coastalmanagement

Waimatuku Estuary 2010

Fine Scale Monitoring and Macrophyte Mapping

Prepared for **Environment Southland**

July 2010

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By

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All photos by Wriggle except where noted otherwise.

WAIMATUKU ESTUARY - EXECUTIVE SUMMARY

Waimatuku Estuary

↓

Vulnerability Assessment
Identifies issues and recommends monitoring and management.
Completed in 2008 (Robertson and Stevens 2008)

↓

Waimatuku Estuary Issues
Moderate eutrophication
Excessive sedimentation
Habitat Loss (Saltmarsh, and terrestrial margin)

↓

Monitoring

Broad Scale Mapping
Sediment type
Saltmarsh
Seagrass
Macroalgae
Land margin

5 -10 yearly
First undertaken in 2008.

Fine Scale Monitoring
Grain size, RPD, Organic Content
Nutrients,
Macroalgae,

3-4yr Baseline then 5 yearly
Baseline started 2009.
Next survey 2011.

↓

Condition Ratings
Area soft mud, Area saltmarsh, Area seagrass, Area terrestrial margin, RPD depth, Organic content, N and P,

Other Information
Previous reports, Observations, Expert opinion

↓

ESTUARY CONDITION
Low Eutrophication
Low Sedimentation
Low Toxicity
Habitat Degraded (saltmarsh, terrestrial margin)

↓

Recommended Management
- Limit intensive landuse.
- Set nutrient, sediment guidelines.
- Margin vegetation enhancement.
- Manage for sea level rise.
- Enhance saltmarsh.
- Manage weeds and pests.

This report summarises the results of the first year of fine scale monitoring of Waimatuku Estuary, a 2km long, shallow, tidal river mouth estuary (20ha) in the Oreti Beach embayment. It is one of the key estuaries in Environment Southland's (ES's) long-term coastal monitoring programme. An outline of the process used for estuary monitoring and management by ES is presented in the margin flow diagram, and the following table summarises fine scale monitoring results, condition ratings, overall estuary condition, and monitoring and management recommendations.

FINE SCALE MONITORING RESULTS

- Sediment Oxygen: Redox Potential Discontinuity (RPD) was >5cm deep indicating good oxygenation.
- The indicator of organic enrichment (Total Organic Carbon) was at low concentrations.
- Nutrient enrichment indicators for total phosphorus were at moderate-high concentrations, and total nitrogen at low-moderate concentrations.
- The sediment had moderately high mud concentrations (approximately 25% mud) in the upper estuary, but low concentrations dominated by sand in the middle and lower estuary.
- Nuisance macroalgal cover was moderate.
- High value macrophytes (*Ruppia*) were present in the upper estuary.

CONDITION RATINGS	Transect D 2010	Transect E 2010	Transect G 2010
RPD Profile (Sediment oxygenation)	Good-Very Good	Good-Very Good	Good-Very Good
TOC (Total Organic Carbon)	Good	Very Good	Very Good
Total Nitrogen (TN) in sediment	Fair	Good	Very Good
Total Phosphorus (TP) in sediment	Fair	Fair	Fair

ESTUARY CONDITION AND ISSUES

The first year of baseline monitoring (undertaken when the estuary was open to the sea and the water level was low), showed that the estuary was generally well flushed and well-oxygenated. It had moderate nuisance macroalgal growth, included high value upper estuary *Ruppia* communities, and clean, lower estuary intertidal and subtidal flats. Elevated mud contents in the upper estuary were associated with moderate-high nutrient concentrations, indicating high catchment inputs.

Maintaining adequate flushing and reducing current nutrient inputs are the key variables to manage to prevent the loss of the native aquatic macrophyte community of the upper estuary and prevent a shift to increased nuisance macroalgal blooms and poorly oxygenated sediments in the lower and middle estuary.

The absence of an extensive vegetated margin also places the estuary at risk because the margin assimilates and filters excess nutrients and sediment. The major threats to further deterioration in saltmarsh and terrestrial margin (including duneland) communities were; increased stock access to the estuary margin, sea level rise, drainage, and invasion by plant pests.

RECOMMENDED MONITORING AND MANAGEMENT

In order to establish baseline conditions in this priority estuary, it is recommended that fine scale monitoring (including macroalgal mapping) be undertaken annually for the next 2-3 years (next monitoring scheduled for February 2011). Broad scale habitat mapping should be undertaken every 5 years (next scheduled in 2013).
The 2010 fine scale monitoring results reinforced the need for management of nutrient and fine sediment sources entering the estuary. It is recommended that sources of elevated loads in the catchment be identified and management undertaken to minimise their adverse effects on estuary uses and values.
In order to improve estuary function, it is also recommended that steps be taken to increase the extent of high value estuary habitat (saltmarsh and natural vegetated margin) wherever possible.

1. INTRODUCTION

OVERVIEW

Maintaining an understanding of the condition and risks to coastal and estuarine habitats is critical to Environment Southland (ES) in their resource management role for Southland. Recently, ES undertook a vulnerability assessment of its region's coastline to establish priorities for a long-term monitoring programme for the region (Robertson and Stevens 2008). The assessment identified Waimatuku Estuary as being a priority for monitoring which ES began in February 2009; the work being undertaken by Wriggle Coastal Management using the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002) plus recent extensions.

The Waimatuku Estuary monitoring consists of three components:

1. **Ecological Vulnerability Assessment** of the estuary to major issues (Table 1) and appropriate monitoring design. This component has been completed for Waimatuku Estuary and is reported on in Robertson and Stevens (2008).
2. **Broad Scale Habitat Mapping** (EMP approach). This component (Table 2), which documents the key habitats within each estuary and changes to these habitats over time, is reported on in Robertson and Stevens (2008).
3. **Fine Scale Monitoring** (Synoptic survey and EMP approach). Monitoring of selected physical and chemical characteristics (water clarity, salinity, depth, sediment oxygenation, muddiness, presence of macrophytes and nuisance macroalgae - see Table 2). This component, which provides detailed information on the condition of the Waimatuku Estuary, began with a synoptic survey in February 2009 (Robertson and Stevens 2009) with monitoring scheduled annually for three years to establish a baseline, then every five years or as determined by condition ratings.

