Marine Sediment Contaminant State and Trends in Tāmaki Makaurau / Auckland 2004-2019. State of the Environment Reporting

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Research and Evaluation Unit RIMU

Auckland Council
Te Kaunihera o Tāmaki Makaurau

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Cover image credit: Polychaete tubes at Cape Horn, Manukau Harbour.
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Executive summary

Estuarine sediments can accumulate chemical contaminants originating from land-based activities. Sediment contamination therefore provides a useful marker of land use impacts on aquatic receiving environments. In addition, the build-up of contaminants can cause changes in the ecological health of an estuary by reducing the abundance or diversity of sensitive species, leaving degraded communities dominated by species that are tolerant of higher contaminant concentrations. Understanding the distribution of chemical contaminants in marine sediments, their potential effects on aquatic ecology, and trends in chemical contamination over time, is therefore important for effective resource management of coastal areas.

Auckland Council monitors contaminants in marine sediments at approximately 120 sites in the Regional Sediment Contaminant Monitoring Programme (RSCMP). The RSCMP data complement those obtained in other Auckland Council programmes (e.g. coastal water quality and benthic ecology), which together aim to provide consistent, long-term information on the quality of Auckland's coastal environment. This monitoring is carried out as part of fulfilling Auckland Council's obligations under the Resource Management Act 1991. Information gained is used to identify issues and inform policy development and environmental decision-making.

This report covers the period 2004 to 2019 (inclusive) and includes assessment of chemical contaminant 'state' in Auckland's estuaries and harbours, spatial patterns of sediment contamination, and the potential impacts of this contamination on benthic ecosystem health. Temporal trends in contaminant concentrations between 2004 and 2019 have also been assessed, focusing on changes over time in the heavy metals copper (Cu), lead (Pb), and zinc (Zn). Previous state and trends analysis of marine sediment contaminants published in 2012, found that the highest contaminant concentrations are generally located in the muddy upper reaches of estuaries receiving run-off from older, intensively urbanised and/or industrialised catchments, particularly in the Tāmaki Estuary and Central Waitematā Harbour. The lowest concentrations were found in rural/forested catchment estuaries and open coastal beaches. In general, this report agrees with those earlier findings, with a similar spatial distribution and level of contamination observed.

Contaminant state was assessed by examining the most recently available metals (Cu, Pb, and Zn) and organic contaminant (polycyclic aromatic hydrocarbons (PAH), organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs)) data. For metals, this includes data up to 2019, and for organic contaminants, includes data up to 2013. Potential effects of contaminants on benthic ecology were assessed principally by comparison with the former Auckland Regional Council's Environmental Response Criteria (ERC). The ERC are conservative thresholds developed specifically for the Auckland region. Comparison with the

more recently published Australian and New Zealand Guidelines for fresh and marine water quality (ANZG) was also made.

Analysis in this report found that 95 (79%) of the 120 sites were assessed as the state level ERC-green. By this measure, adverse effects of contaminants on benthic aquatic life would not be expected to occur. ERC-amber levels were found at eight of the 120 sites (approximately 7%), mostly muddy estuary sites in the Upper Waitematā Harbour and Māngere Inlet. Signs of ecological degradation might be expected to be observed at these amber sites due to the moderate contaminant levels. Only at 17 sites (14%), directly influenced by intensive urban development or local contamination sources, were contaminants at ERC-red state levels, all of which were in muddy inner estuary sites in the Central Waitematā Harbour and Tāmaki Estuary. At these sites, degraded benthic ecology would be expected as a result of elevated contaminant levels.

Similar results were found using the ANZG in place of the ERC to assess contaminant state. Ninety four per cent of the sites had Cu, Pb, or Zn concentrations below the default guideline values (DGVs) and would be assessed as having 'green' state. Six per cent were 'amber' (between the DGV and the higher guideline GV-High), and none were above the GV-High. Exceedances of the DGVs were found for Zn at all the amber sites, and also for Pb at one site. Using the ANZG as indicators of potential ecological effects from these metals, suggests a low level of risk to benthic ecology at the vast majority of sites, with a small number of sites in the inner muddy urbanised zones of the Central Waitematā Harbour and Tāmaki Estuary, having Zn (and Pb at one site) at levels where adverse ecological effects would be expected to occur.

Meaningful trends in total recoverable metals were recorded at 18 of the 56 trends sites;12 had decreasing concentrations of one or more metal, while six sites had increasing concentrations. At the relatively small number of sites with reasonably robust and meaningful trends, decreases outnumbered increases for Cu and Pb, while for the four sites where Zn concentrations had changed more than two per cent per year, all the trends were increases.

There do not appear to be any spatial patterns relating to meaningful increases or decreases in contaminant trends. However, changes over time in sediment texture appears to be an important factor, with increasing muddiness accompanying increasing trends in metals at four of six sites, and evidence for decreasing muddiness accompanying decreasing trends in metals concentrations at two sites.

Overall, the sediment contaminant data analysed in this project indicate that the spatial patterns of contamination are consistent with those reported previously, and that contaminant concentrations in most areas have not changed greatly since 2004. Contaminant state has remained stable at almost all of the monitoring sites, with very few consistent changes over time. Trends over time have shown a general decrease in magnitude (i.e. the amount of change over time is smaller), with small changes in the numbers of sites with increasing or decreasing trends in Cu and Pb, and fewer meaningful trends in Zn concentrations recorded for the 2004-2019 period than reported in 2012 for the 1998-2010 period. Most areas situated away from intensively developed urban catchments have low levels of contamination, below default guideline values. Older, intensively developed urban sites have highest contaminant levels that may exceed DGVs, and at the worst of these would be expected to show a potential risk to benthic ecology as a result.

The monitoring results described in this report provide some reassurance that rapidly increasing contamination in Auckland's estuaries has not been a widespread occurrence over the past 15 years. The available evidence points to relatively low and generally stable or decreasing concentrations of heavy metals in most of the areas monitored. However, while few increasing trends have been detected in recent years, urban Auckland continues to expand, and pressures associated with increasing population, traffic, and associated infrastructure are likely to grow. These increasing pressures may be offset by improvements to the vehicle fleet, construction methods and materials, and infrastructure for managing wastewater, solid waste and stormwater, as well as declining heavy industry which may have historically been a significant source of contamination in some areas. Continued monitoring is important to follow the nett effects of these changes and to ensure any gains made to date are not lost.

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Glossary of abbreviations

AC	Auckland Council
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZG	Australian and New Zealand Guidelines for fresh and marine water quality
ARC	Auckland Regional Council
As	Arsenic
BRS	Bulk Reference Sediment
CPECs	Chemicals of Potential Environmental Concern
CRM	Certified Reference Material
Cu	Copper
DGVs	Default Guideline Values
EDCs	Endocrine Disrupting Chemicals
EOCs	Emerging Organic Contaminants
ERC	Environmental Response Criteria
HCl	Hydrochloric acid
Hg	Mercury
HNO_3	Nitric acid
HWPAH	High Weight Polycyclic Aromatic Hydrocarbons
ISQGs	Interim Sediment Quality Guidelines
LAWA	Land Air Water Aotearoa
MRAs	Marine Reporting Areas

NIWA	National Institute of Water and Atmospheric Research
OCPs	Organochlorine Pesticides
OZ	Outer Zones
PAH	Polycyclic Aromatic Hydrocarbons
Pb	Lead
PCBs	Polychlorinated Biphenyls
PPCPs	Pharmaceuticals and Personal Care Products
PSD	Particle Size Distribution
QA	Quality Assurance
RDP	Regional Discharge Project
RIMU	Research and Evaluation Unit
RSCMP	Regional Sediment Contaminant Monitoring Programme
SOE	State of the Environment
SQGs	Sediment Quality Guidelines
SZ	Settling Zones
TLAs	Territorial Local Authorities
TOC	Total Organic Carbon
USEPA	United States Environmental Protection Agency
UWH	Upper Waitematā Harbour
Zn	Zinc

1.0 Introduction

1.1 Background

Aquatic sediments accumulate chemical contaminants originating from a range of land-based activities. Urban sources can include vehicle brake and tyre wear, building materials, industrial discharges, landfill leachate and vehicle emissions. Contaminants can enter the marine environment from sources such as stormwater outflows, and as surface run-off, either directly to the coast, or transported through stream and riverine systems. Sediment contamination therefore provides a useful marker of land use impacts on aquatic receiving environments and ecosystem health.

Auckland Council, and its predecessor the Auckland Regional Council (ARC), has run a marine sediment contaminant monitoring programme since 1998, which aims to assess the spatial distribution and temporal trends in key chemical contaminants across the region's urban estuaries, harbours, and beaches. Key objectives of this monitoring programme, now known as the 'Regional Sediment Contaminant Monitoring Programme' (RSCMP), are to assess the effects of catchment land use, in particular urbanisation, on marine environmental quality, and the effectiveness of resource management initiatives and policies in mitigating adverse effects arising from land use activities. Monitoring is carried out as part of legislative obligations, including those under section 35 of the Resource Management Act 1991, as well as providing evidence of how the council is maintaining and enhancing the quality of the region's coastal environment, as required under the Local Government Act 2002.

In 2012, RSCMP data acquired between 1998 and 2010 were reviewed (Mills et al., 2012). It was concluded that a clear picture of the spatial distribution of chemical contamination was provided by the monitoring programme. Highest concentrations of key urban-derived heavy metals (copper, lead, and zinc) and polycyclic aromatic hydrocarbons (PAH) were generally found in the muddy upper reaches of estuaries receiving run-off from the older, intensively urbanised and/or industrialised catchments, particularly in the Tāmaki Estuary and Central Waitematā Harbour. When comparing contaminant levels to sediment quality guidelines that provide thresholds for potential ecological effects, adverse effects on sediment-dwelling biota were more likely to be found in these zones, although areas where concentrations were lower, but effects were still possible, were also widely distributed throughout the Central and Upper Waitematā Harbour, in Māngere Inlet (Manukau Harbour), and in the Tāmaki Estuary. Lowest concentrations were found in rural/forested catchment estuaries and open coastal beaches.

Temporal trends were less clear. This was attributed to a range of factors such as the short time period of monitoring at many sites, variations in monitoring approach between contributing programmes, and variable or uncertain data quality for some analytes. However, the monitoring data indicated that trends in the concentrations of copper (Cu), lead (Pb), zinc (Zn) and PAH across the region were generally small. On average, the data suggested that little meaningful change had occurred over the 1998-2010 monitoring period.

The most consistent trend observed was a decrease in Pb concentrations at most urban sites, which probably reflected the beneficial effect of removing Pb from petrol in the mid-1990s.

Trends in Cu and Zn were more variable, with no obvious consistent pattern among sites. Where significant changes in Zn concentrations occurred, these were generally small increases. This supported a commonly held view that Zn concentrations are likely to increase slowly over time at most urban sites, due to inputs from urban land use activities (e.g. stormwater discharges).

The monitoring results, while having some limitations, provided reassurance that rapidly increasing contamination in Auckland's estuaries, was not a widespread occurrence. Continued monitoring was recommended for future trend assessments, so that the effectiveness of ongoing contaminant discharge and land use management policies and practices could be reliably evaluated.

Based on the findings of the 1998-2010 data review (Mills et al., 2012), further work was undertaken to:

- improve the monitoring data base for organochlorines – organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) – at key sites. This work was reported in Mills 2014a and 2014b
- review the performance and operational aspects of the monitoring programme to improve the quality of future monitoring data, and hence provide greater certainty for future trend assessments. This was reported in Mills and Williamson (2014).

Since the previous state and trend data review in 2012, continued monitoring has been undertaken, incorporating the recommendations made in the programme review (Mills & Williamson, 2014) to improve data quality assurance, consistency, and operational efficiency. Key changes to the monitoring have involved:

- introduction of a consistent quality assurance programme for tracking analytical data accuracy and consistency over time

- dropping the analysis of weak acid extractable metals in the mud fraction (<63 μm) from routine monitoring and using total recoverable metals for state and trend assessment at all sites. Prior to 2013, both total recoverable and extractable metals were measured. Extractable metals in the mud fraction (<63 μm), which had been used in the programme for assessing state at sandy Outer Zone (OZ) sites and for temporal trend assessment, were no longer analysed after 2013 because of difficulty in obtaining reliable analytical results
- the adoption of a standardised sieve/pipette method for particle size distribution (PSD) analysis, as widely used in other Auckland Council ecological monitoring programmes.

Since the end of 2010 (the last reported trend analysis period) and the end of 2019, three to four additional rounds of sampling have been undertaken at most monitoring sites.

1.2 This report

This report provides an updated state and trends assessment for key chemical contaminants, using RSCMP monitoring data acquired to the end of 2019.

The following areas are addressed in the report:

1. Assessment of spatial patterns in sediment contaminant distribution across the region and comparison of contaminant concentrations with sediment quality guidelines to assess the potential impacts of contaminants on benthic ecosystem health; i.e. contaminant ‘state’.
2. Assessment of temporal trends in total recoverable Cu, Pb, and Zn concentrations.
3. Comparison of state and trends from the current update with results obtained in the previous assessment (Mills et al. (2012), which used data collected to the end of 2010).

2.0 Regional Sediment Contaminant Monitoring Programme overview

The following sections, updated from Mills et al. (2012), provide background information on the RSCMP; the contributing programmes, site locations and characteristics, sampling methods and the contaminants monitored. Changes made since the previous state and trend assessment in 2012 are outlined.

2.1 Monitoring programmes

In 1998, the ARC initiated a sediment contaminant monitoring programme aimed at assessing the spatial distribution and temporal trends in key chemical contaminants across the region's urban estuaries, harbours, and beaches. Key objectives of this State of the Environment (SOE) monitoring programme were to assess the effects of catchment land use, in particular urbanisation, on marine environmental quality, and the effectiveness of resource management initiatives and policies in mitigating adverse effects arising from land use activities.

Subsequently, two additional programmes were added to acquire additional sediment contaminant data – the 'Regional Discharges Project' (RDP), and the 'Upper Waitematā Harbour Benthic Ecology Programme' (UWH).

These complementary programmes combine benthic invertebrate and sediment contaminant monitoring, and are summarised as follows:

1. State of the Environment (SOE) marine sediment monitoring programme, which covered 27 sites, monitored approximately every two years at most sites since 1998. This programme aimed to provide long-term information on contaminant state and trends across the region.
2. Regional Discharges Project (RDP), which began in 2002, was administered by the ARC on behalf of the region's Territorial Local Authorities (TLAs). This programme was aimed primarily at monitoring the effects of stormwater discharges, as part of the TLAs stormwater network discharge consenting programme. The RDP grew to include 51 sites, which were sampled at 2-5 yearly intervals, depending on their contamination state (see Kelly, 2007).
3. The Upper Waitematā Harbour (UWH) benthic ecology programme, which monitored 13 Upper Waitematā Harbour sites annually from 2005-2009, then again in 2011, 2013, 2016, and 2018. This programme provides specific information on the ecological effects of urban development on the Upper Waitematā Harbour.

Auckland Council has continued the former ARC sediment contaminant monitoring programmes. In order to achieve efficiencies and cost savings, the contaminant chemistry components of the SOE, RDP, and UWH programmes are integrated into a single programme, the ‘Regional Sediment Contaminant Monitoring Programme’ (RSCMP).

The sites from the SOE, RDP, and UWH programmes form the core of the RSCMP. Approximately 70 of these sites are monitored regularly over time at 2-5 yearly intervals depending on their contaminant state and potential for effects associated with catchment land use changes. Approximately 20-30 sites are sampled each year. The total number of sites monitored in the RSCMP changes over time as new sites are added to provide more spatial coverage (e.g. in the south-eastern Manukau Harbour) and some existing sites are removed from routine monitoring; for example, sites may be dropped if they become physically compromised by mangrove encroachment or poor access.

Details of the monitoring programme design, operation, and results are given in a number of reports; e.g. Kelly (2007), Lundquist et al. (2010), and Mills et al. (2012).

Data from the former SOE and RDP, and more recently the RSCMP, monitoring programmes have been compiled and reported annually; e.g. Reed and Gadd (2009) for the SOE, Diffuse Sources (2007-2011) for the RDP programme, and Mills (2014c, 2015, 2021a and 2021b) for the RSCMP.

Sediment contaminant sampling has also been carried out in conjunction with benthic ecology monitoring in a number of additional locations around Auckland. This has included the Kaipara and Mahurangi harbours, as part of the Harbour Ecology programme, and in Whangateau, Wairoa, Waiwera, Puhoi, Mangemangeroa, Waikopua, Okura, Turanga, and Orewa, as part of the East Coast Estuaries programme. The locations of the sites monitored in the RSCMP and associated programmes are shown in Figure 2-1.

The Harbour Ecology and East Coast Estuaries monitoring programmes are not currently part of the ongoing RSCMP. Sampling for sediment contaminants is done less frequently (approximately every few years) than at the core RSCMP sites, and therefore the data are not yet sufficient for trend assessment; only one or two sets of data have been acquired to date from these areas. However, they are suitable for inclusion in the ‘state’ assessment, broadening the spatial coverage of contaminant distribution across the region.

Data for these sites can be found in Hailes et al. (2010) for the Kaipara Harbour; Townsend et al. (2010) for the Whangateau Harbour; Halliday and Cummings (2012) for the Mahurangi Estuary; Hewitt and Simpson (2012) for Waiwera, Puhoi, Mangemangeroa, Waikopua, Okura, Turanga, and Orewa estuaries and Lohrer et al. (2012) for the Wairoa embayment.

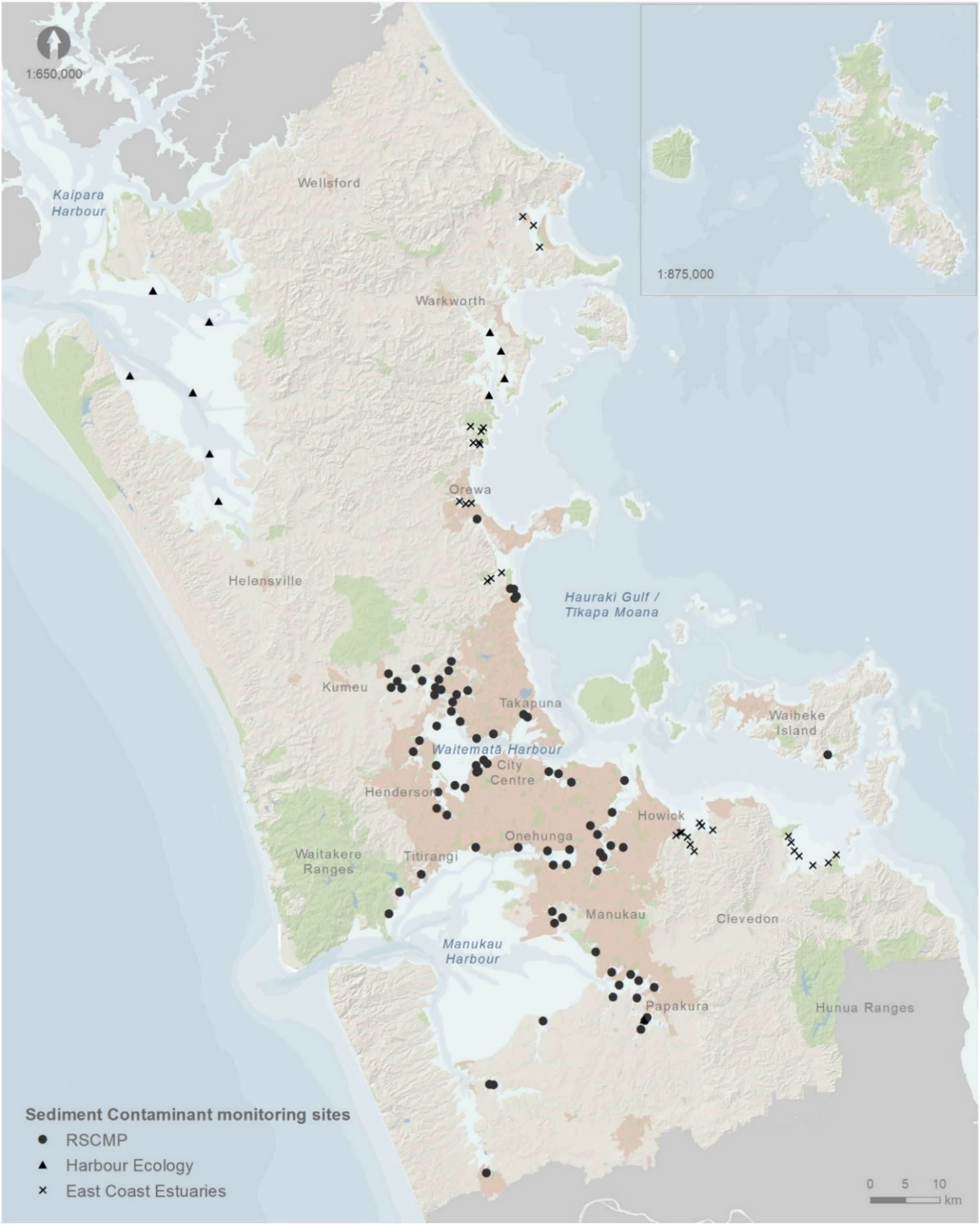

Figure 2-1. Site locations and associated programmes of sediment contaminant monitoring.

2.2 Sites

Monitoring sites are spread across the range of catchment land uses and histories. Because a key focus of the programme is to manage the impacts of urban development, most of the sites are located in areas receiving run-off from predominantly urban catchments. Sediment contaminant concentrations generally reflect the predominant land use in the surrounding catchment, with older, intensively developed catchment sites having highest levels, and rural/reference sites the lowest contaminant levels.

The urban catchments cover a wide range of predominant land use(s) and histories, including:

- old commercial/industrial areas (e.g. Māngere Inlet sites in the upper reaches of the Manukau Harbour)
- newer mixed industrial/commercial/residential areas (e.g. Whau and Tāmaki estuaries)
- older, mainly residential areas (e.g. Hobson Bay and Cox's Bay in the Central Waitematā Harbour)
- newer, but well-established, urban areas (e.g. Pakuranga Creek in the Tāmaki Estuary)
- developing urban catchments (e.g. Weiti at Silverdale, and some sites in the Upper Waitematā Harbour).

Predominantly rural catchment sites include several sites in the Upper Waitematā Harbour such as Brighams, Paremoremo, Rangitopuni, and Rarawaru creeks. Recent additions include sites in the south-eastern Manukau Harbour, which are currently predominantly rural but are undergoing, or are flagged for future, urban development. While outside the core RSCMP, sites in several predominantly rural catchment estuaries including Waiwera, Puhoi, Mangemangeroa, Wairoa, Whangateau, and Kaipara, have also been sampled for sediment contaminants as part of Auckland Council's harbour ecology and east coast estuaries ecology programmes.

Reference sites – rural catchments having very little urban activity and catchment land cover dominated by regenerating bush and/or pasture – include Te Matuku Bay on Waiheke Island, and Big Muddy Creek in the outer reaches of the Manukau Harbour.

Sampling sites are located in the intertidal zone and include a broad range of sediment textures. Sediment texture at many sites can be described as 'soft' and 'muddy' with a significant proportion of silt and clay (particles <63 µm) and very fine sand (63-125 µm). The dominant representation by muddy sites reflects the accumulation of fine sediment in many estuarine locations as a consequence of historical land development. These muddy zones are more likely to trap and accumulate contaminants, and hence they are useful as sentinel sites for assessing the effects of sediment and contaminant discharges from upstream catchments.

Firmer, sandier textured sites include the East Coast beach sites (e.g. Long Bay beaches at the Awaruku and Vaughans Stream mouths), Mill Bay and Blockhouse Bay (Manukau Harbour), and some sites in the main body of the Waitematā Harbour (e.g. Henderson Entrance, Meola Outer, Hobsonville, Herald Island). Sandy sites, particularly open coastal beaches exposed to higher wave energy, generally do not accumulate chemical contaminants to the same extent as muddier sites, and therefore some of the open coastal beach sites that were part of the original SOE programme (e.g. Brown's Bay, Cheltenham Beach) are no longer routinely monitored.

2.3 Sampling

Sampling at both the former SOE and RDP programme sites is carried out using protocols detailed in the monitoring 'blueprint' document, ARC Technical Publication 168 (ARC, 2004a). Briefly, this involves taking five replicate sediment samples from an approximately 50 x 20m plot marked out at each monitoring site. Each replicate is made up from 10 sub-samples taken at regular intervals (approximately every two metres) along two designated longitudinal transects within the sampling plot. The top 2cm of sediment is sampled for laboratory analyses.

Sampling in the UWH programme is undertaken using a different protocol, as described in Townsend et al. (2015). Briefly, this involves collection of replicate cores (5cm diameter, 0-2cm depth) from four random locations across each site (for sites sampled from a boat) or 12 random locations across each site (for sites sampled on foot at low tide). Five replicate samples are prepared, each sample made up from four (for boat-sampled sites) or 12 (for sites sampled on foot) sub-samples.

Sampling frequency is biannual (i.e. every two years) at former SOE programme sites, and 2-5 yearly for former RDP programme sites; more highly contaminated sites are monitored more frequently than cleaner sites. UWH programme sites were sampled annually from 2005 to 2009, then again in 2011, 2013, 2016 and 2018. No sampling was done in 2014, when a review of sites and procedures was undertaken.

Sample collection in the former SOE programme was undertaken between April and September in 1998 and 1999, and in August for 2001-2007. Sampling in the RDP and UWH programmes, and for SOE sites from 2009 onwards, was conducted in late October to early December each year, i.e. generally in November.

The timing of the chemical contaminant sampling is not considered critical, because concentrations are not expected to vary greatly over relatively short time intervals (e.g.

weeks-to-months), and the focus of the monitoring is long-term trends (several years-to-decades). In addition, samples are taken from the top 2cm of the sediment profile. This provides an integrated mixture of freshly deposited material and older sediment from deeper in the profile, the sediments being mixed by biological (bioturbation) and physical processes. This mixing is likely to ‘smooth’ out short-term variations in contaminant levels in the samples taken for analysis.

2.4 Constituents measured

The chemical contaminants and sediment physical properties monitored are described briefly below.

2.4.1 Metals

The contaminants routinely analysed in the RSCMP are currently limited to total recoverable metals – copper (Cu), lead (Pb), zinc (Zn), arsenic (As; a metalloid species), and mercury (Hg).

Copper, lead, and zinc are commonly associated with urban activities, and are often present at elevated concentrations in urban stormwater. Copper and zinc concentrations have generally been predicted to increase in sediments receiving urban stormwater run-off, while lead is anticipated to decrease as its use has declined over time, particularly since the mid-1990s when it was removed from petrol. Arsenic and mercury are toxic contaminants sometimes present at elevated concentrations in Auckland marine sediments. Sources and trends for As and Hg are currently unclear, so routine analysis was instituted in 2012 to obtain more information on state and trends.

Total recoverable metals are extracted from the sediment by hot, strong acid digestion (HNO_3/HCl, USEPA Method 200.2). Samples are analysed on the <500 µm (<0.5 mm) fraction, which approximates the total sediment, with larger coarse particles – e.g. shell hash and gravel – removed to reduce data variability.

The total recoverable metal results are used for state assessment, by comparing concentrations with sediment quality guidelines (SQG), which have generally been derived using metals’ concentrations obtained via strong acid digests of total sediment samples. Total recoverable metal results are also now used for trend monitoring.

A disadvantage of using total recoverable metals for trend analysis is that the concentrations may be more affected by changing particle size distribution (PSD), with finer grained sediments generally having higher total recoverable metals’ concentrations than coarser grained material. Changes in PSD therefore need to be assessed in conjunction with the metals' trends to evaluate the contribution changing PSD may have on any metals' trends.

Prior to 2015, extractable metals, via cold 2 M HCl digestion (a weaker extraction medium than that used in total recoverable digestion for 'total metals') on the <63 µm sediment fraction, were measured. This method, which was developed 'in-house' at the National Institute of Water and Atmospheric Research (NIWA), more closely approximates the 'reactive', and potentially more bioavailable, metal fraction in the sediment. The use of the <63 µm fraction reduces variability associated with particle size variations, improving the comparability between sites and over time. The extractable metals were therefore originally the preferred metals' indicators for temporal trend assessment. However, a review of data quality (Mills & Williamson, 2014) and ongoing quality assurance (QA) assessment in the RSCMP (e.g. see annual RSCMP programme data reports from 2013 onwards) revealed that the extractable metals' results were not sufficiently reproducible for reliable use in trend assessment. Their analysis was therefore discontinued, and total recoverable metals have been used for state and trend assessment since 2015.

The mud-fraction metals' data may be of value at some sites where trends in fine sediment fraction contamination in variable-textured sediments are a particular focus (e.g. Long Bay stream sites), or in more detailed investigations at more contaminated sites where sediment toxicity due to elevated metals' concentrations is a possibility (e.g. following the Australian and New Zealand guidelines for fresh and marine water quality (ANZG, 2018) tiered evaluation protocols).

Five replicates per site are analysed for total recoverable metals. This has varied over the duration of the RSCMP:

- one replicate per site was analysed at former SOE sites from 1998 to 2007
- three replicates were analysed at RDP sites from 2004 to 2013, at UWH sites from 2005 to 2013, and at SOE sites from 2009 to 2013
- five replicates at all sites from 2015 to the present.

The change in replicates analysed was, in part, a result of data reviews which indicated it would be beneficial to increase the numbers analysed to improve the reliability of the median concentration measure from each sampling round. There were also improved efficiencies in sample handling resulting from processing all replicates at once, rather than having to process and analyse separate replicates if the initial set of results (from the first three of five replicates sampled) showed unusual results.

2.4.2 Organic contaminants

Persistent organic pollutants such as polycyclic aromatic hydrocarbons (PAH), organochlorine pesticides (OCP), and polychlorinated biphenyls (PCB) have also been analysed at times in the past. These contaminants are now scheduled to be analysed much less frequently than for metals and at only selected 'at risk' sites (Mills, 2014a, 2014b). This is because these contaminants are much more expensive to reliably analyse than metals, the likely risks to aquatic ecosystem health associated with them at most sites is currently considered to be lower than for metals, and the concentrations are not anticipated to increase much over time. The legacy contaminants, OCP and PCB, should in theory decrease over time as they are no longer legally used, but their environmental persistence may mean that the rates of decrease are slow. PAH may increase over time as a result of ongoing inputs from urban run-off. However, the concentrations of PAH are mostly well below sediment quality guidelines, indicating a low risk of unacceptable effects on aquatic organisms associated with these contaminants (Mills et al., 2012; Mills, 2014b).

Organic contaminant data acquired between 2003 and 2010 was reviewed by Mills (2014a), and based on the findings additional monitoring of PAH, OCPs, and PCBs at 26 mostly 'high risk' sites was conducted in 2012 and 2013 (Mills, 2014b). Based on the data collected, it was recommended that another survey be undertaken after 10 years (i.e. in 2022/23) to assess longer term trends at the 10 or 11 sites with concentrations above, or close to, Environmental Response Criteria (ERC) red levels.

Because of the high cost of analysis, organic contaminants are usually analysed on a single composite sample from each site. As discussed above, they are the subject of special 'one off' surveys of high risk sites and are not routinely monitored.

2.4.3 Total organic carbon

Total organic carbon (TOC), is used for calculating TOC-normalised contaminant concentrations, which are the units used for organic contaminant sediment quality guidelines (e.g. ANZECC (2000), ANZG (2018) and ARC (2004)). This reduces the variability associated with differences in the organic matter (the primary organic contaminant binding phase in sediments) content between samples and/or sites, and makes allowance for changes in contaminant bioavailability with changing organic matter content.

TOC is only analysed on samples analysed for organic contaminants, i.e. not routinely. It is usually analysed on a single composite sample from each site, the same sample analysed for organic contaminants.

2.4.4 Emerging organic contaminants

Emerging Organic Contaminants (EOCs)[1] are a very broad range of chemicals that are not yet routinely monitored in the environment but have potential to cause adverse ecological and/or human health effects. EOCs of major concern include endocrine disrupting chemicals (EDCs), and pharmaceuticals and personal care products (PPCPs). The main sources of EOCs have been found to include municipal sewage treatment plant effluent and associated biosolids, landfill leachate, urban stormwater and agricultural/horticultural run-off.

Chemicals of Potential Environmental Concern (CPECs) of relevance for the Auckland region were reviewed by Ahrens (2008). This review identified 42 CPECs, including flame retardants, plasticisers, estrogens, antifoulants and pesticides, and ranked them along with priority organic pollutants, according to their potential significance and relative environmental hazard. Based on this review, a scoping study of sediments from 13 estuarine locations around Auckland was undertaken in 2008, with samples analysed for 34 of the key CPECs that could be analysed by commercial laboratories at the time (Stewart et al., 2009). Subsequently, a range of common pharmaceuticals was also analysed on these samples (Stewart, 2013; Stewart et al., 2014). The key findings of these studies were summarised in Mills (2014a).

Determining the most appropriate suite of classes and compounds for analysis of EOCs is complex, and the current classes deemed to be of most concern may change or be refined in the future, as research into their fate, toxicity and effects continues. Previous research has identified a tiered approach as being the most appropriate method for monitoring and assessing EOCs, first identifying key EOC classes of concern, before conducting refined monitoring at selected high impact sites (Stewart et al., 2016). Currently, work is underway with a national research programme centred in the Waitematā's Whau Estuary, and the outcomes of this will help to further guide and determine future EOC monitoring direction and priorities in the region. Given that EOCs are not currently an integral component of routine RSCMP monitoring, they are not discussed in further detail in this report.

[1] Definitions of emerging organic contaminants can vary, however a commonly accepted description by the United States Geological Survey (USGS) describes EOCs as any synthetic or naturally occurring chemical or microorganism that is not commonly monitored in the environment but has the potential to enter the environment and cause known or suspected adverse ecological and (or) human health effects (USGS, n.d).

2.4.5 Particle size distribution

Particle size distribution (PSD) is used primarily to assess whether there have been changes in sediment texture that may influence contaminant concentrations e.g. increasing amounts of fine muddy sediment could increase the total recoverable metals' concentrations (and vice versa). It is also an integral component of the benthic ecology monitoring programmes, because sediment texture is a key factor influencing the benthic faunal assemblage and health.

PSD of each sample is measured across several particle size ranges, from very fine clay (<3.9 µm) to very coarse gravel (>2 mm). The most important PSD data used in the RSCMP is the 'mud fraction' (<63 µm fraction). This provides an integrative measure of changes in the proportion of the sediment where most contaminants are likely to be bound.

PSD has historically been determined by two different methods in the RSCMP. The main method used in the former SOE and RDP programmes, up to 2008, was laser particle size analysis. Where benthic ecology was also sampled at SOE and RDP sites, PSD was also analysed by wet sieving/pipette analysis (Lundquist et al., 2010). Since 2009, to obtain greater consistency across the contaminant and ecology monitoring programmes, a single PSD method (wet sieving/pipette analysis) has been used. (see section 4.2.7 for further detail). This is the method used in Auckland Council benthic ecology programmes, including the UWH programme.

