Report prepared for the Department of Conservation

Sedimentation, metal contamination and coastal landscape stability of the Manawatu River Estuary: Environmental Status of the Ramsar-Listed wetland and future monitoring programme

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Executive Summary

- This report entails a sediment monitoring program which aims to establish baseline data for monitoring the Manawatu River Estuary. Of specific interest are the sediment characteristics and what are the potential impacts of the marsh area on the northern bank of the estuary. This marsh/ mudflat area is significant bird habitat
- Aerial photo analysis of the estuary between 1950 and 2005 shows significant extension (547m) of the point bar at Fernbird Flat. It also shows fluctuations in the location of the channel entrance, but no significant channel movement towards the marsh area on the northern bank of the estuary. Flood protection works are likely to have stabilised most of the channel movements. Flood events, such as the 2004 flood occur with the greatest amount of channel migration.
- Aerial photo analysis also revealed the evolution of a sand spit, which separates the marsh area from the main channel. This sand spit has played a significant part in reducing the impact of the river channel on the marsh.
- A significant increase in the area of vegetated dunes over time is also evident in the aerial photo analysis this signifies a decrease in wind erosion and dune mobility at the estuary mouth.
- Grain size analysis of surfical sediments indicated that most are sourced from aeolian (wind) sources, or fluvial (river) deposits of silts and clays in low energy environments. The geospatial distribution of these grain sizes indicates that grain size is mostly indicative of fluvial transport, except for those sites which lie within the dune sequences.
- Observations from the field and grain size analysis indicate that the marsh area was originally dominated by sand, but at present is accumulating clays and silts. The marsh was once open to fluvial and aeolian processes but the vegetation of nearby dunes and the protection of the sand spit has allowed the area to accumulate mainly fine grained sediments and become a mud flat.
- The concentration of organic matter in surfical samples was moderately high, and generally correlates with areas of high mud content. Carbonate content also correlated with the proportion of mud and organics, and likely point to an increased of shelly fauna in areas of higher organic content.
- Sediment samples were analysed for magnesium, manganese, nickel, cobalt, mercury, copper, zinc, arsenic, lead and tin. All concentrations were well below the ANZECC interim sediment quality guideline values. High concentrations of manganese were found, but this is a function of the anoxic environment of the marsh, and not detrimental to the ecosystem. The high concentrations of magnesium are indicative of the salinity of the study area and the carbonate component of the sediment, the concentrations obtained are typical of estuarine environments.
- The recommendations of this report are to maintain the stability of the dune systems, particularly upwind of the marsh area. This can be achieved by limiting some activities on the dunes, maintaining vegetation and limiting removal of woody debris near the channel.
- The suggested monitoring of the estuary is to stake the lee side of dunes to determine rate of dune movement. Returning to sites 29, 30, 32, 33 34, 37 and 38

periodically to asses grain size characteristics, and hence if the depositional environment has changed. A water quality monitoring program should be established, to identify point sources of pollution and determine the relationship between metal concentrations in the water and the sediment. Site 3 and 34 should be returned to for reanalysis of metal concentrations. Continued collection of aerial photos for detailed analysis of channel migration is also recommended.

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1. Introduction

The aim of the sediment monitoring programme is to establish baseline datasets of environmental health of estuarine systems in New Zealand, through a case study of the Manawatu Estuary, at the mouth of the Manawatu River.

Estuarine systems are some of the most vulnerable environments to human influence, being an area of intense recreational and commercial use, but also an environment where land uses in the river's hinterland are concentrated as the river drains the catchment. In addition coastal erosion affects the seaward edge of these landforms and this is likely to be exacerbated under projected scenarios of sea-level rise related to climate change (IPCC 2007).

This project therefore sets out to conduct a scientific investigation of the health of the sedimentary systems of the Manawatu Estuary with the aim of providing a baseline dataset from which future changes can be measured against. This will be combined with an analysis of recent planform changes within the system through study of aerial photographs.

The aim of the project is therefore to provide:

(i) A baseline dataset of the sedimentary environments

(ii) Provide a methodology for continued monitoring of human impacts on this system.

2. Regional setting

The Manawatu Estuary lies in the central-south of the North Island, south of Foxton beach township (figure 1 and 2). The Manawatu River has an extensive catchment area of 5944 km^2 that drains both sides of the Taraua and Ruahine ranges, passing through the ranges via the Manawatu Gorge (Miller et al. 2005). The characteristic land use of the catchment is dominantly rural (forestry, dairy farming and cropping). However the river drains several towns and passes through the major city of Palmerston North, and hence would receive a significant portion of urban run off. The Manawatu River has an average flow of 102 cumecs, with its lowest and highest flows at 4.3, and 1450 cumecs respectively (Duncan 1992).

The soils and geology of the Manawatu district are characterised by the fluvial deposits of the Manawatu River, four extensive Holocene dune fields and the greywacke Taraura ranges (Hesp and Shepherd 1978). The older Holocene dune phases (Foxton sequence) have more developed soil profiles and occur furthest inland, with each younger one occurring as a belt in front. The study area is situated in the youngest dune phase, the Waitarere phase which began formation 100 years ago and continues to present (Cowie 1963). Present dune movement is as large parabolic dunes, sourced from blow outs which migrate landwards at a rate of 20- 25m per year (Hesp 2001). The dune sands are sourced from greywackes (Kasper-Zubillaga et al. 2007), and hence are mainly comprised of lithic fragments, quartz and feldspar (Kasper-Zubillaga and Dickinson 2001).

The geomorphology of the Manawtu estuary is shaped by energy from four sources: the force of the fluvial channel, tidal currents, longshore drift and wave energy, and the westerly winds. The meandering fluvial channel concentrates erosive energy on the convex side of the curves whilst depositing material in on the inside of the curve, also called the point bar. Whilst moving sediment downstream, the channel may also create channel bars. Tidal currents extend around 20km upstream of the river mouth (Miller et al. 2005), and aid the development and function of tidal flats and marshes. The mean spring tidal range is from 0.2 – 2.4 m at the Manawatu estuary mouth, with the mean sea level at 1.3m (LINZ 2008). Incident waves and longsore drift expend their energy on the most seaward part of the estuary. Longshore drift on the Kapiti Coast is in a southerly direction (Kasper-Zubillaga et al. 2007), which would cause sediment to accumulate at the northern side of the estuary mouth. Lastly the extensive dune sequence at the beach may continue to be blown inland by the westerly winds, potentially reshaping and moving any dry subaerial sand.

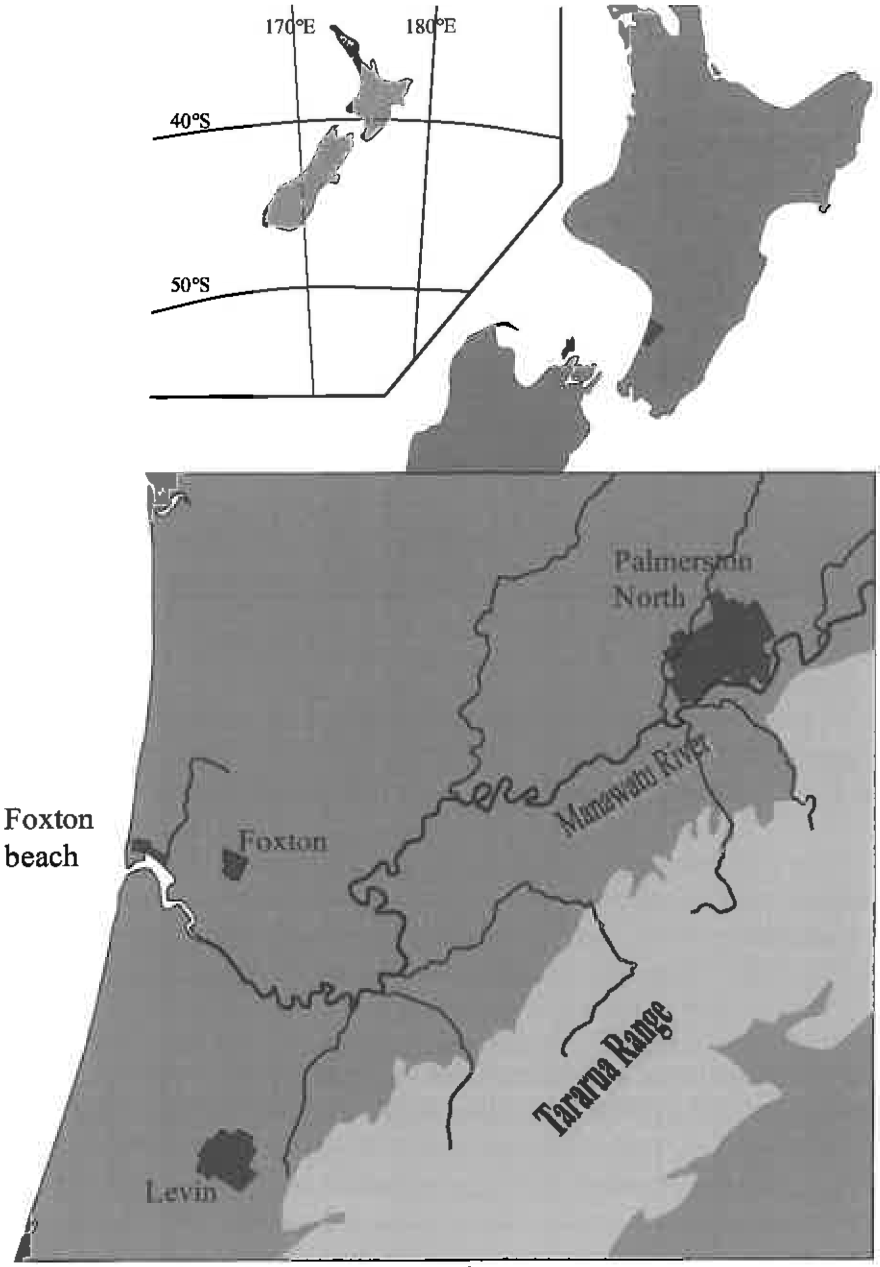


Figure 1. Location of the Manawatu River.

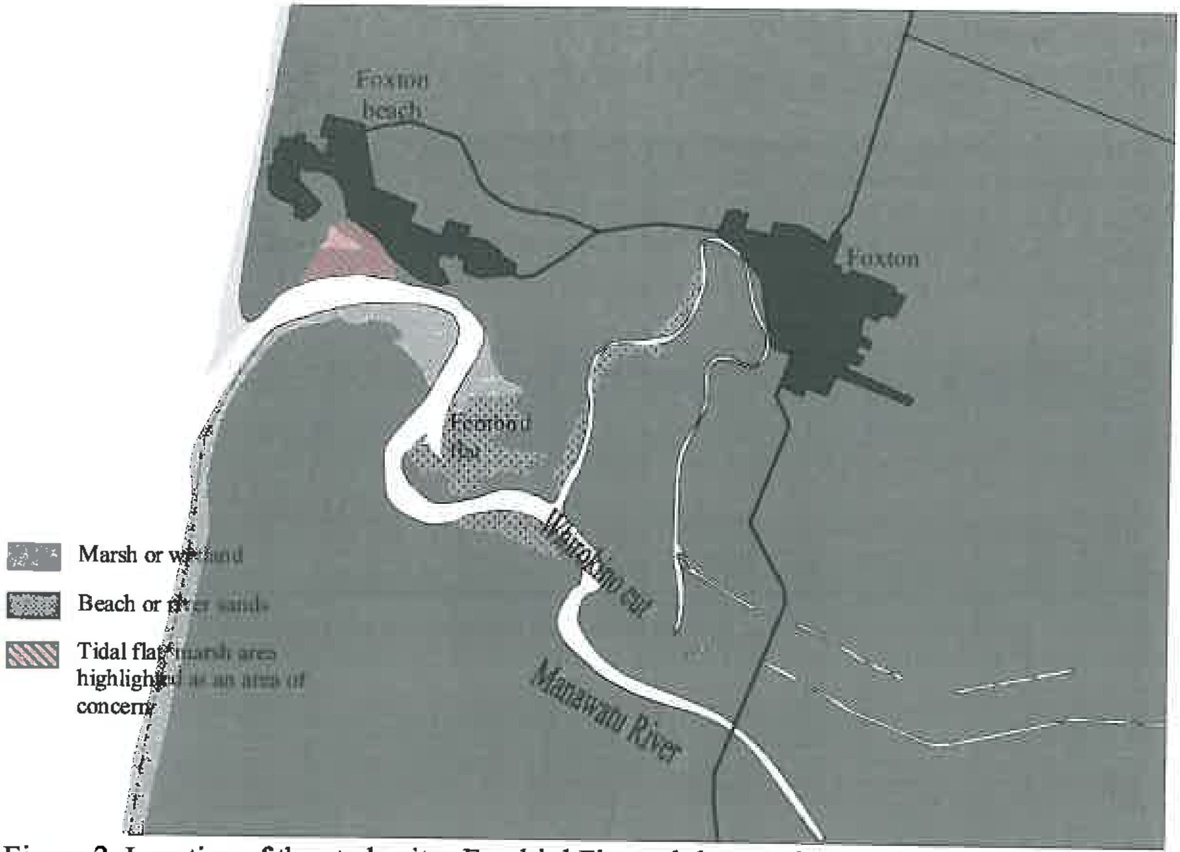


Figure 2. Location of the study sites Fernbird Flat and the marsh area on the Manawatu Estuary.

3. Field observations

The point bar of Fernbird flat, is a large flat marsh area, characterised by thick marsh sedges and rushes (figure 3). It is semi- horizontal, with the exception of the raised track surface that services as a road, ponds dug for duck hunting (visible on aerial photo; figure 20) and deep (~2m), narrow channels inundated each high tide. The banks of the Manawatu River on this point bar are erosional cuts on the west and gently sloping depositional sandy banks at the point bar. Inland of the point bar are curved ridges of sand that roughly align with the main channel.

Figure 3. Photo showing typical vegetation and topography of Fernbird Flat.

Samples taken on the point bar away from the channel were typically waterlogged, and of a grey colouring at depth suggesting anoxic, reduced conditions (figure 4).

The dune areas at the northern side of the Manawatu mouth are extensive, and there is evidence of human activities which would mobilize sand (figure 5). Inland of the dunes the sands become dominated by river and/or tidal movement, characterised by sub- linear ripples (figure 6). Large woody debris (sourced from upstream) acts as a sand trap, accumulating sand and creating an undulating surface (figure 7).

The marsh area on the northern banks of the Manawatu estuary at Foxton Beach town is characterised by mudflats and marsh vegetation (figure 8). Many samples collected in this area showed distinct layering of very fine sand beneath the overlying mud (figure 9). Some areas of the marsh contained iron concretions, formed around faunal burrows and exposed by erosion (figure 10).

Figure 4. Photos of sample sites 4 and 5, (from left to right). Note the excess of water at site 4, and the dark grey colour at the bottom of the sample 5 (far left of right picture). The grey colour indicates a reduced anoxic environment.

Figure 5. Photo of dunes at mouth of Manawatu estuary. Note the tyre tracks which would accelerate erosion and damage sand binding vegetation.

Figure 6. Photo of the northern bank of the Manawatu estuary, looking towards the dunes at the estuary mouth. Figure 7 below is taken from the far side of the woody debris photo looking back westwards.

Figure 7. Photo of woody debris on northern bank of the Manawatu River, just inland of the dunes. Note the raised surfaces around the logs, especially when compared to figure 6

Figure 8. Photo of the marsh/mud flat area on the northern bank of the estuary mouth at Foxton Beach township. Photo taken looking west towards the access road to the dunes.

Figure 9. Sediment sampling at Site 22. Note clear boundary between the upper layer of sediment (composed of muds) and the lower sediment (composed of sands).

Figure 10. Photo of exposed iron nodules, located in marsh/mudflat area. Iron precipitates and forms a hard layer when it is in a reduced environment and comes in contact with oxygen. This occurs on the inside of burrows formed by shelly fauna or polycheats (worms). Mud has eroded from around the burrows, leaving raised iron oxide casts of the burrow.

In mud dominated areas, (such as the low tide edge of the channel margin, and the marsh/mud flat area), meandering channels are cut through the flats by the outgoing tidal flow (figure 11)


Figure 11. Tidal channels cut into the mudflats.

4. Aerial photo analysis

Aerial photos dating back to 1958 were rectified to the NZ datum and analysed using ArcMap 9.2. Overall channel movement, and channel fluctuations at the estuary mouth were specifically analysed and other historical changes noted. Figure 12 shows the total channel movement, over all the years photographed. Figure 13 shows change in channel morphology from 1958 to 2005.

It is important to note that the timing of these photographs in relation to tidal height is unknown, hence some horizontal movement could be simply a product of tidal fluctuations. This is especially true for the photos taken in 1962 and 1994 which appear to be have been captured the river at high tide or in a stage of flood.

