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Waiau Lagoon

Broad Scale Habitat Mapping 2007/08

Prepared for

Environment Southland

September 2008

Cover Photo: Waiau Lagoon looking west towards Bluecliffs

Waiau Lagoon

Broad Scale Habitat Mapping 2007/08

Prepared for
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By

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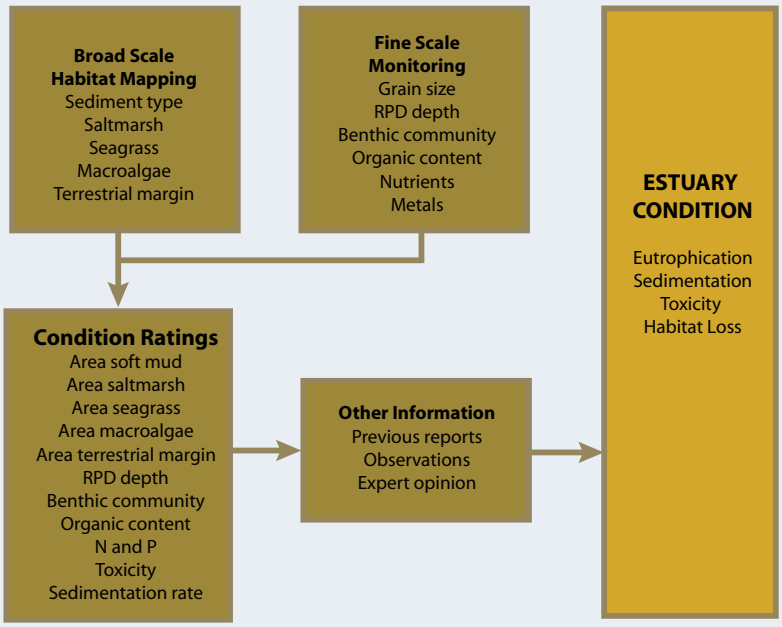
EXECUTIVE SUMMARY

In the 1990's, Environment Southland (ES) established a long-term monitoring programme to assess the condition of key estuaries in its region. Estuaries monitored to date include Jacobs River, New River, Bluff Harbour and Awarua Bay, Toetoes (Fortrose) Harbour, and Haldane, Waikawa, and Freshwater Estuaries. In 2008, ES added the Waiau Estuary to its monitoring programme, a 100ha "river mouth" or hapua type estuary in Te Waewae Bay fed by the Waiau River and the Holly Burn.

The current report describes the broad scale habitat mapping undertaken in February 2008. Broad scale habitat mapping is a tool used to assess the condition of estuaries. It includes mapping and condition ratings for key habitat elements including: estuary sediment types, macroalgal beds (i.e. *Ulva* (sea lettuce), *Gracilaria, Enteromorpha*), macrophytes (e.g. *Zostera* - seagrass), saltmarsh vegetation, and the 200m terrestrial margin surrounding the estuary. The methods used were based on the tools included in the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002), and a number of extensions (Table 1).

The outcome is a series of GIS-based habitat maps (often complex), that provide measures of the extent of different types of habitat cover. Taken in combination with fine scale physical, chemical and biological monitoring results, these measures are applied into different rating scales which are used alongside other relevant expert information to assess the condition of the estuary in relation to the key issues of sedimentation, eutrophication and habitat loss. Toxicity is addressed as part of fine scale monitoring, while disease risk is monitored and reported separately, principally through recreational water quality monitoring programmes. A summary of the approach is outlined in the figure below.



A broad scale summary map is presented on the next page (much reduced but included as a reminder of the more user-friendly GIS-based maps that accompany this report).

Using this approach, the key findings of the broad scale mapping in relation to the condition of Waiau Estuary and the key estuary issues were as follows:

Summary of the broad scale features of Waiau Estuary, February 2008.

BROAD SCALE RESULTS

The broad scale monitoring showed Waiau Estuary is a moderate sized (101ha) river mouth estuary, different from other small mouthed estuaries in the area in that it has a long shallow lagoon with a large subtidal component. Although the lagoon is relatively isolated from the main flow of the Waiau River (which tends to bypass it), it is nevertheless dominated by freshwater and the main river channel is generally well flushed. However, tidal seawater inflow also occurs and creates a salt wedge effect of denser saline water near the estuary bed.

Within the lagoon, resuspension of sediment is expected to be significant due to the large wind fetch and shallow nature of the lagoon. This is likely to push sediment into localised areas where prevailing wind and waves deposit it on shorelines, and in subtidal basin areas. As a result, much of the lagoon's subtidal bed will be dominated by coarse sediments with soft sediment found in localised settlement areas. When the estuary mouth is closed, or flushing of the lagoon is restricted, conditions where sediment settles are likely to tend towards having muddy, anoxic, black sulphide-rich sediments, low dissolved oxygen and low clarity - conditions that may promote undesirable algal growth.

Of the habitat types present in the Waiau, the vast majority of the area was subtidal 86ha (84%). The intertidal area was dominated by unvegetated cobble and gravel (13%). Saltmarsh occupied just 3.1ha (3%), and was mostly restricted to a narrow strip around the lagoon edge (dominated by rushland (mostly jointed wire rush) and tussockland (flax)). Macrophytes and macroalgae were not found in the intertidal area but were observed in the subtidal area.

The dominant terrestrial margin habitats bordering the estuary (a 200m wide margin was mapped) were developed grassland (60%), cobble (17%) - primarily the spit between the estuary and Te Waewae Bay, scrub/forest (11%) - mostly willow and gorse, and tussockland (5%) - where flax was a prominent feature covering many of the steep cliff and hill faces overlooking the eastern and western ends of the estuary.

The intertidal broad scale mapping data were used to determine condition ratings for key broad scale indicators. The results were as follows.

