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TE RAUHITANGA TAIAO

Regional Discharges Project

Sediment Quality Data Analysis

June 2004

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Prepared for

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Executive Summary

This report conducts an exploratory data analysis of the information collected under the Regional Discharges Project (RDP). It does this by examining the relationships between measured contaminants, and using these relationships to examine regional information.

The relationships explored include those between:
copper (Cu), zinc (Zn), lead (Pb) and polycyclic aromatic hydrocarbons (PAH)
the concentrations of the weak acid extracted <63 µm fraction and the strong acid digested <500 µm fraction for each heavy metal.

These relationships, along with concentrations of contaminants, were used to examine the distribution and overall contaminant status of each of the major water bodies (Waitemata, Manukau, Tamaki) as a whole.

The Mid Waitemata Harbour is widely contaminated. Clear contamination gradients extend out from settling zones into adjacent outer zones. As with the other water bodies, the concentrations of the 3 major contaminants Zn, Pb and Cu are reasonably correlated, which suggests that they are distributed in a similar manner – probably by resuspension and dispersal of fine particulates. There is a slight variation in Zn/Pb ratios and this may be due to reducing Pb levels following the removal of Pb from petrol. Contamination is probably carried into the wider outer zone such that Zn levels now exceed 100 mg/kg over much of the harbour.

The concentrations of heavy metals in the mud fraction are low in the Manukau Harbour, with the exception of Mangere Inlet. Concentrations are much lower than in the Waitemata, even than those parts of the Waitemata that are predominantly rural (e.g., Upper Waitemata Harbour). Concentrations in the Puherehere inlet, Clarks Beach etc are probably close to background. The reasons for the low concentrations are a mixture of the factors:

- Large harbour
- Small urban catchments
- Recent urban development
- Relatively large rural catchments

Concentrations in the most contaminated area in the Manukau, Mangere Inlet, may be partly due to historical industrial pollution, which while buried by recent sedimentation, will be continued to be mixed upwards to some extent into the surface layers by bioturbation. Another possibility is that it is partly due to high backgrounds, but this requires further investigation. The rate of change of concentrations at the 2 SoE sites (Cemetery and Anns Creek) is slow, which is consistent with the small catchment/relatively large estuary. It may be that Mangere Inlet is "cleaning up" from levels of gross pollution recorded in the 1980s.

Basically the pattern of contamination in Tamaki Estuary looks simple – there is a clear gradient from the contaminated urbanized headwaters (Middlemore, Pakuranga, Otahuhu, Panmure to the uncontaminated mouth. It appears that the middle reaches are becoming contaminated. The evidence suggests that the outer Tamaki (north of Tahuna Torea) is relatively uncontaminated – i.e., the contamination from the upper estuary is not reaching the outer Tamaki area.

The question was asked whether the results from the weak acid extracted <63 μm sediment fraction for muddy SZ and OZ, correctly classified sites. Of the 50 settling zone and muddy outer zones sites with such data, 11 changed their RDP traffic light status. This demonstrated that although there is a strong correlation between the results from the weak and strong acid extractions, the use of the results from the weak acid extraction of the <63 μm fraction will result in significant mis-assignment of some sites to RDP categories.

The minimum concentrations found in the RDP sediment surveys and the results from shallow cores suggest background concentrations for Cu ~ 5, Zn ~ 35 Pb ~ 5 mg/kg. Results from some estuaries (Mangere Inlet, Purewa and Panmure Basin) suggest that background levels may be higher in specific areas.

1 Brief: Underpinning RDP Technology

The Regional Discharges Project (RDP) has now collected a large body of data that has been appraised regionally to identify contaminant status and future monitoring strategies (ARC 2003), produce State of the Environment (SoE) information (DSL 2003a) and examine the fate of contaminants on the open coast (DSL 2003b). There is a wealth of other information in this data that can be used to uncover regional differences and similarities, backgrounds, relationships between contaminants, relationships between mud and whole sediments. This comes about because up to 4 contaminants are measured (3 of these in different ways), there are different degrees of contamination across the region, and TOC and particle size information has also been collected. Also, there is complementary trend information from the ARC LTB Marine Sediment monitoring program.

It is essential to continue to underpin and upgrade the understanding of the RDP technology. Detailed analysis of the RDP database would help this. Outcomes could be a better understanding for interpreting impacts, identifying contamination sources, gaining a deeper understanding of Outer Zone (OZ) contamination, possible simplification of the monitoring strategy, development of Auckland's own sediment quality guidelines, and improved understanding of relationships between Settling Zone (SZ) and OZ contamination and contaminant transport.

This report conducts an exploratory data analysis of the information collected under the RDP. It does this by examining the relationships between measured contaminants.

These relationships, along with concentrations of contaminants, were used to examine the distribution and overall contaminant status of each of the major water bodies (Waitemata, Manukau, Tamaki).

The RDP database is summarized in Appendix 2.

2 Comparison of Concentrations of Contaminants

2.1 The relationship between contaminants in the same sediment size fraction

The concentrations of the contaminants were compared against one another to see how well the concentration of one contaminant predicts the concentration of another. The RDP analysis protocol for the major key contaminants Zn, Cu and Pb, analyses these metals in two ways.

1. A cold, weaker acid extraction on the <63 μm fraction
2. A hot, stronger acid digestion on the <500 μm fraction

The three <63 um fraction replicates from each site are averaged before doing this comparison. PAH are analysed on the <500 μm fraction only. Table 2.1 shows that heavy metal concentrations are reasonably well correlated, but are poorly correlated with PAH concentrations. Possible explanations for the poor metals–PAH correlation include:

- the production and export of PAH from urban catchments is largely independent of the heavy metals (i.e. the major sources of metals and PAH are different)
- the PAH "signal" (mass exported) is very small compared with the metals, and any relationships between sites is masked by variability (analytical, site factors such as particle size)
- variations in historical pollution, which for PAH could be significant at some sites.

Table 2.1. Correlation coefficients for contaminants (n=80 for metals and 50 for PAH in the <500 μm and n=93 < 63 μm correlations)

	(A) 500 μm fraction			(B) 63μm fraction		
	Zn	Pb	PAH	Zn	Pb	PAH
Cu	0.89	0.86	0.05	0.91	0.89	N/A
Zn		0.91	0.31		0.89	N/A
Pb			0.27			N/A

The correlations shown in Table 2.1 indicate that there is a better relationship between metals measured in the <63 μm fraction than in the <500 μm fraction, but the difference is not great.

The relationship between different contaminants can also be explored through the use of ratios. Assuming that the three metals (Cu, Zn, Pb) come from the same source, then the ratios can be used as fingerprints at any one site or a series of sites. This technique is used later in this report to explore processes. The overall ratios are illustrated in Figure 2.1.

Figure 2.1. Zn/Pb and Zn/Cu ratios for the <63 μm fraction.

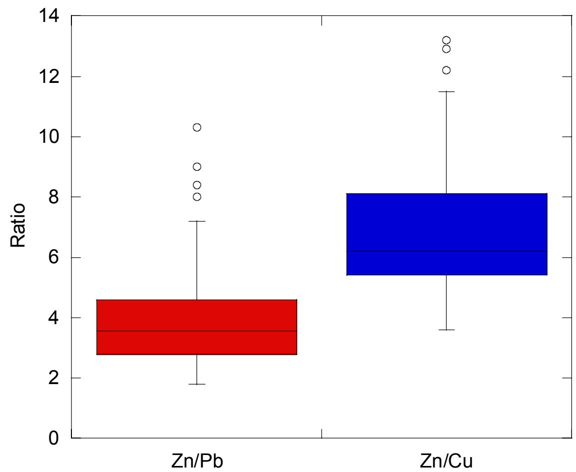
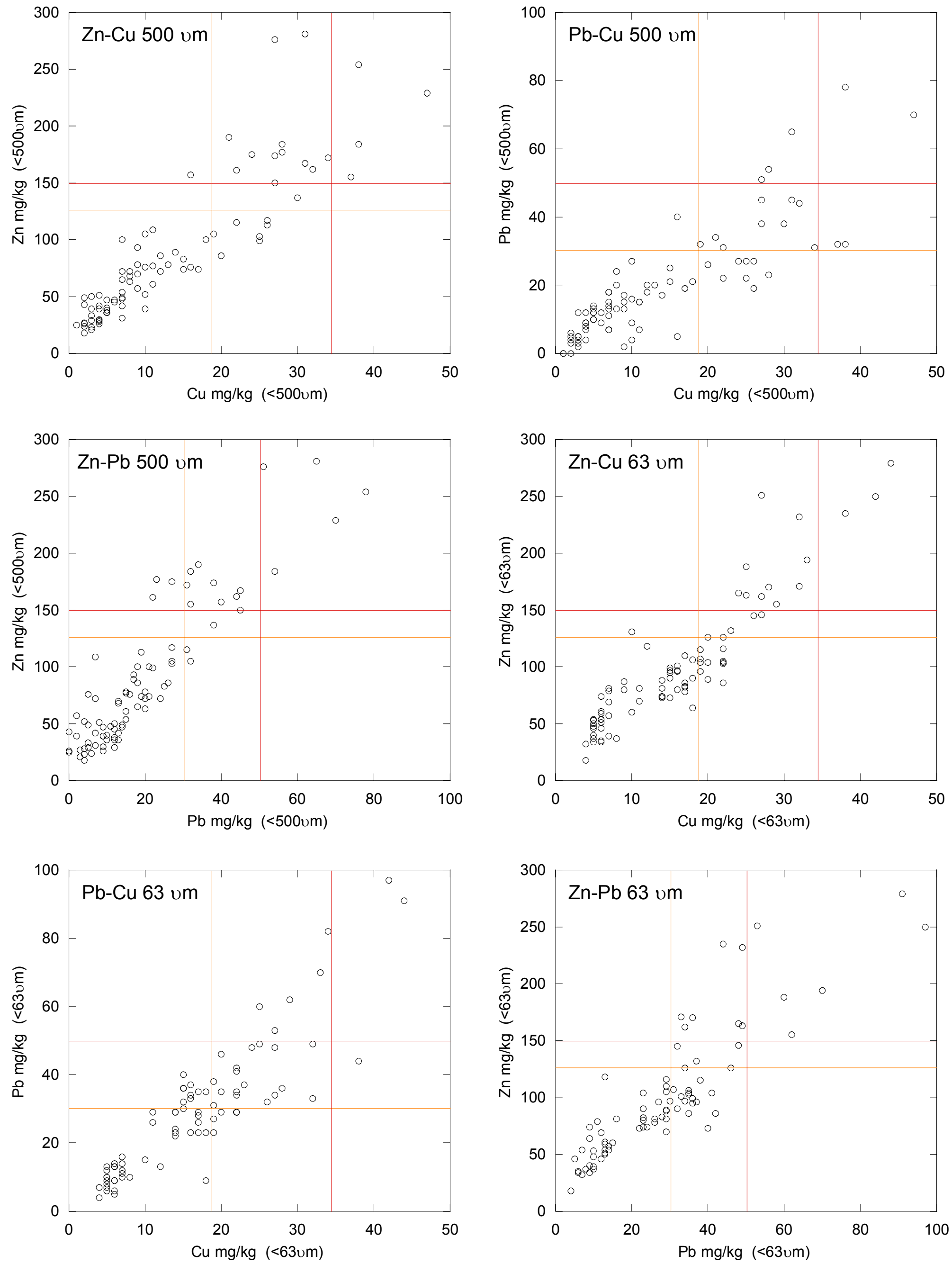


