain the majority of the social and cultural values identified previously.

Overall, in terms of establishing priorities, the ecosystem value scores provide a relatively good guide to which estuaries are likely to deliver the most significant ecological outcomes.

Ideally prioritisation would be derived using a formal objective process. The previous risk frameworks applied by Robertson & Stevens (2007b), Stevens (2013) and Todd et al. (2016), and which were applied in a modified form in the current study, all provide useful criteria for collating and assessing a wide range of information for estuarine assessment. However, the current work highlighted that there is little consistency in the different approaches used, with variable terminology and criteria applied. The approaches routinely mix variables together; e.g. current and historical pressures, current ecological condition and historical change, social/cultural and ecological values, and assume that different criteria are all of equal importance. There is also no guidance on the weighting to give individual measures (each measure is treated as having equal weight), which skews scoring where duplicate or overlapping measures are included. Another issue compounding the current frameworks is the evaluation criteria often use different scales (e.g. 4 or 5 category bands), with the same ranking applied to various components but with different meanings; e.g. 'high' can refer to value, quality, risk, susceptibility, degree of change, pressure, or restoration potential. This makes it very difficult to extract useful management information in a consistent manner. Further, many of the criteria require a subjective appraisal. While the inclusion of subjective assessment is often necessary in the absence of data, it does require clearly defined and transparent guidance to be applied, ideally using expert input as part of a consensus-based approach.

It is recommended that future assessments apply a framework that assesses ecological values separately from other criteria, and which defines standard scoring criteria to enable the objective ranking and assessment of risk, value, condition and susceptibility.

RECOMMENDATIONS

The summary tables highlight that the estuaries with the highest ecological value, highest social/cultural value and highest restoration potential are the Waikanae, Waitohu, Otaki and Whareroa. These estuaries also have moderate to high pressures present. Consequently, of the estuaries assessed, it is recommended that they be prioritised for any targeted management and restoration work being undertaken or coordinated by GWRC on the Kāpiti coast. The following recommendations are made for consideration by GWRC:

- Undertake a repeat synoptic assessment of estuary condition and risk at 10 yearly intervals to maintain a high-level overview of estuary condition and change.
- Continue the management of identified pressures and high biodiversity values through existing programmes like the Key Native Ecosystem (KNE) plans, ensuring that specific estuary components have been identified and included appropriately.
- Where limitations in the risk framework criteria used previously have been identified, refine assessment criteria to enable a more objective assessment of risk to identified pressures.

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APPENDIX 1. BROAD SCALE HABITAT CLASSIFICATION DEFINITIONS

Estuary vegetation was classified using an interpretation of the Atkinson (1985) system, whereby dominant estuarine plant species were coded by using the two first letters of their Latin genus and species names e.g. sea rush, *Juncus kraussii*, was coded as Jukr. An indication of dominance is provided by the use of ( ) to distinguish subdominant species e.g. Jukr(Caed) indicates that sea rush was dominant over ice plant (*Carpobrotus edulis*). The use of ( ) is not always based on percentage cover, but the subjective observation of which vegetation is the dominant or subdominant species within the patch. A measure of vegetation height can be derived from its structural class (e.g. herbfield, rushland). Terrestrial margin vegetation was classified using the field codes included in the Landcare Research Land Cover Database (LCDB4) - see following page.

VEGETATION (mapped separately to the substrates they overlie).

Estuarine shrubland: Cover of estuarine shrubs in the canopy is 20-80%. Shrubs are woody plants <10 cm dbh (density at breast height).

Tussockland: Tussock cover is 20-100% and exceeds that of any other growth form or bare ground. Tussock includes all grasses, sedges, rushes, and other herbaceous plants with linear leaves (or linear non-woody stems) that are densely clumped and >100 cm height. Examples occur in all species of *Cortaderia, Gahnia,* and *Phormium*, and in some species of *Chionochloa, Poa, Festuca, Rytidosperma, Cyperus, Carex, Uncinia, Juncus, Astelia, Aciphylla,* and *Celmisia*.

Grassland: Grass cover (excluding tussock-grasses) is 20-100%, and exceeds that of any other growth form or bare ground.

Sedgeland: Sedge cover (excluding tussock-sedges and reed-forming sedges) is 20-100% and exceeds that of any other growth form or bare ground. "Sedges have edges". If the stem is clearly triangular, it's a sedge. If the stem is flat or rounded, it's probably a grass or a reed. Sedges include many species of *Carex, Uncinia,* and *Scirpus*.

Rushland: Rush cover (excluding tussock-rushes) is 20-100% and exceeds that of any other growth form or bare ground. A tall grasslike, often hollow-stemmed plant. Iincludes some species of *Juncus* and all species of *Apodasmia* (*Leptocarpus)*.

Reedland: Reed cover is 20-100% and exceeds that of any other growth form or open water. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either round and hollow – somewhat like a soda straw, or have a very spongy pith. Unlike grasses or sedges, reed flowers will each bear six tiny petal-like structures. Examples include *Typha, Bolboschoenus, Scirpus lacutris, Eleocharis sphacelata,* and *Baumea articulata*.

