Wriggle coastalmanagement

Waituna Lagoon 2007

Broad Scale Habitat Mapping and Historical Sediment Coring

Prepared for **Environment Southland**
October 2007

Cover Photo: Waituna Lagoon

Waituna Lagoon 2007

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Prepared for
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By

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EXECUTIVE SUMMARY

OVERVIEW

In the 1990's, Environment Southland (ES) established a long-term monitoring programme to assess some of the major issues faced by New Zealand estuaries using the tools included in the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002). The programme, being undertaken in a staged manner in Southland's key estuaries, includes Waituna Lagoon (1,350ha), and its associated wetland (~2,200ha), centred in Toetoes Bay in Eastern Southland.

Waituna Lagoon has been identified as having a high risk of nutrient, sedimentation, pathogen and, to a lesser extent, habitat loss problems (Johnson & Partridge 1998, Thompson & Ryder 2003, Cadmus & Schallenberg 2007, Schallenberg & Tyrrell 2007). ES contracted Wriggle Coastal Management (Wriggle) to undertake an Ecological Vulnerability Assessment (see Stevens and Robertson 2007) to determine monitoring and management priorities, and a series of monitoring studies in February/ March 2007 to provide a baseline against which change can be measured. The present report summarises the results of the 2007 monitoring for Waituna Lagoon, which included the following work:

- Broad scale mapping of sediment types.
- Broad scale mapping of lagoon depth.
- Broad scale mapping of wetland vegetation.
- Broad scale mapping of macroalgal beds (i.e. sea lettuce (*Ulva*), *Gracilaria, Enteromorpha*).
- Broad scale mapping of the 200m terrestrial margin vegetation surrounding the estuary.
- Broad scale mapping of terrestrial vegetation within the RAMSAR site.
- Assessment of the recent historical sedimentation rate (using radio-isotopes).
- Establishment of sediment rate monitoring plates.

In addition, the present report includes the results of work Wriggle undertook for the Department of Conservation Southland Conservancy (DOC) at the same time:

- Broad scale mapping of the dominant lagoon macrophyte - *Ruppia* - see Robertson & Stevens (2007a).

The methods used are based on the broad scale habitat mapping tools described in the EMP (Robertson et al. 2002), and a number of extensions to the EMP and its monitoring outputs developed by Wriggle (see Robertson & Stevens 2006, 2007b). The extensions include:

- Monitoring sedimentation rate.
- Mapping the percent cover of nuisance macroalgae.
- Mapping the percent cover of aquatic macrophytes.
- Mapping the 200m terrestrial margin vegetation/landuse.
- Development of condition ratings for reporting.

The results of the monitoring undertaken in Waituna Lagoon are summarised below:

SEDIMENT TYPE

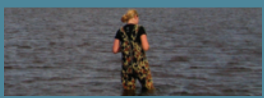
A variety of sediment types occur in the lagoon. Unvegetated sediment (total area 1,365ha) was dominated by firm sand (38%) located mainly in the central basin towards the lagoon mouth, mixed soft mud sand and gravel (28%) predominantly in the eastern arm, and gravels (20%) mostly around the lagoon margin. The extent of soft mud/sand in the lagoon where there was no gravel was relatively low (12%), but overall soft mud was present across 42% of the lagoon. This excludes mud deposited in the rushland when the lagoon level is high. Very soft muds (2%) were mainly associated with small, narrow sediment plumes near the stream mouths, and in the western embayment. There were localised areas of anoxic sediments associated with macroalgal mats and inflowing streams.

EXECUTIVE SUMMARY (CONTINUED)

SEDIMENTATION RATE

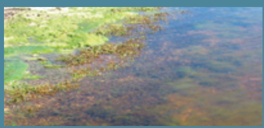
The historical sediment core collected near the mouth of Waituna Creek had three visually distinct layers. The top 6cm was well oxygenated firm sand/mud overlying a crumbly brown organic layer that extended to 18cm. Below this depth the core was predominantly peat, with sand mixed in with the peat below 22cm to the bottom of the core (33cm). Radio-isotope dating using Caesium (^{137}Cs) activity indicated a gross sedimentation rate over the past 47 years (1960-2007) of 2.5-3.0mm/year, greatly exceeding pre-European rates.

LAGOON DEPTH



The majority of the lagoon was less than 1.5m deep when the lagoon was at 1.13m above mean sea level (msl) in early March 2007. The deepest areas (~3m) were in the narrow eastern arm adjacent to Currens Creek. Narrow channels were present at the stream entrances, and also in the southwest near where the lagoon is opened to the sea.

MACROALGAE



Macroalgal growth was relatively low throughout the lagoon in March 2007 with areas of high percent cover only occurring in localised shallow areas near the sea and in the central basin. Most of the growth occurred in the shallow waters around the margins. Macroalgal growth is expected to be greatest when the lagoon is low, open to the sea and exposed to tidal water level changes.

MACROPHYTES

Macrophyte presence was dominated by two species of Horse's mane weed (*Ruppia*). Shallower areas, particularly the north-eastern shoreline, were dominated by relatively small *R. polycarpa*, while deeper parts of the lagoon to the south and east were dominated by much larger *R. megacarpa* plants. Areas with very high cover (80-100%) were spread throughout the lagoon, but appeared limited to areas relatively sheltered from wind and wave disturbance (e.g. the head of Waituna Creek, the western embayment and arm, and the deep and narrow eastern arm near Currans Creek). Most *Ruppia* was in the eastern half of the lagoon in gravels and sands with relatively little mud. Low and very low percentage cover areas (<1%) tended to be restricted to shallow exposed areas with either muddy or sandy sediments.

WETLAND VEGETATION

Wetland vegetation covered 472ha of which 97% was rushland, and was dominated by thick stands of *Leptocarpus similis* (jointed wire rush) fringing the lagoon and providing a relatively wide and uniform band of buffering vegetation. The wetland also included varieties of herbs, sedges, tussocks and many introduced grasses and weeds. In general, the wetland was in good condition as reflected by its largely undeveloped state, however, historical drainage has significantly modified the wetland area.

200m TERRESTRIAL MARGIN VEGETATION

The 200m terrestrial margin vegetation (1,029ha), consisted of a relatively even split of grassland (23%), manuka scrub (30%), and manuka forest (29%). Thick native scrub and forest on elevated land dominated to the south and west of the lagoon. To the north and east the terrestrial margin was dominated by grassland (dairy and beef farms) which had been channelled and drained, and extended close to the edge of the wetland with only a narrow strip of scrub (e.g. manuka, gorse, bracken) or tussockland (flax, toetoe, red tussock) separating the wetland from the surrounding farms.

RAMSAR VEGETATION

Terrestrial and wetland vegetation within the 2,161ha RAMSAR site was dominated by native scrub and forest (78%), and wetland rushland (18%). This represents around 80% of all the remaining forest and rushland within the wider Waituna catchment and, as such, the protected areas of the lagoon are an important repository of local biodiversity. Most of the remaining native scrub and tussockland buffering the northern margins of the lagoon fell outside RAMSAR protection, as did the rushland being reclaimed on the western side of the Currens Creek embayment.

EXECUTIVE SUMMARY (CONTINUED)

KEY ASPECTS

This first report summarises the major habitat types and condition of Waituna Lagoon. It indicates that Waituna is a largely unmodified example of a temperate shallow coastal lagoon (whose water level is artificially controlled) with its remaining coastal wetland system largely intact. Key aspects are:

- Sedimentation rates were elevated and mud was relatively common throughout the lagoon.
- Nuisance macroalgal growth was present around margins in localised areas.
- There were localised areas of anoxic sediments often associated with macroalgal mats and inflowing streams.
- The main submersed aquatic plant, *Ruppia*, was still thriving in the lagoon when conditions were optimal (extended period of lagoon closure, good clarity).
- The wetland and terrestrial margin vegetation in the internationally significant Waituna complex was found to be relatively unmodified, diverse and expansive.
- Localised areas of rushland were being lost through drainage and reclamation.
- Introduced weeds and grasses were relatively common in the wetland.

The information on habitat types, condition and issues collected in this study is used in the second study (the Ecological Vulnerability Assessment - Stevens and Robertson 2007), to identify long term monitoring and management priorities.

1. INTRODUCTION

BACKGROUND

To assess the major issues faced by New Zealand estuaries, Environment Southland (ES) established a long-term monitoring programme in the 1990's based on the tools included in the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002). The EMP consists of two main elements:

1. Broad scale habitat mapping (using GIS based computer software).
2. Fine scale (i.e. detailed) monitoring of dominant intertidal habitat in the mid estuary area.

Planning sampling strategy.

Broad scale habitat mapping records the location and type of vegetation (e.g. saltmarsh, seagrass, macroalgae) and substrate (e.g. mud, sand, gravel, etc); and is used to provide information primarily on the issues of habitat and margin loss, sedimentation (through the mapping of substrate type), and eutrophication (by mapping macroalgae percent cover).

Fine scale monitoring focuses primarily on the physical, chemical, and biological characteristics of estuary sediments as these tend to be the most sensitive to degradation (Church 1975). Fine scale monitoring includes various indicators of estuary condition to provide information on sedimentation, eutrophication, and toxins (i.e. grain size, organic matter, nutrients, heavy metals, and sediment macrofauna).

Recent work undertaken by Wriggle Coastal Management (Wriggle) for ES has expanded the reporting of EMP monitoring data by developing key condition indicators (see Table 1) and proposing interim condition ratings to evaluate estuary condition (e.g. Robertson & Stevens 2006). In addition, a number of other extensions to the EMP and its monitoring outputs have been developed by Wriggle including:

Extensions to the EMP	
Ecological Vulnerability Assessment	A framework used to bring together existing knowledge on the estuary so that the major vulnerabilities can be identified, and used to identify monitoring and management priorities (see Stevens and Robertson 2007).
Sedimentation monitoring	Sedimentation has been identified as a potential issue and has been addressed in two ways. Firstly through the radioisotope analysis of a sediment core to age sediment and determine historical sedimentation rates in the estuary. Secondly, through the establishment of sediment plates so that rates of sediment accumulation from the present time and into the future can be measured. Both methods are described in Section 2 with site locations shown in Figure 1.
Nuisance macroalgal monitoring	Eutrophication, commonly observed through the presence of nuisance macroalgae, has been identified as a potential problem. Methods, for assessing and reporting macroalgal percent cover have been improved and are described in Section 2.
Aquatic macrophyte monitoring	Submersed aquatic macrophytes are important as a habitat for invertebrates and fish, as a food source for invertebrates and waterfowl, and their role in regulating water quality. Methods, for assessing and reporting macroalgal percent cover have been improved and are described in Section 2.
200m wide terrestrial margin monitoring	The vegetation around the lagoon provides an important buffer between the land and the lagoon, influencing the visual character of the area, and playing an important role in lagoon stability, mitigation of contaminant inputs, erosion protection, and the provision of wildlife habitat. The 200m margin provides a continuous description of the landuse adjacent to the wetland and was included as it is also generally a key area under pressure from human use and development.
Recommended development of condition ratings for reporting	Interim condition ratings (see Robertson & Stevens, 2006, 2007b) have been developed specifically for the EMP indicators used by ES for Southland's estuaries (Table 2) to place monitoring results in context, and to guide the frequency of monitoring and type of management responses. Condition ratings have yet to be developed specifically for Waituna Lagoon.

1. INTRODUCTION (CONTINUED)

Recently ES have added Waituna Lagoon, a "coastal lake" type estuary to its long-term estuary monitoring programme. Waituna is a large, brackish intermittently open/closed lagoon separated from the sea by a spit or barrier beach. It is fed by three streams (Currans Creek, Waituna Creek and Moffats Creek) (Figure 1), and drains to the sea through a managed opening at the western end of the lagoon. Historically, the lagoon was surrounded by a huge peat bog wetland (area ~20,000ha stretching from Fortrose Estuary to New River Estuary) whose drainage gave the lagoon water its characteristic clear brown humic stain, low nutrient status, and low pH. Now the catchment is dominated by farmland (intensive sheep, beef and dairying, Figure 2).

Coastal lakes are common in the South Island and Kirk & Lauder (2000) list their distinctive characteristics as:

- Associated with mixed sand and gravel coasts, with high wave energy, strong longshore sediment transport, small tides and undergoing long-term erosion.
- Openings to the sea are rare and short-lived unless created by human action.
- Natural water levels are generally higher and have a smaller range than those now occurring through ongoing human intervention. Lower average water levels relate to agricultural uses of low-lying land marginal to lagoons.
- Ocean salt content of the water body is low. It is derived from salt spray, from overwash of the enclosing barrier beach, or from inlet throughflow by the tide in the later stages of artificial openings.
- Wind waves and currents are an important, if not dominant, agent of mixing within the lagoon.

