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# Broad Scale Habitat Mapping of Sandy Beaches and River Estuaries on the Western Wellington Coast

Prepared for

greater WELLINGTON
THE REGIONAL COUNCIL

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by

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Cover photo: Cawthron 2005. Sunset, Kapiti Island

# EXECUTIVE SUMMARY

Greater Wellington Regional Council (GWRC) contracted the Cawthron Institute to map the substrate of beaches and river estuaries along the Kapiti coastline (total distance ~40km), as well as Karehana Bay and Plimmerton Beach (~4km), Titahi Bay (~1.3km), and Makara Estuary (~7.5Ha). The purpose of the mapping was to provide a big picture overview of the health of these intertidal habitats which provide significant amenity and environmental value, but which are potentially under pressure due to human use and development. This information will assist in both strategic planning and in the management of specific issues associated with resource consents, pollution, and state of the environment monitoring.

The approach taken used a combination of field-verified broad scale mapping of habitat zones, supported by fine scale sampling at specific locations to provide an indication of the general health of beach and estuarine areas, particularly at the mouths of streams and rivers.

- **Broad-scale habitat mapping** provides a robust Geographical Information System (GIS) based methodology for mapping the spatial distribution of intertidal and estuarine substrate characteristics, and flora and fauna features >2m∅.
- **Fine-scale environmental monitoring** uses a standardised methodology to measure the spatial variation and inter-relationships of a suite of commonly measured physical, chemical and biological indicators in a common low-mid water intertidal habitat.

This report presents the results of the 2005 sampling programme. Overall, fine scale measurements of the spatial variation and inter-relationships of a suite of commonly measured physical, chemical and biological indicators in a common low-mid water intertidal habitat showed all of the sites were in a healthy condition. While localised impacts were present, across the majority of the habitat at all of the sites, the intertidal sediment quality of the sites was high.

The results of the current study are summarised as follows:

**Grain Size:** The beaches and estuaries were predominantly (>90%) sand, the only exception being Makara Estuary (77% sand, 21% mud). The general absence of silt and clay fractions from the river estuaries reflects their size – most being only very small streams discharging directly to the beach, and having little in the way of an enclosed estuarine embayment where finer material accumulates.

**Nutrient and Organic Enrichment:** There were no obvious signs of adverse enrichment at any sites. For example, no extensive growths of algae (*e.g. Ulva*), or anoxic sediments were observed.

**Toxic Contaminants**: Using sediment heavy metal concentrations as an indicator of potentially toxic contaminants, fine scale sites all had levels well below ANZECC (2000) ISQG-Low trigger values. The only exception to this was in Makara River Estuary where lead exceeded the ISQG-Low trigger for which further investigation is recommended. Concentrations were all low compared to sites elsewhere in NZ and overseas.

**Sediment Biota:** The abundance of infauna - animals living within the estuary and beach sediments (Appendix 2) - was typical of other New Zealand estuaries and beaches in good condition (*e.g.* Robertson *et al.* 2002). Sandy beach samples generally contained relatively few animals, particularly in upper tidal ranges, reflecting both the type of habitat present, and also the limited sampling undertaken. Dominant species were epifaunal scavengers such as amphipods and isopods, and infaunal deposit feeders such as oligochaete and polychaete worms.

River estuary sites within small streams had very few animals present, reflecting the small area that was estuarine in character, and the sandy substrata present.

Waikanae and Makara estuaries had a much more estuarine character with a range of amphipods, polychaetes and gastropods present, including scavengers and deposit feeders typically present in muddy estuary environments.

**Environmental pressures:** This study assessed the following pressures on beaches and river estuaries during sampling:

- Erosion Protection
- Flooding
- Grooming
- Introduced Weeds
- Landfill Leachate
- Loss of Marginal Habitat
- Nutrient Enrichment
- Residential
- Sand/Gravel Extraction
- Shellfish Collection
- Stormwater
- Vehicles

Overall, many of the identified pressures were not considered to be adversely affecting the sites investigated beyond localised areas. The low impact reflects mainly the low percentage of each area affected, and to a lesser extent, the intermittent nature of the pressure, the assimilative capacity of the environment, and/or likely recovery rates. The most significant impacts are associated with residential development along the coast and the subsequent loss of marginal habitat and increases in erosion protection works. The significance of the impact is primarily due to the near irreversible nature of the changes.

In conclusion, this study found that the intertidal sandy beaches and river estuaries of the Kapiti Coast were generally in a healthy condition and showed no signs of adverse nutrient enrichment or chemical contamination. Environmental pressures do exist but are generally quite localised and currently do not significantly threaten the health of the majority of the areas investigated. Residential development poses the most significant impact to the coastal areas.

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Reviewed and approved for release by:
Dr Barry Robertson, Manager – Coastal and Estuarine

# 1. INTRODUCTION

Greater Wellington Regional Council (GWRC) contracted the Cawthron Institute to map the broad scale habitat features of the sandy beaches on the Kapiti coastline (total distance ~40km), as well as Karehana Bay and Plimmerton Beach (~4km), Titahi Bay (~1.3km), and Makara Estuary (~7.5Ha). The purpose of the mapping was to characterise the type and extent of broad-scale habitat features present along the coastline between mean high and low tide. At selected sites, a suite of commonly measured physical, chemical, and biological indicators were also measured to provide an indication of the general health of beach and estuarine areas, particularly at the mouths of streams and rivers (see Table 1 and Figure 1 for Kapiti sampling locations). All site locations are detailed in Appendix 1. The information generated is intended to assist GWRC in strategic planning, and in the management of specific issues associated with resource consents, pollution, and state of the environment monitoring.

**Table 1** Beach and Estuary sites sampled on the Kapiti coastline.

| Beach Sites | Broad scale | Fine scale | Estuary Sites | Broad scale | Fine scale |
|---|---|---|---|---|---|
| Otaki Beach North | ✓ | ✓ | Waitohu Stream | ✓ | |
| Otaki Beach South | ✓ | ✓ | Otaki River | ✓ | |
| Te Horo | ✓ | | Mangaone Stream | ✓ | |
| Waikanae Beach | ✓ | | Peka Peka Stream | ✓ | |
| Paraparaumu Beach | ✓ | ✓ | Ngarara Stream | ✓ | |
| Paekakariki Beach | ✓ | ✓ | Waikanae River | ✓ | ✓ |
| Karehana Bay | ✓ | ✓ | Tikotu Creek | ✓ | ✓ |
| Plimmerton Beach | ✓ | ✓ | Wharemauku Stream | ✓ | ✓ |
| Titahi Bay | ✓ | ✓ | Whareroa Stream | ✓ | ✓ |
| Makara Beach | ✓ | | Makara River | ✓ | ✓ |

The approach used is based on the National Estuary Monitoring Protocol (Robertson *et al.* 2002) which uses field-verified broad scale mapping of habitat zones to provide a systematic classification of different areas in terms of the dominant vegetation and substrate present. This approach is a rapid and cost effective way to summarise the extent and type of different features. Once a baseline map has been constructed, habitat information can be used to indicate the potential sensitivity of different areas to pressures such as human development, vehicle use, stormwater discharges, *etc*. or to identify areas where further information may be needed to improve resource management.

The mapping also provides a template whereby changes in the position and/or size of habitats (MfE Confirmed Indicators for the Marine Environment, ME6, 2001) can be assessed by repeating the mapping exercise, or comparing it to historical data (usually aerial photographs). This information can then be used to evaluate the implications of natural and human induced changes (and ultimately land use characteristics and related water and sediment quality) on the structure and function of the coastal ecosystem.

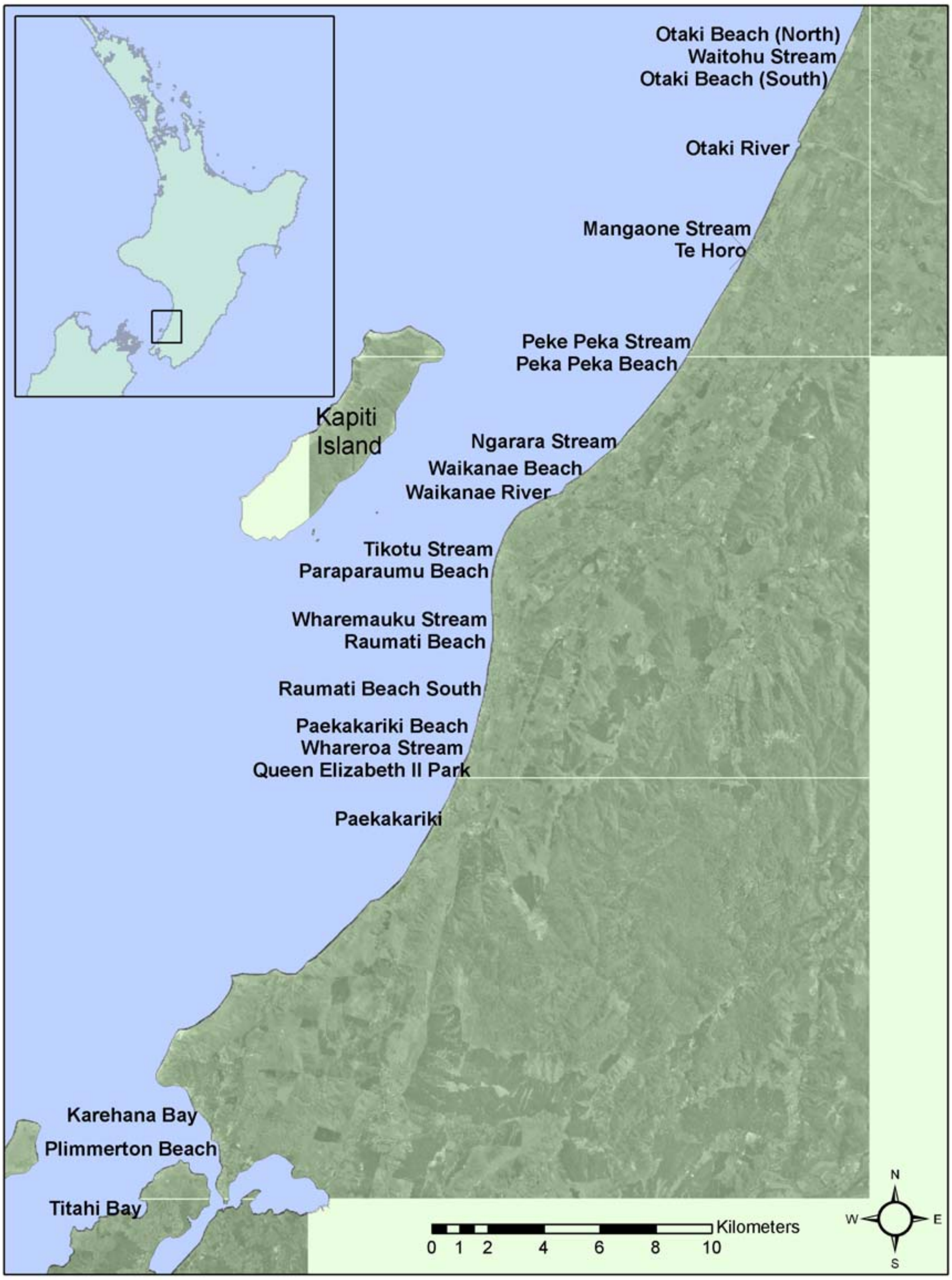



**Figure 1** Extent of mapping and location of key areas along the Kapiti coastline.

The information collected is designed specifically for use within a GIS platform which provides an open and flexible way of using the data to meet management needs as appropriate. GWRC already have a well developed GIS system, and the outputs of this project have been provided as GIS features that will directly integrate with this system. This allows the coastline to be viewed at any scale, and enables other relevant data to be linked to each site of interest using GIS layers or an underlying database as appropriate. This hard copy report provides examples of the type of information that can be generated for representative sites to indicate what is contained within the supplied GIS data layers, and describes the methodology and results of the 2005 broad-scale habitat mapping of the GWRC coastline.

Sections 2 and 3 of this report describe the broad scale and fine scale sampling methods used, while Section 4 summarises and discusses the results, including broad scale habitat maps and the results of the fine scale sampling where relevant, for each site. Appendix 1 contains broad scale maps of the mapped coastline, Appendix 2 contains a summary of biological data.

## 2. BROAD-SCALE HABITAT MAPPING

The aim of the broad-scale habitat mapping is to describe dominant habitat types based on surface features of substrate characteristics (mud, sand, cobble, rock, *etc*) and vegetation type (salt marsh, grassland, coastal plant species, *etc*), in order to develop a baseline map. The procedure, originally developed for use in estuaries (Robertson *et al.* 2002), was recently modified and successfully applied to sections of the coastline around Wellington (Stevens and Robertson 2004), and Hawke's Bay (Stevens and Robertson 2005). The approach uses aerial photography, together with detailed ground-truthing and digital mapping using GIS technology, to record the primary habitat features present. The specific methods used are detailed in the following sections.

### 2.1 Ground-truthing and digitisation of habitat features

Mapping of the coastline was undertaken by experienced coastal scientists identifying the dominant habitat and substrate types and their spatial extents in the field from foot or car at low-mid tide. Identified features were recorded directly on aerial photos at a scale of 1:5,000 or 1:10,000 (*e.g.* Figure 2).

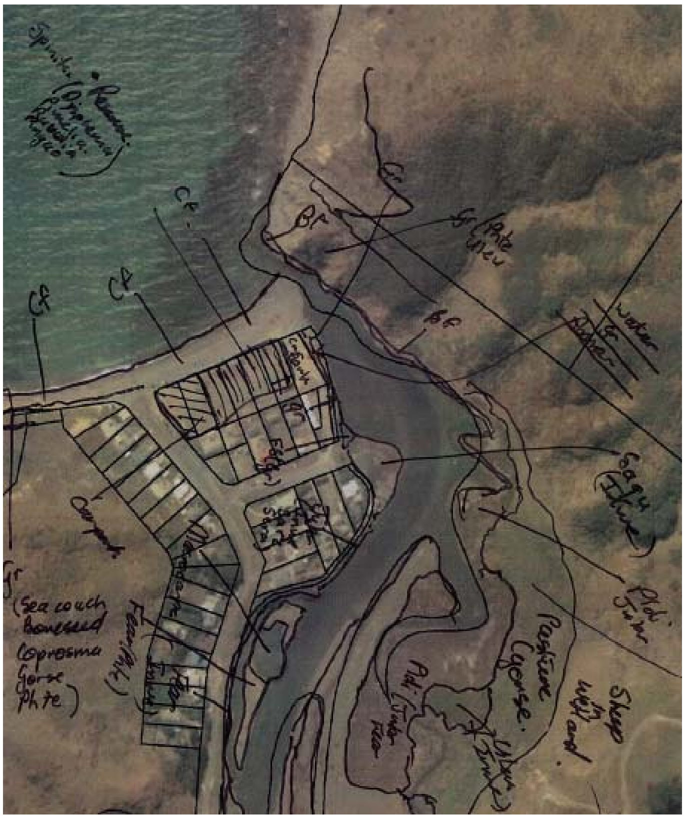



**Figure 2** Field sheet showing habitat classification on an aerial photo of Makara.

For this project, the area mapped focused predominantly on the intertidal zone between mean low and mean high water springs (MLWS and MHWS). However, wherever appropriate, this was extended to the boundary of vegetation features mapped by the Kapiti Coast District Council (KCDC) to provide a continuous cover of the habitat margin adjacent to intertidal beach areas along the entire coastline. In areas not covered by the KCDC vegetation mapping, the substrate and vegetation was mapped to the nearest clear delineation point *e.g.* dunes, roads, manmade seawalls, or ridgelines, to indicate the surrounding features present.

Photographs at a scale of 1:5000 are normally used in the field to identify and ground truth habitat types, with the GIS framework used to zoom in on photos to trace around the habitat features using digital mapping tools. Figure 3 shows how it is possible to clearly see different features like sand, seawalls, and vegetation with a high resolution colour photo, enabling accurate maps to be drawn. The better the quality of photos available, the more accurate mapping is. Along the populated stretches of the Kapiti coastline, KCDC provided very high resolution colour photos (10cm per pixel), while GWRC provided colour photos of Karehana and Plimmerton Beaches, Titahi Bay, and the Makara Estuary at a resolution of ~1 metre per pixel. Areas outside of the provided coverage were filled with 2.5 metre per pixel black and white photos downloaded from the LINZ website, with additional details taken from NZMS 260 series topographical maps. For all photos, the tidal height at the time the photos were taken was unknown so the MLWS boundary has been estimated based on a combination of field observations, local knowledge, and extrapolation from coastal features.

**Figure 3** Example of the ability to discriminate between different habitat features with high quality aerial photos (Location, South Raumati Beach, scale 1:500).

### 2.2 Classification and definitions of habitat types

The substrate and vegetation classification used to define habitat features is listed in Table 2. Note that Table 2 includes a broader range of habitats than found on the Kapiti coast. Classification is based on surface layers only and does not consider underlying substrate; *e.g.* cobble or gravel fields covered by sand would be classed as sand.

### *2.2.1 Classification of vegetation*

Vegetation provides an important buffer between the land and the sea, influencing the visual character of an area, and playing an important role in dune stability, mitigation of contaminant inputs, erosion protection, and the provision of wildlife habitat. KCDC recently completed a detailed vegetation map of the Kapiti coastline and the GIS shape files were provided for inclusion in this project. We have not repeated the KCDC vegetation mapping, but have summarised the information at the defining structural class level *e.g.* native and exotic forest, native and exotic scrub/shrub/trees, tussockland, grassland, etc. and extended its coverage to areas along the Kapiti coastline not mapped by KCDC.

When adding vegetation data we have used an interpretation of the Atkinson (1985) system, whereby dominant plant species were coded by using the two first letters of their Latin species and genus names *e.g.* marram grass, *Ammophila arenaria*, is coded as Amar. An indication of dominance is provided by the use of ( ) to distinguish subdominant species *e.g.* Amar(Caed) indicates that marram grass is dominant over ice plant (*Carpobrotus edulis*). The use of ( ) is not based on percentage cover but the subjective observation of which vegetation is the dominant or subdominant species within the patch. We have not sought to match the level of detail provided in the KCDC work, but have sought to characterise the dominant habitat types present. In this study, vegetation was not specifically classified based on height, although a measure of this can be derived from its structural class. Where relevant, the presence of invasive weeds and exotic vegetation has also been noted, although in many cases invasive weeds were present in patches <2m∅.

# **Table 2** Classification Definitions for Structural Habitat Classes.

**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 ⩾10cm dbh are treated as trees.

**Treeland:** Cover of trees in canopy 20-80%. Trees are woody plants >10cm 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). Shrubs are woody plants <10 cm diameter at breast height (dbh).

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

**Tussockland:** Vegetation in which the cover of tussock in the canopy is 20-100% and in which the tussock cover exceeds that of any other growth form or bare ground. Tussock includes all grasses, sedges, rushes, and other herbaceous plants with linear leaves (or linear non-woody stems) that are densely clumped and >100 cm height. Examples of the growth form occur in all species of Cortaderia, Gahnia, and Phormium, and in some species of Chionochloa, Poa, Festuca, Rytidosperma, Cyperus, Carex, Uncinia, Juncus, Astelia, Aciphylla, and Celmisia.

**Duneland:** Vegetated sand dunes in which the cover of vegetation in the canopy (commonly Spinifex, Pingao or Marram grass) is 20-100% and in which the vegetation cover exceeds that of any other growth form or bare ground.

**Grassland:** Vegetation in which the cover of grass 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.

**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.

**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 grasslike, often hollow-stemmed plant, included in the rush growth form are some species of Juncus and all species of, Leptocarpus. Tussock-rushes are excluded.

**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. Examples include Typha, Bolboschoenus, Scirpus lacutris, Eleocharis sphacelata, and Baumea articulata.

**Cushionfield:** Vegetation in which the cover of cushion plants in the canopy is 20-100% and in which the cushion-plant cover exceeds that of any other growth form or bare ground. Cushion plants include herbaceous, semi-woody and woody plants with short densely packed branches and closely spaced leaves that together form dense hemispherical cushions.

**Herbfield:** Vegetation in which the cover of herbs in the canopy is 20-100% and in which the herb cover exceeds that of any other growth form or bare ground. Herbs include all herbaceous and low-growing semi-woody plants that are not separated as ferns, tussocks, grasses, sedges, rushes, reeds, cushion plants, mosses or lichens.

**Lichenfield:** Vegetation in which the cover of lichens in the canopy is 20-100% and in which the lichen cover exceeds that of any other growth form or bare ground.

**Seagrass meadows:** Seagrasses are the sole marine representatives of the Angiospermae. They all belong to the order Helobiae, in two families: Potamogetonaceae and Hydrocharitaceae. Although they may occasionally be exposed to the air, they are predominantly submerged, and their flowers are usually pollinated underwater. A notable feature of all seagrass plants is the extensive underground root/rhizome system which anchors them to their substrate. Seagrasses are commonly found in shallow coastal marine locations, salt-marshes and estuaries.

**Macroalgal bed:** Algae are relatively simple plants that live in freshwater or saltwater environments. In the marine environment, they are often called seaweeds. Although they contain cholorophyll, they differ from many other plants by their lack of vascular tissues (roots, stems, and leaves). Many familiar algae fall into three major divisions: Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae). Macroalgae are algae observable without using a microscope.

**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.

**Stone field/Gravel field:** Land in which the area of unconsolidated gravel (2-20 mm diameter) and/or bare stones (20-200 mm diam.) exceeds the area covered by any one class of plant growth-form. Stonefields and gravelfields are named based on which form has the greater ground cover. They 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 of ≥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%.

**Artificial structures:** Introduced natural or man-made materials that modify the environment. Includes rip-rap, rock walls, wharf piles, bridge supports, walkways, boat ramps, sand replenishment, groynes, flood control banks, stopgates.