BROAD SCALE CONDITION RATINGS

BROAD SCALE RATING 2008	% COVER INTERTIDAL SOFT MUD	% COVER INTERTIDAL MACROALGAE	% COVER MACROPHYTES	% COVER SALTMARSH	TERRESTRIAL VEGETATED BUFFER
WAIAU ESTUARY	VERY LOW	VERY GOOD	UNKNOWN	LOW	POOR

ESTUARY ISSUES

The intertidal results, in combination with other available information, are used in the following subsections to provide an overview of likely estuary condition in relation to the key issues examined in this broad scale assessment, namely sedimentation, eutrophication and habitat loss.

SEDIMENTATION: Sediment is likely to settle predominantly in localised areas where prevailing wind and waves deposit it on shorelines, and in subtidal basin areas. The presence of sediment may stress aquatic macrophytes through decreased water clarity in the absence of clean flushing flows and during periods of mouth closure. Sediment bound nutrients are also likely to promote undesirable growths of macroalgae and phytoplankton. Although the subtidal area was not mapped, the presence of submerged aquatic macrophytes and generally good water clarity indicated problems commonly associated with lots of fine mud were not conspicuous, although anecdotal evidence suggests the lagoon has got muddier and shallower over the past 40 years.

EUTROPHICATION: There was little indication of nutrient enrichment causing phytoplankton or macroalgal blooms, or a loss of macrophytes within the shallow lagoon margins. This is consistent with relatively low catchment nutrient loads, and generally good water quality in the Waiau River. The exception to this is the isolated ponds in the west which had poor water and sediment quality, and extensive macroalgal growths in shallow areas. These areas highlight the types of problems that can arise when water exchange is restricted, with the main stressors to good flushing being freshwater abstraction and closures of the lagoon mouth.

HABITAT LOSS: There has been extensive saltmarsh and margin habitat loss from past forest clearance, drainage, and grazing. The terrestrial margin is now dominated by grassland, although significant effort has recently been put into replanting saltmarsh and developing whitebait spawning habitat.

Subtidal macrophytes (generally sensitive to increased sedimentation, changes in water flows or salinity, and nutrient increases) were present, and shows the estuary currently supports this important habitat. Anecdotal evidence suggests increases in macrophyte and macroalgal growth over the past 40 years although the extent and vulnerability of this macrophyte habitat in Waiau Estuary is unknown.

MONITORING

Waiau Estuary has been included by ES as part of its long term estuary monitoring programme being undertaken in a staged manner throughout the region. It is recommended that broad scale habitat monitoring of the Waiau Estuary continue on a 5 yearly cycle (next scheduled for December 2013). However, in order to provide a more comprehensive assessment of overall estuary condition, a better understanding of the subtidal component of the estuary is needed. As such it is recommended that a synoptic survey and vulnerability assessment be undertaken of the subtidal area of the estuary upon which monitoring recommendations can then be based.

It is recommended that the synoptic survey include a baseline map of subtidal substrates, sediment and water quality measures (e.g. of RPD, salinity, temperature, DO, pH, Secchi disk, depth, macroinvertebrate presence), and establishment of buried sediment plates to measure the rate of sedimentation. The synoptic survey should also map submerged macrophytes and macroalgae (to identify the location and percentage cover of dominant species). This will enable a better assessment of potential vulnerability and therefore monitoring and management needs.

RECOMMENDED MANAGEMENT

The following management actions are encouraged:

Monitor Key Stressors

- Monitor changes in catchment land use, freshwater abstraction, and mouth openings/closures. Because of the susceptibility of the lagoon, any changes in the key stressors should trigger an evaluation of the likely impact on the lagoon.

Restore Saltmarsh Habitat

- The reduction in saltmarsh habitat as a result of drainage has certainly contributed to reduced biodiversity and increased sedimentation in subtidal areas 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 re-establishment, and to support community restoration initiatives.

Reinstate Margin Buffer

- Human development of the estuary margin has resulted in clearance of surrounding bush. This has almost certainly contributed to reduced biodiversity and increased sedimentation in the estuary. 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 existing revegetation efforts, and to identify where conflict may occur between existing uses and estuary expansion as a consequence of sea level rise.

1. INTRODUCTION

OVERVIEW

Developing an understanding of the condition and risks to coastal and 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. Those monitored to date include Jacobs River, New River, Haldane, and Waikawa Estuaries, Toetoes (Fortrose) Harbour, Bluff Harbour and Awarua Bay (see references). In 2008, ES added Waiau Estuary, a 100ha "river mouth" or hapua type estuary in Te Waewae Bay to its monitoring programme, and Wriggle Coastal Management were contracted to undertake broad scale habitat mapping using the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002) plus recent extensions (see Table 1 and Table 3).

The estuary monitoring programme consists of three components:

1. **Ecological Vulnerability Assessment** of the estuary to major issues (see Table 2) and appropriate monitoring design. A high level overview has been completed as part of a recent wider coastal assessment (see Robertson and Stevens 2008).
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.
3. **Fine scale physical, chemical and biological monitoring**, (EMP approach) including sedimentation plate deployment. This component provides detailed information on estuary condition. Monitoring requirements will be defined after completion of a synoptic survey of subtidal habitat (see Section 5 of the current report).

This report documents the results of the broad scale monitoring undertaken in February 2008 of Waiau Estuary. It includes:

- Broad scale mapping of intertidal sediment types.
- Broad scale mapping of intertidal macroalgae and macrophytes.
- Broad scale mapping of saltmarsh vegetation.
- Broad scale mapping of the 200m terrestrial margin surrounding the estuary.
- Condition ratings for the Waiau Estuary (based on Robertson & Stevens, 2006, 2007). A suggested monitoring or management response is linked to each condition rating.