This current report describes the first year of baseline monitoring of the key fine scale indicators of sediment nutrients - total nitrogen (TN) and phosphorus (TP); Total Organic Carbon (TOC); and grain size, as well as physical and chemical characteristics described in (3) above. The issues of toxicity and disease risk were not incorporated in the baseline monitoring programme as toxicity was considered to be at such a low risk it was not considered necessary to monitor, whilst the presence of disease risk indicators on the Southland coast is assessed separately in ES's recreational water quality monitoring programme.

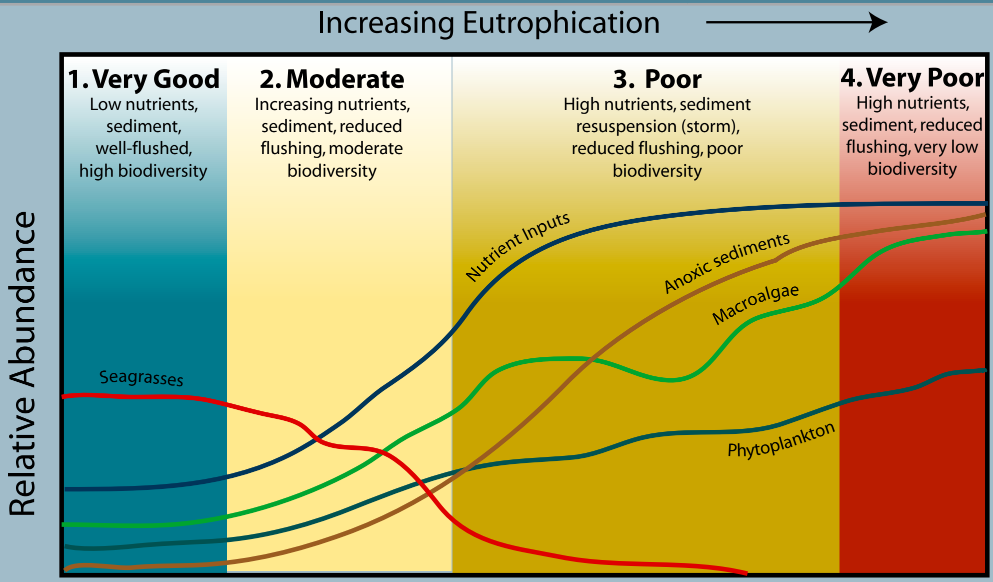
Figure 1. Waimatuku Estuary.

Waimatuku Estuary is a small (20ha at high tide), mainly open, shallow, "tidal river mouth" estuary separated from the sea by a barrier beach (Figures 1 and 4). It is fed by the Waimatuku Stream and drains to the sea through an entrnce that is artificially opened a couple of time per year. Where it flows across the beach berm and discharges to the sea, it cuts through modified duneland dominated by marram grass.

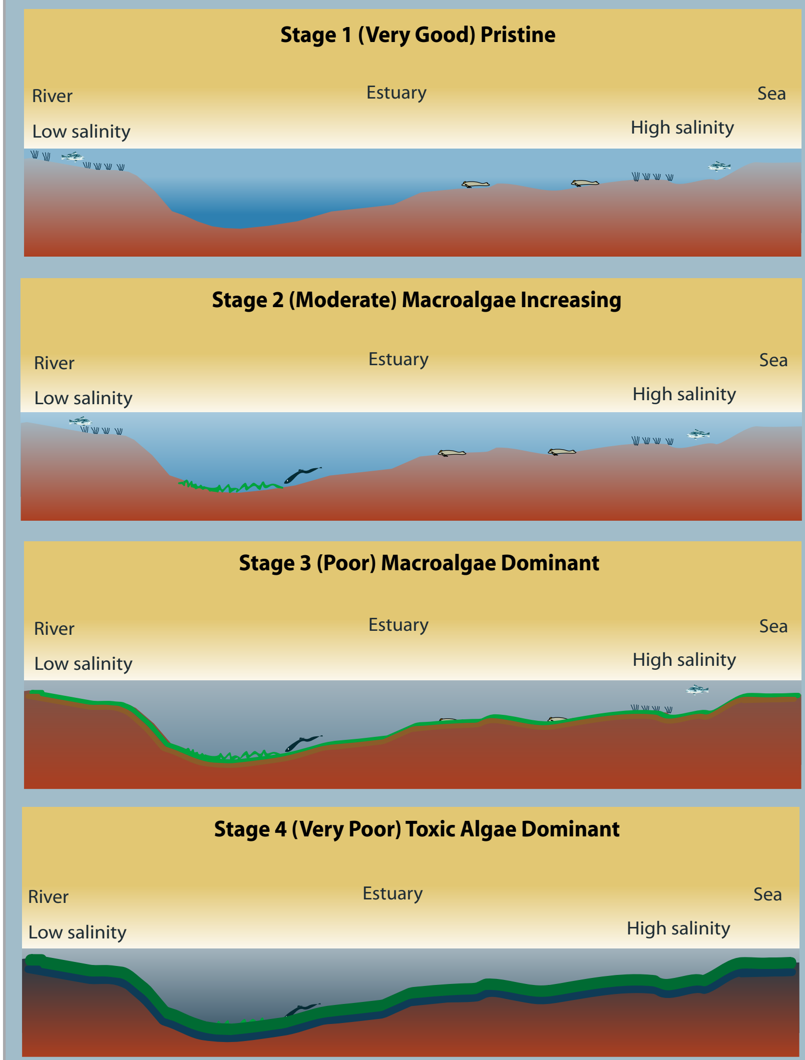
Much of the back dune area has been levelled, grassed, and is used for grazing, and the estuary margins have been significantly modified with just a narrow strip of tall fescue and flax fenced off from surrounding grazed pasture in the upper estuary. The lower estuary contains only small patches of saltmarsh (<1ha - predominantly herbfield) where it runs parallel to Oreti Beach. The catchment (150 km^2) is dominated by farmland (sheep, beef and dairying), and drainage has elevated nutrient concentrations (mean 3.6mgN/l) (ES monitoring data 2009). The estuary water is relatively clear, except during high flows, and the upper estuary has areas of aquatic macrophytes (e.g. *Ruppia* - horse's mane weed). Nuisance macroalgal growths (e.g. *Enteromorpha*) are generally present, particularly in summer in the middle and upper estuary. Information indicates landuse has historically been intensive, and elevated nutrient levels in both groundwater and surface water have been recorded.

