Habitat Mapping of the Taieri River Estuary

Otago Regional Council State of the Environment Report

Prepared by

Ryder Consulting

April 2008

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Cover photo: Taieri 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.

While the Taieri River Estuary is not designated as a Coastal Protection Area (CPA22) under the Otago Regional Council's Regional Plan: Coast, it does have importance in terms of its ecological, scenic, recreational, spiritual and cultural values. The fishing and recreational facilities just downstream of the Taieri Mouth Road bridge are designated as a Coastal Development Area (CDA5). It is recognised that there is the potential for adverse effects on the intertidal ecosystem of the estuary from sediment runoff, discharges, stormwater, recreational use and alterations to the river 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 Taieri 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 (2-20 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 of = 1%.
Cobble field: Land in which the area of unconsolidated cobbles/stones (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%.
Boulder field: Land in which the area of unconsolidated bare boulders (> 200 mm 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 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. i.e. 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 at the different sites include:

- Flooding

- Introduced weeds
- Nutrient pollution
- Stormwater
- Vehicles
- Stock
- Erosion
- 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 Taieri 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 80 mm diameter core was collected to a depth of at least 100 mm 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.

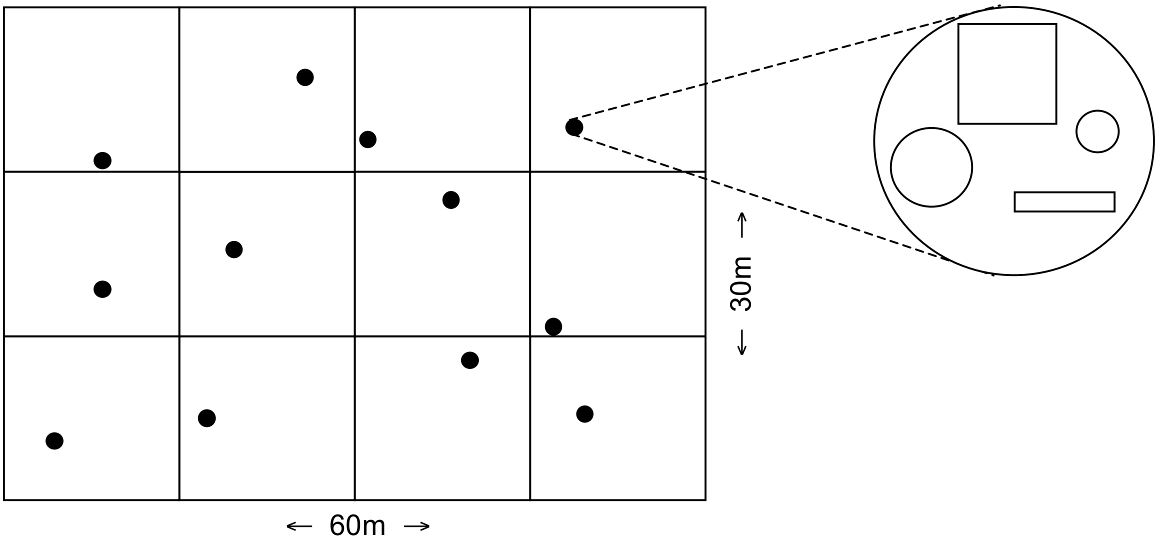

Figure 1. *Layout of sampling area. Squares are sub-areas; black dots are randomly located sampling plots. Circle on right is an enlargement of a sampling plot showing 0.25m^2 quadrat for epibiota analysis, small sediment core for RDL determination, large sediment core for infauna analysis, and small 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 125 mm diameter (area = 0.0039 m^2) corer.
- The corer was driven into the sediments to a depth of 150 mm, removed with core intact and the contents washed through 0.5 mm 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 20 mm 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 each estuary), as done by Stevens *et al*. (2004) for a similar exercise around Wellington and by Stewart (2007, 2008). 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
  Cadmium
  Chromium
  Copper
  Lead
  Nickel
  Zinc

4. Results

4.1 Environmental Pressures

A summary of environmental pressures identified at the Taieri River Estuary 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, 2008), 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 scattered and, where this happened, they were not recorded under broad scale mapping in this survey. However, where dense stands of gorse (*Ulex europaeus*) were encountered these were recorded as scrubland.

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

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

Pressure	Taieri River Estuary
Flooding	A4
Introduced weeds	✓
Nutrient pollution	A3
Stormwater	D4
Vehicles	D4
Litter and dumped items	D3
Stock (grazing/trampling)	D3
Erosion	C3
Reclamation	D2
Degree of modification*	M
Leachate from Landfills	N/A

* 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.

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. For the Taieri Estuary reclamation, in most cases, has occurred where the flood plains of tributaries have been fenced off and drained. There is, however, little evidence of recent reclamation in the estuary.

Within the estuary there were a few places at the upstream end of the gorge that showed signs of relatively recent, and reasonably heavy, erosion (Figure 2). This may be due to the very high flows experienced on 1 August 2007 as the erosion is generally confined to the main channel. Although scoring just a C3 in the level of concern matrix above

(Table 2) due to the relatively small area affected, we believe this issue is of some concern.

Figure 2. *Evidence of relatively recent erosion along the main channel, Taieri River Estuary.*

Although likely not attributable to erosion, we did observe wind damage that will have occurred during the high winds of late October 2007 (Figure 3).

Figure 3. *Wind damage, Taieri River Estuary.*

Overall the presence of only one red cell for the Taieri River Estuary suggests that the estuary is considered to be only slightly to moderately affected by the pressures identified at the present point in time. This reflects the relative isolation of the Taieri River Estuary and the generally low intensity farming along its shores.