REPORT STRUCTURE

The report is structured as follows:

Section 1 Introduction to the scope and structure of the study.
Section 2 Methods - broad scale mapping and estuary condition ratings.
Section 3 Results and Discussion.
Section 4 Conclusions.
Section 5 Monitoring.
Section 6 Recommended Management.
Section 7 Acknowledgements.
Section 8 References.
Appendix 1 Substrate and vegetation classification.

This report characterises the baseline conditions of the estuary, providing detailed information on key broad scale indicators of sedimentation, eutrophication and habitat loss (Table 3). The results will help determine the extent to which the estuary is affected by major estuary issues (Table 2), both in the short and long term.

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 river mouth estuaries.

Key River Mouth 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. Within shallow coastal river mouth estuaries, muds can be easily resuspended. This causes high turbidity which limits (or in some cases curtails) macrophyte growth, which in turn encourages phytoplankton growth and further lowers water clarity. Symptoms of eutrophication can result if nutrient levels are excessive and flushing is restricted (i.e. the mouth is not opened regularly).
Nutrients	Increased nutrient richness of coastal river mouth estuarine ecosystems stimulates the production and abundance of aquatic macrophytes (e.g. *Ruppia*) and saltmarsh vegetation. If excessive, it also stimulates fast-growing algae such as phytoplankton, and short-lived macroalgae (e.g. sea lettuce). Under phytoplankton bloom conditions, water column clarity can be reduced to low levels, limiting light available for macrophyte growth and drastically reducing habitat diversity and ecological richness (e.g. Lake Ellesmere). Also of concern are the mass blooms of macroalgae which can become widespread on intertidal flats and shallow subtidal areas of coastal estuaries and lakes and cause major ecological impacts on water and sediment quality and the animals that live there. They present a significant nuisance problem, especially when loose mats accumulate on shorelines and decompose.
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, aquatic macrophyte beds, saltmarshes (rushlands, herbfields, reedlands etc.), forested wetlands, beaches, river deltas, and hard 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. The major stressors causing habitat degradation or loss in river mouth estuaries and coastal lakes are: artificial mouth openings (increasing salinity and lowering water levels), drainage and reclamation of saltmarsh, sea level rise, population pressures on margins, pest and weed invasion, altered river input flows (damming, diversion 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.

BACKGROUND TO TIDAL RIVER MOUTH ESTUARIES

Looking upstream from the mouth of the Waiau Estuary.

Tidal river mouth type estuaries occur where streams or rivers approach the coast as a single channel, but their entry is often constricted (or sometimes blocked completely) by a sand or gravel barrier located just short of the ocean. In such estuaries, a brackish lagoon may form on the river side of the barrier, whose size, salinity and water quality varies depending on the degree of restriction or choking the river mouth may be experiencing at the time, as well as the river flow and the slope of the coastal plain.

The majority of tidal river mouth estuaries are short and narrow, with saline water intrusion extending only a few hundred metres upstream or not at all. In many cases the estuary channels have been modified by past drainage and channelisation actions. The habitats available for aquatic life in such systems are very limited: tidal flats and saltmarsh are generally small or absent, and the 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 and low clarity). When the mouth is open and flows are high, the small narrow channel and lagoon is flushed clean. Although they are likely to be a natural occurrence, such low water quality conditions are exacerbated when sediment, nutrient and pathogen loadings are elevated (e.g. in catchments with intensive agriculture, urban development, or catchments with high erosion).

1. INTRODUCTION (CONTINUED)

WAIAU ESTUARY SYNOPSIS

(From Robertson and Stevens 2008)

Estuary Type/Area	Tidal River Mouth (with lagoon arm)
Catchment	7904 km^2 (forest/pasture)
Dairy cows	9,266 cows
Nitrogen loading	Low: 1.1 kg/ha/yr
Catchment geology	Igneous, gravel, sandstone/siltstone
Saltmarsh (ha)	3.1ha (rushland, grassland, flax, herbfield)
Salinity	Varies depending on mouth closure (1ppt)
Mean depth (m)	Estimate 2m
Tidal flats	Minor (lagoon floods, tidal influence minor)
Uses/Values	Whitebaiting, scenic, fishing, birds, swimming, duckshooting.

Waiau Lagoon (looking west towards mouth)

Human Use	High
Ecological Value	Moderate
Existing Condition	Good
Susceptibility	High
Stressors	Moderate
OVERALL VULNERABILITY	Moderate-High

The Waiau Estuary is a moderate-sized "tidal river mouth" type estuary (area = 101ha), in the middle of Te Waewae Bay (for further details see Robertson and Stevens 2008). Its main feature is a 4km long shallow, brackish lagoon formed on the coastal plain between the inner margin of a 5km long cobble barrier beach (or spit), and mudstone and alluvial cliffs. It also includes several stranded ponds west of the mouth.

Uses and Values. Human use of the estuary is high and is popular for whitebaiting, fishing, birdlife, swimming, duckshooting and its scenic beauty.

Ecological Values. Ecologically, habitat diversity is moderate, given the presence of considerable areas of saltmarsh, herbfields, and freshwater aquatic macrophytes. Fish, bird and invertebrate life is also expected to be moderate.

Existing Condition. Salinities vary depending on the extent of tidal inflow and constriction of the mouth but are generally low (around 1ppt). The water is humic-stained and its clarity varies depending on river flows. The sediments are mixed with little sign of anoxic conditions near the edges. Currently the water quality in the Waiau River is high (low nutrient and *E. coli* concentrations), reflecting the dominant native forest/pasture landuse and the large catchment area. Estimated nitrogen (the major driver of eutrophication) loadings are low, but suspended solids loadings are high. Because the estuary is primarily riverine, its surface quality is expected to be similar to that of the river. Prior to hydro-electric power development on the river, the mouth moved over a 4km length of the coast without full closure. Now closures occur when periods of low river flow coincide with big seas.

