coastalmanagement

Waikawa Estuary

Broad Scale Habitat Mapping 2008/09

Prepared for

Environment Southland

June 2009

Cover Photo: Waikawa Estuary, looking upstream from near the entrance.


Mapping rushland and terrestrial scrub adjacent to Waikawa River in the upper estuary.

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By

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All photos by Wriggle except where noted otherwise.

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WAIKAWA ESTUARY

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Moderate sedimentation
Landuse intensification
Reduction in saltmarsh, dune and vegetated terrestrial margin habitat

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Next survey 2013.

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5 -10 yearly
Undertaken in 2004, 2009.
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↓

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- Limit intensive landuse
- Enhance saltmarsh
- Enhance margin vegetation
- Manage for sea level rise
- Manage weeds and pests
- Evaluate sedimentation removal

This report summarises the results of 2004 and 2009 broad scale mapping of Waikawa Estuary, a moderate size (675ha) tidal lagoon estuary located in eastern Southland, and one of the key estuaries in Environment Southland's long-term coastal monitoring programme. The margin flow diagram outlines the monitoring and management process for Waikawa Estuary. The tables below summarise broad scale results, condition ratings, overall estuary condition, and monitoring and management recommendations. A summary map of the broad scale habitat features of Waikawa Estuary is also presented on the following page as an example of the more detailed GIS data that accompanies this report.

Broad Scale Monitoring Results

- Very soft muds dominated the upper estuary while firm mud/sand and clean mobile sands dominated the central basin and lower estuary. The area of mobile sand increased from 2004 to 2009 in the central basin and lower estuary.
- Sediment plate measures (2007-2009) showed a decrease in sediment depth in the upper and central estuary, while substrate mapping showed the transition between soft muds and firm sand retreated ~80m between 2004 and 2009.
- Saltmarsh cover was low (previously cleared or restricted by steep land margins), and dominated by jointed wire rush.
- Saltmarsh cover declined slightly between 2004 and 2009 due to erosion of ~0.05ha of herbfield in the eastern arm.
- The 200m vegetated margin was dominated by grazed pasture, although a narrow buffer of primarily native scrub and forest or duneland separates ~80% of the estuary from surrounding farmland.
- Nuisance macroalgal growth (a key indicator of eutrophication) was low (measured in 2007 and 2008).
- Seagrass cover was low, located primarily in the lower estuary, and absent from the soft muds of the upper estuary.
- Sediment Oxygenation: Redox Potential Discontinuity (RPD) was generally <1cm deep in the upper estuary indicating poor oxygenation, and 3->10cm deep in the central basin and lower estuary indicating good oxygenation.

Broad Scale Condition Ratings	2004	2007	2008	2009
Percent cover of soft mud	Poor	Not measured		Poor
Change in soft mud area	Baseline year	Not measured		Very Good
Sedimentation rate	Not measured	Baseline year	Very Good	Moderate
Percent cover of saltmarsh	Very Low	Not measured		Very Low
Change in saltmarsh area	Baseline year	Not measured		Poor
Percent cover vegetated margin	Fair	Not measured		Fair
Change in vegetated margin area	Not measured	Not measured		Baseline year
Percent cover of seagrass	Poor	Not measured		Poor
Change in seagrass area	Baseline year	Not measured		Very Good
Macroalgal cover	Not measured	Good	Good	Not measured
RPD Depth - upper estuary	Not measured	Not measured		Poor
RPD Depth - lower estuary	Not measured	Not measured		Good-Very Good

Estuary Condition

Broad scale monitoring shows this high value estuary is in a good to fair condition. It has problems associated with sedimentation (extensive poorly oxygenated, muddy sediments and turbid water in the upper estuary) and historical habitat loss (little saltmarsh, limited seagrass, and a modified vegetated terrestrial margin). However, there are positive signs of a recent reduction in upper estuary mud, little recent loss of high value vegetated habitat, and few nutrient enrichment issues (sparse nuisance macroalgal growth).

Recommended Monitoring and Management

Undertake broad and fine scale monitoring five yearly (including land use changes, macroalgal mapping). Next due Feb 2013. Monitor sedimentation rate annually (due Feb 2010).
Limit intensive land development, encourage protection and enhancement of saltmarsh, dune, and margin vegetation, and manage for weeds and pests.
Manage for sea level rise.
Evaluate likely sediment re-suspension and removal rates from the estuary.
Monitor erosion and herbfield changes at a representative site in the eastern estuary.

Summary map of the broad scale features of Waikawa Estuary, February 2009.

1. INTRODUCTION

OVERVIEW

Developing an understanding of the condition and risks to estuarine habitats is critical to the management of biological resources. In the 1990's, Environment Southland (ES) established a long-term monitoring programme to assess the condition of key estuaries in its region. The estuaries currently included in the programme are Waikawa, Jacobs River, New River, Haldane, Fortrose (Toetoes), Waiau, Waituna and Freshwater. Risk assessments have been undertaken for a number of other estuaries in order to establish priorities for their management.

Waikawa Estuary was first broad scale mapped in 2004, with fine scale monitoring undertaken in 2005, 2006, 2007 and 2008. In addition, macroalgal mapping was carried out in 2007 and 2008, and sediment rate monitoring plates established in 2007. Results for Waikawa Estuary, along with other key estuaries in the ES monitoring programme, have been presented in a series of separate reports (e.g. Robertson et al. 2004, Stevens & Asher 2005, Robertson & Asher, 2006, Robertson & Stevens, 2006, 2007, 2008). In 2009, Wriggle Coastal Management were contracted to undertake broad scale habitat mapping of Waikawa Estuary using the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002) plus recent extensions (see Table 1 and Table 3).

The Waikawa Estuary monitoring programme consists of three components:

1. **Ecological Vulnerability Assessment** of the estuary to major issues (see Table 2) and appropriate monitoring design. This component has been completed for Waikawa and is reported on in Robertson and Stevens (2008a).
2. **Broad scale habitat mapping,** (EMP approach). This component, which documents the key habitats within the estuary, and changes to these habitats over time, is the subject of the current report. It was first reported on in Robertson et al. (2004).
3. **Fine scale physical, chemical and biological monitoring**, (EMP approach) including sedimentation plate deployment. This component provides detailed information on estuary condition (the 4 years of baseline monitoring are summarised in Robertson and Stevens 2008).

This report documents the broad scale monitoring undertaken in February 2009 including sediment types, redox potential discontinuity (RPD) depth, saltmarsh vegetation, seagrass, and the estuary's 200m terrestrial margin. Macroalgae was not assessed in 2009. Condition ratings (based on Robertson and Stevens 2006, 2007, 2008) are used to assess estuary health in relation to key issues of sedimentation, eutrophication, and habitat loss (see Table 2 for a summary of the major issues affecting most New Zealand estuaries, and Table 3 for a summary of broad and fine scale EMP indicators). Monitoring and management recommendations are also provided.

TIDAL LAGOON ESTUARIES

Waikawa Estuary, like most of the large Southland estuaries (e.g. Jacobs River, New River) fits the "tidal lagoon estuary" category. Such estuaries are shallow, with a large basin, simple shorelines and extensive tidal flats. They generally have a narrow entrance to the sea that is often constricted by a sand bar. Most of the estuary water volume in tidal lagoon estuaries is drained each tidal cycle and hence they have low water residence times (often <3 days), and good flushing, particularly in the lower estuary.

The volume of river water inflow is generally small in comparison to marine inputs. Wind has a large influence and affects currents, mixing, and sediment resuspension. The combination of wave resuspension and good flushing means that the majority of sediments tend to be sandy and homogeneous. However, muddy sediments can be present near freshwater inputs and in sheltered arms.

Tidal lagoon estuaries are also well-mixed and salinity is close to that of the sea. The coastal plumes from such estuaries are generally much cleaner than from tidal river lagoons. Biodiversity is generally high.

1. INTRODUCTION (CONTINUED)

Table 1. Coastal monitoring tools (Wriggle Coastal Management).

Resource	Tools for Monitoring and Management
Estuaries	Estuary vulnerability matrix. Broad scale estuary and 200m terrestrial margin habitat mapping. Fine scale estuary monitoring. Sedimentation rate measures (using plates buried in sediment). Historical sedimentation rates (using radio-isotope ageing of sediment cores). Macroalgae and seagrass mapping (reported as separate GIS layers). Condition ratings for key indicators. Georeferenced digital photos (as a GIS layer). Upper estuary monitoring and assessment.
Beaches, Dunes	Beach and dune vulnerability matrix. Broad scale beach, dune and terrestrial margin mapping. Fine scale beach monitoring. Condition ratings for key indicators. Georeferenced digital photos (as a GIS layer).
Rocky Shores	Rocky shore vulnerability matrix. Broad scale rocky shore and terrestrial margin mapping. Fine scale rocky shore monitoring. Georeferenced digital photos (as a GIS layer).

Table 2. Summary of the major issues affecting most NZ tidal lagoon estuaries.

