Beach Change in the Auckland Region: Current State and Trends

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Beach Change in the Auckland Region: Current State and Trends

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Executive summary

The Auckland Council's Research and Evaluation Unit (RIMU) conducts biannual surveying of beach profiles to monitor beach change over time. This work is undertaken for a range of purposes such as, state of the environment reporting, providing public awareness and informing coastal managers on beach changes within the region, and consent requirements. Detailed beach profile analysis of 12 beaches is presented, with beaches categorised into four groups (west coast, open east coast, inner Hauraki Gulf, and Firth of Thames). These groups represent distinct wave climates around Auckland. This analysis evaluates beach state and trends by assessing variations in beach envelope, beach volume, and beach width (measurable beach change parameters).

Of the west coast beaches, the highest beach profile on record was measured at Piha in 2014, and has shown an upward trend of sand accumulation and beach widening across all profiles over the last 21 years. At Muriwai, the 2014 beach profiles show the foredune is moving landward, particularly in the south. Southern profiles reflect this pattern, with beach volume decreasing over the last 20 years, although more recent beach profiles show slight beach volume increases. Beach volumes at the northern profiles are mostly stable. Beach width remains steady and displays no obvious trends, but does narrow and widen substantially intermittently through the record. The disparity between changes at Piha and Muriwai highlights the independent and site specific nature of sand transport and deposition on the west coast.

Across the open east coast beaches, there are no clear trends. While a few of the 2014 beach profiles at Pakiri and Omaha reach both the maximum and minimum ranges of where the beach face moves, most are placed near the average profile (for entire record). Over the long-term, Pakiri remains stable, and Omaha has presented a net increase in sand volume of 48 per cent. There are also cyclic patterns of increases and losses of sand at both beaches that have occurred twice, at 6 to 10 year intervals, since 1988. These patterns have a weak correspondence with El Nino and La Nina climatic events. Changes in beach widths largely reflect the changes in beach volume.

The inner Hauraki Gulf beaches at Takapuna and Long Bay also have no clear trends of beach change. Cyclic changes of beach volume and width are evident at Long Bay, and display smaller, yet consistent patterns with those of Pakiri and Omaha. Beach profiles at Takapuna show beach volume and width has increased during the calmer summer months and is eroded during the stormier winter months, primarily maintaining a stable system over the survey record.

Within the Firth of Thames beaches, neither Maraetai nor Kawakawa have any discernible trends. However, the most recent surveys at Maraetai have revealed the lowest beach volumes and lowest beach profiles within the beach envelope on record. Continued monitoring may clarify if this is a trend or simply short temporal loss of sand. Kawakawa Bay profiles show small net gains of 2 - 3m^3/m of beach volume with profile four has increased by 364 per cent. In contrast to all the other beaches within the region, both these beaches have not changed as a result of seasonal shifts.

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1.0 Glossary

Accretion	Gains of sand to the beach over a long period of time
Beach envelope	Fluctuation zone of the beach profile, where maximum and minimum heights of all profiles surveyed at a particular beach are contained.
Beach profile	Horizontal cross-section of beach starting from a fixed landward position, usually a benchmark, extending seaward past mean sea level
Beach width	A horizontal measurement usually taken from a benchmark starting point out seaward to a specified vertical contour such as low tide or mean sea level
Dune ridge	Set of dunes, or multiple dunes, that are now landward (behind) of the foredune
ENSO	El Nino Southern Oscillation, periodic shifts in sea surface temperature that results in changes to wave climates in the southern Pacific. Two phases occur, El Nino (warm phase) where dominant wave direction is from the west, and La Nina (cold phase) where dominant wave direction is from the north-east in New Zealand
Equilibrium	General term for beach volume stability, or a steady-state that describes the lack of erosion or accretion trends
Erosion	Losses of sand from the beach over a long period of time
Foredune	Closest dune to the beach – sea interface, built up by sand deposited by wind and trapped in vegetation
Littoral drift	Transport of sand along the beach system, also known as 'longshore drift'
Long-term	Defined in this report as the period defining beach change greater than 30 years
Lower beachface (or sub-aerial beach)	Section of the beach that is uncovered during low/very low tides, but covered during mid-high tides
Mean sea level (MSL)	The average sea level usually taken over a rolling 19 year blocks, measuring the average of all high and low tides. Also serves as a vertical datum from which heights such as elevations are measured.
Medium-term	Defined in this report as the period defining beach change between 10 and 30 years
Morphology	Explains the shape and form of the beach profile in relation to changes driven by sand movements
Short-term	Defined in this report as the period defining beach change between 0 and 10 years
Standard deviation	Provides a value that expresses the average spreading all data points are from the mean or average
Upper beachface (or beach berm)	Section of the beach near the bottom of the dune, usually where there is constantly dry sand and the extent of the high tide

2.0 Report purpose

The purpose of this report is to provide detailed analysis of beach profiles measured bi-annually across 12 beaches within the Auckland region. This information is important as it communicates beach state and trends over time that is required for state of the environment monitoring and reporting, used to provide public awareness on beach conditions, and to better inform coastal managers. The presented analysis allows coastal managers to better understand how a beach responds to beach replenishment, dune replanting projects, coastal erosion due to large storm events, the effects of coastal protection structures and the status of recreational amenity values such as the position of the ‘dry’ beach (Komar, 1998). For example, the data collected by this program informed the decision to construct the new Muriwai surf club approximately 300m landward of the shoreline, where beach profile data which showed recent trends of severe erosion of the foredune of up to 40m (Dahm, 2000).

Analysis from this report also provides information that can be used for planning and maintaining infrastructure and residential suburbs within Auckland. Specifically, this data is of use to numerical modellers to be able to forecast how Auckland’s coast may respond to the impacts of climate change (e.g. storm surge, coastal flooding and sea level rise) now and into the future.

2.1 Report scope

The beaches incorporated into the monitoring program are grouped within four distinct wave energy settings, which help to define the magnitude of beach change in the Auckland region. This report presents and discusses the findings of beach profile analysis up to 2014 for two beaches within each of the four different groups; Group 1 – west coast (Piha, Muriwai); Group 2 – open east coast (Pakiri, Omaha); Group 3 – inner east coast (Long Bay, Takapuna); and Group 4 – Firth of Thames coast (Maraetai, Kawakawa Bay) (Figure 2-1). Analysis of Browns Bay, Campbells Bay, Milford and Cheltenham beaches are not included in the main body of the report, but can be found in Appendix B. Monitoring at these three beaches ceased with the understanding that beach change at these three sites is similar (as previously found in Kench, 2008) and sufficiently represented by analysis of changes at Takapuna and Long Bay. This report also builds on previous beach profile analysis prepared by Kench (2008), which established the original database of beach envelopes and trends for future reporting to build on.

2.2 Report objectives

- Analyse and present the current status and trends at all beaches, including beach sand budget (i.e. losing or gaining sand) and beach condition (beach width and envelope changes).
- Emphasise any beaches that show trends, those being short, medium or long-term.
- Evaluate beach profile movements within the historical beach envelope, highlighting any surveys that place in proximity to the upper/maximum and lower/minimum envelope extents.

- Provide brief discussion on the potential drivers of beach change, including the relationship between environmental factors such as ENSO, storminess, coastal infrastructure, and dune replanting.
- Discuss beach change within same groups and between other groups.

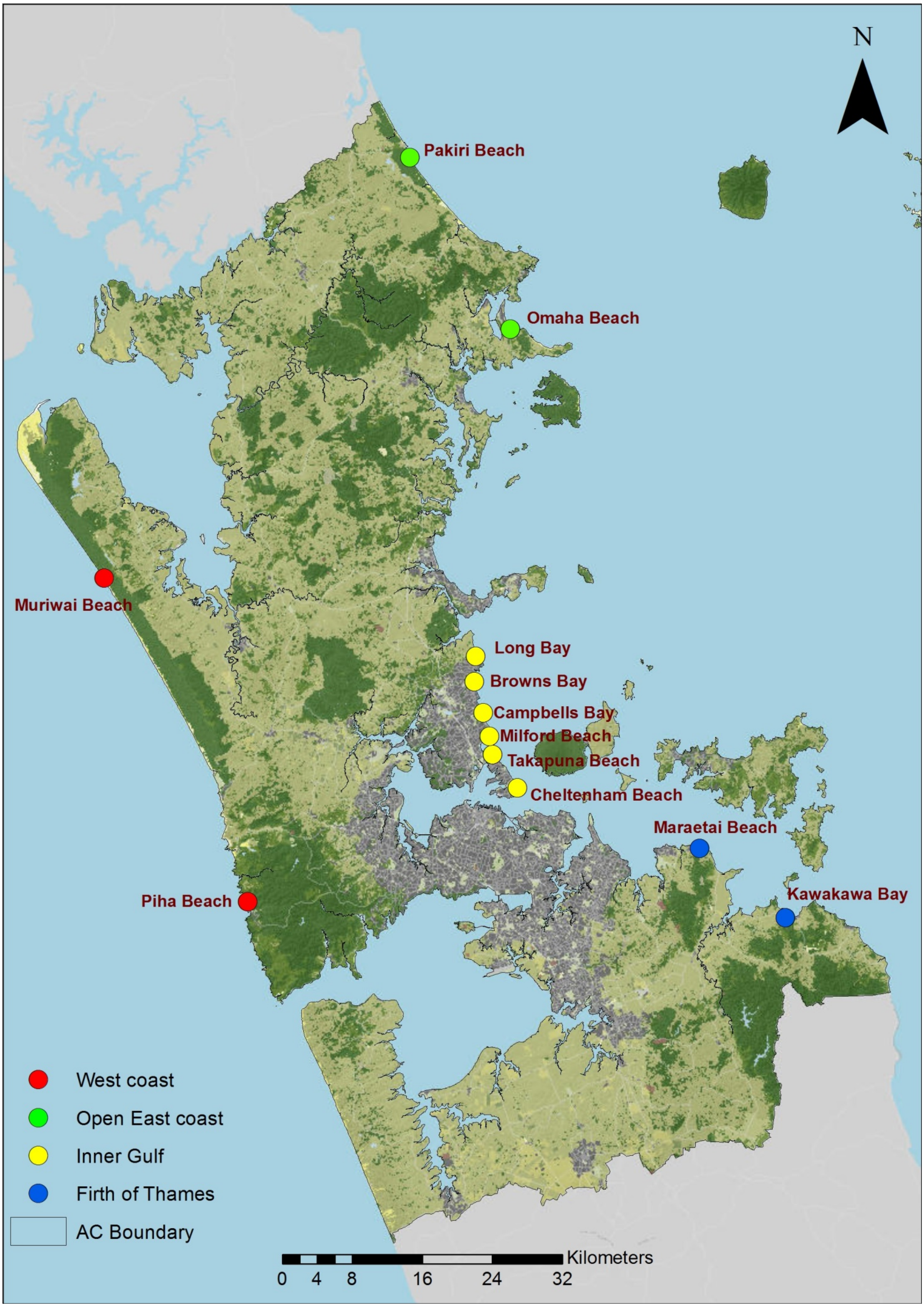

Figure 2-1 Beach monitoring locations within the Auckland region

3.0 Beach data collection and analysis

3.1 Data collection

Beach data was collected by measuring (surveying) the surface of the sand along a cross-section profile, moving from land out to low tide. The 'Emery' method, employing a tape and pole technique, was primarily used to collect surface height data every 2 - 4m, or when beach slope changed, along various length profile lines down to the low tide line (Emery, 1961). More recently, RTK-GPS (real time kinematic global positioning system) has substituted the 'Emery' method, as it increases efficiency by reducing staff resourcing with only one operator required, the time required to undertake each survey, and permits the capture of high resolution broad scale mapping (if required).

All 12 beaches have been surveyed bi-annually or monthly (at inner east coast beaches) capturing the 'summer' and 'winter' beach conditions, with post-storm beach surveying undertaken as complementary information. Lengths of monitoring records vary between 16 and 52 years (Table 3-1), and consequently many of these data sets are now beginning to provide sufficient data points to examine beach change over the medium to long-term.

Table 3-1 Beach surveying details

Beach	Initial Survey Year	Length of record (years)	MHWS contour location	Number of profiles
Cheltenham	1998	16	1.51	3
Takapuna	1998	16	1.51	3
Milford	1998	16	1.51	5
Piha	1981	33	1.76	5
Muriwai	1981	33	1.76	4
Omaha	1962	52	1.41	9
Maraetai	1998	16	1.71	4
Kawakawa	1998	16	1.71	4
Pakiri	1978	36	1.41	9
Long Bay	1982	32	1.51	2
Browns Bay	1998	16	1.51	2
Campbells Bay	1998	16	1.51	2

3.2 Data analysis

Methods for analysis have been adapted from those outlined in Cooper *et al.* (2000) and Kench (2008) in order to interpret beach change results from data collection and provide the most relevant and useable results for understanding how beaches have changed across Auckland. As a result, three parameters have been collated and analysed individually and collectively:

- Movements of individual profiles within the beach envelope
- Beach volume (sediment) stored within the beach profile
- Horizontal movements (changes in beach width), including the position of the dune-beach interface

Beach change data from these parameters was extracted using the Beach Morphology Analysis Programme (BMAP) by entering individual survey data and calculating changes against historical surveys. Results are given as graphed volume and beach width time series and beach envelopes (see Section 4.0).

Specified start and end points (contour heights) are set for each profile within BMAP. Starting points are taken from a fixed position, ideally from a benchmark placed landward of any known or forecast physical changes of the beach profile. Because this is not always pragmatic, benchmarks may be moved, lost or interfered with, therefore starting points may differ across the survey record. Accordingly, these are adjusted to best represent profile changes and capture the maximum useable data. Likewise, end points would preferably extend to the limits of sand exchange within the beach system (known as closure depth, ranging from 5 - 30m offshore) in order to fully quantify where and how sand moves. Auckland Council's beach profile surveys do not extend below low tide, this analysis is constrained to the sub-aerial (or lower beachface) and upper beachface. Primarily, mean sea level (MSL) is used in the analysis for this report, however if there is not sufficient surveys down to this contour or if data is not sufficient, then the mean high water springs (MHWS) or other specified contour (e.g. 1m is employed as a substitute end point.

Beach volume is calculated using the area underneath each profile from the established benchmark to the intersection of the seaward limit, and multiplied by 1m in beach width for outputs expressed in cubic metres per meter of beach (m^3/m). Beach width is calculated by measuring the distance between a fixed starting point and where a specified contour (e.g. MSL or MHWS) intersects each beach profile, given as meters (m). If beach volume and width data at each profile across a beach display similarities, then results are averaged and presented as “beach-wide”. If data is missing from a profile at a particular date, then the date is not used. Alternatively, if there are contrasting changes within a beach, results are presented individual profiles. For beach envelope analysis, BMAP calculates the maximum, minimum and average beach profile based on where all the surveys within the record are positioned. The most recent survey is then over-plotted and compared with the average parameters based on all previous profiles.

Combining these three parameters allows the best overview of the changes experienced at a particular profile or across a beach. For example, if beach volumes may show a decreasing (erosion) trend but if the range of recent profiles within the beach envelope are not exceeded and beach widths remain healthy then coastal management intervention is not likely required.

4.0 Beach change results and discussion

Beach change results are presented in this section, discussing both the current state and any short to long-term trends for two beaches within each of the four groups (currently monitored). Additionally, only one or two profiles (depending on conformity) are presented for beach envelope analysis at each beach as a representative for all other profiles (found in Appendix A). Beach maps and profile locations are found in Appendix A. Table 4-1 outlines the beach change statistics for all 12 beaches, providing an overview of fluctuations in sediment volume and beach width across all profile records.

Table 4-1 Beach change statistics

Beach	Profile	% volume change current survey from initial survey to 2014	Average beach volume (m^3/m)	Standard deviation beach volume (m^3/m)	Average beach width (m)	Standard deviation beach width (m)
Cheltenham	P1	156.63%	33.45	7.69	28.01	3.82
	P2	-16.52%	56.18	4.23	36.00	2.34
	P3	-0.19%	34.08	2.06	26.96	1.18
Takapuna	P1	12.54%	53.56	7.23	55.97	3.81
	P2	30.18%	55.77	7.17	52.27	6.04
	P3	-7.47%	84.39	7.37	57.69	4.94
Milford	P1	17.83%	51.65	5.40	52.41	6.60
	P2	16.36%	38.53	8.48	45.75	5.14
	P3	-0.04%	31.58	7.79	37.80	4.61
	P4	-39.33%	22.12	5.51	23.25	5.42
	P5	-54.22%	23.94	6.38	23.11	5.94
Piha	P1	48.07%	273.93	47.21	79.28	17.19
	P2	229.20%	182.38	64.88	106.73	19.64
	P3	223.61%	139.64	65.27	87.88	25.47
	P4	715.10%	63.21	37.88	71.11	22.38
	P5	88.21%	87.00	24.43	72.35	18.82
Muriwai	P1	-32.22%	196.54	39.86	74.87	8.77
	P2	12.95%	352.55	42.95	88.76	8.32
	P3	-66.35%	290.64	117.94	43.97	12.30
	P4	-43.34%	178.39	56.88	66.11	8.16
Omaha	P1	-23.01%	160.44	26.03	44.44	8.00
	P2	43.30%	146.07	40.99	38.88	10.55
	P3	238.42%	66.29	33.33	39.67	11.65
	P4	250.22%	100.19	45.30	52.37	14.50
	P5	46.89%	161.05	43.25	44.76	12.24
	P6	153.00%	91.37	51.90	68.15	19.55
	P7	201.58%	250.23	48.98	103.27	10.69
	P8	-18.69%	93.08	17.72	29.97	7.36
	P9	-17.71%	170.01	20.03	56.23	4.98
Maraetai	P1	-20.13%	48.42	5.24	57.79	2.41
	P2	-56.98%	32.13	5.70	29.12	1.80
	P3	-54.33%	22.74	4.83	27.97	2.94
	P4	-13.37%	47.08	3.42	42.78	1.77
Kawakawa	P1	15.48%	3.91	0.45	6.61	0.59
	P2	14.29%	2.57	0.56	6.67	1.63
	P3	42.56%	3.78	0.70	8.64	1.52
	P4	364.97%	5.75	2.53	12.06	5.08
Pakiri	P2A	-14.33%	216.17	56.03	51.76	13.59
	P3	1.81%	238.56	37.65	78.90	10.84
	P4	9.28%	290.96	48.51	165.62	11.84
	P5	-4.41%	196.41	43.64	89.96	10.25

Beach	Profile	% volume change current survey from initial survey to 2014	Average beach volume (m^3/m)	Standard deviation beach volume (m^3/m)	Average beach width (m)	Standard deviation beach width (m)
	P6	-23.16%	190.21	44.34	67.03	9.67
	P7	11.35%	138.40	37.71	82.60	9.99
	P8	13.95%	313.58	40.89	73.26	11.67
	P9	-14.71%	214.07	38.85	62.77	9.94
Long Bay	P1	-6.50%	25.25	5.17	26.43	4.48
	P2	47.26%	41.68	4.33	31.39	7.02
Browns Bay	P1	-22.85%	42.41	6.02	56.19	4.47
	P2	28.64%	58.93	19.59	104.82	9.70
Campbells Bay	P1	-41.74%	63.96	8.23	43.44	3.29
	P2	-33.92%	48.75	6.97	40.20	5.27

4.1 Group 1 – West Coast

Piha and Muriwai are situated on the west coast (Appendix A), which is open to southern storms from the 'Roaring Forties' region and has the highest average wave height of all beach at 2.07m (Boyle, 2014). Piha differs from Muriwai in that cliffs surround the beach and help constrain (trap) the movement of sediment within and outside the beach system, as well as offering some protection to the southern profiles 2 – 5, residential housing and southern car park areas. Muriwai is predominantly open to the southern weather systems, only constrained by a rocky headland to the south, and as a result sand is able to move more freely. Muriwai also has an extensive foredune system which is only restricted in the southern section by two car parks and, notwithstanding this infrastructure, the dunes are able to move naturally.

4.1.1 Piha Beach

4.1.1.1 Beach envelope variation

Since records began in 1981 beach shape has remained similar across all five profiles surveyed, presenting a low sloping beachface typical for high-energy west coast beaches (King *et al.*, 2006). Profile 4 (Figure 4-1) has been selected to represent all other profiles (see Appendix A) as it has the longest dataset (30 years) and highlights two key points common across other profiles. Firstly, the most recent survey (02/11/2014) is above the average profile and reaches over 90% of the maximum extent of the envelope. The other four profiles also place above the average profile, and reach the maximum extent at some position along the beachface. This indicates the current beach surface is reaching its highest range on record. Because the supply and storage of sand is greater than the ability for wave energy to strip away, the shape of the beach becomes more convex (rounded) as highlighted. Secondly, the dynamic nature of sand movement within the beach system is shown with maximum vertical fluctuations of up to 3and horizontal excursions of as much as 124m, mostly occurring between the toe of the foredune and MSL. These oscillations are second only to Muriwai (section 4.2.1) in beach envelope variability within Auckland.

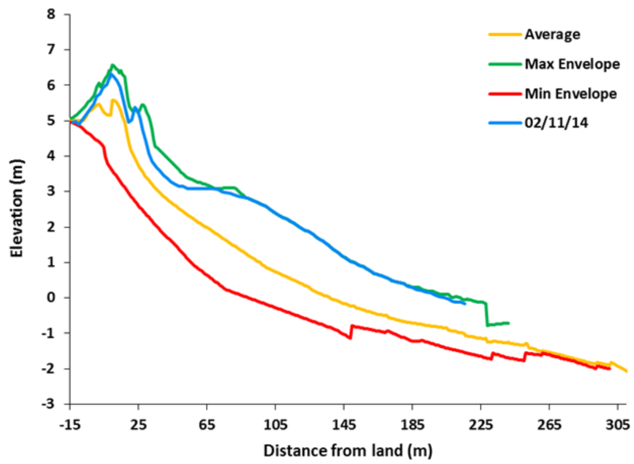

Figure 4-1 Beach envelope of Profile 4, illustrating the average beach profile in orange, the maximum extent of all profiles in green, the minimum extent of all profiles in red and, the most recent beach profile in blue. This profile is indicative of the other four profile envelopes.

4.1.1.2 Beach volume

Across all profiles there has been a long-term trend of accretion (sand gain), where all sections of the beach show a net gain and the current highest record volumes over the 33 year survey period. (Figure 4-2, Appendix A). Beach-wide averaged volumes have more than doubled from 92 m^3/m in 1993 to 203 m^3/m in 2014, with growth more noticeable after 2004. Profile 4 has steadily increased the most by 715% (from 17 m^3/m to 143 m^3/m) from the original survey, at a rate of 3.8 m^3/m/yr. (from 17 m^3/m to 143 m^3/m); with profile 2 also increasing substantially up by 229% (from 80 m^3/m to 266 m^3/m). However, there have also been phases of major sand losses, and periods of variable stability. Profile 1 gained 165 m^3/m between June and August 1997, and subsequently lost 192 m^3/m between August 1997 and April 1998, revealing the largest variability of all profiles as a likely response to large storm events. Between 1993 and 1997, the whole beach gained sand then fluctuated around a mean volume of 136 m^3/m, before losing 40 m^3/m of sand over a 16 month period to 2004. Likewise, severe erosion between May and October 2008 saw a loss of beach volume across all profiles, with up to 60 m^3/m lost at profile 3 between successive surveys.

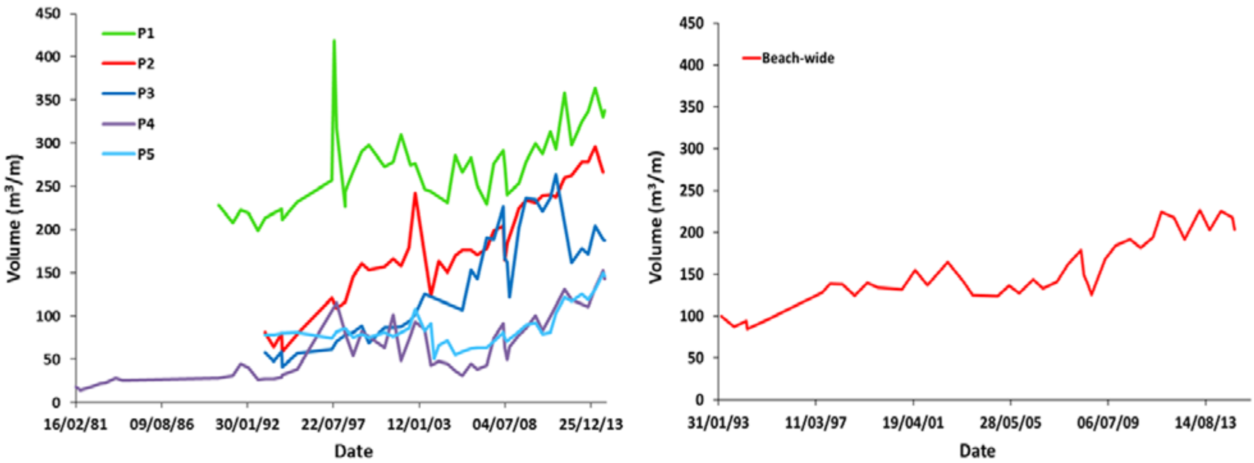

Figure 4-2 Beach volume changes at the MHWS contour, showing individual profile time series on the left, and beach-wide averaged volume time series on the right.

4.1.1.3 Beach width

Consistent with the trend of accretion displayed in beach volume and current upper envelope limits, beach widths have an overall medium-term seaward movement (positive) of the MHWS contour on all profiles (Figure 4-3, Appendix A). Beach-wide averaged change shows a 54m (84%) broadening of the beachface since 1993, with the largest increases evident from November 2004 to 2014 at a rate of 5.4 m/yr. (63m to 117m). This zone of the beach profile is also highly variable. As a result, even though a beach-wide increase is apparent, changes among profiles have not always corresponded. For example, profiles 4 and 5 showed landward retreat (-11m and -13m) between November 2004 and May 2005 while profiles 1 and 2 increased (+30m and +11m). Likewise, profiles also display substantial variability within short periods of time. As with volume, profile 1 has the largest variability increasing 48m between June and August 1997 and decreasing 67m between August 1997 and April 1998.