**Cockle bed:** Area that is dominated by primarily dead cockle shells.

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

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

**Sabellid field:** Area that is dominated by raised beds of sabellid polychaete tubes.

# 3. FINE-SCALE ASSESSMENT

## 3.1 Overview

Fine-scale monitoring 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. The environmental characteristics assessed usually include a suite of commonly used benthic indicators (see Robertson *et al.* 2002, Section 2.4 for justification) including trace metals, nutrients, and organic content. Fine scale sampling, as summarised in Table 3, was undertaken along the Kapiti coast on 5-6 May 2005, with Makara Estuary sampled on 22 May 2005. Three replicate samples were collected at each location and samples were combined for analysis at all sites except for Titahi Bay where replicates were analysed separately. Sampling was undertaken at two tidal levels, low to mid tide, and mid to high tide. These sites are referred to as 'lower' and 'upper' respectively. Due to the coarse sediment expected (predominantly sand), and budget limitations, samples were not analysed for nutrients.

**Table 3** Summary of sampling undertaken at Beach and Estuary sites on the Kapiti coastline.

| | Upper Intertidal | | | | Lower Intertidal | | | |
|---|---|---|---|---|---|---|---|---|
| **Site** | **Infauna** | **Grain Size** | **AFDW** | **Metals** | **Infauna** | **Grain Size** | **AFDW** | **Metals** |
| Otaki Beach North | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |
| Otaki Beach South | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |
| Paraparaumu Beach | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |
| Paekakariki Beach | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |
| Karehana Bay | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |
| Plimmerton Beach | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |
| Titahi Bay - vehicles | ✓✓✓ | ✓✓✓ | ✓✓✓ | ✓ | ✓✓✓ | ✓✓✓ | ✓✓✓ | ✓ |
| Titahi Bay - no vehicles | ✓✓✓ | ✓✓✓ | ✓✓✓ | ✓ | ✓✓✓ | ✓✓✓ | ✓✓✓ | ✓ |
| Waikanae River | ✓✓ | ✓✓ | ✓✓ | ✓ | ✓✓ | ✓✓ | ✓✓ | ✓ |
| Tikotu Creek | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |
| Wharemauku Stream | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |
| Whareroa Stream | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |
| Makara River | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

At Titahi Bay, sites were selected from sections of the beach where vehicle access is both permitted and restricted. This was to see if there was any obvious impact from vehicles that was evident in the biological community or chemical characteristics present. Elsewhere along the coastline, estuary locations targeted sites in the immediate vicinity of stream inputs to assess contaminant or biological features, while beach sites assessed areas away from stormwater or stream inputs to characterise the baseline conditions of the beach away from obvious sources of contamination.

This approach sought to link the broad scale mapping of substrates to the chemical and biological status of the different substrates identified. By verifying the chemical and biological status, general predictions can then be made of the health and likely susceptibility to impact of sites elsewhere in the region within corresponding substrate types.

The ANZECC (2000) Sediment Quality Guidelines have been used to assess and interpret the results of the sediment sampling. These guidelines present Interim Sediment Quality Guideline-Low (ISQG-Low) and –High (ISQG-High) as two threshold levels under which biological effects are predicted (ANZECC 2000). The lower threshold indicates a **possible** biological effect while the upper threshold (ISQG-High) indicates a **probable** biological effect. These trigger values are essentially conservative criteria (*e.g.* for water or sediment quality) that, if complied with, will ensure that specified environmental values are protected. Note, however, that the converse is not necessarily true (*i.e.* exceedance of trigger values does not necessarily suggest environmental damage) hence the intent of these values is to act as a trigger for more intensive assessment if they are not met.

In comparing results it is important to recognise that differences in particle grain sizes between sites can have a significant influence on results, as most contaminants preferentially adsorb to finer particles. Therefore, sites with higher proportions of mud/silt are expected to have higher contaminant concentrations than sands/gravels. Results can be normalised to 100% mud to allow a direct comparison between sites. However, we have reported results for whole sediment fractions to allow a direct comparison with previous data and ANZECC guidelines.

### 3.2 Sampling methods

At each site, composite sediment samples were taken and analysed for the following variables;

- Grain size (%mud, sand, gravel)
- Ash free dry weight (organic content)
- Cadmium
- Chromium
- Copper
- Lead
- Nickel
- Zinc
- Macroinvertebrate abundance and diversity (infauna and epifauna)

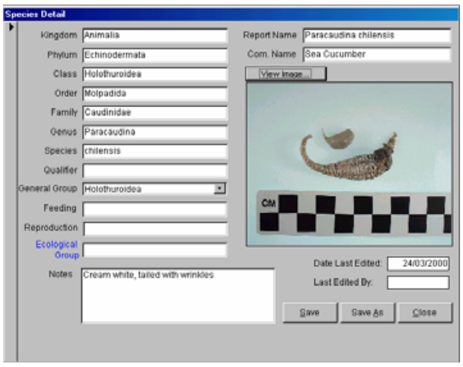
Metal analyses were based on whole sample fractions which were not normalised to allow direct comparison with ANZECC guidelines. The specific sampling methods used are detailed below.

**1. Chemical analyses**

- Composite samples (3 locations per site, each of approx 250 gms) were collected from the top 20 mm of fine sediment areas into pre-labelled ziplock plastic bags. Samples were stored on ice in the field and then frozen prior to shipping to the laboratory for analysis.

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

- Three replicate sediment cores were collected from each site at random positions using a 130 mm diameter (area = 0.0133 m$^2$) PVC tube.
- The core tube was manually driven 150 mm into the sediments, removed with core intact and inverted and washed through an attached 0.5 mm nylon mesh bag using local seawater. The remaining contents were carefully emptied into a plastic container with a waterproof label and preservative (95% ethanol - enough to roughly double the volume of the sample).
- Sample processing was done in a laboratory where samples were washed through a series of sieves (from 4.0 mm to 0.5 mm) within a fume cabinet to roughly sort invertebrates into size classes.
- The contents of each sieve were systematically scanned, by eye or by microscope, and the invertebrate species identified (to at least the family level), counted and recorded.




- The data were then transferred to a spreadsheet or database (as illustrated). Cawthron's database uses a standardised format for all benthic monitoring data which allows for direct and easy comparisons with other regional data. It also utilises a master species list which ensures data accuracy and reporting.

**3. Sediment enrichment**:

- To provide a measure of enrichment, the Redox Discontinuity Layer (RDL) - the depth of the lighter-coloured surface layer - was noted, along with any changes in the stratification of colour and texture within sediments, particularly the occurrence of any black (anoxic) zones.

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

- During sampling, observations were made for the presence of conspicuous epifauna. If present, all animals observed within a 0.25 m$^2$ quadrat on the sediment surface were identified and counted, and any visible microalgal mat development noted.

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

- During sampling, the percent coverage of macroalgae was estimated using a grid quadrat. Vegetation that overlaped grid intersections (49 in total, including the outer frame) was counted and the result converted to a percent (*i.e.* No. x 2 = %).

# 4. RESULTS AND DISCUSSION

## 4.1 Overview

It is intended that the outputs of this project will be used predominantly within the GIS framework. Therefore, this report is intended to provide a general overview of the information and data contained within the GIS files that accompany this report. Results are presented and discussed below, with habitat maps in Appendix 1, and biological data in Appendix 2. The Kapiti Coast is presented first, followed by Karehana Bay/Plimmerton Beach, Titahi Bay, and Makara Estuary.

### *4.1.1 Kapiti Coast*

The Kapiti coastline is characterised by long, wide and gently sloping sandy beaches (Figure 4A), with terrestrial margins predominantly vegetated dunes (Figure 4B), or dunes that have been modified with erosion protection works *e.g.* wooden retaining walls or rocks (Figure 4C) protecting residential developments or amenity areas.


**Figure 4** Examples of the dominant coastal features along the Kapiti Coast.

Along the coastline, many small streams and rivers discharge across the beach to the sea creating small "river estuaries" that maintain a wetted area throughout the tidal cycle (Figure 4C, Figure 5). Of the area mapped, only the Waikanae River Estuary has a large area of intertidal flats that would be commonly recognised as an estuarine area (Figure 5A). In contrast, most of the smaller streams are within defined banks or channels and are commonly modified, for example, with barriers to prevent driftwood from blocking the entrance (Figure 5B), have streamways cleared mechanically (Figure 5C), or have flood or erosion protection around the mouths (Figure 5D, E).

The extent of dunes and the surrounding land cover along the coast directly reflects the extent of modification. In undeveloped areas, *e.g.* north of Otaki and adjacent to the Queen Elizabeth Regional Park between Raumati South and Paekakariki, dune systems are relatively intact with the beach merging into a relatively steep grassland dune covered in a range of species including marram grass, knobby clubrush, flax, coastal coprosma, and introduced weeds. Dunes continue inland, often for several hundred metres. Driftwood is present buried in the sand near the top of the beach protecting scattered patches of marram, and providing a relatively stable substrate. In moderately developed areas, dunes are still present but are restricted in extent by roading or housing (*e.g.* South Otaki and Te Horo Beach). In highly developed areas *e.g.* Raumati South, dunes have been lost with the top of the beach dominated by erosion protection works and residential development within previous dune habitat. In developed areas a wide variety of exotic garden plantings have established along the coastal margins.

Table 4 and Figure 6 show the substrate along the Kapiti coastline was dominated by firm sand (87%), with smaller areas of cobble (4%) and gravel fields (4%). The remainder of the intertidal areas was largely accounted for by water from rivers, streams or estuaries crossing beach areas (5%). Although covering a relative small area overall (<1%), man-made seawalls and boulder fields were a significant feature of the Kapiti coast, covering a linear distance of ~7km, occurring predominantly at Raumati South (~4km), and at Paekakariki (~3km). These seawalls have been constructed to protect against erosion of the coastal dune areas that have been developed for residential housing or as public amenity areas. The seawalls have a significant effect on wave energy and the geomorphology of the beach, changing the natural profile and movement of material. This is most readily evident in the variable substrate zones present where firm sand accumulates landward of the seawall, up-shore of cobble or boulder fields (see Figure 3 for example).


**Figure 5** Examples of the river estuaries along the Kapiti Coast.

**Table 4** Summary of the substrate and vegetation present along the Kapiti coastline.

| KAPITI COAST HABITAT SUMMARY | | | |
|---|---|---|---|
| **Dominant Habitat Class** | **Primary-Subdominant** | **Area (Ha)** | **% of total** |
| **Terrestrial** | | | |
| Native scrub/shrub/trees (NSST) | | **8.1** | 2.1 |
| Exotic scrub/shrub/trees (ESST) | | **79.2** | 20.3 |
| Tussockland | | **3.3** | 0.9 |
| Fernland | | **1.6** | 0.4 |
| Vineland | | **6.3** | 1.6 |
| Reedland | | **1.1** | 0.3 |
| Rushland | | **13.6** | 3.5 |
| Grassland | | **183.5** | 47.1 |
| Sedgeland | | **2.8** | 0.7 |
| Herbfield | | **5.8** | 1.5 |
| Introduced weeds | | **79.6** | 20.4 |
| Unvegetated | | **4.8** | 1.2 |
| TOTAL | | **389.6** | **100** |
| **Intertidal** | | | |
| Man-made seawall | | **0.7** | 0.1 |
| Boulder field man-made | | **1.4** | 0.2 |
| Cobble field | | **25.8** | 4.4 |
| Firm sand | | **488.4** | 83.31 |
| | Boulder field | **2.4** | 0.41 |
| | Cobble field | **15.9** | 2.72 |
| | Gravel field | **2.6** | 0.45 |
| Gravel field | | **3.5** | 0.60 |
| | Cobble field | **17.5** | 2.89 |
| | Soft sand | **0.9** | 0.15 |
| Water | | **27.1** | 4.6 |
| TOTAL | | **586.2** | **100** |

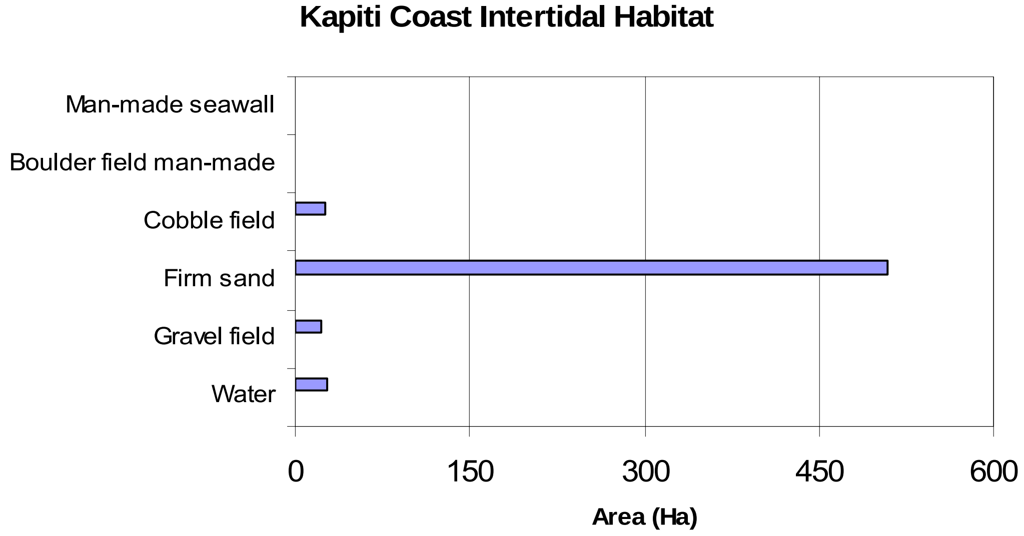



**Figure 6** Area (Ha) of intertidal habitat features mapped along the Kapiti coast.

Vegetation flanking beach areas was largely grassland (47%), dominated by pasture and unmanaged grassland in terrestrial areas, and marram grass in dunes (Table 4, Figure 7). Exotic scrub, shrub and trees (ESST) (20%) and introduced weeds (20%) were also significant and reflected the predominantly urban nature of the terrestrial boundary, especially between Paraparaumu and Raumati South, and at Paekakariki. The contribution of introduced weeds is likely to be underestimated as weeds present beneath canopy species were not always recorded in the vegetation mapping undertaken by KCDC despite exceeding a coverage of <2m∅. Garden waste was apparent in many areas, both directly adjacent to dwellings, and also among dune areas where they have been dumped. This is an obvious source of many of the introduced weeds that have become established, and although the establishment of weeds is generally undesirable, many do contribute to dune stabilisation once they become established. Table 5 provides a full listing of the vegetation recorded from the Kapiti coastline by KCDC and the area it covered. The KCDC data did contain some errors that have been corrected for the purposes of this table. The KCDC data are considered most appropriate to use at structural class rather than at a species level.

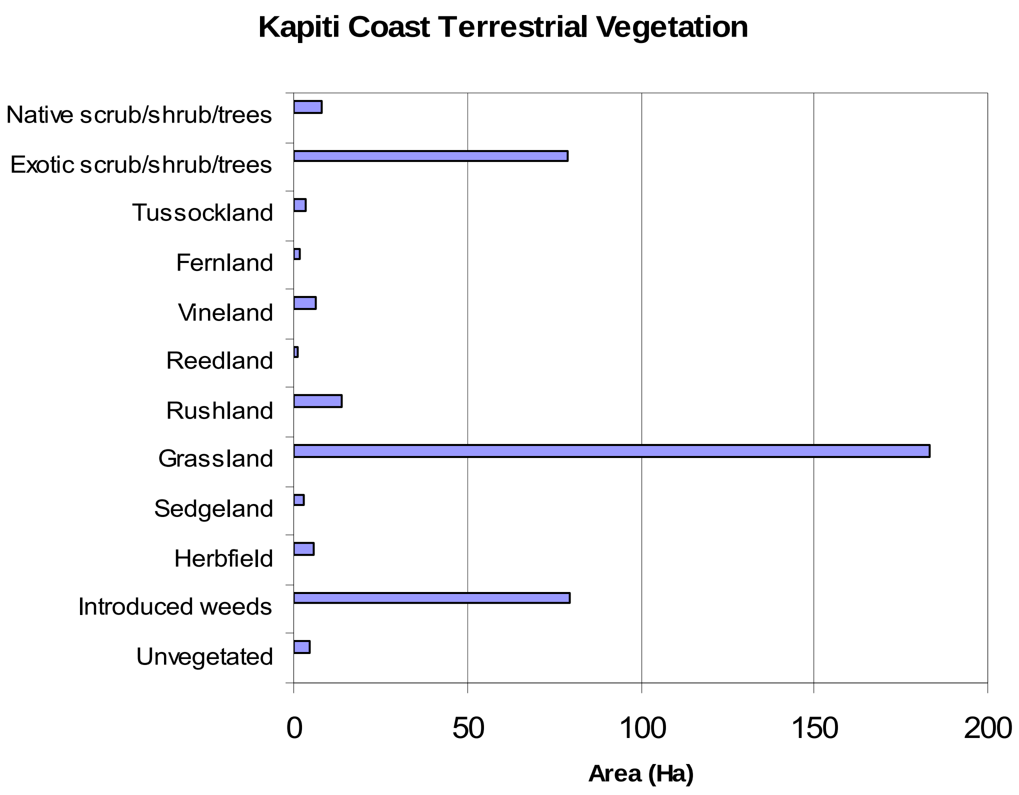



**Figure 7** Area (Ha) of terrestrial habitat features mapped along the Kapiti coast. (source: KCDC and Cawthron).

**Table 5** Detail of the KCDC substrate and vegetation present along the Kapiti coastline.

| KAPITI COAST VEGETATION - Source KCDC | | | | |
|---|---|---|---|---|
| **Class** | **Dominant vegetation** | **Scientific name** | **Area (Ha)** | **% of total** |
| **Native scrub/shrub/trees (NSST)** | | | **8.1** | **2.1** |
| | Cabbage tree | *Cordyline australis* | 0.05 | 0.01 |
| | Coastal tree daisy | *Olearia solandri* | 0.06 | 0.01 |
| | Coprosma proquinqua | *Coprosma proquinqua* | 0.00 | 0.00 |
| | Deadly Nightshade | *Solanum* sp. | 0.07 | 0.02 |
| | Karaka | *Corynocarpus laevigatus* | 0.01 | 0.00 |
| | Mahoe | *Melicytus ramiflorus* | 1.61 | 0.41 |
| | Ngaio | *Myoporum laetum* | 0.11 | 0.03 |
| | Pohutukawa | *Meterosideros excelsa* | 1.50 | 0.38 |
| | Saltmarsh ribbonwood | *Plagianthus divaricata* | 0.00 | 0.00 |
| | Sand Coprosma | *Coprosma acerosa* | 0.15 | 0.04 |
| | Sand Daphne | *Pimelia arenaria* | 0.00 | 0.00 |
| | Taupata | *Coprosma repens* | 4.50 | 1.16 |
| **Exotic scrub/shrub/trees (ESST)** | | | **79.2** | **20.3** |
| | Banksia | *Banksia integrifolia* | 0.07 | 0.02 |
| | Broom | *Cytisus scoparius* | 0.06 | 0.02 |
| | White Correa | *Correa alba* | 0.05 | 0.01 |
| | Exotic trees | | 42.91 | 11.01 |
| | Lupin | *Lupinus arboreus* | 36.01 | 9.24 |
| | Poplar spp. (not silver) | *Poplus* sp. | 0.04 | 0.01 |
| | Tree Lucerne | *Chamaecytisus palmensis* | 0.07 | 0.02 |
| **Tussockland** | | | **3.3** | **0.9** |
| | Flax (Harakeke) | *Phormiun tenax* | 2.68 | 0.69 |
| | Toetoe | *Cortaderia toetoe* | 0.65 | 0.17 |
| **Fernland** | | | **1.6** | **0.4** |
| | Bracken | *Pteridium esculentum* | 1.59 | 0.41 |
| **Vineland** | | | **6.3** | **1.6** |
| | Climbing Dock | *Rumex saggitatus* | 0.61 | 0.16 |
| | Everlasting Pea | *Lathyrus latifolius* | 0.26 | 0.07 |
| | Mulenbeckia/wiwi | *Mulenbeckia complexia/Isolepis nodosa* | 3.24 | 0.83 |
| | Mulenbeckia | *Mulenbeckia complexia* | 1.94 | 0.50 |
| | Nihinihi or panahi | *Calystegia soldanella* | 0.14 | 0.04 |
| | NZ Spinach | *Tetragonia tetragonioides* | 0.09 | 0.02 |
| **Reedland** | | | **1.1** | **0.3** |
| | Raupo | *Typha orientalis* | 1.05 | 0.27 |
| **Rushland** | | | **13.6** | **3.5** |
| | Estuarine wetland | | 4.36 | 1.12 |
| | Lake clubrush | *Schoenoplectus tabernaemontani* | 0.33 | 0.08 |
| | Oioi | *Leptocarpus similis* | 0.47 | 0.12 |
| | Sea rush | *Juncus kraussii* | 0.33 | 0.09 |
| | Sharp rush | *Juncus acutus* | 0.09 | 0.02 |
| | Wiwi | *Isolepis nodosa* | 8.03 | 2.06 |
| **Grassland** | | | **183.5** | **47.1** |
| | Amenity Area | Conifers/mowngrass/playgrounds | 3.95 | 1.01 |
| | Buffalo grass | *Stenotaphrum secundatum* | 0.74 | 0.19 |
| | Dry managed pasture | *Lolium perenne* (predominates) | 47.98 | 12.32 |
| | Marram | *Ammophila arenaria* | 28.10 | 7.21 |
| | Marram-natives | *A. arenaria, Phormium tenax, Coprosma repens, Isolepis nod* | 3.15 | 0.81 |
| | Marram-weeds-natives | *A. arenaria, Ulex europaeus Phormiun tenax, Coprosma repe* | 4.63 | 1.19 |
| | Marram-sand | *Ammophila arenaria* | 11.61 | 2.98 |
| | Marram-wiwi | *Ammophila arenaria-Isolepis nodosa* | 6.51 | 1.67 |
| | | (predominate) | 5.82 | 1.49 |
| | Spinifex | *Spinifex sericeus* | 13.03 | 3.34 |
| | Tall fescue | *Festuca arundinacea** | 2.89 | 0.74 |
| | Tall fescue/catsear | *Festuca arundinacea*/Hypochoeris radicata* | 0.03 | 0.01 |
| | Unmanaged mixed grassland | *Pennisetum clandestinum-Stenotaphrum secundatum* (predominate) | 45.45 | 11.67 |
| | Wet managed pasture | *Holcus lanatus* (predominates) | 8.50 | 2.18 |
| | Wetland grasses | mixed | 1.16 | 0.30 |