4.1 Temporal changes of Fernbird flat

The channel encircling Fernbird Flat has undergone significant changes since 1958. Figure 14 shows the movement of this point bar which has significantly narrowed and also extended 547m ESE. Movement of this nature is common in meandering channels, and it could be expected that this point bar will continue to move in a south westerly direction. Between 1958 and 2005 Fernbird Flat has gained 44.8 ha in area, whilst the opposing side to the east has lost 71.3 ha.

The rate of advance ESE of the point bar has not been constant. The rates of point bar extension are given in table 1. The point bar moved ESE at varying rates until 1995 and then remained relatively stable until 2005. It could be possible that this is due to the large number of flood protection works, which have stabilised the channel to its present form, preventing anything but large floods (such as 2004) causing channel migration. An in depth study of the fluvial mechanics of the Manawatu would be needed to confirm this theory.

Figure 15 demonstrates the variation in the rate of channel movement, and also highlights the change in the channel loop morphology. The loop went from broad and almost flat in 1958, to narrow and more pointed in 2005.

4.2 Temporal changes of estuarine mouth

The mouth of the Manawatu River has undergone considerable fluctuation between 1958 and 2005. The overall changes are mapped in figure 16 and table 2 summarises the channel movements. Measurements and descriptions are with respect to the northern bank of the river channel.

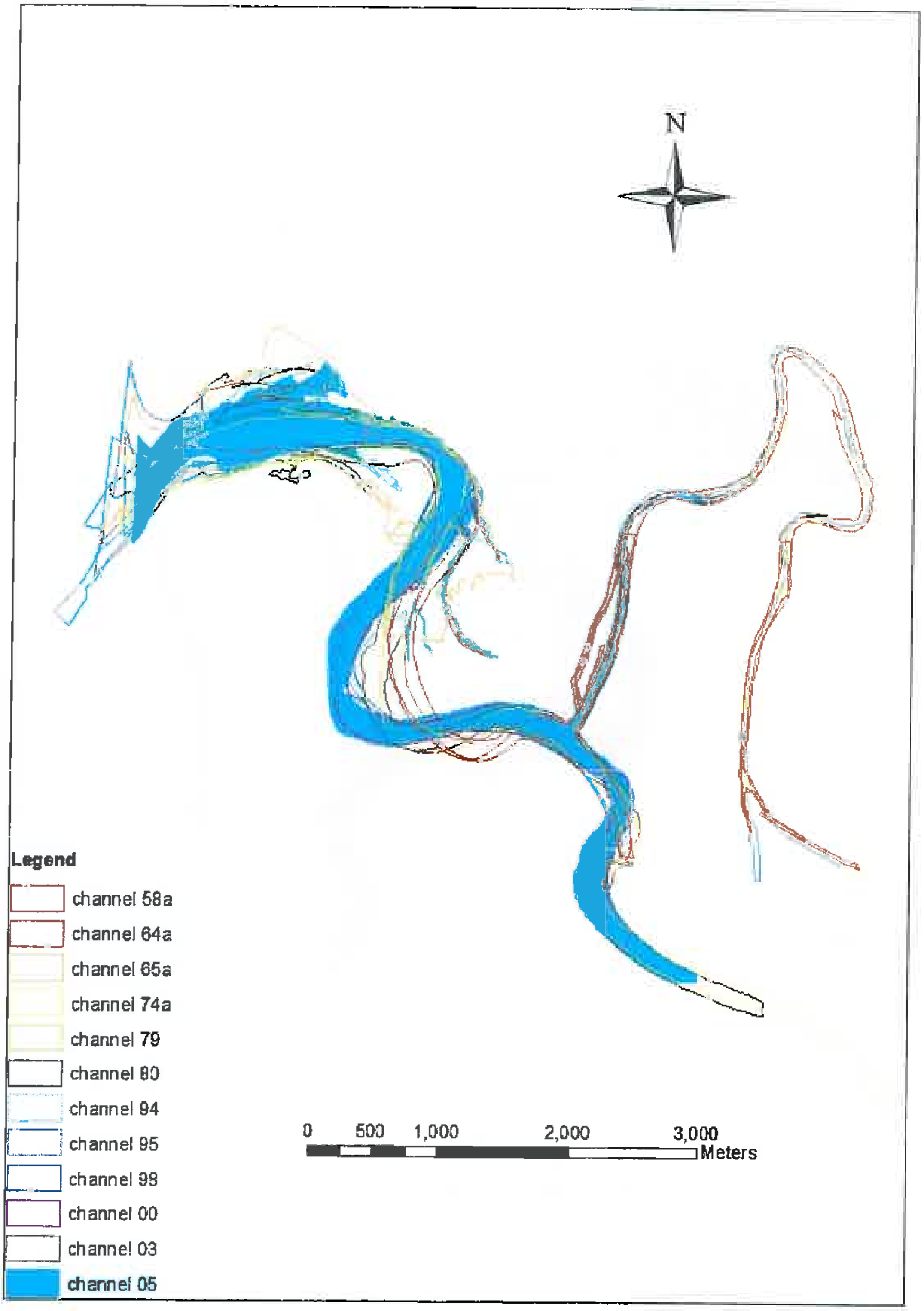


Figure 12. Location of the channel of the Manawatu between the period 1958 and 2005. Determined by aerial photo analysis.

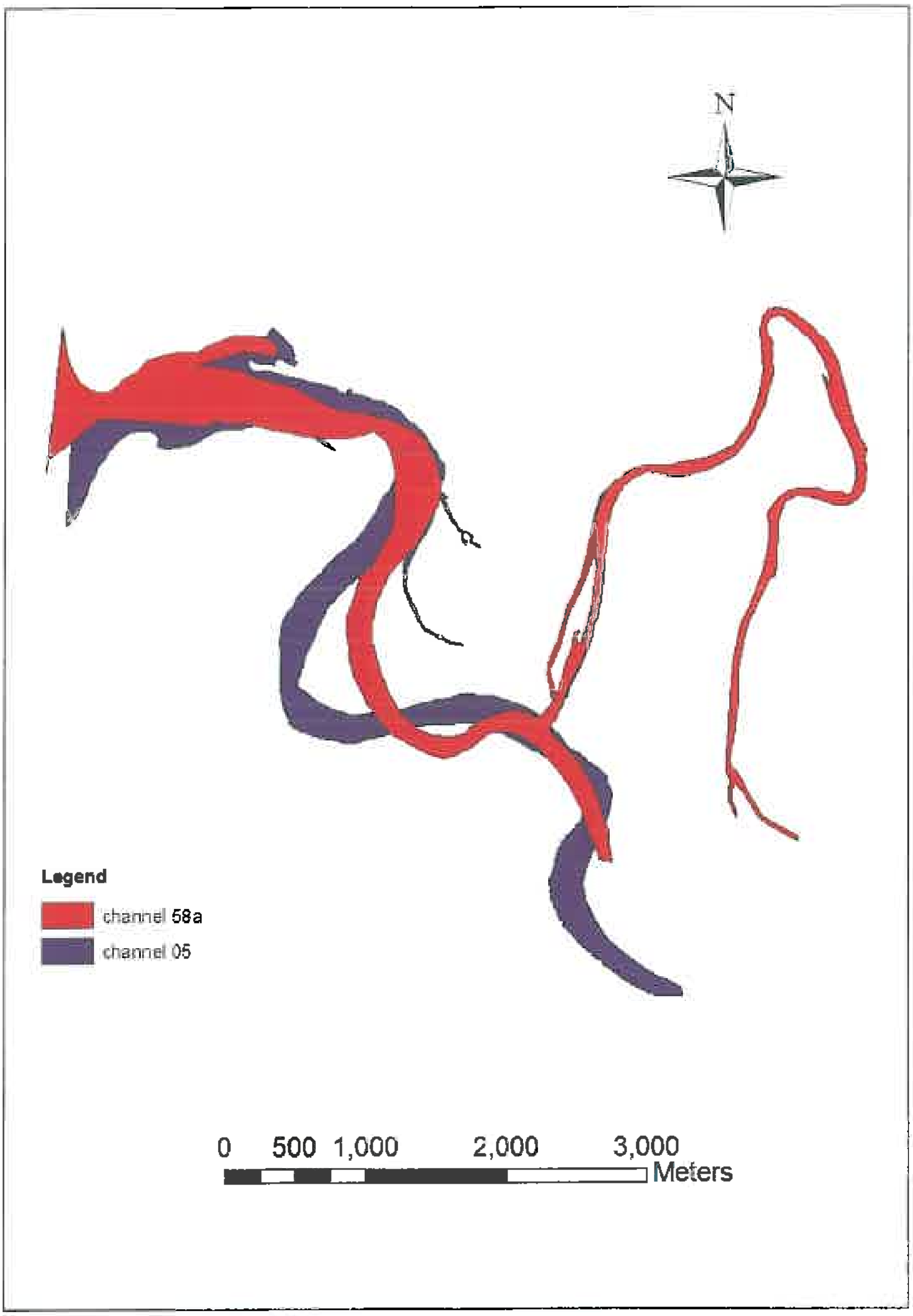


Figure 13. Movement of the Manawatu channel between 1950 and 2005.

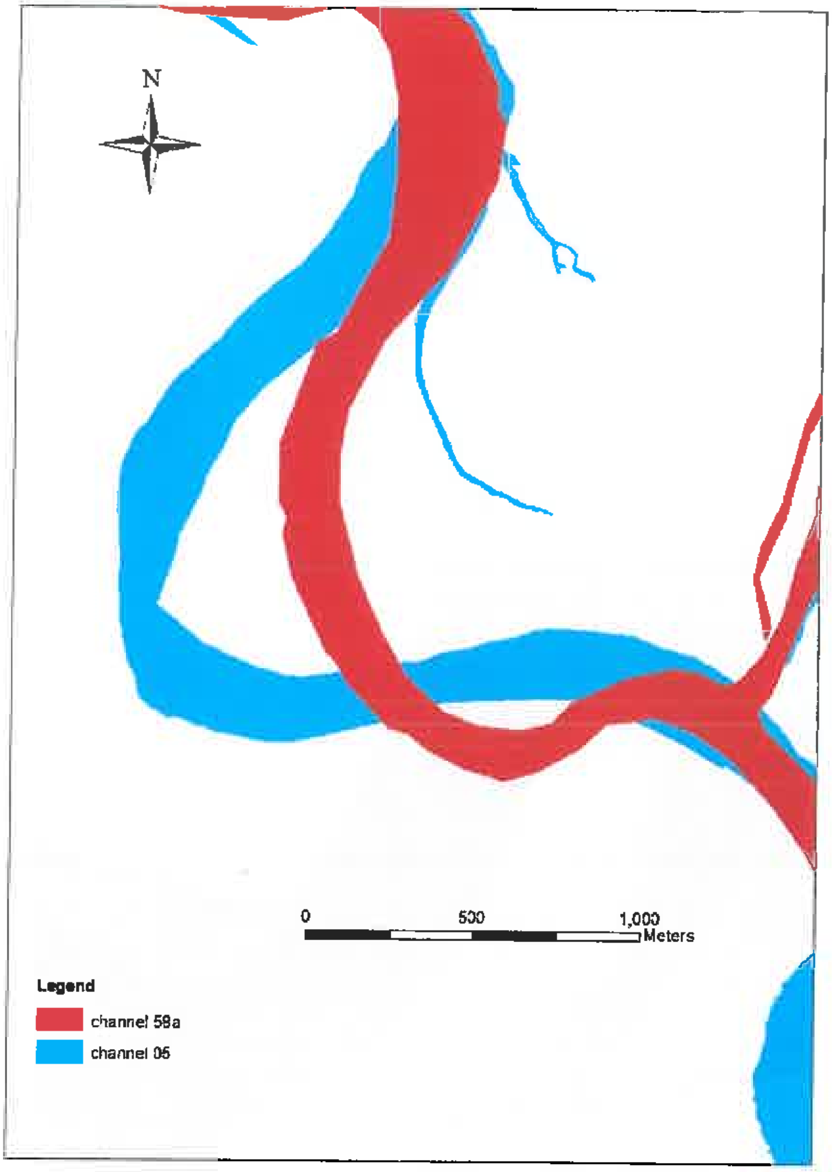


Figure 14. Point bar movement of the Manawatu River, from 1958 to 2005 of the locality known as Fernbird Flat.

There is no general trend of channel movement in any one direction, rather the river fluctuates back and forth, as can be noted in both Figure 16 and Table 2. A significantly large movement occurred between 2003 and 2005 (718m north and 364m east). This substantial movement was in all probability caused by the 2004 flood. It is likely that periods of stronger river currents (such as the 2004 flood) cause the channel mouth to move north. In calmer periods the force of tides and the south trending longshore drift shifts the mouth southwards again. However, even after the 2004 floods the river has not returned to a position as northerly as that of 1958 (Figure 16 a).

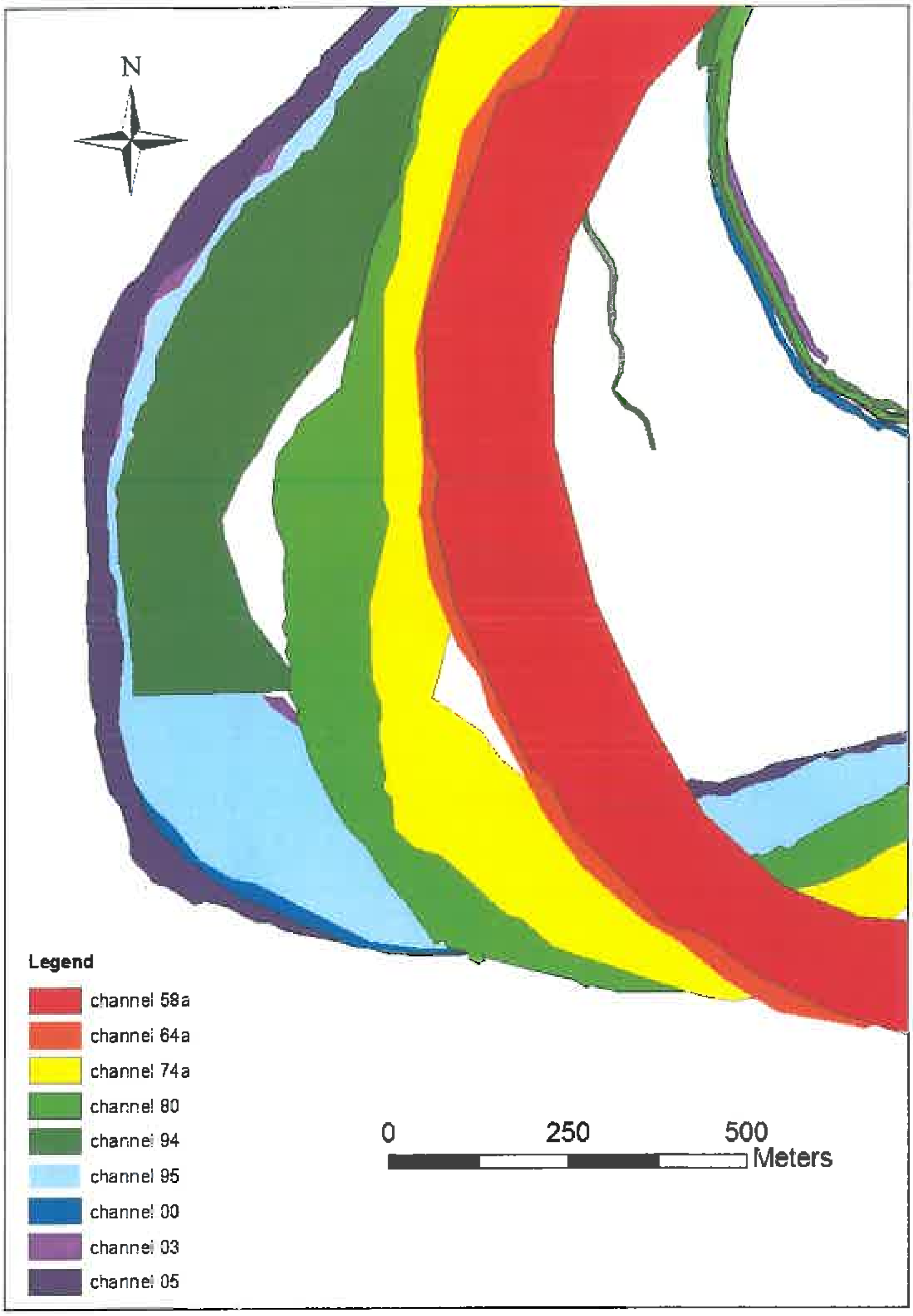


Figure 15. Extension of the point bar- Fernbird Flat, on the Manawatu River. Compiled using aerial photos from 1958 to 2005.

