BEFORE THE INDEPENDENT HEARINGS PANELS APPOINTED TO HEAR AND MAKE RECOMMENDATIONS ON SUBMISSIONS AND FURTHER SUBMISSIONS ON PROPOSED PLAN CHANGE 1 TO THE NATURAL RESOURCES PLAN FOR THE WELLINGTON REGION

UNDER	the Resource Management Act 1991 (the Act)
AND	
IN THE MATTER	of Hearing of Submissions and Further Submissions on Proposed Plan Change 1 to the Natural Resources Plan for the Wellington Region under Schedule 1 of the Act

---

STATEMENT OF EVIDENCE OF JOHN WARWICK OLDMAN

ON BEHALF OF GREATER WELLINGTON REGIONAL COUNCIL

TECHNICAL EVIDENCE (LOAD REDUCTIONS REQUIRED FOR TE AWARUA-O-PORIRUA)

HEARING STREAM 2 – OBJECTIVES, ECOSYSTEM HEALTH AND WATER QUALITY POLICIES

28 FEBRUARY 2025

TABLE OF CONTENTS

INTRODUCTION

1 My full name is John Warwick Oldman. I am a Principal Coastal Scientist at DHI New Zealand and have been working there since 2014.

2 I have prepared this statement of evidence on behalf of Greater Wellington Regional Council (**the Council**) in respect of technical matters arising from the submissions and further submissions on Proposed Plan Change 1 to the Natural Resources Plan for the Wellington Region (**PC1**).

3 This statement of evidence relates to the matters in the Section 42A Report – Objectives and Section 42A Report – Ecosystem health and water quality policies, specifically the sedimentation rate for TAoP Harbour in Objective P.O3, the sediment and metal loads reductions in Policy P.P4 and enterococci load reduction required to achieve the enterococci objective in Table 9.1.

QUALIFICATIONS AND EXPERIENCE

4 I hold a Bachelor of Science (Physics and Mathematics) from Massey University.

5 I have 40 years' experience as a coastal scientist with a background in coastal and estuarine processes, sediment transport and the application of numerical models to assess potential impacts of discharges of contaminants to the marine environment.

6 By way of example my experience includes:

7 Assessing effects of contaminant discharges to the Coromandel, Mahurangi, Porirua, Raglan, Tauranga and Whangamata harbours, quantifying the dynamics of discharges to the coast at Army Bay, Beachlands, Hastings, Hokitika, Masterton, Motueka, Napier, North Shore, Papamoa, Ruakaka, Titahi Bay, Whanganui, Whitford and Whitianga. All these projects have considered the effect of discharges via outfalls to the marine receiving environment with key outcomes of the modelling I have carried out being peer reviewed or otherwise assessed as part of Council consent or Environment Court hearings.

8 Modelling for Watercare in relation to the upgrade of the Clarks Beach wastewater treatment plant (WWTP) (2014 and 2018). This work included Manukau Harbour modelling to assess the cumulative effects of catchment derived contaminants and those from existing WWTPs (Māngere, Waiuku, Kingseat) and the current and planned discharge from the Clarks Beach WWTP into the Waiuku Channel.

9 Carrying out modelling for Auckland Council (2018-2024) on the effects of the discharge of nutrients, heavy metals and sediments to the Okura, Weiti and Tamaki estuaries and the Manukau, Mahurangi and Waitemata Harbours. These projects considered the combined effects of multiple catchment derived sources of contaminants and understanding the effect of potential load reductions within the framework of the National Policy Statement for Freshwater Management.

CODE OF CONDUCT

10 I have read the Code of Conduct for Expert Witnesses set out in the Environment Court's Practice Note 2023 (Part 9). I have complied with the Code of Conduct in preparing this evidence. My experience and qualifications are set out above. Except where I state I rely on the evidence of another person, I confirm that the issues addressed in this evidence are within my area of expertise, and I have not omitted to consider material facts known to me that might alter or detract from my expressed opinions.

SCOPE OF EVIDENCE

11 My evidence addresses the potential effects of proposed load reduction targets in PC1 on sedimentation rates and surface sediment metal accumulation within Te Awarua-o-Porirua Harbour (**TAoP Harbour**), as well as the outcomes of targeted pathogen load reductions at key water quality sites.

12 My evidence includes a summary of previous modelling carried out for the Te Awarua-o-Porirua (**TAoP**) Whaitua process and an overview of additional modelling carried out for PC1, which includes;

12.1 Review of appropriate current day (baseline) loads,

12.2 Review of historical deposition rates,

12.3 Quantifying the relationship between sediment load delivered to the harbour and deposition rates within it,

12.4 Sedimentation rates due to PC1 sediment load reductions, and

12.5 Future metal accumulation in surface sediments and the relative role of sediment and metal load changes.

13 My evidence only considers the PC1 coastal objectives as notified and does not consider the potential changes to the sedimentation rate and sediment metal objectives for TAoP Harbour identified in the evidence of Drs Megan Melidonis and Peter Wilson respectively.

INVOLVEMENT IN PLAN CHANGE 1

14 In 2021, I reviewed a Council memo that summarised the outcomes of TAoP Whaitua modelling in terms of the sedimentation load reductions within the TAoP Whaitua Implementation Programme (**WIP**) and the sediment load reductions required to meet the PC1 target sedimentation rates in TAoP Harbour. This included consideration of the derivation of baseline ("current day") sediment loads.

15 As set out in my evidence, in 2024 I calibrated the TAoP Whaitua metal accumulation model against Council monitoring data. The calibrated metal model has been used to provide estimates of future (2040) metal accumulation in surface sediments within the harbour.

SUMMARY OF WHAITUA MODELLING

16 The basis for my evidence is the modelling that I carried out for the TAoP Whaitua Committee, which was used to develop the WIP. That modelling included consideration of future land use scenarios within the TAoP catchment and what effect changes in contaminant loads would have on sedimentation rates and metal accumulation levels in surface sediments within TAoP Harbour.

17 The land use scenarios considered for the TAoP Whaitua process were as follows:

17.1 Baseline scenario, representative of current land use conditions at the time.

17.2 Business as Usual (**BAU**) scenario, representing land use changes and existing approaches to catchment management; and

17.3 Water Sensitive scenario, representing land use changes and implementation of contaminant source control and stormwater treatment devices.

Figure 1. TAoP Whaitua sub-catchments

18 The outputs from the TAoP Whaitua modelling were used to provide an understanding of the potential changes in nutrients, pathogens, suspended sediment, deposition and current day and future metal accumulation under the land use changes considered and how the different sub-catchments contribute to the estimates at a subestuary level (**Figure 2**). Estimates of averages were derived from an annual simulation (for a year with typical catchment inflows and loads) and to understand the variability of estimates a series of events were also simulated. These shorter-term simulations span periods where high rainfall occurs when loads delivered to the harbour can be close to (or exceed) typical annual loads (discussed in detail below). Table 1 shows the range of predicted basin wide deposit rates for the annual and the event-based model simulations carried out for the TAoP Whaitua.

Table 1. Predicted deposition (mm) in the Onepoto Arm and Pāuatahanui Inlet for individual events and the 2010 simulation for TAoP Whaitua Baseline land use scenario

Simulation	Onepoto Arm deposition (mm)	Pāuatahanui Inlet deposition (mm)
2004 event	14.1	11.6
2005 event	0.1	2.0
2006 event	3.9	4.8
2010 annual	1.0	2.4
2013 event	1.2	2.5
Average (all simulations)	4.1	4.7

Figure 2. Whaitua subestuaries showing delineation between inter-tidal and subtidal

19 The marine models used for the TAoP Whaitua work are all part of the MIKE software suite and include a hydrodynamic model which provides estimates of water level variations and currents within the harbour, a wave model which simulates the dynamics of waves within the harbour due to winds, a sediment transport model which tracks the movement of catchment derived sediments due to harbour currents and waves and accounts for sediment characteristics. It predicts where sediments are deposited within the harbour and areas where sediments erode due to the combined effect of currents and waves. Finally, a transport model was used to track the movement of catchment derived pathogens due to harbour currents. The transport model accounts for decay of pathogens over time in the marine receiving environment.

20 The metal model used for the TAoP Whaitua work (detailed in Appendix B of DHI, 2019) was uncalibrated and assumed current day metal concentrations from monitoring data and a worst-case conditions whereby all metal loads delivered from the catchment remained attached to sediments. This meant that future estimates of metal accumulation in the harbour quickly exceeded the threshold of effects considered for the TAoP Whaitua (**Table 2**) which were derived from ANZECC (2000) guidelines and data from Williamson et al. (2017).

21 The key results from the TAoP Whaitua metal modelling were that it was unlikely that overall metal accumulation in the Pāuatahanui Inlet or the northern sector of the Onepoto Arm would exceed the Probable Effects Levels in Table 2, but under the BAU scenario metal accumulation in the southern sector of the Onepoto Arm would become higher than under Baseline conditions.

Table 2: Zinc and Copper thresholds considered for TAoP Whaitua process.

Metal	Threshold Effects Level	Effects Range Low	Probable Effects Level
Zinc	125 mg/kg	150 mg/kg	271 mg/kg
Copper	19 mg/kg	34 mg/kg	108 mg/kg

ADDITIONAL MODELLING FOR PLAN CHANGE 1

22 Since the TAoP Whaitua (which was used to inform the development of the 1 mm/yr and 2 mm/yr rates listed in Table 9.1 of PC1), DHI have developed the TAoP Harbour Coastal Receiving Environment Scenario Tool (**CREST**) which provides an online portal for visualising model results at a sub-catchment and subestuary level. CREST allows a user to input sub-catchment load reduction scenarios and compare model results to baseline (current land use) estimates. Underlying the CREST portal are the full process-based hydrodynamic, sediment transport, nutrient and metal fate models - details of which are provided DHI (2019).

23 A major component of the CREST development has been to calibrate the metal model. The metal model uses estimates of the predicted level of deposition and assumptions around how much zinc and copper are attached to those sediments to calculate how catchment derived metals mix with legacy sediments (and metal concentrations associated with them). The overall concentration of metal in surface sediments is a combination of the metal concentration within the legacy sediments, the metal concentrations within new

catchment derived sediments and how much of the new and old sediment mix. The mixing is estimated from the level of deposition of new sediments and the depth of disturbance of old sediments that occurs via bioturbation and erosion.

24 An important concept of the metal model is the equilibrium concentration of metals in sediment. This occurs when the concentration in new sediments is equal to those of the legacy sediments. In areas of high deposition (or areas influenced only by high metal load sources) this equilibrium value can be reached relatively quickly but in areas where there is low deposition (or areas influenced only by low metal load sources) it can take many decades for an equilibrium value to be achieved.

25 Firstly, metal concentrations in harbour sediments are assumed to evolve over time from background soil metal concentrations with the build-up of metals calibrated against current day concentrations. Not all metal from the catchment is in particulate form – as discussed in Section 13 of Greer et al. (2023). Some of the predicted load from the catchment models will not attach to sediments but will be in dissolved form. This will lead to elevated dissolved metal concentrations in the immediate vicinity of the catchment outlets. The processes leading to this partitioning is complex and depends on the relative metal and sediment concentrations and water chemistry (such as pH and salinity).

26 Secondly, metals that do attach to fine sediments can revert to dissolved form - this process is again complex and relates to sediment and water chemistry (as discussed in Section 13 of Greer et al. 2023). Rather than attempt to model all the complex processes to derive sediment metal accumulation in the harbour, the metal model simply applies a global loss term which is adjusted to match model predictions to current day observations. This loss term accounts for both the initial loss to dissolved at the sources and the subsequent in harbour loss from sediments back to the water column.

27 The metal model estimates the combined effects of all catchment sources in terms of both their individual contribution to deposition and the relative metal loads associated with each source. A source with a high sediment load will have a relatively widespread influence on overall deposition. If that source only has a relatively low metal load, then it will effectively dilute metals from sources with higher metal loads when their depositional footprint overlaps (e.g. Figures C-14 and C-19 of DHI 2019). However, if a source with a high sediment load also has a relatively high metal load, this will likely result in increases in metal concentrations over time over relatively broad areas. Catchments with lower sediment loads will tend to only have a significant effect on overall deposition closer to the

catchment outlet (e.g. Figure C-13 of DHI 2019). If that source also has a relatively high metal load, then this could lead to hotspots of metal accumulation close to the catchment outlet.

APPROPRIATE BASELINE SEDIMENT LOAD FOR USE IN PLAN CHANGE 1

28 Baseline daily sediment loads to the harbour from different sub-catchments were modelled by Easton et al. (2019a) for the period 1975-2016 using dSedNet. Those baseline loads were then used by Easton et al. (2019b) to model the effects of two future scenarios (BAU and Water Sensitive) on those baseline loads. The sediment load modelling by Easton et al. (2019a & b) then fed into the harbour modelling as annual sediment loads and event sediment loads (**Figure 3**).

29 The harbour modelling carried out for TAoP Whaitua included simulating loads delivered to the harbour during individual events. This was used to quantify the variability of the pattern of erosion (bed level decreases) and deposition (bed level increases) that can occur during and after large rainfall events, when significant loads of sediment are delivered to the harbour (detailed below). An annual simulation was also carried out to provide estimates of the mean annual changes in bed level that can occur within the harbour.

30 The annual simulations used the dSedNet modelled loads for 2010 as the base, as this year was considered to represent the 2005-2014 'average' conditions well. The period 2005-2014 is considered representative of the range of climatic conditions that occur within the catchment of the Te Awarua-o-Porirua (Easton et al. 2019a). The loads delivered to the harbour for TAoP Whaitua simulations are given in Table 3.

Table 3. Sediment loads delivered during individual events and the 2010 annual simulation modelled for TAoP Whaitua.

Simulation	Onepoto Arm Sediment Load (tonnes)	Pāuatahanui Inlet Sediment Load (tonnes)	Total Sediment Load (tonnes)
2004 event	23,200	29,300	52,500
2005 event	900	4,700	5,600
2006 event	7,400	12,400	19,800
2010 annual	3,300	5,500	8,800
2013 event	2,900	6,600	9,500
Average (all simulations)	7,500	11,700	19,200

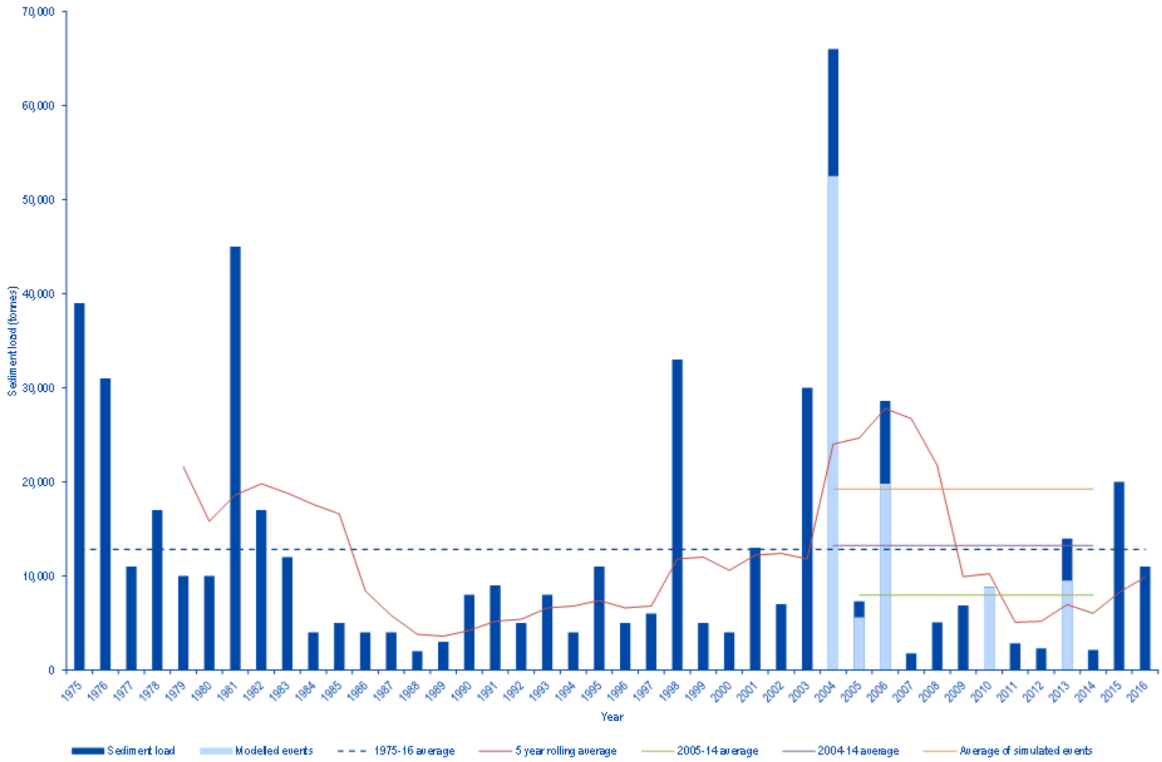


Figure 3. Annual sediment loads delivered to Te Awarua-o-Porirua (dark blue bars) along with mean loads for 1975-2016 (dashed blue line), 2004-2014 (purple line), 2005-2014 (green line) and the five-year rolling average sediment load (red line). The light blue bars are the loads modelled for TAoP Whaitua (Table 3), and the orange line is the average of all the loads modelled for TAoP Whaitua.

31 As can be seen in Figure 3, sediment input loads are highly variable, and the sediment load delivered to Te Awarua-o-Porirua through the 2005-2014 period is lower (at 8,000 tonnes/year – close to the 2010 loads shown in Table 3) than the long-term average of 13,200 tonnes/year derived from the ten year mean from 2004-2014.