The major threat to the estuary is increased eutrophication due to elevated nutrient inputs coupled with variable entrance constrictions and restricted flushing (reflecting the combined influence of river flows and sea state). The likely pattern of increasing eutrophication that these types of estuary follow in response to increased nutrients (particularly nitrogen) is presented in Figure 2.

Figure 2. Small Tidal River Mouth Estuary - Response to Increasing Eutrophication.



Conceptual representation of estuary response to increased nurients in tidal river mouth estuaries.



Stage 1. In their pristine state, these small, narrow estuaries are adequately flushed with river and marine tidal waters. Nutrient and sediment inputs are low and their clear, shallow, waters are dominated by submerged macrophytes where sediments are stable (e.g. seagrass and *Ruppia*) and contain adequate nutrients. Nuisance macroalgae and phytoplankton growth is low. Sediment quality and biodiversity is high.

Stage 2. As nutrient and sediment levels increase, nuisance macroalgae (e.g. *Enteromorpha*), and phytoplankton growth increases. Native macrophyte growth (e.g. seagrass and *Ruppia*), sediment oxygenation and water clarity declines. Introduced, aggressive macrophytes can become dominant in the brackish upper estuary. The bed becomes muddier and a surface sulphide layer is common. If flushing is reduced due to freshwater abstraction or mouth constriction, the susceptibility to eutrophication is enhanced and biodiversity declines.

Stage 3. As nutrient inputs become elevated, native macrophytes are replaced with nuisance short-lived macroalgae and phytoplankton. Introduced macrophytes can also become dominant in upper estuary brackish areas. Water clarity is often low, muddy sediments are anoxic close to the surface and sulphide rich, and sediment macrofauna is dominated by high numbers of a few tolerant species only.

Stage 4. Nutrients in sediments and water continue at high concentrations, but a lowering of the N:P ratio results in nuisance cyanobacteria and toxic bloom events. Sediment macrofauna are often absent, but nuisance macroalgae and phytoplankton are still present. Water clarity is low and sediment quality poor with anoxic and sulphide-rich muds.

Table 1. Summary of the major issues affecting most NZ estuaries.

Major 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.
Eutrophication (Nutrients)	Increased nutrient richness (e.g. nitrogen and phosphorus) of estuarine ecosystems stimulates the production and abundance of fast-growing algae, such as phytoplankton, and short-lived macroalgae (e.g. sea lettuce). Fortunately, because most New Zealand estuaries are well flushed, phytoplankton blooms are generally not a major problem. Of greater concern is the mass blooms of green and red macroalgae, mainly of the genera *Enteromorpha, Cladophora, Ulva,* and *Gracilaria* which are now widespread on intertidal flats and shallow subtidal areas of nutrient-enriched New Zealand estuaries. They present a significant nuisance problem, especially when loose mats accumulate on shorelines and decompose. Blooms also have major ecological impacts on water and sediment quality (e.g. reduced clarity, physical smothering, lack of oxygen), affecting or displacing the animals that live there.
Disease Risk	Runoff from farmland and human wastewater often carries a variety of disease-causing organisms or pathogens (including viruses, bacteria and protozoans) that, once discharged into the estuarine environment, can survive for some time. Every time humans come into contact with seawater that has been contaminated with human and animal faeces, we expose ourselves to these organisms and risk getting sick. Aside from serious health risks posed to humans through recreational contact and shellfish consumption, pathogen contamination can also cause economic losses due to closed commercial shellfish beds. Diseases linked to pathogens include gastroenteritis, salmonellosis, hepatitis A, and noroviruses.
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), heavy metals, polychlorinated biphenyls (PCBs), and pesticides. These chemicals collect in sediments and bio-accumulate in fish and shellfish, causing health risks to people and marine life.
Habitat Loss	Estuaries have many different types of habitats including shellfish beds, seagrass meadows, saltmarshes (rushlands, herbfields, reedlands etc.), forested wetlands, beaches, river deltas, and rocky shores. The continued health and biodiversity of estuarine systems depends on the maintenance of high-quality habitat. Loss of habitat negatively affects fisheries, animal populations, filtering of water pollutants, and the ability of shorelines to resist storm-related erosion. Within New Zealand, habitat degradation or loss is common-place with the major causes cited as sea level rise, population pressures on margins, dredging, drainage, reclamation, pest and weed invasion, reduced flows (damming and irrigation), over-fishing, polluted runoff and wastewater discharges.

Table 2. Summary of the broad and fine scale EMP indicators (shaded cells used in the current report).

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.
Sedimentation	Sedimentation Grain Size	Fine scale measurement of sediment grain size, including changes over time.
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 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.

2. METHODS

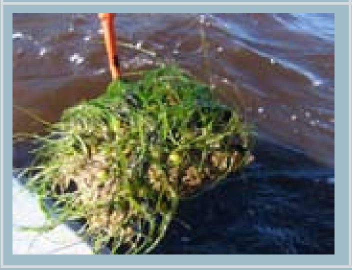
Percent Cover 0-5%

Percent Cover 5-10%

Percent Cover 10-20%

Percent Cover 20-50%

Percent Cover 50-80%



Percent Cover 80-100%

Figure 3. Percent cover categories for aquatic vegetation.

Ten previously established transect sampling sites in Waimatuku Estuary (Robertson and Stevens 2009, Figure 4), representing the range of different conditions present throughout the estuary, were visited by two scientists on 17 and 18 February 2010 when the lagoon was open to the sea. At each site, sampling was undertaken for key indicators of estuary condition as described below. The purpose was to collect information which, through repeat sampling, can be used as a rapid and robust method to indicate change within the estuary.