4.2 Broad Scale Mapping – Taieri River Estuary

4.2.1 Ground-truthing and digitising habitat

The Taieri River Estuary was visited for the purpose of broad scale mapping on 31 October 2007. Five prominent landmarks were located using aerial photographs (Figure 4) 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). Taieri River Estuary cannot be walked in its entirety, so a small boat was used where necessary with notes being taken on substrate type, vegetation cover and type and any other distinguishing features. Drawings were made on field copies of aerial photographs to aid in the digitising of field information. 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.

4.2.2 Habitat and Substrate Features

The Taieri River has a long, generally narrow, and irregularly shaped estuary (Figure 4) that covers in excess of 270 hectares with a relatively low percentage of the estuary area being exposed at low water. It is apparent that large areas of what was once estuary or flood plain along the margins of the upper estuary have been developed for farming at some time in the past, although such areas appear to have been developed for a considerable time. Some areas of the remaining estuary, however, are still exposed to stock from time to time.

Herbfield, common in most other Otago estuaries, is non-existent in the Taieri River estuary (Figure 5, Table 3). Instead, grassland is very widespread, especially in areas that adjoin cultivated farmland and as patches in sheltered bays and on the deltas of both major and minor tributaries (Figure 5).

Rushland is found in patches on either side of the main channel with occasional extensive rush beds on ground that has been reclaimed for farming. Reedlands are relatively rare and are confined to small areas near the upstream end of the estuary (Figure 5).

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

Habitat type	Area (ha)	% of total area
Boulderfield	0.06	0.02
Cobblefield	2.50	0.91
Firm mud/sand	23.96	8.73
Firm sand	56.82	20.71
Grassland	91.57	33.38
Gravelfield	0.90	0.33
Macroalgae	0.85	0.31
Mobile sand	43.91	16.00
Reedland	0.11	0.04
Rockfield	3.02	1.10
Rushland	23.37	8.52
Scrubland	0.39	0.14
Shrubland	7.64	2.79
Soft sand	4.24	1.54
Soft sand/mud	10.55	3.85
Treeland	0.55	0.20
Tussockland	3.94	1.44
Total	274.36	100.00

Macroalgal beds comprising patches of *Gracilaria chilensis* are extensive on sand and mudflats along both banks of the lower estuary and within the confines of the gorge. However, although covering a reasonably large area, these macroalgal beds are quite diffuse, with sand and mud exposed between individual plants.

Marram grass (*Ammophila arenaria*) and tree lupin (*Lupinus arboreus*) are features of the sand dunes on either side of mouth of the estuary, but lie above EHWS so are not strictly part of the estuary habitat.

Substrate within the Taieri River Estuary is characterised by firm mud/sand with soft mud/sand in water channels. Nearer the estuary mouth firm sand predominates with a broad swath of mobile sand lining the main channels. Higher on the shoreline where sand is dry the dominant substrate is soft sand. The middle of larger water channels was generally too deep to sample and such areas are left blank in Figure 5.

Figure 4. *Taieri River estuary with ground truthing sites shown as yellow bars.*