32 This implies that using annual average sediment loads from the 2005-2014 period (used for the load reduction targets in the WIP) as a benchmark for setting a sediment load reduction target is not appropriate - even though this period is deemed to be representative of hydrological and climatic conditions in the Te Awarua-o-Porirua catchment. Instead, basing the target reduction on the long-term average annual loads, as has been done in PC1, is more appropriate. These long-term average loads are 8,000 tonnes/year for the Pāuatahanui Inlet and 5,200 tonnes/year for the Onepoto Arm.

HISTORICAL DEPOSITION RATES

33 Swales et al. (2005) derived an average current day (since 1980) sedimentation rate for the Pāuatahanui Inlet from sediment core data of 4.6 mm/yr. Basin wide sedimentation rates from harbour surveys between 2024 and 2014 of 2.1 mm/yr in the Onepoto Arm and 4.1

mm/yr in the Pāuatahanui Inlet have been estimated (DML, 2024)[1]. Analyses of recent sediment plate data (2015-2024) indicate average sediment rates across inter-tidal and subtidal sites are 1.4 mm/yr in the Onepoto Arm and 3.9 mm/yr in the Pāuatahanui Inlet. These values are all less than the average sedimentation rates across all the simulations considered for TAoP Whaitua modelling of 4.1 mm/yr in the Onepoto Arm and 4.7 mm/yr in the Pāuatahanui Inlet (**Table 1**).

34 Gibb (2009) derived annual sedimentation rates by comparing chart data from 1974 and 2009, adjusting surveys to common vertical datums and estimating the volume of cut (erosion) or fill (i.e. deposition). Estimated basin wide rates for the period 1974-2009 were 5.7 mm/yr for the Onepoto Arm (with increasing rates from north to south) with maximum estimated rates of the order of 20-30 mm/yr in the flood tide delta of the entrance (which are highly influenced by marine sands - not catchment derived sediments). Within the Pāuatahanui Inlet, Gibb (2009) estimated basin wide deposition rates of 9.1 mm/yr. These values are higher than estimates from physical observations (above) but (as detailed in Gibb, 2009) inherent uncertainties relating to the vertical accuracy of historical chart data will result in relatively high uncertainties associated with these estimates.

35 Of note are the estimated recent historical sedimentation rates from Swales et al. (2005) of 3.4 mm/yr from 50 years ago and 2.4 mm/yr from 150 years ago – indicating an ongoing trend of increasing sedimentation since deforestation began in the catchment some 150 years ago.

36 In terms of estimated historical (geological) sedimentation rates, Swales et al. (2005) estimate that over the last several thousand years sediment accumulation rates in the Pāuatahanui Inlet were 1 mm/yr (in agreement with the average Pre-European rates presented in Gibb, 2009) and close to the whole harbour Pre-Human rate of 0.8 mm/yr reported in Hicks et al. (2019).

37 Assuming similar historical sediment yields from the two catchments and the relative areas of the Onepoto Arm and Pāuatahanui Inlet estimated historical deposition rates of 0.7 mm/yr for the Onepoto Arm and 1.2 mm/yr for the Pāuatahanui Inlet can be derived[2]. The whole harbour historical rate would be 1.0 mm/yr. Estimated current sedimentation rates (paragraph 20) are at least 3 times higher than these estimated historical rates.

[1] These are the area weighted averages from the estimated rates within each DML zone within the harbour.

[2] Allowing for some uncertainty relating to the historic estimates in the Pāuatahanui.

38 The PC1 targets of 1 mm/yr and 2 mm/yr listed in Table 9.1 of PC1 (the sedimentation rate parameter) are therefore around 1.5 times the estimated Pre-European sedimentation rates[3].

39 Analyses of the most recent sediment plate data (2020 - 2024) indicate average sedimentation rates of 6.0 and 2.0 mm/yr within Onepoto Arm and the Pāuatahanui Inlet (Table 12 of the evidence of Dr. Melidonis). These estimates are due to the relatively high deposition rates observed at some of the plate data sites in 2022-2023. This is likely to be a result of the high sediment loads delivered in 2022 - mean annual flows for the Porirua Stream (at Town Centre) and Pāuatahanui Stream (at Gorge) for 2022 are the highest on record and so it is likely sediment loads for 2022 will be higher than any previously modelled.

RELATIONSHIP BETWEEN SEDIMENT LOADS AND DEPOSITION RATES

40 Running the harbour modelling for individual events and an annual simulation for 2010 provided quantification of the variability of the pattern of erosion (bed level decreases) and deposition (bed level increases) that can occur during and after large rainfall events (when significant loads of sediment are delivered to the harbour) and estimates of the mean annual changes in bed level that can occur within the harbour. This approach highlighted the dynamic nature of sediment delivery (driven by catchment hydrology and sediment generation within the catchment) and how sediments are transported within and exported from the harbour during and after events.

41 Figure 4 shows the total bed level change for the 2010 annual simulation. These results are for an annual load of 5,500 tonnes delivered to the Pāuatahanui Inlet and 3,300 tonnes delivered to the Onepoto Arm. Results from the event-based simulations are provided in Appendix 1.

[3] These sedimentation rates would be achieved under the Water Sensitive scenario considered in TAoP Whaitua (see Table 6-11, DHI, 2019).

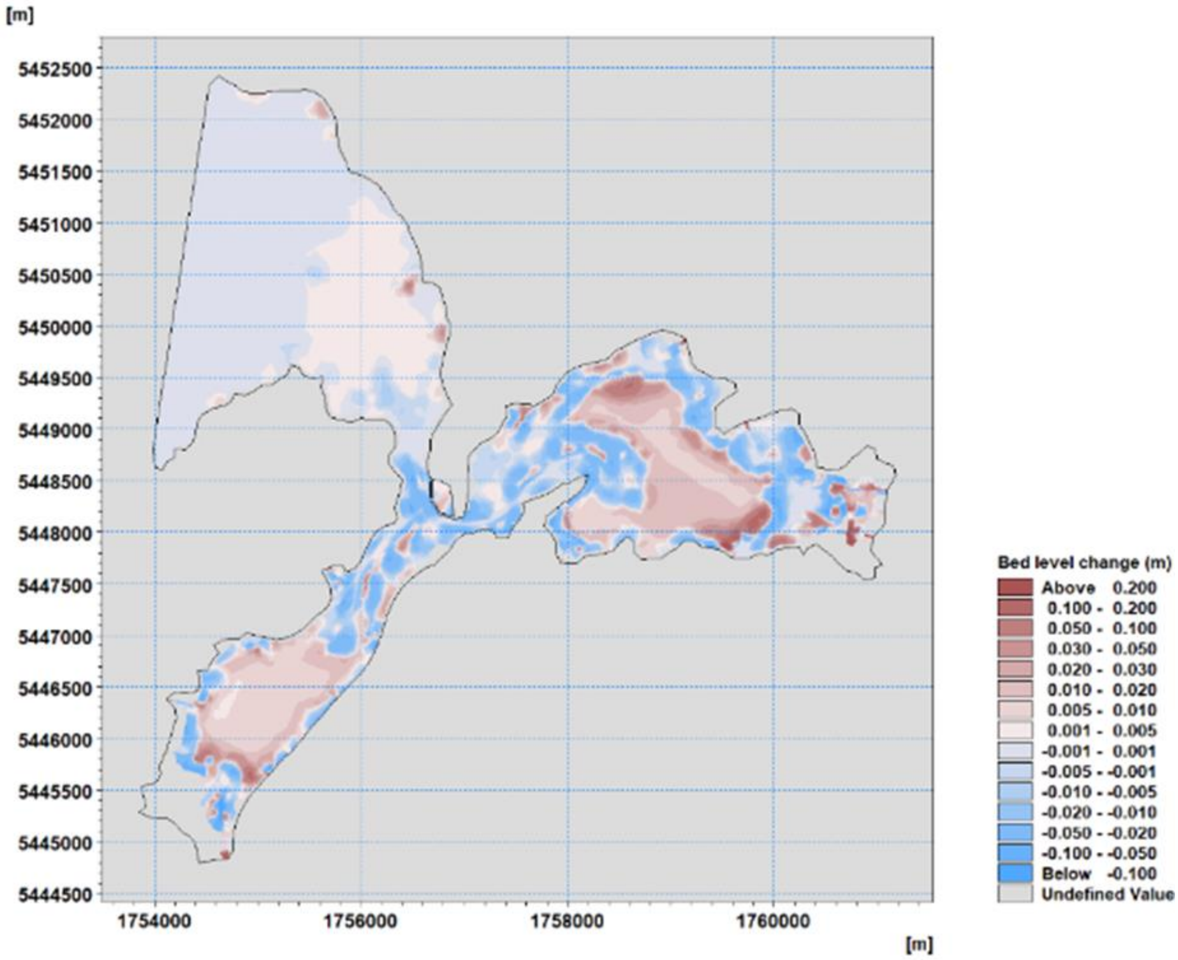


Figure 4. Estimated annual bed level change (m) for 2010 for the baseline land use scenario from TAoP Whaitua work. Annual load of sediment delivered was 8,800 tonnes.

42 This figure shows that bed level changes are made up of areas where higher deposition occurs (typically nearer the catchment outlets and in the subtidal basins), areas where very little change in bed level occurs (e.g. immediately offshore of the entrance) and areas where erosion occurs (typically the more exposed fringes of the inter tidal areas).

43 The model results show the clear gradient in the Onepoto Arm transitioning from a depositional zone to the south to an erosional zone to the north.

44 Within the Pāuatahanui Inlet, the subtidal basins, Bradeys Bay and Pāuatahanui subestuary are the major depositional zones for sediments. Browns Bay has similar sized areas of deposition and erosion (Figure 4) and within other area of Pāuatahanui Inlet there are patches of deposition but the larger areas where erosion occurs (and the magnitude of erosion) means there is net erosion in these areas in 2010.

45 During the 2004 and 2006 events, when higher-than-average loads occurred, we see bands of much higher deposition than for the 2010 annual run and lower levels of erosion (erosion processes are offset by more incoming sediment). For the 2005 event (when the

load was low) we see much lower levels of deposition and for the 2013 event (which has similar loads to the 2010 annual simulation) the overall level of deposition is similar but there are subtle changes at the sub estuary level.

SEDIMENT LOAD REDUCTIONS REQUIRED TO ACHIEVE PLAN CHANGE 1 SEDIMENTATION RATE OBJECTIVES

46 Using the predicted basin wide deposition rates for each of the simulations run for TAoP Whaitua for all three land use scenarios considered a relationship between load and basin wide deposition can be quantified. Figure 5 shows the data for the Onepoto Arm and Figure 6 shows the data for the Pāuatahanui Inlet. The plots show that the relationship is linear.

47 This means that estimates of the basin wide deposition for the long-term (2004-2014) average annual loads of 8,000 tonnes/year for the Pāuatahanui Inlet and 5,260 tonnes/year for the Onepoto Arm can be estimated. The long-term average basin wide deposition rates are 2.6 mm for the Onepoto Arm and 3.2 mm for the Pāuatahanui Inlet. These loads are represented by the right bars on the figures.

48 Conversely, the load required to meet the PC1 deposition targets of 1.0 mm for the Onepoto Arm and 2.0 mm for the Pāuatahanui Inlet can be estimated. These loads are 2,790 tonnes/year for the Onepoto Arm and 4,950 tones/yr for the Pāuatahanui Inlet. These loads are represented by the left bars on the figures. The target sediment load for the whole of TAoP Harbour is therefore 7,740 tonnes/year, representing a 42% reduction from the long-term average of 13,260 tonnes/year. This target load is close to the 2010 sediment load of 8,800 tonnes/year modelled for TAoP Whaitua (Table 3).

49 Table 4 and 5 show the estimated subestuary deposition rates for the 2004-2014 long-term sediment load and the 40% Load Reduction Factor (**LRF**) scenario as depicted in Figure 7. The long-term average estimates are in good general agreement with the longer-term sediment plate data (Stevens and Rabel, 2024).

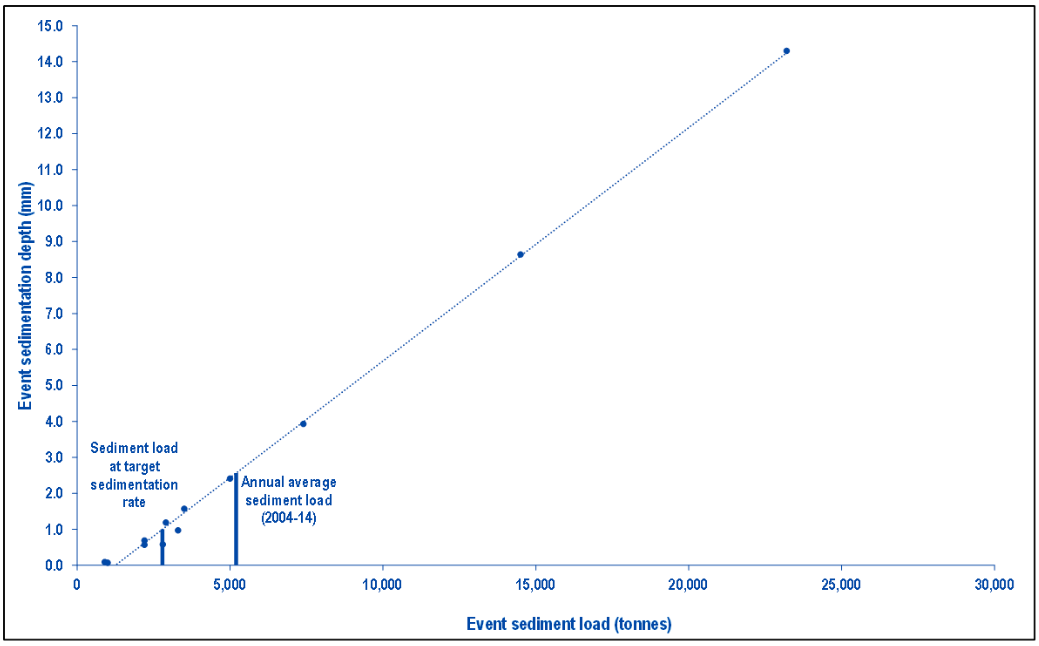


Figure 5. Scatter plot of predicted basin wide deposition within the Onepoto Arm for each of the model simulations conducted for TAoP Whaitua for all three land use scenarios considered. The interpolated deposition rate for the mean long-term annual sediment load of 5,260 tonnes is 2.6 mm (right bar). The target load to achieve a basin wide deposition rate of 1.0 mm is 2,790 tonnes (left bar) close to the 2010 annual load of 3,300 simulated for TAoP Whaitua.

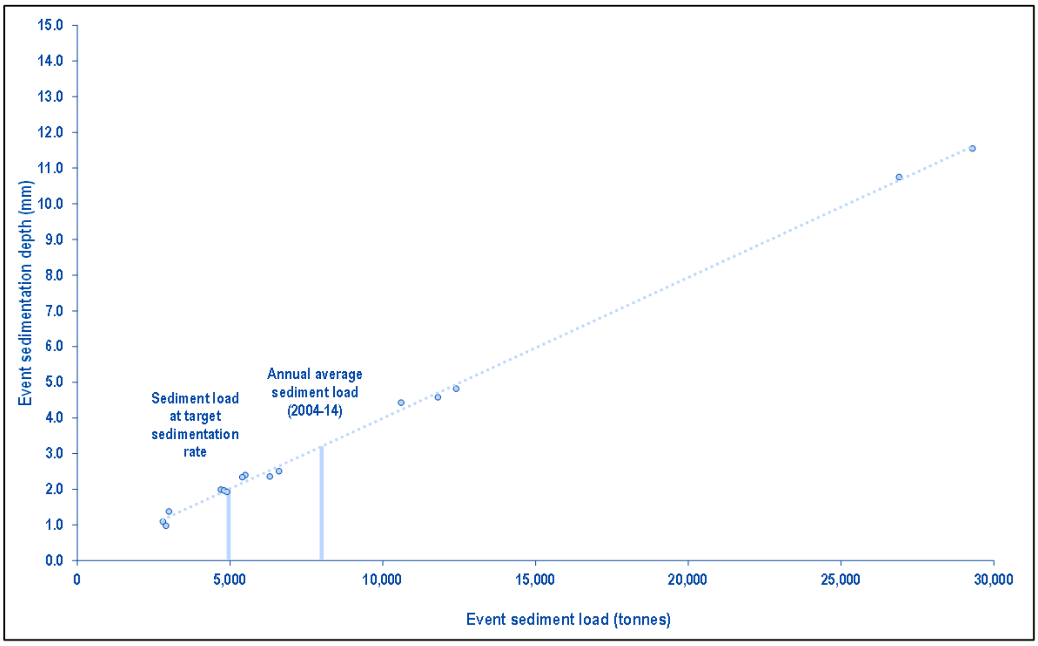


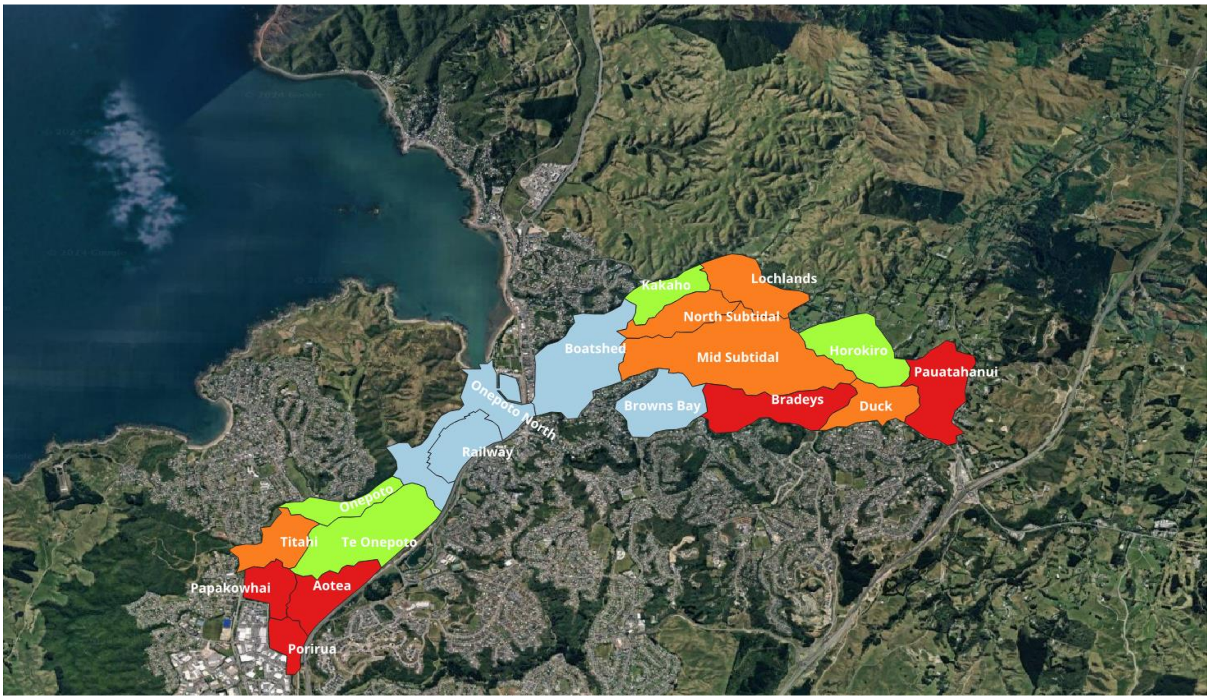
Figure 6. Scatter plot of predicted basin wide deposition within the Pāuatahanui Inlet for each of the model simulations conducted for TAoP Whaitua for all three land use scenarios considered. The interpolated deposition rate for the mean long-term annual sediment load of 8,000 tonnes is 3.2 mm (right bar). The target load to achieve a basin wide deposition rate of 2.0 mm is 4,950 tonnes (left bar) - close to the 2010 annual load of 5,500 simulated for TAoP Whaitua.

