Habitat Mapping of the Tokomairiro River Estuary

Otago Regional Council State of the Environment Report

Prepared by

Ryder Consulting

November 2009

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Cover photo: Looking towards the mouth of the Tokomairiro River Estuary.

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1. Introduction

The Otago Regional Council (ORC) has identified a need to gather information on the biological resources of river estuaries present within Otago to assist in both strategic planning and in the management of specific issues associated with resource consents, pollution, and state of the environment monitoring.

The Tokomairiro River Estuary is considered to be of regional importance in terms of its ecological, scenic, spiritual and/or cultural values and is designated as a Coastal Protection Area (CPA25) under the Otago Regional Council's Regional Plan: Coast. While not designated as a Coastal Recreational Area under the Plan, the coastal settlement of Toko Mouth, at the mouth of the estuary, is important for holidaymaking, swimming, fishing, and walking. It is recognised that there is the potential for adverse effects on the intertidal ecosystem of the Tokomairiro River Estuary from sedimentation, runoff, discharges, stormwater, recreational use and alterations to the stream processes.

To gather robust baseline data against which future changes may be compared a comprehensive estuarine environmental assessment is essential. Such an assessment will comprise broad and fine scale mapping.

The ORC has engaged Ryder Consulting to carry out the estuary mapping.

2. Objectives

To carry out broad and fine scale mapping of the Tokomairiro River Estuary in accordance with the National Estuary Monitoring Protocol and produce a report outlining:

1) The methodology used in the mapping and sampling programme and any problems encountered.
2) A record of the references cited and used to assist in the sampling.
3) Photographs of all the sites surveyed.
4) MapInfo GIS maps of all the surveyed areas with dominant cover habitats shown and sampling site locations.
5) A discussion for each fine-scale site of the fauna and flora identified and any nationally or regionally significant species, and any other information relevant to the Client.

6) An identification of the pressures at each site that will become part of the sensitivity matrix.
7) A set of recommendations on the most suitable method(s) for resource management of identified problems.

Broad scale mapping is a robust GIS-based methodology for mapping the spatial distribution of intertidal estuarine habitats and consists of:

I. Visiting each site to record and ground-truth the key habitat types and substrate features on rectified aerial photographs supplied by the Client.
II. Providing a subjective assessment of the ecological health and vulnerabilities from pressures (human influences). This information will become part of the sensitivity matrix.
III. Digitising habitat and substrate features into MapInfo or other suitable GIS software.

Fine-scale mapping involves measuring environmental characteristics that are known to be indicative of estuary or coastal condition, and are likely to provide a means for detecting habitat degradation, as well as providing a measure of subsequent change. In other words, fine-scale mapping examines the spatial variation and inter-relationships of a suite of commonly measured indicators and consists of:

I. Selecting at least two representative sites within the dominant intertidal habitat.
II. Taking replicate sediment samples at each site and analysing for known important variables.

3. Methodology

3.1 Broad scale mapping

Aerial photographs, supplied by the ORC, were used to generate base maps of vegetation and substrata within the estuary. The photographs were ground truthed by Ryder Consulting staff during field surveys using obvious landmarks and a handheld Garmin GPS unit. A minimum of six landmarks were identified and used, in conjunction with GIS software, to rectify each aerial photograph in an attempt to keep on-ground spatial errors to <5m.

Field surveys were conducted on foot by an experienced coastal marine scientist to verify vegetation and substrate types, and to identify features not distinguishable through aerial photography alone. Using GPS and 100m measuring tapes, the spatial extent of all substrate and habitat features encountered in the field was transcribed to hard copies of photographs/maps with locations accurately defined in relation to obvious landmarks. Positional accuracy was recorded by calculating the root mean square (RMS) error for each landmark. Hard copies of maps and photographs were to be digitised to enable transfer of data to a GIS computer program. However, all images supplied by the ORC were in digital format and this was, therefore, unnecessary. All sites/features visited in the field were digitally photographed.

Classification for wetland types was based on the Atkinson System (Atkinson 1985) that covers four levels, ranging from broad to fine-scale. The broad-scale mapping to be carried out for this project focused on Levels III and IV (below).

Level I Hydrosystem (*e.g.* intertidal estuary)
Level II Wetland Class (*e.g.* saltmarsh, mud/sand flat)
Level III Structural Class (*e.g.* marshland, mobile sand)
Level IV Dominant Cover (*e.g. Zostera muelleri*)

Substrate classification was based on surface layers only and did not consider underlying substrate; e.g., cobble or gravel fields covered by sand were classed as sand flat.

Level III structural classes formed the basis of the broad scale mapping and are detailed below.

Definitions of Classification of Level III Structural Class – Estuaries (from Robertson et al. *2002*).

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.
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. If the reed is broken the stem is both round and hollow – somewhat like a soda straw. The flowers will

each bear six tiny petal-like structures – neither grasses nor sedges will bear flowers, which look like that. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either hollow or have a very spongy pith. Example include *Typha, Bolboschoenus, Scirpus lacutris, Eleocharis sphacelata*, and *Baumea articulata*.

Rushland: Vegetation in which the cover of 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 grass like, often hollow-stemmed plant, included in the rush growth form are some species of *Juncus* and all species of, *Leptocarpus*. Tussock-rushes are excluded.

Sedgeland: Vegetation in which the cover of 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*. Tussock-sedges and reed-forming sedges (c.f. REEDLAND) are excluded.

Grassland: Vegetation in which the cover of grass in the canopy is 20-100%, and in which the grass cover exceeds that of any other growth form or bare ground. Tussock-grasses are excluded from the grass growth-form.

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*.

Shrubland: Cover of shrubs in canopy 20-80%. Shrubs are woody plants <10 cm diameter at breast height (dbh).

Scrub: Woody vegetation in which the cover of shrubs and trees in the canopy is > 80% and in which shrub cover exceeds that of trees (c.f. FOREST).

Treeland: Cover of trees in canopy 20-80%. Trees are woody plants >10cm dbh.

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 dbh. Tree ferns = >10 cm dbh are treated as trees.

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 chlorophyll, 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.

Firm mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When walking on the substrate you'll sink 0-2 cm.

Soft mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When walking on the substrate you'll sink 2-5 cm.

Very soft mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When walking on the substrate you'll sink greater than 5 cm.