Presence of Stressors. The presence of stressors is expected to be moderate. Stressors include; water abstraction, stock grazing saltmarsh, landuse intensification (already have high dairy cow numbers), weed and pest invasions, and sea level rise.

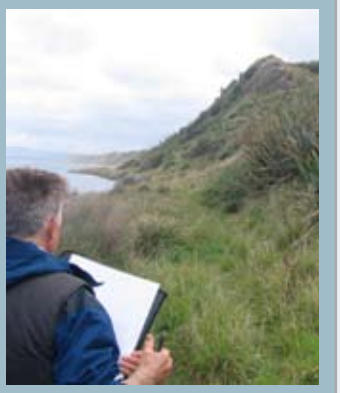
Susceptibility to Stressors. The lagoon is relatively isolated from the main river flow and consequently certain areas may be poorly flushed, which can be exacerbated when the mouth constricts or closes due to high seas. At such times, a salt wedge may form, and water quality may deteriorate and cause symptoms of eutrophication. In addition, because the lagoon and coastal plain is low lying, predicted sea level rise may alter lagoon hydrodynamics (shift to higher salinity regime) and cause loss of saltmarsh and aquatic macrophyte habitat. Given these characteristics, the estuary ecology is susceptible to: any increase in the intensity of landuse in the catchment, loss of flushing flows, grazing in the margins, and constriction of the estuary mouth.

Issues	Monitoring	Management
• Restricted flushing during low flows. • Mouth constricts. • Natural cycles of poor water quality. • Estuary margin deterioration.	• Subtidal monitoring (low flows) DO, salinity, RPD, sediment, aquatic macrophytes, clarity. • Map intensive landuse in the catchment at 5 yearly intervals. • Repeat broad scale survey every 5 years. • Assess lagoon hydrodynamics and response to sea level rise.	• Limit intensive landuse. • Margin vegetation maintenance. • Artificial mouth opening. • Maintain good flushing flows.

Waiau Estuary	Sedimentation	Eutrophication	Disease Risk	Contaminants	Habitat Loss	Invaders	Shellfish Issues
Existing Condition Rating	Good	Good	Very Good	Very Good	Good	Good	Very Good
Susceptibility Rating	High	High	Moderate	Low	Moderate	Low	Very Low
Vulnerability Rating	Moderate-High	Moderate-High	Moderate	Very Low	Low	Low	Very Low

2. METHODS

BROAD SCALE HABITAT MAPPING



Categories of percentage cover used to classify macroalgae and macrophytes

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

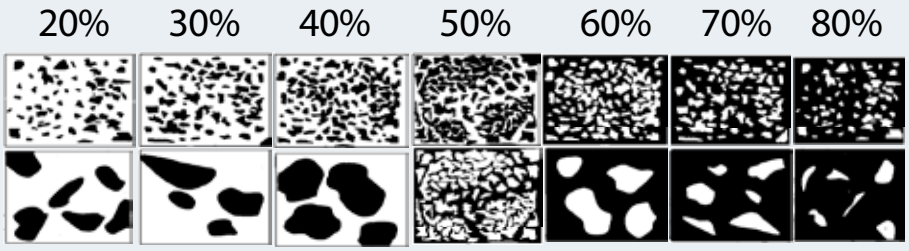
Broad-scale mapping is a method for describing habitat types based on the dominant surface features present (e.g. substrate: mud, sand, cobble, rock; or vegetation: macrophyte, macroalgae, rushland, etc). It follows the EMP approach originally described for use in NZ estuaries by Robertson et al. (2002) 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 2008 study, ES supplied rectified ~0.3m/pixel resolution colour aerial photos. 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 2008.

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.
- Percent cover of dominant intertidal macroalgae (e.g. *Gracilaria, Enteromorpha*).
- 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. Vegetation was further 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).

2. METHODS (CONTINUED)

BROAD SCALE HABITAT MAPPING (CONTINUED)

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.

CONDITION RATINGS

At present, there are no formal criteria for rating the overall condition of estuaries in NZ. Therefore, to help ES interpret monitoring data, a series of interim broad scale estuary "condition ratings" (presented below) have been proposed for Waiau Estuary (based on the ratings developed for New Zealand estuaries - Robertson & Stevens 2006, 2007, 2008a). The condition ratings are designed to be used in combination with each other (usually involving expert input) when evaluating overall estuary condition and deciding on appropriate management responses.

The ratings are based on a review of monitoring data, use of existing guideline criteria, and expert opinion. They indicate whether monitoring results reflect good or degraded conditions, and also include an "early warning trigger" so that ES is alerted where rapid or unexpected change occurs. For each of the condition ratings, a recommended monitoring frequency is proposed and a recommended management response is suggested.

In most cases the management recommendation is simply that ES develop an Evaluation and Response Plan (ERP) to further evaluate an issue and consider what response actions may be appropriate. It is expected that the proposed ratings will continue to be revised and updated as better information becomes available, and as new ratings are developed for other indicators.

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 Low	<2% of estuary substrate is soft mud	Monitor at 5 year intervals after baseline established
Low	2%-5% of estuary substrate is soft mud	Monitor at 5 year intervals after baseline established
Moderate	5%-15% of estuary substrate is soft mud	Post baseline, monitor 5 yearly. Initiate ERP
High	>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)

2. METHODS (CONTINUED)

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)

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 (or Poor)	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)

MACROPHYTE PERCENT COVER

Macrophyte beds are important as a habitat for invertebrates and fish, as a food source for invertebrates and waterfowl, and in their role regulating water quality. The presence of extensive submerged macrophyte (e.g. *Ruppia or Zostera*) beds in shallow open/closed coastal lake estuaries and river mouth estuaries like Waiau Estuary, are likely to be indicative of a healthy and biodiverse ecosystem (i.e. not too muddy or nutrient enriched). Though tolerant of a wide range of conditions, macrophytes are vulnerable to fine sediments in the water column and sediment quality (particularly if there is a lack of oxygen and production of sulphide).

