TE AWARUA-O-PORIRUA HARBOUR

REPORT OF SURVEY & VERIFICATION OF SEDIMENTATION RATES

Project No. SP00041

Report Prepared for Porirua City Council

Surveyed by Discovery Marine Ltd.

Discovery Marine Ltd
PO Box 4048
Mount Maunganui
BAY OF PLENTY

Email: info@dmlsurveys.co.nz
Website: www.dmlsurveys.co.nz

Report Date: 13 February 2015

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REPORT OF SURVEY AND VERIFICATION OF SEDIMENTATION RATES

CONTENTS

REFERENCES:

A. DML Report of Survey dated 25 June 2009

B. DML Report on Calculation of Rates of Sedimentation dated 25 May 2011

13 February 2015

Keith Calder
Porirua Harbour Strategy Coordinator
Porirua City Council
PO Box 50-218
PORIRUA

PORIRUA HARBOUR – REPORT OF SURVEY & VERIFICATION OF SEDIMENTATION RATES

SECTION 1 LIST OF ABBREVIATIONS

1.1 Abbreviated terms which may be used in this document are as follows:

BM	Bench Mark
CD	Chart Datum
DML	Discovery Marine Ltd
GPS	Global Positioning System
GWRC	Greater Wellington (Regional Council)
HAT	Highest Astronomical Tide
IHO	International Hydrographic Organisation
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
LAT	Lowest Astronomical Tide
LINZ	Land Information NZ
PCC	Porirua City Council
PDOP	Positional Dilution of Precision (A figure of merit denoting horizontal positioning accuracy)
RL	Reduced Level
RNZN	Royal New Zealand Navy
RTCM	Radio Transmitted Correction Message (corrections providing higher position accuracy).
RTK	Real Time Kinematic (GPS Positioning Method/System)
SBES	Single Beam Echo Sounder
SD	Sounding Datum
SLR	Sea Level Rise
TS	Total Station Survey Instrument
TX	Transducer (Echo Sounder Transducer)
UHF	Ultra High Frequency (Radio signal)
WVD	Wellington Vertical Datum

SECTION 2 INTRODUCTION

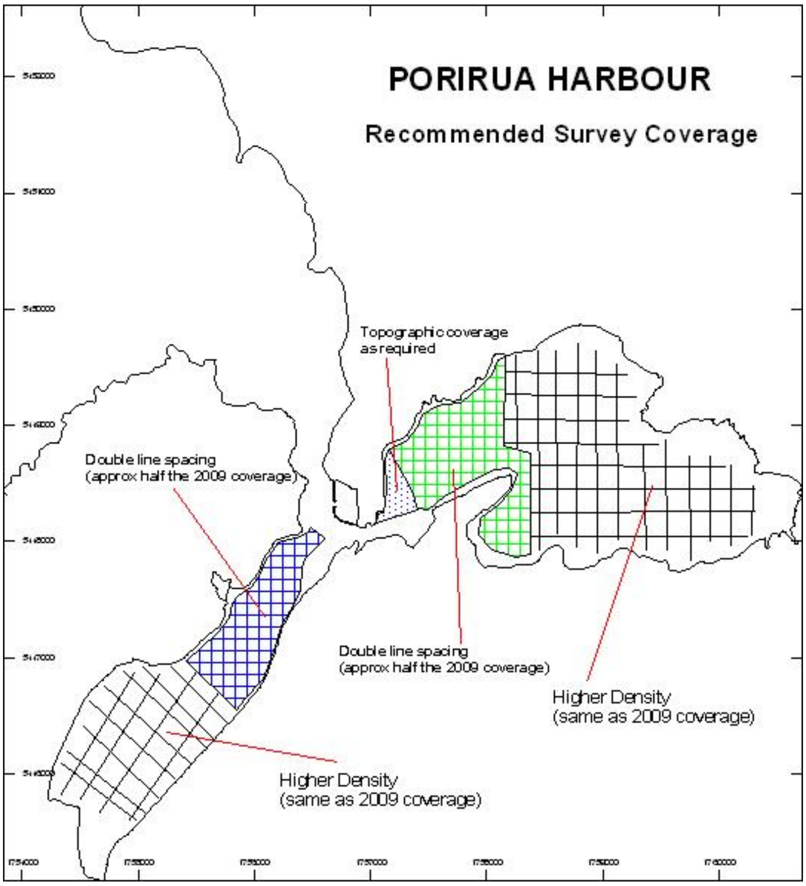
2.1 Discovery Marine Ltd (DML) was contracted by Porirua City Council (PCC) to undertake a repeat hydrographic survey of Porirua Harbour as part of a long-term harbour study involving the assessment of sediment transportation and trends. DML last undertook a full survey of the harbour environment in 2009 (Reference A refers).

2.2 The primary aim of this survey was to derive accurate comparisons between the 2009 and 2014 surveys in order to validate previous sedimentation rates and assessments as detailed at Reference B.

Survey Area

2.3 Due to the dynamic nature of the confluence region in vicinity of the marina, it was agreed to concentrate survey coverage as much as possible within Onepoto Arm and Pauatahanui Inlet. Encompassing the shallow Pauatahanui and Onepoto Arms, survey coverage over all inter-tidal regions up to the MHWS level was required. The fieldwork therefore necessitated a combination of hydrographic and topographic techniques.