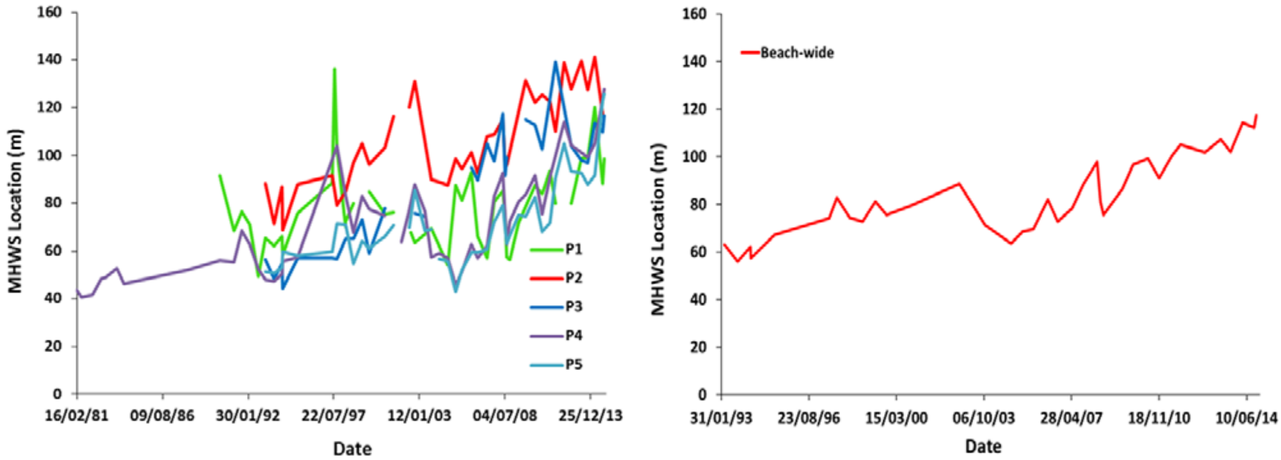

Figure 4-3 Beach width changes at the MHWS contour, showing the time series of the individual profiles on the left, and the beach-wide averaged width time series on the right.

4.1.2 Muriwai Beach

4.1.2.1 Beach envelope variation

The beach envelope at Muriwai has the largest upper/lower limits and vertical/horizontal fluctuations of all beaches within the Auckland region. Maximum vertical and horizontal adjustments occur within the upper beachface across all profiles (Appendix A), with the largest movements of 4.5m and 50m, respectively, observed at profile 3 (Figure 4-4). Most noteworthy is the proximity of the most recent survey to the minimum (landward) extent of all beach envelopes, specifically around the toe of the foredune. Profiles 3 and 4 (south) most clearly demonstrate these movements, with complete loss of the foredune in 2008 at profile 4. Additionally, the foredune slope is steepening which suggests instability resulting from constant erosion. This indicates the shoreline across the system may be retreating, and would agree with similar evidence presented by Dahm (2002).

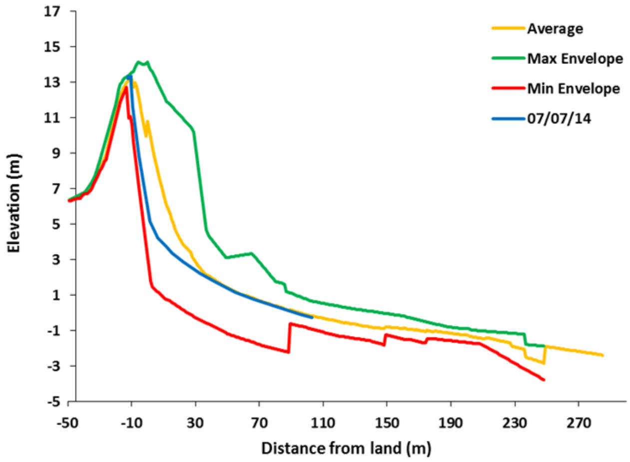

Figure 4-4 Beach envelope of Profile 3, illustrating the average beach profile in orange, the maximum extent of all profiles in green, the minimum extent of all profiles in red and, the most recent beach profile in blue. This profile is indicative of the other two profile envelopes.

4.1.2.2 Beach volume

Since 1990 beach-wide averaged volumes show there is no discernible trend, where the current volume of 225 m^3/m lies just below the mean of 249 m^3/m (Figure 4-5). However, split into northern (profiles 1 and 2) and southern (profiles 3 and 4) sections (Appendix A), it is clear that combined northern profiles are mostly stable and the combined southern beach volumes are experiencing net erosion. Between 1990 and 2009, the southern profiles sand volume dropped 189 m^3/m (from 356 m^3/m to 167 m^3/m) at rate of 9.9 m^3/m/yr. Profile 3 displays the largest successive changes with maximum losses of 170 m^3/m between February and September 1992, as well as a net reduction of 66% since 1981. Moreover, profile 3 has the largest standard deviation of all profiles across the region at 117 m^3/m. However, the most recent surveys on profiles 3 and 4 show a recovery of beach volume from their lowest levels on record. Like Piha, periods of erosion are measured across all profiles in 2005 and 2008 suggesting storm events displaced large amounts of sand on the west coast during these dates. Note that surveying did not occur at profile 4 between 2008 and 2013.

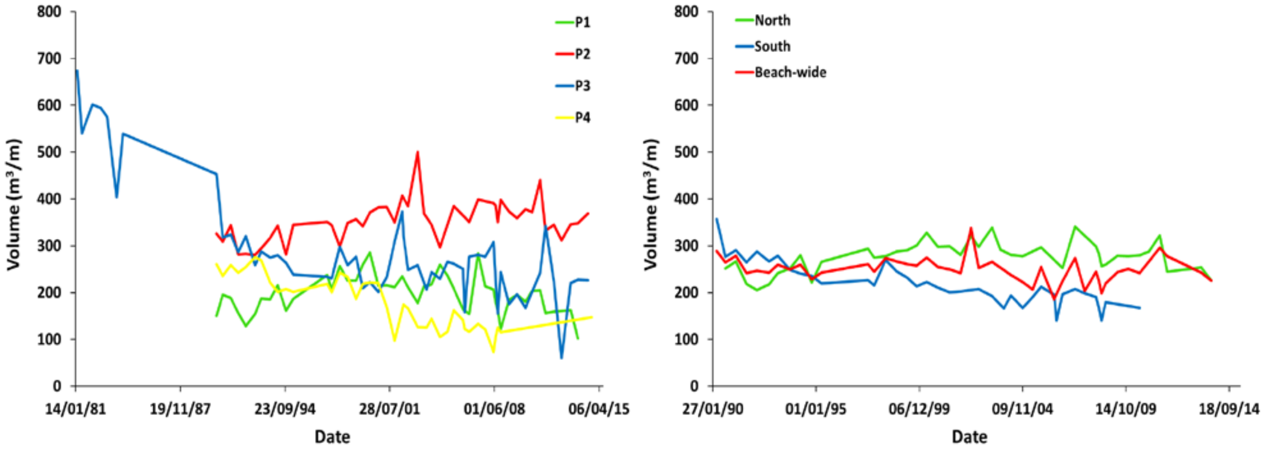

Figure 4-5 Beach volume changes at the 1m contour at Muriwai, showing individual profile time series on the left, and the combined beach-wide, northern and southern averaged volume time series on the right.

4.1.2.3 Beach width

Beach width changes at the MHWS contour do not reveal any medium to long-term trends of narrowing or widening, rather mostly stable patterns intermittent with large fluctuations (Figure 4-6). The current beach width position of 63m remains stable; close to the average contour distance of 67m. Individual profiles also reflect the steadiness of the MWHS contour, only showing large horizontal adjustments between successive surveys. For example, profile 3 increased seaward by 34m from May to October 2011 then retreating landward by as much as 40m to April 2012. Profile 3 has also narrowed the most (-39m) since the original survey from 80m in 1981 to 41 in 2014, however because the short-term fluctuations exceed this range any trend is unclear.

Interestingly, profiles 3 and 4 show their lowest beach widths between 2006 and 2008 followed by a phase of widening to the current survey in 2014. These changes mirror those observed in beach volume.

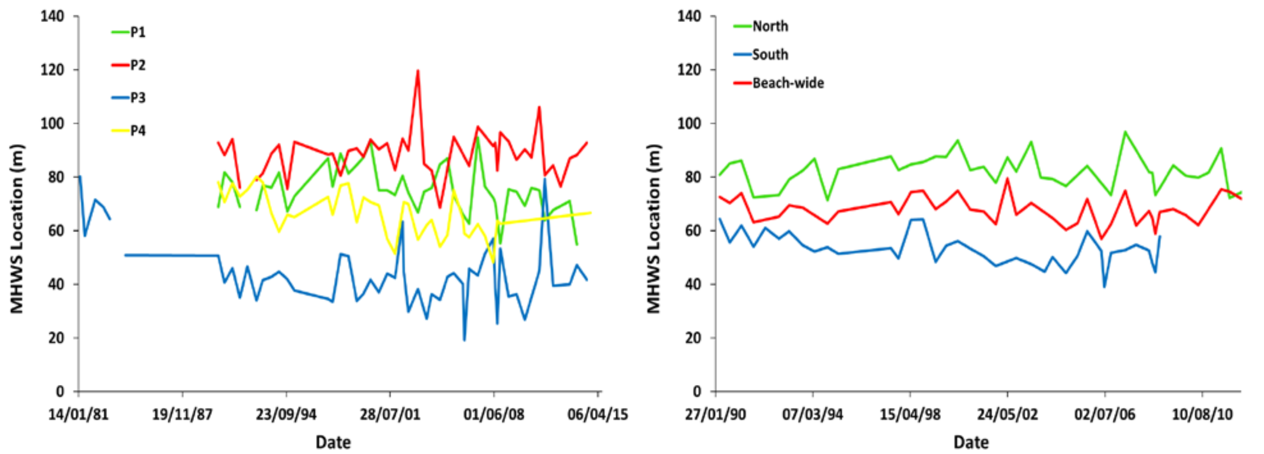

Figure 4-6 Beach width changes at the MHWS contour at Muriwai, showing individual profile time series on the left, and combined beach-wide, northern and southern averaged width time series on the right.

4.1.3 Group 1 discussion

Piha has shown an upward trend in sand gains over the record and this trend is consistent with those found in King *et al.* (2006) and Kench (2008). Numerous dune planting and reshaping works have been undertaken at Piha since the 1980s and these have been concurrent with periods of sand increases. During the early to mid-1990s, dune replanting took place using Pingao (Dahm, 2013) and coincided with the first period of beach growth. Sand levels then reduced across the beach up until 2004. Just prior to this in 2003, major reshaping and replanting of the eroded dune took place in around the surf club and southern car park area (Dahm, 2013). Again, all profiles showed positive changes and increased rapidly in volume up to 2014. However, profile 1 also increases correspondingly and is well north of the other four profiles. There has been no works undertaken here, and therefore the coincidental changes observed with dune works at southern Piha are most likely a result of large external inputs of sand (Dahm, 2013). It is important to note that vegetation and planting traps windblown sand, and surplus sand available in a system like Piha will help grow and restore dunes. Because dunes are at the frontline to wave energy, lack of dune vegetation may mean that surplus sand is not trapped and subsequently removed offshore by waves (Hesp, 2002).

Contrasting to the increases observed at Piha, Muriwai does not display any real gains across profiles, with the two southern profiles decreasing in volume since the original survey. While it is evident that the two beaches are dually affected by the same large storm events, correspondingly eroding during similar periods, sediment influx patterns are more unclear. Dahm (2002) and King *et al.* (2006) suggest that sand travels up the west coast from Taranaki as sediment 'slugs' and is deposited on Auckland's beaches. Research from Blue (2009) and Boyle (2014) show that these large quantities are not deposited simultaneously, rather independently and likely a factor of beach-specific controls like accommodation space (surrounding geology), foredune stability and variations in local hydrodynamics. Because Muriwai is a much larger system and far less constrained than Piha, these sand additions may be diluted or spread out. Foredune reshaping and replanting work has taken place at Muriwai from 2005 to 2009 at profile 4 and 200m north due to landward movements of the beach envelope and dune toe erosion. Since 2009, the southern profiles have displayed short-term recovery and more surveying may reveal that the large amounts of sand measured at Piha are now shifting north.

4.2 Group 2 – Open East Coast

Group 2 beaches, Pakiri and Omaha (Appendix A), are much less exposed than the west coasts beaches with average wave heights of only 0.7m (Dougherty, 2011). Although Pakiri is constrained by headlands to the north and south, the 12 km long beach is open to tropical cyclones from the north and deep low pressure systems to the south-east delivering large waves measured as much as 9m (Dougherty, 2011). Pakiri is the most natural east coast beach with minimal human development and is backed by a natural dune system. Sand mining also takes place offshore from the northern section of the beach as part of resource consent to replenish inner city beaches, which include Mission Bay and Kohimaramara. Conversely, Omaha is much smaller and is fully embayed by cliffs to the north and south, whilst also contains residential housing behind 75% of the foredune. The surrounding cliffs help break up waves, reducing their energy and size as well as limiting the dominant wave angle to the east to south-east.

4.2.1 Pakiri Beach

4.2.1.1 Beach envelope variation

Because of the relatively high wave exposure at Pakiri, the sand is transported and deposited more frequently than all other east coast beaches and, comparable to Muriwai, has resulted in multiple dune ridges. These act as sand reservoirs and allow the beach to move back and forth naturally in response to storms. Accordingly, the beach envelope is much broader and change is greater than the nine other beaches along the east coast. Profiles 2A and 6 (shown in Figure 4-7) illustrate the vertical fluctuations of up to 4m and horizontal shifts extending as much as 90m that take place predominantly around the upper beachface. There is also variation between the northern (2A to 4) and southern sections (5 to 9) in terms of where the most recent beach profiles are positioned. In the north, all surveys are located on or just below the average profile, yet in the south all surveys are below the average. Furthermore, over 80% of surveys at profiles 5 and 6 reach the minimum extent of the envelope, and the dune toe location at profiles 6, 7 and 8 is at its most landward position on record.

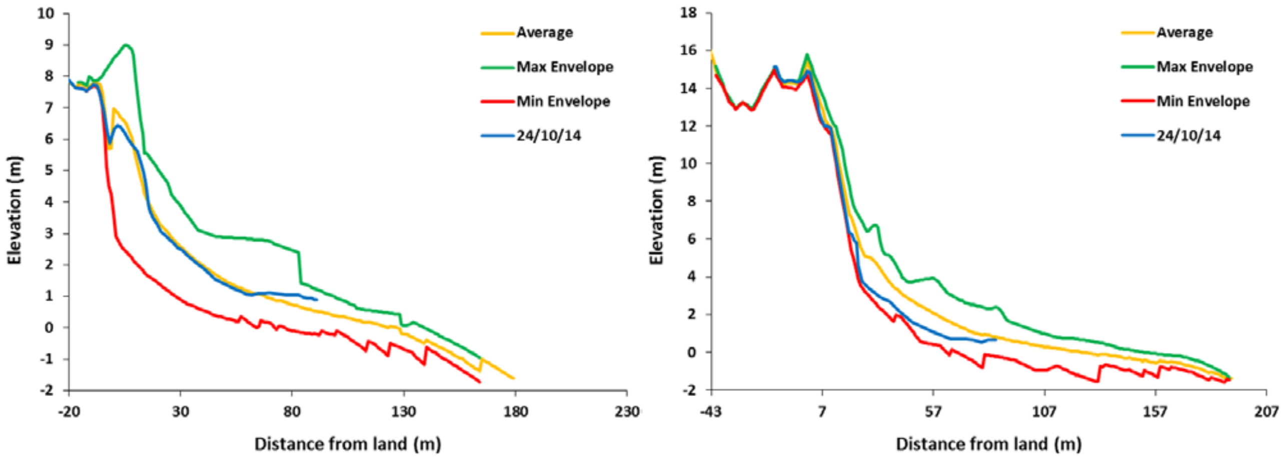

Figure 4-7 Beach profile envelope of Profiles 2A (left) and 6 (right), illustrating the average beach profile in orange, the maximum extent of all profiles in green, the minimum extent of all profiles in red and, the most recent beach profile in blue**.** These profiles are indicative of the other profile envelopes in the northern and southern sections of the beach.

4.2.1.2 Beach volume

There is no long-term trend of erosion or accretion at Pakiri since records began. The current averaged beach-wide sand volume is only $3m^3/m$ less (-12%) than in 1978 at $180m^3/m$ (presented in Figure 4-8). The highest individual change over the record is -23% at profile 6 and lowest of +2% at profile 3. Sand volume appears to increase and decrease consistently across all profiles, with slightly more volume stored in the north. This suggests that despite multiple directions for incoming waves, sand likely moves in and out of the system equally during the same phases.

What is most interesting is the cyclic pattern of volume change occurring every 7-10 years across the beach. Two cyclic phases have taken place, the first following Cyclone Bola which hit the east coast in March 1988, bringing very large waves (sizes not available) and storm surge measured at 0.5m (NIWA, 2013). Beach-wide, sand volumes dropped 60 m^3/m over three surveys (15/03/88, 11/01/89 and 15/09/89 then gradually increased to a peak of 296 m^3/m during the summer of 1994/1995. Then in July 2000 beach volume dropped to its lowest levels on record, displaying an average loss of 96m^3/m between successive surveys, and as much as 121 m^3/m lost at profile 6. Beach recovery followed this, peaking at 271 m^3/m in April 2004.

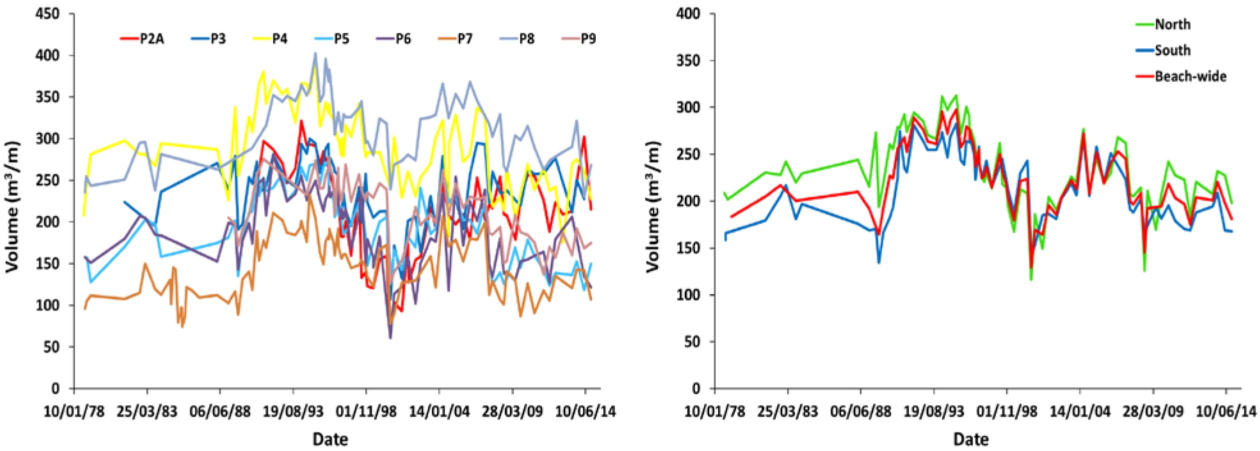

Figure 4-8 Beach volume changes at the 1m contour at Pakiri, showing individual profile time series on the left, and combined beach-wide, northern and southern averaged volume time series on the right.

4.2.1.3 Beach width

All profiles currently measure similar horizontal positions with those of the original survey (average width change of 6.2m), and exhibit no apparent trend for increases or decreases in beach width (Figure 4-9). Additionally, changes in beach width at the MHWS contour largely mirror the cyclic patterns those observed in beach volume at the 1m contour. For example, beach width increased during the same phase as beach volume from 76m in September 1989, peaking at 114m in November 1992. This position then narrowed landward by 63m in 2000, and corresponds well to relationships with ENSO discussed earlier.

For the most part, beach width at all profiles shift similar distances and during the same periods, thus supporting the notion that the beach responds to fluxes of sand as a whole. However, many profiles also exhibit large variations between surveys, with as much as 39m of seaward growth at profile 3 or as much as -34m of landward contraction at profile 4. While beach width changes may be substantial between surveys, it is clear that these do not necessarily drive the longer-term trends.

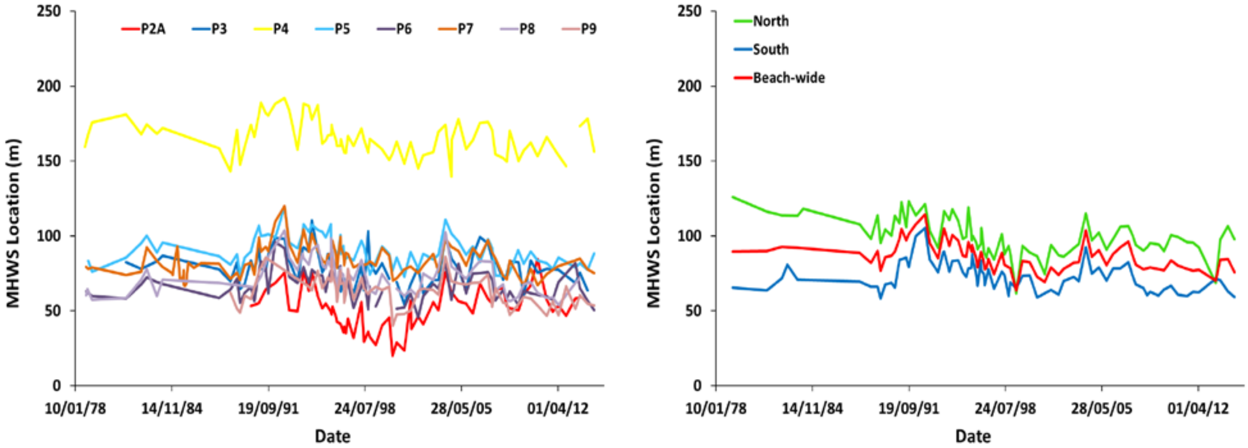

Figure 4-9 Beach width changes at the MHWS contour, showing the time series of the individual profiles on the left, and the combined beach-wide, northern and southern averaged width time series on the right.

4.2.2 Omaha Beach

4.2.2.1 Beach envelope variation

Although Omaha is backed by residential property there are still up to two dune ridges back from the beachface, including the foredune. This means the beach envelope is also reasonably broad, and change is comparable to Pakiri with vertical maximum range of >4m and horizontal excursions of up to 95m. Profile 3 (Figure 4-10); along with profiles 4 to 7, exhibit the largest envelopes. The most recent survey is on or near the upper limits of the envelope's foredune area on all profiles, indicating a healthy reservoir of sand. At the lower beachface, profiles 1 to 7 largely position around the average profile. However, at profiles 8 and 9 the most recent survey lies at the lowest range of all profiles on record. This would indicate these profiles are not receiving as much sand supply as the rest of the beach, likely due to the constraint of the main rock groynes that separates splits the two profiles. Yet, these profiles only date back to 1993, so statements in regards to any medium-term trends cannot be made with a high level of confidence. Importantly, the minimum envelope range across profiles 2 to 7 is largely due to a large east coast storm event in 1978 (Kench, 2008).

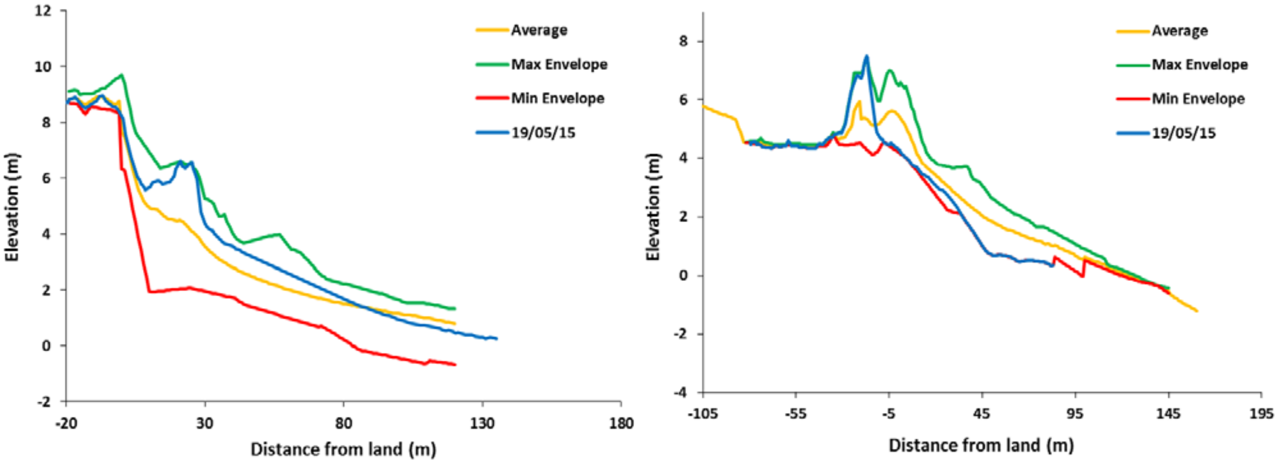

Figure 4-10 Beach profile envelope of Profiles 3 (left) and 8 (right), illustrating the average beach profile in orange, the maximum extent of all profiles in green, the minimum extent of all profiles in red and, the most recent beach profile in blue. These profiles are indicative of the other profile envelopes in the northern and southern sections of the beach.

4.2.2.2 Beach volume

Beach-wide averaged volume analysis shows a 48% increase in sand since 1965, and the most recent volume of 133m^3/m is close to the average of 148 m^3/m (illustrated in Figure 4-11). This suggests the current status of beach volume is stable. However, the combined volumes of northern profiles (5 to 8) show a gain of 307% since 1978, whilst the southern profiles are far less at 54% since 1980. Over the time series, the southern profiles fluctuate in cohesion with those in the north, although recent losses of 65m^3/m from June 2009 to July 2014 are in contrast to the northern profile gains. Continued monitoring may reveal interesting future differences in how sand is stored between the two sections of beach.

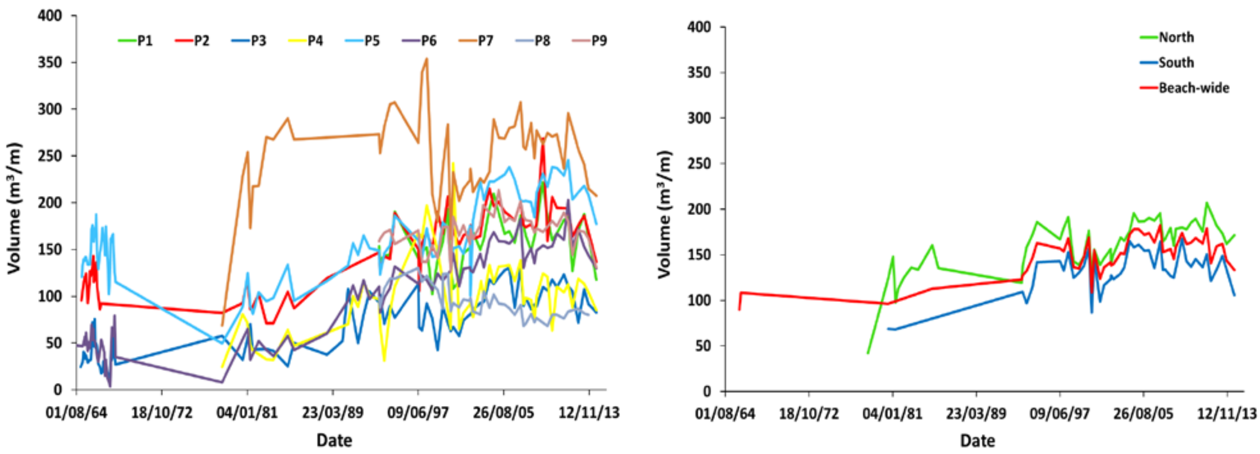

Figure 4-11 Beach volume changes at the 1m contour at Omaha, showing individual profile time series on the left, and the combined beach-wide, northern and southern averaged beach volume time series on the right.

