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Porirua Harbour

Sediment Monitoring 2012/13

Prepared for **Greater Wellington Regional Council**
June 2013

Cover Photo: Browns Bay, Pauatahanui Inlet - Installing intertidal sediment plates, Jan. 2013.


Porirua Harbour, Onepoto Arm - intertidal flats by Porirua Stream mouth.

Porirua Harbour Estuary

Sediment Monitoring 2012/13

Prepared for
Greater Wellington Regional Council

By

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1. INTRODUCTION AND METHODS

Porirua Harbour Estuary

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Vulnerability Assessment
Identifies issues and recommends monitoring and management.
Completed in 2007 (Robertson and Stevens 2007)

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Porirua Estuary Issues
Moderate eutrophication
Excessive sedimentation
Habitat Loss (saltmarsh, dune and terrestrial margin)

↓

Monitoring

Broad Scale Mapping	**Fine Scale Monitoring**
Sediment type Saltmarsh Seagrass Macroalgae Land margin	Grain size, RPD, Organic Content Nutrients, Metals, Invertebrates, Macroalgae, Sedimentation,
5 -10 yearly Undertaken in 2008, 2013. Repeat survey 2018.	**4yr Baseline then 5 yearly** Next survey 2015. **Sedimentation annually** Next survey 2014.

↓

Condition Ratings
Area soft mud, Area saltmarsh, Area seagrass, Area terrestrial margin, RPD depth, Benthic Community, Organic content, N and P, Toxicity, Sedimentation rate.

Other Information
Previous reports, Observations, Expert opinion

↓

ESTUARY CONDITION
Moderate Eutrophication
Excessive Sedimentation
Low Toxicity
Habitat Degraded (saltmarsh, terrestrial margin)

↓

Recommended Management

- Limit intensive landuse.
- Set nutrient, sediment guidelines.
- Margin vegetation enhancement.
- Manage for sea level rise.
- Enhance saltmarsh.
- Manage weeds and pests.

Soil erosion is a major issue in New Zealand and the resulting suspended sediment impacts are of particular concern in estuaries because they act as a sink for fine sediments or muds. The main intertidal flats of developed estuaries (e.g. Porirua Harbour) are usually characterised by sandy sediments reflecting their exposure to wind-wave disturbance, and are hence relatively low in mud content (2-10% mud).

Recent monitoring (Robertson and Stevens 2008, 2009, 2010, 2011, 2012) showed Porirua Harbour Estuary had low-moderate intertidal sedimentation rates and a benthic invertebrate community dominated by species that prefer sand or a little mud. However, the sand dominated sediments had an elevated mud content, showed a general trend of increasing muddiness, and sediments were not very well oxygenated. Based on these findings, in 2011 Greater Wellington Regional Council (GWRC) decided to undertake annual monitoring of sedimentation rates, grain size, and RPD depth at existing intertidal sites in the estuary (e.g. Stevens and Robertson 2011).

In addition to intertidal areas, Porirua Harbour has also been identified as being particularly at risk from subtidal sedimentation because 65% of the estuary is subtidal, and the main subtidal basins are rapidly infilling (Gibb and Cox 2009). Gibb and Cox predict that both estuary arms are highly likely to rapidly infill and change from tidal estuaries to brackish swamps within 145-195 years if rates of deposition over the last ~30 years continue. The dominant sediment sources to the estuary were identified as discharges of both bed-load and suspended load from the various input streams (most notably Pauatahanui, Horokiri and Porirua Streams). Elevated inputs of nutrients from the same streams are also causing symptoms of moderate eutrophication (i.e. poor sediment oxygenation and moderate nuisance macroalgal cover) in the estuary (Stevens and Robertson 2009, 2010, 2011a, 2012a, 2013, Robertson and Stevens 2009, 2010, 2011).

In response to these concerns, GWRC convened a technical workshop in April 2011 which drew on expert scientific advice, combined with existing catchment and estuary models, to highlight the areas of greatest predicted deposition. A key output was the recommendation to increase the number of intertidal plates within areas influenced by priority catchments, and to determine suitable methods and locations for the establishment of subtidal sediment plates which is where the greatest sediment deposition in the estuary is expected to occur. In response, four additional intertidal sites were established in February 2012 (3 in Pauatahanui Arm and 1 in the Onepoto Arm - Figure 1), and methods for installing and measuring subtidal plates were assessed and trialed by Wriggle in Nelson.

The current report presents sedimentation rates measured in January 2013 at established sites in Porirua Harbour, and describes the installation and baseline measurement of eight shallow subtidal, and one intertidal, sediment plates (6 in Pauatahanui Arm and 3 in the Onepoto Arm - Figure 1). Sediment grain size and RPD were measured at all sites, and condition ratings developed for Wellington's estuaries were used to rate the condition of the estuary, and recommend monitoring and management actions.

Installing and checking subtidal plates in the Pauatahanui Arm, January 2013.

1. Introduction and Methods (Continued)

Installing and levelling a sediment plate in Browns Bay, January 2013.

Measuring frame and probe used to measure shallow subtidal plates.

Sediment RPD - Brown (oxic) sediment overlying grey (reduced oxygen) sediment.

Detailed descriptions of existing sampling sites and methods are provided in Robertson and Stevens (2008, 2009, 2010), Stevens and Robertson (2011a), and are briefly summarised below.