Cushionfield: Cushion plant cover is 20-100% and exceeds that of any other growth form or bare ground. Cushion plants include herbaceous, semi-woody and woody plants with short densely packed branches and closely spaced leaves that together form dense hemispherical cushions.

Herbfield: Herb cover is 20-100% and exceeds that of any other growth form or bare ground. Herbs include all herbaceous and low-growing semi-woody plants that are not separated as ferns, tussocks, grasses, sedges, rushes, reeds, cushion plants, mosses or lichens.

Introduced weeds: Introduced weed cover is 20-100% and exceeds that of any other growth form or bare ground.

Seagrass meadows: Seagrasses are the sole marine representatives of the Angiospermae. They all belong to the order Helobiae, in two families: Potamogetonaceae and Hydrocharitaceae. Although they may occasionally be exposed to the air, they are predominantly submerged, and their flowers are usually pollinated underwater. A notable feature of all seagrass plants is the extensive underground root/rhizome system which anchors them to their substrate. Seagrasses are commonly found in shallow coastal marine locations, salt-marshes and estuaries and are mapped separately to the substrates they overlie.

Macroalgal bed: Algae are relatively simple plants that live in freshwater or saltwater environments. In the marine environment, they are often called seaweeds. Although they contain cholorophyll, they differ from many other plants by their lack of vascular tissues (roots, stems, and leaves). Many familiar algae fall into three major divisions: Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae). Macroalgae are algae observable without using a microscope. Macroalgal density, biomass and entrainment are classified and mapped separately to the substrates they overlie.

SUBSTRATE (physical and zoogenic habitat)

Artificial substrate: Introduced natural or man-made materials that modify the environment. Includes rip-rap, rock walls, wharf piles, bridge supports, walkways, boat ramps, sand replenishment, groynes, flood control banks, stopgates. Commonly sub-grouped into artificial: boulder, cobble, gravel, sand or substrates (seawalls, bunds etc).

Rock field: Land in which the area of basement rock exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover is ≥1%.

Boulder field: Land in which the area of unconsolidated boulders (>200mm diam.) exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover is ≥1%.

Cobble field: Land in which the area of unconsolidated cobbles (>20-200 mm diam.) exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover is ≥1%.

Gravel field: Land in which the area of unconsolidated gravel (2-20 mm diameter) exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover is ≥1%.

Sand: Granular beach sand with no conspicuous fines evident when sediment is disturbed i.e. a mud content <1%. Classified as firm sand if an adult sinks <2 cm, soft sand if an adult sinks >2 cm, or mobile when characterised by a rippled surface layer from tidal currents or wind-generated waves.

Sand/Shell: Granular beach sand and shell with no conspicuous fines evident, i.e. a mud content <1%. Classified as firm if you sink 0-2 cm when walking, soft if you sink 2-5cm, or mobile when characterised by a rippled surface layer.

Muddy sand (Low mud content): A sand/mud mixture dominated by sand with a low mud fraction (e.g. 1-10%), the mud fraction conspicuous only when sediment is mixed in water. Granular when rubbed between the fingers. Classified as firm if you sink 0-2 cm when walking, soft if you sink 2-5cm, or mobile when characterised by a rippled surface layer.

Muddy sand (Moderate mud content): A subjective division may be applied where the sand/mud mixture remains dominated by sand, but has an elevated mud fraction (i.e. 10-25%). Granular when rubbed between the fingers, but with a smoother consistency than muddy sand with a low mud fraction, the mud fraction visually conspicuous when walking on it. Classified as firm if you sink 0-2 cm when walking, soft if you sink 2-5cm, or mobile when characterised by a rippled surface layer.

Muddy sand (High mud content): A mixture of mud and sand where mud is a major component (i.e. >25%-50% mud). Sediment rubbed between the fingers is primarily smooth/silken but retains a granular component. Sediments generally soft and only firm if dried out or another component e.g. gravel prevents sinking. Classified as firm if you sink 0-2 cm when walking, soft if you sink 2-5cm, or very soft if you sink >5cm.

Sandy mud: A mixture of mud and sand where mud is the dominant component (e.g. >50-90% mud). Sediment rubbed between the fingers may retain a slight granular component but is primarily smooth/silken. Sediments generally very soft and only firm if dried out or another component e.g. gravel prevents sinking. Classified as firm if you sink 0-2 cm when walking, soft if you sink 2-5cm, or very soft if you sink >5cm.

Mud (>90% mud content): A strongly mud dominated substrate with sand a minor component. Smooth/silken when rubbed between the fingers. Sediments generally very soft and only firm if dried out or another component e.g. gravel prevents sinking. Classified as firm if you sink 0-2 cm when walking, or soft if you sink >2 cm.

Cockle bed /Mussel reef/ Oyster reef: Area that is dominated by both live and dead cockle shells, or one or more mussel or oyster species respectively.

Sabellid field: Area that is dominated by raised beds of sabellid polychaete tubes.

Shell bank: Area that is dominated by dead shells.