Table 4. Subestuary wide average deposition rates (mm/yr) in the Onepoto Arm under the baseline and 40% LRF scenario

	Porirua	Papakowhai	Titahi	Onepoto	Aotea	Te Onepoto	Onepoto North	Railway
Current Land Use (2004-2014 mean load)	18.9	3.2	1.1	0.5	6.2	0.4	0.2	<0.1
40% LRF Sediment Load Reduction	11.2	1.9	0.7	0.3	3.5	0.3	0.2	<0.1

Table 5. Subestuary wide average deposition rates (mm/yr) in the Pāuatahanui Inlet under the baseline and 40% LRF scenario.

	Boatshed	Browns	Bradeys	Duck	Pāuatahanui	Horokiri	Lochlands	Kakaho	North subtidal	Mid subtidal
Current Land Use (2004-2014 mean load)	0.2	0.5	21.1	1.2	8.5	1.2	1.7	0.7	2.0	1.3
40% LRF Sediment Load Reduction	0.1	0.3	11.4	0.8	7.4	0.6	0.7	0.4	1.0	0.7



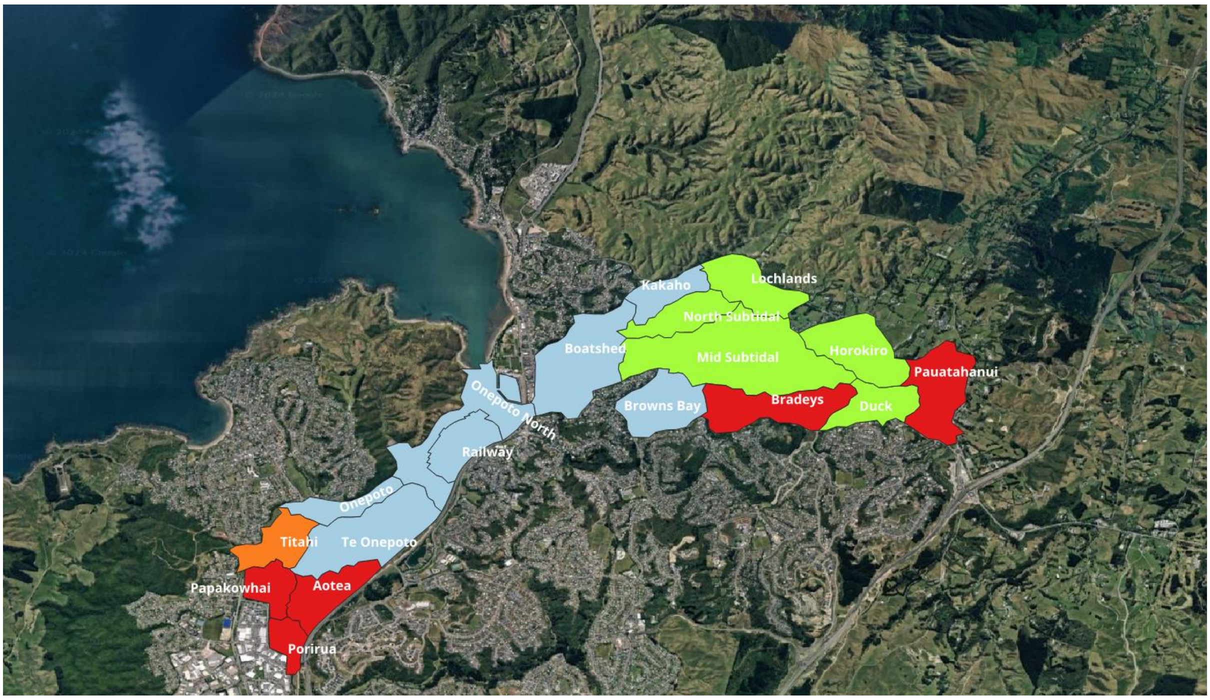


Figure 7. Subestuary deposition (mm/yr) with colour coding reflecting (blue), < 0.5 mm/yr (green), 0.5-1.0 mm/yr (light orange) > 1.0-2.0 mm/yr (orange) and > 5.0 mm/yr (red).

METAL AND SEDIMENT PLAN CHANGE 1 LAND USE SCENARIOS

50 The calibration of the metal model was carried out so to provide realistic estimates of future metal accumulation in surface sediments. This was done to quantify the relative effects of sediment load reductions in isolation, combined with a range of metal load reduction targets. This was done to address the issue discussed in Section 13 of Greer et al (2023) around the relative loading of metals from urban and rural parts of the catchment. Reducing sediment loads within rural catchments will produce relatively low reductions in metal loads. Urban sources have relatively high metal loads so that reducing urban sediment loads in isolation will reduce metal loads. The scenarios considered are as follows:

50.1 Baseline conditions representing the long-term average sediment load of 13,200 tonnes/year,

50.2 A future land use scenarios representing a 40% sediment load reduction target with a 40% metal load reduction.

50.3 A future land use scenarios representing a 40% sediment load reduction target with a 15% metal load reduction[4], and

50.4 A future land use scenarios representing a 40% sediment load reduction target with no change in metal load.

51 Details of the load reductions for each sub-catchment are shown in Table 6. As for TAoP Whaitua modelling, there are significant differences in load changes for different sub-catchments which relate to the relative loads of sediments and metals associated with rural and urban land use (as discussed in Section 13 of Greer et al. 2023).

[4] 15% was chosen as the middle of the road scenario (rather than 20%) as it is consistent with the copper load reductions specified in Policy P.P12 of PC1.

Table 6. Sediment load changes under a LRF 40% land use scenario and metal load changes under a LRF 40% and 15% land use scenario. Negative values mean an increase in load.

Sub-catchment	Sediment	Copper		Zinc	
	LRF 40% Improved	LRF 40% Improved	LRF 15% Improved	LRF 40% Improved	LRF 15% Improved
Whitireia at Mouth	9%	5%	4%	34%	15%
Onepoto Fringe at Elsdon	1%	64%	29%	51%	20%
Hukatai Stream at Mouth	0%	2%	-1%	29%	10%
Porirua at Mouth	41%	41%	15%	40%	15%
Direct to Onepoto mid	11%	8%	3%	24%	9%
Direct to Onepoto North	-5%	22%	13%	41%	22%
Direct to Onepoto South	55%	79%	26%	26%	0%
Kahotea Stream (Onepoto Park)	1%	17%	10%	36%	17%
Next to Mahinawa	-5%	32%	14%	42%	16%
Horokiri and Motukaraka at Mouth	49%	67%	13%	16%	-23%
Kakaho at Mouth	64%	100%	72%	66%	33%
Ration at Mouth	12%	-22%	-109%	-67%	-120%
Motukaraka	26%	25%	25%	47%	32%
Pāuatahanui at Mouth	35%	30%	13%	26%	8%
Pāuatahanui village	0%	40%	38%	60%	46%
Browns Bay	40%	6%	5%	52%	30%
Direct to Pāuatahanui (boat houses)	5%	44%	32%	63%	44%
Direct to Pāuatahanui (mid)	15%	42%	21%	54%	25%
Direct to Pāuatahanui (water ski club)	28%	44%	44%	40%	40%
Lower Duck Creek at Mouth	56%	34%	15%	54%	28%

52 For the baseline conditions, current day and future (2040) the surface sediment Zinc and Copper concentrations were calculated. Here, baseline conditions for sediments and metals are derived from the 2010 model simulations from TAoP Whaitua (consistent with the approach used in CREST) which are 8,800 tonnes/yr of sediment, 340 kg/yr of Copper and 3500 kg/yr of Zinc.

53 For the future land use scenarios, the initial conditions were set to the current day estimates of Zinc and Copper and the metal load changes in Table 6 applied and model estimates in 2040 were calculated. This provides quantification of the relative effects of non-concurrent changes in sediment and metal loads while considering the relative loading

of sediments and metals from urban versus rural land use (as discussed in Greer et al 2019).

RELATIVE ROLE OF SEDIMENT AND METAL LOAD CHANGES ON FUTURE METAL ACCUMULATION

54 In this section, estimates from the calibrated metal model for the land use scenarios considered are presented to provide an understanding of the relative roles of sediment load changes and metal load changes.

CURRENT DAY LAND USE (PRESENT DAY ESTIMATES)

55 Estimated present day Zinc concentrations (Figure A2.1 and Figure A2.2) under current day land use show localised hotspots above 410 mg/kg near the Whitby, Pāuatahanui Boat House, Pāuatahanui Mid, Kahetoa, Onepoto North and Onepoto Mid catchment outlets.

56 Sediments from the Porirua sub-catchment are relatively widely dispersed within the subtidal areas of the Onepoto Arm and, because this catchment source has relatively high metal loads, this leads to the broad area of Zinc concentrations between 200 and 410 mg/kg within the southern Onepoto Arm.

57 Lower deposition rates within the northern sector of the Onepoto Arm and some mixing of Pāuatahanui sourced sediments (which generally have lower metal loads) with Onepoto sediments results in lower estimated Zinc concentrations in this part of the harbour. The generally lower metal loads associated with the Pāuatahanui sources leads to relatively low levels of Zinc across most of the Pāuatahanui Inlet.

58 The average Zinc concentrations in the Onepoto Arm is 140 mg/kg and the average Zinc concentrations in the Pāuatahanui Inlet Arm is 28 mg/kg.

59 Highest subestuary averages of around 270 mg/kg occur within the southern Onepoto Arm. In the Pāuatahanui Inlet highest subestuary averages of between 25-90 mg/kg occur within the Browns and Bradeys subestuaries and the North and Mid subtidal subestuaries. Elsewhere, estimated subestuary averages are very low.

60 For Copper, current day estimates (Figure A2.3 and Figure A2.4) show similar spatial gradients to Zinc estimates, but levels are generally well below 65 mg/kg. The average Copper concentrations in the Onepoto Arm is 13 mg/kg and the average Copper concentrations in the Pāuatahanui Inlet Arm is 3 mg/kg.

61 Highest subestuary averages of between 15 and 25 mg/kg occur within the southern Onepoto Arm. In the Pāuatahanui Inlet highest subestuary averages of between 3-8 mg/kg occur within the Browns and Bradeys subestuaries and the North and Mid subtidal subestuaries. Elsewhere, estimated subestuary averages are very low.

CURRENT DAY LAND USE (FUTURE ESTIMATES)

62 Future Zinc results for 2024 for the current land use (Figure A2.5 and Figure A2.6), show an increase in the central basin of the Onepoto Arm and a gradual expansion of the area of metal concentrations above 400 mg/kg around the hotspots.

63 This is the case for Copper as well (Figure A2.7 and Figure A2.8), although the magnitude of future changes are much smaller than for Zinc because of the lower Copper loadings.

64 The average increase in Zinc across the Onepoto Arm through to 2040 is just over 11 mg/kg and the average increase in Zinc across the Pāuatahanui Inlet Arm through to 2040 is less than 3 mg/kg.

65 The average increase in Zinc through to 2040 is around 12-26 mg/kg within the Onepoto, Titahi and Te Onepoto subestuaries. An increase of around 13 mg/kg is estimated to occur within the Browns Bay subestuary. Elsewhere, average subestuary increases are generally less than 3 mg/kg.

66 The average increase in Copper across the Onepoto Arm through to 2040 is around 1 mg/kg and the average increase in Copper across the Pāuatahanui Inlet Arm through to 2040 is less than 0.3 mg/kg.

67 The average increase in Copper through to 2040 is around 1-3 mg/kg within the Onepoto, Titahi and Te Onepoto subestuaries. An average increase of just over 1 mg/kg is estimated to occur within the Brown Bay subestuary. Elsewhere, average subestuary increases are below 0.3 mg/kg.

SEDIMENT AND METAL LOAD REDUCTIONS OF 40% (FUTURE ESTIMATES)

68 For the 40% LRF sediment load change with a parallel 40% LRF metal load change (Figure A2.9 to Figure A2.10) we see very similar results to the current day land use future (2024) results for both Zinc and Copper. However, within the subtidal basin of the Onepoto Arm there are decreases in Zinc and within the Pāuatahanui Inlet the area of elevated Zinc

concentrations near the Whitby, Pāuatahanui Mid and Boathouse outlets expand slightly. Copper decreases only slightly within both the Onepoto Arm and the Pāuatahanui Inlet.

69 The average decrease in Zinc across the southern Onepoto Arm under this scenario through to 2040 is around 5 mg/kg and there is an average increase[5] in Zinc across the Pāuatahanui Inlet Arm through to 2040 of around 0.2 mg/kg.

70 There are increases in Zinc within the North subtidal (< 1.0 mg/kg) and Browns Bay (< 6 mg/kg) subestuaries but subestuary changes elsewhere are generally less than 1 mg/kg.

71 The average decrease in Copper across the Onepoto Arm through to 2040 is around 0.4 mg/kg and the average decrease in Copper across the Pāuatahanui Inlet Arm through to 2040 is well below 0.1 mg/kg (Figure A2.11 and Figure A2.12).

SEDIMENT LOAD REDUCTIONS OF 40% WITH 15% LOAD REDUCTIONS FOR METAL (FUTURE ESTIMATES)

72 For the 40% LRF sediment load change with a parallel 15% LRF metal load change (Figure A2.13 and Figure A2.14) for Zinc there is a small expansion of the area of hotspots near the catchment outlets and slight increases in Zinc within the central basin of the Onepoto Arm compared to the Current land use future estimates. There are increases in Copper beyond 30 mg/kg on the fringing subtidal areas of the Onepoto Arm. Within the Pāuatahanui Inlet the area of elevated Zinc concentrations near the Whitby, Pāuatahanui Mid and Boathouse outlets expand slightly. Copper levels change only slightly around the Whitby catchment outlet.

73 The average increase in Zinc across the Onepoto Arm through to 2040 is just under 15 mg/kg and the average increase in Zinc across the Pāuatahanui Inlet Arm through to 2040 less than 1 mg/kg.

74 However, there are subestuary average increases in Zinc in 2040 under this scenario of between 13-40 mg/kg within the southern sector of the Onepoto Arm. Average subestuary changes elsewhere are generally less than 1 mg/kg except in the North subtidal, Mid subtidal and Bradeys subestuaries where average subestuary increases range from 2 - 4 mg/kg.

[5] This is because of the relative sediment and metal load reductions for the Pāuatahanui Stream at Mouth catchment (Table 6) leading to increases in the metal-to-sediment ratio for this catchment source.

75 The average increase in Copper across the Onepoto Arm through to 2040 is less than 2 mg/kg and the average increase in Copper across the Pāuatahanui Inlet Arm through to 2040 is 0.2 mg/kg (Figure A2.15 and Figure A2.16).

76 The average increase in Copper in 2040 under this scenario range from 2-4 mg/kg within the southern sector of the Onepoto Arm and average subestuary increases elsewhere are generally less than 0.1 mg/kg. There are a small increases in subestuary average Copper (~ 0.6 mg/kg) within the Bradeys and Browns subestuaries.