Analysis of the data collected by the two PSD methods (Mills & Williamson, 2014) found that the 'mud fraction' (<63 µm fraction) measures were well correlated overall, with, on average, a 1:1 linear relationship. However, the relationship showed considerable scatter, and therefore there may be substantial differences between the two different measures of mud content at individual sites, especially at sandier sites, where the proportions of mud are low. Therefore, for state and trend assessment, only the sieve/pipette method results are now used – no laser PSD data are used.

One composite sample per site, made up from 10 sub-samples of the top 2cm of sediment taken from across the site, is analysed for PSD.

2.5 Quality assurance

Quality assurance (QA) is conducted to check that the RSCMP data are 'fit for purpose' – i.e. suitable for reliably assessing state and temporal trends. The QA system has evolved over time since the SOE programme first began in 1998. Details of the QA approaches used for the period 1998-2011 are given in Mills and Williamson (2014). The information from this review was used to develop a set of QA data quality 'acceptance guidelines', as described in Mills (2016a).

Current data acceptance guidelines include measures for:

- Potential sample contamination, as assessed from procedural blanks.
- Data accuracy, from analysis of Certified Reference Materials (CRM)[2].
- Year-to-year data consistency and within-year variability, as assessed principally from trend and variability analysis of CRM and Bulk Reference Sediment (BRS)[3].

The QA approach currently used, including the use of BRS to track data consistency over time, has been operating since 2011. CRM results have been acquired each year since 2002 for the former RDP programme and from 2009 for the former SOE and UWH programmes.

The application of the QA protocols can be found in annual RSCMP monitoring reports held by Auckland Council's Research and Evaluation Unit (RIMU).

Generally, data quality has found to be satisfactory for the purposes of the RSCMP. However, recent QA data analysis, undertaken for the 2017, 2018, and 2019 RSCMP sampling rounds, found significantly elevated Zn concentrations in the BRS, especially in the more contaminated muddy samples. The concentrations of Zn were approximately 9-12% higher than 'normal' in the low concentration sandy BRS samples, and 14-19% higher in the more contaminated mud samples. This means that Zn results for 2017, 2018, and 2019 may be artificially higher than they really are as a result of analytical artefacts, rather than from real environmental causes. State and trends may therefore be affected as a result.

The potential effects of the Zn analysis issue on trends were investigated by substituting 2017, 2018, and 2019 data with values corrected for the analysis artefacts, then reanalysing trends with the corrected data. This is detailed in section 9.1. As a result of these investigations, the effects on Zn trends were found to be minimal

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[2] Certified Reference Materials (CRM) are used to check data accuracy by comparing the lab-generated results with the certified concentrations and uncertainty limits for the reference materials. Three CRM samples (currently the CRM used is 'AGAL-10') are included in each analytical batch as 'unknowns', and analysed as for field samples. Note that the CRM analysis does not include the sediment preparation steps of sieving and drying prior to digestion and ICP-MS analysis, and therefore the CRM results may not completely reflect the total variation for field sediment sample analyses.

[3] Bulk Reference Sediment (BRS) are 'in-house' reference materials made up from bulk sediments sampled from two estuarine sites in 2011; one, more contaminated, muddy site from Middlemore (Tāmaki Estuary), and another, less contaminated, sandy site from Meola Outer Zone (Central Waitematā Harbour). Multiple replicates from each of these BRS are analysed with each batch of annual RSCMP monitoring samples and the results analysed to assess ongoing trends and variability. Details of BRS preparation are given in Mills (2016a).

provided a threshold for reporting meaningful trends of ±2% of the median per year was applied. The trends have therefore been assessed using the raw data, rather than using any correction for elevated 2017-19 results.

The effects on state assessment were less important, affecting only Zn results close to ERC thresholds. Where it is possible that the analytical elevation of Zn may have changed a site state, this has been mentioned in section 3.3 (state assessment).

2.6 Summary of contaminant data used

For this state and trend update, the data used are as follows:

- Total recoverable Cu, Pb, and Zn, using median concentrations from each sampling occasion for both state (using the latest available results at each site) and trends. Note that raw, uncorrected Zn values have been used.
- Mud content (% by weight <63 µm from sieve/pipette analysis), using a single composite sample result from each sampling, used for evaluating trends that may influence trends in metals' concentrations.
- Organic contaminants – PAH, organochlorine pesticides, and PCBs – single composite sample results at each site from surveys conducted between 2005 and 2013. The latest available results are used for state assessment. No trend data are available for organics.

3.0 Contaminant state

3.1 State assessment

The contaminant state is a measure of the potential risk of adverse ecological effects occurring on benthic organisms residing in the sediment, based on contaminant concentrations present in the sediment.

Contaminant concentrations are compared with sediment quality guidelines (SQGs), to provide an indication of the potential adverse effects of these contaminants on benthic ecology.

The SQGs currently used to assess the state of Auckland's marine sediments are the ARC Environmental Response Criteria (ERC; ARC, 2004). The ERC were derived from the Australian and New Zealand Environment and Conservation Council SQGs (ANZECC, 2000) and other internationally recognised guidelines considered at the time to be the most reliable for application to the Auckland environment. The rationale for the selection of the ERC guideline values is detailed in ARC (2004) and Williamson et al. (2017).

When established in 2000, the ANZECC guideline values were deemed to be 'interim' guidelines, (termed Interim Sediment Quality Guidelines; ISQGs) acknowledging that the science underpinning the values was developing, and that they would likely be revised in the future. A review of the ANZECC guidelines took place in 2013 (and updated in 2018), resulting in a revised set of default guideline values (DGVs) under the Australian and New Zealand guidelines for fresh and marine water quality (ANZG, 2018). The revised DGVs for organic contaminants differed from the previous ANZECC ISQG values, but the metals' guidelines remained unchanged.

The ERC, ANZECC interim guidelines, the more recent ANZG values, and the North American SQGs (CCME, 1999; Long et al., 1995; MacDonald et al., 1996), upon which the ERC (and ANZECC guidelines) are based, are summarised in Table 3-1. Further details of the origins of the ERC values, and their relationship to other associated SQGs are provided in ARC (2004), Williamson et al. (2017), and Mills (2019).

The ERC are considered to be conservative thresholds, generally lower than those recommended by the ANZG. The rationale for selecting lower contaminant thresholds is to provide an early warning of environmental degradation, allowing time for further investigations to take place and/or management responses to be properly assessed and implemented before more serious degradation can occur.

Table 3-1. Environmental Response Criteria (ERC; ARC 2004) and associated sediment quality guidelines. Guideline values the same as (or very similar to) the ERC are highlighted to show the relationship between the various guidelines.

	ERC (ARC 2004)			MacDonald et al. (1996)		CCME (1999)		Long et al. (1995)		ANZECC (2000)		ANZG (2018)	
Metals (mg/kg)[1]	Green	Amber	Red	TEL	PEL	ISQG	PEL	ERL	ERM	ISQG-Low	ISQG-High	DGV	GV-High
Copper	<19	19–34	>34	18.7	108.2	18.7	108	34	270	65	270	65	270
Lead	<30	30–50	>50	30.2	112.2	30.2	112	47	218	50	220	50	220
Zinc	<124	124–150	>150	124	271	124	271	150	410	200	410	200	410

	ERC (ARC 2004)			MacDonald et al. (1996)		CCME (1999)		Long et al. (1995)		ANZECC (2000)		ANZG (2018)	
Organics (µg/kg at 1% TOC)	Green	Amber	Red	TEL	PEL	ISQG	PEL	ERL	ERM	ISQG-Low	ISQG-High	DGV	GV-High
HWPAH[2]	<660	660–1700	>1700	655	6676			1700	9600	1700	9600		
Total PAH[3]	no ERC values			1684	16770			4022	44792	4000	45000	10000	50000
Total DDTs (DDE + DDD + DDT)	<3.9	no ERC amber values	>3.9	3.89	51.7			1.58	46.1	1.6	46		
DDT (o,p'- + p,p-')[4]	<1.2[4]		>1.2[4]	1.19	4.77	1.19	4.77					1.2	5.0
DDE (o,p'- + p,p'-)	<2.1		>2.1	2.07	374	2.07	374	2.2	27	2.2	27	1.4	7.0
DDD (o,p'- + p,p'-)	<1.2		>1.2	1.22	7.81	1.22	7.81			2	20	3.5	9.0
Chlordane	<2.3		>2.3	2.26	4.79	2.26	4.79			0.5	6	4.5	9.0
Dieldrin	<0.72		>0.72	0.72	4.3	0.71	4.3			0.02	8	2.8	7.0
Lindane	<0.3		>0.3	0.32	0.99	0.32	0.99			0.32	1	0.9	1.4
Total PCBs[5]	<22		>22	21.6	189	21.5	189	22.7	180	23		34	280

1. State based on ERC values for metals was originally based on total recoverable metals in the <0.5mm fraction in the settling zone (SZ), and the greater of the total recoverable metals in the <0.5mm fraction or the weak acid extractable metals in the mud fraction (<63 µm) within the outer zone (OZ). Total recoverable metals in the <0.5mm fraction are now used to assess state in both SZ and OZ.
2. High Molecular Weight PAH (HWPAH) is the sum of the concentrations of six PAH compounds – benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, fluoranthene and pyrene (as defined in ANZECC 2000).
3. Total PAH defined in ANZG (2018) as sum of 18 individual PAH compounds.
4. Total DDT (o,p' + p,p'-DDT): the ERC value given in the source document (ARC 2004) is 3.2 mg/kg. This may have been a typo error and should be 1.2, as given in the original source guidelines (CCREM 1999).
5. Total Polychlorinated biphenyls (PCBs)

A summary of the meaning of the ERC and recommended management responses are as follows (ARC, 2004):

- ERC Green conditions reflect a low level of potential chemical contaminant impact. Further investigations are not required unless significant changes in upstream catchment land use occur. State reassessment is recommended to occur every five years. However, more frequent monitoring may be warranted to serve as a baseline for assessing trends at other more contaminated sites.
- ERC Amber conditions are showing signs of contamination, having one or more contaminants above a level at which adverse effects on benthic ecology may be expected to begin to appear. Ecological evaluation is required to assess the actual biological impacts occurring. Depending on the outcome of this monitoring, further chemical testing may be required. Management actions taken as early as possible are likely to be most effective at limiting further degradation. These sites present the best opportunity to make a difference to the future quality of the receiving environment. Continued more frequent monitoring (e.g. every two years) is recommended to track any trends over time.
- ERC Red conditions are higher impact sites where significant degradation has already occurred, and remedial opportunities are often more limited. Restoration of the site may not be feasible in the short term, but actions should be taken to slow the rate of decline and limit the spread of contaminants. As for ERC amber sites, regular ongoing monitoring is recommended to track any trends over time.

Note that the original ERC values for metals were given for total recoverable metals in the <0.5mm fraction for sites located in Settling Zones (SZ), and the greater of the total recoverable metals in the <0.5mm fraction or the weak acid extractable metals in the mud fraction (<63 µm) for sites located in Outer Zones (OZ). Reviews of data quality (Mills et al., 2012; Mills & Williamson, 2014; Mills, 2016) have found that the results for extractable metals in the mud fraction were not reliable enough for ongoing use in the RSCMP. Therefore, metals' state from 2015 onwards has been assessed using the total recoverable metals (<0.5mm fraction) at all sites.

The overall contaminant state of a site is determined by the highest ERC grade of all the contaminants measured; e.g. if a site has an ERC-red Zn value, a green Pb, and an amber Cu and HWPAH, then the site is graded ERC-red.

State is assessed using the latest available data from each site. For metals, this is generally 2016-2019, and for Kaipara Harbour sites, 2009. For organic contaminants (PAH, OCPs, and PCBs), data are from 2005-2013.

Where multiple replicates have been analysed (e.g. for metals in most years), median concentrations at each site are used for state assessment. This provides a robust indicator of ‘average’ or ‘typical’ value, being less affected by occasional outlying values that can sometimes occur in environmental data.

Important note:

The state assessment is primarily based on comparison of contaminant concentrations with ERC values. Comparison with state assessed using the revised ANZG values has also been provided.

The overall state assessment given in this report is based on total recoverable Cu, Pb, and Zn.

Organic contaminants have not been included in the ‘overall state’ assessment because data for these contaminants are older (latest results are from selected sites in 2013) and have not been measured at the same range of sites as metals. However, the state for HWPAH and organochlorines (OCPs and PCBs) has been presented in the state table (Appendix 9.2) and summarised in section 3.5. Two of the 120 state sites, Cox’s Bay and Chelsea Bay in the Central Waitematā Harbour, have moderate HWPAH levels, which in combination with low TOC levels (sandy textures), give TOC-normalised concentrations in the ERC amber and red ranges respectively. This may reflect the low TOC levels (ca. 0.2-0.4%) at these sites as much as the moderate HWPAH levels, and therefore the ecological significance of these values is uncertain.

Arsenic (As) and mercury (Hg) are now routinely analysed at all RSCMP sites, but as yet, there are no regionally specific guideline values for these metals (i.e. no ERC values). Therefore, they have also not been included in state assessment in this report.

3.2 Sites used for state assessment

Sites used for state assessment have been selected to provide best overall spatial coverage without having overrepresentation in any one small area. Where there have been multiple sites in a similar location, these have been rationalised over time to provide more uniform spatial coverage.

Overall, 120 sites were selected for state assessment, with the following allocations between the seven Marine Reporting Areas (MRAs):

- 22 sites in the Central Waitematā Harbour
- 27 sites in the Manukau Harbour
- 9 in Tāmaki Estuary
- 16 in the Upper Waitematā Harbour
- 2 in East Coast Bays
- 10 in Hibiscus Coast

- 17 in the Tāmaki Strait
- 6 in the Kaipara Harbour
- 5 in the Mahurangi Harbour
- 6 in the Warkworth Wellsford MRA.

The locations of these sites are shown in the ‘state’ maps presented in Figure 3-4.

Tabulated data for these sites and are provided in Appendix 9.2.

In addition to these ‘core’ sites, a number of sites have been retired from routine monitoring. The data from these sites is not as up-to-date as for the core sites. The state of these sites at the time of last sampling is summarised in Appendix 9.3.

3.3 Metals’ state

3.3.1 State as assessed from Environmental Response Criteria (ERC)

The contaminant state of monitoring sites, based on total recoverable metals’ concentrations in comparison with ERC values, is summarised in Figure 3-1 and in Table 3-2.

The numbers and proportions of individual contaminant (metals) concentrations within each ERC range are shown in Figure 3-2.

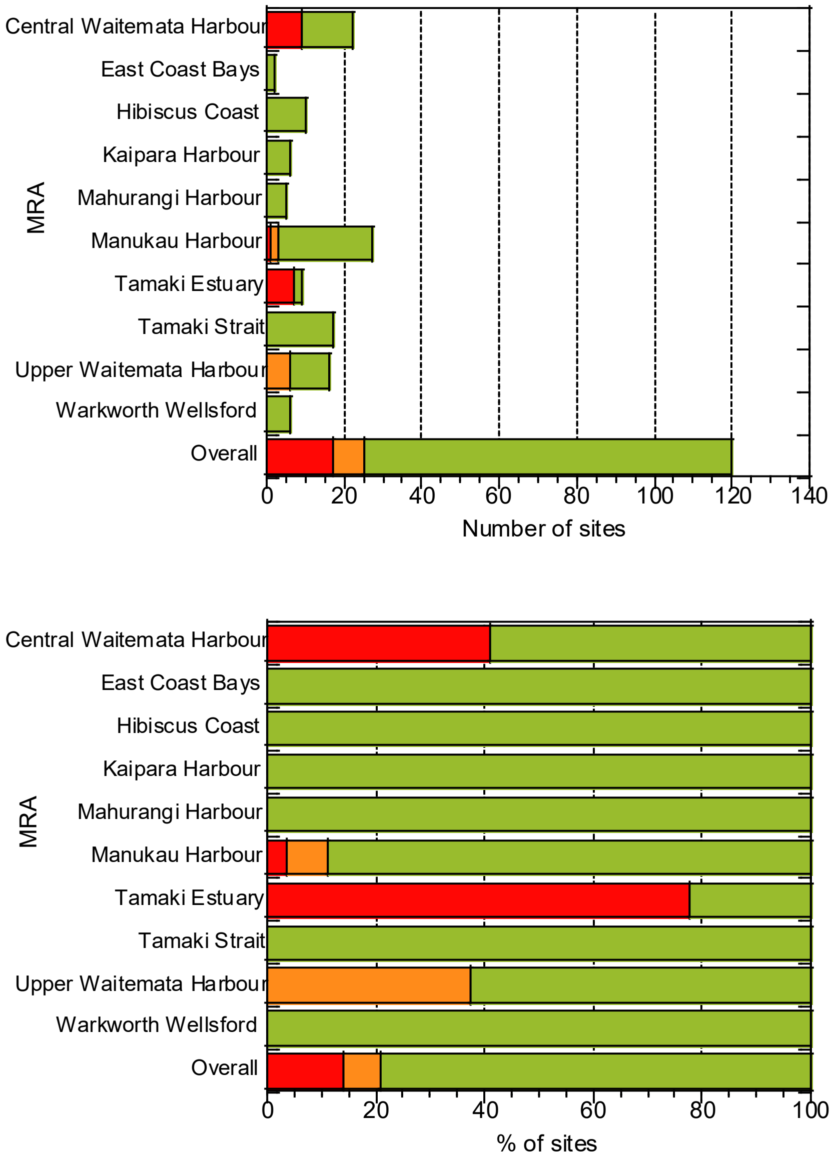

Figure 3-1. State summary for total recoverable metals for each MRA.

Numbers and percentages of sites with total recoverable metals' concentrations within the Environmental Response Criteria (ERC) green, amber, and red ranges for total recoverable metals. Sites are grouped by Marine Reporting Area (MRA) and for all sites used for state assessment.

Table 3-2. Numbers and percentages of monitoring sites within the ERC green, amber, and red ranges for total recoverable metals.

MRA	Numbers of sites				% of sites		
	Total sites	Green	Amber	Red	Green	Amber	Red
Central Waitemata Harbour	22	13	0	9	59.1	0.0	40.9
East Coast Bays	2	2	0	0	100.0	0.0	0.0
Hibiscus Coast	10	10	0	0	100.0	0.0	0.0
Kaipara Harbour	6	6	0	0	100.0	0.0	0.0
Mahurangi Harbour	5	5	0	0	100.0	0.0	0.0
Manukau Harbour	27	24	2	1	88.9	7.4	3.7
Tamaki Estuary	9	2	0	7	22.2	0.0	77.8
Tamaki Strait	17	17	0	0	100.0	0.0	0.0
Upper Waitemata Harbour	16	10	6	0	62.5	37.5	0.0
Warkworth Wellsford	6	6	0	0	100.0	0.0	0.0
Overall	120	95	8	17	79.2	6.7	14.2

Overall, 95 of the 120 state sites (79%) are rated as ERC-green – i.e. having no total recoverable metals (Cu, Pb, or Zn) present at concentrations exceeding the ERC green/amber threshold. Based on this assessment, these metals should pose only a low level of risk to benthic fauna at most sites.

Eight of the 120 sites (approximately 7%) were rated as ERC-amber, i.e. where the highest metals' concentration falls in the ERC-amber concentration range. Six of the eight amber sites are located in the Upper Waitematā Harbour (mostly associated with slightly elevated Cu levels, just above the green/amber threshold), and the other two were in the inner reaches of the Manukau Harbour (Māngere Inlet) with moderate Zn concentrations.

High contaminant concentrations, where at least one of the metals falls in the ERC-red range, were found at 17 sites (14%); nine sites in the Central Waitematā Harbour, seven in the Tāmaki Estuary, and one in Manukau Harbour (Ann's Creek, Māngere Inlet). Of the ERC-Red threshold exceedances, all were for Zn, with one Central Waitematā Harbour site (Whau Wairau) also having ERC-red levels of Cu and Pb. Whilst these sites fell in the ERC red range, indicating that ecological degradation will have already taken place, none exceeded the recommended DGV-High thresholds set in the ANZG.

Note that two of the ERC-red sites, Henderson Lower (Central Waitematā Harbour) and Ann's Creek (Manukau Harbour), had Zn concentrations only marginally above the amber-red threshold (150 mg/kg) at 153 and 152 mg/kg respectively. These values were reported in 2018 and 2019 and may be slightly elevated by laboratory analytical issues for these samplings (see section 2.5, Appendix 9.1). These sites may therefore be ERC-amber rather than red. Similarly, site Central Main in the Upper Waitematā Harbour, had a Zn concentration of 125 mg/kg in 2018, which is just above the ERC green/amber threshold of 124 mg/kg. This site has been ERC-green since monitoring began in 2005. The amber Zn concentration may well, therefore, be a result of laboratory analytical issues rather than an actual increase in Zn state over time.

The Tāmaki Estuary (in its upper reaches and the older urbanised sub-estuaries) and muddy estuaries of the Central Waitematā Harbour have the highest proportions of red sites and are therefore potentially the most likely to be adversely impacted by metals' contamination.

Zinc concentrations exceeded ERC red levels more frequently than Cu or Pb, which were ERC-red at only one site (Whau Wairau in the Central Waitematā). Amber thresholds were exceeded most frequently overall by Cu. In the Central Waitematā Harbour, Pb was noticeably elevated, exceeding the amber ERC threshold at seven of the 22 sites (32%).

Total recoverable metals' concentrations (medians from most recent sampling, as used for ERC state assessment) for all the sites grouped and for each MRA, are shown in Figure 3-3.

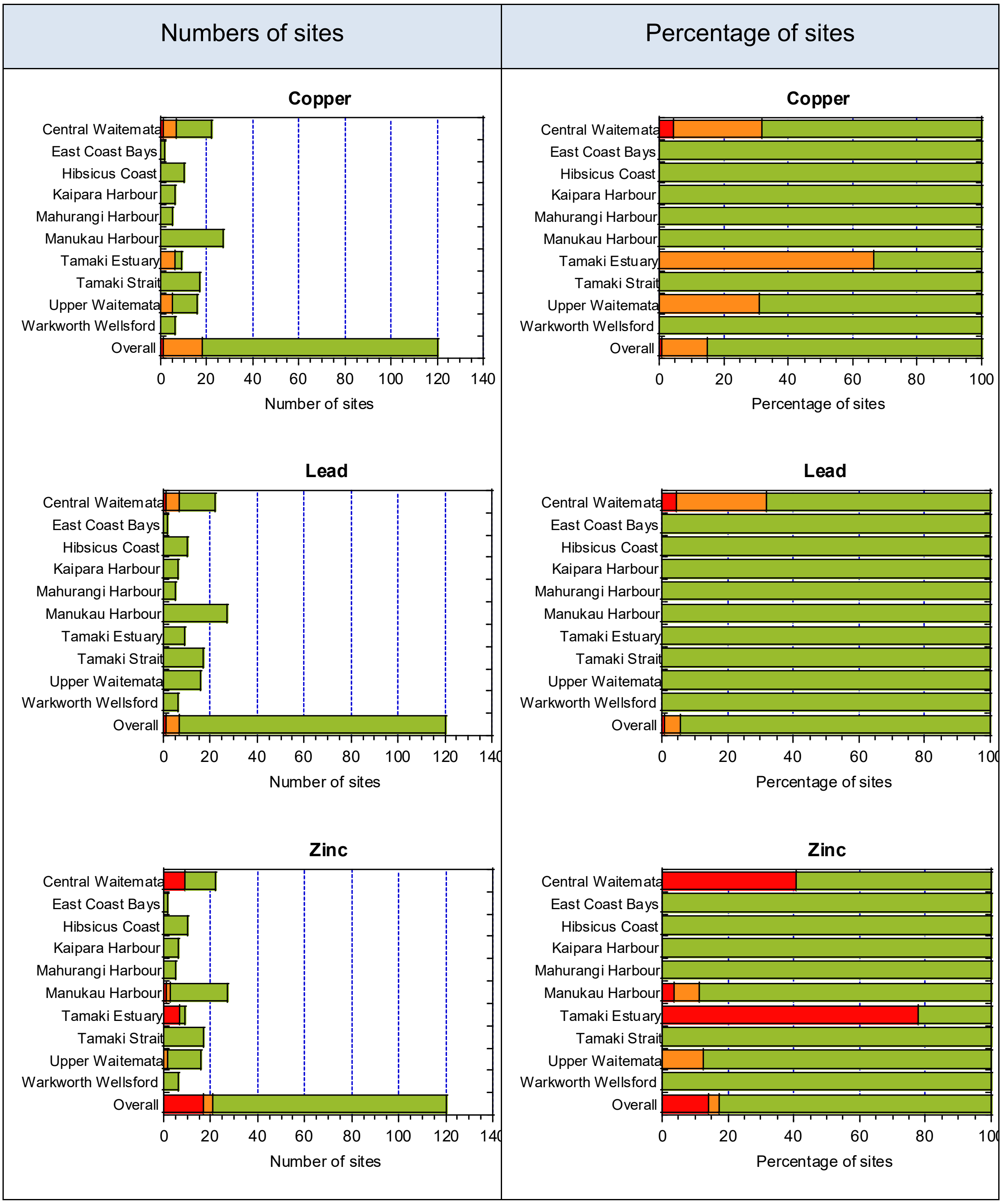

Figure 3-2. Contaminant state for each of copper, lead, and zinc for each MRA.

Numbers and proportions of sites with total recoverable metals' concentrations within the Environmental Response Criteria (ERC) green, amber, and red ranges for each contaminant. Sites are grouped by location (Marine Reporting Area; MRA) and for all sites selected for state assessment (overall).

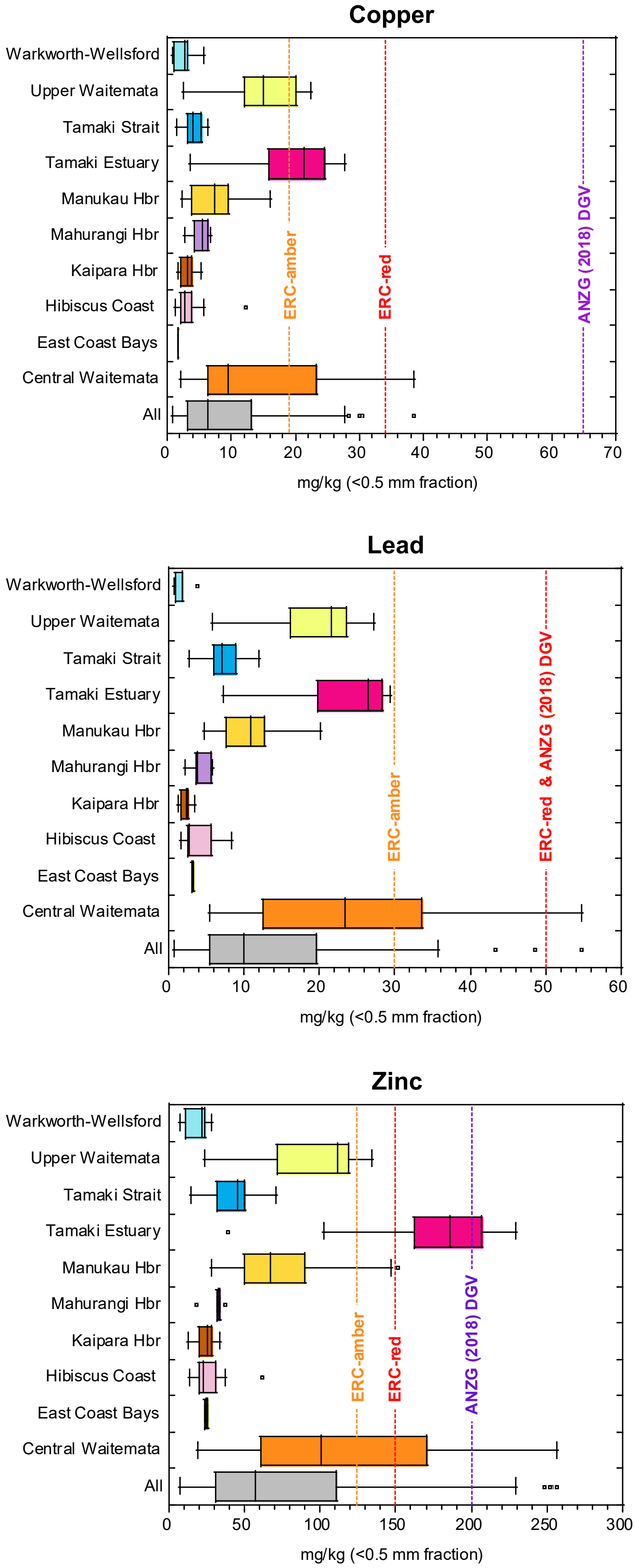

Figure 3-3. Concentrations of total recoverable metals relative to Environmental Response Criteria (ERC) and Australian and New Zealand guidelines for fresh and marine water quality (ANZG) for each MRA.

3.3.2 State as assessed by comparison with Australian and New Zealand guidelines for fresh and marine water quality (ANZG)

The ANZG DGV for copper (65 mg/kg) and zinc (200 mg/kg) are higher than the ERC-red values (34 and 150 mg/kg respectively), while for lead the ANZG (50 mg/kg) is the same as the ERC-red threshold (Table 3-1, Figure 3-3). The ANZG DGVs are all higher than the ERC green-amber threshold values. Fewer sites will therefore trigger the ANZG guideline thresholds for adverse ecological effects than the ERC. More sites will be classed as 'green' (below the DGVs), and fewer will have 'amber' or 'red' state.

Of the 120 sites used for state assessment, 113 (94%) had highest median metals' concentrations below the DGV, seven sites (6%) had concentrations between the DGV and the GV-High, and no sites (0%) had concentrations greater than the GV-High values.

This compares with 95 sites (79%) with ERC-green state for metals, 8 sites (7%) ERC-amber, and 17 sites (14%) ERC-red.

The seven sites with metals' concentrations greater than the DGVs were:

- Meola Inner, Motions, Whau Upper (all for Zn) and Whau Wairau (Pb and Zn) in the Central Waitematā Harbour.
- Bowden, Middlemore, and Pakuranga Upper (all for Zn) in the Tāmaki Estuary.

If the ANZG guidelines were used to assess metals' state in Auckland's marine sediments, only a very small proportion (6%) of sites would have concentrations high enough to trigger further investigations (e.g. metal bioavailability, ecological effects). These sites are muddy inner estuary sites situated in the intensively urbanised catchments of the Central Waitematā Harbour and Tāmaki Estuary. All except one of the DGV exceedances were for Zn, the other was for Pb.

3.4 Spatial patterns of contamination

A wide range and number of potential contamination sources influence the levels and spatial distribution of chemical contaminants present in Auckland's marine receiving environment. These include urban stormwater (the major 'diffuse' pollution source from the urbanised land area), run-off from past and present-horticultural land, landfill leachate, contaminated sites, industrial processes, marinas, and boat mooring areas.

The spatial distribution of ERC grades for each individual metal are shown in Figure **3-4**.

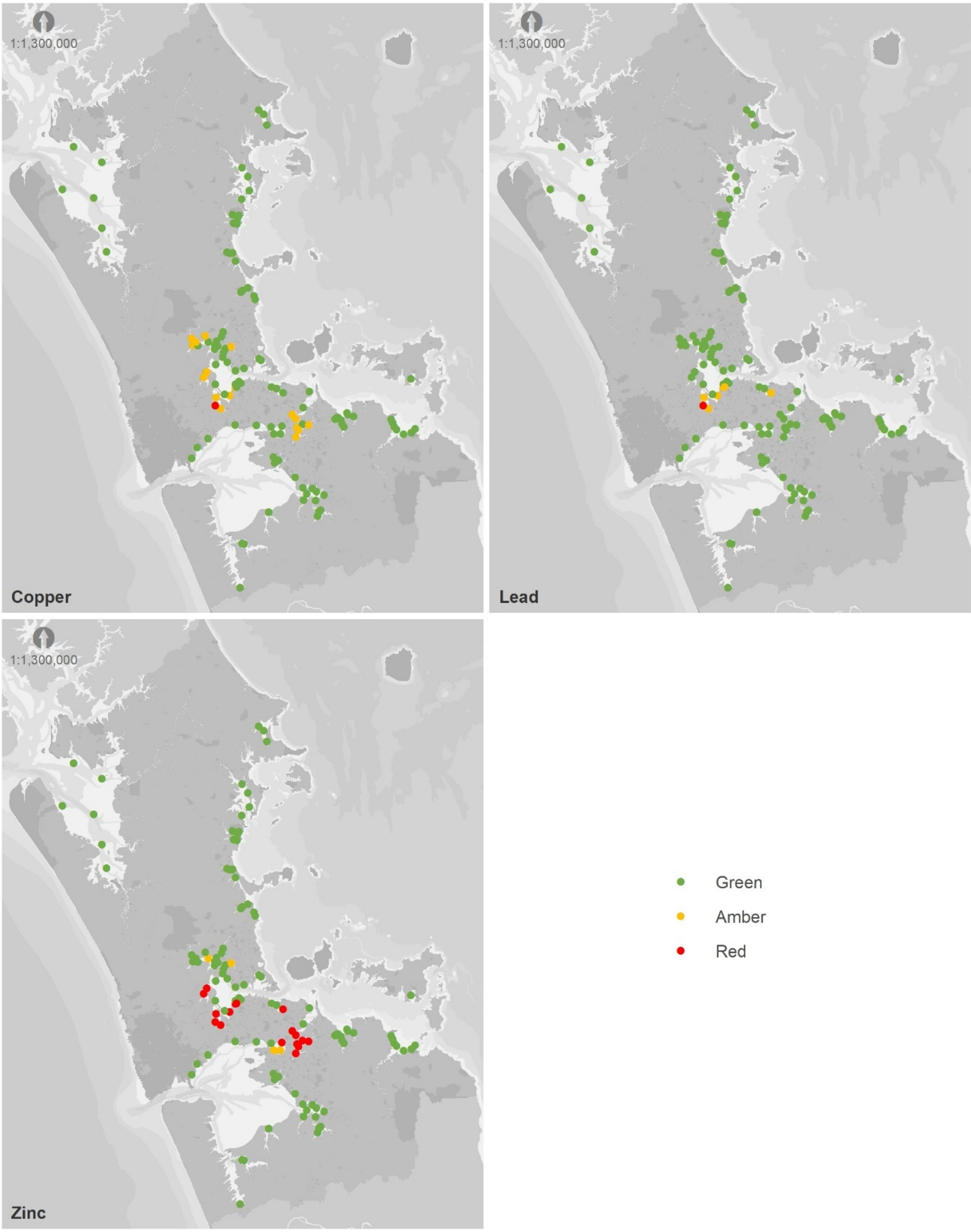

Figure 3-4. Map of Environmental Response Criteria (ERC) contamination state based on concentrations of total recoverable copper, lead and zinc.