2.4 The agreed survey coverage is illustrated in the image below:



2.5 The survey was completed by a team of two experienced surveyors with all work being supervised by an IHO Cat A hydrographic surveyor. The team was accommodated at Mana during the survey with boat operations based from Mana Marina.

2.6 Work Achieved. The project area has been fully surveyed to Client requirements. Overall, greater sounding coverage was achieved in some areas due to the use of a very shallow draught survey vessel. All fieldwork was completed over a 6 day period from 21-26 November 2014.

2.7 Environmental Conditions. The survey was planned to coincide with a spring tide period, providing optimum conditions to survey over the shallow inter-tidal regions. Unfortunately, less than ideal weather and sea conditions were experienced throughout the survey period with strong gusty N winds being typical. However, care was taken to survey areas least exposed to the winds on each day as much as practical. At times, there was a 0.1-0.2m surface chop due to winds opposing tides however sounding was aborted whenever survey data accuracy became an issue. The use of RTK GPS to measure vessel movement was essential in terms of minimising errors associated with the vessel movement.

2.8 Difficulties. Apart from the inclement weather periods, no significant difficulties were encountered during the survey.

SECTION 3 GEODETIC CONTROL

3.1 The survey was undertaken in terms of New Zealand Transverse Mercator coordinate system in accordance with current industry standards. Details are as follows:

Coordinate System:
- Name: NZ Transverse Mercator (NZTM)
- Group: New Zealand GD2000

Ellipsoid: Geodetic Ref System 1980

Projection: Transverse Mercator
- Parameters:
- Central Latitude: 0°00.0000'N
- Central Longitude: 173°00.0000'E
- False Northing: 10000000.00 m
- False Easting: 1600000.00 m
- Scale Factor: 0.9996

Geoid Model: EGM96 (Global)

3.2 All survey marks used during the previous survey were located and checked for movement via a series of network base line measurements. One new survey mark (DML3) was installed adjacent to the Mana Marina boat ramp. This mark became the primary site for the RTK Base Station providing horizontal and vertical positioning to the survey boat.

RTK Base Station at BM DML3- Mana Marina

3.3 A list of survey marks used in the geodetic network is tabled below:

Name Code	**Northing (m)**	**Easting (m)**	**Height**	**Comments**
Mana Marina C1K1	5448512.31	1756787.10	2.55m CD	LINZ mark, with coordinates updated using observations to L14.
DML1	5448534.14	1756824.56	3.209 CD	Temporary SM. Buried IT near entrance to Marina.
DML2	5448867.02	1756671.29	6.642 CD	Temporary SM. Buried IT located in Ngatitoa Domain.
DML3	5448521.78	1756693.28	3.004 CD	New SM. IT at ground level in sand mound, adjacent to boat ramp at marina.
TG Bolt (Terrier Bolt)	5448475.94	1756821.30	2.538 CD	SS hexagonal bolt cemented into top of seawall next to tide gauge – NE corner of Mana Marina.

3.4 RTK positioning was used for topographic work, being the survey of areas not accessible by boat. The same RTK system was used for vessel positioning.

4 VERTICAL CONTROL

4.1 Identical procedures to the 2009 survey were employed for vertical control. The survey is referenced to LINZ Mark C1KI (Mana Marina), which according to LINZ records, was levelled to the original RNZN BM at the Mana Cruising Club. Precise levelling was completed between C1K1, DML1, DML2 and the SS Terrier Bolt at the GWRC tide gauge site.

4.2 Bench Mark Listing

A table listing final heights is provided below:

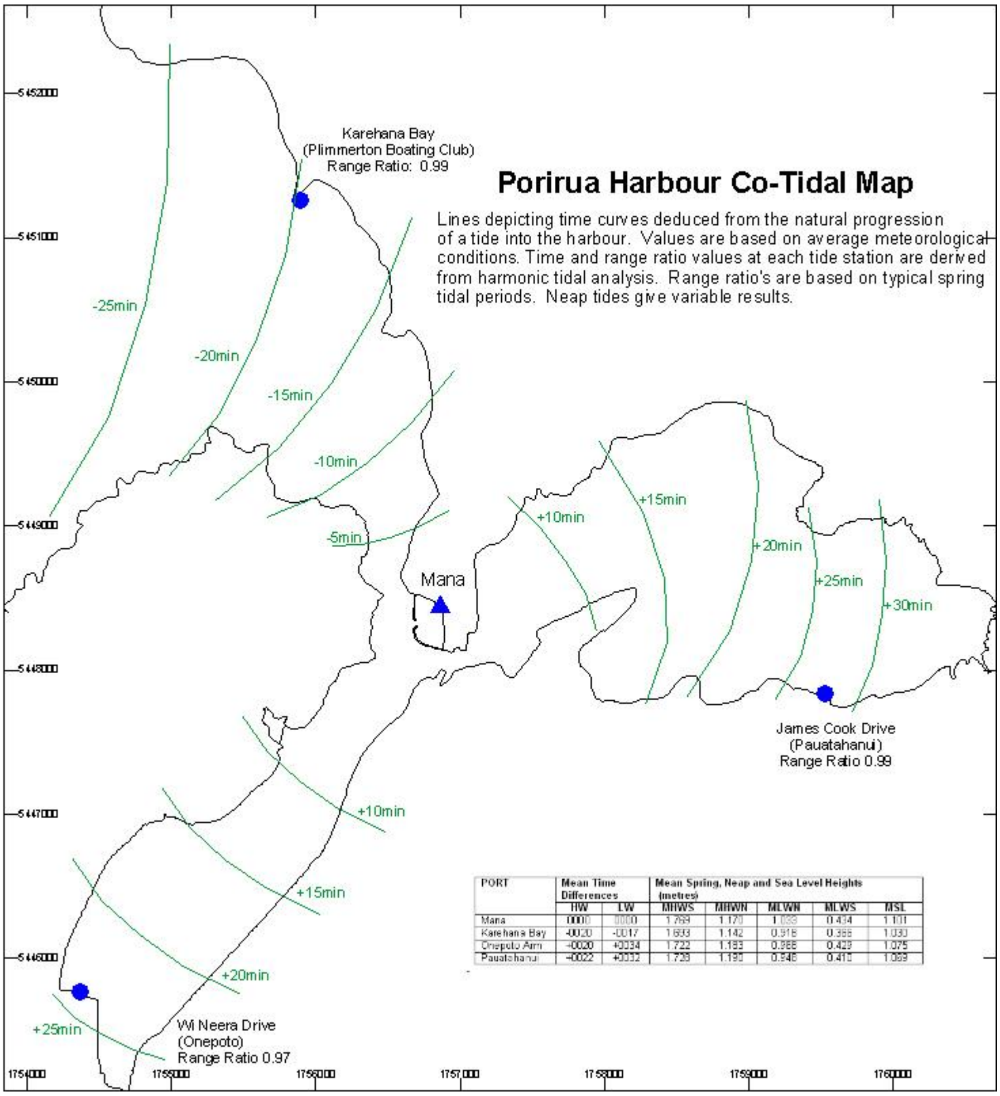
Mark	Height/Origin	Observed Height (above CD)	Comments
C1K1	2.55m above CD (LINZ)	LINZ height adopted	CD Value requires investigation based on recent analysis.
SS Terrier Bolt	Origin not known. Possibly 1991 survey.	2.538m	Mana Marina Tide Gauge. Levelled from C1K1
BM DML1	Established by DML in 2009	3.210m	Levelled from C1K1
BM DML2	Established by DML in 2009	6.642m	From RTK network
BM DML3	New Mark	3.004m	From RTK network

4.3 Tide Information

4.3.1 Occasional water level readings were taken at the Mana gauge site, which were later compared with downloaded digital tide readings supplied by GWRC. An agreement of +/-1cm or better was achieved providing confidence that the permanent gauge has not altered in any way since the last survey.

4.3.2 In 2009 a full harmonic tidal analysis was undertaken to establish the nature of the tidal regime throughout the entire harbour environment. This was completed using tide observations from three gauge sites (Mana, Onepoto & Pauatahanui). The Onepoto and Pauatahanui tide gauges were removed after the 2009 survey however the co-tidal model that was developed was again implemented for this new survey.

4.3.3 Raw soundings were reduced for tide using the co-tidal model to replicate the tidal reduction method employed in 2009. Tide data from the tide gauge was received from the GWRC website and this was used to create tide files for data reduction. The co-tidal diagram, illustrating the time differences and range ratios throughout the harbour is shown below.



PORT	Mean Time Differences		Mean Spring, Neap and Sea Level Heights (metres)				
	HW	LW	MHWS	MHWN	MLWN	MLWS	MSL
Mana	0000	0000	1.769	1.170	1.033	0.434	1.101
Karehana Bay	-0020	-0017	1.693	1.142	0.918	0.366	1.030
Onepoto Arm	+0020	+0034	1.722	1.183	0.988	0.429	1.075
Pauatahanui	+0022	+0032	1.728	1.190	0.948	0.410	1.069

Porirua Harbour Co-tidal Diagram

5 SURVEY SYSTEMS

5.1 DML's 5.3m Stabicraft inshore survey boat '*Penguin II'* was used for all boat sounding. Being a pontoon design, she has a very shallow draught and is a very stable platform for inshore hydrographic surveys.

5.2 The boat was fitted with a standard survey outfit comprising RTK GPS positioning system and high frequency digital sounder logging directly into a hydrographic software package running on a laptop computer. Vessel movement or motion was also measured using the RTK system which compensated for heave effects from swell and or surface chop. This provided improved sounding accuracy for exposed areas. Data from all devices was logged continuously during sounding operations.

SMB Penguin II at Mana

5.3 Details of key equipment used are listed below:

Boat System:

Echo Sounder:	Type:	Tritech PA500
	Depth Acquisition:	8-10 soundings per second
	Frequency:	500 kHz
	Beam width:	SBES - 6°
	Rated Accuracy:	+/-1cm
Positioning System:	Trimble R6 RTK GNSS System. Base Station transmitting CMR+ corrections to survey vessel via UHF radio	
	Accuracy of system –	Horizontal: +/- 10mm + 1ppm
		Vertical: +/- 20mm + 1ppm
Software Package	Trimble HYDROPro Version 2.4 (2012) Depth and positional data logged directly into Navigation Module. Data Editing & Processing Modules Trimble Terramodel Processing Package	

5.4 All equipment was checked, calibrated and operated in accordance with accepted industry procedures. The echo sounder was calibrated daily for vessel draught and sound velocity using the bar check method and verified with a Sound Velocity Probe (SVP). The accuracy of the vessel positioning system was also checked daily by undertaking a static position check against the survey mark (Terrier Bolt) within the Mana Marina. These checks confirmed a horizontal positioning accuracy of better than +/-0.2m at the 95% (2-sigma) confidence level.

