Shoreline Monitoring in Tory Channel and Queen Charlotte Sound

FINAL REPORT

November 2002 – May 2006

Report prepared for the Marlborough District Council

by

Dr Kevin E Parnell
School of Tropical Environment Studies and Geography
James Cook University
Townsville, Queensland 4811
Australia

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1. Introduction

In an agreement between Marlborough District Council and Auckland UniServices Limited, dated 25 January 1997, Auckland UniServices Ltd, was engaged to establish and report on a shoreline monitoring programme in Tory Channel and Queen Charlotte Sound. Initially, the programme was for three years, involving six sets of surveys. Progress reports were provided every six months (following a survey of shoreline profiles), concluding with a final report in December 1999. The programme was then extended through to April 2002 with a further five surveys, concluding with a final report following the April 2002. A contract for a further two surveys (November 2002 and April 2003) was negotiated in late 2002. In November 2003 a new contract was negotiated with James Cook University, Australia for the analysis of surveys in November 2003, April 2004, November 2004, April 2005, November 2005 and April 2006, concluding with a summary report, following Dr Kevin Parnell's move to that University. This is that summary report.

Marlborough District Council entered into an agreement with Ayson and Partners, Surveyors, of Blenheim, to maintain the shoreline profiles and to undertake the required surveys, under the direction of Dr Kevin Parnell.

2. Purpose of the monitoring programme

Following the introduction of fast ferry services between Wellington and Picton in late 1994 there was considerable debate as to the effects of the fast ferry operation on the shorelines and the biota of Tory Channel and Queen Charlotte Sound. One particular area of concern was beach change, particularly erosion of beaches. Considerable data were produced, and interpretations made by a range of experts at a Planning Tribunal hearing in March and April 1995, culminating in a decision (Decision W 40/95) dated May 1995.

Over the summer of 1995/96, Auckland UniServices Ltd was contracted by the Marlborough District Council and the Department of Conservation to measure and report on wake characteristics, establish and report on a series of beach profiles, and undertake some basic sediment tracing experiments. The results were reported by

Parnell, "Monitoring effects of ferry wash in Tory Channel and Queen Charlotte Sound", in April 1996. The study included the monitoring of 13 profiles over the period 8 November 1995 to 29 February 1996.

The present monitoring programme began in April 1997. Surveys were scheduled to follow the end of the fast ferry operating season at Easter, and to precede the summer operating season in December. Since that time, there have been numerous changes to the operating schedules and vessels operating the inter-island route. In particular, different summer and winter operating schedules have been abandoned, with more consistent operating regimes. However, the surveys have continued to be planned in April and November, although some surveys have been outside this time frame (notably June 2001, and May 2006).

Apart from the issues related to vessel wakes, there is poor understanding of how beaches in the Marlborough Sounds behave. Therefore, beaches of a range of types and from locations not directly adjacent to the ferry route have been included in this study.

3. Profile locations and methods

Details of the selection of survey sites, establishment of profiles, benchmarks and datums, and survey methodology are in the final report of the first contract period. Profile descriptions are also in that report. The location of the 21 profiles is shown in Figure 1, and their positions are detailed in Table 1. Positions are with respect to the WGS84 ellipsoid. A list of currently used benchmarks and their levels is in Appendix 1. A visual impression of the profiles can be obtained from the photographs in Section 5 and in Appendix 2.

Table 1: Profile positions

Pr	Name	Lat °	Lat '	Lat "	Long°	Long '	Long "
1	Picton Foreshore	41	17	17.6	174	0	25.1
2	The Snout at Picton Point	41	15	46.5	174	2	10.9
3	Double Bay	41	13	10.3	174	11	36.7
4	Ngaionui Bay (C Thomas)	41	14	16.5	174	11	8.5
5	Blackmore's at Waikawa	41	15	50.0	174	2	58.2
6	Moioio Island 2	41	14	39.4	174	12	56.9
7	Moioio Island 1	41	14	39.6	174	12	56.3
8	Bob's Bay	41	16	31.3	174	1	1.0
9	Te Awaiti	41	12	28.8	174	17	16
10	Tipi Bay	41	13	40.2	174	17	12.8
11	Long Island	41	7	22.3	174	16	12.6
12	Clark Point	41	8	12.6	174	17	30.7
13	Slip Beach	41	15	0.0	174	9	8.3
14	Ngaionui Point	41	14	27.6	174	10	46.2
15	Te Weka Bay	41	14	58.3	174	11	34.0
16	McMillan's Bay	41	14	45.5	174	12	11.4
17	McMillan's Side	41	14	43.5	174	12	9.6
18	Dieffenbach West	41	14	13.4	174	8	9.4
19	Curious Monkey	41	14	28.8	174	6	14.4
20	Patten's Passage	41	10	56.9	174	15	47.4
21	Blumine Island	41	9	37.0	174	14	4.4

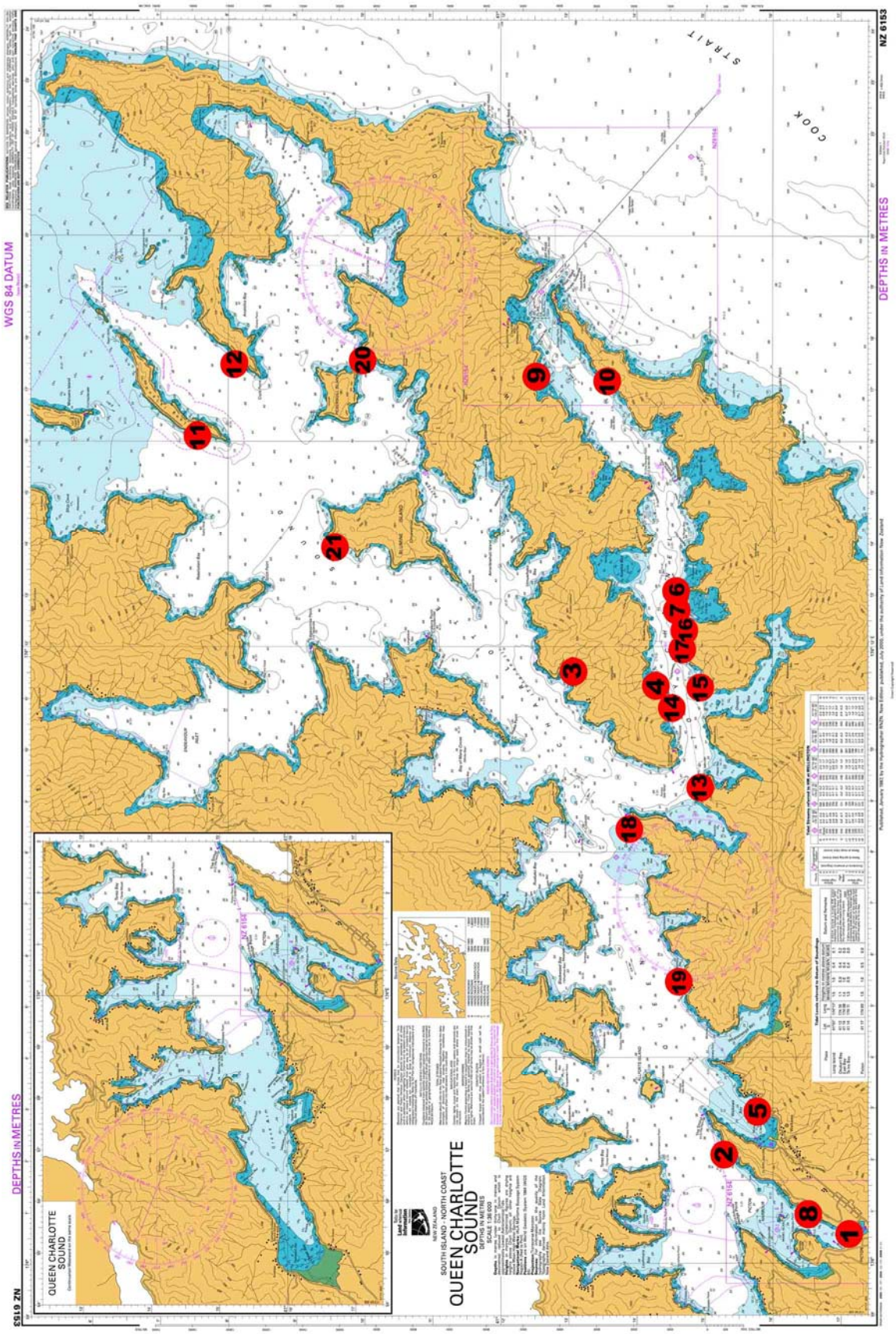


Figure 1: Profile locations

4. Vessel operations affecting the profile sites

Vessels carrying passengers and freight between Wellington and Picton, have operated the Tory Channel/Queen Charlotte Sound route for many years. In late 1994, fast vessel operations started using the route alongside the conventional ferries. Until 2000, various fast ferries operated over the summer months, after which an almost continuous service using fast vessels ran until April 2005. However, in December 2000 the Marlborough District Council enacted a bylaw that had the effect of slowing fast ferries to 18 knots while in the Sounds, so after that time the fast ferries operated at their normal service speed only outside the Marlborough Sounds. The Bylaw did not apply to conventional vessels. Figure 2 shows the time periods over which various vessels have operated. Other vessels, both large and small, also use the route.

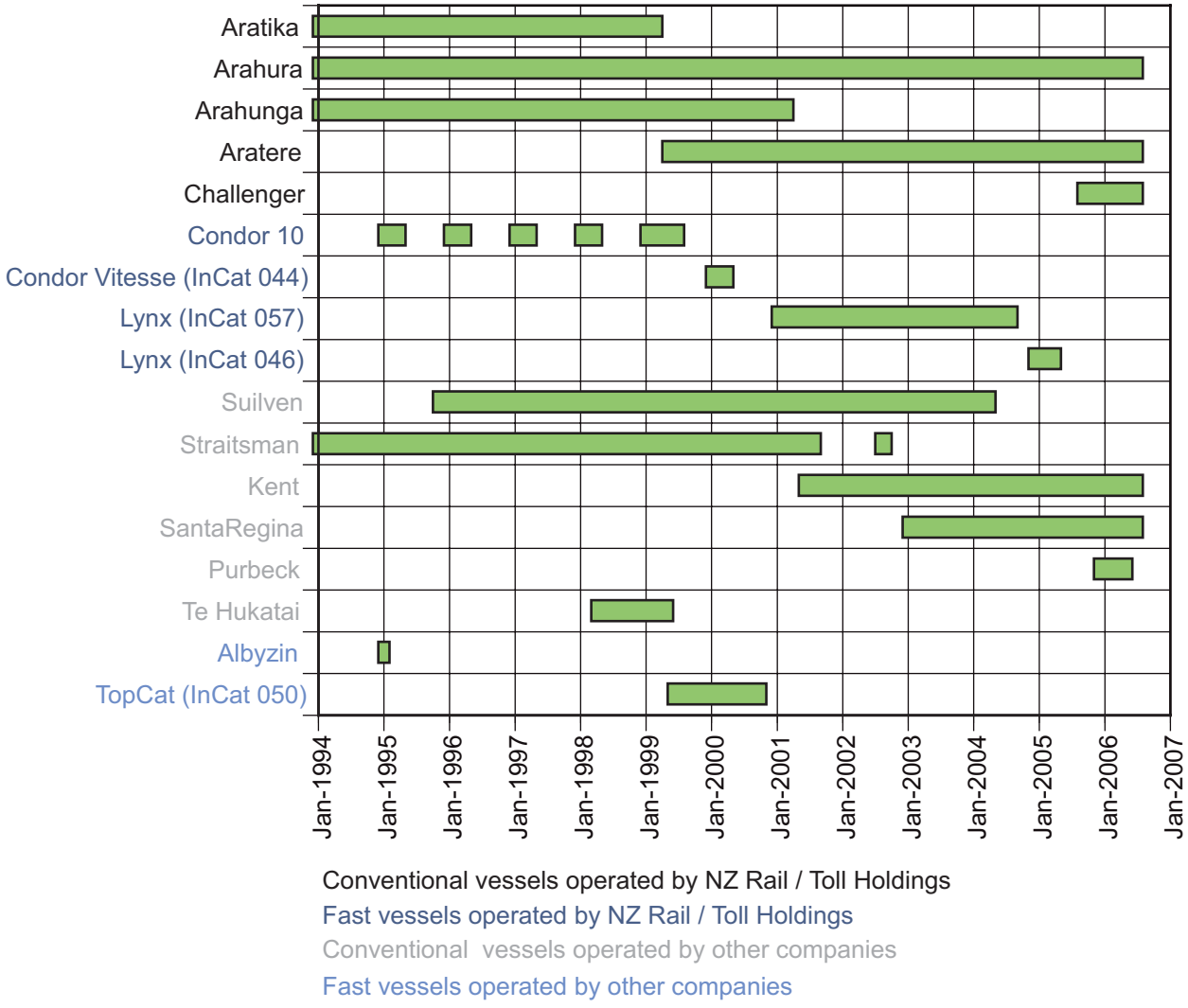


Figure 2: Vessels using the Tory Channel/Queen Charlotte Sound route on regular inter-island services

5. Profile analyses

In this section data are presented for each profile and an interpretation of the changes that have occurred is presented. Each profile analysis is accompanied by three pages of figures. The first page has photographs of the profile site taken from about 20 meters each side looking back towards the profile line (taken in May 2006) at the top. At the bottom of the first page is a diagram of profile lines at the start of the monitoring programme in April 1997, the end of the first contract (November 1999), the end of the second contract period (April 2002), and at the time of the last survey(May 2006) . The second page comprises a 'spaghetti' diagram showing the 19 surveys of the profiles (April 1997, November 1997, April 1998, November 1998, April 1999, November 1999, April/May 2000, November 2000, June 2001, November 2001 and April 2002, November 2002, April 2003, November 2003, April 2004, November 2004, April 2005, November 2005, May 2006) in the upper section, and in the lower section, a different view of the same data commonly known as an 'Excursion Distance Analysis'. For those profiles for which a longer term data set is available (those monitored by Kirk and Single, or by Parnell (1996)), the full record is presented. The final page shows beach volume data (m^3 per linear meter of beach) presented as a graph and a table. The limits for the calculations are determined as shown in Figure 3 and Table 2. The upper beach limit was a point on the upper beach landward of any profile change (if possible) or at the upper limit of the profile measurement. Because changes at the lower beach can indicate erosion, a measurement based on elevation is appropriate. This was taken at profile closure depth if this was evident, or at a point which was reached on most surveys. Where a profile did not reach the chosen lower limit, a value was estimated based on linear extrapolation or on values measured before and after a missing data point.

Table 2: Volume calculation limits

Prof.	Name	Upper beach limit (m)	Lower beach limit (m)
1	Picton Foreshore	6.87	-0.50
2	The Snout at Picton Point	0.00	-1.00
3	Double Bay	-1.50	-1.00
4	Ngaionui Bay (C Thomas)	-2.00	-0.25
5	Blackmore's at Waikawa	2.30	-0.75
6	Moioio Island 2	-2.00	-1.50
7	Moioio Island 1	0.00	-1.50
8	Bob's Bay	0.00	-1.00
9	Te Awaiti	0.30	-1.50
10	Tipi Bay	0.00	-1.25
11	Long Island	0.00	-0.75
12	Clark Point	0.00	-0.25
13	Slip Beach	-1.00	-1.25
14	Ngaionui Point	-2.00	-0.75
15	Te Weka Bay	2.00	-1.50
16	McMillan's Bay	0.00	-0.75
17	McMillan's Side	-2.00	-0.75
18	Dieffenbach West	0.00	-0.50
19	Curious Monkey	0.00	-0.50
20	Patten's Passage	0.00	-0.50
21	Blumine Island	0.00	-0.50

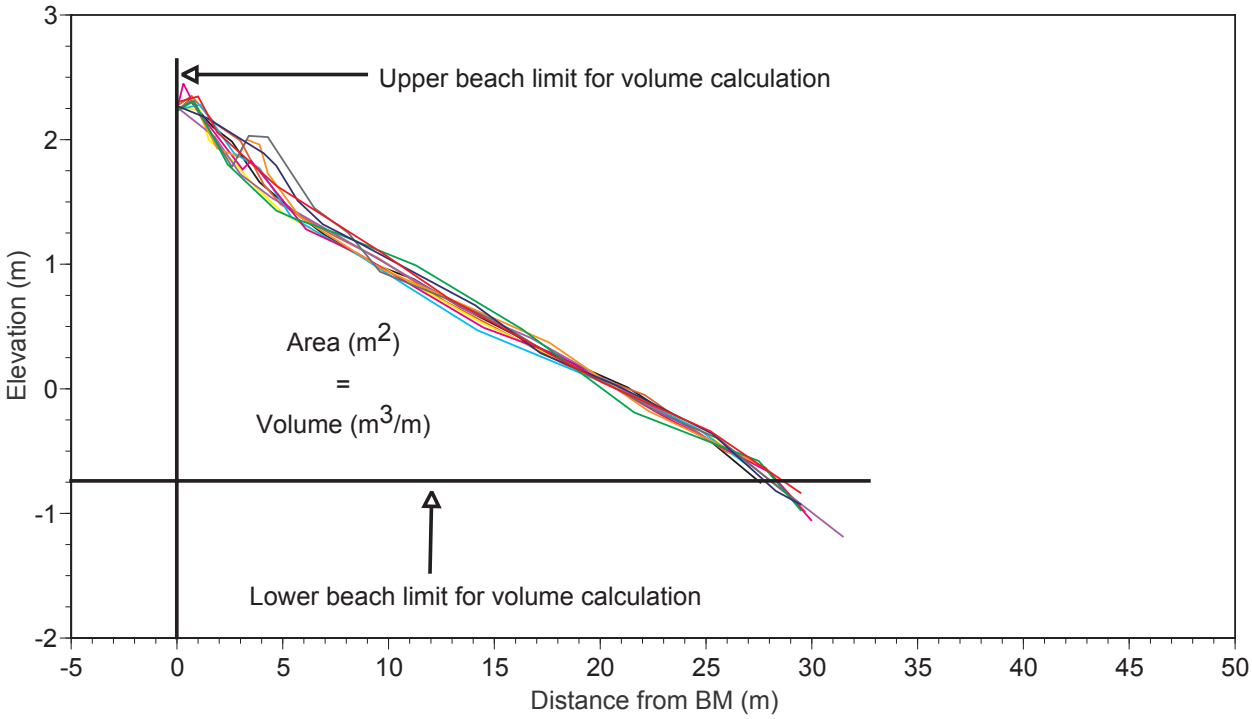


Figure 3: Volume calculation methodology

The ‘spaghetti’ plots of profiles are useful for establishing envelopes of change of the beach shape, but interpretations of changes which have occurred are difficult, due to the clutter of lines that are present. As the data set grows, any useful interpretation based on these plots becomes almost impossible. Excursion distance plots use exactly the same data plotted as a time series, and makes interpretation of beach changes easier. Excursion distance analysis is a method by which three dimensional data sets (distance, height and time) can be illustrated as two dimensional plots. It can be undertaken with either distance or height on the vertical axis, although having distance on the vertical axis is more useful for most purposes. Excursion distances are calculated by determining a set of height values for which calculations will be made. These values are normally equally spaced and in the following figures, are shown in the box on the right hand side of the graph. These numbers are in units of metres above or below the datum (in this case approximate MSL). Using linear interpolation the horizontal distance from the datum is calculated for each of the height values, and these are plotted as a time series with time on the horizontal axis. For each survey this provides a “point contour map” of the profile, and when plotted as a time series, an indication of how levels change through time. The graphs provide a lot of information. If two lines converge, the beach is getting steeper at those contour heights. If two lines diverge, the beach is getting flatter. If the lines trend seaward (increasing values on the distance axis), the beach is accreting. If the lines trend landward, the beach is eroding. Figure 4 attempts to show the methodology of Excursion Distance Analysis.