Substrate classification codes used in the current report

Consolidated substrate			Code
Bedrock		Rock field "solid bedrock"	RF
Coarse Unconsolidated Substrate (>2mm)			
Boulder/ Cobble/ Gravel	>256mm to 4.096m	Boulder field "bigger than your head"	BF
	64 to <256mm	Cobble field "hand to head sized"	CF
	2 to <64mm	Gravel field "smaller than palm of hand"	GF
	2 to <64mm	Shell "smaller than palm of hand"	Shel
Fine Unconsolidated Substrate (<2mm)			
Sand (S)	Low mud (0-10%)	Firm shell/sand	fSS
		Mobile sand	mS
		Firm sand	fS
		Soft sand	sS
Muddy Sand (MS)	Moderate mud (>10-25%)	Firm shell/sand	fSSm
		Mobile muddy sand	mMSm
		Firm muddy sand	fMSm
		Soft muddy sand	sMSm
	High mud (>25-50%)	Firm shell/sand	fSShh
		Mobile muddy sand	mMSh
		Firm muddy sand	fMSh
		Soft muddy sand	sMSh
Sandy Mud (SM)	Very high mud (>50-90%)	Firm sandy mud	fSM
		Soft sandy mud	sSM
		Very soft sandy mud	vsSM
Mud (M)	Mud (>90%)	Firm mud	fM90
		Soft or very soft mud	sM90
Zootic (living)			
		Cocklebed	CKLE
		Mussel reef	MUSS
		Oyster reef	OYST
		Sabellid field	TUBE
Artifical Substrate			
		Substrate (brg, bund, ramp, rail, walk, wall, whf)	aS
		Boulder field	aBF
		Cobble field	aCF
		Gravel field	aGF
		Sand field	aSF

Terrestrial margin (Landcare Research LCBD4) classification codes used in the current report

Artificial Surfaces
1 Built-up Area (settlement)
2 Urban ParklandOpen Space
5 Transport Infrastructure
6 Surface Mines and Dumps

Bare or Lightly Vegetated Surfaces
10 Sand and Gravel
12 Landslide
14 Permanent Snow and Ice
15 Alpine Grass/Herbfield
16 Gravel and Rock

Water Bodies
20 Lake or Pond
21 River

Cropland
30 Short-rotation Cropland
33 Orchard Vineyard & Other Perennial Crops

Grassland, Sedge and Saltmarsh
40 High Producing Exotic Grassland
41 Low Producing Grassland
43 Tall-Tussock Grassland
44 Depleted Grassland
45 Herbaceous Freshwater Vegetation
46 Herbaceous Saline Vegetation

Scrub and Shrubland
47 Flaxland
50 Fernland
51 Gorse and/or Broom
52 Manuka and/or Kanuka
54 Broadleaved Indigenous Hardwoods
55 Sub Alpine Shrubland
56 Mixed Exotic Shrubland
58 Matagouri or Grey Scrub

Forest
64 Forest - Harvested
68 Deciduous Hardwoods
69 Indigenous Forest
71 Exotic Forest

Sampling resolution and accuracy

Broad scale mapping is intended to provide a rapid overview of estuary condition based on the mapping of features visible on aerial photographs, supported by ground truthing to validate the visible features.

The ability to correctly identify and map features is primarily determined by the resolution of available photos, the extent of ground truthing, and the experience of those undertaking the mapping.

The spatial accuracy of the subsequent digital maps is determined largely by the photo resolution and accuracy of the ortho-rectified imagery. In most instances features with readily defined edges such as rushland, rockfields, dense seagrass etc. can be mapped at a scale of ~1:2000 to within 1-2m of their boundaries. The greatest scope for potential error occurs where boundaries are not readily visible on photographs, e.g. sparse seagrass beds, or where there is a transition between features that appear visually similar, e.g. sand, muddy sand and mud. Defining such boundaries requires field validation. Extensive mapping experience has shown that such boundaries can be mapped using NEMP classifications to within ±10m where they have been thoroughly ground truthed. For features with defined boundaries not readily visible on photographs, the overall broad scale accuracy is unlikely to be better than ±20-50m for such features

Where initial broad scale mapping results indicate a need for greater resolution of boundaries (e.g. to increase certainty about the extent of soft mud areas), or to define changes within NEMP categories (e.g. to define the mud content within firm mud/sand habitat), then issue-specific approaches are recommended.

APPENDIX 2. CRITERIA FOR ASSESSING ESTUARY VALUES

Scoring systems used to rank the relative importance of estuarine sites by Stevens (2013). Based on draft criteria presented in Todd et al. (in prep. 2013), and subsequently in Todd et al. (2016).

It is emphasised that scores are relative to each other and a score of very low does not indicate the absence of value.