Sedimentation Rate

To measure the sedimentation rate from now and into the future, concrete plates were buried in December 2007 at 4 intertidal sites and 1 subtidal site in the estuary. An additional 4 intertidal sites (16 plates) were added in January 2012, and 1 intertidal and 8 subtidal plates (30cm diameter concrete pavers) added in January 2013 (Figure 1, see also Appendix 1). Subtidal plates were positioned in soft mud deposition zones by wading from the shore until firmer sediments transitioned to soft muds. These areas were consistently encountered ~1-1.5m below low water depth. Each plate was positioned and relocated using a handheld Trimble GeoXH differential GPS (post-processing accuracy 10-50cm). For measurement, each plate was relocated and the depth of sediment over the plate measured by pushing a probe into the sediment until it hit the plate. A number of measurements on each plate were averaged to account for irregular sediment surfaces and to determine the mean annual rate of sedimentation at each site. Because the subtidal plates were located in very soft muds, a probe was used to carefully locate each plate without disturbing the overlying sediments. A measuring frame (comprising a tube fixed to an aluminium cross piece - see middle sidebar photos) was then aligned over the plate and allowed to settle. A measuring rod was then pushed down through the vertical tube to measure the depth of the plate below the sediment surface, then repositioned to collect a total of 3-5 replicate measures per plate.

Grain Size

To establish a robust baseline from which to monitor changes in the mud content of sediments, triplicate composite samples of the top 20mm of sediment were collected from sediment plate sites. Samples were analysed by Hill Laboratories for grain size (% mud, sand, gravel). It is recommended that triplicate sampling be repeated whenever 5 yearly fine scale monitoring is undertaken to provide a check on within-site sample variability, but that single composite analyses be analysed in intervening years to enable a greater spatial spread of samples to be collected from throughout the estuary within the existing budget.

Redox Potential Discontinuity (RPD) depth

To assess sediment oxygenation, the mean depth to the RPD was determined at each intertidal site by repeatedly digging down from the surface with a hand trowel until the mean RPD transition level was located. The same approach was used at subtidal sites, although representative sediment cores were first collected and brought to the surface where the RPD depth was determined.

1. Introduction and Methods (Continued)

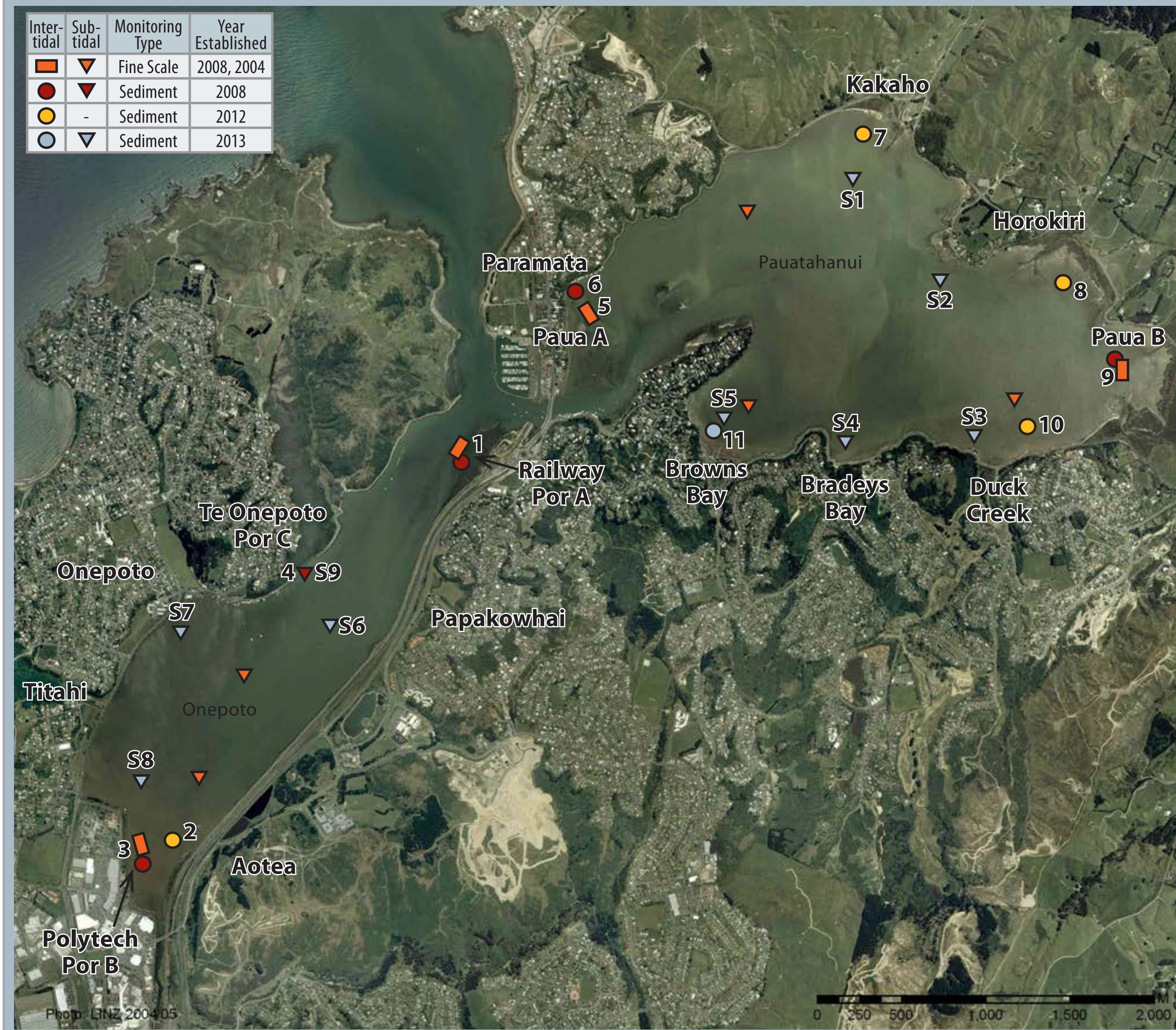
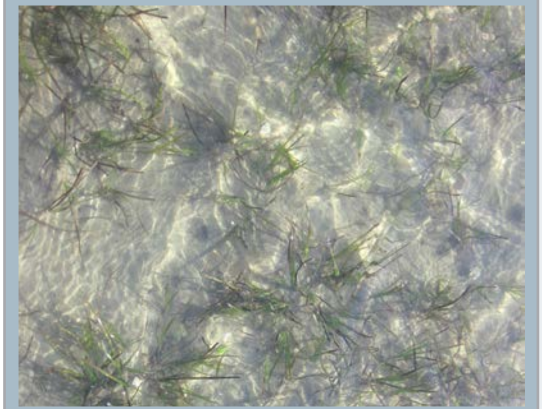