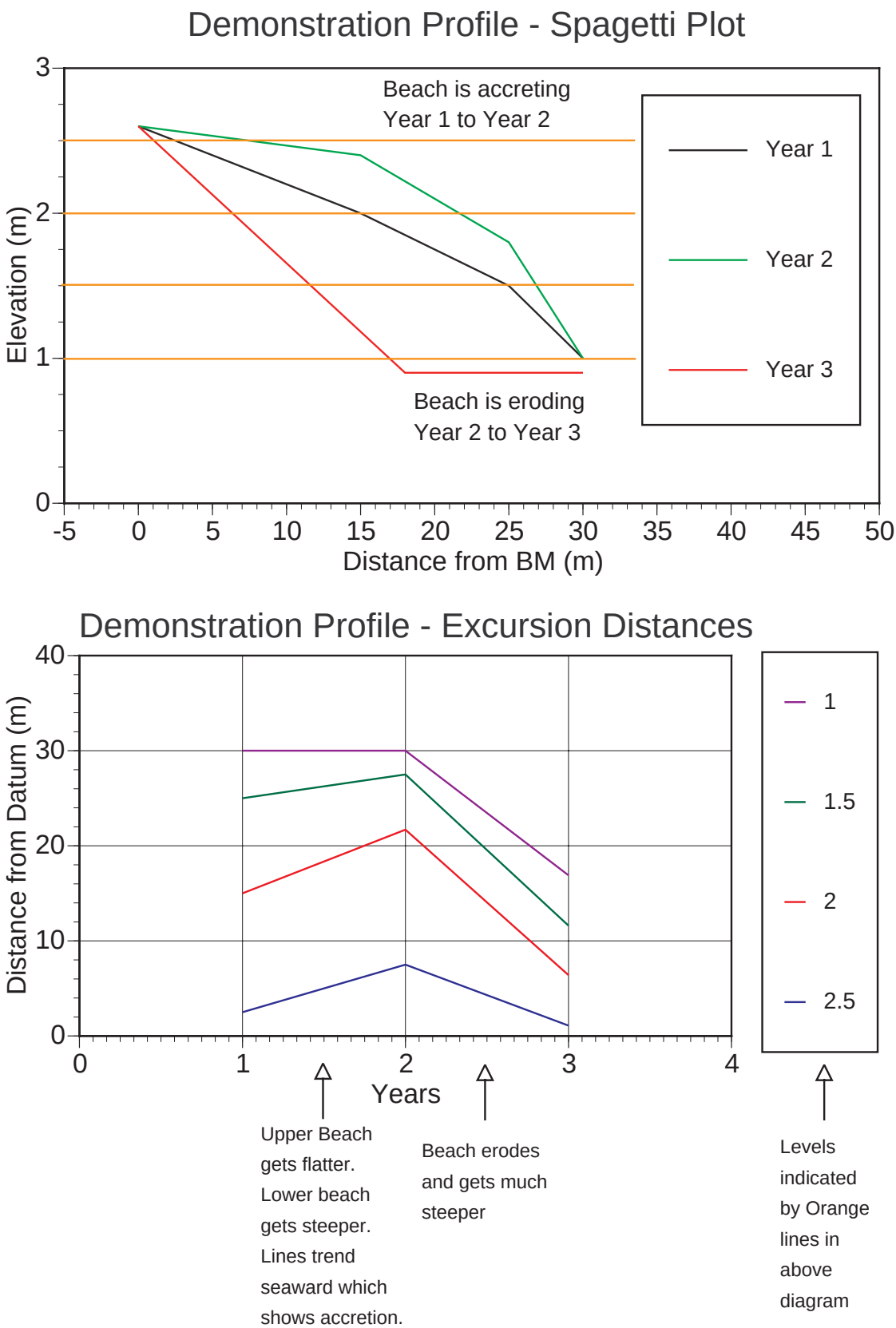
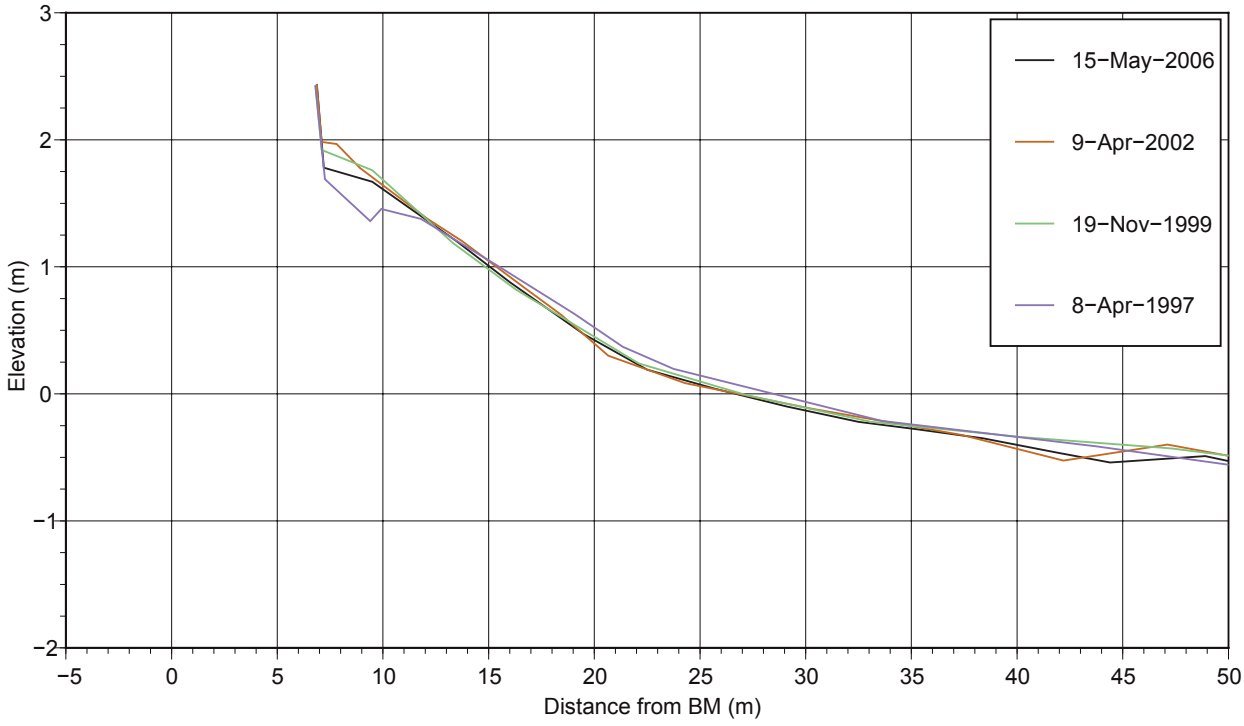


Figure 4 : Excursion Distance Analysis Demonstration

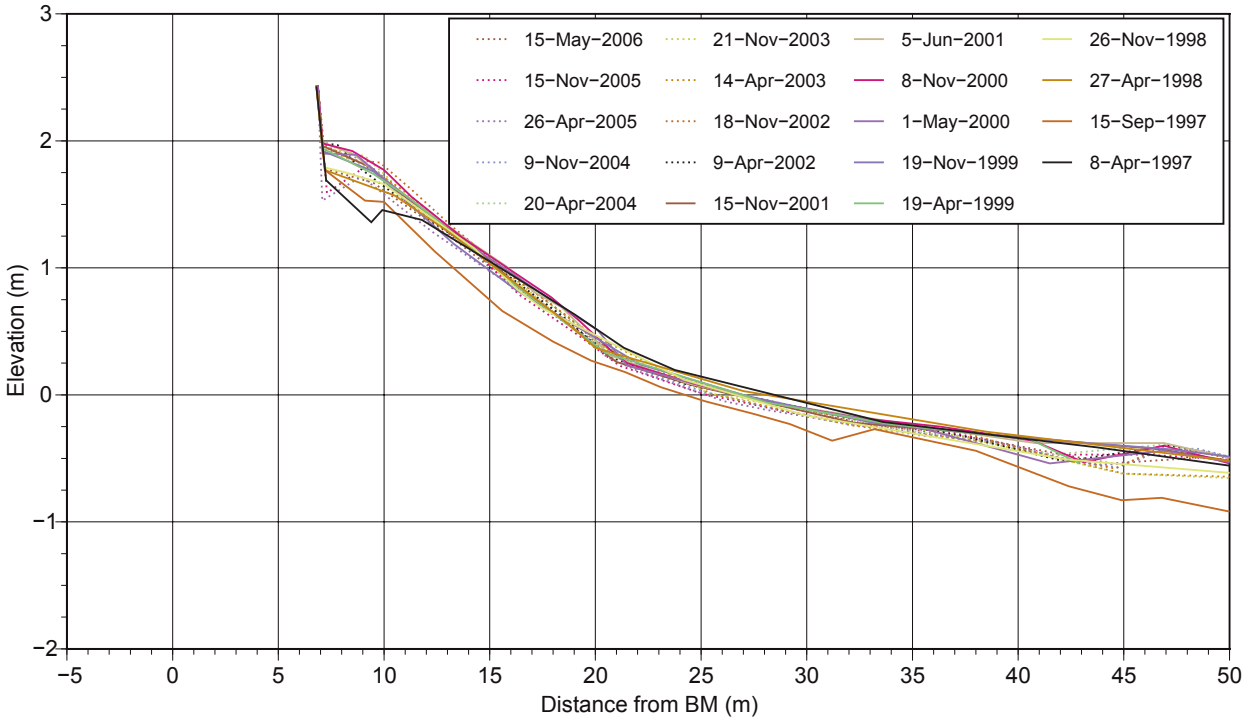
Profile 1 – Picton Foreshore

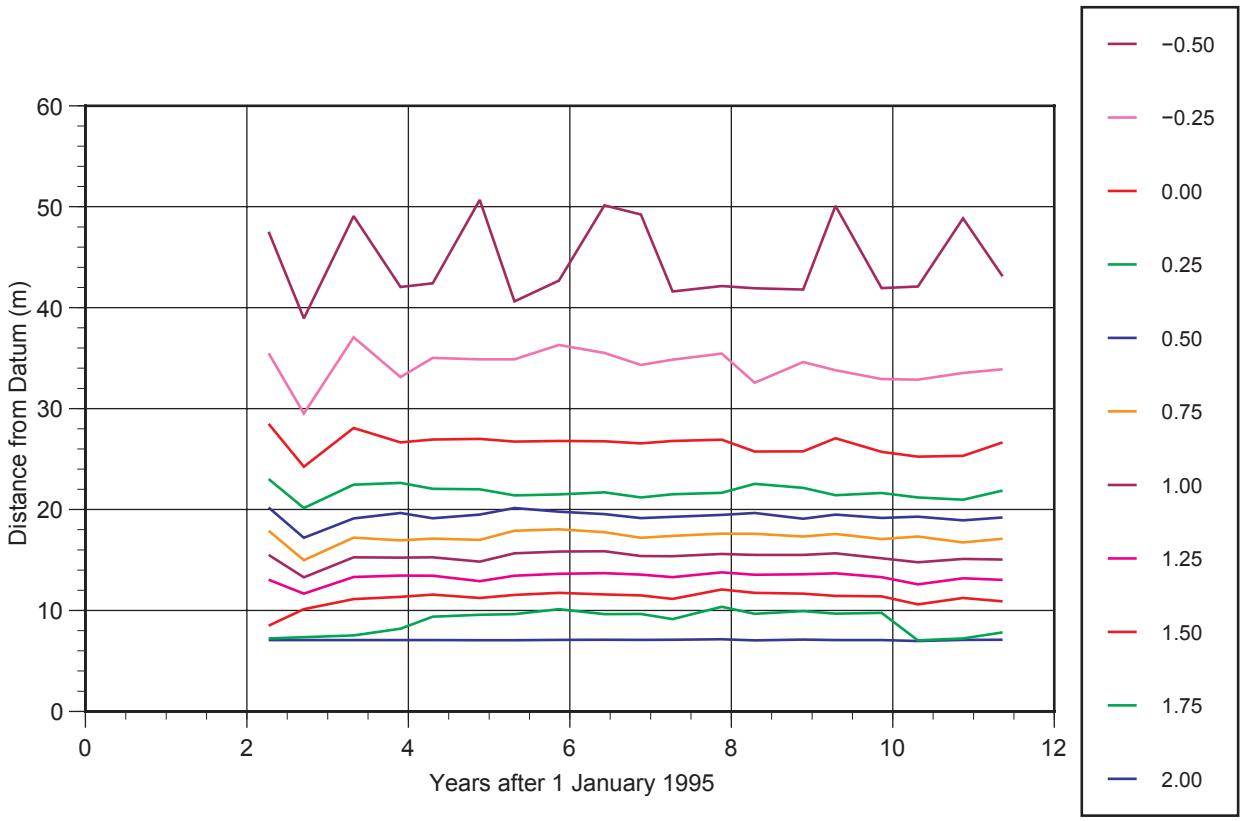
The Picton Foreshore underwent extensive modification with the improvement of the landward side of the retaining wall in late 1997. Sediments on the beach comprise both natural marine sediments and river sand deposited in a beach nourishment programme.

I do not know if further nourishment has taken place since late 1997 or early 1998. If further nourishment has taken place, then the rate of nourishment is clearly appropriate. If there has been no renourishment, then the beach has been very stable since that time. Beach volume has maintained a relatively narrow range since April 1998, between 29.1 m^3/m and 32.9 m^3/m, although there is an indication that a small amount of sediment may have been lost since November 2004, with volumes since that time being at the lower end of the range. There has been no apparent change in sediment characteristics. There is no indication that the seawall has had an adverse effect on beach stability. There is no indication that waves caused by vessel wash in the inner harbour are having an adverse effect on the Picton foreshore beach.

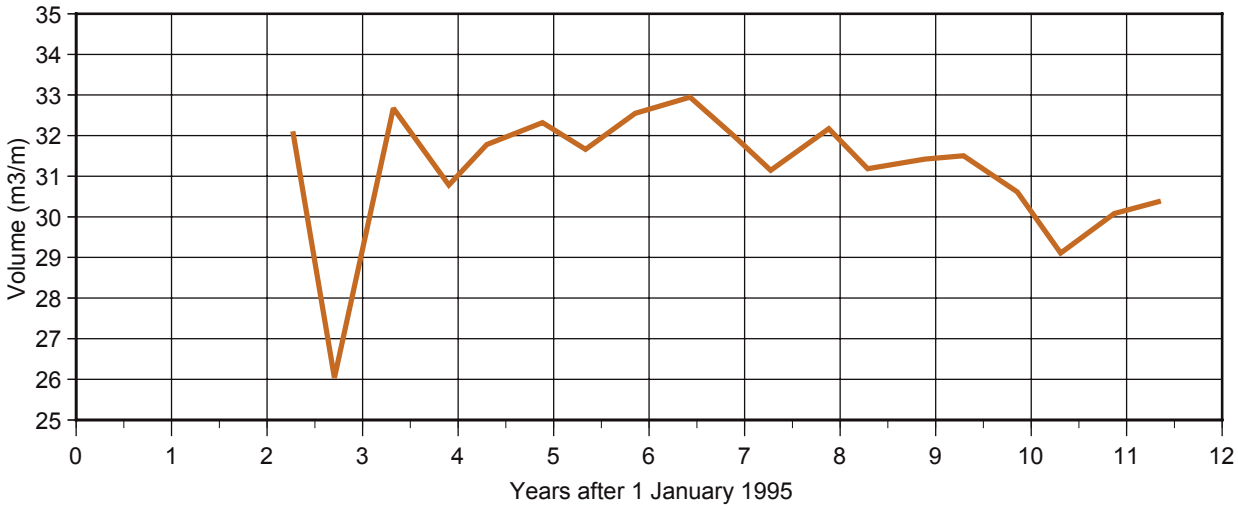


Profile 1: Picton Foreshore





Profile 1: Picton Foreshore

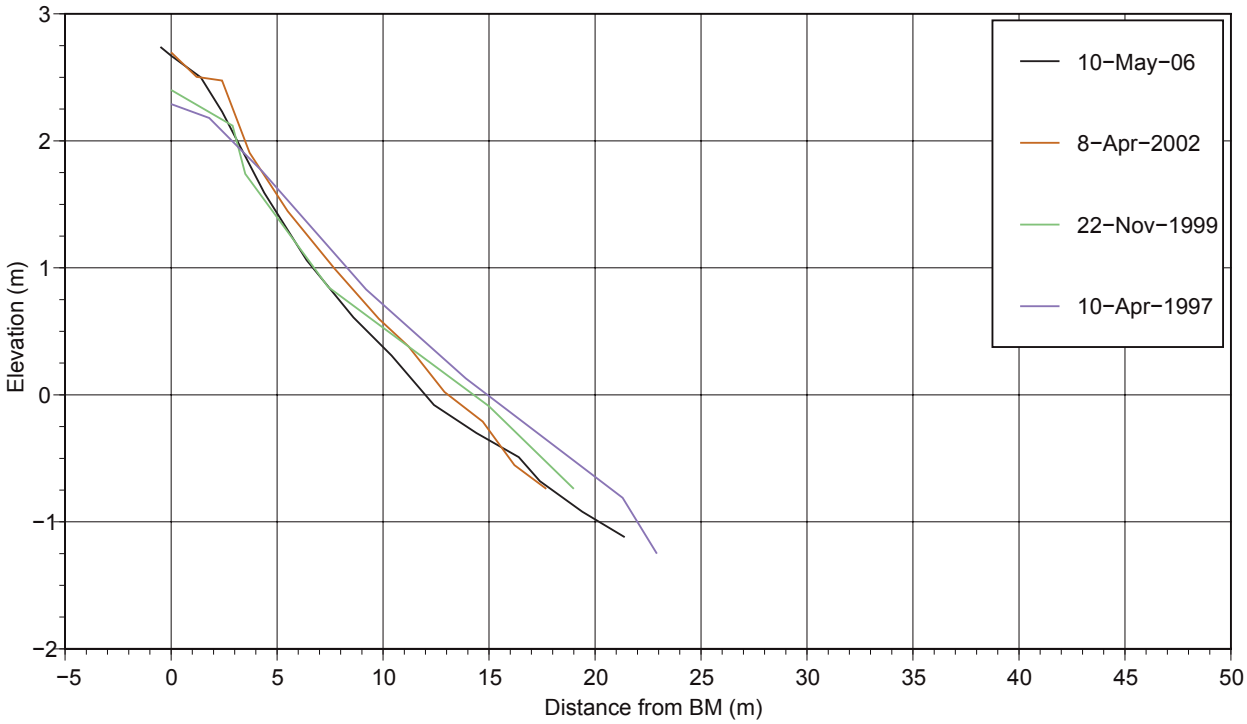


Date	Years after 1/1/95	Volume (m^3/m)
8-Apr-97	2.27	32.1
15-Sep-97	2.71	26.0
27-Apr-98	3.32	32.7
26-Nov-98	3.90	30.8
19-Apr-99	4.30	31.8
19-Nov-99	4.88	32.3
1-May-00	5.33	31.7
8-Nov-00	5.85	32.5
5-Jun-01	6.43	32.9
15-Nov-01	6.87	32.0
9-Apr-02	7.27	31.1
18-Nov-02	7.88	32.2
14-Apr-03	8.29	31.2
21-Nov-03	8.89	31.4
20-Apr-04	9.29	31.5
9-Nov-04	9.86	30.6
26-Apr-05	10.31	29.1
15-Nov-05	10.87	30.1
15-May-06	11.36	30.4

Profile 1: Picton Foreshore

Profile 2 – The Snout at Picton Point

The trend of erosion of the middle and lower beach and some accretion of the upper beach, reported in the last summary report has continued. This has led to a steepening of the beach profile, clearly evidenced by the convergence of lines in the EDA graph. The beach profile lines show that the measured beach profile does not reach closure depth, which indicates that the deep water channel is migrating shoreward. These changes have been accompanied by a significant loss of sediment volume from 36.4 m^3/m in April 1997, to 31.9 m^3/m in May 2006, although similar low volumes have been recorded in November 2000 and in November 2003. There have been no apparent changes in sediment composition over the survey period.



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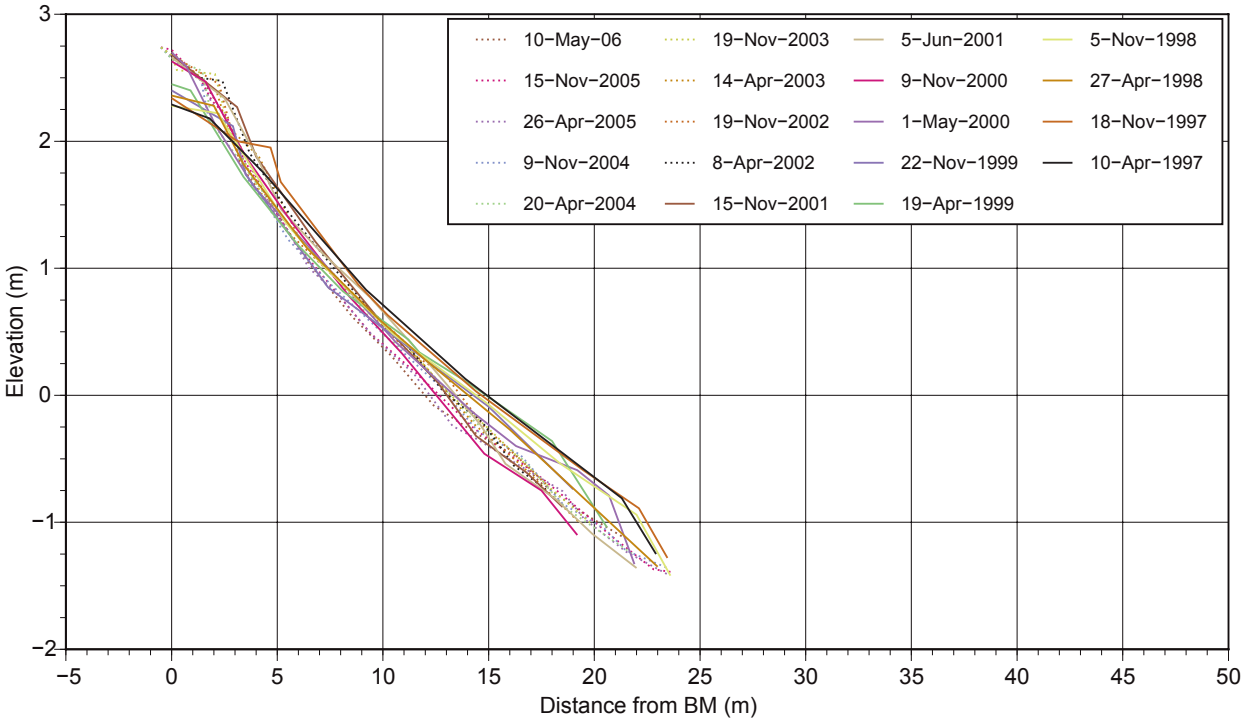
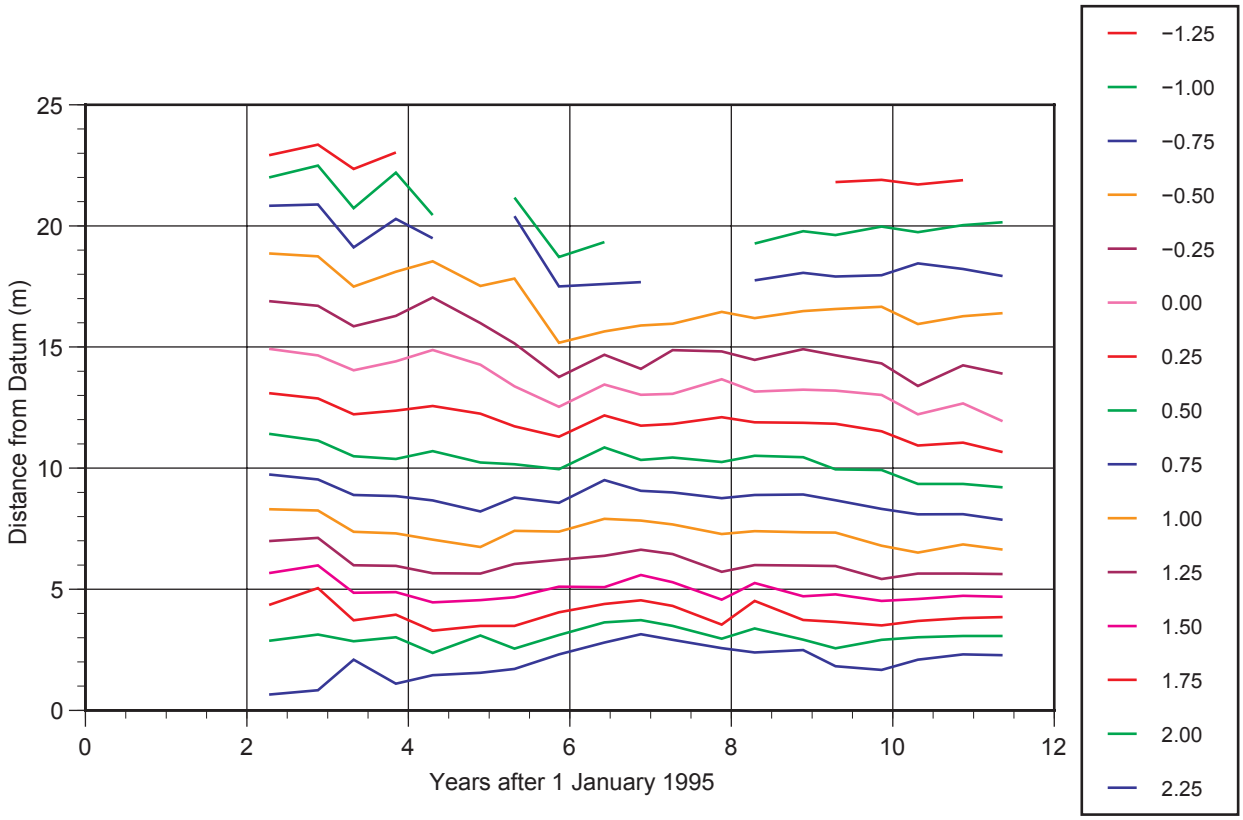
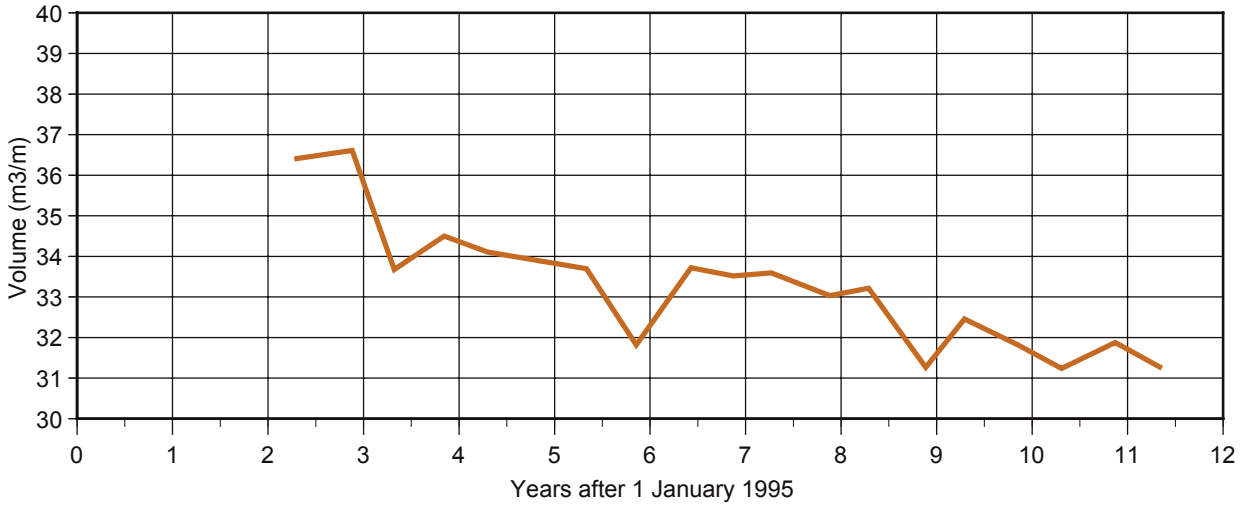