Comparable with volume change and timing at Pakiri, Omaha also displays beach-wide cyclic patterns. Accretion occurred from 1993 (122 m^3/m) to 1998 (168 m^3/m), with a net gain of 46 m^3/m, and then again from 2001 (123 m^3/m) to 2007 (183 m^3/m), with a net gain of 60 m^3/m. Following these peaks, sand mostly decreased, with evidence of large short-term variability. A Storm event in July 2000 had a substantial impact on beach volumes where as much as 121 m^3/m of beach volume was lost at profile 7. The beach also displays the ability to recover well following extensive erosion, for example after the major east coast storm of 1978 profile 7 gained as much as 159 m^3/m gained between August 1978 and July 1980.

4.2.2.3 Beach width

There is no clear trend across all profiles for beach width change at the 1m contour, with the beach-wide width of 83m positioned just below the original of 89m, and just under the average of 97m (Figure 4-12). Horizontal movements across the record largely reflect those observed in volume patterns with some evidence of cyclic seaward growth and landward contractions, although these are less clear. The averaged beach widths at the northern section show the current position (100m) seaward of the position of 1978 (69m), with the southern section showing a slightly more landward current position (76m) to 1965 (97m). Profiles 7 and 2 display the largest fluctuations; where beach width at profile 7 moved seaward 63m in from August 1978 to July 1980, and beach width at profile 2 moved landward 90m from June to November 2009 and is the biggest successive change of all Omaha beach profiles. These highly variable, short-term changes in sand storage exceed the overall beach width movements across the record, masking any trends that may be present

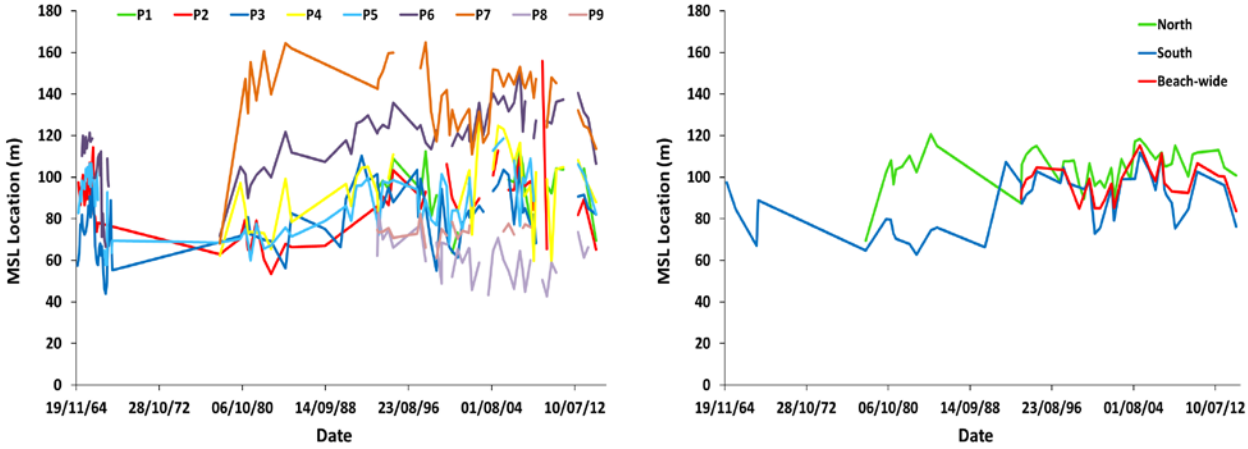

Figure 4-12 Beach width changes at the 1m contour, showing the time series of the individual profiles on the left, and the combined beach-wide, northern and southern averaged widths on the right.

4.2.3 Group 2 discussion

Although the surveying record only captures two cyclical phases of change at Pakiri, there seems to be a decadal (0-10 year periods) relationship with the El Nino-Southern Oscillation climatic phenomenon (ENSO). During El Nino the beach maintains a healthy store of sand, and then during La Nina sand levels are reduced, most likely due to increase north-east storm activity. As illustrated in Figure 4-13, the peak phases of beach volume accretion correspond well with peaks in El Nino. As discussed previously, the two erosion events observed in 1988 and 2000 also happened during La Nina phases, with and additional beach-wide loss in 2008 also occurring during La Nina. However, beach change also occurs contradictory to the fact, gaining sand during La Nina (e.g. 1998-1999) and losing sand during El Nino (e.g. 2013-2014). Because the record is not long enough and there is no wave data to support any statistical correlation, these relationships cannot be fully quantified.

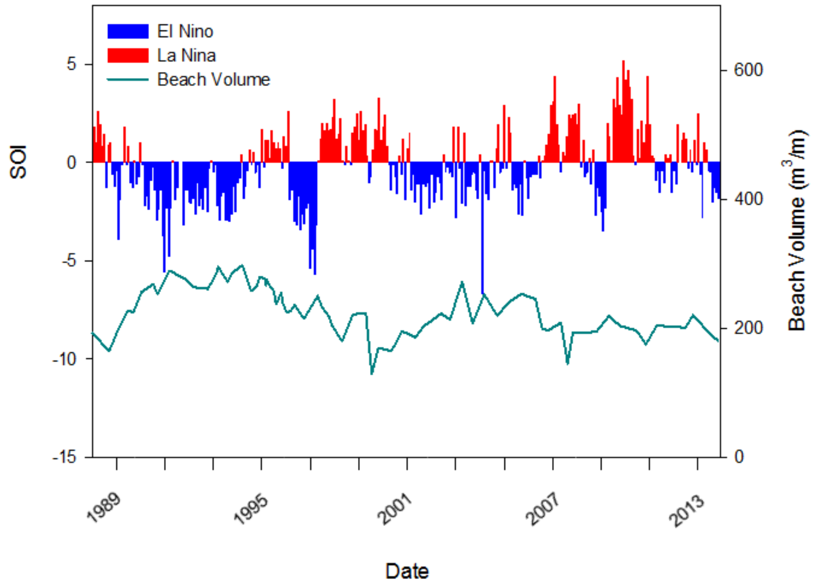

Figure 4-13 Displaying ENSO trends measured by SOI values since 1987, with El Nino represented by blue bars and La Nina in red at the top, and averaged beach-wide volume oscillations at Pakiri are in teal on the bottom. Note the two main cyclic phases of El Nino (between 1989 and 1996; and 2000 and 2006) correspond to increases in beach volume (Source: http://www.cpc.ncep.noaa.gov/data/indices/soi).

Omaha also illustrates cyclic relationships in both beach volume and beach width with ENSO phases, although these are less dynamic than those at Pakiri. Due to the protection of headlands from northerly wave direction at Omaha, it is possible that Omaha is less sensitive to ENSO shifts than Pakiri. This is supported by the lack of erosion observed at Omaha following Cyclone Bola in March 1988, whereas volumes clearly dropped at Pakiri (Figure 4-8).

Based solely on the data presented, it seems that El Nino phases affects beach change more over the medium-term (5-10 years) and La Nina phases impact more severely over the short-term. Future monitoring, combined with accurate wave data, may paint a clearer picture of these relationships and provide the ability to forecast potential beach changes.

4.3 Group 3 – Inner Hauraki Gulf

Within the inner Hauraki Gulf, Group 3 beaches (Appendix A) have lower wave exposure than that of the open east coast beaches, and notwithstanding specific inner gulf data, Reinen-Hamill *et al.* (2006) suggests average wave heights of >0.4m. Long Bay is encased by cliffs to the north and south, and backed by a regional park inland of the foredune. To the north lies the Whangaporaoa peninsula, which serves to protect the beach system from the dominant north-east wave direction, leaving the east and south-east corridors for larger wave energy. Takapuna is less constrained, with small cliffs to the south and a reef system that connects with Milford beach to the north, backed by mostly residential property immediately landward of the upper beachface. Additionally, waves reach the beach from the north through to the south-east.

4.3.1 Takapuna Beach

4.3.1.1 Beach envelope variation

The beach envelope is consistent across all three profiles, with much of the change occurring between 15m and 90m offshore (Figure 4-14). The most notable occurrence is that the recent survey places at the minimum limits of the envelope. Profiles 1 and 3 also show that the minimum limits of the envelope are reached (Appendix A), indicating that sand levels are at their lowest (from 50m to 80m from the benchmark). In 2014, a newly exposed one-million year old petrified kauri forest emerged around the lower beachface and provides further evidence for the lowest sand levels on record (Stuff, 2014).

Conversely, the most recent survey on profiles 1 and 2 also extends to the maximum envelope range at the upper beachface (approximately 20m to 30m from the benchmark), with the survey just below the average at profile 3 (Appendix A).

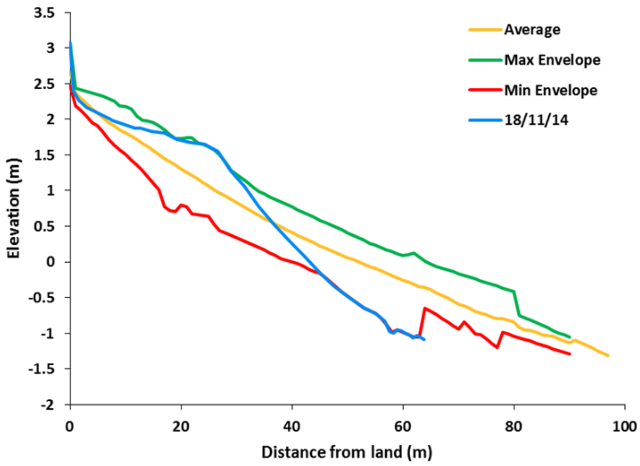

Figure 4-14 Beach profile envelope of profile 2, illustrating the average beach profile in orange, the maximum extent of all profiles in green, the minimum extent of all profiles in red and, the most recent beach profile in blue. This profile is indicative of the other two profile envelopes.

4.3.1.2 Beach volume

As illustrated in Figure 4-15, there is no trend towards net sand gains or losses at all profiles on Takapuna beach, where the current beach-wide volume is equal to that of the original in 1998 at 65 m^3/m. This is also the case for the three individual profiles, with little change across the record. Standard deviations presented in Table 3-1 (section 3.0) show equal variation meaning sand exchange within each profile behaves the same way. Beach change is dominated by seasonal adjustments rather than long-term patterns, gaining sand during the end of summer (calmer months) and losing sand at the end of winter (stormier months). For example, the 2014 survey at profile 2 shows an increase of 30% more sand since 1998, yet consecutive survey measurements meet or exceed this value several times over the record. Between May and November 2013, 36 m^3/m (49%) of sand was lost, accounting for the lowest profile volume across the record. As with Omaha and Pakiri, sand was removed across the beach after the storm event in July 2000, with beach-wide average volume loss of 21 m^3/m since April. However, the cyclic patterns and potential links to ENSO are not evident at Takapuna and patterns of change are not consistent with the more open east coast beaches.

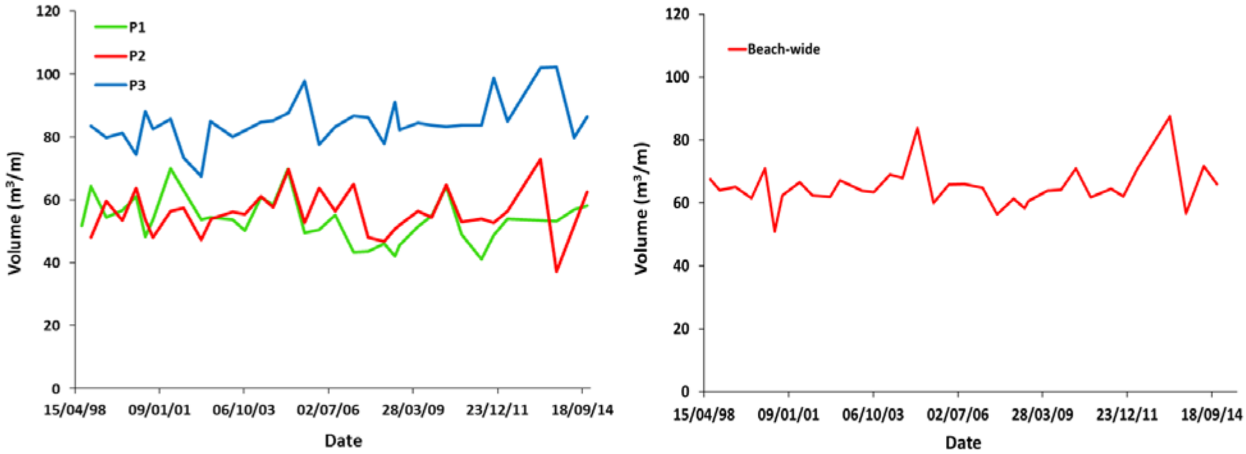

Figure 4-15 Beach volume changes at the MSL contour at Takapuna, showing individual profile time series on the left, and beach-wide averaged volumes time series on the right.

4.3.1.3 Beach width

Whilst the MSL contour does not reveal any marked change in beach widths (Appendix B), the time series at the MWHS contour does show two important points (Figure 4-16). Firstly, profile 3 has a much wider average beach, almost double at 30m compared to profiles 1 (13m) and 2 (16m). Secondly, profiles 1 and 2 are shown to be widening at the MHWS contour, where the most recent survey shows these profiles are at their maximum seaward extent on record, and almost at the same width as profile 3. These changes correspond to the observations previously discussed in envelope variation and the maximum extent of the recent survey in 2014.

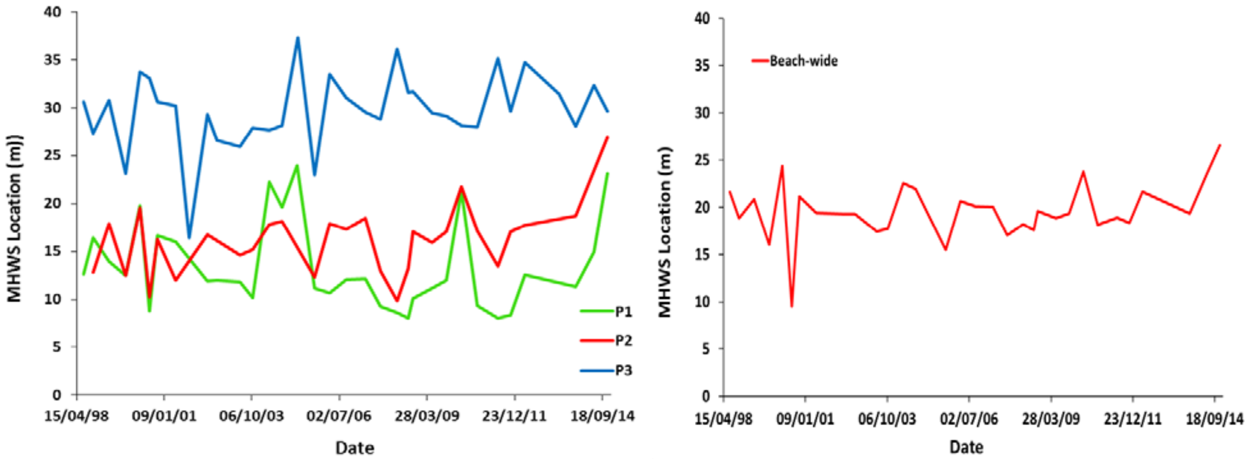

Figure 4-16 Beach width changes at the MHWS contour, showing the time series of the individual profiles on the left, and the beach-wide averaged widths on the right.

4.3.2 Long Bay

4.3.2.1 Beach envelope variation

Due to the relatively low wave exposure, the beach envelope is narrow with little variability and maximum vertical shifts of 1.2m and horizontal movements of 50m (Figure 4-17). Both profiles exhibit the most variation around the MHWS contour (1.51m). The 2014 survey is positioned under the average at both profiles, with around 50% at profile 1 reaching the minimum extent of the envelope. Markedly, the toe of the foredune at both profiles is at its most landward position since surveying began.

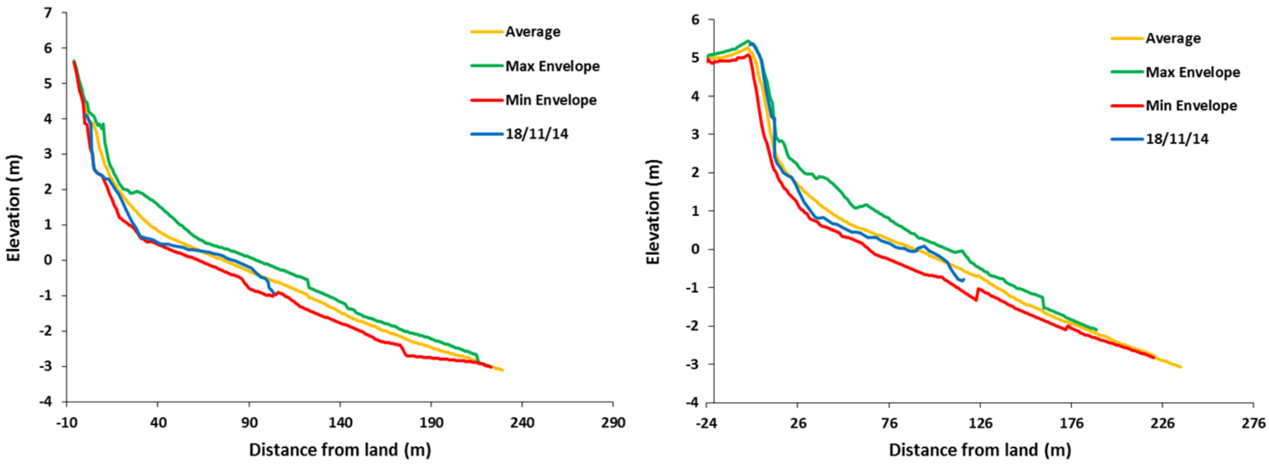

Figure 4-17 Beach profile envelope of profiles 1 (left) and 2 (right), illustrating the average beach profile in orange, the maximum extent of all profiles in green, the minimum extent of all profiles in red and, the most recent beach profile in blue.

4.3.2.2 Beach volume

As with the previously analysed east coast beaches, there is a lack of any underlying long-term trend with apparent stability of sand volumes at Long Bay. At profile 1, the current volume of 21 m^3/m is only 1.5 m^3/m less than that of the original survey of 23 m^3/m. At profile 2, the current volume of 46 m^3/m is above the original survey of 32 m^3/m, and while this may indicate a net gain, this increase is only 4 m^3/m above the average volume of 42 m^3/m. More obvious is two cyclic phases of sand gains and losses that are interspersed with large sand fluctuations (Figure 4-18). The major cyclic phase at profile 1 saw an increase from 23 m^3/m in March 1988 to 38 m^3/m in April 1994. Then volumes reduced 43% over a 2 year period by October 1997, further reducing to the second lowest recorded beach volume of 18 m^3/m by October 2000 following the large July storm event (Kench, 2008). Slight increases occur up to April 2007, then volumes gradually decline until July 2014. Profile 2 behaves much the same way up until the July 2000 storm, when this section of the beach became highly variable (dynamic) between surveys to 2014.

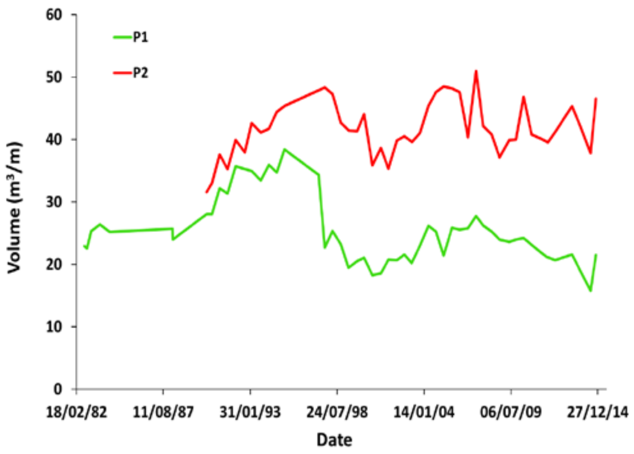

Figure 4-18 Beach volume changes at the MHWS contour at Long Bay, showing the time series of profile 1 in green and profile 2 in red.

4.3.2.3 Beach width

Horizontal migration of the MHWS contour essentially reflects the fluctuations observed in beach volumes, as illustrated in Figure 4-19. As such, there is evidence of a 7-10 year cyclic period increasing seaward from 1988, peaking in 1992 and then retreating landward to the second narrowest width on record by 2000. The beach width at profile 2 shows more dramatic movements between surveys, with as much as 16m compared to 13m at profile 1. However, the most recent survey on both profiles is very close to the beach width values from the original survey (-3m at profile 1, and +1.5m at profile 2), indicating there is no long-term trend.

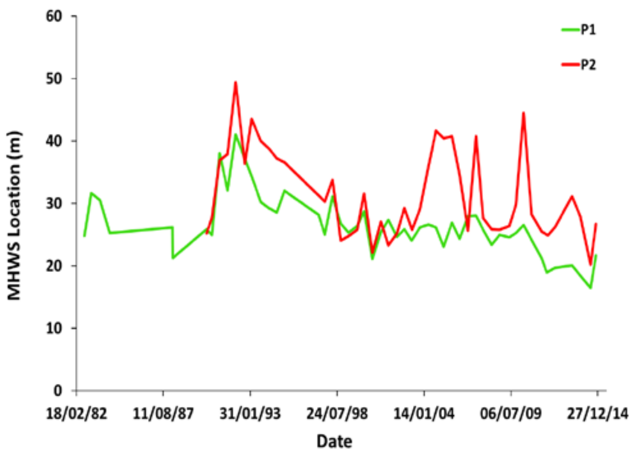

Figure 4-19 Beach width changes at the MHWS contour, showing the time series of profile 1 in green and profile 2 in red.

4.3.3 Group 3 discussion

The lower beachface at southern Takapuna beach (profiles 2 and 3) is constrained by an underlying rock layer. This means that sand levels at this section of the beach cannot get any lower past this surface. Given that the most recent survey places at the maximum and minimum ranges of the beach envelope, it would seem that the beach adjusts to the seasonal wave climate with sand transport and deposition occurring up and down the profile rather than being lost from or coming into the system as new material. The fact there is no medium-term erosion or accretion trend for beach volume supports this, as well as highlighting that Takapuna does not display any relationship with ENSO. Because much of the upper beach is backed by seawall structures and there are no dunes, the ability to store sand is severely limited. The seawalls prevent any landward migration of the upper beach, and therefore preclude extra space for sand to move. As a result, it may be that the effects of ENSO are masked.

On the other hand, Long Bay has more of a natural foredune and no 'hard' structures like seawalls. Beach volume matches the cyclic patterns that are also evident at Omaha and Pakiri, with a phase of accretion from 1988 to 1994 followed by erosion, corresponding with the strong El Nino period. Reshaping and replanting work took place in the early 2000s to help re-establish the eroded foredune following the July storm. After this period, beach volume increased at both profiles.

4.4 Group 4 – Firth of Thames

Group 4 beaches have the lowest wave exposure of all beaches within the Auckland region due to the shadow of Waiheke and Chamberlins Islands and the Coromandel Peninsula, which block wave energy from the north to the east (Appendix A). The Firth of Thames beaches have the lowest average wave heights of all areas (Kench, 2008). Maraetai is a small, steep pocket beach embayed by rocky headlands to the west and east and backed partially by residential/business uses and parkland. A seawall also runs through the middle of the beach protecting car park and road infrastructure. Whilst protected from dominant wave energy to the north and east, Maraetai is subject to west and north-west winds and currents that move east across the Tamaki Straight. Kawakawa Bay is also encapsulated by rocky headlands to the west and east; however it is far more sheltered than all other beaches in the region, including Maraetai and tidally dominated. A road runs directly behind the entire beach, and behind is mostly residential housing. The beach is also the only system in the region that is characterised by tidal flat sediment (including shell fish, muds, and silts).

4.4.1 Maraetai Beach

4.4.1.1 Beach envelope variation

The beach envelope is the steepest of all beaches in the Auckland region, indicating Maraetai is a reflective type beach (low wave energy at the shoreline). As with at least one profile from all the other beaches along the east coast, the most recent survey is placed at the minimum extent of the envelope across the beach and covers over 80% of each profile (represented on profile 2, Figure 4-20). This means, as of 2014, the beach is at its lowest surface height since surveying began in mid-1998. However, because the record is so short the envelope may not have captured enough surveys and confidently measured all vertical and horizontal movements, of which are driven by different seasons, ENSO variation, cyclone activity etc.

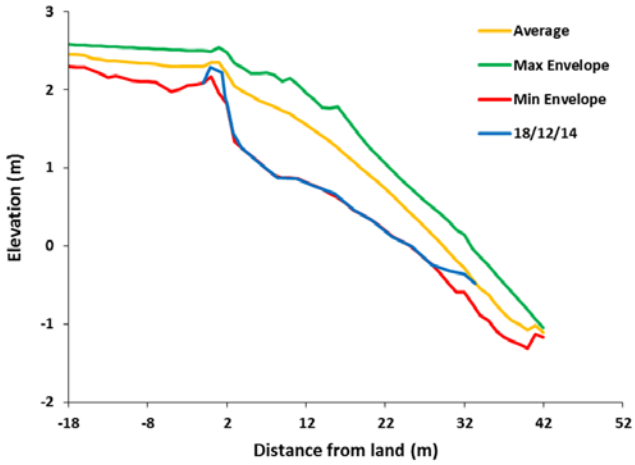

Figure 4-20 Beach profile envelope of profile 2, illustrating the average beach profile in orange, the maximum extent of all profiles in green, the minimum extent of all profiles in red and, the most recent beach profile in blue. This profile is indicative of the three other profiles along the beach.