The spatial patterns in metals' concentrations shown above are broadly the same as those detailed in previous reports (e.g. Mills et al., 2012).

Highest concentrations of metals are present at muddy upper estuary sites receiving run-off from the older urban and industrial catchments of Auckland City – Henderson Creek to Cox's Bay along the southern shores of the Central Waitematā Harbour (including Whau, Motions, and Meola estuaries), in Hobson Bay (Purewa), the upper reaches and side-branches of the Tāmaki Estuary (e.g. Middlemore, Panmure, Ōtāhuhu, and Pakuranga) and, to a lesser degree, Māngere Inlet in the Manukau Harbour.

The Central Waitematā Harbour is widely contaminated. Contamination gradients extend out from the inner estuary, usually muddy, settling zones (where concentrations are generally highest) into adjacent, generally coarser-textured outer zones. The inner reaches of the Meola, Motions, and Whau estuaries represent the most contaminated sites routinely monitored in Auckland, having high concentrations of Zn, and moderately elevated concentrations of Cu and Pb.

Concentrations of metals in the Upper Waitematā Harbour are generally low, but are slightly higher than expected for the predominantly rural surrounding land use. The causes of the slightly elevated metals' concentrations are, as yet, unknown.

The concentrations of metals are generally low in most areas of the Manukau Harbour. Concentrations are moderately elevated in Māngere Inlet, which is likely related to historical industrial pollution. The reasons for the predominantly low concentrations across the Manukau Harbour are a mixture of factors, including the large size of the harbour, relatively small watershed with a small proportion of urban area, and relatively recent urbanisation.

The Tāmaki Estuary has highly contaminated areas in its older, densely urbanised, headwater zones (e.g. Middlemore, Pakuranga, Ōtāhuhu, and Panmure). Contamination decreases with distance away from these areas, so that the lower reaches of the estuary (e.g. Roberta Reserve, Glendowie) have much lower levels of metals. Nearly all of the upper estuary sites had Zn levels in the ERC-Red range, indicating that Zn is a key contaminant for potential ecological impacts in the Tāmaki.

The predominantly rural estuaries and harbours outside of central Auckland – e.g. Orewa, Okura, Mahurangi, Wairoa, Kaipara, Waikopua, Waiwera – have relatively low levels of metal contamination.

The East Coast Bays' sites, Awaruku and Vaughans sites at Long Bay, are located on open coastal beaches. Contaminant build up is limited by the relatively high wave energy, which tends to disperse fine sediments and their associated contaminants. Contaminant concentrations are therefore low at these sites.

3.5 Organic contaminant state

3.5.1 Organic contaminant data for state assessment

Organic contaminants (polycyclic aromatic hydrocarbons (PAH), organochlorine pesticides (OCPs), and polychlorinated biphenyls (PCBs)) have been analysed less frequently, and at fewer sites, than metals. The most recent data were collected from 13 sites in 2012 and another 13 in 2013, covering mostly higher risk sites, where organics were considered to be most likely to pose a risk to benthic aquatic fauna.

PAH data were collected at former SOE sites until 2005, SOE sites sampled in 2003 were also screened for OCPs and PCBs, and a selection of the higher risk SOE sites were analysed for OCPs in 2007. PAH were analysed at UWH programme sites between 2005 and 2013. Analysis of PAH, OCPs, and PCBs was included in one-off surveys of Kaipara and Whangateau Harbours in 2009, and for several predominantly rural estuaries (Okura, Orewa, Waiwera, Waikopua, Puhoi, Mahurangi, and Turanga) in 2010.

The results for these surveys have been documented in Mills (2014a and 2014b), and PAH results to 2010 were included in the previous state and trends assessment (Mills et al., 2012). The state summary table (Appendix 9.2) shows the resulting state and year of sampling for PAH, OCPs, and PCBs from the most recent available data.

3.5.2 Organic contaminant state assessed from Environmental Response Criteria

PAH concentrations at most sites are fairly low (ERC-green), well below the ERC-amber threshold at nearly all sites. Elevated PAH concentrations (ERC-red or amber) were present at only four of the 69 sites (see Appendix 9.2), all in the Central Waitematā Harbour:

- Motions and Chelsea, which exceeded the ERC-red threshold.
- Meola Inner and Cox’s Bay, which were in the ERC-amber range.

The high concentrations at Motions and Meola Inner are possibly a result of historical contamination by coal tar residues used in roading up until the 1960s-1970s (Depree, 2003; Ahrens & Depree, 2006; Depree & Ahrens, 2007a; Depree & Ahrens, 2007b). Leachate from the adjacent historical landfill is also a possible contributor to elevated levels of PAH (and other contaminants) at these sites.

The elevated PAH levels at Chelsea and Cox’s Bay are partly an artefact of the sediment quality guidelines for PAH (and other organic contaminants) being expressed in terms of ‘Total Organic Carbon normalised’ concentrations, where the contaminant concentration is calculated on the basis of the sediment containing 1% TOC. These are both sandy sites, with low TOC content (approximately 0.2-0.4%). The presence of moderate PAH concentrations combined with the low TOC content at these sites results in relatively high TOC-normalised concentrations and hence exceedance of the ERC-amber threshold.

PAH was the state-determining contaminant at Chelsea and Cox’s Bay, the only two sites where metals (usually Zn) do not determine the overall site state.

Organochlorines (OCPs and PCBs) have only an ERC green/red threshold – there is no ERC amber range. To obtain information on concentrations close to the ERC red threshold, the reviews of 2003-2010 organic contaminants data (Mills, 2014a) and the 2012/13 results (Mills, 2014b) gave ‘light red’ grades to data within 10% of the ERC-red threshold (in either absolute, or TOC-normalised concentrations). This enabled sites with elevated concentrations near to, or above, the ERC-red level to be identified and prioritised for future monitoring.

PCBs were below the ERC-red threshold at all sites. However, elevated concentrations were found at Meola Inner and to lesser degree at Whau Wairau and Henderson Upper. While not exceeding the ERC-red threshold, the PCB levels at these sites were markedly higher than those found at other sites.

DDT compounds (DDE, DDD, DDT) were the only organochlorine pesticides (OCPs) that were close to, or exceeded, ERC-red thresholds. The ERC-red threshold was exceeded at only one site – Meola Inner (Central Waitematā Harbour). Sites with DDT concentrations near the ERC-red range were Henderson Upper, Whau Upper, Whau Wairau, and at a lower concentration, Oakley. These sites are all in the Central Waitematā Harbour.

Concentrations of the other OCPs such as lindane, endrin, and chlordane were either below detection limits, or very close to the laboratory blank levels. It appears that DDTs (DDE, DDD, and DDT) remain the most significant OCPs persisting in marine receiving sediments.

Based on their ERC grades, PAHs were at concentrations representing lower environmental risk than metals. Unlike the legacy OCPs and PCBs, which are no longer in use and should therefore be decreasing in the environment, PAHs may possibly increase at some sites over time in response to ongoing urban stormwater inputs. In addition, it is possible that they may contribute to cumulative contaminant multi-stressor effects. For these reasons, PAH analysis at higher risk sites should continue to be undertaken. Another round of PAH, OCP, and PCB monitoring at about 10 of the most contaminated sites has been recommended for 2022/23 (Mills, 2014b).

3.5.3 Organic contaminant state as assessed using ANZG

The ANZG DGVs are higher than the ERC values for all contaminants (Table 3-1) apart from:

- DDT, for which the ANZG DGVs are the same as the ERC-red values (1.2 µg/kg).
- DDE, for which the ANZG DGV (1.4 µg/kg) is lower than the ERC-Red value of 2.1 µg/kg.

As discussed previously (section 3.5.2), using the ERC for state assessment, organic contaminants were found to be in the amber or red ranges for only four sites, all in the Central Waitematā Harbour:

- Motions – ERC-red for high weight polycyclic aromatic hydrocarbons (HWPAH)
- Chelsea – ERC-red for HWPAH
- Cox's Bay – ERC-amber for HWPAH
- Meola Inner – ERC-red for organochlorine pesticides (DDTs).

Motions and Meola Inner were also ERC-red for metals (Zn). Therefore, organic contaminants were 'state-determining' contaminants only for two sites; Chelsea and Cox's Bay, both for HWPAH.

Using the ANZG DGVs, two sites would be classed as having a 'red' state: Meola Inner and Henderson Upper, both for organochlorine pesticides (DDTs). Concentrations were only slightly above the DGVs:

- Henderson Upper had a DDE concentration of 1.95 µg/kg (at 1% TOC) compared with the DVG of 1.4 µg/kg (at 1% TOC).
- Meola Inner had a DDT concentration of 1.3 µg/kg (at 1% TOC) compared with the DGV of 1.2 µg/kg (at 1% TOC).

Meola Inner had a Zn concentration above the DGV, but below the GV-High, and could therefore be classed as having an 'amber' metals state. Metals at Henderson Upper were below the DGVs ('green' state). No sites had PAH concentrations above the DGV (Total PAH of 10,000 µg/kg at 1% TOC[4]).

Using the ANZG, organic contaminants were therefore 'state-determining' contaminants for two sites; Meola Inner and Henderson Upper, both for DDTs. Because these organochlorine pesticides are no longer legally in use, it is likely that

[4] For the status assessment conducted here, Total PAH was estimated from HWPAH by multiplying by 1.86, the average Total PAH:HWPAH ratio calculated from 26 sites sampled in 2012/13 (Mills, 2014).

concentrations will decline over time as a result of source depletion and environmental breakdown, and in future will be present at concentrations well below DGVs.

The overall state picture for the RSCMP is affected very little if organic contaminants are included in state assessment and concentrations compared with the ANZG DGVs. Only two sites (out of 69 sites with organic contaminant data) exceeded the DGVs, and these exceedances were minor and likely to decrease over time.

3.6 Changes in state over time

The state assessment presented in this report, and that from the 2010 assessment (reported in Mills et al., 2012) cannot be directly compared to assess changes in state over time. This is because of:

- the different numbers and locations of sites included in each assessment, with 81 sites used in 2010, and 120 sites (including more predominantly rural sites) in the current assessment
- the change in the way state has been assessed between the two reviews. The previous review followed the approach given in ARC (2004), using a combination of total recoverable metals in Settling Zones (SZs) and the greater of the total recoverable or extractable (<63 μm) metals at Outer Zones (OZs). PAH were also included (although as outlined above, this makes little difference to the overall state). In the current review, state has been based only on total recoverable metals at all sites.

The combination of these differences is likely to give a smaller proportion of contaminated sites (ERC-amber or red) and relatively more ERC-green sites.

Changes in state over time have therefore been examined by compiling the state history from each monitoring round for each site, based on total recoverable metals data only. A summary is presented in Appendix 9.2.3.

The comparison shows that there has been no consistent change in state over time at nearly all the RSCMP sites. The only sites where there has been a definitive change over time in state are:

- Māngere Cemetery (Māngere Inlet, Manukau Harbour), where the metals' levels have dropped sufficiently over time to improve the state from amber in 1998 (and red in 2001) to green (since 2013).
- The nearby Ann's Creek site, which also improved over time, changing from ERC-red (in 1998 to 2005) to amber (in 2013). However, the Zn result in 2018 increased to just above the ERC-red threshold (possibly influenced by analytical artefacts for Zn discussed in Appendix 9.1.). Assuming the elevated 2018 value

for Zn is an analytical artefact, it is likely that, the metals' state at Ann's Creek has probably improved.
- Shoal Hillcrest, in the muddy upper reaches of Shoal Bay (Central Waitematā Harbour), where Pb has decreased sufficiently over time to change the state from amber (2004 to 2012) to green (2015 to 2019).

Other sites have shown no consistent change in state or have been variable (sometimes because concentrations show small variations around ERC thresholds). See the state history table (Appendix 9.2.3) for site specific detail.

3.7 State summary

Contaminant state was assessed by examining the most recently available total recoverable metals (Cu, Pb, and Zn) and organic contaminant (PAH, OCP, PCB) data.

At the vast majority of sites, the overall state was determined by metals (usually Zn). Based on ERC grades, only two of the 120 sites used to assess state had organics as the state determining contaminants; these were Chelsea and Cox's Bay, where PAH levels were sufficiently elevated to trigger ERC-red and amber grades respectively (partly because of low-TOC, sandy textured sediments), while metals were in the ERC-green range. Organochlorine pesticides (DDTs) at Meola Inner, and PAH at Motions, were also high enough to give ERC-red state, which was equalled by the Zn state at these sites.

Using total recoverable metals to assess contaminant state, 95 of the 120 sites (79%) were assessed as ERC-green. By this measure, risks to benthic aquatic life associated with metals' contamination would be expected to be low at most monitoring sites. Only at 17 sites (possibly 15, see footnote) directly influenced by intensive urban development or local contamination sources were contaminants at ERC-red state levels, all of which were in muddy inner estuary sites in the Central Waitematā Harbour and Tāmaki Estuary[5]. At these sites, higher risks to benthic ecology may be expected as a result of elevated contaminant levels. ERC-amber levels were found in a few mostly muddy estuary sites in the Upper Waitematā Harbour (which were mostly just in the amber range for Cu) and at two muddy sites (possibly three if Ann's Creek is included – see footnote) in Māngere Inlet, Manukau Harbour, which were in the amber range for Zn. Risks to benthic health at these amber sites associated with the moderate contaminant levels are likely to be higher than at ERC-green sites but lower than those at ERC-red sites.

[5] Ann's Creek in Māngere Inlet, Manukau Harbour, and Henderson Lower (Central Waitematā) were just ERC-red for Zn in 2018 and 2019 respectively, which may have been influenced by analytical issues. These sites have otherwise been ERC-amber since 2007 and 2002 respectively.

Using the ANZG and total Cu, Pb, and Zn to assess state gave a larger proportion (94%) of green state sites, and smaller proportions of amber (6%) and red (0%) than found when basing state on ERC grades. This reflects the higher values for the ANZG DGVs than the ERC amber or red values. If the ANZG DGVs were used in place of the ERC, fewer (6%) sites would require further investigation (compared with 21% based on ERC-amber or red graded sites).

Contaminant state has remained stable at nearly all the monitoring sites, with very few consistent changes over time. Only three of the 120 state sites showed changing state, and these were all improvements due to decreasing metals' concentrations – Māngere Cemetery and Ann's Creek (both in Māngere Inlet, Manukau Harbour), and Shoal Hillcrest, in the muddy upper reaches of Shoal Bay (Central Waitematā Harbour). The lack of major changes in state is consistent with the generally small trends in metals' concentrations over time that have occurred at most sites (section 5.0).

Overall, the sediment contaminant state of the region's harbours and estuaries remains essentially the same as previously reported (Mills et al., 2012). Most areas situated away from intensively developed urban catchments have low levels of contamination, below those usually associated with adverse ecological effects. Older, intensively developed urban sites have highest contaminant levels and at the worst of these would be expected to pose risks to benthic ecological health

Cautionary note:

It is important to note that the contaminant data represent only one part of the overall environmental picture required to assess ecological effects. While most of the monitored sites have contaminant concentrations in the 'green' range (i.e. below the ERC-amber threshold or ANZG DGVs, where there is a low risk of adverse biological effects due to contaminants), AC's Benthic Health Model (see Anderson et al., 2006; Drylie, 2021; Hewitt et al., 2009; Hewitt et al., 2012) indicates that adverse effects on benthic community health are being found in the ERC-green range of metals' concentrations. Hence, conclusions on ecological effects based solely on comparisons of contaminant concentrations with ERC or ANZG DGVs must be treated with some caution. As intended by the ERC and ANZG, the contaminant data are just one 'line of evidence' and, rather than representing 'pass/fail' thresholds, they represent a measure of relative risk which should be used to trigger or guide further investigations (e.g. contaminant bioavailability, effects of other variables such as fine sediment accumulation, trend assessment, contaminant source investigations) at locations considered to be at higher risk of unacceptable ecological impacts.

4.0 Trend assessment

4.1 Overview

A key component of the RSCMP is the assessment of ‘temporal trends’; changes in contaminant concentrations over time. Trend assessment aims to determine whether contaminant concentrations in receiving marine sediments are increasing, decreasing, or remaining constant over time. This provides an indicator of the effects of land use over time on receiving waters, and of the effectiveness of catchment land use and environmental resource management policies and interventions.

Trend assessment involves undertaking statistical analysis of the monitoring data to obtain the ‘trend slopes’ (magnitude of change per year, and the direction of change) and a measure of the likelihood of these changes over time being real (or whether the changes are more likely to be attributable to chance, given the combination of data variability in relation to the magnitude of the change).

The real-world relevance, or ‘meaningfulness’, of trends should also be assessed. For example, changes might be considered ‘meaningful’ if they are linked with changes in ecological health, if they can be associated with known changes in catchment land use or management, or if the rates of change exceed those required to exceed defined triggers (e.g. Environmental Response Criteria; ERC) within time frames considered relevant for management purposes.

The trend analysis results presented here form only one part of the ’weight-of-evidence’ for overall assessment of potential impacts on the marine environment. When combined with other information – e.g. trends in ecological health, catchment land use changes, contaminant management measures being implemented, targets or triggers for unacceptable rates of change in contaminant levels – a more complete evaluation of the ‘meaningfulness’ of the trends reported here could be made.

4.2 Factors to be considered when assessing trends

A range of factors need to be taken into consideration when analysing and interpreting the meaningfulness of the RSCMP trend monitoring data. These were discussed by Mills et al. (2012) for the previous trend assessment review. Many of these factors remain relevant to the trends update provided here, and therefore edited excerpts from the Mills et al. (2012) report are given below.

Assessing the nature and magnitude of temporal trends in environmental monitoring data is not necessarily straightforward. Many environmental data do not necessarily follow simple trends or patterns (e.g. linear changes over time) that can be described using simple descriptive parameters (e.g. linear ‘regression slopes’ or ‘rates of change’). Rather, trends can change in magnitude and/or direction over time in response to the combinations of many influential variables, both natural and anthropogenic (e.g. climatic variation, catchment development, implementation of management interventions such as stormwater treatment). This complexity needs to be considered when interpreting the trend analysis results.

In addition, the ‘robustness’ of trend monitoring results may be affected by factors associated with the monitoring itself – for example; analytical variability, sampling frequency and length of monitoring period, consistency in sampling and analysis methods over time, and monitoring site disturbance.

Ideally, the trend monitoring data would be acquired over the same time period, at the same frequency, using the same sampling methodology, and the samples analysed by exactly the same laboratory methods. This is not the case for the RSCMP sediment contaminant monitoring undertaken to date. This is partly because the three major contributing monitoring programmes were originally designed with different primary objectives in mind (e.g. SOE mainly aimed at long-term state and trends assessment, RDP for stormwater impacts assessment, and UWH primarily focused on ecological health monitoring).

The following sections (4.2.1 - 4.2.9) outline the characteristics of the available monitoring data and how they have been used to obtain the most consistent data set for use in trend assessment.

4.2.1 Monitoring periods and sampling frequencies

Sediment chemistry monitoring data from the former SOE, RDP, and UWH programmes were available for assessing temporal trends. Each programme differs in the number of sites, the monitoring period covered, and the number of samplings that have been undertaken:

- The former SOE programme, with data from 27 sites, covers a 20 year period for most sites, from 1998 to 2018. Not all 27 sites were monitored over this entire period, with some sites (e.g. beach sites) being retired from regular sampling at various times. Twenty two SOE sites had data series considered suitable for trend assessment. To provide a time period more consistent with the RDP and UWH programme data set, a selection of data covering the period 2005-2018, rather than the whole data set, was used for the trend assessment. The effect of this approach is discussed below.
- The former RDP programme had suitable monitoring data for a 13 -15 year period, from 2004 to 2016-2019 (depending on the site) from a total of 22 sites. Some RDP sites were also sampled in 2002 by ARC (KML, 2003), North Shore City Council (URS, 2002), and Auckland City/Metrowater (Webster et al., 2004),

at a range of locations across the region, with some sites close to those later sampled in the routine RDP programme. The exact location of some of these sites is uncertain, and the comparability of the analytical results with later RDP data could generally not be checked. The 2002 data were therefore excluded from this trend assessment.

- The UWH programme, which had 12 sites monitored over a 13 year period from 2005-2018 (inclusive).

To provide a more reliable basis for assessing regional trends across all the sites, a core set of monitoring data covering a common time period (and preferably consistent sampling and analysis protocols) is required.

State of the environment sites have been monitored for longer than sites in the RDP or UWH programmes. To minimise potential bias introduced from the longer monitoring period and earlier starting date at former SOE sites, the SOE data from 1998-2003 were excluded, and only the 2005-2018 data were included in the trend assessment. This also reduced the inconsistency in sample replication between the programmes (see section 4.2.4).

This provided a ‘core’ set of monitoring data, covering the period 2004 to 2019; from 2005 to 2018 for most of the SOE sites, 2004-2019 for most RDP sites, and 2005-2018 for UWH sites. The monitoring data selected for trend assessment are shown in Figure 4-1.

The effect of excluding the 1998-2003 SOE data on trend results was assessed in an interim analysis conducted with data collected to 2016, by comparing trends in metals’ concentrations obtained from each of three time periods in the SOE programme:

- 1998-2005 – a ‘short-term’ (ST) period of 7 years at the start of the monitoring programme.
- 2005-2016 – a ‘medium-term’ (MT) period of 11 years, comparable with that covered by the RDP (2004-2016) and UWH (2005-2016) programmes.
- 1998-2016 – a ‘long-term’ (LT) period of 18 years, covering the entire SOE monitoring period (to the end of 2016).

The results from these trend assessments are summarised graphically in Figure 4-2. They indicate that trends in the medium-term (2005-16) SOE data were similar to those observed in the long-term (1998-2016) data record. Therefore, the selection of SOE data from 2005 onwards (exclusion of the early 1998-2003 data) for the trend analysis presented in this report, is likely to have little effect on the overall trend results for SOE sites.

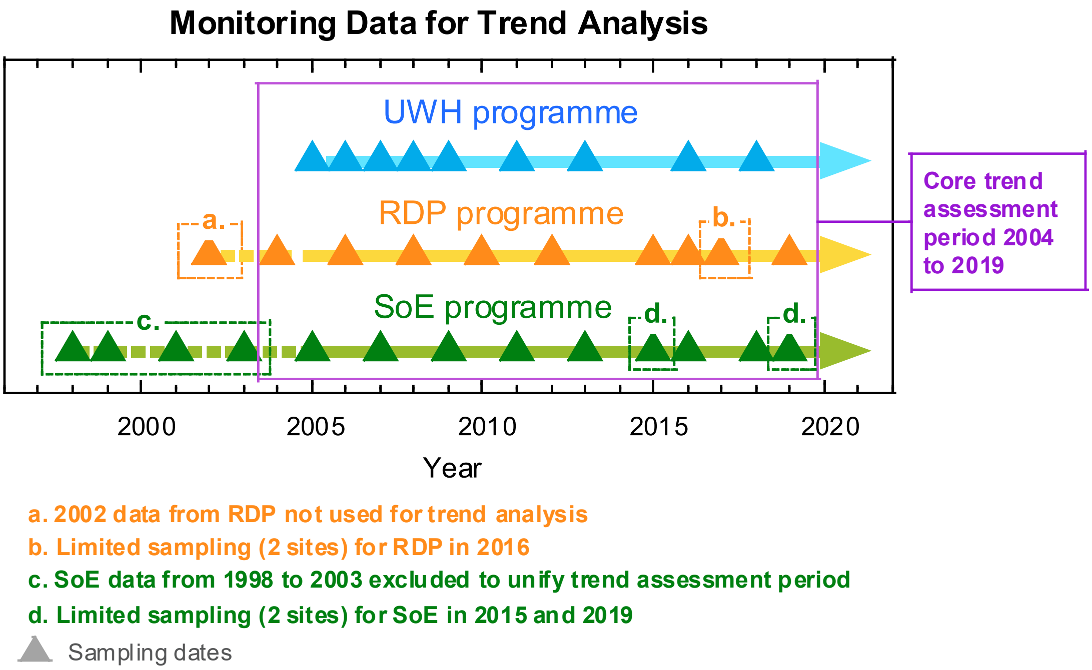

Figure 4-1. Monitoring data selected for trend assessment from each of the SOE, RDP, and UWH monitoring programmes. Sampling dates for most sites shown.

The trend data set had a common core time period across the three contributing programmes for nearly all sites. The start dates were either 2004 or 2005 at all sites (with three exceptions, see footnote[6]), with the last sampling dates being from 2017 to 2019 for all but one site (Awatea Rd, Hobson Bay, which was last sampled in 2016). Details of the sampling intervals and numbers of samplings at each site are provided in the detailed trend results tables provided in Appendix 9.3.

[6] Three sites in the Manukau Harbour – Pahurehure Upper, Pahurehure Middle, and Papakura Lower – were sampled five times from 2008 to 2019. These sites were included as they met the 2004 to 2019 time window (with the last sampling being up-to-date) and had at least five samplings.

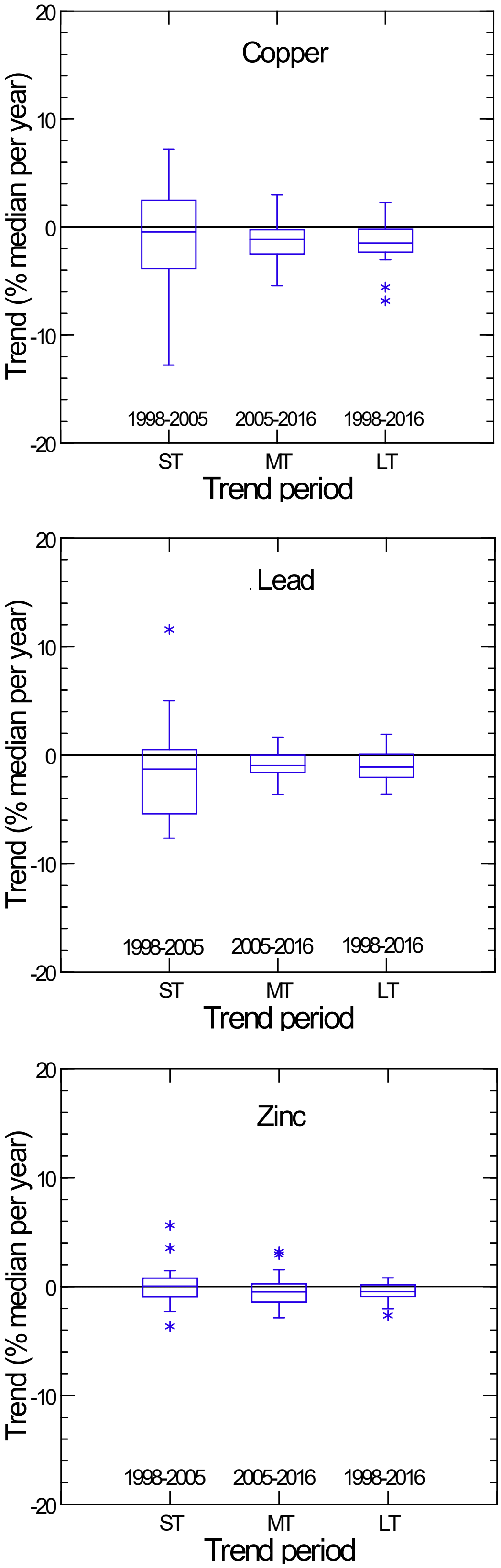

Figure 4-2. Comparison of trends (% median per year) in total recoverable copper, lead, and zinc from SOE monitoring sites in three periods: 1998-2005 ('ST'), 2005-2016 ('MT'), and 1998-2016 ('LT').

4.2.2 Sample numbers

The number of samplings (or 'data points') in the time series record is still relatively small. This is the result of approximately two-yearly sampling intervals at most sites (compare this with water quality sampling, which is generally undertaken at monthly intervals). The programme is aimed at assessing long-term trends, and therefore growing the data base invariably takes time, realistically decades to produce a robust time series.

The numbers of samplings for the 2004-2019 data set ranged from five, the minimum number we considered acceptable for trend assessment, to 10. At most sites there were between six and nine samplings.

Because the number of samplings is still relatively small, any trends measured are potentially sensitive to the effects of additional data, although to a lesser degree now compared with the previous trend assessment. As the sampling record grows, the sensitivity of the calculated trends to new monitoring data will decrease. This can be seen from the comparison of the trend results from the SOE sites for the 2005-2016 and 1998-2016 periods discussed previously, which showed similar trends in Cu, Pb, and Zn for these two periods (Figure 4-2).

4.2.3 Variable providers and procedures

Ideally, to maximise data consistency, a single provider would be consistently used for all, or at least each one of, the steps involved in the monitoring and sample analysis process.

As summarised in Table 4-1, a variety of sampling and analytical providers and methods have previously been used in the three monitoring programmes.

Use of multiple providers and methods is acceptable, provided that consistent results are obtained across the various approaches used. While the comparability of the results obtained by the various providers and methods identified in Table 4-1 is not completely known, a review of the available data (Mills & Williamson, 2014) concluded that within-year data variability for the metals Cu, Pb, and Zn was similar across the RDP, SOE, and UWH programmes, suggesting that differences in sampling, sample processing, and analytical procedures had no major effect on variability. No major changes in data variability occurred over time, indicating that changes in monitoring and analytical practices have not greatly affected variability.

Since 2013, analytical providers have been consistent, with NIWA's Hamilton laboratory conducting the sample preparation for metals' analysis (sieving, freeze drying), R.J. Hill laboratories have done the metals' digestions and ICP-MS analyses, and NIWA Hamilton has done all the PSD analyses.

Table 4-1. A summary of sampling and analysis providers and methods used in the SOE, RDP, and UWH programmes between 1998 and 2019.

Programme[a]	Years	Sampling[b]	Metals			PSD[e]
			Sieving[c]	Digestion[c]	Analysis[d]	
SoE	1998–2001	ARC	NIWA-H	NIWA-H	NIWA: AAS	NIWA-H: Laser
	2003–2007	ARC	NIWA-A	NIWA-A	RJ Hill: ICP-MS	NIWA-H: Laser
	2009 & 2011	DSL	RJ Hill	RJ Hill	RJ Hill: ICP-MS	NIWA-H: Sieve/pipette
	2013	DSL	NIWA-H	RJ Hill	RJ Hill: ICP-MS	NIWA-H: Sieve/pipette
	2015–2019	NIWA-H	NIWA-H	RJ Hill	RJ Hill: ICP-MS	NIWA-H: Sieve/pipette
RDP	2002	ARC and KML	RJ Hill	RJ Hill	RJ Hill	RJ Hill: Sieve
	2004–2008	DSL	RJ Hill	RJ Hill	RJ Hill	NIWA-H: Laser
	2009–2012	DSL	RJ Hill	RJ Hill	RJ Hill	NIWA-H: Sieve/pipette
	2015–2019	NIWA-H	NIWA-H	RJ Hill	RJ Hill: ICP-MS	NIWA-H: Sieve/pipette
UWH	2005–2007	NIWA-H	NIWA-H	RJ Hill	RJ Hill	NIWA-H: Sieve/pipette
	2008 & 2009	NIWA-H	RJ Hill	RJ Hill	RJ Hill	NIWA-H: Sieve/pipette
	2011–2018	NIWA-H	NIWA-H	RJ Hill	RJ Hill	NIWA-H: Sieve/pipette

a. Original programmes. The SOE and RDP programme were integrated into the RSCMP in 2011.
b. Sampling providers: Auckland Regional Council (ARC), Kingett Mitchell Ltd (KML), Diffuse Sources Ltd (DSL), NIWA Hamilton (NIWA-H).
c. Analytical providers: NIWA Hamilton (NIWA-H), NIWA Auckland (NIWA-A), RJ Hill Laboratories.
d. Metals' analysis methods: 'Atomic Absorption Spectroscopy' (AAS), 'Inductively Coupled Plasma Mass Spectrometry' (ICP-MS)
e. PSD: Particle Size Distribution analysis methods – Laser particle size analyser (Galai instrument at NIWA); Sieve/pipette – wet sieving and pipette analysis into 6 size fractions (NIWA), or wet sieving into 3 size fractions (RJ Hill Labs)

4.2.4 Differences in replication between monitoring programmes

At the RDP and UWH programme sites, three replicates per site (each composited from 10 sub-samples taken from across each site, as per the sampling method described in ARC, 2004) were analysed for total recoverable metals from 2004 to 2013. At the SOE sites, only one of these replicates was analysed for total recoverable metals between 1998 and 2007. From 2009-2013, the same number of replicates per site (three) was analysed at the SOE sites as at the RDP and UWH sites. For 2015-19, five replicates per site were analysed at all sites.

Trends have been calculated using median concentrations from each sampling round at each site, so different numbers of replicates has no effect on the calculated trend. However, the reliability of the median as a measure of the sample concentration improves with more replicates. Therefore, the early SOE data, from 1998 to 2007 where only one sample was analysed for each sampling, will be less reliable than later samplings with three or five replicates per sampling. Excluding the 1998 to 2003 SOE data reduces the numbers of single replicate samples used for trend analysis from six to two per site. This improves the comparability of the data sets from the three contributing programmes and provides a more robust set of SOE programme data.

4.2.5 Beach sites

The original SOE monitoring programme had four open coastal beach sites; Awaruku, Vaughans, Cheltenham, and Browns Bay. These former SOE programme sites have coarse, sandy textures, and low mud content. Contaminants, which tend to associate with the finer sediment fractions, are therefore unlikely to accumulate for significant periods at these sites. Changes (if any) in contaminant concentrations at these sites would therefore be expected to be short-term event-driven episodic responses, rather than long-term accumulation (trends).

All but two beach sites, Awaruku and Vaughans beach sites at Long Bay, have been retired from routine monitoring. Browns Bay was last sampled in 2007, and Cheltenham Beach in 2011.

Awaruku and Vaughans sites are on opposite ends of Long Bay beach, close to the mouths of Awaruku and Vaughans Streams (respectively). Monitoring at these two beach sites has continued because of potential impacts associated with ongoing urbanisation of the Awaruku and Vaughans catchments on marine receiving waters. Monitoring data collected from the Long Bay sites (including the two associated stream sites) for 1998-2013 was reported by Mills (2016d). Since then, the beach sites have been sampled once more, in 2018, giving a total of six samplings for the 2005-2018 trend assessment period.

While strong trends would not be expected to occur at the beach sites, they are useful to include in the trend assessment as a 'reality check' – if strong trends were detected at these sites, further investigation of the reliability and meaningfulness of trends from other sites might be warranted.

4.2.6 Extractable metals in the <63 μm fraction

The previous trend assessment excluded extractable metals' data from samplings conducted in 2003, 2005, and 2007 at SOE programme sites, because of quality assurance issues associated with the results from these years (Mills & Williamson, 2014). The extractable metals' data from other sampling rounds were used in the trend assessment.