Criteria and Score	1 (Very Low)	2 (Low)	3 (Moderate)	4 (High)	5 (Ver yHigh)
Ecosystem value - the scale and degree of ecological integrity in the estuarine system, combined with the regional rarity of habitats contained within A site must satisfy two of three criteria in order to achieve a score	Site area is <1 ha	Site area is >1 ha	Site area is>5 ha	Site area is >15 ha	Site area is >50 ha
	<20% of the site is considered healthy and intact	>20% of the site is considered healthy and intact	>40% of the site is considered healthy and intact	>60% of the site is considered healthy and intact	>80% of the site is considered healthy and intact
	Contains no rare ecosystems	Contains at least one ecosystem found in no more than ten sites in the ecological district	Contains at least one ecosystem found in no more than two sites elsewhere in the ecological district or in no more than ten other sites in the ecological region	Contains at least one ecosystem found in no more than two sites elsewhere in the ecological region or in no more than ten other sites in the lower North Island	Contains at least one ecosystem found in no more than two sites elsewhere in the lower North Island
Restoration opportunity - the degree the estuary is capable of reflecting or returning to its original biological diversity and ecological patterns	>50% of the site is structurally modified or <20% of the indigenous ecosystem remains	>20% of the site is structurally modified or 20% - 40% of the indigenous ecosystem remains	>5% of the site is structurally modified or 40% - 60% of the indigenous ecosystem remains	<5% of the site is structurally modified or 60% - 80% of the indigenous ecosystem remains	At least 80% of the indigenous ecosystem remains
Pressures - the variety and severity of disruptions to ecosystem ecological integrity	More than three disruption types occurring at a severe level	More than three disruption types occurring at a high level or no more than three disruption types occurring at a severe level	More than three disruption types occurring at a low level or no more than three disruption types occurring at a high level or no more than one disruption type occurring at a severe level	No more than three disruption types occurring at a low level or no more than one disruption type occurring at a high level	No more than one disruption type to ecological integrity occurring at a low level
Cultural value - presence of historic, customary, or recreational values held by the community	No cultural, significance	Obscure cultural value to a small sector of the local community	General cultural values held by most of the local community	Specific cultural values held by most of local community and small sector of wider community	Highly significant cultural values held by the majority of the local and wider community
Birds/Fish/Invertebrates/Plants* - number of species in each group X score	Not threatened (Note : the number of non-threatened plant species is not included in the listing)	At Risk	Threatened		
			Nationally Vulnerable	Nationally Endangered	Nationally Critical

*Lists of indigenous fauna (birds, fish and aquatic invertebrates, lizards) presented in and early draft of Todd et al. (2016) were generated from a variety of sources including OSNZ surveys, databases, records made during the DOC survey and from local knowledge. Freshwater fish presence/absence data was drawn from the New Zealand Freshwater Fish Database. For all species, only those recorded within the last 20 years were listed, but it should not be considered a comprehensive list. The threat classifications used above are described in Todd et al. (2016) and are based on the Department of Conservation New Zealand threat classification system manual (Townsend et al. 2008).

Narrative descriptors used to assess values by Stevens (2013)

Values and Rating	Very Low	Low	Moderate	High
Social, Amenity & Recreation	Low to moderate local recreational use, community or amenity values.	Regionally significant seasonal recreational use, community or amenity values.	Regionally significant year round recreational use, community or amenity values.	Nationally significant seasonal, and year round regional, recreational use, community or amenity values.
Culture and Heritage	No special cultural importance. Some importance to individuals.	Some importance to hapu, iwi or the local community.	Important to hapu, iwi and the local community (e.g. important historical site).	Important to hapu, iwi and local community with some national significance (e.g. Mataitai or Taiapure).
Ecological	Habitat degraded and supports only non-threatened or migrant species	Supports endemic and non-threatened species (e.g. breeding colony) or known habitats for at risk or endemic species.	Supports species in serious or gradual decline (e.g. breeding colony) or known habitats for endangered or vulnerable species.	Supports nationally endangered or vulnerable species (e.g. breeding colony) or part of known range for nationally critical species.
Economic	Very low economic significance for the region (<$150K per 1km of coast)	Low economic significance for the region ($150K-$500K per 1km of coast)	Some economic significance for the region, none nationally ($500K-$1.5 million per 1km of coast)	High regional economic significance, some national significance ($1.5-$5 million per 1km of coast)

APPENDIX 3. ESTUARY TROPHIC INDEX (ETI) SCORING CRITERIA

Note, the ETI criteria remain under development and those currently in use may differ from the published ETI documentation included below - source Robertson et al. (2016b)