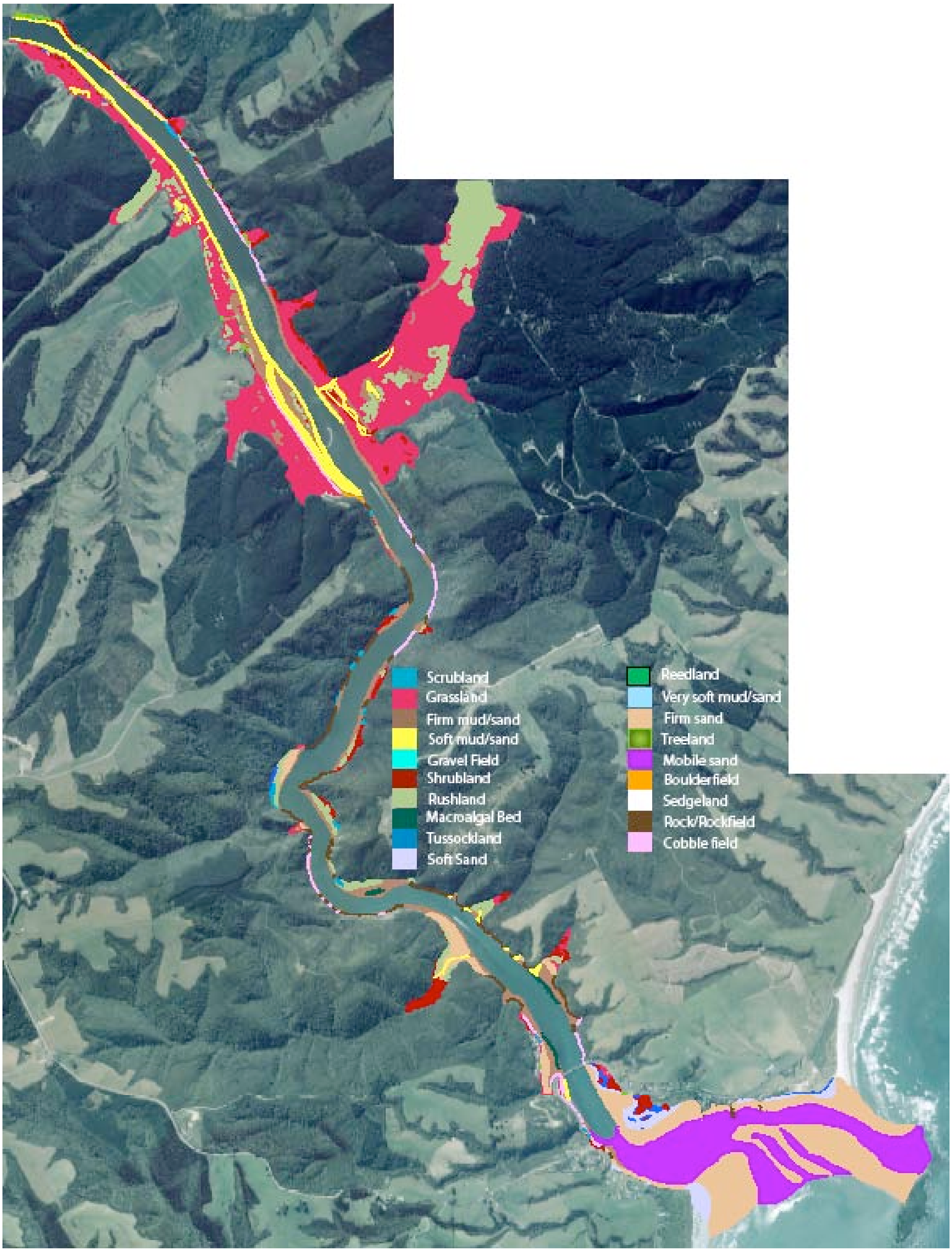

Figure 5. *Taieri River Estuary with different habitats mapped. More clarity and detail is available on GIS files lodged with the ORC.*

4.3 Fine Scale mapping – Taieri River Estuary

The Taieri River Estuary was visited on 31 October and 1 November, 2007. Two sites (Figure 6), selected during the broad scale mapping, were sampled according to the methodology described above. Both sites were located on low tidal sand flats, representative of much of the greater estuarine area.

Figure 6. *Taieri River Estuary with locations of Downstream (blue) and Upstream (red) fine scale mapping sites shown.*

4.3.1 Sediment Core Profiles

Photographs of sediment cores are presented in Appendix 1. The downstream site (Site 1) comprised predominantly firm fine sand. A redox discontinuity layer (RDL) appeared in just two of the cores (Table 4) and was quite diffuse. In no instance was a smell of hydrogen sulphide detectable.

Table 4. *Brief description of sediment cores at downstream site (Site 1), Taieri River Estuary.*

Core #	Substrate	RDL begins (mm depth)	RDL ends (mm depth)	Nature of RDL	H_2S detected
1	Fine sand	nil	nil	nil	No
2	Fine sand	nil	nil	nil	No
3	Fine sand	nil	nil	nil	No
4	Fine sand	nil	nil	nil	No
5	Fine sand	100	150	diffuse	No
6	Fine sand	50	70	diffuse	No
7	Fine sand	nil	nil	nil	No
8	Fine sand	nil	nil	nil	No
9	Fine sand	nil	nil	nil	No
10	Fine sand	nil	nil	nil	No
11	Fine sand	nil	nil	nil	No
12	Fine sand	nil	nil	nil	No

The upstream site (Site 2) was once again predominantly firm fine sand but with a proportion of silt (Appendix 1). A redox discontinuity layer was discernible in all cores with intensity ranging from well defined to patchy (Table 5).

Table 5. *Brief description of sediment cores at upstream site (Site 2), Taieri River Estuary.*

Core #	Substrate	RDL begins (mm depth)	RDL ends (mm depth)	Nature of RDL	H_2S detected
1	fine sand/silt	20	>150	well defined	No
2	fine sand/silt	0	>150	patchy	No
3	fine sand/silt	10	>150	intense	No
4	fine sand/silt	40	>150	well defined	No
5	fine sand/silt	50	>150	patchy	No
6	fine sand/silt	50	>150	patchy	No
7	fine sand/silt	60	>150	patchy	No
8	fine sand/silt	60	>150	patchy	No
9	fine sand/silt	60	>150	intense	No
10	fine sand/silt	30	>150	well defined	No
11	fine sand/silt	30	>150	well defined	No
12	fine sand/silt	30	>150	patchy	No

4.3.2 Epifauna

At each subsite a randomly placed $0.25m^2$ quadrat was photographed to assess epifauna. The photographs are presented in Appendix 1. At the downstream site (Site 1) all sub sites were devoid of macroalgae and were characterised by fine sand with no epifauna in evidence, although burrows of polychaete worms and amphipods were common.

Site 2 (upstream) also displayed a relative paucity of epifauna with just occasional mud snails (*Amphibola crenata*) and crab (*Helice crassa*) burrows seen within most $0.25m^2$ quadrats (Figure 7, Table 6). Overall density of epifauna at Site 2 was; mud snails 10.4 per square metre crab, cockles 0.66 per square metre, topshells 0.66 per square metre and crab burrows 3 per square metre.