Extractable metals (2 M HCl extraction of the <63 μm fraction) were originally designated as the primary tool for tracking trends in metals' concentrations over time, because the analysis of the mud fraction (<63 μm) reduces variation associated with changes in sediment particle size distribution (e.g. muddiness).

Since 2011, a routine quality assurance protocol based on analysis of Bulk Reference Sediment (BRS) has been used to validate the metals and PSD analytical data. These QA assessments concluded that extractable metals' analysis was subject to higher year-to-year (i.e. between batch) variability than total recoverable metals; see, for example, the RSCMP data report containing extractable metals results, from sampling in Drury Creek in June 2015 (Mills, 2016b).

The decision was made to discontinue the extractable metals from routine analysis and for use in assessing trends in metals' concentrations. The present trend assessment therefore uses only the total recoverable metals (in the <500 μm fraction).

4.2.7 Particle size distribution

Particle size distribution (PSD) data are primarily used in the RSCMP to assess whether there have been changes in mud content (proportion of the sediment in the <63 μm range) that may affect interpretation of the total recoverable metals results. Finer grained sediments (i.e. more muddy) generally have higher metals' concentrations than coarser (e.g. sandy) material. Trends in metals and PSD therefore need to be considered together to assess the possible contribution of changing PSD to trends in metals over time.

Particle size distribution has been measured by different methods in the SOE, RDP, and UWH programmes, and the methods used in the SOE and RDP programmes have changed over time (Table 4-1). The agreement between the different methods, laser particle size analysis and wet sieving/pipette analysis, is not considered good enough at each site to provide reliable trend records at individual sites (Mills & Williamson, 2014).

The method used in the contaminant chemistry components of the SOE and RDP programmes, up to 2008, was laser particle size analysis. Wet sieving/pipette analysis (Lundquist et al., 2010) has always been used in the UWH, since 2005. From 2009, PSD has been determined by the same wet sieving/pipette analysis method at all SOE, RDP, UWH and RSCMP monitoring sites.

Benthic ecology sampling was also undertaken at RDP and SOE sites, starting in 2004 at RDP sites and in 2005 at SOE sites. Sediment samples from the benthic ecology sampling also had PSD analysed, using the wet sieving/pipette method. Therefore, a PSD record using a consistent analysis method can be assembled for the 2004-2019 period for all SOE, RDP, and UWH sites.

The RDP and SOE sites sampled for ecology varied depending on their contaminant state, so not all sites were sampled in each sampling round. The number of PSD samples used for trend analysis may, therefore, be smaller than the number of metals' samplings. Sixteen of the 56 sites used for trend analysis had fewer sample data for PSD (mud content) than metals. To retain a consistent site list for metals and PSD, eight sites with only four samplings (i.e. fewer than the five considered necessary for metals' trends) were included. The PSD (mud content) trends are primarily used to help interpret the metals' trends, to assess whether any changes observed in metals' concentrations could be associated with changing sediment texture (in particular muddiness). For this purpose, the PSD data was considered acceptable, despite the sometimes smaller than ideal number of samples.

4.2.8 Organic contaminants

Trends in PAH were reported in the previous trend assessment (Mills et al., 2012), using a very limited database of only four samplings from the SOE programme from 1998-2005 and the UWH programme from 2005-2009. Few significant trends were observed for PAH, with a lack of any definitive patterns. Only seven of the 39 sites where trends were assessed showed significant trends in PAH concentrations; five of these sites showed increases, and two were decreases. PAH concentrations were generally low, and showed moderate variability, which were considered likely to be a significant contributor to the observed changes. It was considered unlikely that any of the changes in PAH observed at the time had any real world significance. There were inadequate data for organochlorines (pesticides and PCBs) for trend analysis at that time.

Since then, there has been no routine analysis of organic contaminants in the RSCMP. An assessment of changes in OCPs between 2003 and 2012/13, based on very limited data, was given in Mills (2014b). This suggested stable-to-decreasing concentrations of OCPs over that period. A slow decline in environmental concentrations is consistent with the combined effects of discontinued use (giving slow degradation of source material stored in estuary catchments) and the persistence (i.e. slow degradation) of these chemicals in receiving water sediments.

Since 2012/13, no organic contaminant data have been collected in the RSCMP, and therefore no further trend assessment of PAH or organochlorines is possible.

4.2.9 Metals' data quality issues for 2017-2019 data

As outlined in section 2.5, a consistent quality assurance (QA) programme has been operating since 2011. Generally, data quality has found to be satisfactory for the purposes of the RSCMP. However, recent QA data analysis, undertaken for the 2017, 2018, and 2019 RSCMP sampling rounds (Mills, 2021a, 2021b), reported significantly elevated Zn concentrations in the Bulk Reference Sediment (BRS), especially in the more contaminated muddy BRS samples. The concentrations of Zn were approximately 9-12% higher than expected in the low concentration sandy BRS samples, and 14-19% higher in the more contaminated mud BRS samples. This means that Zn results for sites monitored in 2017, 2018, and 2019 may be artificially higher than they really are as a result of laboratory analytical artefacts, rather than from actual environmental causes. As raw, uncorrected data has been used in this report, trend results for Zn may therefore be affected, potentially giving higher than expected trends.

The potential effects of the Zn analysis issue on trends were investigated by substituting 2017, 2018, and 2019 data with values corrected for the analytical artefacts, then reanalysing trends with the corrected data. This approach is detailed in Appendix 9.1.

The overall finding of this investigation was that Zn trends were subtly increased by the higher 2017-2019 results, enough to require application of a 'meaningfulness threshold' to be confident that the reported trends were unaffected by the high 2017-2019 results:

- If a 1% change (of the median concentration) per year 'meaningfulness threshold' was applied to the trend results, an appreciable effect on trends was still observed, with 14 sites with very likely increasing trends dropping to five when the Zn data were corrected. A greater number of decreasing trends were observed, increasing from three sites using the raw trend results to 4-10 sites depending on the level of correction applied.
- With a 2% of the median change per year threshold applied, the effect of the elevated Zn data from 2017-2019 was very small, with only one site being affected with correction for increasing (Benghazi) or decreasing (Māngere Cemetery) trends.

This means that if the ±2% per year 'meaningfulness threshold' is applied to the Zn raw trend data (i.e. no trends less than ±2% per year are considered reliable), only two sites are affected:

- Benghazi (Tāmaki Estuary), which had a raw data increasing trend of 3.2% per year, which dropped to 2.1-1.6% per year with varying levels of correction applied (i.e. the trend may actually be less than the ±2% per year threshold).
- Māngere Cemetery (Māngere Inlet, Manukau Harbour), which had a raw data decreasing trend of -1.5% per year, which 'increased' to -2.7% per year with all levels of correction (i.e. moved to greater than the ±2% per year threshold).

Based on this approach:

- Benghazi could have an increasing Zn trend closer to 2% per year (rather than the 3.2% obtained from the raw data). Because the raw data trend is >2% per year, it has been included in the reported trend results as being 'meaningful'.
- Māngere Cemetery is not included in the 'meaningful' trend results, but it possibly should be, as correction shifted it into the 'meaningful' range. Because

the raw data trend is <2% per year, it has not been included in the trend results as being meaningful.

The lack of a strong effect of the elevated 2017-2019 Zn trends, especially when applying the 'very likely' probability (see section 4.4) and ±2% (of the median) per year meaningfulness threshold, reflects a combination of relatively small trends at most sites, the relatively smaller trends (when expressed as % of median per year) at higher concentration sites, and that strongest trends (when expressed as % of median per year) were observed at sites with relatively low concentrations of Zn.

Based on the assessment for Zn outlined above and detailed in Appendix 9.1, trends were assessed using the raw analytical data (i.e. not corrected for the elevated 2017-2019 results) and a 'meaningfulness threshold' for reliable trends of two per cent of the median per year has been applied to all the trend results for all metals. This should ensure that the reported trends are reliable given potential artefacts associated with variable analysis results, but it may result in losing information on smaller emerging trends (especially for Cu and Pb, where no major data quality issues were identified). Ongoing QA work is required to continually improve analytical data quality to reduce any future issues and maximise the reliability and sensitivity of the monitoring programme.

While not based directly on analysis of QA data, a similar approach was adopted in the previous trend assessment (Mills, 2012). In that analysis, trends <±1% per annum were classed as reflecting no meaningful trend, ±1-2% per annum indicated a small, or emerging, 'possible' trend, and >±2% indicated stronger trends, termed 'probably increasing/decreasing' trends.

A two per cent per year trend is also approximately the rate of change required to increase the average Zn concentration across all sites (approximately 100 mg/kg) to the ERC-amber threshold (124 mg/kg) over 10 or so years. This magnitude of change is considered to be of 'real world meaningfulness'.

4.3 Data used for trend assessment

Based on the data characteristics and limitations discussed in section 4.2, trends for total recoverable metals and PSD (mud content, % <63 μm) at 56 sites were analysed. The locations of the trend sites are shown in Figure 4-3. Additional detail on the data used in the trend analysis for each site is provided in the trend summary tables attached as Appendix 9.3.

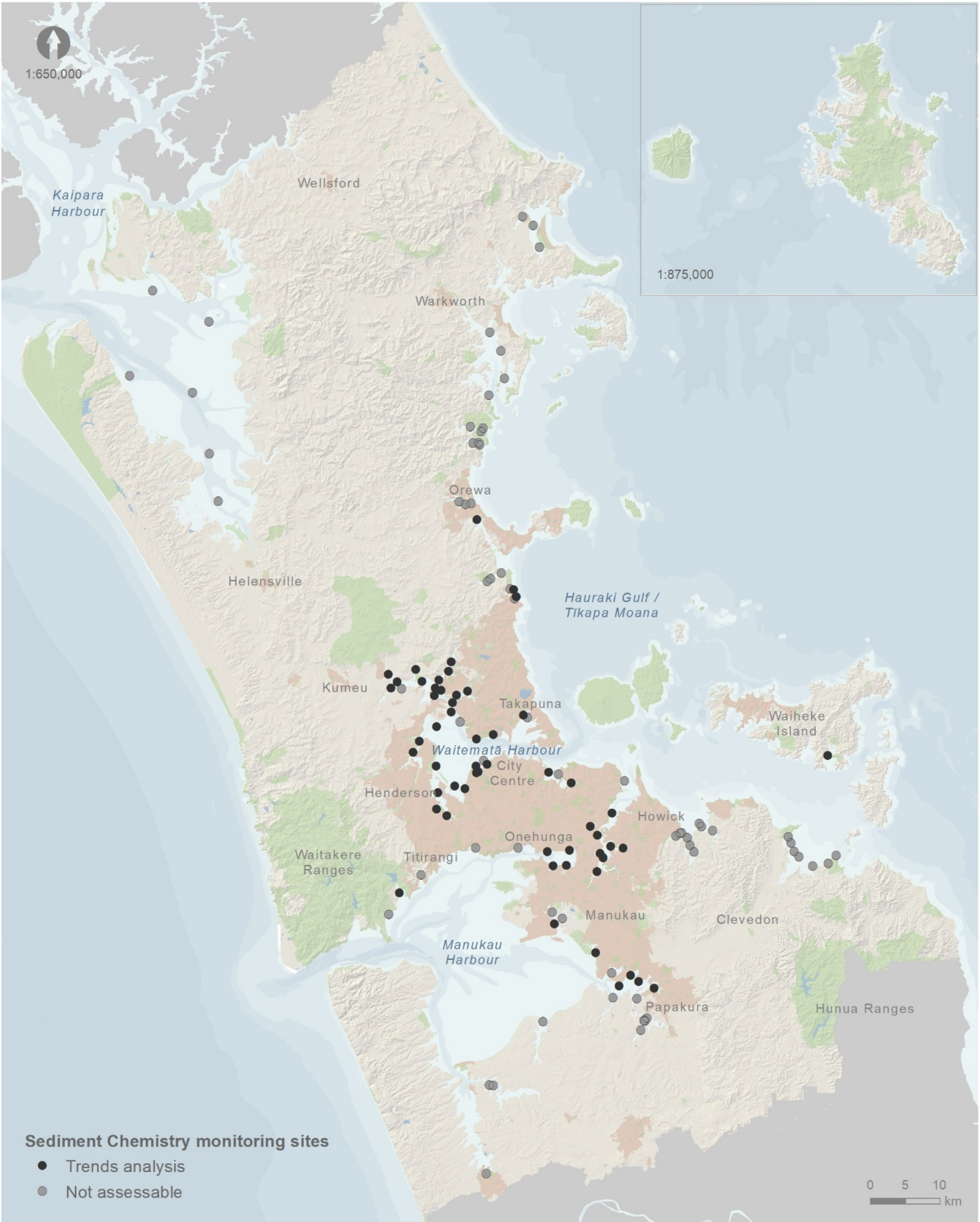

Figure 4-3. Locations of the 56 monitoring sites used for trend analysis.

4.4 Trend analysis

Trends were assessed by the non-parametric Mann-Kendall (MK) trend test, using Time Trends software (Jowett Consulting Ltd) using the median values for each sampling (as outlined in section 4.2.4). The magnitude of the trend (or 'rate of change') was obtained from the Sen Slope estimate, also provided by Time Trends software package. The Sen Slope is the median slope of all the slopes between all the data pairs in the data set (excluding ties, in values or in time).

The likelihood of the trend being increasing or decreasing was assessed from the Sen Slope probability, as provided in Time Trends. Likelihood was categorised into five groups, as described by Land, Air and Water Aotearoa (LAWA, 2019):

- 'very likely' increasing or decreasing trends, where the Sen Slope probability is 90-100%. For contaminants, an increasing trend reflects a degrading or worsening state, while a decreasing trend indicates improving conditions
- 'likely' increasing or decreasing trends (Sen Slope probability 67-90%). The lower certainty reflects the fact that while there is an indication of a trend, there is less statistical support for it
- 'indeterminate' trends, where the Sen Slope probability is lower (<67%), reflecting insufficient evidence to confidently determine if there is an improving or degrading trend.

This approach is consistent with that used for other programmes at Auckland Council and for national water quality monitoring trend assessment and reporting (LAWA, 2019). These trend testing procedures are similar to those used in the previous assessment of the 1998-2010 data (Mills et al., 2012) with the presentation of the statistical test results updated to reflect currently used trend reporting methods (i.e. LAWA likelihood categorisation).

4.5 Trend data presentation

As for the previous trend assessment (Mills et al., 2012), trend magnitudes have been calculated as:

- absolute values, in units of mg/kg per year for metals, and %<63 µm per year for mud content
- relative values, by dividing the absolute trend value by the median concentration over the time interval of the trend measurement. The trend units are per cent of the median concentration per year (or % per year)
- as relative values benchmarked against ecological effect guideline values, expressed as a percentage of the guideline values per year. The guidelines used are the Auckland Council Environmental Response Criteria (ERC) amber

guidelines (ARC, 2004). The trends were expressed as per cent of the ERC per year, calculated as the absolute trend (in mg/kg/year) divided by the ERC amber value (in mg/kg), multiplied by 100 (to give a percentage).

The percentage of the ERC per year approach provides a meaningful scale that is referenced to relevant ecological effects concentrations. It avoids potential problems associated with trends measured relative to the median concentrations, for which small changes can result in large percentage changes as a result of low median concentrations, for example at cleaner sites.

The disadvantage of the trends relative to guidelines-based approach for reporting trends is that it has been found to be more difficult for people to understand. Therefore, while it was used in the previous trend assessment report, the discussion and presentation of trends in this report are based on trends expressed as per cent of the median per year. Trend data expressed as percentage of the ERC per year have also been tabulated in the full trend data tables given in Appendix 9.3.

As discussed previously in section 4.2.9, quality assurance results indicated a ‘meaningfulness threshold’ of ±2% per year and ‘very likely’ probability as being appropriate for reliable reporting of Zn trends. This has been applied to all metals in this report. Trends have been calculated using the raw analytical data, with no correction for elevated 2017-2019 Zn results.

4.6 Interpreting trend data: a cautionary note

While the monitoring data collected to date is comprehensive, it has some limitations (as discussed in previous sections). Overall, we consider the data and trend results to be sufficiently reliable to provide the regional overview of trend direction and magnitude required for this assessment. However, it is important not to put too much emphasis on the exact magnitude or statistical significance of the trends at each site measured to date. This is because of the fairly limited numbers of samplings undertaken to date, the variable laboratory analytical methods used between the programmes prior to 2009, and the lack of benchmarking for the data record prior to 2011 (when the BRS quality assurance protocol was introduced). As the combined monitoring approach continues under the RSCMP, the data generated by the consistent protocols will increase, and both state and trends will be able to be assessed with greater confidence and reliability.

The trend data provides a broader assessment tool about the general direction and magnitude of changes over time in sediment contamination. The trend monitoring results have therefore been presented and discussed within this broader context. If detailed assessment of trends at individual sites is required, or the ecological significance of trends at a particular site(s) is of great importance, the monitoring data for the site(s) should be examined carefully to check data variability and the presence of any unusual data that may be influencing the trend results. If, after this more in-depth analysis, trends at important site(s) are found to be significant (statistically and in magnitude), further investigation of ecological effects may be warranted using a 'multiple lines of evidence' approach as suggested by the ANZ guidelines (ANZG, 2018).

5.0 Trends in metals

5.1 Regional overview

The distribution of trends across the 56 sites assessed for trends is summarised graphically in Figure 5-1 and Figure 5-2. A summary of statistical trend values for all data and for 'very likely' trends is provided in Table 5-1. A summary of the numbers of sites with trends in each of the five likelihood categories is given in Table 5-2.

The magnitude of trends were generally small. Median trends for all trend data (Table 5-1 A) were small increases for mud (0.26% of the median per year) and Zn (0.57% per year), and small decreases for Cu (-0.72% per year) and Pb (-0.80% per year). The range of trends was larger for mud (from -7.3% to +11% per year) than for metals, which ranged from -5.1% per year (for Cu) to +5.7% per year (for Zn).

Median trends with a 'very likely' probability (Table 5-1 B) were slightly larger than for all the trend data but showed the same pattern – small increases for mud (0.32% per year) and Zn (1.2% per year), and small decreases for Cu (-1.5% per year) and Pb (-1.6% per year).

Note that some of the increasing trends shown for Zn may be associated with the elevated results obtained for 2017, 2018, and 2019 monitoring data (see section 4.2.9 and 9.1). The difference in trends between Cu and Pb (which have small decreasing median trends), and Zn (which shows a small increasing median trend) may therefore be smaller than shown in Figure 5-1 and Figure 5-2.

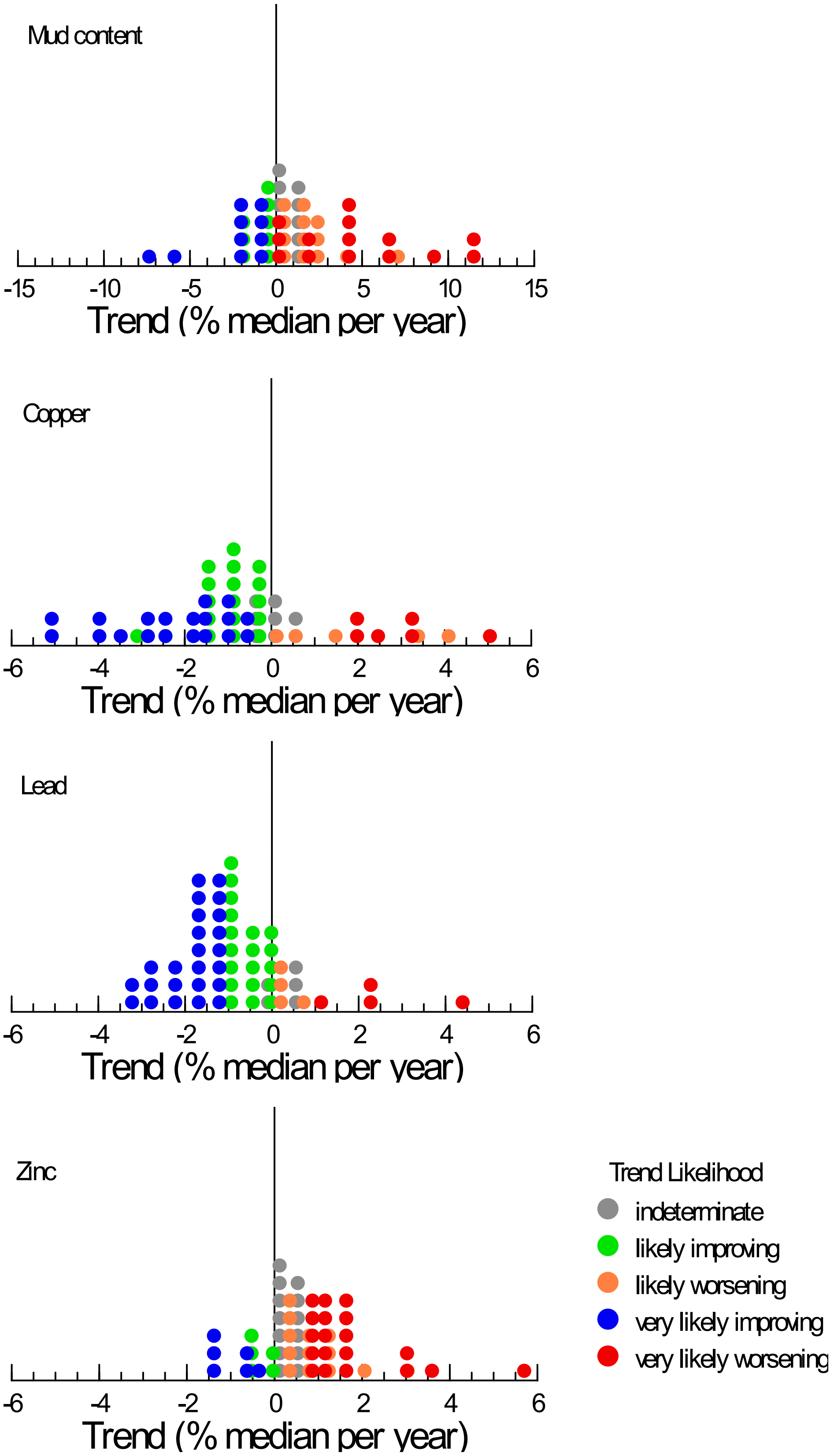

Figure 5-1. Distribution of trends in mud content, and total recoverable copper, lead, and zinc from 56 monitoring sites for the period 2004-2019.

Table 5-1. Summary of statistical trends for mud content, copper, lead, and zinc.

A. All trends from 56 sites

Analyte	Trend statistic median	minimum	maximum
Mud:			
% <63 µm per year	0.17	-3.30	1.47
% median per year	0.26	-7.33	11.27
Copper:			
mg/kg per year	-0.08	-0.98	0.38
% median per year	-0.72	-5.05	5.07
Lead:			
mg/kg per year	-0.15	-1.28	0.33
% median per year	-0.80	-3.34	4.41
Zinc:			
mg/kg per year	0.54	-2.30	3.26
% median per year	0.57	-1.50	5.72

B. Very likely trends

Analyte	Trend statistic median	minimum	maximum
Mud (n=24)			
% <63 µm per year	0.22	-3.30	1.47
% median per year	0.32	-7.33	11.27
Copper (n=25)			
mg/kg per year	-0.32	-0.98	0.38
% median per year	-1.51	-5.05	5.07
Lead (n=28)			
mg/kg per year	-0.42	-1.28	0.33
% median per year	-1.63	-3.34	4.41
Zinc (n=25)			
mg/kg per year	1.12	-2.30	3.26
% median per year	1.17	-1.50	5.72

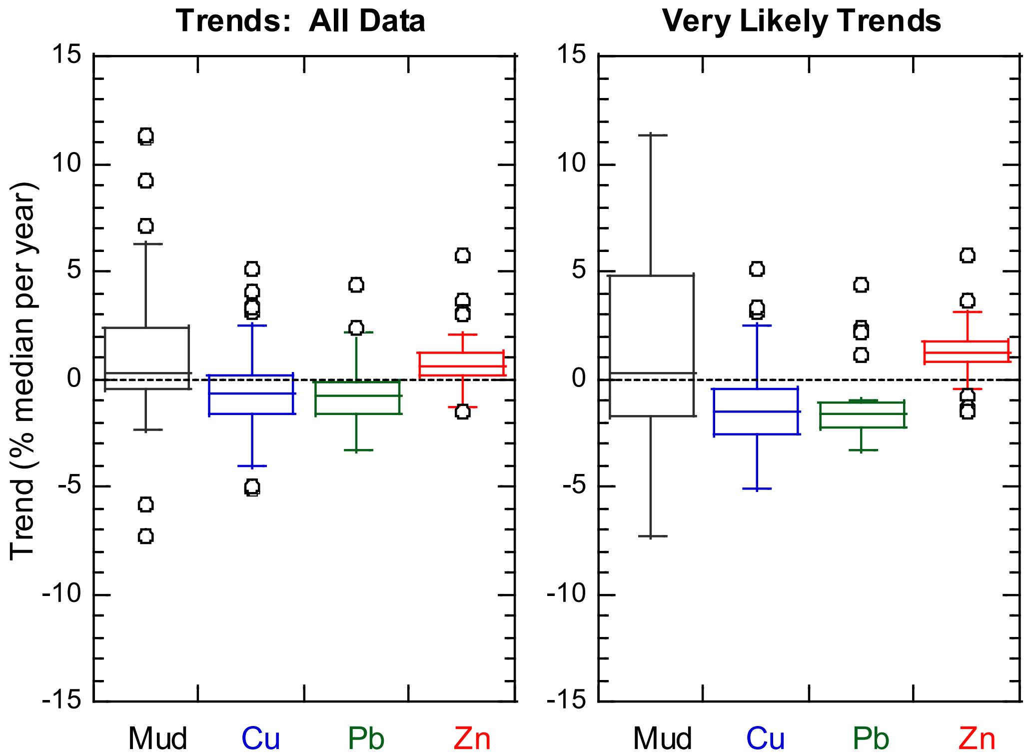

Figure 5-2. Distribution of trends in mud content, and total recoverable copper, lead, and zinc from all trend data, and for 'very likely' trends only for the period 2004-2019.

Relatively few of the 56 trend sites showed 'very likely' trends in metals' concentrations greater than the ±2% per year meaningfulness threshold (Table 5-2):

- Cu had 18 sites with >2% per year trends, 14 of which were 'very likely'; 9 showed decreasing trends and 5 were increasing
- Pb had 11 sites with >2% per year trends, all 11 of which were 'very likely'; 8 showed decreasing trends and 3 were increasing
- Zn had only 6 sites with >2% per year trends, 4 of which were 'very likely'; all 4 were increasing.

Overall, the majority of sites (38 out of 56 trend sites) showed no meaningful trend in total Cu, Pb, and Zn concentrations. At the 18 sites with reasonably robust and meaningful trends (i.e. greater than ±2% of the median per year and very likely probability), decreases outnumbered increases for Cu and Pb. For the few (four) sites where Zn concentrations had changed more than two per cent per year, all the trends were increases.

Mud content showed a wider range of trend magnitudes than metals. Of the 56 trend sites, 18 sites showed likely or very likely decreasing trends, and 27 showed likely or very likely increasing trends.

Fourteen of the 56 trend sites showed changes in mud content over two per cent of the median per year and very likely probability. Of these, four showed very likely decreasing trends, while 10 showed increases (Table 5-2).

The 10 sites showing relatively large increases in mud content (i.e. very likely worsening over time) were fairly sandy sites. (Table 5-3). Because these sites have relatively low mud content, even small changes may result in relatively large changes when expressed as per cent of the median mud content.

Table 5-2. Numbers of sites within trend likelihood categories. Data are listed for all trend data and for trends greater than the ±2% of the median per year 'meaningfulness' threshold.

Trend likelihood category	Mud		Copper		Lead		Zinc	
	All trends	>2% per yr	All trends	>2% per yr	All trends	>2% per yr	All trends	>2% per yr
Total sites	56	20	56	18	56	11	56	6
very likely improving (P 90-100%)	10	4	19	9	24	8	6	0
likely improving (P 67-90%)	8	1	18	2	19	0	5	0
indeterminate (P<67%)	11	0	8	0	5	0	13	0
likely worsening (P 67-90%)	13	5	5	2	4	0	13	2
very likely worsening (P 90-100%)	14	10	6	5	4	3	19	4

5.2 Trends at individual monitoring sites

A compilation of all trend data (including likelihood and magnitude) for metals and mud content at each of the 56 monitoring sites used for this trend assessment is shown in Figure 5-3 and listed in detail in Appendix 9.3.

A summary of trends for sites with at least one 'meaningful' trend (very likely probability and >±2% of the median per year) is given in Table 5-3 and, in more detail, in Table 5-4. Trend plots for these meaningful trends are given in Appendix 9.5. Key features of these results are described below.

Six sites had 'very likely' increasing metals' concentrations >2% median per year:

- Three sites in the Central Waitematā Harbour – Cox's Bay (Cu, Pb, and Zn), Kendall Bay (Cu), and Whau Entrance (Cu, Pb, and Zn).
- Two sites in the Tāmaki Estuary – Benghazi (Cu and Zn) and Princes (Cu).
- One site in the Upper Waitematā Harbour – Herald Island Waiarohia (Pb and Zn).

All these sites, with the exception of Princes (a muddy site in Tāmaki Estuary), are relatively sandy sites and showed increasing trends in mud content (>2% per year, very likely probability). Increasing muddiness may therefore be a significant factor influencing the strongly increasing trends in metals at these sites.

Twelve sites had very likely decreasing metals' concentrations >2% median per year:

- Four sites in the Central Waitematā Harbour – Awatea Rd (Cu), Meola Inner (Pb), Motions (Cu and Pb), and Whau Upper (Pb).
- One site in the Tāmaki Estuary – Pakuranga Upper (Cu and Pb).
- Four sites in the Manukau Harbour – Ann's Creek (Cu and Pb), Harania (Cu), Māngere Cemetery (Cu and Pb), and Tararata (Cu and Pb). These sites are all muddy sites in Māngere Inlet, in the upper reaches of the harbour.
- Three sites in the Upper Waitematā Harbour – Hellyers Upper (Pb), Hobsonville (Cu), and Lucas Te Wharau (Cu).

Table 5-3. Summary of sites where meaningful (>2% median per year, very likely probability) increasing (▲) or decreasing (▼) trends in metals' concentrations were recorded.

Site	MRA	Programme	Meaningful trends			
			Mud	Cu	Pb	Zn
Awatea Rd	Central Waitemata	RDP		▼		
Coxs Bay	Central Waitemata	RDP	▲	▲	▲	▲
Kendall Bay	Central Waitemata	RDP	▲	▲		
Meola Inner	Central Waitemata	SoE			▼	
Motions	Central Waitemata	SoE	▼	▼	▼	
Whau Entrance	Central Waitemata	RDP	▲	▲	▲	▲
Whau Upper	Central Waitemata	SoE			▼	
Anns Creek	Manukau	SoE		▼	▼	
Harania	Manukau	RDP		▼		
Mangere Cemetery	Manukau	SoE		▼	▼	
Tararata	Manukau	RDP		▼	▼	
Benghazi	Tamaki	RDP		▲		▲
Pakuranga Upper	Tamaki	SoE	▼	▼	▼	
Princes	Tamaki	RDP		▲		
Hellyers Upper	Upper Waitemata	UWH			▼	
Herald Island Waiarohia	Upper Waitemata	UWH	▲		▲	▲
Hobsonville	Upper Waitemata	UWH	▼	▼		
Lucas Te Wharau	Upper Waitemata	UWH		▼		

Note: The table above shows only sites where meaningful trends in *metals* were recorded. The number of sites for mud is therefore smaller than given in Table 5-2 and Table 5-4.

The data suggest that meaningful increasing trends in metals are occurring at sandy sites in the Waitematā Harbour (possibly associated with deposition of fine muddy sediments) as evidenced by increasing trends in metals at Cox's Bay, Kendall Bay, Whau Entrance, and Herald Island Waiarohia. The only other sites showing meaningful increases in metals were at Princes and Benghazi, both moderately muddy sites in the Tāmaki Estuary.

Decreasing metals' concentrations were recorded at a wider range of sites, including:

- Motions, a highly contaminated (ERC-red) site in the Central Waitematā Harbour. This site has a mixed sediment texture, in part reflecting its location on a small flat area between mangroves (muddy) and low tide stream channel. The median texture is 23% mud, but this varies across the site. The decreasing metals' concentrations were accompanied by decreasing mud content, suggesting a textural influence on metals' trends.
- Pakuranga Upper, a contaminated site (ERC-red) in the Tāmaki Estuary. As for Motions, this site has a mixed sediment texture, in part reflecting its location

nestled on a small area between mangroves (muddy) and a highly eroding low tide stream channel. The median mud content is 75%, but texture varies across the site. The decreasing metals' concentrations were accompanied by decreasing mud content, again suggesting a textural influence on metals' trends.
- Ann's Creek, Māngere Cemetery, and Tararata, all located in Māngere Inlet, Manukau Harbour, which showed decreasing Cu and Pb. Harania, also in Māngere Inlet, showed decreasing Cu (Pb also decreased but by 1.8%, which is just below the two per cent meaningfulness threshold). These are all muddy, inner estuary sites surrounded by intensively developed land with a long history of commercial and industrial uses. The improving metals' trends observed in Māngere Inlet presumably reflects improved site and stormwater management associated with modernising industry in the catchment.

The generally decreasing Pb concentrations presumably reflects ongoing benefits of removal of Pb from widespread use, for example from petrol and paint. Sites showing increasing Pb were sandy Waitematā Harbour sites with increasing trends in muddiness, probably reflecting the effect of deposition of fine sediment on metals concentrations at these sites. Because the concentrations of metals and mud content at these sites are low, they are sensitive to the effects of fine sediment deposition. Addition of fine sediment (i.e. mud) at the rates shown at, for example, Whau Entrance, is enough to raise the concentrations of metals significantly even if the fine sediment is not especially contaminated.

Table 5-4. Summary of trends in mud content and metals at sites with at least one ‘meaningful’ trend (very likely probability and >±2% of median per year).