SEDIMENT LOAD REDUCTIONS OF 40% WITH NO LOAD REDUCTIONS FOR METAL (FUTURE ESTIMATES)

77 For the 40% LRF sediment load change and no change in metal loads (Figure A2.17 and Figure A2.18) there are expansions of the areas of hotspots above 400 mg/kg for Zinc and there are increases in Copper beyond 30 mg/kg on the fringing subtidal areas of the Onepoto Arm. Within the Pāuatahanui Inlet the area of elevated Zinc concentrations near the Whitby, Pāuatahanui Mid and Boathouse outlets expand slightly. Copper levels change only slightly around the Whitby catchment outlet.

78 The average increase in Zinc across the Onepoto Arm through to 2040 is just under 6 mg/kg and the average decrease in Zinc across the Pāuatahanui Inlet Arm through to 2040 is around 0.2 mg/kg.

79 The subestuary average increase in Zinc in 2040 under this scenario range from 20 -90 mg/kg within the southern sector of the Onepoto Arm and average subestuary changes elsewhere are generally less than 1 mg/kg except in the North subtidal, Browns, Mid subtidal and Bradeys subestuaries where average subestuary increases range from 7-10 mg/kg.

80 The average increase in Copper across the Onepoto Arm through to 2040 is less than 3 mg/kg and subestuary average Copper concentrations across the Pāuatahanui Inlet increase by 0.2 mg/kg (Figure A2.19 and Figure A2.20).

81 The average subestuary increase in Copper in 2040 under this scenario range from 2-6 mg/kg within the southern sector of the Onepoto Arm and average subestuary decreases elsewhere are generally less than 0.1 mg/kg. There are a small increases in Copper of less than 1 mg/kg within the Browns Bradeys, Mid subtidal, and North subtidal subestuaries.

TABULATED DATA

82 Table A2.1 to Table A2.6 show the basin wide average Zinc and Copper concentrations within the Onepoto Arm and Pāuatahanui Inlet, as well as the estimates for the inter-tidal and sub-tidal areas.

83 The inter-tidal estimates tend to be smaller because of the patchier nature of the predicted metal accumulation - with hotspots of metal accumulation close to sources and much lower estimates away from catchment sources.

84 Within the sub-tidal areas, the estimates are much more uniform which is a result of more widespread dispersal of sediments within the deeper parts of the harbour, which act as long-term sinks of sediments (as discussed in DHI, 2019).

85 Table A2.7 to Table A2.12 provide the percentile estimates of the Zinc and Copper concentrations within each of the subestuaries. These percentile estimates provide a sound statistical metric of the range of values that occur within the different subestuaries and the Onepoto Arm and Pāuatahanui Inlet. The 50th percentile values for the Onepoto Arm are close to the average estimates but for the Pāuatahanui Inlet the 50th percentile estimates are much lower because of the relatively large areas where low metal concentrations occur. The 95th percentile estimates give a representative measure of the upper limit of the predicted metal concentrations rather than reporting the maximum estimated value (which may only occur within one very small area of the model).

86 Data in these tables provides the basis for assessing the ecological significance of the effect of proposed changes in sediment and metal loads.

PATHOGEN LOAD REDUCTIONS

87 The CREST portal allows a user to input sub-catchment load reduction scenarios and compare model results to baseline (current land use) estimates.

88 Sub-catchment pathogen load reductions associated with the freshwater target attribute state defined in PC1 and the minimum required improvement under the National Policy Statement for Freshwater Management 2020 are shown in Table 7.

89 These sub-catchment load reductions have been input into the CREST portal and time-series of predicted pathogen concentrations for baseline and load reduction scenarios at key water-quality monitoring sites provided to Dr. Wilson for analyses.

Table 7. Pathogen load reductions under a freshwater target attribute state (TAS) scenario and one attribute state improvement scenario.

Sub-catchment	Freshwater target attribute state scenario	One attribute state improvement
Whitireia at Mouth	67%	48%
Onepoto Fringe at Elsdon	92%	60%
Hukatai Stream at Mouth	92%	60%
Porirua at Mouth	92%	60%
Direct to Onepoto mid	92%	60%
Direct to Onepoto North	92%	60%
Direct to Onepoto South	92%	60%
Kahotea Stream (Onepoto Park)	92%	60%
Next to Mahinawa	92%	60%
Horokiri and Motukaraka at Mouth	67%	48%
Kakaho at Mouth	67%	48%
Ration at Mouth	67%	48%
Motukaraka	67%	48%
Pāuatahanui at Mouth	59%	15%
Pāuatahanui village	59%	15%
Browns Bay	92%	60%
Direct to Pāuatahanui (boat houses)	92%	60%
Direct to Pāuatahanui (mid)	92%	60%
Direct to Pāuatahanui (water ski club)	92%	60%
Lower Duck Creek at Mouth	83%	54%

CONCLUSION

90 A calibrated sediment model has been used to estimate basin wide annual deposition rates based on the long-term average annual sediment load delivered to the TAoP Harbour of 13,260 tonnes/year. These estimates are based on an analysis of deposition estimates from the TAoP Whaitua work where a number of model simulations with a range of sediment loads were considered.

91 For the Onepoto Arm a basin wide average deposition rate of 2.6 mm/yr is estimated for a long-term (2004-2014) annual sediment load of 5,260 tonnes. For the Pāuatahanui Inlet a basin wide average deposition rate of 3.2mm/yr is estimated for a long-term (2004-2014) annual sediment load of 8,000 tonnes.

92 Note that most recent 5-year mean deposition rates from sediment plate data are estimated to be 6.0 mm/yr and 2.4 mm/yr for the Onepoto Arm and Pāuatahanui Inlet. These rates are higher than those derived from the mean annual load from 2004-2014 and reflect the natural variability of loads delivered to the harbour (Figure 3) and the more recent events within the catchment which would contribute to higher-than-average loads being delivered to the harbour (as discussed in the evidence of Dr. Melidonis).

93 An overall sediment load reduction of 42% is required to meet the PC1 targets. This is made up of a 47% reduction in sediment load (to 2,790 tonnes/yr) to the Onepoto Arm – which would result in a basin wide deposition to 1.0 mm/yr and a 38% reduction in sediment load (to 4,950 tonnes/yr) to the Pāuatahanui Inlet which would result in a basin wide deposition to 2.0 mm/yr.

94 A calibrated metal accumulation model has been used to estimate future surface sediment metal concentrations for combinations of metal and sediment load reductions. Results are benchmarked against predicted future (2040) metal accumulation under current land use.

95 If metal load reductions match the proposed 40% reduction in sediment loads future (2040) metal accumulation is predicted to be very similar to those under the current day land use. There are decreases in future Zinc accumulation within the subtidal basin of the Onepoto Arm compared to what would happen under current land use and minor increases in Zinc accumulation in the Pāuatahanui Inlet. Compared to future estimates under current land use, future Copper accumulation decreases slightly within Onepoto Arm and does not significantly change in the Pāuatahanui Inlet.

96 If a metal load reduction of 15% occurs in parallel to the proposed 40% reduction in sediment loads there is a small expansion of the area of Zinc hotspots near the catchment outlets compared to the Current land use future estimates. There are increases in Copper beyond 32.5 mg/kg on the fringing subtidal areas of the Onepoto Arm. There are increase in future Zinc accumulation within the subtidal basin of the Onepoto Arm compared to what would happen under current land use and minor increases in Zinc accumulation in the Pāuatahanui Inlet. Compared to future estimates under current land use, future Copper accumulation increases slightly within both the Onepoto Arm and Pāuatahanui Inlet.

97 If no reduction in metal load is applied in parallel to the proposed 40% reduction in sediment load reductions the localised hotspots of Zinc accumulation (above 410 mg/kg or "Poor") near catchment outlets expands compared to the current day load estimates in 2040. For Copper, a broad band of Copper accumulation above 32.5 mg/kg (still graded "Good") occurs within the fringing subtidal areas of the Onepoto Arm. There are increases in future Zinc accumulation within the subtidal basin of the Onepoto Arm and the Pāuatahanui Inlet compared to what would happen under current land use. Compared to future estimates under current land use, future Copper accumulation increases within both the Onepoto Arm and Pāuatahanui Inlet.

98 Results from the enterococci, sediment and metal models have been used by Dr. Wilson and Dr. Melidonis to assess the ecological significance of the changes in sediment deposition rates, future metal accumulation and human health risk to inform recommendations on Objective P.O3, Table 9.1 and Policy P.P4 in PC1.

DATE: 28 FEBRUARY 2025

JOHN WARWICK OLDMAN
PRINCIPAL COASTAL SCIENTIST, DHI

REFERENCES

ANZECC 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. National Water Quality Management Strategy. Australian and New Zealand Environment and Conservation Council. Agriculture and Resource Management Councils of Australia and New Zealand. Canberra, Australia.

DHI 2019. Porirua Harbour - Modelling for Whaitua Collaborative Modelling Group (DHI Report No. Report 44800943/01). DHI, Auckland, New Zealand.

DML, 2024. Report of Survey. Porirua Harbour Bathymetric Survey 2024:

Easton, S., Shrestha, M., Cetin, L., Blyth, J., Sands, M., 2019a. Porirua Whaitua Collaborative Modelling Project. Baseline Modelling Technical Report (Jacobs Report No. IZ080700). Jacobs New Zealand Ltd, Wellington, New Zealand.

Easton, S., Shrestha, M., Cetin, L., Sands, M., 2019b. Porirua Whaitua Collaborative Modelling Project. Scenario Modelling Technical Report (Jacobs Report No. IZ080700). Jacobs New Zealand Ltd, Wellington, New Zealand.

Greer, M.J.C., Blyth, J., Eason, S., Gadd, J., King, B., Nation, T., Oliver, M., Perrie, A. 2023. Technical assessments undertaken to inform the target attribute state framework of proposed Plan Change 1 to the Natural Resources Plan for the Wellington Region. Torlesse Environmental Limited, Christchurch, New Zealand.

Hicks, M., Semademi-Davies, A., Haddadchi, A., Shankar, U., Plew, D. 2019. Updated sediment load estimator for New Zealand. NIWA Client Report No. 2018341CH, prepared for Ministry for the Environment.

Stevens LM, Rabel H. 2024. Te Awarua-o-Porirua Harbour Sediment Plate Monitoring 2023/2024. Salt Ecology Report 136, prepared for Greater Wellington Regional Council, July 2024. 22p.

Swales, A., Bentley, S.J., McGlone, M.S., Ovenden, R., Hermanspahn, N., Budd, R., Hill, A., Pickmere, S., Haskey, R., Okey, M.J. 2005. Pauatahanui inlet: effects of historical catchment land cover changes on inlet sedimentation. National Institute of Water & Atmospheric Research Ltd Client Report HAM2004-149, April 2005 prepared for Greater Wellington Regional Council and Porirua City Council. 135p.

Williamson, R.B., Hickey, C.W., Robertson, B.M. 2017. Preliminary assessment of limits and guidelines available for classifying Auckland coastal waters. Prepared by Diffuse Sources, NIWA and Wriggle Coastal Management for Auckland Council. Auckland Council technical report, TR2017/035.

APPENDIX 1. EVENT BASED DEPOSITIONAL RESULTS FROM THE TAOP WHAITUA WORK

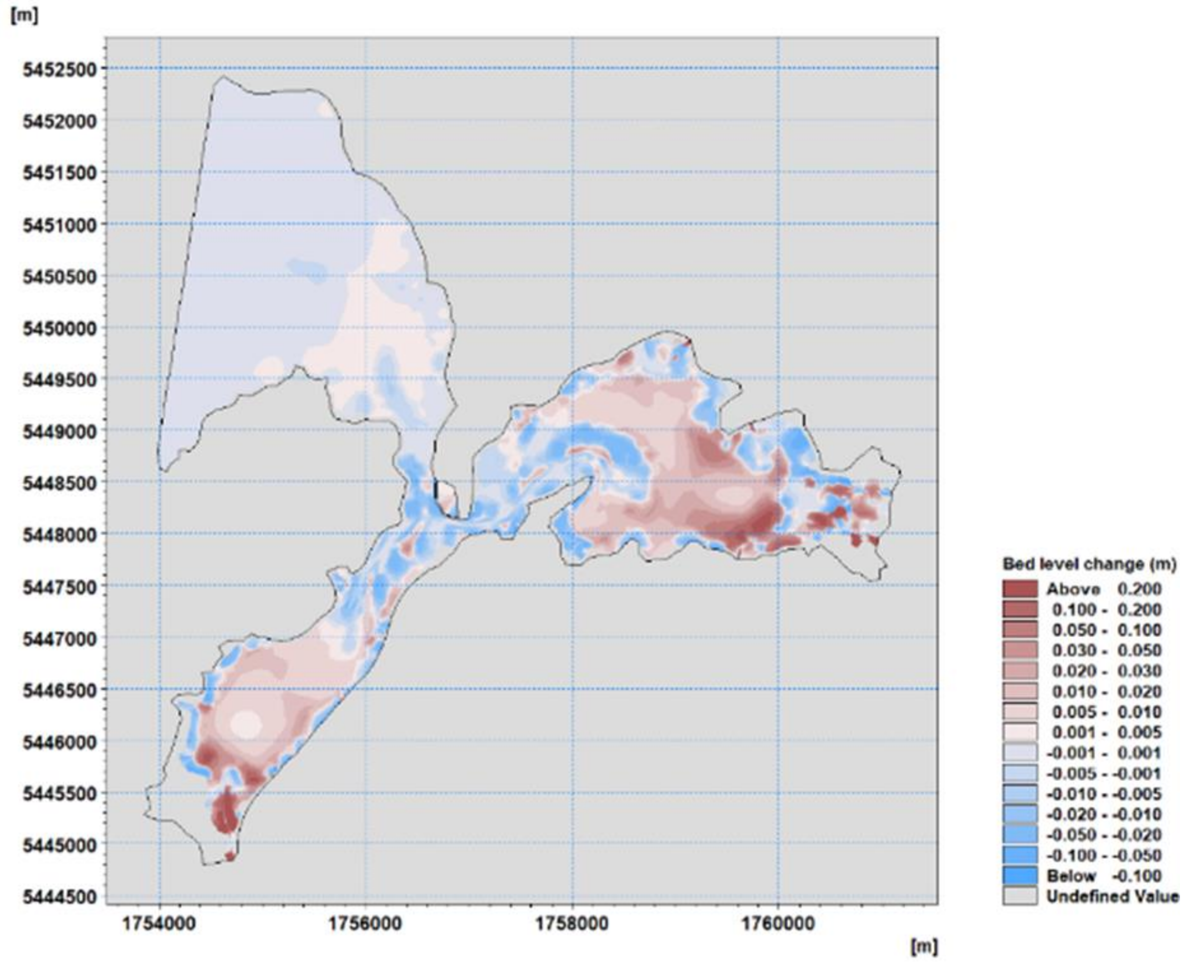


Figure A1.1 Predicted bed level change under baseline land use after the 2004 event that delivered 52,500 tonnes of sediment.

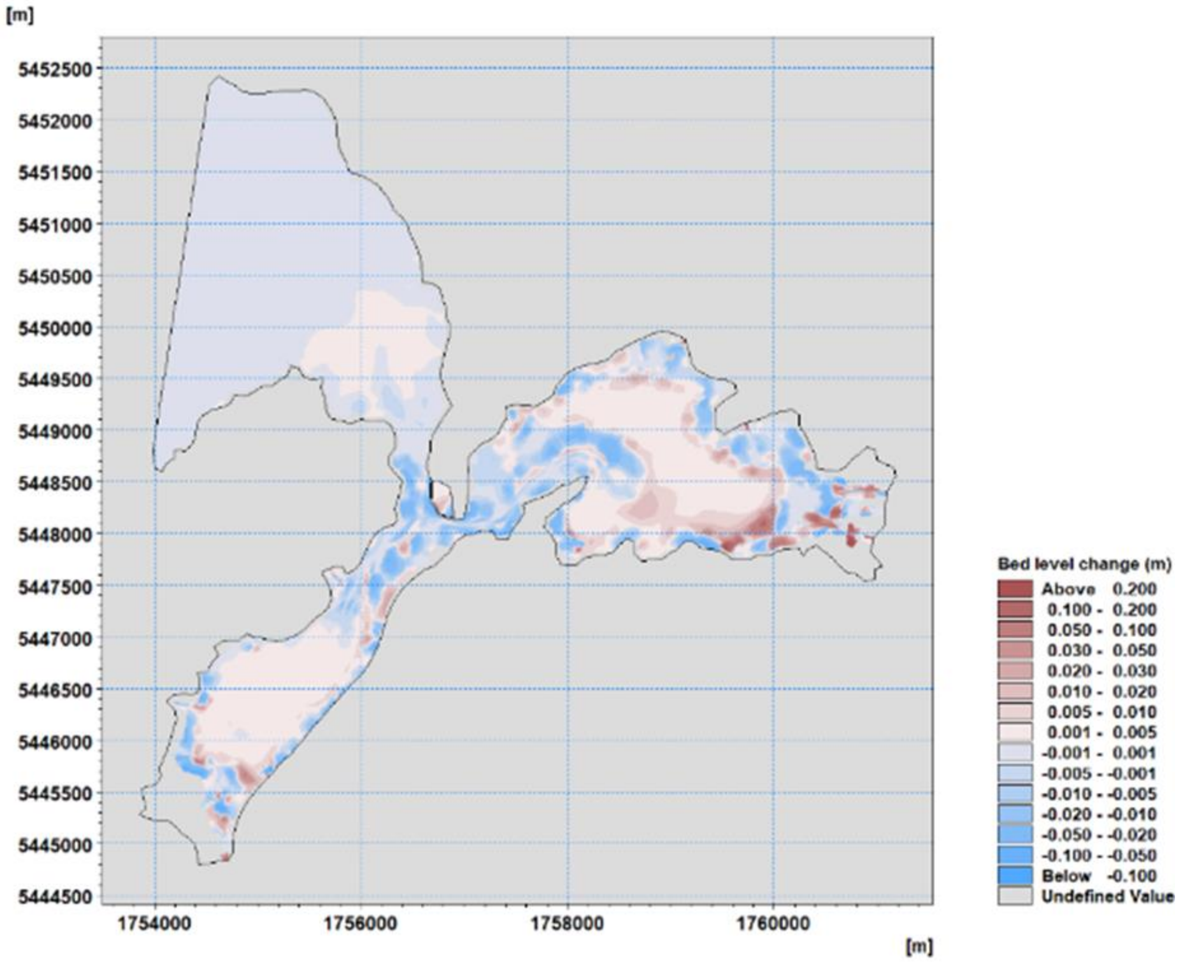


Figure A1.2 Predicted bed level change under baseline land use after the 2005 event that delivered 5,600 tonnes of sediment.