Profile 2: The Snout at Picton Point

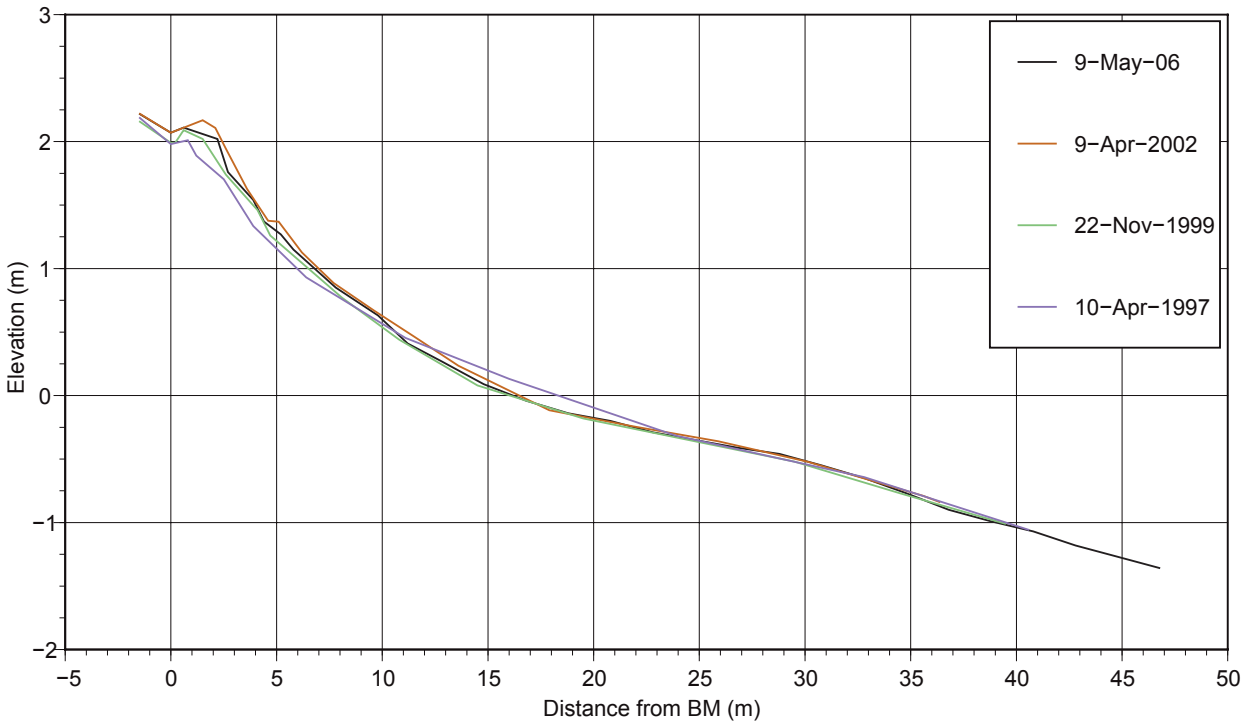


Date	Years after 1/1/95	Volume (m^3/m)
10-Apr-97	2.28	36.4
18-Nov-97	2.88	36.6
27-Apr-98	3.32	33.7
5-Nov-98	3.84	34.5
19-Apr-99	4.30	34.1
1-May-00	5.33	33.7
1-May-00	5.33	33.7
9-Nov-00	5.86	31.8
5-Jun-01	6.43	33.7
15-Nov-01	6.87	33.5
8-Apr-02	7.27	33.6
19-Nov-02	7.88	33.0
14-Apr-03	8.29	33.2
19-Nov-03	8.89	31.3
20-Apr-04	9.29	32.5
9-Nov-04	9.86	31.8
26-Apr-05	10.31	31.2
15-Nov-05	10.87	31.9

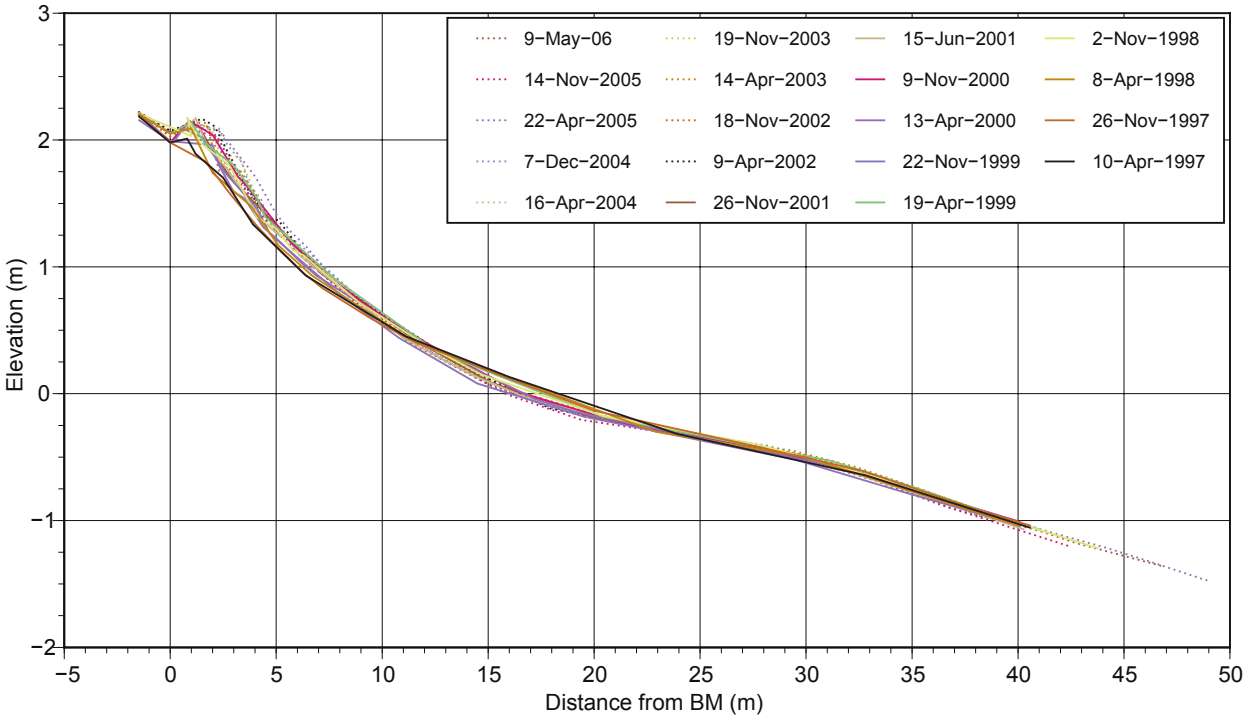
Profile 2: The Snout at Picton Point

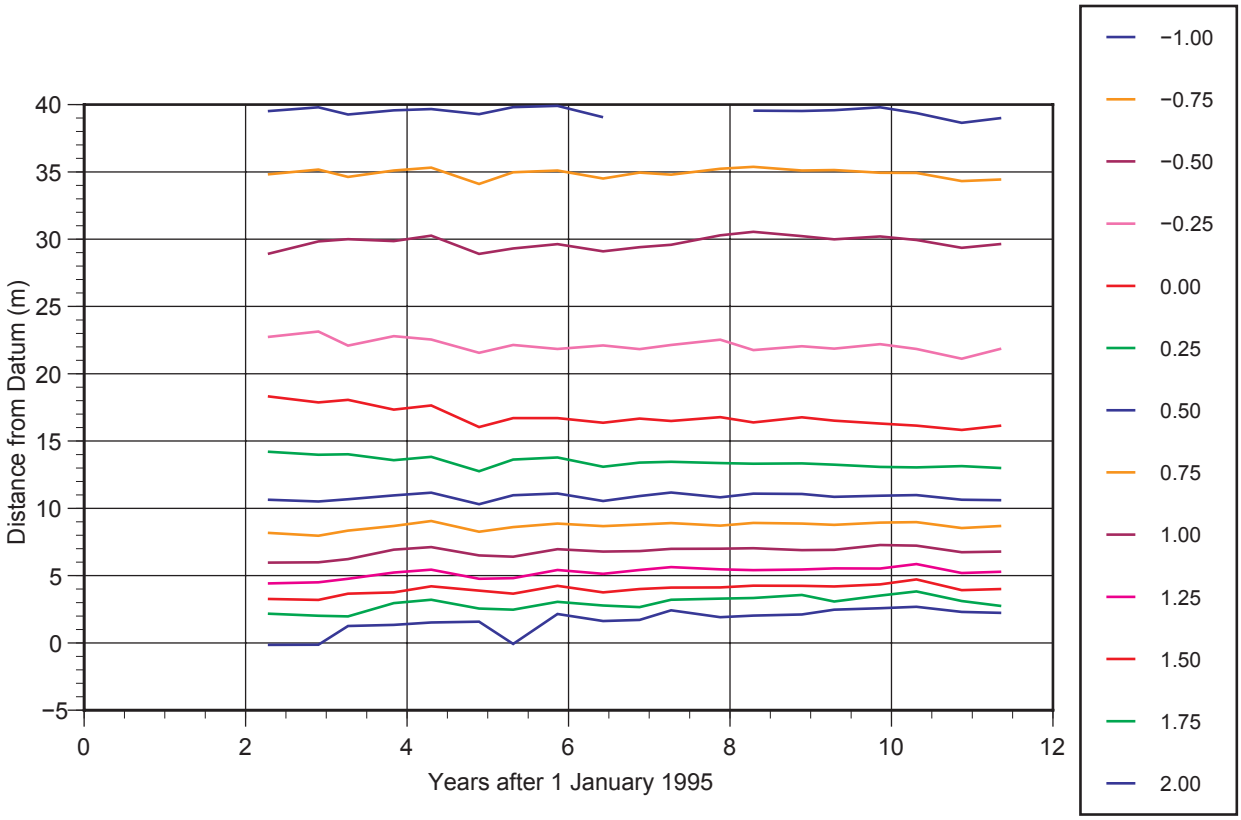
Profile 3 – Double Bay

The Double Bay beach profile has changed within a very narrow range over the period April 1997 to May 2006. The most recent profile data sits close to the centre of the long-term sweep, with beach volume in 2006 being almost exactly the same as it was in April 1997. There has been a minor steeping of the beach with the construction of a berm and a minor lowering of the mid-beach surface, although this peaked in 2002. The profiles clearly reach closure depth at about -0.5m. There is some indication that the sediments may have become slightly more sandy over the last 10 years.

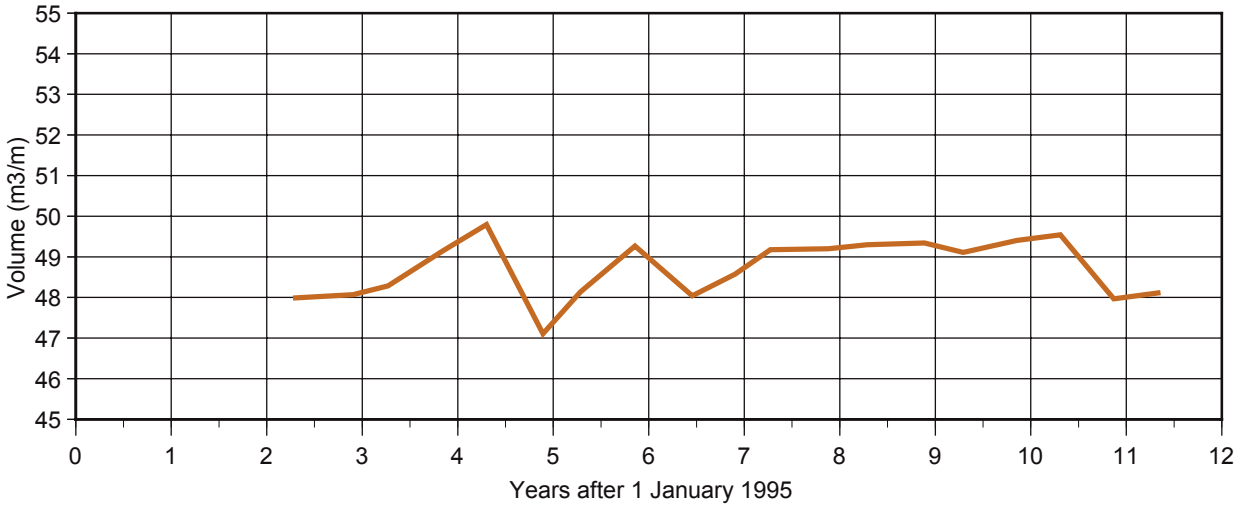


Profile 3: Double Bay





Profile 3: Double Bay



Date	Years after 1/1/95	Volume (m^3/m)
10-Apr-97	2.28	48.0
26-Nov-97	2.90	48.1
8-Apr-98	3.27	48.3
2-Nov-98	3.84	49.1
19-Apr-99	4.30	49.8
22-Nov-99	4.89	47.1
13-Apr-00	5.28	48.1
9-Nov-00	5.86	49.3
15-Jun-01	6.46	48.0
26-Nov-01	6.90	48.6
9-Apr-02	7.27	49.2
18-Nov-02	7.88	49.2
14-Apr-03	8.29	49.3
19-Nov-03	8.89	49.3
16-Apr-04	9.29	49.1
7-Dec-04	9.86	49.4
22-Apr-05	10.31	49.5
14-Nov-05	10.87	48.0
9-May-06	11.36	48.1

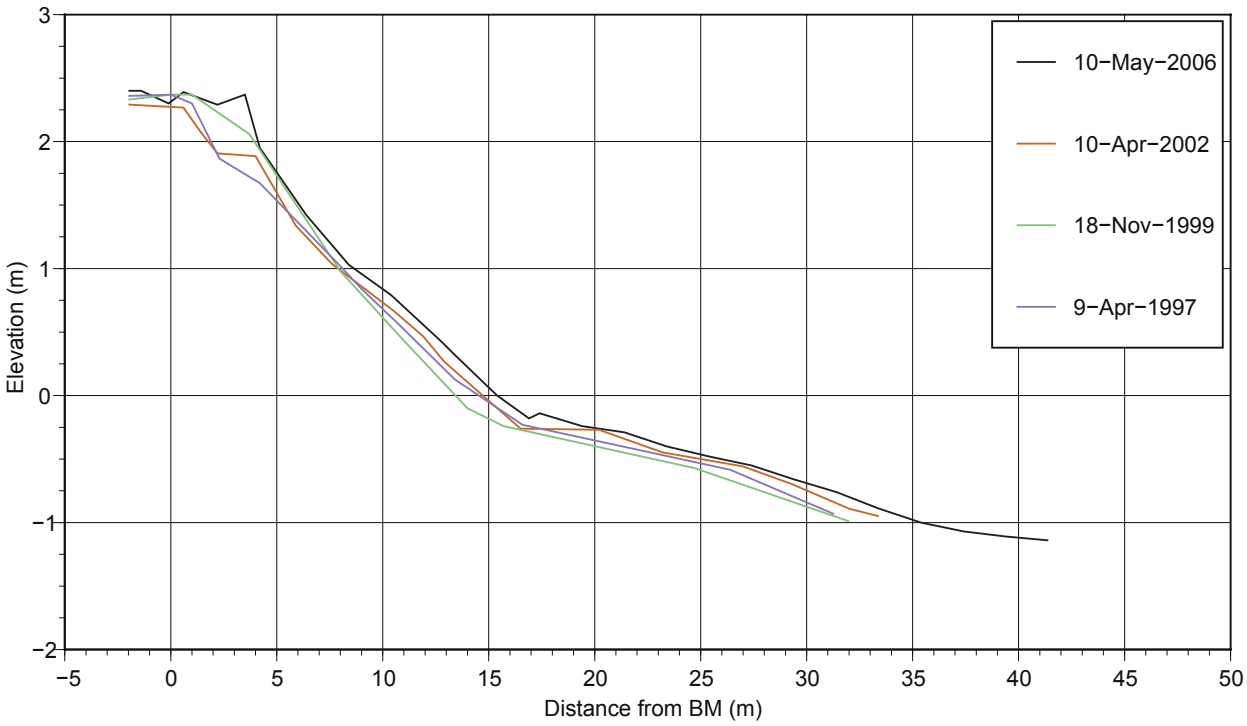
Profile 3: Double Bay

Profile 4 – Ngaionui Bay

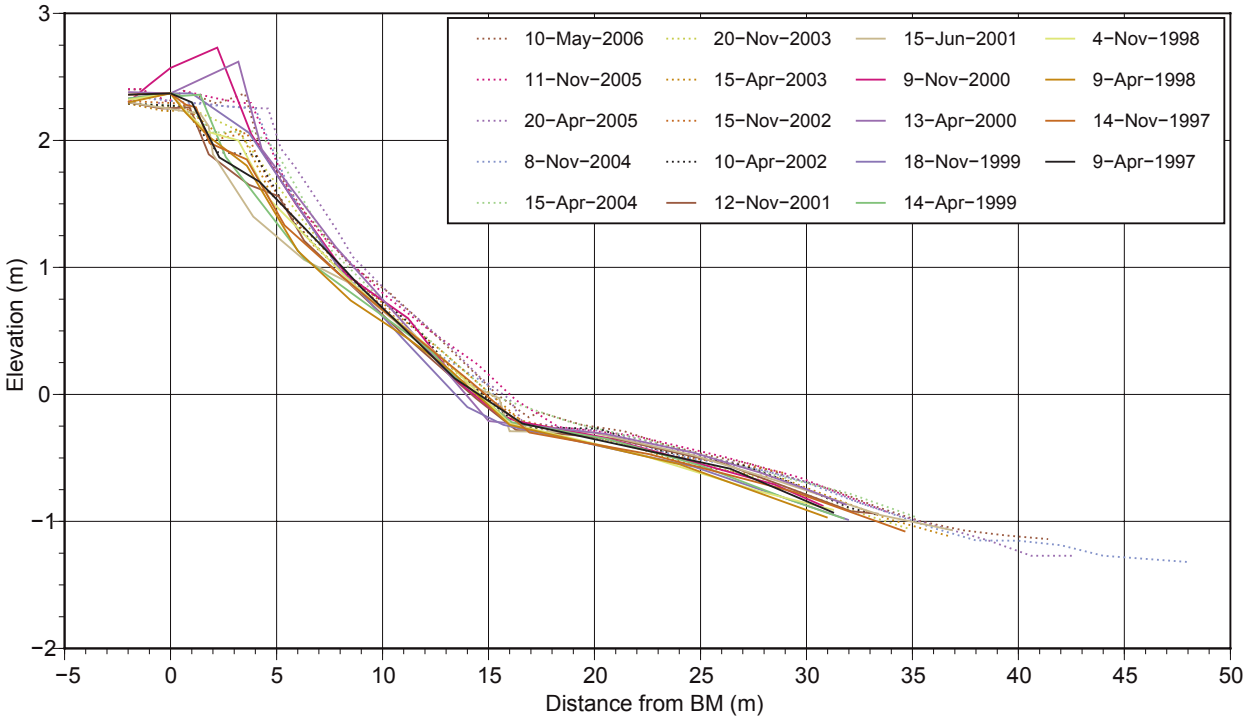
Between April 1999 and April 2000 a substantial berm built at the top of the beach. The upper beach prograded and the middle beach retreated. Between November 2000 and April 2001, beach works removed the berm and much of the sediment on the upper beach. It is unfortunate that these beach works coincided with the slowing of the fast ferries in December 2000. The build up of the berm had previously been interpreted as possibly relating to the continuation of the fast ferry service through the winter months, or to the wake characteristics of the ferries operating at that time. Since the beach works in late 2000 or early 2001 there has been recovery of the beach (and consequently the beach volume) through to the present. Beach volume now exceeds that of November 2000, with 'new' sediment being distributed over the whole profile, rather than in the berm as was the case in November 2000. The surveyors indicated that there may have been further beach works between April 2005 and November 2005, although this is not evident from the data. This profile has a very distinct change in slope at approximately –0.25m, previously interpreted as indicating closure depth. However, sediment has built up significantly seawards of this point along with the rest of the profile, indicating this interpretation was not accurate.