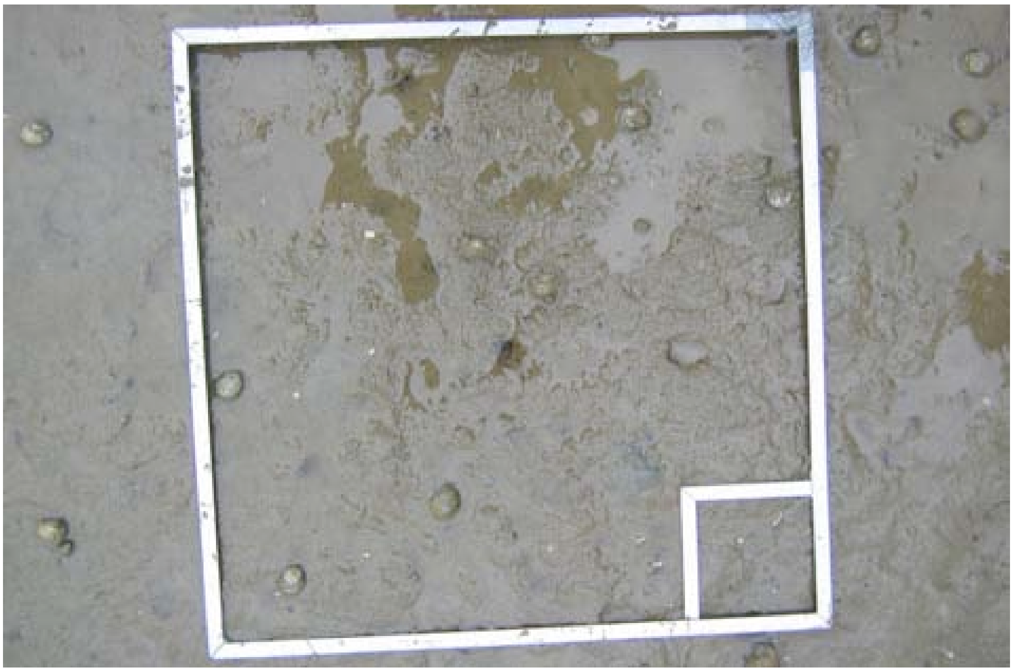

Figure 7. Helice crass*a burrows and mud snails (*Amphibola crenata*) at Site 2, Taieri River Estuary.*

Table 6. *Epifauna (individuals per square metre) at upstream site (Site 2), Taieri River Estuary.*

Quadrat #	Substrate surface	Mud snails (m^{-2})	Cockles (m^{-2})	Topshells (m^{-2})	Crabs (m^{-2})
1	Muddy sand	1	4	-	-
2	Muddy sand	4	-	-	-
3	Muddy sand	-	-	-	-
4	Muddy sand	-	-	-	-
5	Muddy sand	-	-	-	-
6	Muddy sand	4	-	-	-
7	Muddy sand	12	-	-	-
8	Muddy sand	16	-	-	4
9	Muddy sand	8	-	-	4
10	Muddy sand	20	4	4	-
11	Muddy sand	28	-	4	12
12	Muddy sand	32	-	-	16

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 Site 1 there was no macroalgae observed in any quadrat. At Site 2 macroalgae was very scarce. *Gracilaria chilensis* was barely noticeable at Site 2 with <1% cover at Quadrats 2 and 3. Beyond the quadrats in deeper channels sparsely scattered small clumps of *Gracilaria chilensis* were more common and covered quite extensive areas. An extremely fine surface film of centric diatoms was evident in most quadrats at Site 2.

4.3.4 Infauna

Infauna at Site 1 were characterised by a variety of burrowing polychaete worms and amphipods (Table 7).

Mean number of infaunal animals per square metre at Site 1 is 1650 with a mean of 3 taxa present for the site.

At Site 2 the infauna was dominated by burrowing polychaete worms and amphipods with a small number of molluscs (Table 8).

Table 7. *Infauna at three sub sites sampled at downstream site (Site 1), Taieri River Estuary.*

				Downstream site		
			GPS	E2292832	E2292854	E2292796
			co-ordinates	N5457657	N5457649	N5457683
			Sample	1	2	3
Phylum		Family	Genus/species			
Annelida						
	Polychaeta					
		Nephtyidae		1	1	1
		Neriididae		7	1	
		Spionidae			1	
Crustacea						
	Amphipoda					
		Phoxocephalidae			1	51
Mollusca						
	Bivalvia					
		Mesodesmatidae				
			Paphies australis	1		
		Veneridae				
			Austrovenus stutchburyi	1		
Number of Animals				10	4	52
Animals/m ^{2}				750	300	3900
Number of Taxa				4	4	2

Table 8. *Infauna at three sub sites sampled at upstream site (Site 2), Taieri River Estuary.*

				Upstream site		
			GPS	E2291641	E2291685	E2291754
			co-ordinates	N5459234	N5459207	N5459138
			Sample	1	2	3
Phylum		Family	Genus/species			
Annelida						
	Polychaeta					
		Glyceridae		3		
		Nephtyidae		8	23	3
		Neriididae		4	5	
Crustacea						
	Amphipoda					
		Phoxocephalidae		13	38	46
Mollusca						
	Gastropoda					
		Amphibolidae				
			Amphibola crenata			2
		Hydrobiidae				
			Pomatopyrgus estuarinus	4	3	4
	Bivalvia					
		Veneridae				
			Austrovenus stutchburyi			1
Number of Animals				32	69	56
Animals/m^2				2400	5175	4200
Number of Taxa				5	4	5

Mean number of infaunal animals per square metre at Site 2 is 3925 with a mean of 5 taxa present for the site.

4.3.5 Chemical Analysis

Replicate 250ml samples were scooped from the top 20mm of substrate at each of the twelve subsite 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 except phosphorus were found at very low levels (Table 9). Phosphorus levels were slightly elevated but, as already stated, there are no guidelines for phosphorus contamination of sediments. There was some minor contamination by heavy metals at both sites but it is at levels well below the ANZECC ISQG – Low Trigger values (Table 9).

Observations in the field that the substrate at the upstream site was slightly more muddy than at the downstream site were confirmed with a higher proportion of the <63µm fraction present at Site 2 than at Site 1 (Table 9).