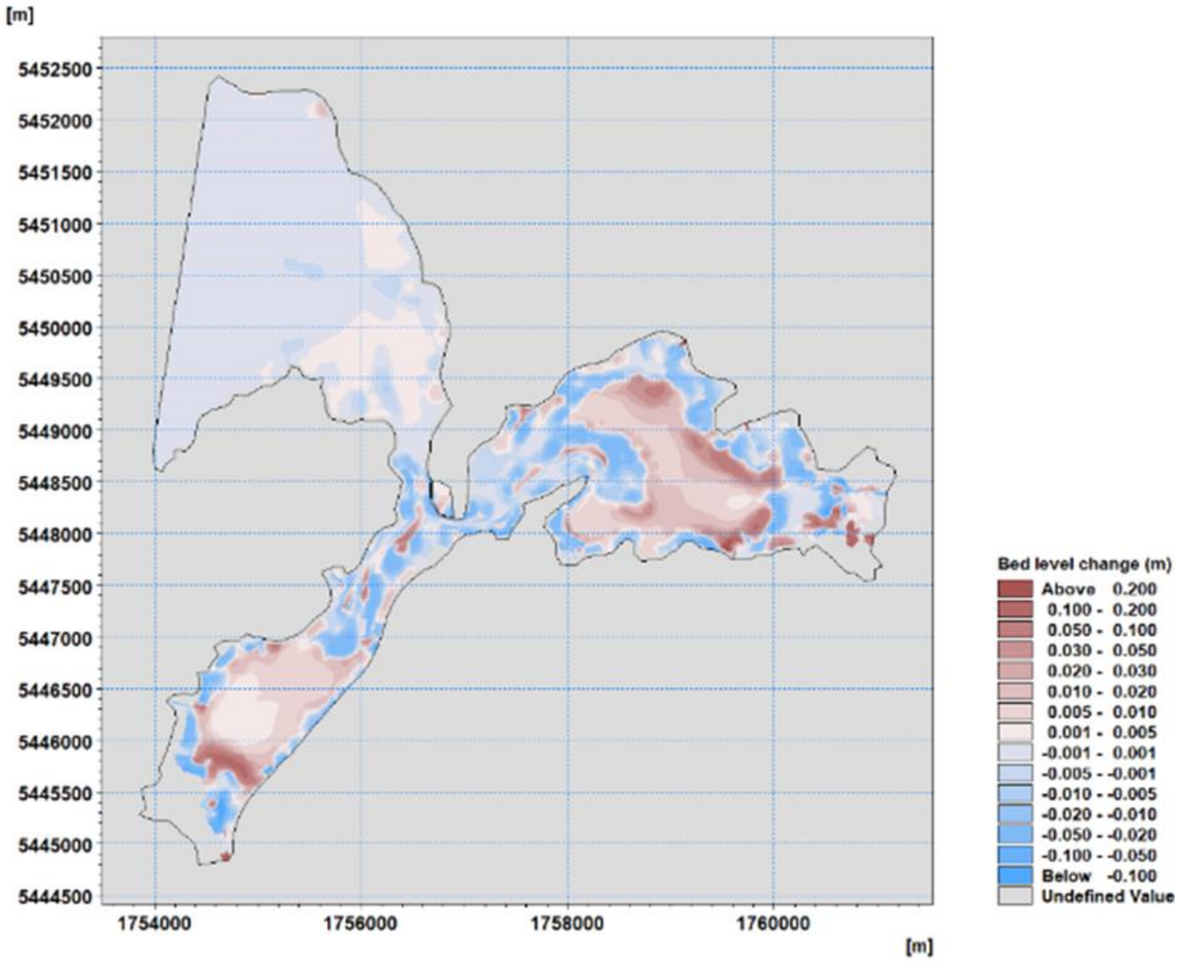


Figure A1.3 **Predicted bed level change under baseline land use after the 2006 event that delivered 19,800 tonnes of sediment.**

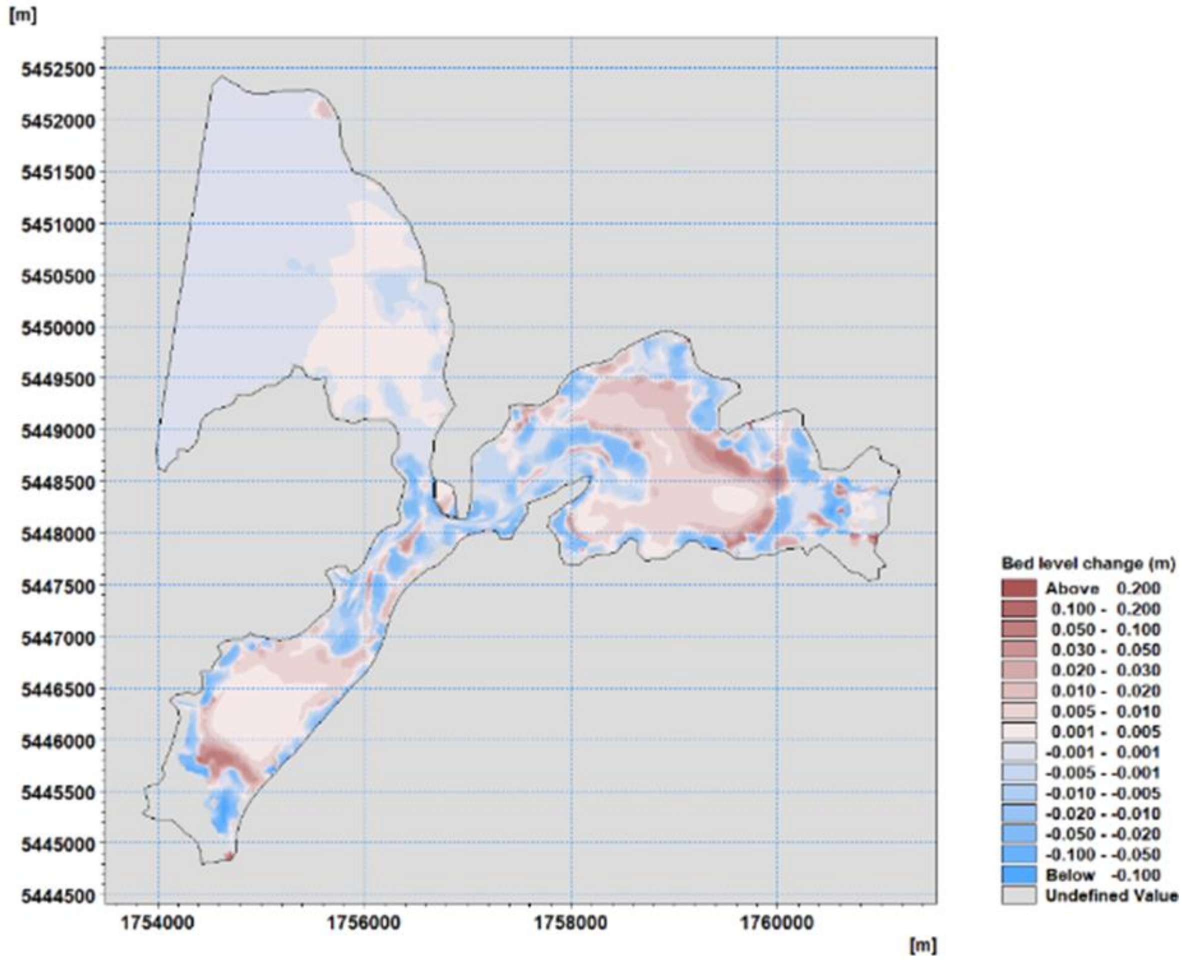


Figure A1.4 Predicted bed level change under baseline land use after the 2013 event that delivered 9,500 tonnes of sediment.

APPENDIX 2. CALIBRATED METAL MODEL RESULTS

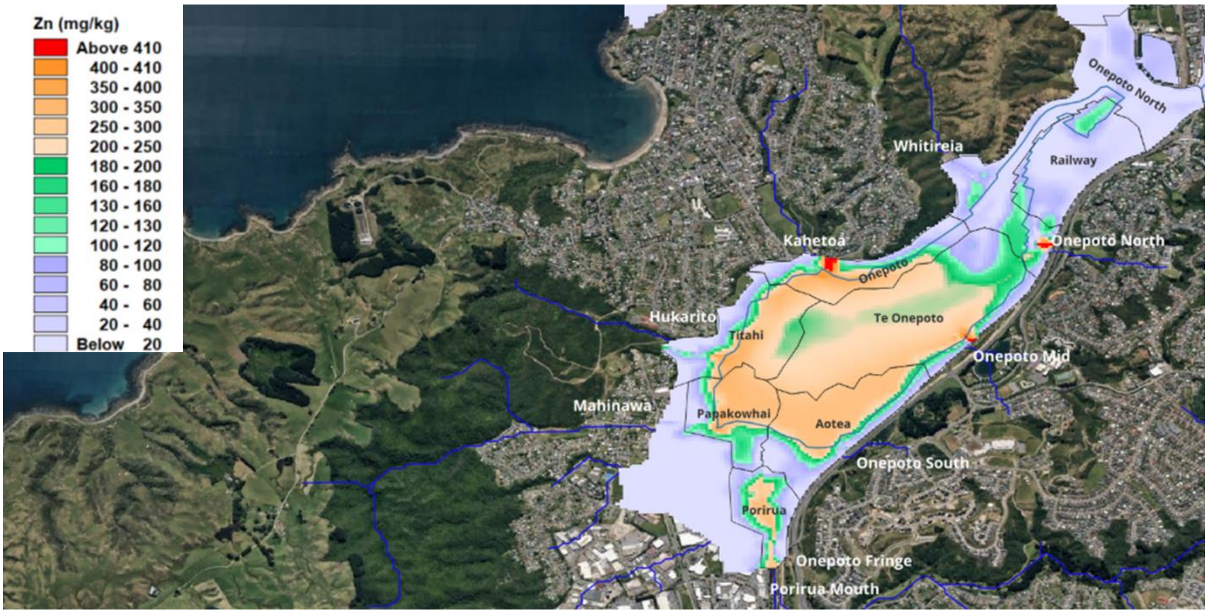


Figure A2.1. Current land use, present day Zinc concentrations (Onepoto Arm).

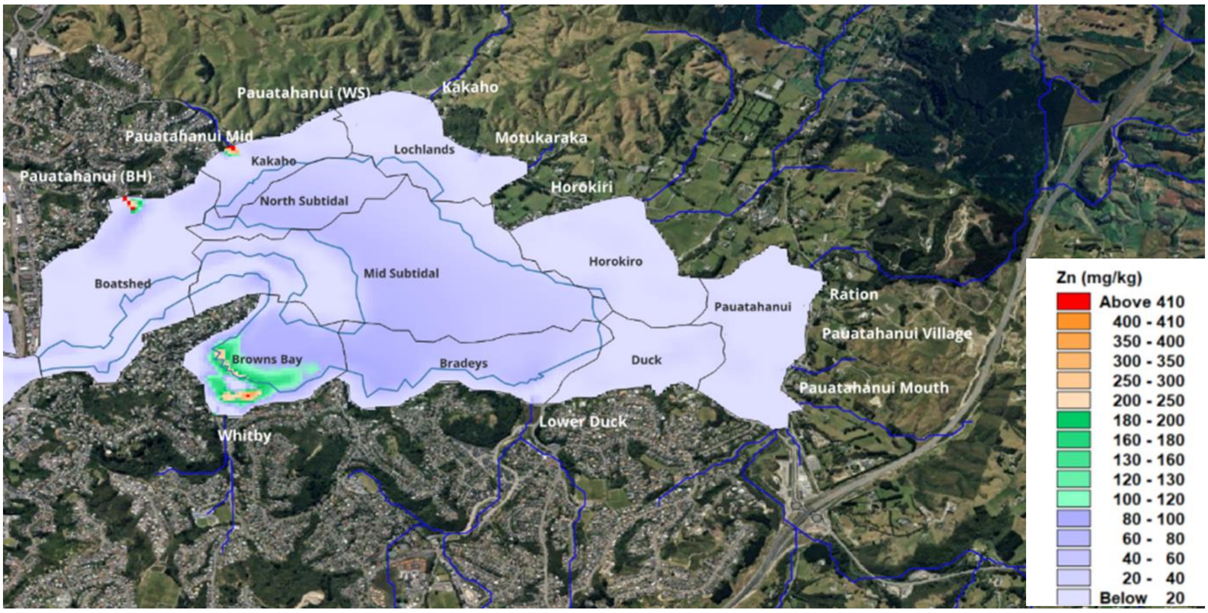


Figure A2.2. Current land use, present day Zinc concentrations (Pāuatahanui Inlet).

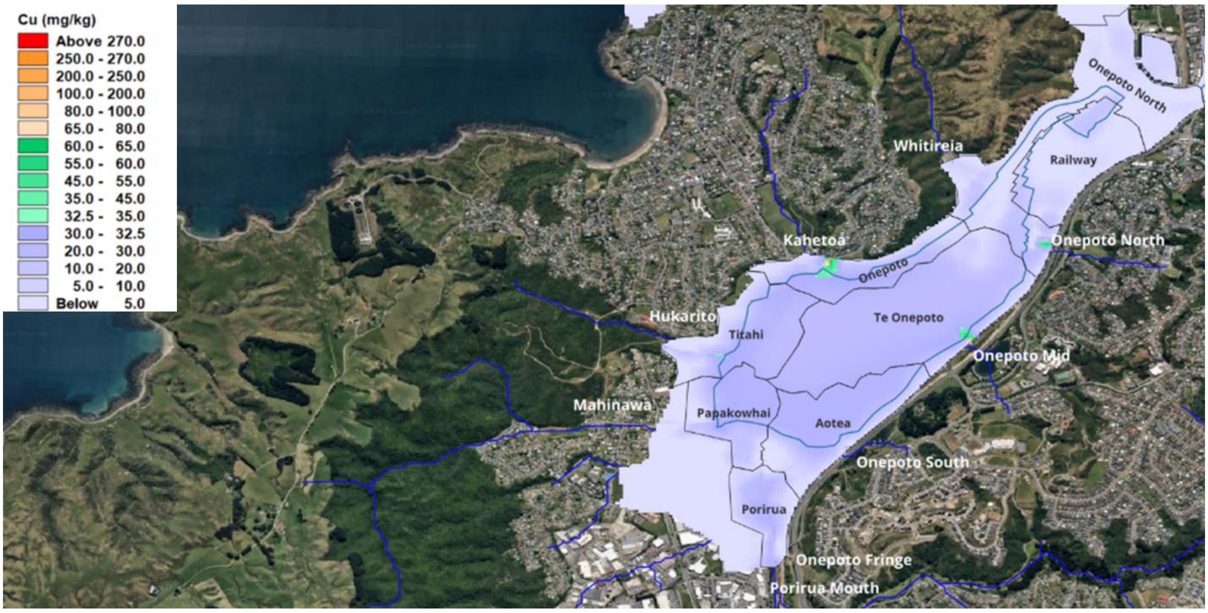


Figure A2.3. Current land use, present day Copper concentrations (Onepoto Arm).

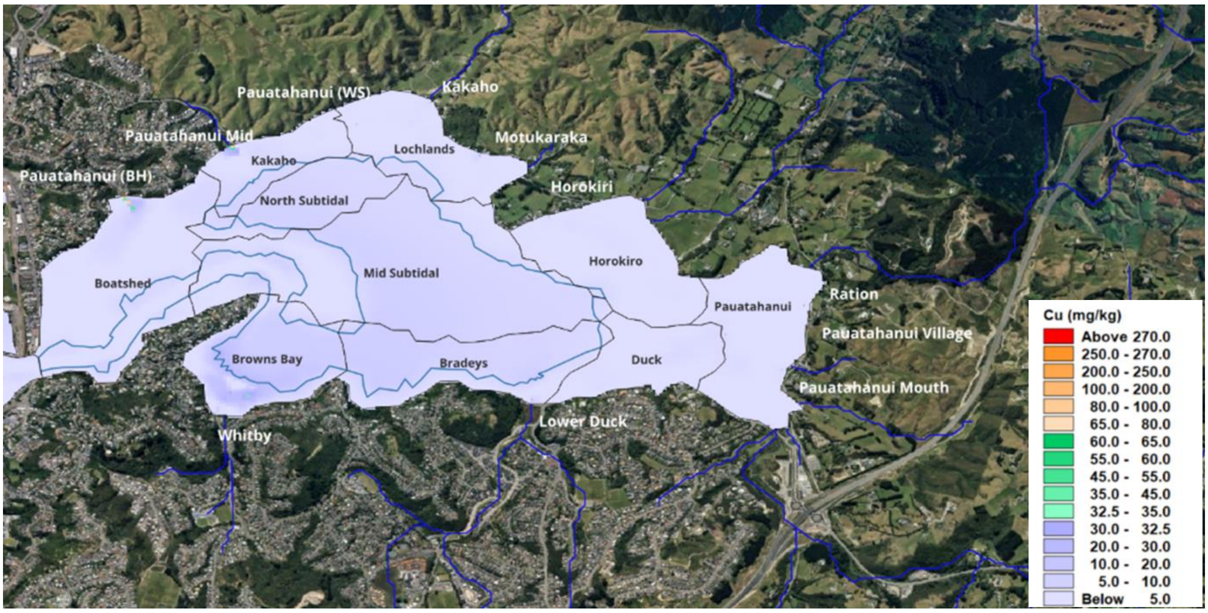


Figure A2.4. Current land use, present day Copper concentrations (Pāuatahanui Inlet).