4.4.1.2 Beach volume

Up until 2012, beach volume showed small fluctuations around a beach-wide averaged volume of 38 m^3/m, with no discernible trend of accretion or erosion (Figure 4-21). However, the time series shows that volumes began to drop on all profiles from this date to their lowest levels on record, with an average loss of 14 m^3/m. Profiles 2 and 3 have lost the most sand since the original survey, with net losses of 20 m^3/m (56%) and 14 m^3/m (54%) respectively. There does not appear to be much variation between profiles east to west, although the two outer most profiles (1 and 4) contain the most sand within their profile. Similarly, there are a few instances where sand fluxes do contrast between profiles. For example, from September 2005 to 2008, profile 1 exhibited a phase of sand volume growth and during the same period profile 2 lost sand. A comparable period of disparity also occurred from 2008 to 2010. Likewise with the eastern profiles, profile 4 lost 8 m^3/m between May and October 2003 and profile 3 showed little change.

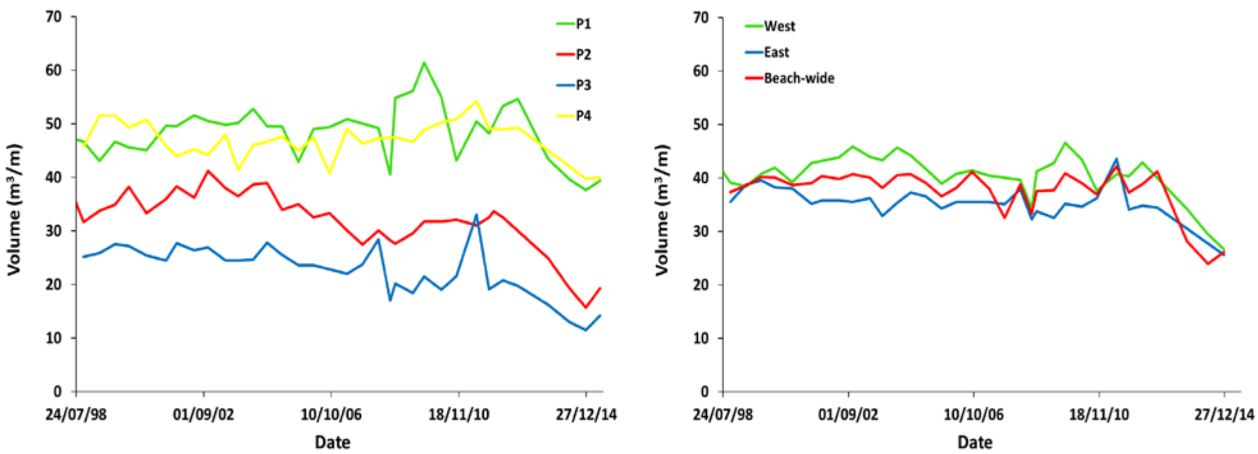

Figure 4-21 Beach volume changes at the MSL contour at Maraetai, showing individual profile time series on the left, and the combined beach-wide, eastern and western averaged volumes time series on the right.

4.4.1.3 Beach width

Interestingly, beach width at the MSL contour shows a high degree of stability with little variation across the record, as presented in Figure 4-22. The average standard deviation of 2.23 m^3/m is very low and further supports steadiness of this contour across the beach. Small horizontal fluctuations do occur over most profiles, yet these are greater than the overall trend since surveying was initiated, meaning the identification of any trends is difficult. This point is particularly important over such a short record, where longer time series may capture more notable movements and start to tease out trends. Similar to the storage of sand in the most eastern (profile 4) and western profile (profile 1), the widest parts of the beach are found at these outer most profiles.

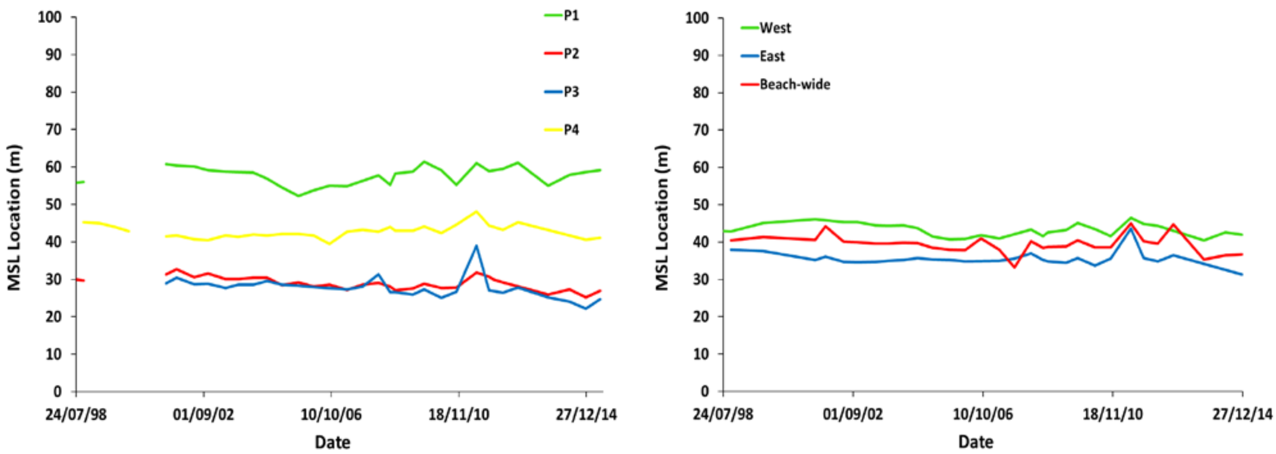

Figure 4-22 Beach width changes at the MSL contour, showing the time series of the individual profiles on the left, and the combined beach-wide, eastern and western averaged widths on the right.

4.4.2 Kawakawa Bay

4.4.2.1 Beach envelope variation

Because surveying has not extended to the MSL contour, analysis is restricted to the upper beachface and the MWHS contour. Most change within the envelope occurs around 30m (upper beachface) seaward of the benchmark (Figure 4-23). All three profiles show little variation in envelope morphology, likely as result of protection from large wave events. Vertical adjustments are therefore limited a maximum of 0.4m, and are the lowest out of all beaches in the region. Interestingly, the most recent survey shows the beach profile is at its lowest on record at three of the four profiles 40m seaward of the 0 starting point. Contrastingly, the most recent survey is positioned at or near the maximum limit of the beach envelope landward of 40m, and specifically at the berm/dune area. Because there is minimal change in these envelopes (both horizontally and vertically) over such a short record period, it is difficult to discern any long term trend.

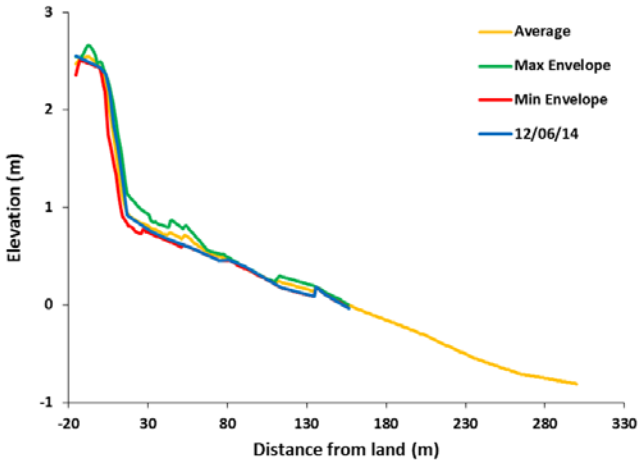

Figure 4-23 Beach profile envelope of profile 3, illustrating the average beach profile in orange, the maximum extent of all profiles in green, the minimum extent of all profiles in red and, the most recent beach profile in blue. This profile is indicative of the three other profiles within Kawakawa Bay.

4.4.2.2 Beach volume

Net increases in sand are evident at all four profiles at the MHWS contour, where beach-wide average volumes show the system has increased from 3 m^3/m to 5 m^3/m in the 16 year period (Figure 4-24). Aside from profile 4, net gains remain small and indicate stability rather than an accretion trend. Profile 4 has had the highest net gain, increasing 364% from 3 m^3/m to 12 m^3/m, and does show a trend towards accretion. Storm erosion is apparent in September 2008, displaying beach-wide losses of sand. Following this period, all profiles demonstrate net sand gains, where this is especially obvious in Profile 4.

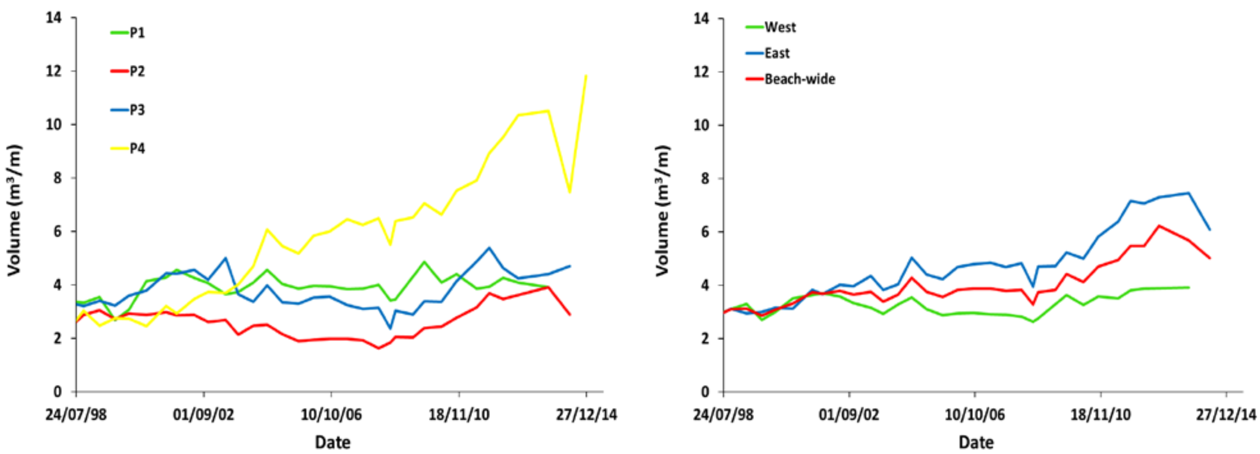

Figure 4-24 Beach volume changes at the MHWS contour at Kawakawa Bay, showing individual profile time series on the left, and the combined beach-wide, eastern and western averaged volumes time series on the right.

4.4.2.3 Beach width

Measured changes of the beach width at the MHWS contour directly reflect the adjustments in beach volume (Figure 4-24), with all profiles exhibiting net seaward increases since 1998 (Figure 4-25). Change at this contour takes place at the intersection point between the upper beach berm and the grass verge, meaning that increases in width correspond with additions of sand to the berm area. Profile 4 has again increased the most, broadening 20m over the record, and display the most variability with the highest standard deviation of 5 m^3/m compared to the next closest of 1.6 m^3/m (Table 5-1). One interesting sequence is the correspondent oscillation of profiles 2 and 3 (also evident in volume time series) over the record. Both profiles widen and narrow similarly over 4 – 6 year phases, decreasing between October 2003 and April 2008, and then broadening to their current state. It is striking that these shifts occur in spatially different parts of the system, separated by a rock outcrop.

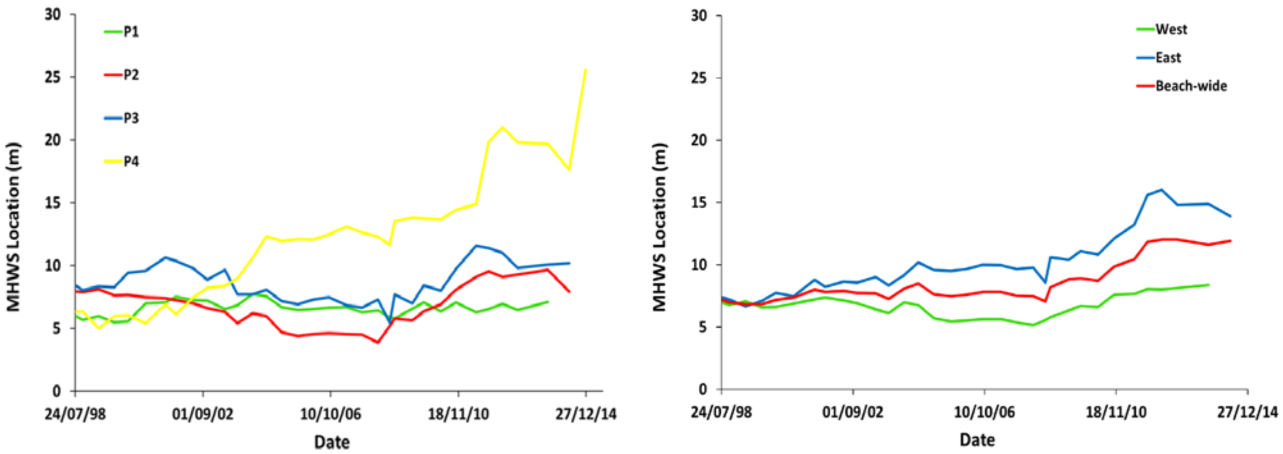

Figure 4-25 Beach width changes at the MHWS contour, showing the time series of the individual profiles on the left, and the combined beach-wide, eastern and western averaged widths on the right.

4.4.3 Group 4 discussion

All four profiles at Maraetai exhibit consistency in their beach envelope shape, and in both beach volume and widths. This suggests that sand moves and is deposited relatively evenly across the beach. However, in contrast, profiles 2 and 3 (middle beach) have the lowest volumes, with both decreasing over 50% since the original survey (Table 4-1). Additionally, these two profiles also have the narrowest beach widths. Seawall construction in 2010 took place as a means to prevent further erosion of the upper beach berm and restrict landward movements into the car park and road. In 2011, there was some sand replenishment at this section of the beach, and then again in early 2014, there were some major repairs and more sand transfers. It would seem that the middle of the beach acts as a focal point for incoming energy, and at its present position, in relation to water level, is vulnerable to further sand losses. Because profiles 1 and 4 do not show any evidence of corresponding volume increases, sand is likely lost offshore. These adjustments are important to note for any future management decisions.

Much of the beach change at Kawakawa Bay seems to be occurring around the berm/upper beachface area. There is evidence of grass growing at the beach/berm interface at all four profiles, indicating this section of the beach is stable or increasing seaward. Of all the beaches within the region, Maraetai and Kawakawa Bay are the only beaches that do not exhibit any seasonal variation in respect to beach change. The influence of the Tamaki Straight may therefore be more important than any wave energy supplied from the north in determining how these beaches operate.

5.0 Regional conclusion

Beach change within the Auckland region is largely driven by exposure to wave energy. The highest wave energy within the region is on the west coast, with the lowest found in the Firth of Thames area. Piha and Muriwai display the most variability, and Kawakawa Bay and Maraetai display the least. Between these two hydrodynamic extremes sit the open east coast beaches, and the inner Hauraki Gulf beaches. Changes in sand movement at these beaches declines north to south in accordance with decreases in wave exposure. Changes in beach morphology are not always consistent within each group’s coastal setting. This may be influenced by site-specific characteristics such as sediment supply, accommodation space (local geology), dune formation and stability, coastal infrastructure, hydrodynamics (local waves and currents).

From the analysis reported, it is apparent that beach change is driven seasonally (winter vs. summer wave climates), inter-annually (between years), and cyclically (over 6-10 year periods). With the exception of a few, most beaches have surveying records beginning around the late 1980s to late 1990s, and are still too short to be able to accurately define medium to long-term trends.

Notwithstanding the temporal limitation of the dataset, analysis has revealed a number of key points:

- Piha Beach has shown a clear increased trend of accretion and beach widening across all profiles since surveying began, and most rapidly since 2003. Major increases in sand volumes have coincided with dune reshaping and replanting work at the southern section. The most recent survey exceeds the maximum extent of the beach envelope at all profiles, indicating peak sand levels at this beach.
- At Muriwai, the two northern profiles appear to be stable while the two profiles in the south have decreased in volume. Beach volume at all four profiles are equally affected by large wave events, yet their recovery occurs unevenly. Similar to Piha, recent dune reshaping and replanting has corresponded with slight beach volume recovery from 2009 to 2014.
- Disparity between change at Piha and Muriwai highlights the independent and site specific nature of wider sand transport and deposition mechanisms on the west coast.
- Beach profiles at Pakiri and Omaha exhibit substantial short-term variability over the record, and although Omaha shows a 48% increase in sand volumes, both beaches appear to be stable. The multiple dunes landward of the foredune at both beaches may serve to buffer the impacts of storm waves and act as sand reservoirs to the system when sand levels are low.
- At Pakiri, there are cyclic patterns where sand increases and decreases over 6 to 10 year blocks. There appears to be a broad relationship with ENSO. Sand accumulation occurred during strong El Nino phases, when predominant westerly weather patterns have allowed beach recovery. On the other hand, storm erosion is shown to rapidly displace beach volumes, with the most notable events occurring during 1988, 2000 and 2007 and within strong La Nina phases.

- These cyclic patterns are also evident at Omaha, although the relationship with ENSO is far less apparent. Headland protection at Omaha has subdued some of the storm impacts observed at Pakiri and may have served to dilute the effects of ENSO variation. For example, sand volumes and beach widths did not reduce following Cyclone Bola in 1988, whereas the reverse was observed at Pakiri.
- At both the two inner Hauraki Gulf beaches, there are no medium to long-term trends and both beaches appear stable. However, recent surveys place at the minimum extent of the beach envelope, likely as a result of extended easterly storms in June and July 2014. The four other inner gulf beaches also exhibit this (Appendix B).
- Takapuna displays only seasonal fluctuations, where sand accumulates during the calmer summer months and reduces over winter.
- Beach volume at Long Bay follows the cyclic patterns presented at Pakiri and Omaha, and occurs during the strong El Nino phase from 1988 to 1994. After the July 2000 storm, dune works took place and subsequent beach recovery followed at both profiles.
- Maraetai has no discernible trends of accretion or erosion across the record, although more recent surveys have revealed the lowest volumes and minimum envelope extents on record. Extension of the dataset is required to clarify if these changes are short-term event driven or more of a medium-term pattern.
- Kawakawa Bay shows net sand gains at the MHWS contour across all profiles since records began, most of these gains are limited to 2 – 3 m^3/m although profile 4 has increased by 364%.
- Both the Firth of Thames beaches do not change as a result of seasonal shifts, most likely due to the lower exposure to wave energy.

6.0 Recommendations

As highlighted by Kench (2008), further monitoring will extend these datasets and begin to form clearer pictures of how the beaches are behaving over a longer period, particularly beaches with datasets less than 20 years. This allows a distinction between short-term oscillations, where sand may appear to be lost but can come back, and net gains or losses (broader system changes).

Bathymetric monitoring extending seaward of mean sea level is required to understand how sand moves between the dry beach and the subtidal (below the low tide) beach. Differentiation can then be made between actual inputs into the system rather than between zone sand exchanges (onshore-offshore movements).

Dune monitoring is also required to understand the success of dune planting and reshaping projects, such as those at Piha. Monitoring may include RTK-GPS mapping, quadrant surveys, drone mapping or photographic evidence, and may be undertaken in conjunction with community groups or public. Such data will then link well with beach profile information and lend insights into how much a dune builds up following replanting or responds to significant vegetation loss (including erosion events).

Additionally, it is of primary importance to gather and synthesise accurate wave data (wave direction, wave period, wave height, wave setup/run-up) and sea level data, as this will provide the ability to match how much a beach will change during and after any given storm and predict future responses through numerical modelling based on similar conditions. This data permits statistical analysis with climatic events like ENSO and changes in sea level (including storm surge).

Modelling with high resolution information will enable the prediction of sand transport and deposition in and around ‘hard’ engineered structures such as seawalls and rock groynes and ‘soft’ engineering approaches like dune reshaping and sand replenishment. Coastal managers can then better assess the effectiveness of these approaches in curbing the impacts of coastal erosion and climate change, and make more informed decisions.

7.0 Acknowledgements

Members of the Environmental Monitoring and Reporting team (Auckland Council) are thanked for assisting in data collection around the region's beaches. Sam Morgan, previously from the Coastal Management Services team, is thanked for his input into the report, as well as feedback from Natasha Carpenter from the same team. Overview and assistance with this report is greatly appreciated from Jarrod Walker (Auckland Council) and Nicholas Holwerda (Auckland Council). The peer review panel is thanked for the review process, ensuring a high degree of quality in developing this report into a technical publication.

8.0 References

Barnes, F. A., and King, C. A. M. (1955). Beach changes in Lincolnshire since the 1953 storm surge. *The East Midland Geographer*, 4, 18-28.

Bird, E. (2008). *Coastal Geomorphology: An Introduction, Second Edition*. John Wiley & Sons Ltd, West Sussex.

Brampton, A.H. (1990). *Coastline monitoring*. Hydraulics Research Report IT 345, Wallingford.

Blue, B. (2009). *Multi-Decadal Shoreline Change on Auckland's West Coast: Whatipu, Karekare, Piha and Te Henga Beaches, Aotearoa/New Zealand*. Unpublished honours dissertation, University of Auckland.

Boyle, J.J. (2014). *An Investigation into Coastal Change at Whites Beach, Auckland, New Zealand*. Unpublished MSc Thesis, University of Auckland.

Cooper, N.J., Leggett, D.J., and Lowe, J.P. (2000). Beach-Profile Measurement, Theory and Analysis: Practical Guidance and Applied Case Studies. *Water and Environment Journal*, 14(2), 79-88.

Dahm, J. (2002). *Coastal Hazard Management Strategy: Muriwai*. Report prepared for Auckland Regional Council and Rodney District Council. Coastline Consultants Ltd, Hamilton.

Dahm, J. (2013). *Dune Management at Piha: Review and Proposed Management Plan*. Report prepared for Auckland Regional Council. Eco Nomos Ltd.

Dougherty, A.J. (2011). *Evolution of Prograded Coastal Barriers in Northern New Zealand*. Unpublished PhD Thesis, University of Auckland.

Emery, K.O. (1961). A Simple Method of Measuring Beach Profiles. *Limnology and Oceanography*, 6(1), 90-93.

Harley, M.D., Turner, I.L., Short, A.D., and Ranasinghe, R. (2011). Assessment and integration of conventional, RTK-GPS and image-derived beach survey methods for daily to decadal coastal monitoring. *Coastal Engineering*, 58, 194-205.

Hesp, P.A. (2002). *Foredunes and blowouts: initiation, geomorphology and dynamics*. Geomorphology, 48: 245-268.

Kench, P. (2008). *Beach monitoring in the Auckland region: Beach profile analysis*. Prepared by Auckland Uniservices Limited for Auckland Regional Council. Regional Technical Report 2008/015. 71 pages.

King, D.N.T., Nichol, S.L., and Hume, T.M. (2006). Rapid onshore sand flux in a high energy environment littoral cell: Piha Beach, New Zealand. *Journal of Coastal Research*, 22, 1360-1369.

Lee, J.M., Park, J.Y., and Choi, J.Y. (2013). Evaluation of Sub-aerial Topographic Surveying Techniques Using Total Station and RTK-GPS for Applications in Macrotidal Sand Beach Environment. *Journal of Coastal Research*, 65, 535-540.

McLean, R.F., and Thom, B.G. (1975). Beach changes at Moruya, 1972-74. *Proceedings 2nd Australian Conference on Coastal and Ocean Engineering*, 75(2), 12-17.

McLean, R.F., and Shen, J.S. (2006). From Foreshore to Foredune: Foredune Development Over the Last 30 Years at Moruya Beach, New South Wales, Australia. *Journal of Coastal Research*, 22 (1), 28 – 36.

NIWA. (2013). *NZ Historic Weather Events Catalogue*. Available at http://hwe.niwa.co.nz. Website accessed on 22/08/2016.

NOAA. (2016). Southern Oscillation Index. Available at http://www.cpc.ncep.noaa.gov/data/indices/soi. Website accessed on 22/08/2016.

Reinen-Hamill, R., Hegan, B., Shand, T. (2006). *Regional Assessment of Areas Susceptible to Coastal Erosion*. Prepared by Tonkin & Taylor Ltd for Auckland Regional Council. Auckland Regional Council Technical Report 2009/009.

Stuff. (2014). *Fossilised forest discovery excites Walker*. Available at http://www.stuff.co.nz/national/10099821/Fossilised-forest-discovery-excites-walker. Website accessed on 30/05/2014.