* listed as *Schenodorus phoenix* in KCDC data

**Table 5 cont…** Detail of the KCDC substrate and vegetation present along the Kapiti coastline.

| KAPITI COAST VEGETATION - Source KCDC | | | | |
|---|---|---|---|---|
| **Class** | **Dominant vegetation** | **Scientific name** | **Area (Ha)** | **% of total** |
| **Sedgeland** | | | **2.8** | **0.7** |
| | Giant umbrella sedge | *Cyperus ustulatus* | 0.11 | 0.03 |
| | Isolepis prolifer-(arrow grass)-(sand buttercup) | *Isolepis prolifer-(Triglochin striata)-(Ranunculus acaulis)* | 0.17 | 0.04 |
| | Palustine wetland | | 2.20 | 0.56 |
| | Pingao | *Desmoschoenus spiralis* | 0.06 | 0.02 |
| | Sand carex | *Carex pumilia* | 0.06 | 0.02 |
| | Sharp spike sedge | *Eleocharis acuta* | 0.07 | 0.02 |
| | Three square-(arrowgrass) | *Schoenoplectus pungens/Triglochin striata* | 0.09 | 0.02 |
| | Three square-(arrowgrass)-(sea primrose)-(slender clubrush) | *Schoenoplectus pungens/(Triglochin striata)-(Samolus repens)-(Isolepis cernua)* | 0.08 | 0.02 |
| **Herbfield** | | | **5.8** | **1.5** |
| | Agapanthus | *Agapanthus praecox* | 0.17 | 0.04 |
| | Aloe | *Aloe* sp. | 0.02 | 0.01 |
| | Bachelor's button | *Cotula coronopifolia* | 0.00 | 0.00 |
| | Daisy | *Arctotus* sp. | 0.33 | 0.08 |
| | Daisy/iceplant | *Arctotus* sp./*Carpobrotus edulis* | 0.50 | 0.13 |
| | Trailing African daisy | *Osteospermum fruticosum* | 0.04 | 0.01 |
| | Fathen | *Atriplex prostrata* | 0.04 | 0.01 |
| | Fennel | *Foeniculum vulgare* | 0.02 | 0.00 |
| | Ice Plant | *Carpobrotus edulis* | 4.48 | 1.15 |
| | Native ice plant | *Disphyma australe* | 0.03 | 0.01 |
| | Wild parsnip | *Pastinaca sativa* | 0.05 | 0.01 |
| | Remuremu or selleria | *Selleria radicans* | 0.03 | 0.01 |
| | Sea primrose | *Samolus repens* | 0.00 | 0.00 |
| | Water pepper/lake clubrush | *Polygonum hydropiper* | 0.06 | 0.02 |
| **Introduced weeds** | | | **79.6** | **20.4** |
| | Bears breaches | *Acanthus mollis* | 0.02 | 0.00 |
| | Blackberry | *Rubus fruticosus* agg. | 1.74 | 0.45 |
| | Blackberry-tall fescue | *Rubus fruticosus* agg. / *Festuca arundinacea* | 1.09 | 0.28 |
| | Blue Morning Glory | *Ipomoea indica* | 0.04 | 0.01 |
| | Boneseed | *Chrysanthemoides monilifera* | 0.37 | 0.09 |
| | Boxthorn | *Lycium ferocissimum* | 14.71 | 3.77 |
| | Boxthorn/grasses-weeds | *Lycium ferocissimum* | 15.51 | 3.98 |
| | Boxthorn/lupin | *Lycium ferocissimum/Lupinus arboreus* | 0.07 | 0.02 |
| | Boxthorn/marram | *Lycium ferocissimum/Ammophila arenaria* | 25.17 | 6.46 |
| | Boxthorn/mixed grassland | *Lycium ferocissimum/Lupinus arboreus* | 0.19 | 0.05 |
| | Brush Wattle | *Paraserianthes lophantha* | 0.98 | 0.25 |
| | Buddleja | *Buddleja davidii* | 0.00 | 0.00 |
| | Cape Ivy | *Senecio angulatus* | 1.32 | 0.34 |
| | Cape ivy-unmanaged grassland | *Senecio angulatus* | 0.00 | 0.00 |
| | Cape ivy-unmanaged mixed grass | *Senecio angulatus* | 1.62 | 0.42 |
| | Evergreen Buckthorn | *Rhamnus alaternus* | 0.26 | 0.07 |
| | Garden Escapes/Dumping | | 2.24 | 0.57 |
| | Gorse | *Ulex europaeus* | 6.76 | 1.73 |
| | Gorse-weeds | *Ulex europaeus* and mixed introduced weeds | 0.85 | 0.22 |
| | Japanese Honeysuckle | *Lonicera japonica* | 0.17 | 0.04 |
| | Karo | *Pittosporum crassifolium* | 1.25 | 0.32 |
| | Mixed weeds | | 3.37 | 0.86 |
| | Pampas | *Cortaderia jubata/selloana* | 1.40 | 0.36 |
| | Silver Poplar | *Populus alba* | 0.34 | 0.09 |
| | Willow | *Salix* sp. | 0.10 | 0.03 |
| **Unvegetated** | | | **4.8** | **1.2** |
| | Asphalt | | 4.47 | 1.15 |
| | Burnt vegetation | | 0.30 | 0.08 |
| **Grand Total** | | | **389.6** | **100** |

Fine scale sampling was undertaken along the Kapiti Coast to provide detail on the chemical and physical properties of the dominant sandy habitat (Table 6). Both beach and river estuary sites were sampled and compared to see if any gross differences were present in areas with different potential inputs of contaminant. Composite samples were collected only from lower intertidal areas where fine sediment bound contaminants have a greater tendency to accumulate. This was to provide a worst case assessment of background beach quality away from obvious point sources of contaminants.

**Table 6** Physico-chemical characteristics of whole sediments from fine scale sites on the Kapiti Coast compared to ANZECC sediment quality guidelines (mg.kg$^{-1}$).

| Site | AFDW | Silt&Clay | Sand | Gravel | Cadmium | Chromium | Copper | Nickel | Lead | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|
| **GWRC data (2005)** | | | | | | | | | | |
| Otaki Beach North | 0.4 | <0.1 | 98.4 | 1.7 | <0.1 | 6.0 | 1.9 | 5.0 | 3.1 | 19.0 |
| Otaki Beach South | 0.5 | 5.7 | 93.7 | 1.6 | <0.1 | 5.7 | 2.4 | 5.0 | 3.8 | 18.0 |
| Paraparaumu Beach | 0.8 | <0.1 | 98.1 | 1.9 | <0.1 | 5.7 | 2.6 | 5.0 | 4.4 | 23.0 |
| Paekakariki Beach | 0.8 | 2.7 | 97.0 | 1.6 | <0.1 | 6.7 | 2.7 | 8.0 | 4.4 | 19.0 |
| Waikanae River | 0.7 | 0.2 | 98.1 | 1.7 | <0.1 | 6.4 | 2.9 | 6.0 | 4.7 | 21.5 |
| Tikotu Creek | 0.5 | 0.1 | 99.3 | 0.7 | <0.1 | 6.6 | 2.2 | 6.0 | 3.8 | 22.0 |
| Wharemauku Stream | 0.7 | 0.1 | 99.4 | 0.6 | <0.1 | 6.4 | 2.5 | 6.0 | 4.1 | 24.0 |
| Whareroa Stream | 0.7 | 0.3 | 98.9 | 0.9 | <0.1 | 6.2 | 2.7 | 5.0 | 4.2 | 22.0 |
| **ANZECC ISQG-Low** | | | | | ***1.5*** | ***80*** | ***65*** | ***21*** | ***50*** | ***200*** |
| **ANZECC ISQG-High** | | | | | ***10*** | ***370*** | ***270*** | ***52*** | ***220*** | ***410*** |

The results showed all metal concentrations were well below ANZECC sediment quality trigger values and there was no significant difference in the chemical status of the different areas. The low organic content of sediment (AFDW <1 mg.kg$^{-1}$), and the absence of algal blooms or sediment anoxia, indicate enrichment is not a significant problem at any of the sites sampled.

Within beach sediments, biological samples indicated relatively few animals were present (Table 7). This reflects both the type of habitat present, and also the limited sampling undertaken. The vast majority of animals were epifaunal scavengers such as amphipods and isopods, and infaunal deposit feeders such as oligochaete and polychaete worms. This is consistent with the typical assemblage commonly present on beaches of this type as outlined in Figure 8. Bivalve shellfish (tuatua) were only found in samples at Paraparaumu and Paekakariki beaches however shellfish collection was evident at Otaki beach and shellfish are certainly present along the entire Kapiti Coast, although are likely to be most abundant below MLWS.

**Figure 8** Schematic cross-section of infauna commonly present on sandy beaches.

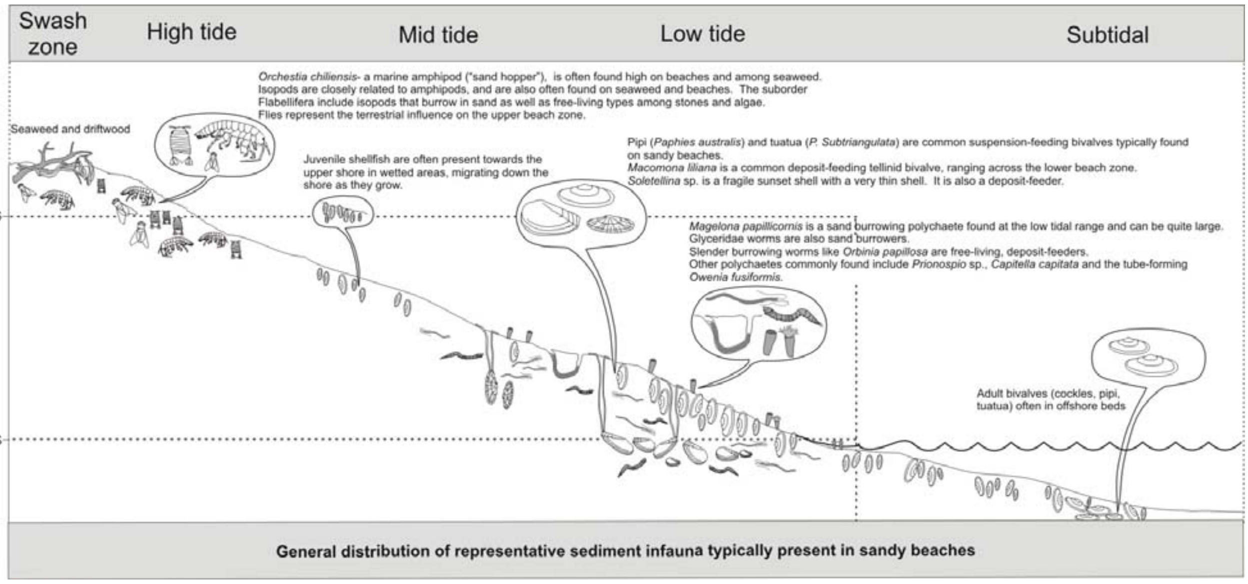



**Table 7** Sediment dwelling infauna collected from beaches on the Kapiti Coast.

| Kapiti Beaches | | Shore height | Otaki Nth Lo | Otaki Nth Up | Otaki Sth Lo | Otaki Sth Up | Para'umu Lo | Para'umu Up | Paekak. Lo | Paekak. Up |
|---|---|---|---|---|---|---|---|---|---|---|
| **Taxa** | **Common Name** | **FEEDING TYPE** | | | | | | | | |
| **NEMERTEA** | Ribbon worms | Carnivorous | | 2 | | | | 1 | | |
| **NEMATODA** | Roundworm | | | | | | 1 | | | |
| **BIVALVIA** | | | | | | | | | | |
| *Paphies subtriangulata* | Tuatua | Filter feeder | | | | | | 12 | 1 | |
| **OLIGOCHAETA** | Oligochaete worms | Infaunal deposit feeder | | | 1 | | | | | |
| **POLYCHAETA** | | | | | | | | | | |
| *Heteromastus filiformis* | | Infaunal deposit feeder | | | | 1 | | | | 1 |
| Glyceridae | Blood worm | Infaunal carnivore & deposit feeder | | | 1 | 15 | | | | |
| *Dispio sp.* | | Surface deposit & filter feeder | | | | | | | | 1 |
| **MYSIDACEA** | Mysid shrimp | Filter and deposit feeder | | | | | 1 | | | |
| **ISOPODA** | | | | | | | | | | |
| Flabellifera | Sea louse | Epifaunal scavenger | | 1 | 6 | | | 1 | | |
| Asellota | Isopod | | 1 | | | | 9 | | | |
| **AMPHIPODA** | | | | | | | | | | |
| Amphipoda b | Amphipods | Epifaunal scavenger | | | | 2 | 18 | 53 | | |
| Amphipoda c | Amphipods | Epifaunal scavenger | 8 | 2 | 1 | | 3 | | 1 | |
| **DECAPODA** | | | | | | | | | | |
| *Callianassa filholi* | Ghost Shrimp | | | | 1 | | | | | |
| **INSECTA** | | | | | | | | | | |
| *Chironomus spa.* | Midge | Algal grazer | | | | | 1 | | | |
| **Total No. of Taxa** | | | **2** | **3** | **5** | **3** | **6** | **4** | **2** | **2** |
| **Total No. of Individuals** | | | **9** | **5** | **10** | **18** | **33** | **67** | **2** | **2** |

Within river estuary sites the small streams at Tikotu and Wharemauku had very few animals present, particularly in the upper tidal region (Table 8). Both these sites have small flows, are within urban catchments and discharge into firm sand beaches. The area of habitat that was estuarine in character was very small and extended at most 2-3m from the streambed at low tide.

Whareroa, in a largely undeveloped catchment, had slightly higher species richness and abundance, but like the previous two sites, few estuarine or marine species, most being common to terrestrial or freshwater habitats. The higher number of insects reflects the standing water present in this waterway as evident in Figure 5E.

In contrast, Waikanae Estuary had a much more estuarine character with a range of amphipods, polychaetes and gastropods present. It is relatively well protected from the open coast by the river delta, and the substrate appears relatively stable. The presence of high numbers of amphipods reflects the presence of organic material, predominantly terrestrial plant matter on the sediment surface, while other species are typical of a sandy coastal estuary.

**Table 8** Sediment dwelling infauna collected from river estuary sites on the Kapiti Coast.

| **Kapiti Riever Estuaries** | | | **Tikotu** | | **Waikanae** | | | | **Wharemauku** | | **Whareroa** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Taxa** | **Common Name** | **FEEDING TYPE** | **Lo** | **Up** | **Lo** | **Up** | **Lo** | **Up** | **Lo** | **Up** | **Lo** | **Up** |
| **NEMERTEA** | Ribbon worms | Carnivorous | | | | | | | | | | |
| **NEMATODA** | Roundworm | | | | | | | 1 | | | | |
| **GASTROPODA** | | | | | | | | | | | | |
| *Amphibola crenata* | Mud Snail | Microalgal grazer | | | | | 2 | 3 | | | | |
| *Potamopyrgus antipodarum* | Estuarine snail | Microalgal & detrital grazer | 1 | | 39 | 3 | 392 | 3 | | | | 1 |
| *Potamopyrgus pupoides* | Estuarine snail | Microalgal & detrital grazer | | | 1 | | | 1 | | | | |
| **BIVALVIA** | | | | | | | | | | | | |
| *Paphies australis* | Pipi | Filter feeder | | | | | 6 | | | | | |
| **OLIGOCHAETA** | Oligochaete worms | Infaunal deposit feeder | | | 18 | | 1 | | | | 1 | 1 |
| **POLYCHAETA** | | | | | | | | | | | | |
| *Heteromastus filiformis* | | Infaunal deposit feeder | | | | 1 | | | | | | |
| Paraonidae | | Infaunal deposit feeder | | | | | | | | | 1 | |
| *Neanthes cricognatha* | Rag Worm | Omnivorous | | | | | | | | | | |
| *Nicon aestuariensis* | Rag worm | Omnivorous | | | | | 47 | | | | | |
| *Boccardia sp.* | | Surface deposit feeder | | | | | | | | | | |
| *Prionospio sp.* | | Surface deposit feeder | | | | 1 | | | | | | |
| *Scolecolepides benhami* | | Surface deposit feeder | | | 16 | | 12 | | | | | |
| *Scolelepis sp.* | | Surface deposit & filter feeder | | | 46 | | 6 | 3 | | | | |
| **MYSIDACEA** | | | | | | | | | | | | |
| Mysidacea | Mysid shrimp | Filter and deposit feeder | | | | | 1 | | | | | |
| **ISOPODA** | | | | | | | | | | | | |
| Flabellifera | Sea louse | Epifaunal scavenger | | | | 16 | | 6 | | | | |
| **AMPHIPODA** | | | | | | | | | | | | |
| *Paracorphium sp.* | Freshwater amphipod | | | | 163 | | 792 | 54 | 3 | | 12 | 2 |
| Amphipoda b | Amphipods | Epifaunal scavenger | | | 1 | | | 38 | | | | |
| Amphipoda c | Amphipods | Epifaunal scavenger | 5 | 3 | | | | | | | 1 | 1 |
| Amphipoda d | Amphipods | Epifaunal scavenger | | | | | | | | | | |
| *Macrophthalmus hirtipes* | Stalk-eyed Mud Crab | Deposit feeder & scavenger | | | 1 | | | | | | | |
| **OSTRACODA** | Ostracods | Omnivorous scavenger | | | | | | | | | | |
| **INSECTA** | | | | | | | | | | | | |
| Formicidae | Ants | | | | | | | | | | | |
| Muscidae | Fly larvae | Deposit feeder & scavenger | | 1 | | | | 1 | | | | |
| Orthocladiinae | Midges | Algal grazer | | | | | | | | | 7 | 1 |
| *Chironomus spa.* | Midge | Algal grazer | 71 | | | | | | | | 114 | 12 |
| *Corynoneura scutellata* | Midges | Algal grazer | | | | | | | | | 1 | |
| *Ephydrella sp.* | Shore fly larvae | Deposit feeder & scavenger | | | | | | | | | | 3 |
| *Limonia sp.* | Crane fly larvae | Deposit feeder & scavenger | | | | | | | | | | 5 |
| Collembola | Springtails | | 2 | | | | | | | | | |
| **ARACHNIDA** | | | | | | | | | | | | |
| Acarina | Mites | Carnivorous (sucking liquids) | | | | | | | | | 1 | |
| **CHLOROPHYTA** | | | | | | | | | | | | |
| *Enteromorpha sp.* | Green seaweed | Photosynthetic | | | | | | | | | 1 | |
| **Total No. of Taxa** | | | **4** | **2** | **8** | **4** | **9** | **9** | **1** | **0** | **9** | **8** |
| **Total No. of Individuals** | | | **79** | **4** | **285** | **21** | **1259** | **110** | **3** | **0** | **139** | **26** |

### *4.1.2 Karehana Bay / Plimmerton Beach*

In contrast to the wide, open sandy beaches of the Kapiti coast, beaches between Karehana in the north to the Plimmerton marina in the south were significantly different in character. The coastline was dominated by extensive areas of boulder field between the beaches (51% of the area mapped). Sand beaches were present at Karehana and Plimmerton (35% of the area mapped), with a band of cobble present low in the tidal zone at Karehana Beach, and a narrow band of sand and cobble further south near the marina (Table 9).

Vegetation was sparse with Karehana and Plimmerton beaches flanked at the landward margin by artificial seawalls, with roading or housing immediately behind the seawalls (Figures 9A, B). This is most pronounced at Plimmerton where housing extends right to the foreshore and the beach largely disappears at high tide as water comes in and laps against the seawall (Figure 9B). The rocky substrate of the foreshore between the beaches and seaward of the road also has little vegetation present other than small areas of grass.

**Table 9** Summary of the substrate and vegetation present at Karehana and Plimmerton Beaches.

| PLIMMERTON & KAREHANA BEACH HABITAT SUMMARY | | | |
|---|---|---|---|
| **Dominant Habitat Class** | **Primary-Subdominant** | **Area (Ha)** | **% of total** |
| **Terrestrial** | | | |
| **Grassland** | Marram grass (*Ammophila arenaria*) | 0.35 | 55.1 |
| | Unidentified grass | 0.29 | 44.9 |
| TOTAL | | **0.6** | **100** |
| | | | |
| **Intertidal** | | | |
| Man-made seawall | | 0.47 | 3.5 |
| Boulder field | | 6.94 | 51.3 |
| Boulder field man-made | | 0.50 | 3.7 |
| Cobble field | | 0.90 | 6.6 |
| Firm sand | | 4.71 | 34.9 |
| TOTAL | | **13.5** | **100** |

Sediment chemistry results showed all metal concentrations were well below ANZECC sediment quality trigger values (Table 10). Sediment organic content was slightly higher than along the Kapiti Coast but there were no indications of adverse enrichment at the sites sampled. Overall, there was no obvious contamination of the beach sediments.