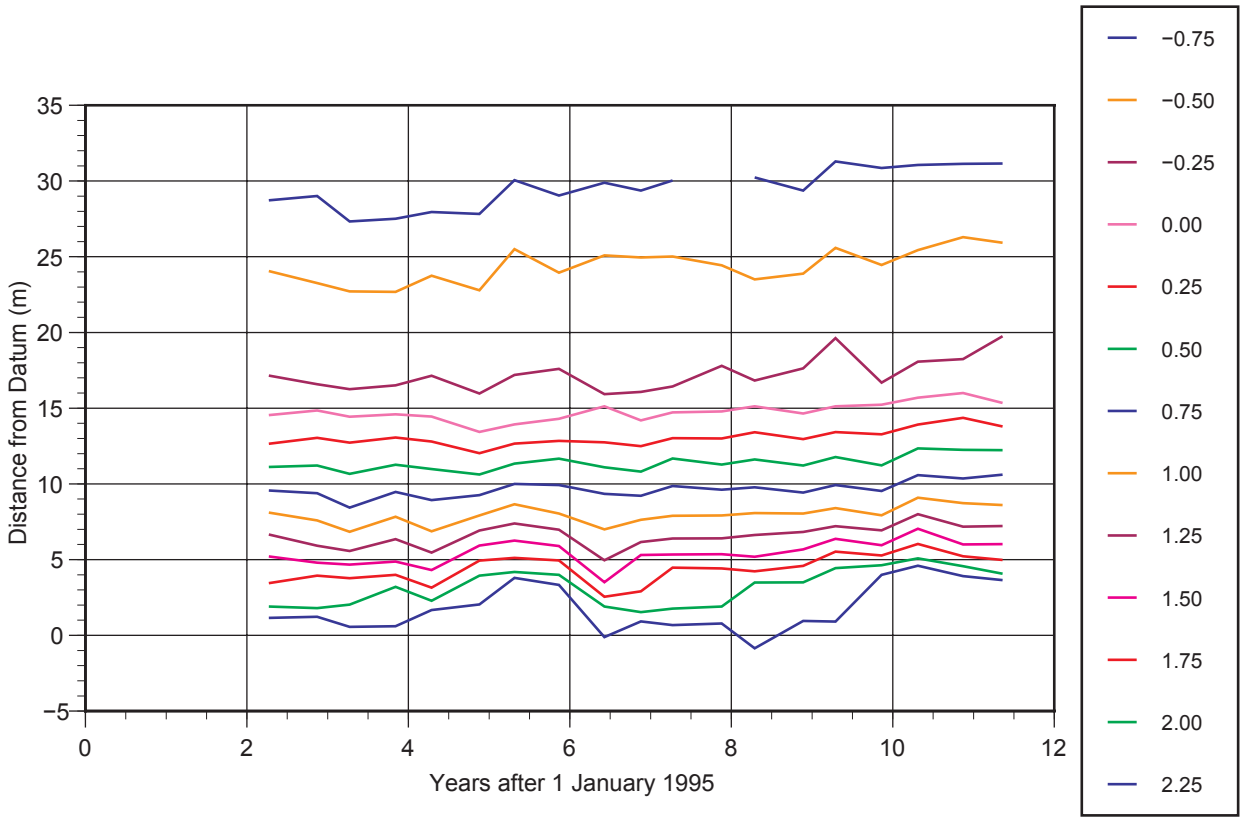
It is clear that fast ferry operation contributed to significant accretion of relatively coarse sediments at the top of the beach. After reconstruction, sediment has continued to build, probably indicating that all waves, including conventional vessel wakes cause sediment to accrete at the top of the beach. Interpretation of this site is complicated by two things. Firstly, there have been beach works, including a significant lowering of the upper beach in late 2000 or early 2001, and perhaps at other times. Secondly, prior to surveys commencing, there was a significant landslide at the western end of the beach that contributed significantly to the sediment supply. It is highly likely that much of the accretion can be attributed to that event, as the material is redistributed through the bay. This is likely to account for the accretion of the middle and lower profile, and has provided material for waves to build a high tide berm.

Photographs indicate that the sediments on the upper beach since 2001 considerably finer than those on the surface from 1997-2000, prior to beach works.

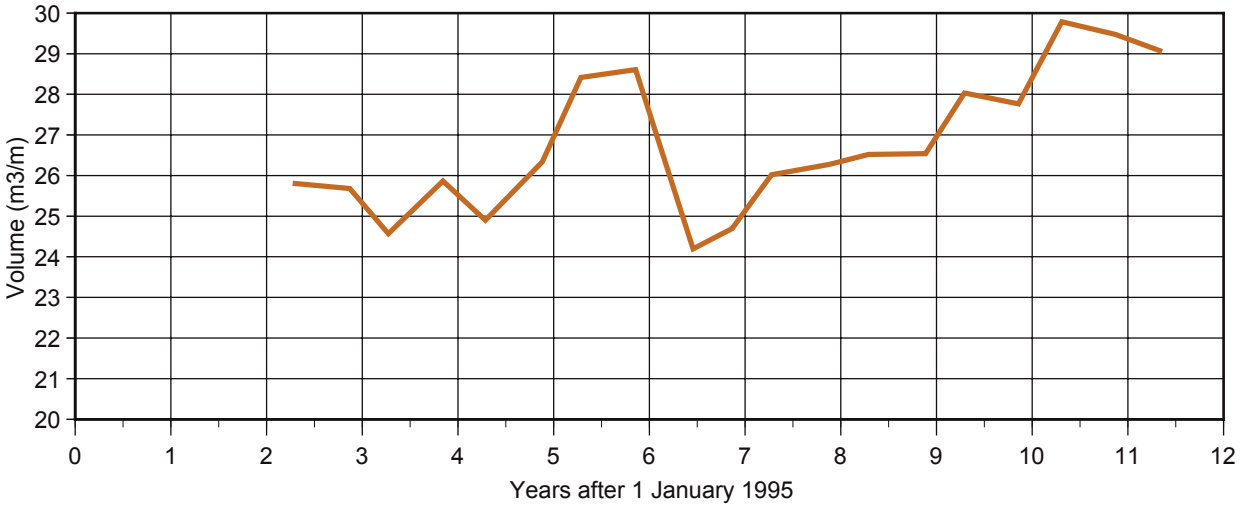


Profile 4: Ngaionui Bay





Profile 4: Ngaionui Bay



Date	Years after 1/1/95	Volume (m^3/m)
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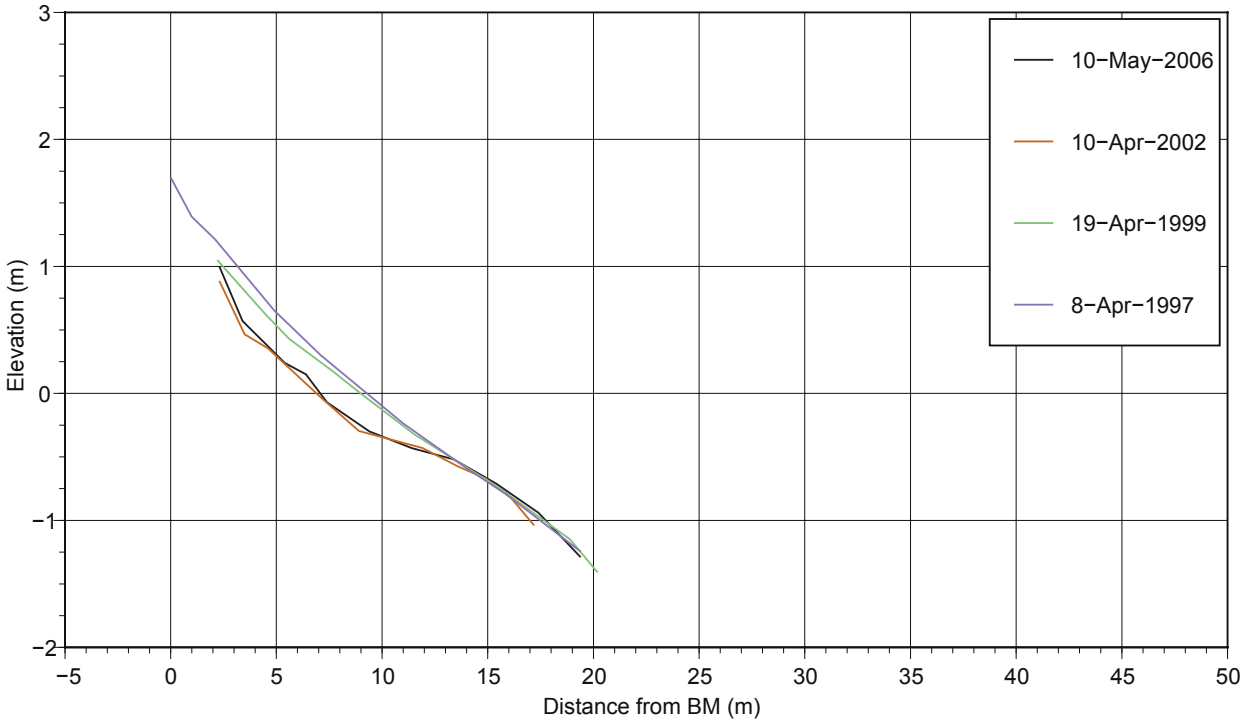
9-Apr-98	3.27	24.6
4-Nov-98	3.84	25.9
14-Apr-99	4.29	24.9
18-Nov-99	4.88	26.3
13-Apr-00	5.28	28.4
9-Nov-00	5.86	28.6
15-Jun-01	6.46	24.2
12-Nov-01	6.86	24.7
10-Apr-02	7.28	26.0
15-Nov-02	7.88	26.3
15-Apr-03	8.29	26.5
20-Nov-03	8.89	26.5
15-Apr-04	9.29	28.0
8-Nov-04	9.86	27.8
20-Apr-05	10.31	29.8
11-Nov-05	10.87	29.5
10-May-06	11.36	29.1

Profile 4: Ngaionui Bay

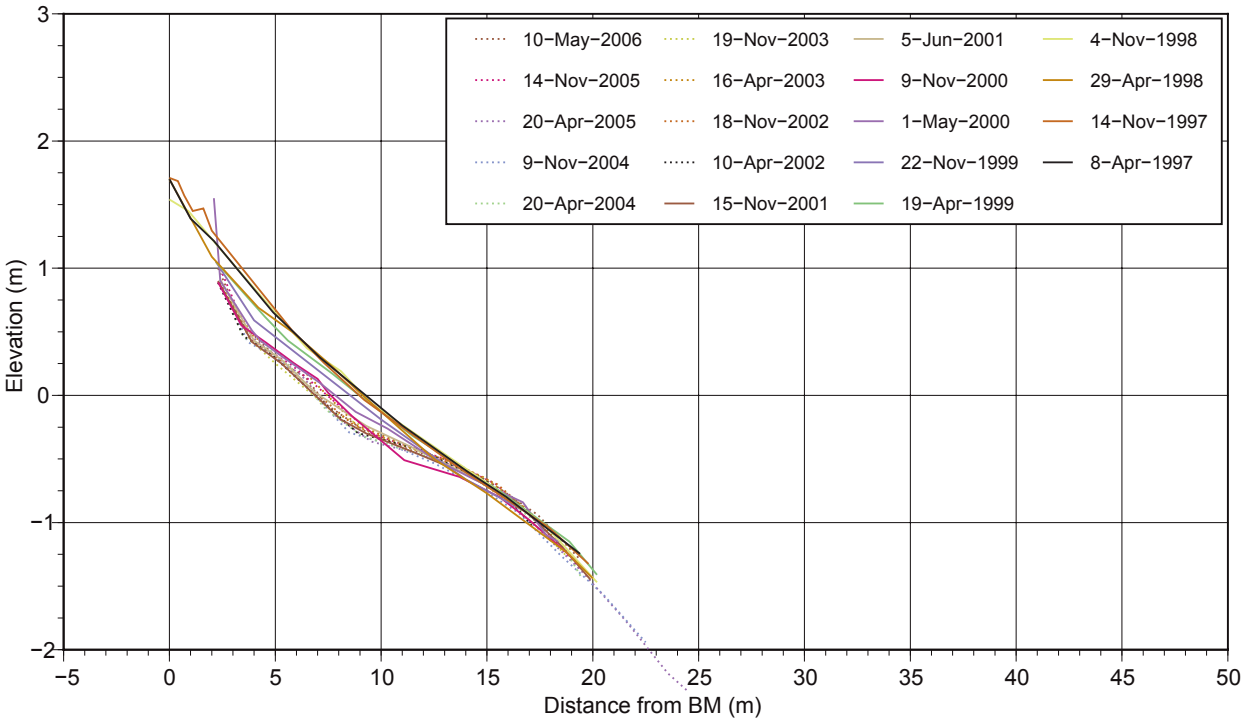
Profile 5 – Blackmore's at Waikawa

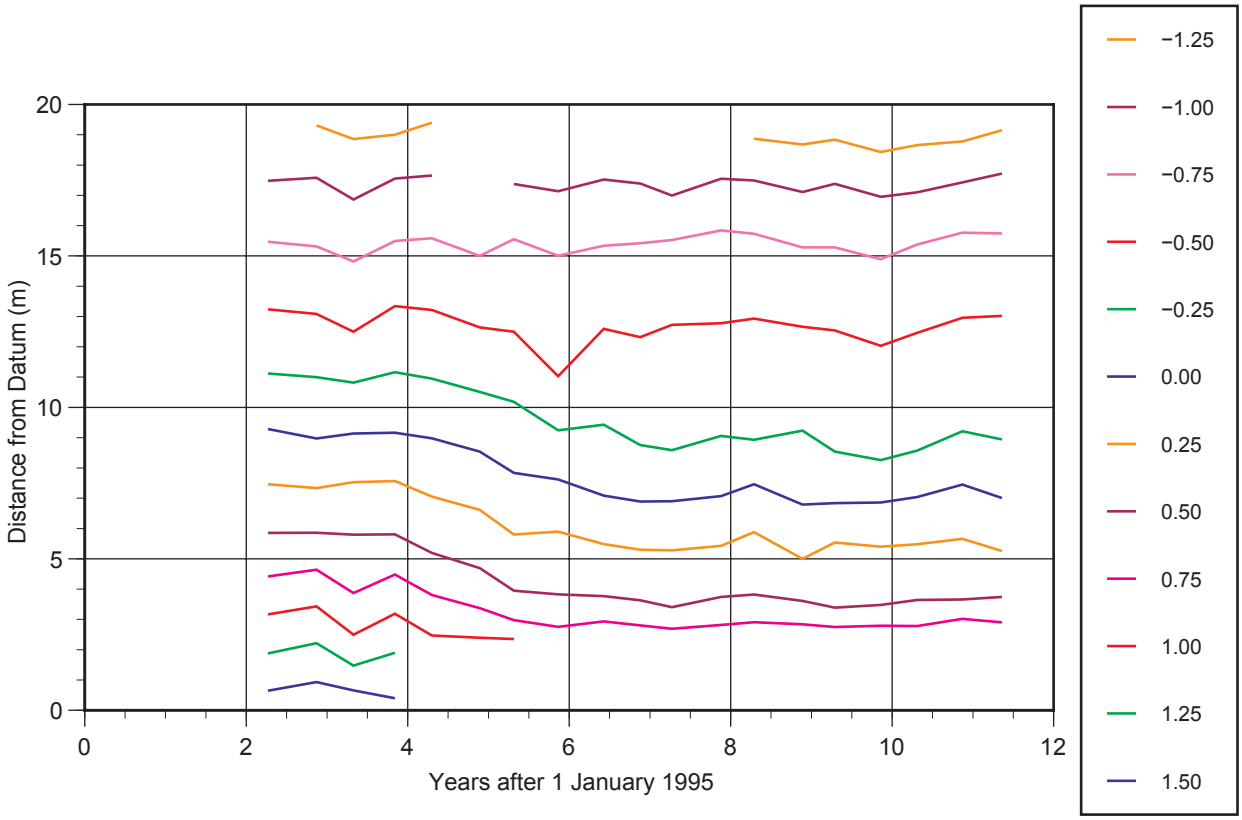
Between April 1999 and November 1999, sand on the small beach started to disappear. By November 2001, the beach had been stripped to bedrock, and it has remained essentially devoid of sediment since that time. Further loss of sediment is therefore not possible. There has been no recovery since the fast ferries slowed down in December 2000. Minor changes in profiles and volumes recorded since that time are likely to be the result of slightly different survey alignments, and possibly minor changes in sediments on the lower profile.

There has, at various times, been building work in the vicinity of this profile line, the most significant of which occurred between November 1997 and April 1998 and it may be that these events have contributed to the change.

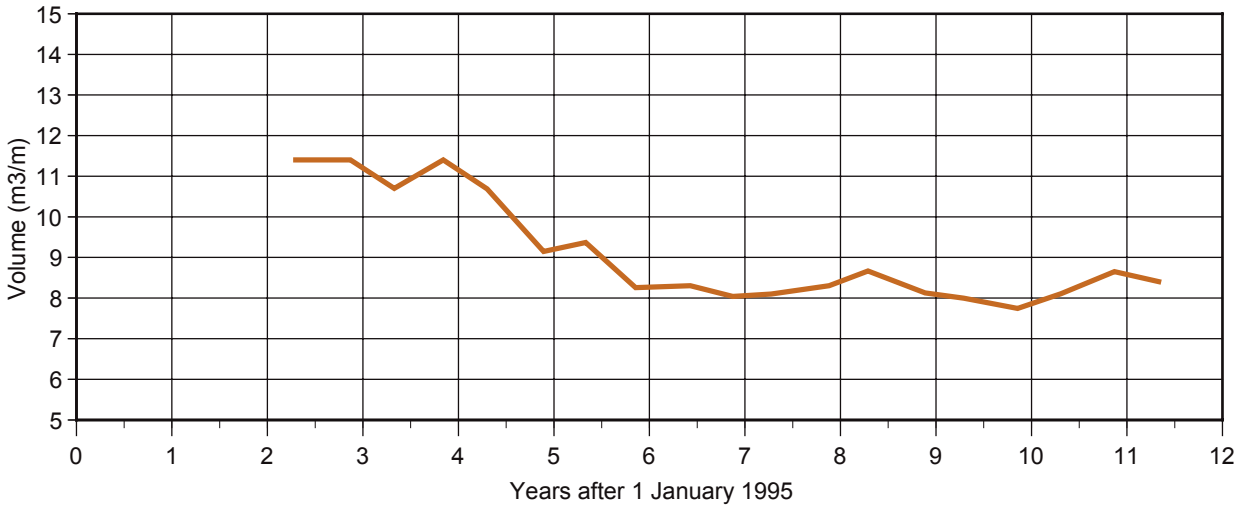


Profile 5: Blackmore's at Waikawa





Profile 5: Blackmore's at Waikawa



Date	Years after 1/1/95	Volume (m^3/m)
8-Apr-97	2.27	11.4
14-Nov-97	2.87	11.4
29-Apr-98	3.33	10.7
4-Nov-98	3.84	11.4
19-Apr-99	4.30	10.7
22-Nov-99	4.89	9.1
1-May-00	5.33	9.4
9-Nov-00	5.86	8.3
5-Jun-01	6.43	8.3
15-Nov-01	6.87	8.0
10-Apr-02	7.28	8.1
18-Nov-02	7.88	8.3
16-Apr-03	8.29	8.7
19-Nov-03	8.89	8.1
20-Apr-04	9.29	8.0
9-Nov-04	9.86	7.7
20-Apr-05	10.31	8.1
14-Nov-05	10.87	8.7
10-May-06	11.36	8.4

Profile 5: Blackmore's at Waikawa

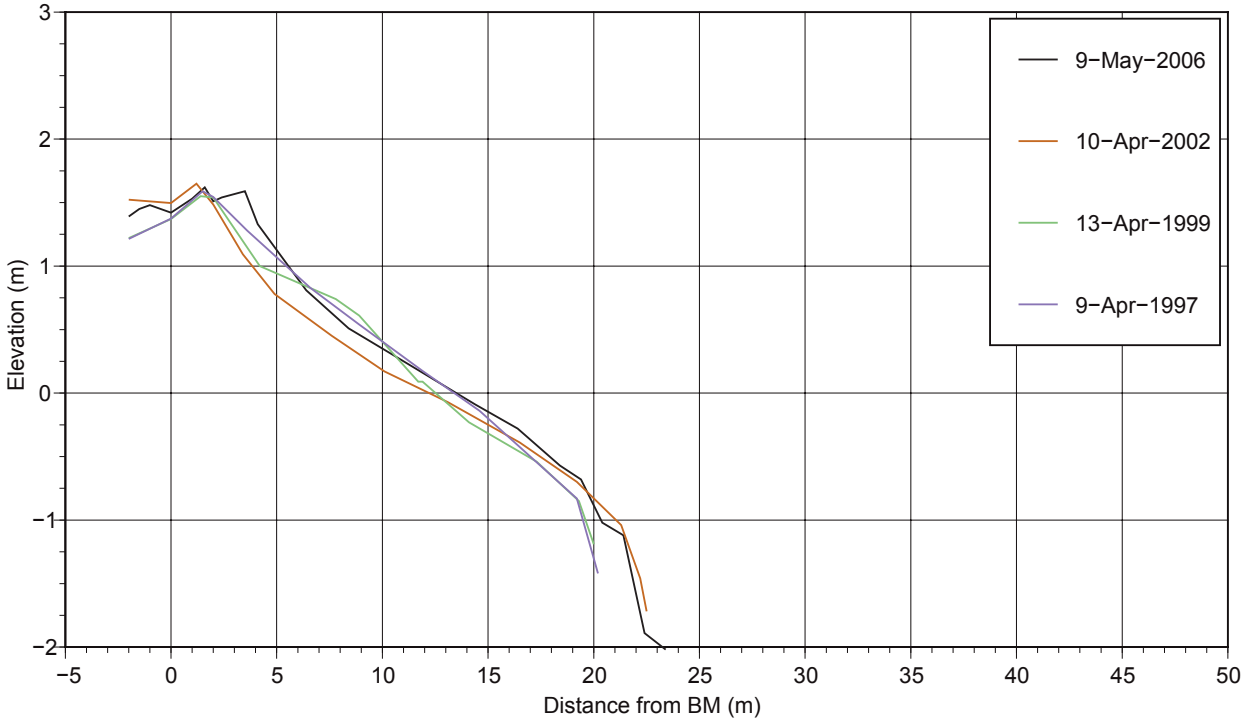
Profile 6 – Moioio Island 2

Moioio Island 2 is at the eastern end of the beach on the island, near the slip that has been of considerable concern to Te Ati Awa. This profile has a record going back to November 1995 and until 1999 the beach profile demonstrated seasonality, with a build up of a berm on the upper beach over the winter months, and its removal over the summer months, after which time, seasonal patterns have not been evident. Overall however, there has been a trend of accretion, with a significant reversal between November 2000 and April 2002.