Figure 1. Location of fine scale sites and buried sediment plates established in 2007/8, 2012, and 2013 in Porirua Harbour.

View southeast over Pauatahanui Inlet to Browns Bay

1. Introduction and Methods (Continued)

WELLINGTON ESTUARIES: CONDITION RATINGS



A series of interim fine scale estuary "condition ratings" (presented below) have been proposed for Porirua Harbour Estuary (based on the ratings developed for New Zealand estuaries - e.g. Robertson & Stevens 2006, 2007, 2008, 2009). The ratings are based on a review of monitoring data, guideline criteria, and expert opinion. They are designed to be used in combination with each other, and with other fine and broad scale indicators (usually involving expert input) when evaluating overall estuary condition and deciding on appropriate management. The condition ratings include an "early warning trigger" to highlight rapid or unexpected change, and each rating has a recommended monitoring and management response. In most cases initial management is to further assess an issue and consider what response actions may be appropriate (e.g. develop an Evaluation and Response Plan - ERP).

Sedimentation Rate

Elevated sedimentation rates are likely to lead to major and detrimental ecological changes within estuary areas that could be very difficult to reverse, and indicate where changes in land use management may be needed.

SEDIMENTATION RATE CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Low	0-1mm/yr (typical pre-European rate)	Monitor at 5 year intervals after baseline established
Low	1-2mm/yr	Monitor at 5 year intervals after baseline established
Moderate	2-5mm/yr	Monitor at 5 year intervals after baseline established
High	5-10mm/yr	Monitor yearly. Initiate ERP
Very High	>10mm/yr	Monitor yearly. Manage source
Early Warning Trigger	Rate increasing	Initiate Evaluation and Response Plan

Redox Potential Discontinuity

The RPD is the grey layer between the oxygenated yellow-brown sediments near the surface and the deeper anoxic black sediments. It is an effective ecological barrier for most but not all sediment-dwelling species. A rising RPD will force most macrofauna towards the sediment surface to where oxygen is available. The depth of the RPD layer is a critical estuary condition indicator in that it provides a measure of whether nutrient enrichment in the estuary exceeds levels causing nuisance anoxic conditions in the surface sediments. The majority of the other indicators (e.g. macroalgal blooms, soft muds, sediment organic carbon, TP, and TN) are less critical, in that they can be elevated, but not necessarily causing sediment anoxia and adverse impacts on aquatic life. Knowing if the surface sediments are moving towards anoxia (i.e. RPD close to the surface) is important for two main reasons:

1. As the RPD layer gets close to the surface, a "tipping point" is reached where the pool of sediment nutrients (which can be large), suddenly becomes available to fuel algal blooms and to worsen sediment conditions.
2. Anoxic sediments contain toxic sulphides and very little aquatic life.

The tendency for sediments to become anoxic is much greater if the sediments are muddy. In sandy porous sediments, the RPD layer is usually relatively deep (>3cm) and is maintained primarily by current or wave action that pumps oxygenated water into the sediments. In finer silt/clay sediments, physical diffusion limits oxygen penetration to <1cm (Jørgensen and Revsbech 1985) unless bioturbation by infauna oxygenates the sediments.

RPD CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	>10cm depth below surface	Monitor at 5 year intervals after baseline established
Good	3-10cm depth below sediment surface	Monitor at 5 year intervals after baseline established
Fair	1-3cm depth below sediment surface	Monitor at 5 year intervals. Initiate ERP
Poor	<1cm depth below sediment surface	Monitor at 2 year intervals. Initiate ERP
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

2. RESULTS, RATING AND MANAGEMENT

Three indicators were used to assess sedimentation in 2013: sedimentation rate, grain size, and RPD depth.

Rate of Sedimentation. A total of 42 sedimentation plates have now been buried at 18 sites in Porirua Harbour since Dec. 2007 (Figure 1). Plate depths were measured in early 2013 as part of annual long term sedimentation rate monitoring in the estuary, with results (see Appendix 1) summarised in Table 1 and Figure 2.