Key Estuary Issues	
Sedimentation	Because estuaries are a sink for sediments, their natural cycle is to slowly infill with fine muds and clays. Prior to European settlement they were dominated by sandy sediments and had low sedimentation rates (<1 mm/year). In the last 150 years, with catchment clearance, wetland drainage, and land development for agriculture and settlements, New Zealand's estuaries have begun to infill rapidly. Today, average sedimentation rates in our estuaries are typically 10 times or more higher than before humans arrived.
Nutrients	Increased nutrient richness of estuarine ecosystems stimulates the production and abundance of fast-growing algae, such as phytoplankton, and short-lived macroalgae (e.g. sea lettuce). Fortunately, because most New Zealand estuaries are well flushed, phytoplankton blooms are generally not a major problem. Of greater concern is the mass blooms of green and red macroalgae, mainly of the genera *Enteromorpha, Cladophora, Ulva,* and *Gracilaria* which are now widespread on intertidal flats and shallow subtidal areas of nutrient-enriched New Zealand estuaries. They present a significant nuisance problem, especially when loose mats accumulate on shorelines and decompose. Blooms also have major ecological impacts on water and sediment quality and the animals that live there.
Disease Risk	Runoff from farmland and human wastewater often carries a variety of disease-causing organisms or pathogens (including viruses, bacteria and protozoans) that, once discharged into the estuarine environment, can survive for some time. Every time humans come into contact with seawater that has been contaminated with human and animal faeces, we expose ourselves to these organisms and risk getting sick. Aside from serious health risks posed to humans through recreational contact and shellfish consumption, pathogen contamination can also cause economic losses due to closed commercial shellfish beds. Diseases linked to pathogens include gastroenteritis, salmonellosis, and hepatitis A.
Toxic Contamination	In the last 60 years, New Zealand has seen a huge range of synthetic chemicals introduced to estuaries through urban and agricultural stormwater runoff, industrial discharges and air pollution. Many of them are toxic in minute concentrations. Of particular concern are polycyclic aromatic hydrocarbons (PAHs), toxic heavy metals, polychlorinated biphenyls (PCBs), and pesticides. These chemicals collect in sediments and bio-accumulate in fish and shellfish, causing health risks to people and marine life.
Habitat Loss	Estuaries have many different types of habitats including shellfish beds, seagrass meadows, saltmarshes (rushlands, herbfields, reedlands etc.), forested wetlands, beaches, river deltas, and rocky shores. The continued health and biodiversity of estuarine systems depends on the maintenance of high-quality habitat. Loss of habitat negatively affects fisheries, animal populations, filtering of water pollutants, and the ability of shorelines to resist storm-related erosion. Within New Zealand, habitat degradation or loss is common-place with the major causes cited as sea level rise, population pressures on margins, dredging, drainage, reclamation, pest and weed invasion, reduced flows (damming and irrigation), over-fishing, polluted runoff and wastewater discharges.

1. INTRODUCTION (CONTINUED)

Table 3. Summary of the broad and fine scale EMP indicators.

Issue	Indicator	Method
Sedimentation	Soft Mud Area	Broad scale mapping - estimates the area and change in soft mud habitat over time.
Sedimentation	Sedimentation Rate	Fine scale measurement of sediment deposition.
Eutrophication	Nuisance Macroalgal Cover	Broad scale mapping - estimates the change in the area of nuisance macroalgal growth (e.g. sea lettuce (*Ulva*), *Gracilaria* and *Enteromorpha*) over time.
Eutrophication	Organic and Nutrient Enrichment	Chemical analysis of total nitrogen, total phosphorus, and total organic carbon (calculated from ash free dry weight) in replicate samples from the upper 2cm of sediment.
Eutrophication	Redox Profile	Measurement of depth of redox potential discontinuity profile (RPD) in sediment estimates likely presence of deoxygenated, reducing conditions.
Toxins	Contamination in Bottom Sediments	Chemical analysis of indicator metals (total recoverable cadmium, chromium, copper, nickel, lead and zinc) in replicate samples from the upper 2cm of sediment.
Toxins, Eutrophication, Sedimentation	Biodiversity of Bottom Dwelling Animals	Type and number of animals living in the upper 15cm of sediments (infauna in 0.0133m^2 replicate cores), and on the sediment surface (epifauna in 0.25m^2 replicate quadrats).
Habitat Loss	Saltmarsh Area	Broad scale mapping - estimates the area and change in saltmarsh habitat over time.
Habitat Loss	Seagrass Area	Broad scale mapping - estimates the area and change in seagrass habitat over time.
Habitat Loss	Vegetated Terrestrial Buffer	Broad scale mapping - estimates the area and change in buffer habitat over time.

TIDAL LAGOON ESTUARIES (CONTINUED)

Waikawa Estuary - Photo Environment Southland, February 2008.

In a good state, well flushed tidal lagoon estuaries have high water clarity, low nutrient and sediment inputs, high sediment quality (very little mud), high biodiversity, and an intact saltmarsh and terrestrial margin that buffers against weed and pest invasions. Disease risk and toxicity are low, and there are no extensive growths of nuisance macroalgae, microalgae or phytoplankton.

Following catchment development, sediment and nutrient inputs increase, and modification of the estuary margin (primarily drainage and reclamation) commonly occurs. If inputs of sediment and nutrients are high, there will be a shift to increased eutrophication. Eutrophication indicators are the presence of extensive nuisance macroalgal growths, development of benthic microalgal mats, and sediments that are poorly oxygenated, sulphide rich, have nuisance odours, and have low sediment biodiversity.

High sediment inputs will also generally result in extensive areas of soft mud accumulating in the upper estuary and on sheltered tidal flats, decreasing water clarity, and often resulting in the loss of seagrass. Farm runoff, human wastewater, and inputs from urban and agricultural stormwater runoff will increase disease risk and toxicity.

Modification of the upper intertidal margins and terrestrial buffer vegetation will result in habitat loss, particularly saltmarsh and whitebait spawning areas, will facilitate the encroachment of weeds into saltmarsh and dune areas, reduce natural assimilation and filtering of sediment and nutrients, and reduce its role in flood attenuation.

1. INTRODUCTION (CONTINUED)

WAIKAWA ESTUARY (HARBOUR)

Source: Robertson and Stevens (2008a)

Estuary Type/Area	Tidal Lagoon
Catchment	237 km^2
Dairy cows	599 cows
Nitrogen loading	Low-Mod: 7 kg/ha/yr
Catchment geology	Gravel, sandstone/siltstone, peat
Saltmarsh (ha)	40 ha primarily *Leptocarpus*
Salinity	Well mixed, sea water dominated
Mean depth (m)	1-2m
Tidal flats	High
Uses/Values	Walking, shellfish collection, birds, scenic, fishing, duckshooting, whitebaiting, bathing.

Lower Waikawa Estuary

Human Use		High
Ecological Value		High
Existing Condition		Fair
Susceptibility		Low
Stressors		Low
OVERALL VULNERABILITY		Moderate

A summary of the key features and vulnerability of the estuary, taken from Robertson and Stevens 2008a, is provided below.

Waikawa Estuary is a moderate-sized "tidal lagoon" type estuary (~700ha), that discharges to the east end of Porpoise Bay. Situated at the mouth of the Waikawa River, it drains a mixed catchment of high production pasture and native bush. The estuary is relatively shallow (mean depth approximately 2m) and bordered by a mix of vegetation and landuses (bush and grazed pasture). The estuary has a wide range of habitats (extensive tidal flats, seagrass and saltmarsh areas) but has lost areas through drainage and reclamation. It has a 3m spring tidal range and serves as a port for several fishing boats which operate from the jetties near the centre of the Waikawa township. The estuary is regularly monitored by Environment Southland.

Uses and Values. Human use of the estuary is high - mainly shellfish gathering, swimming, boating, bird study, fishing, walking, and aesthetics.

Ecological Values. Ecologically, it is valued for it's high biodiversity including fish and birdlife. In addition, the endemic Hector's dolphins, which are resident in the Porpoise Bay area during the months of October to March, are dependent on the Waikawa Estuary and Porpoise Bay for food.

Existing Condition. Water quality is expected to be good. Nuisance macroalgal blooms are rated relatively low and the sediments are well-oxygenated. Sediment type is mixed, but approximately half of the estuary surface is covered by soft muds and recent sedimentation rates are high. Metal concentrations are low. Estimated nitrogen (the major driver of eutrophication) loadings are low-moderate.

Presence of Stressors. The presence of stressors is moderate. Landuse intensification, sea level rise and habitat migration, absence of natural vegetated margins, grazed margins, and weed invasions are the main threats.

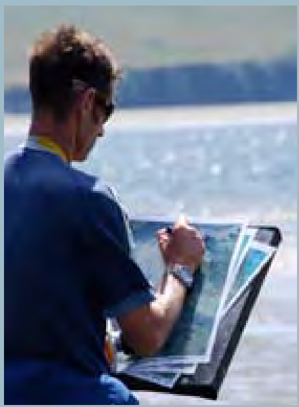
Susceptibility to Stressors. Susceptibility to stressors is expected to be low given that the estuary is well flushed (low residence time), and already modified.

Issues	Monitoring	Management
Catchment runoff. Grazing near margin. Developed margin. Sea level rise.	• Map intensive landuse every 5 years. • Habitat map estuary every 5 years. • Fine scale phys/chem/biota monitoring 5 yearly (after baseline established). • Sedimentation rate monitoring. • Map macroalgal cover 5 yearly.	• Limit intensive landuse development. • Encourage margin vegetation enhancement. • Plan for estuary expansion with sea level rise. • Reduce sediment inputs.

Waikawa Estuary 2008	Sedimentation	Eutrophication	Disease Risk	Contaminants	Habitat Loss	Invaders	Shellfish
Existing Condition Rating	Fair	Good	Good	Very Good	Fair	Good	Good
Susceptibility Rating	Low	Low	Low	Low	Low	Low	Low
Vulnerability Rating	Moderate	Low	Low	Low	Moderate	Low	Low

2. METHODS

BROAD SCALE HABITAT MAPPING



>1 %
1-5%
5-10 %
10-20 %
20-50 %
50-80 %
80-100 %

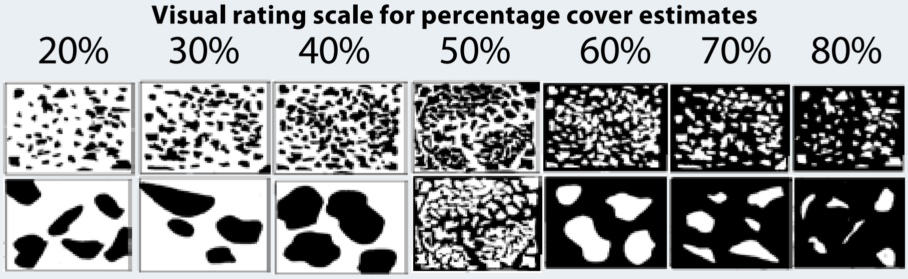
Broad-scale mapping is a method for describing habitat types based on the dominant surface features present (e.g. substrate: mud, sand, cobble, rock; or vegetation: macrophyte, macroalgae, rushland, etc). It follows the EMP approach originally described for use in NZ estuaries by Robertson et al. (2002) with a combination of aerial photography, detailed ground-truthing, and GIS-based digital mapping used to record the primary habitat features present. Very simply, the method involves three key steps:

- Obtaining laminated aerial photos for recording dominant habitat features.
- Carrying out field identification and mapping (i.e. ground-truthing).
- Digitising the field data into GIS layers (ArcMap 9.2).