Figure 2.1 Relationships between contaminant concentrations. The amber and red Environmental Response Criteria (ERC) are shown for reference.



2.2 Comparison of <63 μm and <500 μm heavy metal results

The RDP analysis protocol for the major key contaminants Zn, Cu and Pb, analyses these metals in two ways.

1. A cold, weaker acid extraction on the <63 μm fraction
2. A hot, stronger acid digestion on the <500 μm fraction

For Settling Zones, or muddy Outer Zones, results from the hot acid digestion on the <500 μm fraction are compared with Environmental Response Criteria. For Sandy Outer Zones the results from the cold acid extraction on the <63 μm fraction are compared with Environmental Response Criteria (ERC). The rationale for this is described elsewhere (ARC 2003).

2.2.1 The relationship between <500μm and < 63 μm concentrations

The relationship between the same contaminant in the different size fractions illustrates a fair degree of scatter around the 1:1 line (Figure 2.2). One way of exploring this data is to examine the ratios of the concentrations in the <500 μm fraction with that in the <63μm fraction.

The ratios are reasonably correlated between the parameters (Table 2.2). There is a wide spread of ratios (Figure 2.3). Low ratios are associated with outer zones, which is expected from the sediment textural effect, (i.e. sandier OZ sediments have a higher proportion of coarse particles that have relatively low levels of extractable metals in them). High ratios are associated with settling zones, where the sediments have a finer texture (greater proportion of <63 um fraction containing greater levels of metals). If we separate the data into OZ and SZ, then the ratios cover a smaller range (Figure 2.3).

Table 2.2 Ratios of metals in the <500μm to < 63 μm fractions.

	Cu500/Cu63	Zn500/Zn63	Pb500/Pb63
Cu500/Cu63	1	0.77	0.65
Zn500/Zn63	0.77	1	0.89
Pb500/Pb63	0.65	0.89	1

Of the 3 metals, the most accurate ratios are probably for Zn, because many Pb and Cu are often low and close to detection limits, so ratios will be only approximate in these cases.

The wide spread in the ratios means that concentrations of one fraction can only be approximately predicted from the concentration in the other fraction. There appeared to be few geographical differences, and these are discussed below. There were no differences due to the magnitude of the concentrations; for example, higher (or lower) ratios were not found with higher (or lower) concentrations (i.e. the variation in ratios is not a "concentration effect").

Figure 2.2. Plots of concentrations of heavy metals extracted after acid digestion of the <500 µm fraction compared with cold acid extraction of the <63 m fraction. 1:1 ratios are shown as a solid black line.

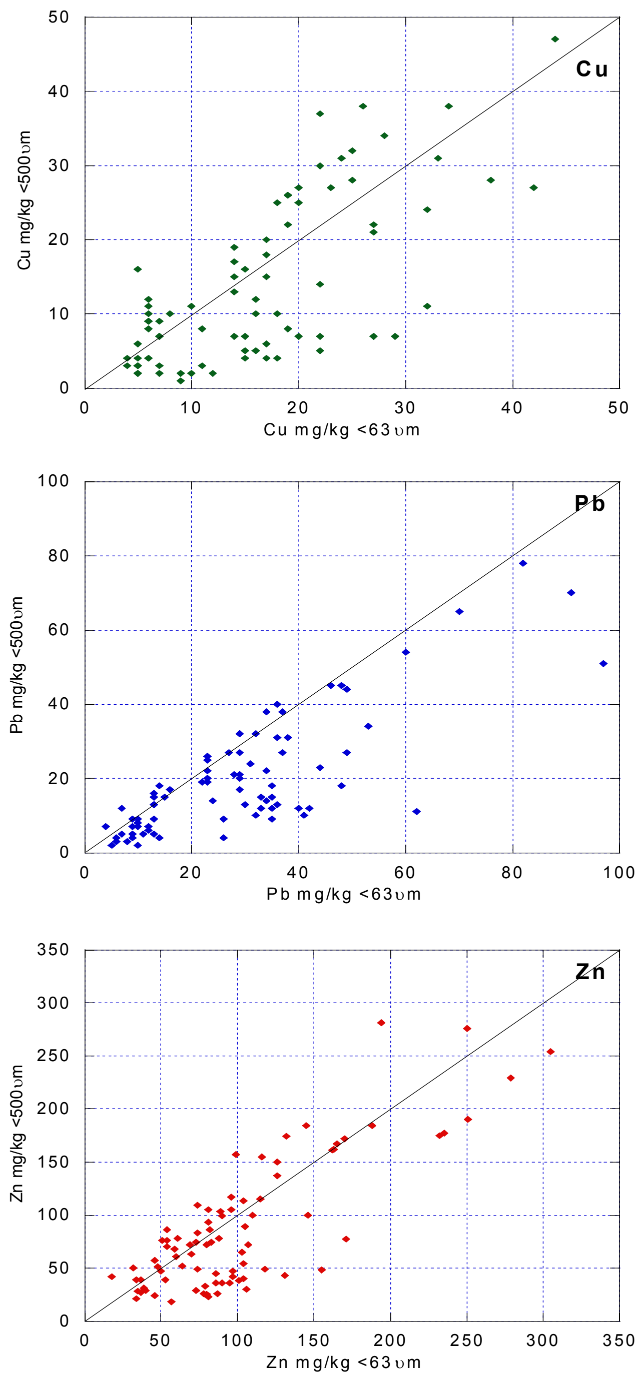
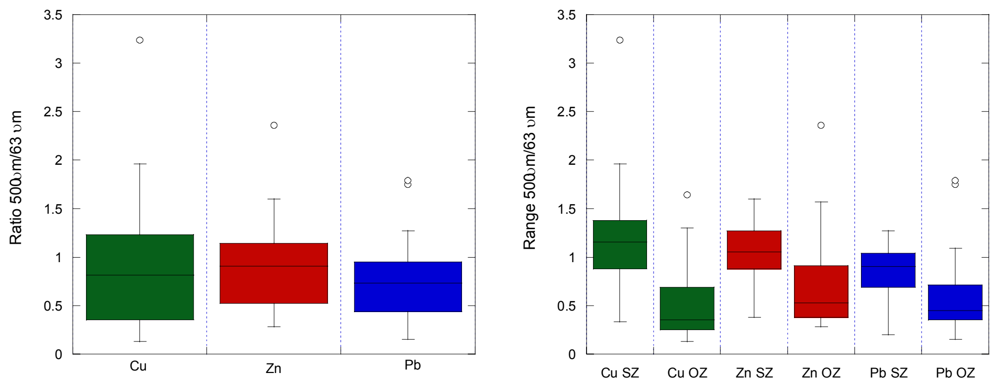


Figure 2.2. Box and whisker plot of ratios of all data.



2.2.2 Comparing metals in the mud fraction from the settling zone with ERC

For Settling Zones, or muddy Outer Zones, results from the hot acid digestion on the <500 μm fraction are compared with Environmental Response Criteria. For sandy Outer Zones the results from the cold acid extraction on the <63 μm fraction are compared with Environmental Response Criteria. Do the results from the cold acid extraction on the <63 μm fraction from both Settling Zones and muddy Outer Zones give similar results (i.e., correctly classify a site according to the traffic lights) as the hot acid digestion on the whole sample?

The ERC were compared with the results from the cold acid extraction on the <63 μm fraction for Settling Zones, and muddy Outer Zones. Mis-assignments to the RDP traffic light category are listed in Table 2.3a; in all, 11 out of 50 sites examined were incorrectly assigned. (Note: Not all outer zones had <500 μm data (most of these were from the Auckland City Council database), so ratios could not be compared within this data.)