**Table 10** Physico-chemical characteristics of whole sediments from fine scale sites at Karehana and Plimmerton compared to ANZECC sediment quality guidelines (mg.kg$^{-1}$).

| Site | AFDW | Silt&Clay | Sand | Gravel | Cadmium | Chromium | Copper | Nickel | Lead | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|
| **GWRC data (2005)** | | | | | | | | | | |
| Karehana Bay | 1.0 | 2.1 | 96.5 | 1.5 | <0.1 | 8.0 | 2.5 | 5.0 | 3.9 | 24.0 |
| Plimmerton Beach | 1.5 | 0.9 | 97.4 | 1.8 | <0.1 | 9.3 | 2.8 | 6.0 | 5.1 | 27.0 |
| **ANZECC ISQG-Low** | | | | | ***1.5*** | ***80*** | ***65*** | ***21*** | ***50*** | ***200*** |
| **ANZECC ISQG-High** | | | | | ***10*** | ***370*** | ***270*** | ***52*** | ***220*** | ***410*** |

The sediment dwelling infauna at both Karehana and Plimmerton was relatively sparse (Table 11). Only a single sea louse at Plimmerton was present in upper beach samples, while further down the shore a mix of scavenging amphipods and isopods were present. At Karehana, a similar assemblage was present on the lower shore, with the addition of a single bivalve (tuatua). At Karehana, cobble underlying the sand prevented direct coring and required the sample to be collected with a trowel.

**Table 11** Sediment dwelling infauna collected from Karehana Bay and Plimmerton Beach.

| **Karehana Bay and Plimmerton Beach** | | | | **Karehana** | | **Plimmerton** | |
|---|---|---|---|---|---|---|---|
| | | | **Shore height** | **Lo** | **Up** | **Lo** | **Up** |
| **Taxa** | **Common Name** | **FEEDING TYPE** | | | | | |
| **BIVALVIA** | | | | | | | |
| *Paphies subtriangulata* | Tuatua | Filter feeder | | 1 | | | |
| **POLYCHAETA** | | | | | | | |
| *Dispio sp.* | | Surface deposit & filter feeder | | | | 7 | |
| **ISOPODA** | | | | | | | |
| Flabellifera | Sea louse | Epifaunal scavenger | | 13 | | | 1 |
| Asellota | Isopod | | | | | 6 | |
| **AMPHIPODA** | | | | | | | |
| Amphipoda b | Amphipods | Epifaunal scavenger | | | | 11 | |
| Amphipoda c | Amphipods | Epifaunal scavenger | | 1 | | 1 | |
| **Total No. of Taxa** | | | | **3** | **0** | **4** | **1** |
| **Total No. of Individuals** | | | | **15** | **0** | **25** | **1** |

### *4.1.3 Titahi Bay*

Titahi Bay was different in character again to the other beaches, being a relatively sheltered, crescent-shaped beach dominated by sand (70%), with a patch of cobble along the upper shore near the surf club (20%) (Table 12).

Boatsheds are present at either end of the bay (Figure 9C) with ramps and access sites across the beach. Relatively steep dunes and plantings are present at the head of the beach. Marram grass and tussockland (flax) dominate the dune to the north of the beach, while a seawall protects the dune to the south which has been planted in marram grass (Figure 9E). Rocky headlands are present at either end of the bay.

One of the most visible features of Titahi Bay is vehicle use which is permitted on the northern part of the beach with access down a concrete ramp. The area is well utilised as evident by the tyre marks in Figure 9D. The substrate is noticeably compacted in this area compared to the beach areas where vehicles are not permitted Figure 9E.

To investigate the possible impact of vehicle use, biological and physio-chemical samples were collected from both the upper and lower shore in vehicle and non-vehicle zones.

Sediment chemistry results showed all metal concentrations were well below ANZECC sediment quality trigger values (Table 13) with no significant differences between the sites. The slightly elevated lead level where vehicles are allowed is attributable to the higher silt and mud fraction of the sample at this site.


**Figure 9** Photos of Karehana, Plimmerton and Titahi.

Sediment organic content was slightly higher than along the Kapiti Coast but there were no indications of adverse enrichment at the sites sampled. Overall, there was no obvious contamination of the beach sediments.

**Table 12** Summary of the substrate and vegetation present at Titahi Bay.

| TITAHI BAY HABITAT SUMMARY | | | |
|---|---|---|---|
| **Dominant Habitat Class** | **Primary-Subdominant** | **Area (Ha)** | **% of total** |
| **Terrestrial** | | | |
| Tussockland | Harakeke (*Phormiun tenax* ), native trees, Marram grass (*Ammophila arenaria* ) | 0.73 | 59.1 |
| Grassland | Marram grass (*Ammophila arenaria* ) / Taupata (*Coprosma repens* ) | 0.51 | 40.9 |
| TOTAL | | **1.2** | **100** |
| **Intertidal** | | | |
| Man-made seawall | | 0.10 | 1.4 |
| Boulder field | | 1.46 | 20.3 |
| Cobble field | | 0.60 | 8.4 |
| Firm sand | | 5.03 | 69.9 |
| TOTAL | | **7.2** | **100** |

**Table 13** Physico-chemical characteristics of whole sediments from fine scale sites at Titahi Bay compared to ANZECC sediment quality guidelines (mg.kg$^{-1}$).

| Site | AFDW | Silt&Clay | Sand | Gravel | Cadmium | Chromium | Copper | Nickel | Lead | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|
| **GWRC data (2005)** | | | | | | | | | | |
| Titahi Bay - vehicles | 1.3 | 3.9 | 96.5 | 1.6 | <0.1 | 13.1 | 1.7 | 11.5 | 10.4 | 19.5 |
| Titahi Bay - no vehicles | 0.7 | 0.5 | 98.4 | 1.5 | <0.1 | 9.8 | 1.5 | 10.0 | 3.7 | 17.5 |
| **ANZECC ISQG-Low** | | | | | ***1.5*** | ***80*** | ***65*** | ***21*** | ***50*** | ***200*** |
| **ANZECC ISQG-High** | | | | | ***10*** | ***370*** | ***270*** | ***52*** | ***220*** | ***410*** |

Sediment dwelling infauna at both Titahi Bay sites was sparse in the upper shore (Table 14), consistent with the other sites sampled along the Kapiti Coast. At the lower shore sites, very few animals were present in the area open to vehicles with only 3 individuals from 1 site being recorded. This compares to 60 from all 3 sites in the southern beach closed to vehicles. However, this is not considered a direct indication of vehicle impacts, but is considered a function of the slightly different habitats present at the sites. To the south, the beach has a greater mix of substrate types present, is slightly steeper, and undulates more (has slight humps and hollows). In contrast, the north of the beach is very flat (see Figure 9D and E). While vehicles may have a role in this, further investigation would be necessary to further explore any potential relationship.

**Table 14** Sediment dwelling infauna collected from Titahi Bay.

| Titahi Bay | | Shore height | Vehicles | | | | | | No vehicles | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lower | | | Upper | | | Lower | | | Upper | | |
| **Taxa** | **Common Name** | **FEEDING TYPE** | **A** | **B** | **C** | **A** | **B** | **C** | **A** | **B** | **C** | **A** | **B** | **C** |
| **BIVALVIA** | | | | | | | | | | | | | | |
| *Paphies subtriangulata* | Tuatua | Filter feeder | 1 | | | | | | | | | | | |
| **OLIGOCHAETA** | | | | | | | | | | | | | | |
| *Dispio sp.* | | Surface deposit & filter feeder | | | | | 1 | | | | | | | |
| **MYSIDACEA** | | | | | | | | | | | | | | |
| Mysidacea | Mysid shrimp | Filter and deposit feeder | 1 | | | | | | | | | | | |
| **ISOPODA** | | | | | | | | | | | | | | |
| Asellota | Isopod | | | | | | | | 1 | 1 | 9 | | | |
| **AMPHIPODA** | | | | | | | | | | | | | | |
| Amphipoda b | Amphipods | Epifaunal scavenger | | | | | | | 30 | 3 | 13 | | | |
| Amphipoda c | Amphipods | Epifaunal scavenger | 1 | | | | | | 2 | 1 | | | | |
| **INSECTA** | | | | | | | | | | | | | | |
| Collembola | Springtails | | | | | | | | | | | | 1 | |
| **Total No. of Taxa** | | | **3** | **0** | **0** | **0** | **1** | **0** | **3** | **3** | **2** | **0** | **1** | **0** |
| **Total No. of Individuals** | | | **3** | **0** | **0** | **0** | **1** | **0** | **33** | **5** | **22** | **0** | **1** | **0** |

### *4.1.4 Makara Estuary*

Figures 10 and 11 and Table 15 show Makara Estuary was dominated by water (80%) with the intertidal habitat predominantly cobble (16%) and boulder (4%). Surrounding the 4.4 Ha wetted part of the estuary was 3.1 Ha of estuarine vegetation, dominated by native shrub/scrub/trees (78%) comprising mainly saltmarsh ribbonwood and searush, with smaller areas of flax and sedge tussockland (12%) around the terrestrial margins. Grassland (4%), comprising tall fescue, marram grass and introduced weeds, and rushland (1%), comprising searush and introduced weeds flanked the larger species, while in the estuary herbfield (5%) was dominated by glasswort and introduced weeds (Table 16). Terrestrial vegetation (Table 17) was dominated by introduced weeds (78%) and grassland (10%).

**Figure 10** Examples of habitat within Makara Estuary.

**Table 15** Summary of the substrate and vegetation present in Makara Estuary.

| MAKARA ESTUARY HABITAT SUMMARY | | |
|---|---|---|
| **Dominant Habitat Class** | **Area (Ha)** | **% of total** |
| **Terrestrial** | | |
| Exotic scrub/shrub/trees (ESST) | 0.76 | 10.6 |
| Tussockland | 0.10 | 1.4 |
| Grassland | 0.73 | 10.2 |
| Introduced weeds | 5.54 | 77.8 |
| TOTAL | **7.1** | **100.0** |
| **Estuarine** | | |
| Native scrub/shrub/trees (NSST) | 2.42 | 78.1 |
| Tussockland | 0.36 | 11.5 |
| Grassland | 0.14 | 4.4 |
| Rushland | 0.04 | 1.2 |
| Herbfield | 0.15 | 4.9 |
| TOTAL | **3.1** | 100.0 |
| **Intertidal** | | |
| Boulder field | 0.17 | 3.9 |
| Cobble field | 0.72 | 16.2 |
| Firm sand (Gravel field) | 0.01 | 0.3 |
| Water | 3.54 | 79.7 |
| TOTAL | **4.4** | **100** |

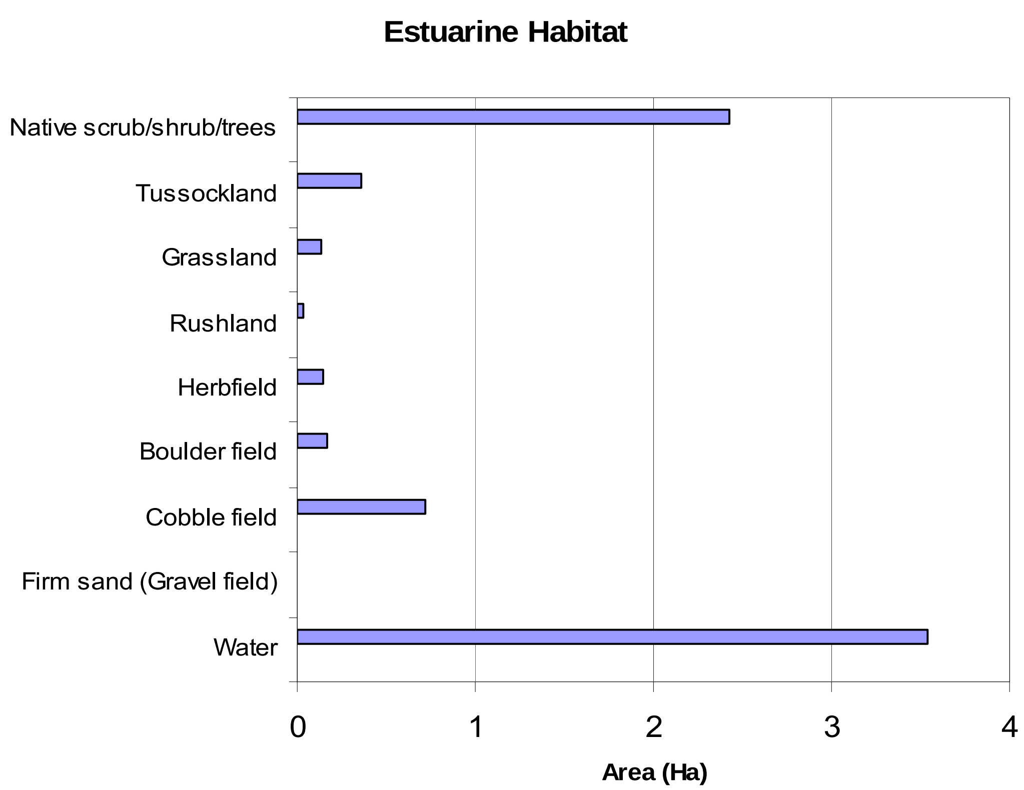



**Figure 11** Area (Ha) of intertidal habitat features mapped in Makara Estuary.

**Table 16** Detail of the estuarine vegetation present in Makara Estuary.

| MAKARA: ESTUARY VEGETATION | | | | |
|---|---|---|---|---|
| **Class** | **Dominant vegetation** | **Scientific name** | **Area (Ha)** | **% of total** |
| **Native scrub/shrub/trees (NSST)** | | | **2.42** | **78.1** |
| | Saltmarsh ribbonwood / Searush | *Plagianthus divaricatus / Juncus kraussii* | 2.42 | 78.1 |
| **Tussockland** | | | **0.36** | **11.5** |
| | Flax (Harakeke) / Sedge | *Phormium tenax / Carex* spp. | 0.36 | 11.5 |
| **Grassland** | | | **0.14** | **4.4** |
| | Tall fescue / Introduced weeds | *Festuca arundinacea* / Unidentified weeds | 0.10 | 3.2 |
| | Marram grass | *Ammophila arenaria* | 0.04 | 1.2 |
| **Rushland** | | | **0.04** | **1.2** |
| | Searush / Introduced weeds | *Juncus kraussii* / Unidentified weeds | 0.04 | 1.2 |
| **Herbfield** | | | **0.15** | **4.9** |
| | Glasswort / Introduced weeds | *Sarcocornia quinqueflora* / Unidentified weeds | 0.15 | 4.9 |
| **Estuarine Total** | | | **3.10** | **100** |

**Table 17** Detail of the terrestrial vegetation present in Makara Estuary.

| MAKARA: TERRESTRIAL VEGETATION | | | | |
|---|---|---|---|---|
| **Class** | **Dominant vegetation** | **Scientific name** | **Area (Ha)** | **% of total** |
| **Exotic scrub/shrub/trees (ESST)** | | | **0.76** | **10.6** |
| | Exotic scrub/shrub/trees | | 0.29 | 4.1 |
| | Macrocarpa | *Cupressus macrocarpa* | 0.46 | 6.5 |
| **Tussockland** | | | **0.10** | **1.4** |
| | Flax (Harakeke) | *Phormium tenax* | 0.04 | 0.5 |
| | Sedge / Gorse | *Carex* spp. */ Ulex europaeus* | 0.06 | 0.8 |
| **Grassland** | | | **0.73** | **10.2** |
| | Silvery grass | *Spinifex sericeus* | 0.30 | 4.3 |
| | Unidentified grass | | 0.21 | 2.9 |
| | Tall fescue / flax | *Festuca arundinacea / Phormium tenax* | 0.22 | 3.0 |
| **Introduced Weeds** | | | **5.54** | **77.8** |
| | Purple pampas grass | *Cortaderia jubata* | 0.05 | 0.7 |
| | Gorse / Introduced weeds | *Ulex europaeus* / Unidentified weeds | 0.34 | 4.8 |
| | Introduced weeds | Unidentified weeds | 3.53 | 49.6 |
| | Introduced weeds / Gorse | Unidentified weeds / *Ulex europaeus* | 1.61 | 22.7 |
| **Terrestrial Total** | | | **7.13** | **100** |

**Table 18** Physico-chemical characteristics of sediments from fine scale sites in Makara Estuary compared to ANZECC sediment quality guidelines (mg.kg$^{-1}$).

| **Site** | **AFDW** | **Silt&Clay** | **Sand** | **Gravel** | **Cadmium** | **Chromium** | **Copper** | **Nickel** | **Lead** | **Zinc** |
|---|---|---|---|---|---|---|---|---|---|---|
| **GWRC data (2005)** | | | | | | | | | | |
| Makara River | 1.3 | 21.2 | 76.5 | 2.4 | <0.1 | 8.5 | 33.5 | 7.0 | **106.0** | 66.0 |
| **ANZECC ISQG-Low** | | | | | ***1.5*** | ***80*** | ***65*** | ***21*** | ***50*** | ***200*** |
| **ANZECC ISQG-High** | | | | | ***10*** | ***370*** | ***270*** | ***52*** | ***220*** | ***410*** |

Whole sample sediment chemistry results (Table 18) showed metal concentrations were below ANZECC sediment quality trigger values for all except lead which exceeded the ISQG-Low value. While the high silt and mud fraction (21.2%) of the sediment accounts for much of the reason for the elevated level compared to other sites. A likely source of the lead is a boat launching and maintenance area, although very little in known about its use. While exceedance of trigger values does not necessarily suggest environmental damage, further investigation as to the potential source and possible impact of this value is recommended.

The sediment dwelling infauna contained large numbers of scavengers and deposit feeders typically present in muddy estuary environments (Table 19).

**Table 19** Sediment dwelling infauna collected from Makara Estuary.

| **Makara Estuary** | | | **Lower** | | **Upper** | |
|---|---|---|---|---|---|---|
| **Taxa** | **Common Name** | **FEEDING TYPE** | **A** | **B** | **A** | **B** |
| **NEMERTEA** | Ribbon worms | Carnivorous | 1 | | | |
| **NEMATODA** | Roundworm | | 25 | 162 | 2 | 10 |
| **GASTROPODA** | | | | | | |
| *Potamopyrgus antipodarum* | Estuarine snail | Microalgal & detrital grazer | 277 | 1698 | | 3 |
| *Potamopyrgus pupoides* | Estuarine snail | Microalgal & detrital grazer | 1109 | 565 | 5 | 1 |
| **OLIGOCHAETA** | Oligochaete worms | Infaunal deposit feeder | 45 | 102 | | 241 |
| **POLYCHAETA** | | | | | | |
| *Neanthes cricognatha* | Rag Worm | Omnivorous | 41 | 19 | | |
| *Boccardia sp.* | | Surface deposit feeder | 44 | 42 | | |
| **MYSIDACEA** | | | | | | |
| Mysidacea | Mysid shrimp | Filter and deposit feeder | 7 | 16 | 3 | 19 |
| **AMPHIPODA** | | | | | | |
| *Paracorphium sp.* | Freshwater amphipod | | 70 | 225 | 1 | |
| Amphipoda c | Amphipods | Epifaunal scavenger | | 1 | 7 | |
| Amphipoda d | Amphipods | Epifaunal scavenger | | | 16 | |
| **OSTRACODA** | Ostracods | Omnivorous scavenger | | 10 | | |
| **INSECTA** | | | | | | |
| Formicidae | Ants | | | | 1 | |
| Muscidae | Fly larvae | Deposit feeder & scavenger | | 1 | | |
| Orthocladiinae | Midges | Algal grazer | | 1 | | |
| Collembola | Springtails | | | | 1 | |
| **Total No. of Taxa** | | | **9** | **12** | **8** | **5** |
| **Total No. of Individuals** | | | **1619** | **2842** | **36** | **274** |

## 4.2 Environmental pressures

During mapping, observations were made on potential environmental pressures that were evident including:

- Erosion Protection
- Flooding
- Grooming
- Introduced Weeds
- Landfill Leachate
- Loss of Marginal Habitat
- Nutrient Enrichment
- Residential
- Sand/Gravel Extraction
- Shellfish Collection
- Stormwater
- Vehicles

In general, GWRC are likely to already be aware of where most pressures are, or have existing data which compliments the current project. Combining the available information should allow the location and potential significance of identified pressures to be further refined, with priority areas targeted for more detailed field surveys as appropriate.

A basic risk assessment matrix (Figure 12) provides a simple tool to define the level of concern associated with different pressures on a habitat in terms of potential sensitivity and consequence using a colour ranking from high (red) to low (green). 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 timeframe for recovery. It is important to note that the matrix does not confirm the presence of an impact, it simply indicates where pressures may be present, and the possible consequences associated with specific pressures should they occur.

| | | 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 |

**Figure 12** Risk assessment matrix for evaluating levels of concern to habitat pressures.

The major benefit of the matrix is that it provides a simple but robust way of comparing impacts at different sites and defining planning, monitoring or remediation priorities. This can be done for existing conditions, as well as for predicting previous or future impacts under changed conditions *e.g.* assessing what the pressures may have been prior to residential development, or if there was to be a doubling of a population in an area.

For the Kapiti coastline, the residential development of farmland and duneland adjacent to the beach at Raumati provides a good example of the changes evident in the area. Over time, the area has been gradually modified through an increased population, with housing and impervious surfaces (roads, roofs) altering land use and surface runoff characteristics, and other changes occurring such as wetland drainage, sewage and stormwater disposal through on-site systems (eventually draining to the sea), modification of natural dune systems, the introduction of exotic plants and weeds, boat ramps, vehicle use on the beach, shellfish gathering *etc.* Subsequent pressures include protection from coastal erosion and flooding through the construction of seawalls, reclamations, stream culverts, roading, *etc*. Each of these factors can be assessed and given a score to indicate its likely significance as shown in Table 20.

**Table 20** Example of environmental pressures and possible levels of concern at Raumati Beach.

| | Raumati Beach |
|---|---|
| Erosion Protection | C1 |
| Flooding | - |
| Grooming | - |
| Introduced weeds | D2 |
| Landfill Leachate | - |
| Loss of Marginal Habitat | C1 |
| Nutrient Enrichment | - |
| Residential Development | B1 |
| Sand/Gravel Extraction | |
| Shellfish collection | D3 |
| Stormwater | D3 |
| Vehicles | D3 |
| | |
| Degree of Modification | VH |

In terms of the risk posed by such pressures at Raumati Beach, many are reversible and affect only a small portion of the total habitat (*e.g.* stormwater impacts). That is, while they may have a local impact, if the source was removed, recovery would be relatively rapid. The most significant pressures are associated with residential areas as once an area is developed there is little chance that it will be returned to its natural state so the impact is essentially irreversible. Similarly, once an area is developed, the consequences of erosion and flooding of such areas assume a greater importance and pressure is exerted to modify the environment further to protect against changes that may have occurred naturally in the past, such as dune migration in response to storm events.