Mean annual sedimentation rates from baseline measures to 2013 range from -3.2 to +12.3mm/yr (Table 1). Such rates fall within the “very low” to “very high” condition ratings. The greatest measured cumulative intertidal deposition is in the Onepoto Arm (Figure 2), the three sites classified as either “moderate” or “very high” (Table 1). The subtidal site (S9), for which multi-year measures are available, showed sediment erosion. In Pauatahanui Inlet, the intertidal sites established in 2008 had sedimentation rates in the “very low” category, while the three sites established in 2012 were rated “very low” (Duck Creek), “moderate” (Horokiri), and “high” (Kakaho). Monitoring over a longer period at these three sites is needed to determine the significance of the initial trends, particularly as wind driven waves have an obvious effect on intertidal sediments through localised resuspension and deposition.

Baseline measures for the nine new plate sites established in 2013 will be reported on after they are re-measured (next scheduled for January 2014). Ongoing annual monitoring of all plates for the next five years is recommended to assess the impacts of predicted land disturbance from proposed forest harvesting, urban development, and road construction in the catchment.

Table 1. Mean sediment plate depths (2007-2013), and 2013 condition rating, Porirua Harbour.

Site		No	Name	Calendar Year Baseline Commenced	Site Mean (mm/yr) 2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	Mean Annual Sedimentation since baseline (mm/yr)	2013 Sedimentation Rate Condition Rating
Onepoto Arm	Intertidal	1	Por A Railway (FS)	2008	Baseline	0.8	2.3	-4.5	-0.3	14.3	2.5	MODERATE
		2	Aotea	2012					Baseline	12.3	12.3	VERY HIGH
		3	Por B Polytech (FS)	2008	Baseline	7.0	0.5	2.0	0.3	4.3	2.2	MODERATE
	Subtidal	S6	Titahi	2013						Baseline	-	-
		S7	Onepoto	2013						Baseline	-	-
		S8	Papakowhai	2013						Baseline	-	-
		S9	Te Onepoto	2008	Baseline	-2.5	-2.5	3.0	-1.0	-14.0	-3.2	VERY LOW
Pauatahanui Arm	Intertidal	6	Boatsheds	2008		Baseline	0.5	-0.8	0.3	3.5	0.9	VERY LOW
		7	Kakaho	2008					Baseline	9.3	9.3	HIGH
		8	Horokiri	2009					Baseline	2.0	2.0	MODERATE
		9	Paua B (FS)	2008	Baseline	2.3	3.8	0.3	-5.3	-0.8	0.1	VERY LOW
		10	Duck Creek	2012					Baseline	-3.0	-3.0	VERY LOW
		11	Browns Bay	2013						Baseline	-	-
	Subtidal	S1	Kakaho	2013						Baseline	-	-
		S2	Horokiri	2013						Baseline	-	-
		S3	Duck Creek	2013						Baseline	-	-
		S4	Bradeys Bay	2013						Baseline	-	-
		S5	Browns Bay	2013						Baseline	-	

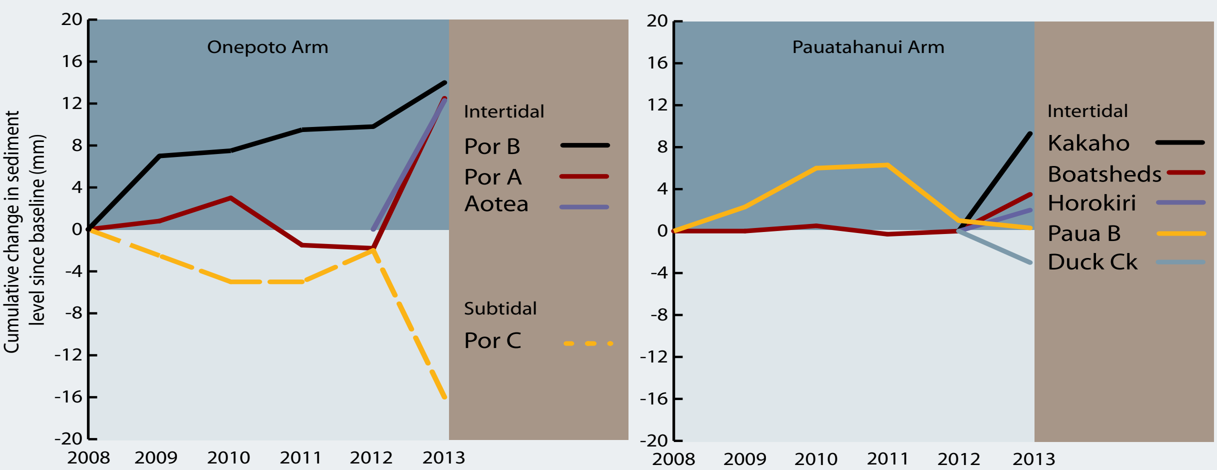


Figure 2. Mean change in sediment showing trends over buried plates from 2008-2013.

2. Results, Rating and Management (Continued)

Grain Size. Grain size (% mud, sand, gravel) is a key indicator of both eutrophication and sediment changes. Increasing mud content signals a deterioration in estuary condition and can exacerbate eutrophication symptoms.