6 METHODOLOGY

6.1 Sounding operations were undertaken using standard hydrographic principles. Where possible; conventional lines of sounding were run perpendicular to the general seabed contours in order to accurately delineate the gradient changes. Cross lines or check lines were sounded to provide overlaps in data for internal checking and QA requirements.

6.2 In order to replicate the 2009 survey, the previous vessel tracks were loaded into the acquisition software and the Pauatahanui and Onepoto inlets were sounded using the same grid pattern to maximise time and provide sufficient coverage for modelling requirements.

6.3 In 2009, many shallow regions not accessible by boat had to be surveyed during low water periods using the RTK GPS rover unit. However, due to the spring high tides and very shallow draught vessel, all areas were able to be sounded from the boat with the exception of only a very small area within Pauatahanui Inlet. The boat was able to access the Porirua Stream and Pauatahanui Stream mouths without difficulty.

SECTION 7 DATA EDITING AND PROCESSING

7.1 All sounding data was edited and processed using the Trimble HYDROPro Edit and Processing software suite. Obvious depth spikes (outliers) were removed via automatic filtering and manually checked for each survey line. The edited data was then exported into Terramodel processing package where data was checked for coverage and consistency. Individual surveys (separate days or distinct areas) were imported as separate layers in order that overlaps of data could be easily inspected. Topographic data was imported and merged with the depth layers.

7.2 From the final merged dataset, all data was exported as an ASCII xyz file and used for the creation of the accompanying 2D contour images. Using the Surfer8 surface modelling software package, both the 2009 and 2014 surveys were gridded at 30m intervals using the 'Kriging' technique. Volume figures could then be derived from the respective gridded surfaces.

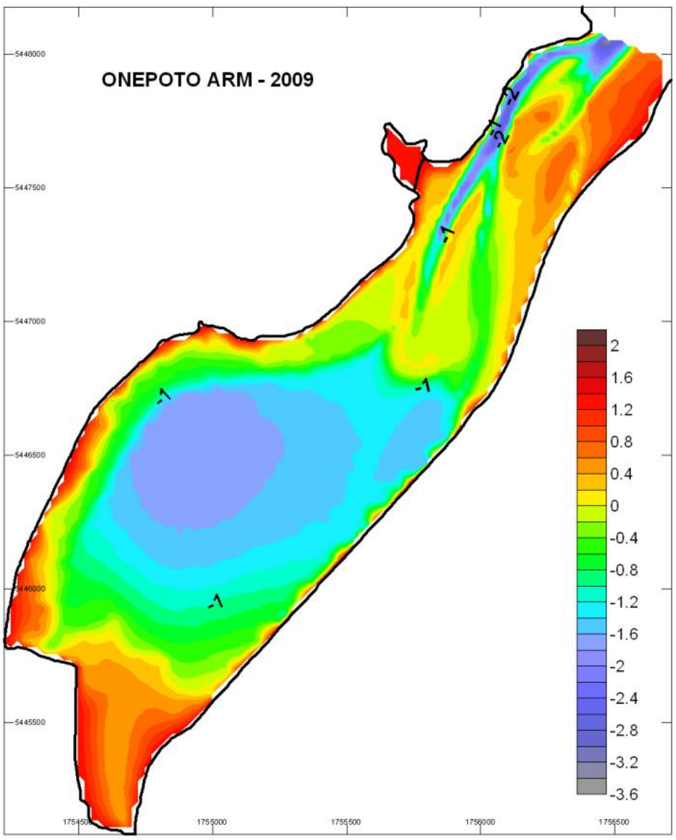
SECTION 8 RESULTS AND ACCURACIES

8.1 Rigorous checks have been undertaken of the survey data. Based on daily positioning checks, the horizontal accuracy of soundings is estimated to be better than +/-0.2m. The accuracy of depth data (reduced suing the co-tidal model) has been checked digitally via inspection of overlapping soundings. Overall, excellent results have been achieved in most areas with close agreements in cross line comparisons, despite overlapping survey data being gathered on different days and in varying sea conditions. Spot checks throughout the final database indicate general cross line agreements of +/-0.03m or better.