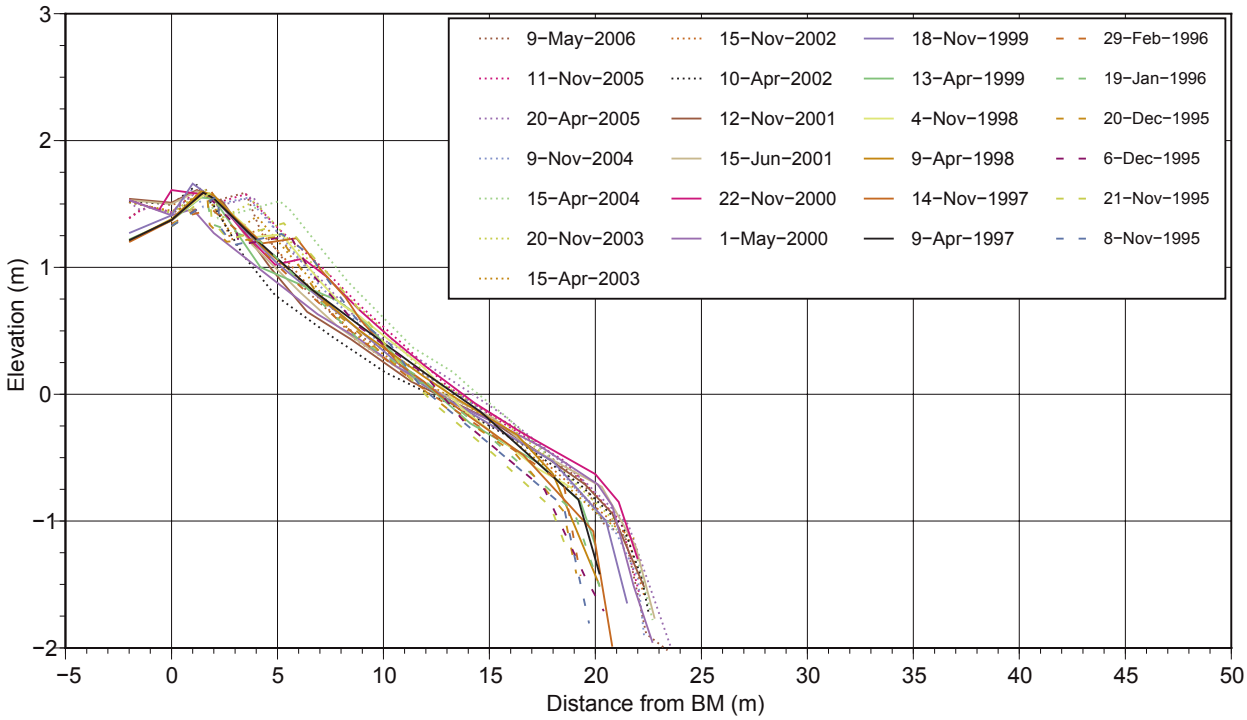
Up until 2000 much of the accretion was on the lower beach with the steep slope into the channel accreting. Because of the high angle, this required significant sediment. After that time, the upper beach accreted, with the lower beach remaining relatively stable. Between April 2003 and April 2004 there was a very significant accretion event across the upper and middle profile, with the placement of a new berm. This berm was subsequently modified by being pushed landward, but is still evident.

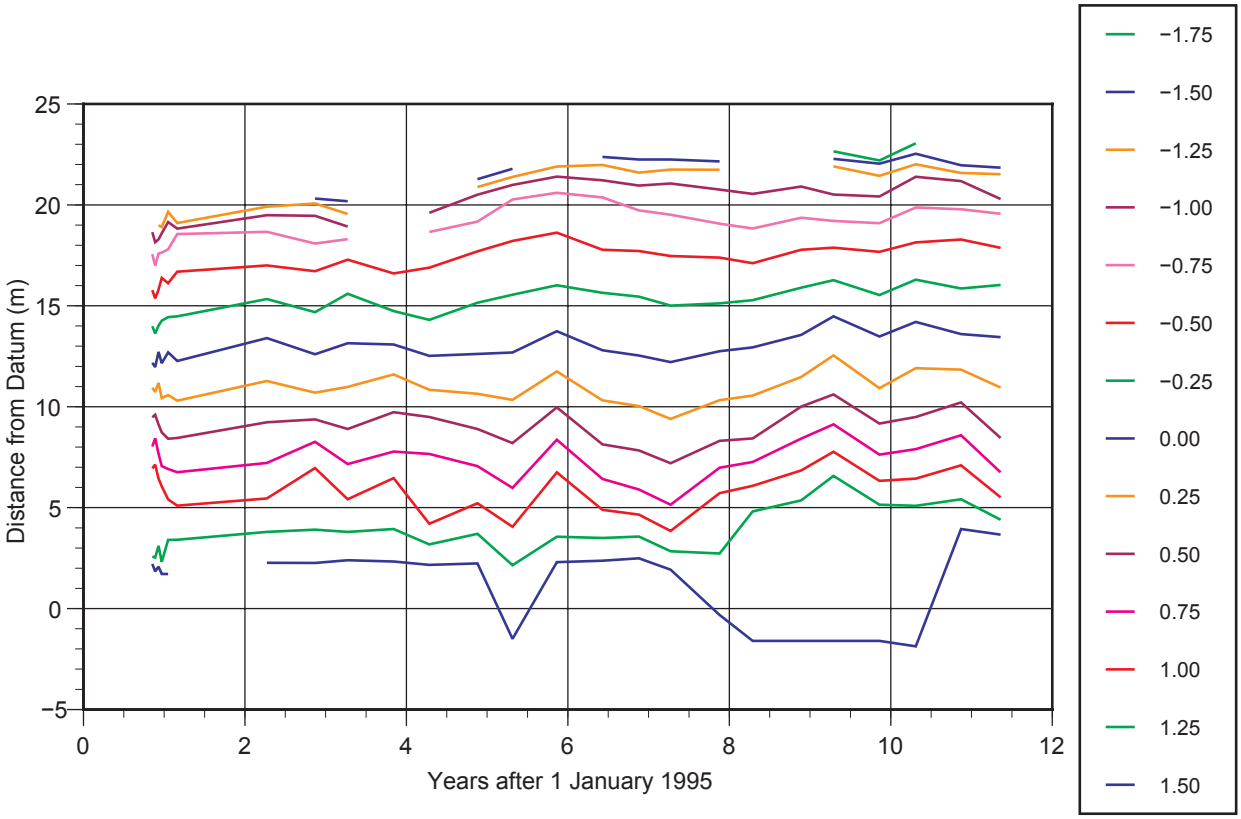
The most significant effect on this profile has almost certainly been the adjacent slip. Major fluctuations in beach shape and volume, and indeed the general accretion is related to sediment supply from periods of activity and inactivity of the slip. There is no other plausible explanation for the rapid accretion between April 2003 and April 2004

It was apparent in the early years of the survey that vessel wakes were having a considerable influence on this profile, and this was confirmed by process measurements. However, this was contradicted by events following the slowing of the fast ferries in December 2000, after which the beach eroded for a period of time. It remains likely that this site reacts to changes in ferry operation. However, it is also likely that it reacts to changes in sediment supply from the adjacent slip. Determining the relative effects of the two sets of events is difficult.

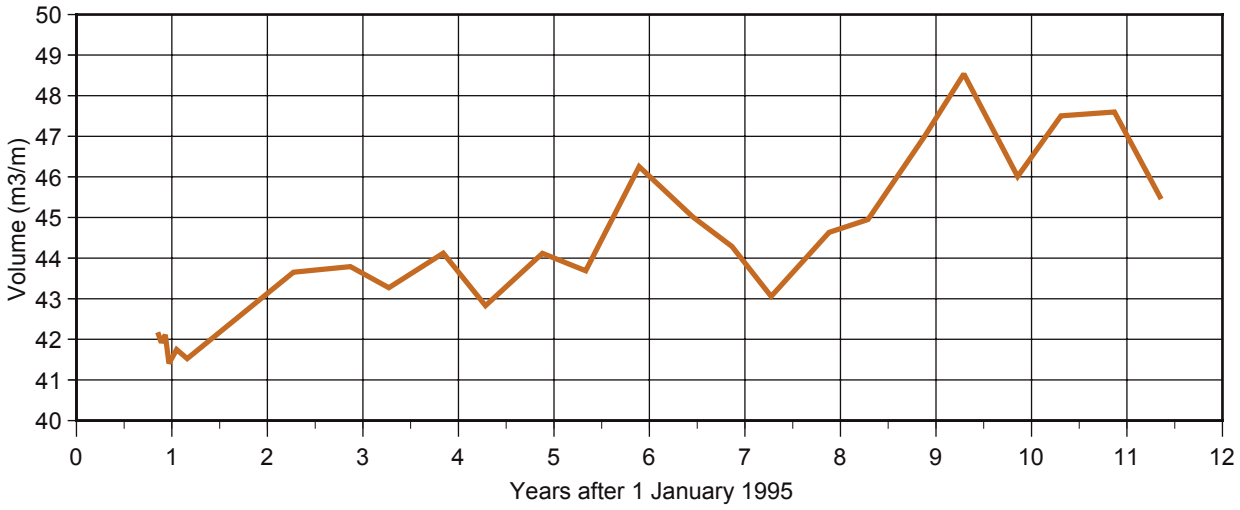


Profile 6: Moioio Island 2





Profile 6: Moioio Island 2



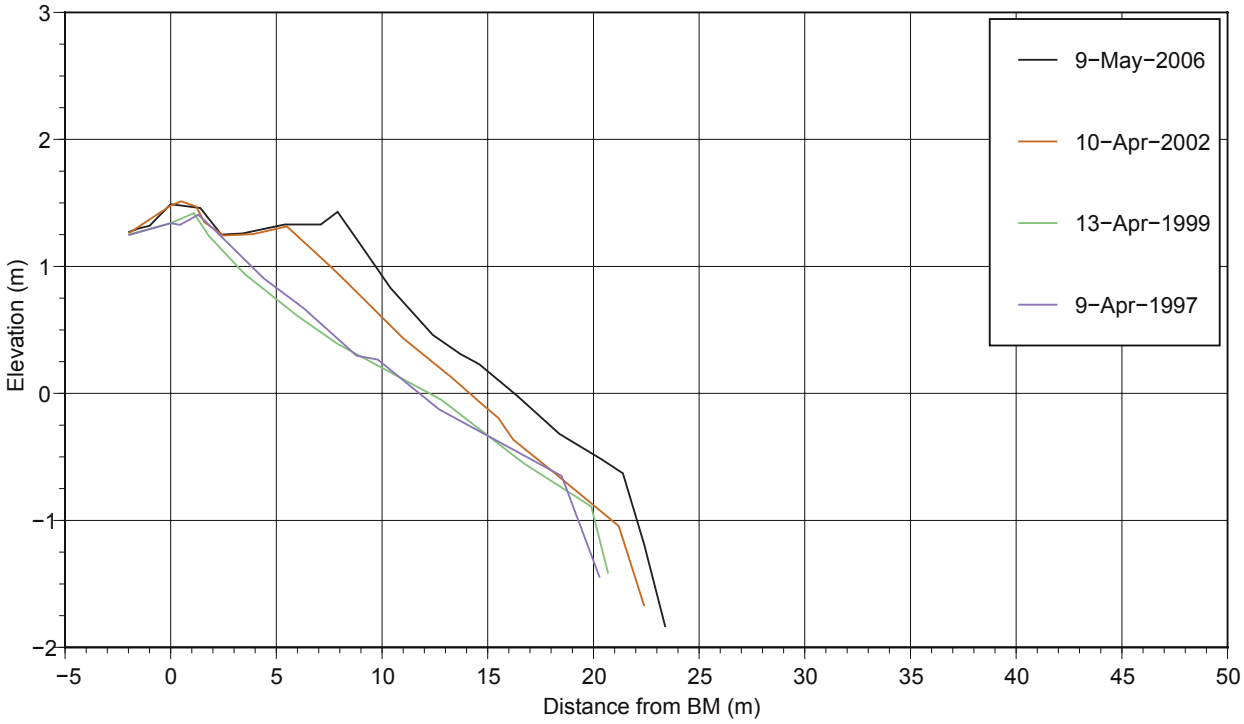
Date	Years after 1/1/95	Volume (m^3/m)
8-Nov-95	0.85	42.17
21-Nov-95	0.89	41.92
6-Dec-95	0.93	42.11
20-Dec-95	0.97	41.40
19-Jan-96	1.05	41.75
29-Feb-96	1.16	41.52
9-Apr-97	2.27	43.65
14-Nov-97	2.87	43.79
9-Apr-98	3.27	43.27
4-Nov-98	3.84	44.12
13-Apr-99	4.28	42.83
18-Nov-99	4.88	44.12
1-May-00	5.33	43.69
22-Nov-00	5.89	46.26
15-Jun-01	6.46	45.01
12-Nov-01	6.86	44.29
10-Apr-02	7.28	43.06
15-Nov-02	7.88	44.6
15-Apr-03	8.29	44.9
20-Nov-03	8.89	47.0
15-Apr-04	9.29	48.5
9-Nov-04	9.86	46.0
20-Apr-05	10.31	47.5
11-Nov-05	10.87	47.6
9-May-06	11.36	45.5

Profile 6: Moioio Island 2

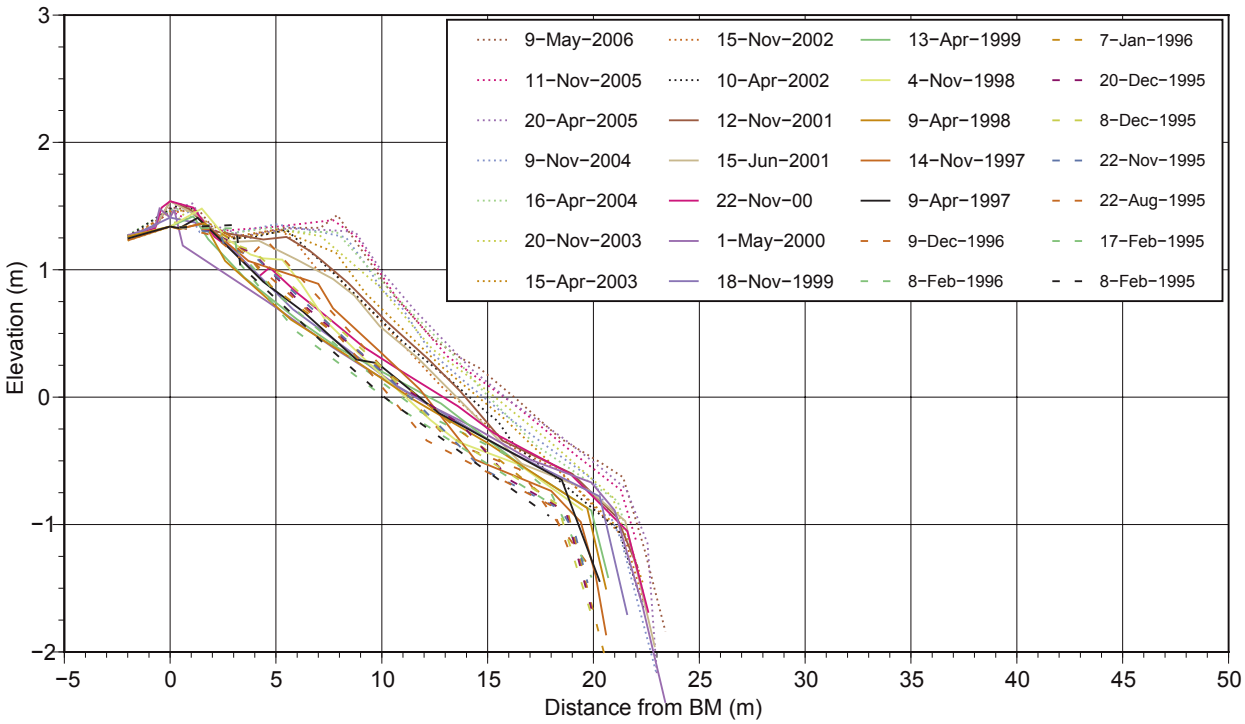
Profile 7 – Moioio Island 1

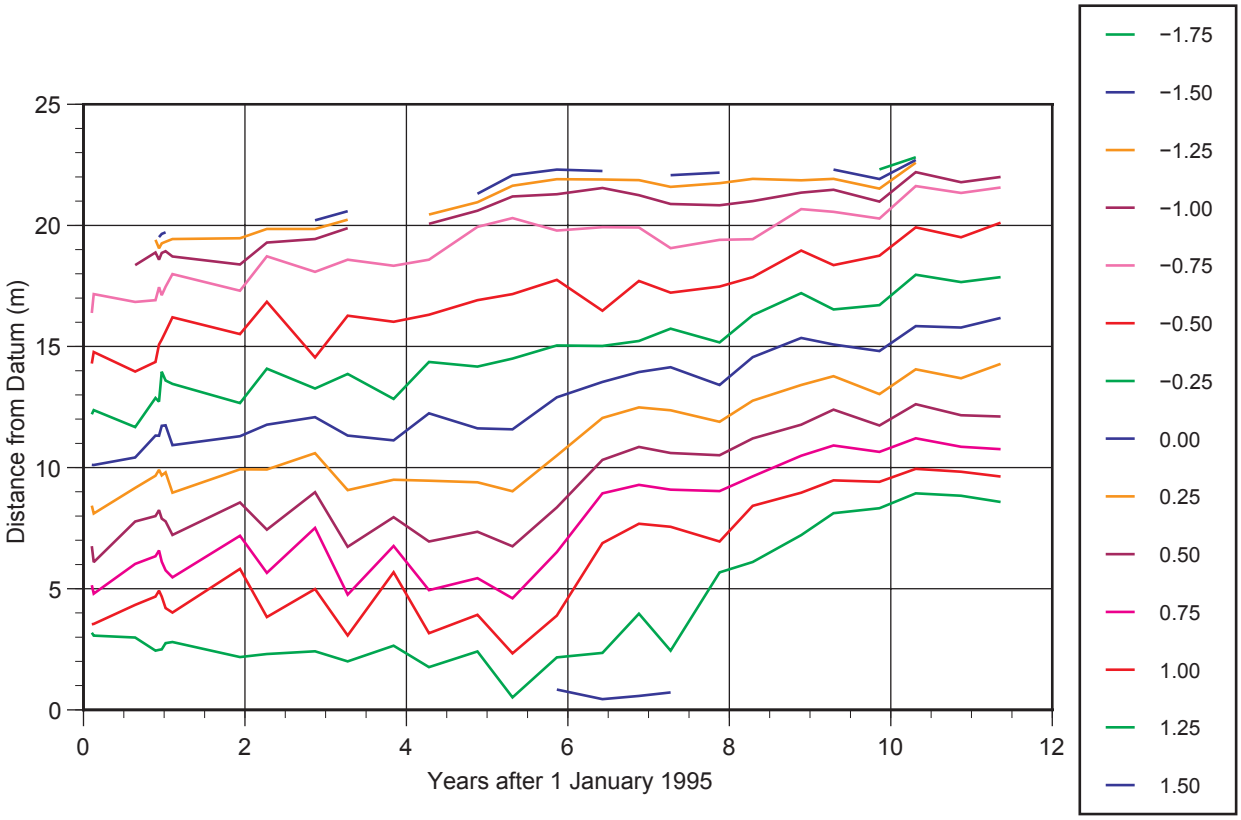
The Moioio Island 1 profile is to the west of Profile 6. There was remarkable seasonality up to the winter of 1999,, with the growth of a berm over winter and its loss over summer. Up until the end of 2000, the upper beach was generally stable, with seasonality, and with the lower beach accreting into the channel. Since that time, the whole profile has accreted rapidly with very substantial volume increases. There has been substantial accretion of the upper beach since May 2000, with a major increase in volume, particularly between May 2000 and April 2001. This probably indicates an increase in sediment supply from the slip. Accretion on the middle and lower beach has continued since surveys began in 1995.

There is little doubt that the beach changes taking place on this profile are caused by the ferry operation regime (evidenced by the very strong seasonal signal when fast ferries were operating seasonally), but affected by changes in sediment supply. The accretion event observed on Profile 6 between April 2003 and April 2004 is reflected on Profile 7 between November 2004 and April 2005.

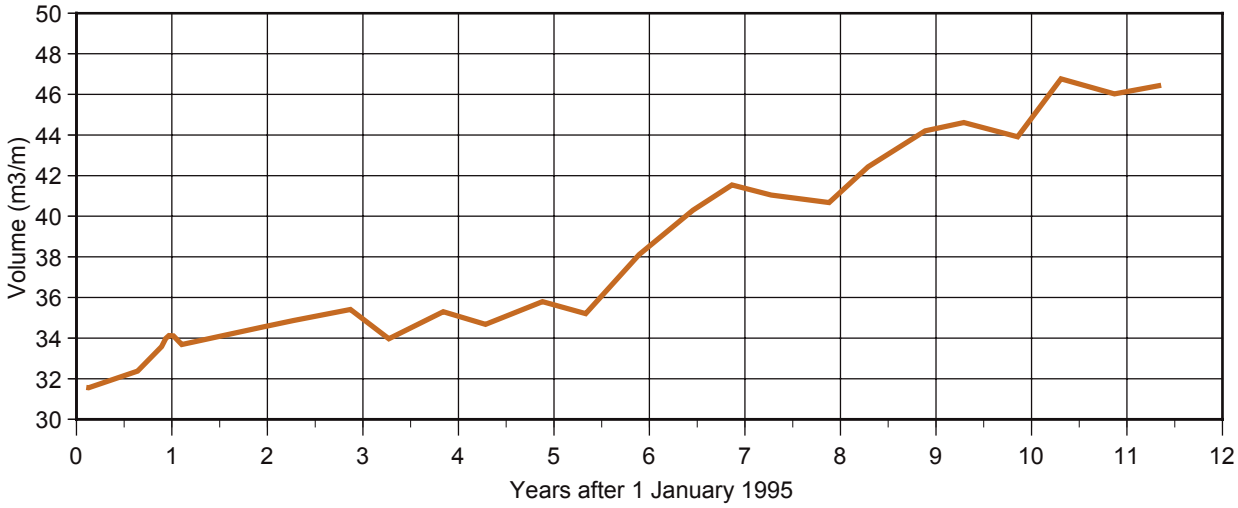


Profile 7: Moioio Island 1





Profile 7: Moioio Island 1



Date	Years after 1/1/95	Volume (m^3/m)
1977		38.3
8-Feb-95	0.10	31.6
17-Feb-95	0.13	31.6
22-Aug-95	0.64	32.4
22-Nov-95	0.89	33.6
8-Dec-95	0.94	34.0
20-Dec-95	0.97	34.1
7-Jan-96	1.02	34.1
8-Feb-96	1.10	33.7
9-Dec-96	1.94	34.5
9-Apr-97	2.27	34.9
14-Nov-97	2.87	35.4
9-Apr-98	3.27	34.0
4-Nov-98	3.84	35.3
13-Apr-99	4.28	34.7
18-Nov-99	4.88	35.8
1-May-00	5.33	35.2
22-Nov-00	5.89	38.1
15-Jun-01	6.46	40.3
12-Nov-01	6.86	41.5
10-Apr-02	7.28	41.0
15-Nov-02	7.88	40.7
15-Apr-03	8.29	42.4
20-Nov-03	8.89	44.2
16-Apr-04	9.29	44.6
9-Nov-04	9.86	43.9
20-Apr-05	10.31	46.8
11-Nov-05	10.87	46.0
9-May-06	11.36	46.4