In terms of the ecology, coastal lakes (in their natural state) tend to have high habitat diversity and ecological richness, which is driven to a large extent by the following features:

- **Extensive Saltmarsh Habitat:** Because coastal lakes have a large area of shallow, wet marginal land with relatively low water level fluctuations, they tend to have a large proportion of their total area in saltmarsh vegetation.

- **Extensive Aquatic Macrophyte Beds:** Because catchment-specific sediment yields are relatively small (providing good water clarity) and the lakes are shallow (less than 3m deep), they grow extensive beds of aquatic macrophytes (e.g. horse's mane weed, *Ruppia* spp.). *Ruppia* has been suggested as a keystone species in Waituna Lagoon (Schallenberg & Tyrrell 2007) because of its importance as a habitat for invertebrates and fish, as a food source for invertebrates and waterfowl, and its role in regulating water quality.

Table 1. Summary of the broad and fine scale EMP indicators used by Environment Southland.

Level	#	Indicator	Method
Broad Habitat	1	Saltmarsh Habitat Index	Broad scale mapping - estimates the change in saltmarsh habitat over time.
Broad Habitat	2	Seagrass Habitat Index	Broad scale mapping - estimates the change in seagrass habitat over time.
Nutrient Enrichment	3	Nuisance Macroalgal Cover Index	Broad scale mapping - estimates the change in the area of nuisance macroalgal growth (e.g. sea lettuce (*Ulva*), *Gracilaria* and *Enteromorpha*) over time.
Sedimentation	4	Soft Mud Sediment Index	Broad scale mapping - estimates change in the amount of soft mud habitat over time.
Organic & Nutrient Enrichment	5	Organic and Nutrient Enrichment Indicator	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.
Contamination	6	Contamination in Bottom Sediments Indicator	Chemical analysis of indicator metals (cadmium, chromium, copper, nickel, lead and zinc) in replicate samples from the upper 2cm of sediment.
Biodiversity	7	Condition of Bottom Dwelling Animals	Type and number of animals living in the upper 15cm of sediments (infauna) - 0.0133m^2 replicate cores. Type and number of animals living on the sediment surface (epifauna) - 0.25m^2 replicate quadrats.

SCOPE (CONT.)

The major issues associated with coastal lakes are summarised in Table 2.

Table 2. Summary of the major issues affecting NZ coastal lakes/lagoons.

Key Coastal Lake Issues	
Excessive Sedimentation	Because coastal lakes are a sink for sediments, their natural cycle is to slowly infill with fine muds and clays. Today, average sedimentation rates in our estuaries are typically 10 times or more higher than before humans arrived. Because coastal lakes are shallow, the muds are easily resuspended. This causes low 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).
Excessive Nutrients	Increased nutrient richness of coastal lake ecosystems stimulates the production and abundance of aquatic macrophytes (e.g. *Ruppia*) and saltmarsh vegetation. If excessive, it stimulates fast-growing algae such as phytoplankton, and short-lived macroalgae (e.g. sea lettuce and *Enteromorpha*). 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 lakes and cause 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 coastal lake environment, can survive for some time. Every time we come into contact with the lake water that has been contaminated with human and animal faeces, we expose ourselves to these organisms and risk getting sick.
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 some can bio-accumulate in fish and shellfish, causing health risks to people and marine life.
Habitat Loss	Coastal lakes have many different types of habitats including shellfish beds, aquatic macrophyte beds, salt marshes (rushlands, herbfields, reedlands etc.), forested wetlands, beaches, river deltas, and hard shores. The major stressors causing habitat degradation or loss in coastal lakes are: artificial mouth openings (increasing salinity and lowering lake levels), drainage and reclamation of salt marsh, 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.

Recently Waituna Lagoon has been identified as having a high risk of nutrient, sedimentation, pathogen and, to a lesser extent, habitat loss problems (Johnson & Partridge 1998, Thompson & Ryder 2003, Cadmus & Schallenberg 2007, Schallenberg & Tyrrell 2007).

In response to these concerns, and as part of the existing long-term estuary monitoring programme, ES contracted Wriggle to undertake two studies:

1. A series of broad scale mapping and sedimentation studies (this report).
2. An Ecological Vulnerability Assessment to determine monitoring and management priorities.

SCOPE (CONT.)

The purpose of the mapping and sedimentation component was to provide a baseline against which change can be measured, and to identify relevant issues. The work included:

- Broad scale mapping of sediment types.
- Broad scale mapping of lagoon depth.
- Broad scale mapping of wetland vegetation.
- Broad scale mapping of macroalgal beds (i.e. sea lettuce (*Ulva*), *Gracilaria, Enteromorpha*).
- Broad scale mapping of the 200m terrestrial margin vegetation surrounding the estuary.
- Broad scale mapping of terrestrial vegetation within the RAMSAR site.
- Assessment of the recent historical sedimentation rate (using radio-isotopes).
- Establishment of sediment rate monitoring plates.

In addition, Wriggle undertook related work for the Department of Conservation Southland Conservancy (DOC) at the same time:

- Broad scale mapping of the dominant lagoon macrophyte - *Ruppia* - see Robertson & Stevens (2007a).

The issues identified in the mapping and sedimentation component, along with others, were then incorporated within the Ecological Vulnerability Assessment component. This assessment is described fully in Stevens and Robertson (2007) and is essentially a framework used to bring together existing knowledge on the estuary so that the major vulnerabilities can be identified, and used to identify monitoring and management priorities.

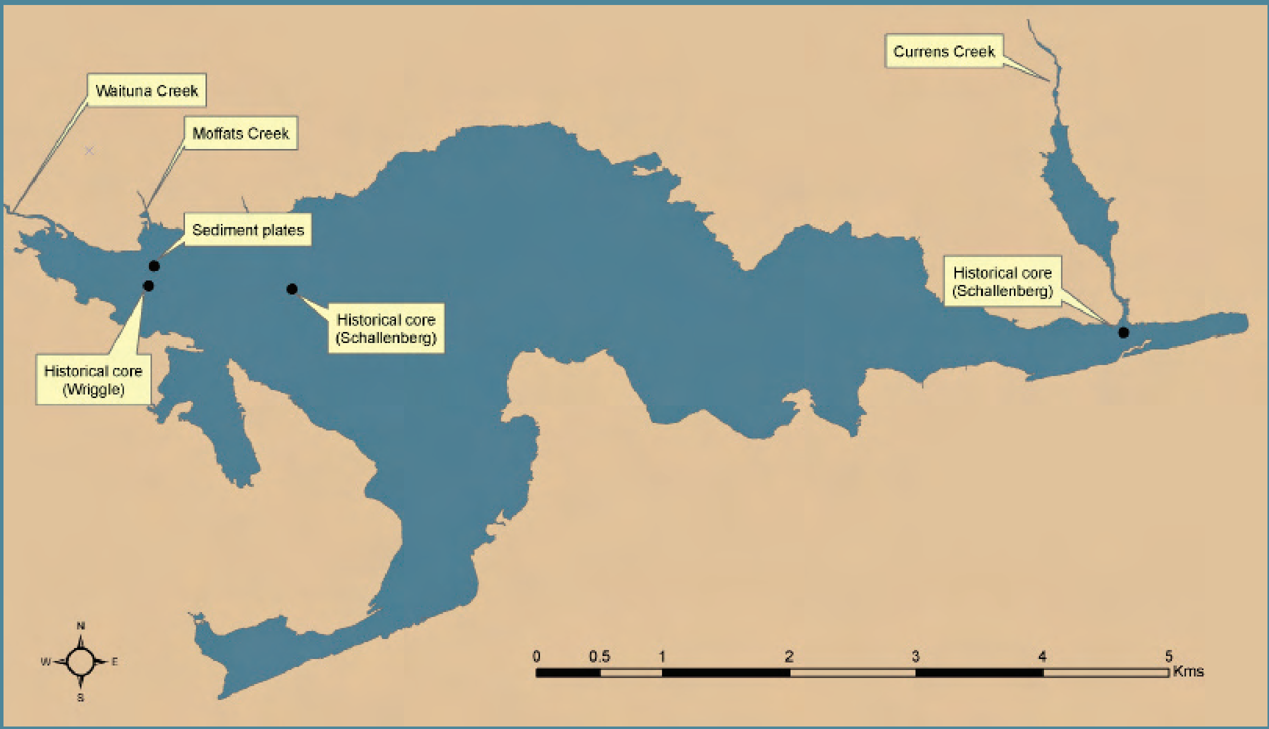
The current report presents the results of the mapping and sedimentation component outlined above (including the DOC funded macrophyte mapping).

The report is structured in the following general sections:

Section 1. Introduction to the scope and structure of the study.
Section 2. Methods for the broad scale mapping of habitat types, assessment of sedimentation rate, and mapping of macroalgal and macrophyte percent cover.
Section 3. Results and discussion.
Section 4. Summary and conclusions.
Section 5. Acknowledgements.
Section 6. References.

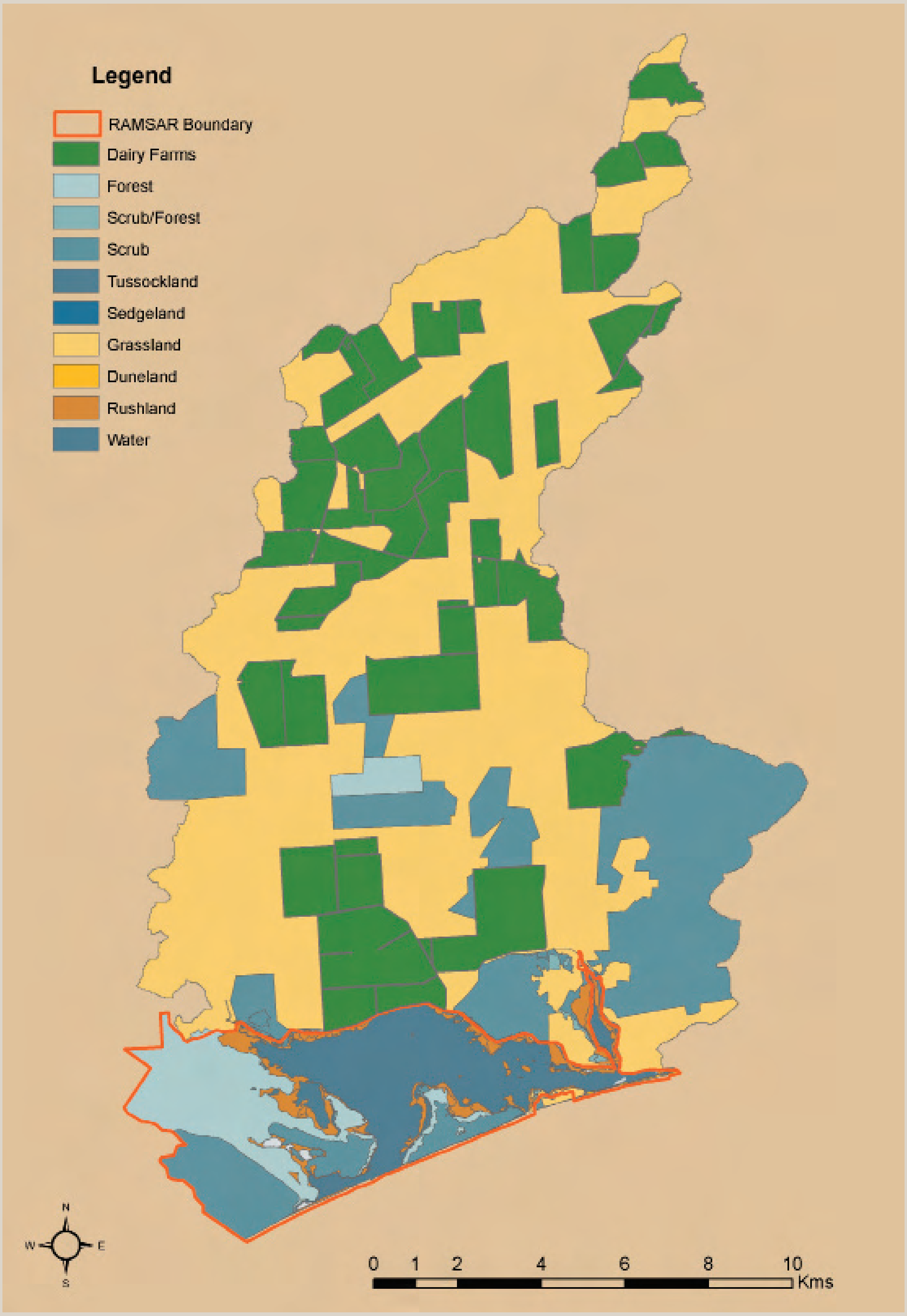
Appendix 1: Classification definitions.