Table 2.3a: Changes in RDP categories using the <63μm results for Settling Zones and muddy Outer Zones

Amber-Green	Paremoremo (Cu) Kaipatiki (Cu) Upper Lucas (Cu) Beachaven (Pb)	General drop in Cu in the Upper Waitemata Harbour
Green-Amber	Island (Cu, Pb) Kendalls (Pb)	Kendalls should be an OZ Island Bay sandy – OZ?
Red-Amber	Panmure (Zn) Meadowbank (Purewa) SZ (Zn) Hillcrest (Zn) Anns Creek (Mangere) (Zn) Cemetery (Mangere) (Zn)	Large change Large change Small change, it was barely red. Large change Large change

The comparisons show that there are significant changes if the <63 μm data is substituted for the <500 μm data for settling zones, and using the weak acid extracted mud fraction would result in significant mis-assignments of RDP categories.

One of the reasons for these differences may be in the background concentrations at some sites. Evidence for this comes from Mangere Inlet, where the 2 sites show some large differences in concentrations, with major changes in the RDP category. An earlier study (ARC ASP 1996) found large differences between metals' concentrations from digested sediments compared with weak acid extractions. This appears to be a 'background" geological effect – where the matrix of the mineral particles which make up the sediment has relatively high concentrations of heavy metals. These matrix metals are only partially extracted with weak acid. High backgrounds would be expected if the source of estuarine sediment was dominated by catchment volcanic soils or rocks. Auckland's volcanic soils contain relatively high concentrations of heavy metals compared with the dominant soils derived from sandstones and siltstones (e.g., the Waitemata series) (ARC 1999). It may be that some of the other differences are also due to the difference in background concentrations, notably Panmure Basin and Purewa Estuary.

Nevertheless, this far from clear. An earlier study (Williamson et al 1992) refers to data from cores that suggest background concentrations in Mangere inlet were low. Clearly, the possibility of high background concentrations at some RDP sites warrants further investigation.

Changes in the traffic light category for each individual heavy metal are listed in Table 2.3b-2.3d and reveals some interesting information. (Note: The overall RDP category is determined by the most contaminated metal).

Copper

Significant differences are found in the Upper Waitemata Harbour (Table 2.3b). This is possibly a regional (i.e., UWH) effect where using the mud fraction 'changes' a number of sites from 'amber' (alert mode) to 'green'. This includes Lucas Creek, where concentrations are rapidly increasing with the urbanization and an "amber" warning signal seems highly appropriate.

Other significant differences are found for Island and Kendalls. Kendalls should be an OZ and has been mis-assigned in the Gap II report (ARC 2003). Large differences are found for Mangere Inlet, and this is possibly due to a background effect as described above.

Table 2.3b Changes in Cu Traffic Light status when <63 um fraction data used. The numbers are concentrations of Cu (mg/kg). The column 'Does change result in change in RDP category?' identifies if Cu concentrations determine the RDP traffic light category. Red >34, amber 20–34, green <20 mg/kg.

Site	Type	<500	<63	Does change result in change in RDP category?
Upper Whau	SZ	38	34	No
Paremoremo	SZ	25	18	Yes
Upper Lucas	SZ	26	19	Yes
Kaipatiki	SZ	22	19	Yes
Kendalls	OZ	5	20	Yes
Island	SZ	7	20	Yes
Mangere Cemetery	OZ	37	22	Yes
Anns Creek	OZ	38	26	Yes

Zinc

Significant differences in Zn concentrations between the two methods were observed. at 5 sites. Differences are quite large at 4 sites, with Zn levels 'changing' from Red to Amber or to Green. As already discussed above, this may be partly a background effect.

Table 2.3c: Changes in Zn Traffic Light status when <63 um fraction data used. The numbers are concentrations of Zn (mg/kg). The column 'Does change result in change in RDP category?' identifies if Zn concentrations determine the RDP traffic light category. Red >150, amber 125–150, green <125 mg/kg.

Site	Type	<500	<63	Does change result in change in RDP category?
Panmure	SZ	174	132	Yes
Meadowbank (Purewa)	SZ	157	99	No
Hillcrest, Shoal Bay	SZ	150	126	Yes
Mangere Cemetery	OZ	155	116	No
Anns Creek	OZ	184	145	Yes

Lead (Pb)

Significant differences are found in Beachhaven, Island and Kendalls. Kendalls should be categorized as an outer zone, so this change is appropriate and will be discussed later.

Pb levels are often higher in the <63µm weak acid extraction (Table 2.3d). Given that Pb is often poorly extracted with weak acid compared with hot acid digestion, it suggests that Pb is concentrated on the smaller particles – more than the other metals. This is also shown in Figure 2.2.

Table 2.3d: Changes in Pb Traffic Light status when <63 um fraction data used. The numbers are concentrations of Pb (mg/kg).. The column 'Does change result in change in RDP category?' identifies if Pb concentrations determine the RDP traffic light category. Red >50, amber 30–50, green <30 mg/kg.

Site		<500	<63	Does change result in change in RDP category?
Upper Tamaki (Middlemore)	SZ	27	49	No
Pakuranga Upper	SZ	23	44	No
Beachhaven	SZ	32	29	Yes
Island	SZ	15	35	Yes
Kendalls	OZ	10	41	Yes
Mangere Cemetery	OZ	32	29	No
Pakuranga Lower	SZ	22	34	No
Deep Creek, Torbay	SZ	34	53	No

3 Background Concentrations

Concentrations of metals and PAH at sites remote from urban areas or having a relatively small proportion of urban catchment are listed in Table 3.1.

Table 3.1: Concentrations (metals in mg/kg, PAH in g/kg) in the predominantly rural Auckland estuaries from the ARC RDP study.

Location	Type	Cu	Zn	Pb	Cu	Zn	Pb	PAH
		<500 m fraction			<63 m fraction			
Okura	OZ	10	39	9	8	37	10	
Okura West	SZ	7	31	7	7	39	10	16
Orewa South	SZ	4	28	4	6	35	6	
Orewa	OZ	3	21	3	5	34	6	
Rangitopuni	SZ	20	86	26	17	82	23	
Rangitopuni	SZ	15	83	25	14	74	23	
Brighams	SZ	17	74	19	14	73	22	
Rarawaru	SZ	12	72	21	16	80	23	
Puherehere Upper	OZ	2	18	3	7	57	14	
Puherehere Middle	OZ	2	24	5	5	46	12	
Airport LT site	OZ	3	29	5	5	40	9	
Puhinui	OZ	4	51	7	5	48	10	23
Big Muddy	SZ	9	57	2	6	46	5	41
Cape Horn LT Site	OZ	3	23	4	11	81	26	21
Clarks Beach LT Site	OZ	2	26	3	5	37	8	
Te Matuku, Waiheke	SZ	3	39	2	5	53	10	15

Some of these rural sites seem either contaminated or have higher background levels. In particular, the Upper Waitemata Harbour sites (Rangitopuni, Brighams and Rarawaru) and the Cape Horn site in Manukau Harbour. The former are being investigated in another study (Green et al. 2004), which has found relatively high levels of Zn and Cu in the sediments coming down the Rangitopuni River – but the reason for these high levels is unknown (see later). The Cape Horn site is known to be contaminated – possibly from a contamination gradient down the northern shores of the Manukau (see later).

Taking this into account, a cursory look at Table 3.1 would suggest that minimum concentrations for the mud fraction (<63 μm) would be as listed in Table 3.2.

Table 3.2 Minimum concentrations (mg/kg) Auckland surface sediments for 2 M HCl-extracted mud (<63 m) fraction.

Metal	Concentration
Cu	5
Pb	5
Zn	35

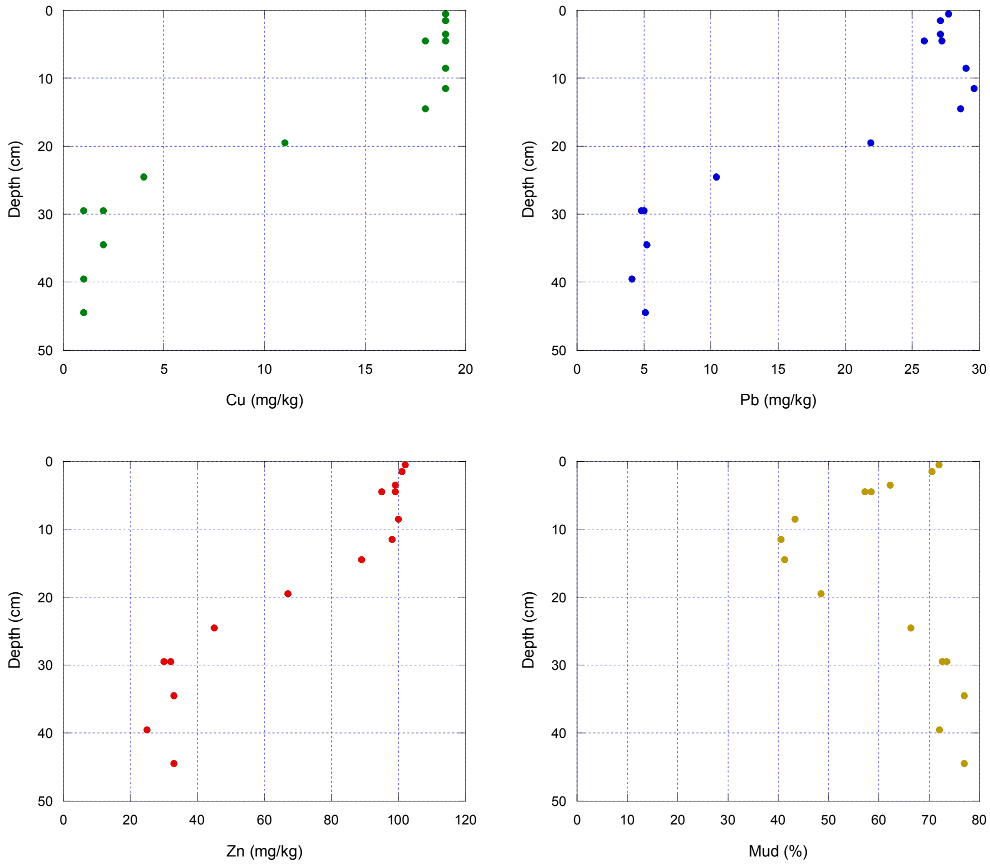
Other evidence for background concentrations comes from shallow cores taken in the Lucas estuary, described elsewhere (Green et al. 2004) and cores taken in the Middle Waitemata Harbour (Appendix 1). Figure 3.1, taken from Green et al 2004, suggests background levels consistent with the minimum levels described above (Table 3.3). The Mid Waitemata cores returned slightly higher levels (see discussion in Appendix 1), but there was no guarantee that cores had reached background (pre-European) sediments. The difference between the minimum levels for Cu (Table 3.1) and those found in cores may be due to the immobilization of Cu in the deeper core sediments due to digenetic processes (i.e., chemical reactions in the sediments that convert the copper into more immobile, and hence non-extractable, forms).