Appendix A Beach envelopes and profile maps

Piha

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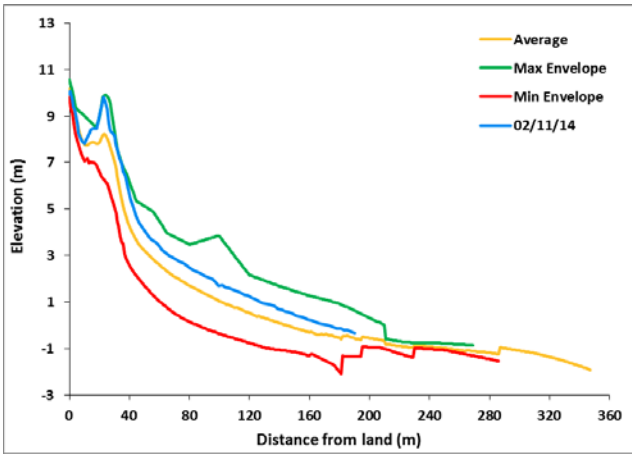

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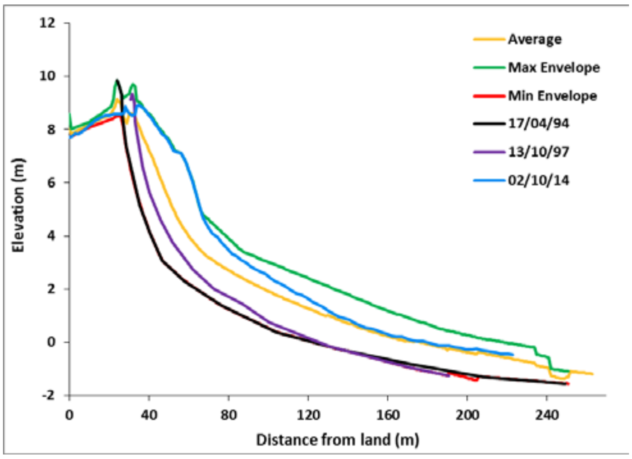

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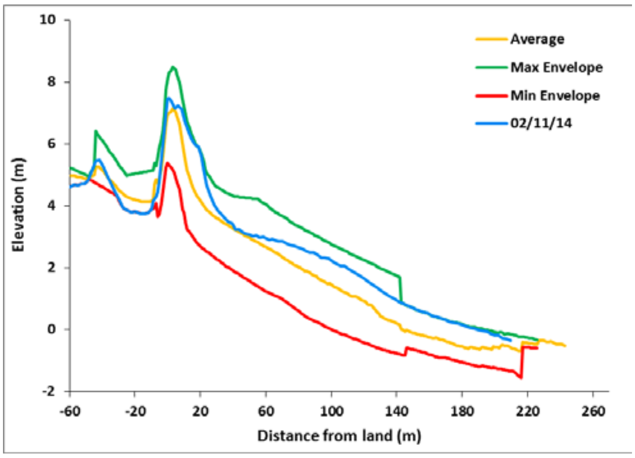

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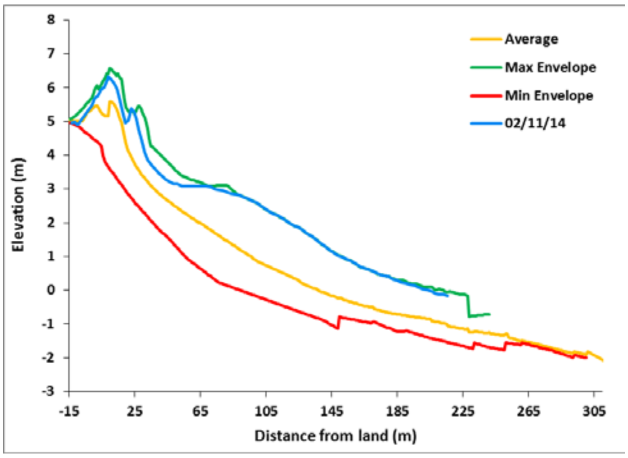

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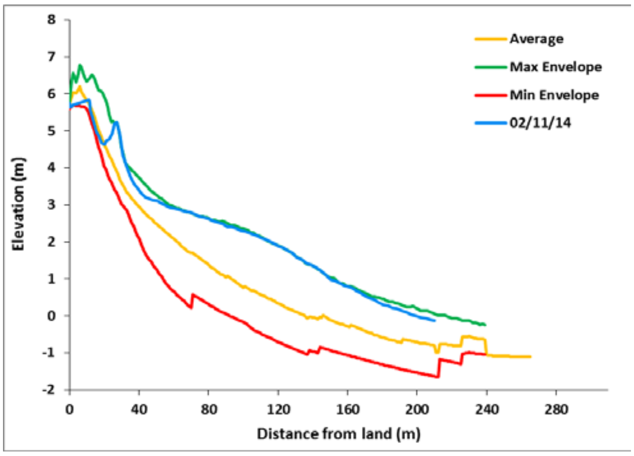
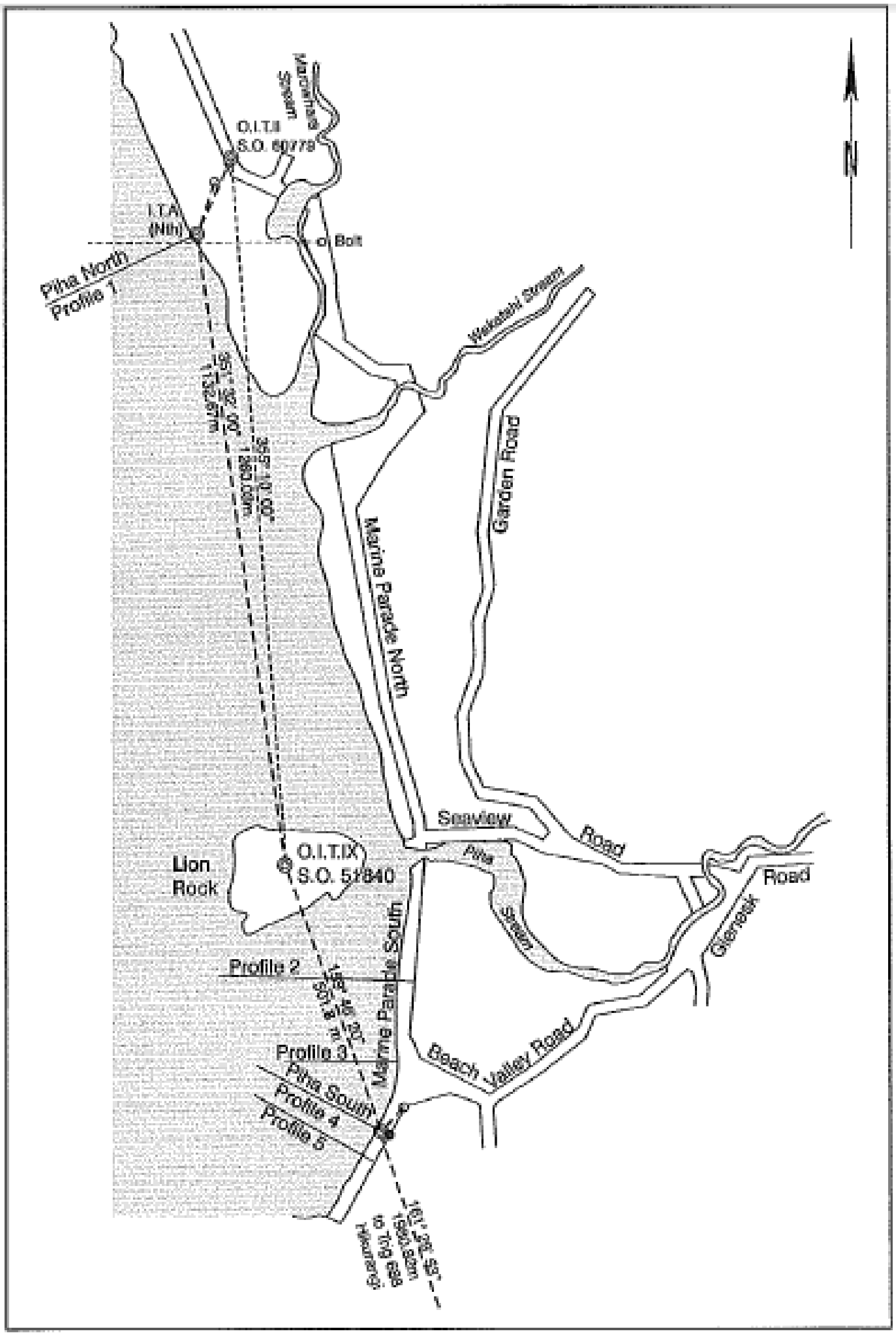
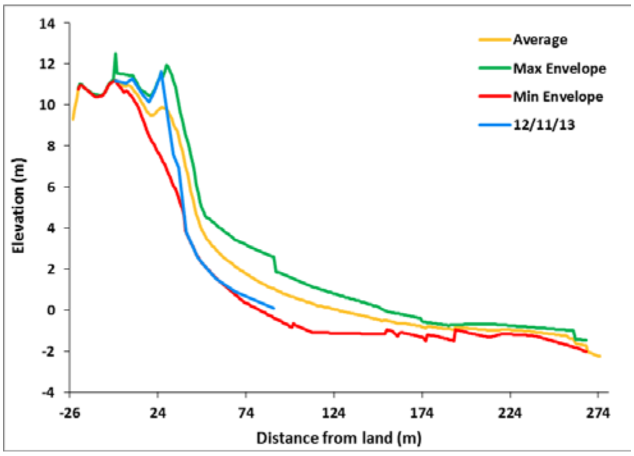



N
Marawhara Stream
O.I.T.II
S.O. 60779
I.T.A
(Nth)
Bolt
Piha North
Profile 1
Wekatahi Stream
Garden Road
Marine Parade North
Seaview
Road
Piha
Stream
Lion
Rock
O.I.T.IX
S.O. 51840
Road
Glenesk
Profile 2
Marine Parade South
Profile 3
Beach Valley Road
Piha South
Profile 4
Profile 5

Muriwai

Profile 1



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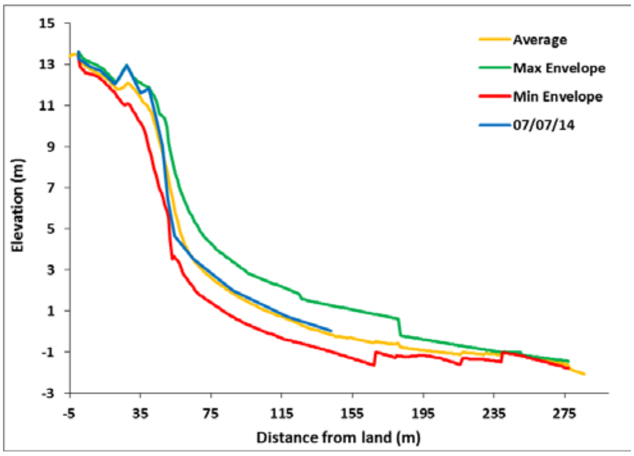

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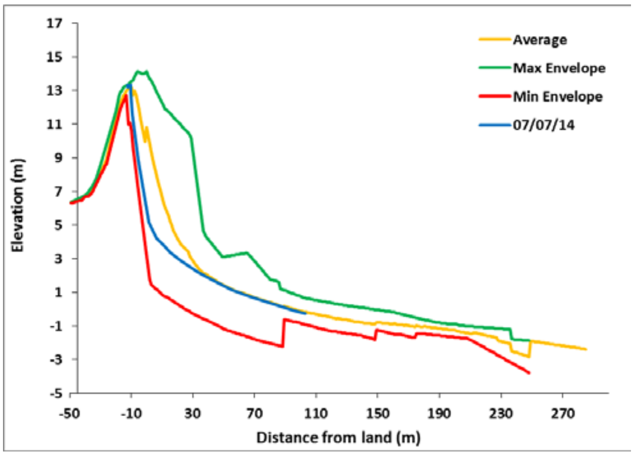

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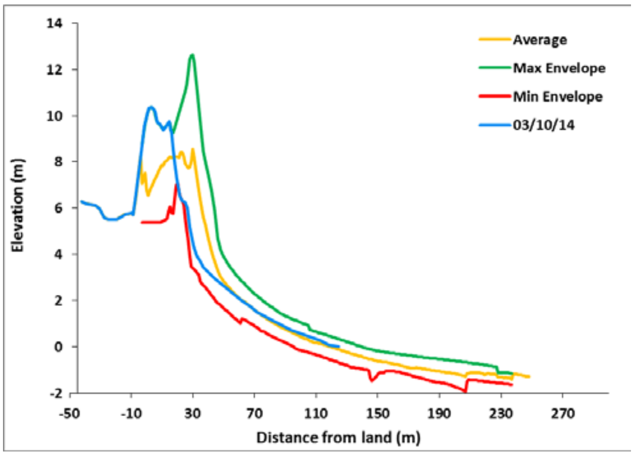
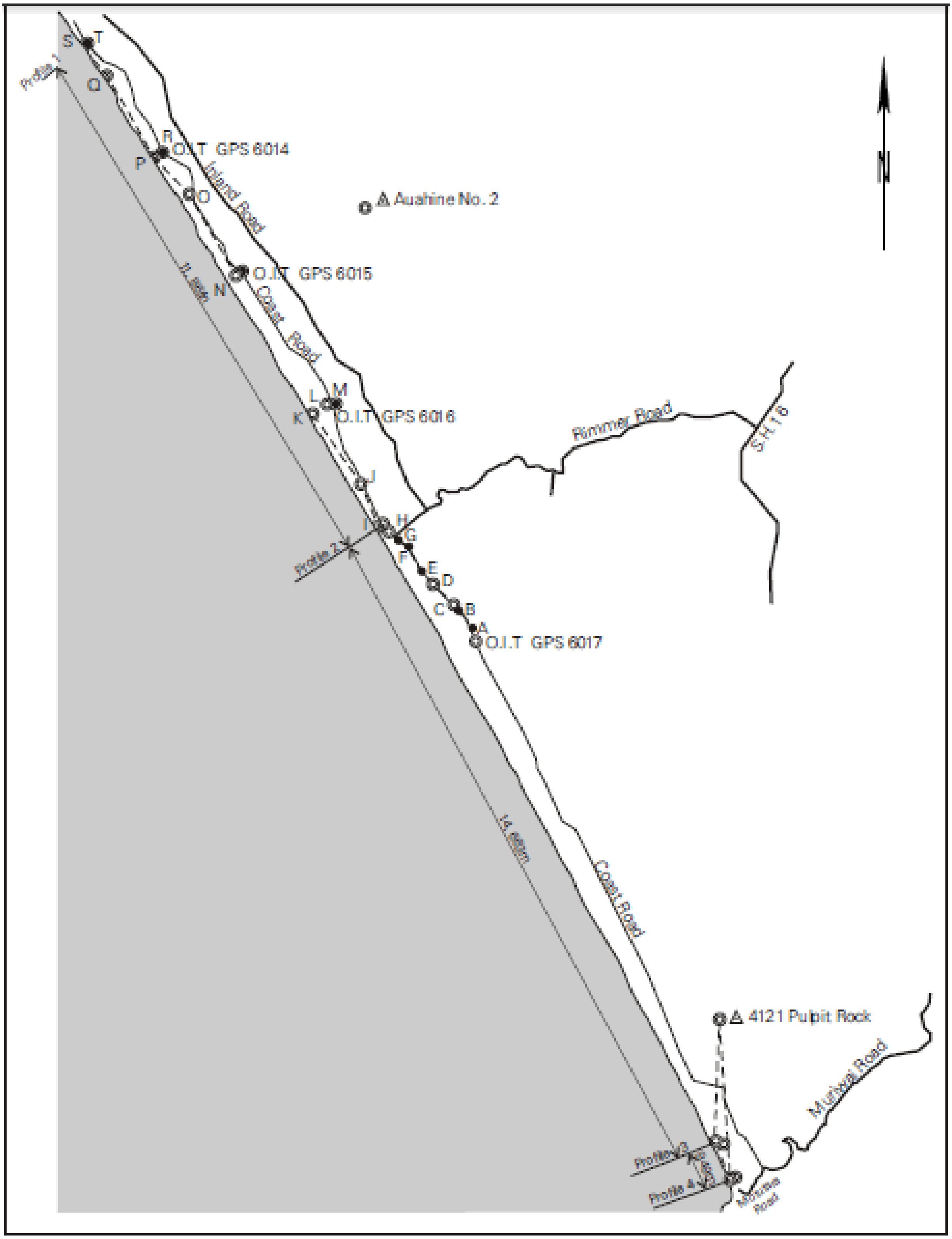
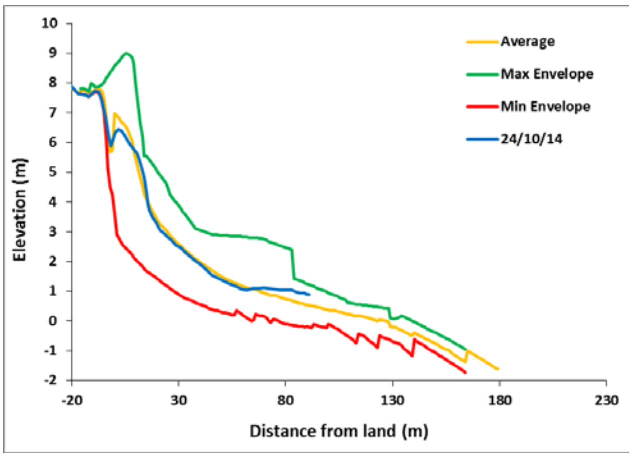




Profile 1
S
T
Q
R
P
O.I.T GPS 6014
O
Inland Road
Auahine No. 2
O.I.T GPS 6015
N
Coast Road
L
M
K
O.I.T GPS 6016
Rimmer Road
S.H.16
J
H
G
F
Profile 2
E
D
C
B
A
O.I.T GPS 6017
Coast Road
4121 Pulpit Rock
Muriwai Road
Profile 3
Profile 4
Motutara Road

Pakiri

Profile 2A



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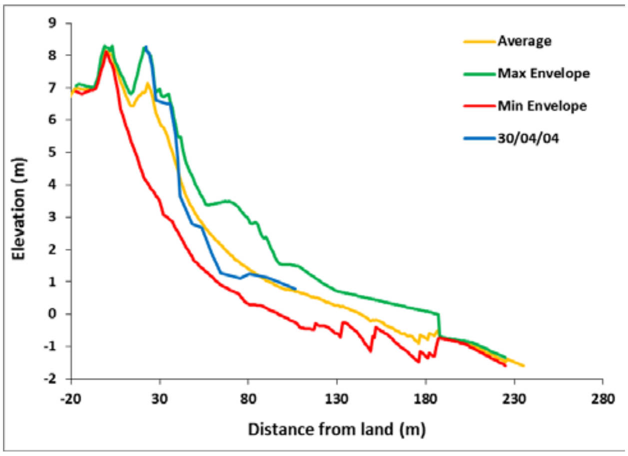

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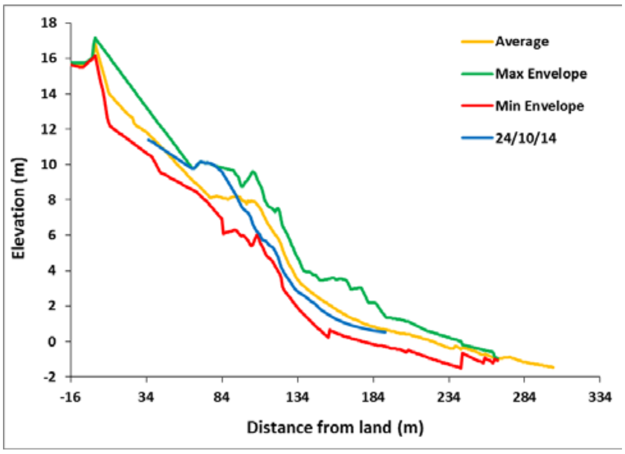

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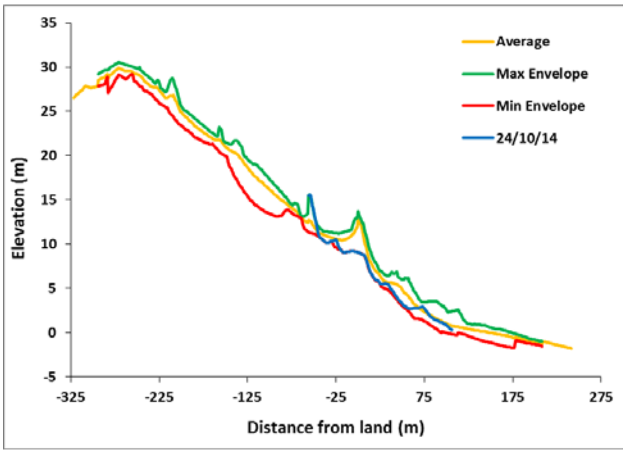

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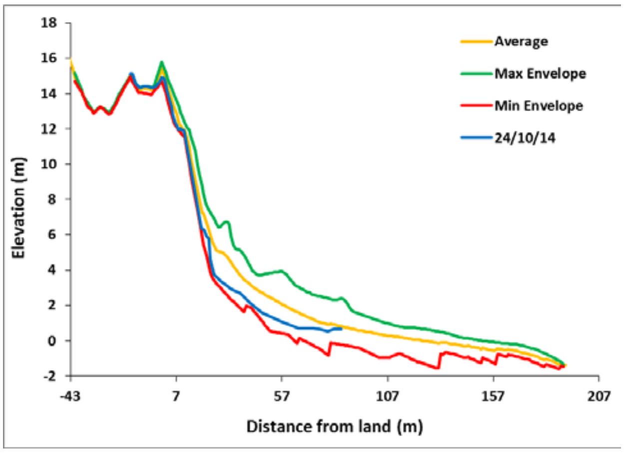

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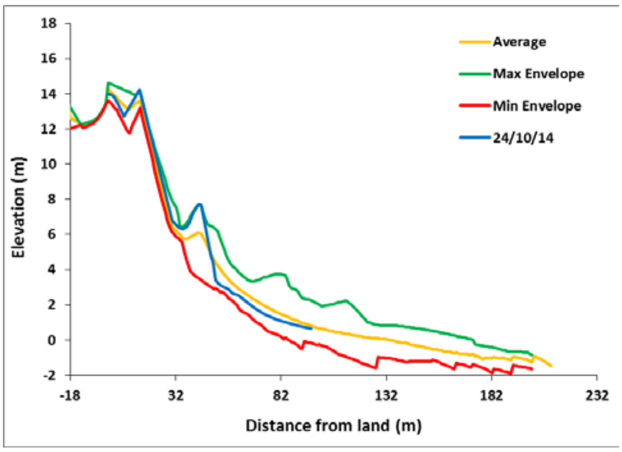

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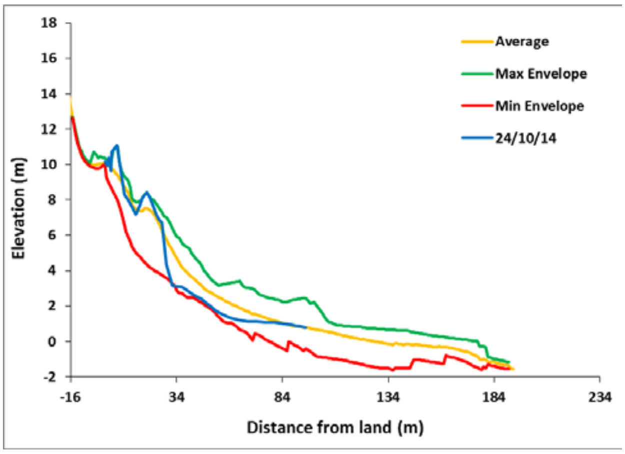

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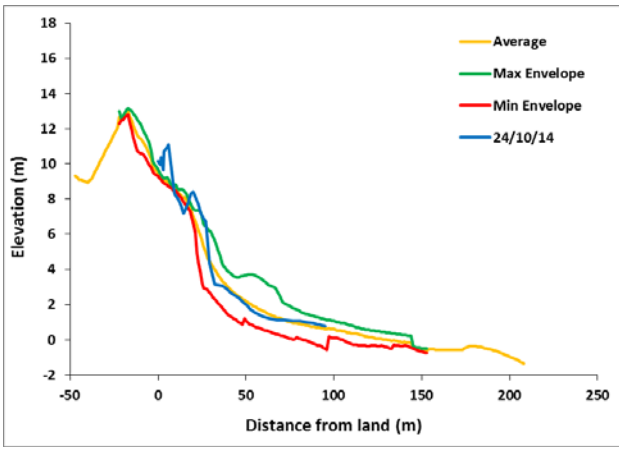
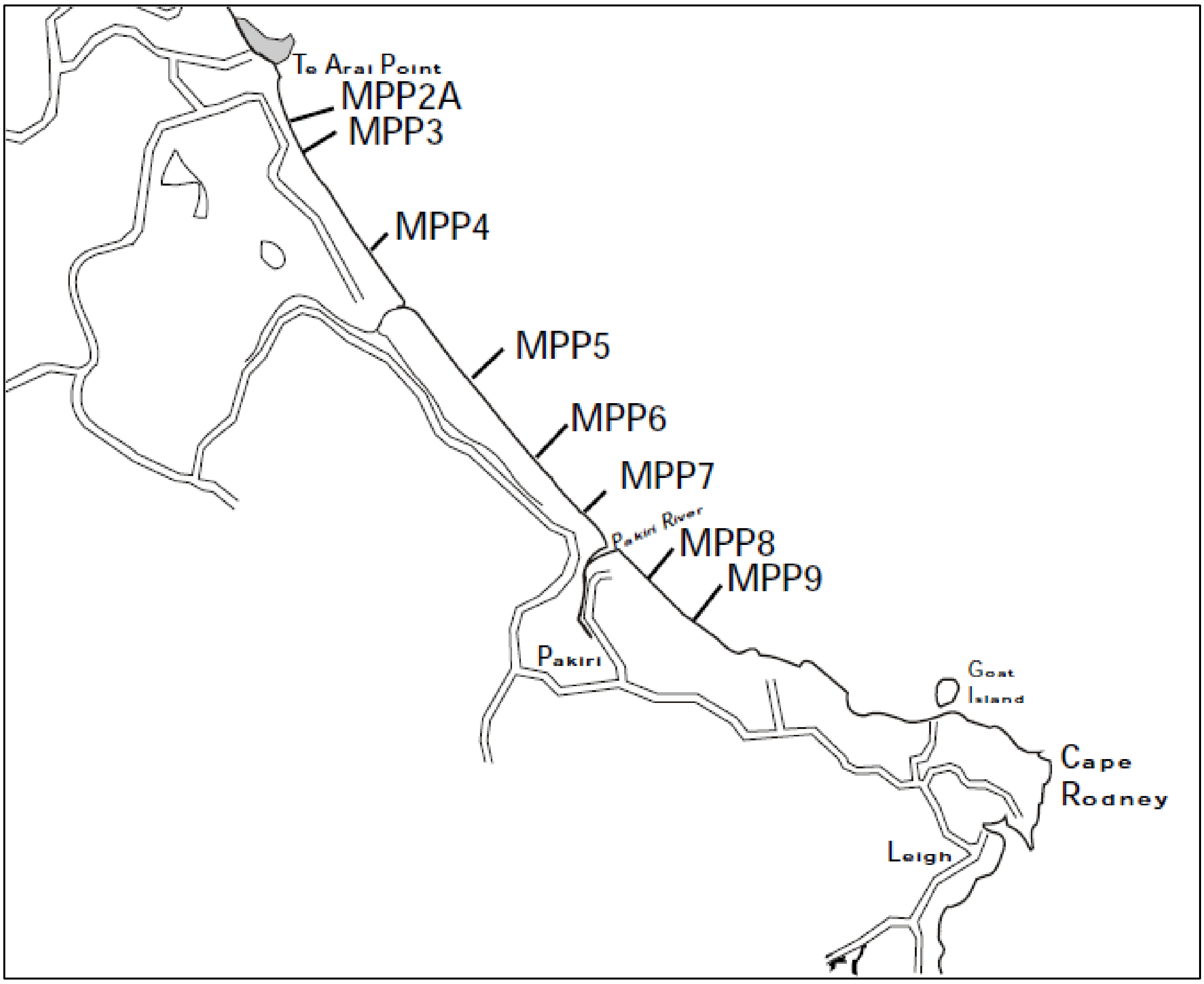
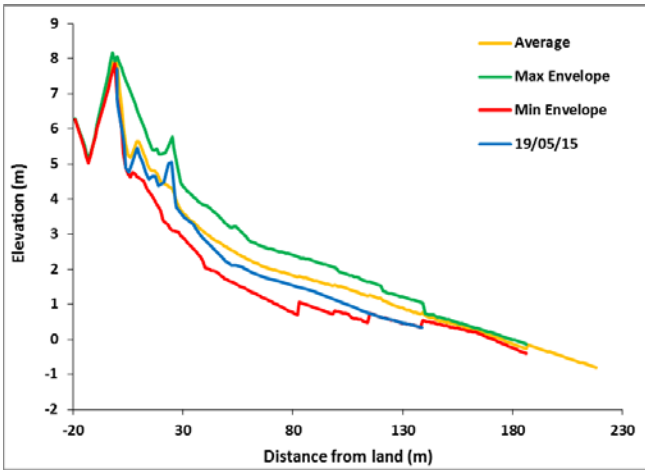