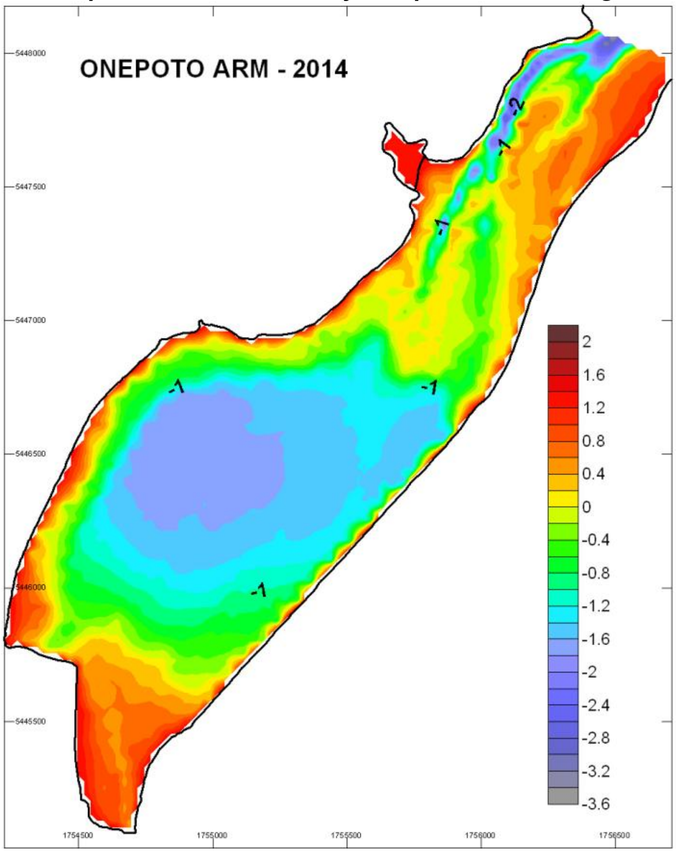
8.2 Overall, excellent results have been achieved. A high level of depth accuracy has been accomplished and the density of coverage meets the project requirements.

SECTION 9 SURVEY COMPARISONS & SEDIMENTATION RATES

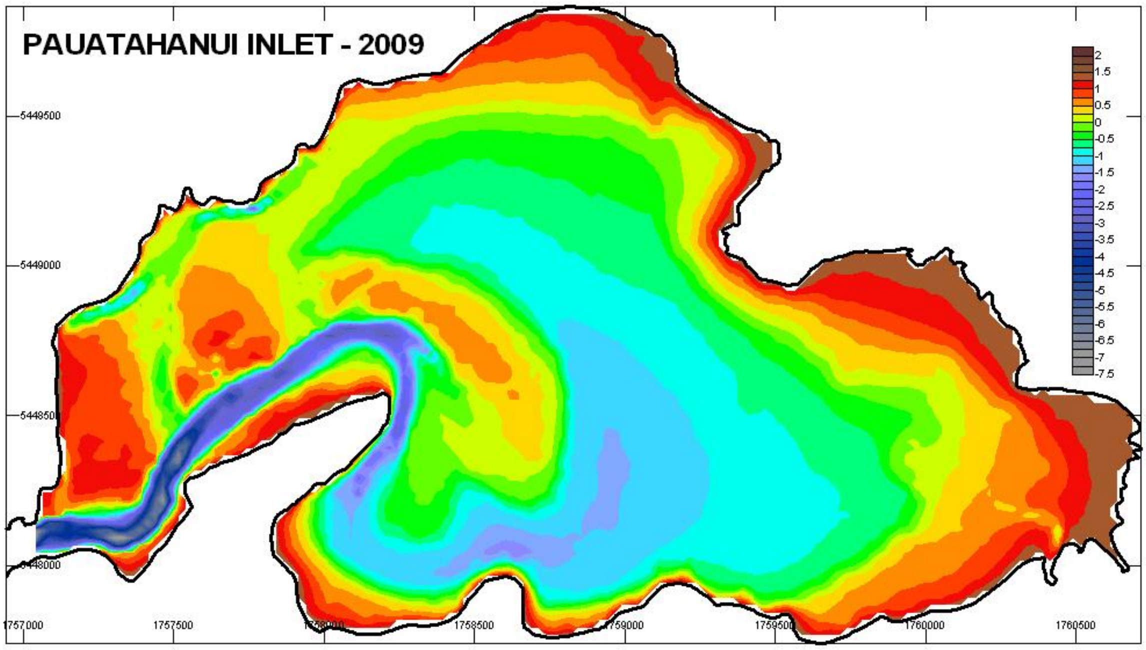
9.1 Final datasets from the 2009 and 2014 surveys were gridded using identical techniques and gridding constraints to derive 2D depth contour images. These are provided below. All depth levels are shown in metres and decimetres.



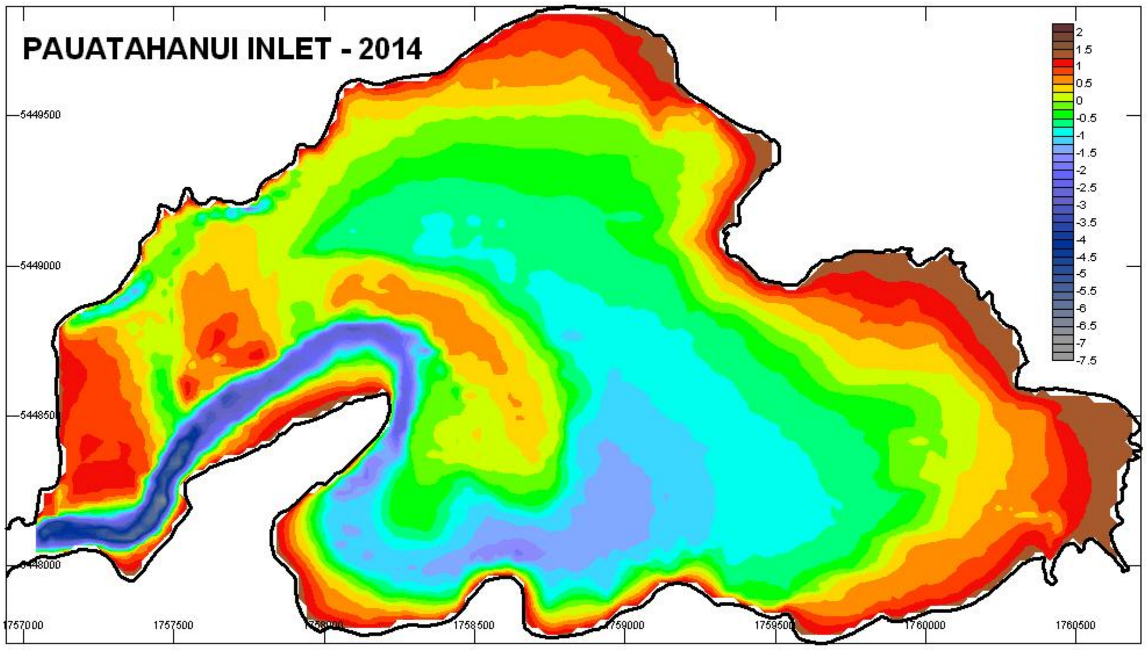
Onepoto Arm - 2009 Survey – Depth Contour Image