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 less than 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 impossible.
Soft sand: Substrate containing greater than 99% sand. When walking on the substrate you'll sink greater than 2 cm.
Gravel field: Land in which the area of unconsolidated gravel (2-20mm 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 of = 1%.
Cobble field: Land in which the area of unconsolidated cobbles/stones (20-200mm 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%.
Boulder field: Land in which the area of unconsolidated bare boulders (>200mm diam.) exceeds the area covered by any one class of plant growth-form. Boulderfields are named from the leading plant species when plant cover is =1%.
Rock/Rock field: Land in which the area of residual bare rock exceeds the area covered by any one class of plant growth-form. Cliff vegetation often includes rocklands. They are named from the leading plant species when plant cover is = 1%

During the field visit to the estuary any obvious environmental pressures were noted. A simple risk assessment matrix (Table 1) was used to define the level of concern associated with different environmental pressures on habitats encountered and a colour ranking (red = high, green = low) was used to indicate risk or level of concern. The use of letters and numbers (A1 – D4) enables further definition of the drivers for the level of concern based on the percentage of the resource affected and the likely recovery time. For example. if an environmental pressure affects say 30% of the area and the area would take approximately 3 years to recover from that impact a risk of B3 would be assigned for that pressure (e.g. see Table 1). It is important to note that the matrix does not confirm the presence of an impact, merely the presence of pressures and possible consequences of that pressure on the environment.

Table 1. *Risk assessment matrix for evaluating levels of concern regarding habitat pressures at each site. Red = high; yellow = moderate concern; green = low.*

		Recovery from impact			
		(Slow) >10 years	5-10 years	1-4 years	(Rapid) <1 year
% of habitat affected		1	2	3	4
>50% (Large)	A	A1	A2	A3	A4
30-50%	B	B1	B2	B3	B4
10-30%	C	C1	C2	C3	C4
0-10% (Small)	D	D1	D2	D3	D4

The environmental pressures identified during this survey include:

- Flooding
- Introduced weeds
- Nutrient pollution
- Stormwater
- Vehicles
- Stock
- Erosion
- Litter
- Reclamation

This report gives a broad overview of the activities that may influence the environmental quality within the estuary, and possible significance of each.

3.2 Fine scale mapping

The Tokomairiro River Estuary is not particularly large so just two representative sites were selected within the estuary, based on broad scale mapping and field observations. The sites were located in the mid- to low-water zone within the dominant habitat type, taking care to avoid channels and areas of significant vegetation. Each site comprised an area 60m x 30m divided into 12 sub-areas (Figure 1). Within each sub-area a randomly selected plot was sampled as follows:

1 **Sediment core profiles** (and depth of Redox Discontinuity Layer):

- One randomly positioned 80mm diameter core was collected to a depth of at least 100mm from each plot.
- The core was extruded onto a white plastic tray, labelled, and photographed alongside a ruler for scale.
- The stratification of colour and texture, particularly the occurrence of any black (anoxic) zones, was used to assess the depth of any lighter-coloured surface layer - the depth of the Redox Discontinuity Layer (RDL).

2. **Epifauna** (surface-dwelling animals):

- Epifauna was assessed from one randomly placed 0.25m^2 quadrat within 1m of the core sample in each plot. All animals observed on the sediment surface were identified and counted, and any visible microalgal mat development noted. The species, abundance and related descriptive information were recorded on specifically designed, waterproof field data sheets containing a checklist of expected species.

- Field notes were transferred to a spreadsheet or database for statistical analyses.

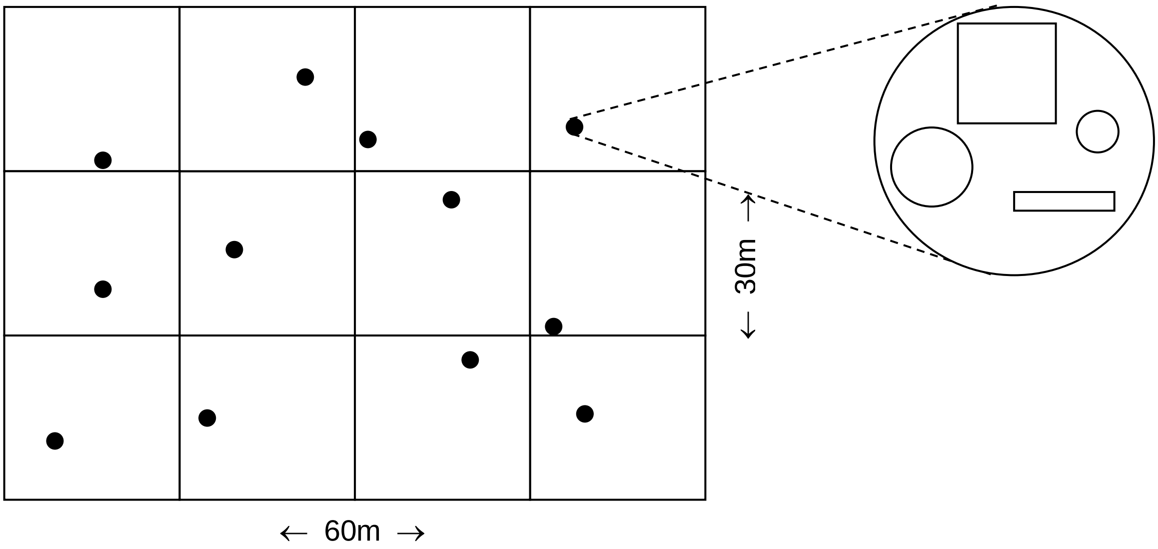

Figure 1. *Layout of sampling area. Squares are sub-areas; black dots are randomly located sampling plots. Circle on right is an enlargement of a sampling plot showing 0.25m^2 quadrat for epibiota analysis, small sediment core for RDL determination, large sediment core for infauna analysis, and small rectangle for sediment physico/chemical analysis.*

3. **Macroalgae** (seaweeds) % cover:

- Where a significant macroalgal cover existed, the percent coverage was estimated using a grid quadrat.

4. **Infauna** (animals living buried in the sediments):

- Three replicate sediment cores were collected from each site at random positions (i.e. six per estuary) using a 125mm diameter (area = 0.0039m^2) corer.
- The corer was driven into the sediments to a depth of 150mm, removed with core intact and the contents washed through 0.5mm Endicott® sieve using local seawater. Captured material and fauna was carefully emptied into labelled plastic containers and preserved using 95% ethanol.
- Samples were returned to the laboratory and examined using a 10X dissecting microscope.
- Invertebrate species were identified to the lowest taxonomic level possible, counted and recorded.
- Data was transferred to a spreadsheet/database for future comparisons.