For the 2009 study, ES supplied rectified ~0.3m/pixel resolution colour aerial photos flown in February 2008. Photos covering the estuary at a scale of 1:5,000 were laminated, and two scientists ground-truthed the spatial extent of dominant habitat and substrate types by walking the extent of the estuary recording features directly on the laminated aerial photos over two days in February 2009. Increased resolution and spatial accuracy of the 2008 aerial photos allowed habitat features to be more accurately digitised than the 2004 broad scale mapping, with a subsequent improvement in the classification of many estuary features.

Classification of macroalgae and macrophyte percentage cover within the estuary was assessed using a seven category visual rating scale (see examples below and left). The results are used to describe macroalgae and macrophyte density and distribution within the estuary.

Visual rating scale for percentage cover estimates



Sampling positions and photographs were georeferenced and the information collected was used to produce GIS-based habitat maps showing the following:

- Dominant substrate.
- Depth of the Redox Potential Discontinuity (RPD).
- Percent cover of intertidal macrophytes (*Zostera*).
- Dominant saltmarsh vegetation.
- 200m wide terrestrial margin vegetation/landuse.

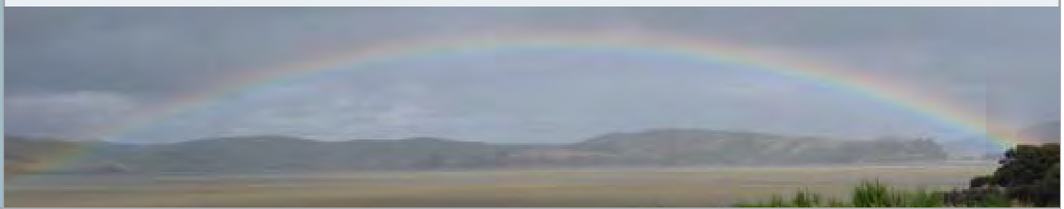
Appendix 1 lists the class definitions used to classify substrate and vegetation.

Digital mapping results were entered by digitising features directly off aerial photos in the GIS using a Wacom Intuos3 electronic drawing tablet within ArcMap 9.2. The spatial location, size, and type of broad scale habitat features in the estuary are provided as ArcMap 9.2 GIS shapefiles on a separate CD. Georeferenced digital field photos (GPS-Photolink) are also supplied as a GIS layer. The broad scale results are summarised in the current report in Section 3, with the supporting GIS files providing much more detail in a data set designed for easy interrogation to address specific monitoring and management questions.

2. METHODS (CONTINUED)

CONDITION RATINGS

A series of interim broad scale estuary "condition ratings" (presented below) have been proposed for Waikawa Estuary, based on the ratings developed for Southland's estuaries - e.g. Robertson & Stevens 2006, 2007, 2008. The ratings are based on a review of estuary monitoring data, guideline criteria, and expert opinion. They are designed to be used in combination with each other (usually involving expert input) when evaluating overall estuary condition and deciding on appropriate management. The condition ratings include an "early warning trigger" to highlight rapid or unexpected change, and each rating has a recommended monitoring and management response. In most cases initial management is to further assess an issue and consider what response actions may be appropriate (e.g. develop an Evaluation and Response Plan - ERP).



REDOX POTENTIAL DISCONTINUITY (RPD)

The RPD is the grey layer between the oxygenated yellow-brown sediments near the surface and the deeper anoxic black sediments. The RPD marks the transition between oxygenated and reduced conditions and is an effective ecological barrier for most but not all sediment-dwelling species. A rising RPD will force most macrofauna towards the sediment surface to where oxygen is available. In addition, nutrient availability in estuaries is generally much greater where sediments are anoxic, with consequent exacerbation of the eutrophication process.

RPD CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	>10cm depth below surface	Monitor at 5 year intervals after baseline established
Good	3-10cm depth below sediment surface	Monitor at 5 year intervals after baseline established
Fair	1-3cm depth below sediment surface	Post baseline, monitor 2 yearly. Initiate ERP
Poor	<1cm depth below sediment surface	Post baseline, monitor 2 yearly. Initiate ERP
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate ERP (Evaluation and Response Plan)

SOFT MUD (PERCENT COVER)

Estuaries are a sink for sediments. Where large areas of soft mud are present, they are likely to lead to major and detrimental ecological changes that could be very difficult to reverse, and indicate where changes in land use management may be needed.

SOFT MUD PERCENT COVER CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<2% of estuary substrate is soft mud	Monitor at 5 year intervals after baseline established
Good	2%-5% of estuary substrate is soft mud	Monitor at 5 year intervals after baseline established
Fair	5%-15% of estuary substrate is soft mud	Post baseline, monitor 5 yearly. Initiate ERP
Poor	>15% of estuary substrate is soft mud	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	>5% of estuary substrate is soft mud	Initiate ERP (Evaluation and Response Plan)

SOFT MUD (AREA)

Soft mud in estuaries decreases water clarity, lowers biodiversity and affects aesthetics and access. Increases in the area of soft mud indicate where changes in catchment land use management may be needed.

SOFT MUD AREA CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	Area of cover (ha) not increasing	Monitor at 5 year intervals after baseline established
Good	Increase in area of cover (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Fair	Increase in area of cover (ha) 5-15% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Poor	Increase in area of cover (ha) >15% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	Trend of increase in area of cover (ha)	Initiate ERP (Evaluation and Response Plan)

2. METHODS (CONTINUED)

SEDIMENTATION RATE

Elevated sedimentation rates are likely to lead to major and detrimental ecological changes within estuary areas that could be very difficult to reverse, and indicate where changes in land use management may be needed.

SEDIMENTATION RATE CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Low	<1mm/yr (typical pre-European rate)	Monitor at 5 year intervals after baseline established
Low	1-5mm/yr	Monitor at 5 year intervals after baseline established
Moderate	5-10mm/yr	Monitor at 5 year intervals after baseline established
High	10-20mm/yr	Monitor yearly. Initiate ERP
Very High	>20mm/yr	Monitor yearly. Manage source
Early Warning Trigger	Rate increasing	Initiate ERP (Evaluation and Response Plan)

MACROALGAE INDEX

Certain types of macroalgae can grow to nuisance levels in nutrient-enriched estuaries causing sediment deterioration, oxygen depletion, bad odours and adverse impacts to biota. A continuous index (the macroalgae coefficient - MC) has been developed to rate macroalgal condition based on the percentage cover of macroalgae in defined categories using the following equation: ***MC=((0 x %macroalgal cover <1%)+(0.5 x %cover 1-5%)+(1 x %cover 5-10%)+(3 x %cover 10-20%)+(4.5 x %cover 20-50%)+(6 x %cover 50-80%)+(7.5 x %cover >80%))/100.*** Overriding the MC is the presence of either nuisance conditions within the estuary, or where >5% of the intertidal area has macroalgal cover >50%. In these situations the estuary is given a minimum rating of FAIR and should be monitored annually with an Evaluation & Response Plan initiated.

MACROALGAE CONDITION RATING		
RATING	DEFINITION (+Macroalgae Coefficient)	RECOMMENDED RESPONSE
Over-riding rating: Fair	Nuisance conditions exist, or >50% cover over >5% of estuary	Monitor yearly. Initiate Evaluation & Response Plan
Very Good	Very Low (0.0 - 0.2)	Monitor at 5 year intervals after baseline established
Good	Low (0.2 - 0.8)	Monitor at 5 year intervals after baseline established
	Low Low-Moderate (0.8 - 1.5)	Monitor at 5 year intervals after baseline established
Fair	Low-Moderate (1.5 - 2.2)	Monitor yearly. Initiate ERP
	Moderate (2.2 - 4.5)	Monitor yearly. Initiate ERP
Poor	High (4.5 - 7.0)	Monitor yearly. Initiate ERP
	Very High (>7.0)	Monitor yearly. Initiate ERP
Early Warning Trigger	Trend of increasing Macroalgae Coefficient	Initiate ERP (Evaluation and Response Plan)

SEAGRASS INDEX

Seagrass (*Zostera muelleri*) grows in soft sediments in NZ estuaries where its presence enhances estuary biodiversity. Though tolerant of a wide range of conditions, it is vulnerable to fine sediments in the water column and sediment quality (particularly if there is a lack of oxygen and production of sulphide). A continuous index (the seagrass coefficient - SC) has been developed to rate seagrass condition based on the percentage cover of seagrass in defined categories using the following equation: ***SC=((0 x %seagrass cover <1%)+(0.5 x %cover 1-5%)+(2 x %cover 5-10%)+(3.5 x %cover 10-20%)+(6 x %cover 20-50%)+(9 x %cover 50-80%)+(12 x %cover >80%))/100.***

SEAGRASS CONDITION RATING		
RATING	DEFINITION (+Seagrass Coefficient)	RECOMMENDED RESPONSE
Poor	Very Low (0.0 - 0.2)	Post baseline, monitor 5 yearly. Initiate ERP
Fair	Low (0.2 - 0.8)	Post baseline, monitor 5 yearly. Initiate ERP
	Low Low-Moderate (0.8 - 1.5)	Post baseline, monitor 5 yearly. Initiate ERP
Good	Low-Moderate (1.5 - 2.2)	Monitor at 5 year intervals after baseline established
	Moderate (2.2 - 4.5)	Monitor at 5 year intervals after baseline established
Very Good	High (4.5 - 7.0)	Monitor at 5 year intervals after baseline established
	Very High (>7.0)	Monitor at 5 year intervals after baseline established
Early Warning Trigger	Trend of decreasing Seagrass Coefficient	Initiate ERP (Evaluation and Response Plan)

2. METHODS (CONTINUED)

SALTMARSH (PERCENT COVER)

A variety of saltmarsh species (commonly dominated by rushland but including scrub, sedge, tussock, grass, reed, and herb fields) grow in the upper margins of most NZ estuaries where vegetation stabilises fine sediment transported by tidal flows. Saltmarshes have high biodiversity, are amongst the most productive habitats on earth and have strong aesthetic appeal. Where saltmarsh cover is limited, these values are decreased.