Figure 1. Location map of Waituna Lagoon showing major creeks and sediment sampling sites.



Checking for *Ruppia*, at surface, Waituna Lagoon.

Figure 2. Map of Waituna Lagoon and catchment showing the RAMSAR site boundary.



2. METHODS

BROAD SCALE HABITAT MAPPING

Sandy lagoon sediments.

Wetland vegetation at the eastern end of Waituna Lagoon.

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: seagrass, macroalgae, rushland, etc). The approach, originally described for use in NZ estuaries by Robertson et al. (2002), uses a combination of aerial photography, together with detailed ground-truthing and GIS-based digital mapping, to record the primary habitat features present. Very simply, the method involves three key steps:

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

For the 2007 study, ES supplied ~1.0m/pixel resolution aerial photos flown in August 2006. The individual photos were mosaiced and then georeferenced to rectified LINZ images using rubber-sheet splining within ArcMap. Colour aerial photos covering the estuary at a scale of 1:5,000 were then laminated and two scientists ground-truthed the spatial extent of dominant habitat and substrate types by recording features directly on the laminated aerial photos over four days. Features were assessed by collecting samples of the sub-surface sediments or vegetation from a jetboat, canoe, by wading in shallower water, and by use of an underwater viewing scope. Surrounding vegetated areas were accessed by a combination of boat, walking or quadbiking.

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

- Dominant substrate.
- Depth.
- Percent cover of dominant macrophytes (*Ruppia* spp.).
- Percent cover of dominant macroalgae (e.g. *Enteromorpha*).
- Dominant wetland vegetation.
- 200m wide terrestrial margin vegetation/landuse.
- Dominant terrestrial vegetation within the RAMSAR site.

The mapping focused predominantly on the wetland vegetation and the surrounding terrestrial margin of Waituna Lagoon. Wetland vegetation surrounding the multitude of other tiny lagoons that dot the Waituna complex was not mapped. Instead, the general characteristics of the types of vegetation surrounding these lagoons is described in the results section.

Substrate and vegetation were classified using the class definitions listed in Appendix 1. 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)

MACROALGAE AND MACROPHYTE PERCENT COVER

Figure 3. *Enteromorpha* (80-100% cover) at the eastern end of Waituna Lagoon.

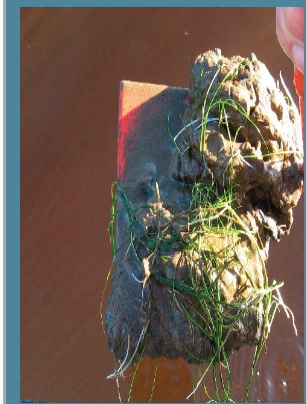


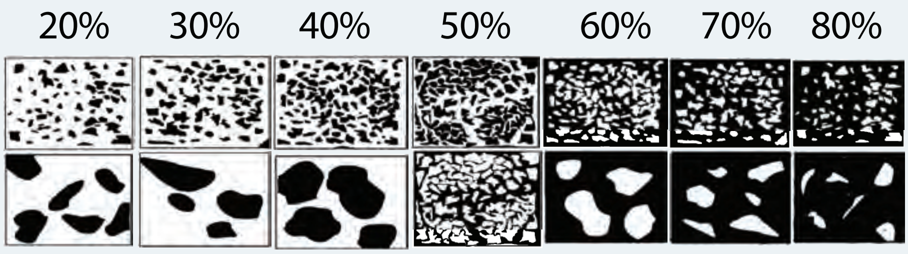
Figure 4. Sandy sediments, with 1-10% *Ruppia* cover.

Using the same broad scale methods described above, macroalgae and macrophytes within the lagoon were visually classified based on six bands of percentage cover:

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

Estimates of percentage cover were made by experienced scientists and recorded on aerial photos using a visual rating scale as presented below, with field examples shown in Figures 3 and 4. Where macrophyte beds could not be assessed directly by viewing flower heads at the water surface, or through the water column with a viewing scope, samples of the surface sediments and attached macrophyte species were brought to the surface (Figure 4).

Visual rating scale for percentage cover estimates



This enabled a spatial picture (recorded in separate GIS layers) to be presented of where different densities of macroalgae and macrophytes were concentrated within the lagoon.

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 lagoon are provided as ArcMap 9.2 Geographic Information System (GIS) shapefiles on a separate CD. Georeferenced digital field photos (GPS-Photolink) are also supplied as a GIS layer.

As the GIS structure allows data to be easily managed, and contains a much greater level of detail than can be concisely presented in a summary report, the GIS should be used as the primary resource for assessing broad scale data. Results are summarised in the current report in Section 3.

2. METHODS (CONTINUED)

HISTORICAL SEDIMENTATION RATE

Figure 5. Waituna Lagoon sediment core.

To age sediment using radio-isotopes and calculate recent sediment deposition to ~100 years before present, a historical sediment core was taken from soft subtidal muds in Waituna Lagoon on 11 March 2007 (Figure 5). The core was collected by slowly inserting a 1m long, 10cm diameter PVC pipe into the lagoon muds, measuring core compression, then removing the pipe (and intact core) from the lagoon bed and transporting it upright on a canoe to the lagoon margin for processing. From here, the PVC pipe was laid horizontally, split in half, the core photographed, and then cut into 2cm slices. Each slice was described, bagged and labelled. Samples from representative depths were selected based on the visual character of the core (e.g. changes grain size/texture/colour/biota) for analysis at the National Radiation Laboratory, Christchurch for the following:

Beryllium (^{7}Be): a natural isotope (very short half-life) used to indicate the depth of surface mixing (i.e. it will not be present in older sediments).
Caesium (^{137}Cs): an isotope with a half life of 30 years that was introduced by atmospheric nuclear weapons tests beginning in 1953 (i.e. will only be present in sediments post 1953).
Lead (^{210}Pb): a natural isotope (half life of 22 years); useful in dating sediments younger than 100-150 years. The difference between the ^{210}Pb concentration in the core sample below the surface and the concentration at the surface is used to age the sediment.
Radium (^{226}Ra & ^{228}Ra): the two most common isotopes of radium. ^{226}Ra has a long half-life (1,600 years) compared to that of ^{228}Ra (5.75 years). ^{226}Ra decays by emitting the nucleus of a helium atom (alpha particle), whereas ^{228}Ra emits an electron (beta particle).

At the National Radiation Laboratory, 15g samples of dried sediment were ground, homogenised, embedded in epoxy resin, and then left for 30 days to allow equilibration between ^{226}Ra, ^{214}Bi (Bismuth - a radon decay product), and ^{214}Pb. Samples were then placed on a Hyper Pure Germanium gamma detector, counted for 23 hours, and then counts were analysed with GENIE-2000 software. This allowed total ^{7}Be, ^{137}Cs, ^{210}Pb, ^{226}Ra, and ^{228}Ra to be calculated with a 95% confidence interval. Appendix 2 details methods used to calculate the historic sedimentation rates using the isotope results.

FUTURE SEDIMENTATION RATE

Figure 6. Inserting sediment plates with SCUBA.

Determining the sedimentation rate from now into the future involves a simple method of measuring how much sediment builds up over a buried plate over known period of time. Once a plate has been buried, levelled, and the elevation measured, probes are pushed into the sediment until they hit the plate and the penetration depth is measured. A number of measurements on each plate are averaged to account for irregular sediment surfaces, and a number of plates are buried to account for small scale variance.

One site was established in the western end of Waituna Lagoon on 11 March 2007 (Figure 1) near Waituna Creek where sedimentation rates are likely to be greatest. Four plates (20cm square concrete blocks) were buried approximately 15m apart along a transect line deep in the sediments where stable substrate is located. Water depth at the site during sampling was approximately 1m deep and plates were inserted with the aid of SCUBA and canoes (Figure 6).

The position of each plate was marked with wooden stakes driven into the sediment, their GPS positions logged, and the depth from the undisturbed mud surface to the top of the sediment plate and the top of the wooden stakes was recorded. In the future, these distances will be measured annually and, over the long term, will provide a measure of rates of sedimentation in the estuary.

3. RESULTS AND DISCUSSION

SEDIMENT TYPE MAPPING

Sandy mud sediments.

The results of the broad scale mapping of sediment type (Figure 7 and Table 3) showed a variety of sediment types occur in the lagoon. Unvegetated sediment (total area 1,365ha) is dominated by firm sand (38%) located mainly in the central basin towards the lagoon mouth, mixed soft mud sand and gravel (28%) predominantly in the eastern arm, and gravels (20%) mostly around the lagoon margin.

The extent of soft mud/sand in the lagoon where there was no gravel was relatively low (12%), but overall soft mud (although often only a thin layer) was present across 42% of the lagoon. This excludes mud deposited in the rushland when the lagoon level is high. Very soft muds (2%) were mainly associated with small, narrow sediment plumes near the stream mouths, and in the western embayment. There were localised areas of anoxic sediments in the lagoon in some of the stream channels, and where uprooted macroalgae and macrophytes had accumulated.

Table 3. Summary of broad scale mapping of substrate type, March 2007.

Dominant Substrate Type	Area (ha)	Percentage	Comments
Gravel	73	5	Common around shorelines, except western end
Gravel (plus Firm Sand)	204	15	Common around shorelines, except western end
Firm Sand (plus Gravel)	179	13	Common in western central basin near lagoon outlet
Firm Sand	317	23	Common in western central basin near lagoon outlet
Firm Mud/Sand	23	2	Uncommon
Soft Mud/Sand (plus Gravel)	381	28	Common in central basin towards eastern end
Soft Mud/Sand	160	12	Waituna Creek plume, Currans Creek plume
Very Soft Mud/Sand	28	2	In sheltered western embayment
Total	1,365	100	

SEDIMENTATION PLATE DEPLOYMENT

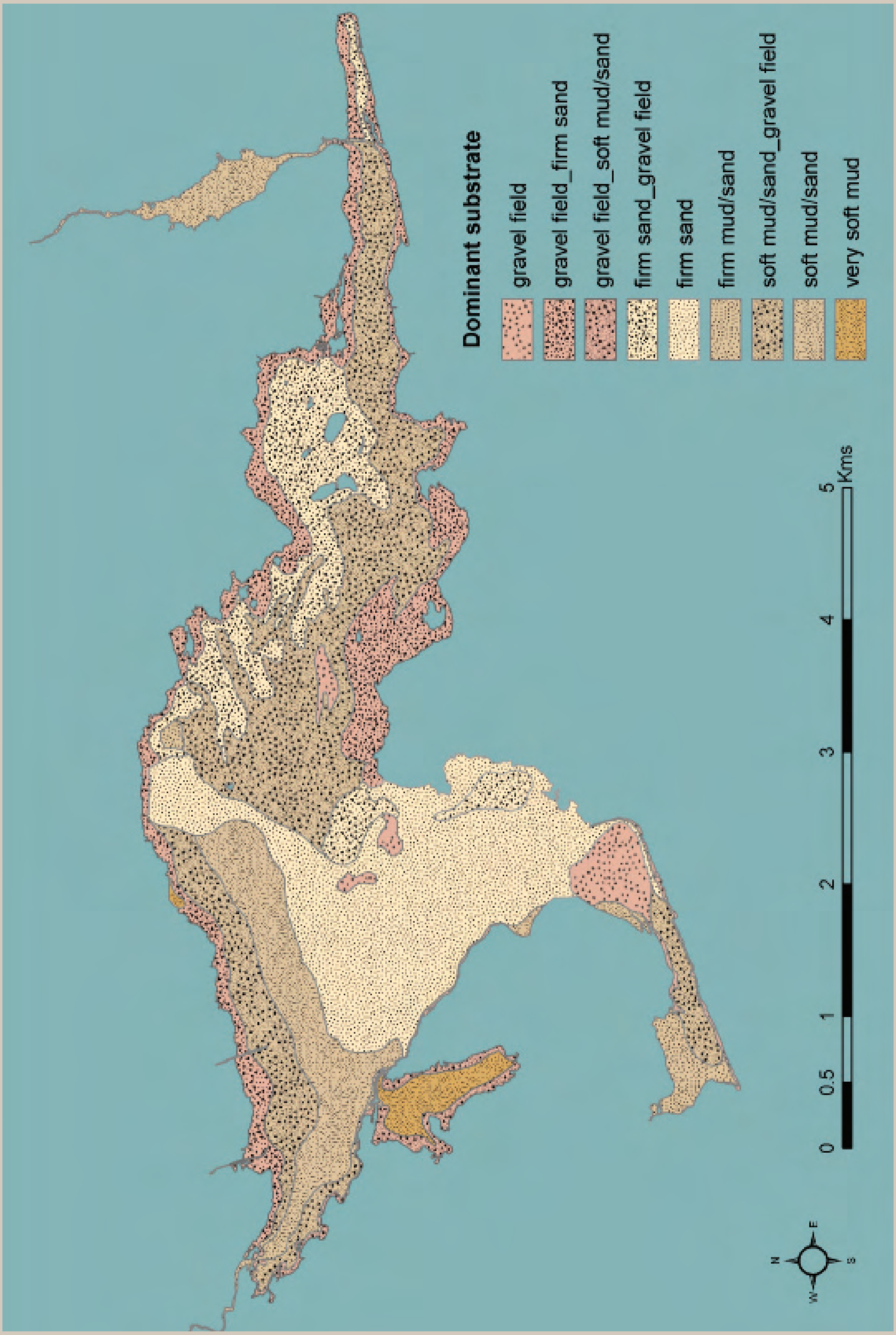
Sediment plate deployment in Waituna Lagoon.