Table 3.3 Minimum concentrations (mg/kg) from Waitemata Harbour cores for 2 M HCl-extracted mud fraction.

Metal	Lucas Background	Mid-Waitemata
Cu	2	1.5
Pb	5	8.5
Zn	32	37

Overall, Tables 3.2 and 3.3 suggest general background concentrations of Cu ~ 5, Zn ~ 35 and Pb ~ 5 mg/kg. Background concentrations in the whole sediment fraction (i.e., <500 μm) would depend on the relative amounts of sand and mud.

Figure 3.1 Concentration profiles of Zn, Cu and Pb (mg/kg, <63 m fraction) in the top 45 cm of sediment from the lower mudflat in Lucas Creek, Auckland.



4 Analysis of Waitemata Harbour Data

4.1 The Mid Waitemata Harbour

A map of the Zn values in the Middle Waitemata Harbour reveals some clear patterns (Figure 4.1): (Note: The filled circle shows the RDP category as determined by RDP protocols – SZ use < 500 m data, OZ use < 63 m data), but the numbers are the concentrations in the< 63 m fraction. The mud fraction is used for regional comparison because it does not suffer from the textural effect on concentrations).

- There are high concentrations in many of the settling zones (Henderson, Whau, Motions, Meola, Purewa, Hillcrest (Shoal Bay).

- There are high Zn concentrations in the Outer Zone around Motions, Meola, Coxes Bay – exceeding the Zn Red ERC.

- There are moderate-high concentrations in Hobson Bay, exceeding the amber ERC in one case.

- There are moderate concentrations near the mouth of other major catchments – Waterview, Henderson and Whau. More modest concentrations would be expected because the estuary arms here are probably pretty efficient traps for contaminants.

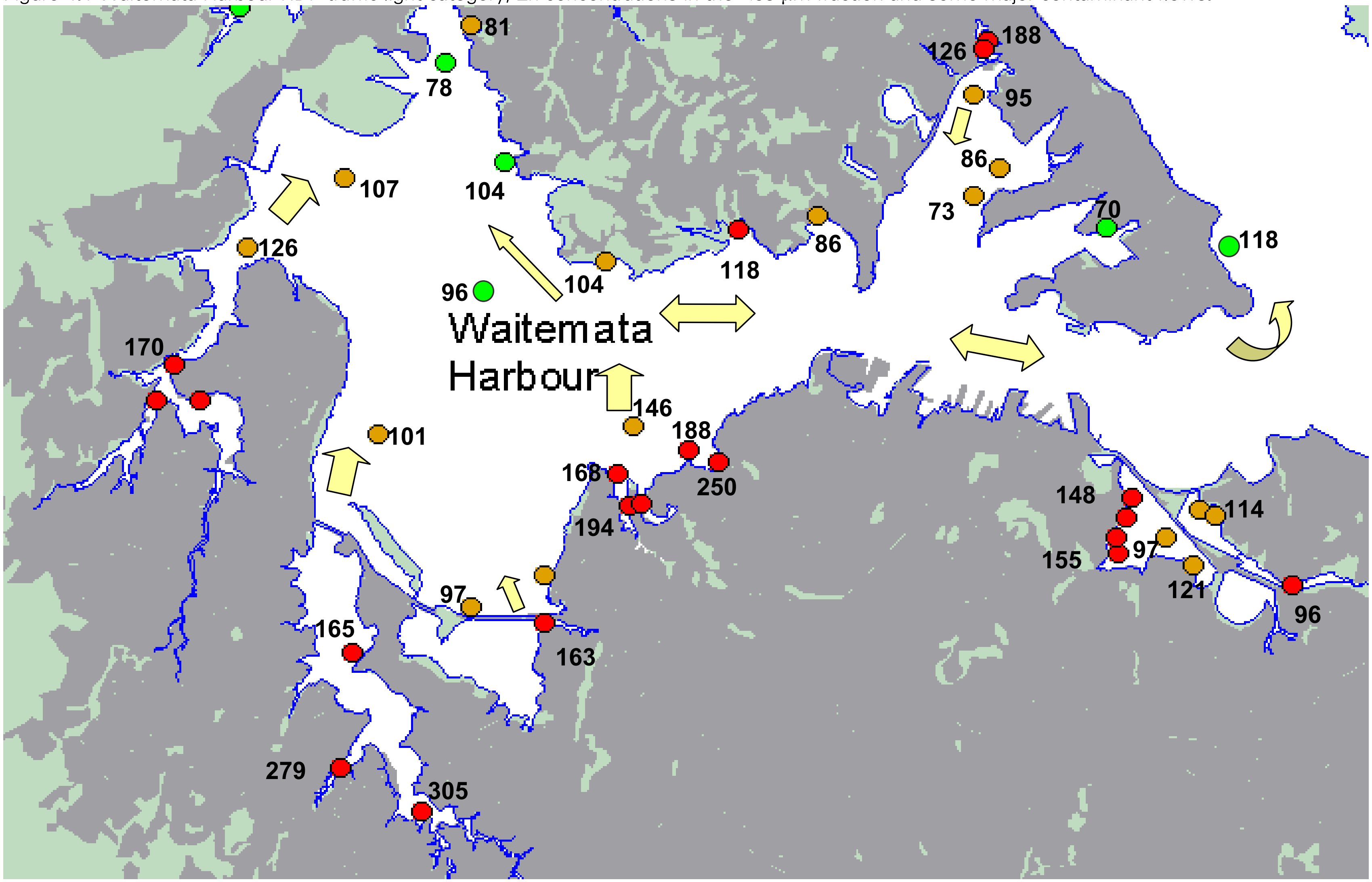
- There seems to be a gradient across the harbour and along the northern shore. For example Kendalls Bay has a very small urban catchment, yet levels are reasonably high. The middle Waitemata subtidal site has similar concentrations. This extends up to Island Bay, but the gradient falls off by Hobsonville and Waiarohia. This gradient may reflect major currents in the harbour, because the main channel sweeps close to Kendalls Bay. At low tide, storm-carried contaminants are delivered to the main channel from Motion, Meola, Coxes, Waterview and possibly Whau River. Currents would also carry contaminants discharged from the CBD up and down harbour.

- No such gradient extends into Shoal Bay. There is a gradient out of Shoal Bay, which probably due to the largest input located in the head of the Bay from Hillcrest. Overall the loads into Shoal Bay are relatively small, so concentrations are not high, and it will have relatively little effect on the Mid-Waitemata Harbour as a whole.

- Cheltenham is unusually high given its small catchment. The LTB site has continued to increase slowly throughout the LTB program. This may also reflect this dispersal pattern for Zn by strong tidal currents in the mainstream of the harbour that deliver contaminants through the mouth and into the backwater enclosed by Cheltenham beach. The Pb levels however are low, which argues against simple translocation of fine sediments from the middle harbour. (PAH are unusually high at Cheltenham also)

> Overall, the Mid Waitemata Harbour is widely contaminated. Clear contamination gradients extend out from settling zones into adjacent outer zones. This can be seen at Henderson, Whau Creek, Waterview and the Motions/Meola embayments. Contamination is probably carried into the wider outer zone such that Zn levels now exceed 100 mg/kg over much of the harbour.

Figure 4.1 Waitemata Harbour RDP traffic light category, Zn concentrations in the <63 μm fraction and some major contaminant flows.



Lead and Cu levels reinforce the picture formed by the Zn concentrations. In addition:

- Concentrations frequently exceed amber ERC for Pb for many of these sites. There seems to be a trend in Zn/Pb ratios in the harbour, with the value of the ratio decreasing (i.e., Pb concentrations increasing more than Zn concentrations) with distance from the source. This trend is confirmed in the Tamaki estuary, which has a much stronger and clearer contamination gradient (see Section 5). There are a number of explanations for this. One is that Zn/Pb ratios are higher near the source because of effect of the removal of Pb from petrol. This effect is not so pronounced at greater distances from the source because levels more closely reflect historical use of Pb in petrol.

- The ratios of Zn to Cu are reasonably consistent around the harbour. This suggests that Zn and Cu are being dispersed at the same rate and in the same manner. This is an interesting result because Zn is generally regarded as being more soluble and mobile than Cu, so the constant ratio suggest that the primary mechanism for dispersal in resuspension/dispersal rather than solubilsation/dispersal.

Overall the Zn/Pb and Zn/Cu ratios are not very different, apart from the slight gradient in Zn/Pb ratios described above. This suggests that Zn, Cu and Pb are distributed through the same mechanism – probably resuspension and dispersal.

Recent State of the Environment analysis (Diffuse Sources 2003) suggested the key ARC LTB sites were increasing at the rates given in Table 4.1. The monitoring confirms the rapidly increasing levels of contamination in the settling zones and sheltered outer zones of the harbour. However, as yet, no clear rate can be determined for the Meola Reef site, which is representative of the wider harbour.