SCREENING TOOL 1: PHYSICAL AND NUTRIENT LOAD SUSCEPTIBILITY							
Use the combined physical and nutrient load factors described in Screening Tool 1 to determine the Final Susceptibility Rating (FSR) to eutrophication for the selected estuary (or subcomponent of estuary) type being assessed.							
This Tool 1 susceptibility rating is not used in determining the Final ETI Score (Trophic Condition Rating).							
SCREENING TOOL 2: MONITORING INDICATORS AND ASSESSMENT OF TROPHIC STATE							
Condition Band and Normalised Score Range				**Band A (0-0.25)**	**Band B (0.25-0.50)**	**Band C (0.50-0.75)**	**Band D (0.75-1.0)**
PRIMARY SYMPTOM INDICATORS (AT LEAST 1 PRIMARY SYMPTOM INDICATOR REQUIRED)							
Required	Opportunistic Macroalgae (Includes epiphytic cover on SAV)	EQR	shallow/ intertidal	≥0.8 - 1.0	≥0.6 - < 0.8	≥0.4 - < 0.6	0.0 - < 0.4
Optional	Phytoplankton biomass - Chl- a (90 pctl) If issue identified, assess assemblage inc HAB's	Euhaline	water column	<3 ug/l	3-8 ug/l	8-12 ug/l	>12 ug/l
		Oligo/Meso/Polyhaline		<5 ug/l	5-10 ug/l	>10-16 ug/l	>16 ug/l
	Cyanobacteria (if issue identified)			Requires development			
SUPPORTING INDICATORS (MUST INCLUDE A MINIMUM OF 1 REQUIRED INDICATOR)							
Required Indicators	Sediment Redox Potential (mV) under development]*	Spatial Cover	shallow/ intertidal habitat	RP >0mV over 50% of estuary	RP 0-50 mV over 50% of estuary	RP 50 to -150 mV over 50% of estuary or >100ha	RPD>-150 mV/ aRPD 0 cm over 10% of estuary or >30ha
		Representative sites (1cm)		>100 mV	100 to -50 mV	<-50 to -150 mV	< -150 mV
	Sediment Total Organic Carbon*	Spatial Cover		<0.5% over 50% of estuary	0.5-1% over 50% of estuary	>1-2 % over 50% of estuary or >100ha	>2% over 10% of estuary or >30ha
		Representative sites		<0.5%	0.5-1.0%	>1-2%	>2%
	Sediment Total Nitrogen*	Spatial Cover		<250 mg/kg over 50% of estuary	250-1000 mg/kg over 50% of estuary	>1000-2000 mg/kg over 50% of estuary or >100ha	>2000 mg/kg over 10% of estuary or >30ha
		Representative sites		<250mg/kg	250-1000 mg/kg	>1000-2000 mg/kg	>2000 mg/kg
	Macroinvertebrates*	AMBI rating		0-1.2	>1.2-3.3	>3.3-4.3	>4.3
		% area with AMBI >4.3		<1% > AMBI 4.3	1-5% > AMBI 4.3	>5-10% > AMBI 4.3	>10% > AMBI 4.3
		TBI (if toxicity an issue)		not yet developed for NZ SIDEs			
Optional Indicators	Sediment Sulphur			Under development			
	% Mud Content (mean of whole estuary area)			Requires development			
	% Estuary Area with Soft Mud (>25% mud content)			<1%	1-5%	5-15%	>15%
	Sedimentation Ratio (current annual mean relative to NSR)			CSR 1 to 1.1 x NSR	CSR 1.1 to 2 x NSR	CSR 2 to 5 x NSR	CSR > 5 x NSR
	% Estuary Area with Sedimentation Rate >5xNSR			<1%	1-5%	5-15%	>15%
	SAV (Seagrass) Extent (% of ENSC)		all habitat	100% of ENSC	>95-99% of ENSC	85-95% of ENSC	<85% of ENSC
	Water column nutrients (TN and TP)		water column	Requires development			
	Water Clarity			at least 20% of the sunlight that strikes the water's surface (incident light) should reach the estuary bed			

*** denotes required supporting indicator (must include at least 1)**
**** normalised scores derived from table on page 28.**