Table 9. *Physico-chemical analysis of sediments in Taieri River Estuary.*

Parameter	ANZECC ISQG-Low Trigger Value	ANZECC ISQG-High Trigger Value	Downstream (Site 1)	Upstream (Site 2)
Dry Matter (g/100g)	-	-	74	70
Ash (g/100g)	-	-	99	98
Loss on Ignition (g/100g)	-	-	0.74	1.9
Total Nitrogen (g/100g)	-	-	<0.05	0.076
Total Phosphorus (mg/kg)	-	-	450	450
Cadmium (mg/kg)	1.5	10	<0.01	0.021
Chromium (mg/kg)	80	370	3.2	7.0
Copper (mg/kg)	65	270	1.9	4.4
Nickel (mg/kg)	21	52	3.2	6.4
Lead (mg/kg)	50	220	2.0	5.3
Zinc (mg/kg)	200	410	12.0	27.0
Dry matter sieved (g/100g)	-	-	74	70
>2mm fraction (g/100g)	-	-	<0.1	0.6
63μm – 2mm fraction (g/100g)	-	-	98.5	82.0
<63μm fraction (g/100g)	-	-	1.5	17.4

5. Discussion and Recommendations

The Taieri River Estuary is typical of moderately enriched southern South Island estuaries. There has been some reclamation for farmland, but the remaining estuarine area is largely intact with no further reclamation in progress. There are some environmental pressures within the estuary, mainly from nutrient loadings, stock grazing and erosion. While the estuary is subject to flooding on occasion the rocky nature of the Taieri Gorge generally limits impacts. Thus, erosion of concern at the estuary is largely confined to the edges of deltas formed by tributaries.

The estuary shows a healthy suite of estuarine flora dominated by grassland generally bordering farmland. Macroalgae are relatively scarce and nuisance growths that could be attributed to enrichment are not evident anywhere within the estuary.

Fauna too, are representative of typical estuarine animals found in healthy environments (Morton and Miller 1973). Mud crabs, mud snails, polychaete worms and amphipods are a feature of all estuaries in the Otago region and densities of these animals are as one would expect. Shellfish, such as cockles, are relatively scarce and, despite some anecdotal evidence of cockle gathering at Taieri Mouth, there is little pressure from recreational harvesting.

The levels of contaminants at the Taieri River Estuary are considerably lower than at, for example, Kaikorai Estuary (Stewart (2008). This is likely a reflection of the more remote location of this estuary. As can be expected, levels of heavy metals usually associated with urban and road runoff (Zn, Cu, Fe) are very low.

The sediments within the estuary reflect the geology of the catchment, with the Taieri Estuary having a lower proportion of very fine sediment compared with some other Otago estuaries (Stewart 2008). There are patches of anoxic sediment within the inlet, but nothing that would not be expected in moderately enriched estuaries.

In conclusion the Taieri River Estuary appears to be in good health. Areas of concern that may require further investigation are erosion along some of the grassed banks in the upper estuary. It may be worthwhile monitoring this over the coming years.

6. References

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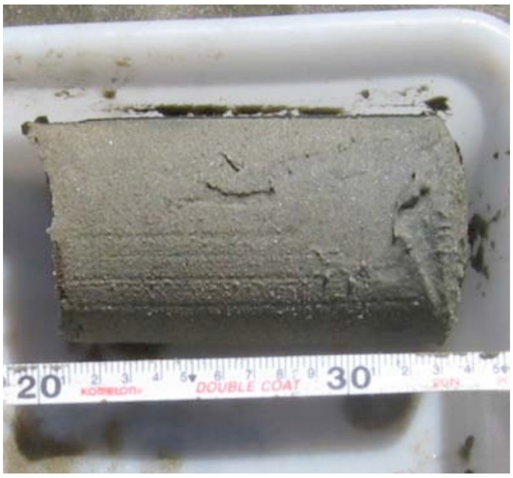
APPENDIX 1

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

Taieri River Estuary
Site 1 (Downstream)

Quadrat 1


Quadrat 2

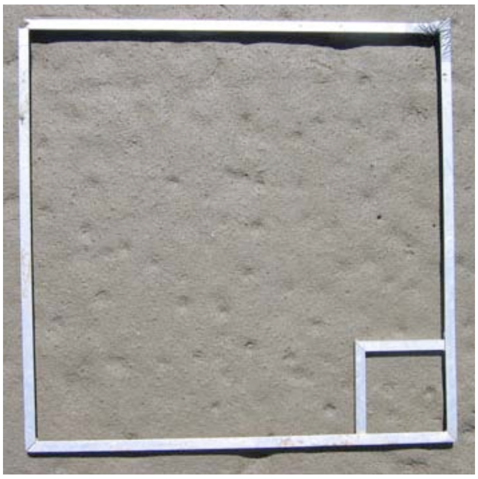
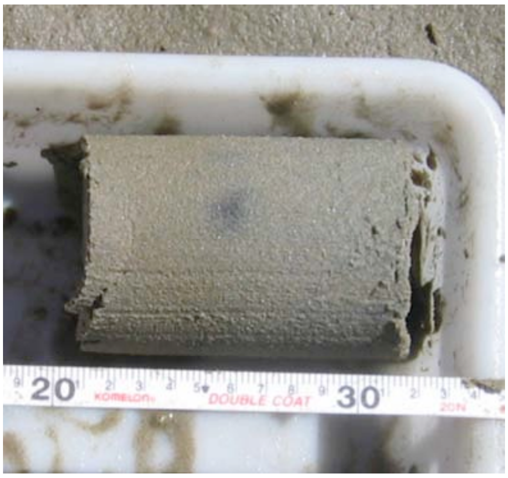