MACROPHYTE CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	Macrophyte cover exceeds that of baseline	Monitor annually after baseline established
Good	Macrophyte cover similar to baseline	Monitor annually after baseline established
Moderate	Macrophyte cover 10-30% less than baseline	Monitor annually. Initiate ERP
Fair	Macrophyte cover 30-70% less than baseline	Monitor annually. Initiate ERP
Poor	Macrophyte absent from lagoon	Monitor annually. Initiate ERP
Early Warning Trigger	Trend of decreasing macrophyte cover	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

ESTUARY SUBSTRATE AND VEGETATION

This section describes the dominant features of the estuary, which are summarised in Tables 4, 5, and 6, and Figures 1 and 2. At the end of the section, condition ratings are applied to each indicator, which are then evaluated along with other relevant expert information to assess the condition of the estuary in relation to the key issues of sedimentation, eutrophication and habitat loss.

The Waiau Estuary is a moderate sized estuary (101ha) at the mouth of the Waiau River, separated and protected from the sea by a large (5km) cobble spit. The vast majority of the estuary is located to the east of the river mouth where it stretches in a long (4km), narrow (~150m) and relatively shallow (mean depth ~2m) lagoon. The estuary is dominated by water (typical for river mouth estuaries), with 84% of the estuary submerged at low tide (Table 4, Figure 1, top photo), and although this high submerged proportion is due primarily to the physical structure of the estuary, it also reflects the loss of saltmarsh surrounding the lagoon through drainage and reclamation (much has been converted to farmland).

The estuary is primarily freshwater (<1ppt salinity), and has a small intertidal range. Intertidal substrate is present as a narrow strip of cobble and gravel around the estuary margin (middle photos), with the largest areas of unvegetated substrate being cobble fields near the mouth, and where the Waiau River enters the middle of the estuary (Figure 1). Freshwater inflow from the Waiau River is usually sufficient to keep the estuary mouth open, although it may occasionally close during periods of low flow and high seas. Water abstraction (e.g. the Manapouri Hydro-Electric Power Scheme in 1969 diverted up to 400 cumecs of flow) is likely to have contributed to more frequent mouth closures, and reduced flushing of the lagoon, in recent times.

When the estuary is closed, or flushing of the lagoon is restricted, indicators of eutrophication and sedimentation (i.e. muddy, anoxic, black sulphide-rich sediments, algal blooms, low dissolved oxygen and low clarity) are most likely to be apparent. The only instance of this was to the west of the river mouth where several isolated 1-3m deep ponds in the upper beach cobbles (12ha in total) were cut off from both river and tidal flows (bottom photo). These ponds were seawater dominated (salinity 25ppt) and the edges had anoxic sulphide-rich muds, poor water clarity and macroalgae blooms (*Enteromorpha*). Conditions like this were not seen elsewhere in the estuary, but it is likely that they do exist in deeper subtidal basins where salt wedge conditions are expected to occur.

Table 4. Summary of dominant intertidal broad scale features.

Dominant Class	Area (Ha)	Area (%)
Saltmarsh	**3.1**	**3.1**
Tussockland	1.0	1.0
Grassland	0.3	0.3
Rushland	1.7	1.7
Unvegetated	**98.6**	**96.9**
Cobble field	10.4	10.3
Gravel field	2.7	2.6
Water	85.5	84.0
TOTAL	**101.7**	**100**

Figure 1. Map of Unvegetated Substrate and Saltmarsh Vegetation - Waiau Estuary, February 2008.

ESTUARY SUBSTRATE AND VEGETATION (CONTINUED)

Narrow strip of jointed wire rush and flax along the estuary margin.

Grassland extending to the estuary edge.

Narrow rushland margin bordering managed pasture.

Submerged aquatic macrophytes in the eastern arm.