APPENDIX 4. ESTUARY TROPHIC INDEX (ETI) TOOL 1 INPUT DATA

NZ ETI Tool 1 Input details	Calculator Heading	Unit									
Estuary Name	Est_name		Waitohu	Otaki	Mangaone	Peka Peka	Waimeha	Waikanae	Tikotu	Wharemakau	Whareroa
Estuary Number	Est_no		Salt 23	242	Salt 24	Salt 25	Salt 26	178	Salt 27	Salt 28	Salt 29
Regional Council	Reg_Council		GWRC	GWRC	GWRC	GWRC	GWRC	GWRC	GWRC	GWRC	GWRC
Island	Island		North Island	North Island	North Island	North Island	North Island	North Island	North Island	North Island	North Island
NZCHS geomorphic code	NZCHS_code		4C	6C	4C	4C	4C	6B	4C	4C	4C
NZCHS geomorphic class	NZCHS_class		Beach Stream (stream with pond)	Tidal river mouth (barrier beach enclosed)	Beach Stream (stream with pond)	Beach Stream (stream with pond)	Beach Stream (stream with pond)	Tidal river mouth (spit enclosed)	Beach Stream (stream with pond)	Beach Stream (stream with pond)	Beach Stream (stream with pond)
ETI Class	ETI_class		SSRTRE	SSRTRE	SSRTRE	SSRTRE	SSRTRE	SSRTRE	SSRTRE	SSRTRE	SSRTRE
Latitude	LAT	decimal degrees	-40.7292413	-40.76251947	-40.7894209	-40.8244779	-40.8612796	-40.86176844	-40.8914867	-40.9174073	-40.9561128
Longitude	LON	decimal degrees	175.1228706	175.1002365	175.0840009	175.0604149	175.0292322	174.9941548	174.980399	174.9782059	174.9695868
Freshwater inflow	Qf	m^3/s	0.96	30.08	0.84	0.21	0.33	4.27	0.004	0.28	0.37
Annual river total nitrogen loading	TNriver	T/yr	48.1	195.9	46.0	6.2	25.2	81.5	NA	8.1	8.9
Annual river total phosphorus loading	TPriver	T/yr	3.1	41.4	3.6	0.7	4.8	13.6	NA	1.0	2.5
Volume	V	m^3	56000	487150	1000	5500	18000	618297	1000	1375	2250
Tidal Prism	P	m^3	52000	325037	750	5362.5	16575	451237	900	1138	2038
Return flow fraction	b	unitless	NA	NA	NA	NA	NA	NA	NA	NA	NA
ACExR fitted exponent	A	unitless		-0.5				-0.5			
ACExR fitted constant	B	unitless		150.6				126.7			
Ratio NO3	R_NO3	unitless		0.8				0.7			
Ratio DRP	R_DRP	unitless		0.7				0.8			
Ocean salinity	OceanSalinity_mean	ppt	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Ocean nitrate concentration	NOcean	mg/m^3	16.8	16.6	16.8	16.8	16.8	16.8	16.8	16.8	16.8
Ocean DRP concentration	POcean	mg/m^3	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7
Intertidal area	Intertidal	%	86	66	50	95	84	82	80	65	81
Typical closure length	TI	days		NA				NA			
ICOE class	isICOE	one of: TRUE, FALSE	TRUE	FALSE	TRUE	TRUE	TRUE	FALSE	TRUE	TRUE	TRUE
Closure length	closure_length	one of: days, months	days	NA	days	days	days	NA	days	days	days
Estuary Area	est_area_m^2	m^2	112000	162113	4000	22000	36000	331270	4000	5500	9000
Mean depth	mean_depth	m	0.5	3.0	0.25	0.25	0.5	1.9	0.25	0.25	0.25
Tidal height	tidal_height	m	1.8	2.0	1.8	1.8	1.8	1.8	1.8	1.8	1.8

APPENDIX 5. ESTUARY TROPHIC INDEX (ETI) SUSCEPTIBILITY AND SCORES FOR NINE KĀPITI COAST ESTUARIES

	Waitohu		Ōtaki		Mangaone		Peka Peka		Waimeha		Waikānae		Tikotu		Wharemakau		Whareroa	
ETI Tool 1 Eutrophication Susceptibility Rating[1]	Low		Low		Very High		Low		Low		Very High		Low		High		High	
ETI Tool 2 Criteria (Primary=green, Supporting =grey)	data	score	data	score	data	score	data	score	data	score	data	score	data	score	data	score	data	score
Chlorophyll a (summer 90%ile) (mg/m³)	1.1	2	0.6	1	2.6	3	5.3	5	6.1	5	16.5	13	5.5	5	6.3	6	6.2	5
Macroalgae GNA/Estuary Area score (%GNA)	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Macroalgae GNA Area score (ha GNA)	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Macroalgae EQR score	1	1	1	1	1	1	1	1	1	1	0.72	6	1	1	1	1	1	1
PRIMARY INDICATOR RATING SCORE		2.0		1.0		3.0		5.0		5.0		13.0		5.0		6.0		5.0
Dissolved Oxygen (1 day minimum) (mg/m³)	6.11	2	8.63	1	8.11	1	6.1	2	1.68	15	9.8	1	2.4	14	3.5	13	4.24	12
Sediment Redox Potential (mV) measured at 1cm depth *	100	4	-75	9	100	4	100	4	100	4	75	4	-150	12	75	4	100	4
TOC (%) measured at 0-2cm depth *											0.3	3						
TN (mg/kg) measured at 0-2cm depth *											250	5						
NZ AMBI *											4.3	13						
Proportion of Total Est. Area with Soft Muds (>25% mud)			0.14	12							0.07	9						
Current Sediment Load to Natural Sediment Load ratio[2]	5.3	13	4.1	11	9.3	15	7.0	14	9.9	15	4.4	12			7.0	14	9.9	15
SUPPORTING INDICATOR RATING SCORE		6.3		8.3		6.7		6.7		11.3		6.7		13.0		10.3		10.3
ETI SCORE		**0.26**		**0.29**		**0.30**		**0.36**		**0.51**		**0.62**		**0.56**		**0.51**		**0.48**
ETI BAND		B		B		B		B		C		C		C		C		B
ETI Narrative of Eutrophic Symptoms		Low		Low		Low		Low		Mod		Mod		Mod		Mod		Low

1. See Section 3.11 for Tool 1 ICOLL rating criteria. Other input data presented in Appendix 4

**must represent most impacted sediments and at least 10% of estuary area. Redox potential estimated from aRPD depth*

2. Sediment load based on output from NIWA CLUES model 10.6 run using LCDB4 under default settings.

Natural Sediment Load estimated by converting land cover to native forest and assuming 75% retention of sediment through wetland attenuation

Waikānae Estuary data sourced from Robertson and Stevens (2017)