Quadrat 3


Quadrat 4


Quadrat 5


Quadrat 6

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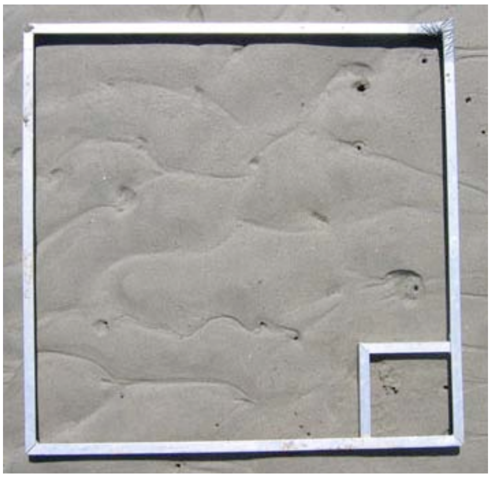
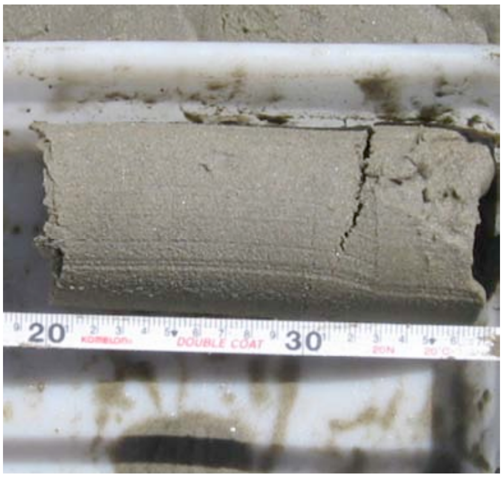
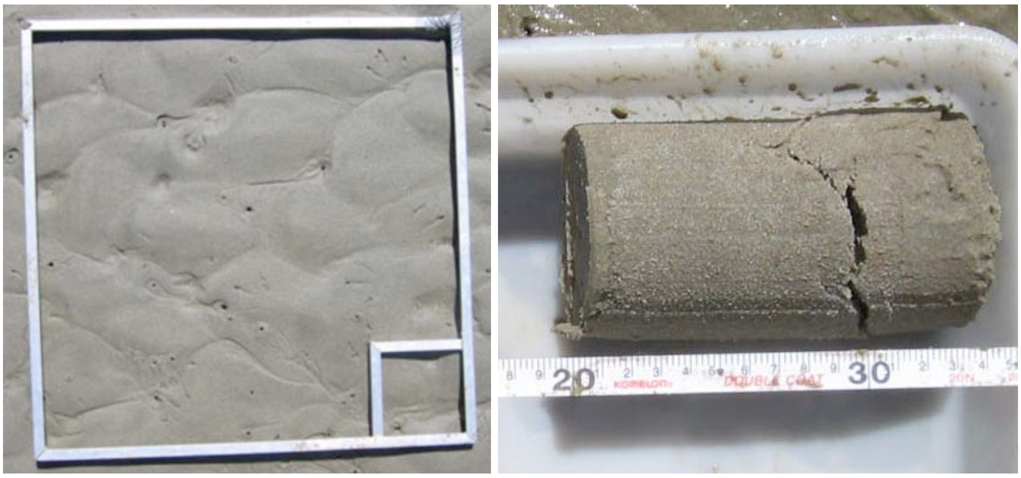



Quadrat 8


Quadrat 9



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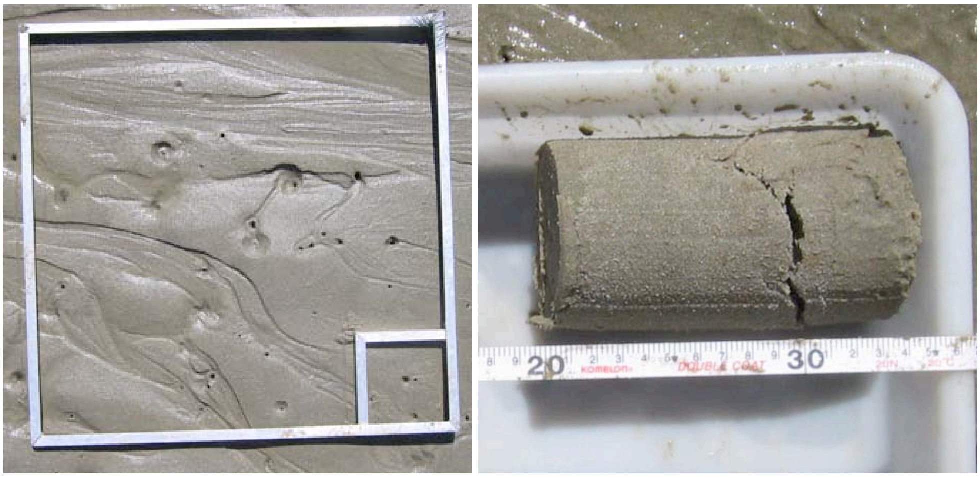

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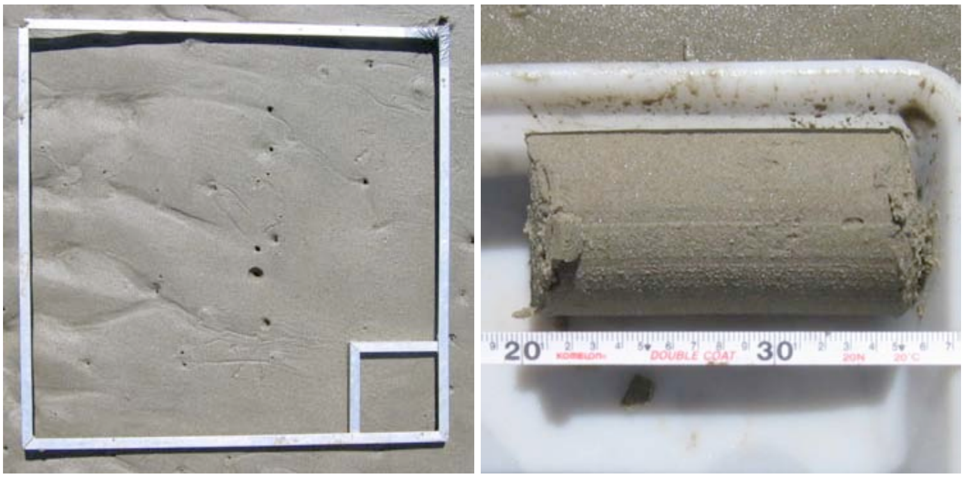