SALTMARSH PERCENT COVER CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very High	>20% of estuary area is saltmarsh	Monitor at 5 year intervals after baseline established
High	10%-20% of estuary area is saltmarsh	Monitor at 5 year intervals after baseline established
Moderate	5%-10% of estuary area is saltmarsh	Monitor at 5 year intervals after baseline established
Low	2%-5% of estuary area is saltmarsh	Post baseline, monitor 5 yearly. Initiate ERP
Very Low	<2% of estuary area is saltmarsh	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	<5% of estuary area is saltmarsh	Initiate ERP (Evaluation and Response Plan)

SALTMARSH (AREA)

Saltmarshes are sensitive to a wide range of pressures including land reclamation, margin development, flow regulation, sea level rise, grazing, wastewater contaminants, and weed invasion. Decreases in saltmarsh extent is likely to indicate an increase in these types of pressures.

SALTMARSH AREA CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	Area of cover (ha) not decreasing	Monitor at 5 year intervals after baseline established
Good	Decline in area of cover (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Fair	Decline in area of cover (ha) 5-20% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Poor	Decline in area of cover (ha) >20% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	Trend of decrease in area of cover (ha)	Initiate ERP (Evaluation and Response Plan)

TERRESTRIAL VEGETATED BUFFER (PERCENT COVER)

The presence of a terrestrial margin dominated by a dense assemblage of scrub/shrub and forest vegetation acts as an important buffer between developed areas and the saltmarsh and estuary. This buffer protects against introduced weeds and grasses, naturally filters sediments and nutrients, and provides valuable ecological habitat.

TERRESTRIAL VEGETATED BUFFER PERCENT COVER CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very High	80%-100% cover of terrestrial vegetated buffer	Monitor at 5 year intervals after baseline established
High	50%-80% cover of terrestrial vegetated buffer	Monitor at 5 year intervals after baseline established
Fair	25%-50% cover of terrestrial vegetated buffer	Post baseline, monitor 5 yearly. Initiate ERP
Poor	5%-25% cover of terrestrial vegetated buffer	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	<50% cover of terrestrial vegetated buffer	Initiate ERP (Evaluation and Response Plan)

TERRESTRIAL VEGETATED BUFFER (AREA)

Estuaries are sensitive to a wide range of pressures including land reclamation, margin development, flow regulation, sea level rise, grazing, wastewater contaminants, and weed invasion. Reduction in the vegetated buffer around the estuary is likely to result in a decline in estuary quality.

TERRESTRIAL VEGETATED BUFFER AREA CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	Terrestrial buffer is 100% dense vegetation	Monitor at 5 year intervals after baseline established
Good	Decline in vegetated buffer (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Fair	Decline in vegetated buffer (ha) 5-10% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Poor	Decline in vegetated buffer (ha) >10% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	Trend of decrease in area of vegetated buffer (ha)	Initiate ERP (Evaluation and Response Plan)

3. RESULTS AND DISCUSSION

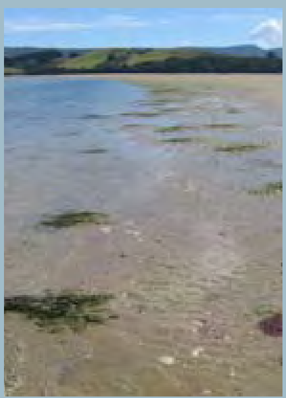
OVERVIEW

This section summarises the dominant habitats of the estuary and their likely condition, particularly in relation to the key estuary issues of sedimentation, eutrophication and habitat loss. The broad scale mapping showed that at low tide the estuary is 15% water, 84% unvegetated intertidal flats, and 1% saltmarsh (Table 4). Such characteristics are typical of tidal lagoon estuaries, although the saltmarsh cover is low (Figure 1).

Table 4. Summary of dominant estuary features, January 2009.

Dominant Estuary Feature	Area (Ha)	Area (%)
Saltmarsh	5.3	0.8
Intertidal flats	569.0	84.3
Water	100.7	14.9
TOTAL (excludes terrestrial margin features)	**675**	**100**

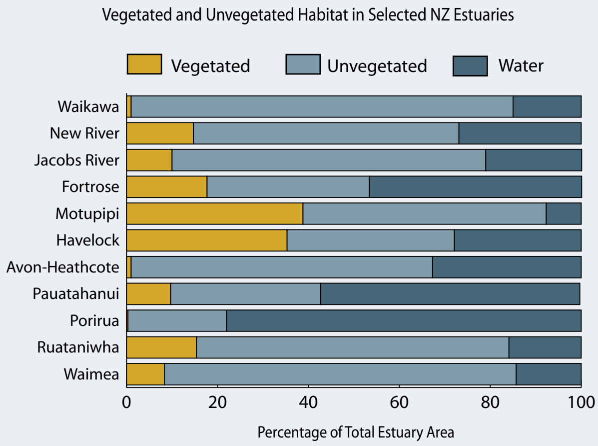
WATER



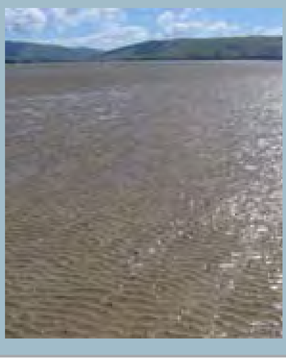
Waikawa is typical of New Zealand seawater dominated tidal lagoon estuaries in that it has a relatively small subtidal component (Figure 1), and almost completely drains on each tidal cycle, exposing extensive unvegetated tidal flats.

Particularly in the lower estuary the high rate of flushing mobilises sediments and keeps them well oxygenated and relatively free of fine muds.

Figure 1. Summary of Habitat Features in Selected New Zealand Estuaries.



UNVEGETATED INTERTIDAL FLATS



The broad scale substrate mapping results (Table 5, Figure 2) showed the intertidal area in the upper estuary was dominated by soft and very soft muds (239.8ha, 41.8%), while mobile sand and firm sand, and firm mud/sand (318ha, 55.5%) dominated the lower estuary and central basin. Clean sands were most common near the well flushed mouth of the estuary, while firm muddy sands in the central basin were very close to falling into the mobile sand classification. These extensive sand flats are expected to support a healthy sediment invertebrate community and provide extensive foraging areas for shorebirds.

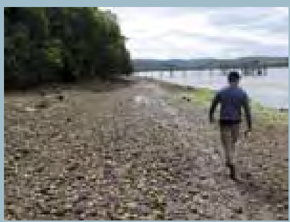
The percent cover rating of soft mud placed the estuary in the "poor" category (>25% of the estuary is soft mud). Its presence detracts from human use of the estuary, contributes to decreased water clarity, and is commonly associated with reduced sediment oxygenation and biodiversity. However, there were few signs of excessive nutrient enrichment with low nuisance macroalgal growth in 2007 and 2008, a condition rating of "good".

The Redox Potential Discontinuity (RPD) depth (Figure 3, Table 6), reflects the reduced sediment oxygenation in the muddier sediments and the better oxygenation of more porous sands which allow greater oxygen penetration. Throughout the majority of the muddy upper estuary, the RPD depth was within 1cm of the surface, achieving a "poor" rating. Although sediments were not overly sulphide enriched they are still likely to create an ecological barrier to sediment dwelling macrofauna.

Figure 2. Map of Unvegetated Intertidal Flats - Waikawa Estuary, February 2009.

UNVEGETATED INTERTIDAL FLATS

Very soft mud, upper estuary.



Cobble field by Waikawa wharf.

Rockfield by estuary mouth.

Extensive mobile sand flats in the lower estuary.

Table 5. Summary of dominant unvegetated substrate, February 2009.

Dominant Substrate	Area (ha)	%	Comments
Boulder field (manmade)	0.1	0.02	Reclaimed margin adjacent to Waikawa township
Rockfield	8.3	1.4	Narrow margins along upper intertidal zone. Most is present on the east of the estuary, near the entrance and between the sheltered east arms in the central estuary, but also near the wharf, and where the river enters the upper estuary
Cobblefield	4.3	0.7	
Gravelfield	0.9	0.2	
Shellbank	2.1	0.4	Near the low tide channel in the lower southwest estuary
Mobile Sand	103.0	17.9	Mobile and firm sand dominates across the lower estuary and parts of the central basin
Firm Sand	53.8	9.4	
Firm Mud/Sand	162.0	28.2	Firm muddy sand dominates in the central basin (where it is very close to being classified as mobile), and in the southeast arm
Soft Mud	29.0	5.0	Predominantly at the upper estuary/central basin transition
Very Soft Mud	210.8	36.7	Dominant in the upper estuary and head of sheltered arms
TOTAL	**574.3**	**100**	

3. RESULTS AND DISCUSSION (CONTINUED)

UNVEGETATED INTERTIDAL FLATS (CONTINUED)

In the central basin of the estuary, where sediments transition from soft muds to firm muddy sands, the RPD was generally between 1-3cm deep with a condition rating of “fair” (Table 6).

Throughout the majority of the lower estuary (59% of the total estuary area) the RPD depth fitted the “good” or “very good” condition rating. Sediments appeared well oxygenated, not particularly sulphide enriched, and a healthy sediment dwelling community was evident in and on the dominant intertidal sand flats.

SUBSTRATE CHANGE BETWEEN 2004 AND 2009

A significant change identified in 2009 was the migration of the transition point between the very soft muds of the upper estuary and the soft muds/firm muddy sands of the central basin approximately 80m towards the upper estuary. This was associated with an increase in the area of mobile sand (areas with large and obvious sand ripples) in the central basin, and particularly in the lower estuary. In the central basin, a reduction in mud was visually obvious near the fine scale and lower sediment monitoring sites.

The improvement in sediment conditions, while occurring in a relatively narrow band in the central basin, showed that water flows at the time of mapping were sufficient to turn over the top sediments, flushing fine particulate from coarser sands, and creating well oxygenated conditions. It demonstrated that there is a natural capacity for muddy parts of the estuary to return to being sandy again.

Support for a reduction in mud in the upper estuary is also provided by sedimentation plate measurements which show an overall decrease in sediment levels at the three monitoring sites between 2007 and 2009. These sedimentation results are discussed in the following section.

Table 6. Percent of substrate in each RPD depth class.