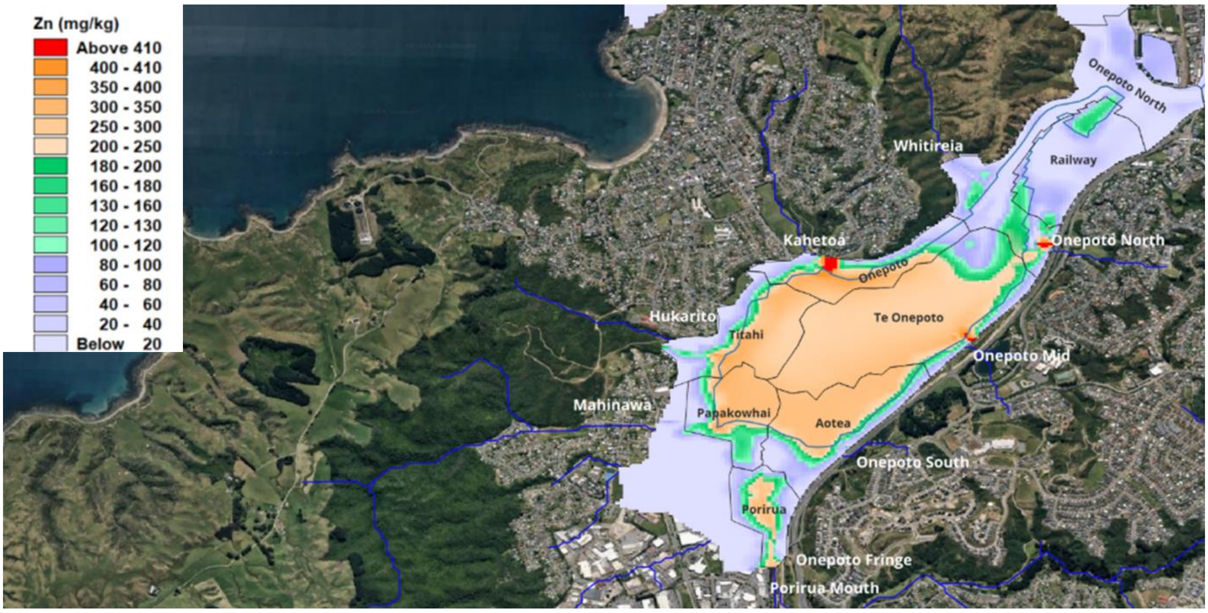


Figure A2.5. Current land use, 2040 Zinc concentrations (Onepoto Arm).

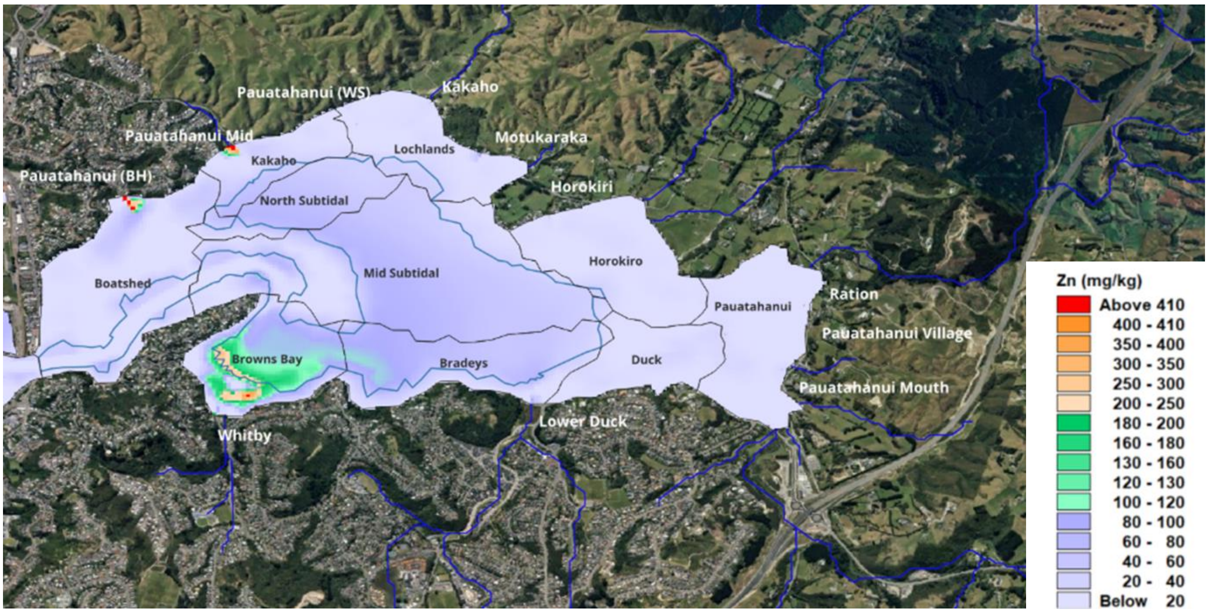


Figure A2.6. Current land use, 2040 Zinc concentrations (Pāuatahanui Inlet)

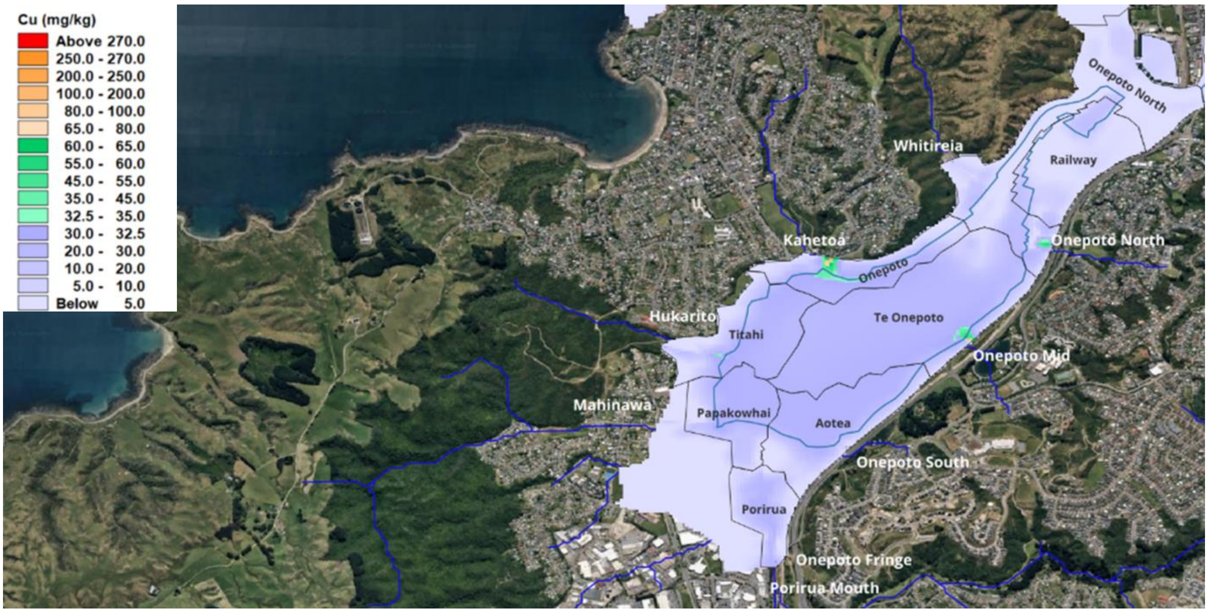


Figure A2.7. Current land use, 2040 Copper concentrations (Onepoto Arm)

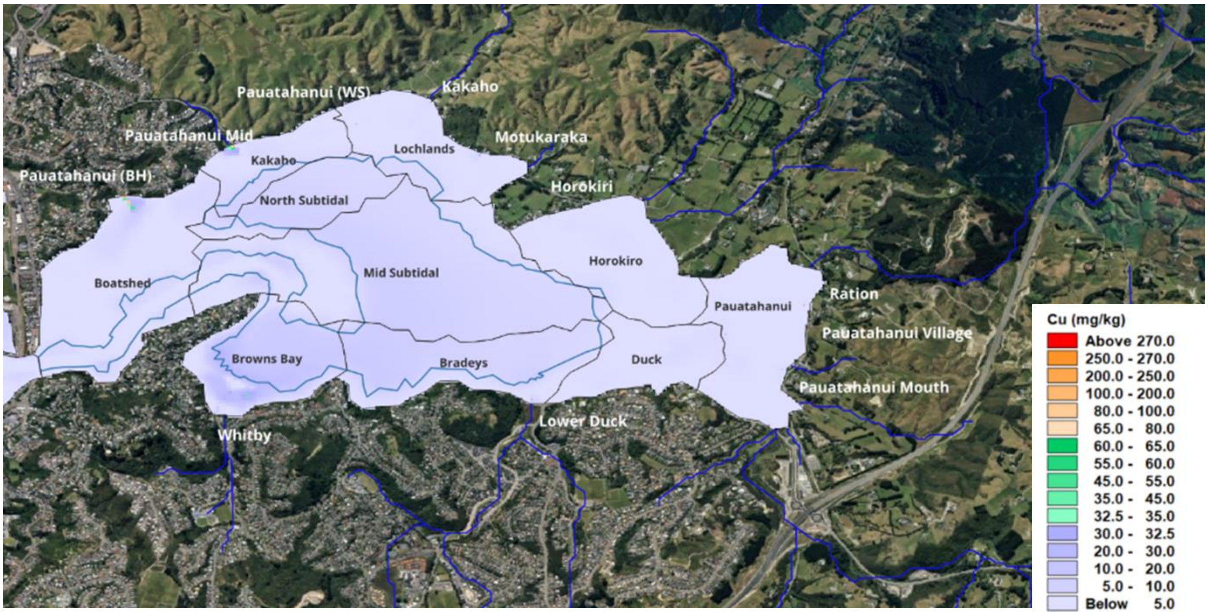


Figure A2.8. Current land use, 2040 Copper concentrations (Browns Bay, Pāuatahanui Inlet)

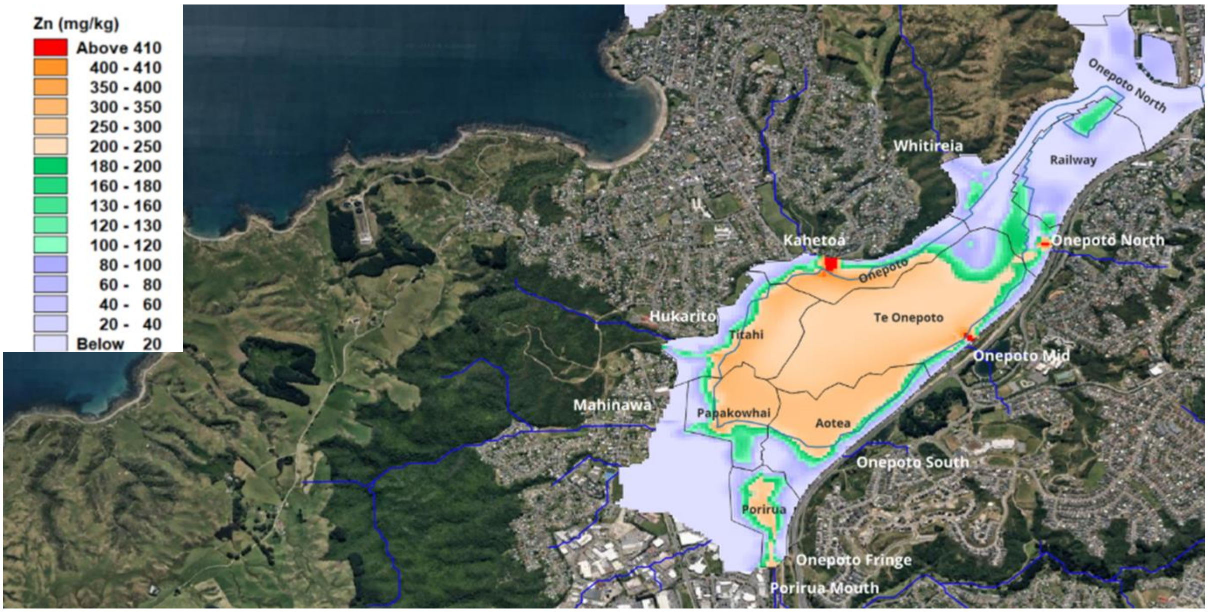


Figure A2.9. LRF 40% sediment load change and LRF 40% metal change land use, 2040 Zinc concentrations (Onepoto Arm)

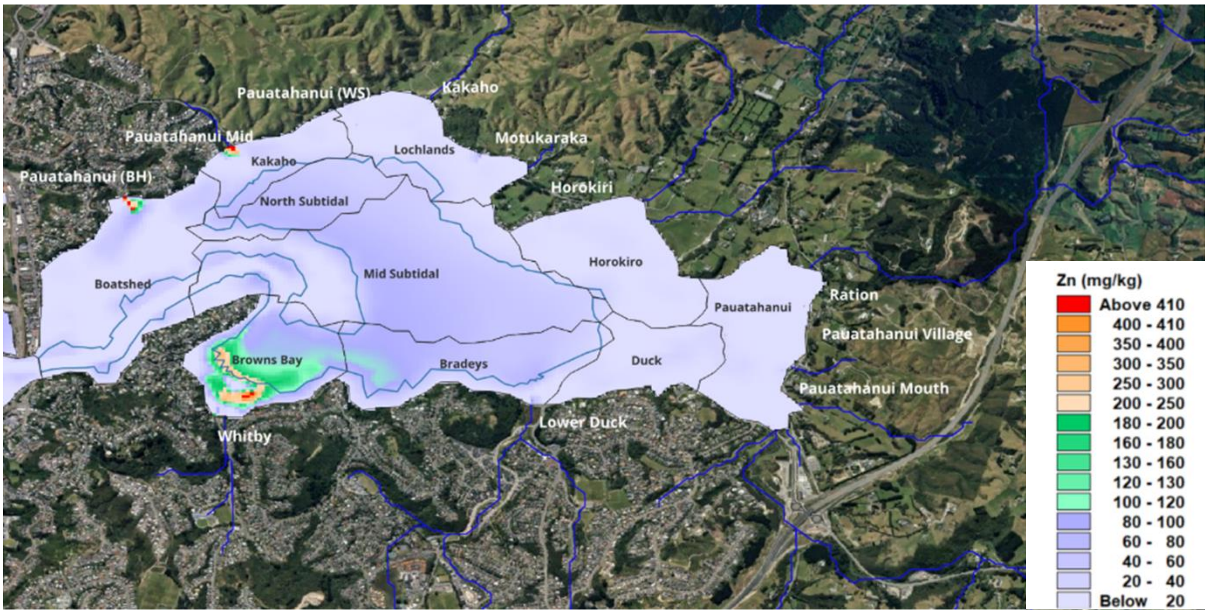


Figure A2.10. LRF 40% sediment load change and LRF 40% metal change land use, 2040 Zinc concentrations (Pāuatahanui Inlet).