3.3 Chemical analyses

- Twelve replicate sediment samples (each of approximately 250 grams, with one from each plot) were collected from the top 20mm of fine sediment within each sub-area. The 12 samples were thoroughly mixed to provide one composite sample per site (i.e. a total of two samples for the estuary), as done by Stevens *et al*. (2004) for a similar exercise around Wellington and by Stewart (2007, 2008a,b, 2009a,b) for other Otago estuaries. Samples were placed into pre-labelled ziplock plastic bags and stored on ice in the field before being frozen prior to shipping to the Hill Laboratories in Hamilton for analysis.
- The following analyses was carried out:

  Grain size (% mud silt and sand)
  Ash free dry weight
  Total nitrogen
  Total phosphorus
  Arsenic
  Cadmium
  Chromium
  Copper
  Lead
  Nickel
  Zinc

4. Results

4.1 Environmental Pressures

A summary of environmental pressures identified at each site and a subjective assessment of the level of concern for each is shown in Table 2 using the matrix presented in Table 1. Blank spaces indicate that the identified pressure is not considered significant or relevant, while a "?" indicates that the pressure may be present, but needs confirmation.

Introduced weeds were widely present, but as in Stevens *et al.* (2004) and Stewart (2007, 2008a,b, 2009a,b), any influence from this pressure has not been defined due to the fact that impact and recovery from this pressure is species and location specific. Although common, the coverage of introduced weeds was often extremely patchy and, where this happened, they were not recorded under broad scale mapping in this survey. However, where dense stands of gorse (*Ulex europaeus*) or, less commonly, lupins (*Lupinus arboreus*) were encountered these were recorded as shrubland.

A subjective assessment of the degree of modification to the estuary has also been included. In the case of the Tokomairiro River Estuary modification is generally limited to reclamation, the formation of vehicle tracks, installation of fences, and the construction of bridges and stop banks.

Table 2. *Summary of environmental pressures at the Tokomairiro River Estuary and level of concern. Red = high concern; yellow = moderate concern; green = low concern (Refer to Table 1).*

Pressure	Tokomairio River
Flooding	B3
Introduced weeds	✓
Nutrient pollution	B3
Stormwater	D4
Vehicles	D4
Litter and dumped items	D3
Stock (grazing/trampling)	B3
Erosion	D3
Reclamation	B2
Degree of modification*	M

* VH = Very High, H = High, M = Moderate, L = Low.

This identification and ranking of pressures should be viewed as a starting point for discussion. Detailed information is likely to be available on many aspects, and local knowledge could be of great benefit. Such further investigation is beyond the scope of this survey. It is envisaged that this summary will provide a starting point for deciding whether further investigation is justified, and, if so, where priorities may lie.

Considering the amount of cultivated farmland upstream or adjacent to the estuary, nutrient enrichment is likely, but is difficult to quantify without further investigation.

A considerable amount of reclamation has certainly occurred in past years, but the majority of pasture and fencing on reclaimed land appears to be very well established and may be in the order of many decades old. There is no evidence of more recent reclamation in the estuary.

For the Tokomairiro River Estuary the presence of just one red cell for reclamation, which appears to have ceased, in Table 2 shows there is little need for any further investigation and/or action with respect to environmental stressors on the estuary.

Erosion does not appear to be a major issue at the Tokomairiro River Estuary. There is evidence of relatively recent scouring of gravel in a tributary along the true right bank of the river (Figure 2) but this is not considered serious. The sand banks nearer the mouth may be more prone to erosion (Figure 2b). Flooding certainly occurs, as evidenced by debris left in fences some 1-2m above river level (Figure 3), with very large areas of low lying land likely to be inundated.

Figure 2a. *Erosion in a tributary along the true right bank of the Tokomairiro River Estuary.*

Figure 2b. *Erosion of sand banks along the true left bank of the Tokomairiro River Estuary near the mouth.*

Figure 3. *Flood debris in a fenceline along the true right bank of the Tokomairiro River Estuary.*

4.2 Broad Scale Mapping – Tokomairiro River Estuary

4.2.1 Ground-truthing and digitising habitat

The Tokomairiro River Estuary was visited for the purpose of broad scale mapping on the 9th of November 2009 and again on 13th November 2009. Four prominent landmarks were located using aerial photographs (Figures 4a and 4b) and GPS readings taken at points either end of each landmark. The distance between points on each landmark was measured using a 100m tape, then compared with maps generated using aerial photographs and tfw files supplied by the ORC. Aerial photographs were ortho-rectified using MAPublisher® 6.2. All distances measured on photographs corresponded with ground truth measurements to within 2m.

Estuary boundaries were set by EHWS (extreme high water spring tide) and ELWS (extreme low water spring tide). However, areas that would be likely inundated during flood events were also included in the habitat mapping. The entire estuary was walked with notes being taken on substrate type, vegetation cover and type, and any other distinguishing features. At the same time, drawings were made on field copies of aerial photographs to aid in the digitising of field information and a photographic record made of the entire area. Vegetation and substrate features identified during the field surveys were digitally mapped as precisely as possible on-screen from the rectified photograph. GIS shape files were then used to visually represent each specific feature, as well as to calculate the area of cover for different habitat/substrate types.

Figure 4. *Tokomairiro River Estuary with ground truthing sites marked as yellow bars.*

4.2.2 Habitat and Substrate Features

The Tokomairiro River has a long (12.5km) and relatively narrow (no more than 370m wide) estuary (Figures 5a and 5b) covering slightly more than 340ha, excluding deep water (Table 3). A relatively small percentage of the estuary area is exposed at low water and it would appear that a considerable amount of the area of the lower estuary has been reclaimed for farming.