			Mud Content		Cu		Pb		Zn	
Site	Programme	MRA	% per year	Likelihood	% per year	Likelihood	% per year	Likelihood	% per year	Likelihood
Awatea Rd	RDP	Central Waitemata	1.31	likely worsening	**-2.97**	**very likely improving**	-0.92	likely improving	-0.74	very likely improving
Chelsea	RDP	Central Waitemata	**3.96**	**very likely worsening**	1.86	very likely worsening	0.21	likely worsening	0.93	very likely worsening
Coxs Bay	RDP	Central Waitemata	**4.81**	**very likely worsening**	**5.07**	**very likely worsening**	**2.37**	**very likely worsening**	**3.61**	**very likely worsening**
Kendall Bay	RDP	Central Waitemata	**4.71**	**very likely worsening**	**3.14**	**very likely worsening**	-0.07	indeterminate	1.76	very likely worsening
Meola Inner	SoE	Central Waitemata	0.76	likely worsening	-0.99	likely improving	**-2.11**	**very likely improving**	0.00	indeterminate
Meola Outer	RDP	Central Waitemata	**4.66**	**very likely worsening**	1.50	likely worsening	0.43	likely worsening	1.66	very likely worsening
Motions	SoE	Central Waitemata	**-2.21**	**very likely improving**	**-2.62**	**very likely improving**	**-2.34**	**very likely improving**	0.40	likely worsening
Whau Entrance	RDP	Central Waitemata	**11.27**	**very likely worsening**	**3.30**	**very likely worsening**	**2.16**	**very likely worsening**	**3.04**	**very likely worsening**
Whau Upper	SoE	Central Waitemata	-1.77	very likely improving	-1.51	very likely improving	**-2.33**	**very likely improving**	-0.38	likely improving
Weiti	SoE	Hibiscus Coast	**-2.32**	**very likely improving**	-0.59	likely improving	-0.56	likely improving	0.36	indeterminate
Anns Creek	SoE	Manukau	-0.56	likely improving	**-5.05**	**very likely improving**	**-2.66**	**very likely improving**	-0.13	likely improving
Harania	RDP	Manukau	-0.02	indeterminate	**-2.43**	**very likely improving**	-1.75	very likely improving	1.17	very likely worsening
Mangere Cemetery	SoE	Manukau	-1.13	very likely improving	**-5.02**	**very likely improving**	**-3.34**	**very likely improving**	-1.49	very likely improving
Tararata	RDP	Manukau	0.04	indeterminate	**-3.78**	**very likely improving**	**-3.16**	**very likely improving**	0.14	indeterminate
Benghazi	RDP	Tamaki	1.85	likely worsening	**2.48**	**very likely worsening**	1.15	very likely worsening	**3.15**	**very likely worsening**
Pakuranga Upper	SoE	Tamaki	**-5.86**	**very likely improving**	**-4.09**	**very likely improving**	**-2.90**	**very likely improving**	-0.64	likely improving
Princes	RDP	Tamaki	0.54	indeterminate	**2.22**	**very likely worsening**	0.66	indeterminate	1.68	very likely worsening
Te Matuku	SoE	Tamaki Strait	**11.20**	**very likely worsening**	-0.01	likely improving	-0.39	likely improving	0.23	likely worsening
Central Main	UWH	Upper Waitemata	**2.18**	**very likely worsening**	-1.43	likely improving	-0.10	likely improving	1.78	very likely worsening
Hellyers Upper	UWH	Upper Waitemata	0.18	indeterminate	-0.91	very likely improving	**-2.51**	**very likely improving**	0.18	indeterminate
Herald Island North	UWH	Upper Waitemata	**6.29**	**very likely worsening**	-2.42	likely improving	-0.54	likely improving	0.46	likely worsening
Herald Island Waiarohia	UWH	Upper Waitemata	**9.22**	**very likely worsening**	4.11	likely worsening	**4.41**	**very likely worsening**	**5.72**	**very likely worsening**
Hobsonville	UWH	Upper Waitemata	**-7.33**	**very likely improving**	**-3.46**	**very likely improving**	-1.44	very likely improving	-1.35	very likely improving
Lucas Te Wharau	UWH	Upper Waitemata	-1.57	likely improving	**-2.34**	**very likely improving**	-1.79	very likely improving	-0.34	very likely improving
Outer Main Channel	UWH	Upper Waitemata	**7.07**	**very likely worsening**	-3.08	likely improving	-1.47	very likely improving	0.41	indeterminate

Colour coding is very likely worsening, likely worsening, likely improving, very likely improving, and indeterminate. Bolded values are trends > ±2% of median per year and of ‘very likely’ probability.

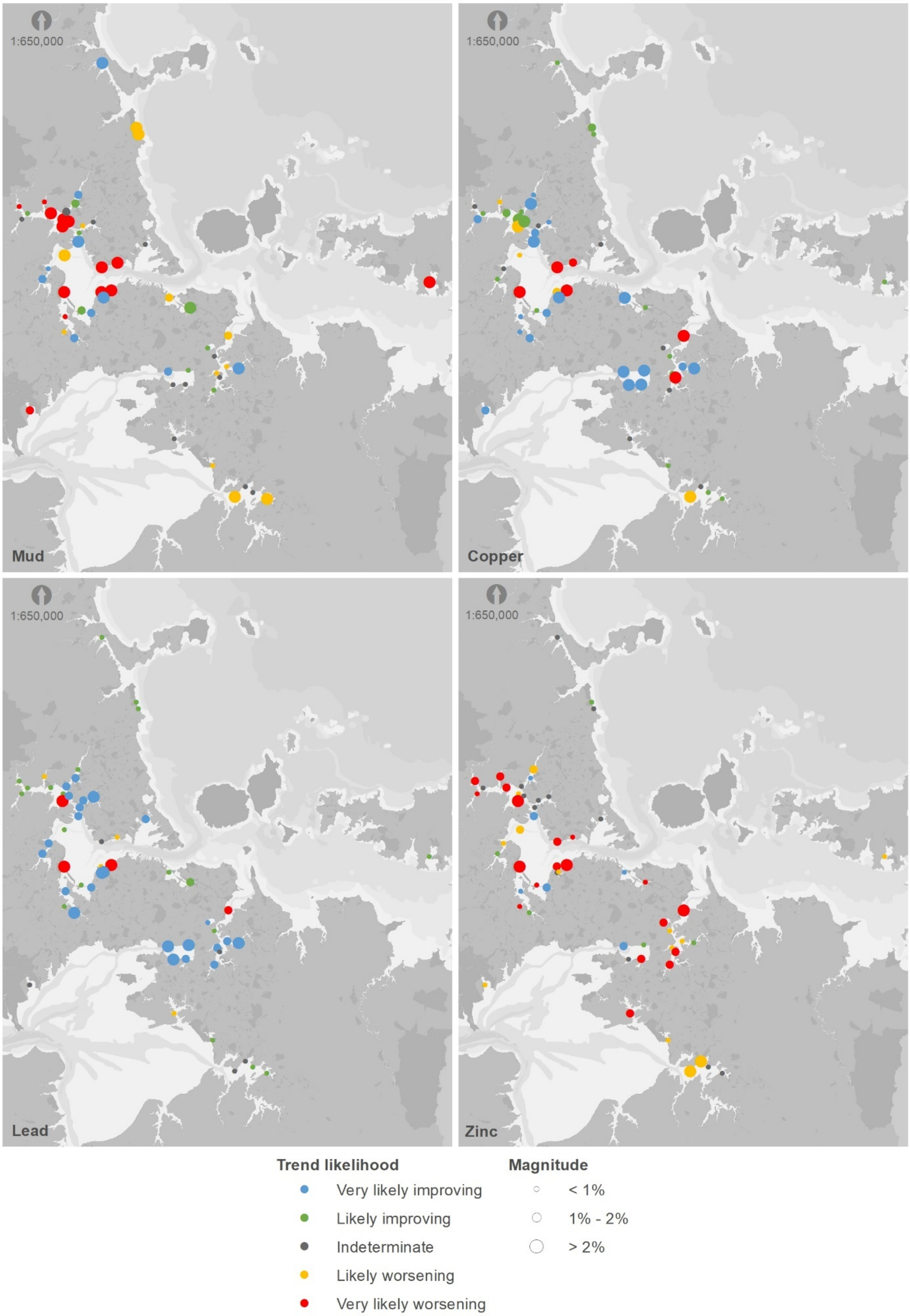

Figure 5-3. Trend likelihood and magnitude in mud content, copper, lead and zinc at 56 RSCMP trend monitoring sites between 2004 and 2019.

5.3 Comparison of trends in metals from 1998-2010 and 2004-2019

The results from the previous trend assessment covering the period 1998-2010 (Mills et al., 2012) were compared with those from the present update covering 2004-2019, to see whether there have been any major changes in trends between the two periods. About six years of the monitoring data used in these reviews overlap, with the earlier review beginning five years earlier than the current review, and the current review finishing nine years later than the earlier review.

Direct comparison of trend results reported in Mills et al. (2012) for the 1998-2010 period and the results presented in this report (for 2004-2019) is limited due to several factors:

- The total number of sites analysed in the earlier review (57) and the current review (56) were very similar, but the site locations were not the same, with 14 sites differing between the two reviews.
- The trend analysis and presentation methods used in the two studies differed. The same statistical test methods (Mann Kendall and Sen Slope tests) were used for both periods. However, the 1998-2010 review used all the replicate data from each sampling round in the trend tests and included sites with at least four samplings, while the 2004-2019 analysis used the median from each sampling and included only sites with at least five samplings. The use of all data and fewer minimum numbers of samplings for the earlier trend analysis period was undertaken to capture as much information as possible from the limited data set available at that time. Trends were classed as 'significant' for the 1998-2010 period when the Mann Kendall test probability was $P<0.05$, whereas for the 2004-2019 period, the Sen Slope probability $P>0.9$ ('very likely' probability) was used. Both test periods used a trend magnitude threshold of ±2% per year (of the median or ERC) for 'meaningfulness'.

To provide a reliable comparison of trends between the two periods, the trends for the 1998-2019 period were reanalysed using the same procedures as used for the 2004-2019 period. The same set of 40 sites having data from five or more samplings in each period was used. Comparisons of the trends for the two periods are summarised in Table 5-5 and Figure 5-4, and at individual sites in Table 5-6.

Table 5-5. Comparison of trends (all data) in total recoverable metals from 1998-2010 and 2004-2019.

Total Recoverable Metal	Trend (% median per year)		
	median	minimum	maximum
Copper:			
1998-2010	-1.61	-13.5	4.7
2004-2019	-0.86	-5.1	4.1
Lead:			
1998-2010	-0.75	-6.7	4.3
2004-2019	-0.99	-3.3	4.4
Zinc:			
1998-2010	0.46	-7.3	14.0
2004-2019	0.39	-1.5	5.7

Median trends between the two periods were similar for Zn, smaller (i.e. less negative) for Cu for the more recent period, and slightly larger (i.e. more negative) for Pb in the recent period. While there were differences for Cu and Pb trends, the magnitudes are still relatively small – smaller than the 2% per year threshold set for 'meaningfulness'.

The comparison also indicates that the magnitude of the larger trends has decreased (i.e. the trends tend to have become weaker over time). This may reflect a decreasing influence over time associated with changes that occurred historically (e.g. reductions associated with removal of Pb in the 1990s, clean-up of older heavy industrial sites, expansion of stormwater treatment systems).

Relatively few 'meaningful' trends (>±2% per year, 'very likely' probability) were recorded in either period (Table 5-7). There were more meaningful decreasing trends than increasing trends for Cu and Pb for both assessment periods. Fewer meaningful trends were recorded in 2004-2019 than for 1998-2010. For Zn, the numbers of increases (six) and decreases (five) were similar for 1998-2010 and fell to zero decreases and one increase for 2004-2019.

At individual sites, meaningful trends that were measured in both 1998-2010 and 2004-2019 periods were all decreasing trends in Cu and/or Pb recorded at:

- Ann's Creek, Māngere Inlet, Manukau Harbour (Cu and Pb)
- Māngere Cemetery Māngere Inlet, Manukau Harbour (Cu, Pb, and possibly also Zn – see footnote to Table 5-6)
- Hobsonville, Central Waitematā Harbour (Cu)
- Oakley, Central Waitematā Harbour (Cu)
- Motions, Central Waitematā Harbour (Cu and Pb)
- Meola Inner, Central Waitematā Harbour (Pb)
- Whau Upper, Central Waitematā Harbour (Pb).

At these sites, decreasing trends in Cu and/or Pb recorded for the 1998-2010 period continued for the 2004-2019 period.

The only sites that changed from either a ‘non-meaningful’ trend (i.e. <±2% median per year, probability less than ‘very likely’) in 1998-2010 to an increasing trend in 2004-2019 were Herald Island Waiarohia (Upper Waitematā Harbour) for Pb and Zn, and Kendall Bay (Central Waitematā Harbour, for Cu). Both these relatively sandy sites recorded increasing muddiness, which (as discussed previously) is likely to have contributed to the increasing trends in metals’ concentration. No sites recorded changes from meaningful decreasing to increasing trends.

Seven sites changed from a meaningful increasing trend in 1998-2010 to ‘non-meaningful’ trend (i.e. <±2% median per year, probability less than ‘very likely’) in 2004-2019. These changes were all for Zn:

- Brighams Creek, Central Main, Hellyers Upper, and Outer Main Channel, all in the Upper Waitematā Harbour
- Pakuranga Upper (Tāmaki Estuary)
- Weiti (Hibiscus Coast).

Decreasing muddiness may have contributed to the changes in Zn concentrations at three of these sites (Outer Main Channel, Pakuranga Upper and Weiti).

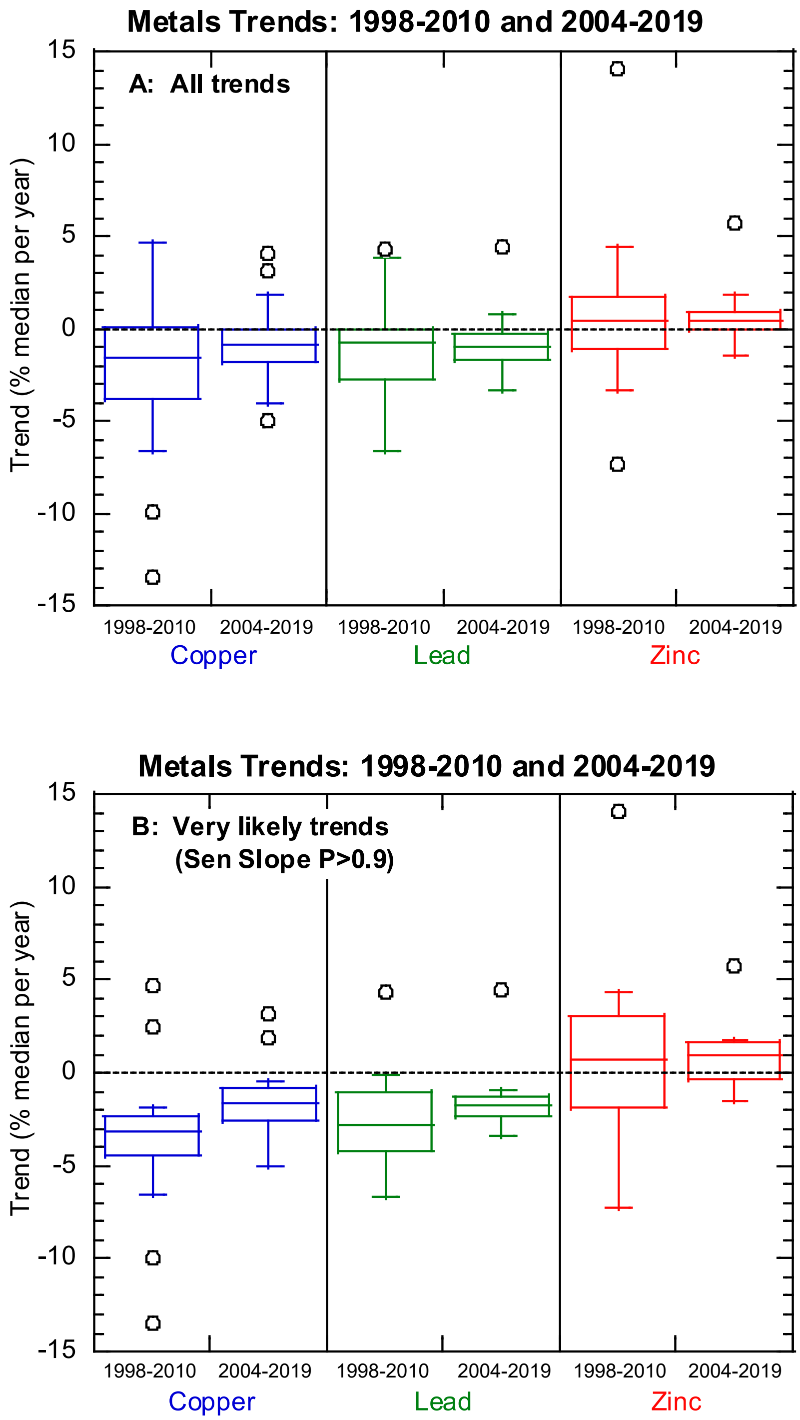

Figure 5-4. Comparison of trends (expressed as percentage change in median per year) in total recoverable metals for 1998-2010 and 2004-2019 for A. all trend data and B. for meaningful trends only (>±2% median per year and very likely probability).

Table 5-6. Comparison of meaningful (>±2% median per year, very likely probability) increasing (▲) or decreasing (▼) trends in metals' concentrations for the periods 1998-2010 and 2004-2019.

Site	Programme	MRA	Type	Copper 1998 - 2010	Copper 2004 - 2019	Lead 1998 - 2010	Lead 2004 - 2019	Zinc 1998 - 2010	Zinc 2004 - 2019
Anns Creek	SoE	Manukau	OZ	▼	▼	▼	▼	▼	
Awaruku Beach	SoE	East Coast Bays	OZ						
Big Muddy	SoE	Manukau	SZ						
Brigham Creek	UWH	Upper Waitematā	SZ	▼				▲	
Central Main	UWH	Upper Waitematā	OZ	▼				▲	
Chelsea	RDP	Central Waitematā	OZ						
Hellyers Creek	UWH	Upper Waitematā	SZ						
Hellyers Upper	UWH	Upper Waitematā	SZ				▼	▲	
Henderson Lower	RDP	Central Waitematā	SZ						
Henderson Upper	SoE	Central Waitematā	SZ	▼					
Herald Island North	UWH	Upper Waitematā	OZ	▼				▼	
Herald Island Waiarohia	UWH	Upper Waitematā	OZ				▲		▲
Hobsonville	RDP	Upper Waitematā	OZ	▼	▼	▼			
Kendall Bay	RDP	Central Waitematā	OZ		▲	▼		▼	
Lucas Te Wharau	UWH	Upper Waitematā	SZ		▼				
Lucas Upper	SoE	Upper Waitematā	SZ						
Lucas UWH	UWH	Upper Waitematā	SZ						
Mangere Cemetery	SoE	Manukau	OZ	▼	▼	▼	▼	(▼)	(▼)
Meola Inner	SoE	Central Waitematā	SZ	▼		▼	▼		
Middlemore	SoE	Tāmaki	SZ						
Motions	SoE	Central Waitematā	SZ	▼	▼	▼	▼	▼	
Oakley	SoE	Central Waitematā	SZ	▼		▼			
Opposite HBV	UWH	Upper Waitematā	OZ						
Outer Main Channel	UWH	Upper Waitematā	OZ					▲	
Pahurehure Papakura	SoE	Manukau	SZ	▼					
Pakuranga Lower	SoE	Tāmaki	SZ			▼			
Pakuranga Upper	SoE	Tāmaki	SZ		▼		▼	▲	
Panmure	RDP	Tāmaki	SZ						
Paremoremo	SoE	Upper Waitematā	SZ	▼					
Puhinui Upper	SoE	Manukau	SZ						
Pukaki Airport	SoE	Manukau	SZ					▼	
Purewa	RDP	Central Waitematā	SZ						
Rangitopuni Creek	UWH	Upper Waitematā	SZ						
Te Matuku	SoE	Tāmaki Strait	SZ						
Upper Main Channel	UWH	Upper Waitematā	OZ						
Vaughans Beach	SoE	East Coast Bays	OZ						
Weiti	SoE	Hibiscus Coast	SZ					▲	
Whau Lower	SoE	Central Waitematā	SZ	▼		▼			
Whau Upper	SoE	Central Waitematā	SZ			▼	▼		
Whau Wairau	SoE	Central Waitematā	SZ	▼		▼			

Note: (▼) for Zn at Māngere Inlet indicates very close to meaningful trend in 1998-2010 and possibly also meaningful in 2004-2019 as the data was likely to have been affected by the Zn analysis issue (described in Appendix 9.1).

Table 5-7. Numbers of sites with 'meaningful' trends ('very likely' probability and >2% median per year) for total recoverable metals in the 1998-2010 and 2004-2019 periods.

Trend direction	Copper 1998-2010	Copper 2004-2019	Lead 1998-2010	Lead 2004-2019	Zinc 1998-2010	Zinc 2004-2019
Decreasing (improving)	14	6	11	7	5	0
Increasing (worsening)	0	1	0	1	6	1

5.4 Trend summary

Trends for the 2004-2019 period were assessed at 56 sites with five or more samplings. A threshold of ±2% of the median per year and 'very likely' probability was used to define 'meaningfulness', indicating trends meeting this threshold were considered to be reliable and have 'real world' significance.

Meaningful trends in total recoverable metals were recorded at 18 of the 56 sites assessed:

- Twelve sites had decreasing concentrations of one or more metals – four sites in the Central Waitematā Harbour, one site in the Tāmaki Estuary, four sites in the Manukau Harbour, and three sites in the Upper Waitematā Harbour.
- Six sites had very likely increasing concentrations in one or more metals – three sites in the Central Waitematā Harbour, two sites in the Tāmaki Estuary, and one site in the Upper Waitematā Harbour.

Increasing muddiness accompanied the increasing trends in metals at four of the six sites with increasing metals' concentrations, and there was evidence for decreasing muddiness accompanying decreasing trends in metals' concentrations at two sites. Changes in sediment texture are therefore considered important factors influencing the trends in metals.

Trends in individual metals were as follows:

- Cu had meaningful trends at 14 sites; nine were decreasing trends and five were increasing.
- Pb had meaningful trends at 11 sites; eight were decreasing trends and three were increasing.
- Zn had meaningful trends at only four sites; all four were increasing.

Overall, the majority of monitoring sites showed little or no meaningful trends in total Cu, Pb, and Zn concentrations. At the small number of sites with robust and meaningful trends (i.e. greater than ±2% of the median per year and 'very likely' probability), decreasing trends outnumbered increases for Cu and Pb. For the few (four) sites where Zn concentrations had changed more than two per cent per year, all the trends were relatively small increases.

The current assessment showed generally comparable findings to the previous state and trends review (Mills et al., 2012). Overall, the two assessments both reported small median trends (<±2% of the median per year) and a general decrease in the magnitude, and the variability, of trends for the 2004-2019 period. Fewer meaningful trends in metals' concentrations were recorded for the 2004-2019 period than for 1998-2010.

6.0 Overall summary

Contaminant state was assessed at 120 sites. Results were similar to those reported previously (Mills et al., 2012). Contaminant concentrations are elevated in the muddy, urbanised, inner estuary zones of the Central Waitematā Harbour and Tāmaki Estuary, and to a lesser degree in Māngere Inlet (Manukau Harbour) and Upper Waitematā Harbour. At sites in predominantly rural catchments, or at open coastal sites, contaminant concentrations are low. Contaminant state has changed very little over time.

Few sites showed meaningful trends over time in total recoverable metals' concentrations. The results suggest little meaningful change over time at most sites, although a small general improvement in environmental contamination might be inferred from small decreases in Cu and Pb concentrations at most of the sites where meaningful change was measured. Changes in Zn occurred at very few sites – increases occurred at these sites, possibly associated with increasing sediment muddiness.

The reasons for the changes, and the lack of change observed at many sites has not been directly quantified in this assessment. However, the overall lack of evidence for increasing levels of sediment contamination by metals is encouraging given the increasing intensity of urban activity in Auckland (e.g. population growth, increased numbers of motor vehicles registered, ongoing land development and in-fill). It may point to the combined effects of increasing pressures being offset (indeed more than offset for Cu and Pb) by improvements in motor vehicle emissions (newer fleet), replacement of older building materials with cleaner products (e.g. coated steel, lead-free paints etc), improved stormwater management, and changes in established land use (e.g. a decrease in heavy industry).

Integrating the RSCMP monitoring results with information from marine benthic ecological and freshwater quality monitoring, and with data on changes in land use and associated urban pressures over time, would provide a more complete picture of the cause/effect relationships associated with chemical contaminants in Auckland's marine receiving environment. Continuing the work towards obtaining a more holistic understanding of these relationships is recommended.

The available evidence points to generally stable or decreasing concentrations of heavy metals over the past 15-20 years in most of the areas monitored. Continued monitoring is, however, important, as Auckland expands with increasing population, traffic, development and infrastructure. The RSCMP provides a robust framework for ongoing trend assessment, analysis of spatial patterns of contamination, assessment of contaminant state and the identification of potential risks for ecological health.

Recommendations for the monitoring programme:

- Continued PSD analysis – changes in sediment texture appear to be related to metals' accumulation and therefore particle size distribution monitoring needs to continue as an integral part of the RSCMP.
- Emerging contaminants may be of value to include in the future. The findings of research currently underway will provide the basis for integrating key contaminants and sites into the RSCMP.
- The suitability of existing sites should continue to be regularly reviewed to ensure they continue to meet the requirements of the RSCMP. Changes made to site locations may require additional monitoring 'overlap' to provide assurance that consistent data are obtained from replacement sites.
- New sites will need to be added in future to provide coverage of Auckland's expanding urban areas. Where possible, these should be established in advance of development to ensure data for pre-development baseline conditions are obtained.

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9.0 Appendix

9.1 Effects of Zn data quality on trend results

Issue

Quality assurance (QA) checks done on RSCMP annual monitoring round results found that the concentrations of Zn measured in Bulk Reference Sediment (BRS) samples in 2017, 2018, and 2019 were high compared with previous 2011-2016 results (see Mills 2021a; Mills, 2021b). The high Zn results meant that a trend in the BRS data from 2011-2019 was detected when using the same trend analysis method as used on the RSCMP monitoring data (Mann Kendall and Sen Slope tests).

The QA targets (mean concentrations within ±10% of the previous data average and trends <±2% per year), were not met for the higher concentration Middlemore BRS sample. For the 2019 data, the mean Zn in the Middlemore BRS was 15% higher than the mean from 2011-2018 and a very likely trend of 3% per year from 2011-2019 was calculated. For the lower concentration Meola OZ BRS sample, the effect was smaller; the 2019 mean was 9% higher than for previous data, and a likely trend of 1.4% per year for 2011-2019 was obtained.

This suggests that Zn trends measured at RSCMP sites sampled in 2017, 2018, and 2019 may be upwardly biased, and may be attributable (at least in part) to analytical artefacts rather than 'real' environmental change.

Therefore, we needed to assess the possible impact the elevated Zn results from 2017-2019 may have on trend results.

Approach

The potential effects on Zn trends resulting from elevated analytical results by 'correcting' for elevated concentrations based on Zn concentrations observed in BRS samples in 2017, 2018, and 2019 were assessed.

The greater effect observed for the higher concentration Middlemore BRS samples suggests a 'concentration effect' – sites may be affected differently depending on their Zn concentration. This suggests the use of an 'average' single correction factor may under-correct trends for high concentration samples, and over-correct low concentration site trends. Therefore the effects were assessed using high and low concentration BRS data, and also an average of the two.

The differences in BRS concentrations measured in 2017, 2018, and 2019 and the 'long term' averages pre-2017 (i.e. 2011 to 2016) were calculated in Table A1.

Table A1. Differences in mean zinc concentrations in Bulk Reference Sediment from 2017, 2018 and 2019.

Year	Meola OZ		Middlemore	
	mg/kg	% high	mg/kg	% high
2017	44.1	11.76	252.7	14.11
2018	42.9	9.01	251.5	13.63
2019	44.1	11.76	266.6	19.42
2011-2016 means	39.2		219.4	

Based on these BRS concentrations, 'correction factors' were calculated and applied to the site monitoring data for each of 2017, 2018, and 2019. The 'corrected' Zn concentration is the raw concentration x correction factor. Data pre-2017 was left unchanged. The correction factors are described below and presented in Table 2A.

- a 'minimum' correction factor, based on the results from the low concentration Meola OZ BRS
- a 'maximum' correction factor, based on the results from the high concentration Middlemore BRS, and
- an 'average' correction factor, the average of the minimum and maximum values:

Table A2. Minimum, maximum and average correction factors from Bulk Reference Sediment zinc data from 2017, 2018 and 2019.

Year	correction factors		
	min (MeOZ)	average	max (Middlemore)
2017	0.88	0.87	0.86
2018	0.91	0.89	0.86
2019	0.88	0.84	0.81

The trends were reanalysed using each of the 'minimum', 'average' and 'maximum' corrected data sets. These results were compared with the 'raw' trend data obtained using the original 'uncorrected' data (Table A3).

The trends were summarised using the LAWA (2019) likelihood categorisation approach, using both 'all data' and filtered results based on 'real world meaningfulness' of thresholds of 1% and 2% of median per year and 'very likely' trend likelihood.

The results for the QA samples (CRM, Meola BRS and Middlemore BRS) were examined to see what effect each level of correction has on trends for samples that should show no trend over time.

Trends at 57 RSCMP sites for the period 2004 to 2019 (approximately, varies for each site) were examined:

- 22 sites were sampled in 2017 (four of these sites were sampled only in 2017, and 18 were also sampled again in 2019)
- 33 sites were sampled in 2018
- 18 sites were sampled in 2019 (all of these were also sampled in 2017).

Two of the 57 sites would not have been affected, as they were not sampled in 2017, 2018 or 2019:

- Awatea Rd, last sampled in 2016, and
- Meola Reef Te Tokoroa (SOE site). This site was not included in the final list of sites included for trend reporting, as it did not have adequately up-to-date data (last sampled in 2013).

Neither of these two sites had Zn trends that were in the ‘meaningful’ trend category (Awatea Rd -0.74%/yr, ‘very likely’ improving; Meola Reef -1.56%/yr, ‘likely’ improving).

Results

Table A3. Trend results (1% and 2% of median per year filters) using the raw, minimum, maximum and average corrected data (for 2017, 2018 and 2019) of Certified Reference Material and Bulk Reference Sediment. It is noted that no trends over time should occur.

1% of median per year filter:

	Raw trends		Min corr		Ave corr		Max corr	
	All trends	>1%/yr	All trends	>1%/yr	All trends	>1%/yr	All trends	>1%/yr
Total sites	3	2	3	0	3	1	3	1
very likely improving (P 90-100%)	0	0	1	0	2	1	2	1
likely improving (P 67-90%)	0	0	1	0	0	0	1	0
indeterminate (P<67%)	0	0	0	0	0	0	0	0
likely worsening (P 67-90%)	2	1	1	0	1	0	0	0
very likely worsening (P 90-100%)	1	1	0	0	0	0	0	0
very likely improving samples	none	none	CRM	none	CRM, MeOZ BRS	MeOZ BRS	CRM, MeOZ BRS	MeOZ BRS
very likely worsening samples	Mid BRS	Mid BRS	none	none	none	none	none	none

2% of median per year filter:

	Raw trends		Min corr		Ave corr		Max corr	
	All trends	>2%/yr	All trends	>2%/yr	All trends	>2%/yr	All trends	>2%/yr
Total sites	3	1	3	0	3	0	3	0
very likely improving (P 90-100%)	0	0	1	0	2	0	2	0
likely improving (P 67-90%)	0	0	1	0	0	0	1	0
indeterminate (P<67%)	0	0	0	0	0	0	0	0
likely worsening (P 67-90%)	2	0	1	0	1	0	0	0
very likely worsening (P 90-100%)	1	1	0	0	0	0	0	0
very likely improving samples	none	none	CRM	none	CRM, MeOZ BRS	none	CRM, MeOZ BRS	none
very likely worsening samples	Mid BRS	Mid BRS	none	none	none	none	none	none

Raw trends showed a 'very likely' increasing trend >2% per year for Middlemore BRS, and a 'likely' increasing trend >1% per year for MeOZ BRS.

Applying the minimum correction factor removed trends >1% per year and 2% per year for all QA samples.

Applying average correction factors resulted in an improving trend >1% per year for MeOZ BRS (i.e. overcorrection), but not for >2% per year (i.e. overcorrection is less than 2% per year).

Applying the maximum correction factor resulted in an improving trend >1% per year for MeOZ BRS (i.e. overcorrection) but not for >2% per year.

These results suggested that applying the 'minimum' correction factor would remove analytical trend artefacts without introducing 'over-correction'.

Reference sites:

Reference sites are RSCMP sites located where no changes would be expected to occur. Trend analysis for these sites was conducted and the results presented in Table 4A.

Table A4. Trend results (% of median per year and trend probability) using the raw, minimum, maximum and average corrected zinc data (for 2017, 2018 and 2019).

	Raw		Min correction		Ave correction		Maximum Correction	
Site	%/year	P	%/year	P	%/year	P	%/year	P
Awaruku Beach	0.16	0.576	-0.36	0.831	-0.41	0.957	-0.69	0.957
Big Muddy	0.87	0.820	0.07	0.539	-0.02	0.602	-0.21	0.717
Te Matuku	0.23	0.676	0.00	0.560	-0.39	0.676	-0.41	0.914
Vaughans Beach	-0.15	0.717	-0.15	0.831	-0.18	0.910	-0.38	0.982

No meaningful trends in raw data were measured at these sites, although Big Muddy had a small 'likely' increasing trend (but <1% per year).

Minimum correction reduced the small trend at Big Muddy, but introduced a decreasing trend at Awaruku Beach, where Zn concentration is low (24 mg/kg).

Average and maximum corrections gave overcorrection, leading to larger decreasing trends.

Overall, trends obtained from the raw data were small (<1% per year), but a slight improvement – smaller increasing trends at Big Muddy and Te Matuku – were obtained with the minimum correction (which would be appropriate given the low Zn concentrations at these sites; medians of 51 mg/kg and 31 mg/kg respectively).

Table A5. Trends results (1% and 2% of median per year filters) using the raw, minimum, maximum and average corrected zinc data at 57 RSCMP sites from 2004 to 2019.

1% of median per year filter:

	Raw trends		Min corr		Ave corr		Max corr	
	All trends	>1%/yr	All trends	>1%/yr	All trends	>1%/yr	All trends	>1%/yr
Total sites	57	22	57	13	57	17	57	17
very likely improving (P 90-100%)	6	3	9	4	16	7	19	10
likely improving (P 67-90%)	6	1	13	2	10	3	12	1
indeterminate (P<67%)	13	0	17	0	13	0	14	0
likely worsening (P 67-90%)	13	4	7	2	10	2	6	1
very likely worsening (P 90-100%)	19	14	11	5	8	5	6	5

2% of median per year filter:

	Raw trends		Min corr		Ave corr		Max corr	
	All trends	>2%/yr	All trends	>2%/yr	All trends	>2%/yr	All trends	>2%/yr
Total sites	57	6	57	5	57	4	57	4
very likely improving (P 90-100%)	6	0	9	1	16	1	19	1
likely improving (P 67-90%)	6	0	13	0	10	0	12	0
indeterminate (P<67%)	13	0	17	0	13	0	14	0
likely worsening (P 67-90%)	13	2	7	0	10	0	6	0
very likely worsening (P 90-100%)	19	4	11	4	8	3	6	3

Raw trend data indicated that 19 of the 57 sites had 'very likely' increasing (worsening) trends and 6 sites had very likely decreasing (improving) trends.