Table 4.1. Definitive trends at ARC LTB sites in the Waitemata Harbour, summarised from Diffuse Sources (2003). Colours = RDP categories., except Blue signifies the time to reach the Probable Effects Level (PEL).

Estuary Type	Catchment type	Estuary Status Present day	Time to next category (y)
Settling Zone	New urban area	Lucas	5
	New urban area	Paremoremo	6
Outer Zone, tidal creek	New urban area	Hellyers	3
Settling Zone	Old urban area	Upper Whau	1
	Old urban area	Wairau (Whau)	2
	Old urban area	Motions	0
	Old urban area	Oakley	17
Outer Zone, tidal creek	Old urban area	Lower Whau	8
Outer Zone, sandy embayment	Old urban area	Hobson	11
	Old urban area	Meola Reef	No significant change

4.2 Hobson Bay

Hobson Bay shows small but distinct gradients away from the main Newmarket stream source. This is an important result, because Hobson Bay is an enclosed OZ, where there should be a reasonable degree of resuspension by waves and redistribution to other parts of the bay. If this were an efficient process, then we would expect similar concentrations in the mud fraction across the bay. The fact that this hasn't occurred suggests that concentration gradients are maintained in estuaries such as Hobson Bay.

Pb levels are relatively high (Zn/Pb ratios are amongst the lowest in the RDP dataset – typically 2.1-2.5 c.f. Figure 2.2. There may be another source of Pb or the Pb levels are more representative of historical levels of Pb. It may be that Pb has been effectively trapped in the Hobson Bay.

Figure 4.2 Hobson Bay RDP traffic light category and Zn concentrations in the <63 µm fraction.

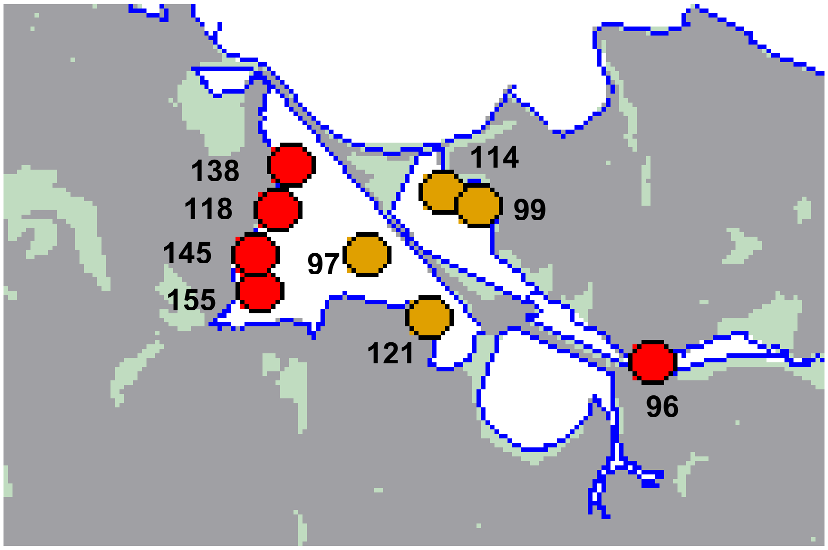
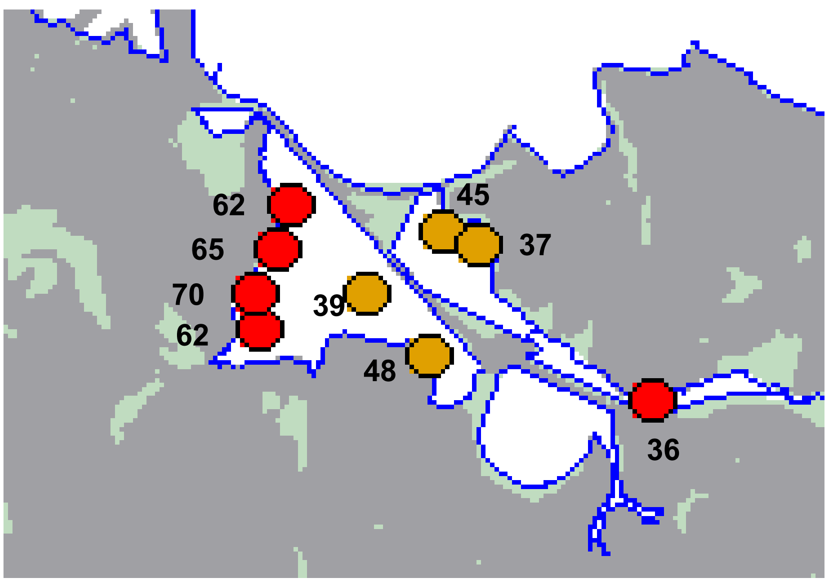


Figure 4.3 Hobson Bay RDP traffic light category and Pb concentrations in the <63 µm fraction.



4.3 Upper Waitemata Harbour

The catchment of the Upper Waitemata Harbour is predominantly rural, and the concentrations should reflect this. In fact, Zn levels are somewhat elevated, not only in the urbanizing estuaries, but in the rural estuaries as well. Zn levels (Figure 4.4) can be contrasted with other 'background' or predominantly rural sites. We have good information from Orewa, Okura and rural parts of the Manukau (Table 3.1).

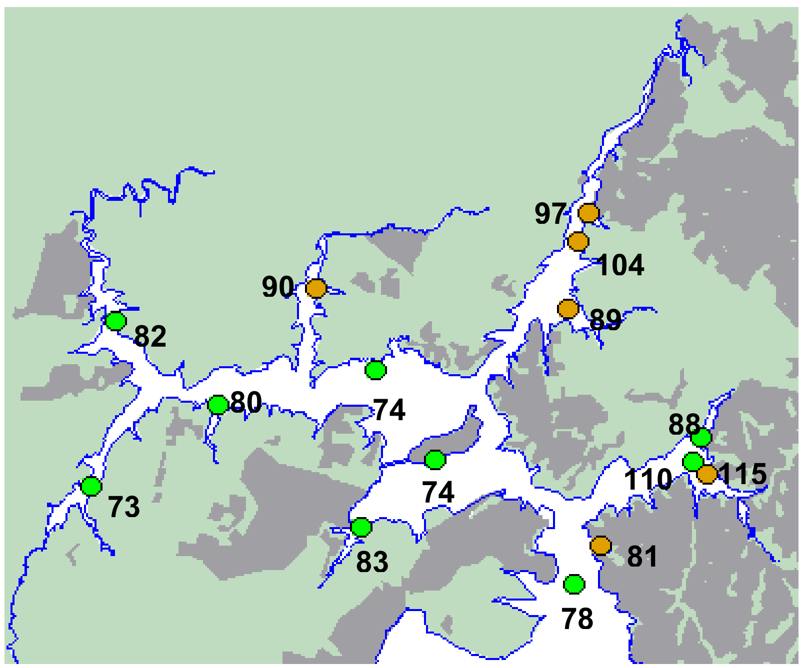
The interesting things to note when examining the data for the UWH in Figure 4.4 and contrasting it to Table 3.1 are:

1. The other sites (particularly Orewa, Okura) approach the "background" Zn concentrations of 35 mg/kg. This is nowhere observed in the UWH.

2. There are relatively high levels in the Rangitopuni arm, despite the relatively large sediments inputs from this large rural catchment.

   The concentrations of Cu and Pb are also elevated in the UWH compared with other sites with rural catchments (Okura, Orewa, Manukau); it is not just Zn that is elevated throughout the UWH. The distribution of contaminants and the predicted increases in concentrations are discussed elsewhere (Green et al 2004).

Figure 4.4 The RDP traffic light status and Zn concentrations (mg/kg, <63 m fraction) of RDP sites for the Upper Waitemata Harbour.



5 Manukau Harbour

Basically, the concentrations of heavy metals in the mud fraction are low in the Manukau Harbour, with the exception of Mangere Inlet (Figure 5.1). (Note: The filled circle shows the RDP category as determined by RDP protocols – SZ use < 500 m data, OZ use < 63 m data), but the numbers are the concentrations in the < 63 m fraction. The mud fraction is used for regional comparison because it does not suffer from the textural effect on concentrations. Some sites lack < 63 m data).

Concentrations are much lower than in the Waitemata, even than those parts of the Waitemata that are predominantly rural (e.g., Upper Waitemata Harbour). Concentrations in the Puherehere inlet, Clarks Beach etc are probably close to background.

The reason for the low concentrations are a mixture of the factors:

- Large harbour
- Small urban catchments
- Recent urban development
- Relatively large rural catchments

They are slightly elevated at Hillsborough and Cape Horn – and this is probably the reflection of the concentration gradient along the northern shore from Mangere Inlet, which has been described earlier (Williamson et al 1992).