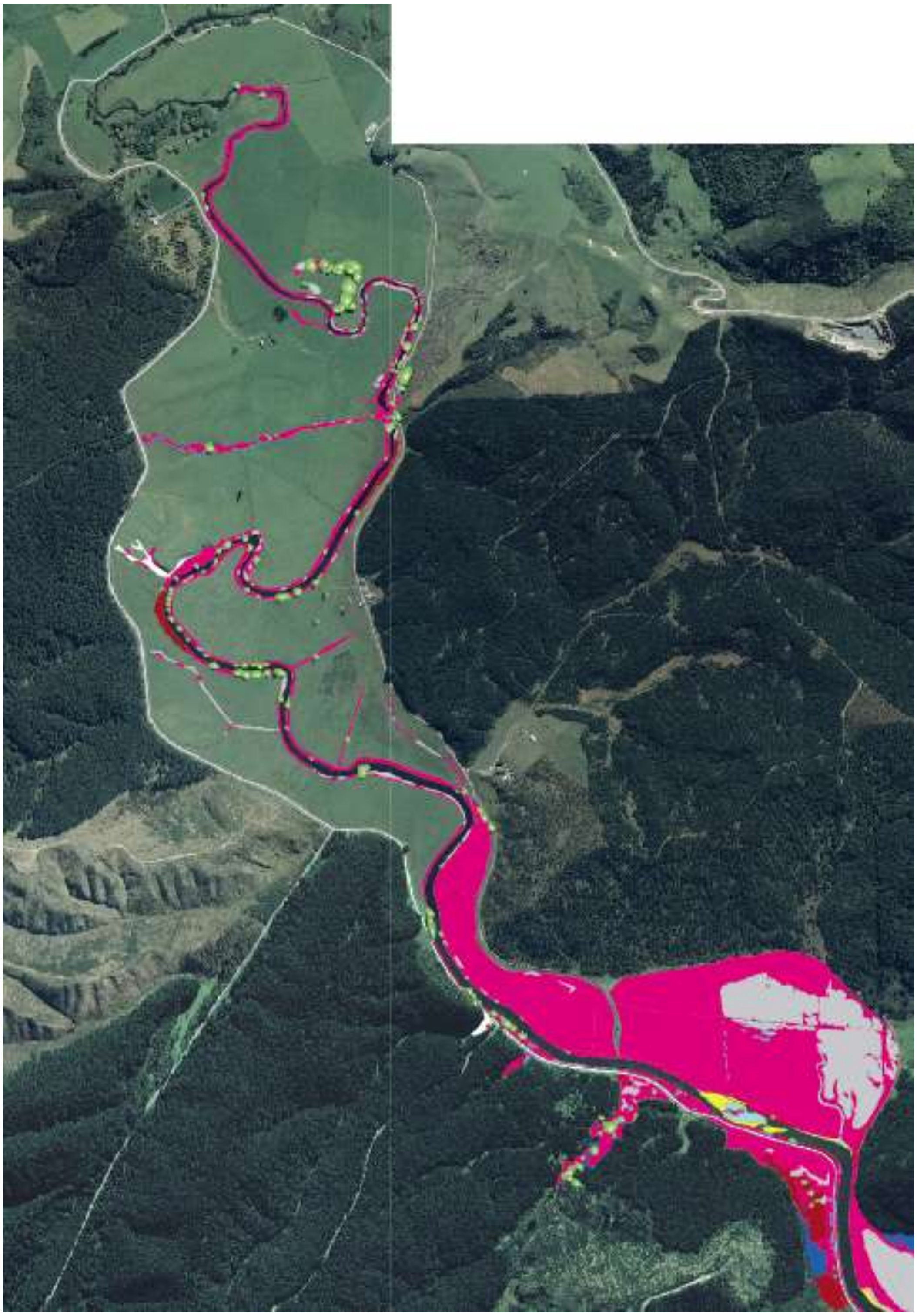

Figure 5a. *Upper Tokomairiro River Estuary showing habitat types (legend overleaf).*