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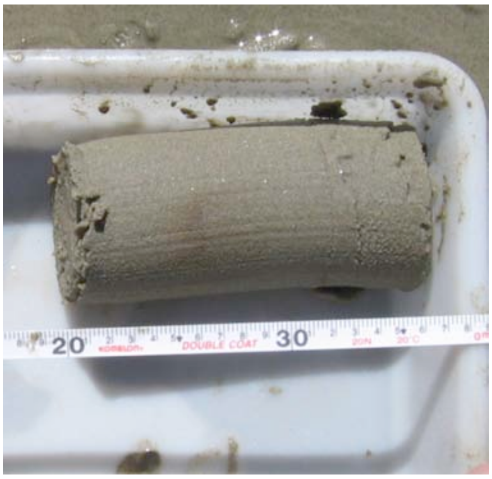
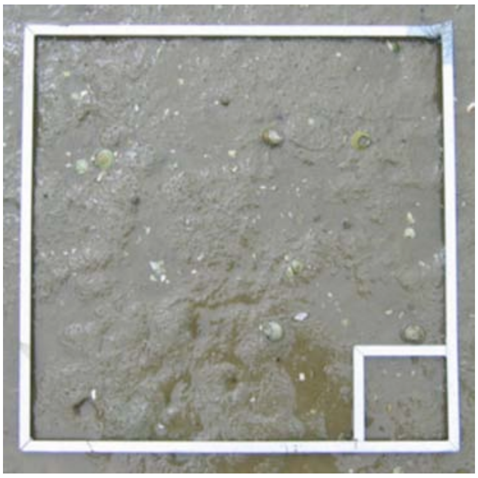
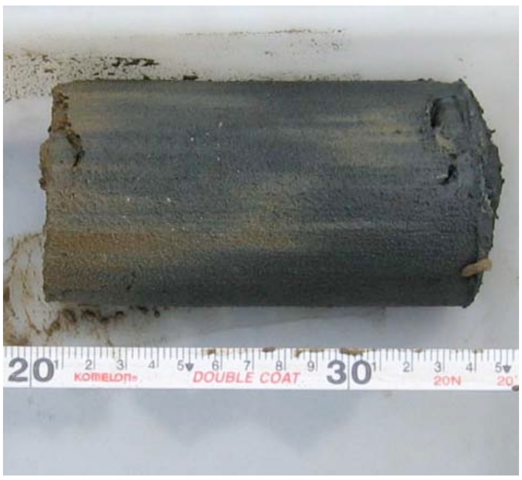


Taieri River Estuary
Site 2 (Upstream)

Quadrat




Quadrat 2

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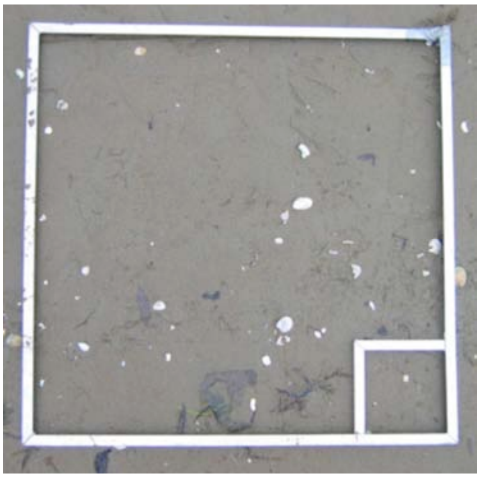


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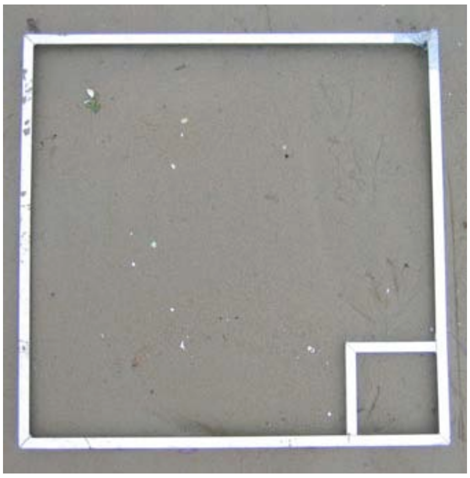


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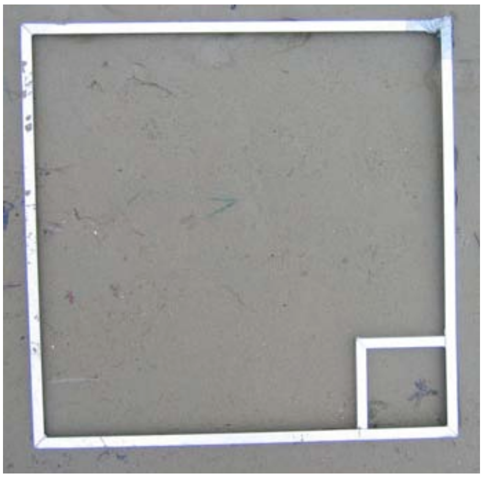
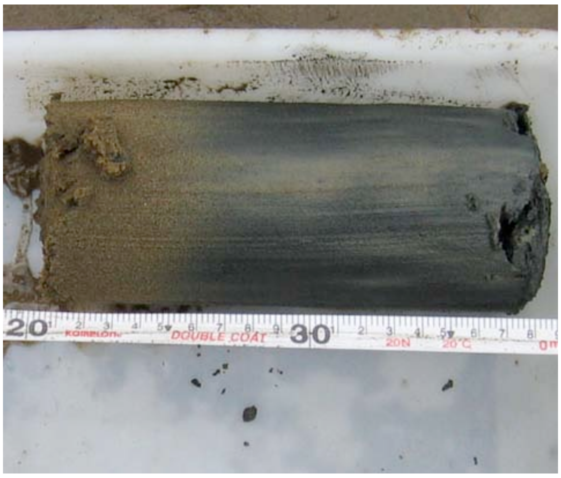