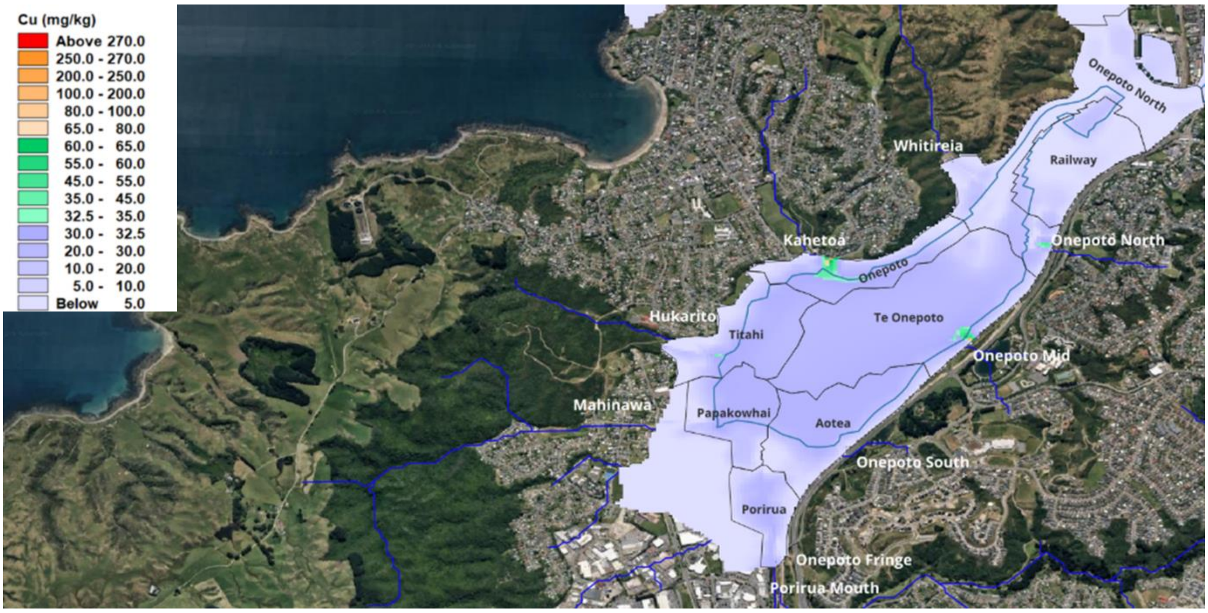


Figure A2.11. LRF 40% sediment load change and LRF40% metal change land use, 2040 Copper concentrations (Onepoto Arm)

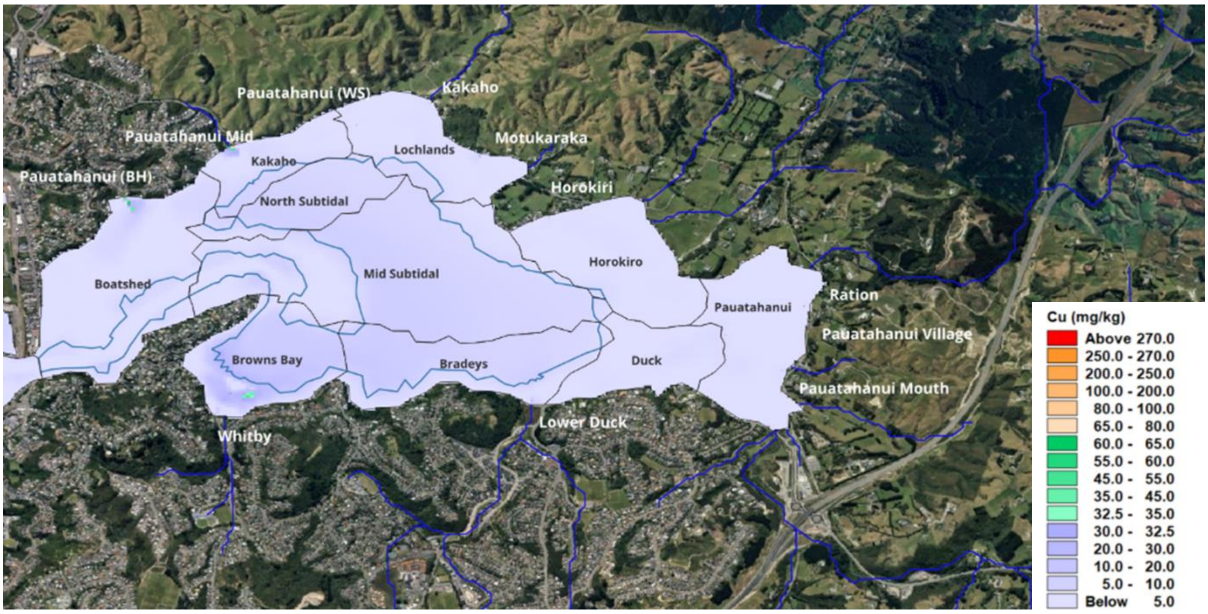


Figure A2.12. LRF 40% sediment load change and LRF40% metal change land use, 2040 Copper concentrations (Browns Bay, Pāuatahanui Inlet)

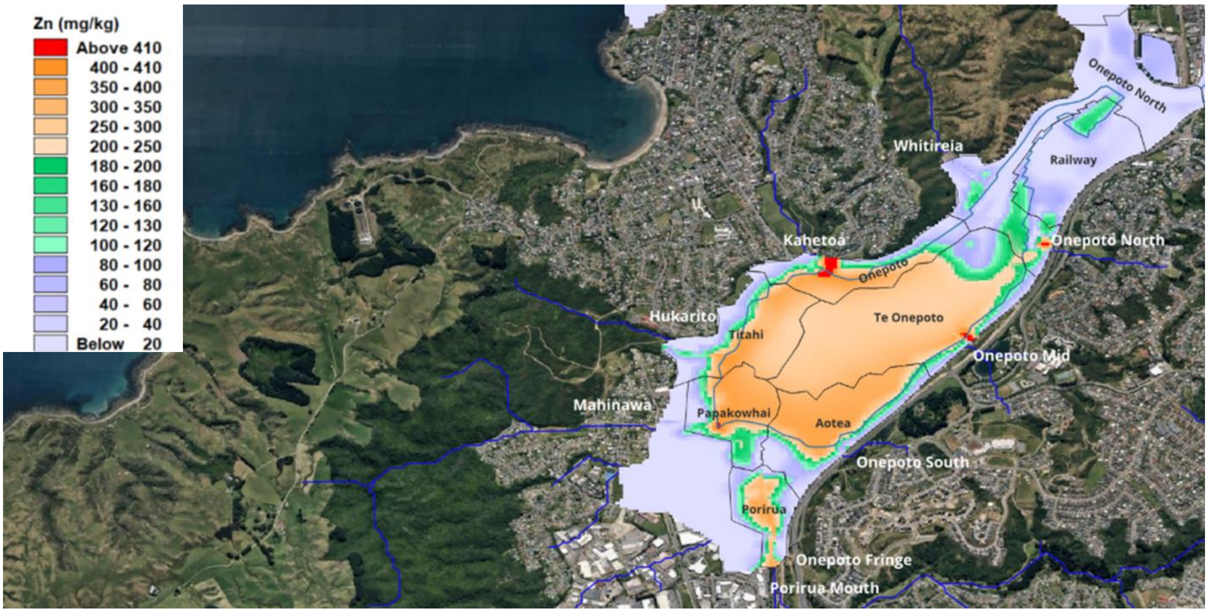


Figure A2.13. LRF 40% sediment load change and LRF 15% metal change land use, 2040 Zinc concentrations (Onepoto Arm)

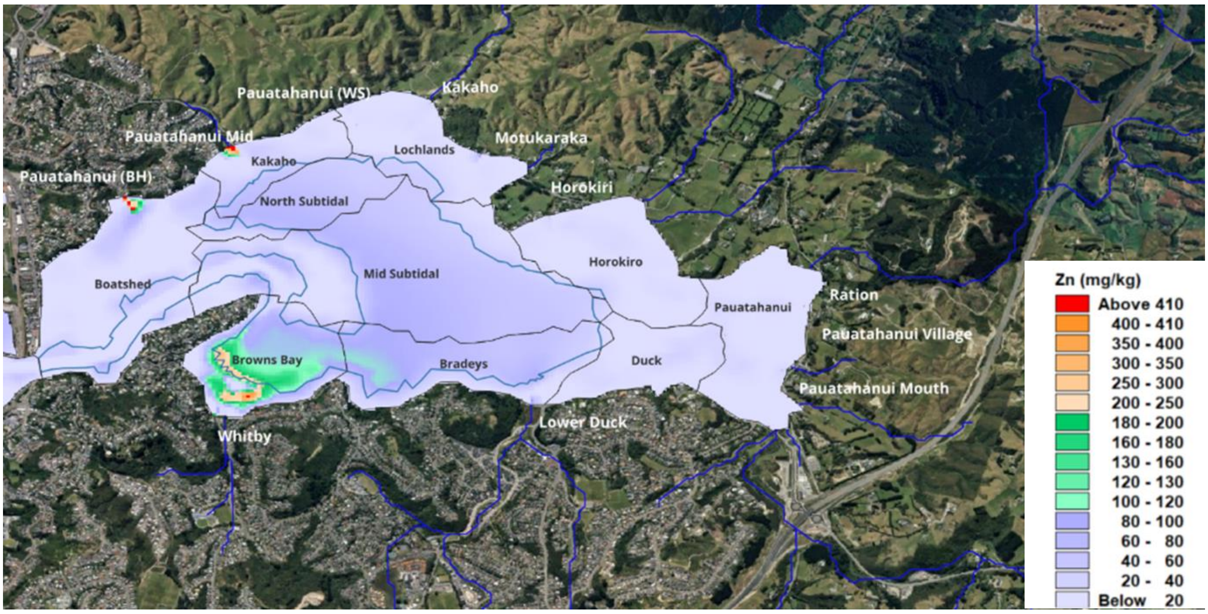


Figure A2.14. LRF 40% sediment load change and LRF 15% metal change land use, 2040 Zinc concentrations (Pāuatahanui Inlet).

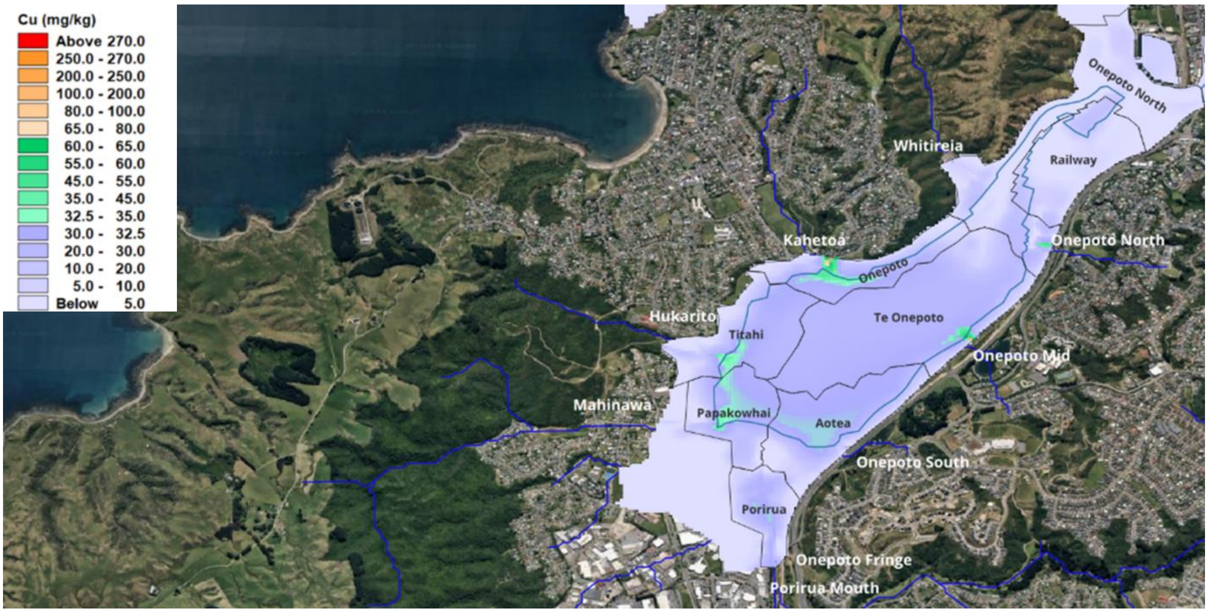


Figure A2.15. LRF 40% sediment load change and LRF15% metal change land use, 2040 Copper concentrations (Onepoto Arm)

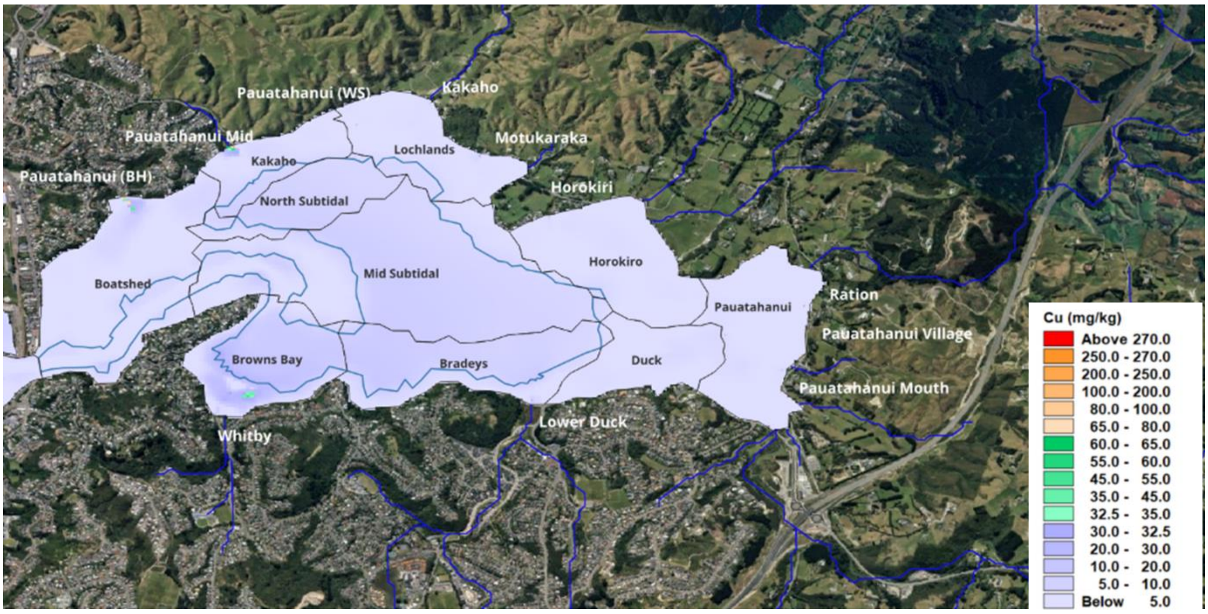


Figure A2.16. LRF 40% sediment load change and LRF15% metal change land use, 2040 Copper concentrations (Browns Bay, Pāuatahanui Inlet)

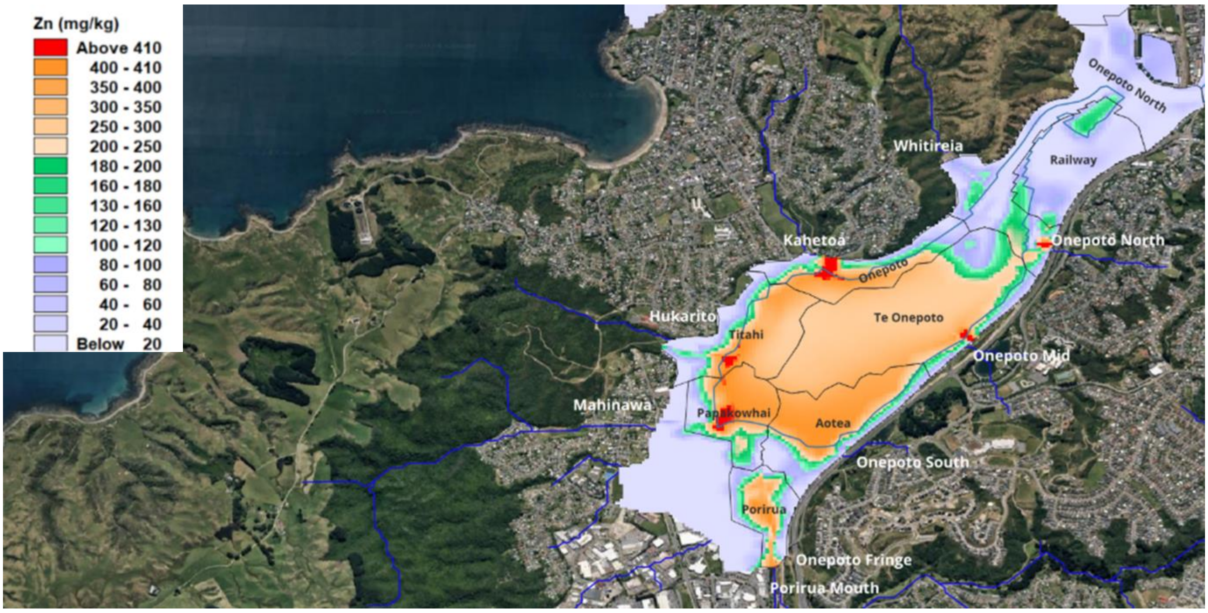


Figure A2.17. LRF 40% sediment load change and no metal change land use, 2040 Zinc concentrations (Onepoto Arm)

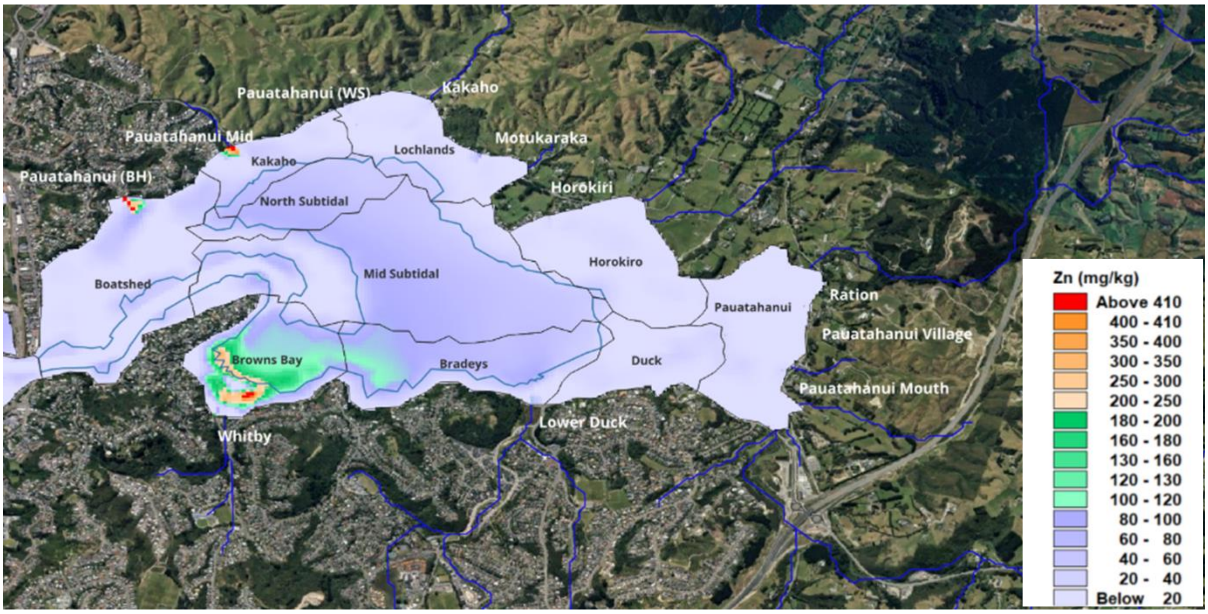


Figure A2.18. LRF 40% sediment load change and no metal change land use, 2040 Zinc concentrations (Pāuatahanui Inlet)