APPENDIX 6. SUMMARY OF WATER QUALITY DATA COLLECTED IN JANUARY 2019 FROM NINE KĀPITI COAST ESTUARIES

Site	Waitohu		Otaki			Mangaone		Pekapeka		Waimeha					
Station	Upper	Dune	TRB Otaki	N. Lagoon	S. Lagoon	Upper beach	Upstream	Upper beach	Upstream	Dune	Bridge	Waimeha	Ngarara	Upper beach	Dune
NZTM East	1766671	1766582	1777594	1777679	1777396	1775830	1775908	1773748	1773826	1771052	1771011	1771024	1771064	1771027	1771045
NZTM North	5468524	5468528	5485996	5486180	5485758	5482529	5482504	5478684	5478591	5474933	5474820	5474660	5474678	5475042	5474900
Measurement depth (m)	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Temperature (°C)	20.1	20.4	19.2	18.2	19.4	20	19.9	24.4	21.7	17.2	18.4	16.9	21.4	19.4	19
DO saturation (%)	69.3	67.7	90.9	103.6	95.4	88.5	90.1	100.5	69.2	52.9	74	99.5	19.2	85	76.6
DO concentration (mg/l)	6.25	6.11	8.43	9.77	8.63	8.01	8.11	8.36	6.1	5.06	6.9	9.5	1.68	7.7	7.06
Salinity (ppt)	0.09	0.11	0.11	0.07	2.5	0.09	0.09	0.19	0.19	0.1	0.11	0.08	0.17	0.11	0.11
pH	7.57	7.64	7.66	7.59	7.65	7.83	8.17	8.05	7.91	7.88	7.54	7.98	7.52	7.5	7.38
Chl-a (ug/l)	0.9	1.1	0	0.1	0.6	2.1	2.6	4.7	5.25	2.1	1.8	0	6.1	1.6	1.7
Stratified	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
Secchi depth (m)	0.7	1.2	na	0.8	1	0.3	1	0.1	0.4	0.7	0.5	0.4	0.6	0.2	0.6
Maximum depth (m)	0.7	1.2	na	0.8	1	0.3	1	0.1	0.4	0.7	0.5	0.4	0.6	0.2	0.6
Channel width (m)	13	14	85	18	100	4	11	5	5	10	10	6	5	5	20
Sediment type	FS	FS	CF	sSMh	sSMh	GF	GF	FS	FS	FS	GF	FS	FS	FS	FS
aRPD depth (mm)	100	100	na	20	20	na	na	100	100	100	2	5	5	100	100

Site	Waikanae					Tikotu				Wharemakau				Whareroa		
Station	Lagoon at floodgat	A	Bend	C	Main bend	Bridge	Upstream	Bridge	Mouth	Footbridge	Road bridge	Footbridge	Mouth	Wall	Bridge	Upstream bridge
NZTM East	1765760	1765811	1765827	1779218	1779271	1766832	1766902	1766832	1766794	1769342	1769244	1769158	1769306	1769170	1766673	1766745
NZTM North	5464247	5464277	5464233	5488880	5489132	5471401	5471425	5471398	5471385	5473433	5473371	5473512	5473208	5473479	5468522	5468554
Measurement depth (m)	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.05	0.1	0.2	0.1	0.1	0.2	0.2	0.2
Temperature (°C)	23.3	23.1	23.6	23.6	21.5	18.8	17.8	19.2	21.2	18.9	18.5	19.1	20.6	17.7	16.9	17.3
DO saturation (%)	103.2	106.4	106.6	108.1	134.4	54.7	27	36	83.2	37.5	73.6	88.7	94.1	48.2	57.4	43.9
DO concentration (mg/l)	8.73	9.14	9.02	9.21	9.86	5.09	2.4	3.4	7.37	3.5	6.9	8.24	8.46	4.65	5.58	4.24
Salinity (ppt)	2.96	0.79	1.1	0.53	32.9	0.17	0.16	0.16	0.16	0.22	0.17	0.18	0.23	0.15	0.15	0.14
pH	8.68	8.82	8.58	8.8	8.56	7.65	7.59	7.58	7.74	7.87	7.88	7.89	7.9	7.71	7.6	7.76
Chl-a (ug/l)	3.18	0	0.7	8.6	0.5	5.1	5.5	3.8	4.4	6.3	4.5	4.5	5.1	5.9	4.9	6.2
Stratified	yes	no	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no
Secchi depth (m)	1.5	1.8	1.8	1.8	1.8	0.1	0.4	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.3	0.8
Maximum depth (m)	1.5	1.8	2.5	1.8	2.5	0.1	0.7	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.3	0.8
Channel width (m)	na	20	30	20	30	5	2	5	2	10	10	10	10	5	5	6
Sediment type	sSMh	sSMh	sSMh	FMS	sSMh	FS	FS	FS	FMSm	FMSl	FMSl	FMS	FS	FS	FMSl	sSMh
aRPD depth (mm)	3	2	30	100	5	5	5	5	25	30	20	30	80	50	100	20
Halocline depth (m)	1		0.8	0.6	1											
Thermocline depth (m)	1		0.8	0.6	1											
Measurement depth 2 (m)	1.5		2	0.6	1.8											
Temperature (°C)	19.2		19.8	22.3	21.5											
DO saturation (%)	76.8		86.1	111.6	134.4											
DO concentration (mg/l)	6.1		6.56	8.52	9.86											
Salinity (ppt)	25.1		32.47	28.7	32.9											
pH	8.32		8.33	8.3	8.56											
Chl-a (ug/l)	0.9		1.2	1.7	16.5											

See Appendix 1 for detail on sediment type classifications

APPENDIX 7. TABLE OF DOMINANT LAND COVER (HA, %, LCDB4 2012/13) FOR ESTUARY CATCHMENTS IN THE KĀPITI COAST WHAITUA. SEE ALSO FIG 3.