Omaha

Profile 1



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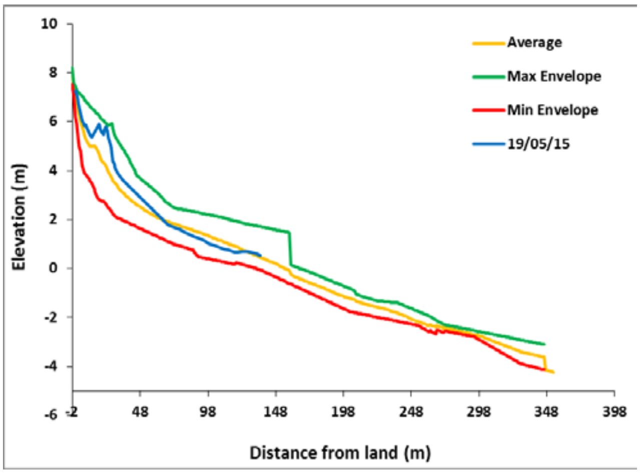

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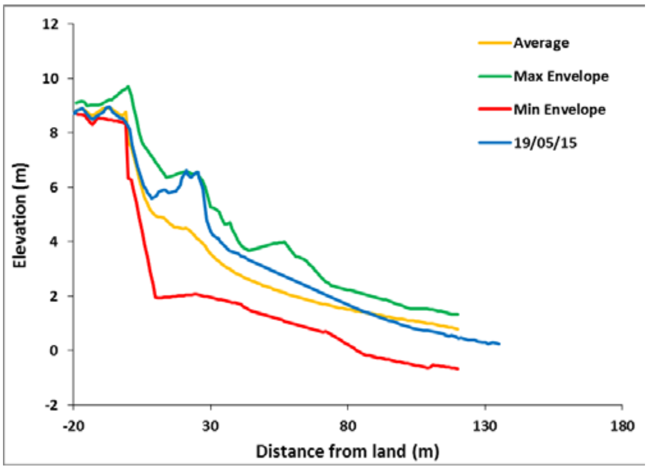

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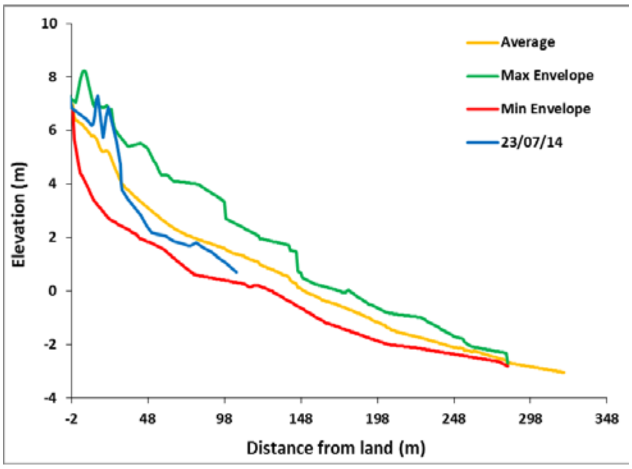

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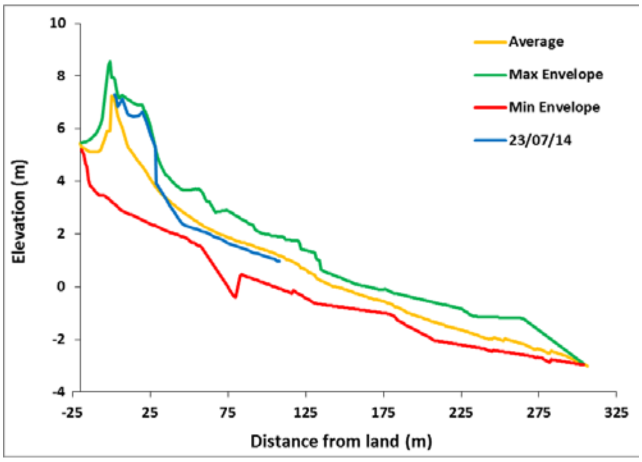

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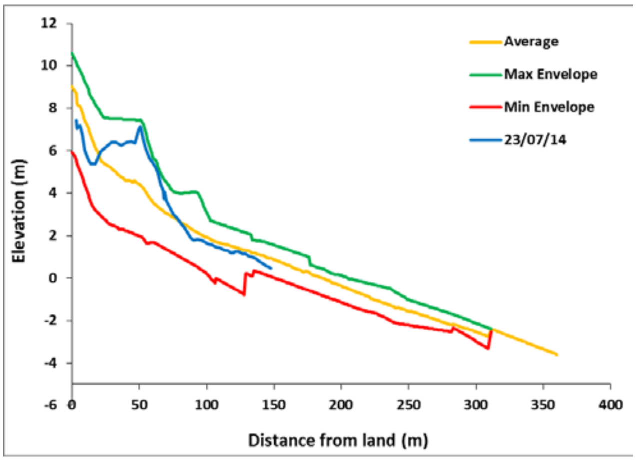

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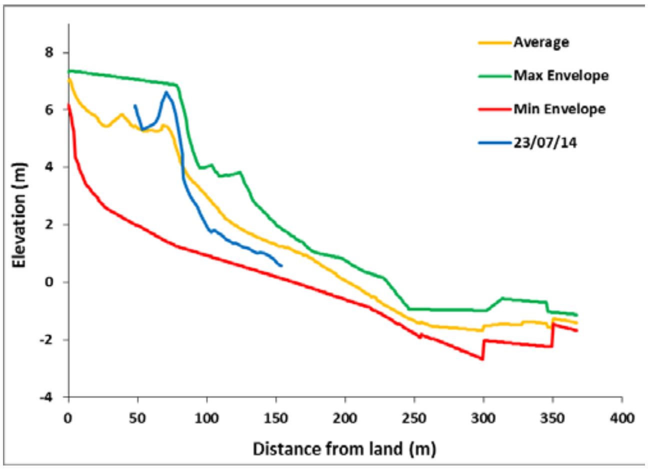

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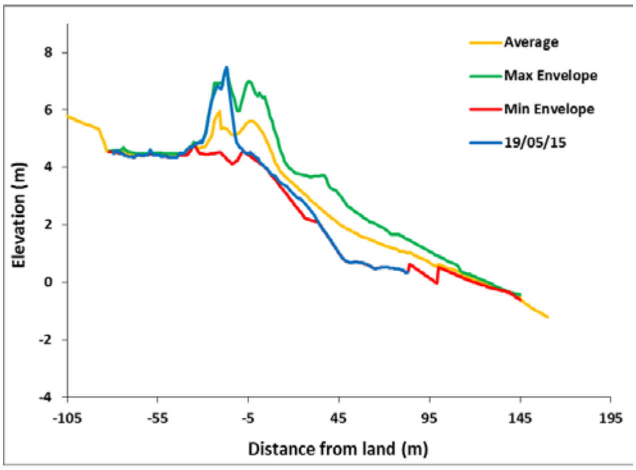

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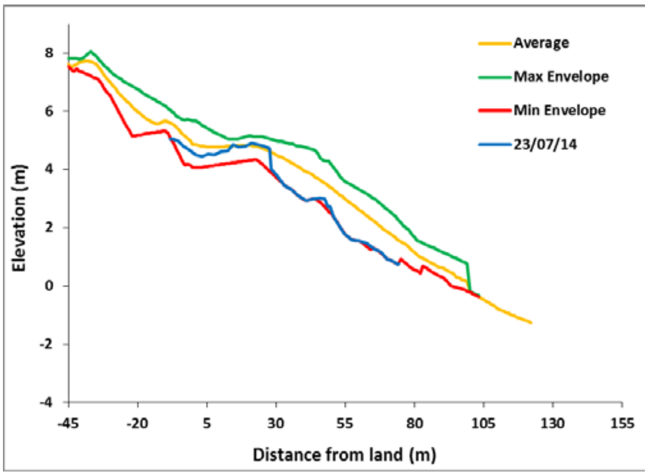
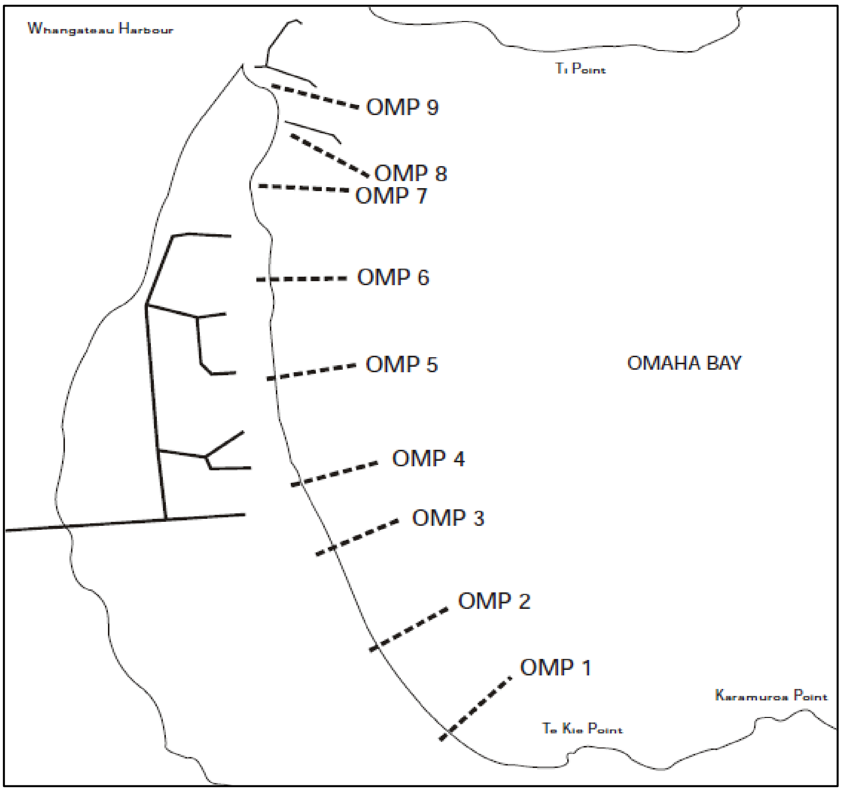
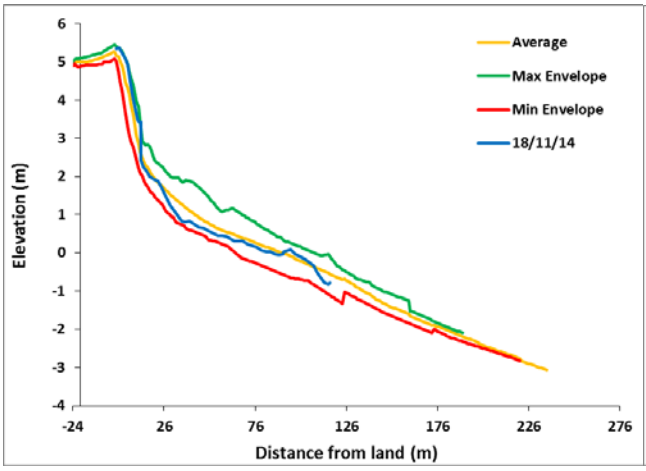
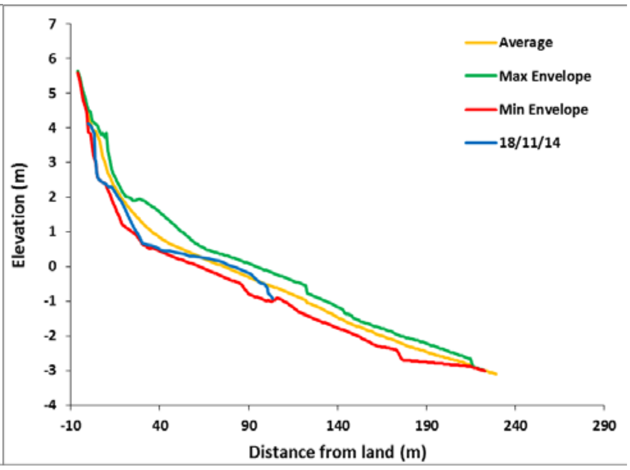