Applying a 1% per year filter to these trends reduced the number of 'meaningful' trends to 14 increasing (3 decreasing), while a 2% per year filter gave only 4 meaningful increasing trends (0 decreasing).

Applying the minimum, average, and maximum correction factors to the 2017, 2018, and 2019 data resulted in:

- smaller numbers of sites with 'very likely' increasing trends; 14, 5, 5, and 5 sites with >1% per year trends for raw data, minimum, average, and maximum corrections respectively. Correcting the data therefore made a substantial difference (a drop from 14 to 5 sites) in the number of 'meaningful' trends. The 5 sites with these trends were Benghazi, Cox's Bay, Herald Island Waiarohia, Central Main Channel, and Whau Entrance.
- increasing the meaningfulness threshold to 2% per year resulted in only a small change in the number of very likely increasing trends from 4 (raw) to 4 (minimum correction) to 3 (average and maximum correction). The 4 sites with these trends were Benghazi, Cox's Bay, Herald Island Waiarohia, and Whau

Entrance. Benghazi dropped off the list when greater than minimum correction was applied.

- a greater number of sites with decreasing trends; 3, 4, 7, and 10 sites with >1% per year trends for raw, minimum, average, and maximum correction respectively. With a 2% per year threshold applied, the number of decreasing trends changed little, from 0 (raw) to 1 (minimum, average, and maximum correction applied). The site with a decreasing trend >2% per year with the correction applied was Māngere Cemetery, which shifted from -1.5% per year (raw) to -2.7% per year with any of the corrections applied.

The magnitude of trends (ignoring ‘significance’ or ‘likelihood’) showed only relatively subtle shifts in trend values between raw and corrected data – see plots of trend distributions (Figure A1). Trends were ‘compressed’ slightly towards ‘zero’, with fewer increasing trends apparent when corrections were applied:

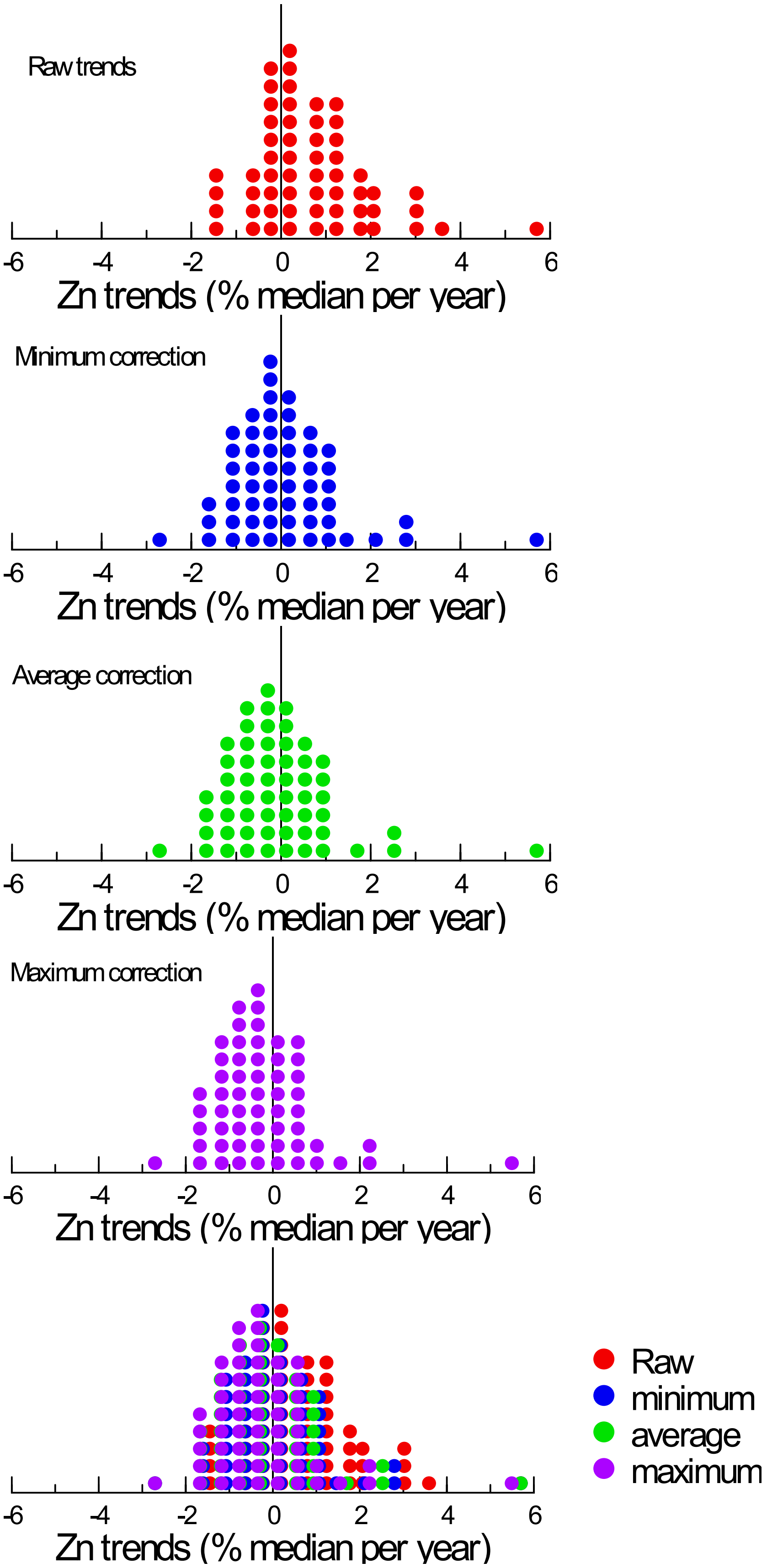


Figure A1. Distribution of trends in raw data (uncorrected) and data where 2017, 2018, and 2019 results have been corrected for higher than usual analytical results.

Conclusions

Trends measured from the Sen Slope are the medians of the slopes between data points. This reduces the effects of occasional outlying data. The effect of one or two elevated data points in the trend series is likely to be subtle.

When the trend data are summarised with a 'meaningfulness' threshold of 2% per year (and 'very likely' trend likelihood), the effect of the elevated Zn data from 2017, 2018, and 2019 is very small; only a change in one site with correction for increasing or decreasing trends. If a 1% per year threshold is applied, an appreciable effect is observed, with 14 sites with meaningful increasing trends dropping to 5 when the Zn data are corrected, and a greater number of decreasing trends observed (3, 4, 7, and 10 sites for raw, minimum, average, and maximum corrections respectively).

The lack of a strong effect, especially when applying the 'very likely' and 2% per year meaningfulness threshold, reflects a combination of relatively small trends at most sites, the relatively smaller trends (when expressed as % of median per year) at higher concentration sites, and that strongest trends (when expressed as % of median per year) were observed at relatively low concentration sites.

The distribution of Zn concentrations at the trend sites, where relatively few sites have high concentrations (only 5/57 sites have Zn >200 mg/kg) is probably also a factor (since the greatest increase in the QA samples was observed for the high concentration Middlemore BRS sample; median Zn = 227 mg/kg). The median Zn concentration (of the 57 individual trend site medians) was 102 mg/kg.

<u>Overall:</u>

If the trends are reported with a 2% per year (and very likely probability) meaningfulness threshold applied, then the high 2017, 2018, and 2019 data will have little practical effect on the overall conclusions.

If the actual numerical trend data are reported, or if a smaller threshold is applied (e.g. 1% of the median per year), then the high 2017, 2018, and 2019 results will have an effect.

This analysis suggests that the overall effect of correcting for high results in 2017-2019 appears to be a subtle decrease in the magnitude of Zn trends across the sites.

Note:

The state and trends data used in this report are based on the RAW metals' data, with no corrections applied. The ±2% median per year meaningfulness threshold for trends has been used to ensure that the data quality issues discussed here do not affect the validity of the conclusions drawn from the data.

9.2 State tables

9.2.1 State table for core RSCMP sites, based on ERC grades obtained from total recoverable Cu, Pb, and Zn concentrations (mg/kg), and HWPAH, OCPs and PCBs. Current state-determining metal(s) are given for amber and red grades.

			Current status	Other status	Status & assessment year				Total metals (<0.5 mm, mg/kg)		
Site	Marine Reporting Area	Programme	Based on metals	Possibly historical	Metals	HWPAH	OCPs	PCBs	Cu	Pb	Zn
Awatea	Central Waitemata	RDP			2016				9.1	28.6	96.2
Chelsea	Central Waitemata	RDP		HWPAH	2019	2012	2012	2012	6.4	12.5	54.0
Coxs Bay	Central Waitemata	RDP		HWPAH	2019	2012	2012	2012	9.6	19.4	105.2
Henderson Entrance	Central Waitemata	RDP		HWPAH, OCs	2019	2012	2012	2012	7.6	19.7	90.3
Henderson Lower	Central Waitemata	RDP	Zn	HWPAH	2019	2002			30.0	28.4	153.6
Henderson Upper	Central Waitemata	SoE	Zn	HWPAH, OCs	2018	2013	2013	2013	30.4	27.2	168.7
Island Bay	Central Waitemata	RDP			2018				6.9	12.6	60.7
Kendall Bay	Central Waitemata	RDP			2019				5.7	8.3	41.9
Meola Inner	Central Waitemata	SoE	Zn	DDTs	2018	2013	2013	2013	30.1	48.5	252.9
Meola Outer	Central Waitemata	RDP			2019				4.1	9.6	39.6
Meola Reef	Central Waitemata	CWHEco		OCPs (PCBs)	2019		2003		7.6	15.6	85.0
Motions	Central Waitemata	SoE	Zn	HWPAH	2018	2005	2007	2003	16.1	32.1	251.6
Oakley	Central Waitemata	SoE	Zn	HWPAH, OCs	2018	2013	2013	2013	23.2	35.8	167.1
Pollen Island	Central Waitemata	RDP		HWPAH	2018	2002			9.3	18.1	89.3
Purewa	Central Waitemata	RDP	Zn	HWPAH, OCs	2017	2012	2012	2012	13.2	33.5	170.4
Shoal Bay Charles St	Central Waitemata	CWHEco			2018				2.2	5.5	19.2
Shoal Bay Hillcrest	Central Waitemata	RDP		HWPAH, OCs	2019	2012	2012	2012	18.3	27.2	111.2
Whakataka Bay	Central Waitemata	RDP		HWPAH	2018	2002			6.3	16.2	90.6
Whau Entrance	Central Waitemata	RDP			2019				6.1	10.6	50.2
Whau Lower	Central Waitemata	SoE	Zn	HWPAH, OCs	2018	2013	2013	2013	23.0	34.5	177.8
Whau Upper	Central Waitemata	SoE	Zn	HWPAH, OCs	2018	2013	2013	2013	28.3	43.4	256.6
Whau Wairau	Central Waitemata	SoE	Cu Pb Zn	HWPAH, OCs	2018	2013	2013	2013	38.6	54.8	248.2
Awaruku Beach	East Coast Bays	SoE		HWPAH, OCPs, (PCBs)	2018	2005	2003	2003	1.8	3.2	25.3
Vaughans Beach	East Coast Bays	SoE		HWPAH, OCPs, (PCBs)	2018	2005	2003	2003	1.6	3.0	23.8
Okura S1	Hibiscus Coast	estuaries			2016				1.3	1.7	13.9
Okura S7	Hibiscus Coast	estuaries			2016				2.7	3.7	22.3
Okura S9	Hibiscus Coast	estuaries		HWPAH, OCs	2016	2010	2010	2010	3.8	5.7	30.8
Orewa S1	Hibiscus Coast	estuaries			2016				1.4	1.8	15.3
Orewa S4	Hibiscus Coast	estuaries			2016				2.3	2.5	19.9
Orewa S8	Hibiscus Coast	estuaries		HWPAH, OCs	2016	2010	2010	2010	2.1	2.6	21.6
Waiwera S1	Hibiscus Coast	estuaries		HWPAH, OCs	2016	2010	2010	2010	5.7	7.5	37.6
Waiwera S3	Hibiscus Coast	estuaries			2016				2.7	2.6	23.7
Waiwera S8	Hibiscus Coast	estuaries			2016				3.1	2.8	23.9
Weiti	Hibiscus Coast	SoE		HWPAH, OCs	2018	2005	2007	2003	12.2	8.4	62.1
Haratahi Creek	Kaipara	estuaries		HWPAH, OCs	2009	2009	2009	2009	3.2	2.5	25.5
Kaipara Bank	Kaipara	estuaries		HWPAH, OCs	2009	2009	2009	2009	5.4	3.5	33.5
Kaipara Flats	Kaipara	estuaries		HWPAH, OCs	2009	2009	2009	2009	2.1	1.7	19.6
Kakarai Flats	Kaipara	estuaries		HWPAH, OCs	2009	2009	2009	2009	3.1	2.6	28.5
Ngapuke Creek	Kaipara	estuaries		HWPAH, OCs	2009	2009	2009	2009	3.9	2.2	25.0
Tapora Bank	Kaipara	estuaries		HWPAH, OCs	2009	2009	2009	2009	1.8	1.3	13.0
Dyers Creek	Mahurangi	estuaries			2016				2.7	2.1	17.9
Hamiltons Landing	Mahurangi	estuaries		HWPAH, OCs	2016	2010	2010	2010	6.3	5.8	33.2
Jamiesons Bay	Mahurangi	estuaries		HWPAH, OCs	2016	2010	2010	2010	6.8	5.6	37.5
Mid Harbour	Mahurangi	estuaries			2016				4.2	3.6	31.8
Te Kapa Inlet	Mahurangi	estuaries			2016				5.6	3.9	32.5
Anns Creek	Manukau	SoE	Zn	HWPAH, OCPs, (PCBs)	2018	2005	2007	2003	15.2	19.5	151.7
Big Muddy	Manukau	SoE		HWPAH, OCPs, (PCBs)	2018	2005	2003	2003	8.5	9.4	63.6
Blockhouse Bay	Manukau	RDP			2018				4.5	10.1	63.2
Bottle Top Bay	Manukau	RSCMP			2019				9.5	12.8	85.8
DoC Island Mud	Manukau	RSCMP			2019				3.7	6.6	48.4
Drury Inner	Manukau	RSCMP			2019				6.3	9.2	66.6
Harania	Manukau	RDP	Zn		2019				16.1	20.2	146.8
Hillsborough	Manukau	RDP			2015				7.4	10.8	63.3
Karaka / Te Hihi estuary	Manukau	RSCMP			2019				3.7	5.5	38.8
Little Muddy	Manukau	RDP			2018				10.1	11.4	73.0
Mangere Cemetery	Manukau	SoE		HWPAH, OCs	2018	2013	2013	2013	11.5	16.7	114.9
Mauku/ Taihiki River A	Manukau	RSCMP			2019				3.3	5.4	39.3
Mauku/ Taihiki River B	Manukau	RSCMP			2019				2.4	4.7	29.5
Mill Bay	Manukau	RDP			2015				4.0	8.6	51.0
Pahurehure Middle	Manukau	RDP			2019				2.3	6.3	40.7
Pahurehure Papakura	Manukau	SoE		HWPAH, OCPs, (PCBs)	2018	2005	2003	2003	7.0	12.7	86.8
Pahurehure Upper	Manukau	RDP		HWPAH, OCs	2019	2012	2012	2012	8.8	12.4	91.2
Papakura Lower	Manukau	RDP		HWPAH, OCs	2019	2012	2012	2012	9.4	12.9	89.1
Puhinui Upper	Manukau	SoE		HWPAH, OCPs, (PCBs)	2019	2005	2003	2003	9.7	12.3	117.6
Pukaki Airport	Manukau	SoE		HWPAH, OCPs, (PCBs)	2019	2005	2003	2003	8.2	11.1	77.0
Pukaki Upper	Manukau	RDP			2018				3.7	5.8	44.5
Pukaki Waokauri	Manukau	RDP			2018				5.6	8.6	65.1
Tararata	Manukau	RDP	Zn		2019				15.0	18.5	131.9
Waimahia Central	Manukau	RDP			2019				8.6	11.5	85.5
Waiuku	Manukau	RDP		HWPAH, OCs	2017	2012	2012	2012	8.8	16.3	110.2
Whangamaire	Manukau	RSCMP			2019				3.0	6.1	27.7
Whangapouri	Manukau	SoE			2019				6.7	10.3	66.7

Note: Paler green shading for PCBs in 2003, and bracketed (PCBs) in the 'other status' columns reflects screening analysis performed in 2003 with higher than desirable detection limits. It is very highly likely that these sites are ERC-green.

State data table continued

Site	Marine Reporting Area	Programme	Current status Based on metals	Other status Possibly historical	Status & assessment year: Metals	HWPAH	OCPs	PCBs	Total metals (<0.5 mm, mg/kg): Cu	Pb	Zn
Benghazi	Tamaki Estuary	RDP		HWPAH, OCs	2019	2012	2012	2012	12.7	16.3	102.9
Bowden	Tamaki Estuary	RDP	Zn	HWPAH, OCs	2017	2012	2012	2012	20.4	29.0	206.8
Middlemore	Tamaki Estuary	SoE	Zn	HWPAH, OCs	2018	2011	2013	2013	26.6	28.3	229.5
Otahuhu Creek	Tamaki Estuary	RDP	Zn	HWPAH, OCs	2017	2012	2012	2012	24.6	26.9	177.6
Pakuranga Lower	Tamaki Estuary	SoE	Zn	HWPAH, OCPs, (PCBs)	2018	2005	2003	2003	15.8	19.8	162.4
Pakuranga Upper	Tamaki Estuary	SoE	Zn	HWPAH, OCs	2018	2013	2013	2013	21.3	22.8	217.4
Panmure	Tamaki Estuary	RDP	Zn	HWPAH, OCs	2019	2012	2012	2012	27.7	29.3	196.1
Princes St	Tamaki Estuary	RDP	Zn	HWPAH, OCs	2017	2012	2012	2012	22.5	26.4	185.9
Roberta Reserve	Tamaki Estuary	RDP			2015				3.6	7.3	39.1
Mangemangeroa S3	Tamaki Strait	estuaries			2016				4.1	7.0	34.6
Mangemangeroa S6	Tamaki Strait	estuaries			2016				5.6	10.3	45.9
Mangemangeroa S9	Tamaki Strait	estuaries			2016	2010	2010	2010	5.5	11.7	50.6
Te Matuku	Tamaki Strait	SoE		HWPAH, OCs	2018	2013	2013	2013	2.9	6.9	34.2
Turanga S4	Tamaki Strait	estuaries			2016				3.1	6.2	27.8
Turanga S7	Tamaki Strait	estuaries			2016				4.0	8.8	45.0
Turanga S8	Tamaki Strait	estuaries		HWPAH, OCs	2016	2010	2010	2010	6.2	11.9	52.5
Waikopua S1	Tamaki Strait	estuaries			2016				1.5	2.8	14.3
Waikopua S3	Tamaki Strait	estuaries			2016				2.1	4.0	19.8
Waikopua S9	Tamaki Strait	estuaries		HWPAH, OCs	2016	2010	2010	2010	3.8	6.8	24.6
Wairoa 1	Tamaki Strait	estuaries			2018				6.3	8.1	70.9
Wairoa 2	Tamaki Strait	estuaries			2018				3.1	5.2	32.8
Wairoa 3	Tamaki Strait	estuaries			2018				2.7	4.9	31.7
Wairoa 4	Tamaki Strait	estuaries			2018				4.5	7.8	47.8
Wairoa 5	Tamaki Strait	estuaries			2018				3.4	6.0	47.9
Wairoa 6	Tamaki Strait	estuaries			2018				5.4	8.6	53.4
Wairoa 7	Tamaki Strait	estuaries			2018				5.3	8.8	50.1
Brigham Creek	Upper Waitemata	UWH	Cu	HWPAH	2018	2013			20.1	22.7	117.9
Central Main	Upper Waitemata	UWH	Zn	HWPAH	2018	2013			13.8	26.5	125.3
Hellyers Creek	Upper Waitemata	UWH		HWPAH	2018	2013			14.1	20.2	98.4
Hellyers Upper	Upper Waitemata	UWH	Cu Zn	HWPAH	2018	2013			20.0	25.2	134.2
Herald Island North	Upper Waitemata	UWH		HWPAH	2018	2013			6.8	13.3	60.9
Herald Island Waiarohia	Upper Waitemata	UWH		HWPAH	2018	2013			5.6	9.7	40.9
Hobsonville	Upper Waitemata	UWH		HWPAH	2019	2009			2.5	5.8	23.5
Lucas Te Wharau	Upper Waitemata	UWH		HWPAH	2018	2013			12.7	16.3	80.8
Lucas Upper	Upper Waitemata	SoE		HWPAH, OCPs, (PCBs)	2018	2005	2007	2003	19.0	20.6	122.1
Lucas UWH	Upper Waitemata	UWH		HWPAH	2018	2013			13.2	22.8	114.9
Opposite HBV	Upper Waitemata	UWH		HWPAH	2018	2013			18.7	27.2	118.6
Outer Main Channel	Upper Waitemata	UWH		HWPAH	2018	2013			11.4	15.9	67.7
Paremoremo	Upper Waitemata	SoE	Cu	HWPAH, OCPs, (PCBs)	2018	2005	2007	2003	21.1	22.8	108.8
Rangitopuni Creek	Upper Waitemata	UWH	Cu	HWPAH, OCs	2018	2013	2013	2013	22.5	23.7	118.6
Rarawaru	Upper Waitemata	RDP			2015				15.9	19.6	75.4
Upper Main Channel	Upper Waitemata	UWH	Cu	HWPAH	2018	2013			21.6	23.5	114.3
Puhoi S1	Warkworth/Wellsford	estuaries			2016				2.9	1.8	23.6
Puhoi S4	Warkworth/Wellsford	estuaries			2016				3.1	1.9	23.5
Puhoi S9	Warkworth/Wellsford	estuaries		HWPAH, OCs	2016	2010	2010	2010	5.8	3.8	27.7
Whangateau S1	Warkworth/Wellsford	estuaries		HWPAH, OCs	2016	2009	2009	2009	0.8	0.7	7.2
Whangateau S4	Warkworth/Wellsford	estuaries		HWPAH, OCs	2016	2009	2009	2009	1.1	1.0	10.6
Whangateau S5	Warkworth/Wellsford	estuaries		HWPAH, OCs	2016	2009	2009	2009	2.5	1.8	19.5

Note: Paler green shading for PCBs in 2003, and bracketed (PCBs) in the 'other status' columns reflects screening analysis performed in 2003 with higher than desirable detection limits. It is very highly likely that these sites are ERC-green.

9.2.2 Retired site state table, based on ERC grades obtained from total recoverable Cu, Pb, and Zn concentrations (mg/kg), and HWPAH, OCPs and PCBs. State-determining metal contaminants are given for ERC-amber and red grades, and year of last sampling shown.

			Current status	Other status	Status & assessment year				Total metals (<0.5 mm, mg/kg)		
Site	Marine Reporting Area	Programme	Based on metals	Possibly historical	Metals	HWPAH	OCPs	PCBs	Cu	Pb	Zn
Beachhaven	Central Waitemata	RDP	Pb	HWPAH	2002	2002			18.5	32.0	105.0
Brighams (RDP)	Upper Waitemata	RDP	Cu		2007				22.0	26.8	104.0
Brow ns	East Coast Bays	RDP		HWPAH, OCPs, (PCBs)	2007	2005	2003	2003	2.0	4.5	34.0
Cape Horn	Manukau Hbr	RDP		HWPAH	2002	2002			2.9	3.9	23.3
Central Basin Mahurangi (CB)	Mahurangi	Estuaries			2010				3.0	3.4	30.0
Cheltenham	East Coast Bays	SoE		HWPAH	2011	2005	2003	2003	2.9	10.0	45.0
Clarks Beach	Manukau Hbr	RDP			2002				2.0	3.2	26.4
Coxs Inner	Central Waitemata	BHM extras			2005				4.5	13.8	44.3
DoC Island Sand	Manukau Hbr	RSCMP			2015				2.5	10.3	29.2
Glendow ie	Tamaki Estuary	BHM extras			2005				3.5	5.0	32.5
Hellyers SoE	Upper Waitemata	SoE		HWPAH, OCPs, (PCBs)	2011	2005	2003	2003	13.5	22.0	102.0
Hellyers Upper RDP	Upper Waitemata	RDP			2007				15.0	21.0	93.6
Herald Island RDP	Upper Waitemata	RDP			2005				7.8	15.0	76.0
Hobson New market	Central Waitemata	SoE		HWPAH	2011	2005	2003	2003	5.6	12.1	43.0
Hobson Purew a Bridge	Central Waitemata	BHM extras	Zn		2005				14.0	33.3	156.0
Hobson Tohunga	Central Waitemata	BHM extras			2005				4.4	14.3	44.5
Hobson Victoria	Central Waitemata	RDP			2008				3.8	11.0	39.0
Hobson Whakataka Site 1	Central Waitemata	RDP			2007				8.6	24.3	104.0
Kaipatiki	Upper Waitemata	RDP	Cu Pb		2009				20.0	31.0	120.0
Little Shoal Bay	Central Waitemata	BHM extras			2005				5.2	13.1	37.4
Lucas Te Wharau RDP	Upper Waitemata	RDP	Cu Pb		2008				24.0	31.0	110.0
Mangere Cemetery NZTA	Manukau Hbr	NZTA			2016				11.3	17.2	94.9
Mangere Kiw i Esplanade	Manukau Hbr	BHM extras			2005				18.7	20.6	104.0
Meola Reef Te Tokaroa	Central Waitemata	SoE		HWPAH, OCPs, (PCBs)	2013	2005	2003	2003	8.3	18.4	84.0
Meola West	Central Waitemata	BHM extras			2005				13.0	29.4	155.0
Motions East	Central Waitemata	BHM extras			2005				5.1	15.2	89.8
Ngataringa	Central Waitemata	RDP	Cu Pb		2007				22.1	37.9	123.0
Pakuranga Mid	Tamaki Estuary	BHM extras	Zn		2005				22.6	25.8	153.0
Papakura Upper	Manukau Hbr	RDP			2008				12.0	17.0	89.0
Paremoremo UWH	Upper Waitemata	UWH	Cu	HWPAH	2008	2007			23.0	29.0	103.0
Point England	Tamaki Estuary	RDP			2010				12.0	20.0	92.0
Puhinui Entrance	Manukau Hbr	RDP			2009				8.8	13.0	110.0
Rangitopuni 2005	Upper Waitemata	BHM extras	Cu		2005				22.0	23.9	90.9
Rangitopuni RDP	Upper Waitemata	RDP	Cu		2007				19.1	22.4	97.3
Shoal Low er	Central Waitemata	RDP			2013				4.1	9.5	43.0
Shoal Upper	Central Waitemata	RDP			2008				4.6	12.0	44.0
Waiarohia	Upper Waitemata	RDP	Cu		2010				19.0	26.0	95.0
Waimahia East	Manukau Hbr	RDP			2008				11.0	16.0	88.0
Waimahia West	Manukau Hbr	RDP			2008				9.3	13.0	74.0
Whau East	Central Waitemata	BHM extras	Pb Zn		2005				27.3	50.6	182.0
Whau Outer A	Central Waitemata	RDP?			2002				4.2	8.8	29.4
Whau Outer A	Central Waitemata	RDP?			2002				4.6	10.2	35.9
Whau Outer D	Central Waitemata	RDP?			2002				7.3	13.5	40.7
Whau West	Central Waitemata	BHM extras	Cu Zn		2005				48.9	47.4	172.0

Note: Paler green shading for PCBs in 2003, and bracketed (PCBs) in the 'other status' columns reflects screening analysis performed in 2003 with higher than desirable detection limits. It is very highly likely that these sites are ERC-green.

9.2.3 State history table for core RSCMP sites, based on ERC grades obtained from total recoverable Cu, Pb, and Zn concentrations. State-determining metal(s) are given for amber and red grades.

Site	MRA	Programme	Year sampled																					
			2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998
Awatea Rd	Central Waitemata	RDP									Pb			Pb				Pb						
Chelsea	Central Waitemata	RDP																						
Coxs Bay	Central Waitemata	RDP																						
Henderson Entrance	Central Waitemata	RDP																						
Henderson Lower	Central Waitemata	RDP	Zn		Cu Zn		Cu Zn			Cu Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn				
Henderson Upper	Central Waitemata	SoE		Zn		Zn			Cu Pb Zn		Zn		Cu Pb Zn		Zn		Zn		Cu Zn		Zn		Cu Zn	Cu Zn
Island Bay	Central Waitemata	RDP																						
Kendall Bay	Central Waitemata	RDP																						
Meola Inner	Central Waitemata	SoE		Zn		Pb Zn			Pb Zn		Pb Zn		Pb Zn		Pb Zn		Cu Pb Zn		Pb Zn		Pb Zn		Cu Pb Zn	Cu Pb Zn
Meola Outer	Central Waitemata	RDP																						
Meola Reef	Central Waitemata	CWHeco																						
Motions	Central Waitemata	SoE		Zn		Zn		Pb Zn		Pb Zn		Zn	Pb Zn											
Oakley	Central Waitemata	SoE		Zn		Cu Pb Zn			Cu Pb Zn		Zn		Cu Pb Zn		Zn		Zn		Zn		Zn		Cu Pb Zn	Pb Zn
Pollen Island	Central Waitemata	RDP																						
Purewa	Central Waitemata	RDP			Zn					Zn		Zn		Zn		Zn		Zn		Zn				
Shoal Bay Charles St	Central Waitemata	CWHeco																						
Shoal Hillcrest	Central Waitemata	RDP								Pb		Pb		Cu Pb Zn				Pb						
Whakataka Bay	Central Waitemata	RDP																						
Whau Entrance	Central Waitemata	RDP																						
Whau Lower	Central Waitemata	SoE		Zn		Cu Pb Zn			Zn		Zn		Zn		Zn		Zn		Pb Zn		Zn		Cu Pb Zn	Pb Zn
Whau Upper	Central Waitemata	SoE		Zn		Pb Zn			Pb Zn		Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn	Cu Pb Zn
Whau Wairau	Central Waitemata	SoE		Zn		Pb Zn			Pb Zn		Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn	Cu Pb Zn
Awaruku Beach	East Coast Bays	SoE																						
Vaughans Beach	East Coast Bays	SoE																						
Okura S1	Hibiscus Coast	estuaries																						
Okura S7	Hibiscus Coast	estuaries																						
Okura S9	Hibiscus Coast	estuaries																						
Orewa S1	Hibiscus Coast	estuaries																						
Orewa S4	Hibiscus Coast	estuaries																						
Orewa S8	Hibiscus Coast	estuaries																						
Waiwera S1	Hibiscus Coast	estuaries																						
Waiwera S3	Hibiscus Coast	estuaries																						
Waiwera S8	Hibiscus Coast	estuaries																						
Weiti	Hibiscus Coast	SoE																						

State history data table continued

Site	MRA	Programme	Year sampled																					
			2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998
Haratahi Creek	Kaipara	estuaries																						
Kaipara Bank	Kaipara	estuaries																						
Kaipara Flats	Kaipara	estuaries																						
Kakarai Flats	Kaipara	estuaries																						
Ngapuke Creek	Kaipara	estuaries																						
Tapora Bank	Kaipara	estuaries																						
Dyers Creek	Mahurangi	estuaries																						
Hamiltons Landing	Mahurangi	estuaries																						
Jamiesons Bay	Mahurangi	estuaries																						
Mid Harbour	Mahurangi	estuaries																						
Te Kapa Inlet	Mahurangi	estuaries																						
Anns Creek	Manukau	SoE		Zn		Zn			Zn		Zn		Cu Zn		Cu Zn		Zn		Cu Zn		Cu Zn		Cu Zn	Cu Zn
Big Muddy	Manukau	SoE																						
Blockhouse Bay	Manukau	RDP																						
Bottle Top Bay	Manukau	RSCMP																						
DoC Island Mud	Manukau	RSCMP																						
Drury Inner	Manukau	RSCMP																						
Harania	Manukau	RDP	Zn		Zn		Zn					Zn					Cu							
Hillsborough	Manukau	RDP																						
Karaka Te Hihi estuary	Manukau	RSCMP																						
Little Muddy	Manukau	RDP																						
Mangere Cemetery	Manukau	SoE									Cu Zn				Cu Zn		Cu Zn		Cu Pb Zn		Cu Zn		Cu Pb Zn	Cu Pb Zn
Mauku/Taihiki River A	Manukau	RSCMP																						
Mauku/Taihiki River B	Manukau	RSCMP																						
Mill Bay	Manukau	RDP																						
Pahurehure Middle	Manukau	RDP																						
Pahurehure Papakura	Manukau	SoE																						
Pahurehure Upper	Manukau	RDP																						
Papakura Low er	Manukau	RDP																						
Puhinui Upper	Manukau	SoE																						
Pukaki Airport	Manukau	SoE																						
Pukaki Upper	Manukau	RDP																						
Pukaki Waokauri	Manukau	RDP																						
Tararata	Manukau	RDP	Zn		Zn							Zn					Cu Zn							
Waimahia Central	Manukau	RDP																						
Waiuku	Manukau	RDP																						
Whangamaire	Manukau	RSCMP																						
Whangapouri	Manukau	RSCMP																						

State history data table continued

Site	MRA	Programme	Year sampled																					
			2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998
Benghazi	Tamaki Estuary	RDP																						
Bowden	Tamaki Estuary	RDP			Zn		Zn			Zn		Zn		Zn		Zn		Zn						
Middlemore	Tamaki Estuary	SoE		Zn		Zn			Zn		Zn		Zn		Zn		Zn		Zn		Zn		Zn	Cu Pb Zn
Otahuhu	Tamaki Estuary	RDP			Zn					Zn		Zn		Zn		Zn		Zn						
Pakuranga Lower	Tamaki Estuary	SoE		Zn		Zn			Zn		Zn		Zn		Zn		Cu Zn				Zn		Cu Zn	Cu Zn
Pakuranga Upper	Tamaki Estuary	SoE		Zn		Zn			Zn		Zn		Zn		Zn		Cu Zn		Zn		Zn		Cu Zn	Zn
Panmure	Tamaki Estuary	RDP	Zn		Zn					Zn		Zn		Zn		Zn		Cu Pb Zn		Zn				
Princes	Tamaki Estuary	RDP			Zn		Zn			Zn		Zn		Zn		Zn		Zn						
Roberta Reserve	Tamaki Estuary	RDP																						
Mangemangeroa S3	Tamaki Strait	estuaries																						
Mangemangeroa S6	Tamaki Strait	estuaries																						
Mangemangeroa S9	Tamaki Strait	estuaries																						
Te Matuku	Tamaki Strait	SoE																						
Turanga S4	Tamaki Strait	estuaries																						
Turanga S7	Tamaki Strait	estuaries																						
Turanga S8	Tamaki Strait	estuaries																						
Waikopua S1	Tamaki Strait	estuaries																						
Waikopua S3	Tamaki Strait	estuaries																						
Waikopua S9	Tamaki Strait	estuaries																						
Wairoa 1	Tamaki Strait	estuaries																						
Wairoa 2	Tamaki Strait	estuaries																						
Wairoa 3	Tamaki Strait	estuaries																						
Wairoa 4	Tamaki Strait	estuaries																						
Wairoa 5	Tamaki Strait	estuaries																						
Wairoa 6	Tamaki Strait	estuaries																						
Wairoa 7	Tamaki Strait	estuaries																						
Brigham Creek	Upper Waitemata	UWH		Cu		Cu			Cu		Cu		Cu	Cu	Cu	Cu	Cu							
Central Main	Upper Waitemata	UWH		Zn																				
Hellyers Creek	Upper Waitemata	UWH																						
Hellyers Upper	Upper Waitemata	UWH		Cu Zn					Cu Pb Zn		Cu Pb Zn		Cu Pb Zn	Cu Pb Zn	Cu Pb Zn	Cu Pb	Cu Pb							
Herald Island North	Upper Waitemata	UWH																						
Herald Island Waiarohia	Upper Waitemata	UWH																						
Hobsonville	Upper Waitemata	UWH																						
Lucas Te Wharau	Upper Waitemata	UWH											Cu											
Lucas Upper	Upper Waitemata	SoE							Cu		Cu				Cu		Cu		Cu		Cu		Cu	Cu
Lucas UWH	Upper Waitemata	UWH																						
Opposite HBV	Upper Waitemata	UWH				Pb			Pb		Cu Pb		Cu Pb	Cu Pb	Cu Pb	Cu Pb	Cu Pb							
Outer Main Channel	Upper Waitemata	UWH																						
Paremoremo	Upper Waitemata	SoE		Cu		Cu			Cu		Cu				Cu		Cu		Cu		Cu		Cu	Cu
Rangitopuni Creek	Upper Waitemata	UWH		Cu		Cu			Cu		Cu		Cu	Cu	Cu	Cu	Cu							
Raraw aru	Upper Waitemata	RDP																						
Upper Main Channel	Upper Waitemata	UWH		Cu		Cu			Cu		Cu		Cu	Cu	Cu	Cu	Cu							
Puhoi S1	Warkw orth / Wellsford	estuaries																						
Puhoi S4	Warkw orth / Wellsford	estuaries																						
Puhoi S9	Warkw orth / Wellsford	estuaries																						
Whangateau 1	Warkw orth / Wellsford	estuaries																						
Whangateau 4	Warkw orth / Wellsford	estuaries																						
Whangateau 5	Warkw orth / Wellsford	estuaries																						

9.3 Trend tables

9.3.1 Trends in mud content (% <63 µm by weight). Data are median annual rates of change (% median per year). Trend likelihood is assessed from Sen Slope probabilities and categorised as ‘very likely’ (>90%), ‘likely’ (67-90%), and ‘indeterminate’ (<67%). MRA = Marine Reporting Area; OZ = Outer Zone; SZ = Settling Zone.