At each site, a 5-6cm deep layer of the surface sediments was collected with a garden hoe (area 15 x 15cm) and carefully brought to the surface (a canoe was used for sampling at the deeper sites). At the surface, the sample was photographed and records taken of;

- The taxa, height, percentage cover, and life stage of aquatic vegetation (Figure 3 gives examples of percentage cover estimates for macrophytes).
- The sediment type and depth to the blackened sulphide rich layer (Redox Potential Discontinuity layer - RPD).

Composite samples of the top 20mm of sediment (each approx. 250gms) were collected from 5 places across transects D, E and G. These transects, located near the middle estuary, capture the transition from the deeper more riverine upper estuary to the shallow intertidal lower estuary. Sediment samples were chilled and sent to R.J. Hill Laboratories for analysis of:

* Grain size/Particle size distribution (% mud, sand, gravel).
* Nutrients - total nitrogen (TN), total phosphorus (TP), and
* Total Organic Carbon (TOC).

Analytical details are provided in Appendix 1.

In addition, the water column at each site was sampled for:

- Secchi disc clarity
- Depth
- Dissolved oxygen
- Temperature
- Salinity (at surface and bottom)

A visual examination of the whole estuary was also undertaken to assess the extent of aquatic vegetation occurring outside of the chosen transects. Appendix 2 presents the 2010 field measurements. Results of the 2009 monitoring are reported in Robertson and Stevens (2009).

CONDITION RATINGS

A series of interim fine scale estuary "condition ratings" (presented on page 6) have been proposed for Waimatuku Estuary (based on the ratings developed for Southland's estuaries - e.g. Robertson & Stevens 2006). The ratings are based on a review of estuary monitoring data, guideline criteria, and expert opinion. They are designed to be used in combination with each other (usually involving expert input) when evaluating overall estuary condition and deciding on appropriate management.

2. Methods (Continued)

Waimatuku Estuary - Locations of Transects (NZMG260)

Transect	EAST	NORTH
A	2136771	5418019
B	2136633	5417563
C	2136458	5417395
D	2136760	5417105
E	2136660	5416977
F	2136766	5416945
G	2136924	5416900
H	2137006	5416642
I	2137314	5416421
J	2137420	5416346

Figure 4. Sampling sites in the Waimatuku Estuary.

2. Methods (Continued)

CONDITION RATINGS

The condition ratings presented below include an "early warning trigger" to highlight rapid or unexpected change, and each rating has a recommended monitoring and management response. In most cases initial management is to further assess an issue and consider what response actions may be appropriate (e.g. develop an Evaluation and Response Plan - ERP).

Total Nitrogen

In shallow estuaries like the Waimatuku, the sediment compartment is often the largest nutrient pool in the system, and nitrogen exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.

TOTAL NITROGEN CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<500mg/kg	Monitor at 5 year intervals after baseline established
Good	500-2000mg/kg	Monitor at 5 year intervals after baseline established
Fair	2000-4000mg/kg	Monitor at 2 year intervals and manage source
Poor	>4000mg/kg	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Total Phosphorus

In shallow estuaries like the Waimatuku, the sediment compartment is often the largest nutrient pool in the system, and phosphorus exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.

TOTAL PHOSPHORUS CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<200mg/kg	Monitor at 5 year intervals after baseline established
Good	200-500mg/kg	Monitor at 5 year intervals after baseline established
Fair	500-1000mg/kg	Monitor at 2 year intervals and manage source
Poor	>1000mg/kg	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Total Organic Carbon

Estuaries with high sediment organic content can result in anoxic sediments and bottom water, release of excessive nutrients, and adverse impacts to biota - all symptoms of eutrophication.

TOTAL ORGANIC CARBON CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<1%	Monitor at 5 year intervals after baseline established
Good	1-2%	Monitor at 5 year intervals after baseline established
Fair	2-5%	Monitor at 2 year intervals and manage source
Poor	>5%	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Redox Potential Discontinuity

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

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

3. RESULTS AND DISCUSSION

A summary of the results of the 17-18 February 2010 fine scale monitoring of Waimatuku Estuary is presented below, with detailed results of aquatic vegetation, sediment type, sediment oxygenation, and water quality (secchi disc clarity, dissolved oxygen, salinity and temperature), contained in Appendix 2. A summary of the condition ratings are presented in the figures accompanying the sediment chemistry results on page 10.

Table 3. Sediment chemistry results (composite sample) for Waimatuku Estuary, February 2010.

Site	RPD (cm)	Salinity (ppt)	TOC (%)	Mud (%)	Sand (%)	Gravel (%)	TN (mg/kg)	TP (mg/kg)
Transect D	>5	0.0	1.80	25.3	55.8	18.9	2400	820
Transect E	>5	1.1	0.76	9.8	90.2	<0.1	1400	850
Transect G	>5	18.6	0.24	2.6	97.2	0.2	<500	770

Aquatic Macrophyte and Macroalgal Cover

As in 2009, the lower Waimatuku Stream and the upper Waimatuku Estuary supported growths of rooted aquatic macrophytes. *Ranunculus trichophyllus* (water buttercup) was relatively abundant in the clear, 0-0.5m deep, flowing freshwater of the lower Waimatuku Stream section, growing in 1-2m long strands in the clean gravel bed, while *Mimulus guttatus* (monkey musk) was common along the margins.

In the brackish upper estuary, the native *Ruppia megacarpa* (horse's mane weed) and introduced *Potamogeton crispus* (pondweed) were the dominant rooted plants. *Ruppia* was present throughout the upper estuary as occasional dense patches in the 0-1m depth range. *Potamogeton* was present at similar depths, but restricted to patches in the upper reaches of the upper estuary.

The nuisance filamentous green macroalgae *Enteromorpha* was also common throughout the estuary. Dense mats were present among *Ruppia* beds in the brackish upper estuary, almost certainly restricting its growth through smothering, and reducing water and sediment quality.

Enteromorpha was also present in mats on the intertidal flats in the middle estuary, and on the bed of the estuary wherever the current was not too strong. These macroalgal mats, when present in high densities, were contributing to black, anoxic, sulphide-rich surface sediments.