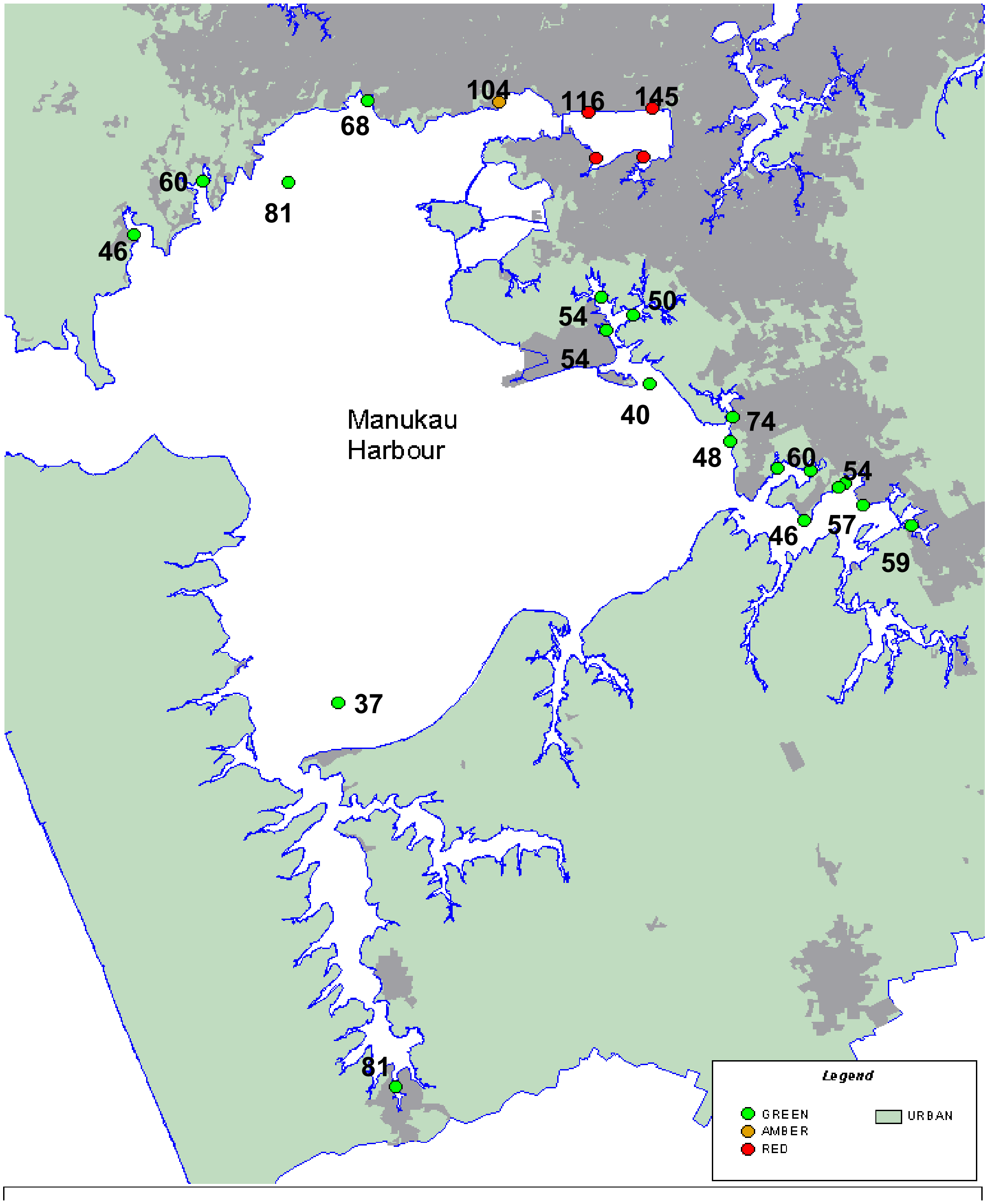
Recent State of the Environment analysis (Diffuse Sources 2003) suggested the key ARC LTB sites were increasing at the following rates (Table 5.1), and these rates are in line with the generally low concentrations described above.

Table 5.1 ARC LTB sites for Manukau Harbour. Years for that site to reach the next ERC indicated by colour, note: Blue = PEL.

Estuary	Present status	Years for Zn to reach ERC or PEL
Big Muddy		100
Puhinui		10
Puherehere		25
Pukaki		15
Mangere, Cemetery		20
Mangere, Anns Creek		No significant change, may be decreasing

The most contaminated sites in the Manukau, in Mangere Inlet, are not deteriorating quickly. The rate of change at the 2 SoE sites (Cemetery and Anns Creek) is slow (Table 5.1). This is consistent with the small catchment/relatively large estuary. The red Zn levels may be partly due to a high background effect or to historical pollution. The evidence for high backgrounds is equivocal, as described earlier, but historical pollution will still be having some effect despite being buried by recent sediments. This is because bioturbation is continually mixing sediment up through the sediment column. It may be that Mangere Inlet is "cleaning up" from levels of gross pollution recorded in the 1980s (Glasby et al 1988, Williamson et al 1992).

Figure 5.1. RDP traffic light status and Zn concentrations in the <63 µm fraction at sites in the Manukau Harbour.



6 Tamaki Estuary

Basically the pattern of contamination looks really simple – there is a clear gradient from the contaminated urbanized headwaters (Middlemore, Pakuranga, Otahuhu, Panmure to the uncontaminated mouth. It appears that the middle reaches (Figure 6.1) are becoming contaminated.). (Note: The filled circle shows the RDP category as determined by RDP protocols – SZ use < 500 m data, OZ use < 63 m data), but the numbers are the concentrations in the < 63 m fraction. The mud fraction is used for regional comparison because it does not suffer from the textural effect on concentrations. Some sites lack < 63 m data).

The evidence suggests that the outer Tamaki (north of Tahuna Torea) is relatively uncontaminated – i.e., the contamination from the upper estuary is not reaching the outer Tamaki area, and/or is being diluted and dispersed)

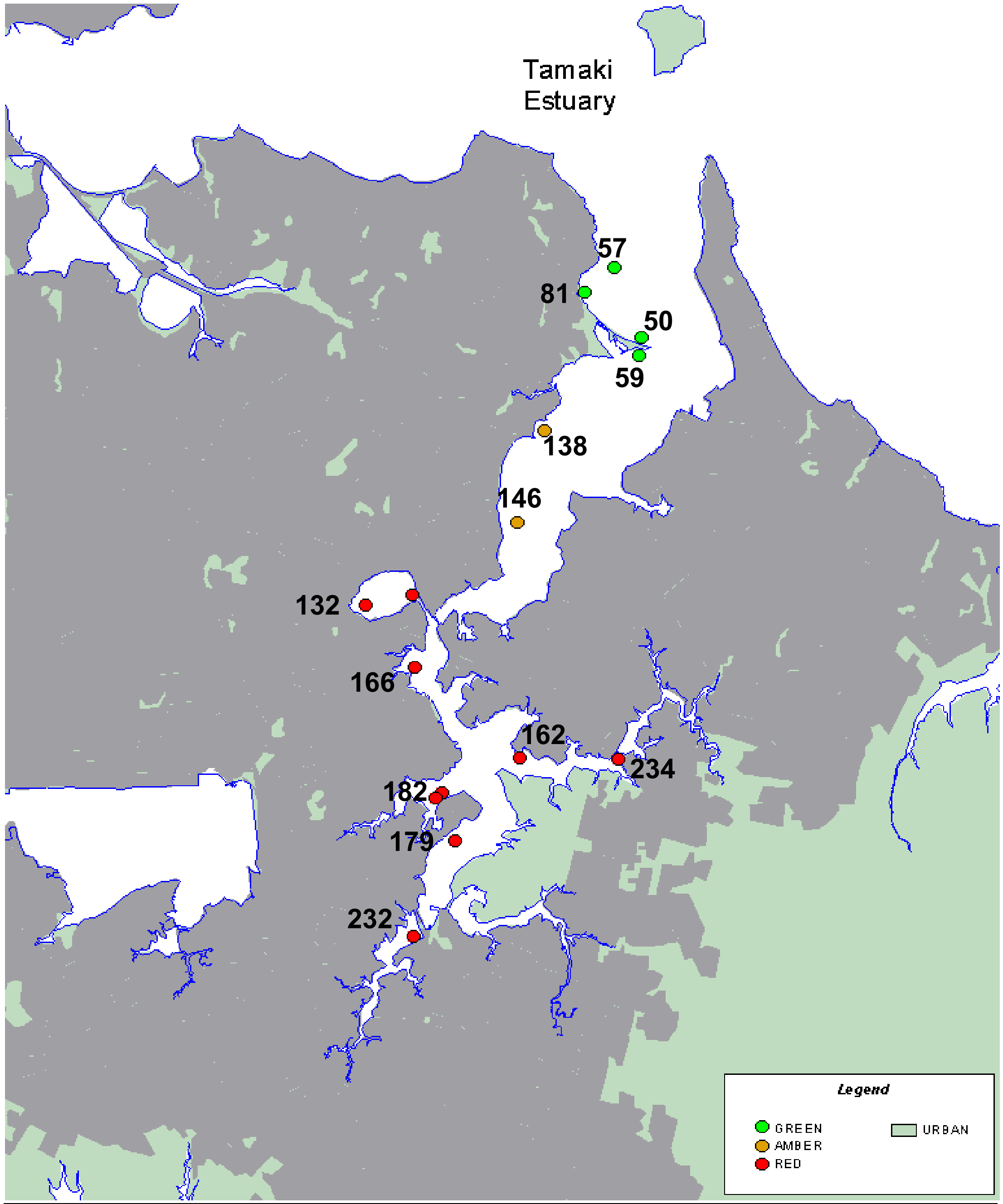
Tamaki Estuary shows the gradient in Zn/Pb ratios, which decrease with distance from the headwater estuaries. The Zn/Cu ratios show no such pattern, however. This suggests that Zn and Cu are being dispersed at the same rate and by the same processes, as described in section 4.1. The decrease in Zn/Pb ratios down the estuary may reflect the removal of Pb from petrol.

Recent State of the Environment analysis (Diffuse Sources 2003) suggested the key ARC LTB sites in the Upper Tamaki were increasing at the following rates (Table 6.1), and these rates are in line with the high concentrations found there.

Table 6.1 ARC LTB sites for Tamaki Estuary. Years for that site to reach the next ERC or PEL is indicated by colour. Red = time to breach the red ERC, blue = time to breach PEL, green=time to fall to green ERC (Pb only). Brackets denote a probability>0.05 that there is no change.

Time to next 'traffic light' or PEL				
	Cu	Zn	Pb	PAH
Tamaki	6	6	*0*	(never)
Pakuranga (U)	3	6	*0*	never
Pakuranga (L)	*23*	*26*	0	(never)

Figure 6.1 RDP traffic light status and Zn concentrations in the <63 µm fraction at sites in the Tamaki Estuary.