A total of four sedimentation plates were buried near the edge of the soft mud sediment plume offshore of the mouth of Waituna Creek, ~15m apart on a straight line transect between a maimai and a large cabbage tree (Table 4 and Figure 1). This site was chosen to represent the sedimentation rates in the area with the greatest expected stream sediment input. The depth of the plate below the sediment surface and the plate locations are shown in Table 4. It is proposed that the depth of the plates to the surface will be next measured in 2008 and annually thereafter.

Table 4. Sedimentation plate site locations and depth of plates below surface.

Site	No.	Date	NZMG East	NZMG North	Sediment Surface to Plate (mm)
Offshore Waituna Creek	1	11/3/07	2169420	5395853	111
Offshore Waituna Creek	2	11/3/07	2169423	5395870	100
Offshore Waituna Creek	3	11/3/07	2169425	5395885	95
Offshore Waituna Creek	4	11/3/07	2169426	5395900	135
Maimai (Transect point)		11/3/07	2169419	5395838	-
Cabbage Tree (Transect point)		11/3/07	2169515	5396551	-

Figure 7. Map of sediment type - Waituna Lagoon 2007.



3. RESULTS AND DISCUSSION (CONTINUED)

HISTORICAL SEDIMENT CORE ANALYSIS

2007	0-6cm Firm mud/sand. No animals.
	RPD boundary (6cm)
1960	6-18cm Crumbly brown organic layer.
	18-22cm Peat. Live worm at 22cm.
	22-33cm Sand and peat mix.

Figure 8. Waituna Lagoon sediment core showing core age and composition.

Location of Waituna Lagoon sediment core.

Site	Date	NZMG East	NZMG North
Waituna Creek	11/3/07	2169414	5395841

The Waituna Lagoon core was collected from offshore, subtidal sediments located at the western end of the lagoon in soft muds (Figure 1) on 11 March 2007.

The sediment core was compressed by 30.2% (145mm) during collection (total corer depth 480mm, compressed core depth 335cm). While it is possible that some sediment bypass occurred, it was assumed that all core shortening was a result of sediment compaction spread equally over the entire core. Depths shown in Figure 8 and used in the text are compressed depths. Both compressed and uncompressed core depths, along with the results of the radio-isotope analysis by the National Radiation Laboratory are presented in Table 5.

The core (Figure 8) had three visually distinct layers. The top 6cm was well oxygenated firm sand/mud overlying a crumbly brown organic layer that extended to 18cm. Below this depth the core was predominantly peat, with sand mixed in with the peat below 22cm to the bottom of the core (33cm).

The estimated age of the sediments, derived from radio-isotope analysis, is shown on Figure 8 and described below. ^{7}Be, because it has a short half life (53.3 days) and originates from the atmosphere, is used to determine the depth of sediment recently exposed to the atmosphere (i.e. the upper mixed sediment layer exposed within the past few months). The presence of ^{7}Be in the upper 2-4cm of the Waituna core and its absence below 4cm (Table 5) indicates a 2-4cm deep well-mixed layer at this site.

Below this depth, the decline in isotope values was irregular and only provided data suitable for ageing the core using ^{137}Cs activity to an uncompressed depth of 12-14cm.

HISTORICAL SEDIMENT CORE ANALYSIS (CONTINUED)

^{137}Cs activity introduced following atmospheric nuclear weapons tests beginning in 1953 provides a marker for recent sediment deposition. Peak atmospheric fall-out of ^{137}Cs in New Zealand occurred in 1964, with elevated levels occurring from 1959-1964 (Cambray et al. 1979; Loughran et al. 1988). Based on this, the maximum depth of ^{137}Cs activity has been ascribed to 1960 and used to estimate a gross sedimentation rate over the past 47 years (1960-2007) of 2.5-3.0mm/year.

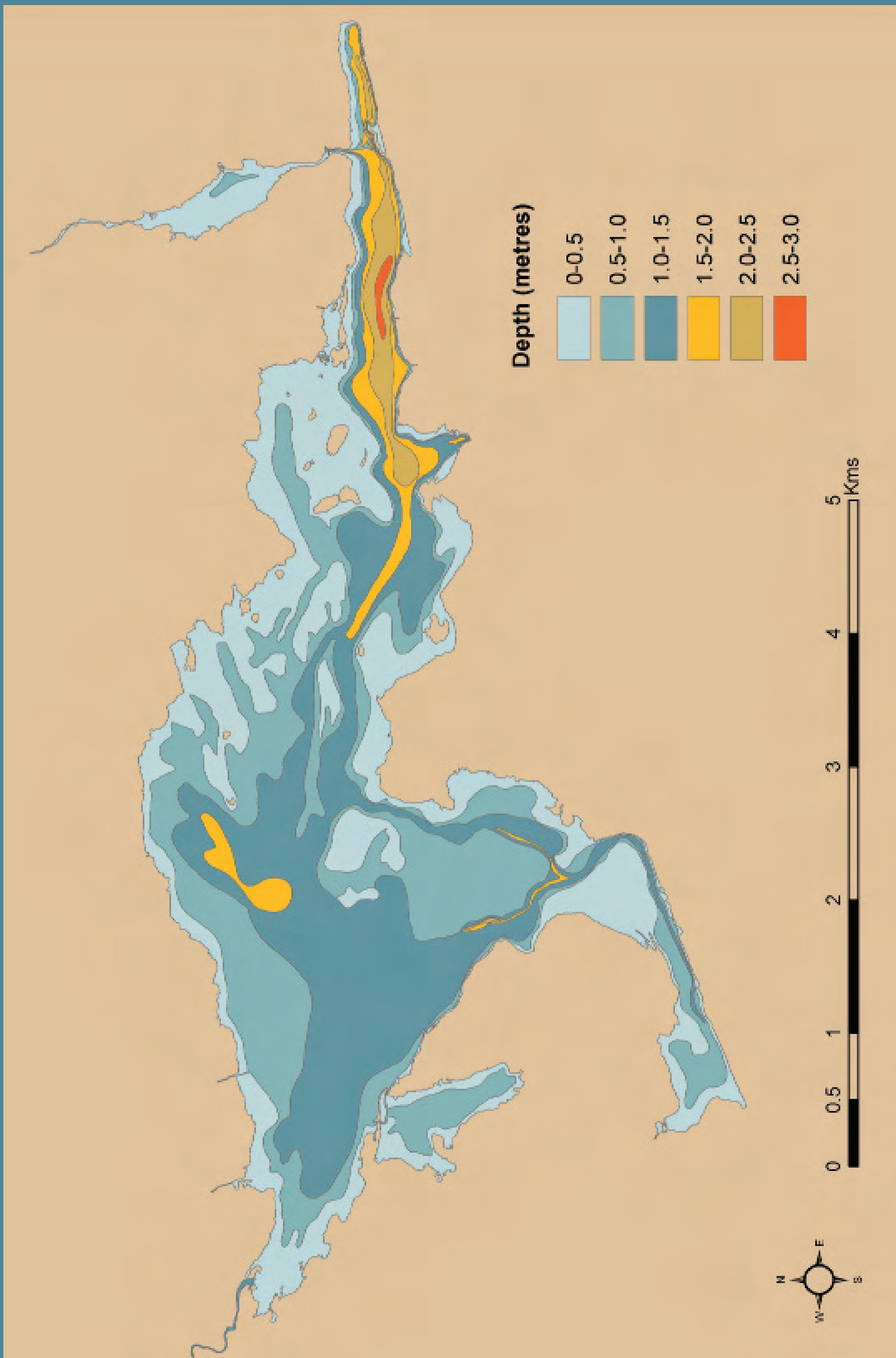
Table 5. Results of the radio-isotope analysis of the historical sediment core.

Compressed Depth (cm)	Uncom-pressed Depth (cm)	Total ^{210}Pb	^{226}Ra (=Supported ^{210}Pb)	Unsupported ^{210}Pb	^{137}Cs	^{7}Be
0-2	2.60	22.5	15.9	6.6	0.35	12.1
2-4	5.21	19.6	13.7	5.9	0.33	5.0
4-6	7.82	17.0	13.5	3.5	0.40	<5.1
6-8	10.42	16.7	13.0	3.7	0.34	<5.1
8-10	13.02	15.1	12.2	2.9	0.27	<5.0
12-14	18.23	15.3	12.1	3.2	0.37	<5.1
18-20	26.04	17.2	10.7	6.5	<.55	<5.8
24-26	33.85	14.4	13.4	1.0	<.58	<6.5
32-34	44.27	16.7	16.3	0.4	<.46	<5.5

^{210}Pb is used to determine sedimentation rates over the last 100-150 years and enables estimates to be made of different deposition rates within this period. However, the total ^{210}Pb depth profile at Waituna Lagoon did not show the expected exponential decline, invalidating ^{210}Pb dating for this core. This was either the result of changes in sediment grain size (which can influence ^{210}Pb retention in sediments and redistribution into the water column), and/or historical changes in the input of ^{210}Pb (Appleby & Oldfield 1992) as the hydrology of the lagoon was anthropogenically altered. As a result, the data were too erratic to be used to date the core.

These results are very similar to those measured by Cadmus & Schallenberg (2007) at two other locations in the lagoon; near Currans Creek and in the northwest of Waituna Lagoon east of Moffats Creek (Figure 1). They measured a mean rate of 2.8mm/year for the period 1960 till 2007. However, they also used carbon (^{14}Ca) dating techniques to show that from at least 7,000 years before present (YBP) until the time of European settlement (1860s), there was an extremely low sediment accumulation rate of 0.005 to 0.006cm/year at the site. The modern sediment accumulation rate based on ^{137}Cs indicates that the rate at the Currans Creek mouth has increased 44 fold since European arrival.

Figure 9. Map of water depth - Waituna Lagoon, March 2007.



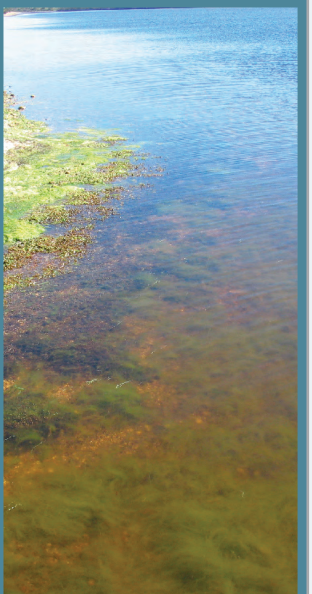
3. RESULTS AND DISCUSSION (CONTINUED)

DEPTH

An estimation of lagoon depth was made using a combination of existing data supplied by ES, field measures, local knowledge, and aerial photography. This information was then used to draw depth contours within ArcMap 9.2 (Figure 9).

The majority of the lagoon was less than 1.5m deep when the lagoon was at 1.13m above mean sea level (msl) in early March 2007. The deepest areas (~3m) were in the narrow eastern arm adjacent to Currens Creek. Narrow channels were present at the stream entrances, and also in the southwest near where the lagoon is opened to the sea.

MACROALGAL MAPPING



Enteromorpha blooms in Waituna Lagoon.

The results of the broad scale mapping of macroalgal percent cover (Figure 10 and Table 6) showed:

- Macroalgal growth does occur in the lagoon.
- Is dominated by the green alga *Enteromorpha* spp.
- Is restricted to certain preferred locations.
- Varies in abundance and locations depending on lagoon level and season.