Grain size monitoring at intertidal sites (Table 2, Figure 3) shows that although sandy sediments dominate the sites, mud was also a significant component (2-11% mud). The highest intertidal mud contents were recorded from the lower estuary ('A' sites), and at Kakaho and Horokiri. Consistent with these results, prevailing weather during sampling was noted to be mobilising and depositing fine sediments from the southern side of Pauatahanui Inlet to the northern intertidal flats at Kakaho and Horokiri. For the intertidal sites monitored annually for the past 6 years, there was no clear trend in the reported mud content.

For subtidal sites S1-S8, significantly more mud was present than at intertidal sites (Table 2, Figure 3) with the mean subtidal mud content 3 to 5 times greater than in the intertidal sediments. The subtidal mud content was consistently high in the Pauatahanui Arm. These results clearly indicate much of the muddy sediment entering the Harbour is being deposited and retained in the deeper subtidal basins. In these areas the sediments generally comprise deeper consolidated muds and sands overlain by a relatively incohesive layer of soft aqueous surface muds which is readily disturbed by water movement. This upper layer of unconsolidated mud is likely to be a key contributor to low clarity in the harbour when wind generated waves disturb the bottom sediments.

Table 2. Sediment grain size and RPD depth results, Porirua Harbour Estuary (January 2013).

Site		No	Name	Site Mean				2013 RPD Condition Rating
				% Mud (g/100g dry wt)	% Sand (g/100g dry wt)	% Gravel (g/100g dry wt)	RPD depth (cm)	
Onepoto Arm	Intertidal	1	Por A Railway (FS)	9.4	89.8	0.7	1	POOR
		2	Aotea	2.7	95.8	1.5	1.5	FAIR
		3	Por B Polytech (FS)	2.9	94.8	2.2	1.5	FAIR
	Subtidal	S6	Titahi	9.8	90.2	<0.1	0	POOR
		S7	Onepoto	11.6	87.1	1.3	1	POOR
		S8	Papakowhai	37.4	62.3	0.3	2	FAIR
		S9	Te Onepoto	7.8	91.5	0.7	2	FAIR
Pauatahanui Arm	Intertidal	5	Paua A (FS)	7.6	84.2	8.2	2	FAIR
		6	Boatsheds	11.1	85.7	3.2	1	POOR
		7	Kakaho	10.7	84.7	4.6	1	POOR
		8	Horokiri	8.1	90.5	1.4	1	POOR
		9	Paua B (FS)	3.2	95.3	1.4	1	POOR
		10	Duck Creek	1.7	98.2	0.1	3	FAIR
		11	Browns Bay	6.0	77.2	16.7	2	FAIR
	Subtidal	S1	Kakaho	49.0	50.4	0.7	1	POOR
		S2	Horokiri	46.7	52.2	1.3	1	POOR
		S3	Duck Creek	42.7	56.9	0.5	1	POOR
		S4	Bradeys Bay	16.2	83.1	0.7	1	POOR
		S5	Browns Bay	45.1	51.3	3.6	1	POOR

Redox Potential Discontinuity (RPD). The depth to the RPD boundary is a critical estuary condition indicator in that it provides a direct measure of sediment oxygenation. This commonly shows whether nutrient enrichment in the estuary exceeds levels causing nuisance anoxic conditions in the surface sediments, and also reflects the capacity of tidal flows to maintain and replenish sediment oxygen levels.

In well flushed sandy intertidal sediments, tidal flows typically oxygenate the top 5-10cm of sediment. However, when fine muds fill the interstitial pore spaces, less re-oxygenation occurs and the RPD moves closer to the surface. In response to the presence of both fine muds and nutrient enrichment, the RPD depth has decreased at all fine scale sites in Porirua Harbour since 2008 (Figure 4). In 2013, the measured intertidal RPD depth (Table 2) remained relatively shallow (1-1.5cm) indicating relatively poorly oxygenated sediments that fall within the "fair-poor" condition rating. For the subtidal sites, sediment RPD depth was rated "poor" at all sites except for the two relatively well flushed sites (S8 and S9) in the lower Onepoto Arm which were rated "fair" (Table 2).