A summary of the environmental pressures identified at each site, and a subjective assessment of the level of concern for each, is provided in Table 21 using the matrix presented in Figure 12. Blank cells indicate that the identified pressure is not considered significant/relevant, while a "?" indicates that the pressure may be present but needs confirmation.

**Table 21** Example of environmental pressures and possible levels of concern across all survey sites.

| | Erosion or Flood Protection | Flooding | Grazing | Grooming | Introduced weeds | Landfill Leachate | Loss of Marginal Habitat | Nutrient Enrichment | Residential Development | Sand/Gravel Extraction | Shellfish Collection | Stormwater | Vehicles | Degree of Modification |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Beach Sites** | | | | | | | | | | | | | | |
| Otaki Beach North | | | | | D3 | | | | | | D3 | | D3 | L |
| Otaki Beach South | | | | | D2 | | D1 | | D1 | | D3 | | D3 | M |
| Te Horo | | | | | D2 | | D1 | | D1 | | D3 | | D3 | M |
| Peka Peka | | | | | D2 | | D1 | | D1 | | D3 | | D3 | L |
| Waikanae Beach | | | | | D2 | | D1 | | D1 | | D3 | | D3 | M |
| Paraparaumu Beach | D1 | | | | D3 | | D1 | | C1 | | D3 | D3 | D3 | H |
| Raumati Beach | C1 | | | | D2 | | C1 | | B1 | | D3 | D3 | D3 | VH |
| Paekakariki Beach | D1 | | | | D2 | | D1 | | C1 | | D3 | D3 | D3 | H |
| Karehana Bay | D1 | | | | | | D1 | | C1 | | D3 | D3 | | H |
| Plimmerton Beach | D1 | | | | | | D1 | | C1 | | D3 | D3 | | VH |
| Titahi Bay | D1 | | | | D3 | | D1 | | C1 | | D3 | D3 | D3 | H |
| Makara Beach | | | | | D2 | | D1 | | D1 | | D3 | D4 | | L |
| **Estuary Sites** | | | | | | | | | | | | | | |
| Waitohu Stream | | | | | D3 | | | | D1 | | | | D4 | L |
| Otaki River | | D4 | | | C2 | | | | | D1 | | D4 | D4 | M |
| Mangaone Stream | | | | | D3 | | | | | | | D4 | | L |
| Peka Peka Stream | | | | | D3 | | | | | | | D4 | | L |
| Ngarara Stream | | | | | D2 | | D1 | | D1 | | | D4 | | M |
| Waikanae River | | D4 | | | D2 | | D1 | | D1 | | D3 | D4 | ? | M |
| Tikotu Creek | D1 | | | | D2 | | C1 | | C1 | | | D3 | | H |
| Wharemauku Stream | D1 | | | | D2 | | C1 | | C1 | | | D3 | | H |
| Whareroa Stream | D1 | | | | D2 | | | | | | | | | L |
| Makara River | | D4 | C3 | | D2 | | D1 | | C1 | | D3 | | | H |

Bacterial contamination was excluded from this assessment as it is monitored and addressed elsewhere through GWRC water quality monitoring. Introduced weeds were widely present, and in many instances, introduced plantings may provide important protection for the establishment of native species, or may have been introduced for their amenity or functional value. For example, marram grass carries out an important dune stabilisation role. Table 21 therefore seeks to indicate where introduced species have the potential to become pests, with indications of recovery predominantly reflecting the dominance of weeds over other species.

A subjective assessment of the degree of modification to the beach area has also been included, such as the construction of seawalls, reclamations, stream culverts, building developments, *etc.* to provide an indication of "naturalness".

Overall, the most significant impacts are associated with residential development along the coast and the subsequent loss of marginal habitat and increase in erosion protection works. The significance of the impact is primarily due to the near irreversible nature of the changes.

We have included the identification and ranking of pressures as a starting point for discussion of whether further investigation is justified, and if so, where the priorities may lie. GWRC is likely to hold resource consent information on many of the point source discharges, while local knowledge could also make a helpful contribution, activities which are outside the scope of the current project.

Although beyond the scope of the current project, placing existing knowledge within a risk assessment framework has been found previously to greatly assist in resource planning and management, particularly as it provides a meaningful way to incorporate local knowledge and engage stakeholders. Furthermore, overarching stressors such as land-use/management or climate change which have a direct influence on the local stressors *e.g.* flooding, erosion, can subsequently be incorporated into the assessment process through the use of qualitative models, for example Cawthron's Bayesian network and complex systems models (*e.g.* Gibbs 2005, Elemetri and Gibbs 2005). The models look at cause and effect relationships between stressors and are very useful in identifying the types of management strategies that are best suited for dealing with various pressures under a wide range of different scenarios.

Overall, unshaded cells indicate that sites are not considered to be significantly adversely affected by the pressures identified at the present point in time. Green cells show minimal impacts reflecting mainly the low percentage of each beach area affected, and to a lesser extent, the intermittent nature of the pressure, the susceptibility of the environment, and/or likely recovery rates. For example, scoring largely being C’s and D’s (<30% affected), and the recovery from impacts scoring 3’s and 4’s (<5 years). Those pressures with longer recovery times or covering large areas (indicated by yellow or red cells) all relate to human pressures through either residential development, a loss of habitat margins around beaches and streams, and erosion protection work. As such, these impacts are largely irreversible so while the area affected may be small (*e.g.* score of D), the recovery period is long (*e.g.* score of 1).

### 4.3 Summary

The primary output of coastal mapping is to define the type and location of the different habitats across the coastal margins of the region. The primary benefit of such work is to:

1. Help end users better understand the ecological status of the region and the impacts of human activities.
2. Assess environmental quality (*e.g.* the extent of sensitive/rare habitat types).
3. Select appropriate monitoring locations.
4. Develop effective management strategies.
5. Provide a regional, and contribute to a national, context of disturbance impacts.
6. Facilitate the assessment of the significance of potential impacts.

At the simplest level, habitat maps provide fundamental knowledge about where different habitat features are located, and their spatial extent. Therefore, this work will provide a valuable foundation by defining the existing coastal margin habitat types of the region, allowing undeveloped areas to be identified and their environmental values assessed, as well as providing an understanding of what features are susceptible to different pressures and whether development may enhance or adversely or irreversibly affect the area. Furthermore, it provides insight to the type of infrastructure that may be needed to mitigate the effects of development (*e.g.* sewage reticulation), or to make development feasible (*e.g.* flood control works).

Habitat mapping also maximises the benefit that can be gained from existing data sets. In many instances extensive GIS datasets are available recording infrastructure (*e.g.* sewers, water reservoirs), natural hazards (*e.g.* flood plains, erosion zones), and environmental features (*e.g.* wetlands, forest remnants, parks). By combining this information it is possible to understand how existing environmental pressures may be affecting environmental quality, and how changes to management, or changes to environmental conditions, may influence the region, thereby providing a solid underpinning context for planning and management decisions (including decisions to collect more information).

At a finer scale, measurements of the spatial variation and inter-relationships of a suite of commonly measured physical, chemical and biological indicators in a common low-mid water intertidal habitat showed all of the sites were in a healthy condition. Clearly, some localised impacts are present, but across the majority of the habitat at all of the sites, the intertidal sediment quality of the sites was high.

The overall results of the current study are summarised as follows:

**Grain Size:** The beaches and estuaries were predominantly (>90%) sand, the only exception being Makara Estuary (77% sand, 21% mud). The general absence of silt and clay fractions from the river estuaries reflects their size – most being only very small streams discharging directly to the beach, and having little in the way of an enclosed estuarine embayment where finer material accumulates.

**Nutrient and Organic Enrichment:** There were no obvious signs of adverse enrichment at any sites. For example, no extensive growths of algae (*e.g. Ulva*), or anoxic sediments were observed.

**Toxic Contaminants**: Using sediment heavy metal concentrations as an indicator of potentially toxic contaminants, fine scale sites all had levels well below ANZECC (2000) ISQG-Low trigger values. The only exception to this was in Makara River Estuary where lead exceeded the ISQG-Low trigger for which further investigation is recommended. Concentrations were all low compared to sites elsewhere in NZ and overseas (Table 22).

**Sediment Biota:** The abundance of infauna - animals living within the estuary and beach sediments (Appendix 2) - was typical of other New Zealand estuaries and beaches in good condition (*e.g.* Robertson *et al.* 2002). Sandy beach samples generally contained relatively few animals, particularly in upper tidal ranges, reflecting both the type of habitat present, and also the limited sampling undertaken. Dominant species were epifaunal scavengers such as amphipods and isopods, and infaunal deposit feeders such as oligochaete and polychaete worms.

River estuary sites within small streams had very few animals present, reflecting the small area that was estuarine in character, and the sandy substrata present.

Waikanae and Makara estuaries had a much more estuarine character with a range of amphipods, polychaetes and gastropods present, including scavengers and deposit feeders typically present in muddy estuary environments.

**Table 22** Average metal characteristics of whole sediments from NZ and overseas sites ($mg.kg^{-1}$).

| | Location | Cd | Cr | Cu | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|
| **GWRC (2005)** | Otaki Beach North | <0.1 | 6.0 | 1.9 | 5.0 | 3.1 | 19.0 |
| | Otaki Beach South | <0.1 | 5.7 | 2.4 | 5.0 | 3.8 | 18.0 |
| | Waikanae River | <0.1 | 6.4 | 2.9 | 6.0 | 4.7 | 21.5 |
| | Paraparaumu Beach | <0.1 | 5.7 | 2.6 | 5.0 | 4.4 | 23.0 |
| | Tikotu Creek | <0.1 | 6.6 | 2.2 | 6.0 | 3.8 | 22.0 |
| | Wharemauku Stream | <0.1 | 6.4 | 2.5 | 6.0 | 4.1 | 24.0 |
| | Whareroa Stream | <0.1 | 6.2 | 2.7 | 5.0 | 4.2 | 22.0 |
| | Paekakariki Beach | <0.1 | 6.7 | 2.7 | 8.0 | 4.4 | 19.0 |
| | Karehana Bay | <0.1 | 8.0 | 2.5 | 5.0 | 3.9 | 24.0 |
| | Plimmerton Beach | <0.1 | 9.3 | 2.8 | 6.0 | 5.1 | 27.0 |
| | Titahi Bay - vehicles | <0.1 | 13.1 | 1.7 | 11.5 | 10.4 | 19.5 |
| | Titahi Bay - no vehicles | <0.1 | 9.8 | 1.5 | 10.0 | 3.7 | 17.5 |
| | Makara River | <0.1 | 8.5 | 33.5 | 7.0 | 106.0 | 66.0 |
| **GWRC (2004)** | Hutt Estuary | <0.2 | 13.8 | 8.1 | 11.5 | 18.5 | 92.8 |
| | Petone Beach | <0.2 | 11.8 | 3.9 | 9.8 | 15.1 | 98.1 |
| | Lowry Bay | <0.2 | 5.9 | 2.8 | 4.5 | 10.2 | 62.7 |
| | Fitzroy Bay | <0.2 | 11.3 | 5.4 | 10.4 | 6.5 | 57.0 |
| **EMP Study*** | Otamatea Arm | 0.4 | 20.5 | 13.8 | 9.4 | 11.4 | 54.5 |
| | Ohiwa | 0.1 | 7.4 | 4 | 3.9 | 3.4 | 27.7 |
| | Ruataniwha | 0.1 | 24 | 7.1 | 13.7 | 4.7 | 37.5 |
| | Waimea | 0.3 | 67.6 | 9.6 | **72.5** | 7.4 | 41.8 |
| | Havelock | 0.3 | 48.8 | 10.7 | 26.5 | 5.6 | 43 |
| | Avon-Heathcote | 0.1 | 15.6 | 3.2 | 6.6 | 6.3 | 38.3 |
| | Kaikorai | 0.1 | 48.4 | 16.8 | 15.6 | 45.3 | 184.2 |
| | New River | 0.1 | 11.1 | 3.8 | 5 | 0.7 | 17.1 |
| **Other NZ sites** | New River Estuary | 0.2 | 11.1 | 3.7 | 5.6 | 3.7 | 15.7 |
| | Jacobs River Estuary | 0.3 | 12.3 | 11.9 | 7.6 | 5.6 | 35.9 |
| | Tamaki A (E1) [a] | | 14.5 | 27.8 | **56.9** | 132.1 | 136.1 |
| | Tamaki B (E2) [a] | | 20.6 | 26.1 | 6.6 | 72.9 | 167 |
| | Tamaki C (E3) [a] | | 17.3 | 29.4 | 9.3 | 69.7 | 173 |
| | Tamaki D (E4)[a] | | 35.9 | 38.5 | 12.8 | 145.2 | 233 |
| | Manukau (rural catch)[b] | 0.03 | | 20 | 15 | 9 | 114 |
| | Manukau (industrial catch) [b] | 0.25 | | 90 | 14 | 58 | 285 |
| | Waitemata Harbour [h] | <0.5 | 52 | 60 | 28 | 65 | 161 |
| | Otago (mid-upper harbour)[c] | 0.26 | 21 | 17 | 9.7 | 19 | 110 |
| | Lambton Harbour, Wellington [d] | | 91 | 68 | 21 | 183 | 249 |
| | Porirua Harbour, Wellington [e] | | 20 | 48 | 20 | 93 | 259 |
| | Aparima Estuary[f] | 0.067 | 15 | 12 | 10 | 11 | 49 |
| | Mataura Estuary[f] | 0.024 | 7.1 | 6.6 | 6 | 6.2 | 27 |
| **Overseas sites** | Delaware Bay, USA [g] | 0.24 | 27.8 | 8.3 | | 15 | 49.7 |
| | Lower Chesapeake Bay, USA[g] | 0.38 | 58.5 | 11.3 | | 15.7 | 66.2 |
| | San Diego Harbour, USA [g] | 0.99 | 178 | 218.7 | | 51 | 327.7 |
| | Salem Harbour, USA [g] | 5.87 | **2296.7** | 95.1 | | 186.3 | 238 |
| | Rio Tinto Estuary, Spain[f] | 4.1 | | **1400** | | **1600** | **3100** |
| | Restronguet Estuary, UK[f] | **12** | **1060** | **4500** | | **1620** | **3000** |
| **ANZECC ISQG-Low** | | 1.5 | 80 | 65 | 21 | 50 | 200 |
| **ANZECC ISQG-High** | | **10** | **370** | **270** | **52** | **220** | **410** |

*Robertson *et al.* (2002)
a Sites positioned from inner (E4) to outer (E1) estuary locations in heavily urbanised area (Thompson 1987)
b Subtidal on open coast (Roper 1990)
c Largely undisturbed estuary near Nelson (Gillespie & MacKenzie 1990)
d Slightly modified estuary near Nelson; affected by urban stormwater, roading, marina development (Gillespie & MacKenzie 1990)
e Slightly modified estuary near Motueka; affected by food processing industry wastes, urban runoff (Gillespie *et al.* 1995)
f Site affected by a high nutrient freezing works discharge (Gillespie & MacKenzie 1990)
g Kennish (1997)
h Jezus Belzunce et al. (2001)

**Environmental pressures:** This study identified the following pressures on beaches and river estuaries during sampling:

- Erosion Protection
- Flooding
- Grooming
- Introduced Weeds
- Landfill Leachate
- Loss of Marginal Habitat
- Nutrient Enrichment
- Residential
- Sand/Gravel Extraction
- Shellfish Collection
- Stormwater
- Vehicles

Overall, many of the identified pressures were not considered to be adversely affecting the sites investigated beyond localised areas. The low impact reflects mainly the low percentage of each area affected, and to a lesser extent, the intermittent nature of the pressure, the assimilative capacity of the environment, and/or likely recovery rates. The most significant impacts are associated with residential development along the coast and the subsequent loss of marginal habitat and increase in erosion protection works. The significance of the impact is primarily due to the near irreversible nature of the changes.

In conclusion, this study found that the intertidal sandy beaches and river estuaries of the Kapiti Coast were generally all in a healthy condition and showed no signs of adverse nutrient enrichment or chemical contamination. Environmental pressures do exist but are generally quite localised and currently do not significantly threaten the health of the majority of the areas investigated. Residential development poses the most significant impact to the coastal areas.

## 5. REFERENCES


ANZECC & ARMCANZ. 2000. *Australian and New Zealand guidelines for fresh and marine water quality 2000 Volume 1.* National Water Quality Management Strategy Paper No 4. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Atkinson, I.A.E. 1985. Derivation of vegetation mapping units for an ecological survey of Tongariro National Park North Island, New Zealand. New *Zealand Journal of Botany* 23: 361-378.

Elmetri, I.; Gibbs, M. ; Landis, W. 2005. **A**pplication of Relative Risk Model (RRM) to investigate risks of a proposed aquaculture development on the Firth of Thames Habitats. *Cawthron Report No. 1058.*

Gibbs, M. 2005. Application of a Bayesian network model and a complex systems model to investigate risks of a proposed aquaculture development on the carrying capacity of shorebirds at the Miranda Ramsar wetland. *Cawthron Report No. 1055*.

Gillespie P.A.; MacKenzie, A.L. 1990. Microbial activity in natural and organically enriched intertidal sediments near Nelson, New Zealand. New Zealand Journal of Marine and Freshwater Research 24: 471-480.

Gillespie, P.A.; Stark, J.D.; Asher, R.A.; Fenemor, A.D. 1995. Moutere Inlet ecosystem investigation. Prepared for the Tasman District Council. *Cawthron Report No. 273.* 37p plus plates and appendices.

Glasby, G.P.; Moss, R.L.; Stoffers, P. 1990. Heavy metal pollution in Porirua Harbour, New Zealand. *New Zealand Journal of Marine and Freshwater Research 24*:233-237.

Jezus Belzunce, M.; Solaun, O.; Franco, J.; Valencia, V.; Borja, A. 2001. Accumulation of organic matter, heavy metals and organic compounds in surface sediments along the Nervion Estuary (northern Spain). *Marine Pollution Bulletin 42*:1407-1411.

Kennish, M. J. 1997. *Pollution Impacts on Marine Biotic Communities.* CRC Press, New York. 310p.

Ministry for the Environment. 2001. Environmental performance indicators: Confirmed indicators for the marine environment. ME No. 398, Ministry for the Environment, Wellington. 65p.

Robertson, B.M.; Asher, R. 2003. Environment Southland Estuary Monitoring 2003. Prepared for Environment Southland *Cawthron Report No.831.* 11p + appendices.

Robertson, B.M.; Gillespie, P.A.; Asher, R.A.; Frisk, S.; Keeley, N.B.; Hopkins, G.A.; Thompson, S.J.; Tuckey, B.J. 2002. *Estuarine Environmental Assessment and Monitoring: A National Protocol.* Part A. Development, Part B. Appendices, and Part C. Application. Prepared for supporting Councils and the Ministry for the Environment, Sustainable Management Fund Contract No. 5096. Part A. 93p. Part B. 159p. Part C. 40p plus field sheets.

Roper D. S.; Thrush, S.F.; Smith, D.G. 1988. The influence of runoff on intertidal mudflat benthic communities. *Marine Environmental Research 26*: 1-18.

Stevens, L.; Robertson, B. 2004: Broad scale habitat mapping of the coastline of the Hawke’s Bay region. Prepared for Hawke’s Bay Regional Council. *Cawthron Report No. 1034.* 37p plus appendices.

Stevens, L.; Robertson, B. 2004: Broad scale mapping of intertidal habitat and ecology of 16 sandy beaches and 4 river estuaries in Wellington Harbour, 2004. Prepared for Greater Wellington Regional Council. *Cawthron Report No. 913.*

Thompson, B.A. 1987. Tamaki Estuary water quality guidelines 1985-86. Report Number TP42. Auckland Regional Water Board, Auckland. 30p.