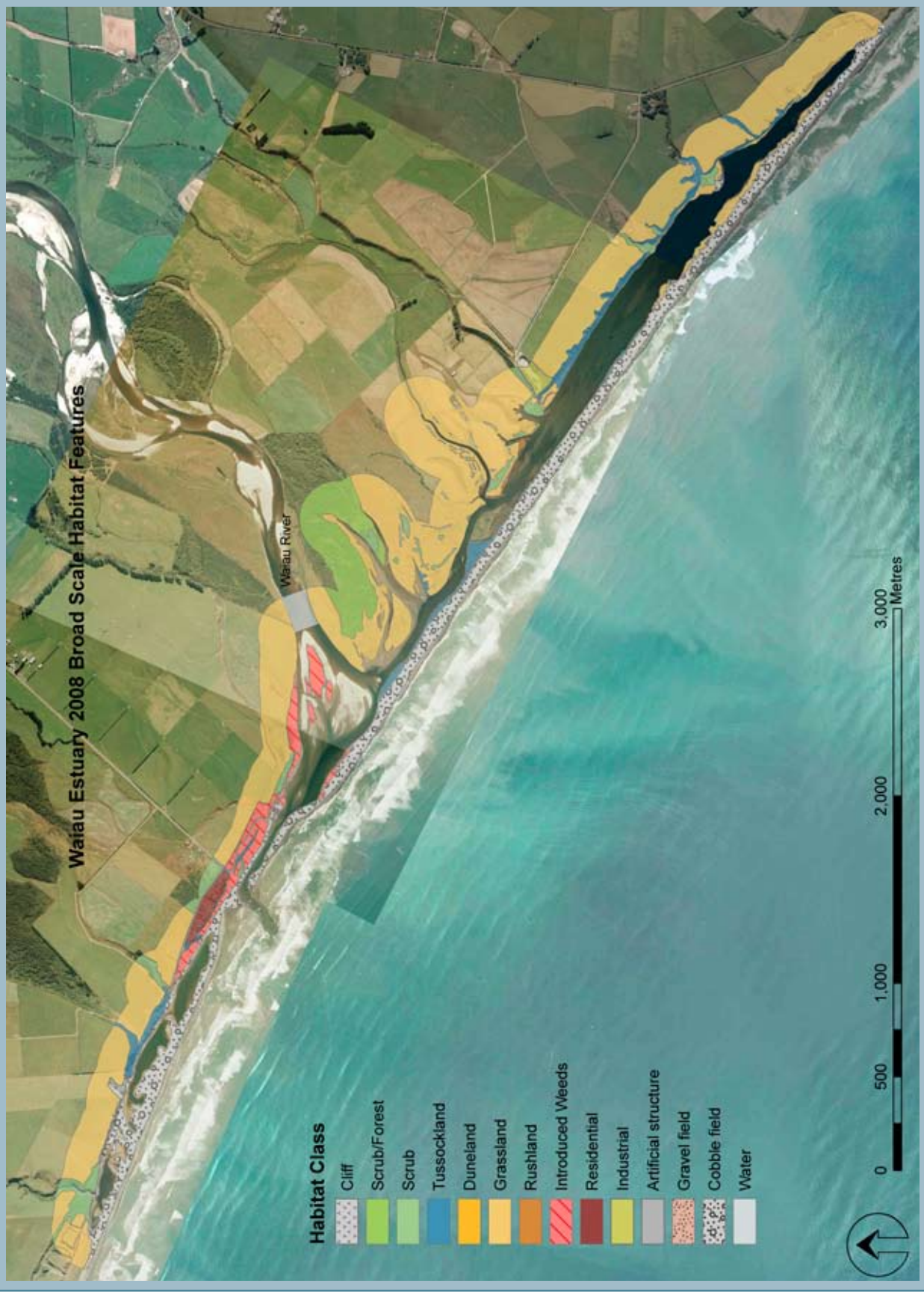
Saltmarsh vegetation (vegetation able to tolerate saline conditions and where terrestrial plants are unable to survive) is summarised in Tables 4 and 5, with the broad vegetation class shown in Figure 1. Overall, there was very little saltmarsh around the lagoon, most in a narrow strip (~1-2m) at the edge of the estuary, where rushland (jointed wire rush - *Apodasmia (Leptocarpus) similis*) dominated, with tussockland (mostly flax - *Phormium tenax*) generally slightly higher up the shore between the rushland and surrounding pasture. The largest vegetated areas were located on small islets in the central eastern side of the lagoon (Figure 1, lower photo). The narrow extent of saltmarsh vegetation can be attributed predominantly to drainage of wetland areas to create pasture, combined with the freshwater dominance of the estuary, meaning many terrestrial plants are able to establish to the waters edge. No vegetation was present around the edges of the ponds to the west of the estuary.

Table 5. Summary of dominant saltmarsh vegetation.

Class	Dominant Species	Primary subdominant	Area (Ha)	Area (%)
Tussockland			1.0	33.6
	Phormium tenax (New Zealand flax)	*Apodasima similis* (Jointed wirerush)	0.2	5.2
		Lupininus arboreus (Tree lupin)	0.9	28.4
Grassland			0.3	10.4
	Unidentified grass		0.002	0.1
		Phormium tenax (New Zealand flax)	0.2	5.0
		Cobble field	0.1	3.7
		Apodasima similis (Jointed wirerush)	0.0	1.6
Rushland			1.7	56.0
	Apodasima similis (Jointed wirerush)		0.3	11.2
		Phormium tenax (New Zealand flax)	0.3	11.1
		Unidentified grass	0.2	5.5
		Juncus pallidus (Pale rush)	0.1	3.1
	Juncus pallidus (Pale rush)	*Eleocharis acuta* (Spike sedge)	0.4	13.4
		Apodasima similis (Jointed wirerush)	0.4	11.7
TOTAL			**3.1**	**100**

No macroalgae or macrophytes were recorded within the intertidal area. However, a range of aquatic macrophytes were observed submerged in the lagoon. These included *Ranunculus trichophyllus, Nitella hookeri* and *Potamogeton crispus*. The presence of macrophytes and the relative dominance of the submerged part of the estuary, emphasise the need to include subtidal habitat in the assessment of key estuary issues of sedimentation, eutrophication and habitat loss.

Figure 2. Map of 200m terrestrial margin vegetation - Waiau Estuary, February 2008.



3. RESULTS AND DISCUSSION (CONTINUED)

TERRESTRIAL MARGIN MAPPING

The results of the 200m terrestrial margin mapping are summarised in Table 6 and Figure 2. Overall, 60% of the estuary margin was developed grassland on flat alluvial terraces, reflecting the dominant land cover of the lower catchment. Tussockland, although much less dominant (5%) was a prominent feature on the coastal fringe with dense flax covering many of the steep cliff and hill faces overlooking both the eastern and western arms of the estuary (see report cover photo for an example). Many native plants were beginning to establish among flax on these hillsides.

Scrub and forest areas (11%) were generally poor quality, mainly introduced species such as gorse and willows, located in old channels of the Waiau River, with small pockets of scrub around the narrow creek gullies cutting into the alluvial terraces. Introduced weeds were a common feature in most areas, and were the dominant cover around the residential area to the west where a range of common weeds (e.g. gorse, blackberry) as well as garden escapees were found. Immediately west of the river mouth, the beach's protective cobble spit had been washed away with evidence of recent erosion occurring adjacent to the coastal residential area.