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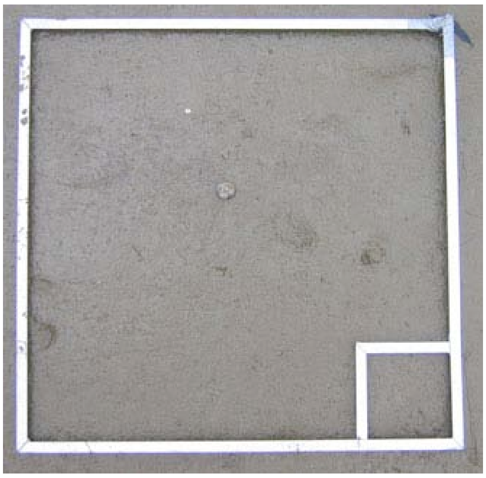 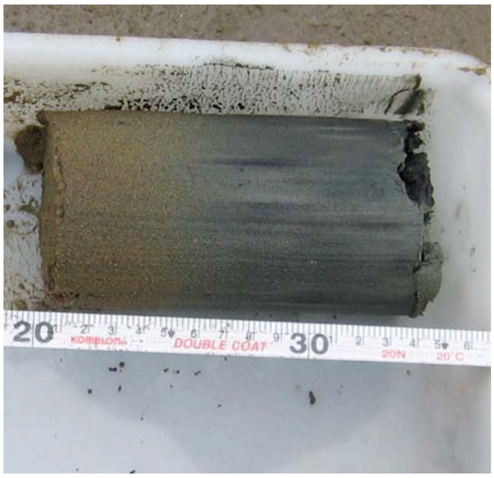

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 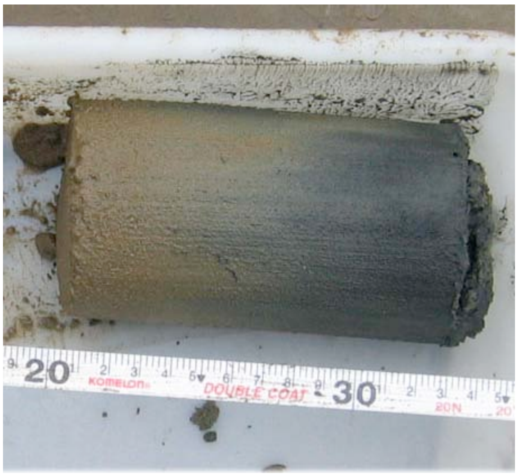

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 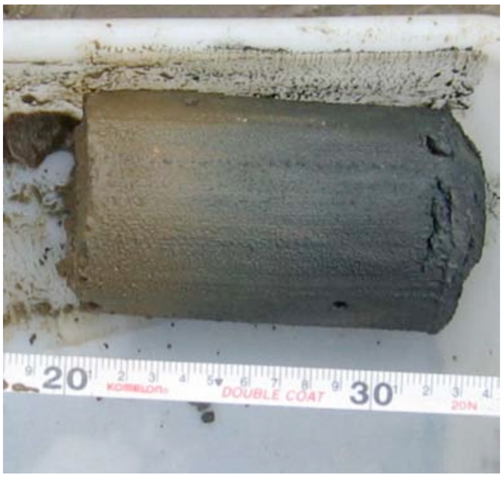

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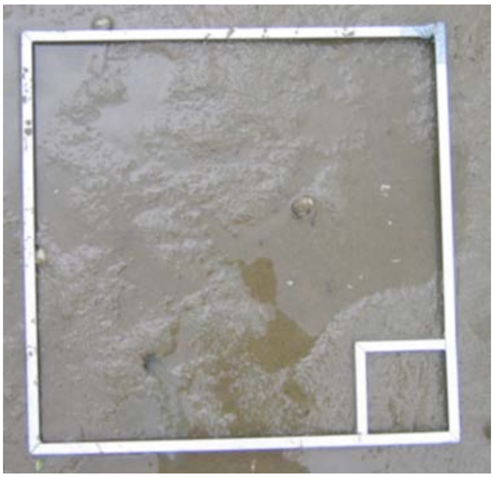


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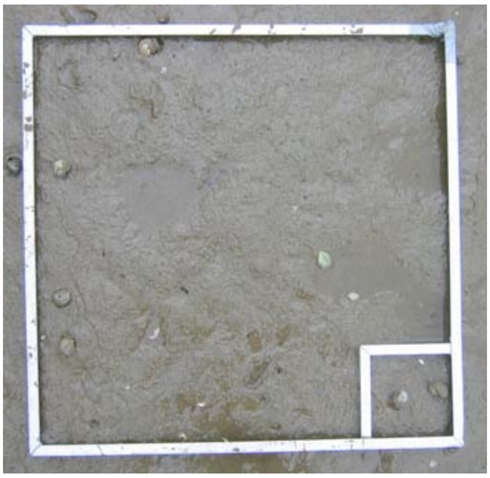


Quadrat 11


Quadrat 12