Class	Waitohu	Otaki	Mangaone	PekaPeka	Waimeha	Waikanae	Wharemakau	Whareroa
1 Built-up Area (settlement)	170 (4%)	181 (1%)	46 (1%)	0 (0%)	193 (11%)	804 (5%)	430 (30%)	15 (1%)
2 Urban Parkland/Open Space	90 (2%)	9 (0%)	0 (0%)	0 (0%)	55 (3%)	87 (1%)	90 (6%)	0 (0%)
5 Transport Infrastructure	0 (0%)	1 (0%)	2 (0%)	1 (0%)	0 (0%)	1 (0%)	24 (2%)	2 (0%)
6 Surface Mine or Dump	3 (0%)	14 (0%)	1 (0%)	0 (0%)	0 (0%)	18 (0%)	9 (1%)	0 (0%)
10 Sand or Gravel	12 (0%)	56 (0%)	3 (0%)	4 (0%)	4 (0%)	0 (0%)	0 (0%)	2 (0%)
12 Landslide	0 (0%)	26 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
16 Gravel or Rock	0 (0%)	249 (1%)	0 (0%)	0 (0%)	0 (0%)	13 (0%)	0 (0%)	0 (0%)
20 Lake or Pond	34 (1%)	11 (0%)	2 (0%)	4 (0%)	9 (1%)	15 (0%)	2 (0%)	0 (0%)
21 River	0 (0%)	97 (0%)	0 (0%)	0 (0%)	0 (0%)	9 (0%)	0 (0%)	0 (0%)
22 Estuarine Open Water	2 (0%)	15 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
30 Short-rotation Cropland	24 (0%)	202 (1%)	68 (1%)	5 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
33 Orchard, Vineyard or Other Perennial Crop	18 (0%)	173 (0%)	114 (2%)	9 (1%)	6 (0%)	13 (0%)	0 (0%)	8 (0%)
40 High Producing Exotic Grassland	2126 (44%)	3067 (9%)	2882 (60%)	642 (59%)	850 (48%)	2979 (20%)	235 (17%)	946 (60%)
41 Low Producing Grassland	63 (1%)	198 (1%)	304 (6%)	41 (4%)	46 (3%)	167 (1%)	113 (8%)	8 (0%)
43 Tall Tussock Grassland	0 (0%)	540 (2%)	0 (0%)	0 (0%)	0 (0%)	17 (0%)	0 (0%)	0 (0%)
45 Herbaceous Freshwater Vegetation	70 (1%)	21 (0%)	41 (1%)	13 (1%)	79 (5%)	24 (0%)	3 (0%)	24 (2%)
50 Fernland	0 (0%)	27 (0%)	0 (0%)	0 (0%)	0 (0%)	8 (0%)	0 (0%)	4 (0%)
51 Gorse and/or Broom	74 (2%)	197 (1%)	14 (0%)	1 (0%)	27 (2%)	54 (0%)	28 (2%)	161 (10%)
52 Manuka and/or Kanuka	42 (1%)	120 (0%)	1 (0%)	0 (0%)	14 (1%)	255 (2%)	55 (4%)	41 (3%)
54 Broadleaved Indigenous Hardwoods	494 (10%)	2275 (6%)	519 (11%)	132 (12%)	60 (3%)	1516 (10%)	110 (8%)	178 (11%)
55 Sub Alpine Shrubland	0 (0%)	1000 (3%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
56 Mixed Exotic Shrubland	5 (0%)	5 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
58 Matagouri or Grey Scrub	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	19 (0%)	0 (0%)	0 (0%)
64 Forest - Harvested	11 (0%)	20 (0%)	51 (1%)	1 (0%)	26 (1%)	218 (1%)	2 (0%)	2 (0%)
68 Deciduous Hardwoods	40 (1%)	57 (0%)	10 (0%)	4 (0%)	14 (1%)	47 (0%)	2 (0%)	2 (0%)
69 Indigenous Forest	1310 (27%)	26519 (74%)	277 (6%)	23 (2%)	286 (16%)	7014 (46%)	5 (0%)	34 (2%)
71 Exotic Forest	255 (5%)	684 (2%)	434 (9%)	203 (19%)	85 (5%)	1995 (13%)	315 (22%)	140 (9%)
Grand Total	**4842 (100%)**	**35764 (100%)**	**4770 (100%)**	**1081 (100%)**	**1754 (100%)**	**15275 (100%)**	**1424 (100%)**	**1566 (100%)**


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