Depth	<1cm	1-3cm	3-10cm	>10cm
Substrate Rating	**“POOR”**	**“FAIR”**	**“GOOD”**	**“VERY GOOD”**
Cobble field	-	-	0.7	-
Gravel field	-	-	0.2	-
Shellbank	-	-	-	0.4
Mobile sand	-	-	-	18.2
Firm sand	-	-	3.7	5.8
Firm mud/sand	-	-	21.3	7.3
Soft mud	-	4.0	1.2	-
Very soft mud/sand	34.2	3.0		-
Total	**34.2**	**7.0**	**27.1**	**31.7**

Shallow RPD (<1cm, “poor” condition rating) and anoxic sediment in soft mud in the upper estuary.

Moderate RPD (3-10cm, “good” condition rating) in firm sands in the lower estuary.

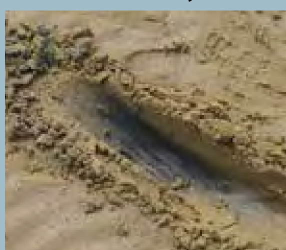
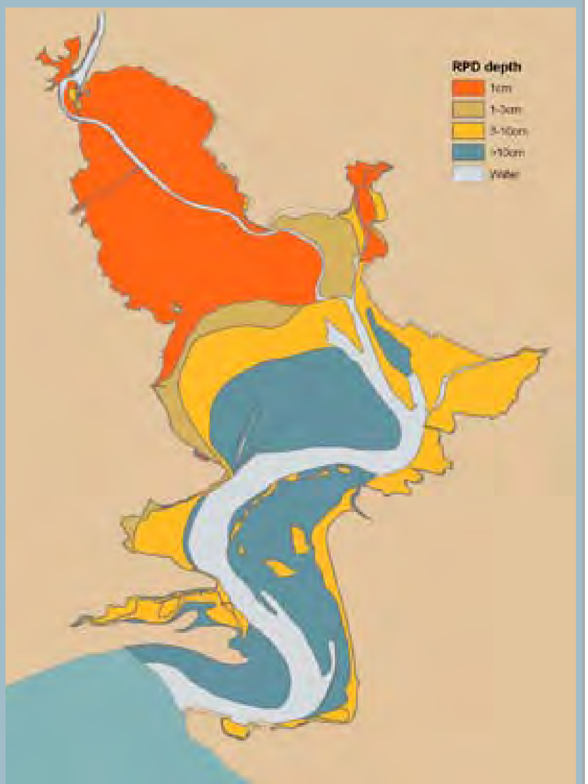


Figure 3. RPD Depth - Waikawa Estuary, Feb. 2009.



3. RESULTS AND DISCUSSION (CONTINUED)

SEDIMENTATION

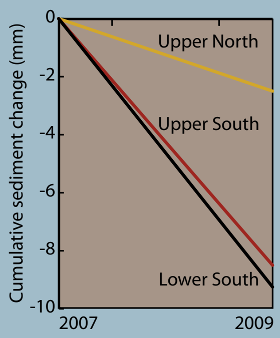


Figure 4a. Cumulative mean decrease in sediment levels over buried plates from 2007-2009.

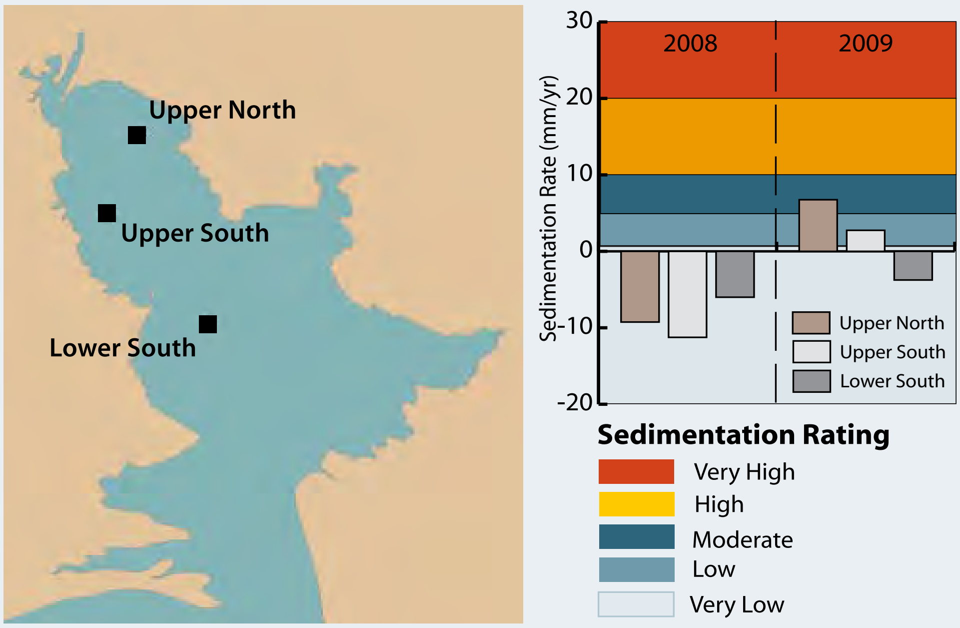
Sediment plate monitoring between February 2007 and 2009 has shown an overall trend of decreasing sediment levels (see sidebar Figure 4a), a condition rating of "very good". However, the recently established sediment plates show expected localised variation - mean sediment depth decreased at all 3 sites in 2007-2008, but increased at the two upper sites in 2009 (Figure 4, Table 7, Appendix 4). As such, a longer monitoring interval is needed to determine the stability of the current trend.

As catchment sediment inputs are not thought to have changed significantly over the past two years, and are relatively low (estimated at 65 t/km^2/yr - NIWA WRENZ model), the most likely cause of the sediment decrease over the plates is sediment redistribution within the estuary, or sediment removal from the estuary.

If sediment is being exported from the estuary, which appears likely given the broad scale substrate results, a cumulative mean loss of between 2mm and 10mm in two years across the three sites represents a major change. This is in sharp contrast to the estimated average 3mm to 10mm per year increase in sedimentation in the upper estuary over the past 30 years, calculated from radio-isotope aging of sediment cores (Robertson and Stevens 2007).

Ongoing monitoring of the estuary will continue to track sediment changes, while it is recommended that catchment landuse changes and the recent flood history of Waikawa River be assessed for recent possible influences on sediment inputs.

Figure 4. Sediment plate sites and mean change in sediment depth from 2007 baseline.



2007-2009 SEDIMENTATION CONDITION RATING
VERY GOOD

Table 7. Mean change in depth to sediment plates.

SEDIMENTATION RATE	Mean change in sediment depth (4 plates per site)		Total change from Baseline
Site	3/2/07 - 10/2/08	10/2/08 - 14/02/09	3/2/07 - 14/02/09
Upper North	-9.25mm	+6.75mm	-2.5mm
Upper South	-11.25mm	+2.75mm	-8.5mm
Lower South*	-6.0mm	-3.75mm	-9.75mm

*(located at sand/mud transition in the central basin)

SALTMARSH MAPPING

Overall, very little saltmarsh was present in the estuary (5.3ha, 0.8% - Table 4), providing a rating of "very low". This is largely a reflection of previous losses, and the steep, often rocky, margins which surround much of the estuary and restrict the intertidal area suitable for saltmarsh growth (see top two sidebar photos).

Saltmarsh (Table 8) was dominated by rushland (jointed wire rush - 91%) and herbfield (7%). The most extensive areas of rushland were adjacent to gently sloping land near the Waikawa River (Figure 5). A common sequence (heading landwards from the unvegetated mudflats) was for a 5-10m wide strip of jointed wire rush to be present in very soft muds at the top of the intertidal area, before a transition to terrestrial ribbonwood scrub and grassland, often containing a variety of introduced weeds (e.g. gorse, blackberry) as sediments became elevated above the tidal reaches.

Elsewhere small pockets of rushland were located in sheltered arms along both sides of the estuary, with herbfields most common in the lower half of the estuary in firm sand/mud sediments. The herbfields were often elevated 0.5-1m above the estuary flats, particularly in the east, where they grew along a narrow strip of land periodically inundated by small waves and salt spray that prevented terrestrial grasses from establishing (see lower sidebar photo and Figure 5).

Most of the tussockland and duneland present in the lower estuary was above the intertidal reaches of the estuary with only occasional patches of intertidal salt grass and southern sand daphne present.

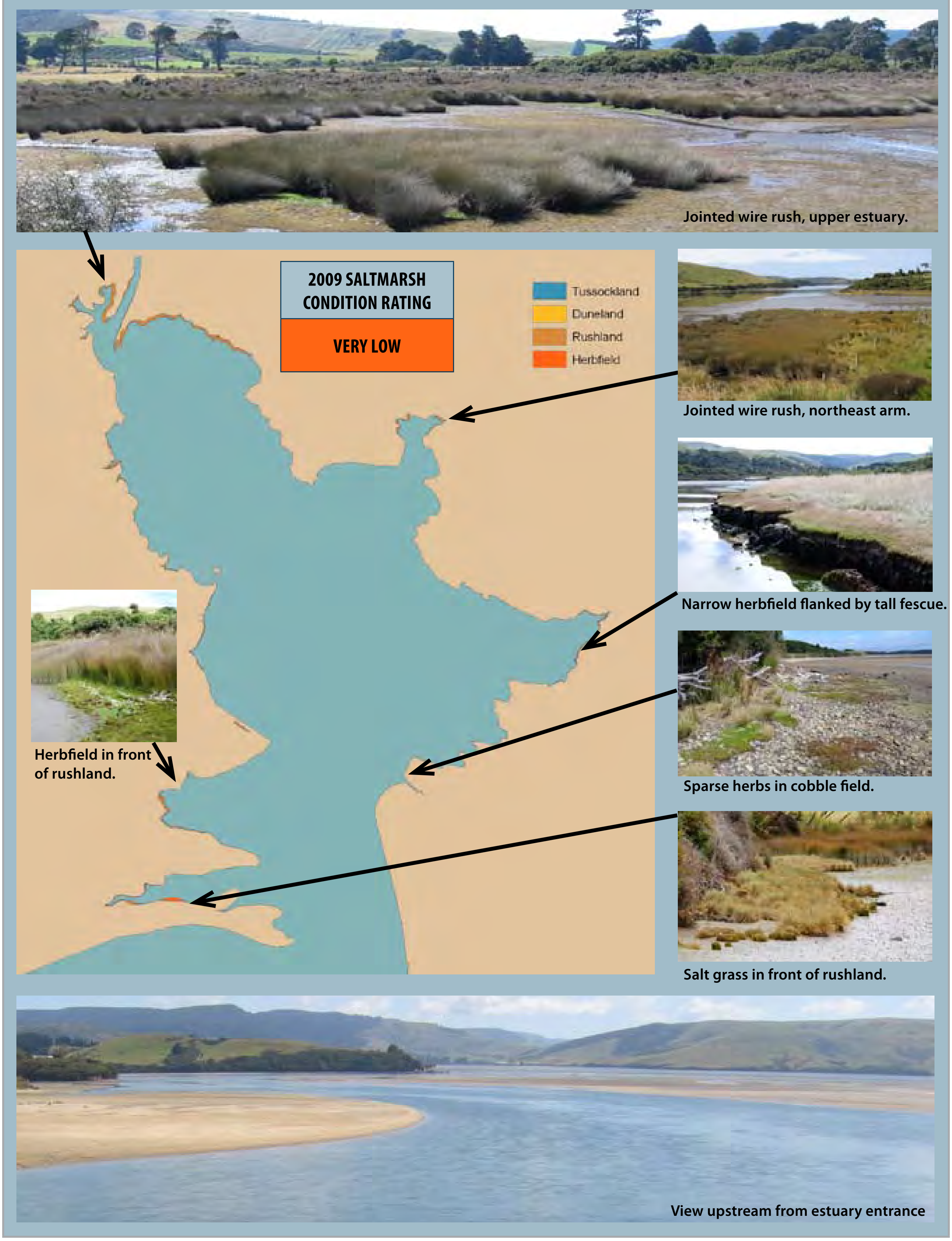
Saltmarsh is highly productive, provides important habitat for a variety of species (including whitebait), naturally filters sediments and nutrients, and acts as an important buffer that protects against introduced weeds and grasses, therefore its small extent detracts from the value of the estuary. Because large parts of the estuary are physically unsuitable for saltmarsh growth, it is important to protect remaining areas and to allow for expansion in response to predicted sea level rise.