## 6. ACKNOWLEDGEMENTS

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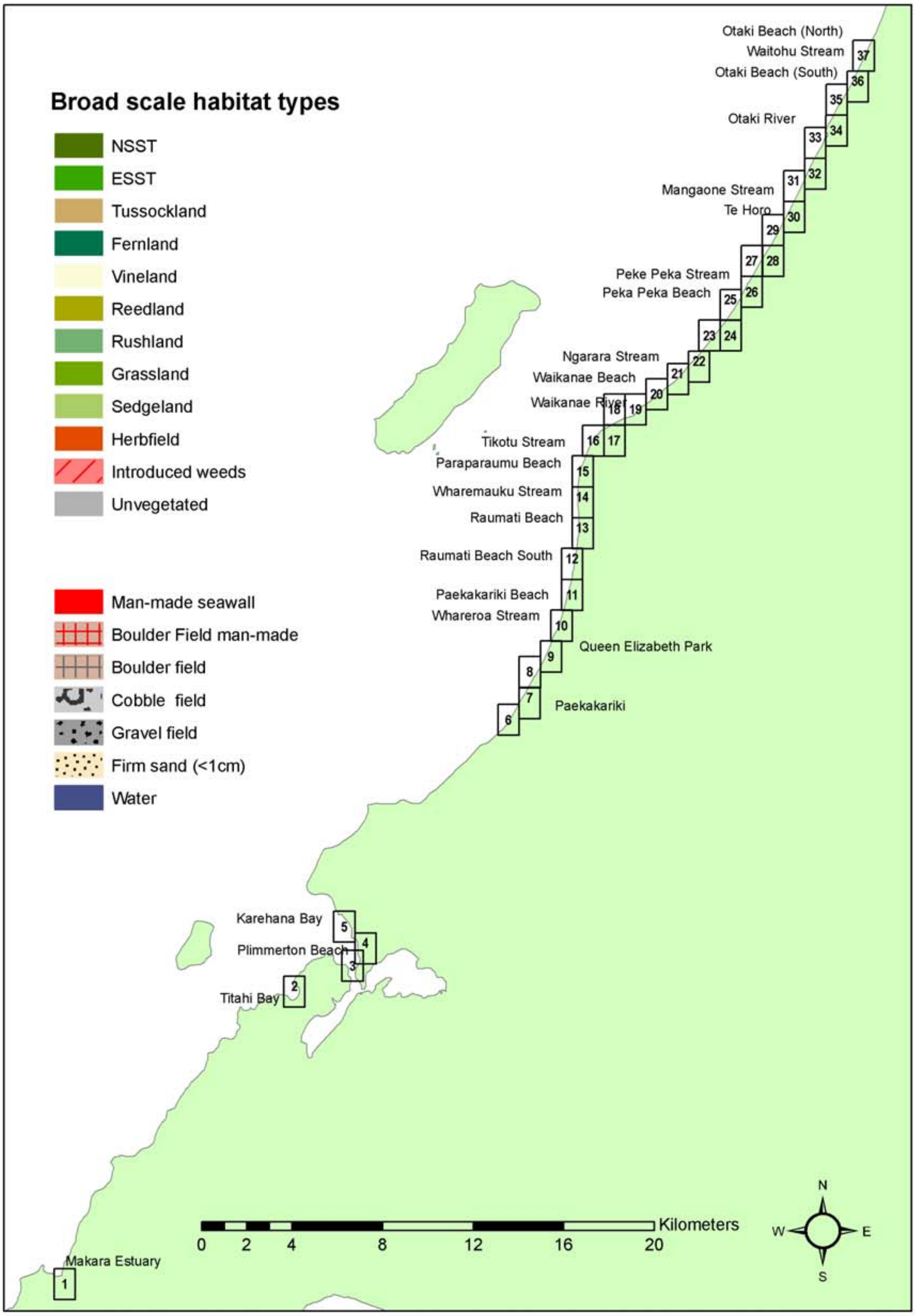
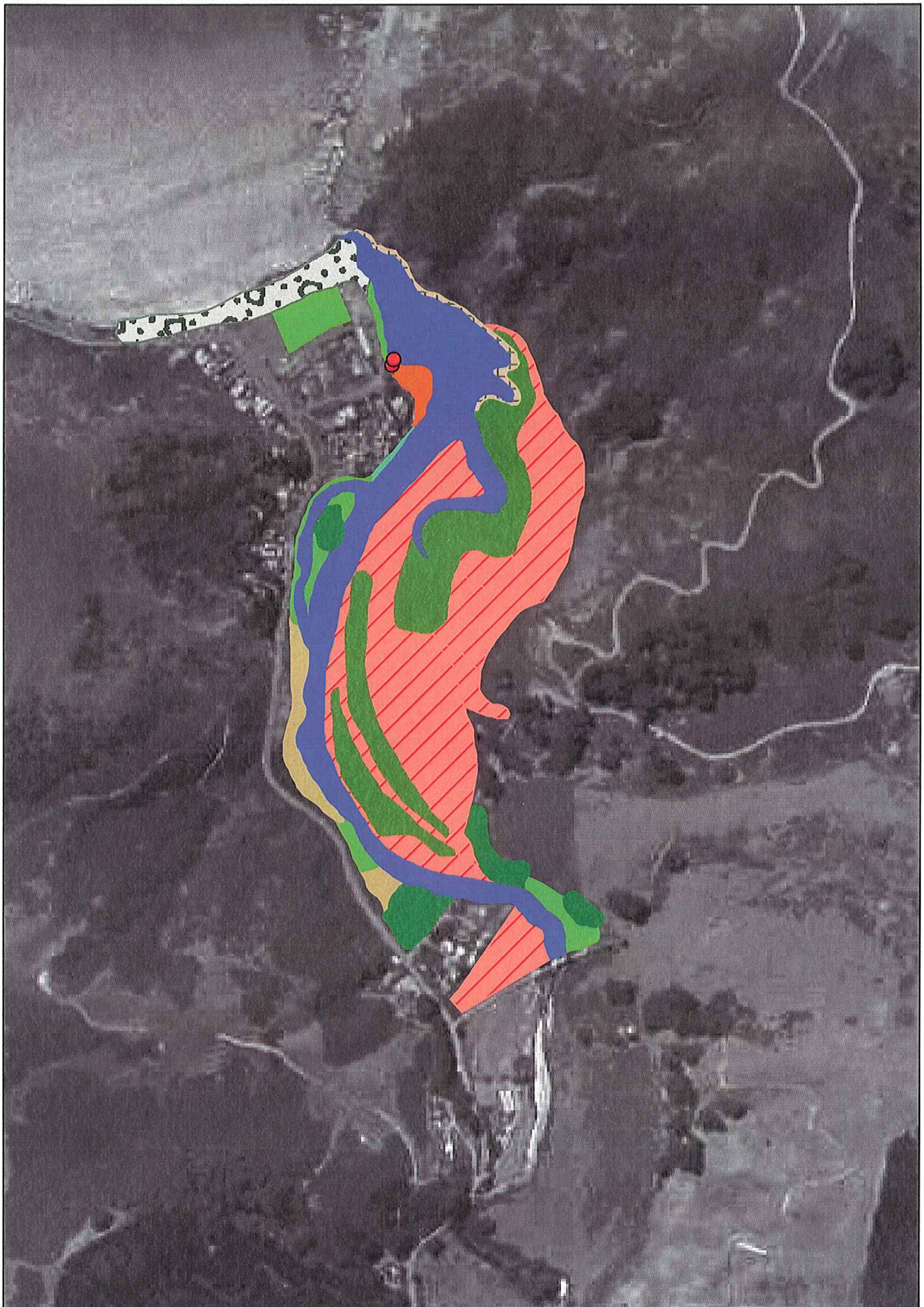
# 7. APPENDIX 1 – BROAD SCALE HABITAT MAPS

**Figure 13** Location of numbered GIS maps of the GWRC coast and map legend for Appendix 1.





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Sheet 2 of 37 Scale 1:5000

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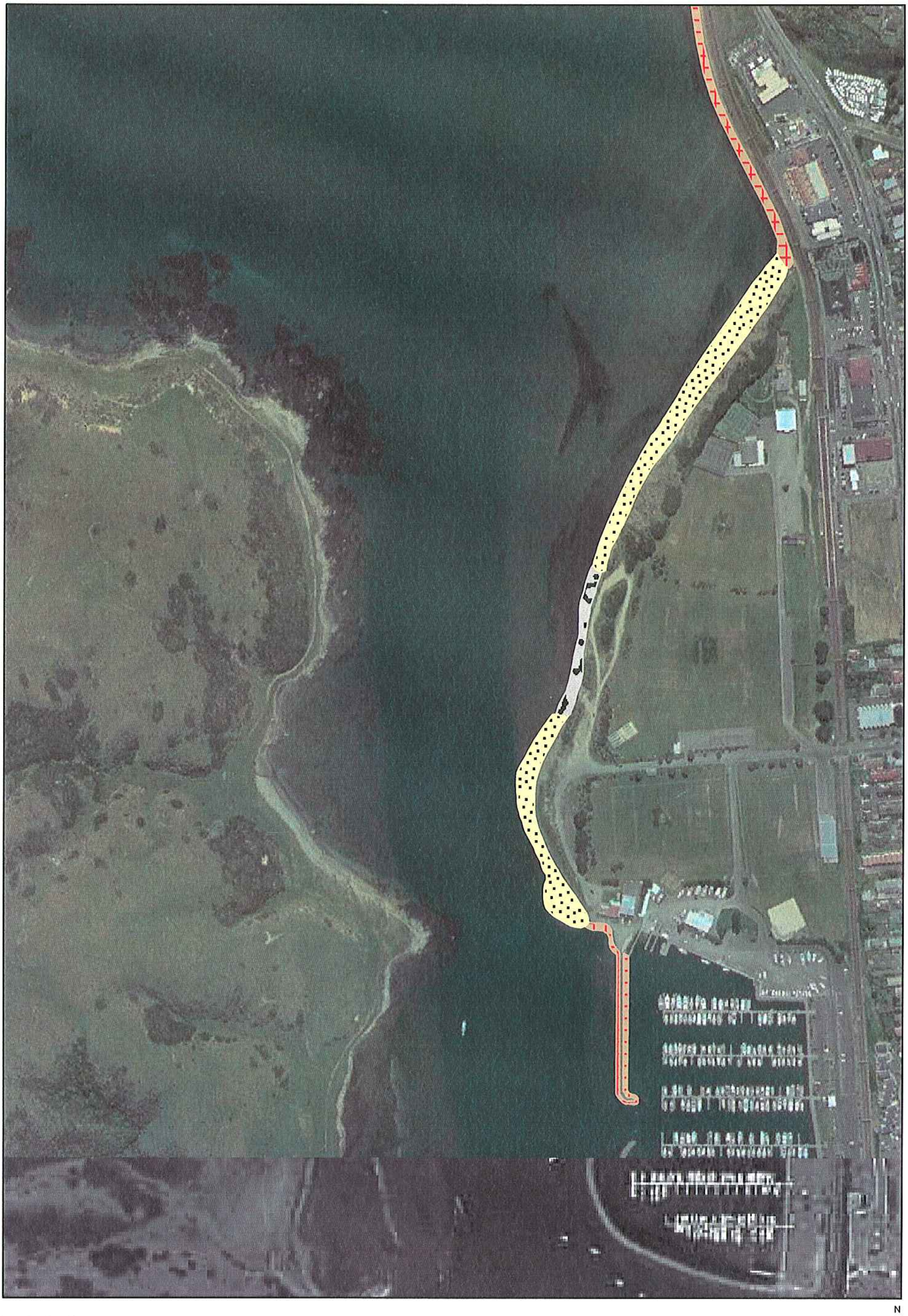

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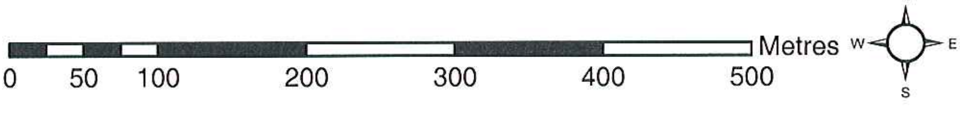


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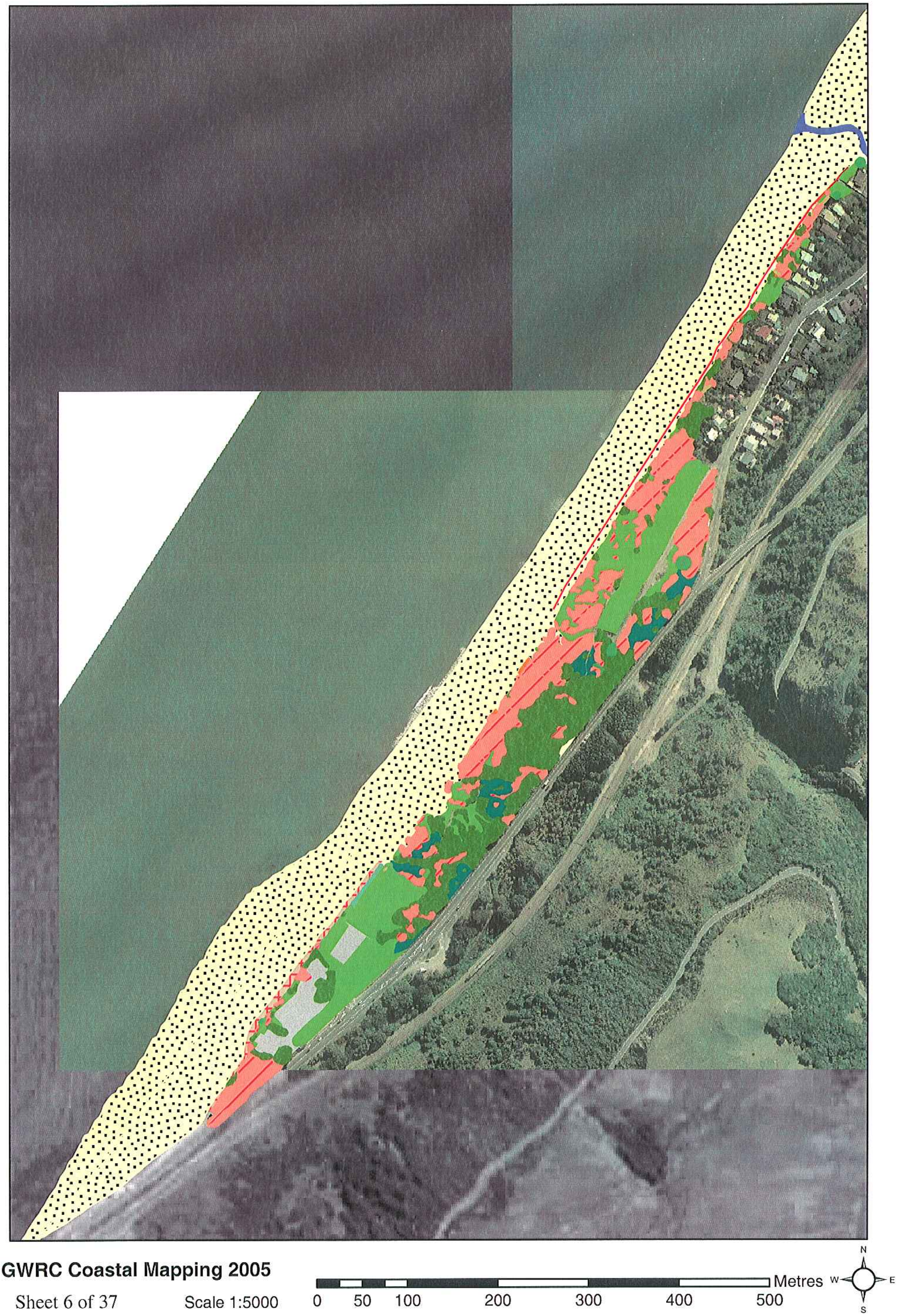



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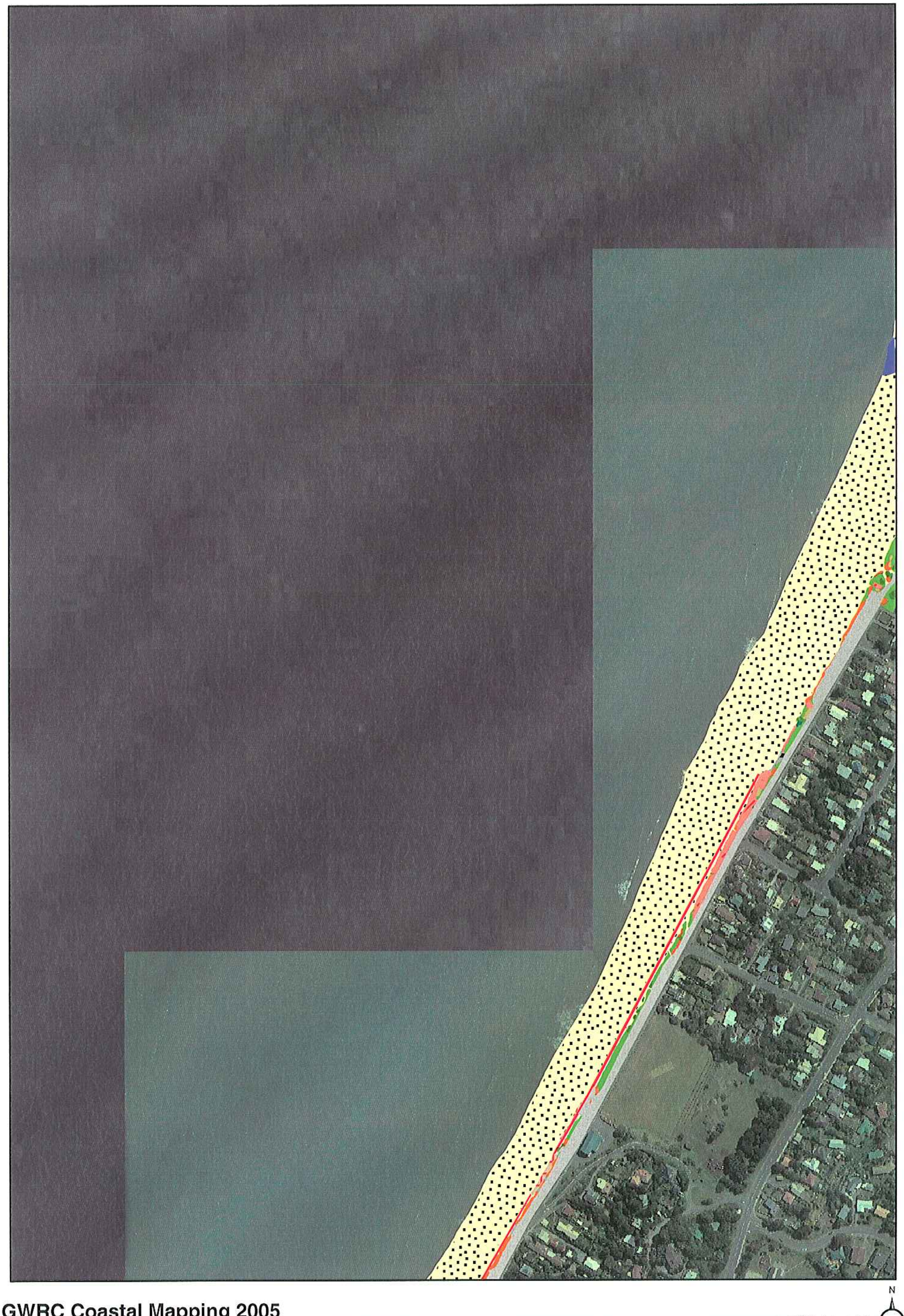

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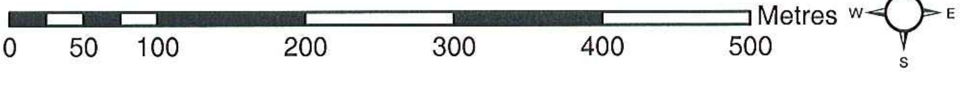

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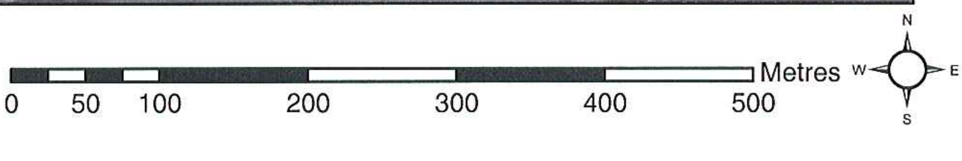

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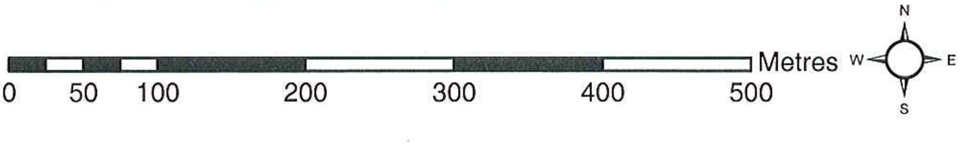

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**GWRC Coastal Mapping 2005**

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**GWRC Coastal Mapping 2005**

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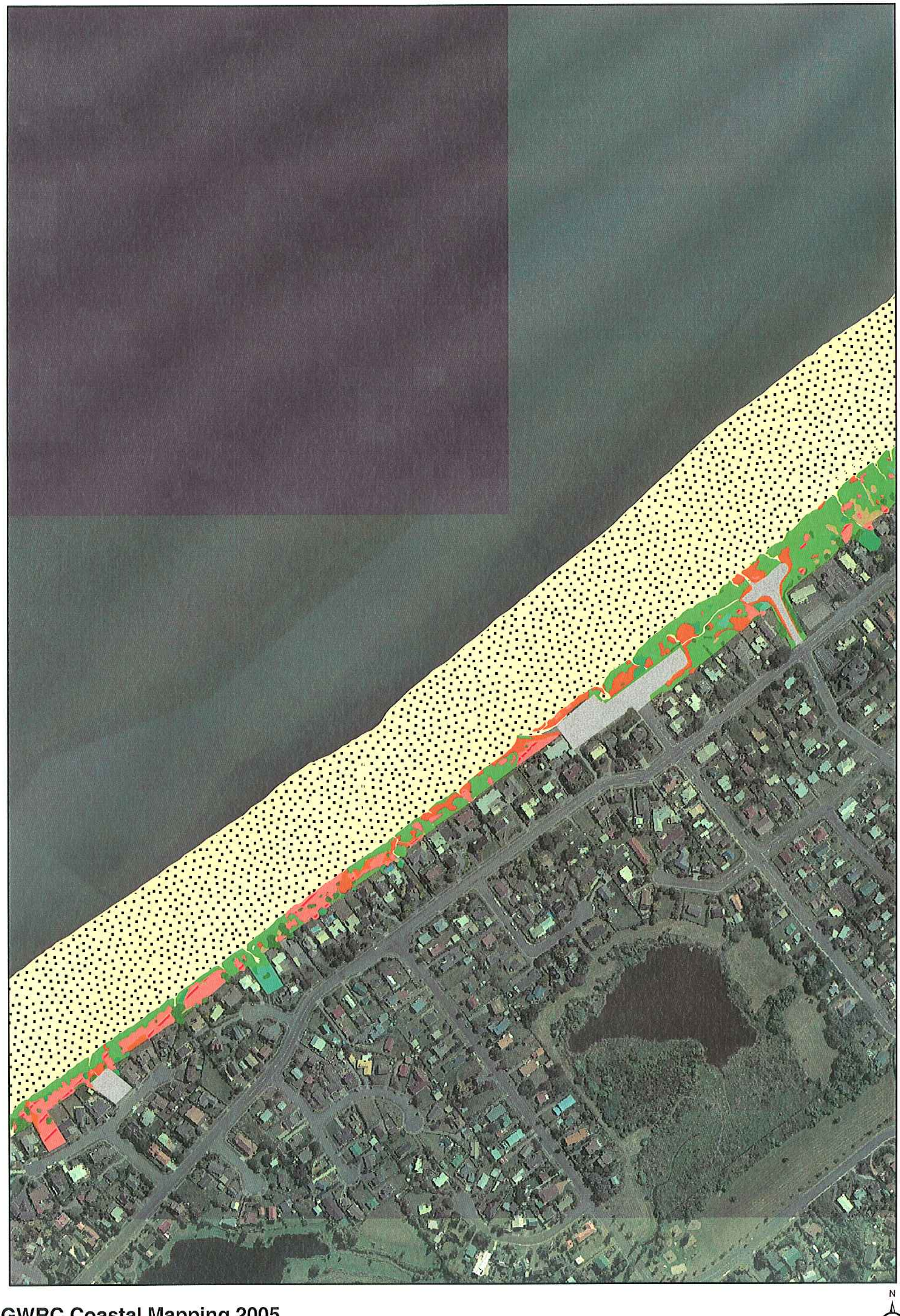