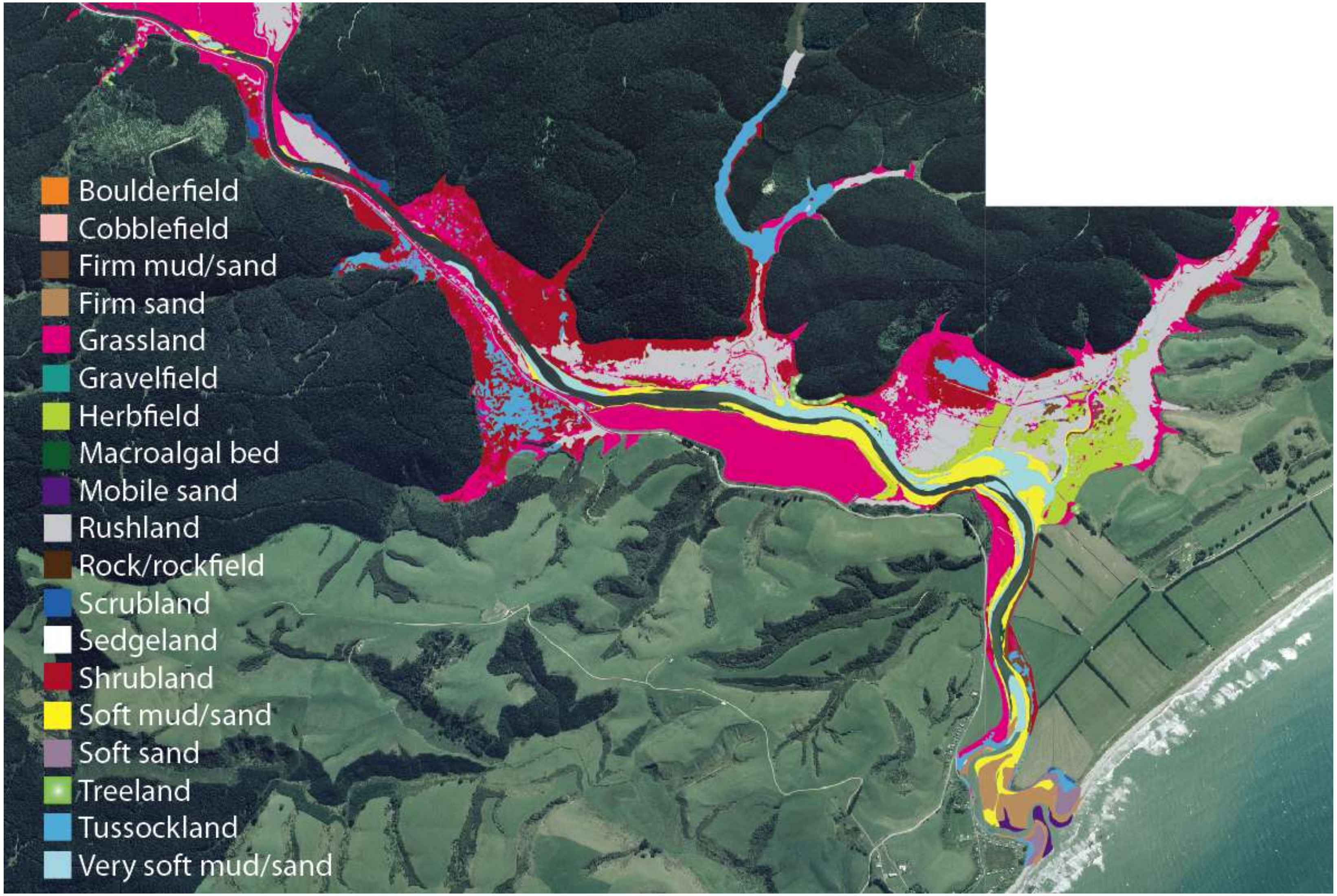

Figure 5b. *Lower Tokomairiro River Estuary showing habitat types.*

However, most of these tracts on both the true left bank and true right banks can be described as flood plain and, although currently used for grazing, may become inundated at times of high flood. A small portion of this floodplain has been set aside as a wetland reserve (Figure 6) and a large proportion of previously drained land appears to have been allowed to revert to its natural state (Figure 7).

Figure 6. *Lower Tokomairiro Wetland Reserve, true right bank, Tokomairiro River Estuary.*

Figure 7. *Extensive areas or rushland and herbfield on the true left bank, lower Tokomairiro River Estuary.*

Grassland is the dominant vegetation type surrounding the Tokomairiro River Estuary. Grasses are generally associated with flatter areas adjoining cultivated farmland and dominate the upper estuary on both sides, mid estuary on the true left bank and towards the estuary mouth on the true right bank (Figures 5a, 5b). The dominant grass along the estuary edge is tall fescue (*Festuca arundinacea*), with other common grass species including cocksfoot (*Dactylis glomerata*), sweet vernal (*Anthoxanthum odoratum*), Yorkshire fog (*Holcus lanatus*) and patches of reed sweet grass (*Glyceria maxima*).

The rushland vegetation type occurs most frequently on the true left bank, with reed beds ranging from the middle of the estuary to the furthest downstream floodplain (on the true left bank) (Figures 5a, 5b). Reed beds are dominated by *Juncus* species and to a lesser degree jointed wire rush (*Apodasmia similis*).

Large areas of shrubland are most common around mid estuary on the true right and left banks (Figures 5a, 5b). Shrubland generally occurs in conjunction with other vegetation types such as rushland and tussockland and generally comprises weed species such as gorse (*Ulex europaeus*), broom (*Cytisus scoparius*) and to a lesser extent, tree lupin (*Lupinus arboreus*).

Scattered individual flaxes (*Phormium tenax*) are common within the tussockland in the upper Tokomairiro River Estuary (Figure 5a), while a wetland reserve full of flax and toetoe is situated mid estuary on the true right bank (Figure 5b). Tussockland near the estuary mouth is dominated by marram grass (*Ammophila arenaria*) (Figure 5b).

A large expanse of herbfield covers the most downstream floodplain on the true left bank. Herbfield is generally dominated by sea primrose (*Samolus repens*) and swampweed (*Selliera radicans*), with the occasional appearance of glasswort (*Salicornia australis*), especially near the estuary mouth.

Stands of treeland, comprising of mainly crack willow (*Salix fragilis*) and cabbage tree (*Cordyline australis*), are scattered on both banks of the upper Tokomairiro River Estuary and occur less frequently towards the estuary mouth (Figures 5a, 5b).

Small clumps of scrubland, comprising of mainly manuka (*Leptospermum scoparium*), *Coprosma* species and saltmarsh ribbonwood (*Plagianthus divaricatus*), are most reasonably common mid estuary, but are generally situated at some distance from the river (Figure 5b).

Sedgeland is quite sparse and found at just three locations along the estuary (Figure 5a and 5b). Sedgeland in the upper estuary is generally dominated by *Carex* species, with three-square (*Schoenoplectus pungens*) dominating nearer the estuary mouth.

Exposed substrate is generally confined to a gravelfield in the bed of a small tributary on the true right bank of the upper estuary (Figure 5a). Firm sand is a feature of the lower estuary just upstream of the mouth with softer sand/mud substrates lining the shores as one moves upstream.

Table 3. *Proportions of the various habitat types at Tokomairiro River Estuary shown as hectares and percentage.*

Habitat	Area (ha)	% of total area
Firm mud/sand	2.57	0.76
Firm sand	7.34	2.16
Grassland	129.24	38.01
Gravelfield	0.12	0.03
Herbfield	16.89	4.97
Macroalgal bed	0.57	0.17
Mobile sand	1.38	0.41
Rockfield	0.01	0.00
Rushland	69.13	20.33
Scrubland	2.81	0.83
Sedgelend	0.47	0.14
Shrubland	53.60	15.76
Soft mud/sand	22.51	6.62
Soft sand	0.47	0.14
Treeland	4.89	1.44
Tussockland	21.33	6.27
Very soft mud/sand	15.22	4.48
Whole Estuary	348.53	100.00

4.3 Fine Scale mapping – Tokomairiro River Estuary

The Tokomairiro River Estuary was visited on 9th of November 2009. Two sites (Figure 8) were sampled according to the methodology described above. The two sites are perhaps a little closer together than ideal but further up the estuary from the upstream site the substrate became difficult to access. Both sites were located on low tidal sand/mud flats, representative of much of the lower estuarine area.

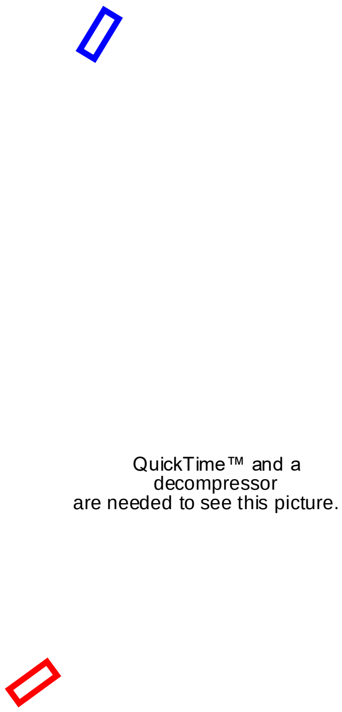

Figure 8. *Location of fine scale sites at the Tokomairiro River Estuary. Upstream site in blue, downstream site in red.*

4.3.1 Sediment Core Profiles

Photographs of sediment cores are presented in Appendix 1. The upstream site (Site 1) comprised predominantly soft sand and mud with a fine gravel component and abundant decaying fibrous organic material. A redox discontinuity layer (RDL) appeared in many of the cores (Table 4) and varied in nature from a deep but relatively diffuse layer to a very intensely discoloured upper layer. A very mild smell of hydrogen sulphide associated with each core was detectable at Site 1 but not at Site 2.