Table 6. Summary of broad scale macroalgal percent cover mapping, March 2007.

% Cover Category		Area (ha)	Percentage	Species
Very low	<1%	1,199	87.7	
Low	1-10%	146	10.7	*Enteromorpha*
Low-Mod	10-20%	2	0.2	*Enteromorpha*
Moderate	20-50%	0	0.0	*Enteromorpha*
High	50-80%	12	0.9	*Enteromorpha*
Very High	>80%	7	0.5	*Enteromorpha*
Total		**1,366**	**100**	

Macroalgal growth was relatively low throughout the lagoon in March 2007 with areas of high percent cover only occurring in localised shallow areas near the sea and in the central basin. Most of the growth occurred in the shallow waters around the margins. Macroalgal growth is expected to be greatest when the lagoon is low, open to the sea and exposed to tidal water level changes.

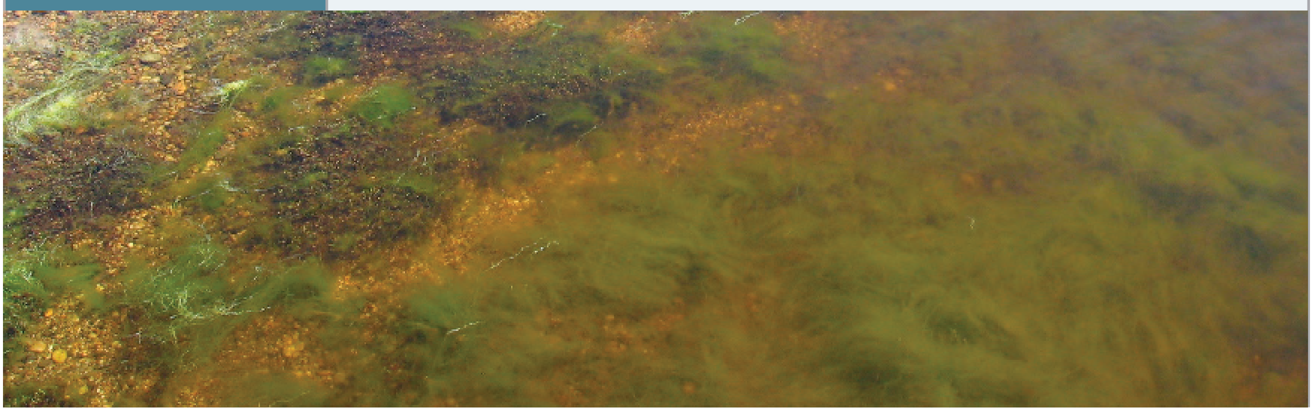
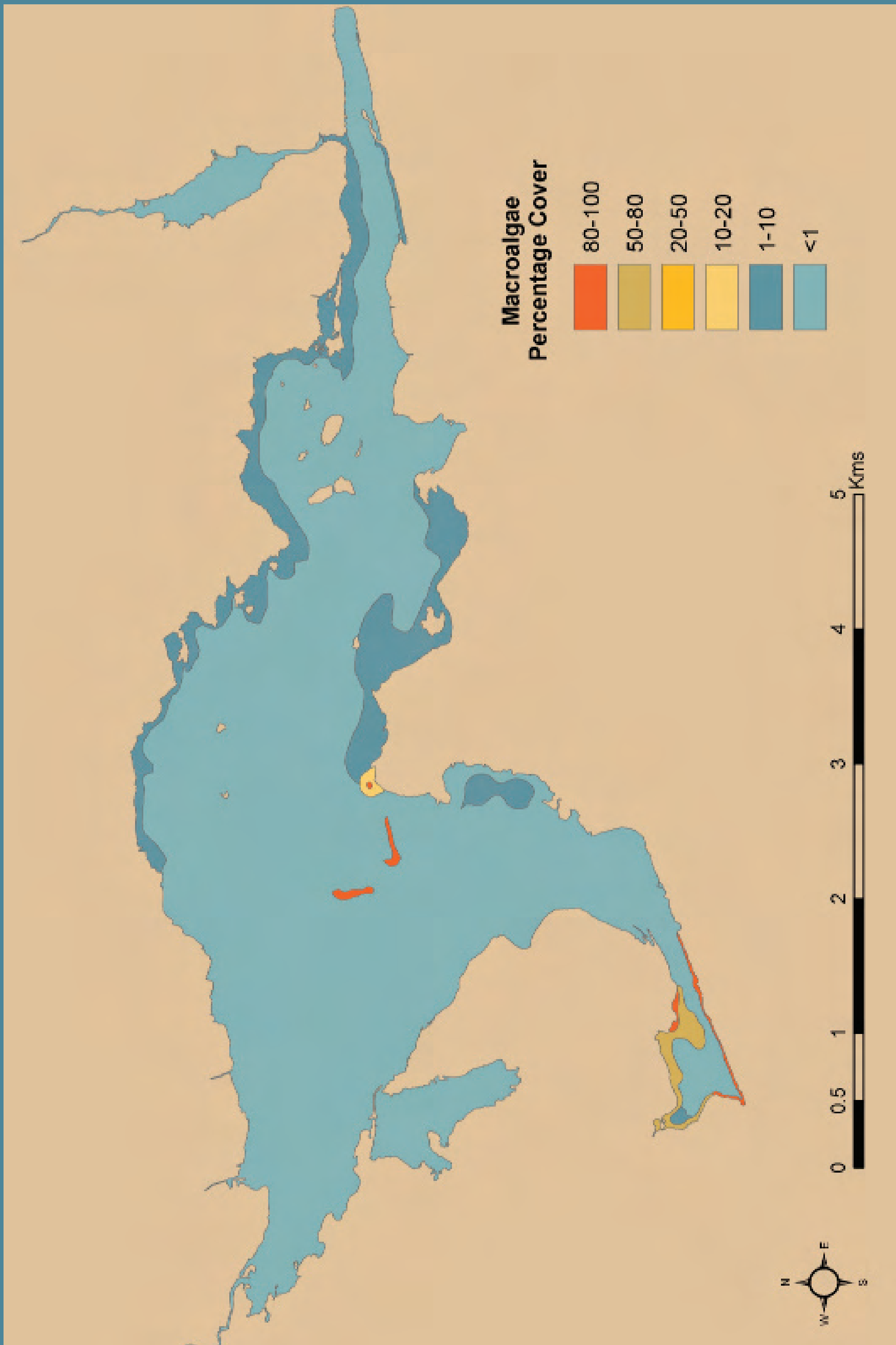


Figure 10. Map of macroalgal percentage cover - Waituna Lagoon 2007.



RUPPIA MAPPING

Checking for *Ruppia*, Waituna Lagoon western end

Dense *Ruppia* growth, western end of Waituna Lagoon.

Physical Conditions

Physical conditions during the time of sampling were favourable for both the germination of *Ruppia* and for its subsequent growth as follows:

- Water salinity was near freshwater at <5ppm.
- Water clarity was relatively high for this deeply humic stained lagoon (Secchi depth 1.5-2m). This meant that light was reaching the bed over most of the lagoon.
- Water depth was generally less than 2m (Figure 9) - Lagoon level 1.13m above mean sea level (msl).
- The lagoon had been closed for nine months.
- Conditions in the preceding weeks had been relatively calm.

Macrophyte Cover

The results of the dominant macrophyte survey (Figure 11, 12 and 13 and Table 7) indicate that macrophyte presence was dominated by two species of *Ruppia*: *R. polycarpa* and *R. megacarpa*, and that they were restricted to certain preferred locations.

Table 7. Summary of broad scale *Ruppia* percent cover mapping, March 2007.

% Cover Category		Area (ha)		Percentage	
		R.polycarpa	*R. megacarpa*	*R. polycarpa*	*R. megacarpa*
Very Low	<1%	458		33.5	
Low	1-10%	155	306	11.3	22.4
Low-Mod	10-20%	1	4	0.1	0.3
Moderate	20-50%	28	16	2.1	1.2
High	50-80%	231	127	16.9	9.3
Very High	>80%	-	41	-	3.0

The areas of high percentage cover (50-100% cover) were found predominantly in the eastern half of the lagoon. Shallower areas, particularly along the north-eastern shoreline, were dominated by relatively small *R. polycarpa*, while deeper parts of the lagoon to the south and east were dominated by much larger *R. megacarpa* plants. Substrates in these areas were mostly gravels and sands with relatively little mud. Areas with very high cover (80-100%) were spread throughout the lagoon, but appeared limited to areas relatively sheltered from wind and wave disturbance (e.g. the head of Waituna Creek, the western embayment and arm, and the deep and narrow eastern arm near Currans Creek). Soft muds dominated in the sheltered areas to the west while gravels and sands dominated in the east.

The areas of low to moderate percentage cover (1-50% cover) were located mainly through the central part of the lagoon and in the Currans Creek embayment.

The areas of low and very low percentage cover (<1% cover) tended to be restricted to shallow exposed areas with either muddy or sandy sediments.

Figure 11. Map of *Ruppia* spp. percentage cover - Waituna Lagoon 2007.

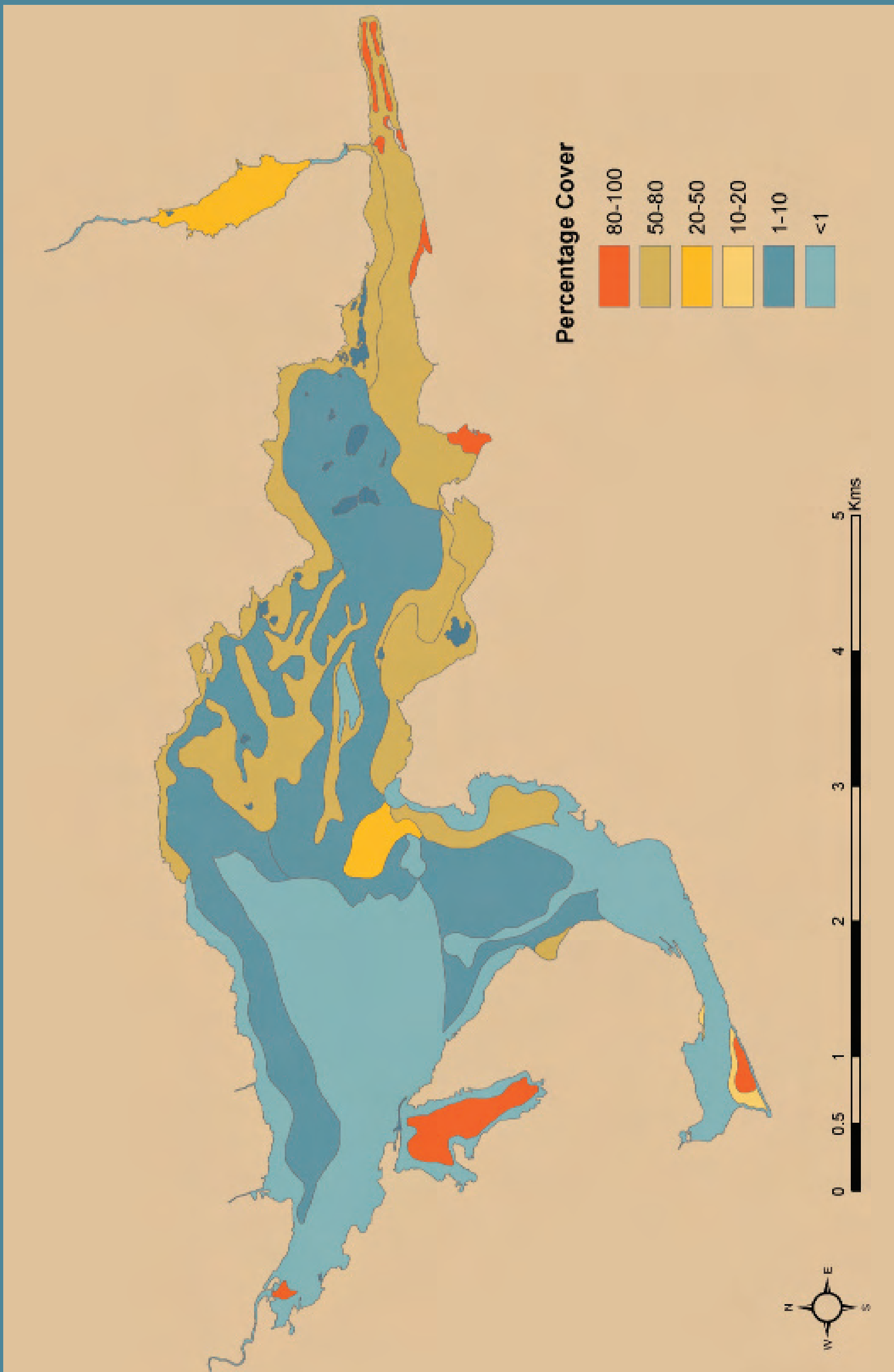


Figure 12. Map of *Ruppia megacarpa* percentage cover - Waituna Lagoon 2007.