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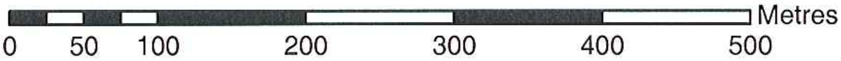


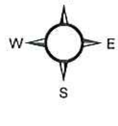

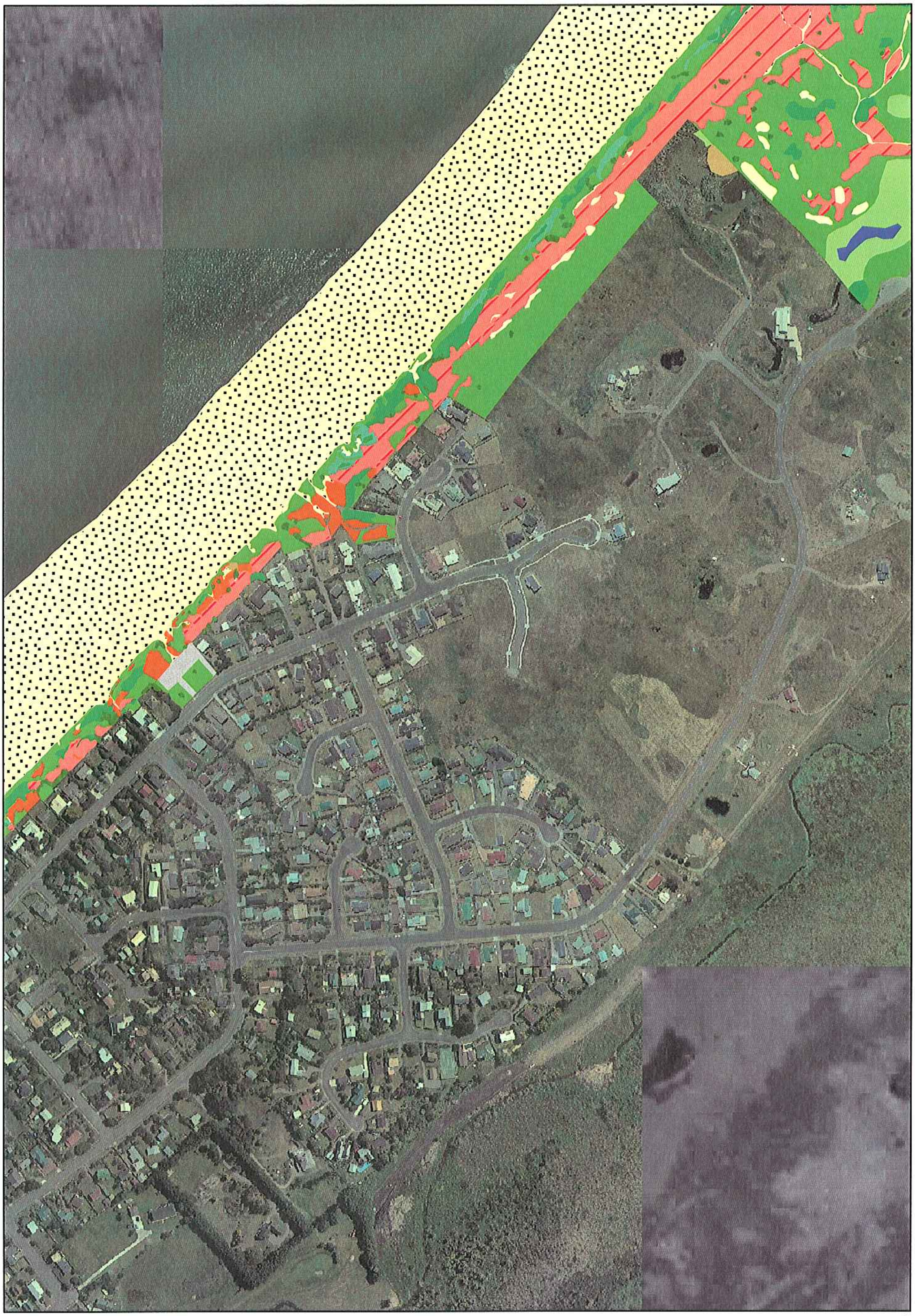

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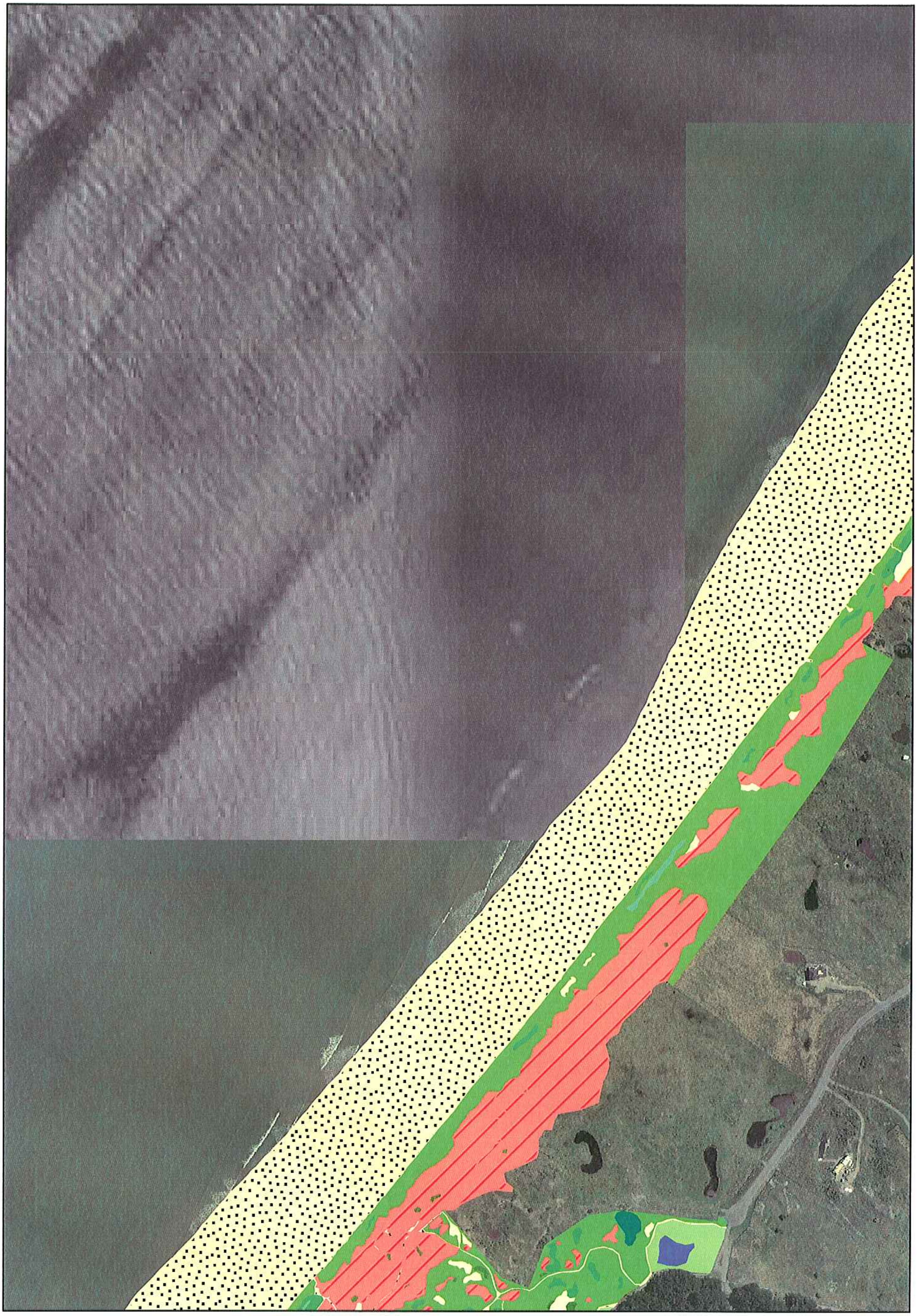

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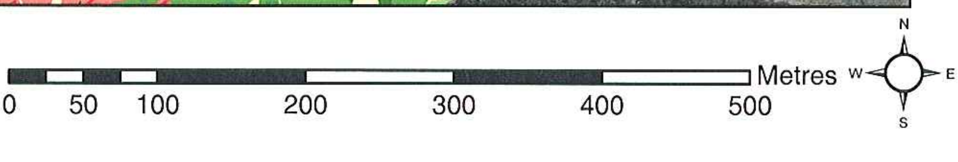



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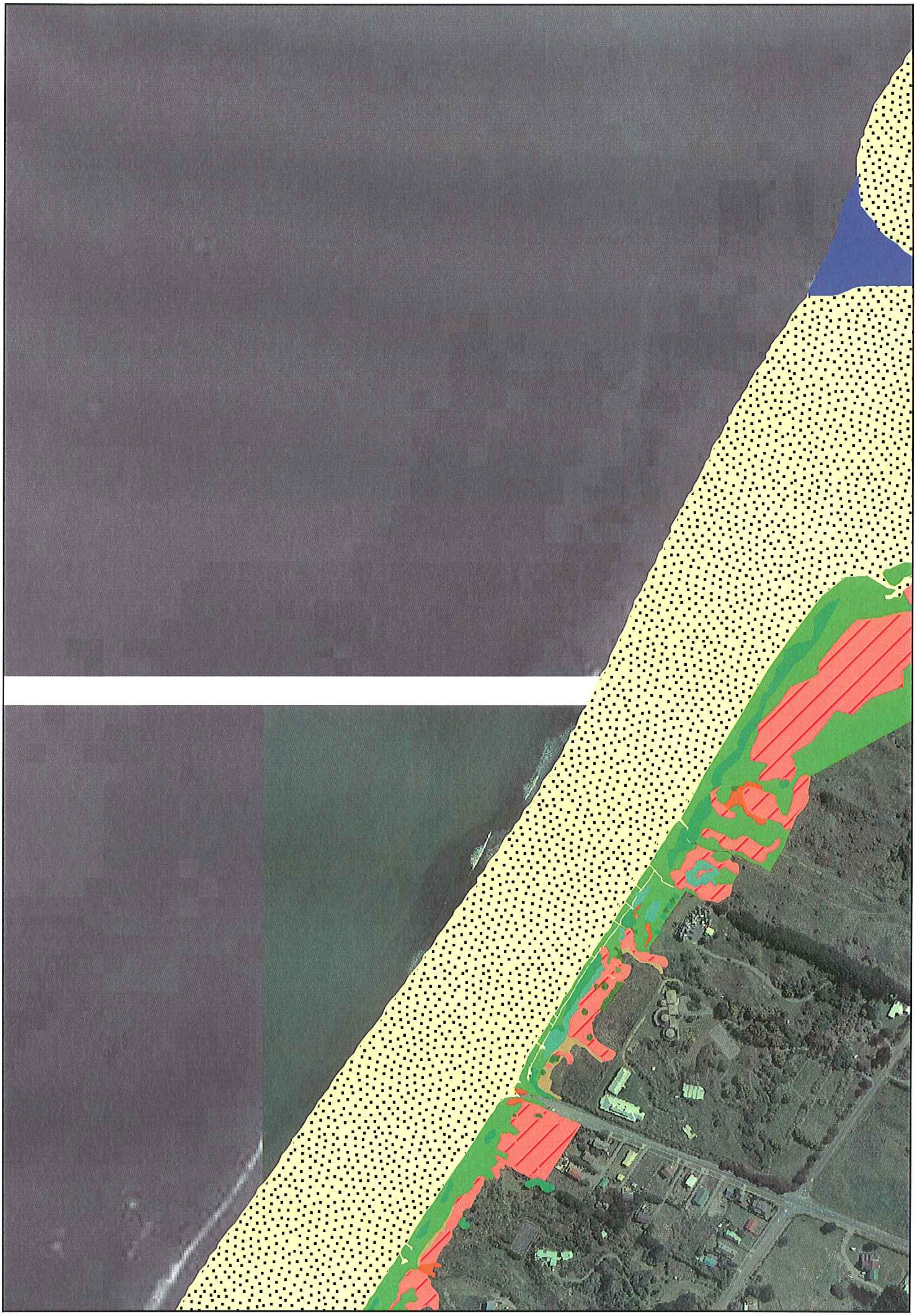

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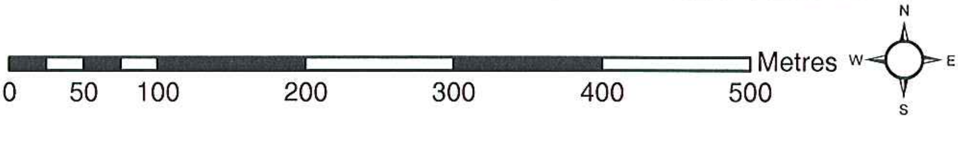

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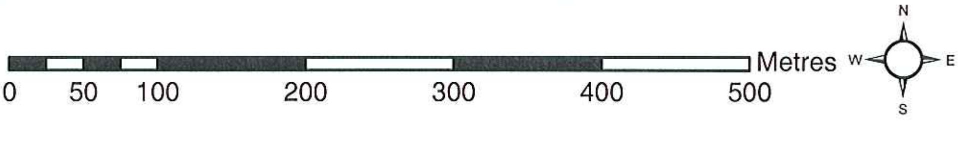


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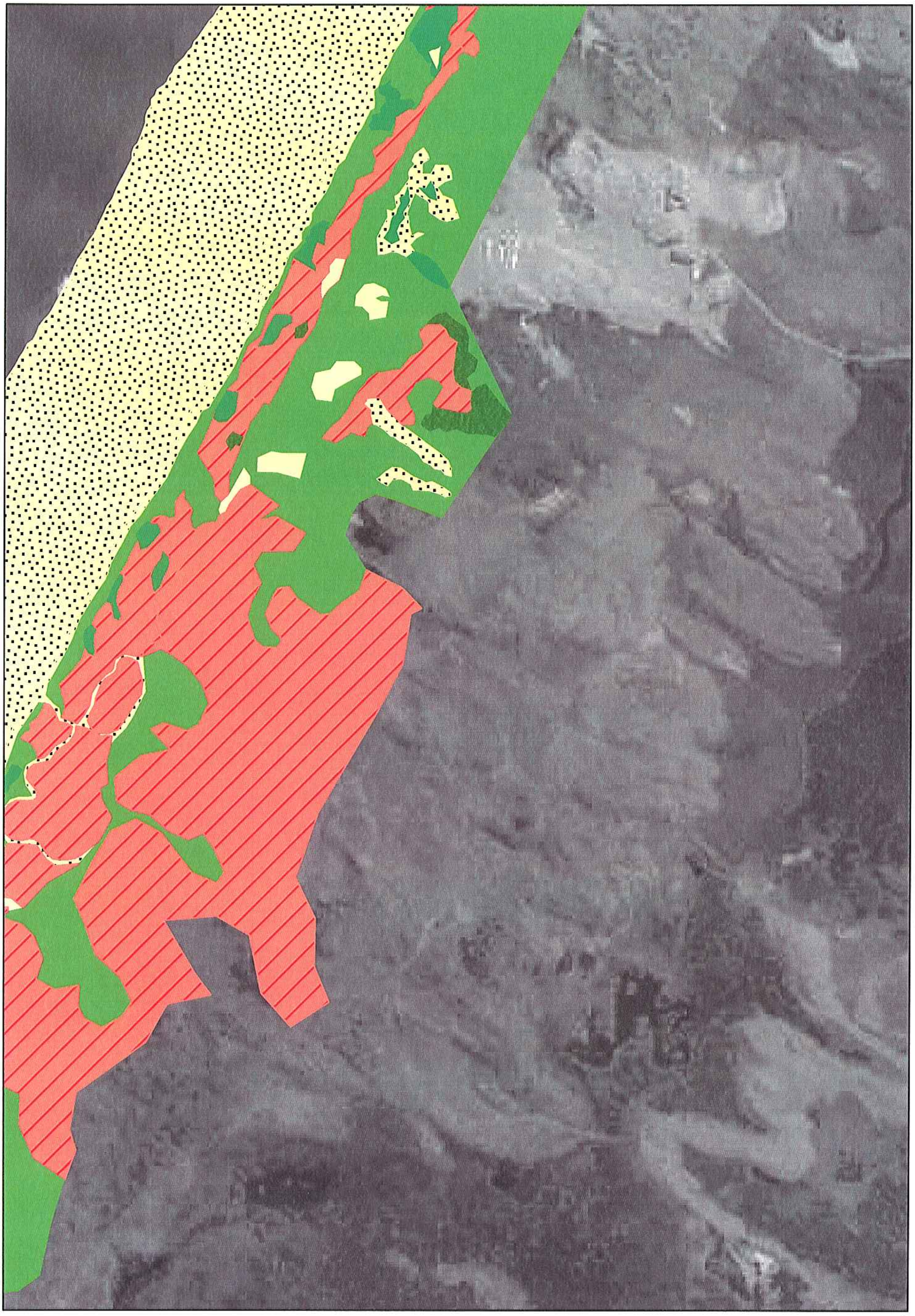

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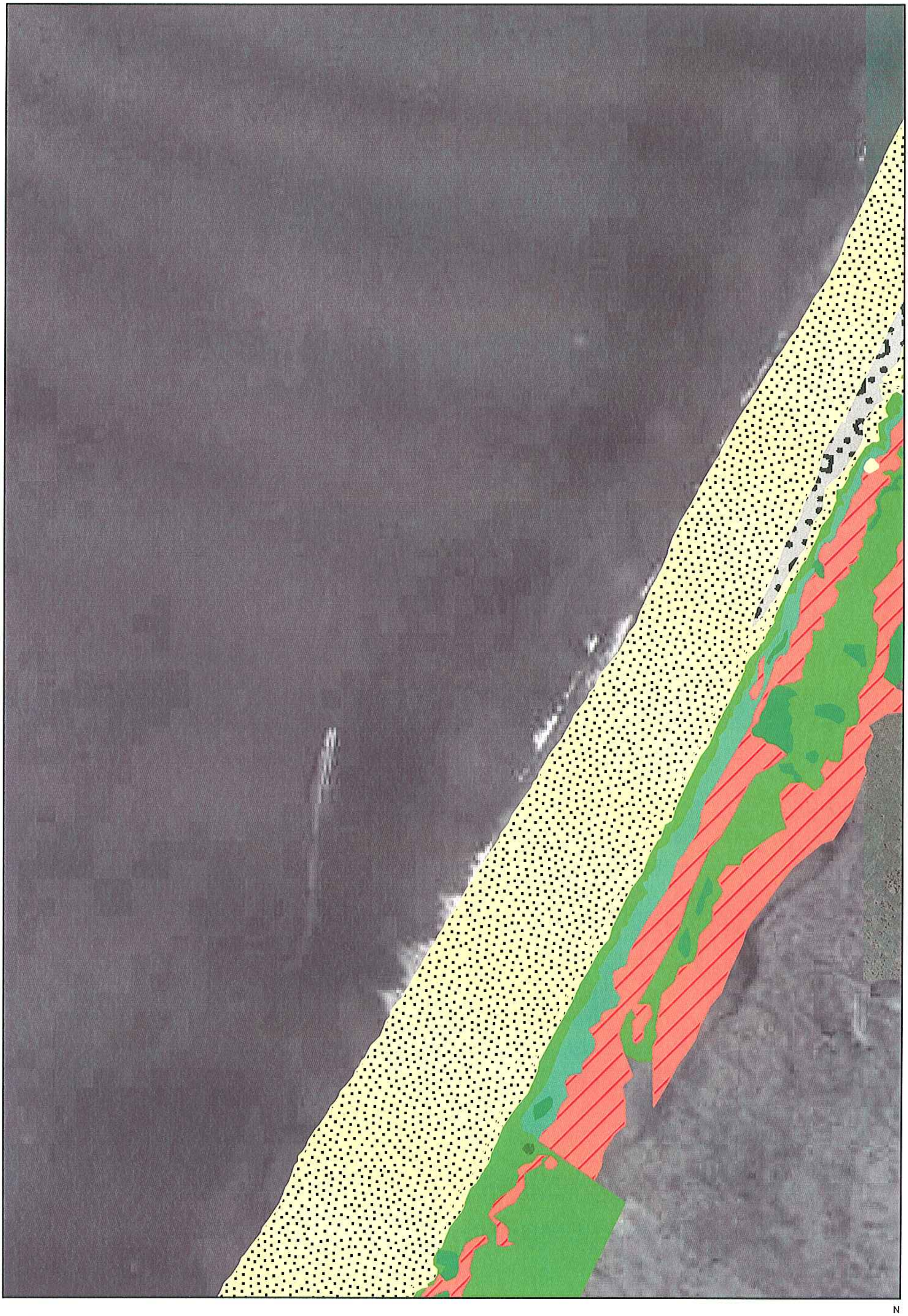