Table 4. *Brief description of sediment cores at the upstream site (Site 1), Tokomairiro River Estuary.*

Core #	Substrate	RDL begins (mm depth)	RDL ends (mm depth)	Nature of RDL	H_2S detected
1	Fine sand/mud	2	120	Diffuse	Mild
2	Fine sand/mud	2	80	Well defined	Mild
3	Fine sand/mud	2	110	Diffuse	Mild
4	Fine sand/mud	2	110	Diffuse	Mild
5	Fine sand/mud	2	130	Diffuse	Mild
6	Fine sand/mud	2	>150	Diffuse	Mild
7	Fine sand/mud	2	70	Well defined	Mild
8	Fine sand/mud	5	130	Well defined	Mild
9	Fine sand/mud	2	70	Intense	Mild
10	Fine sand/mud	5	70	Diffuse	Mild
11	Fine sand/mud	2	120	Well defined	Mild
12	Fine sand/mud	2	55	Well defined	Mild

The downstream site (Site 2) comprised firm fine sand with a very sparse fine gravel component (Table 5, Appendix 1). The redox discontinuity layer was discernible as a diffuse to patchy layer extending to beyond 200mm in most cores.

Table 5. *Brief description of sediment cores at the downstream site (Site 2), Tokomairiro River Estuary.*

Core #	Substrate	RDL begins (mm depth)	RDL ends (mm depth)	Nature of RDL	H_2S detected
1	Fine sand	30	>200	Diffuse	No
2	Fine sand	30	>200	Diffuse	No
3	Fine sand	15	>200	Diffuse	No
4	Fine sand	50	>200	Very Diffuse	No
5	Fine sand	30	>200	Diffuse to intense	No
6	Fine sand	5	>200	Patchy	No
7	Fine sand	30	>200	Patchy	No
8	Fine sand	15	>200	Diffuse	No
9	Fine sand	20	>200	Diffuse	No
10	Fine sand	25	>200	Patchy	No
11	Fine sand	20	>200	Patchy	No
12	Fine sand	10	90	Diffuse	No

4.3.2 Epifauna

At each sub-site a randomly placed 0.25m^2 quadrat was photographed to assess epifauna. The photographs are presented in Appendix 1. At the upstream site (Site 1) the substrate surface characterised by fine mud, fine sand and occasional very small pebbles. Epifauna, comprising almost exclusively the mudsnail *Amphibola crenata*, were evident in all to the quadrats, albeit sparsely in a few (Figure 8).

Site 2 (downstream) had a substrate surface characterised by fairly uniform fine sand and the very occasional broken shell fragment and very small pebble. There was also a real paucity of epifauna with no animals seen within the majority of the quadrats. Very low densities of *Amphibola crenata* were present in two quadrats and the burrows of the small burrowing mud crab, *Helice crassa,* were evident in a further quadrat. Amphipod burrows, however, were reasonably common.

Figure 8. *Soft muddy sand with a sprinkling of* Amphibola crenata *at Site 1, Tokomairiro River Estuary.*

4.3.3 Macroalgae

At each subsite the randomly placed 0.25m^2 quadrat photographed to assess epifauna was used to assess macroalgal cover at the fine scale, in addition to the broad scale mapping of macroalgae already discussed. At both Sites 1 and 2 macroalgae was almost totally absent. Some *Gracilaria chilensis* was present in small tufts at Site 1, but not within any of the quadrats. Site 2 had some very small remnants of drift *Ulva lactuca,* but once again, not within quadrats.

4.3.4 Infauna

At each sub-site the contents from a 125mm diameter corer, driven into the substrate to a depth of 150mm at three randomly located sites, were sieved through a 0.5mm mesh Endicott® sieve. Retained material was examined in the laboratory using a 10X power dissecting microscope to assess infauna. Infauna at Site 1 was moderately rich and was characterised by burrowing polychaete worms and amphipods (Table 6) with occasional bivalve and gastropod molluscs. Mean number of infaunal animals per square metre at Site 1 is 5000 with a mean of 8 taxa present for the site (Table 6).

At Site 2 there are slightly fewer animals per square metre, due largely to the lower number of phoxocephalid amphipods. The infauna is once again dominated by amphipods, with a diversity of burrowing polychaete worms and a rare bivalve mollusc (Table 7). Mean number of infaunal animals per square metre at Site 2 is 4225 with a mean of 8 taxa present for the site (Table 7).

Table 6. *Infauna at three sub sites sampled at the upstream site (Site 1), Tokomairiro River Estuary.*

			GPS	E1372023	E1372024	E1372021
			co-ordinates	N4878427	N4878436	N4878438
			Sample	1	2	3
Phylum		Family	Genus/species			
Annelida						
	Polychaeta					
		Glyceridae		4	2	5
		Nephtyidae	*Aglaophamus macroura*	1	1	3
		Nereididae		2	3	6
		Spionidae			1	1
Hemichordata						
	Enteropneusta					1
Crustacea						
	Amphipoda					
		Gammaridae		13	2	16
		Haustoriidae				1
		Lysianassidae		8		9
		Phoxocephalidae		57	18	43
	Isopoda					
		Scolioidea	*Isocladus armatus*			1
Mollusca						
	Gastropoda					
		Amphibolidae				
			Amphibola crenata		1	
	Bivalvia					
		Veneridae				
			Austrovenus stutchburyi			1
Number of Animals				85	28	87
Animals/m^2				6375	2100	6525
Number of Taxa				6	7	11

Table 7. *Infauna at three sub sites sampled at the downstream site (Site 2), Tokomairiro River Estuary.*