Table 1. Rate of point bar extension for the channel loop encircling Fernbird Flat.

Years compared	Distance moved (m)	Rate of movement (m/year)
1958 – 1964	16.6	2.8
1964 – 1974	63.8	6.4
1974 – 1980	157.4	26.2
1980 – 1994	238.4	17
1994 – 1995	18.4	18.4
1995 – 1998	0	0
1998 – 2000	0	0
2000 – 2003	0	0
2003 – 2005	43.0	21.5
1958 - 2005		**11.5**

Table 2. Measurements of channel movement at the mouth of the Manawatu, using aerial photos. Measurements are relative to the positions of the northern channel bank.

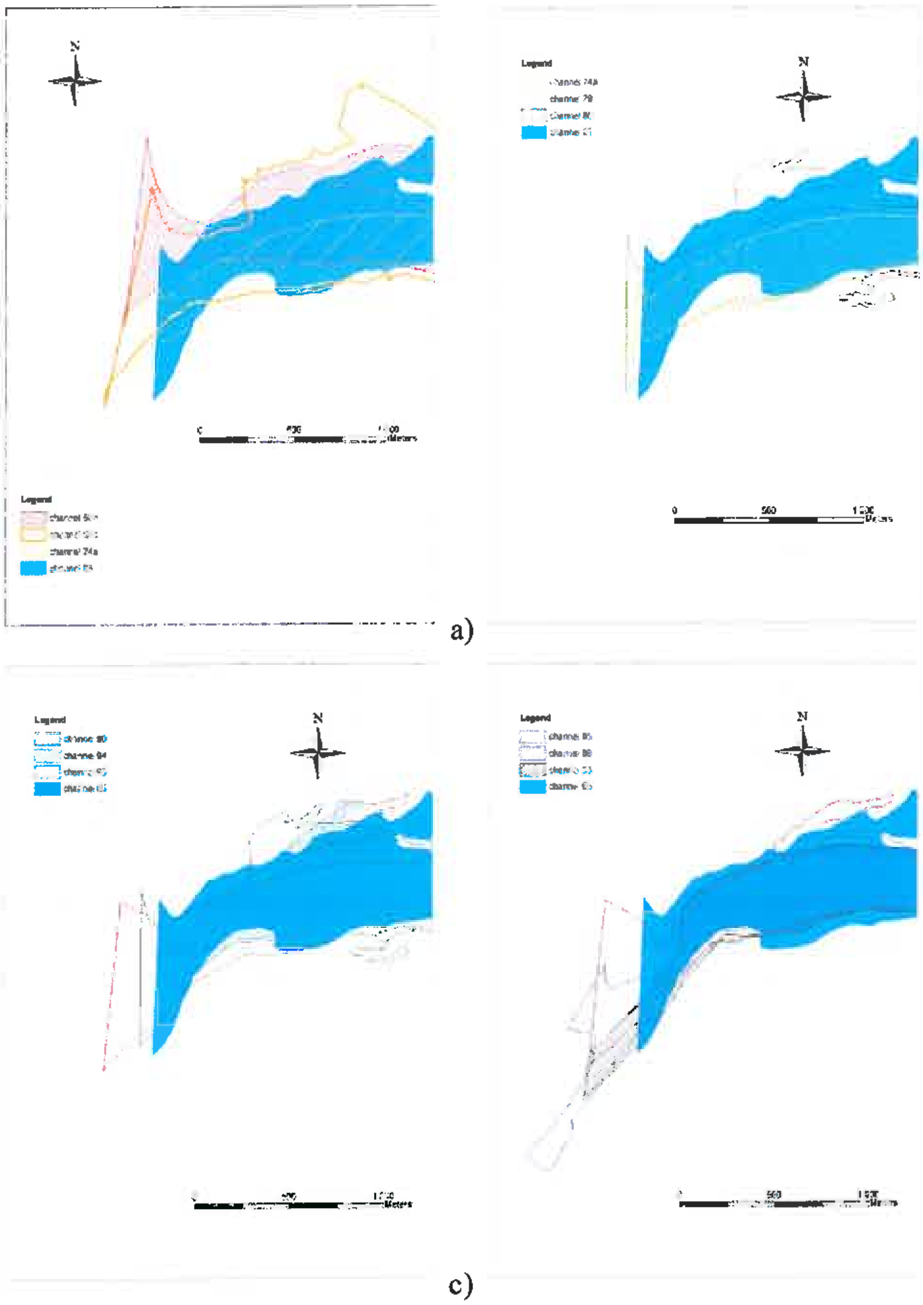
Years compared	North –South movement (m)		East-West movement (m)	
1958 - 1965	South	92	-	-
1965 - 1974	South	314	West	204
1974 - 1979	North	64	East	102
1979 - 1980	North	68	West	107
1980 - 1994	South	150	East	36
1994 - 1995	North	28	East	66
1995 - 1998	South	223	West	271
1998 - 2003	South	323	West	105
2003 - 2005	North	718	East	364

The changes in channel width are shown in table 3. Between 2003 and 2005 the channel widens by 192m. It is likely that the mouth widens in response to increased fluvial power (such as the 2004 flood) and narrows when longshore drift, tidal, and wave power are greater than the fluvial force.

The southern bank, after considerable movement in the period 1958 - 1975 (370m south, see figure 16 a) remains fairly stable, with only minimal movement post 1975. For this reason the southern bank is not used to compare the channels' movements through time. It is possible that the initial dramatic movements in the southern bank were caused by the channel adjusting to the Whirokino cut, after which the location of the bank became more stable.

4.3 Marsh area, estuary mouth (Foxton Beach Township).

On the northern bank of the estuary mouth behind the dunes is a marsh area that is significant as a wading bird feeding area. Movement of the river channel towards the marsh area would be detrimental as erosion decreases the area of marsh, and stronger currents remove muds and deposit sands. The movement of the adjacent channel is shown in figure 17. Unfortunately the movement of the northern bank is unclear, as photos taken at different times in the tidal cycle or on flood events significantly change the channel margin location. For this reason the southern bank has been used to determine alterations in channel position.



a) b) c) d)

Figure 16. Movement of the Manawatu estuary mouth between 1958 and 2005. a) 1958, 1965 and 1974; b) 1974, 1979 and 1980; c) 1980, 1994 and 1995; d) 1995, 1998 and 2003. The position of the channel in 2005 is present in a) through c) for comparison.

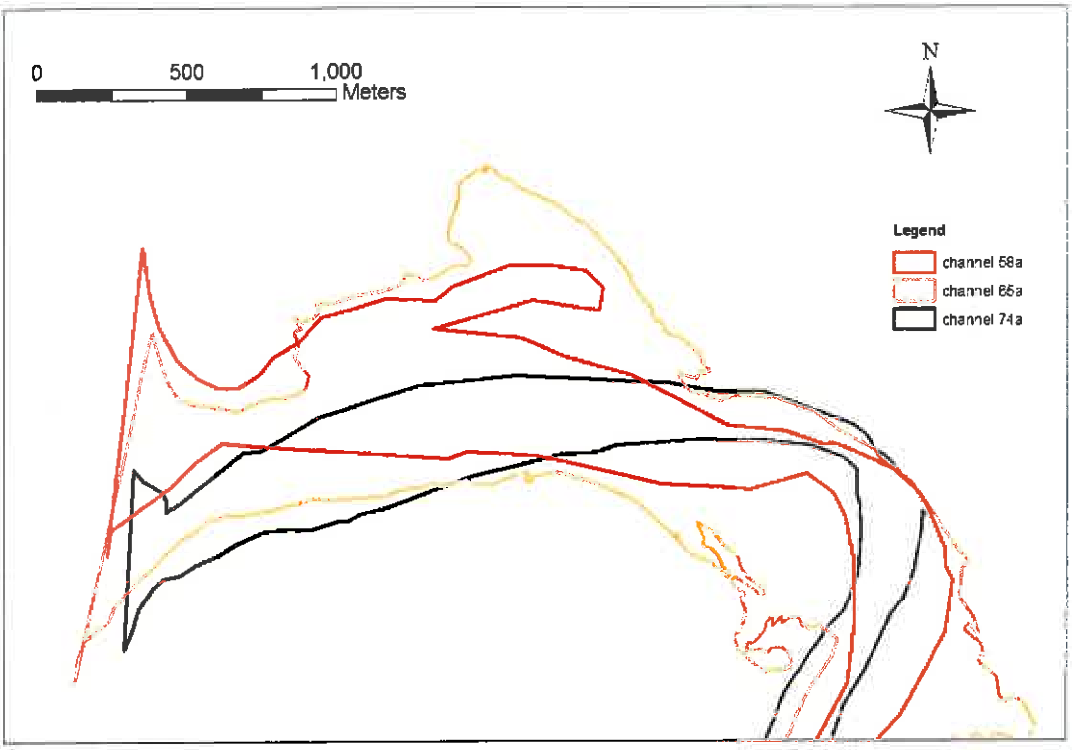
Table 3. Change in width of the Manawatu channel at the river mouth between 1958 and 2005. Measurements made at the narrowest section of the channel from aerial photos captured in years indicated.

Year	**Channel width (m)**
1958	182
1965	342
1974	224
1979	292
1980	350
1994	183
1995	160
1998	105
2003	110
2005	302

Between 1958 and 1965 the southern bank moved south 43m (figure 17 a). The angle of the channel alters between 1965 and 1974 (figure 17 a) and this orientation remains unchanged. The stability may be due to the flood protection structures in place on the outside edge of the river loop, which prevents the point bar progressing north east, and also prevented large channel movement downstream of this point. (Notice the constant position of the end of the point bar in Figure 17 b-d). From 1974 to 1994 the position of the southern bank is similar, with minor accretion northwards. The change in position of the south bank to 63m north occurs between 1994 and 1995 and is subsequently maintained until 2003. In 2005 the river has returned to the former 1974 position (figure 17 d). The 2005 position is probably a factor of the erosive power of the 2004 floods, removing sediments that have accumulated on the southern bank since 1974.

4.4 Formation and temporal changes of the sand spit

Between the mud flats at the estuary mouth and the main channel of the river is a vegetated sand spit that runs roughly parallel to the river (figure 18). This spit protects the saltmarsh behind it from the erosive power of the river. It also slows the tidal outflow-allowing for silt and clay deposition. This spit has evolved over time from a small sand bar in 1958, which has been reworked by river currents to lie parallel to the main channel and stablised by vegetation. Its present day shape was mostly achieved by 1994, since then it has been pushed back slightly, and continues to elongate westwards.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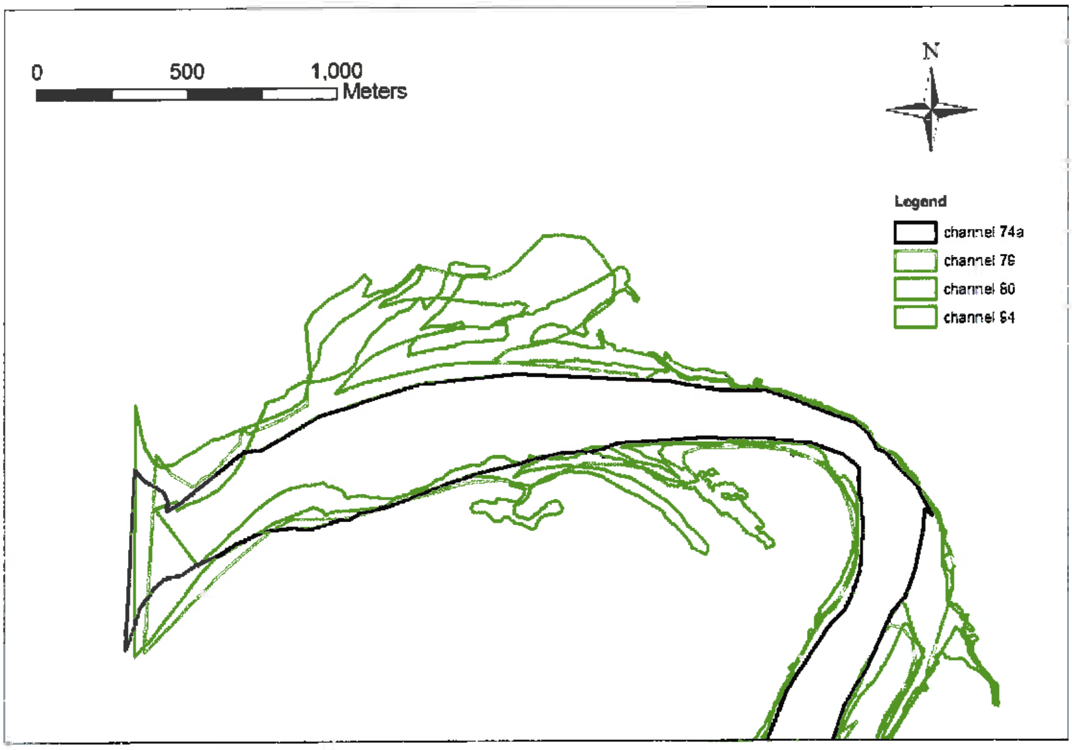
channel 74a

a)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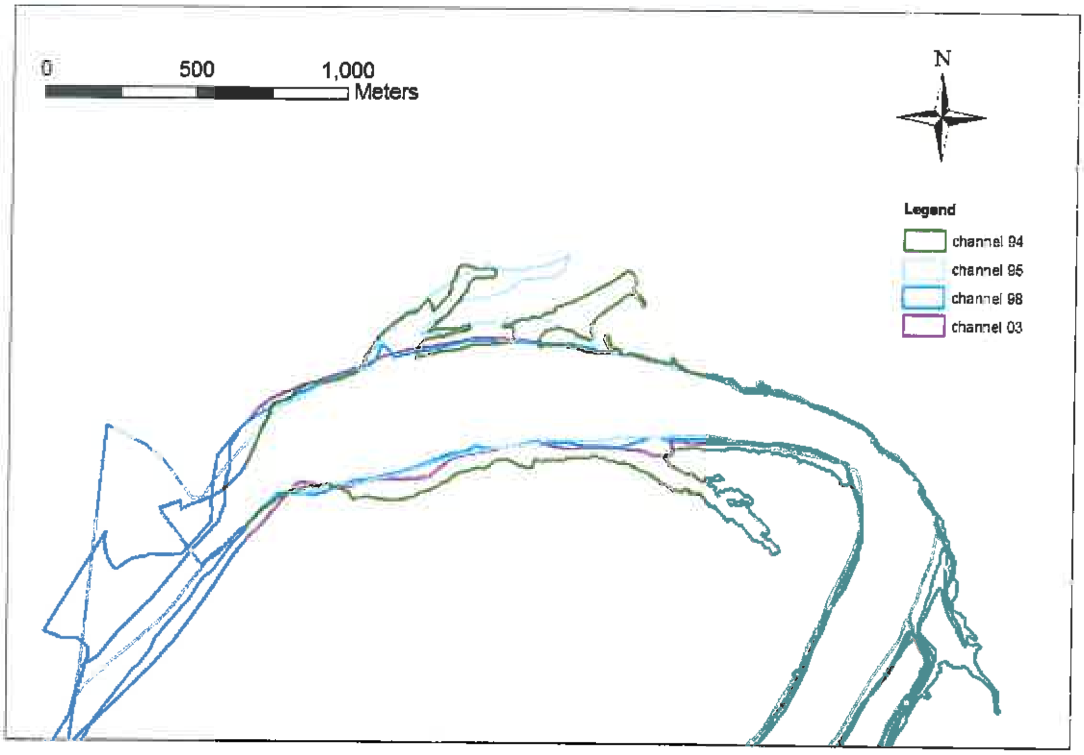