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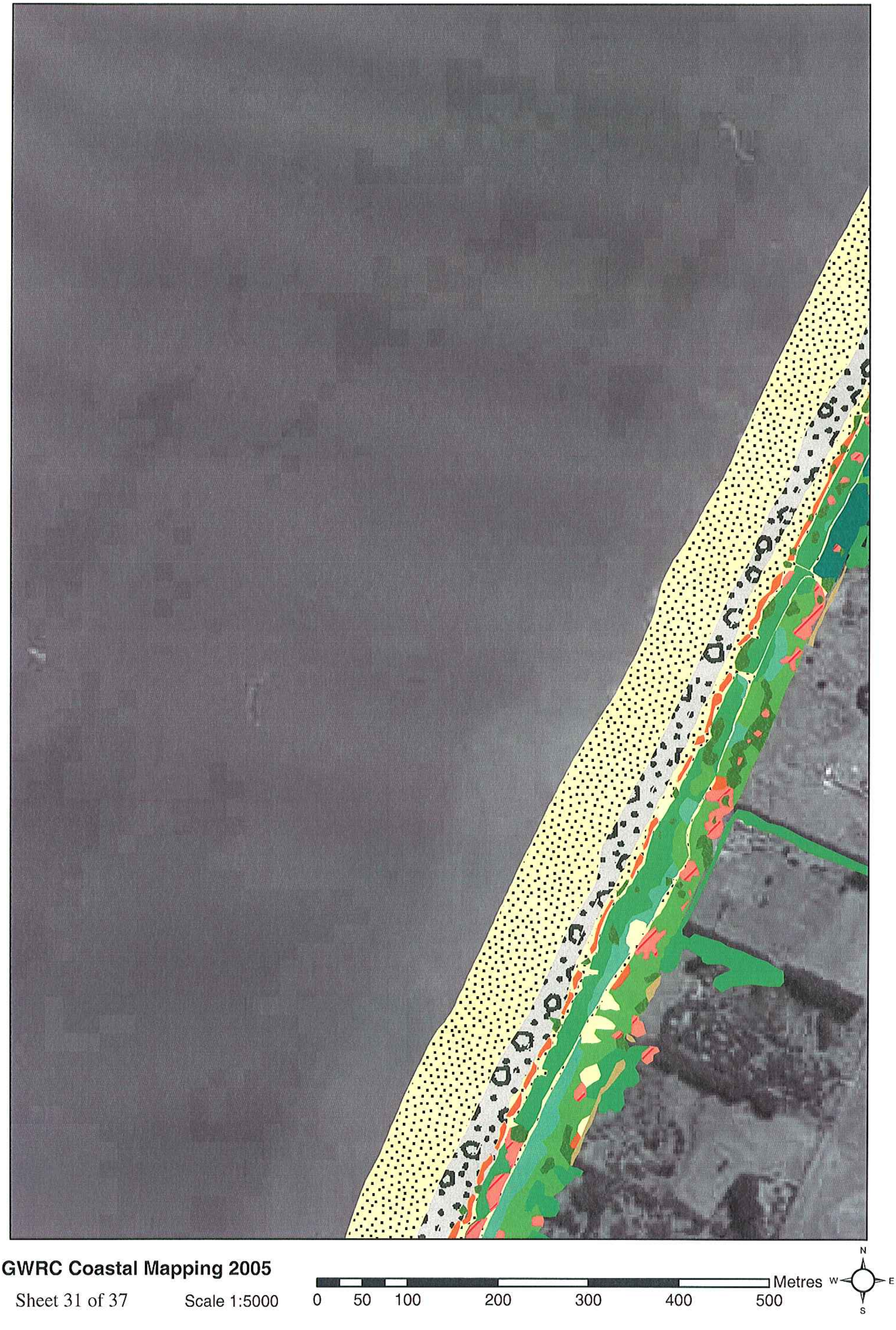


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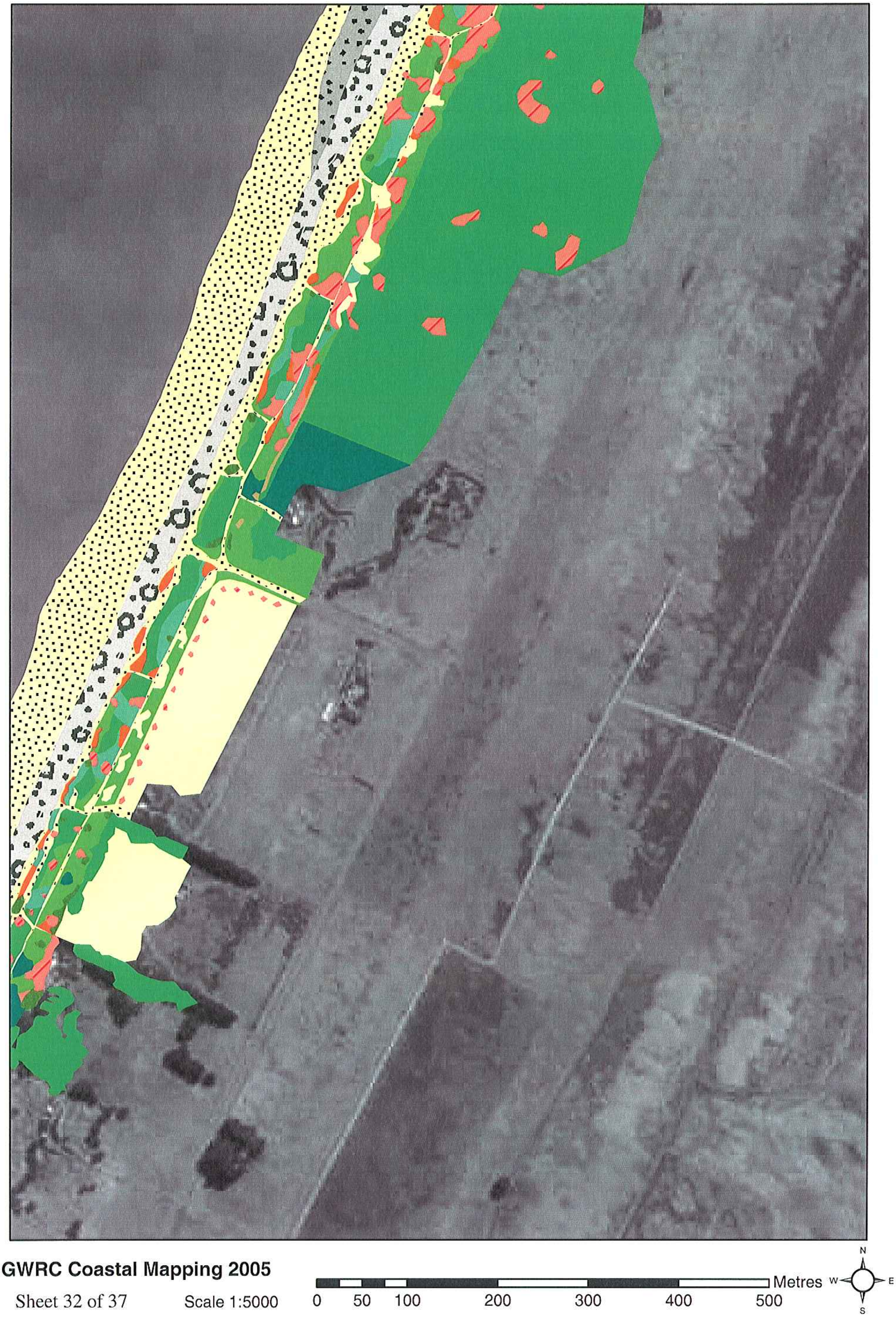


**GWRC Coastal Mapping 2005**

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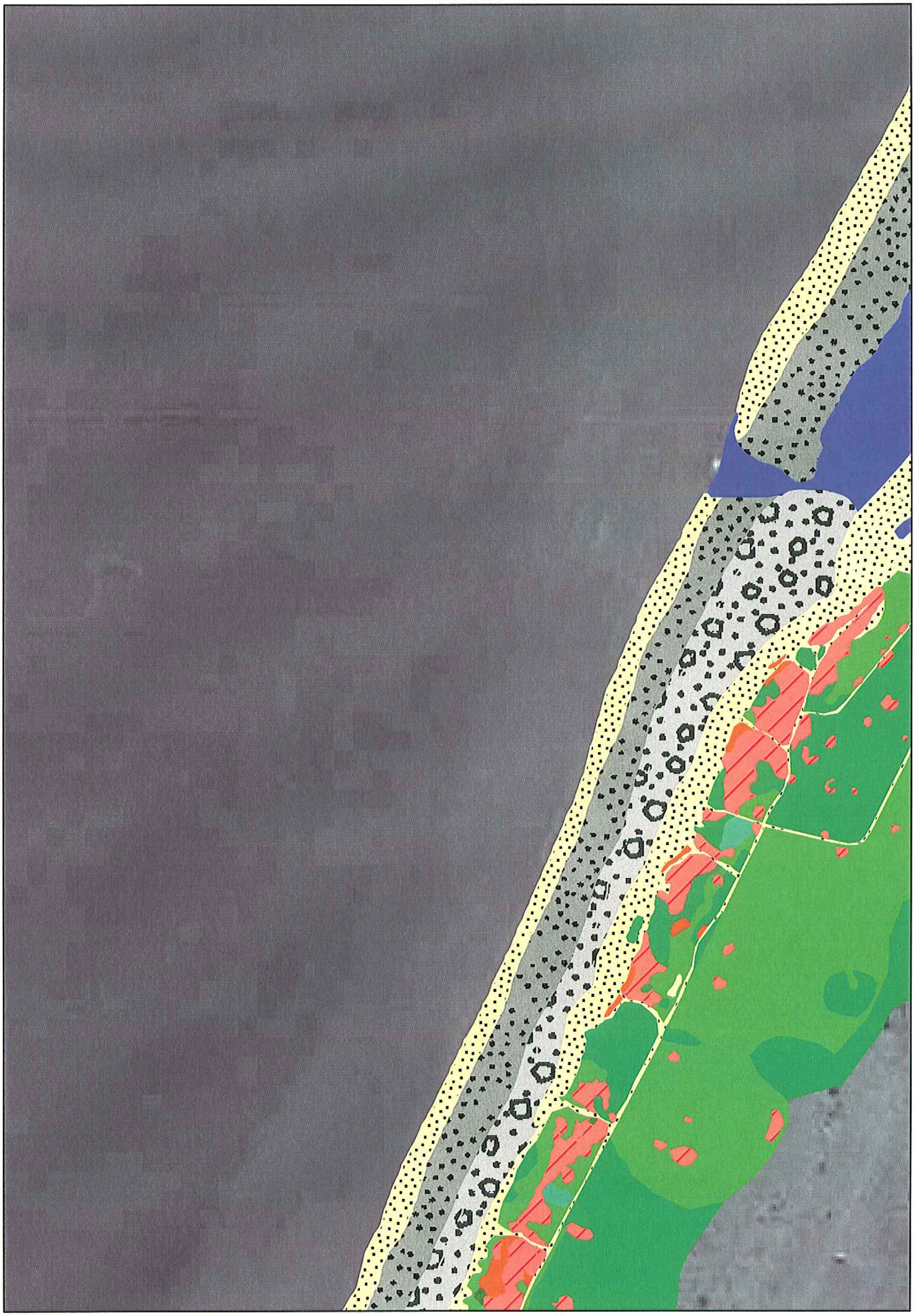
Scale 1:5000

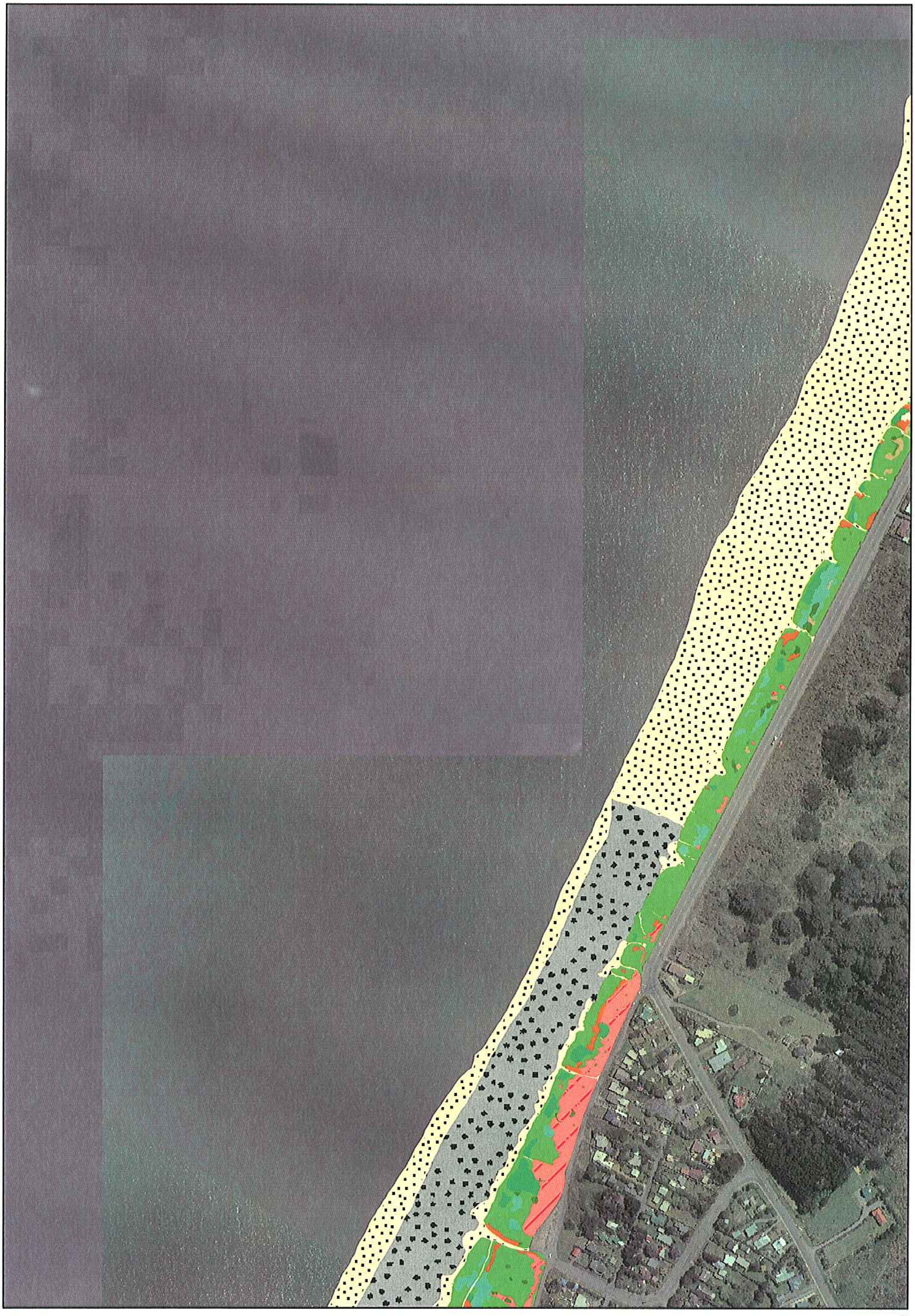


**GWRC Coastal Mapping 2005**

Sheet 33 of 37 Scale 1:5000

**GWRC Coastal Mapping 2005**

Sheet 34 of 37    Scale 1:5000



**GWRC Coastal Mapping 2005**

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**GWRC Coastal Mapping 2005**

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**GWRC Coastal Mapping 2005**

Sheet 37 of 37 Scale 1:5000

0 50 100 200 300 400 500 Metres

N W E S

# 8. APPENDIX 2 – SUMMARY OF BIOLOGICAL DATA

| | | Otaki Nth | | Otaki Sth | | Para'umu | | Paekak. | | Karehana | | Plimm. | | Titahi -Vehicles | | | | | | Titahi - No vehicles | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Shore height | Lo | Up | Lo | Up | Lo | Up | Lo | Up | Lo | Up | Lo | Up | Lower | | | Upper | | | Lower | | | Upper | | |
| Taxa | Common Name | | | | | | | | | | | | | | | | | | | | | | | | |
| **NEMERTEA** | Ribbon worms | | 2 | | | | 1 | | | | | | | | | | | | | | | | | | |
| **NEMATODA** | Roundworm | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| *Paphies subtriangulata* | Tuatua | | | | | | 12 | 1 | | 1 | | | | 1 | | | | | | | | | | | |
| OLIGOCHAETA | Oligochaete worms | | | 1 | | | | | | | | | | | | | | | | | | | | | |
| *Heteromastus filiformis* | | | | | 1 | | | | 1 | | | | | | | | | | | | | | | | |
| Glyceridae | Blood worm | | | 1 | 15 | | | | | | | | | | | | | | | | | | | | |
| *Dispio sp.* | | | | | | | | | 1 | | | 7 | | | | | | 1 | | | | | | | |
| **Mysidacea** | Mysid shrimp | | | | | 1 | | | | | | | | 1 | | | | | | | | | | | |
| Flabellifera | Sea louse | | 1 | 6 | | | 1 | | | 13 | | | 1 | | | | | | | | | | | | |
| **Asellota** | Isopod | 1 | | | | 9 | | | | | | 6 | | | | | | | | 1 | 1 | 9 | | | |
| **Amphipoda b** | Amphipods | | | | 2 | 18 | 53 | | | | | 11 | | | | | | | | 30 | 3 | 13 | | | |
| **Amphipoda c** | Amphipods | 8 | 2 | 1 | | 3 | | 1 | | 1 | | 1 | | 1 | | | | | | 2 | 1 | | | | |
| *Callianassa filholi* | Ghost Shrimp | | | 1 | | | | | | | | | | | | | | | | | | | | | |
| *Chironomus spa.* | Midge | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| **Collembola** | Springtails | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| **Total No. of Taxa** | | **2** | **3** | **5** | **3** | **6** | **4** | **2** | **2** | **3** | **0** | **4** | **1** | **3** | **0** | **0** | **0** | **1** | **0** | **3** | **3** | **2** | **0** | **1** | **0** |
| **Total No. of Individuals** | | **9** | **5** | **10** | **18** | **33** | **67** | **2** | **2** | **15** | **0** | **25** | **1** | **3** | **0** | **0** | **0** | **1** | **0** | **33** | **5** | **22** | **0** | **1** | **0** |

| | | Tikotu | | Waikanae | | | | Wharemauku | | Whareroa | | Makara | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Shore height | Lo | Up | Lo | Up | Lo | Up | Lo | Up | Lo | Up | Lower | | Upper | |
| Taxa | Common Name | | | | | | | | | | | A | B | A | B |
| **NEMERTEA** | Ribbon worms | | | | | | | | | | | 1 | | | |
| **NEMATODA** | Roundworm | | | | | | 1 | | | | | 25 | 162 | 2 | 10 |
| *Amphibola crenata* | Mud Snail | | | | | 2 | 3 | | | | | | | | |
| *Potamopyrgus antipodarum* | Estuarine snail | 1 | | 39 | 3 | 392 | 3 | | | | 1 | 277 | 1698 | | 3 |
| *Potamopyrgus pupoides* | Estuarine snail | | | 1 | | | 1 | | | | | 1109 | 565 | 5 | 1 |
| *Paphies australis* | Pipi | | | | | 6 | | | | | | | | | |
| OLIGOCHAETA | Oligochaete worms | | | 18 | | 1 | | | | 1 | 1 | 45 | 102 | | 241 |
| *Heteromastus filiformis* | | | | | 1 | | | | | | | | | | |
| Paraonidae | | | | | | | | | | 1 | | | | | |
| *Neanthes cricognatha* | Rag Worm | | | | | | | | | | | 41 | 19 | | |
| *Nicon aestuariensis* | Rag worm | | | | | 47 | | | | | | | | | |
| *Boccardia sp.* | | | | | | | | | | | | 44 | 42 | | |
| *Prionospio sp.* | | | | | 1 | | | | | | | | | | |
| *Scolecolepides benhami* | | | | 16 | | 12 | | | | | | | | | |
| *Scolelepis sp.* | | | | 46 | | 6 | 3 | | | | | | | | |
| **Mysidacea** | Mysid shrimp | | | | | 1 | | | | | | 7 | 16 | 3 | 19 |
| Flabellifera | Sea louse | | | | 16 | | 6 | | | | | | | | |
| *Paracorphium sp.* | Freshwater amphipod | | | 163 | | 792 | 54 | 3 | | 12 | 2 | 70 | 225 | 1 | |
| **Amphipoda b** | Amphipods | | | 1 | | | 38 | | | | | | | | |
| **Amphipoda c** | Amphipods | 5 | 3 | | | | | | | 1 | 1 | | 1 | 7 | |
| **Amphipoda d** | Amphipods | | | | | | | | | | | | | 16 | |
| *Macrophthalmus hirtipes* | Stalk-eyed Mud Crab | | | 1 | | | | | | | | | | | |
| OSTRACODA | Ostracods | | | | | | | | | | | | 10 | | |
| Formicidae | Ants | | | | | | | | | | | | | 1 | |
| Muscidae | Fly larvae | | 1 | | | | 1 | | | | | | 1 | | |
| Orthocladiinae | Midges | | | | | | | | | 7 | 1 | | 1 | | |
| *Chironomus spa.* | Midge | 71 | | | | | | | | 114 | 12 | | | | |
| *Corynoneura scutellata* | Midges | | | | | | | | | 1 | | | | | |
| *Ephydrella sp.* | Shore fly larvae | | | | | | | | | | 3 | | | | |
| *Limonia sp.* | Crane fly larvae | | | | | | | | | | 5 | | | | |
| **Collembola** | Springtails | 2 | | | | | | | | | | | | 1 | |
| **Acarina** | Mites | | | | | | | | | 1 | | | | | |
| *Enteromorpha sp.* | Green seaweed | | | | | | | | | 1 | | | | | |
| **Total No. of Taxa** | | **4** | **2** | **8** | **4** | **9** | **9** | **1** | **0** | **9** | **8** | **9** | **12** | **8** | **5** |
| **Total No. of Individuals** | | **79** | **4** | **285** | **21** | **1259** | **110** | **3** | **0** | **139** | **26** | **1619** | **2842** | **36** | **274** |