The lower estuary was relatively clean of all vegetation except for a thin film of micro-algae on the intertidal sediment surface, and occasional patches of *Gracilaria* and *Enteromorpha* in the low tide channel near the estuary mouth.

Figure 5. Dominant macrophytes and macroalgae, Waimatuku Estuary, February 2010.

***Ruppia megacarpa* (Horse's mane weed)** is a native surface-flowering submerged aquatic annual or perennial; stems 20-30 cm long and are often zigzag in form. Grows in fresh to hypersaline coastal lakes, lagoons and estuaries and is relatively common in the 0-1.5m depth range (depending on water clarity).

***Potamogeton crispus* (Curly pondweed)** is an introduced species that is tolerant of slightly brackish as well as freshwater. It can survive in low light and low temperatures, and prefers high nutrient water. It spreads mostly by means of vegetative buds (turions) that germinate in autumn, grow vigorously in spring, and die off in the summer. The decaying plant matter can make the water extremely enriched, encourage nuisance algal mats near the sediment surface, inhibit the growth of native aquatics, and can interfere with boating and other water recreation. These plants germinate in autumn, grow vigorously in spring, and die off in the summer.

***Ranunculus trichophyllus* (Water buttercup)** is an introduced species common in freshwater and slightly saline waterbodies. Stems are up to 2m long, leaves are narrow and bright green. Flowers are white with a yellow centre.

***Enteromorpha*,** a nuisance green macroalgae, is found worldwide, and can grow to nuisance proportions in nutrient enriched estuaries, coastal lagoons and embayments. It can cause sediment deterioration, oxygen depletion, bad odours and have adverse impacts to biota.

***Gracilaria* spp.,** a relatively small (10-25cm) red macroalgae that grows in dense tufts both subtidally and intertidally in harbours, estuaries and moderately exposed open coasts, on rock, pebbles and shells in sandy/muddy areas. Generally bright crimson to dark maroon, but gets bleached by the sun.

Mid Waimatuku Estuary - clean sands and strands of *Enteromorpha*.

Collecting sediment for analysis, Site E, Waimatuku Estuary.

Lower Waimatuku Estuary - clean mobile sands.

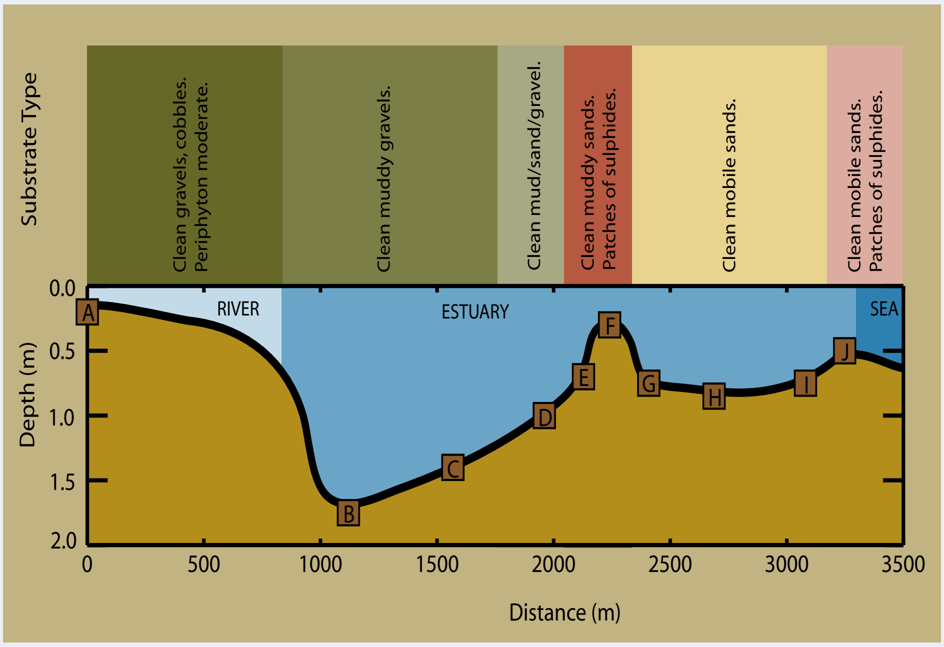
Water Depth and Level

There was little change in the water depth and level measured in February 2009 compared to February 2010. In 2010, the estuary was open to the sea with the low tide water depth predominantly <1.5m, and the deepest area (~2m) at Transect B (Figures 6 and 7). At high water the lagoon water level was approximately 0.5m deeper in the lower and mid estuary, with little change in the freshwater dominated upper estuary.

Sediment Type and Anoxic Layer

The substrate also showed little change compared to 2009. It comprised predominantly clean gravels and cobbles in the lower Waimatuku Stream, clean muddy gravels in the upper estuary, muddy sands and gravels in the middle estuary, and clean mobile sands in the lower estuary (Figure 6). Anoxic, sulphide rich sediments common in 2009 in the middle estuary around sites E and F, as well as in patches near the mouth, were much less common in February 2010. The depth to the redox potential discontinuity was >5cm throughout the majority of the estuary, a condition rating of "good".

Figure 6. Longitudinal profile (river to sea) of maximum water depth (at low water) and sediment type, 18 February 2010.



Salinity, Temperature and Dissolved Oxygen

Salinity measurements show that in 2010 the upper and middle estuary (transects A-F) were freshwater-dominated and unstratified during low flow and low tide conditions; salinities ranging from 0 to 1.2ppt (Appendix 2). In the lower estuary, surface salinity ranged from 1.2-4.0ppt at sites G and H, with a salt wedge below 0.5m depth (18.6-23.0ppt). Downstream of site H salinity throughout the water column ranged between 19.9-23.4ppt.

Water temperature varied from 14.5°C in the upper estuary to 17.5°C at the estuary mouth and there was little difference between the surface and bottom. Dissolved oxygen concentrations in the water column were relatively high, 100% saturation at the mouth and lower estuary, and 87-110% in the upper estuary.

Water Clarity (Secchi Disc)

In the 2010 survey, the estuary was moderately clear with the bottom visible at all sites in the estuary except at the deepest site (B) where Secchi disk clarity was 1.3m.