			GPS	E1371919	E1371928	E1371939
			co-ordinates	N4877687	N4877698	N4877711
			Sample	1	2	3
Phylum		Family	Genus/species			
Annelida						
	Polychaeta					
		Glyceridae		4	2	6
		Nephtyidae	*Aglaophamus macroura*	12	9	6
		Nereidae		2		2
		Nereididae		3		3
		Spionidae		2	4	6
Crustacea						
	Amphipoda					
		Gammaridae		8	10	48
		Lysianassidae			8	14
		Phoxocephalidae		9	2	6
	Decapoda					
		Ocypodidae				
			Macrophthalmus hirtipes	1		
Mollusca						
	Bivalvia					
		Veneridae				
			Austrovenus stutchburyi	1	1	
Number of Animals				42	36	91
Animals/m^2				3150	2700	6825
Number of Taxa				9	7	8

4.3.5 Chemical Analysis

Replicate 250ml samples were scooped from the top 20mm of substrate at each of the 12 sub-sites at Sites 1 and 2. The replicate samples were thoroughly combined in a plastic bucket and a 500ml composite sample taken for each site. The composite samples were returned to the laboratory and frozen before being sent to Hill Laboratories in Hamilton for analysis.

All measured parameters were found at low levels at both Site 1 (upstream) and Site 2 (downstream) (Table 8). Site contaminants were present in uniformly slightly higher concentrations (Table 8).

Observations in the field with respect to the nature of the substrate at each site were confirmed by particle size analysis with the higher proportion of finer sediments being found at the upstream site (Table 8). This result and the slightly higher concentration of metals at this site likely reflects the more sheltered and less well flushed nature of the upstream site (Figure 8).

Table 8. *Chemical analysis of sediments in Tokomairiro River Estuary.*

Parameter	ANZECC ISQG-Low Trigger Value	ANZECC ISQG-High Trigger Value	Site 1 (Upstream)	Site 2 (Downstream)
Dry Matter (g/100g)	-	-	71	82
Ash (g/100g)	-	-	98	99
Loss on Ignition (g/100g)	-	-	2.2	1.2
Total Nitrogen (g/100g)	-	-	0.093	0.061
Total Phosphorus (mg/kg)	-	-	410	350
Arsenic	20	70	4.1	3.3
Cadmium (mg/kg)	1.5	10	<0.10	<0.10
Chromium (mg/kg)	80	370	8.9	4.2
Copper (mg/kg)	65	270	5.3	2.5
Nickel (mg/kg)	21	52	6.8	3.4
Lead (mg/kg)	50	220	5.5	2.9
Zinc (mg/kg)	200	410	37	16
Dry matter sieved (g/100g)			71	80
>2mm fraction (g/100g)	-	-	5.2	0.6
63µm – 2mm fraction (g/100g)	-	-	51.0	88.1
<63µm fraction (g/100g)	-	-	43.8	11.3

5. Discussion and Recommendations

The Tokomairiro River Estuary is typical of moderately enriched southern South Island estuaries. There has been a considerable amount of reclamation for farmland, but the remaining estuarine area remains largely intact with no further reclamation in progress. There are some environmental pressures within the estuary, mainly from nutrient loadings and stock grazing. Direct human impacts are limited to some littering and dumping of anthropogenic debris, plus a small amount of damage by vehicular movements. While the Tokomairiro River Estuary is subject to flooding on occasion the relatively narrow nature of the upper estuary generally limits impacts. In the lower estuary there are quite large tracts of land that would be inundated during moderate to high floods.

The estuary shows a healthy suite of estuarine flora dominated by grassland that generally borders farmland. There are also extensive areas of rushland, shrubland and herbfield. Macroalgae are relatively scarce and nuisance growths that could be attributed to enrichment were not evident anywhere within the estuary during this survey.

Fauna, although not overly abundant or diverse, are representative of typical estuarine animals found in healthy environments (Morton and Miller 1973). Polychaete worms and amphipods are a feature of all estuaries in the Otago region but densities of these animals are slightly lower than one would expect. Shellfish, such as cockles, are very scarce within the lower estuary and there is, consequently, little pressure from recreational harvesting. Mud crabs, mud snails are notably scarce in the lower estuary, likely due to the absence of suitable habitat. Mud crab burrows are, however, evident in mud banks along the margins of the river slightly further upstream in the estuary.

There is some evidence of very slight contamination of the sediments within the Tokomairiro River Estuary. However, levels are very low and are most likely stem from runoff from farmland or possibly stormwater runoff from Milton, although this is well upstream from the estuary.

The sediments within the estuary reflect the geology of the Tokomairiro River catchment and the poorly flushed nature of much of the estuary, with there being a high proportion of fine sediment, silt and mud no more than 1.5km upstream from the mouth. There are patches of anoxic sediment within the estuary, but nothing that would not be expected in moderately enriched estuaries.

In conclusion the Tokomairiro River Estuary appears to be in relatively good health. Areas of concern that may require further investigation are nutrient enrichment and also the direct impacts of humans (vehicles) along portions of the shore of the estuary. These pressures are not significant but may require monitoring over the coming years.

It is gratifying to note the reversion of much of the reclaimed land to natural rushland and herbfield. Whether or not this is by design or merely because such areas are no longer economic to farm/keep cleared is a moot point.

6. References

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APPENDIX 1

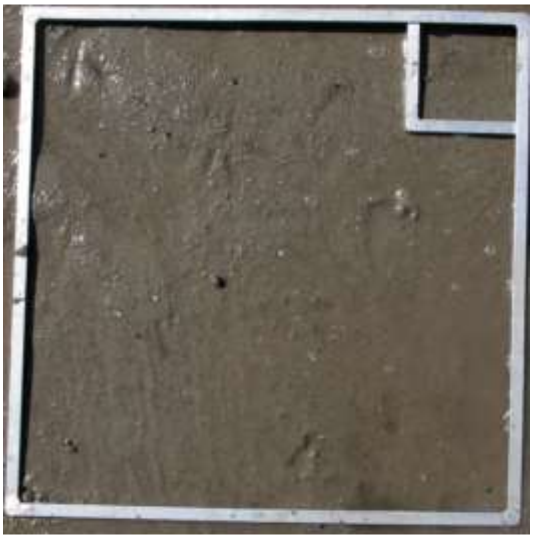
Quadrats and a representative core from each quadrat for fine-scale mapping.