A large proportion of the terrestrial margin (17%) was the cobble spit between the estuary and Te Waewae Bay. While the seaward side is subjected to frequent disturbance from wave action, the top and inside of the spit were relatively stable and covered in lots of driftwood. Grass and small areas of herb (e.g. *Selleria radicans*) and cushionfield (e.g. *Raoulia*) were present in patches on the more sheltered inland side (see photo below). Hardy species such as *Muehlenbeckia complexa* (wire vine) formed a dense ground cover in places, and a range of introduced weeds were also present.

Access tracks wove along the spit to a variety of hunting and fishing huts (brown and rainbow trout are important recreational species in the lagoon, along with whitebait, flounder, eels, and mullet), and the lagoon and spit are important roosting and feeding areas for spotted shags, oyster catchers, banded dotterels, mottled petrels, and gamebirds.

Along the margins of tributaries in the east of the estuary, a series of linked ponds and wetland plants have been established as part of local restoration efforts to improve the availability of whitebait spawning habitat (see photo bottom left).

Where the public road provides access to the north eastern side of the lagoon, a series of fishing huts and a boat ramp were present, as was a small quarry.

Table 6. Summary of 200m terrestrial margin vegetation.

Class	Dominant Species	Primary subdominant species	Ha	%
Scrub/Forest			19.3	6.9
	Salix sp. (Willow - species not identified)	*Grassland*	*19.3*	*6.9*
Scrub			11.7	4.2
	Native scrub		*3.4*	*1.2*
		Grassland	*1.6*	*0.6*
		Unidentified introduced weeds	*1.1*	*0.4*
	Lupininus arboreus (Tree lupin)	*Ulex europaeus (Gorse)*	*0.4*	*0.2*
	Mixed native and exotic scrub	*Unidentified introduced weeds*	*0.4*	*0.1*
	Ulex europaeus (Gorse)		*1.9*	*0.7*
		Rubrus fruticosus (Blackberry)	*1.0*	*0.4*
		Phormium tenax (New Zealand flax)	*0.7*	*0.2*
		Grassland	*0.6*	*0.2*
		Unidentified introduced weeds	*0.6*	*0.2*
Tussockland			13.8	5.0
	Phormium tenax (New Zealand flax)		*3.3*	*1.2*
		Native scrub	*3.8*	*1.4*
		Lupininus arboreus (Tree lupin)	*2.9*	*1.0*
		Rubrus fruticosus (Blackberry)	*1.2*	*0.4*
		Ulex europaeus (Gorse)	*1.0*	*0.3*
		Isolepis nodosa (Knobby clubrush)	*1.0*	*0.3*
		Apodasima similis (Jointed wirerush)	*0.7*	*0.2*
Grassland			166.3	59.5
	Unidentified grass		*155.9*	*55.8*
		Phormium tenax (New Zealand flax)	*3.3*	*1.2*
		Native scrub	*1.2*	*0.4*
		Native/exotic scrub	*1.1*	*0.4*
		Muehlenbeckia complexa (Wire vine)	*2.9*	*1.1*
		Phormium tenax (New Zealand flax)	*1.5*	*0.5*
		Lupininus arboreus (Tree lupin)	*0.3*	*0.1*
Duneland			0.03	0.01
	Ammophila arenaria (Marram grass)		*0.03*	*0.01*
Rushland			0.6	0.2
	Apodasima similis (Jointed wirerush)		*0.1*	*0.0*
		Phormium tenax (New Zealand flax)	*0.5*	*0.2*
Introduced Weeds			11.3	4.0
	Unidentified introduced weeds	*Phormium tenax (New Zealand flax)*	*4.4*	*1.6*
		Ulex europaeus (Gorse)	*6.8*	*2.4*
Residential			2.6	0.9
Industrial (Quarry)			1.5	0.5
Cliff			1.0	0.4
Cobble field			46.1	16.5
Artificial structure (Road)			1.2	0.4
Water			3.9	1.4
Grand Total			279.4	100.0

3. RESULTS AND DISCUSSION (CONTINUED)

CONDITION RATINGS

The 2008 broad scale mapping has enabled condition ratings to be applied for the key issues of sedimentation (extent of soft mud), eutrophication (macroalgal cover), and habitat loss (extent of macrophytes, saltmarsh, and terrestrial vegetated buffer). In addition a baseline has been established against which future changes in the estuary can be assessed. A summary of condition ratings is presented in Table 7, and results discussed for each issue in the following section.

Table 7. Summary of Condition Ratings for indicators of estuary issues.

BROAD SCALE RATING 2008	% COVER INTERTIDAL SOFT MUD	% COVER INTERTIDAL MACROALGAE	% COVER MACROPHYTES	% COVER SALTMARSH	TERRESTRIAL VEGETATED BUFFER
WAIAU ESTUARY	VERY LOW	VERY GOOD	UNKNOWN	LOW	POOR

4. CONCLUSIONS

The broad scale monitoring showed Waiau Estuary was a moderate sized (101ha) river mouth estuary, different from other small mouthed estuaries in the area in that it has a long shallow lagoon with a large subtidal component (84%). Although the lagoon is relatively isolated from the main flow of the Waiau River (which tends to bypass it), it is nevertheless dominated by freshwater and the main river channel is generally well flushed. However, tidal seawater inflow also occurs and creates a salt wedge effect of denser saline water near the estuary bed. The estuary had a narrow intertidal area dominated by unvegetated cobble and gravel, with saltmarsh limited to a narrow strip around the lagoon edge, and much of the terrestrial margin developed grassland. Macrophytes and macroalgae were not found in the intertidal area.