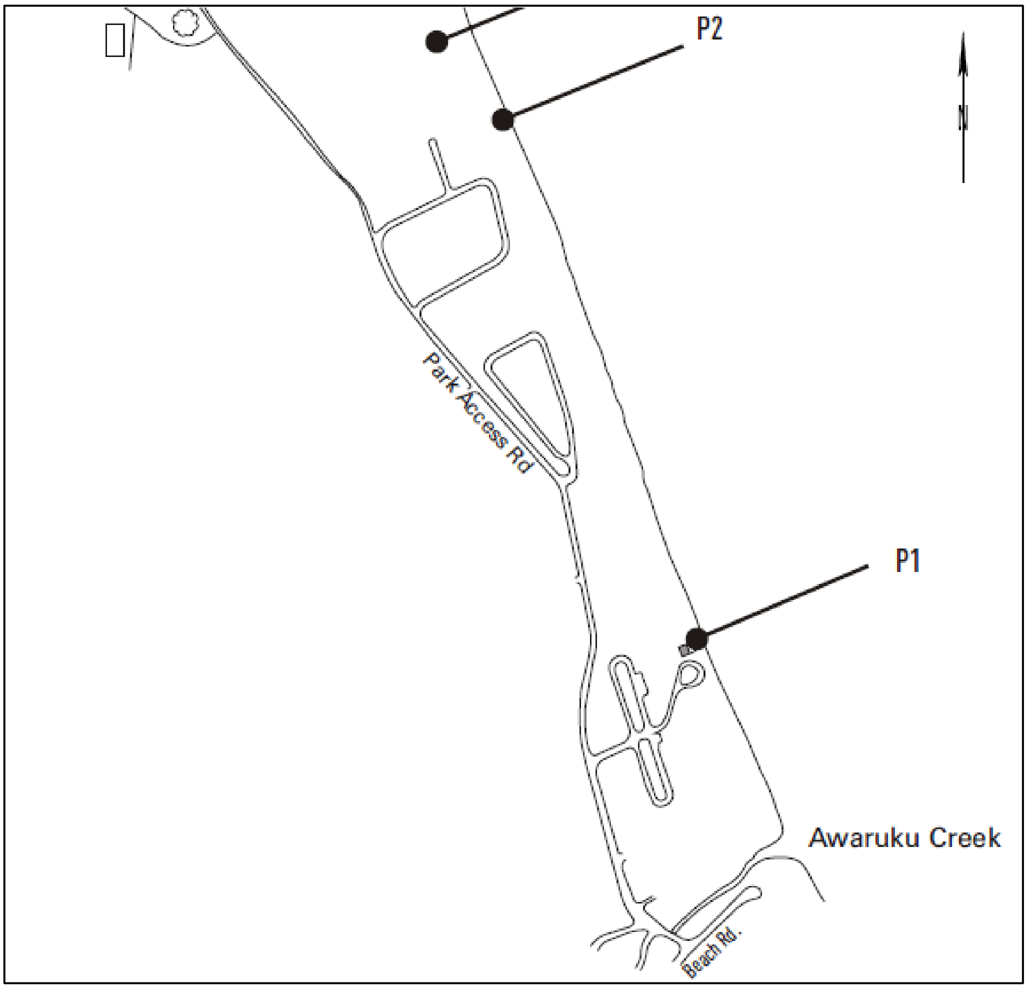


Long Bay

Profile 1 Profile 2

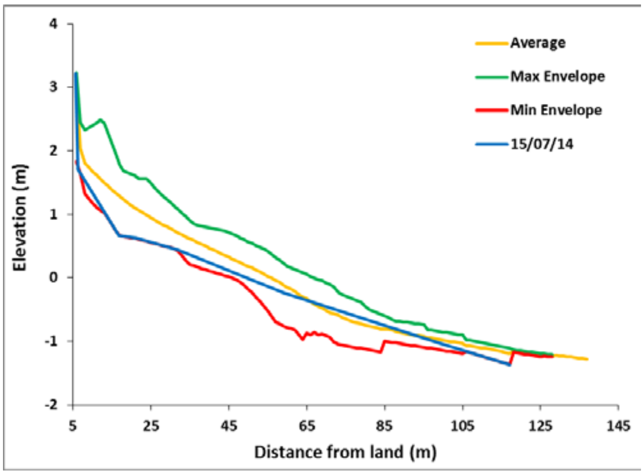




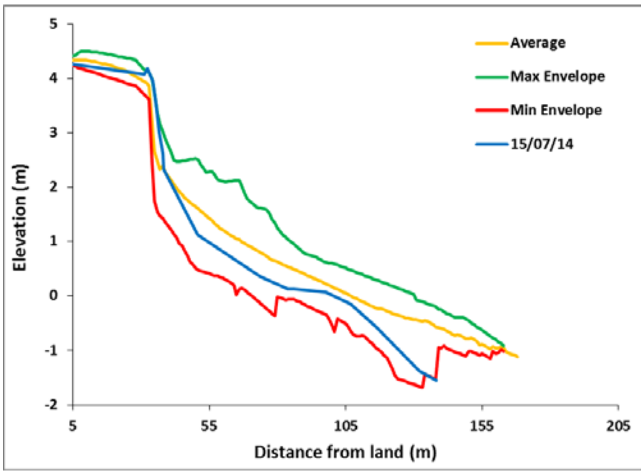


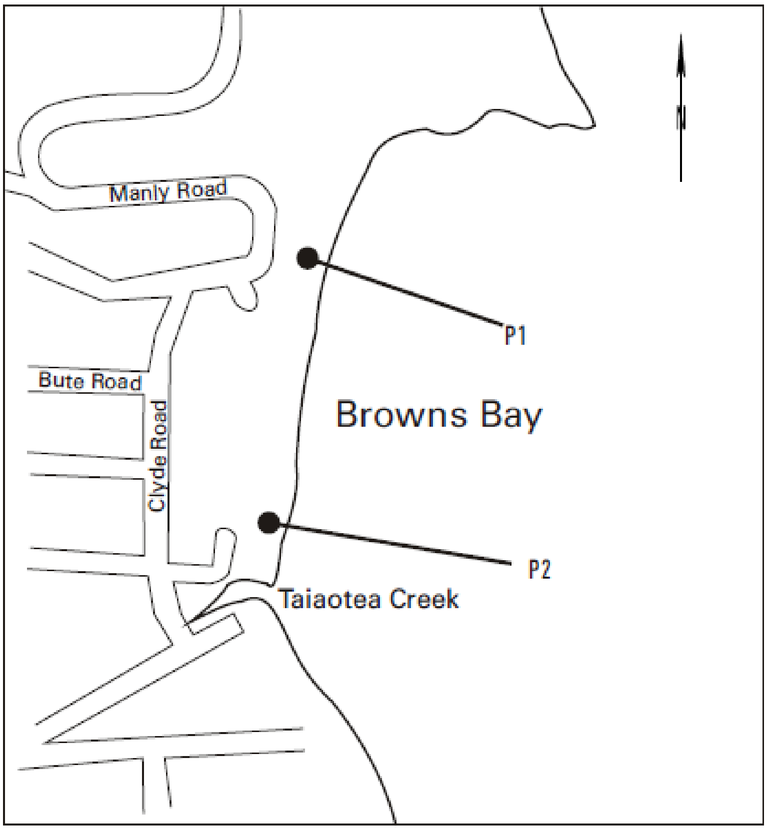
Browns Bay

Profile 1



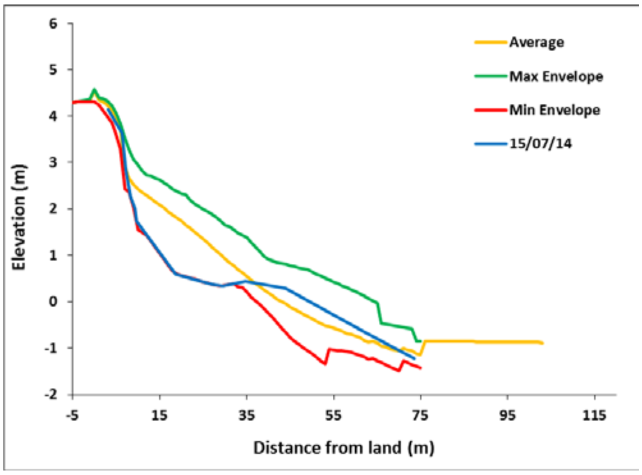
Profile 2



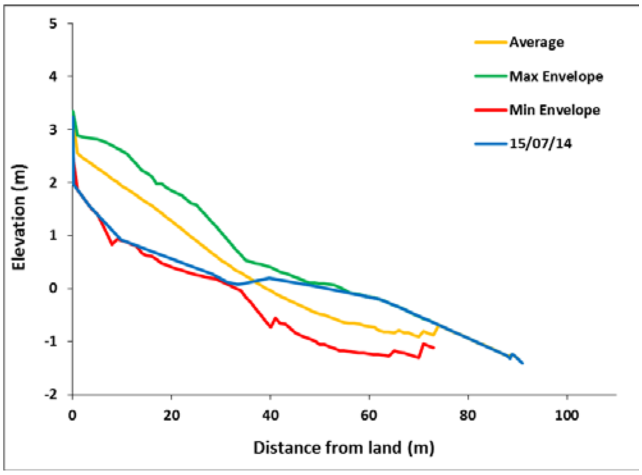


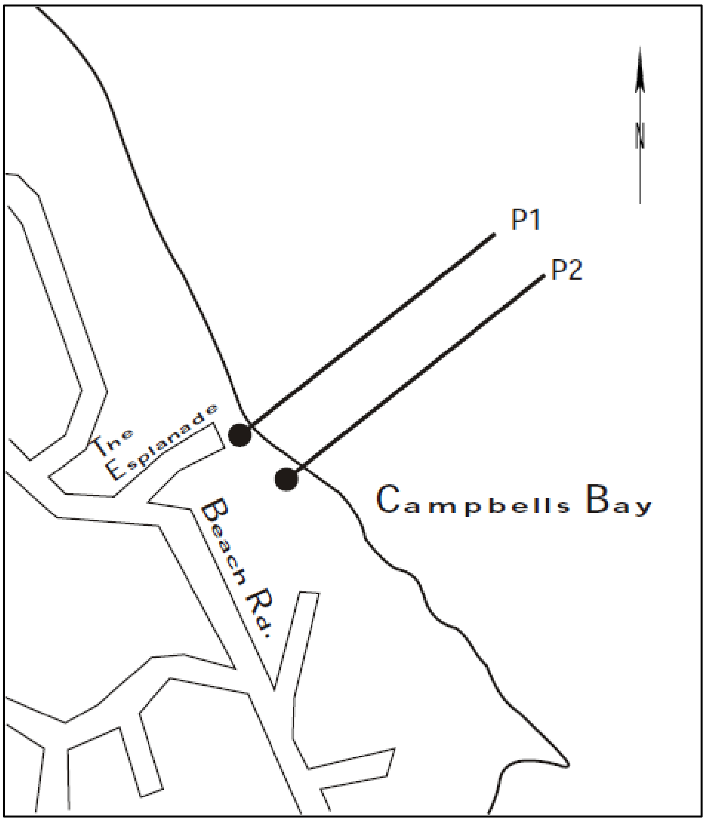
Campbells Bay

Profile 1



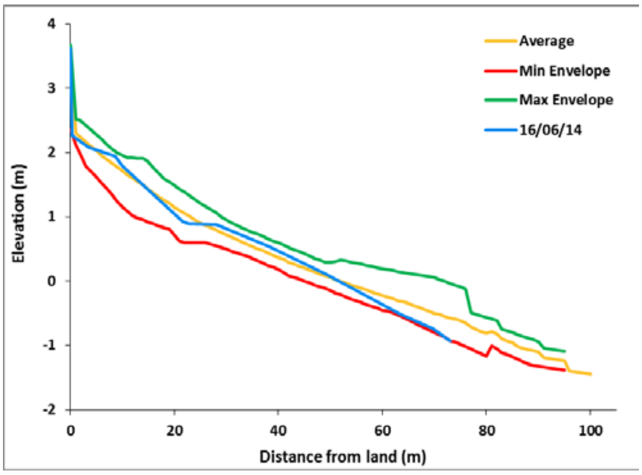
Profile 2



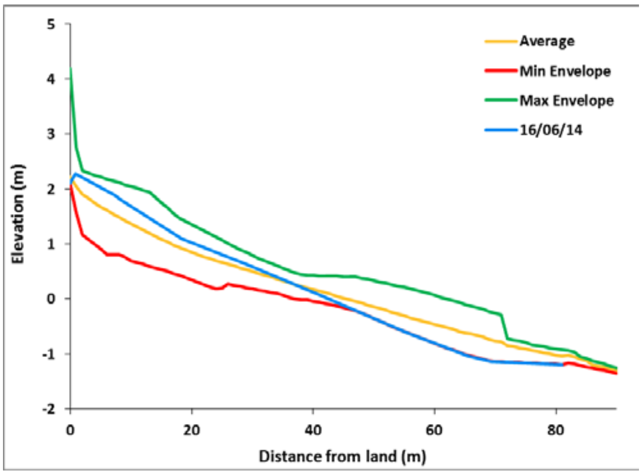


Milford

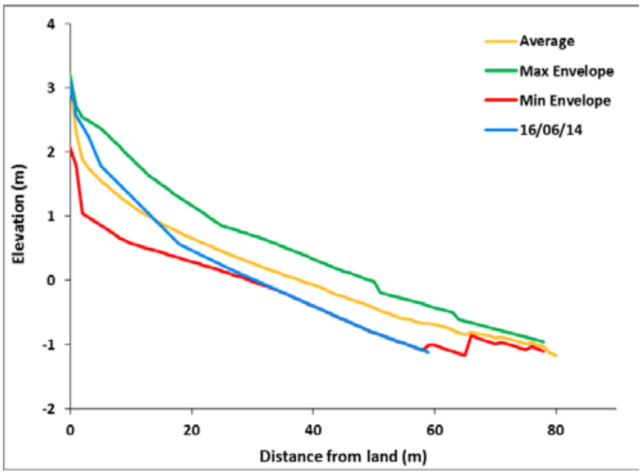
Profile 1



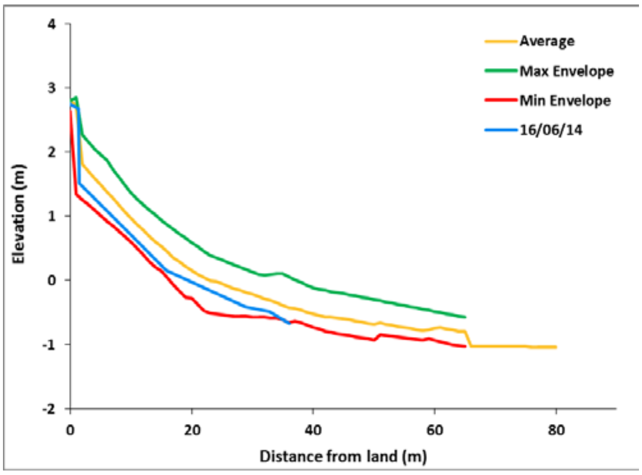
Profile 2



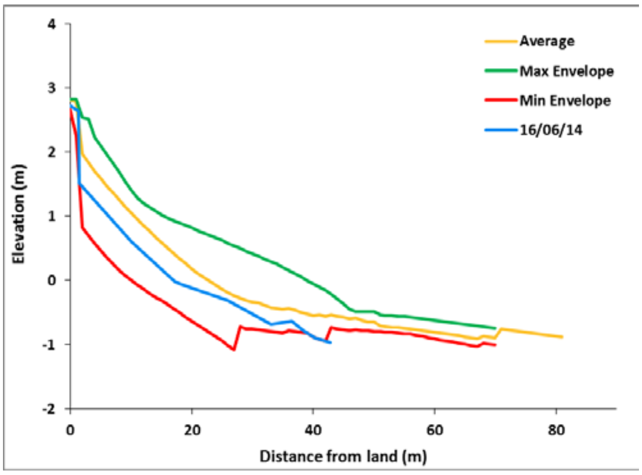
Profile 3

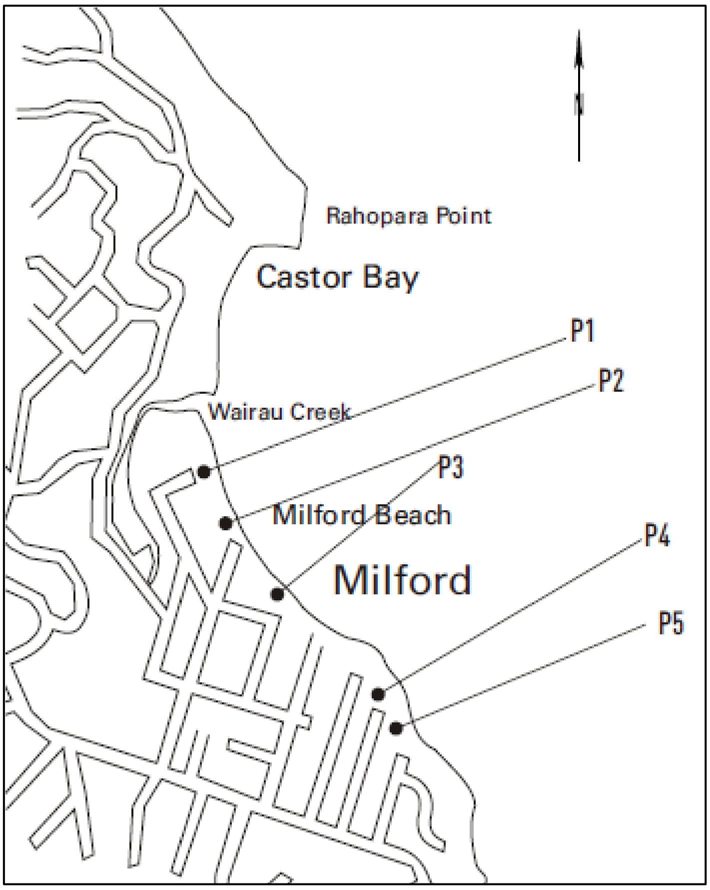


Profile 4



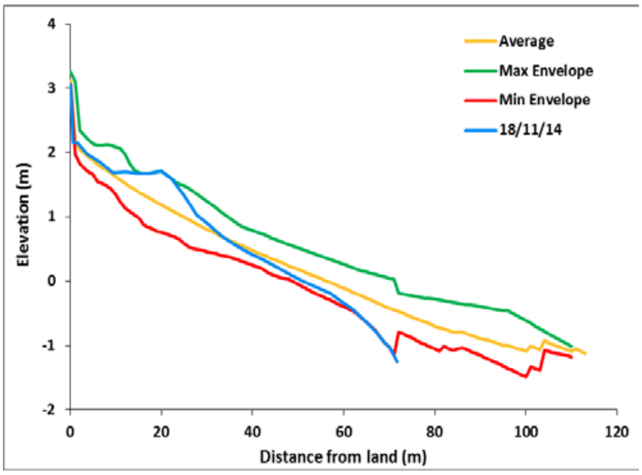
Profile 5



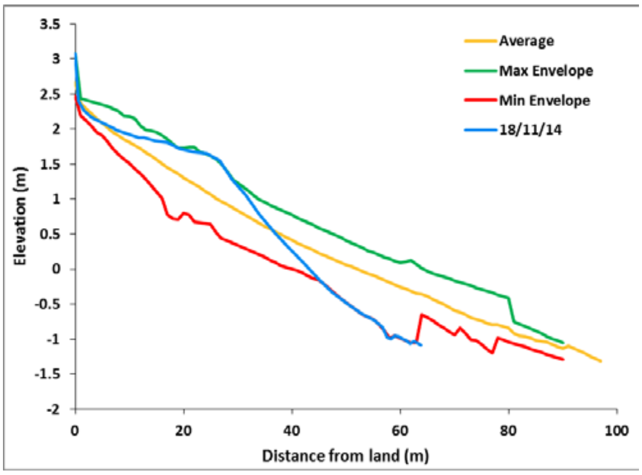


Takapuna

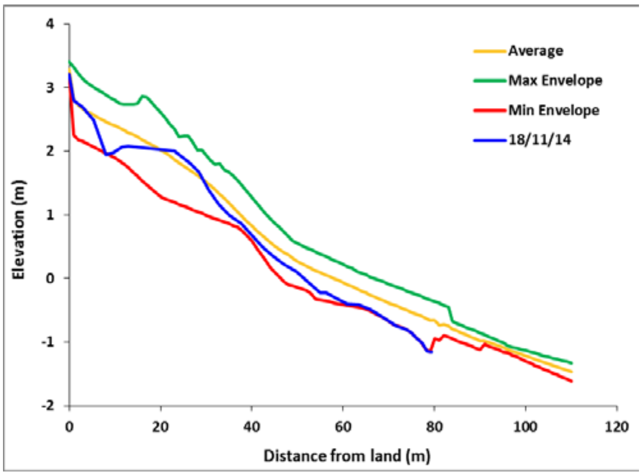
Profile 1



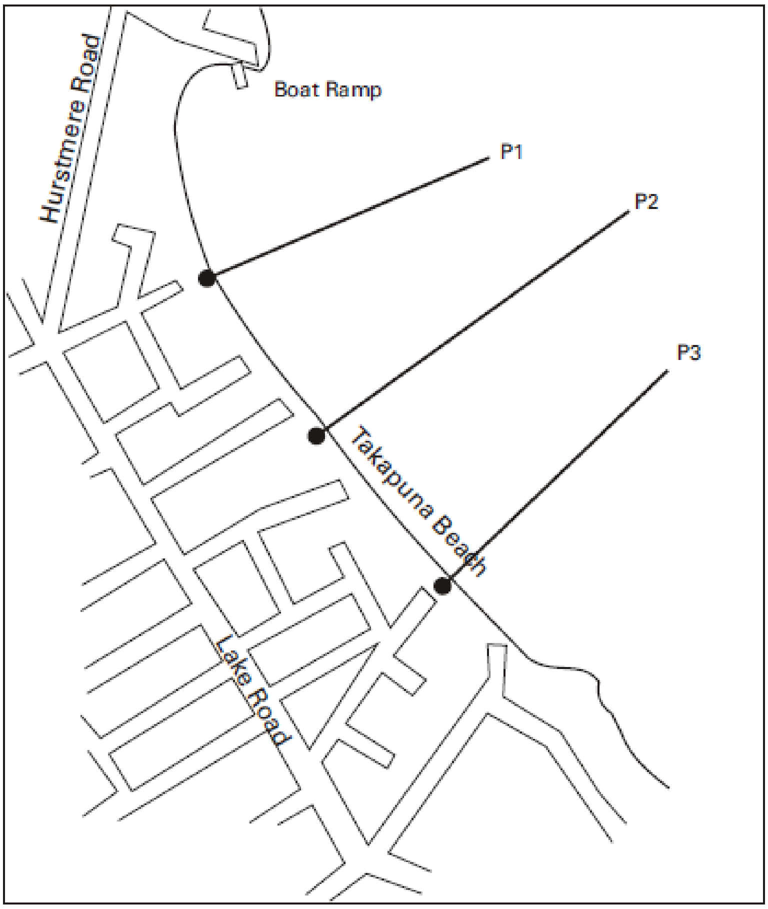
Profile 2



Profile 3



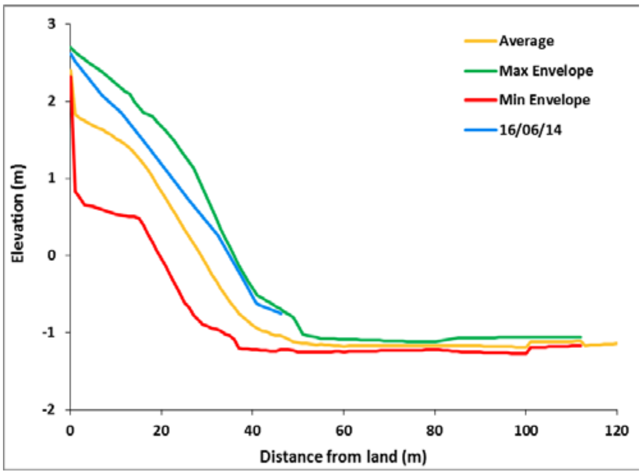
Average
Max Envelope
Min Envelope
18/11/14
Elevation (m)
Distance from land (m)
4
3
2
1
0
-1
-2
0
20
40
60
80
100
120



Hurstmere Road
Boat Ramp
P1
P2
P3
Takapuna Beach
Lake Road

Cheltenham Beach

Profile 1



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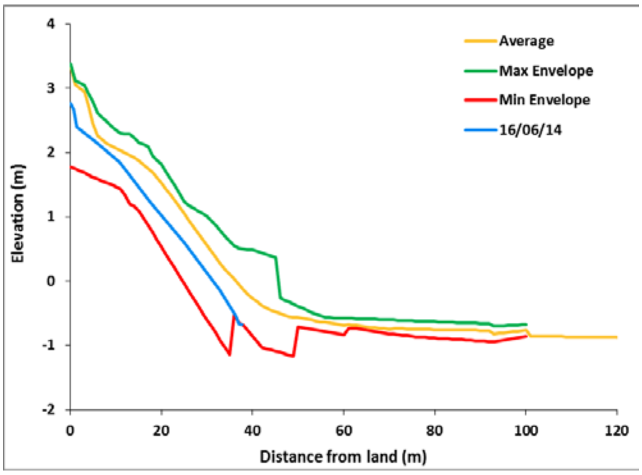

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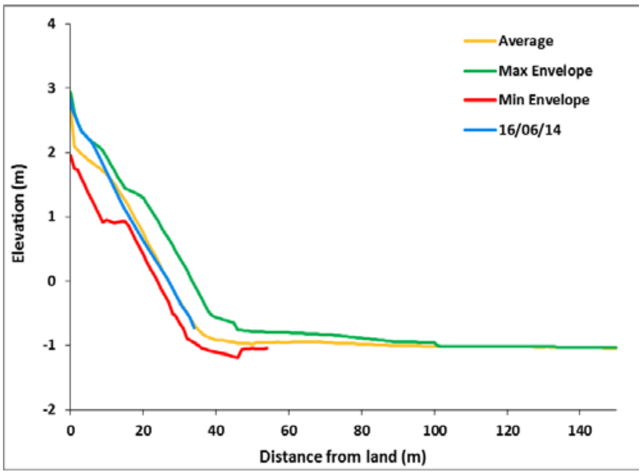
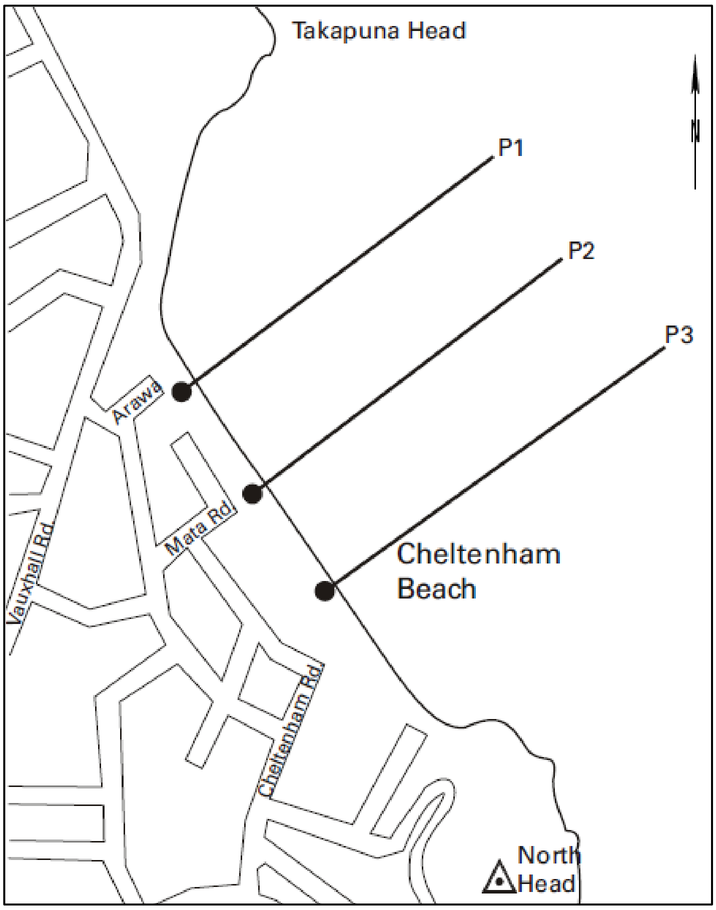
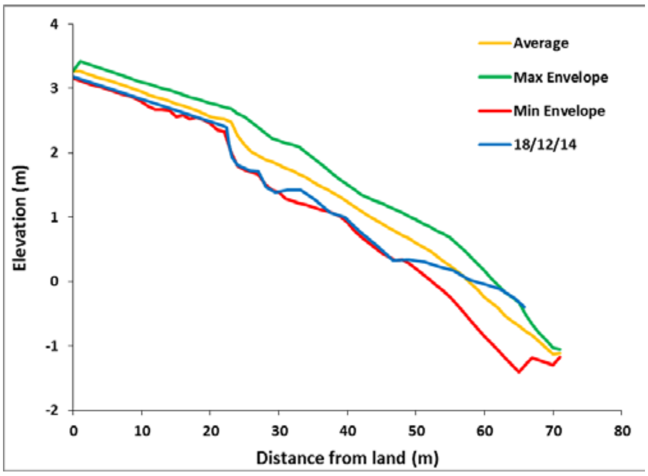


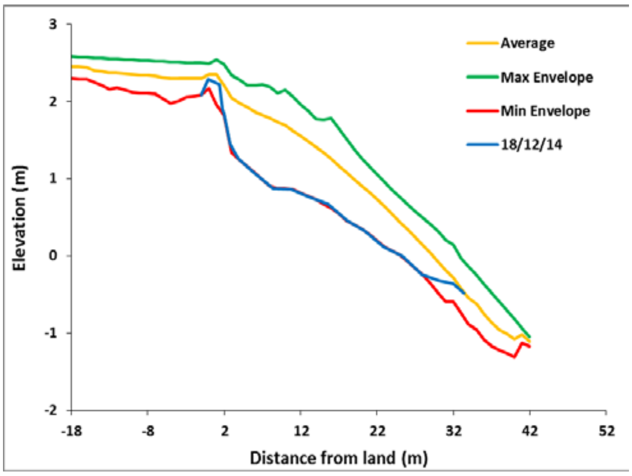


Maraetai

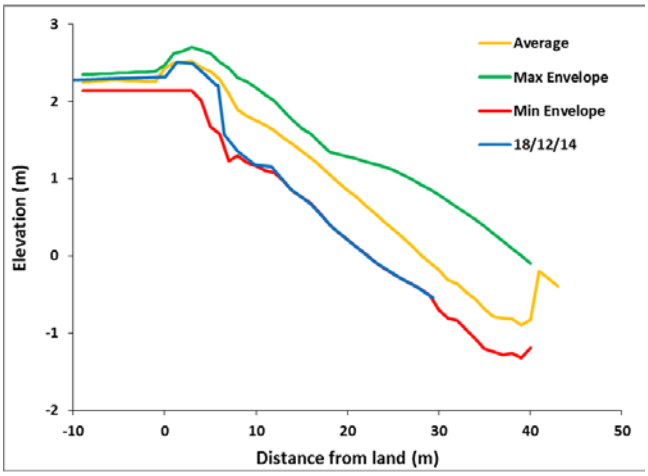
Profile 1



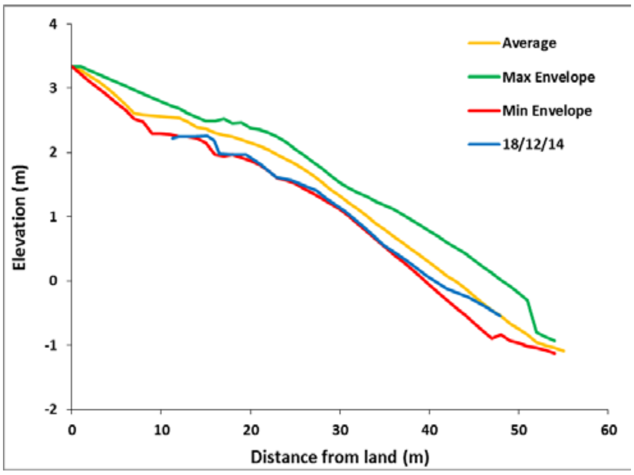
Profile 2

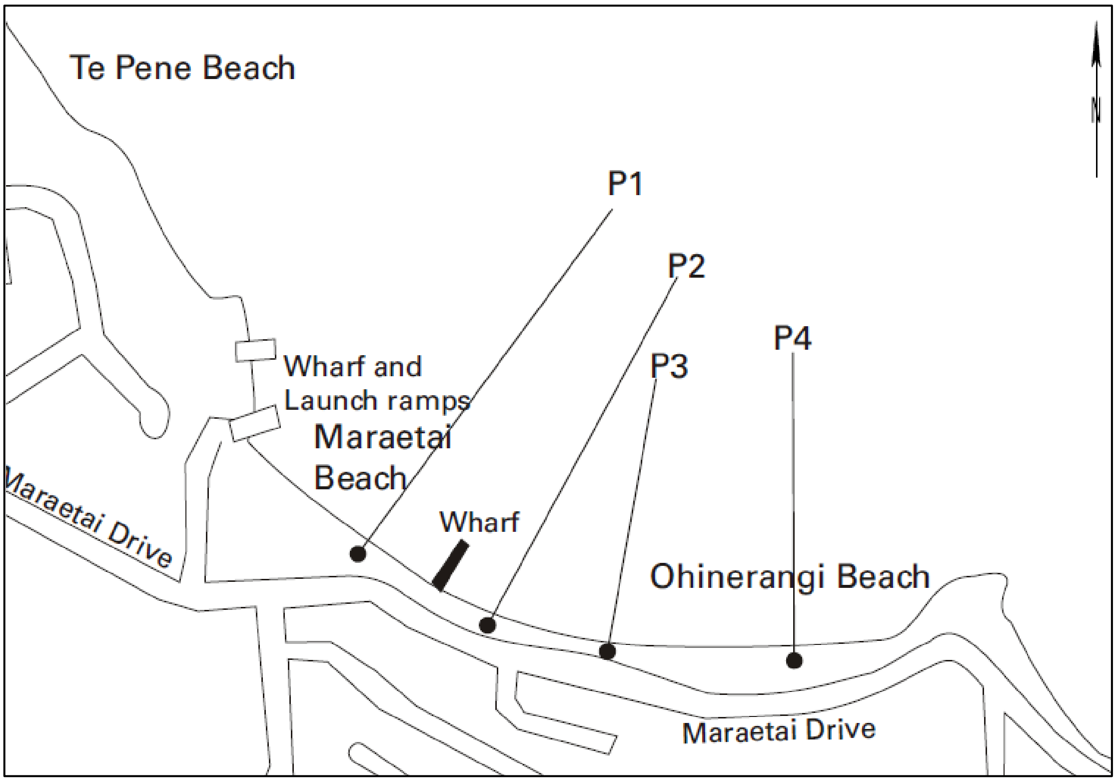


Profile 3



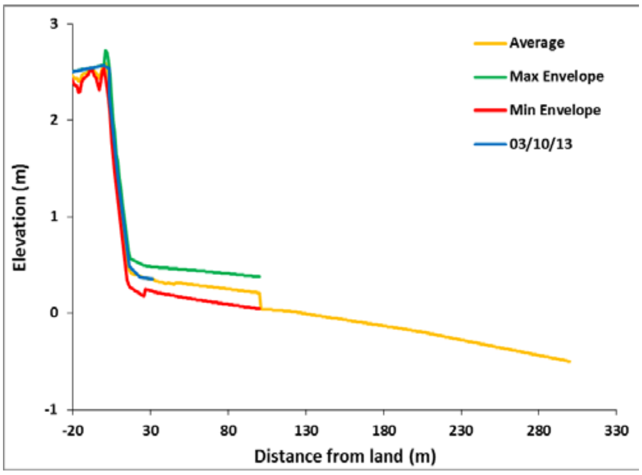
Profile 4



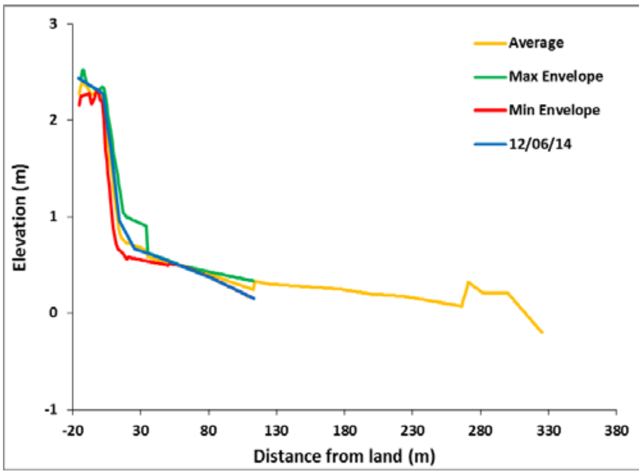


Kawakawa Bay

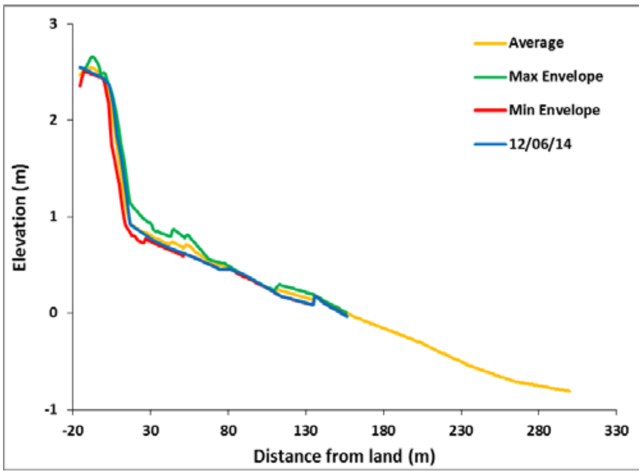
Profile 1



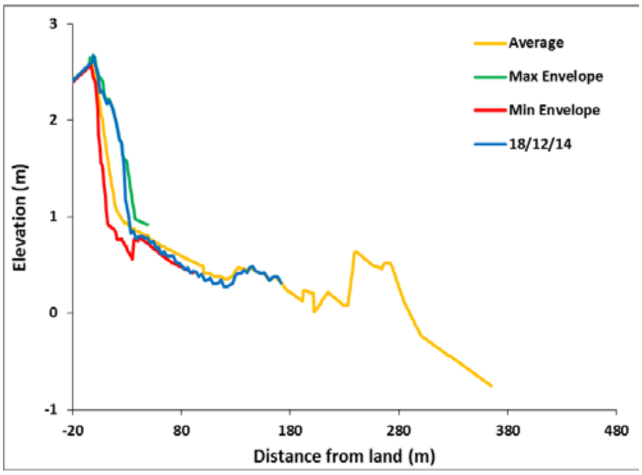
Profile 2

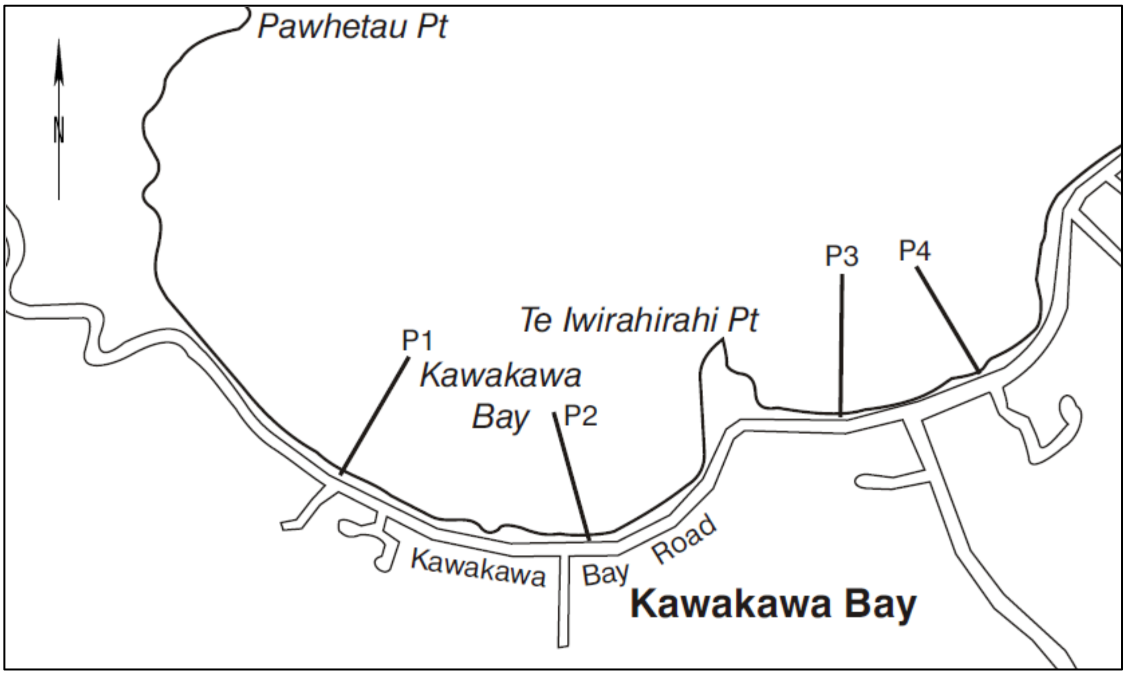


Profile 3



Profile 4





Appendix B Inner Hauraki Gulf beaches

Browns Bay

Beach envelope variation

Browns Bay displays similar shape and form to the other beaches within the inner Hauraki Gulf. Whilst the average profile is similar at both profiles, profile 2 exhibits a larger beach envelope and has up to 2m of vertical change opposed to only around 1m at profile 1, as shown in Figure 6-1. Similarly, horizontal migration is larger at profile 2, with as much as 69m movement within the envelope opposed to profile 1 with only 25m. This is supported by the larger standard deviation of the two at 19m compared to 6m of profile 1. Approximately 45 % of the current survey on profile 1 is at the minimum recorded levels of the beach envelope. Profile 2 sits near or just below the average, although the current survey also reaches the minimum level around 140m seaward of the benchmark.