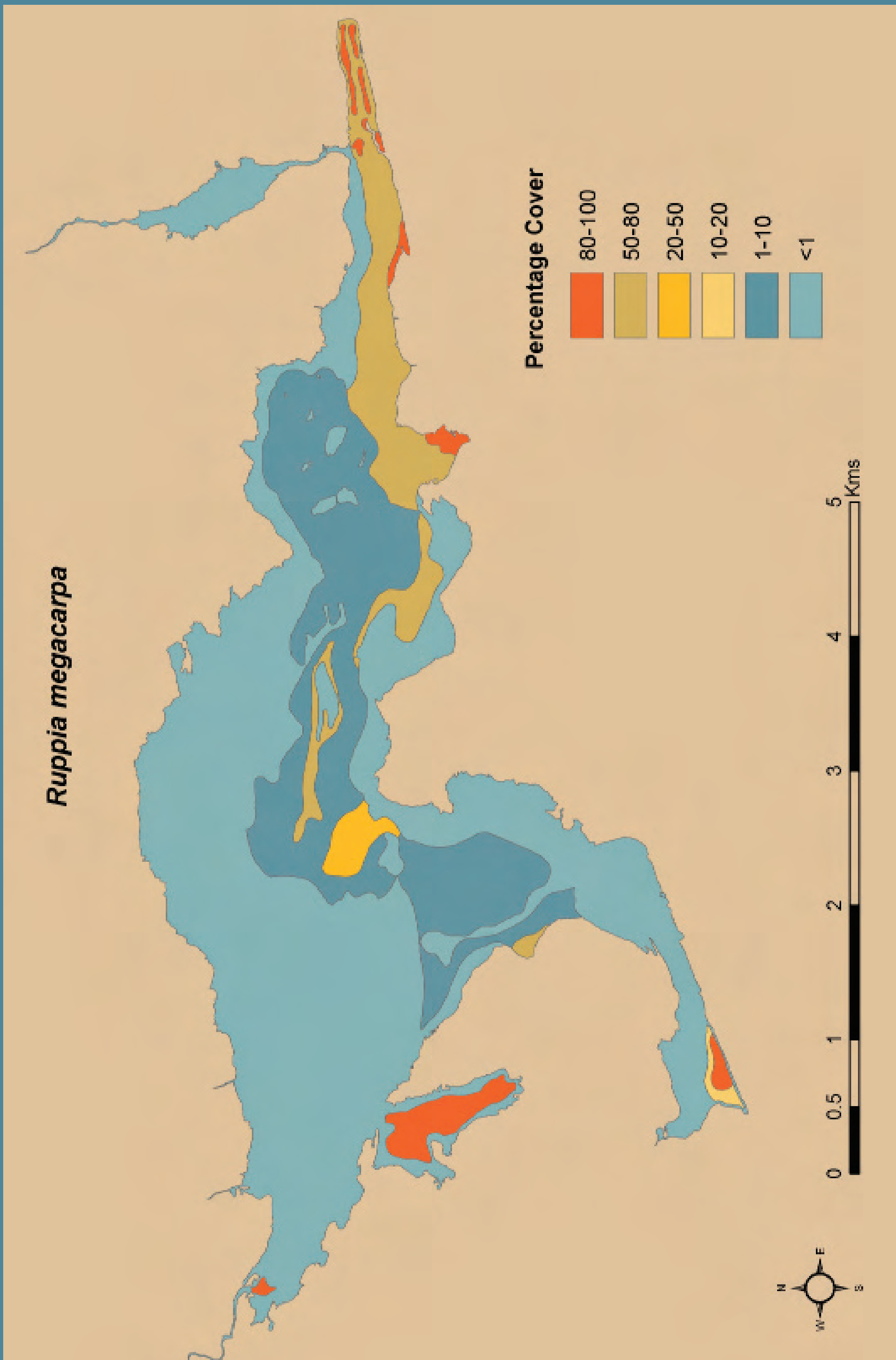
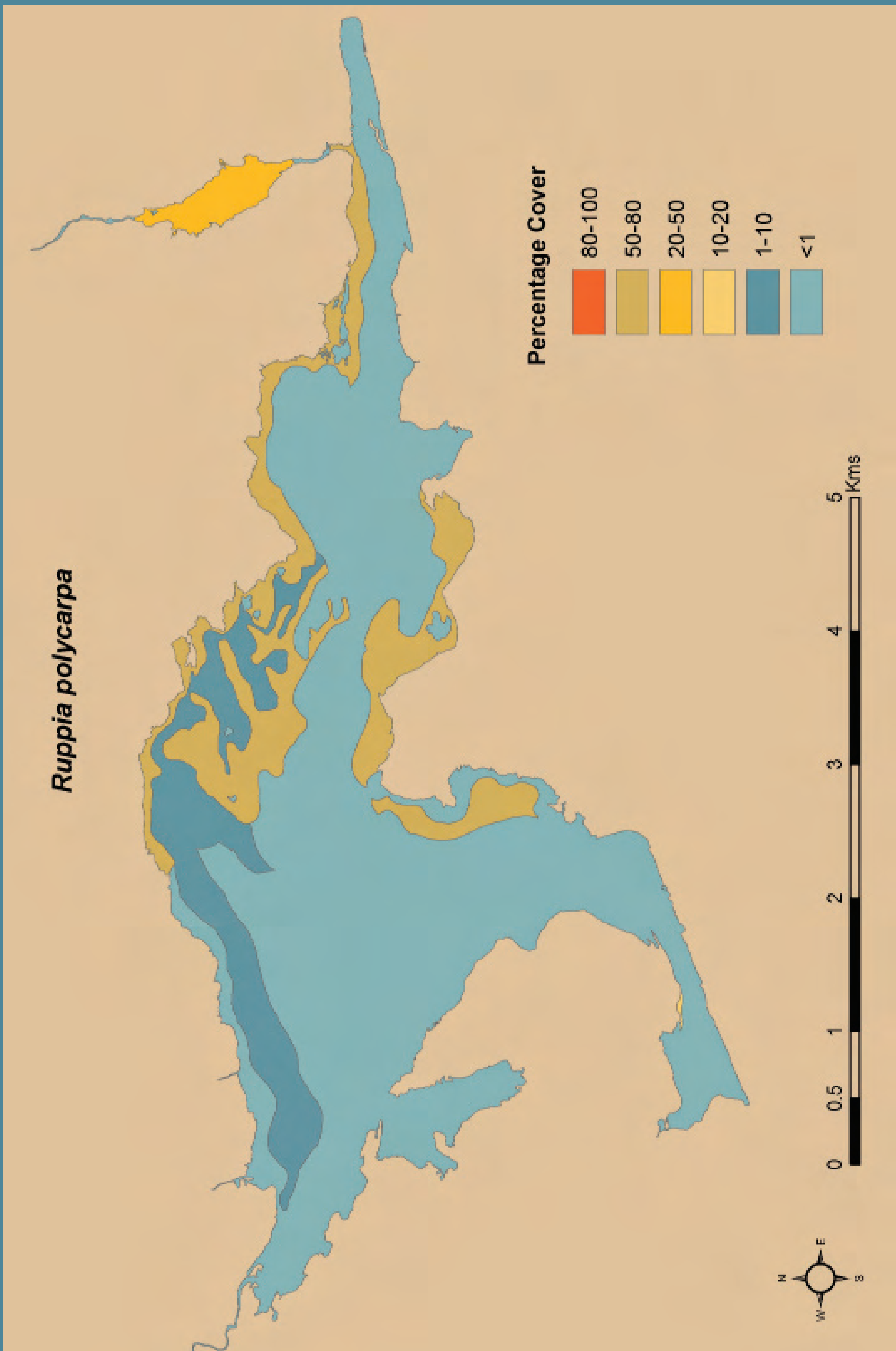


Figure 13. Map of *Ruppia polycarpa* percentage cover - Waituna Lagoon 2007.



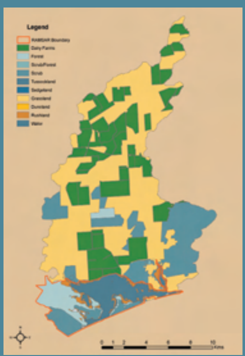
3. RESULTS AND DISCUSSION (CONTINUED)

BROAD SCALE VEGETATION MAPPING

OVERVIEW

The dominant vegetation surrounding Waituna Lagoon has been grouped in four distinct zones (details in the CD of GIS layers provided separately to ES).

1. **Wetland Vegetation**; defined as areas periodically inundated with fresh or saltwater and dominated by reed, rush, sedge, or tussockland communities.
2. **Terrestrial Margin Vegetation**; defined as a strip 200m landward of wetland vegetation.
3. **RAMSAR Site Vegetation**; includes most of the wetland and 200m terrestrial margin and part of the terrestrial vegetation outside of the 200m margin.
4. **Terrestrial Vegetation**; defined as all plants landward of the wetland margin including those within the Terrestrial Margin (see Figure 2 and inset on this page).



Thumbnail of catchment vegetation and landuse (see Figure 2).

KEY POINTS

The results show the following key points:

- Overall, the vegetation in the Waituna complex was relatively unmodified, diverse and expansive. Major assemblages included lagoon edge saltmarsh, turf and cushion bogs characterised by herbs and shrubs, tussock lands, and manuka and inaka scrublands. The wetland is internationally significant.
- Wetland vegetation was dominated by rushland (*Leptocarpus similis*, jointed wire rush) which surrounded the lagoon but also included varieties of herbs, sedges, tussocks and many introduced grasses and weeds. In general, this was in good condition as reflected by its largely undeveloped state, however, historical drainage has significantly modified the wetland area.
- Terrestrial margin vegetation (200m strip outside of the wetland) was dominated by grazed grassland (used for beef and dairy farming) along the north and east of the lagoon, and to the west and south it consisted of manuka-dominated scrub and forest.
- Within the protected RAMSAR site, there was no grazed grassland and the vegetation was dominated by scrub and forest species (80%) and wetland plants (20%).
- Looking at the bigger whole catchment picture of the vegetation within the 200m margin as well as that outside of it, it was found that landuse was dominated by grazed grassland (used for intensive sheep, beef and dairy farming), with only small areas of forest and scrub.

ISSUES

Given the relatively undeveloped state of the wetland vegetation, and to a certain extent, that of the margin, the issues were relatively minor and include:

- Expansion of rushland areas in response to increased sedimentation, nutrients and longer periods of lagoon opening.
- Encroachment of farmland into the terrestrial margin and rushland through vegetation clearance and drainage to the north and east of the lagoon.
- The establishment of various introduced weeds and grasses within the wetland area.

WETLAND VEGETATION MAPPING

Wetland vegetation in front, terrestrial behind.

Wetland vegetation covered 472ha of which 97% was rushland, and was dominated by thick stands of *Leptocarpus similis* (jointed wire rush) fringing the lagoon and providing a relatively wide and uniform band of buffering vegetation (Table 8 and Figure 15). The outer edge of rushes often comprised clumped plants on unevenly elevated islands, with plants more uniform on flatter ground further inland (Figure 14a). This uniformly flat rushland habitat was unusual in an estuary and may be an important settlement area for sediment entering the lagoon, and may also play an important role in the uptake and processing of nutrients.

Isolepis nodosa (knobby clubrush) and *Juncus gregiflorus* were the other dominant rushes, but were a minor feature overall, as was the sedge three square, present in small patches in the heads of a couple of bays. On the flatter ground, a large variety of relatively inconspicuous plants were present beneath the rush canopy and in more open areas (Figure 14b). Johnson & Partridge (1998) provide excellent detail on these plant assemblages, which although very much a minor part of the wetland biomass, were very diverse. Particularly along the north and east of the lagoon many introduced weeds and grasses were establishing adjacent to farmland.

At the upper (landward) edge of the rushland, a narrow border of flax, toetoe, saltmarsh ribbonwood and the occasional mingimingi grew where the land became higher and wetland plants grade towards terrestrial vegetation (Figure 14c). Although in a narrow band, these plants were dense and difficult to move through.