Figure 7. Location of dominant macrophytes and macroalgae, Waimatuku Estuary, 18 February 2010.

3. Results and Discussion (Continued)

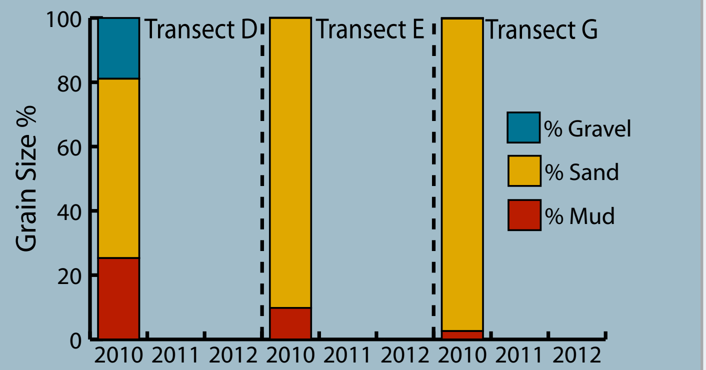


Figure 8. Grain size, at 3 subtidal sites (composite across transect), February 2010.

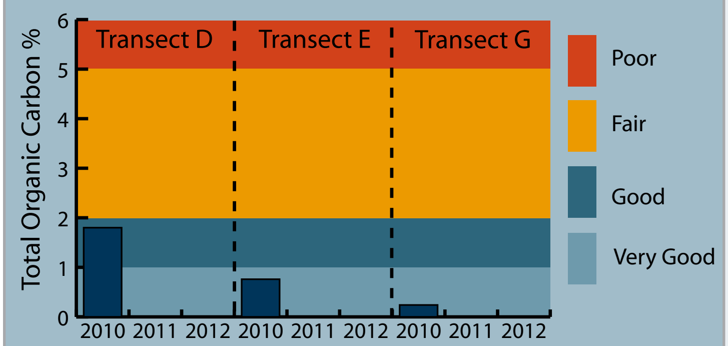


Figure 9. Total organic carbon at 3 subtidal sites (composite across transect), February 2010.

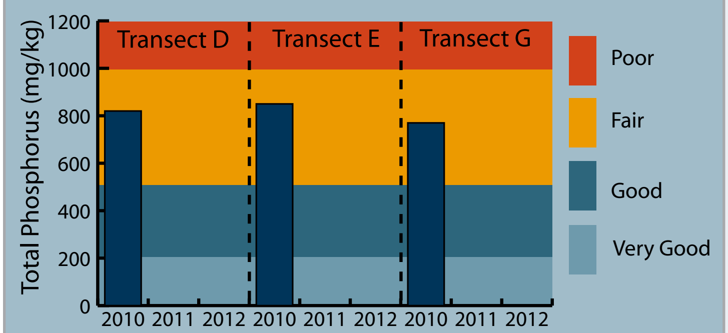


Figure 10. Total phosphorus at 3 subtidal sites (composite across transect), February 2010.

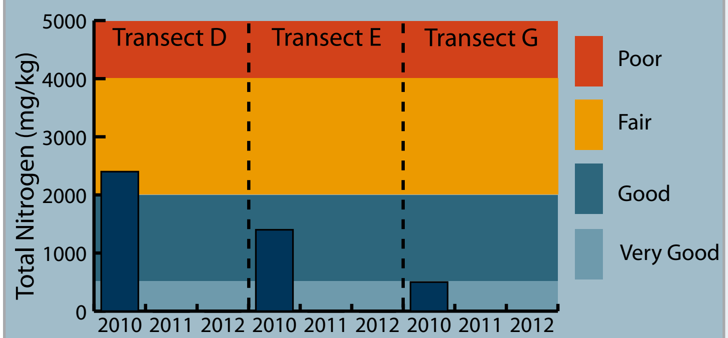


Figure 11. Total nitrogen at 3 subtidal sites (composite across transect), February 2010.

In 2010, the first stage of a 3 year baseline was completed to collect information on key indicators of eutrophication, the primary threat identified to the Waimatuku Estuary (Robertson and Stevens 2008, 2009).

GRAIN SIZE (%MUD, SAND, GRAVEL)

Grain size measurements indicate the muddiness of a particular site. Because of greater relative surface area, muds are generally associated with higher organic content and nutrient concentrations than sands and gravels. Thus muddier areas generally act as a sink concentrating these catchment inputs. Results from the 3 transects sampled (Figure 8) show muds from the catchment accumulate predominantly in the deeper reaches of the upper estuary, indicating it is more at risk of sediment eutrophication effects than the better flushed middle and lower estuary which are much sandier.

ORGANIC MATTER (TOC)

Fluctuations in organic input are considered to be one of the principal causes of faunal change in estuarine and near-shore benthic environments, and elevated organic enrichment causes changes in physical and biological parameters, which in turn have effects on the sedimentary and biological structure of an area.

The indicator of organic enrichment (TOC) in 2010 was at low concentrations (<2%) at all sites (Figure 9) and met the "good" to "very good" condition ratings.

TOTAL PHOSPHORUS

Total phosphorus (a key nutrient in the eutrophication process) in 2010 was in the "fair" category indicating "moderate enrichment" (Figure 10). The high phosphorus concentrations in sediments at Transect G, which had a very low mud content, indicates large catchment inputs of phosphorus to the estuary.

This means that the Waimatuku Estuary sediments have a moderate - high store of P in the sediments (sourced from both recent and historical catchment inputs).

TOTAL NITROGEN

Total nitrogen (the other key nutrient in the eutrophication process) was rated in the "fair", "good" and "very good" categories" (Figure 11). This means that the Waimatuku sediments have a low-moderate store of N in the sediments (sourced from both recent and historical catchment inputs), with loads decreasing in the sandier lower estuary as mud content diminishes.

3. Results and Discussion (Continued)

The combined 2010 results showed Waimatuku Estuary was in relatively good condition at the time of monitoring. Conditions were similar to those encountered in 2009 when monitoring was also undertaken when the mouth was open and the estuary was well-flushed.