Conclusions

This exploratory data analysis of the information collected under the Regional Discharges Project (RDP) examined the relationships between measured contaminants, and used these relationships to examine the distribution and overall contaminant status of each of the major water bodies (Waitemata, Manukau, Tamaki).

The relationships between copper (Cu), zinc (Zn), lead (Pb) and polycyclic aromatic hydrocarbons (PAH) showed that the heavy metal concentrations were reasonably well correlated but not with PAH concentrations.

The concentrations of each heavy metal in the weak acid extracted <63 μm fraction and the strong acid digested <500 μm fraction were reasonably correlated. The question was asked whether it was possible to use the results from the weak acid extracted <63 μm sediment fraction, instead of the strong acid digested <500 μm sediment fraction, to compare contamination levels with Environmental Response Criteria. Of the 50 settling zone and muddy outer zones sites with such data, 11 changed their RDP traffic light status, demonstrating that although there is a strong correlation between the results from the weak and strong acid extractions, the use of the results from the weak acid extraction of the <63 μm fraction will result in significant mis-assignment of some sites to RDP categories.

The minimum concentrations found in the RDP sediment surveys and the results from shallow cores suggest background concentrations for Cu ~ 5, Zn ~ 35 Pb ~ 5 mg/kg. Results from some estuaries (Mangere Inlet, Purewa and Panmure Basin) suggest that background levels may be higher in specific areas, but this requires further investigation.

The Mid Waitemata Harbour is widely contaminated. Clear contamination gradients extend out from settling zones into adjacent outer zones. As with the other water bodies, the concentrations of the 3 major contaminants Zn, Pb and Cu are reasonably correlated, which suggests that they are distributed in a similar manner – probably by resuspension and dispersal of fine particulates. There is a slight variation in Zn/Pb ratios and this may be due to reducing Pb levels following the removal of Pb from petrol. Contamination is probably carried into the wider outer zone such that Zn levels now exceed 100 mg/kg over much of the harbour.

The concentrations of heavy metals in the mud fraction are low in the Manukau Harbour, with the exception of Mangere Inlet. Concentrations are much lower than in the Waitemata, even than those parts of the Waitemata that are predominantly rural (e.g., Upper Waitemata Harbour). Concentrations in the Puherehere inlet, Clarks Beach etc are probably close to background. The reasons for the low concentrations are a mixture of the factors:

- Large harbour
- Small urban catchments
- Recent urban development
- Relatively large rural catchments

The most contaminated sites in the Manukau, in Mangere Inlet, may be partly due to a high background effect (related to historical industrial pollution and/or high natural background levels). The rate of change of concentrations at the 2 SoE sites (Cemetery and Anns Creek) is slow, which is consistent with the small catchment/relatively large estuary. It may be that that Mangere Inlet is "cleaning up" from levels of gross pollution recorded in the 1980s.

Basically the pattern of contamination in Tamaki Estuary looks simple – there is a clear gradient from the contaminated urbanized headwaters (Middlemore, Pakuranga, Otahuhu, Panmure to the uncontaminated mouth. It appears that the middle reaches are becoming contaminated. The evidence suggests that the outer Tamaki (north of Tahuna Torea) is relatively uncontaminated – i.e., the contamination from the upper estuary is not reaching the outer Tamaki area.

Future work

The following investigations would help extend the technical basis of the Regional Discharges Project:

- Examine the apparent "recovery" or "self cleansing" of Mangere Inlet

- Review recent core data collected for Mangere Inlet and Panmure Basin to assess background concentrations

- Use these results to assess the background correction when applying ERC. Note that there is no need to change the RDP procedure – background correction can be carried out during detailed investigations.

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Appendix 1: Analysis of Mid Waitemata Subtidal Cores

Swales et al (2003) examined sediment cores from various subtidal sites around Auckland, including the Mid Waitemata. They analysed the Zn in the cores as part of their dating technique. They used weak acid extraction (2M HCl) on the total sample. Concentrations were moderately high for a site some distance from sources – typically 100-105 mg/kg - which suggested that Zn was being dispersed around the Mid Waitemata Harbour.

The opportunity was taken to re-analyze the cores using RDP protocols, so that the subtidal core could be compared with intertidal surface samples taken around the shores of the Mid Waitemata Harbour. As the cores were in the outer zone, the <63 µm fraction was analysed in the surface (1-2 cm depth) and at the bottom of the shallow cores (~26-28 cm depth). The bottom samples were analysed in the hope that they would indicate background levels. There was no guarantee that the cores had reached background or pre-industrial levels at the relatively shallow depth of 27 cm, but the 1-2 cm slice will be a reasonable sample of the surface sediments.

To check against the possibility that these levels were due to high backgrounds, the <63 µm fraction was also analysed after strong acid digestion. Results are shown in Table A1.

The results confirm the moderate levels found in the earlier study. Two of the cores were close to typical background levels for Auckland, and this suggests that the levels of Cu, Pb and Zn in the surface sediments are due to urban inputs (e.g., stormwater etc).

Table A1: Analyses of the <63 µm fraction from subtidal cores collected in the Mid Waitemata Harbour.

		HCl	Digest	HCl	Digest	HCl	Digest
Core	Depth	Cu	Cu	Pb	Pb	Zn	Zn
S1	1-2 cm	15	18.8	30.5	32.5	97	102
S1	26-27 cm	20	27.4	15.8	18.3	83	94.2
S2	1-2 cm	14	20.5	32.2	37.5	89	106
S2	27-28 cm	2	8.2	9.9	12.1	40	50.5
S3	1-2 cm	15	19.9	34.6	37.3	102	109
S3	27-28 cm	1	11.3	7.1	10.8	34	41.6

Appendix 2.1

Recommended RDP monitoring sites and existing data on mean chemical contaminant concentrations on the 63µm and 500 µm sediment fractions. Abbreviations used in the table are: RREA = Regional Receiving Environment Area, SZ = Settling Zone, DZ = Deposition Zone (doesn't fully meet SZ criteria), OZ = Outer Zone. The status of PAH, Cu, Zn, and Pb is ranked as 1 = green, 2 = amber, and 3 = red.

							500um			63um			500um		Status		
RREA	Location	Type	SZ	OZ	Easting	Northing	Cu	Zn	Pb	Cu	Zn	Pb	PAH	PAH	Cu	Zn	Pb
2	Upper Tamaki (Middlemore)	SZ			2675627	6470765	24	175	27	32	232	49	282	1	2	3	2
2	Otahuhu, Brady Rd	DZ			2676041	6472877				35	202	51		0	2	3	2
2	U Tamaki Upper, Princess	OZ			2676238	6472175				28	166	41		0	2	3	1
2	U Tamaki Lower, Bowden	OZ			2675645	6474695				32	179	44		0	2	3	2
2	Panmure	SZ			2674939	6475596	27	174	38	23	132	37	490	1	2	3	2
2	Pakuranga Upper	SZ			2678591	6473361	28	177	23	38	235	44	83	1	2	3	1
2	Mid Tamaki Upper, Bengazi	OZ			2677115	6476792				27	146	39		0	2	1	2
2	Mid Tamaki Lower, Pt England	OZ			2677510	6478145				24	138	37		0	2	1	2
3	Outer Tamaki (Roberta?)	OZ			2678535	6480522				10	81	24		0	1	1	1
5	Hobson1	OZ			2670161	6480662	7	48	11	29	155	62	976	2	2	2	3
5	Hobson2, Victoria	OZ			2671315	6480490				21	121	48		0	2	1	1
5	Hobson3, Awatea	OZ			2670397	6481488				23	138	62		0	2	1	3
5	Meadowbank (Purewa)	SZ			2672799	6480182	16	157	40	15	99	36	429	1	1	3	2
5	Meadowbank (Purewa)	OZ			2671621	6481222	10	105	27	16	96	37	91	1	1	1	2
5	Meola	SZ			2662817	6481374	31	281	65	33	194	70	885	2	2	3	3
7	Meola, ACC	OZ			2662668	6481869				27	168	61		0	2	3	3
7	Motions	SZ			2663020	6481413	27	276	51	42	250	97	2819	3	2	3	3
7	Meola Reef	OZ			2662897	6482580	7	100	18	27	146	48	325	1	2	2	2
7	Coxes, ACC	OZ			2663732	6482215				26	181	71		0	2	3	3
8	Upper Whau	SZ			2659738	6476817	38	254	78	34	305	82	228	1	3	3	3
8	Wairau	SZ			2658525	6477463	47	229	70	44	279	91	198	1	3	3	3
8	Lower Whau	OZ			2658691	6479191	31	167	45	24	165	48	126	1	2	3	2
8	Outer Whau, WHO C	OZ			2658550	6482000	5	38	12	16	101	33		0	1	1	2