2. Results, Rating and Management (Continued)

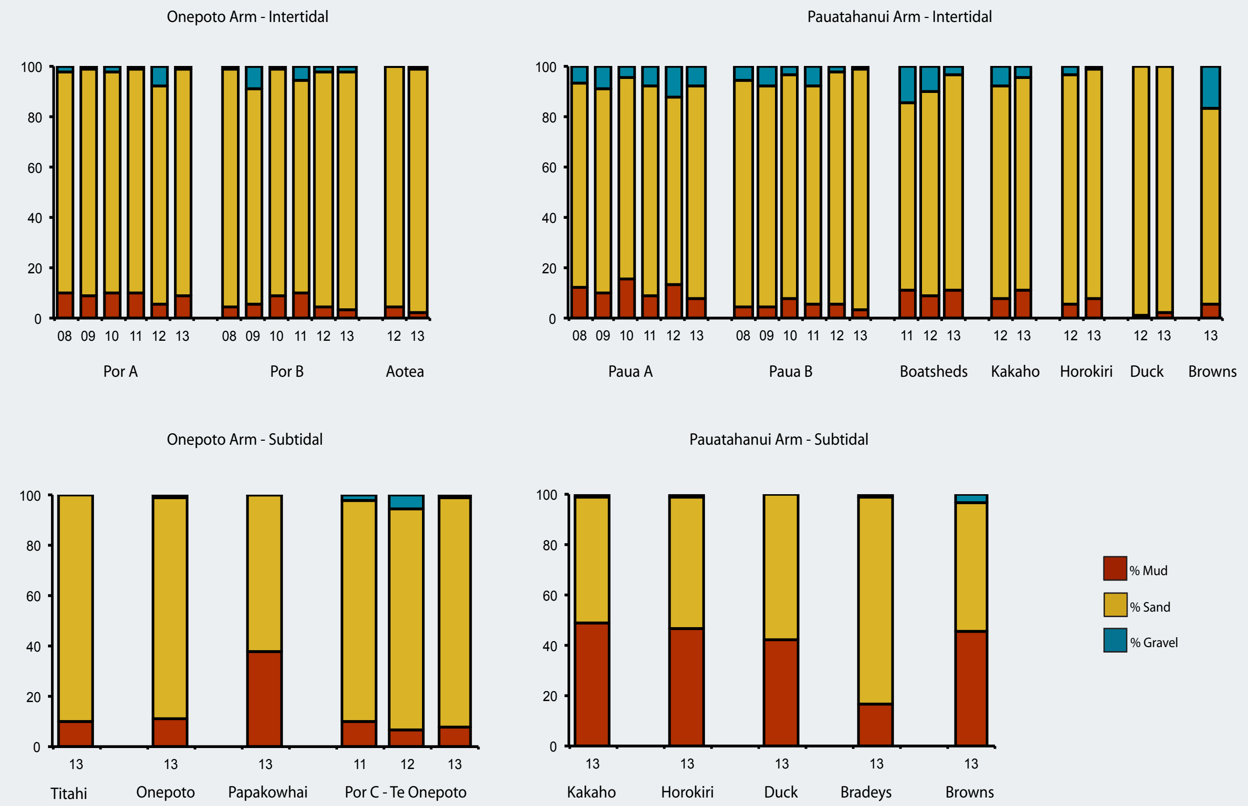


Figure 3. Mean sediment grain size (%) at Porirua Harbour intertidal (upper) and subtidal (lower) sites, (2008-2013).

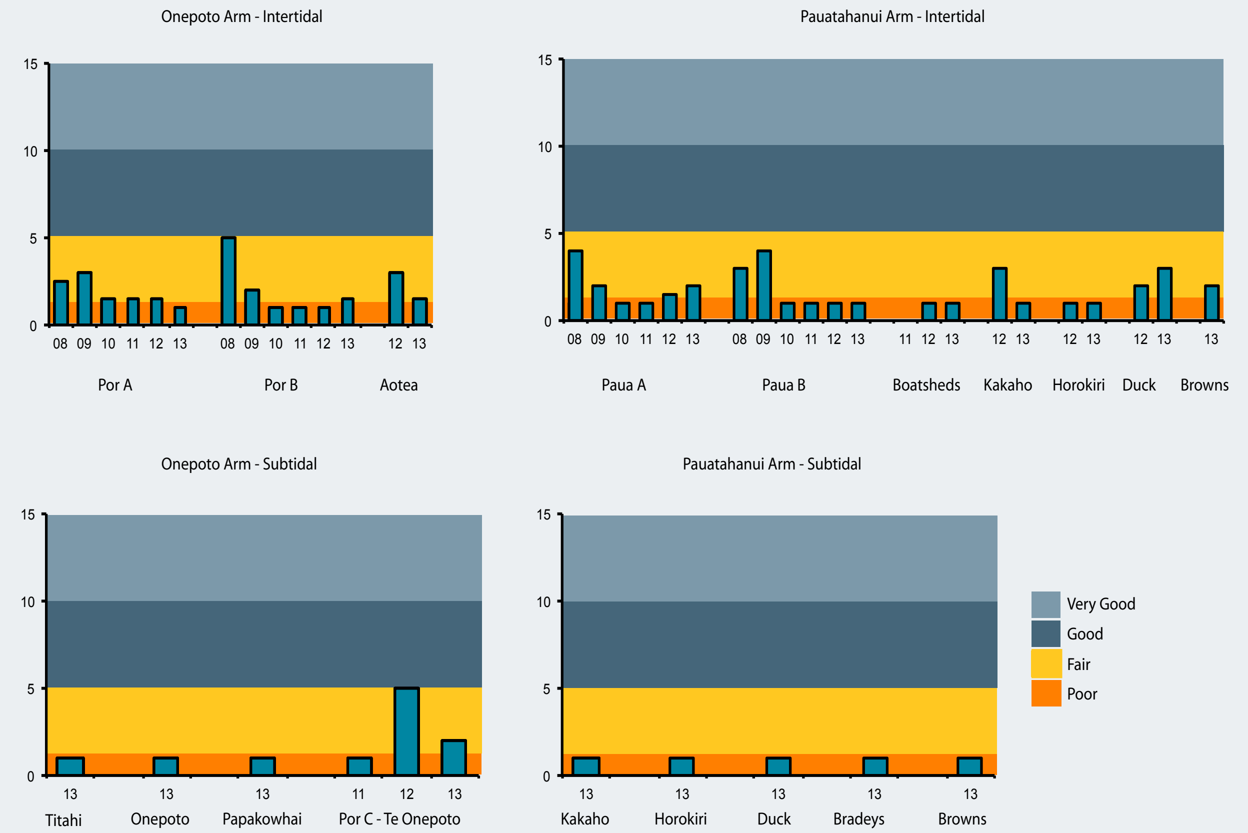


Figure 4. Mean sediment RPD depth (cm) at Porirua Harbour intertidal (upper) and subtidal (lower) sites, (2008-2013).