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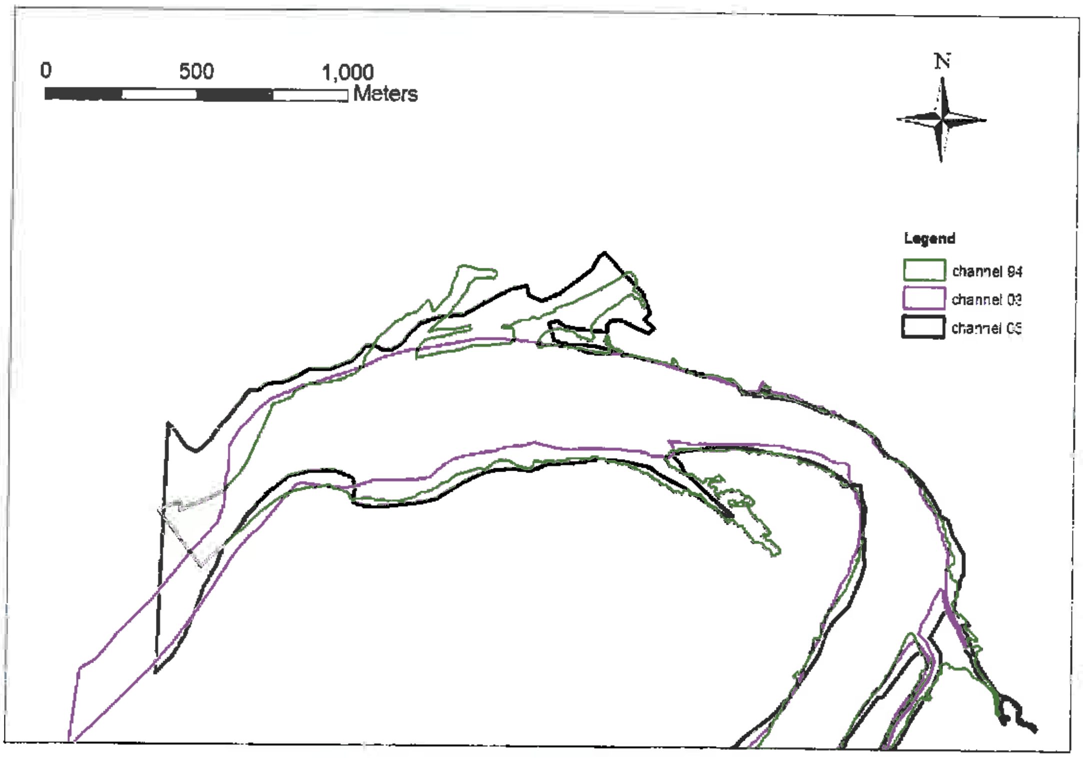
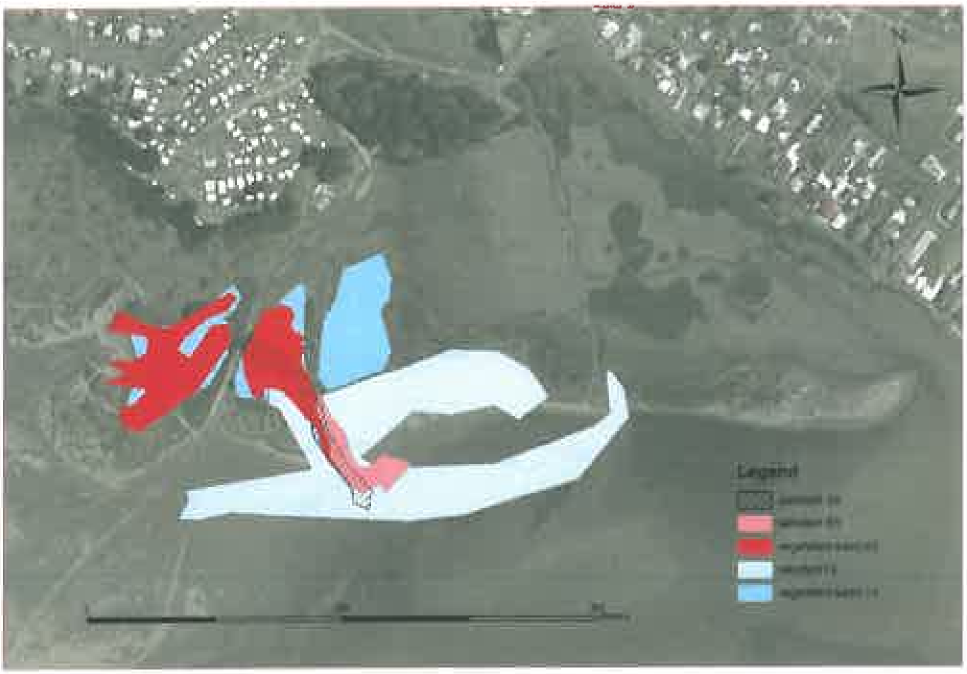
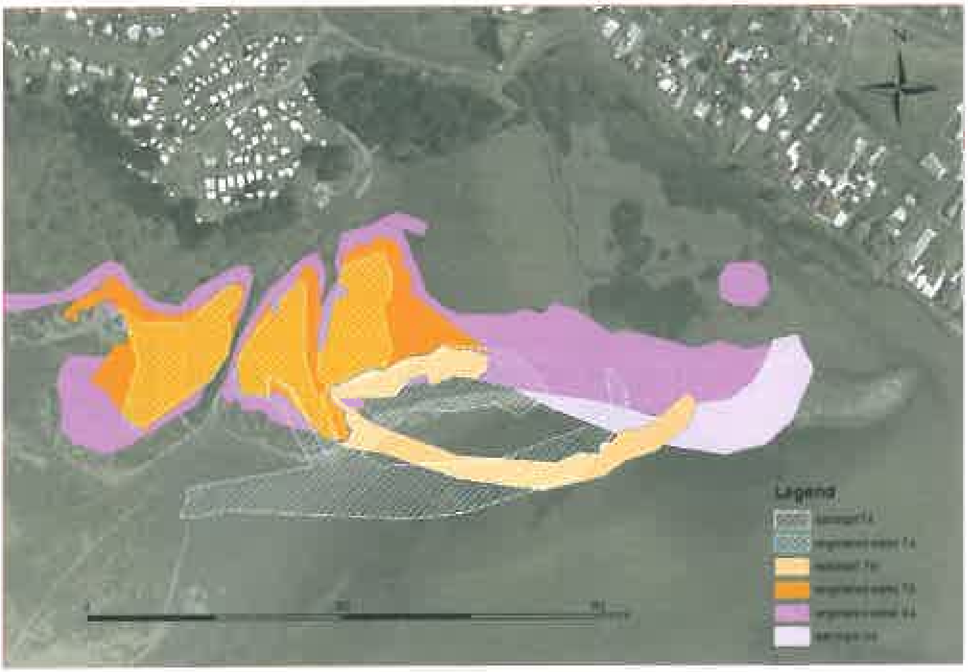


d)

Figure 17. Movement of the Manawatu river channel adjacent to the marsh area. a) 1958, 1965 and 1974; b) 1974, 1979 1980 and 1994; c) 1994, 1995 1998 and; 2003 d) 1994, 2003 and 2005.



a)



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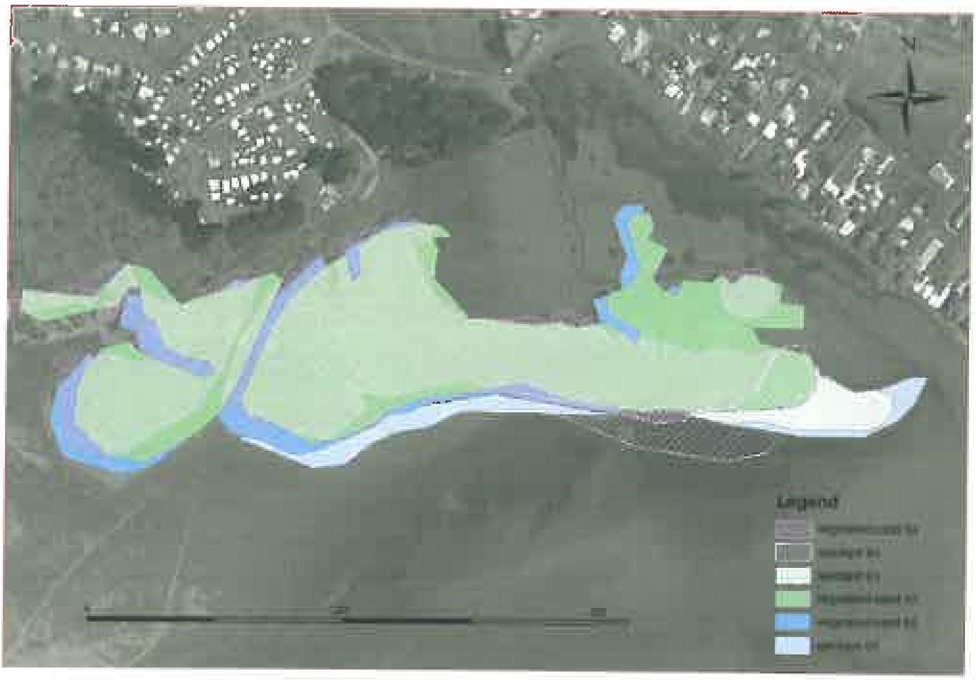

c)

Figure 18. The development of the vegetated sand spit between the marsh area and the river channel. In the years: a) 1958, 1965 and 1974; b) 1974, 1979 and 1994; c) 1994, 2003 and 2005.

4.5 Temporal changes in dune characteristics

The Foxton Beach area is characterised by large aeolian dunes, that characteristically migrate inland driven by the prevailing westerly winds. Therefore there is a possibility for the dunes to encroach on the marsh areas and bury the muds with sand. This seems less probable when the amount of unvegetated dunes in 1958 is compared to that of present day (figure 19). Unvegetated dunes are significantly more mobile than those with vegetation to stabilise and protect sands from wind energy. Dunes with little or no vegetation covered a much greater area in 1958, especially downwind of the marsh area (far right of figure 19). Since then the dunes have been actively stablised and the potential for sand to be sourced downwind of the marsh area is greatly reduced.

Figure 19. Comparison of unvegetated dunes between 1958 and 2005. Major wind direction indicated with green arrow.

5. Surface sediment analysis

Surfical samples were collected from the locations indicated in figure 20 and figure 21. GPS points for these sites was determined by a hand held Garmin GPS, and are available in the appendix. Samples were collected on the 27th and 30th of June and the 1st of July 2008. Field work was undertaken on these dates due to the timing and height of low tide, and appropriate weather conditions.

Sediment was collected from a depth greater than 40cm. If samples were bedded (figure 9), a mixture of sediment was collected to obtain a composite sample. In the case of samples to be analysed for metal concentration, sites with a high mud composition were chosen. This is due to the preference metal contaminants have for finer sediments (deGroot 1995). Samples to be analysed for metal concentration were collected with a plastic trowel to avoid metallic contamination. In the laboratory, subsamples for each analysis were obtained by coning and quartering techniques.

5.1 Grain size

The grain size composition of the surface samples collected was analysed by dry sieving at half phi (ϕ) intervals according to Folk and Ward (1957). The grain size composition of all samples is shown in figure 22. There are two clear peaks in the overall grain size data, at 3ϕ and <4ϕ (figure 22). The narrow peak at 3ϕ typifies the grain size distribution of aeolian sands, fine grained and well sorted. Previous studies of grain size at Foxton beach have also found surfical sediments to be composed of fine, very well sorted sand (Kasper-Zubillaga et al. 2007) with a mean of 2.72ϕ (Kasper-Zubillaga and Dickinson 2001). Even for those sites dominated by muds, a small peak is present at 3ϕ whilst other grain sizes are not represented. This is not surprising considering the study area location in the Foxton dune sequences. There is so little variation in grain sizes between sites, that composition can be simplified into three classifications; coarse sand, aeolian sand and silts/clays (figure 23). Coarse sands are a very minor component (figure 23) and only signify those sites with high fluvial energy. Fine aeolian sands and muds dominate; if fine sand is the dominant grain size it indicates that fluvial currents are too strong for muds and silts to be deposited, but not strong enough that the sand is completely eroded away. High mud and silt content indicates a slower fluvial regime such as a tidal back water or marsh.

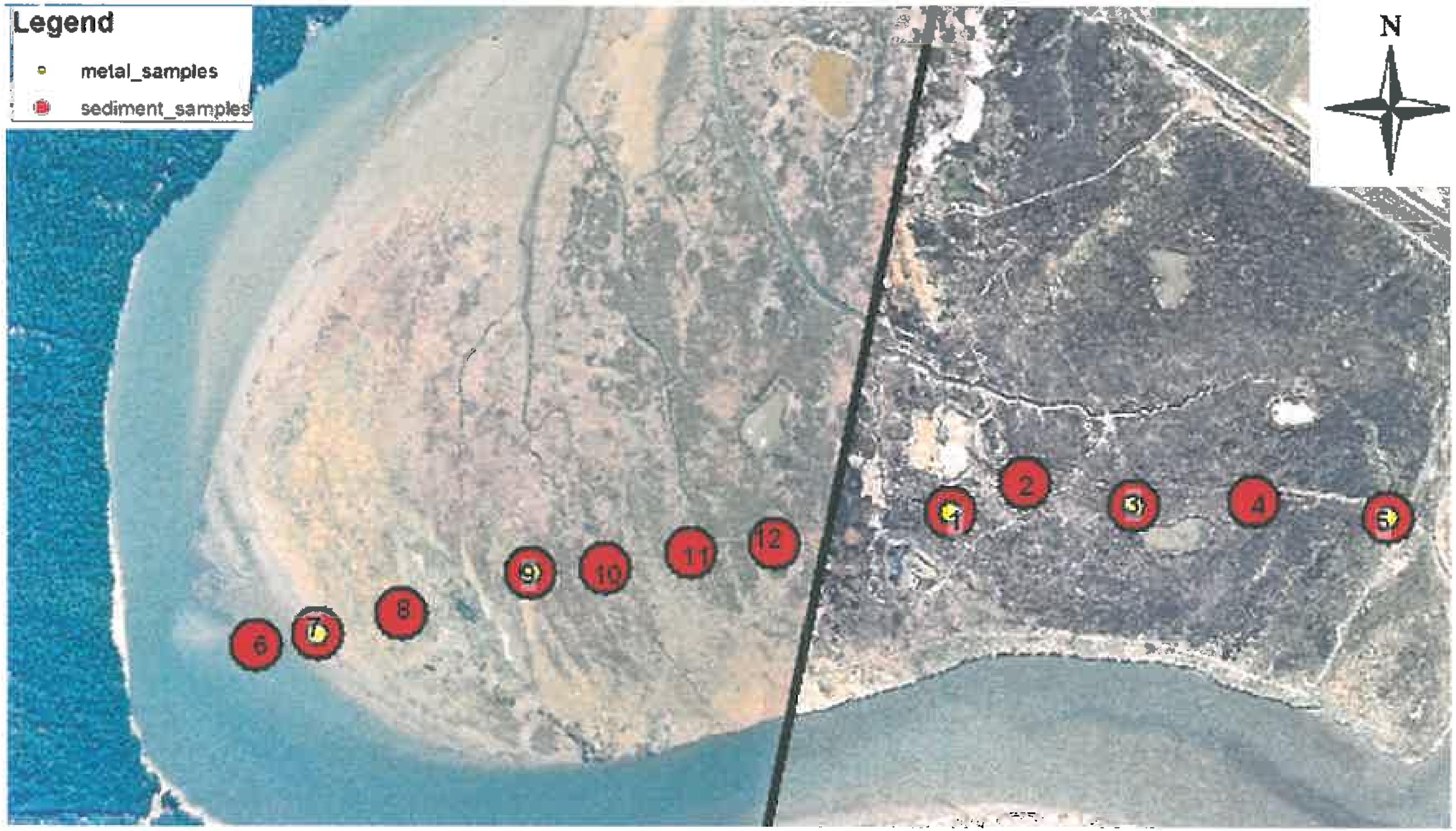

Figure 20. Location of surfical sediment samples sites and metal concentration sample sites on Fernbird Flat.