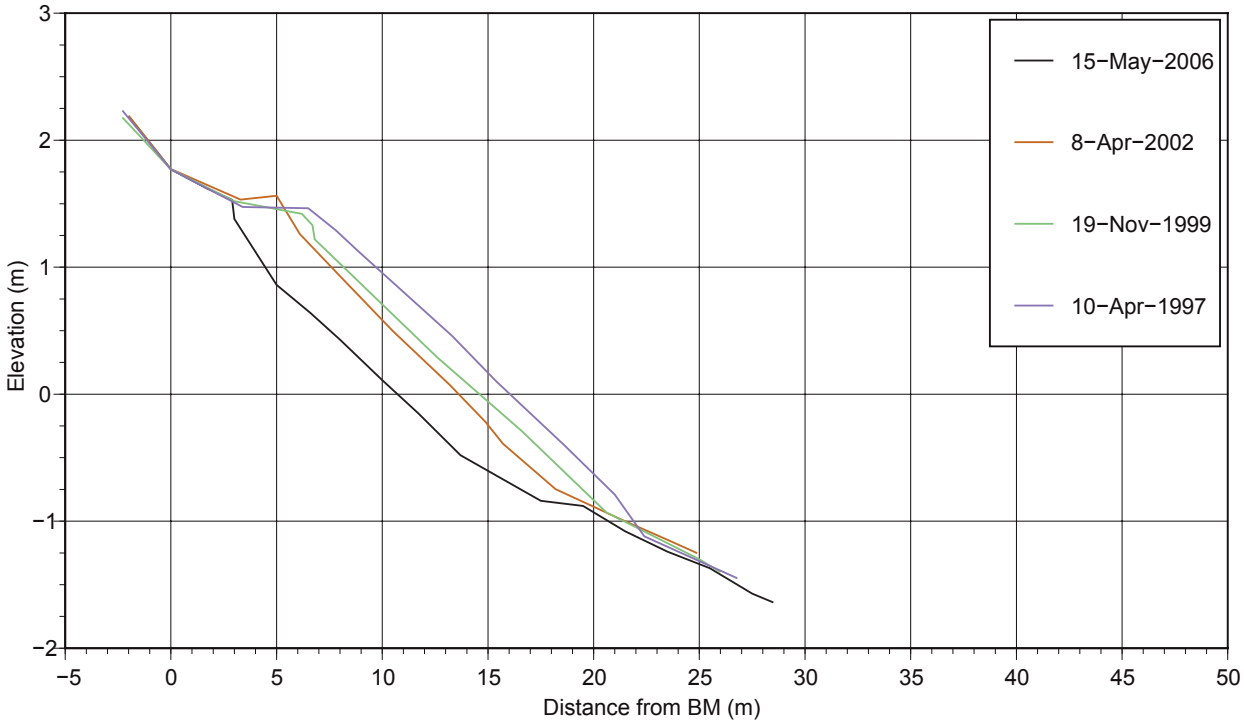
Profile 7: Moioio Island 1

Profile 8 – Bob's Bay

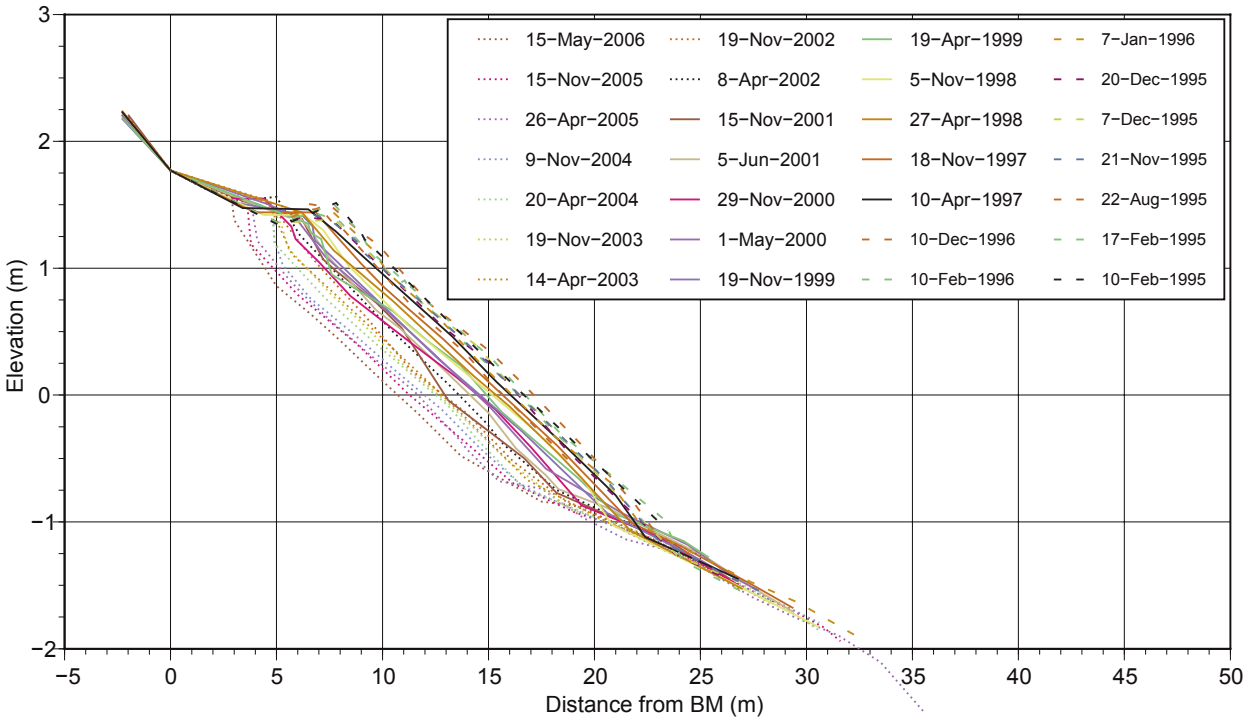
Bob's Bay has demonstrated an almost linear erosion trend since 1995 across the whole beach profile down to the change in slope (and probable closure depth) at about –1 m. Most of the beach has lowered in level by about 1m. Volume data shows a loss of 14 m^3/m since 1995. This erosion is very significant within the context of beaches in this study. The beach slope has stayed relatively constant.

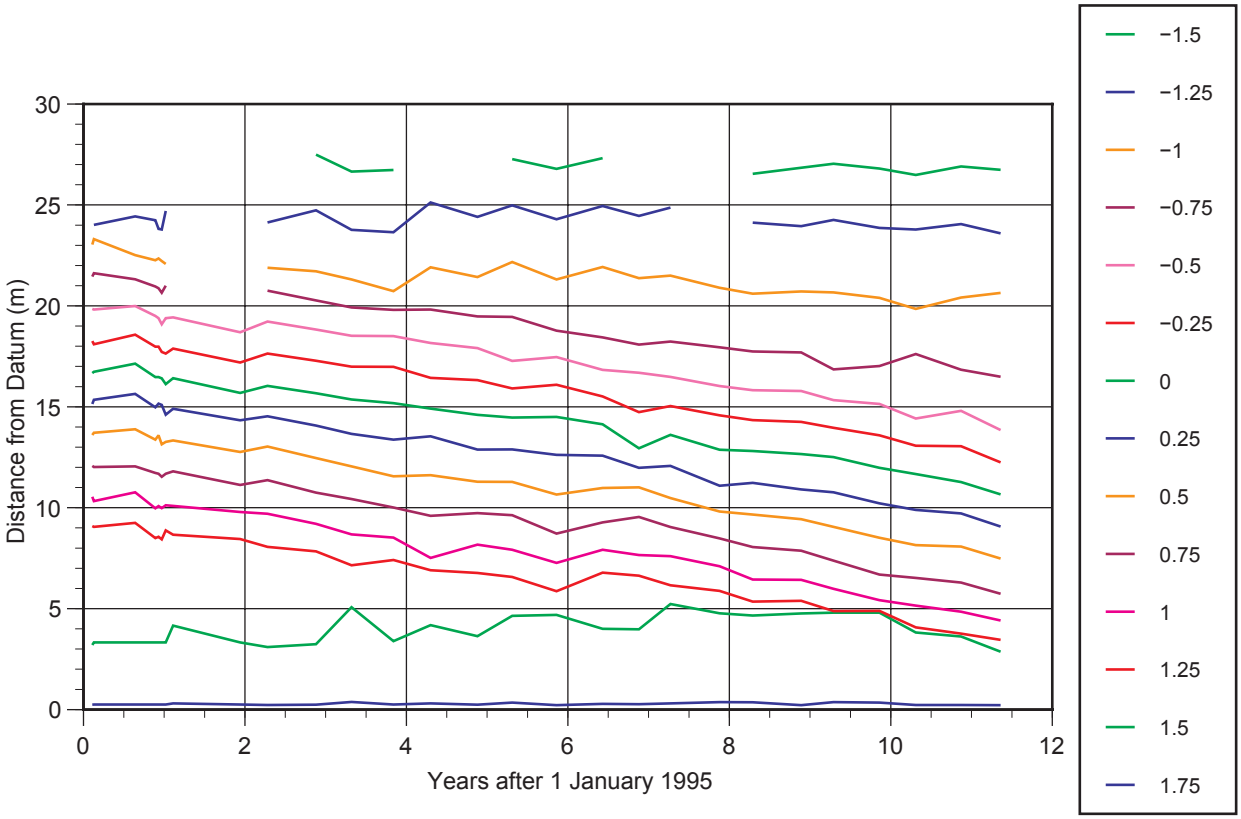
The location of this profile is at the northern end of the beach, adjacent to a headland of significance to Te Ati Awa. It may be that the erosion is accompanied by accretion elsewhere in the embayment.

The cause of the erosion is not known. The site is well inside Mabel Island, and all major shipping movements should be at low speed with small wakes. There is also limited fetch, so natural waves should also be small. The mechanism of sediment transport away form the profile line, and where the sediment goes could be investigated if erosion at this particular point becomes of concern.

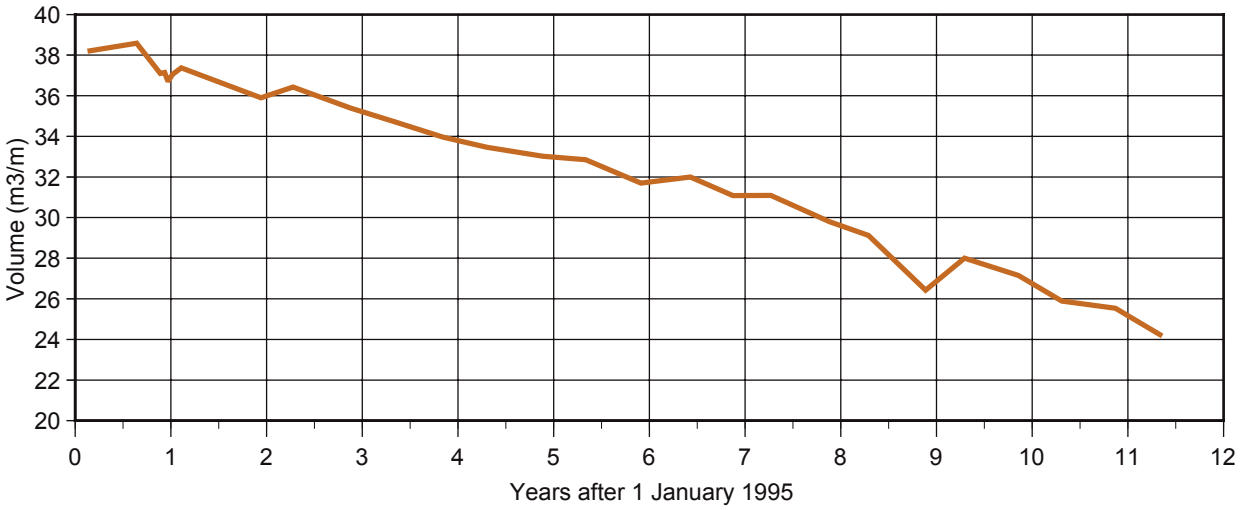


Profile 8: Bobs Bay





Profile 8: Bobs Bay

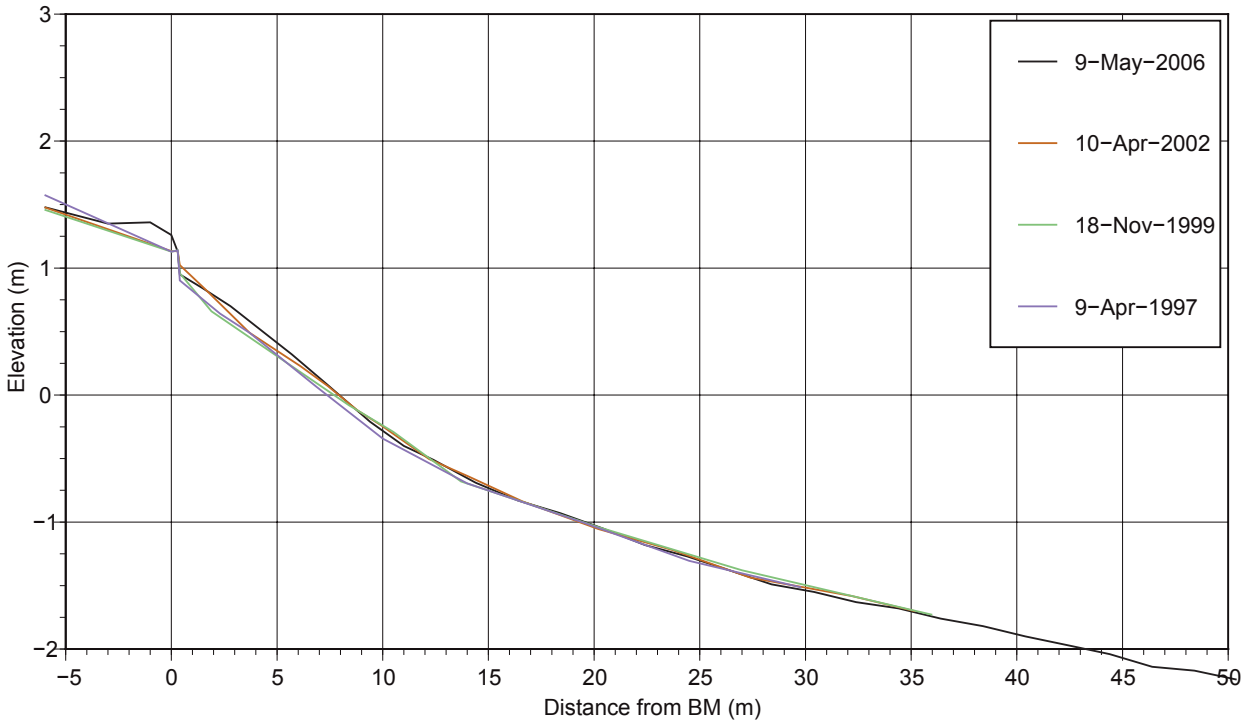


Date	Years after 1/1/95	Volume (m^3/m)
17-Feb-95	0.13	38.2
22-Aug-95	0.64	38.6
21-Nov-95	0.89	37.1
7-Dec-95	0.93	37.1
20-Dec-95	0.97	36.7
7-Jan-96	1.02	37.0
10-Feb-96	1.11	37.4
10-Dec-96	1.94	35.9
10-Apr-97	2.28	36.4
18-Nov-97	2.88	35.4
27-Apr-98	3.32	34.7
5-Nov-98	3.84	34.0
19-Apr-99	4.30	33.5
19-Nov-99	4.88	33.0
1-May-00	5.33	32.8
29-Nov-00	5.91	31.7
5-Jun-01	6.43	32.0
15-Nov-01	6.87	31.1
8-Apr-02	7.27	31.1
19-Nov-02	7.88	29.8
14-Apr-03	8.29	29.1
19-Nov-03	8.89	26.4
20-Apr-04	9.29	28.0
9-Nov-04	9.86	27.1
26-Apr-05	10.31	25.9
15-Nov-05	10.87	25.5
15-May-06	11.36	24.2

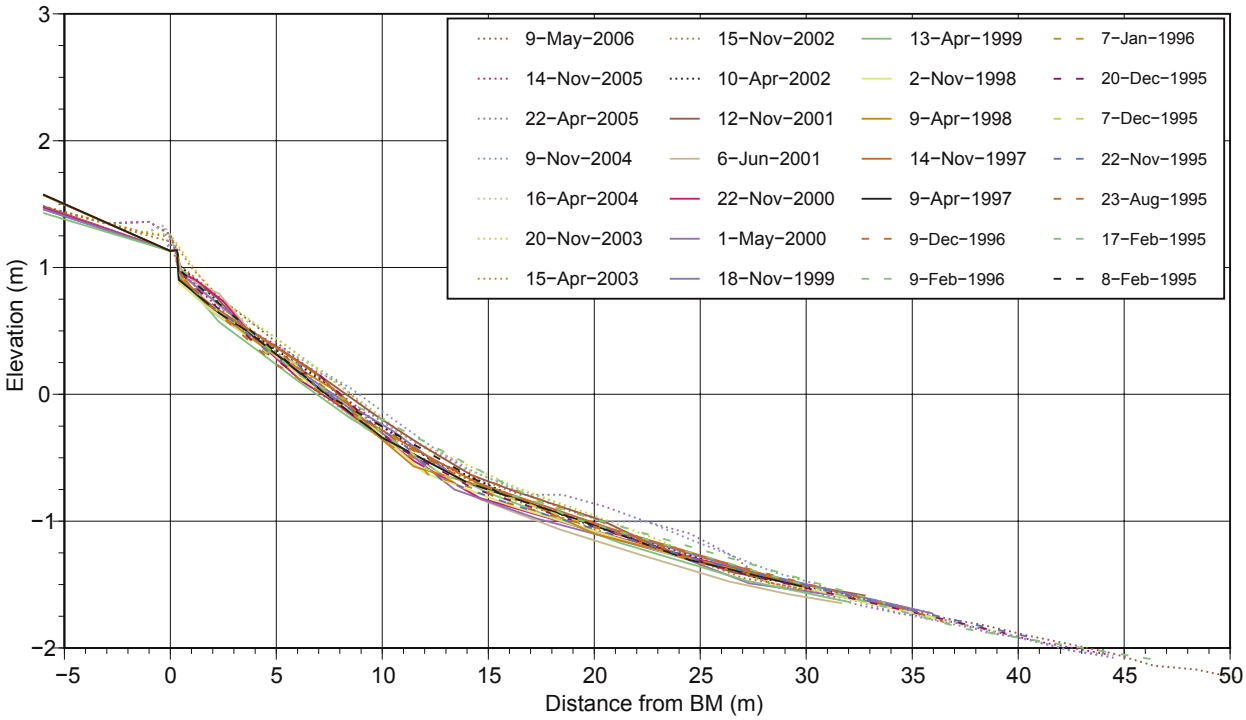
Profile 8: Bobs Bay

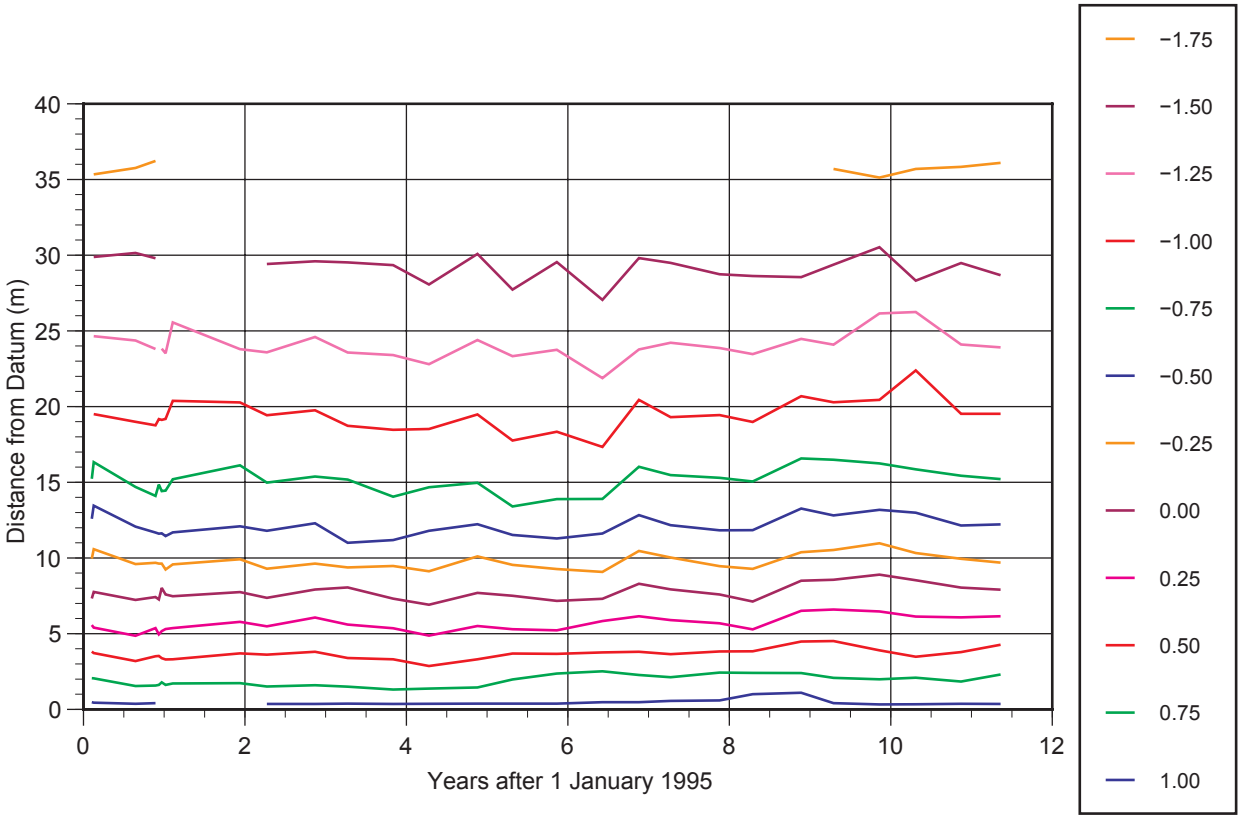
Profile 9 – Te Awaiti Bay

There has been no significant change in the profile of this beach over the survey period. Over the period November 2003 to November 2005 a lower beach bar developed, but it was not evident in May 2006. Its presence is reflected in a significant increase in beach volume over this period. Minor changes evident in the plots at the top of the profile are the result of slightly different survey pole placement. Until 2003, the most remarkable aspect of this beach was the change in surficial sediment characteristics that occurred. At times the cobbles were covered by a thin veneer of sand making the beach appear to be comprised of sand, and at other times, the cobbles were completely exposed, completely changing the beach character. Since 2003, however, the sand covering has been present continuously.