Table 8. Summary of dominant saltmarsh class and species composition, February 2009.

Class	Dominant Species	Primary subdominant species	Species code*	Ha	%
Tussockland				0.02	0.4
	Puccinella stricta (Salt grass)		pust	*0.02*	*0.4*
Duneland				0.01	0.2
	Pimelea lyallii (Southern sand daphne)		pily	*0.01*	*0.2*
Rushland				4.83	90.7
	Apodasima similis (Jointed wirerush)		lesi	*4.38*	*82.1*
		Plagianthus divaricatus (Saltmarsh ribbonwood)	lesi pldi	*0.16*	*3.1*
		Puccinella stricta (Salt grass)	lesi pust	*0.07*	*1.4*
		Festuca arundinacea (Tall fescue)	lesi fear phte	*0.07*	*1.4*
		Selliera radicans (Remuremu)	lesi sera sare	*0.065*	*1.2*
		Selliera radicans (Remuremu)	lesi sera sare pust isce	*0.08*	*1.5*
Herbfield				0.46	8.6
	Samolus repens (Primrose)	*Selliera radicans (Remuremu)*	sare sera	*0.02*	*0.3*
	Samolus repens (Primrose)	*Selliera radicans (Remuremu)*	sare sera saqu isce lesi	*0.26*	*4.8*
	Sarcocornia quinqueflora (Glasswort)		saqu	*0.01*	*0.3*
	Sarcocornia quinqueflora (Glasswort)	*Selliera radicans (Remuremu)*	saqu sera	*0.01*	*0.2*
	Selliera radicans (Remuremu)	*Samolus repens (Primrose)*	sera sare	*0.03*	*0.5*
	Selliera radicans (Remuremu)	*Sarcocornia quinqueflora (Glasswort)*	sera saqu isce	*0.12*	*2.3*
	Samolus repens (Primrose)	*Pimelea lyallii (Southern sand daphne)*	sera pily isce	*0.01*	*0.2*
Grand Total				5.3	100

*Appendix 2 lists the subdominant vegetation mapped in the estuary.

Figure 5. Map of Saltmarsh Vegetation Class - Waikawa Estuary, February 2009.



3. RESULTS AND DISCUSSION (CONTINUED)

SALTMARSH CHANGE BETWEEN 2004 AND 2009

Eroding herbfield in the eastern estuary.

The 2009 broad scale mapping showed no significant change in the location or extent of rushland which dominates saltmarsh in the estuary. For herbfield areas, small scale changes were assessed by directly comparing the 2004 and 2009 field notes. This was because relatively large (~20m) differences in the spatial accuracy of the 2004 and 2009 aerial photos precluded a direct comparison of 2004 and 2009 broad scale GIS shapefiles and summary outputs.

The only significant change to herbfield was the loss of small areas in the eastern arm of the estuary. In 2004, herbfields were present as a 10-12m wide strip on land elevated 0.5-1m above the intertidal flats. In 2009, this strip had reduced in width by ~1-2m due to eroding wave action causing the land margin and attached herbfields (total area <0.05ha) to slump into the estuary (see sidebar photo).

While saltwater conditions at the estuary edge will favour herbfields re-establishing ahead of terrestrial grasses, the rate of erosion will obviously strongly influence re-establishment. As such, it is recommended that localised erosion and herbfield changes be monitored at a representative site in the eastern estuary.

SEAGRASS MAPPING

Table 9. Summary of seagrass cover results, February 2009.

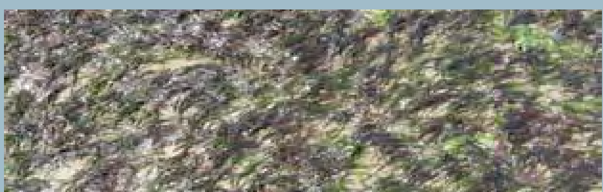
SEAGRASS		
% Cover	Area (ha)	%
<1%	559.4	98.3
1-5%	2.3	0.4
5-10%	0.5	0.1
10-20%	0.8	0.1
20-50%	1.4	0.3
50-80%	2.2	0.4
>80%	2.3	0.4
TOTAL	**569**	**100**

Table 9 and Figure 6 summarise the results of seagrass (*Zostera muelleri*) mapping within Waikawa Estuary. The "low" Seagrass Coefficient (SC) for the estuary (0.1), a condition rating of "poor", reflects that seagrasses were not widespread.

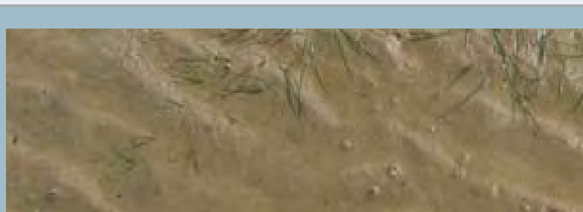
Seagrass was most common along the edge of the subtidal channel and in the firm mud/sands of the central basin and lower estuary, with cover mostly in the 50-100% range (Figure 6). In these well oxygenated areas flushed with relatively clear seawater the beds appeared healthy and relatively stable, with no significant changes observed between 2004 and 2009. Within the more mobile sands of the lower estuary, seagrass cover was sparse (e.g. 1-5% cover). Constant cycles of burial and exposure are likely to prevent dense beds from readily establishing in these areas.

No seagrass was present in the muddy upper estuary apart from a healthy bed of 80-100% cover in the subtidal reach of the Waikawa River where it enters the head of the estuary. As seagrass requires high light levels to grow, its absence from the muddy upper estuary is likely to relate to a combination of factors. Wave resuspension of surface muds create turbid conditions that push seagrass growth towards shallow areas with higher light levels. These areas are subject to greater tidal exposures (and plant stress) and, in Waikawa Estuary, are associated with a shallow RPD layer (<1cm) and anoxic conditions close to the surface. Such conditions, present across the upper estuary, are generally unfavourable for seagrass growth.

Seagrass plays multiple roles in primary production, nutrient cycling, sediment stabilisation, and as a feeding and nursery area for fish and invertebrates. The associated high ecological values make it an important component of estuary habitat. Further, seagrass meadows are a major source of detrital material, and the bacteria and fungi that decompose this material provide a food source for zooplankton, worms, etc. which are the base of the predatory food web. Seagrass also helps stabilise sediments and improve water clarity at a localised scale. The low incidence of seagrass in Waikawa detracts from these values, and restoration should be encouraged.



50-80% cover of seagrass.

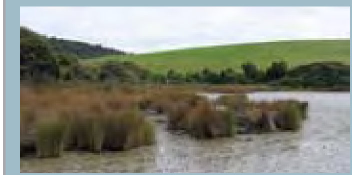


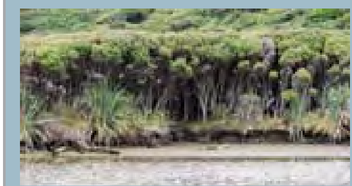
1-5% cover of seagrass in mobile sands.

Figure 6. Map of Seagrass Percentage Cover - Waikawa Estuary, February 2009.

3. RESULTS AND DISCUSSION (CONTINUED)

TERRESTRIAL MARGIN MAPPING





The results of the 200m terrestrial margin mapping are presented in Figure 7, Table 10, and Appendix 3. They show grassland (58% mostly grazed pasture) was by far the most common feature surrounding the estuary. A dense vegetated cover of scrub and forest (28%) and dune-, rush- and tussock-land (8%), was also present and placed the estuary in the "fair" condition rating (25-50% cover).

As most of the dense vegetated cover was located in a narrow strip surrounding the estuary (on steep banks and hillsides unsuitable for grazing), it provided a narrow buffer separating around 80% of the estuary from surrounding farmland. Of particular note were the totara stands in the lower south east of the estuary. Elsewhere native scrub was commonly dominated by manuka, but contained a range of other native species, while gorse and flax was also common, particularly in areas regenerating after being previously cleared.

In the lower estuary, sand dunes were present on both sides of the estuary. These dunes play a vital role in coastal protection and provide important habitat for many plants and animals. The dune vegetation is dominated by the introduced sand binder marram grass, which is prolific and has tended to out-compete the native sand-binders like pingao. Marram grass dunes are generally taller, have a steeper front, are more stable and occupy more area than native dunes. Such dunes tend to be susceptible to erosion of the dune front during storms, with evidence of recent foredune erosion indicating it is an issue (see photo below).