The intertidal results, in combination with other available information, are used in the following subsections to provide an overview of likely estuary condition in relation to the key issues examined in this broad scale assessment, namely sedimentation, eutrophication and habitat loss. However, in order to provide a more comprehensive assessment of overall estuary condition, a better understanding of the subtidal component of the estuary is needed. As such it is recommended that a synoptic survey and vulnerability assessment be undertaken of the subtidal area of the estuary upon which monitoring recommendations can then be based.

SEDIMENTATION: If sediment inputs to an estuary are excessive, they infill quickly with muds, reducing biodiversity and human values and uses. River mouth and lagoon type estuaries are susceptible to sediment impacts if sediment is not readily flushed from the system (the main stressors being flow reductions from water abstraction and mouth closures), and where high wind fetch and shallow lagoon depth promote sediment resuspension. Under such conditions, sediment is likely to settle predominantly in localised areas where prevailing wind and waves deposit it on shorelines, and in subtidal basin areas. The presence of excessive sediment may result in muddy, anoxic, black sulphide-rich sediments, low dissolved oxygen and low clarity - conditions that can stress aquatic macrophytes and promote undesirable growths of macroalgae and phytoplankton.

Because fine sediment is expected to settle predominantly in subtidal central basin areas and sheltered arms in the Waiau, the intertidal broad scale mapping (which showed a "very low" rating for intertidal soft mud) provides only a limited picture regarding sedimentation issues within the Waiau. Although the subtidal area was not mapped, the presence of submerged aquatic macrophytes and generally good water clarity indicated problems commonly associated with lots of fine mud were not conspicuous, although anecdotal evidence suggests the lagoon has got muddier and shallower over the past 40 years.

4. CONCLUSIONS (CONTINUED)

EUTROPHICATION: Typical New Zealand river mouth estuaries are freshwater dominated, have a large subtidal component relative to the intertidal area, and may experience periods of little or no flushing. In such estuaries, nuisance intertidal macroalgal growth, as a broad scale indicator of eutrophication, needs to be considered in conjunction with subtidal macroalgal growth as the subtidal area of the estuary is where eutrophication impacts are most likely.

There was little indication of nutrient enrichment causing phytoplankton or macroalgal blooms, or a loss of macrophytes within the shallow lagoon margins. This is consistent with relatively low catchment nutrient loads, and generally good water quality in the Waiau River. The exception to this is the isolated ponds in the west which had poor water and sediment quality, and extensive macroalgal growths in shallow areas. These areas highlight the types of problems that can arise when water exchange is restricted, with the main stressors to good flushing being freshwater abstraction and closures of the lagoon mouth.

HABITAT LOSS: Estuaries function best with a large area of rooted vegetation, i.e. saltmarsh and macrophytes, as well as a healthy vegetated terrestrial margin. Loss of this habitat reduces wildlife, recreational and aesthetic values, while also adversely impacting on an estuary's role in flood and erosion protection, contaminant mitigation, sediment stabilisation, and nutrient cycling.

There has been extensive saltmarsh and margin habitat loss from past forest clearance, drainage, and grazing. The terrestrial margin is now dominated by grassland, although significant effort has recently been put into replanting saltmarsh and developing whitebait spawning habitat.

Subtidal macrophytes (generally sensitive to increased sedimentation, changes in water flows or salinity, and nutrient increases) were present, and shows the estuary currently supports this important habitat. Anecdotal evidence suggests increases in macrophyte and macroalgal growth over the past 40 years although the extent and vulnerability of this macrophyte habitat in Waiau Estuary is unknown.

5. MONITORING

Waiau Estuary has been included by ES as part of its long term estuary monitoring programme being undertaken in a staged manner throughout the region. It is recommended that broad scale habitat monitoring of the Waiau Estuary continue on a 5 yearly cycle (next scheduled for December 2013) under low flow and neap tide conditions. However, in order to provide a more comprehensive assessment of overall estuary condition, a better understanding of the subtidal component of the estuary is needed. As such it is recommended that a synoptic survey and vulnerability assessment be undertaken of the subtidal area of the estuary upon which monitoring recommendations can then be based.

It is recommended that the synoptic survey include a baseline map of subtidal substrates, sediment and water quality measures (e.g. of RPD, salinity, temperature, DO, pH, Secchi disk, depth, macroinvertebrate presence), and establishment of buried sediment plates to measure the rate of sedimentation. The synoptic survey should also map submerged macrophytes and macroalgae (to identify the location and percentage cover of dominant species). This will enable a better assessment of potential vulnerability and therefore monitoring and management needs.

6. RECOMMENDED MANAGEMENT

The following management actions are encouraged:

Monitor Key Stressors

- Monitor changes in catchment land use, freshwater abstraction, and mouth openings/closures. Because of the susceptibility of the lagoon, any changes in the key stressors should trigger an evaluation of the likely impact on the lagoon.

Restore Saltmarsh Habitat

- The reduction in saltmarsh habitat as a result of drainage has certainly contributed to reduced biodiversity and increased sedimentation in subtidal areas 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 re-establishment, and to support community restoration initiatives.

Reinstate Margin Buffer

- Human development of the estuary margin has resulted in clearance of surrounding bush. This has almost certainly contributed to reduced biodiversity and increased sedimentation in the estuary. 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 existing revegetation efforts, and to identify where conflict may occur between existing uses and estuary expansion as a consequence of sea level rise.

7. ACKNOWLEDGEMENTS

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APPENDIX 1. BROAD SCALE HABITAT CLASSIFICATION DEFINITIONS

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: Area that is dominated by both live and dead cockle shells.

Mussel reef: Area that is dominated by one or more mussel species.

Oyster reef: Area that is dominated by one or more oysters species.

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.