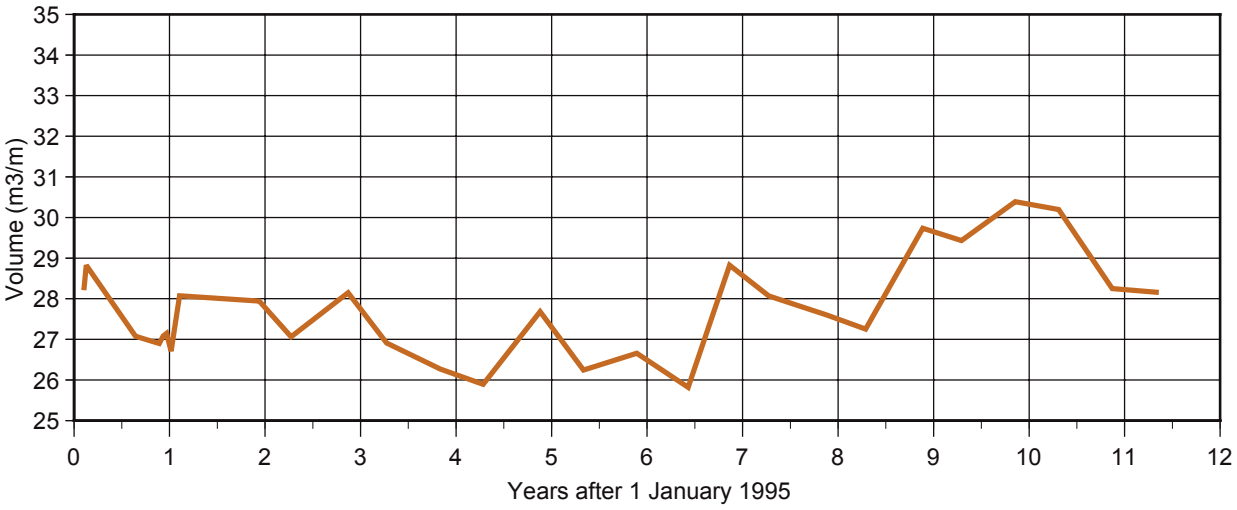


Profile 9: Te Awaiti Bay





Profile 9: Te Awaiti Bay

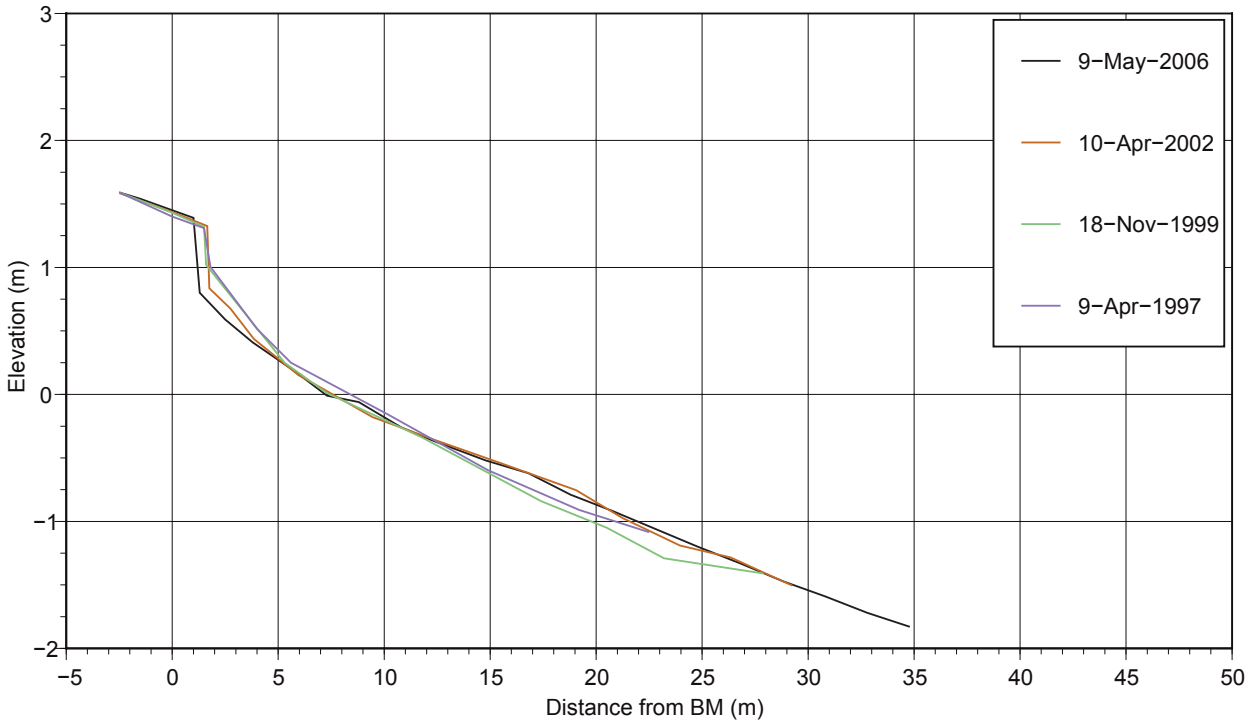


Date	Years after 1/1/95	Volume (m^3/m)
8-Feb-95	0.10	28.2
17-Feb-95	0.13	28.8
23-Aug-95	0.64	27.1
22-Nov-95	0.89	26.9
7-Dec-95	0.93	27.1
20-Dec-95	0.97	27.1
7-Jan-96	1.02	26.7
9-Feb-96	1.11	28.1
9-Dec-96	1.94	27.9
9-Apr-97	2.27	27.1
14-Nov-97	2.87	28.1
9-Apr-98	3.27	26.9
2-Nov-98	3.84	26.3
13-Apr-99	4.28	25.9
18-Nov-99	4.88	27.7
1-May-00	5.33	26.2
22-Nov-00	5.89	26.7
6-Jun-01	6.43	25.8
12-Nov-01	6.86	28.8
10-Apr-02	7.28	28.1
15-Nov-02	7.88	27.6
15-Apr-03	8.29	27.3
20-Nov-03	8.89	29.7
16-Apr-04	9.29	29.4
9-Nov-04	9.86	30.4
22-Apr-05	10.31	30.2
14-Nov-05	10.87	28.2
9-May-06	11.36	28.2

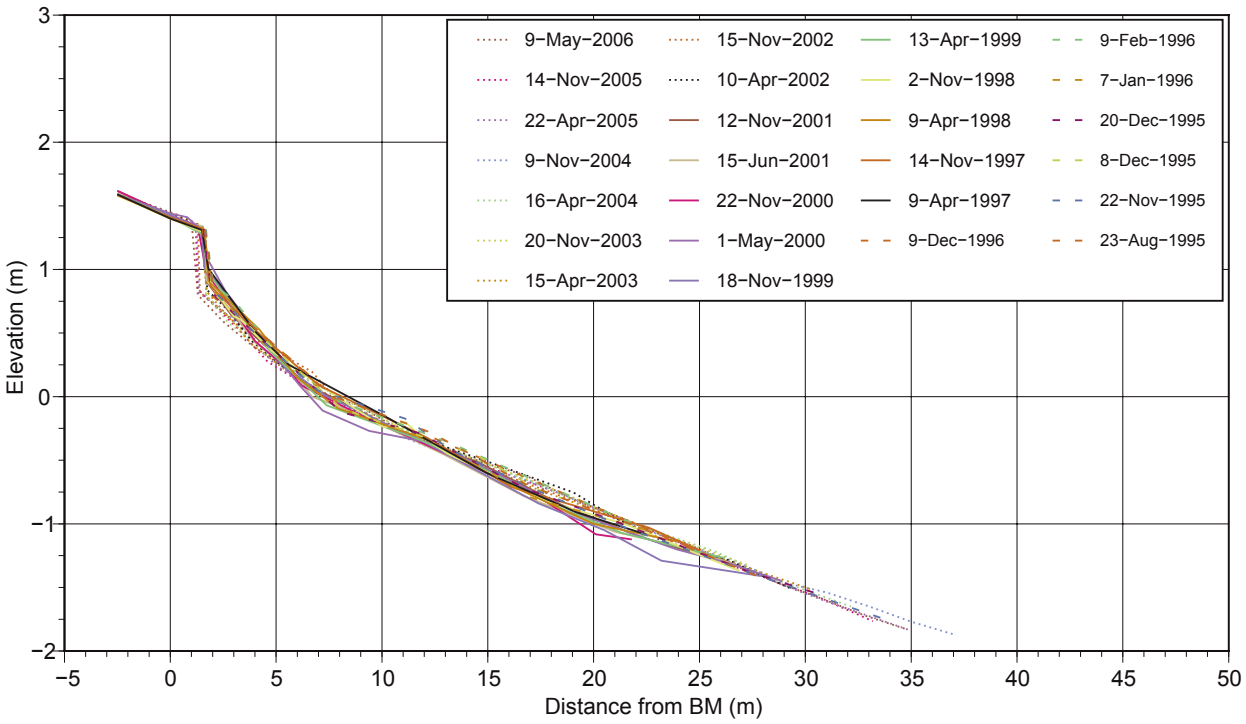
Profile 9: Te Awaiti Bay

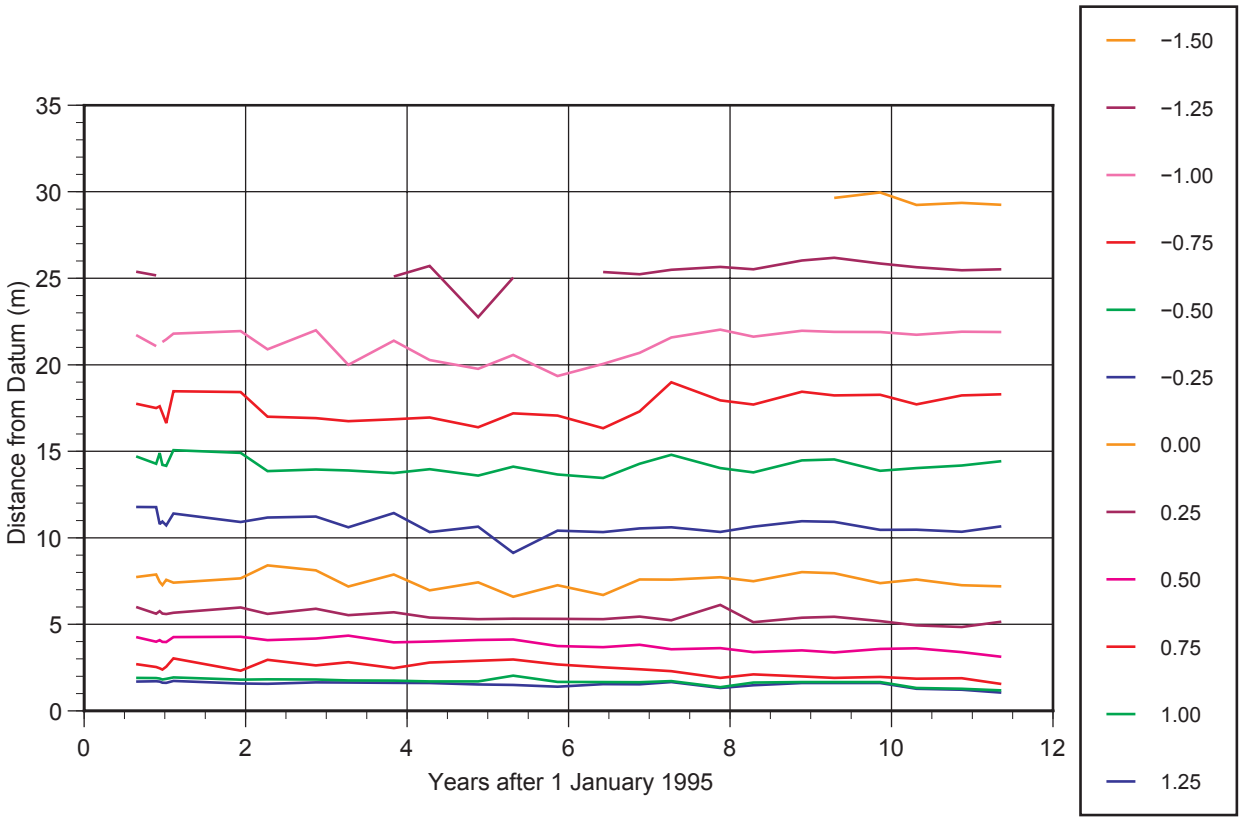
Profile 10 – Tipi Bay

There has been some retreat of the upper beach scarp (approximately 1m) and a corresponding increase in the level of the middle beach, but the changes have generally been minor. Because of the relatively coarse nature of the sediments, the placement of the survey staff can have significant impact on the apparent appearance of the profile line. The photographs indicate that there has been some sand deposited on the cobble dominated profile in the last 4 years.

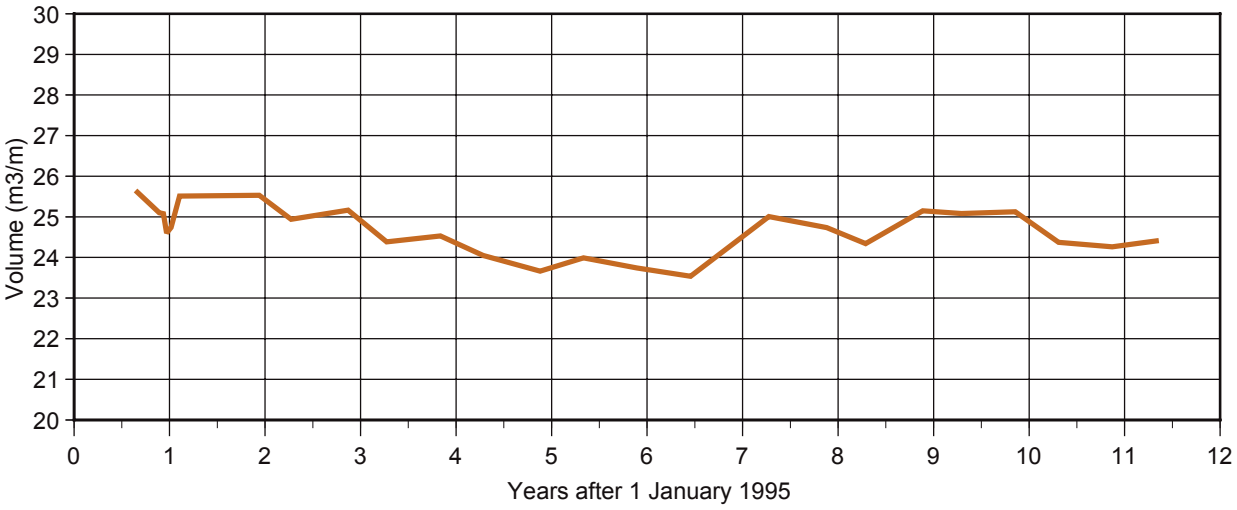


Profile 10: Tipi Bay





Profile 10: Tipi Bay

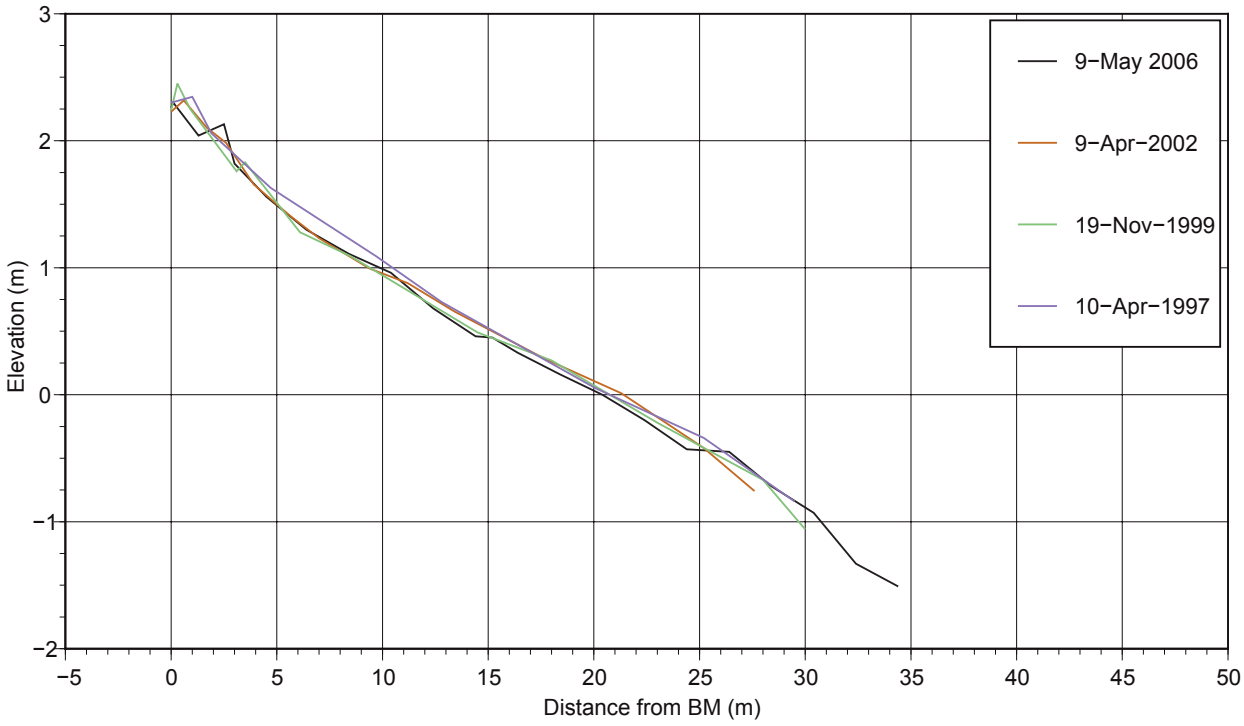


Date	Years after 1/1/95	Volume (m^3/m)
23-Aug-95	0.64	25.6
22-Nov-95	0.89	25.1
8-Dec-95	0.94	25.1
20-Dec-95	0.97	24.6
7-Jan-96	1.02	24.7
9-Feb-96	1.11	25.5
9-Dec-96	1.94	25.5
9-Apr-97	2.27	24.9
14-Nov-97	2.87	25.2
9-Apr-98	3.27	24.4
2-Nov-98	3.84	24.5
13-Apr-99	4.28	24.0
18-Nov-99	4.88	23.7
1-May-00	5.33	24.0
22-Nov-00	5.89	23.7
15-Jun-01	6.46	23.5
12-Nov-01	6.86	24.3
10-Apr-02	7.28	25.0
15-Nov-02	7.88	24.7
15-Apr-03	8.29	24.3
20-Nov-03	8.89	25.1
16-Apr-04	9.29	25.1
9-Nov-04	9.86	25.1
22-Apr-05	10.31	24.4
14-Nov-05	10.87	24.3
9-May-06	11.36	24.4

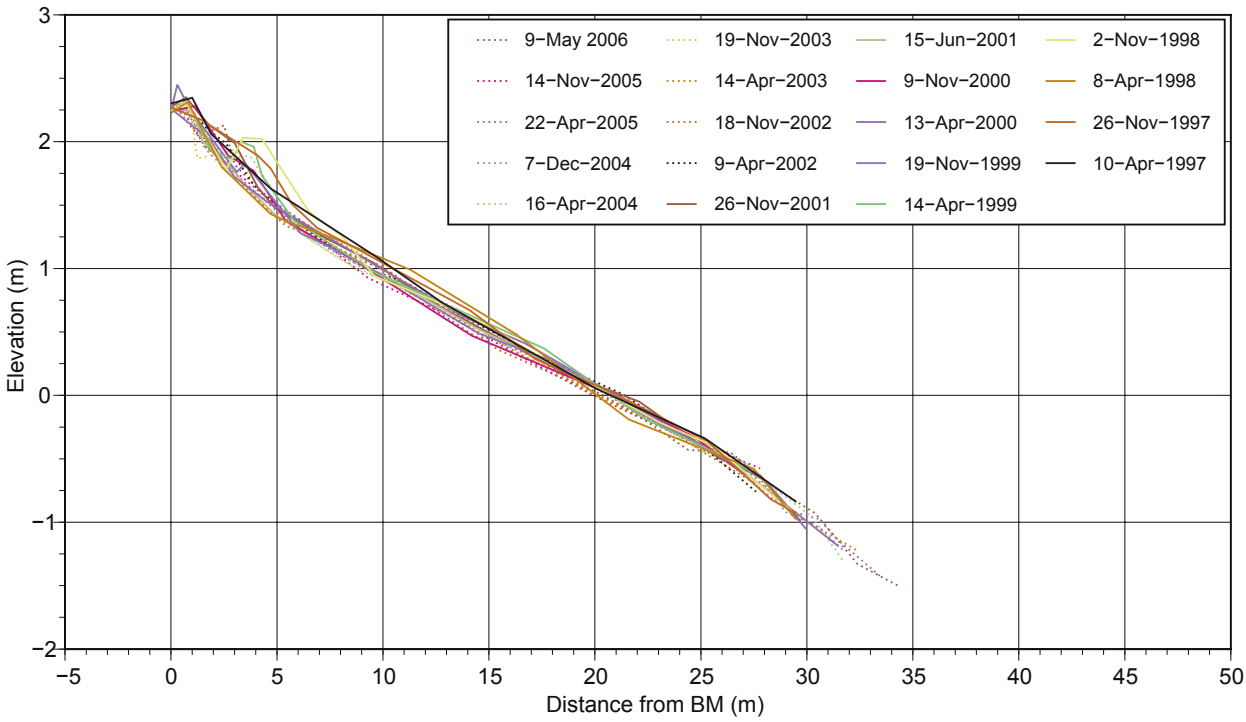
Profile 10: Tipi Bay

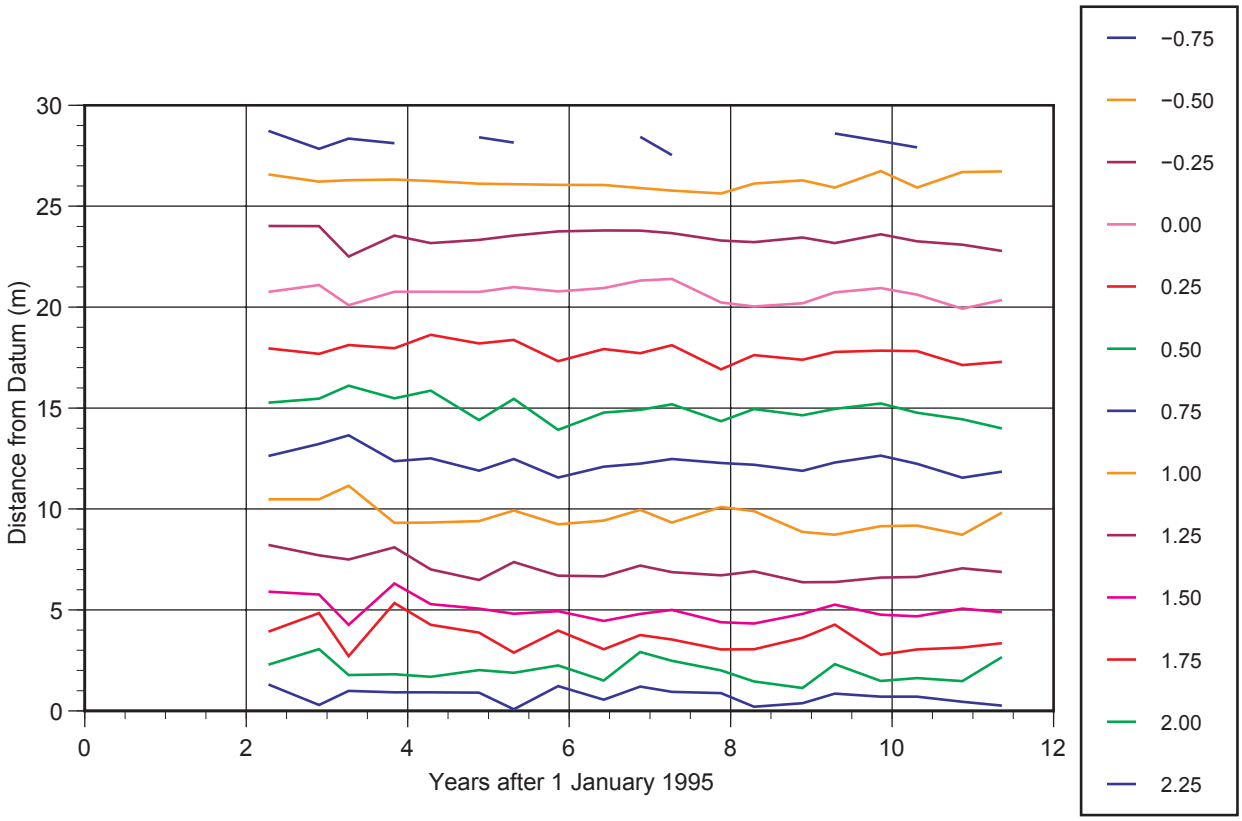
Profile 11 – Long Island

The Long Island profile is relatively exposed to storm events that cause waves to propagate through the northern entrance to Queen Charlotte Sound. There is considerable variability in the level of the upper beach, with the build up and removal of a berm, although this has been less evident since about 2000. The level of the middle and lower beach also shows some variability, but with no obvious seasonal trends. There has been a small overall decrease in sediment volume over the last 10 years. There are no significant sedimentary trends.