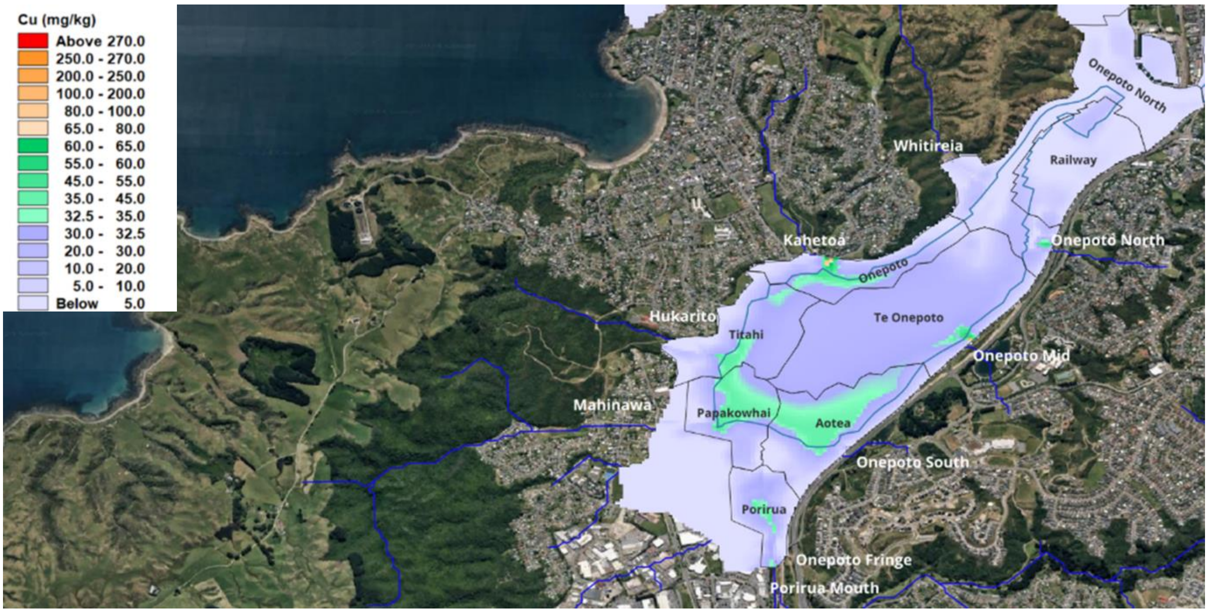


Figure A2.19. LRF 40% sediment load change and no metal change land use, 2040 Copper concentrations (Onepoto Arm)

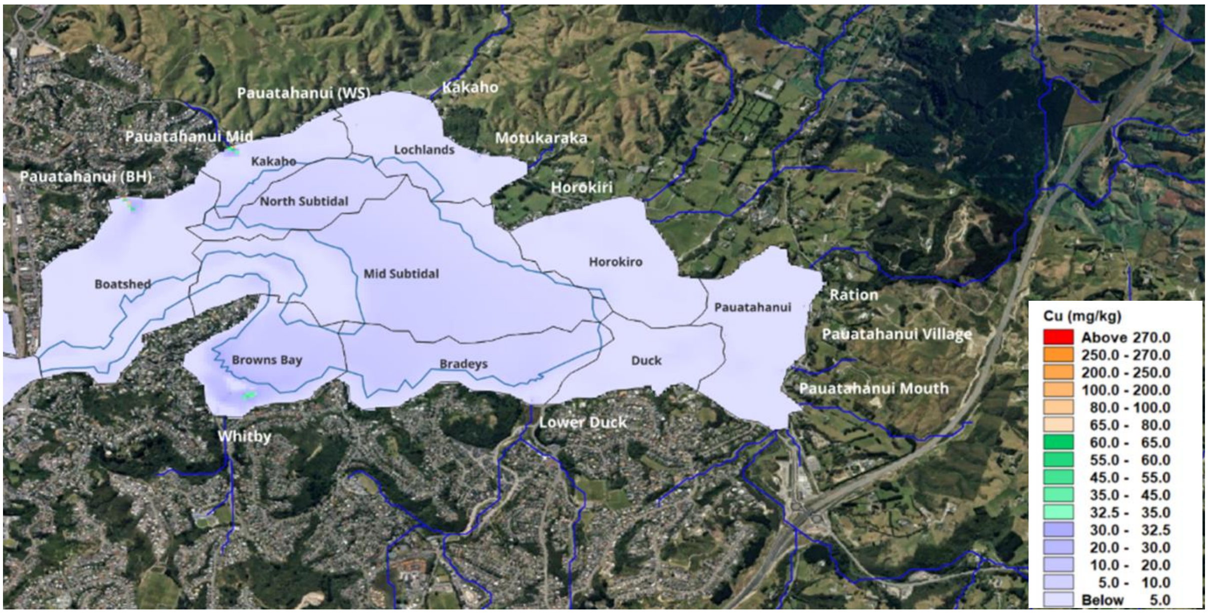


Figure A2.20. LRF 40% sediment load change and no metal change land use, 2040 Copper concentrations (Browns Bay, Pāuatahanui Inlet)

Table A2.1. Basin wide average Zinc concentrations (mg/kg) under the baseline and LRF scenarios.

Zinc concentration (mg/kg) in surface sediments	Onepoto Arm	Pāuatahanui Inlet
Current Land Use (Present Day)	141.4	28.2
Current Land Use (2040)	152.7	31.2
40% LRF Sediments 40% LRF Sediments Metals (2040)	148.0	31.4
40% LRF Sediments 15% LRF Sediments Metals (2040)	167.1	32.1
40% LRF Sediments No change in Metals (2040)	181.2	35.1

Table A2.2. Basin wide average Zinc concentrations (mg/kg) within the inter-tidal areas under the baseline and LRF scenarios.

Zinc concentration (mg/kg) in surface sediments	Onepoto Arm	Pāuatahanui Inlet
Current Land Use (Present Day)	105.7	17.6
Current Land Use (2040)	112.5	19.2
40% LRF Sediments 40% LRF Sediments Metals (2040)	107.4	19.3
40% LRF Sediments 15% LRF Sediments Metals (2040)	122.6	19.3
40% LRF Sediments No change in Metals (2040)	135.2	21.7

Table A2.3. Basin wide average Zinc concentrations (mg/kg) within the sub-tidal areas under the baseline and LRF scenarios.

Zinc concentration (mg/kg) in surface sediments	Onepoto Arm	Pāuatahanui Inlet
Current Land Use (Present Day)	199.8	45.0
Current Land Use (2040)	216.1	50.3
40% LRF Sediments 40% LRF Sediments Metals (2040)	210.9	50.8
40% LRF Sediments 15% LRF Sediments Metals (2040)	237.6	52.4
40% LRF Sediments No change in Metals (2040)	256.0	56.2

Table A2.4. Basin wide average Copper concentrations (mg/kg) under the baseline and LRF scenarios.

Zinc concentration (mg/kg) in surface sediments	Onepoto Arm	Pāuatahanui Inlet
Current Land Use (Present Day)	13.0	2.7
Current Land Use (2040)	14.0	2.9
40% LRF Sediments 40% LRF Sediments Metals (2040)	13.6	3.0
40% LRF Sediments 15% LRF Sediments Metals (2040)	15.4	3.1
40% LRF Sediments No change in Metals (2040)	16.6	3.3

Table A2.5. Basin wide average Copper concentrations (mg/kg) within the inter-tidal areas under the baseline and LRF scenarios.

Zinc concentration (mg/kg) in surface sediments	Onepoto Arm	Pāuatahanui Inlet
Current Land Use (Present Day)	9.7	1.6
Current Land Use (2040)	10.3	1.8
40% LRF Sediments 40% LRF Sediments Metals (2040)	9.9	1.8
40% LRF Sediments 15% LRF Sediments Metals (2040)	11.4	1.9
40% LRF Sediments No change in Metals (2040)	12.3	2.0

Table A2.6. Basin wide average Copper concentrations (mg/kg) within the sub-tidal areas under the baseline and LRF scenarios.

Zinc concentration (mg/kg) in surface sediments	Onepoto Arm	Pāuatahanui Inlet
Current Land Use (Present Day)	18.3	4.3
Current Land Use (2040)	19.8	4.8
40% LRF Sediments 40% LRF Sediments Metals (2040)	19.4	4.8
40% LRF Sediments 15% LRF Sediments Metals (2040)	21.8	5.1
40% LRF Sediments No change in Metals (2040)	23.4	5.4

Table A2.7. Basin wide 50th and 95th (bracketed) percentile Zinc concentrations (mg/kg) under the baseline and LRF scenarios.

Zinc concentration (mg/kg) in surface sediments	Onepoto Arm	Pāuatahanui Inlet
Current Land Use (Present Day)	138.2 (316.6)	2.7 (81.0)
Current Land Use (2040)	166.3 (322.1)	3.6 (95.4)
40% LRF Sediments 40% LRF Sediments Metals (2040)	159.3 (316.7)	3.3 (94.2)
40% LRF Sediments 15% LRF Sediments Metals (2040)	164.6 (372.5)	3.3 (94.7)
40% LRF Sediments No change in Metals (2040)	171.9 (413.8)	3.5 (101.3)

Table A2.8. Basin wide 50th and 95th (bracketed) percentile Copper concentrations (mg/kg) under the baseline and LRF scenarios.

Zinc concentration (mg/kg) in surface sediments	Onepoto Arm	Pāuatahanui Inlet
Current Land Use (Present Day)	12.9 (28.3)	0.2 (7.3)
Current Land Use (2040)	15.6 (29.0)	0.3 (8.7)
40% LRF Sediments 40% LRF Sediments Metals (2040)	14.9 (28.4)	0.3 (8.6)
40% LRF Sediments 15% LRF Sediments Metals (2040)	15.8 (33.7)	0.3 (8.9)
40% LRF Sediments No change in Metals (2040)	16.2 (37.0)	0.3 (9.2)

Table A2.9. Subestuary wide 50th and 95th (bracketed) percentile Zinc concentrations (mg/kg) in the Onepoto Arm subestuaries under the baseline and LRF scenarios.

Zinc concentration (mg/kg) in surface sediments	Porirua	Papakowhai	Titahi	Onepoto	Aotea	Te Onepoto	Onepoto North	Railway
Current Land Use (Present Day)	276.3 (287.4)	279.9 (341.3)	272.3 (330.4)	281.3 (491.4)	273.8 (280.8)	205.2 (274.3)	3.1 (158.9)	0.1 (144.0)
Current Land Use (2040)	276.7 (287.4)	281.7 (341.3)	290.3 (330.6)	301.3 (529.6)	275.3 (281.3)	237.2 (297.4)	4.1 (194.9)	0.2 (176.6)
40% LRF Sediments 40% LRF Sediments Metals (2040)	269.9 (274.6)	274.6 (330.0)	284.0 (325.6)	296.0 (533.4)	269.9 (276.6)	229.7 (295.7)	3.8 (186.7)	0.2 (168.4)
40% LRF Sediments Metals 15% LRF Sediments Metals (2040)	334.5 (361.1)	327.2 (421.5)	312.5 (382.2)	322.7 (555.9)	329.6 (352.6)	243.1 (316.6)	3.9 (191.9)	0.2 (174.2)
40% LRF Sediments No change in Metals (2040)	368.6 (408.6)	352.2 (482.4)	332.2 (426.3)	343.6 (609.0)	360.7 (397.6)	255.3 (336.7)	4.1 (201.6)	0.2 (182.4)

Table A2.10. Subestuary wide 50th and 95th (bracketed) percentile Zinc concentrations (mg/kg) in the Pāuatahanui Inlet subestuaries under the baseline and LRF scenarios.

Zinc concentration (mg/kg) in surface sediments	Boatshed	Browns	Bradeys	Duck	Pāuatahanui	Horokiri	Lochlands	Kakaho	North subtidal	Mid subtidal
Current Land Use (Present Day)	0.1 (64.0)	69.4 (351.8)	46.7 (77.6)	<0.1 (17.4)	0.2 (14.8)	<0.1 (14.8)	<0.1 (22)	13.9 (47.9)	39.6 (58.0)	28.8 (63.7)
Current Land Use (2040)	0.1 (72.8)	83.3 (388.4)	47.1 (87.7)	<0.1 (17.4)	0.3 (14.8)	<0.1 (15.6)	<0.1 (22.1)	16.6 (53.6)	41.1 (66.5)	30.3 (73.2)
40% LRF Sediments 40% LRF Sediments Metals (2040)	0.1 (72.5)	81.3 (415.4)	47.1 (89.4)	<0.1 (17.7)	0.3 (15.5)	<0.1 (14.6)	<0.1 (22.9)	16.3 (53.6)	42.8 (66.0)	30.5 (73.3)
40% LRF Sediments Metals 15% LRF Sediments Metals (2040)	0.1 (75.3)	82.6 (386.7)	51.9 (89.6)	<0.1 (20.8)	0.3 (18.8)	<0.1 (21.5)	<0.1 (27.5)	16.9 (55.8)	46.0 (68.1)	33.5 (75.2)
40% LRF Sediments No change in Metals (2040)	0.1 (81.1)	87.0 (428.2)	59.0 (98.1)	<0.1 (22.3)	0.3 (20.0)	<0.1 (19.9)	<0.1 (29.9)	17.5 (59.2)	49.1 (72.0)	35.9 (79.4)

Table A2.11. Subestuary wide 50th and 95th (bracketed) percentile Copper concentrations (mg/kg) in the Onepoto Arm under the baseline and LRF scenarios.

Zinc concentration (mg/kg) in surface sediments	Porirua	Papakowhai	Titahi	Onepoto	Aotea	Te Onepoto	Onepoto North	Railway
Current Land Use (Present Day)	24.6 (25.4)	25.0 (29.9)	24.4 (29.5)	25.3 (46.2)	24.6 (25.0)	19.1 (26.1)	0.2 (15.0)	<0.1 (13.5)
Current Land Use (2040)	24.6 (25.4)	25.1 (29.9)	26.0 (29.8)	27.1 (50.3)	24.7 (25.1)	22.0 (28.6)	0.3 (18.3)	<0.1 (16.5)
40% LRF Sediments 40% LRF Sediments Metals (2040)	24.1 (24.4)	24.5 (29.0)	25.5 (29.6)	26.6 (50.9)	24.2 (24.9)	21.4 (29.1)	0.3 (17.6)	<0.1 (15.8)
40% LRF Sediments Metals 15% LRF Sediments Metals (2040)	29.6 (31.6)	29.2 (36.9)	28.1 (34.8)	29.5 (53.9)	29.6 (31.2)	22.8 (31.3)	0.3 (18.4)	<0.1 (16.5)
40% LRF Sediments No change in Metals (2040)	32.7 (36.0)	31.3 (42.1)	29.7 (38.2)	31.1 (57.4)	32.5 (35.3)	23.7 (32.4)	0.3 (19.1)	<0.1 (17.1)

Table A2.12. Subestuary wide 50th and 95th (bracketed) Copper concentrations (mg/kg) in the Pāuatahanui Inlet under the baseline and LRF scenarios.

Zinc concentration (mg/kg) in surface sediments	Boatshed	Browns	Bradeys	Duck	Pāuatahanui	Horokiri	Lochlands	Kakaho	North subtidal	Mid subtidal
Current Land Use (Present Day)	<0.1 (6.1)	6.4 (29.9)	4.4 (7.1)	<0.1 (2.1)	<0.1 (1.9)	<0.1 (2.0)	<0.1 (2.6)	1.4 (4.7)	4.0 (5.5)	3.1 (6.0)
Current Land Use (2040)	<0.1 (6.9)	7.7 (32.7)	4.4 (8.0)	<0.1 (2.1)	<0.1 (1.9)	<0.1 (2.1)	<0.1 (2.6)	1.8 (5.2)	4.2 (6.3)	3.2 (6.9)
40% LRF Sediments 40% LRF Sediments Metals (2040)	<0.1 (6.9)	7.5 (35.2)	4.5 (8.2)	<0.1 (2.2)	<0.1 (2.0)	<0.1 (1.9)	<0.1 (2.6)	1.6 (5.2)	4.4 (6.2)	3.2 (6.8)
40% LRF Sediments Metals 15% LRF Sediments Metals (2040)	<0.1 (7.3)	7.8 (35.6)	5.3 (8.5)	<0.1 (2.5)	<0.1 (2.4)	<0.1 (2.6)	<0.1 (3.1)	1.7 (5.5)	4.7 (6.6)	3.6 (7.2)
25% LRF Sediments No change in Metals (2040)	<0.1 (7.7)	8.0 (36.4)	5.8 (8.9)	<0.1 (2.8)	<0.1 (2.6)	<0.1 (2.8)	<0.1 (3.5)	1.8 (5.9)	5.0 (6.8)	3.9 (7.4)