In contrast, the back dunes are relatively stable and have a number of well established plants growing (e.g. totara, ribbonwood, mingimingi, flax, knobby clubrush, jointed wire rush). Introduced grasses (e.g. tall fescue) and weeds (e.g. gorse) are also present in dune hollows which are grazed by sheep.

Like saltmarsh, a densely vegetated terrestrial margin provides important habitat for a variety of species, naturally filters sediments and nutrients entering the estuary, and acts as an important buffer protecting against introduced weeds and grasses. The presence of a narrow strip of vegetation around most of the estuary has the capacity to filter some sediment and nutrient inputs to the estuary, and to provide wildlife habitat. Maintenance of the existing vegetated buffer area should be encouraged, grazing discouraged, and the buffer expanded where possible.

Table 10. Summary of 200m terrestrial margin vegetation, February 2009.

Class	Ha	%
Forest	17.7	4.4
Scrub/Forest	48.6	12.0
Scrub	46.0	11.4
Tussock/Sedgeland	3.9	1.0
Grassland	233.8	57.8
Duneland	20.3	5.0
Rushland	8.3	2.1
Introduced Weeds	1.6	0.4
Residential	14.2	3.5
Road	9.2	2.3
Water	0.6	0.2
Total	404.2	100

Windblown totara behind an eroding marram grass dune, lower southeast estuary.

Figure 7. Map of 200m Terrestrial Margin Features - Waikawa Estuary, February 2009.

5. SUMMARY AND CONCLUSIONS

In summary, the broad scale monitoring of Waikawa Estuary showed that it is a well flushed tidal lagoon with extensive intertidal flats (569ha, 84%), draining a mixed catchment of high production pasture and native bush. The high value estuary is in a good to fair condition, although extensive areas of soft mud have accumulated in the upper estuary. The soft muds are poorly oxygenated (shallow RDP depth) and have low sediment biodiversity. The lower estuary is well flushed, dominated by firm and mobile sands, supports small areas of seagrass, and is in good condition.

Only a small area of saltmarsh (5.3ha, 0.8%) surrounds the estuary, and the 200m terrestrial margin is dominated by grazed pasture, although a narrow vegetated buffer (primarily native scrub and forest) separates ~80% of the estuary from surrounding farmland. Historical habitat loss has mainly resulted from drainage, reclamation, forest clearance for farming, and grazing.

Changes in broad scale features recorded between 2004 and 2009 were a small loss of herbfield as a result of erosion, and a recent decrease in the area and depth of soft mud in the upper estuary.

The condition of the mapped habitats indicated problems associated with sedimentation (extensive muddy sediments and turbid water in the upper estuary) and historical habitat loss (little saltmarsh, limited seagrass, and a modified vegetated terrestrial margin). There were few nutrient enrichment issues evident (sparse nuisance macroalgal growth), which is consistent with the low-moderate nitrogen loading from the catchment (~7kg/ha/yr, NIWA website WRENZ model), and good estuary flushing.

There are positive signs of a reduction in upper estuary mud, and little recent loss of vegetated habitat.

6. MONITORING

Waikawa Estuary has been identified by ES as a priority for monitoring, and is a key part of ES's existing estuary monitoring programme being undertaken in a staged manner throughout Southland. Based on existing monitoring results, it is recommended that monitoring continue as outlined below:

Fine Scale Monitoring	Undertake fine scale monitoring on a five yearly cycle (next scheduled for 2013) and as deemed necessary thereafter based on the condition ratings.
Broad Scale Habitat, Macroalgae and RPD Mapping	Repeat broad scale habitat, macroalgae and RPD mapping at five yearly intervals (next scheduled for 2013) and then as deemed necessary based on the condition ratings. Assess changes in catchment landuse five yearly.
Broad Scale Sedimentation Monitoring	Monitor sediment plates annually and assess any changes to the transition point between very soft mud/soft mud/firm mud/sand in the central basin of the estuary (next scheduled for 2010).
Sedimentation Issues	Assess sediment loss from resuspension and tidal flushing by measuring turbidity on incoming and outgoing tides under windy conditions.
Localised erosion and habitat loss	Monitor sediment erosion and associated changes to herbfields at a representative site in the eastern estuary.

The ongoing monitoring will provide a robust framework for identifying, evaluating and providing management options for any significant issues that arise within Waikawa Estuary.

7. RECOMMENDED MANAGEMENT

The following management actions are recommended to address key issues in Waikawa Estuary:

Monitor Key Stressors

- As intensification of land use is a key stressor, monitor changes in catchment land use with any changes in the key stressors triggering an evaluation of the likely impact on the estuary.

Identify and Implement Catchment BMPs

- Catchment runoff is one of the major stressors in estuaries with the likely ecological response one of lowered biodiversity and lowered aesthetic and human use values. To prevent avoidable inputs, best management practices (BMPs) should be identified and implemented to reduce sediment, nutrient, and pathogen runoff from catchment "hotspots".

Restore Saltmarsh Habitat

- The reduction in saltmarsh habitat as a result of drainage and reclamation has certainly contributed to reduced biodiversity and increased sedimentation of the estuary, while also lowering aesthetic and human use values. It has also allowed weeds and grass to establish to the estuary edge. Because of the importance of saltmarsh, it is recommended that a plan be developed to encourage its protection, re-establishment, and to support community restoration initiatives.

Reinstate Margin Buffer

- Human development of the estuary margin has resulted in clearance of surrounding bush and almost certainly contributed to reduced biodiversity and increased estuary sedimentation. Many areas are also adversely affected by nuisance weeds. Because of the importance of a natural vegetated margin around the estuary, it is recommended that a strategy be developed to encourage its re-establishment where possible.

Coastal Squeeze

- Sea level rise is a key estuary stressor. The ability of estuary vegetation to respond to sea level rise relies to a large extent on saltmarsh and terrestrial margin vegetation being able to migrate landward to maintain suitable growing conditions. Areas where coastal squeeze is likely to occur should be identified and used to guide future revegetation efforts, and to identify where conflict may occur between existing uses and estuary expansion as a consequence of sea level rise.

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Firm sands and native forest in the eastern arm.

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APPENDICES

APPENDIX 1. BROAD SCALE HABITAT CLASSIFICATION DEFINITIONS.

Vegetation was classified using an interpretation of the Atkinson (1985) system, whereby dominant plant species were coded by using the two first letters of their Latin genus and species names e.g. marram grass, *Ammophila arenaria*, was coded as Amar. An indication of dominance is provided by the use of ( ) to distinguish subdominant species e.g. Amar(Caed) indicates that marram grass 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. rushland, scrub, forest).

Forest: Woody vegetation in which the cover of trees and shrubs in the canopy is >80% and in which tree cover exceeds that of shrubs. Trees are woody plants ≥10 cm diameter at breast height (dbh). Tree ferns ≥10cm dbh are treated as trees. Commonly sub-grouped into native, exotic or mixed forest.
Treeland: Cover of trees in the canopy is 20-80%. Trees are woody plants >10cm dbh. Commonly sub-grouped into native, exotic or mixed treeland.
Scrub: Cover of shrubs and trees in the canopy is >80% and in which shrub cover exceeds that of trees (c.f. FOREST). Shrubs are woody plants <10 cm dbh. Commonly sub-grouped into native, exotic or mixed scrub.
Shrubland: Cover of shrubs in the canopy is 20-80%. Shrubs are woody plants <10 cm dbh. Commonly sub-grouped into native, exotic or mixed shrubland.
Tussockland: Vegetation in which the cover of tussock in the canopy is 20-100% and in which the tussock cover 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 of the growth form 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*.
Duneland: Vegetated sand dunes in which the cover of vegetation in the canopy (commonly Spinifex, Pingao or Marram grass) is 20-100% and in which the vegetation cover exceeds that of any other growth form or bare ground.
Grassland: Vegetation in which the cover of grass (excluding tussock-grasses) in the canopy is 20-100%, and in which the grass cover exceeds that of any other growth form or bare ground.
Sedgeland: Vegetation in which the cover of sedges (excluding tussock-sedges and reed-forming sedges) in the canopy is 20-100% and in which the sedge cover exceeds that of any other growth form or bare ground. "Sedges have edges." Sedges vary from grass by feeling the stem. If the stem is flat or rounded, it's probably a grass or a reed, if the stem is clearly triangular, it's a sedge. Sedges include many species of *Carex, Uncinia,* and *Scirpus*.
Rushland: Vegetation in which the cover of rushes (excluding tussock-rushes) in the canopy is 20-100% and where rush cover exceeds that of any other growth form or bare ground. A tall grasslike, often hollow-stemmed plant, included in rushland are some species of *Juncus* and all species of *Leptocarpus*.
Reedland: Vegetation in which the cover of reeds in the canopy is 20-100% and in which the reed cover 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: Vegetation in which the cover of cushion plants in the canopy is 20-100% and in which the cushion-plant cover 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: Vegetation in which the cover of herbs in the canopy is 20-100% and where herb cover 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.
Lichenfield: Vegetation in which the cover of lichens in the canopy is 20-100% and where lichen cover exceeds that of any other growth form or bare ground.
Introduced weeds: Vegetation in which the cover of introduced weeds in the canopy is 20-100% and in which the weed cover 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.
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.
Cliff: A steep face of land which exceeds the area covered by any one class of plant growth-form. Cliffs are named from the dominant substrate type when unvegetated or the leading plant species when plant cover is ≥1%.
Rock field: Land in which the area of residual 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. Boulder fields 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. Cobble fields 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. Gravel fields are named from the leading plant species when plant cover is ≥1%.
Mobile sand: The substrate is clearly recognised by the granular beach sand appearance and the often rippled surface layer. Mobile sand is continually being moved by strong tidal or wind-generated currents and often forms bars and beaches. When walking on the substrate you'll sink <1 cm.
Firm sand: Firm sand flats may be mud-like in appearance but are granular when rubbed between the fingers, and solid enough to support an adult's weight without sinking more than 1-2 cm. Firm sand may have a thin layer of silt on the surface making identification from a distance difficult.
Soft sand: Substrate containing greater than 99% sand. When walking on the substrate you'll sink >2 cm.
Firm mud/sand: A mixture of mud and sand, the surface appears brown, and may have a black anaerobic layer below. When walking you'll sink 0-2 cm.
Soft mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When you'll sink 2-5 cm.
Very soft mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When walking you'll sink >5 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.
Artificial structures: 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.