The most notable direct impacts on rushland at present are two-fold:

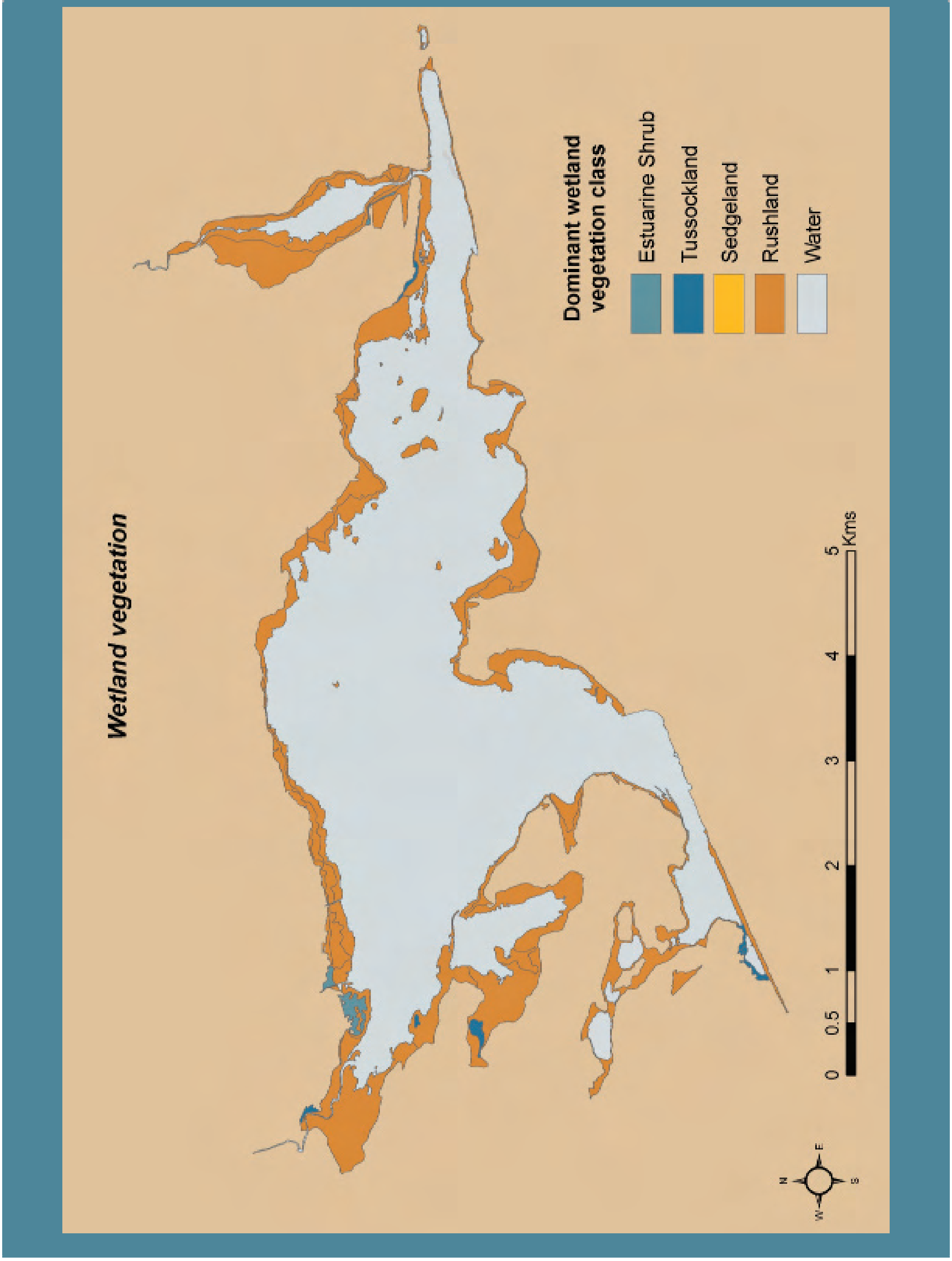
- Increased extent of *Leptocarpus* rushland in response to a generally lower lagoon level, combined with increases in sedimentation and nutrients.
- Encroachment of farmland into the rushland through vegetation clearance and drainage on the western side of Currens Creek (~30ha).

Table 8. Summary of broad scale wetland vegetation mapping, March 2007.

Class	Dominant Vegetation	Area (ha)	Percentage
Estuarine shrubs	*Plagianthus divaricatus* (saltmarsh ribbonwood) *Coprosma propinqua* (mingimingi)	7.8	1.6
Tussockland	*Phormium tenax* (NZ flax) *Cortaderia richardii* (toetoe)	8.1	1.7
Sedgeland	*Schoenoplectus pungens* (three square)	0.01	0.01
Rushland	*Leptocarpus similis* (jointed wire rush) *Isolepis nodosa* (knobby clubrush) *Juncus gregiflorus*	456	96.6
TOTAL		472	100

Figure 14. Examples of wetland vegetation.

Figure 15. Map of wetland vegetation - Waituna Lagoon 2007.



200M TERRESTRIAL MARGIN MAPPING

Immediately inland of the wetland plants, the terrestrial vegetation buffer (200m wide) covering 1,029ha, consisted of a relatively even split of grassland (23%), manuka scrub (30%), and manuka forest (29%) (Table 9 and Figure 17). Thick native scrub and forest on elevated land, dominated to the south and west of the lagoon. The large central southern headland protruding into the lagoon was dominated by scrub and forest, with significant stands of toetoe and red tussock (Figure 16a).

To the north and east the terrestrial margin was dominated by grassland (dairy and beef farms) which had been channelled and drained, and extended close to the edge of the wetland (Figure 16b). Most of the previous forest and scrub cover has been removed, with only a narrow strip of scrub (e.g. manuka, gorse, bracken) or tussockland (flax, toetoe, red tussock) separating the wetland from the surrounding farms. Development (conversion to pasture) of the margin was still occurring around Moffats Creek, the Currens Creek embayment, and in the ~2.5km band of scrub near the DOC viewing area along the middle of the northern shoreline. Development of grassland was also occurring on the south eastern edge of the lagoon, adjacent to the coast.

Duneland, dominated by marram grass with knobby clubrush, mixed grasses and introduced weeds, was restricted to a narrow band along the coastal (southern) margin of the lagoon at the top of the beach (Figure 16c).

Overall, a buffer of tussockland, scrub, and forest surrounded the majority of the lagoon. It was narrowest adjacent to the farms in the north and east and continued to be eroded in these areas, but was wide and stable in the south and west.

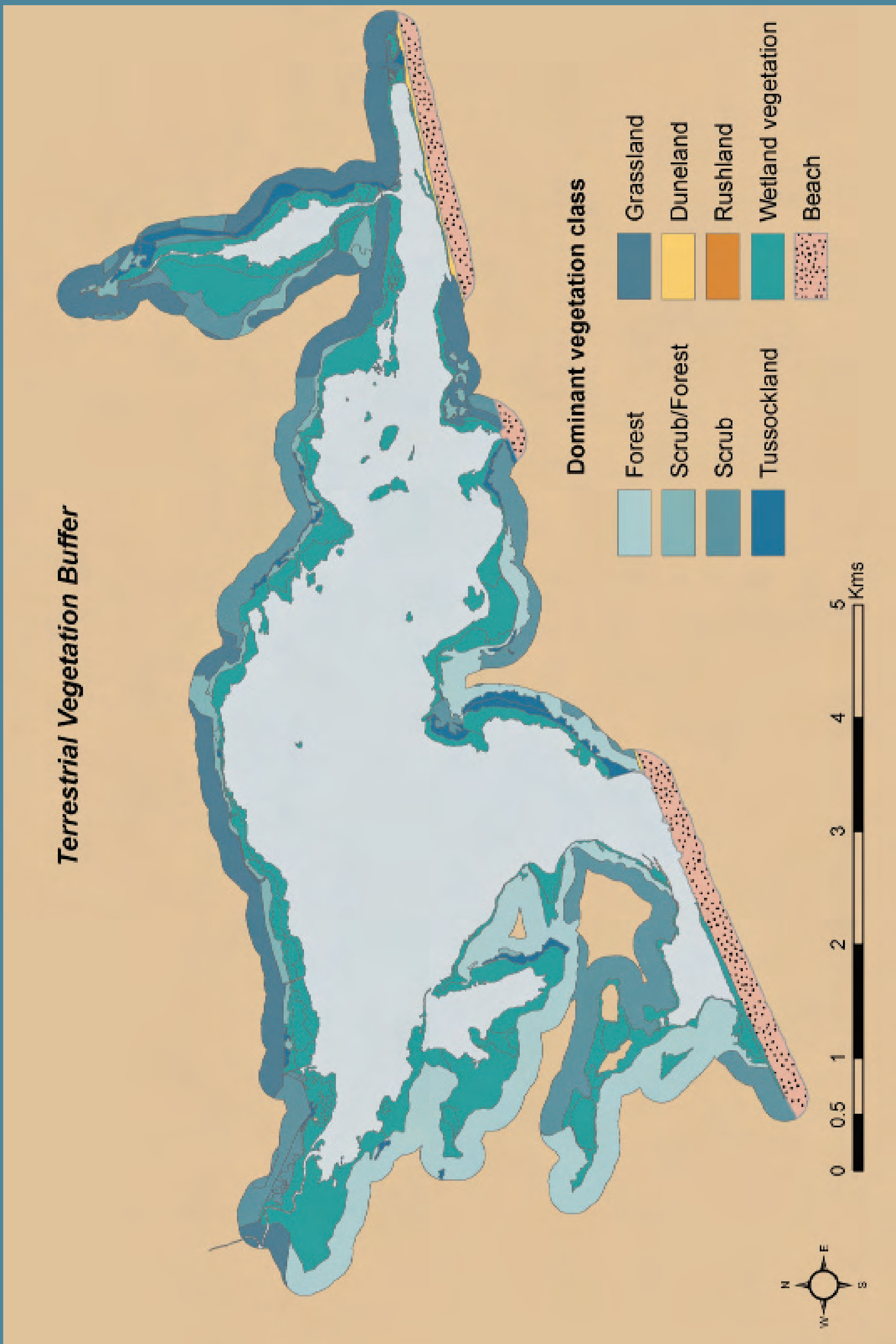
Transition from terrestrial to wetland vegetation.

Table 9. Summary of broad scale 200m terrestrial margin mapping, March 2007.

Class	Dominant Vegetation	Area (ha)	Percentage
Forest	*Leptospermum scoparium* (manuka)	303	29.4
Scrub	*Leptospermum scoparium* (manuka) *Plagianthus divaricatus* (saltmarsh ribbonwood) *Coprosma propinqua* (mingimingi)	310	30.2
Tussockland	*Phormium tenax* (NZ flax) *Cortaderia richardii* (toetoe) *Chionochloa rubra* (red tussock)	51	4.9
Grassland	Unidentified grass *Festuca arundinacea* (tall fescue)	239	23.3
Duneland	*Ammophila arenaria* (marram grass) *Isolepis cernua* (slender clubrush)	8	0.8
Beach		118	11.4
TOTAL		1,029	100

Figure 16. Examples of terrestrial margin vegetation.

Figure 17. Map of 200m terrestrial margin vegetation - Waituna Lagoon 2007.



RAMSAR SITE VEGETATION MAPPING

Within the RAMSAR site (based on a DOC GIS boundary), terrestrial and wetland vegetation covered 2161ha, dominated by terrestrial native scrub and forest (78%), and wetland rushland (18%) (Table 8 and Figure 19). This represents around 80% of all the remaining forest and rushland within the wider Waituna catchment and, as such, the protected areas of the lagoon are an important repository of local biodiversity. The vast majority of the scrub and forest was located to the south and west of the lagoon. The scrub was generally <2m tall, uniform in height, and was dominated by manuka and inaka (see inset photos). Forest areas were manuka dominated extending to ~5m and located mainly on higher ground.

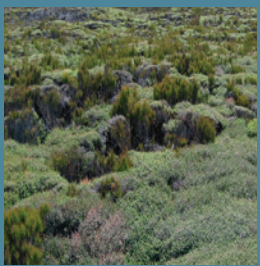
Within the scrub and forest were numerous small ponds. These ponds supported a diverse range of freshwater vegetation and were very different in character e.g. dominated by flax (Figure 18a), rushes (Figure 18b), or turf communities (Figure 18c). Vegetation was often limited to a narrow strip around the pond edge, and although susceptible to disturbance, the physical barriers afforded by the surrounding vegetation provided excellent natural defences to these fragile areas. Many of the ponds were used by hunters, who also maintain access tracks.