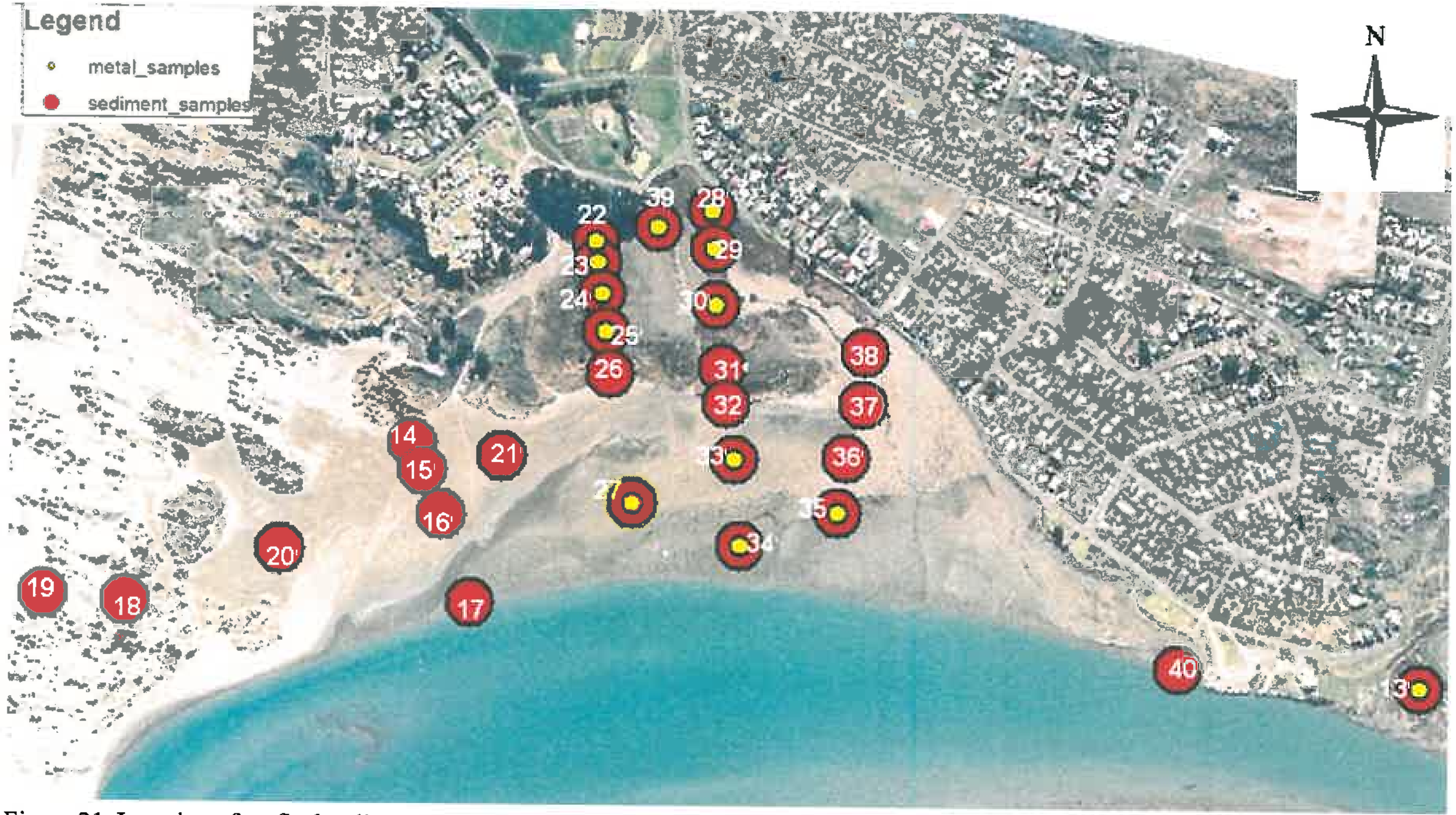

Figure 21. Location of surfical sediment sample sites and metal concentration sample sites at the estuary mouth, near Foxton Beach township.

Figure 24 highlights those sites that are wholly characterised by dune sand. The characteristic narrow peak at 3ϕ (fine sand) indicates that the aeolian dunes are the key influence on grain size at these sites. As expected, sites18, 19 and 20 exhibit the strongest peak at 3ϕ (figure 24), as they are located within the dune sequence (figure 21). The sites located in the flat, sand dominated bank of the river channel (sites 14, 15, 16, 17 and 21 figure 21) also peak at 3 ϕ (figure 24). This location is dominated by fluvial processes (area shown photographically in figure 6), hence small amount of silts and clays present (figure 24). The sands graphed in figure 24 either represent wind derived sand where river processes are weak, or strong fluvial currents. It is obvious by comparing these two sets of sites (dune and river bank) that grain size can not be used to determine if fluvial or aeolian processes are controlling sediment size at the estuary mouth. This is because both aeolian and fluvial processes have the same source for sedimentary material.

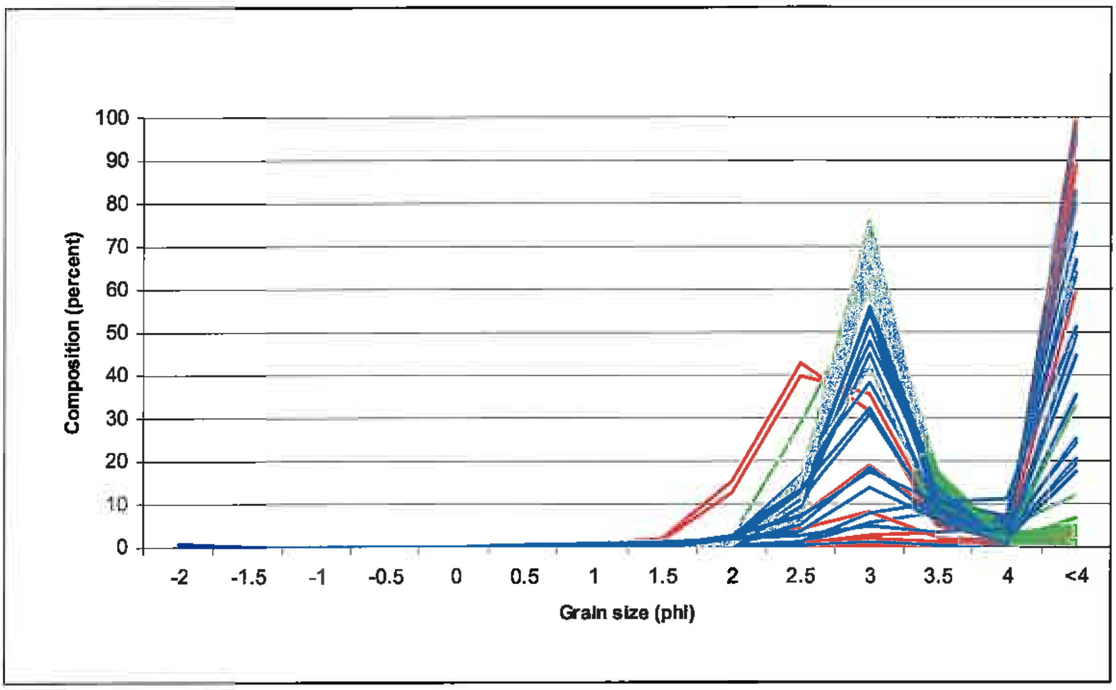

Figure 22. Grain size composition in percent by weight of all sites.

Sites 26, 31, 32 and 37 are also dominated by fine sands (figure 24). These sites are located along the sand spit between the main channel and the tidal flat/marsh area (figure 21). Site 33 is a transitional site. It exhibits a peak at 3ϕ, similar to the other sites in figure 24, but it also has a significant mud component. This site is also composed of the finer grain sizes that dominate those sites shown in figure 25.

The sites adjacent to the river channel are shown in figure 25. The lowest energy environment (sites 34 and 35, figure 21), dominated by muds occurs adjacent to the channel below mean tide level. Higher energy sites are located inland where fluvial energy deposits fine sand (sites 26, 27 and 40). As mentioned above, site 33 is transitional between the fine grained, low energy, low tide sites and the higher energy sandy sites. These two distinct zones, of low energy muds adjacent to the channel and higher energy sands are demonstrated in figure 26. Tidal forces deposit muds at sites 27, 34, 35 and 36 whilst stronger fluvial currents dominate the sand spit and sites westward.

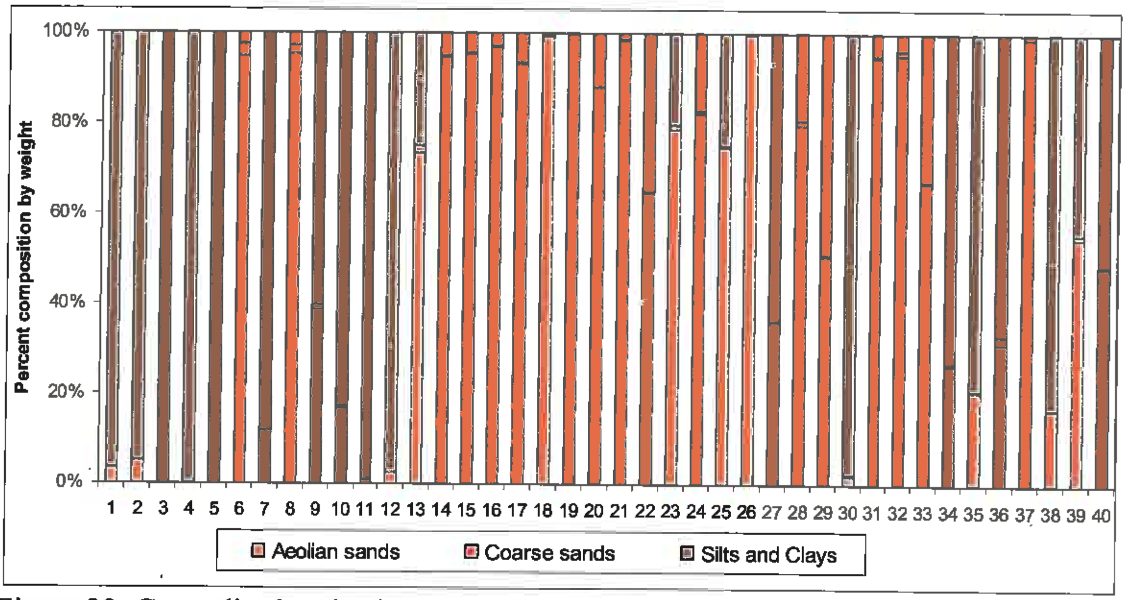

Figure 23. Generalised grain size composition of surfical samples in percent by weight. Coarse (beach or river derived) sands -2 to 1.5 ϕ ; Aeolian sands (dune sands) 2 to 4 ϕ; Silts and Clays (muds) <4 ϕ.

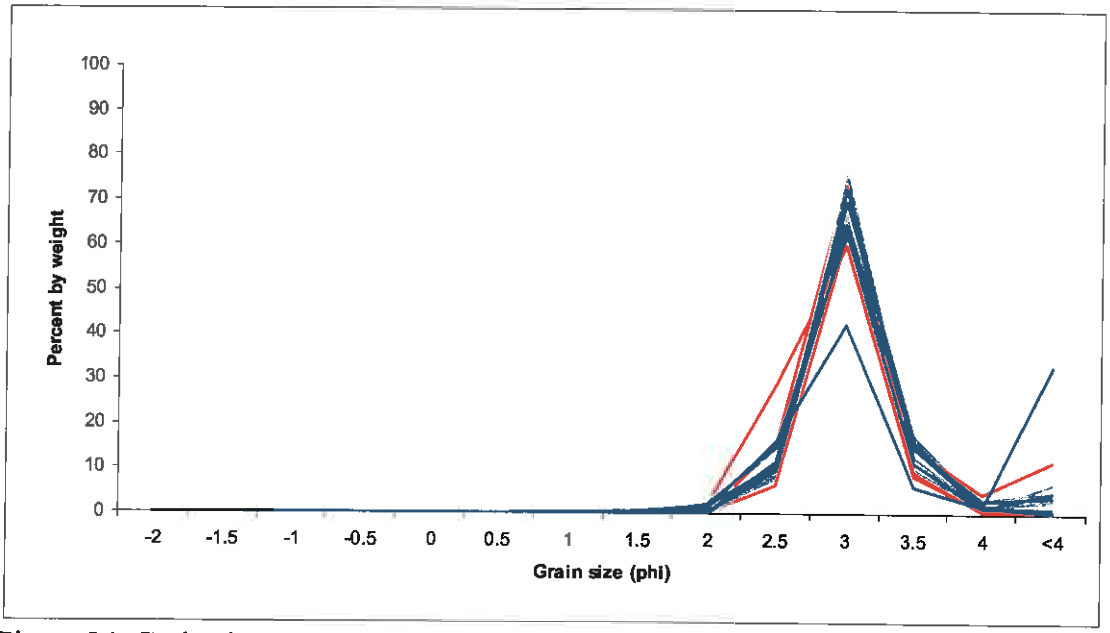

Figure 24. Grain size composition in percent by weight of sites mainly composed of dune sand. Red= sites 18, 19 and 20; green =sites 14, 15, 16, 17, and 21; blue=sites 26, 31, 32, 33 and 37.

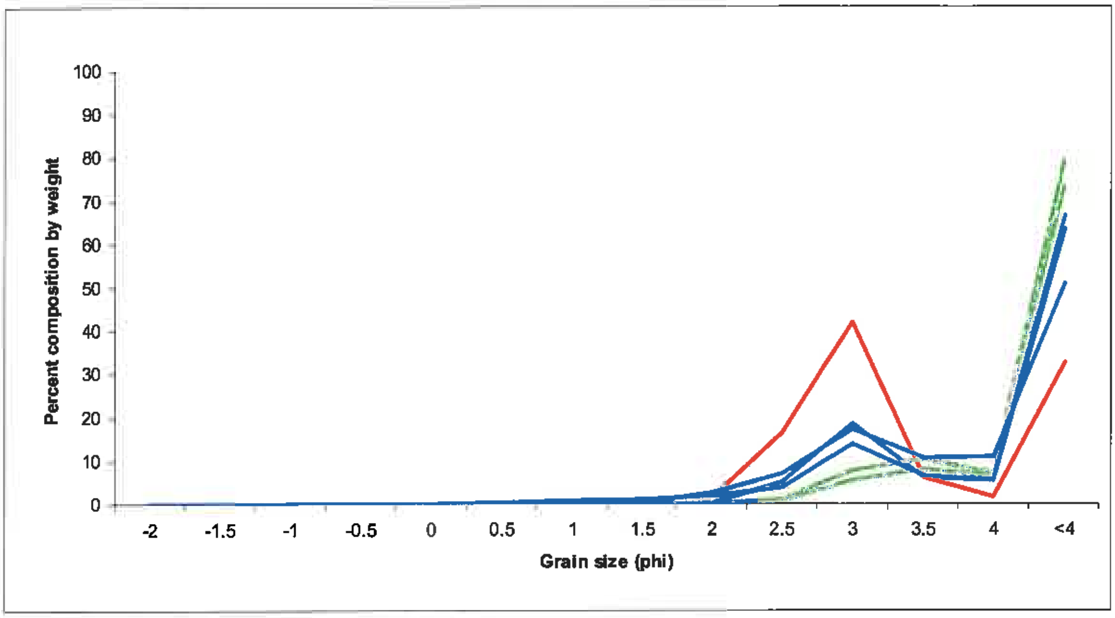

Figure 25. Grain size composition in percent by weight of sites located adjacent to the river channel. Red = site 33; green = sites 34, and 35; blue = sites 27, 36 and 40.

The area located behind the sand spit in the marsh/ mudflat area is more complicated. Figure 27 shows the grain size distribution of sites in this location. Sites 30 and 38 are comprised of the greatest percentage of silts and clays, reflecting the low energy environment in which they are located. All other sites in this mudflat/marsh area have a moderately high (up to 56%) 3ϕ peak. However, this does not indicate a higher energy environment, or aeolian sand influx. The sites indicated in green in figure 27 were typified by a mud layer of around 10cm thick overlying a fine sand (photograph figure 9). Both sediment types were collected and mixed together in the sample. Hence the fine sand component represents the underlying sediment, whilst the silts and clays are representative of the current depositional environment. The high percentage of mud at site 30 (figure 26) is also due to the presence of marsh vegetation at this location.

On the point bar (Fernbird Flat), sediments collected adjacent to the channel are slightly coarser and a greater range of grain sizes (figure 28). This represents the higher energy fluvial currents, which can deposit coarser material. The point bar shows a typical grain size distribution, with sediments becoming finer away from the channel (figure 28 and 29). Site 7 is only an anomaly due to the preferential selection of finer grained sediment for metal analysis. The sites located furthest landward (sites 3, 4, and 5) are typical floodplain deposits, containing only silts and muds deposited in slow moving water during flood events (figure 29).