2. Results, Rating and Management (Continued)

SUMMARY

Sediment plate monitoring since 2007/08 at strategic intertidal sites within the Porirua Harbour indicates elevated rates of sedimentation at the upper Onepoto Arm site, but relatively low mean rates at other sites. The “moderate-high” intertidal rates reported at Horokiri and Kakaho in 2013 appear to reflect the intertidal deposition of sediment remobilised by wave action. This material appears to be frequently deposited in this part of the estuary by prevailing winds.

The establishment of subtidal plates confirmed significant deposits of soft muds were present in the subtidal basins of both estuary arms, which is where the greatest rates of sedimentation are predicted. Baseline sediment rate measures in both intertidal and subtidal areas will allow representative mean sedimentation rates throughout the estuary to be assessed in future.

The results also indicated a relatively low sediment RPD depth, and elevated sediment mud contents at many of the sites. Both highlight mud deposition as a continuing concern within the estuary.

RECOMMENDED MONITORING

It is recommended that monitoring continue as outlined below:

Annual Sediment Monitoring. To address problems associated with increasing muddiness and a “poor-fair” RPD rating, monitor sedimentation rate, RPD depth and grain size at the existing intertidal and subtidal sites annually until the situation improves (next monitoring due in January 2014).

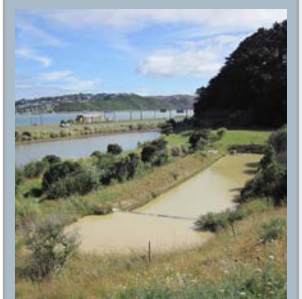
It is recommended that a spreadsheet of sediment plate measures be provided annually, with results reported fully every 5 years.

Fine Scale Monitoring. It is recommended that a “complete” fine scale monitoring assessment (including sedimentation rate and macroalgal mapping) be undertaken at 5 yearly intervals (next scheduled for Jan-Feb 2015). Fine scale subtidal monitoring, currently undertaken independently of the intertidal programme, should be reviewed and integrated within a ‘whole of estuary’ monitoring approach.

Broad Scale Habitat Mapping. It is recommended that broad scale intertidal habitat mapping be repeated every 5 years (next monitoring due in January 2018).

In addition, it is recommended that broad scale mapping of subtidal habitat be undertaken to characterise dominant substrate type, sediment condition (RPD), and vegetative cover, particularly seagrass. If this work is undertaken, it is recommended that additional sediment plates be established in the deeper subtidal basins near the existing fine scale subtidal sites.

RECOMMENDED MANAGEMENT



The sediment indicators monitored in 2013 reinforce the 2008 to 2010 fine scale monitoring results about the need to manage fine sediment inputs to the estuary.

In particular the following specific management actions are recommended:

- Limit catchment suspended sediment inputs to levels that will not cause excessive estuary infilling i.e. limit sedimentation rates to an estuary average of 1mm/yr. It is expected that there will be areas of very high and very low sedimentation throughout the estuary, which together will average 1mm/yr. Such an approach will allow the development of input load guidelines for suspended sediment and targeted management of problem areas.

Greater Wellington’s ongoing catchment and sediment transport modelling will help determine the catchment suspended sediment load inputs and the target reductions required to reduce in-estuary sedimentation rates. GWRC and PCC are also undertaking desktop assessments to determine the likely sediment input loads from different landuses, including the Transmission Gully motorway development, and modelling the zones of deposition within the estuary, to determine strategies for best managing sediment within the catchment.

2. Results, Rating and Management (Continued)

ACKNOWLEDGEMENTS

Many thanks to Juliet Milne and Megan Oliver (GWRC) for their support and feedback on the draft report, and to Ben Robertson for help with the field component.

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Appendix 1

DETAILED RESULTS

Grain size results, Porirua Harbour Estuary (January 2013).