Along the northern and eastern margins, the RAMSAR boundary was generally located within the rushland. Therefore, most of the remaining native scrub and tussockland buffering the northern margins fell outside RAMSAR protection, as did the rushland being reclaimed on the western side of the Currens Creek embayment.

Terrestrial scrub vegetation.

Table 10. Summary of broad scale RAMSAR site terrestrial vegetation mapping, March 2007.

Class	Dominant Vegetation	Area (ha)	Percentage
Forest	*Leptospermum scoparium* (manuka)	954	44.1
Scrub	*Leptospermum scoparium* (manuka) *Dracophyllum longifolium* (inaka)	738	34.1
Tussockland	*Phormium tenax* (NZ flax) *Cortaderia richardii* (toetoe) *Chionochloa rubra* (red tussock)	39	2.2
Grassland	Unidentified grass *Festuca arundinacea* (tall fescue)	25	1.4
Duneland	*Ammophila arenaria* (marram grass) *Isolepis cernua* (slender clubrush)	9	0.5
Rushland	*Leptocarpus similis* (jointed wire rush) *Isolepis nodosa* (knobby clubrush) *Juncus gregiflorus*	389	18
TOTAL		2,161	100



Manuka and inaka scrub.

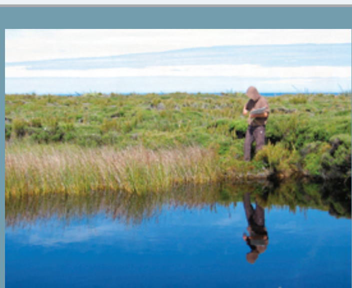
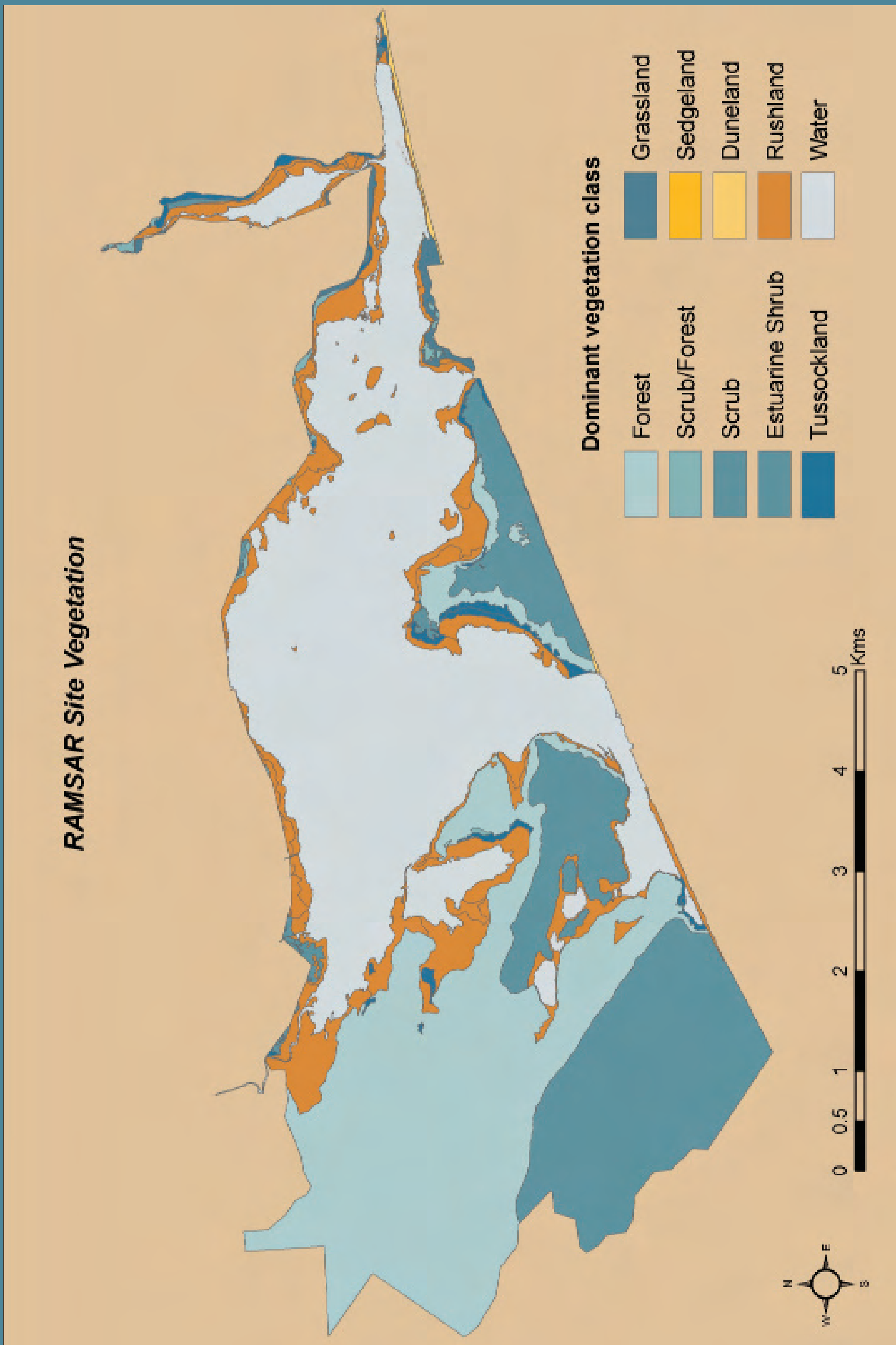
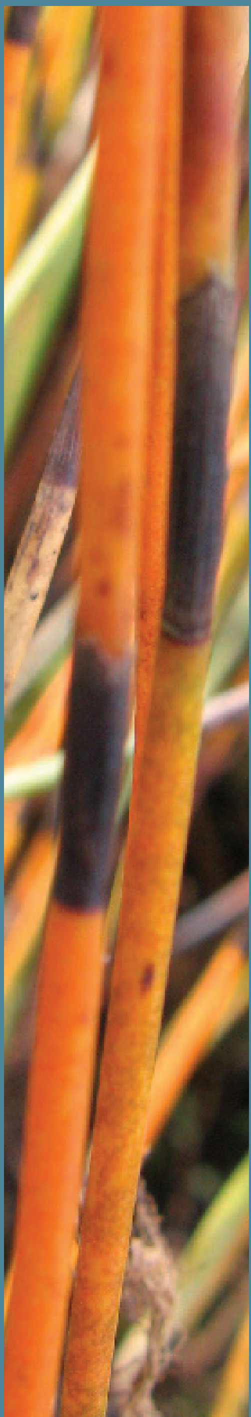


Figure 18. Examples of terrestrial vegetation around ponds.

Figure 19. Map of terrestrial vegetation within the RAMSAR site - Waituna Lagoon 2007.



4. SUMMARY AND CONCLUSIONS



This first report summarises the major habitat types and condition of Waituna Lagoon. The spatial location, size, and type of broad scale habitat features are provided as ArcMap 9.2 Geographic Information System (GIS) shapefiles on a separate CD. As the GIS structure allows data to be easily managed, and contains a much greater level of detail than can be concisely presented in a summary report, the GIS should be used as the primary resource for assessing broad scale data. The results are summarised as follows:

SEDIMENTATION TYPE: A variety of sediment types occur in the lagoon. Unvegetated sediment (total area 1,365ha) was dominated by firm sand (38%) located mainly in the central basin towards the lagoon mouth, mixed soft mud sand and gravel (28%) predominantly in the eastern arm, and gravels (20%) mostly around the lagoon margin. The extent of soft mud/sand in the lagoon where there was no gravel was relatively low (12%), but overall soft mud was present across 42% of the lagoon. This excludes mud deposited in the rushland when the lagoon level is high. Very soft muds (2%) were mainly associated with small, narrow sediment plumes near the stream mouths, and in the western embayment. There were localised areas of anoxic sediments associated with macroalgal mats and inflowing streams.

SEDIMENTATION RATE: The historical sediment core collected near the mouth of Waituna Creek had three visually distinct layers. The top 6cm was well oxygenated firm sand/mud overlying a crumbly brown organic layer that extended to 18cm. Below this depth the core was predominantly peat, with sand mixed in with the peat below 22cm to the bottom of the core (33cm). Radio-isotope dating using ^{137}Cs activity indicated a gross sedimentation rate over the past 47 years (1960-2007) of 2.5-3.0mm/year, greatly exceeding pre-European rates.

LAGOON DEPTH: The majority of the lagoon was less than 1.5m deep when the lagoon was at 1.13m above mean sea level (msl) in early March 2007. The deepest areas (~3m) were in the narrow eastern arm adjacent to Currens Creek. Narrow channels were present at the stream entrances, and also in the southwest near where the lagoon is opened to the sea.

MACROALGAE: Macroalgal growth was relatively low throughout the lagoon in March 2007 with areas of high percent cover only occurring in localised shallow areas near the sea and in the central basin. Most of the growth occurred in the shallow waters around the margins. Macroalgal growth is expected to be greatest when the lagoon is low, open to the sea and exposed to tidal water level changes.

MACROPHYTES: Macrophyte presence was dominated by two species of Horse's mane weed (*Ruppia*). Shallower areas, particularly the north-eastern shoreline, were dominated by relatively small *R. polycarpa*, while deeper parts of the lagoon to the south and east were dominated by much larger *R. megacarpa* plants. Areas with very high cover (80-100%) were spread throughout the lagoon, but appeared limited to areas relatively sheltered from wind and wave disturbance (e.g. the head of Waituna Creek, the western embayment and arm, and the deep and narrow eastern arm near Currans Creek). Most *Ruppia* was in the eastern half of the lagoon in gravels and sands with relatively little mud. Low and very low percentage cover areas (<1%) tended to be restricted to shallow exposed areas with either muddy or sandy sediments.

4. SUMMARY AND CONCLUSIONS (CONTINUED)

WETLAND VEGETATION: Wetland vegetation covered 472ha of which 97% was rushland, and was dominated by thick stands of *Leptocarpus similis* (jointed wire rush) fringing the lagoon and providing a relatively wide and uniform band of buffering vegetation. The wetland also included varieties of herbs, sedges, tussocks and many introduced grasses and weeds. In general, the wetland was in good condition as reflected by its largely undeveloped state, however, historical drainage has significantly modified the wetland area.

200m TERRESTRIAL MARGIN VEGETATION: The 200m terrestrial margin vegetation (1,029ha), consisted of a relatively even split of grassland (23%), manuka scrub (30%), and manuka forest (29%). Thick native scrub and forest on elevated land dominated to the south and west of the lagoon. To the north and east the terrestrial margin was dominated by grassland (dairy and beef farms) which had been channelled and drained, and extended close to the edge of the wetland with only a narrow strip of scrub (e.g. manuka, gorse, bracken) or tussockland (flax, toetoe, red tussock) separating the wetland from the surrounding farms.

RAMSAR VEGETATION: Terrestrial and wetland vegetation within the 2,161ha RAMSAR site was dominated by native scrub and forest (78%), and wetland rushland (18%). This represents around 80% of all the remaining forest and rushland within the wider Waituna catchment and, as such, the protected areas of the lagoon are an important repository of local biodiversity. Most of the remaining native scrub and tussockland buffering the northern margins of the lagoon fell outside RAMSAR protection, as did the rushland being reclaimed on the western side of the Currens Creek embayment.

Overall, the results indicate that Waituna is a largely unmodified example of a temperate shallow coastal lagoon (whose water level is artificially controlled) with its remaining coastal wetland system largely intact. Key aspects are:

- Sedimentation rates were elevated and mud was relatively common throughout the lagoon.
- The wetland and terrestrial margin vegetation in the internationally significant Waituna complex was found to be relatively unmodified, diverse and expansive.
- Localised areas of rushland were being lost through drainage and reclamation.
- The main submersed aquatic plant, *Ruppia*, was still thriving in the lagoon when conditions were optimal (extended period of lagoon closure, good clarity).
- Nuisance macroalgal growth was present around margins in localised areas.
- There were localised areas of anoxic sediments often associated with macroalgal mats and inflowing streams.
- Introduced weeds and grasses were relatively common in the wetland.

The information on habitat types, condition and issues collected in this study is used in the second study (i.e. the Ecological Vulnerability Assessment - Stevens and Robertson 2007), to identify long term monitoring and management priorities. Examples of proposed condition ratings to assess the monitoring results are also included in the second report.

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APPENDIX 1. 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 in which the rush cover exceeds that of any other growth form or bare ground. A tall grasslike, often hollow-stemmed plant, included in the rush growth form 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 in which the 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 in which the 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.