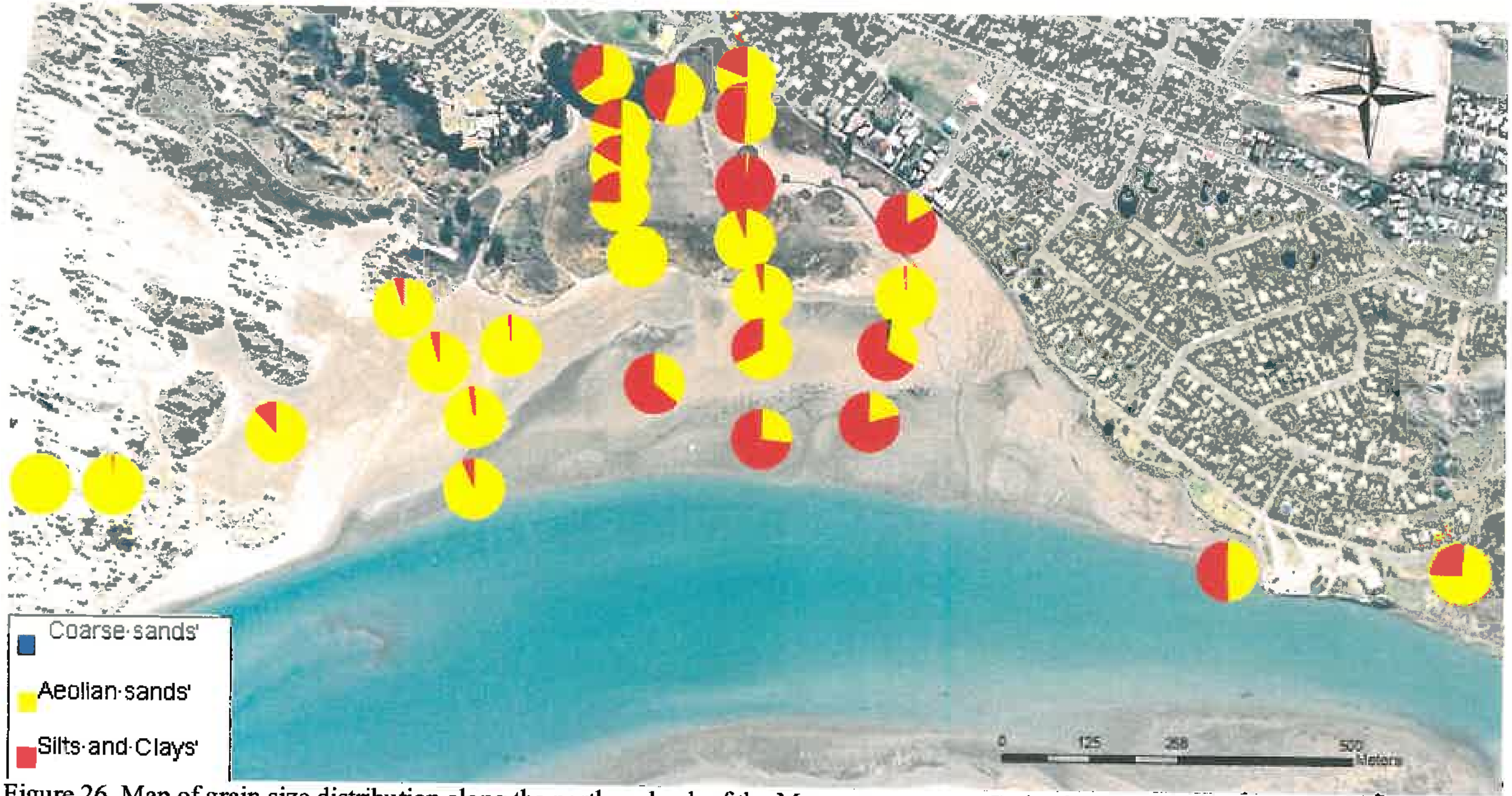

Figure 26. Map of grain size distribution along the northern bank of the Manawatu estuary. Grain size is determined in percent by weight and grouped as: coarse sand (-2 to 1.5 ϕ), dune sands (2 to 4 ϕ), and muds (<4 ϕ)

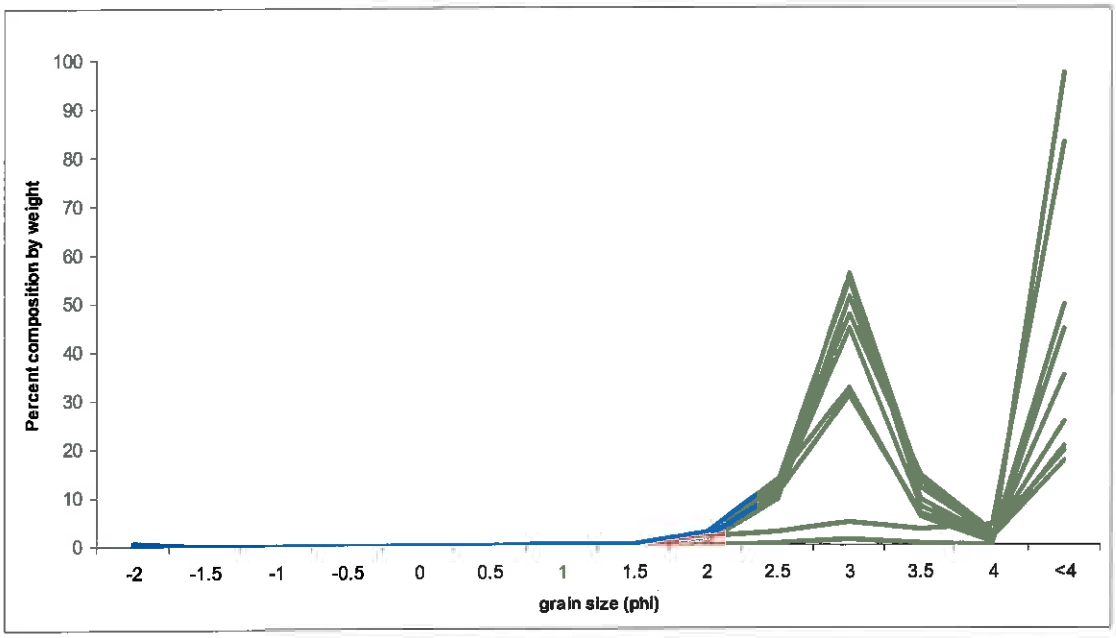

Figure 27. Grain size composition in percent by weight of sites located behind the sand spit in the marsh/ mudflat area. Red = sites 30 and 38; blue = sites 29 and 39; Green = sites 22, 23, 24, 25 and 28.

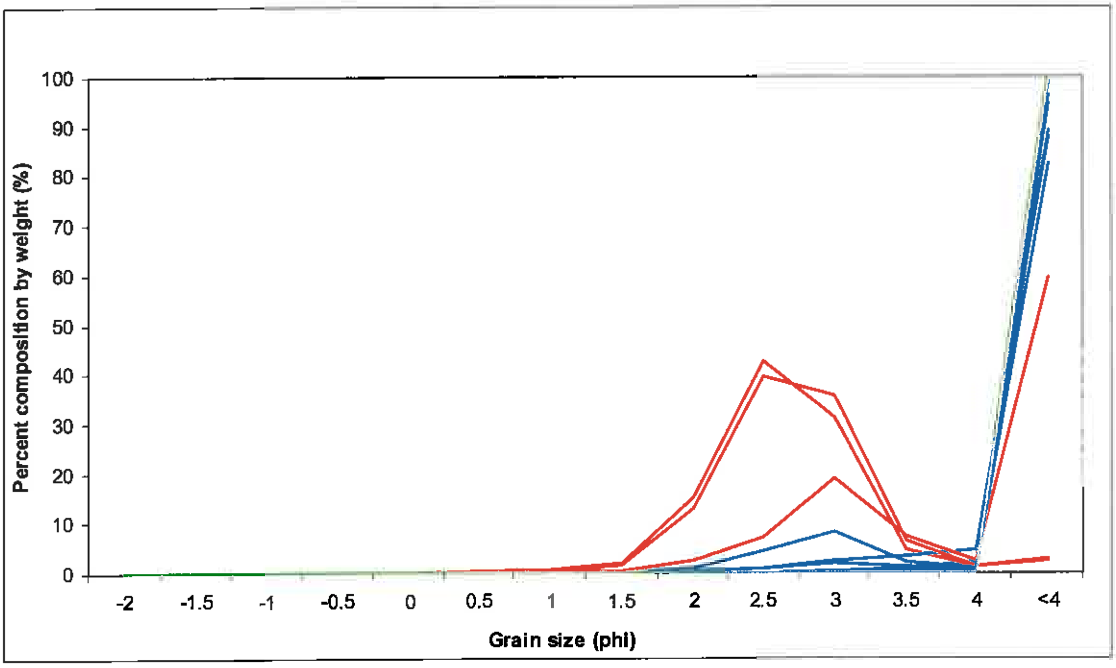

Figure 28. Grain size composition in percent by weight of sites located on the point bar, Fernbird Flat. Red= Sites closest to the channel (6, 8 and 9); Blue= Sites 7, 10, 11, 12, 1 and 2; Green= Sites 3, 4 and 5.

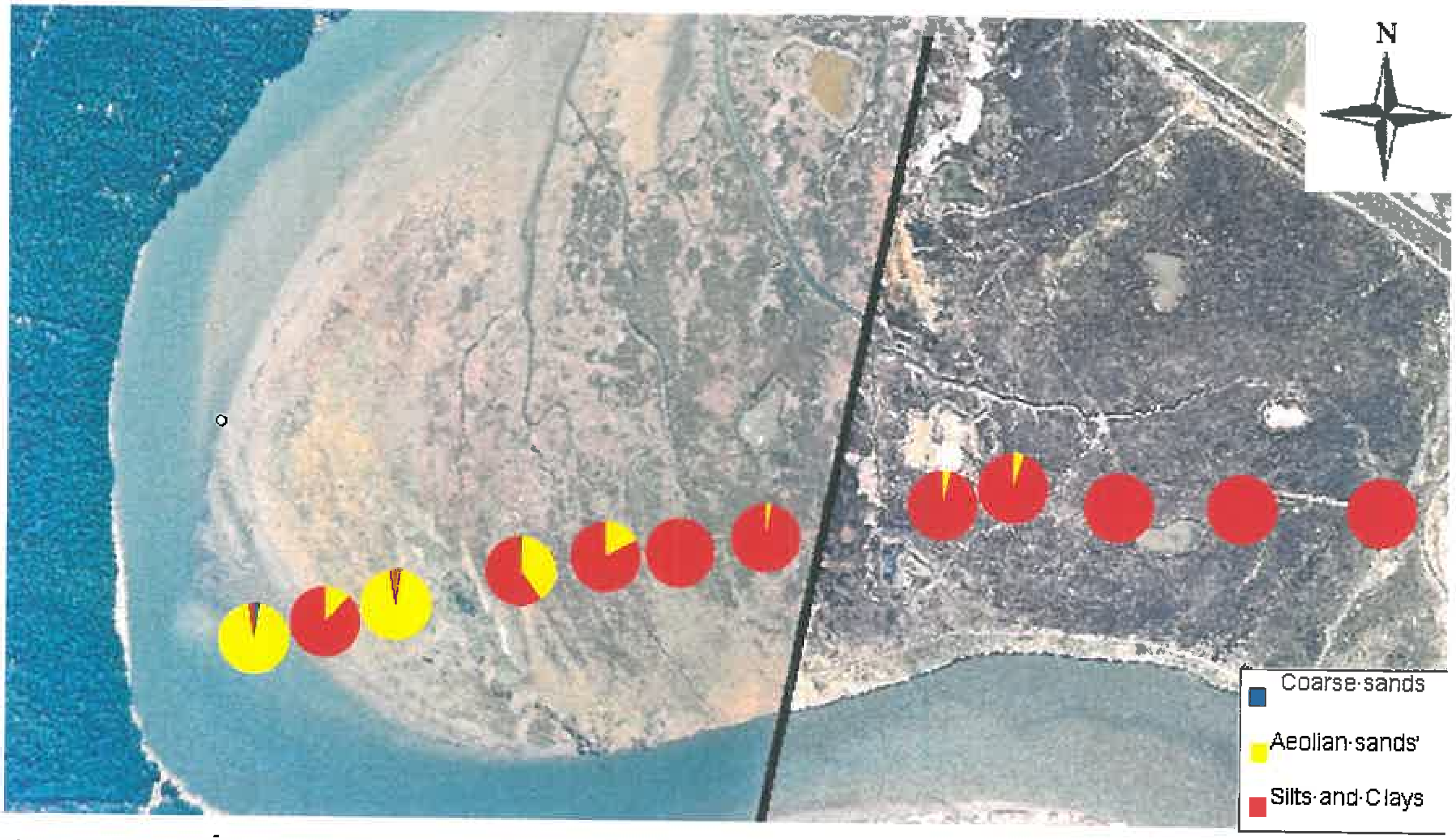

Figure 29. Map of grain size distribution along Fernbird Flat. Grain size is determined in percent by weight and grouped as: coarse sand (-2 to 1.5 ϕ), dune sands (2 to 4 ϕ), and muds (<4 ϕ)

5.2 Organic component

The concentration of organic matter was determined on each sample by reaction with hydrogen peroxide. This method gives the amount of organic carbon in a sample, not including fossil carbon or charcoal. Inorganic carbon, such as bicarbonates or carbonates are also not determined using this methodology. The percentage of organic matter over the sites analysed is shown in Figure 30.

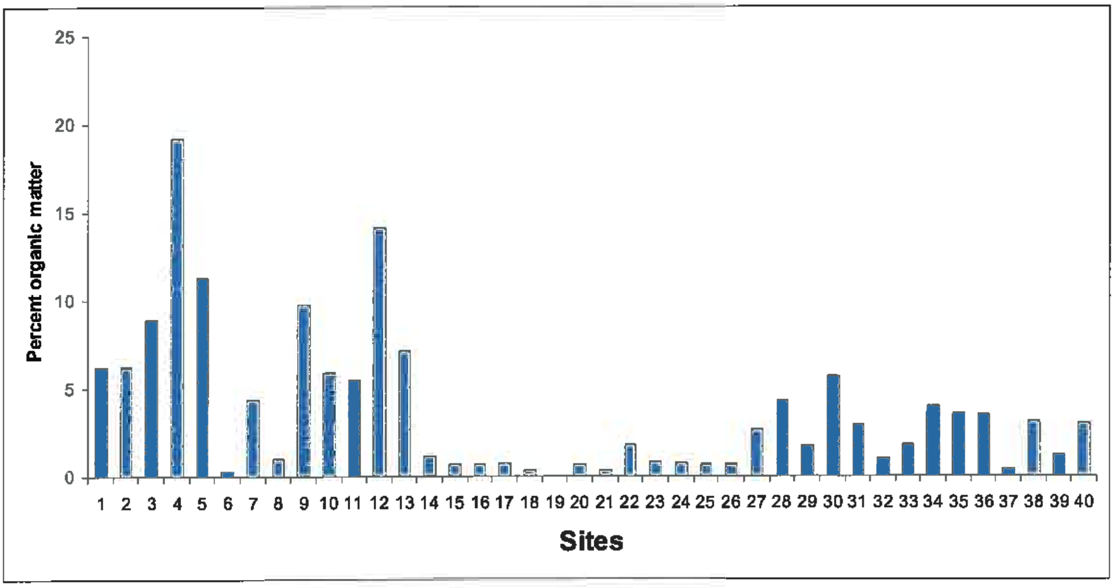

Figure 30. Percentage of organic matter at each sample site.

The values range from 19% (site 4) to just 0.03% (site 19) organic carbon, with an average of 3.7%. Those sites that have a high percentage of sands have a lower percentage of organic carbon, which is typical for sandy soils (Gray 1999). Those sites that have the highest amount of organic matter lie on Fernbird Flat, corresponding to high mud and silt content (see figure 29). Those sites with a moderate level of organic matter (sites 27, 28, 30, 34, 35, 36, 38 and 40), also correspond to a sites with a high mud content and are situated between mean and low tide.

The correlation between the percentage of muds and organic carbon is high ($r=0.74$ $\alpha=0.05$), which is not unusual. These areas are either highly productive, the soil containing nutrients and water for greater plant growth or, the fine organic matter is settling out of the water column in low velocity areas where mud also tends to be deposited. Rivers in New Zealand can transport large amounts of organic carbon (Scott et al. 2004), although river transport cannot be the only source of organic carbon as the R^2 value is 0.54. This value determines if changes in the mud content cause changes in the organic carbon content, and this only happens in 54% of the sites sampled. Hence onsite consumption or production is occurring to alter river transported organic matter. Alternatively there could be a local anthropogenic source augmenting the percentage of organic matter, however further research would be needed to identify any such source.

In a description of New Zealand soils, Landcare Research reports this study area at only 2% total carbon (Landcare Research 2008). A low value of 2% correlates with the organic carbon values obtained here for sandy soils. The Foxton dunes are mainly composed of quartz and feldspar (Kasper-Zubillaga and Dickinson 2001) which yield soils of low productivity and organic carbon content (Gray 1999). The Landcare study probably did not sample the estuarine sites, as they are not classified as soils, hence they did not record the higher values that are obtained here.

There is also the possibility that the high percentage concentration of organic carbon found on the point bar has an anthropogenic source. Untreated sewage or other organic refuse would increase organic carbon content in the environment. However, the results here are not indicative of a anthropogenic input of organic matter.

5.3 Carbonate component

The percentage of carbonate was determined by reaction with 10% Hydrochloric acid. The sites contained, on average 7.9% carbonate with values ranging from 4.2% (Site 21) to 18.9% (site 4) (Figure 31). As with the concentration of organic matter, the highest concentrations of carbonate are found in areas typified by a silts and clays. Carbonate is equally correlated with organic matter ($r = 0.85$ $\alpha = 0.05$) and mud content ($r=0.83$ $\alpha = 0.05$). The most likely source of carbonate is decayed shells, hence there is probably a higher mollusc population in muddy organic rich areas.