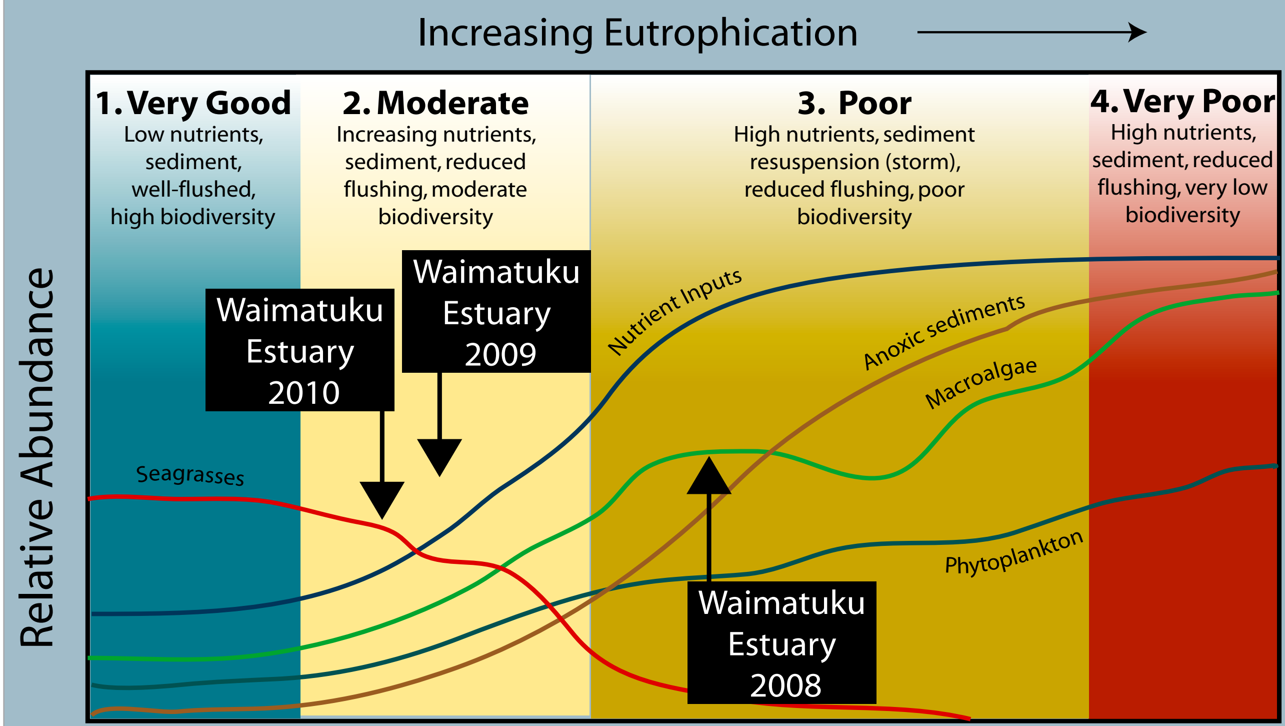
Monitoring showed concentrations of N, P and TOC ranged from fair to very good, sediment oxygenation (RPD depth) was rated good, while limited nuisance macroalgae indicated a low presence of eutrophication symptoms. This is despite sediment phosphorus concentrations indicating high catchment inputs, which have also been trending upwards over the past 10 years. The results indicate the estuary is in a Stage 2 "moderate" state (Figure 12). The short residence time of water within the estuary when the mouth is open to the sea greatly minimising the development of eutrophication symptoms, although it is a priority to manage phosphorus inputs.

Despite this, the estuary remains susceptible to the loss of the native aquatic macrophyte community of the upper estuary, and a shift to increased nuisance macroalgal blooms in the lower and middle estuary if the estuary mouth closes, although this is not a regular occurrence, and closures are not prolonged.

The overall health of the estuary is also dependent on the protection and enhancement of saltmarsh and terrestrial margin habitat. Maintaining these habitats in good condition will help other important parts of the ecosystem (e.g. macroinvertebrates, fish and birdlife) to thrive, as well as providing important filtering and uptake of sediment and nutrient inputs.

Pathogen input is the other key issue facing the estuary and these are currently being addressed as part of Environment Southland's state of the environment monitoring programme.

Figure 12. Waimatuku Estuary - condition rating and trophic state, 2008, 2009 and 2010.



Conceptual representation of estuary response to increased nurients in tidal river mouth estuaries.

4. MONITORING

Previous assessments (Robertson and Stevens 2008, 2009) identified a need for regular targeted monitoring, as well as intensive studies, for effective ongoing management of this estuary as follows:

Macrophyte and Sediment Condition

Monitor the condition of *Ruppia* beds, macroalgal status, and sediment quality, during summer prolonged low river flows as follows (monitor annually for three years to establish a baseline then every five years):

- Map aquatic macrophytes and nuisance macroalgae presence, location, % cover and life stage (including salinity, depth and clarity at established transect sites).
- Monitor sediment quality - broad scale (depth to RPD layer, sediment type) and fine scale (grain size, total nitrogen, total phosphorus and total organic carbon) at 3 sites.

Water Quality

Continue monitoring nutrients and turbidity in the lower Waimatuku Stream in order to assess the nutrient inflows to Waimatuku Estuary. In addition, characterise pathogen inputs to the estuary.

Catchment Landuse, Freshwater Abstractions, Mouth Openings/Constrictions.

Monitor key stressors including reduced flushing, catchment landuse, freshwater abstraction, mouth constriction, and changes to water level. Any significant changes to stressors should trigger an evaluation of the likely impact on estuary susceptibility.

5. MANAGEMENT

Five major issues require management as follows:

1. Develop Nutrient and Sediment Input Guidelines.

Develop appropriate nutrient and sediment input guidelines for the estuary based on existing data.

2. Ensure Adequate Freshwater Input Flushing Flows.

Ensure estuary flushing is not reduced by maintaining or improving existing freshwater inflow volumes.

3. Maintain Natural Opening Regime.

Avoid artificial opening of the estuary without a thorough environmental risk assessment of potential impacts to ensure high value communities e.g. *Ruppia* are not inadvertently affected.