Tokomairiro River Estuary
Site 1 (Upstream)

Quadrat 1

Quadrat 2

Quadrat 3



Quadrat 4

Quadrat 5

Quadrat 6

Quadrat 7

Quadrat 8

Quadrat 9


Quadrat 10

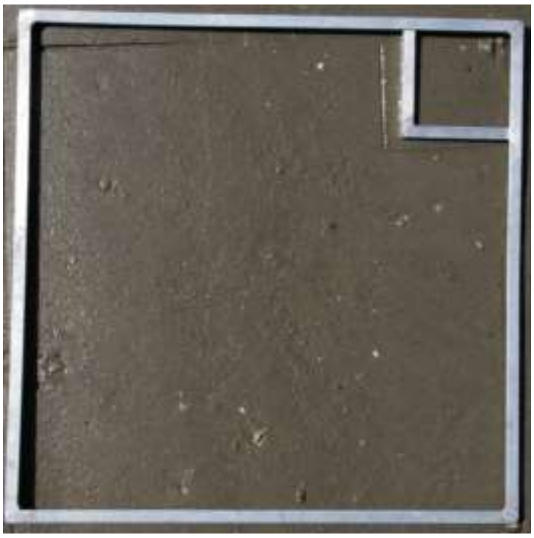

Quadrat 11


Quadrat 12


Tokomairiro River Estuary
Site 2 (Downstream)
Quadrat 1


Quadrat 2

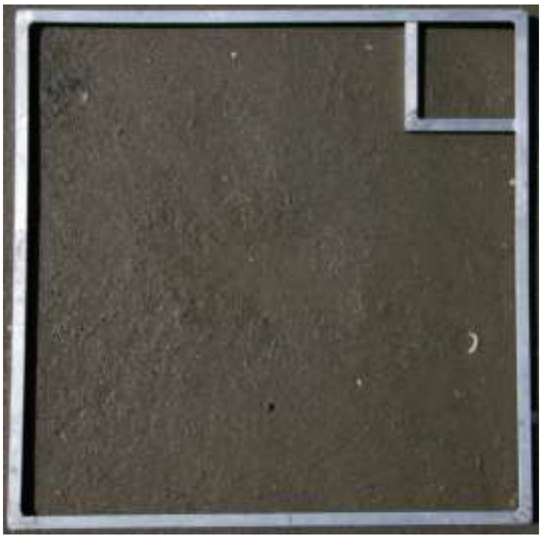

Quadrat 3



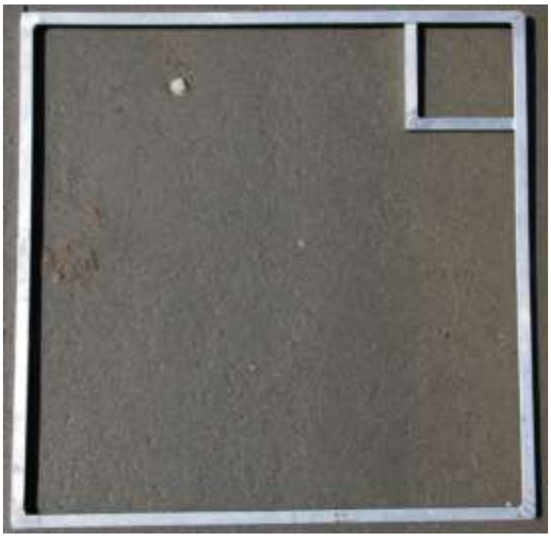

Quadrat 4


Quadrat 5

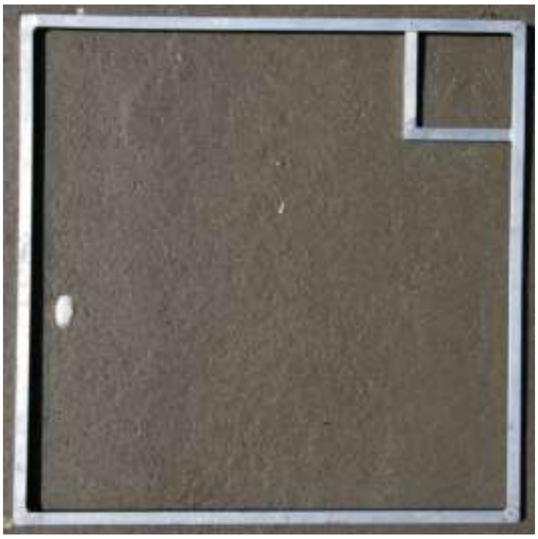

Quadrat 6



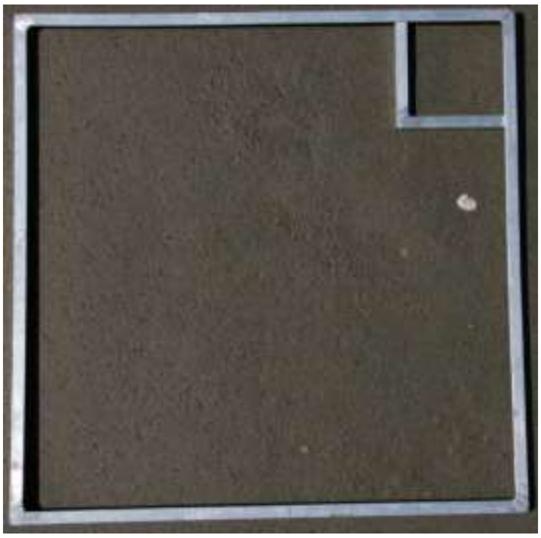

Quadrat 7



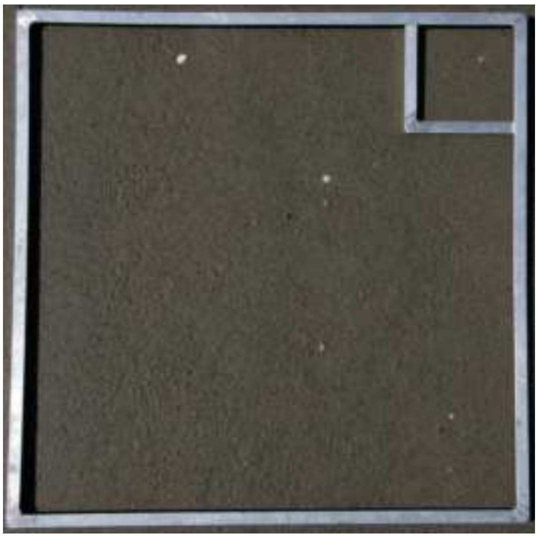

Quadrat 8



Quadrat 9



Quadrat 10



Quadrat 11

Quadrat 12