Site		No	Name	Dry Matter			% Mud			% Sand			% Gravel		
				rep1	rep2	rep3	rep1	rep2	rep3	rep1	rep2	rep3	rep1	rep2	rep3
Onepoto Arm	Intertidal	1	Por A Railway (FS)	73	72	68	0.9	1	0.2	89.9	88.2	91.4	9.1	10.7	8.4
		2	Aotea	77	70	72	2.1	2.3	0.2	94.8	95.6	96.9	3.2	2	2.8
		3	Por B Polytech (FS)	79	72	71	1.7	1.8	3.2	95.7	95.1	93.7	2.6	3.1	3.1
	Subtidal	S6	Titahi	71	72	72	< 0.1	< 0.1	< 0.1	90.6	90.2	89.7	9.4	9.8	10.3
		S7	Onepoto	80	80	79	0.5	2.8	0.6	87.6	85.5	88.1	11.9	11.7	11.3
		S8	Papakowhai	66	63	62	0.3	0.3	0.4	64.7	60.6	61.5	35	39.1	38.1
		S9	Te Onepoto	79	79	80	1	0.7	0.5	91.5	91.3	91.6	7.6	8	7.9
Pauatahanui Arm	Intertidal	5	Paua A (FS)	73	70	76	9.9	7	7.8	83.3	84.7	84.5	6.8	8.3	7.7
		6	Boatsheds	70	65	67	1.6	6.1	2	86.8	82.7	87.6	11.6	11.2	10.4
		7	Kakaho	72	79	74	3.6	4.1	6.2	85.9	84.2	83.9	10.5	11.8	9.9
		8	Horokiri	79	79	79	1.1	1.3	1.9	91.1	90.6	89.8	7.8	8.1	8.3
		9	Paua B (FS)	76	76	76	0.8	1.9	1.5	96.1	94.8	95	3	3.2	3.5
		10	Duck Creek	73	75	78	0.1	< 0.1	< 0.1	97.9	98.3	98.5	2	1.6	1.5
		11	Browns Bay	73	71	77	12.7	22.4	15.1	79.9	70.9	80.9	7.4	6.7	4
	Subtidal	S1	Kakaho	66	73	71	0.2	0.7	1.1	54.1	49.1	48.1	45.8	50.3	50.8
		S2	Horokiri	70	69	-	2.3	0.2	-	53.6	50.7	-	44.2	49.1	-
		S3	Duck Creek	65	68	-	0.2	0.7	-	52.4	61.3	-	47.4	37.9	-
		S4	Bradeys Bay	72	70	78	1	0.8	0.3	82	83.6	83.8	17	15.6	15.9
		S5	Browns Bay	74	73	71	3.4	3.9	3.4	53.8	52.8	47.3	42.7	43.3	49.3

Sediment Plate Depths, Onepoto Arm, Porirua Harbour Estuary (2007-2013).

	No.	Site	PLATE	NZTM EAST	NZTM NORTH	13/12/07	15/1/09	20/1/10	18/1/11	21-24/2/12	2013
Onepoto Arm - Intertidal	1	Por A Railway (fine scale site)	1	1756505.7	5447788.6	168	164	159	155	160	183
			2	1756477.9	5447784.8	150	152	158	156	151	150
			3	1756478.8	5447762.7	152	155	163	150	145	174
			4	1756508.1	5447755.8	93	95	95	96	100	106
	2	Aotea	1	1754771.8	5445520.0					138	145
			2	1754770.5	5445521.2					108	126
			3	1754768.3	5445523.1					103	118
			4	1754767.3	5445523.9					100	109
	3	Por B Polytech (fine scale site)	1	1754561.9	5445430.3	237	237	240	242	245	243
			2	1754577.9	5445403.8	230	244	242	244	244	256
			3	1754561.6	5445529.5				110	110	109
			4	1754559.9	5445528.6				75	73	81
Subtidal	S6	Titahi	1	1755704.1	5446797.6						191
	S7	Onepoto	1	1754811.3	5446762.9						194
	S8	Papakowhai	1	1754580.9	5445864.0						183
	S9	Te Onepoto	1	1755551.8	5447105.3	120	-	115	115	118	104

Appendix 1

DETAILED RESULTS

Sediment Plate Depths, Pauatahanui Arm, Porirua Harbour Estuary (2007-2013).

	No.	Site	PLATE	NZTM EAST	NZTM NORTH	13/12/07	15/1/09	20/1/10	18/1/11	21-24/2/12	2013
Pauatahanui Arm - Intertidal	5	Paua A (fine scale site)		1757243.0	5448644.0						
	6	Boatsheds	1	1757267.5	5448785.8		171	172	165	166	172
			2	1757265.6	5448785.2		213	213	215	216	221
			3	1757263.6	5448784.7		232	232	233	234	233
			4	1757262.0	5448784.1		234	235	236	234	238
	7	Kakaho	1	1758885.4	5449747.8					73	89
			2	1758884.9	5449746.0					100	106
			3	1758884.4	5449744.2					90	103
			4	1758884.0	5449742.3					92	94
	8	Horokiri	1	1760040.2	5448827.6					106	104
			2	1760039.8	5448825.5					108	111
			3	1760039.6	5448823.5					118	124
			4	1760039.1	5448821.5					98	99
	9	Paua B (fine scale site)	1	1760333.9	5448378.8	181	182	186	186	181	180
			2	1760349.2	5448355.8	215	218	228	233	228	225
			3	1760375.1	5448366.9	182	186	183	183	181	182
			4	1760362.3	5448391.9	176	177	181	177	168	168
	10	Duck Creek	1	1759829.3	5447944.8					134	121
			2	1759828.7	5447946.7					108	108
			3	1759828.1	5447948.7					122	122
			4	1759827.6	5447950.6					88	89
	11	Browns Bay	1	1757971.4	5447956.8						220
Subtidal	S1	Kakaho	1	1758810.9	5449470.5						165
	S2	Horokiri	1	1759325.4	5448867.9						176
	S3	Duck Creek	1	1759529.0	5447896.3						194
	S4	Bradeys Bay	1	1758763.2	5447865.0						124
	S5	Browns Bay	1	1758040.6	5448015.1						179

ANALYTICAL METHODS

Indicator	Laboratory	Method	Detection Limit
Grain Size	R.J Hill	Wet sieving (2mm and 63µm sieves), gravimetry (calculation by difference).	0.1 g/100g dry wgt