4. Saltmarsh and Terrestrial Margin Restoration.

It is recommended a plan be developed to encourage saltmarsh and terrestrial margin re-vegetation.

5. Plan to Minimise Ecological Impacts of Sea Level Rise.

Develop a plan to minimise the loss of ecosystem services of Waimatuku Estuary that are vulnerable to climate change effects, particularly sea level rise. A preliminary requirement is a detailed vulnerability assessment of climate change effects.

6. ACKNOWLEDGEMENTS

This survey and report has been undertaken with the extensive help and support of Greg Larkin (Coastal Scientist, Environment Southland), and Maz Robertson (Wriggle) for editing.

7. REFERENCES

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APPENDIX 1. DETAILS ON ANALYTICAL METHODS

Indicator	Laboratory	Method	Detection Limit
Grain Size	R.J Hill	Air dry (35 degC, sieved to pass 2mm and 63um sieves, gravimetric - (% sand, gravel, silt)	N/A
Total Organic Carbon	R.J Hill	Catalytic combustion, separation, thermal conductivity detector (Elementary Analyser).	0.05g/100g dry wgt
Total Recoverable Phosphorus	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	40 mg/kg dry wgt
Total Nitrogen	R.J Hill	Catalytic combustion, separation, thermal conductivity detector (Elementary Analyser).	500 mg/kg dry wgt

APPENDIX 2. SURVEY RESULTS

Aquatic Vegetation and Site Details - Waimatuku Estuary - Low Tide (15.30h) 18 February 2010

Transect	Distance from western bank	Depth of Sample	Water Depth	Secchi Disk Clarity	Temperature	Salinity	DO	Sediments	RPD Depth	Vegetative Cover	Height	Stage	Percent Cover
	(m)	(m)	(m)	(m)	°C	ppt	%		cm		m		%
A	3	Surface	0.2	Bottom	14.5	0.0	102	Cobble	-	*Ranunculus*	1-2	Fl	50
	3	0.2	0.2	Bottom	14.5	0.0	102		>5	Periphyton and filamentous algae	0.2	-	50
B	15	Surface	1.3	Bottom	14.7	0.0	110		-	No macrophytes			
	15	1.3	1.3	Bottom	14.7	0.0	110	Clean muddy Gravels	>5	No macrophytes			
	20	-	2.0	1.3	-	-	-		-	No macrophytes			
C	8	Surface	1.2	Bottom	15.0	0.0	87	Clean muddy Gravels	-	*Enteromorpha*	0.2	v	10
	8	1.2	1.2	Bottom	15.0	0.0	87		>5	*Potamogeton crispus*	0.2	v	1-5
	Ruppia beds above and below site.												
D	10	Surface	0.5	Bottom	15.8	0	99	Clean muddy Sand, occasional gravel patches	-	*Enteromorpha*	0.2	v	20
	5	0.5	0.5	Bottom	15.8	0	99		>5	No macrophytes/macroalgae			
	10	1.2	1.2	Bottom	15.8	0	99		>5	No macrophytes/macroalgae			
	18	0.8	0.8	Bottom	15.8	0	99		>5	*Enteromorpha*	0.3	v	50
E	15	Surface	0.5	Bottom	15.3	1.1	100	muddy Sand	-	*Enteromorpha*	10	v	10
	2	0.5	0.5	Bottom	15.3	1.1	100	muddy Sand	>5	*Enteromorpha*	10	v	10
	15	1.1	1.1	Bottom	15.3	1.1	100	muddy Gravel/Sand	>5	No macrophytes/macroalgae			
	25	0.9	0.9	Bottom	15.3	1.1	100	mud/gravel Sand	>5	*Enteromorpha*	5	v	5
	35	0.9	0.9	Bottom	15.3	1.1	100	muddy Sand	>5	*Enteromorpha*	15	v	80
	40	0.2	0.2	Bottom	15.3	1.1	100	Clean mobile Sand	>5	No macrophytes/macroalgae			
	Small patches of anoxic sediments and decaying macroalgae in shallow water (0.8m) near western bank												
F	5	Surface	0.2	Bottom	15.3	1.2	100	Clean mobile Sand	-	No macrophytes/macroalgae			
	3	0.2	0.2	Bottom	15.3	1.2	100	gravel/mud Sand	>5	*Enteromorpha*	0.2	v	50
	5	1.2	1.2	Bottom	15.3	1.2	100	Clean mobile Sand	>5	No macrophytes/macroalgae			
	15	0.5	0.5	Bottom	15.3	1.2	100	Clean mobile Sand	>5	No macrophytes/macroalgae			
G	5	Surface	0.2	Bottom	15.3	2.8	100	Clean mobile Sand	-	No macrophytes/macroalgae			
	5	0.2	0.2	Bottom	15.3	2.8	100	Clean mobile Sand	>5	No macrophytes/macroalgae			
	12	1.3	1.3	Bottom	16.0	18.6	100	Clean mobile Sand	>5	No macrophytes/macroalgae			
H	10	Surface	0.2	Bottom	15.3	4.0	100	Clean mobile Sand	-	No macrophytes/macroalgae			
	3	0.5	0.5	Bottom	17.0	23.0	100	Clean mobile Sand	>5	No macrophytes/macroalgae			
	13	0.9	0.9	Bottom	17.0	23.0	100	Clean mobile Sand	>5	No macrophytes/macroalgae			
I	6	Surface	0.2	Bottom	16.2	19.9	100	Clean mobile Sand	-	No macrophytes/macroalgae			
	6	0.2	0.2	Bottom	17.5	19.9	100	Clean mobile Sand	>5	No macrophytes/macroalgae			
	10	0.7	0.7	Bottom	17.5	19.9	100	Clean mobile Sand	2	No macrophytes/macroalgae			
J	4	Surface	0.2	Bottom	16.3	23.4	100	Clean mobile Sand	-	*Enteromorpha*	20	v	100
	8	1.0	1.0	Bottom	16.3	23.4	100	Clean mobile Sand	>5	No macrophytes/macroalgae			
	4	0.2	0.2	Bottom	16.3	23.4	100	Clean mobile Sand	>5	*Enteromorpha/Gracilaria*	20	v	50