Site Descriptions				Sampling period for mud content				Mud Content				
								Median	Sen Slope	Trend Magnitude		Trend likelihood
Site	Programme	MRA	Type	Start date	End date	Years	Samplings	% <63 um	Probability	%<63um/yr	%median/yr	LAWA category
Anns Creek	SoE	Manukau	OZ	16/08/2005	7/11/2018	13.2	7	86.1	0.86	-0.48	-0.56	likely improving
Awaruku Beach	SoE	East Coast Bays	OZ	8/12/2010	30/11/2018	8.0	4	0.4	0.81	0.01	2.47	likely worsening
Awatea Rd	RDP	Central Waitematā	OZ	13/10/2004	15/11/2016	12.1	6	32.1	0.68	0.42	1.31	likely worsening
Benghazi	RDP	Tāmaki	OZ	14/10/2004	1/11/2019	15.0	8	25.9	0.83	0.48	1.85	likely worsening
Big Muddy	SoE	Manukau	SZ	21/10/2009	6/11/2018	9.0	4	75.3	**0.91**	1.47	1.95	very likely worsening
Bowden	RDP	Tāmaki	OZ	27/10/2004	16/11/2017	13.1	7	50.5	0.67	0.20	0.39	indeterminate
Brigham Creek	UWH	Upper Waitematā	SZ	30/11/2005	9/11/2018	12.9	9	87.5	0.61	0.24	0.27	indeterminate
Central Main	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	25.7	**0.92**	0.56	2.18	very likely worsening
Chelsea	RDP	Central Waitematā	OZ	15/10/2004	13/11/2019	15.1	8	8.5	**0.92**	0.34	3.96	very likely worsening
Coxs Bay	RDP	Central Waitematā	OZ	10/10/2004	13/11/2019	15.1	8	7.7	**0.99**	0.37	4.81	very likely worsening
Harania	RDP	Manukau	SZ	14/10/2010	1/11/2019	9.0	4	88.0	0.66	-0.02	-0.02	indeterminate
Hellyers Creek	UWH	Upper Waitematā	SZ	30/11/2005	9/11/2018	12.9	9	46.6	0.73	0.38	0.82	likely worsening
Hellyers Upper	UWH	Upper Waitematā	SZ	30/11/2005	10/11/2018	12.9	9	80.6	0.50	0.15	0.18	indeterminate
Henderson Entrance	RDP	Central Waitematā	OZ	11/10/2004	30/10/2019	15.1	5	8.2	0.71	0.21	2.58	likely worsening
Henderson Lower	RDP	Central Waitematā	SZ	25/10/2004	13/11/2019	15.1	8	91.1	**0.99**	-0.26	-0.29	very likely improving
Henderson Upper	SoE	Central Waitematā	SZ	3/08/2005	7/11/2018	13.3	7	74.1	**0.96**	-1.20	-1.61	very likely improving
Herald Island North	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	9.2	**0.99**	0.58	6.29	very likely worsening
Herald Island Waiarohia	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	10.9	**0.98**	1.01	9.22	very likely worsening
Hobsonville	RDP	Upper Waitematā	OZ	4/11/2009	30/10/2019	10.0	6	3.5	**0.95**	-0.26	-7.33	very likely improving
Kendall Bay	RDP	Central Waitematā	OZ	15/10/2004	1/11/2019	15.0	7	5.6	**0.97**	0.26	4.71	very likely worsening
Lucas Te Wharau	UWH	Upper Waitematā	SZ	30/11/2005	10/11/2018	12.9	9	45.7	0.79	-0.72	-1.57	likely improving
Lucas Upper	SoE	Upper Waitematā	SZ	15/08/2005	27/11/2018	13.3	6	77.1	**0.97**	-1.33	-1.73	very likely improving
Lucas UWH	UWH	Upper Waitematā	SZ	30/11/2005	9/11/2018	12.9	9	30.1	0.60	0.31	1.01	indeterminate
Mangere Cemetery	SoE	Manukau	OZ	2/08/2005	7/11/2018	13.3	7	89.4	**0.97**	-1.01	-1.13	very likely improving
Meola Inner	SoE	Central Waitematā	SZ	19/08/2005	7/11/2018	13.2	7	62.9	0.67	0.48	0.76	likely worsening
Meola Outer	RDP	Central Waitematā	OZ	10/10/2004	13/11/2019	15.1	7	4.2	**0.99**	0.20	4.66	very likely worsening
Middlemore	SoE	Tāmaki	SZ	2/08/2005	29/11/2018	13.3	7	56.0	0.84	-0.42	-0.75	likely improving
Motions	SoE	Central Waitematā	SZ	19/08/2005	7/11/2018	13.2	7	23.2	**1.00**	-0.51	-2.21	very likely improving
Oakley	SoE	Central Waitematā	SZ	5/08/2005	5/11/2018	13.3	7	86.1	**1.00**	-1.50	-1.74	very likely improving
Opposite HBV	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	75.2	0.67	-0.20	-0.27	likely improving
Otahuhu Creek	RDP	Tāmaki	SZ	26/10/2004	7/11/2017	13.0	6	89.8	0.82	0.33	0.36	likely worsening
Outer Main Channel	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	14.2	**0.98**	1.00	7.07	very likely worsening
Pahurehure Middle	RDP	Manukau	OZ	5/11/2012	1/11/2019	7.0	4	13.4	0.69	0.96	7.13	likely worsening
Pahurehure Papakura	SoE	Manukau	SZ	21/10/2009	4/11/2018	9.0	5	46.9	0.79	1.16	2.47	likely worsening
Pahurehure Upper	RDP	Manukau	OZ	6/11/2012	1/11/2019	7.0	4	74.9	0.64	0.14	0.18	indeterminate
Pakuranga Lower	SoE	Tāmaki	SZ	15/10/2009	29/11/2018	9.1	5	43.1	0.77	0.26	0.60	likely worsening
Pakuranga Upper	SoE	Tāmaki	SZ	2/08/2005	29/11/2018	13.3	7	56.4	**1.00**	-3.30	-5.86	very likely improving
Panmure	RDP	Tāmaki	SZ	27/10/2004	1/11/2019	15.0	7	82.9	0.86	-0.19	-0.23	likely improving
Papakura Lower	RDP	Manukau	SZ	5/11/2012	2/11/2019	7.0	4	88.2	0.61	0.12	0.13	indeterminate
Paremoremo	SoE	Upper Waitematā	SZ	16/08/2005	28/11/2018	13.3	6	94.6	**0.94**	0.22	0.23	very likely worsening
Pollen Island	RDP	Central Waitematā	OZ	19/10/2005	6/12/2018	13.1	6	38.1	0.81	-0.50	-1.31	likely improving
Princes St	RDP	Tāmaki	OZ	26/10/2004	7/11/2017	13.0	7	40.8	0.50	0.22	0.54	indeterminate
Puhinui Upper	SoE	Manukau	SZ	21/10/2009	1/11/2019	10.0	5	80.6	0.70	0.15	0.18	likely worsening
Pukaki Airport	SoE	Manukau	SZ	21/10/2009	1/11/2019	10.0	5	81.0	0.59	0.03	0.04	indeterminate
Purewa	RDP	Central Waitematā	SZ	14/10/2004	7/11/2017	13.1	6	34.9	0.87	-0.76	-2.19	likely improving
Rangitopuni Creek	UWH	Upper Waitematā	SZ	30/11/2005	9/11/2018	12.9	9	95.5	**0.98**	0.37	0.39	very likely worsening
Shoal Hillcrest	RDP	Central Waitematā	SZ	25/10/2004	1/11/2019	15.0	8	87.0	0.64	-0.09	-0.10	indeterminate
Tararata	RDP	Manukau	SZ	14/10/2010	1/11/2019	9.0	4	92.8	0.61	0.03	0.04	indeterminate
Te Matuku	SoE	Tāmaki Strait	SZ	31/10/2009	4/11/2018	9.0	5	12.4	**0.92**	1.39	11.20	very likely worsening
Upper Main Channel	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	85.1	0.70	-0.13	-0.15	likely improving
Vaughans Beach	SoE	East Coast Bays	OZ	8/12/2010	30/11/2018	8.0	4	0.2	0.76	0.01	4.17	likely worsening
Weiti	SoE	Hibiscus Coast	SZ	22/10/2009	27/11/2018	9.1	5	27.6	**0.96**	-0.64	-2.32	very likely improving
Whau Entrance	RDP	Central Waitematā	OZ	11/10/2004	13/11/2019	15.1	8	11.1	**1.00**	1.25	11.27	very likely worsening
Whau Lower	SoE	Central Waitematā	SZ	5/08/2005	5/11/2018	13.3	7	93.1	**0.98**	0.23	0.25	very likely worsening
Whau Upper	SoE	Central Waitematā	SZ	5/08/2005	6/11/2018	13.3	7	63.0	**0.98**	-1.12	-1.77	very likely improving
Whau Wairau	SoE	Central Waitematā	SZ	3/08/2005	6/11/2018	13.3	7	73.6	0.83	0.55	0.74	likely worsening

9.3.2 Trend data table for total recoverable copper. Data are median annual rates of change (% median per year and % ERC per year). Trend likelihood is assessed from Sen Slope probabilities and categorised as ‘very likely’ (>90%), ‘likely’ (67-90%), and ‘indeterminate’ (<67%). MRA = Marine Reporting Area; OZ = Outer Zone; SZ = Settling Zone.

Site Descriptions				Sampling period for metals				Copper (<500 um)						
								Median	Sen Slope	Trend Magnitude			Trend likelihood
Site	Programme	MRA	Type	Start date	End date	Years	Samplings	mg/kg	Probability	mg/kg/yr	%median/yr	%ERC/yr	LAWA category
Anns Creek	SoE	Manukau	OZ	16/08/2005	7/11/2018	13.2	7	19.0	**1.00**	-0.960	-5.05	-5.05	very likely improving
Awaruku Beach	SoE	East Coast Bays	OZ	1/08/2005	30/11/2018	13.3	6	2.0	0.72	-0.017	-0.85	-0.09	likely improving
Awatea Rd	RDP	Central Waitematā	OZ	13/10/2004	15/11/2016	12.1	6	11.0	**0.97**	-0.325	-2.97	-1.71	very likely improving
Benghazi	RDP	Tāmaki	OZ	14/10/2004	1/11/2019	15.0	8	9.6	**0.96**	0.237	2.48	1.25	very likely worsening
Big Muddy	SoE	Manukau	SZ	3/08/2005	6/11/2018	13.3	6	9.3	**0.91**	-0.097	-1.04	-0.51	very likely improving
Bowden	RDP	Tāmaki	OZ	27/10/2004	16/11/2017	13.1	7	22.0	0.79	-0.182	-0.83	-0.96	likely improving
Brigham Creek	UWH	Upper Waitematā	SZ	30/11/2005	9/11/2018	12.9	9	21.9	**0.99**	-0.241	-1.10	-1.27	very likely improving
Central Main	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	12.8	0.71	-0.183	-1.43	-0.96	likely improving
Chelsea	RDP	Central Waitematā	OZ	15/10/2004	13/11/2019	15.1	8	5.7	**0.98**	0.107	1.86	0.56	very likely worsening
Coxs Bay	RDP	Central Waitematā	OZ	10/10/2004	13/11/2019	15.1	8	5.5	**0.99**	0.280	5.07	1.47	very likely worsening
Harania	RDP	Manukau	SZ	1/11/2005	1/11/2019	14.0	5	18.0	**0.97**	-0.437	-2.43	-2.30	very likely improving
Hellyers Creek	UWH	Upper Waitematā	SZ	30/11/2005	9/11/2018	12.9	9	13.2	0.58	-0.062	-0.47	-0.33	indeterminate
Hellyers Upper	UWH	Upper Waitematā	SZ	30/11/2005	10/11/2018	12.9	9	21.0	**0.93**	-0.191	-0.91	-1.01	very likely improving
Henderson Entrance	RDP	Central Waitematā	OZ	11/10/2004	30/10/2019	15.1	7	6.6	0.72	0.038	0.58	0.20	likely worsening
Henderson Lower	RDP	Central Waitematā	SZ	25/10/2004	13/11/2019	15.1	8	28.5	0.52	0.033	0.12	0.17	indeterminate
Henderson Upper	SoE	Central Waitematā	SZ	3/08/2005	7/11/2018	13.3	7	30.4	0.85	-0.234	-0.77	-1.23	likely improving
Herald Island North	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	6.4	0.88	-0.156	-2.42	-0.82	likely improving
Herald Island Waiarohia	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	3.6	0.90	0.148	4.11	0.78	likely worsening
Hobsonville	RDP	Upper Waitematā	OZ	30/11/2005	30/10/2019	13.9	10	2.6	**0.98**	-0.090	-3.46	-0.47	very likely improving
Kendall Bay	RDP	Central Waitematā	OZ	15/10/2004	1/11/2019	15.0	7	4.4	**1.00**	0.138	3.14	0.73	very likely worsening
Lucas Te Wharau	UWH	Upper Waitematā	SZ	30/11/2005	10/11/2018	12.9	9	15.0	**0.98**	-0.351	-2.34	-1.85	very likely improving
Lucas Upper	SoE	Upper Waitematā	SZ	15/08/2005	27/11/2018	13.3	6	19.8	**0.93**	-0.101	-0.51	-0.53	very likely improving
Lucas UWH	UWH	Upper Waitematā	SZ	30/11/2005	9/11/2018	12.9	9	13.0	0.77	-0.051	-0.39	-0.27	likely improving
Mangere Cemetery	SoE	Manukau	OZ	2/08/2005	7/11/2018	13.3	7	18.0	**1.00**	-0.904	-5.02	-4.76	very likely improving
Meola Inner	SoE	Central Waitematā	SZ	19/08/2005	7/11/2018	13.2	7	30.1	0.86	-0.297	-0.99	-1.56	likely improving
Meola Outer	RDP	Central Waitematā	OZ	10/10/2004	13/11/2019	15.1	7	3.6	0.90	0.054	1.50	0.28	likely worsening
Middlemore	SoE	Tāmaki	SZ	2/08/2005	29/11/2018	13.3	7	25.8	0.56	0.024	0.09	0.13	indeterminate
Motions	SoE	Central Waitematā	SZ	19/08/2005	7/11/2018	13.2	7	17.8	**0.95**	-0.466	-2.62	-2.45	very likely improving
Oakley	SoE	Central Waitematā	SZ	5/08/2005	5/11/2018	13.3	7	25.0	**0.99**	-0.479	-1.92	-2.52	very likely improving
Opposite HBV	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	21.0	**0.98**	-0.377	-1.80	-1.98	very likely improving
Otahuhu Creek	RDP	Tāmaki	SZ	26/10/2004	7/11/2017	13.0	6	27.9	0.70	-0.022	-0.08	-0.12	likely improving
Outer Main Channel	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	11.4	0.84	-0.350	-3.08	-1.84	likely improving
Pahurehure Middle	RDP	Manukau	OZ	31/10/2008	1/11/2019	11.0	5	2.1	0.85	0.070	3.41	0.37	likely worsening
Pahurehure Papakura	SoE	Manukau	SZ	29/08/2005	4/11/2018	13.2	7	5.9	0.78	-0.054	-0.92	-0.28	likely improving
Pahurehure Upper	RDP	Manukau	OZ	31/10/2008	1/11/2019	11.0	5	7.9	0.71	-0.030	-0.38	-0.16	likely improving
Pakuranga Lower	SoE	Tāmaki	SZ	2/08/2005	29/11/2018	13.3	7	17.3	**0.97**	-0.319	-1.85	-1.68	very likely improving
Pakuranga Upper	SoE	Tāmaki	SZ	2/08/2005	29/11/2018	13.3	7	24.0	**0.99**	-0.981	-4.09	-5.16	very likely improving
Panmure	RDP	Tāmaki	SZ	27/10/2004	1/11/2019	15.0	7	25.0	0.58	0.064	0.26	0.34	indeterminate
Papakura Lower	RDP	Manukau	SZ	31/10/2008	2/11/2019	11.0	5	8.1	0.55	0.036	0.44	0.19	indeterminate
Paremoremo	SoE	Upper Waitematā	SZ	16/08/2005	28/11/2018	13.3	6	20.9	0.74	0.029	0.14	0.15	likely worsening
Pollen Island	RDP	Central Waitematā	OZ	19/10/2005	6/12/2018	13.1	6	9.9	0.81	-0.090	-0.91	-0.47	likely improving
Princes St	RDP	Tāmaki	OZ	26/10/2004	7/11/2017	13.0	7	16.9	**0.91**	0.376	2.22	1.98	very likely worsening
Puhinui Upper	SoE	Manukau	SZ	29/08/2005	1/11/2019	14.2	7	9.2	0.68	-0.001	-0.01	-0.01	likely improving
Pukaki Airport	SoE	Manukau	SZ	16/08/2005	1/11/2019	14.2	7	7.9	0.62	0.012	0.15	0.06	indeterminate
Purewa	RDP	Central Waitematā	SZ	14/10/2004	7/11/2017	13.1	6	13.7	0.78	-0.118	-0.86	-0.62	likely improving
Rangitopuni Creek	UWH	Upper Waitematā	SZ	30/11/2005	9/11/2018	12.9	9	23.0	0.62	-0.007	-0.03	-0.04	indeterminate
Shoal Hillcrest	RDP	Central Waitematā	SZ	25/10/2004	1/11/2019	15.0	8	17.7	0.64	-0.044	-0.25	-0.23	indeterminate
Tararata	RDP	Manukau	SZ	1/11/2005	1/11/2019	14.0	5	15.0	**0.95**	-0.567	-3.78	-2.98	very likely improving
Te Matuku	SoE	Tāmaki Strait	SZ	31/08/2005	4/11/2018	13.2	7	2.8	0.68	-0.001	-0.01	-0.01	likely improving
Upper Main Channel	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	22.0	0.90	-0.137	-0.62	-0.72	likely improving
Vaughans Beach	SoE	East Coast Bays	OZ	1/08/2005	30/11/2018	13.3	6	1.7	0.75	-0.023	-1.38	-0.12	likely improving
Weiti	SoE	Hibiscus Coast	SZ	1/08/2005	27/11/2018	13.3	7	12.1	0.68	-0.071	-0.59	-0.37	likely improving
Whau Entrance	RDP	Central Waitematā	OZ	11/10/2004	13/11/2019	15.1	8	4.3	**0.92**	0.143	3.30	0.75	very likely worsening
Whau Lower	SoE	Central Waitematā	SZ	5/08/2005	5/11/2018	13.3	7	24.0	**0.90**	-0.160	-0.67	-0.84	very likely improving
Whau Upper	SoE	Central Waitematā	SZ	5/08/2005	6/11/2018	13.3	7	32.0	**1.00**	-0.483	-1.51	-2.54	very likely improving
Whau Wairau	SoE	Central Waitematā	SZ	3/08/2005	6/11/2018	13.3	7	39.0	**0.92**	-0.326	-0.84	-1.72	very likely improving

9.3.3 Trend data table for total recoverable lead. Data are median annual rates of change (% median per year and % ERC per year). Trend likelihood is assessed from Sen Slope probabilities and categorised as 'very likely' (>90%), 'likely' (67-90%), and 'indeterminate' (<67%). MRA = Marine Reporting Area; OZ = Outer Zone; SZ = Settling Zone.

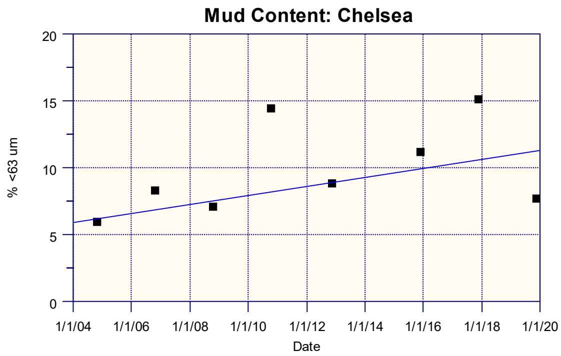
Site Descriptions				Sampling period for metals				Lead (<500 um)					
								Median	Sen Slope	Trend Magnitude			Trend likelihood
Site	Programme	MRA	Type	Start date	End date	Years	Samplings	mg/kg	Probability	mg/kg/yr	%median/yr	%ERC/yr	LAWA category
Anns Creek	SoE	Manukau	OZ	16/08/2005	7/11/2018	13.2	7	25.2	**0.99**	-0.669	-2.66	-2.23	very likely improving
Awaruku Beach	SoE	East Coast Bays	OZ	1/08/2005	30/11/2018	13.3	6	3.6	0.83	-0.029	-0.80	-0.10	likely improving
Awatea Rd	RDP	Central Waitematā	OZ	13/10/2004	15/11/2016	12.1	6	29.7	0.87	-0.274	-0.92	-0.91	likely improving
Benghazi	RDP	Tāmaki	OZ	14/10/2004	1/11/2019	15.0	8	15.4	**0.91**	0.178	1.15	0.59	very likely worsening
Big Muddy	SoE	Manukau	SZ	3/08/2005	6/11/2018	13.3	6	9.8	0.59	-0.001	-0.01	0.00	indeterminate
Bowden	RDP	Tāmaki	OZ	27/10/2004	16/11/2017	13.1	7	29.0	0.67	-0.038	-0.13	-0.13	likely improving
Brigham Creek	UWH	Upper Waitematā	SZ	30/11/2005	9/11/2018	12.9	9	25.0	0.80	-0.112	-0.45	-0.37	likely improving
Central Main	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	27.0	0.74	-0.027	-0.10	-0.09	likely improving
Chelsea	RDP	Central Waitematā	OZ	15/10/2004	13/11/2019	15.1	8	12.6	0.69	0.026	0.21	0.09	likely worsening
Coxs Bay	RDP	Central Waitematā	OZ	10/10/2004	13/11/2019	15.1	8	14.1	**0.90**	0.333	2.37	1.11	very likely worsening
Harania	RDP	Manukau	SZ	1/11/2005	1/11/2019	14.0	5	22.2	**0.98**	-0.388	-1.75	-1.29	very likely improving
Hellyers Creek	UWH	Upper Waitematā	SZ	30/11/2005	9/11/2018	12.9	9	20.2	**0.96**	-0.240	-1.19	-0.80	very likely improving
Hellyers Upper	UWH	Upper Waitematā	SZ	30/11/2005	10/11/2018	12.9	9	32.0	**1.00**	-0.802	-2.51	-2.67	very likely improving
Henderson Entrance	RDP	Central Waitematā	OZ	11/10/2004	30/10/2019	15.1	7	18.4	0.81	-0.131	-0.71	-0.44	likely improving
Henderson Lower	RDP	Central Waitematā	SZ	25/10/2004	13/11/2019	15.1	8	31.1	**1.00**	-0.413	-1.33	-1.38	very likely improving
Henderson Upper	SoE	Central Waitematā	SZ	3/08/2005	7/11/2018	13.3	7	32.0	**1.00**	-0.572	-1.79	-1.91	very likely improving
Herald Island North	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	13.7	0.85	-0.074	-0.54	-0.25	likely improving
Herald Island Waiarohia	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	6.3	**0.97**	0.278	4.41	0.93	very likely worsening
Hobsonville	RDP	Upper Waitematā	OZ	30/11/2005	30/10/2019	13.9	10	6.4	**0.97**	-0.093	-1.44	-0.31	very likely improving
Kendall Bay	RDP	Central Waitematā	OZ	15/10/2004	1/11/2019	15.0	7	7.4	0.58	-0.005	-0.07	-0.02	indeterminate
Lucas Te Wharau	UWH	Upper Waitematā	SZ	30/11/2005	10/11/2018	12.9	9	20.6	**0.98**	-0.369	-1.79	-1.23	very likely improving
Lucas Upper	SoE	Upper Waitematā	SZ	15/08/2005	27/11/2018	13.3	6	22.2	0.85	-0.159	-0.72	-0.53	likely improving
Lucas UWH	UWH	Upper Waitematā	SZ	30/11/2005	9/11/2018	12.9	9	24.3	**0.95**	-0.412	-1.70	-1.37	very likely improving
Mangere Cemetery	SoE	Manukau	OZ	2/08/2005	7/11/2018	13.3	7	23.0	**0.99**	-0.768	-3.34	-2.56	very likely improving
Meola Inner	SoE	Central Waitematā	SZ	19/08/2005	7/11/2018	13.2	7	56.0	**1.00**	-1.179	-2.11	-3.93	very likely improving
Meola Outer	RDP	Central Waitematā	OZ	10/10/2004	13/11/2019	15.1	7	9.3	0.78	0.040	0.43	0.13	likely worsening
Middlemore	SoE	Tāmaki	SZ	2/08/2005	29/11/2018	13.3	7	31.0	**0.99**	-0.313	-1.01	-1.04	very likely improving
Motions	SoE	Central Waitematā	SZ	19/08/2005	7/11/2018	13.2	7	38.4	**0.98**	-0.899	-2.34	-3.00	very likely improving
Oakley	SoE	Central Waitematā	SZ	5/08/2005	5/11/2018	13.3	7	40.6	**1.00**	-0.639	-1.57	-2.13	very likely improving
Opposite HBV	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	31.6	**0.99**	-0.336	-1.06	-1.12	very likely improving
Otahuhu Creek	RDP	Tāmaki	SZ	26/10/2004	7/11/2017	13.0	6	32.6	**0.97**	-0.575	-1.76	-1.92	very likely improving
Outer Main Channel	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	17.0	**0.93**	-0.250	-1.47	-0.83	very likely improving
Pahurehure Middle	RDP	Manukau	OZ	31/10/2008	1/11/2019	11.0	5	6.3	0.55	0.029	0.46	0.10	indeterminate
Pahurehure Papakura	SoE	Manukau	SZ	29/08/2005	4/11/2018	13.2	7	11.8	0.68	-0.024	-0.20	-0.08	likely improving
Pahurehure Upper	RDP	Manukau	OZ	31/10/2008	1/11/2019	11.0	5	12.4	0.89	-0.093	-0.75	-0.31	likely improving
Pakuranga Lower	SoE	Tāmaki	SZ	2/08/2005	29/11/2018	13.3	7	23.2	**0.96**	-0.417	-1.80	-1.39	very likely improving
Pakuranga Upper	SoE	Tāmaki	SZ	2/08/2005	29/11/2018	13.3	7	31.0	**0.99**	-0.899	-2.90	-3.00	very likely improving
Panmure	RDP	Tāmaki	SZ	27/10/2004	1/11/2019	15.0	7	33.0	**0.99**	-0.318	-0.96	-1.06	very likely improving
Papakura Lower	RDP	Manukau	SZ	31/10/2008	2/11/2019	11.0	5	12.8	0.53	0.056	0.44	0.19	indeterminate
Paremoremo	SoE	Upper Waitematā	SZ	16/08/2005	28/11/2018	13.3	6	24.3	0.72	0.182	0.75	0.61	likely worsening
Pollen Island	RDP	Central Waitematā	OZ	19/10/2005	6/12/2018	13.1	6	19.7	0.69	-0.130	-0.66	-0.43	likely improving
Princes St	RDP	Tāmaki	OZ	26/10/2004	7/11/2017	13.0	7	25.2	0.64	0.166	0.66	0.55	indeterminate
Puhinui Upper	SoE	Manukau	SZ	29/08/2005	1/11/2019	14.2	7	12.3	0.87	-0.025	-0.20	-0.08	likely improving
Pukaki Airport	SoE	Manukau	SZ	16/08/2005	1/11/2019	14.2	7	11.0	0.68	0.010	0.09	0.03	likely worsening
Purewa	RDP	Central Waitematā	SZ	14/10/2004	7/11/2017	13.1	6	34.2	0.87	-0.361	-1.06	-1.20	likely improving
Rangitopuni Creek	UWH	Upper Waitematā	SZ	30/11/2005	9/11/2018	12.9	9	26.8	0.74	-0.063	-0.24	-0.21	likely improving
Shoal Hillcrest	RDP	Central Waitematā	SZ	25/10/2004	1/11/2019	15.0	8	30.0	**0.99**	-0.429	-1.43	-1.43	very likely improving
Tararata	RDP	Manukau	SZ	1/11/2005	1/11/2019	14.0	5	18.5	**0.94**	-0.585	-3.16	-1.95	very likely improving
Te Matuku	SoE	Tāmaki Strait	SZ	31/08/2005	4/11/2018	13.2	7	6.7	0.83	-0.026	-0.39	-0.09	likely improving
Upper Main Channel	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	26.0	0.80	-0.210	-0.81	-0.70	likely improving
Vaughans Beach	SoE	East Coast Bays	OZ	1/08/2005	30/11/2018	13.3	6	3.0	0.76	-0.016	-0.54	-0.05	likely improving
Weiti	SoE	Hibiscus Coast	SZ	1/08/2005	27/11/2018	13.3	7	8.8	0.76	-0.049	-0.56	-0.16	likely improving
Whau Entrance	RDP	Central Waitematā	OZ	11/10/2004	13/11/2019	15.1	8	8.3	**0.97**	0.179	2.16	0.60	very likely worsening
Whau Lower	SoE	Central Waitematā	SZ	5/08/2005	5/11/2018	13.3	7	39.0	**0.98**	-0.513	-1.32	-1.71	very likely improving
Whau Upper	SoE	Central Waitematā	SZ	5/08/2005	6/11/2018	13.3	7	55.0	**1.00**	-1.281	-2.33	-4.27	very likely improving
Whau Wairau	SoE	Central Waitematā	SZ	3/08/2005	6/11/2018	13.3	7	57.0	0.88	-0.550	-0.96	-1.83	likely improving

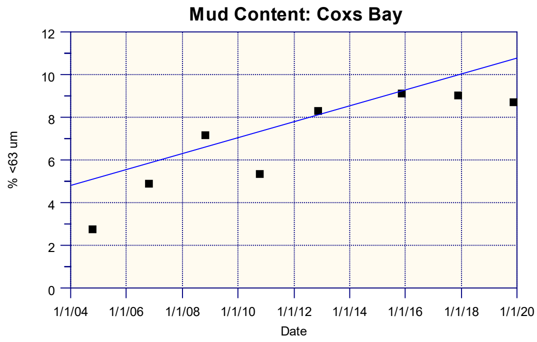
9.3.4 Trend data table for total recoverable zinc. Data are median annual rates of change (% median per year and % ERC per year). Trend likelihood is assessed from Sen Slope probabilities and categorised as ‘very likely’ (>90%), ‘likely’ (67-90%), and ‘indeterminate’ (<67%). MRA = Marine Reporting Area; OZ = Outer Zone; SZ = Settling Zone.