APPENDIX 2. HABITAT CLASSIFICATION SUMMARY.

ESTUARY: VEGETATION AND SUBSTRATE			
Level I Hydrosystem: Estuary (alternating saline and freshwater)			
Level IA Subsystem: Intertidal/supratidal			
Level II Class:			
Saltmarsh	**Level III Structural Class:**	**Species/Feature**	**Field Code**
	Estuarine Shrub	*Pimelea lyallii (Southern sand daphne)* *Plagianthus divaricatus (Saltmarsh ribbonwood)*	Pily Pldi
	Tussockland	*Phormium tenax (New Zealand flax)* *Puccinella stricta, (Salt grass)*	Phte Pust
	Sedgeland	*Isolepis cernua (Slender clubrush)*	Isce
	Grassland	*Festuca arundinacea (Tall fescue)*	Fear
	Rushland	*Apodasima (Leptocarpus) similis (Jointed wirerush)*	Lesi
	Herbfield	*Sarcocornia quinqueflora (Glasswort)* *Samolus repens (Primrose)* *Selliera radicans (Remuremu)*	Saqu Sare Sera
Substrate	Rock field	Rock field	RF
	Boulder field man-made	Boulder field	BFmm
	Shell bank	Shell bank	SHEL
	Mobile sand	Mobile sand	MS
	Firm sand	Firm sand	FS
	Firm mud/sand	Firm mud/sand	FMS
	Soft mud	Soft mud	SM
	Very soft mud/sand	Very soft mud/sand	VSM
Subtidal	Water	Water	WTER

TERRESTRIAL MARGIN: VEGETATION, SUBSTRATE, AND LANDUSE			
Terrestrial species	Forest	*Eucalyptus spp. (Gum tree)*	Eusp
	Scrub/Forest	*Leptospermum scoparium (Manuka)* *Pinus radiata (Pine tree)* *Podocarpus totara (Totara)* *Cupressus macrocarpa* *Coprosma propinqua (Mingimingi)* *Cytisus scoparius (Broom)* *Lupinus arboreus (Tree lupin)* *Plagianthus divaricatus (Saltmarsh ribbonwood)* *Ulex europaeus (Gorse)*	Lesc Pira Poto Cuma Copr Cysc Luar Pldi Uleu
	Tussockland	*Carex spp. (Sedge)* *Phormium tenax (New Zealand flax)*	Casp Phte
	Grassland	*Festuca arundinacea (Tall fescue)*	Fear
	Duneland	*Ammophila arenaria (Marram grass)*	Amar
	Rushland	*Isolepis nodosa (Knobby clubrush)* *Apodasima similis (Jointed wirerush)*	Isno Lesi
	Introduced Weeds	Unidentified introduced weeds	Inwe

General terrestrial categories	Exotic forest, Native forest, Mixed native and exotic forest	EF, NF, NEF
	Native scrub/forest, Exotic scrub/forest, Mixed native and exotic scrub/forest	NSF, ESF, NESF
	Native scrub, Exotic scrub, Mixed native and exotic scrub	NS, ES, NES
	Tussockland	Tuss
	Rushland	Rush
	Duneland	Dune
	Pasture	Past
	Maintained park/amenity area	Park
	Unmaintained introduced grass	Gras
	Introduced Weeds	Inwe
	Residential, Commercial, Industrial	RESI, Comm, INDU
	Road	Road

APPENDIX 3. SUMMARY OF 200M TERRESTRIAL MARGIN VEGETATION.

Class	Dominant Species	Primary subdominant species	Ha	%
Forest			17.7	4.4
	Native forest		*17.4*	*4.3*
	Eucalyptus spp. (Gum tree)		*0.3*	*0.1*
Scrub/Forest			48.6	12.0
	Native scrub/forest		*17.6*	*4.4*
	Podocarpus totara (Totara)	*Native forest*	*14.1*	*3.5*
	Leptospermum scoparium (Manuka)	*Native scrub*	*11.2*	*2.8*
	Leptospermum scoparium (Manuka)	*Phormium tenax (New Zealand flax)*	*3.8*	*0.9*
	Pinus radiata (Pine tree)		*1.0*	*0.3*
	Cupressus macrocarpa		*0.4*	*0.1*
	Podocarpus totara (Totara)	*Lupinus arboreus (Tree lupin)*	*0.2*	*0.1*
	Podocarpus totara (Totara)	*Phormium tenax (New Zealand flax)*	*0.2*	*0.0*
Scrub			46.0	11.4
	Native scrub		*18.9*	*4.7*
	Ulex europaeus (Gorse)	*Native scrub*	*5.6*	*1.4*
	Native scrub	*Ulex europaeus (Gorse)*	*5.4*	*1.3*
	Native scrub	*Isolepis nodosa (Knobby clubrush)*	*3.7*	*0.9*
	Ulex europaeus (Gorse)		*2.5*	*0.6*
	Ulex europaeus (Gorse)	*Phormium tenax (New Zealand flax)*	*2.5*	*0.6*
	Plagianthus divaricatus (Saltmarsh ribbonwood)	*Apodasima similis (Jointed wirerush)*	*2.9*	*0.7*
	Native scrub	*Phormium tenax (New Zealand flax)*	*1.6*	*0.4*
	Plagianthus divaricatus (Saltmarsh ribbonwood)	*Festuca arundinacea (Tall fescue)*	*1.0*	*0.2*
	Pteridium esculentum (Bracken fern)	*Phormium tenax (New Zealand flax)*	*0.9*	*0.2*
	Mixed native and exotic scrub		*0.5*	*0.1*
	Plagianthus divaricatus (Saltmarsh ribbonwood)		*0.3*	*0.1*
	Plagianthus divaricatus (Saltmarsh ribbonwood)	*Coprosma propinqua subsp. propinqua (Mingimingi)*	*0.1*	*0.02*
	Ulex europaeus (Gorse)	*Festuca arundinacea (Tall fescue)*	*0.1*	*0.03*
	Cytisus scoparius (Broom)		*0.03*	*0.01*
Tussockland/Sedgeland			3.9	1.0
	Phormium tenax (New Zealand flax)	*Plagianthus divaricatus (Saltmarsh ribbonwood)*	*1.7*	*0.4*
	Phormium tenax (New Zealand flax)	*Native scrub*	*0.9*	*0.2*
	Carex spp. (Sedge)	*Phormium tenax (New Zealand flax)*	*1.3*	*0.3*
	Cyperus ustulatus (Giant umbrella sedge)		*0.1*	*0.02*
Grassland			233.8	57.8
	Pasture		*219.5*	*54.3*
	Pasture	*Native forest*	*6.1*	*1.5*
	Festuca arundinacea (Tall fescue)	*Isolepis nodosa (Knobby clubrush)*	*3.1*	*0.8*
	Maintained park/amenity area		*2.2*	*0.5*
	Unmaintained introduced grass		*1.3*	*0.3*
	Festuca arundinacea (Tall fescue)	*Apodasima similis (Jointed wirerush)*	*0.7*	*0.2*
	Festuca arundinacea (Tall fescue)	*Phormium tenax (New Zealand flax)*	*0.6*	*0.1*
	Festuca arundinacea (Tall fescue)	*Unidentified introduced weeds*	*0.3*	*0.1*
Duneland			20.3	5.0
	Ammophila arenaria (Marram grass)	*Lupinus arboreus (Tree lupin)*	*16.3*	*4.0*
	Ammophila arenaria (Marram grass)		*2.8*	*0.7*
	Ammophila arenaria (Marram grass)	*Festuca arundinacea (Tall fescue)*	*1.2*	*0.3*
Rushland			8.3	2.1
	Isolepis nodosa (Knobby clubrush)	*Pasture*	*4.7*	*1.2*
	Isolepis nodosa (Knobby clubrush)	*Festuca arundinacea (Tall fescue)*	*3.0*	*0.7*
	Apodasima similis (Jointed wirerush)	*Plagianthus divaricatus (Saltmarsh ribbonwood)*	*0.6*	*0.2*
Introduced Weeds			1.6	0.4
	Unidentified introduced weeds	*Festuca arundinacea (Tall fescue)*	*0.8*	*0.2*
	Unidentified introduced weeds	*Native scrub*	*0.4*	*0.1*
	Unidentified introduced weeds		*0.3*	*0.1*
Residential			14.2	3.5
Artificial structure (Road)			9.2	2.3
Water			0.6	0.2
Grand Total			404.2	100.0

APPENDIX 4. SEDIMENTATION PLATE DATA, 2007-2009.

Sediment Plate Depths		Depth to sediment plate (mm)		
Site	No	3/2/07	2/10/08	14/02/09
Upper South Arm	1	212	203	205
Upper South Arm	2	223	206	215
Upper South Arm	3	215	210	212
Upper South Arm	4	230	216	214
Upper North Arm	5	253	237	250
Upper North Arm	6	210	207	212
Upper North Arm	7	270	259	265
Upper North Arm	8	257	250	253
Lower South Arm	9	255	250	242
Lower South Arm	10	248	238	235
Lower South Arm	11	225	213	214
Lower South Arm	12	250	253	248

Sediment Depth Changes		Change (mm)		
Site	No	3/2/07	2/10/08	14/02/09
Upper South Arm	1	Baseline	-9	2
Upper South Arm	2	Baseline	-17	9
Upper South Arm	3	Baseline	-5	2
Upper South Arm	4	Baseline	-14	-2
Upper North Arm	5	Baseline	-16	13
Upper North Arm	6	Baseline	-3	5
Upper North Arm	7	Baseline	-11	6
Upper North Arm	8	Baseline	-7	3
Lower South Arm	9	Baseline	-5	-8
Lower South Arm	10	Baseline	-10	-3
Lower South Arm	11	Baseline	-12	1
Lower South Arm	12	Baseline	3	-5

Mean Overall Changes		Cumulative mean change from baseline (mm)		
Site	No	2007	2007-2008	2007-2009
Upper South Arm	1-4	Baseline	-11.25	-8.50
Upper North Arm	5-8	Baseline	-9.25	-2.50
Lower South Arm	9-12	Baseline	-6.0	-9.75