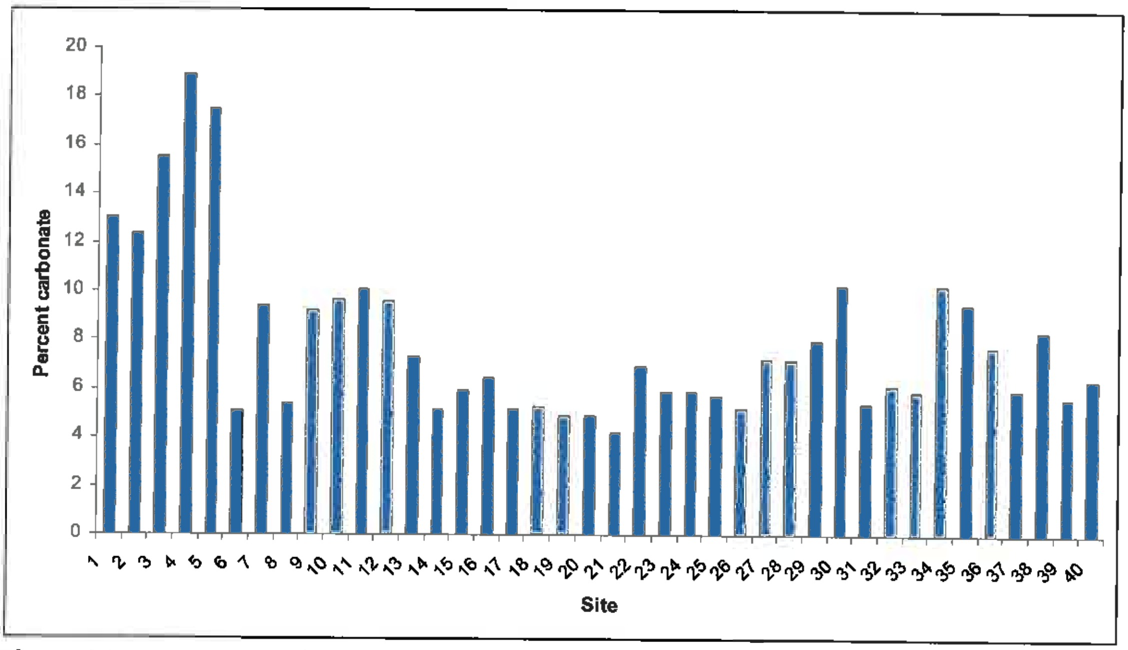

Figure 31. Percentage of carbonate at each sample site.

5.4 Metal concentration

Metal samples were collected at the locations identified in figures 20 and 21. Once subsampled via coning and quartering, samples were wet sieved to <250 micron and the fine fraction kept for analysis. Only the fine fraction is analysed due to the affinity metals have for the fine fraction; meaning a higher metal concentration is found in clays and silts(deGroot 1995) and this fraction also best represents metal availability (Arakel 1995). Samples were digested using 1mol HNO_3, a weak digest was used as this gives the best indication of the concentration of bioavailable metals (Forstner and Wittmann 1979), and is also the methodology recommended in the Australian and New Zealand Environment Conservation Council (ANZECC) interim sediment quality guidelines (ANZECC and ARMANZ 2000). Analysis of total metals would give a result which included forms (silicates, and natural detritus) that are chemically inert and not bioavailble (Batley 1987). Samples were analysed on an Agilent 7500 Series ICPMS at Victoria University of Wellington.

The median concentration of the metals analysed is shown in figure 32. Cobalt, nickel, lead and copper are below 10ppm (2.86, 4.44, 8.45 and 4.47 ppm, respectively). Arsenic, tin and mercury are lower than 2ppm (1.17, 0.167 and 0.014 ppm, respectively) and zinc has a comparatively higher concentration of 23.8ppm. These concentrations are low, and lie well below the interim sediment quality guidelines for problem metals (table 4). Table 5 shows the concentrations obtained at each site, and all values are at least an order of magnitude below the guideline 'low' value.

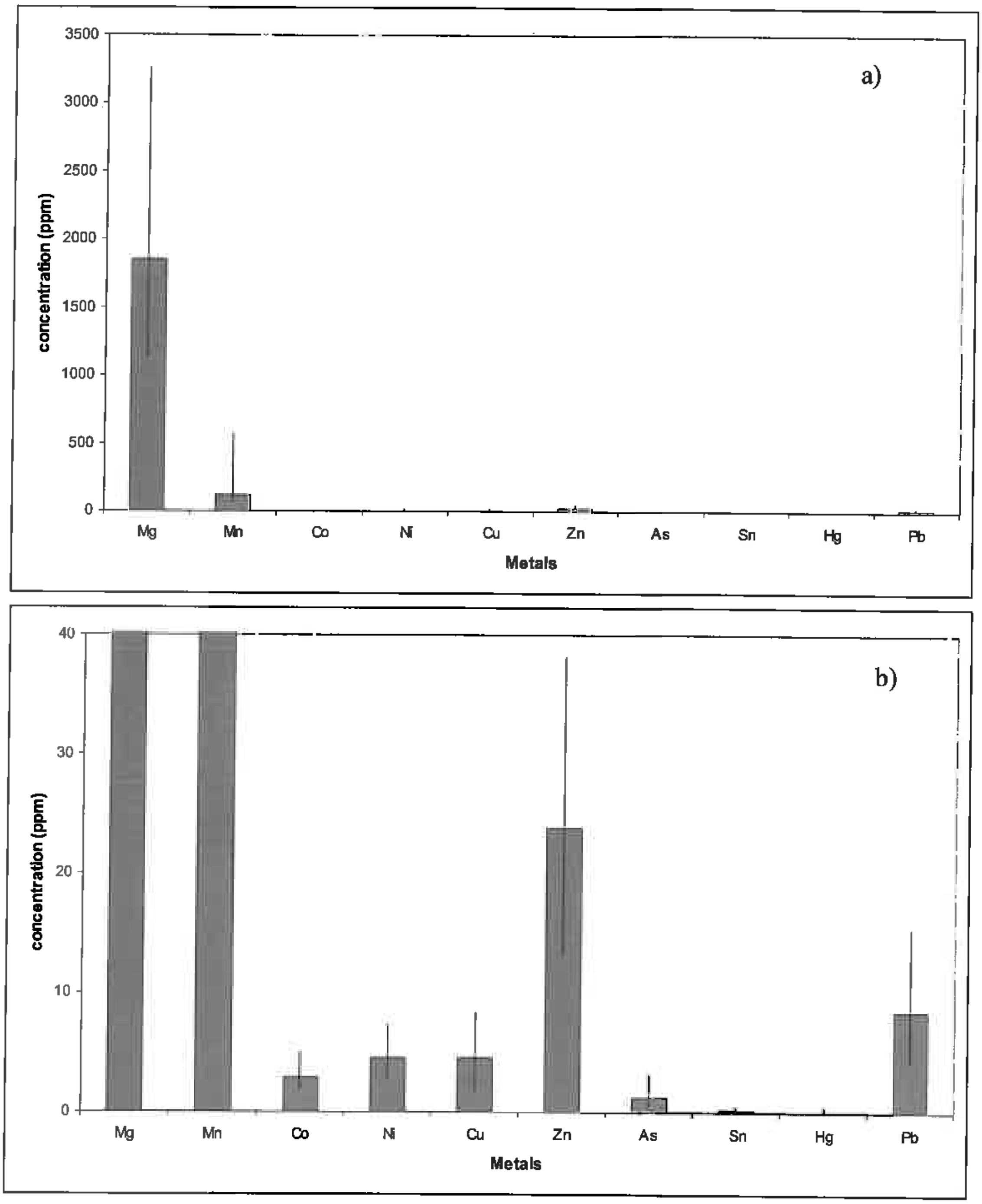

Figure 32. Median concentration of metals detected in study area. Error bars denote maximum and minimum concentrations detected across all sites. a) and b) are the same graph with different concentration scales. Mg = magnesium, Mn = manganese, Co= cobalt, Ni = nickle, Zn = zinc, As = arsenic, Sn= Tin, Hg = mercury, Pb = lead.

Table 4. Australian and New Zealand interim sediment quality guidelines for the concentrations of major metal pollutants. Concentrations found in sediments above the ISCG max indicate sever pollution, those between the min and max concentrations are of concern. Concentrations below the ISCG min are considered not harmful to the environment (ANZECC and ARMANZ 2000).

Metal	**ISCG min (ppm)**	**ISCG max (ppm)**
Cu	65	270
Pb	50	220
Hg	0.15	1
Zn	200	410
As	20	70

Table 5. Concentration of metals at sites analysed. Values are in ppm (μg of metal per g of sediment). * indicates sample was below detection limit. Sample 34 was replicated for precision.

Sample	Metal concentration									
	Mg	Mn	Co	Ni	Cu	Zn	As	Sn	Hg	Pb
1	2710	368	4.91	7.21	6.78	31.53	0.88	0.17	*	11.69
3	3252	563	4.78	7.21	8.33	38.14	1.63	0.21	0.00	15.33
5	2508	448	4.26	6.15	6.15	33.97	1.39	0.31	0.01	12.50
7	1768	70	1.98	4.38	4.85	20.58	0.85	0.07	0.05	8.45
9	1627	135	2.28	4.03	3.97	18.99	0.82	0.07	0.03	7.56
13	1315	104	2.00	3.10	2.04	13.18	0.48	0.08	0.00	4.30
22	1869	147	2.68	4.28	4.47	24.51	1.24	0.25	0.07	9.60
23	1809	78	2.43	3.57	2.79	16.73	0.62	0.14	*	5.50
24	1682	94	1.96	2.83	2.06	14.67	0.68	0.12	*	5.30
25	1570	139	2.41	3.49	2.74	15.94	0.85	0.15	0.00	5.42
27	2800	110	3.82	6.92	7.57	29.65	2.21	0.32	0.08	9.21
28	1118	69	1.80	2.84	1.69	14.99	0.39	0.07	*	5.14
29	1749	117	2.93	4.44	4.32	23.85	1.17	0.19	0.01	8.27
30	2591	128	3.32	6.87	7.12	32.69	1.43	0.27	0.08	11.70
33	1483	63	2.45	3.74	3.18	15.92	1.31	0.16	0.01	4.87
34	2655	104	3.85	6.65	6.34	32.12	2.77	0.28	0.09	9.55
34	2638	105	4.00	6.62	6.25	28.44	2.98	0.28	0.39	8.58
35	2611	109	4.15	6.71	7.02	28.43	2.72	0.21	0.10	8.84
39	1852	103	2.86	4.46	4.25	21.42	1.09	0.15	0.03	7.10

The magnesium concentrations presented here are two orders of magnitude higher than the other metals analysed, with a median value of 1852ppm. This is not surprising as magnesium is the second most abundant cation in seawater, second only to calcium. Magnesium can also be sourced from calcites (Rao 1996), hence the high value could be sourced from the carbonate component. On first inspection the concentration of manganese also appears enhanced, with a median value across sites of 109ppm. The average global concentration of manganese in sea water ranges from 0.4- 10ppm (Howe 2004), well below the concentration obtained here. However, the concentrations of metals in sediments is usually an order of magnitude greater than the overlying water column (Arakel 1995). In addition the concentration of manganese in anoxic environments increases to 500-1500ppm (Howe 2004). Thus the high concentration found here is indicative only of the anoxic nature of estuarine muds, and the inclusion of manganese in pyrite compounds typical of estuarine muds.

Sample 34 was replicated to determine internal consistency. The values obtained (table 5, figure 33) give equivalent concentrations for each metal analysed. Any variations in concentrations is representative of analysing different sub samples.

Across the sites sampled, Site 3 returns the highest concentration for most of the metals analysed. Magnesium, manganese, copper, zinc, and lead all peak in concentration at this location (figure 33). The nearby Site 1 records the highest concentrations of nickel and cobalt, with site 3 close to this concentration (figure 33). It appears that the highest concentration of metals occur along the inward end of the point bar. This could be a function of receiving urban runoff from Foxton via the Foxton loop, and the lower flushing effect due to the lower flow compared to the Manawatu. Alternatively, it could simply be a function of grain size, as metals are found at higher concentrations in clays and silts (Forstner and Wittmann 1979), and this area is wholly composed of the finer fractions (figure 29).

Sample sites located along the edge of the Manawatu channel that are comprised of a greater percentage of muds (figure 26) also have enhanced concentrations of some metals (figure 33). Site 27, 30, 34 and 35 all have higher readings of magnesium, cobalt, nickel copper zinc and tin. However, these values do not necessarily represent anthropogenic enhancement, as they are very low values and below the guidelines. They are only higher relative to the very low values obtained at the other sites. These sites simply indicate the influence finer grained sediments have on metal concentration.

Without a background concentration for the metals analysed, it is difficult to determine if there has been anthropogenic enrichment to the catchment. The lowest concentrations are recorded at Site 28, (figure 33), however this is also a function of grain size, as site 28 is comprised of coarser sediments than the others analysed (figure 26). Although these values cannot determine if metal concentrations have increased, they proveide a baseline to compare with future monitoring programmes.

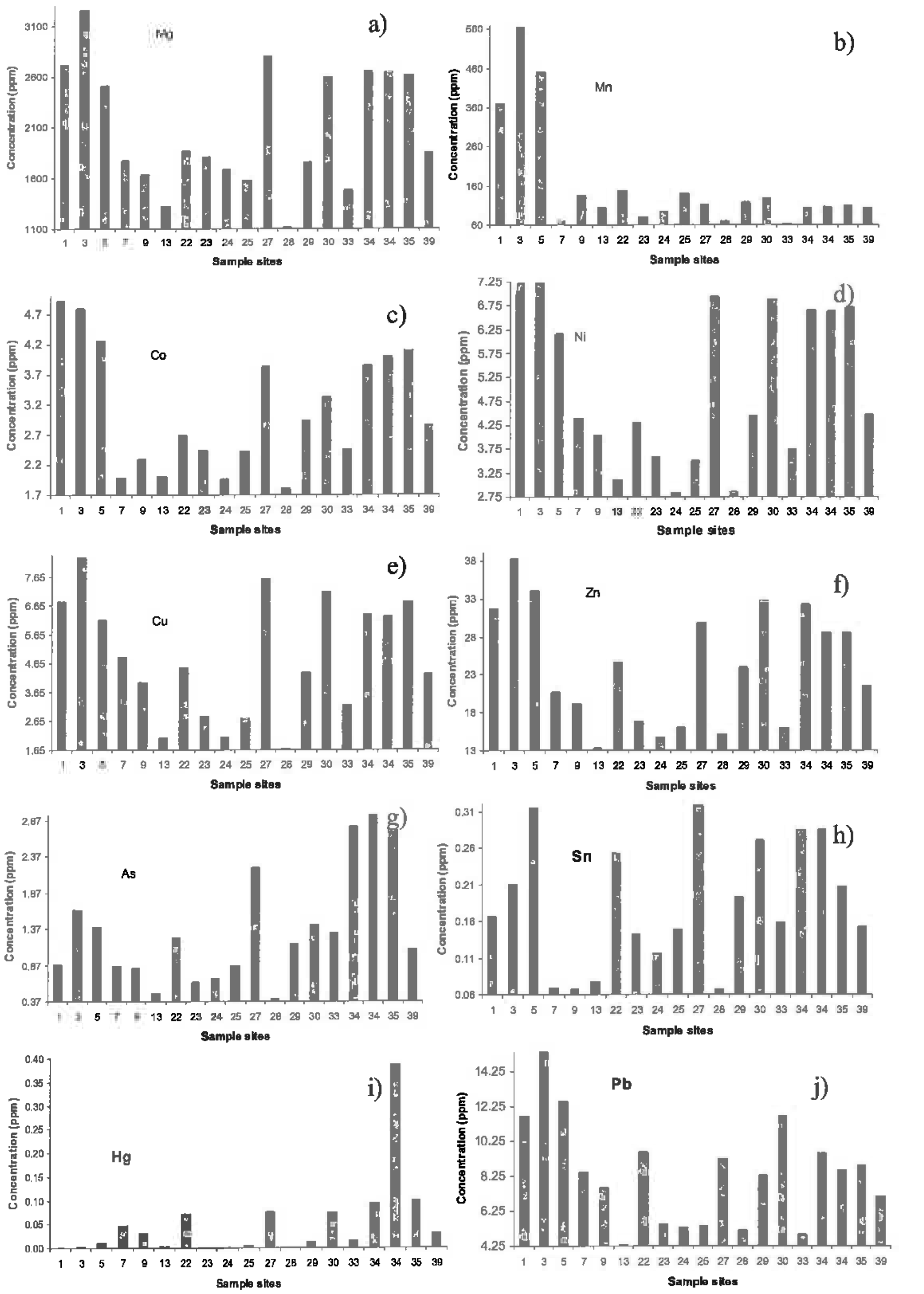

Figure 33. Metal concentrations in ppm at sites analysed. a) Mg = manganese. 95% Confidence interval (CI) = 3.9; b) Mn = manganese. 95% CI 0.6; c) Co = cobalt. 95% CI 0.006; d) Ni = nickel. 95% CI 0.008; e) Cu = copper. 95% CI 0.009; f) Zn = zinc. 95% CI 0.04; g) As = arsenic. 95% CI 0.0034; h) Sn = tin. 95% CI 0.00067; i) Hg = mercury 95% CI 0.00045; j) Pb = lead. 95% CI 0.017.