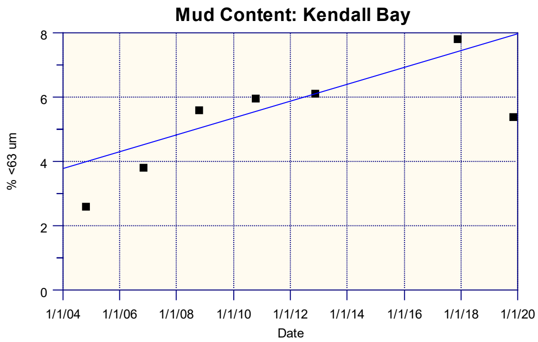
Site Descriptions				Sampling period for metals				Zinc (<500 um)					
								Median	Sen Slope	Trend Magnitude			Trend likelihood
Site	Programme	MRA	Type	Start date	End date	Years	Samplings	mg/kg	Probability	mg/kg/yr	%median/yr	%ERC/yr	LAWA category
Anns Creek	SoE	Manukau	OZ	16/08/2005	7/11/2018	13.2	7	150.0	0.82	-0.193	-0.13	-0.16	likely improving
Awaruku Beach	SoE	East Coast Bays	OZ	1/08/2005	30/11/2018	13.3	6	23.9	0.58	0.038	0.16	0.03	indeterminate
Awatea Rd	RDP	Central Waitematā	OZ	13/10/2004	15/11/2016	12.1	6	104.0	**0.93**	-0.774	-0.74	-0.62	very likely improving
Benghazi	RDP	Tāmaki	OZ	14/10/2004	1/11/2019	15.0	8	78.8	**0.98**	2.484	3.15	2.00	very likely worsening
Big Muddy	SoE	Manukau	SZ	3/08/2005	6/11/2018	13.3	6	59.3	0.82	0.515	0.87	0.42	likely worsening
Bowden	RDP	Tāmaki	OZ	27/10/2004	16/11/2017	13.1	7	197.0	0.83	1.453	0.74	1.17	likely worsening
Brigham Creek	UWH	Upper Waitematā	SZ	30/11/2005	9/11/2018	12.9	9	102.0	**0.93**	0.848	0.83	0.68	very likely worsening
Central Main	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	104.0	**0.99**	1.846	1.78	1.49	very likely worsening
Chelsea	RDP	Central Waitematā	OZ	15/10/2004	13/11/2019	15.1	8	46.1	**0.99**	0.430	0.93	0.35	very likely worsening
Coxs Bay	RDP	Central Waitematā	OZ	10/10/2004	13/11/2019	15.1	8	75.5	**0.98**	2.726	3.61	2.20	very likely worsening
Harania	RDP	Manukau	SZ	1/11/2005	1/11/2019	14.0	5	138.3	**0.98**	1.621	1.17	1.31	very likely worsening
Hellyers Creek	UWH	Upper Waitematā	SZ	30/11/2005	9/11/2018	12.9	9	84.4	0.63	0.328	0.39	0.26	indeterminate
Hellyers Upper	UWH	Upper Waitematā	SZ	30/11/2005	10/11/2018	12.9	9	131.0	0.59	0.231	0.18	0.19	indeterminate
Henderson Entrance	RDP	Central Waitematā	OZ	11/10/2004	30/10/2019	15.1	7	75.2	0.78	0.845	1.12	0.68	likely worsening
Henderson Lower	RDP	Central Waitematā	SZ	25/10/2004	13/11/2019	15.1	8	148.0	0.85	0.506	0.34	0.41	likely worsening
Henderson Upper	SoE	Central Waitematā	SZ	3/08/2005	7/11/2018	13.3	7	166.0	0.70	-0.492	-0.30	-0.40	likely improving
Herald Island North	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	51.5	0.69	0.236	0.46	0.19	likely worsening
Herald Island Waiarohia	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	20.5	**0.98**	1.172	5.72	0.95	very likely worsening
Hobsonville	RDP	Upper Waitematā	OZ	30/11/2005	30/10/2019	13.9	10	23.6	**0.91**	-0.319	-1.35	-0.26	very likely improving
Kendall Bay	RDP	Central Waitematā	OZ	15/10/2004	1/11/2019	15.0	7	32.3	**0.94**	0.569	1.76	0.46	very likely worsening
Lucas Te Wharau	UWH	Upper Waitematā	SZ	30/11/2005	10/11/2018	12.9	9	81.8	**0.95**	-0.275	-0.34	-0.22	very likely improving
Lucas Upper	SoE	Upper Waitematā	SZ	15/08/2005	27/11/2018	13.3	6	103.1	0.87	1.440	1.40	1.16	likely worsening
Lucas UWH	UWH	Upper Waitematā	SZ	30/11/2005	9/11/2018	12.9	9	100.0	0.53	0.389	0.39	0.31	indeterminate
Mangere Cemetery	SoE	Manukau	OZ	2/08/2005	7/11/2018	13.3	7	114.9	**0.97**	-1.711	-1.49	-1.38	very likely improving
Meola Inner	SoE	Central Waitematā	SZ	19/08/2005	7/11/2018	13.2	7	240.0	0.56	0.000	0.00	0.00	indeterminate
Meola Outer	RDP	Central Waitematā	OZ	10/10/2004	13/11/2019	15.1	7	36.0	**0.97**	0.596	1.66	0.48	very likely worsening
Middlemore	SoE	Tāmaki	SZ	2/08/2005	29/11/2018	13.3	7	192.7	**0.99**	3.261	1.69	2.63	very likely worsening
Motions	SoE	Central Waitematā	SZ	19/08/2005	7/11/2018	13.2	7	239.0	0.68	0.952	0.40	0.77	likely worsening
Oakley	SoE	Central Waitematā	SZ	5/08/2005	5/11/2018	13.3	7	153.6	**0.94**	-2.300	-1.50	-1.85	very likely improving
Opposite HBV	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	117.0	0.60	0.093	0.08	0.08	indeterminate
Otahuhu Creek	RDP	Tāmaki	SZ	26/10/2004	7/11/2017	13.0	6	177.3	0.84	1.431	0.81	1.15	likely worsening
Outer Main Channel	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	62.0	0.54	0.257	0.41	0.21	indeterminate
Pahurehure Middle	RDP	Manukau	OZ	31/10/2008	1/11/2019	11.0	5	32.0	0.84	0.978	3.06	0.79	likely worsening
Pahurehure Papakura	SoE	Manukau	SZ	29/08/2005	4/11/2018	13.2	7	66.0	0.55	0.252	0.38	0.20	indeterminate
Pahurehure Upper	RDP	Manukau	OZ	31/10/2008	1/11/2019	11.0	5	79.9	0.64	0.614	0.77	0.50	indeterminate
Pakuranga Lower	SoE	Tāmaki	SZ	2/08/2005	29/11/2018	13.3	7	161.0	0.70	0.566	0.35	0.46	likely worsening
Pakuranga Upper	SoE	Tāmaki	SZ	2/08/2005	29/11/2018	13.3	7	217.4	0.81	-1.395	-0.64	-1.13	likely improving
Panmure	RDP	Tāmaki	SZ	27/10/2004	1/11/2019	15.0	7	181.0	**0.96**	2.128	1.18	1.72	very likely worsening
Papakura Lower	RDP	Manukau	SZ	31/10/2008	2/11/2019	11.0	5	76.0	0.75	1.577	2.08	1.27	likely worsening
Paremoremo	SoE	Upper Waitematā	SZ	16/08/2005	28/11/2018	13.3	6	94.0	**0.96**	1.123	1.19	0.91	very likely worsening
Pollen Island	RDP	Central Waitematā	OZ	19/10/2005	6/12/2018	13.1	6	79.5	**0.92**	0.621	0.78	0.50	very likely worsening
Princes St	RDP	Tāmaki	OZ	26/10/2004	7/11/2017	13.0	7	148.1	**0.95**	2.484	1.68	2.00	very likely worsening
Puhinui Upper	SoE	Manukau	SZ	29/08/2005	1/11/2019	14.2	7	110.0	0.86	0.745	0.68	0.60	likely worsening
Pukaki Airport	SoE	Manukau	SZ	16/08/2005	1/11/2019	14.2	7	63.9	**0.96**	1.112	1.74	0.90	very likely worsening
Purewa	RDP	Central Waitematā	SZ	14/10/2004	7/11/2017	13.1	6	161.0	**0.96**	1.209	0.75	0.98	very likely worsening
Rangitopuni Creek	UWH	Upper Waitematā	SZ	30/11/2005	9/11/2018	12.9	9	104.0	**0.91**	1.219	1.17	0.98	very likely worsening
Shoal Hillcrest	RDP	Central Waitematā	SZ	25/10/2004	1/11/2019	15.0	8	110.1	0.54	0.190	0.17	0.15	indeterminate
Tararata	RDP	Manukau	SZ	1/11/2005	1/11/2019	14.0	5	127.0	0.59	0.173	0.14	0.14	indeterminate
Te Matuku	SoE	Tāmaki Strait	SZ	31/08/2005	4/11/2018	13.2	7	30.8	0.68	0.072	0.23	0.06	likely worsening
Upper Main Channel	UWH	Upper Waitematā	OZ	30/11/2005	9/11/2018	12.9	9	98.7	0.59	0.307	0.31	0.25	indeterminate
Vaughans Beach	SoE	East Coast Bays	OZ	1/08/2005	30/11/2018	13.3	6	21.1	0.72	-0.032	-0.15	-0.03	likely improving
Weiti	SoE	Hibiscus Coast	SZ	1/08/2005	27/11/2018	13.3	7	52.0	0.52	0.186	0.36	0.15	indeterminate
Whau Entrance	RDP	Central Waitematā	OZ	11/10/2004	13/11/2019	15.1	8	37.2	**0.99**	1.133	3.04	0.91	very likely worsening
Whau Lower	SoE	Central Waitematā	SZ	5/08/2005	5/11/2018	13.3	7	161.0	**0.91**	-0.725	-0.45	-0.58	very likely improving
Whau Upper	SoE	Central Waitematā	SZ	5/08/2005	6/11/2018	13.3	7	256.6	0.77	-0.965	-0.38	-0.78	likely improving
Whau Wairau	SoE	Central Waitematā	SZ	3/08/2005	6/11/2018	13.3	7	220.0	**0.91**	1.799	0.82	1.45	very likely worsening

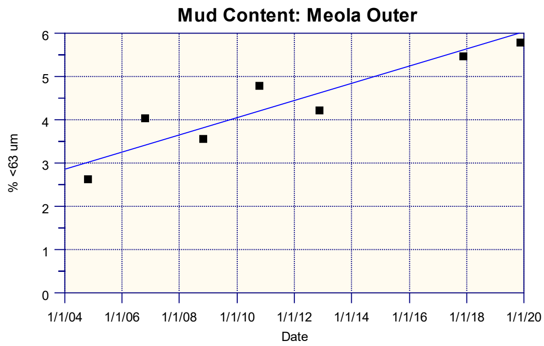
9.4 Trend plots

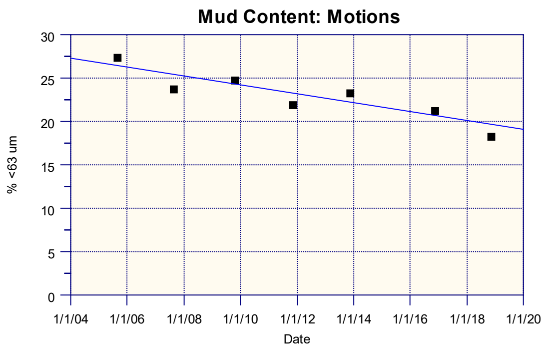
9.4.1 Mud content trend plots for sites with meaningful trends (>±2% median per year and very likely probability). The data plotted are median values from each sampling. The trend line is the Sen Slope.

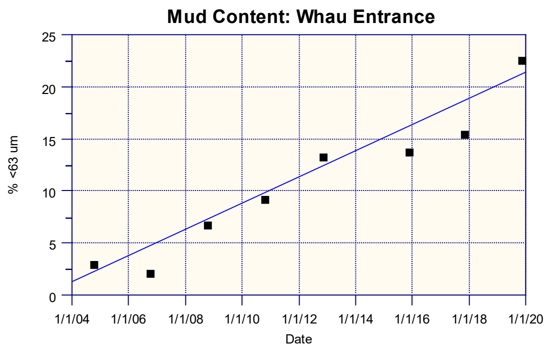


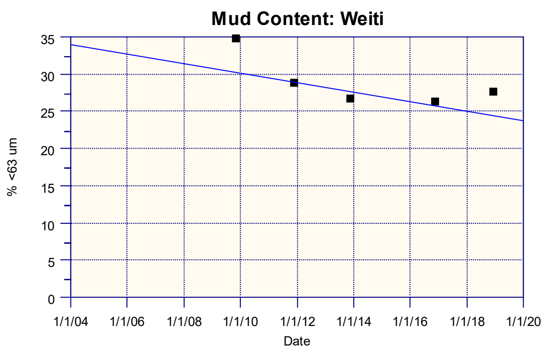


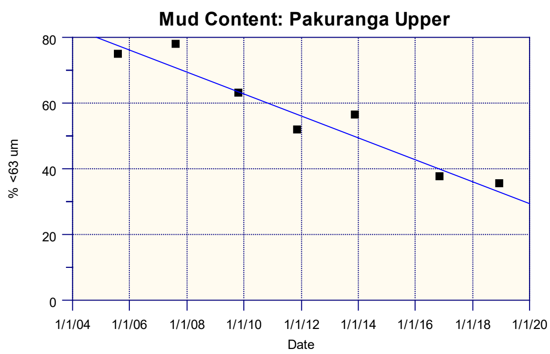




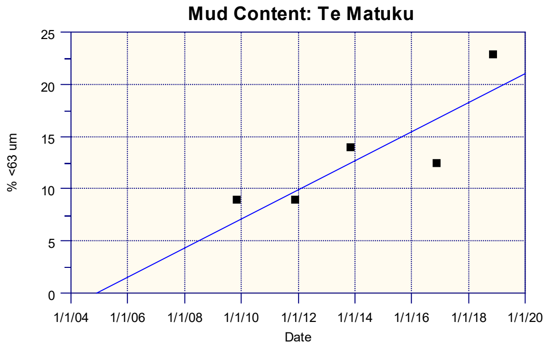


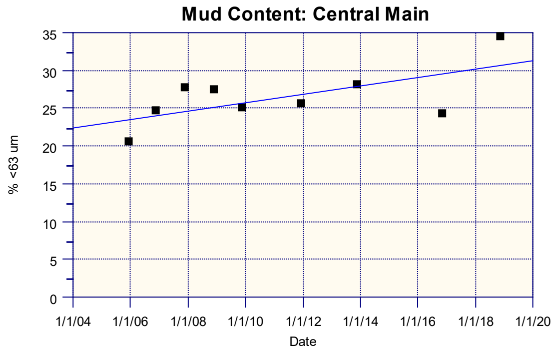


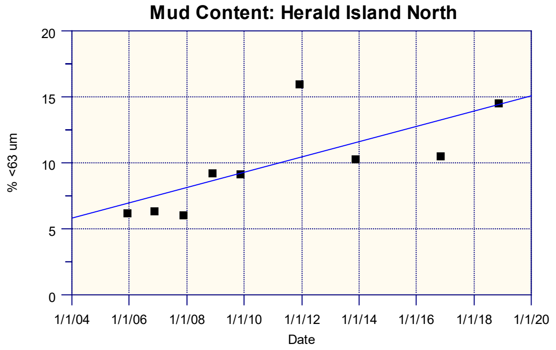


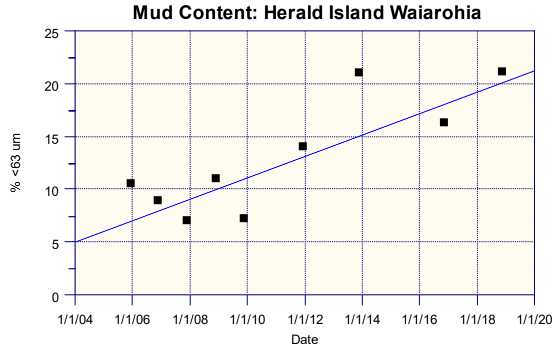


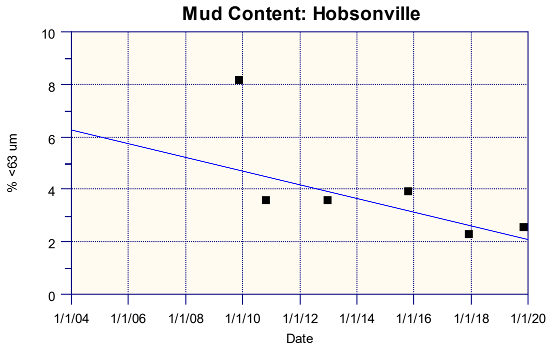
Mud content trend plots continued

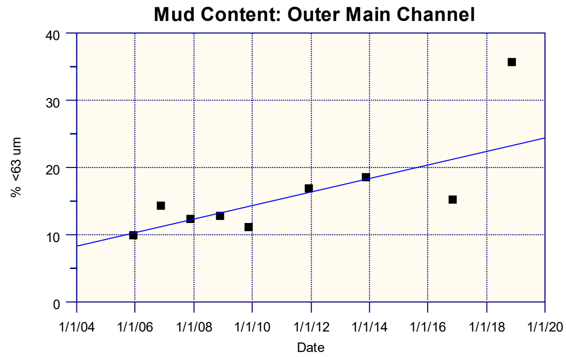






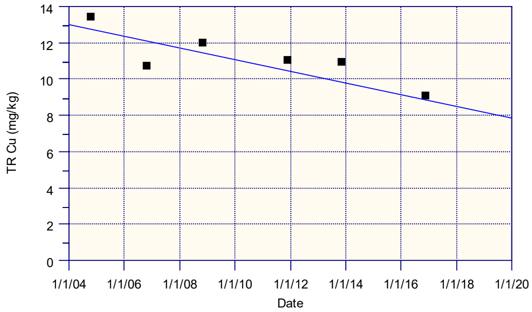




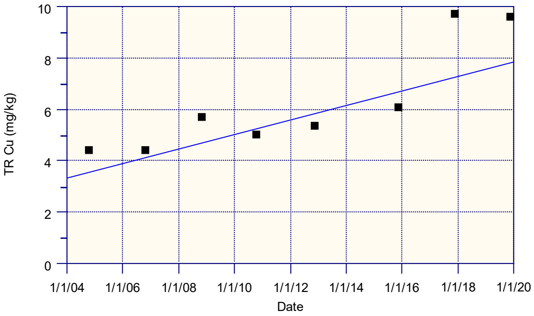


9.4.2 Trends in Copper for sites with meaningful trends (>±2% median per year and very likely probability). The data plotted are median values from each sampling. The trend line is the Sen Slope.

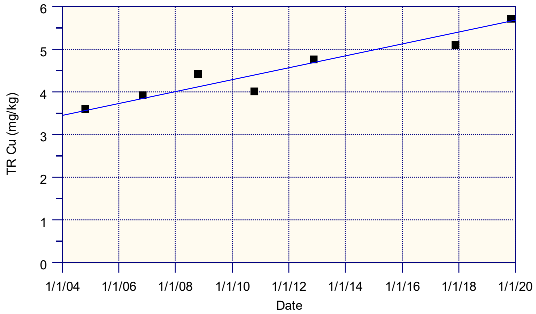
Copper: Awatea Rd



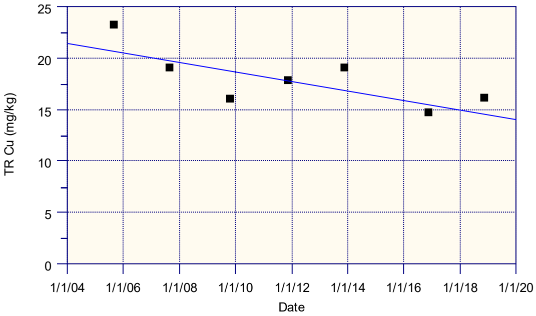
Copper: Coxs Bay



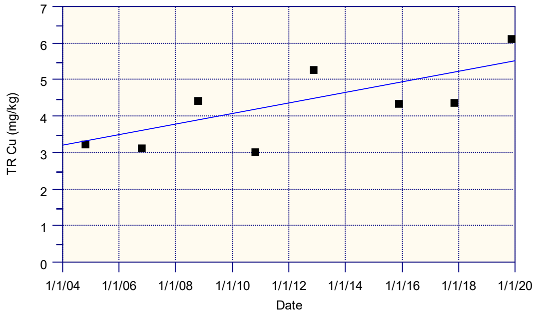
Copper: Kendall Bay



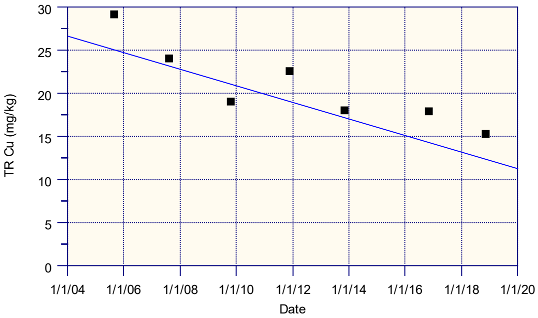
Copper: Motions



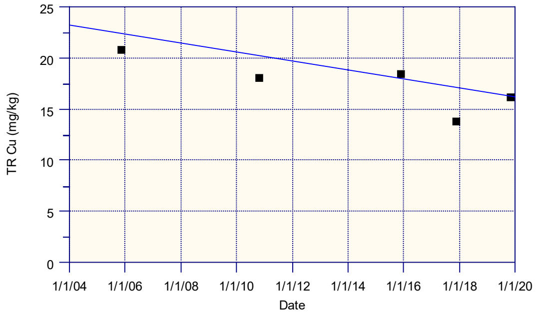
Copper: Whau Entrance



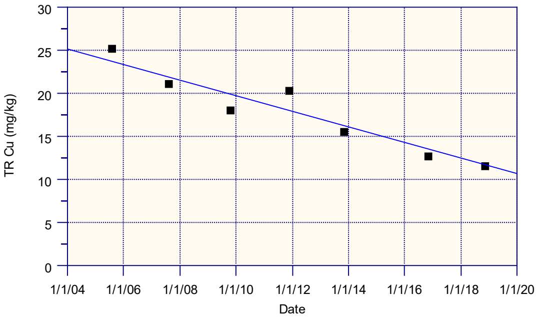
Copper: Anns Creek



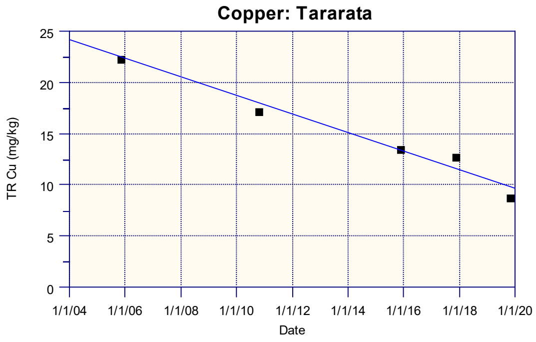
Copper: Harania

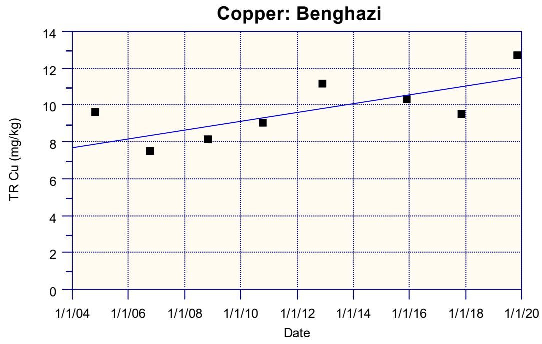


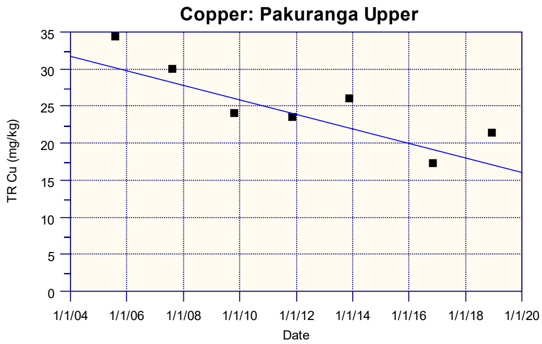
Copper: Mangere Cemetery

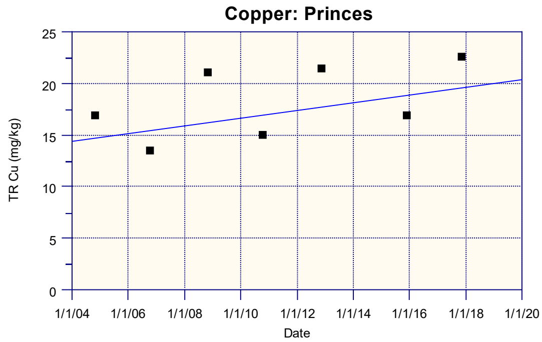


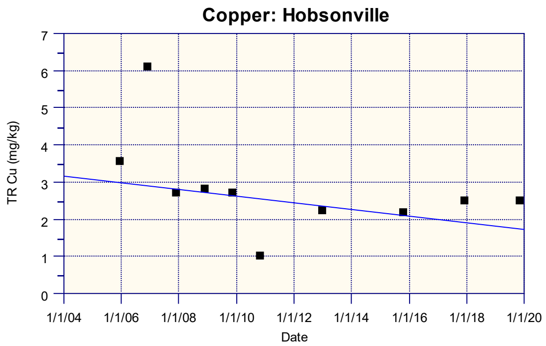
Copper trend plots continued

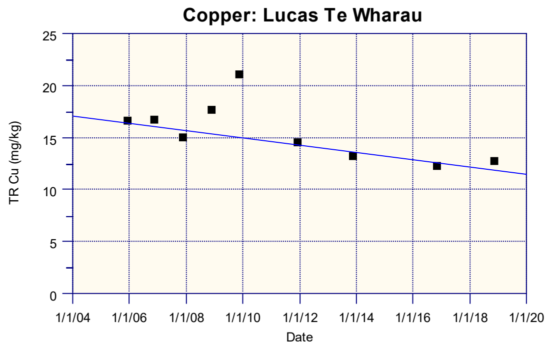




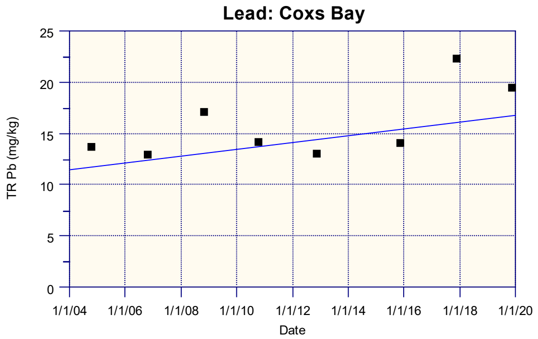


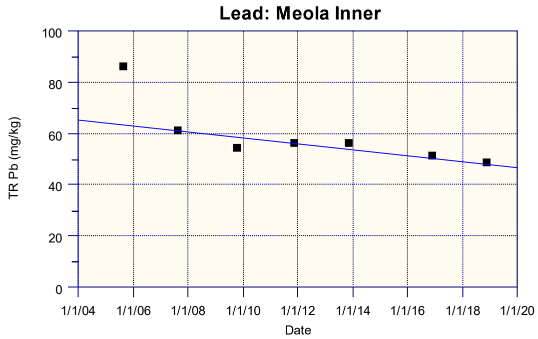


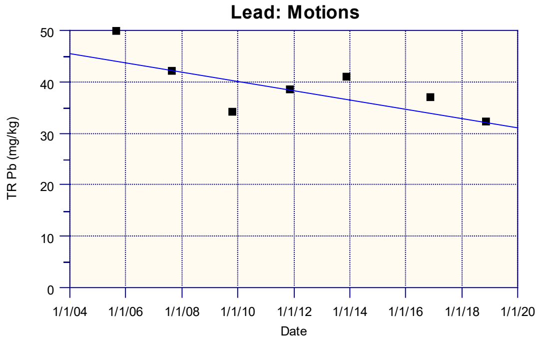


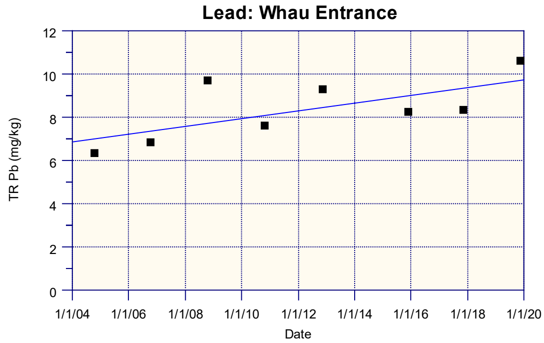


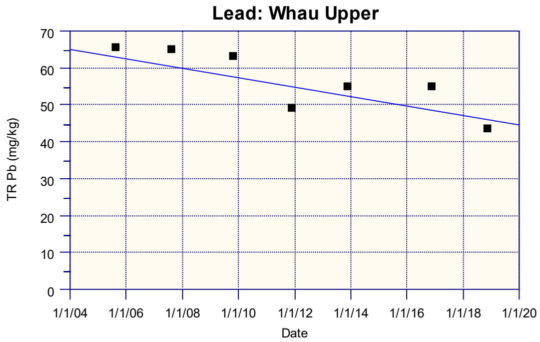
9.4.3 Trends in Lead for sites with meaningful trends (>±2% median per year and very likely probability). The data plotted are median values from each sampling. The trend line is the Sen Slope.

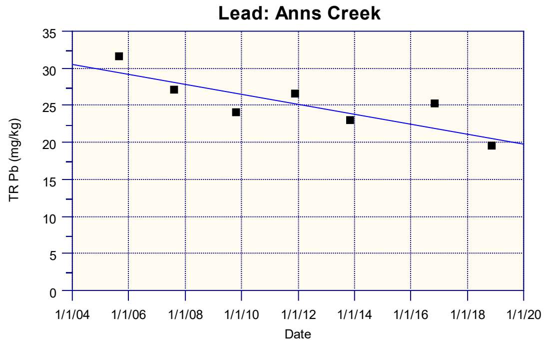


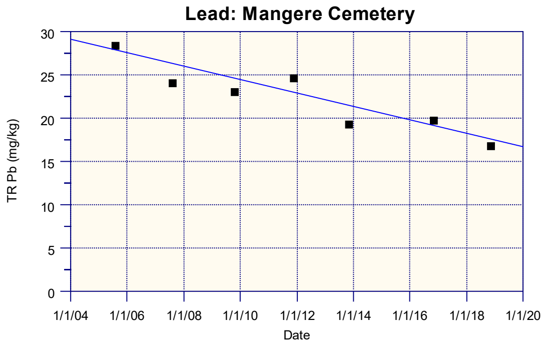


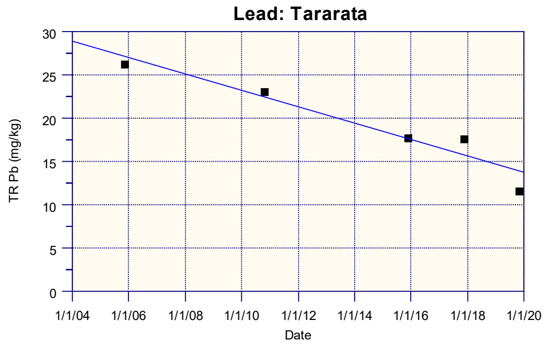




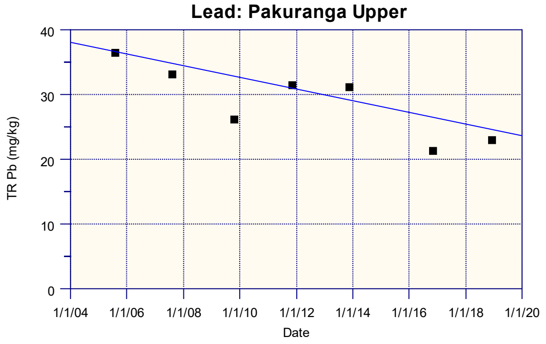


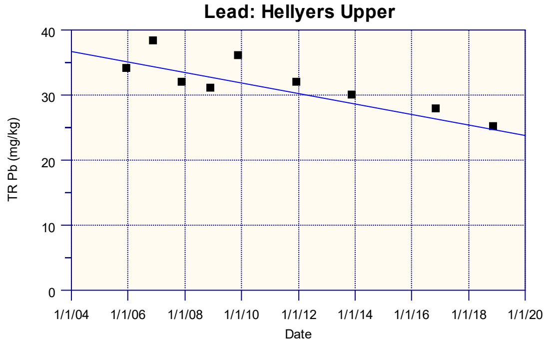


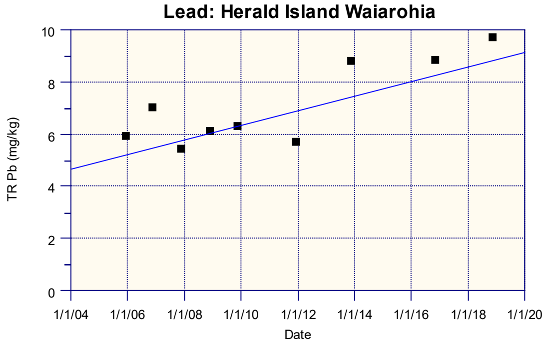




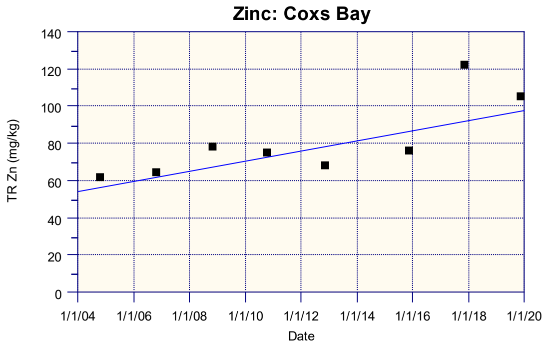
Lead trend plots continued

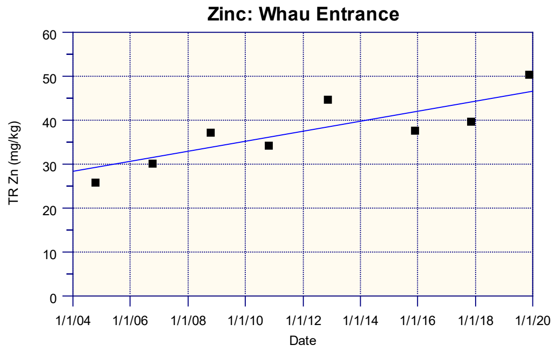


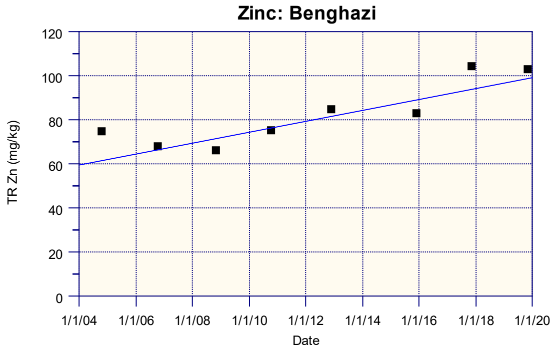


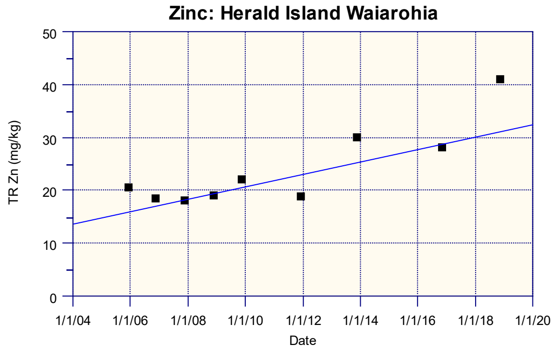


9.4.4 Trends in Zinc for sites with meaningful trends (>±2% median per year and very likely probability). The data plotted are median values from each sampling. The trend line is the Sen Slope.









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