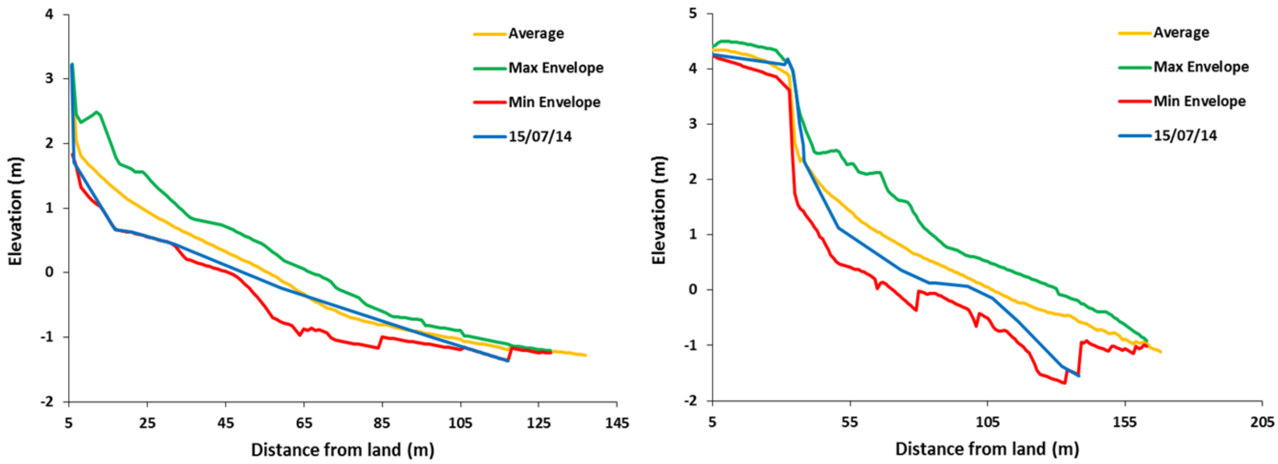


Figure 8-1 Beach profile envelopes illustrating the average beach profile in orange, the maximum extent of all profiles in green, the minimum extent of all profiles in red and, the most recent beach profile in blue. Profile 1 is on the left and profile 2 is on the right.

Beach volume

No clear trends are evident at both profiles. Current volumes on both profiles supports lack of trend, with the current status of sand volumes having just under or just over the amount since the original survey (profile 1 at 26 m^3/m versus 34 m^3/m in 1998, and profile 2 at 43 m^3/m versus 33 m^3/m) (Figure 6-2). Profile 2 exhibits much larger sand exchanges with double the volume of change between successive surveys (30 m^3/m compared to 15 m^3/m). Smaller cyclic periods of sand storage and release are present at profile 2, increasing and decreasing in volumes every 3 to 5 years. This cyclic change is not present at profile 1 where any such behaviour is either masked by the limited variability or the surveying is not undertaken frequently enough to capture.

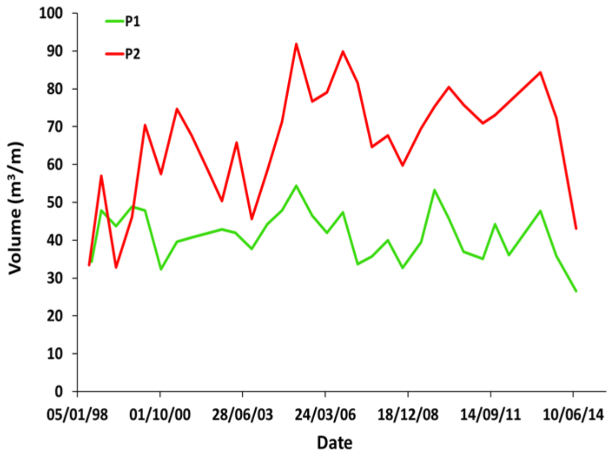


Figure 8-2 Beach volume changes at the MSL contour at Browns Bay, showing Profile 1 in green and profile 2 in red.

Beach width

Profile 2 has double the average beach width of 104m compared to 56m at profile 1, shown in Figure 6-3. Sporadic data points due to insufficient surveying to MSL contour. Both profiles show beach-width moves about a mean position, with very little evidence for a trend of beach widening or narrowing. Profile 1 currently displays a beach width of 50m close to the mean width of 55 m; profile 2 currently displays a beach width of 100m close to the mean width of 107m.

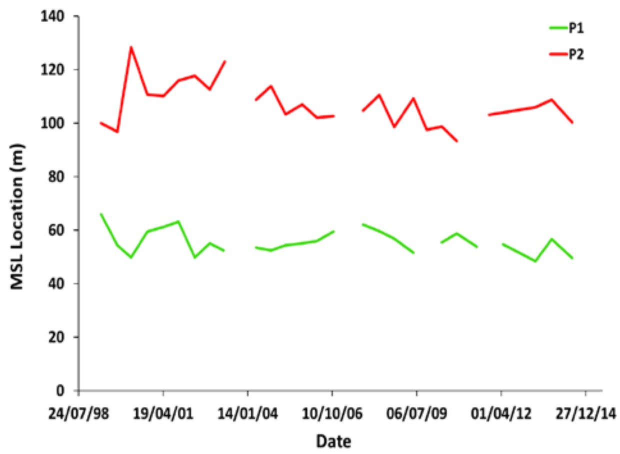


Figure 8-3 Beach width changes at the MSL contour, showing profile 1 in green and profile 2 in red.

Campbells Bay

Beach envelope variation

Campbell's Beach presents an intermediate state beach, with a moderate beach slope and minimal vertical and horizontal fluctuations resulting from limited wave energy. Interestingly, the current survey (15/07/14) on both profiles reaches the minimum envelope extent for the dune/upper beachface (Figure 6-4). But from approx. 35m offshore, or seaward of the MSL contour, this survey lies above the average and at the maximum envelope extent for profile 2. This may indicate that sand has been stripped out from the upper beach and deposited on the lower beachface. Easterly storm activity during June occurred over a three week period and would help explain the observed adjustment. Both profiles exhibit similar vertical and horizontal fluctuations, up to 1.5m and 30m respectively.

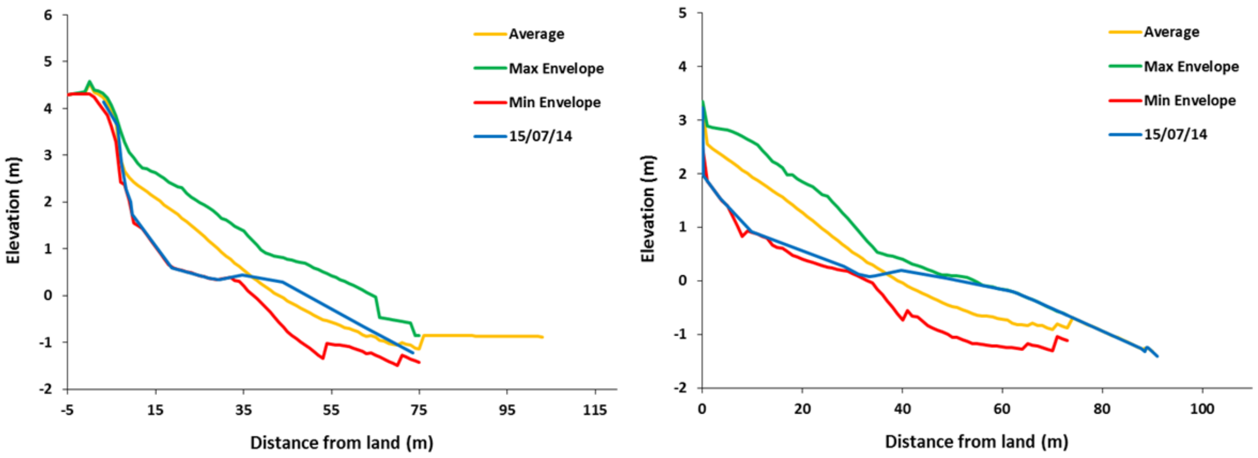


Figure 8-4 Beach profile envelopes illustrating the average beach profile in orange, the maximum extent of all profiles in green, the minimum extent of all profiles in red and, the most recent beach profile in blue. Profile 1 is on the left and profile 2 is on the right.

Beach volume

Both profiles show variable sand exchange across the record with no apparent trend of accretion or erosion (Figure 6-5). Reasonable short-term variability is apparent, for instance from October 1998 to April 1999 profile 1 increased 40 % in sand volumes. Likewise, profile 2 lost 29 % volume from May to November 2009 then gained 52 % to April 2010. What is most interesting is that the lowest volumes on record are from the current survey, with both profiles showing a sharp reduction of 18 m^3/m and 20 m^3/m at profile 1 and 2 respectively. This corresponds with beach envelope extents discussed previously. Further monitoring may reveal more of a net loss pattern.

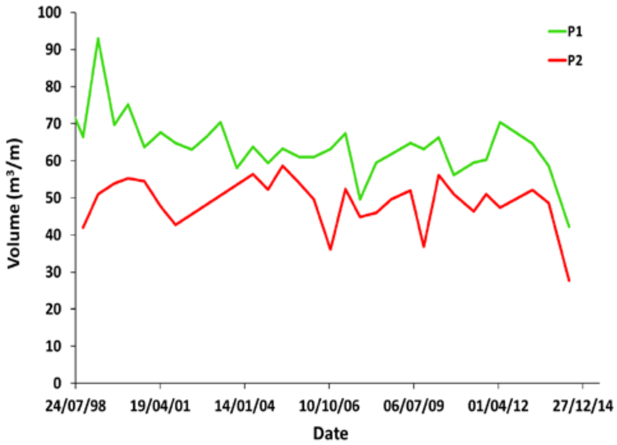


Figure 8-5 Beach volume changes at the MSL contour at Campbells Bay, showing Profile 1 in green and profile 2 in red.

Beach width

There is no obvious trend for increasing or decreasing beach-width. The MSL contour is subject to high variability, with up to 15m of change between successive surveys (Figure 6-6). Of note, whilst the current surveys show sand volumes at their lowest, both profiles have their second widest position on record at 49m (profile 1) and 51m (profile 2). This would indicate that at the current status sand has shifted seaward and built up on the lower beachface. Storm events transfer sand offshore as a response to increased energy and this exchange would support such a shift following the June 2014 easterly storms.

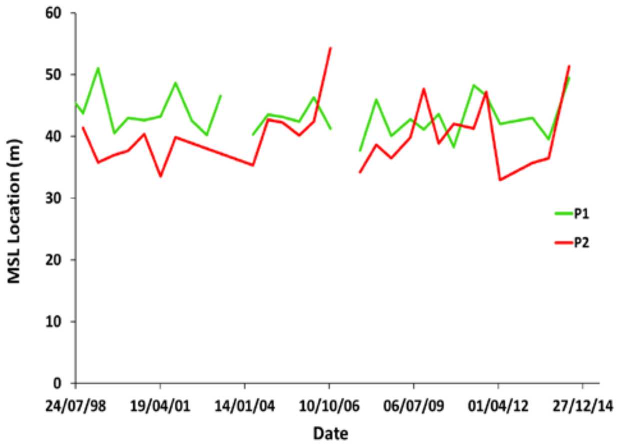


Figure 8-6 Beach width changes at the MSL contour. Profile 1 is in green and profile 2 is in red.

Milford Beach

Beach envelope variation

All profiles show similar envelopes, in terms of their morphology and min/max extents, since records began in 1998. It is within the upper beach (0-50m) that the largest envelope variation has occurred with little change occurring seaward of approximately 80m (Figure 6-7). Interestingly, the most recent survey profile (16/06/14) at the lower beachface reaches the minimum envelope level. This is similar to the changes that have occurred at Takapuna, with the exception that near the berm has not built up as Takapuna data has shown. Large and prolonged easterly storm events during June/July and September 2014 may have contributed to the observed changes, removing sand from the mid beachface area seaward. Visual confirmation of bedrock on profiles 1, 4, and 5 around 50m (distance from land) would suggest that no more losses of sand at these positions could occur. However, because the extent and depth of bedrock landward is unknown, it is unclear how much accommodation space (or substrate limitation) there is for sand storage (or erosion). Generally, the most recent survey places the beach profile below the average profile position.

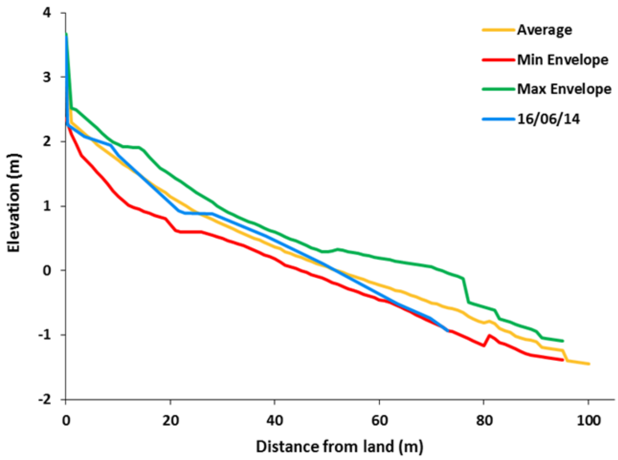


Figure 8-7 Beach profile envelope of profile 1, illustrating the average beach profile in orange, the maximum extent of all profiles in green, the minimum extent of all profiles in red and, the most recent beach profile in blue. This profile is indicative of the four other profiles.

Beach volume

Figure 6-8 illustrates that all profiles exhibit reasonable fluctuations; however, the current beach-wide combined volume of 32 m^3/m is very close to the average volume for the entire record of 33 m^3/m. The northern section of the beach contains more sand volume, most likely due to the lack of consistent seawall and more accommodation space for sand storage. Both the north and south experienced a large loss of sand in October 2000, indicating a major event. Additionally, interesting change occurred between August 2008 and June 2011, where the northern section of the beach showed a peak and fall, increasing in sand volume until April 2010 then decreasing in 2011. On the other hand, the southern section behaved directly in the opposite manner during the same period. The southern section has decreased by as much as 54% from original survey; however the high variability over such a short record gives little confidence in determining any apparent erosion trend. These changes contrast to the mostly random sand volume changes between all profiles across the record.

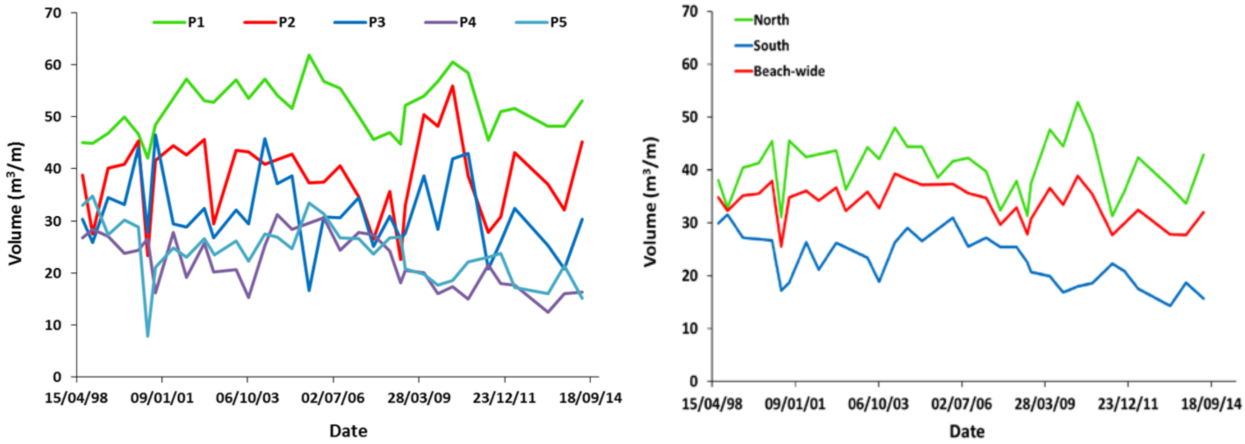


Figure 8-8 Beach volume changes at the MSL contour at Milford Beach, showing individual profile time series on the left, and the combined beach-wide, northern and southern averaged volumes time series on the right.

Beach width

Similar to the volume analysis, there is no trend of beach widening at the MSL contour over the survey record (Figure 6-9). What is most interesting is the increase in beach width during the observed erosion period during winter 2000. Width increased from 42m to 72m over a 3 month period (narrowest and widest on record). During this same period beach volume reduced. While this is not a substantial change in sand, it does highlight the capacity for rapid sand movement during a short time, either from offshore sources or the upper beachface/berm areas. Profile 1 has the widest beach at the MHWS contour, with profile 5 having the narrowest. This is likely a result of the ability for the beach at profile 1 to move freely and the inability of other profiles to move due to hard protection structures.

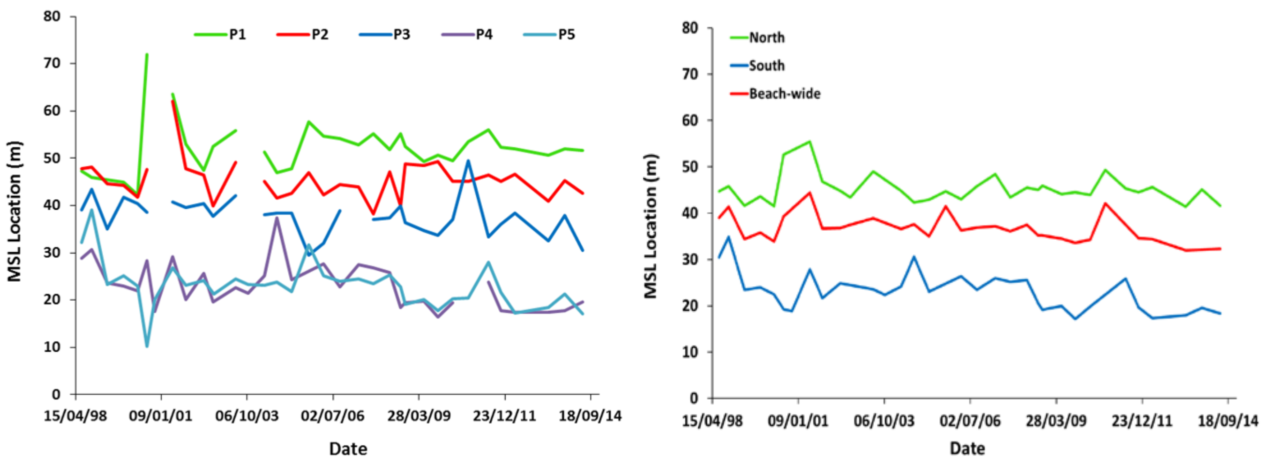


Figure 8-9 Beach width changes at the MSL contour, showing the time series of the individual profiles on the left, and the combined beach-wide, northern and southern averaged widths on the right.

Cheltenham Beach

Beach envelope variation

All profiles show similar envelopes, in terms of their morphology. It is within the upper beach that most change has occurred, with very little change occurring past approx. 40m (Figure 6-10). The most recent surveys (16/06/14) lie within the range of all profile envelopes, with profile 2 and profile 3 mostly sitting near or below the average profile position along the beach (Appendix A). The most recent survey on profile 1, however, is placed near the maximum range of all surveys especially at the toe of the beach berm. Given that profile 1 is the most northern and profile 3 is southern, observed differences may support the notion of longshore drift towards the south even with potential sand gains into the system.

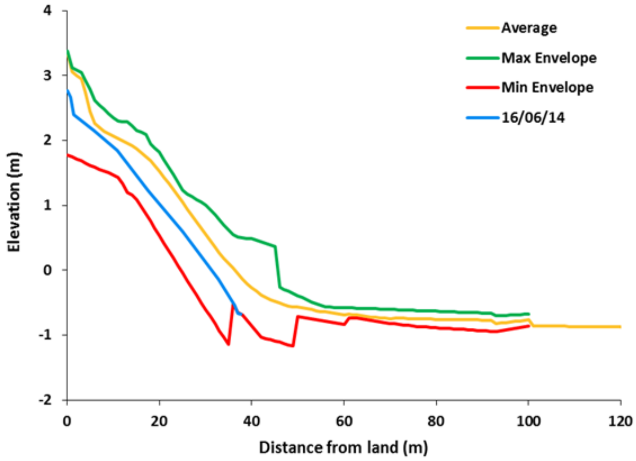


Figure 8-10 Beach profile envelope of profile 2, illustrating the average beach profile in orange, the maximum extent of all profiles in green, the minimum extent of all profiles in red and, the most recent beach profile in blue. This profile is indicative of the two other profiles.

Beach volume

At the beach-wide scale, the overall beach condition (budget) remains relatively stable (maintained within a dynamic equilibrium), with the current sand volume of 41.75 m^3/m similar to the average of 41.2 m^3/m (Figure 6-11). Profile 1 displays cyclic patterns where sand is gained and lost over 2-5 year periods. Additionally, there is contrast between profiles 1 and 3 (north and south respectively), where profile 1 has gained 29 m^3/m (from 18 m^3/m to 47 m^3/m), and profile 2 has lost 8 m^3/m (from 51 m^3/m 43 m^3/m). Profile 3 remains stable. Compared to the other beaches within the inner Hauraki Gulf, Cheltenham does not seem to be affected by the recent easterly storms in 2014.

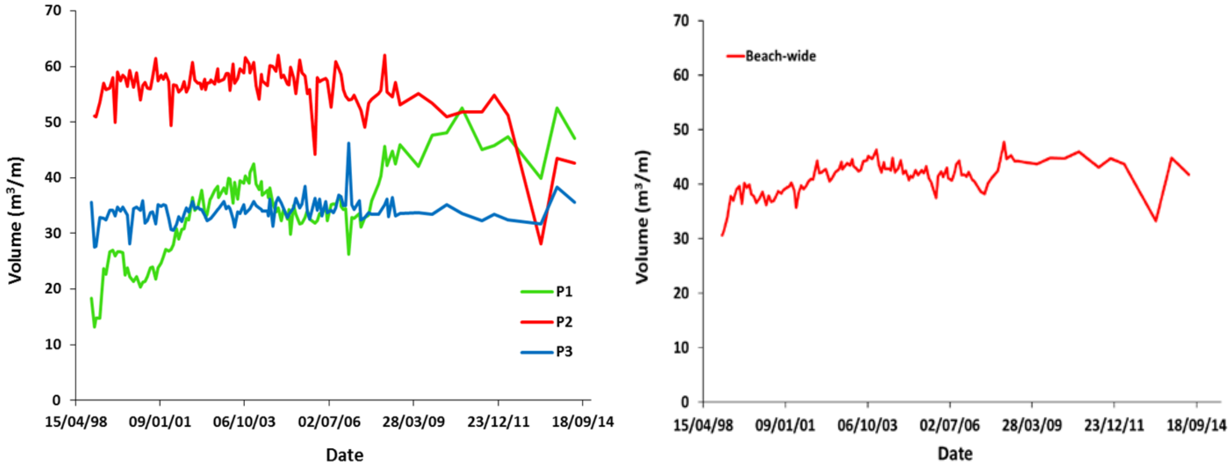


Figure 8-11 Beach volume changes at the MSL contour at Cheltenham Beach, showing individual profile time series on the left, and the combined beach-wide, northern and southern averaged volumes time series on the right.

Beach width

Contour change reflects changes in volume across all profiles, with no real widening or narrowing of the beach width across the beach (Figure 6-12). Profile 1 does show a cyclic pattern, whilst steadily increasing in the MSL contour. Profile 1 also has the highest standard deviation of 3.82m. Profile 2 shows a similar decrease in widths to that of the volume changes since 2011. This profile also has the highest beach width (36m). Profile 3 shows a stable width of an average of 26.96m, and consists of small oscillations throughout the dataset.

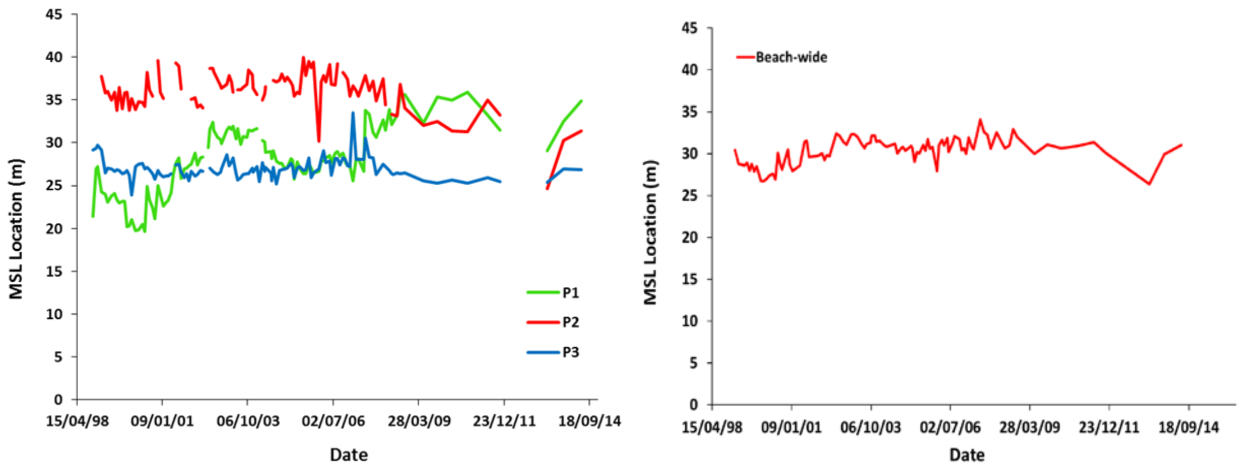


Figure 8-12 Beach width changes at the MSL contour, showing the time series of the individual profiles on the left, and the combined beach-wide, eastern and western averaged widths on the right.

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Te Kaunihera o Tāmaki Makaurau