Onepoto Arm - 2014 Survey – Depth Contour Image



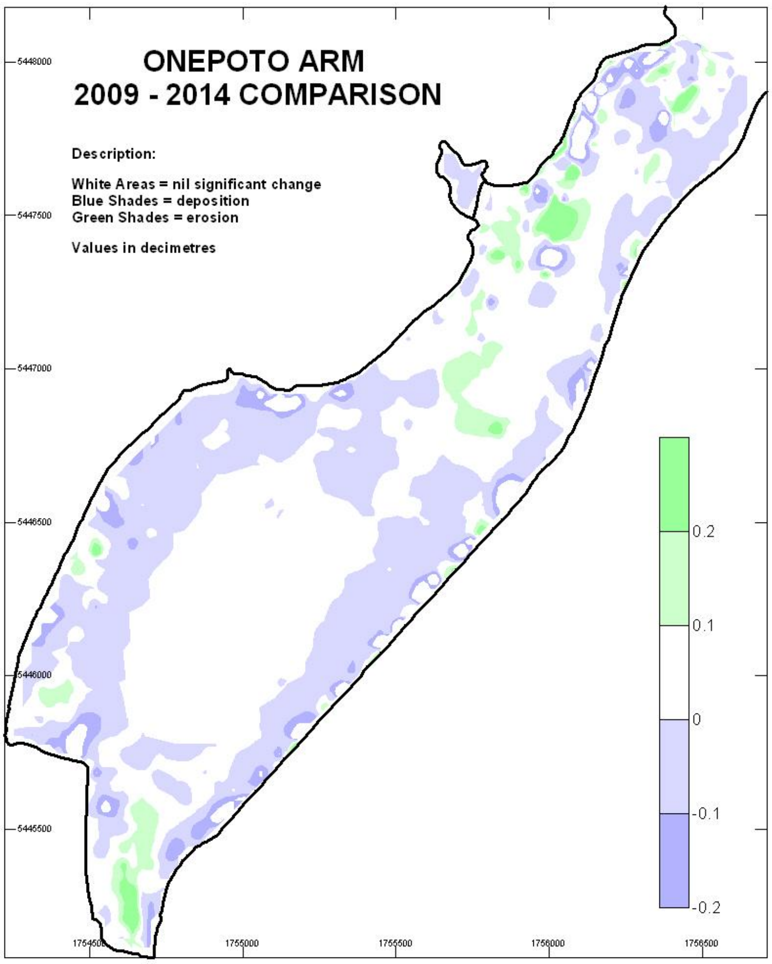
Pauatahanui Inlet - 2009 Survey – Depth Contour Image



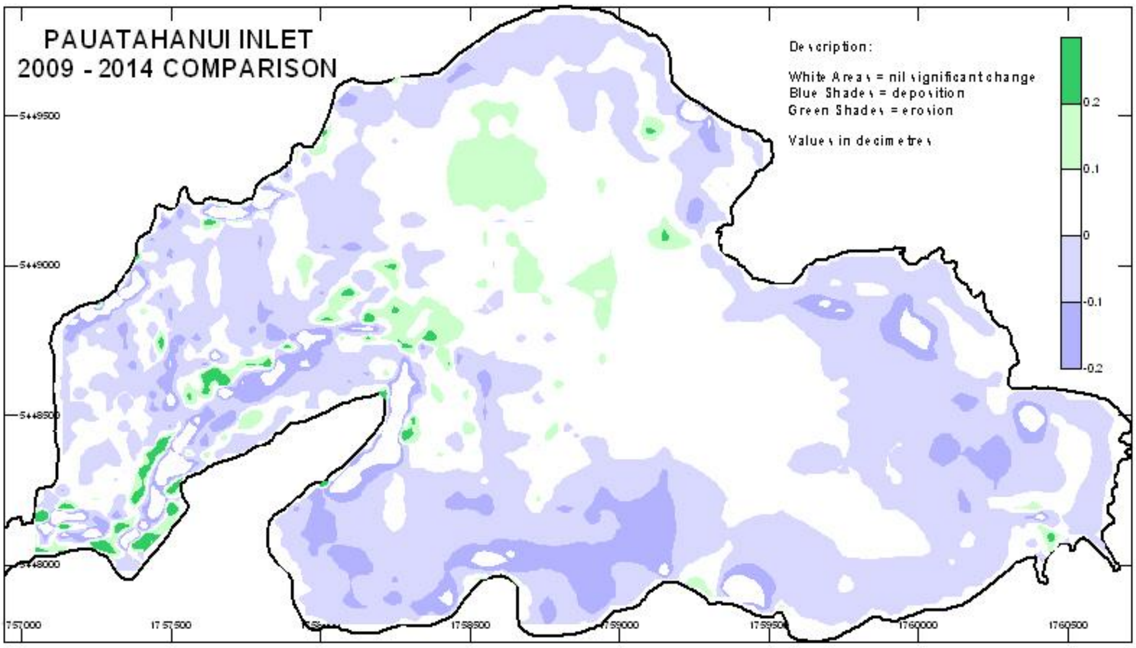
Pauatahanui Inlet - 2014 Survey – Depth Contour Image