							500um			63um			500um		Status		
RREA	Location	Type	SZ	OZ	Easting	Northing	Cu	Zn	Pb	Cu	Zn	Pb	PAH	PAH	Cu	Zn	Pb
8	Waterview, Oakley	DZ			2661590	6479618	32	162	44	25	163	49	242	1	2	3	2
8	Waterview	OZ			2660470	6479877	5	47	14	16	97	34	108	1	1	1	2
8	Henderson Upper	SZ			2656017	6483479	34	172	31	28	170	36	87	1	2	3	2
9	Henderson Lower	SZ			2657114	6485207	30	137	38	22	126	34	170	1	2	2	2
9	Henderson	OZ			2658591	6486244	8	72	24	19	107	31	205	1	2	1	2
9	Hobsonville	OZ			2660106	6487972	4	26	9	17	78	26	87	1	1	1	1
10	Brighams	SZ			2653087	6489420	17	74	19	14	73	22		0	1	1	1
10	Paremoremo	SZ			2656364	6492284	25	99	22	18	90	23	72	1	2	1	1
10	Upper Lucas	SZ			2660154	6492967	26	113	19	19	104	23	94	1	2	1	1
10	Te Wharau (Lucas)	SZ			2660000	6492000	25	103	27	20	89	29		0	2	1	1
10	Upper Hellyers	SZ			2661953	6490127	13	78	20	14	88	29	230	1	1	1	1
10	Kaipatiki	SZ			2662042	6489586	22	115	31	19	115	38	183	1	2	1	2
10	Hellyers	OZ			2661807	6489767	18	100	21	17	110	29	118	1	1	1	1
10	Waiarohia	SZ			2657008	6488815	15	74	21	17	83	28		0	1	1	1
10	Waiarohia	OZ			2658089	6489784	7	49	14	14	74	24		0	1	1	1
10	Rarawaru	SZ			2654930	6490600	12	72	20	16	80	23		0	1	1	1
10	Rangitopuni Upper	SZ			2653449	6491807	20	86	26	17	82	23		0	1	1	1
10	Rangitopuni Middle	SZ			2657200	6491100	15	83	25	14	74	23		0	1	1	1
11	Beachhaven	SZ			2660470	6488550	19	105	32	14	81	29	377	1	1	1	2
11	Island	SZ			2661000	6486500	7	54	15	20	104	35		0	1	1	1
11	Kendalls	OZ			2662500	6485000	5	40	10	22	104	41		0	1	1	1
11	Chelsea	OZ			2664480	6485475	7	65	18	22	103	35	1747	3	2	1	2
11	Ngataringa	OZ			2670000	6485500	8	63	20	11	70	29		0	1	1	1
12	Hillcrest, Shoal Bay	SZ			2668200	6488300	27	150	45	20	126	46		1	2	3	2
12	Mid Shoal Bay Landsdown	OZ			2668400	6486400	6	45	12	17	86	35		0	1	1	2
12	Low Shoal Bay, Sulphur	OZ			2668000	6486000	4	29	12	15	73	40		0	1	1	2
14/15	Cheltenham	OZ			2671700	6485300	2	49	5	12	118	13	339	1	1	1	1
17	Weymouth East	DZ			2678182	6460344	9	78	15	6	61	13	49	1	1	1	1
17	Weymouth West	DZ			2677005	6460443	8	68	13	6	59	13	58	1	1	1	1

							500um			63um			500um		Status		
RREA	Location	Type	SZ	OZ	Easting	Northing	Cu	Zn	Pb	Cu	Zn	Pb	PAH	PAH	Cu	Zn	Pb
17	Papakura Stm Upper	SZ			2679398	6459888	12	86	18	6	54	14		0	1	1	1
17	Papakura Stm Lower	SZ			2679152	6459749	10	76	16	6	51	13		0	1	1	1
17	Puherehere, Papakura	DZ			2681696	6458386	7	72	7	7	69	12	83	1	1	1	1
17	Puherehere Upper	OZ			2680000	6459100	2	18	4	7	57	14		0	1	1	1
17	Puherehere Middle	OZ			2677950	6458600	2	24	6	5	46	12		0	1	1	1
17	Pukaki, Waitekauri	SZ			2671938	6465795	9	70	13	6	54	13	57	1	1	1	1
18	Pukaki	SZ			2670814	6466440	6	47	9	5	50	13	125	1	1	1	1
18	Pukaki Airport	SZ			2671025	6465235	16	76	5	5	54	7	39	1	1	1	1
18	Puhinui Inner	SZ			2675460	6462232	11	109	7	6	74	9	27	1	1	1	1
18	Puhinui	OZ			2675350	6461350	4	51	8	5	48	10	23	1	1	1	1
19	Mangere Cemetery	OZ			2670400	6472900	37	155	32	22	116	29	65	1	3	3	2
19	Anns Creek	OZ			2672634	6473059	38	184	32	26	145	32	55	1	3	3	2
20	Hillsborough	OZ			2667246	6473291	14	89	17	22	105	29		0	2	1	1
21	Blockhouse Bay	OZ			2662689	6473324				11	68	19		0			
21	Little Muddy	SZ			2656894	6470502	11	61	15	10	60	15		0	1	1	1
31	Orewa North	SZ			2661955	6510345	3	33	5	7	79	11		0	1	1	1
31	Orewa South	SZ			2661275	6509775	4	28	4	6	35	6		0	1	1	1
31	Orewa	OZ			2661197	6510298	3	21	3	5	34	6		0	1	1	1
31	Weiti	SZ			2662420	6508229	10	52	4	18	64	9	51	1	1	1	1
23	Waiuku	SZ			2663665	6438752	9	93	17	7	81	16		0	1	1	1

Appendix 2.2

Mean contaminant (Cu, Zn, Pb, and PAH) concentrations and contaminant status at reference sites in the Auckland Region. Abbreviations used in the table are: RREA = Regional Receiving Environment Area, SZ = Settling Zone, DZ = Deposition Zone (doesn't fully meet SZ criteria), OZ = Outer Zone.

			Type				500um			63um			500um		Status		
RREA	Location	Type	SZ	OZ	Easting	Northing	Cu	Zn	Pb	Cu	Zn	Pb	PAH	PAH	Cu	Zn	Pb
1	Mangamangaroa	SZ			2684300	6474700								0	1	1	1
2	Otahuhu	DZ			2675950	6472800				33	181	47		1	2	3	2
2	Panmure	SZ			2675613	6475738								0	2	3	3
2	Pakuranga Lower	SZ			2677159	6473386	22	161	22	27	162	34	129	1	2	3	1
2	Middle Tamaki, Spit-S	OZ			2678896	6479231				10	59	15		0	1	1	1
2	Outer Tamaki, Spit-N	OZ			2678931	6479497				8	49	16		0	1	1	1
2	Glendowie Vista	OZ			2678111	6480163				8	57	16		0	1	1	1
5	Hobson	OZ			2670300	6481200				14	118	65		0	1	1	3
5	Hobson Centre	OZ			2670889	6480895				14	97	39		0	1	1	2
5	Hobson, Elam	SZ			2670140	6480907				25	145	70		0	2	1	3
5	Purewa OZ, Ngapipi	OZ			2671380	6481337				17	114	45		0	1	1	2
7	Coxs	OZ			2664170	6482030				42	351	132		0	3	3	3
8	Outer Whau, WHO A	OZ			2659100	6482450	4	30	9	18	106	35		0	1	1	2
8	Outer Whau, WHO B	OZ			2658700	6482300	5	36	10	15	90	32		0	1	1	2
8	Outer Whau, WHO D	OZ			2658700	6482600	7	42	13	15	97	30	168	1	1	1	1
8	Waterview, Walkers	OZ			2661586	6480331				21	121	38		0	2	1	2
8	Henderson, Matipo	SZ			2656400	6482950	41	199	59					1	3	3	3
8	Huruhuru	SZ			2655750	6482950	32	161	42					0	2	3	2
10	Upper Lucas	SZ			2660300	6493400	26	117	27	19	96	27		0	2	1	1
11	Little Shoal	OZ			2665650	6485700	5	36	12	22	86	42	1190	2	2	1	2
12	Esmonde Rd Estuary	SZ			2668150	6488200	28	184	54	25	188	60		0	2	3	3
12	Up Shoal Bay, Sydney St	OZ			2668000	6487500	5	36	13	15	95	36		0	1	1	2
15	Wairau surf zone	OZ			2668700	6491600	4	39	9	6	34	9	163	1	1	1	1
15	Wairau Beach	OZ			2668300	6491500	3	50	12	4	32	7	877	2	1	1	1

			Type					500um			63um			500um		Status		
RREA	Location	Type	SZ	OZ	Source	Easting	Northing	Cu	Zn	Pb	Cu	Zn	Pb	PAH	PAH	Cu	Zn	Pb
15	Wairau Mouth	OZ			NSCC	2668100	6491550	11	77	15	32	171	33	601	1	2	3	2
15	Milford Marina	SZ			Works	2668050	6491200								0	3	3	3
15	Deep Creek, Torbay	SZ			NSCC	2666750	6498500	21	190	34	27	251	53		0	2	3	2
15	Deep Creek Mouth, Torbay	OZ			NSCC	2667070	6498400	4	42	7	4	18	4		0	1	1	1
15	Browns Bay	OZ			ARC LTB	2666850	6496845	2	43	0	10	131		49	1	1	2	0
15	Long Bay, Awaruku	OZ			ARC LTB	2667077	6500048	2	26	0	9	87		15	1	1	1	0
15	Long Bay, Vaughan	OZ			ARC LTB	2666838	6500766	1	25	0	9	80		12	1	1	1	0
31	Okura	OZ			NSCC	2664500	6502000	10	39	9	8	37	10		0	1	1	1
31	Okura West	SZ			NSCC	2663000	6501500	7	31	7	7	39	10	16	1	1	1	1
18	Airport LT site	OZ			GAP	2672515	6463388	3	29	5	5	40	9		0	1	1	1
19	Harania	SZ			ASP	2672300	6471350				45	207	61		1	3	3	3
19	Taratata	SZ			ASP	2670650	6471300				41	150	50		0	3	3	3
21	Big Muddy	SZ			ARC LTB	2654500	6468600	9	57	2	6	46	5	41	1	1	1	1
22	Cape Horn LT Site	OZ			GAP	2659917	6470448	3	23	4	11	81	26	21	1	1	1	1
22	Clarks Beach LT Site	OZ			GAP	2661675	6452219	2	27	3	5	37	8		0	1	1	1
31	Te Matuku, Waiheke	SZ			ARC LTB	2700252	6482581	3	39	2	5	53	10	15	1	1	1	1