6. Overview

From the results collected, a general picture of the estuary morphology and the affect of tidal, wind and fluvial forces can be developed. At the estuary mouth, dune sand is moved by wind in a south easterly direction as indicated in figure 34. Once sand reaches the far side of the dunes, it comes under the influence of fluvial and tidal forces. Grain size analysis (see figure 26) indicates that these forces push sand above the mean tide mark (figure 34). Over time this process has developed and extended the sand spit adjacent to the channel in an easterly direction (figure 18). If sand continues to be supplied to this area (behind the dunes, base of arrows; figure 34) the spit may potentially extend and further restrict flow into the marsh area (hatched area figure 34). However, a threshold may also be reached where the daily tidal flow and spit extension are equal and whereby openness to the marsh area is maintained.

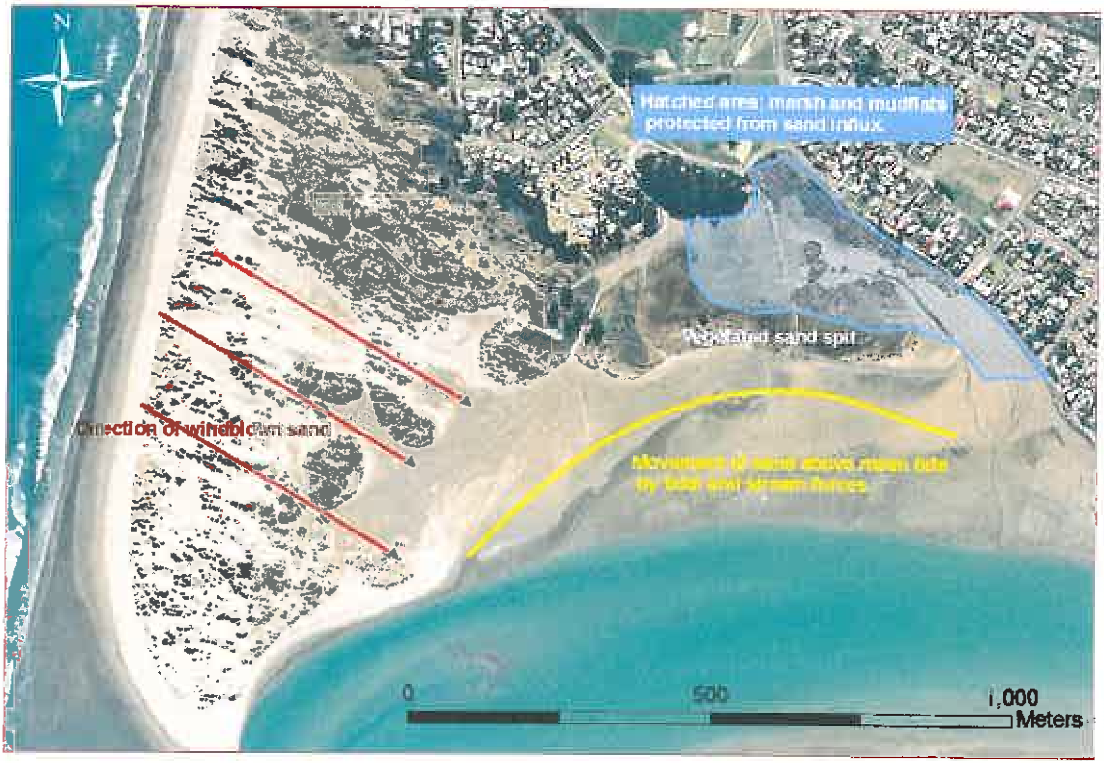

Figure 34. Generalised interpretation of sediment movement and marsh formation.

The marsh area highlighted in figure 34 was singled out as an important feeding area for wading and migratory birds which may be adversely affected by dune encroachment. With the stabilising of the dunes discussed in section 4.6, the potential for wind to move sand into this area (in the direction indicated in figure 34) is greatly reduced. The vegetated sand spit to the south of the marsh prevents strong fluvial currents from initiating erosion of muds or depositing sand. This marsh area is therefore protected from sand influx. This protection has allowed muds deposited on the ebb tide to accumulate, and over time these have been colonised by marsh vegetation (see figure 8). Prior to the spit development this area was a high energy environment, as evidenced by the coarser grains (fine sand) observed below the mud layer at sample sites in these locations (figure 9).

The future development of the marsh and mudflat area could follow a number of routes. Mud could continue to accumulate and with the establishment and stablisiation of vegetation accretion could reach above MHW, essentially becoming a low lying flood plain. However, accumulation rates of muds are extremely slow, around 2.3-3.3 mm/year under anthropogenically influenced conditions (Goff and Chagué-Goff 1999). The rate of change from mudflats to saltmarsh would be slowed due to the current rate of sea level rise, which is on average 1.8mm/ year (Kennedy 2008). However, there are significant tidal forces in this location, which could prevent accumulation and also erode tidal channels in the mudflats (such as depicted in figure 11), thus maintaining flow above a critical level. Erosion will be hindered by vegetation and by the iron concretion layer that has formed in some areas of the marsh (figure 10). If the sand spit extends and blocks the mudflat/ marsh area (as discussed above) the location may become a fresh or brackish swamp.

At the point bar (Fernbird Flat) the force shaping the morphology of this location is primarily fluvial. As the former channels migrated south west they left signature deposits across this point bar as they shifted. In the field, curved ridges of sand were observed that aligned with the present day river course. These appear to represent the former river channels indicated in Figure 15. Surfical grain size analysis is typical of a point bar, with coarser deposits occurring adjacent to the main flow, and grain size decreasing away from the channel (figure 29).

7. Recommendations

The following recommendations are presented in order to preserve and maintain the mars area.

- Maintain the stability of the dunes. Dunes that are vegetated should be maintained and unvegetated ones planted out. Even though marram grass (*Ammophila arenaria*) is not a native species, removal of marram would significantly mobilise sand. Hence if Marram grass is to be removed, a significant area of dune must first be effectively stabilised with native vegetation prior to removal. Access to the relatively unvegetated dunes on the northernside of the estuary mouth should be further restricted to prevent erosion. Activities here should be of minimal impact, such as pedestrian access.
- Allow woody debris to accumulate. Restricting collection of woody debris on the northern bank will slow sand movement and slow the further extension of the vegetated sand spit. Woody debris is also beneficial as it has been shown to increase fish numbers (House and Boehne 1986) and biodiversity (Dudley and Anderson 1982) and also provides a refuge from predation in aquatic habitats (Everett and Ruiz 1993)
- Continue to monitor for any sedimentary change.

7.1 Monitoring program

To assess changes occurring in the Manawatu estuary, it is recommended that the following monitoring program be implemented:

- Collection of surfical sediment samples from the locations demonstrated in Figure 35 (GPS coordinates shown in table 6). Analysis for changes in grain size should be undertaken, to determine if depositional environments are altering. Sites 37 and 38 are of particular interest in order to monitor if the sand spit continues to extend.
- Erosion staking of the lee side of dunes in the partially vegetated dunes would allow quantification of the amount of dune movement. This would provide information on the rate of change in the dunes and also would help to determine the potential influx of sand.
- Continued collection of aerial photos for analysis of geomorphological change. Collection should be annual, with photos also collected post flood events to observe the impact of increased discharge.
- Sediment traps or plates to monitor influx of sediment. This would allow for the monitoring of the rate of accumulation in the marsh area.
- Continued analysis of metal concentrations within the sediment. Site 3 (see figure 20) and Site 34 (figure 35) should be revisited at least every 5 years, as these sites contained the highest concentration of metals.
- Water quality monitoring should be established for basic parameters (such as turbidity, salinity, pH, DO) and also for metal concentrations. Samples should be located within the main channel near the marsh, the drain entering the marsh (near sample 39, figure 21) and on Foxton loop just upstream of where it rejoins the Manawatu River. This should establish any point sources of pollution, and the

relationship between the concentration of pollutants in the sediment and the water column. Once water quality monitoring is established, return times to sediment sites for analysis of metal concentration can be reduced if water quality remains stable.

Table 6. GPS coordinates of recommended monitoring sites for surfical sediments.

Site	latitude	longitude	NZ datum	
			Eastings	Nortings
29	-40.466494	175.2266978	2698799	6079794
30	-40.4672574	175.22673	2698799	6079709
32	-40.4686137	175.2269805	2698817	6079558
33	-40.4693535	175.2271495	2698829	6079475
34	-40.4705131	175.2272865	2698837	6079346
37	-40.468564	175.2294236	2699024	6079558
38	-40.4678436	175.2294402	2699027	6079638

Figure 35. Map of recommended sediment sample sites for monitoring program

8. Appendix

Site	latitude	longitude	NZ datum	
			Eastings	Nortings
1	-40.4898786	175.245831	2700354	6077157
2	-40.4894846	175.2470639	2700460	6077198
3	-40.4897377	175.2488352	2700609	6077166
4	-40.4896412	175.2508297	2700779	6077172
5	-40.4897971	175.2530189	2700964	6077150
6	-40.4917886	175.2344806	2699387	6076969
7	-40.4916097	175.2354669	2699471	6076987
8	-40.4913387	175.2368468	2699589	6077014
9	-40.4907875	175.2389318	2699767	6077071
10	-40.4907133	175.2401579	2699871	6077076
11	-40.4904852	175.2415834	2699993	6077099
12	-40.4903274	175.2429504	2700109	6077113
13	-40.4721333	175.2395207	2699870	6079140
14	-40.4692653	175.2213664	2698339	6079497
15	-40.4696297	175.2215874	2698357	6079456
16	-40.4702374	175.2219356	2698385	6079388
17	-40.4714071	175.2224814	2698428	6079257
18	-40.4715181	175.2163656	2697909	6079258
19	-40.4714633	175.2149195	2697786	6079267
20	-40.470779	175.2190701	2698140	6079334
21	-40.4694054	175.2229763	2698475	6079478
22	-40.466448	175.2245454	2698616	6079830
23	-40.4667286	175.2246097	2698621	6079772
24	-40.4671766	175.224696	2698627	6079722
25	-40.4676725	175.2247874	2698633	6079667
26	-40.4682289	175.2248807	2698640	6079605
27	-40.4700013	175.2253458	2698674	6079407
28	-40.4659872	175.2266231	2698794	6079850
29	-40.466494	175.2266978	2698799	6079794
30	-40.4672574	175.22673	2698799	6079709
31	-40.4681092	175.2268845	2698810	6079614
32	-40.4686137	175.2269805	2698817	6079558
33	-40.4693535	175.2271495	2698829	6079475
34	-40.4705131	175.2272865	2698837	6079346
35	-40.4700409	175.2290184	2698985	6079395
36	-40.4693044	175.2291573	2698999	6079476
37	-40.468564	175.2294236	2699024	6079558
38	-40.4678436	175.2294402	2699027	6079638
39	-40.4662395	175.2256841	2698714	6079824
40	-40.4719825	175.2351796	2699502	6079166

Sites underlined were analysed for metal concentration in addition to the other analyses.

Sample	% organic	% carbonate
1	6.18	13.03
2	6.23	12.37
3	8.87	15.49
4	19.19	18.92
5	11.30	17.44
6	0.23	5.03
7	4.39	9.41
8	0.99	5.37
9	9.77	9.18
10	5.88	9.64
11	5.50	10.04
12	14.08	9.55
13	7.10	7.31
14	1.15	5.15
15	0.65	5.91
16	0.62	6.43
17	0.69	5.10
18	0.31	5.28
19	0.03	4.86
20	0.61	4.89
21	0.32	4.19
22	1.76	6.88
23	0.81	5.88
24	0.72	5.85
25	0.62	5.70
26	0.67	5.21
27	2.69	7.25
28	4.30	7.16
29	1.68	7.96
30	5.67	10.23
31	2.93	5.35
32	0.99	6.10
33	1.77	5.88
34	3.96	10.23
35	3.54	9.45
36	3.47	7.71
37	0.44	5.91
38	3.09	8.35
39	1.20	5.60
40	2.96	6.34

Sample	Grain size composition (phi) % by weight													
	-2.00	-1.50	-1.00	-0.50	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	<4
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.14	0.31	0.97	2.03	95.93
2	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.06	0.29	1.01	1.68	1.27	0.74	94.62
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
6	0.00	0.00	0.00	0.03	0.07	0.18	0.64	1.99	15.09	42.54	31.30	4.64	1.30	2.42
7	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.04	0.26	0.86	2.57	3.51	4.48	87.82
8	0.00	0.00	0.00	0.06	0.09	0.09	0.18	1.51	12.71	39.46	35.53	6.53	1.23	2.74
9	0.00	0.00	0.07	0.00	0.00	0.15	0.28	0.41	2.44	7.13	18.87	7.47	2.32	59.41
10	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.89	4.26	8.19	2.27	1.06	82.16
11	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.14	0.19	0.47	98.66
12	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.06	0.13	0.45	0.61	0.93	89.01
13	0.00	0.00	0.00	0.00	0.00	0.41	0.86	0.32	2.14	16.68	38.21	9.88	3.72	23.92
14	0.00	0.07	0.00	0.03	0.01	0.04	0.07	0.14	0.71	10.32	65.20	15.50	3.12	4.88
15	0.00	0.00	0.00	0.02	0.02	0.02	0.04	0.11	0.70	9.64	66.02	16.40	2.79	4.40
16	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.08	0.49	7.91	69.57	17.31	1.81	2.96
17	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.11	1.05	14.86	66.35	10.04	1.02	6.65
18	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.17	15.10	74.67	9.08	0.63	0.59
19	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	2.05	28.59	59.78	8.46	0.93	0.32
20	0.00	0.00	0.00	0.01	0.01	0.03	0.03	0.07	0.35	6.17	62.54	14.84	4.37	11.75
21	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.07	0.50	8.75	75.82	12.48	1.21	1.35
22	0.00	0.00	0.00	0.03	0.03	0.06	0.09	0.15	0.84	9.91	44.69	7.96	1.20	35.11
23	0.59	0.00	0.00	0.03	0.03	0.03	0.06	0.10	0.73	12.82	54.57	9.38	1.42	20.42
24	0.00	0.00	0.00	0.02	0.04	0.02	0.12	0.28	1.06	10.75	55.87	13.23	1.58	17.25
25	0.00	0.00	0.04	0.00	0.01	0.01	0.02	0.06	0.47	9.33	51.20	11.65	2.15	25.17
26	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.05	0.45	9.87	72.67	14.77	1.72	0.32
27	0.00	0.00	0.00	0.00	0.03	0.03	0.05	0.08	0.45	5.25	18.45	6.19	5.53	63.56
28	0.00	0.00	0.07	0.00	0.00	0.13	0.25	0.24	2.54	12.07	47.74	14.45	2.60	19.42
29	0.00	0.00	0.02	0.01	0.02	0.05	0.06	0.15	1.61	10.59	30.76	6.57	1.04	49.28
30	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.10	0.37	1.08	0.34	0.12	97.10

	31	0.00	0.00	0.00	0.00	0.00	0.10	0.21	0.14	2.08	14.81	62.76	11.36	1.27	4.77
	32	0.00	0.00	0.00	0.00	0.02	0.03	0.19	0.68	1.89	10.87	64.71	15.18	2.76	3.82
	33	0.00	0.00	0.00	0.00	0.00	0.08	0.10	0.08	1.16	16.19	42.14	5.95	1.50	32.73
	34	0.00	0.00	0.00	0.00	0.04	0.06	0.08	0.08	0.22	1.05	7.80	10.36	7.20	72.99
	35	0.00	0.00	0.00	0.00	0.00	0.10	0.12	0.06	0.18	0.62	5.50	7.97	6.41	79.13
	36	0.00	0.00	0.00	0.00	0.00	0.21	0.75	1.01	1.90	3.71	13.75	6.34	5.41	66.69
	37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	11.67	69.57	15.80	1.84	0.83
	38	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.12	1.75	2.76	4.77	3.19	4.22	82.88
	39	0.00	0.00	0.05	0.07	0.09	0.11	0.15	0.41	2.57	13.47	32.29	5.88	0.66	44.34
	40	0.00	0.00	0.00	0.01	0.02	0.02	0.07	0.36	2.46	7.11	17.35	10.53	10.98	51.12

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