Survey Comparisons

9.2 The two data sets for each inlet were combined to derive a comparison image. This was derived by overlaying the DTM surfaces and computing difference values for corresponding depth points. These comparison images are provided below. Pale areas indicate little or negligible change whilst blue areas indicate deposition and green areas indicate erosion or deepening.



Onepoto Arm – 2009-2014 – Depth Comparisons



Pauatahanui Inlet – 2009-2014 – Depth Comparisons

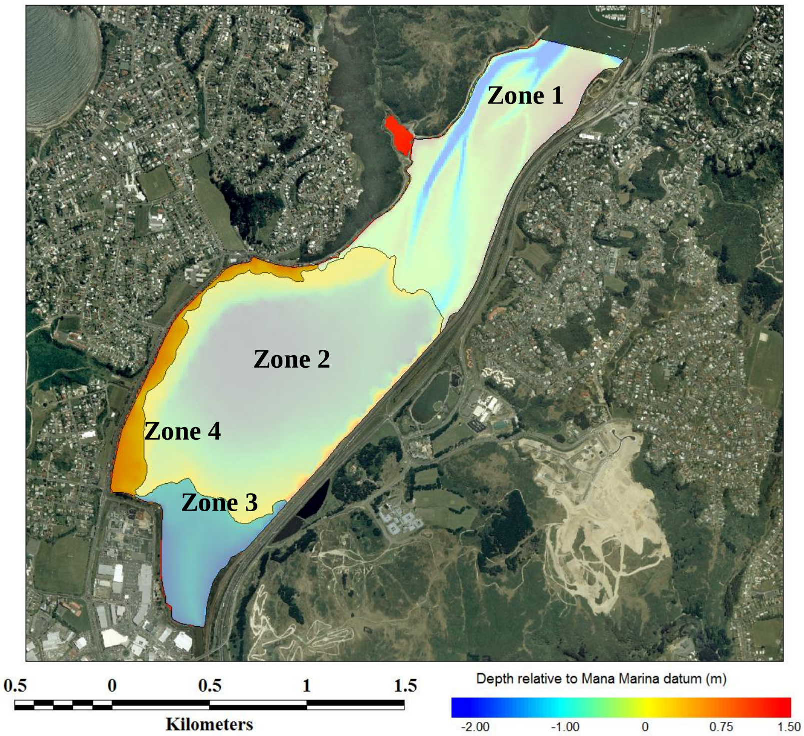
Rates of Sedimentation

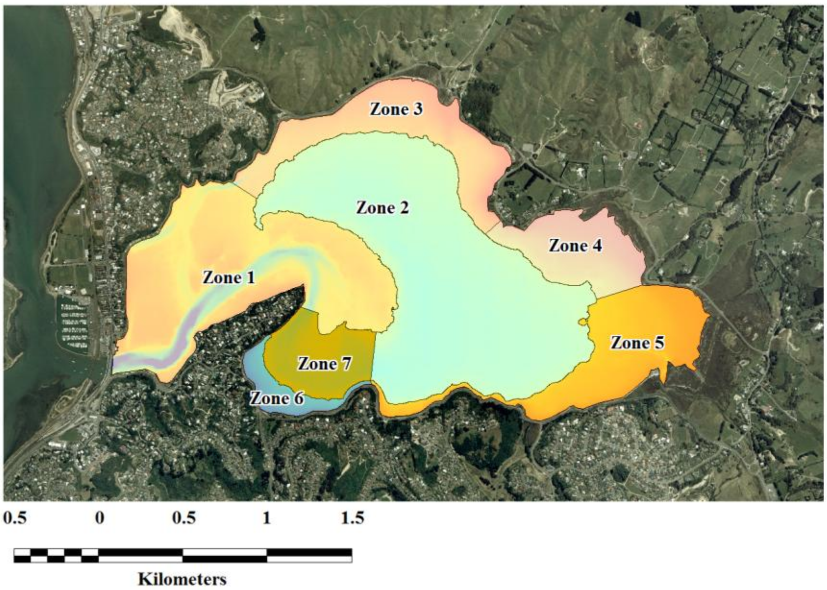
9.3 Reference B details the calculation of annual sedimentation rates for Onepoto Arm and Pauatahanui Inlet primarily based on surveys between 1974 (RNZN) and 2009 (DML). Initial accretion rates were adjusted for Sea Level Rise (SLR) which was adopted as 1.9mm per year over the last 35 years. For completeness, the figures derived in 2011 are summarised in Table 1 below:

Table 1: 2011 Sedimentation Estimates

Location	**Raw Accretion Rate** mm.yr^{-1}	**Accretion Rate (adjusted for SLR)** mm.yr^{-1}	**Estimated Error (±)** mm.yr-1
Pauatahanui Inlet			
Zone 1	9	7.0	4.1
Zone 2	13	10.8	4.1
Zone 3	10	8.0	5.3
Zone 4	10	8.2	7.0
Zone 5	10	7.9	7.0
Zone 6	16	14.3	6.1
Zone 7	17	15.2	4.1
Onepoto Arm			
Zone 1	8	5.7	4.1
Zone 2	10	7.8	4.5
Zone 3	5	3.4	7.0
Zone 4	8	6.5	4.9

The calculation zones are illustrated below:


Zone 1
Zone 2
Zone 4
Zone 3
0.5
0
0.5
1
1.5
Kilometers
Depth relative to Mana Marina datum (m)
-2.00
-1.00
0
0.75
1.50


Zone 3
Zone 2
Zone 4
Zone 1
Zone 5
Zone 7
Zone 6
0.5
0
0.5
1
1.5
Kilometers

9.4 Using the re-gridded 2009 and 2014 datasets, updated sedimentation rates have been calculated. Calculations for each inlet have been undertaken as follows:

- Entire Inlet Area
- Main Basin (excluding the entrance region to the inlet)

Rates are calculated as follows:

(2014 Volume – 2009 Volume) / Mean surface area

This value is then divided by the number of months between surveys

Table 2: Revised Sedimentation Rates

PORIRUA HARBOUR - VOLUME SUMMARY			
Onepoto Arm			
Calculation 1 - Entire Arm		Calculation 2 - Basin (Zones 2-4)	
2009 Volume (Cut)	8649754	2009 Volume (Cut)	5633387
2014 Volume	8700956	2014 Volume	5650981
Difference	51202	Difference	17594
2009 Surface Area	2320200	2009 Surface Area	1615897
2014 Surface Area	2320467	2014 Surface Area	1617409
Mean Surface Area	2320333.5	Mean Surface Area	1616653
Deposition	0.022066656	Deposition	0.01088298
No. of Months	68	No. of Months	68
Rate per month	0.00032451	Rate per month	0.00016004
Rate per annum	0.003894116	Rate per annum	0.00192053
ACCRETION RATE PER ANNUM	***3.9mm***	***ACCRETION RATE PER ANNUM***	***1.9mm***
Comments			
Using DTM as upper surface and -4m as lower surface. 30m grid.			
Pauatahanui Inlet			
Calculation 1 - Entire Inlet		Calculation 2 - Basin Only (Zones 2-7)	
2009 Volume (Cut)	37120143	2009 Volume (Cut)	31009012
2014 Volume	37167603	2014 Volume	31031637
Difference	47460	Difference	22625
2009 Surface Area	4522550	2009 Surface Area	3784934
2014 Surface Area	4519225	2014 Surface Area	3781038
Mean Surface Area	4520887.5	Mean Surface Area	3782986
Deposition	0.010497939	Deposition	0.00598073
No. of Months	68	No. of Months	68
Rate per month	0.000154381	Rate per month	8.7952E-05
Rate per annum	0.001852577	Rate per annum	0.00105542
ACCRETION RATE PER ANNUM	***1.8mm***	***ACCRETION RATE PER ANNUM***	***1.1mm***
Comments			
Using DTM as upper surface and -8m as lower surface. 30m grid.			

9.5 The rates derived for the basin areas are believed to be more accurate, since the basins were afforded ‘high priority’ and were surveyed to a very similar sounding density for both surveys. The 3.9mm value for Onepoto Arm (Calculation 1 – Entire Arm) is considered high when compared to the other calculations due to potential anomalies in the grid comparisons where overlapping survey data did not exist for the entire Zone 1.

9.6 Based on the assessment of the relative survey coverage and accuracy of data, it is our professional opinion that the current rate of accretion for both inlets is approximately 2mm per year.

9.7 This is at variance to the previous figures (Reference B) where rates varied between 3-15mm per year. It is considered that the reduction in the accretion rate can be attributed to several factors, the obvious ones being:

- Variations in survey methodology, accuracy and completeness between 1972 and 2009 having an impact on the computed volumes. (An assessment as to the level of survey error was made and is listed in the table at Para 9.4 above).
- The rate of accretion has slowed in recent years and that a greater volume of marine and terrestrial sediment was entering the harbour system during the 1970-1980’s, considered to be a busy urbanisation period with resultant higher influx of sediment from the surrounding catchment.
- Reduction of transportable marine sediments entering the harbour system from the coastal margin as is believed to have been reported separately.

SECTION 10 SUMMARY

10.1 The re-survey of Porirua Harbour is considered complete in all respects. The primary aim of acquiring a repeat data set for survey comparisons has been achieved.

10.2 It is interesting to note that despite a period of wind and rain leading up to the survey, water clarity throughout the inlets was considered very good. In particular, the upper reaches of the Onepoto Arm were very clear and a variety of marine life was observed during the survey including numerous sting rays, schools of small fish and also a fur seal.

10.3 DML wishes to thank PCC for the opportunity to undertake this latest survey. Assistance provided by Keith Calder (PCC), Mana Marina Management and the Mana Cruising Club is greatly appreciated.

G.J. COX
Managing Director
Discovery Marine Ltd
MNZIS