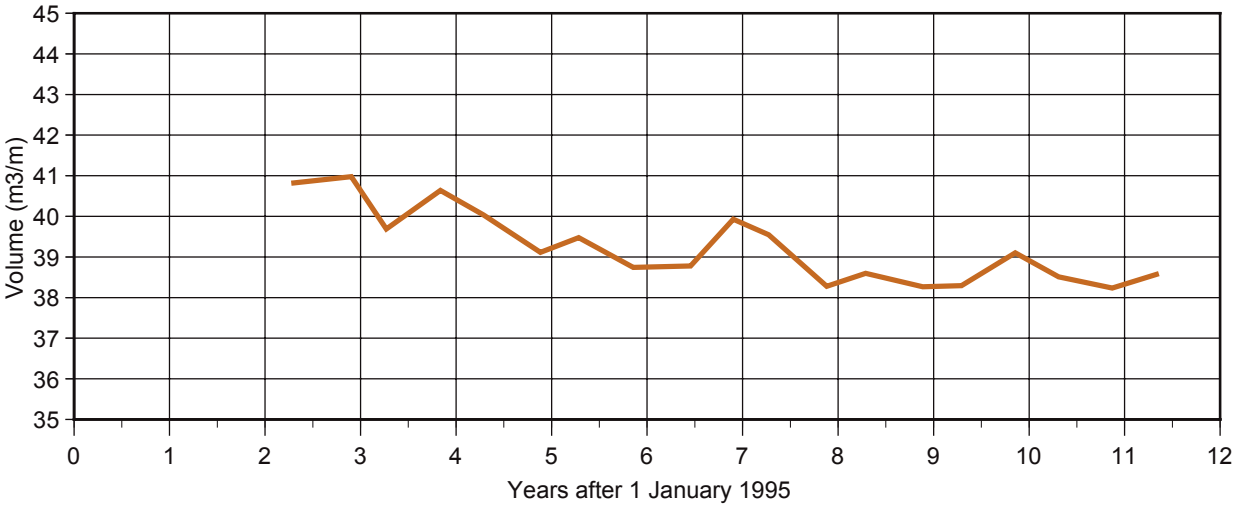


Profile 11: Long Island





Profile 11: Long Island

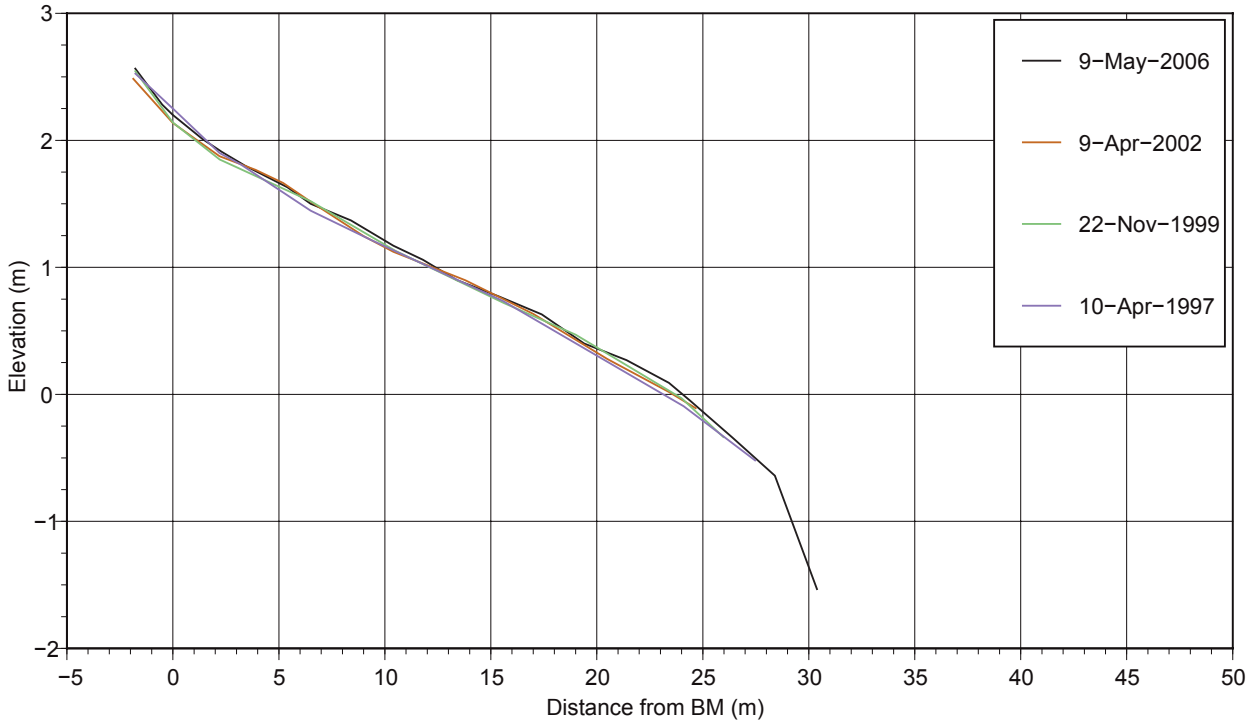


Date	Years after 1/1/95	Volume (m^3/m)
10-Apr-97	2.28	40.8
26-Nov-97	2.90	41.0
8-Apr-98	3.27	39.7
2-Nov-98	3.84	40.6
14-Apr-99	4.29	40.0
19-Nov-99	4.88	39.1
13-Apr-00	5.28	39.5
9-Nov-00	5.86	38.7
15-Jun-01	6.46	38.8
26-Nov-01	6.90	39.9
9-Apr-02	7.27	39.5
18-Nov-02	7.88	38.3
14-Apr-03	8.29	38.6
19-Nov-03	8.89	38.3
16-Apr-04	9.29	38.3
7-Dec-04	9.86	39.1
22-Apr-05	10.31	38.5
14-Nov-05	10.87	38.2
9-May-06	11.36	38.6

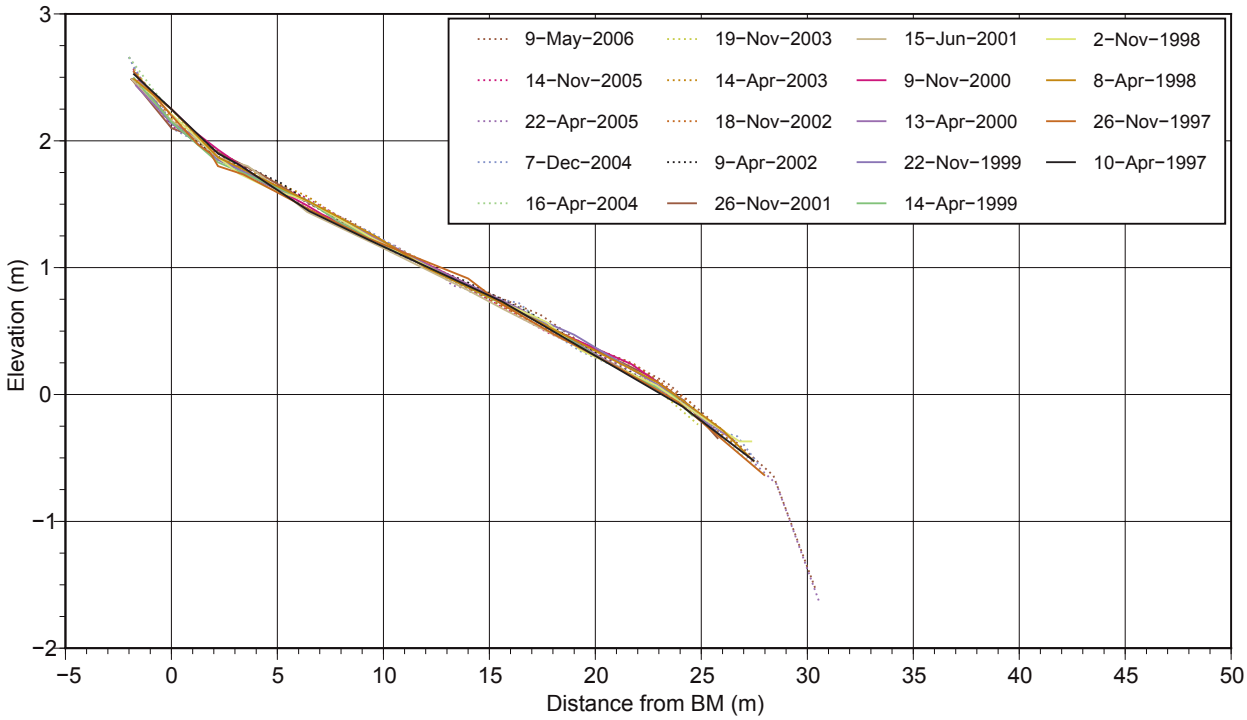
Profile 11: Long Island

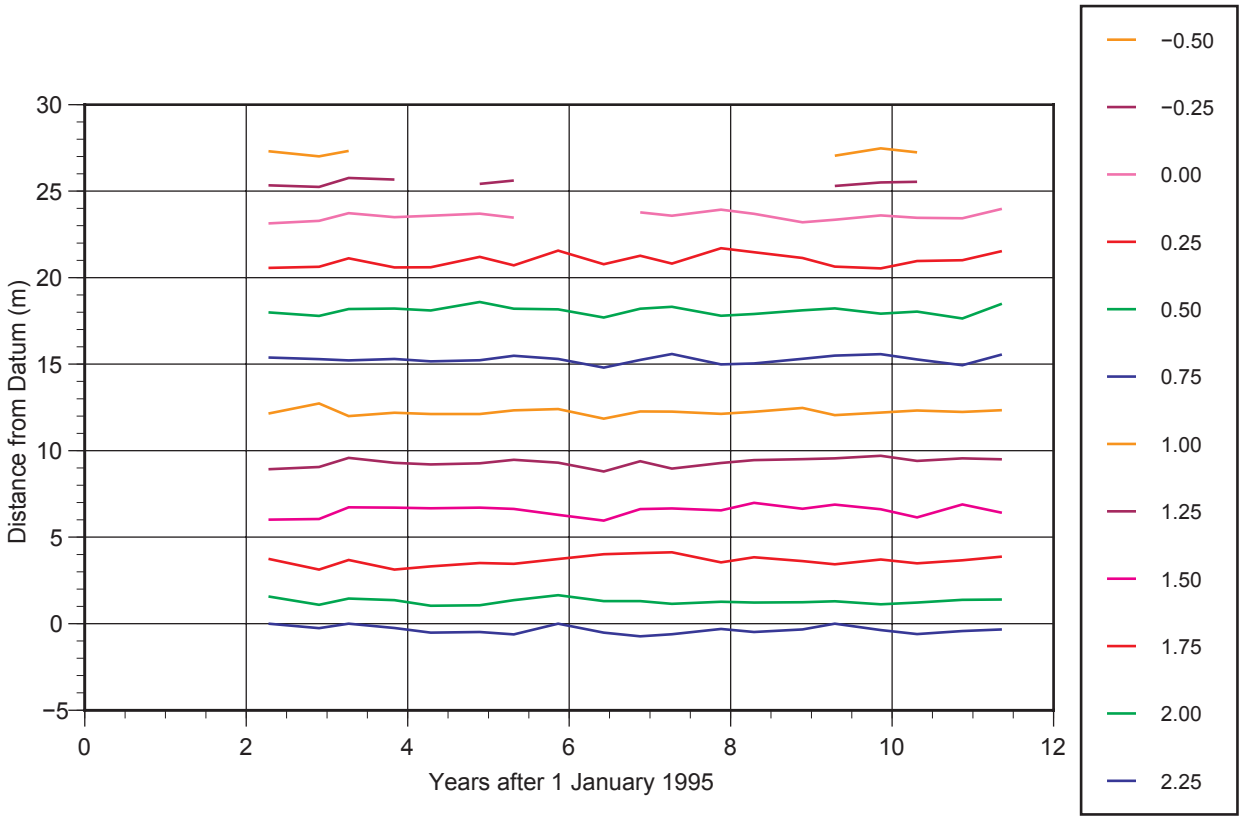
Profile 12 – Clark Point

This profile, with a similar aspect to Profile 11 (Long Island), has shown no significant change in level, volume or sedimentary characteristics since 1997.

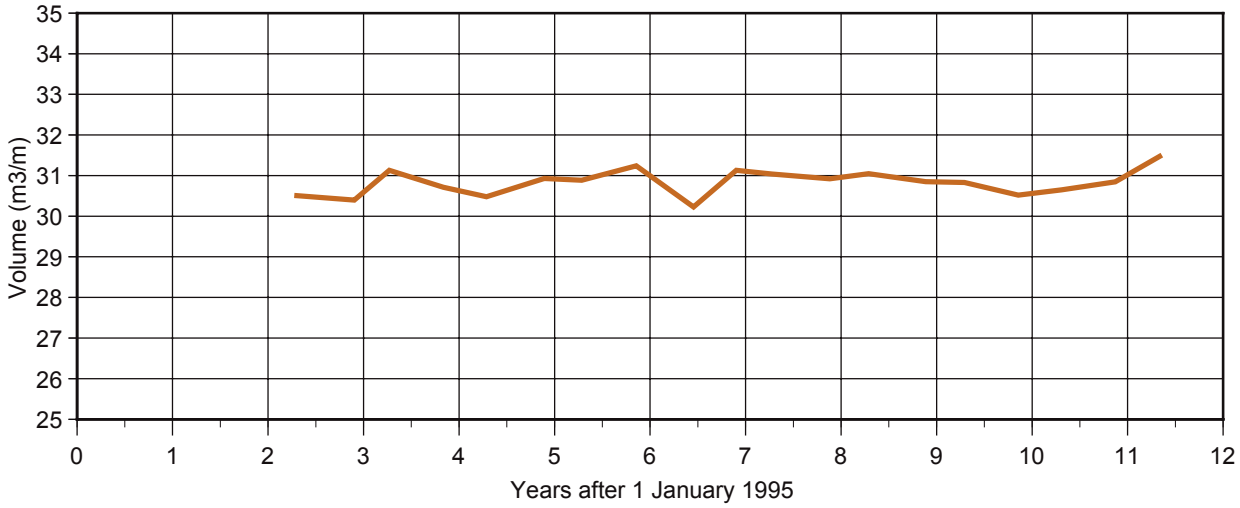


Profile 12: Clark Point





Profile 12: Clark Point



Date	Years after 1/1/95	Volume (m^3/m)
10-Apr-97	2.28	30.5
26-Nov-97	2.90	30.4
8-Apr-98	3.27	31.1
2-Nov-98	3.84	30.7
14-Apr-99	4.29	30.5
22-Nov-99	4.89	30.9
13-Apr-00	5.28	30.9
9-Nov-00	5.86	31.2
15-Jun-01	6.46	30.2
26-Nov-01	6.90	31.1
9-Apr-02	7.27	31.0
18-Nov-02	7.88	30.9
14-Apr-03	8.29	31.0
19-Nov-03	8.89	30.9
16-Apr-04	9.29	30.8
7-Dec-04	9.86	30.5
22-Apr-05	10.31	30.6
14-Nov-05	10.87	30.8
9-May-06	11.36	31.5

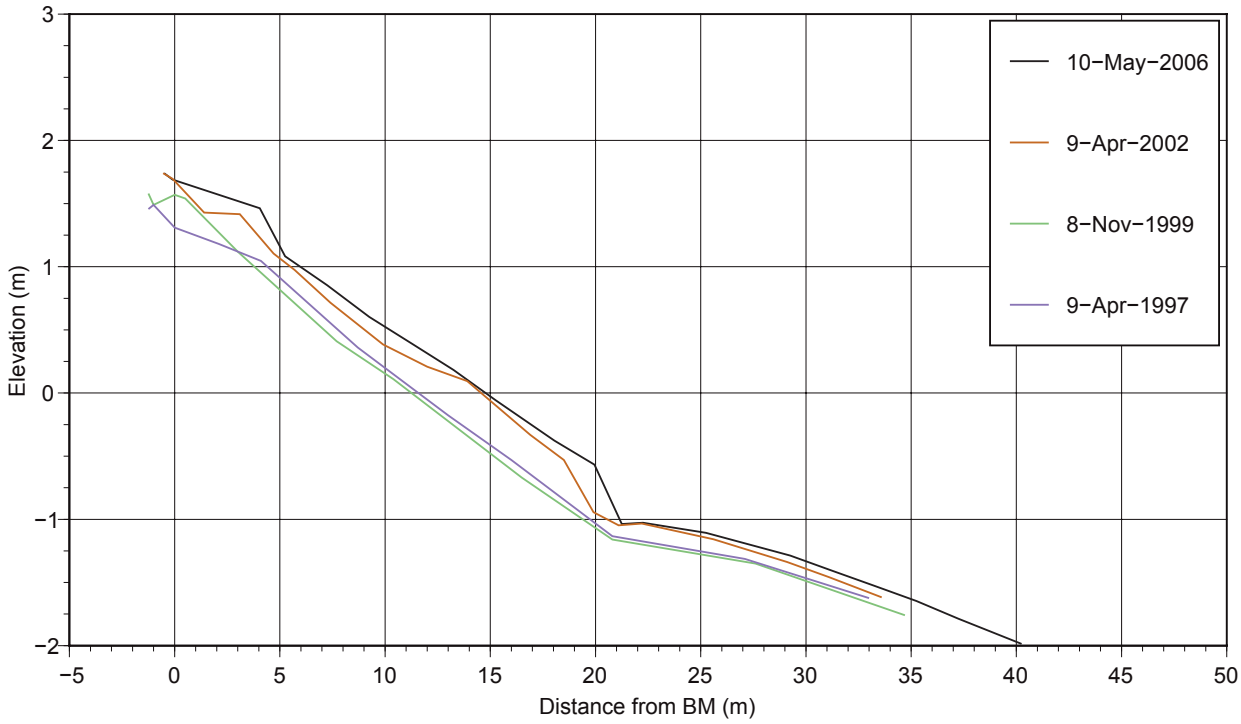
Profile 12: Clark Point

Profile 13 – Slip Beach

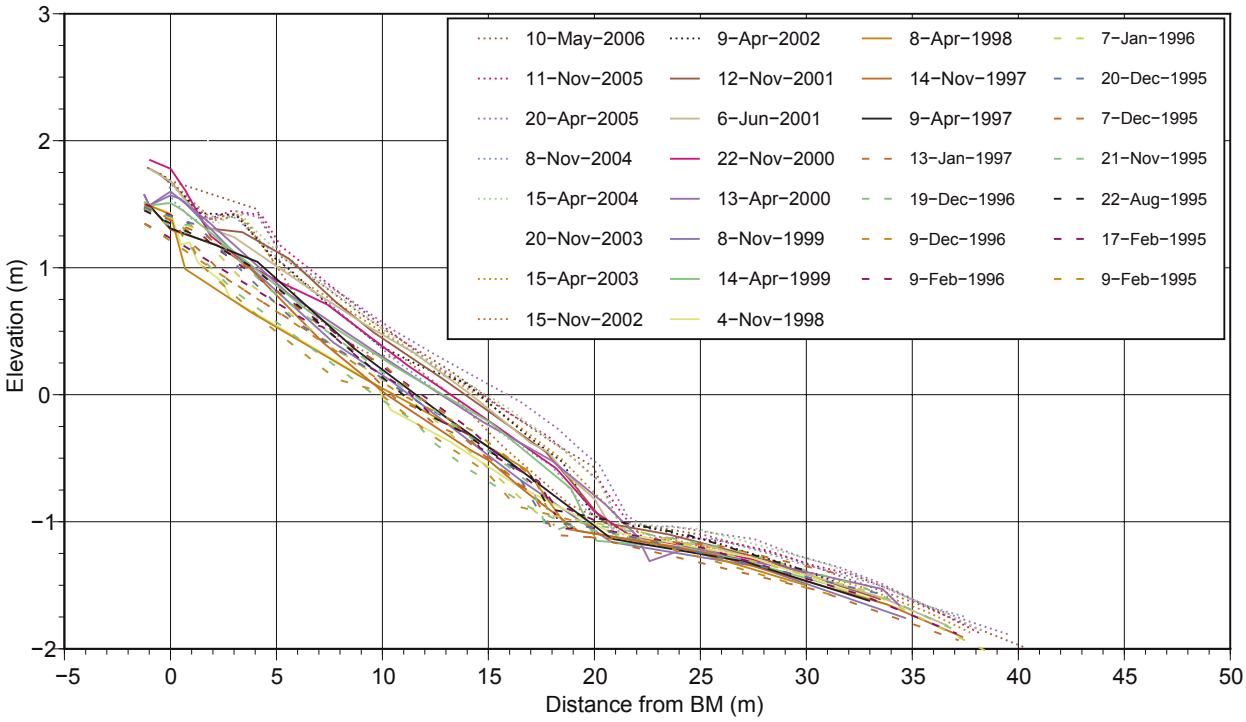
Slip Beach demonstrated considerable variability between 1995 and April 1998 when it reached its lowest level. Up until the end of 2000, there was variability but in the context of accretion. Since the end of 2000 there has been less variability, but with continued accretion.

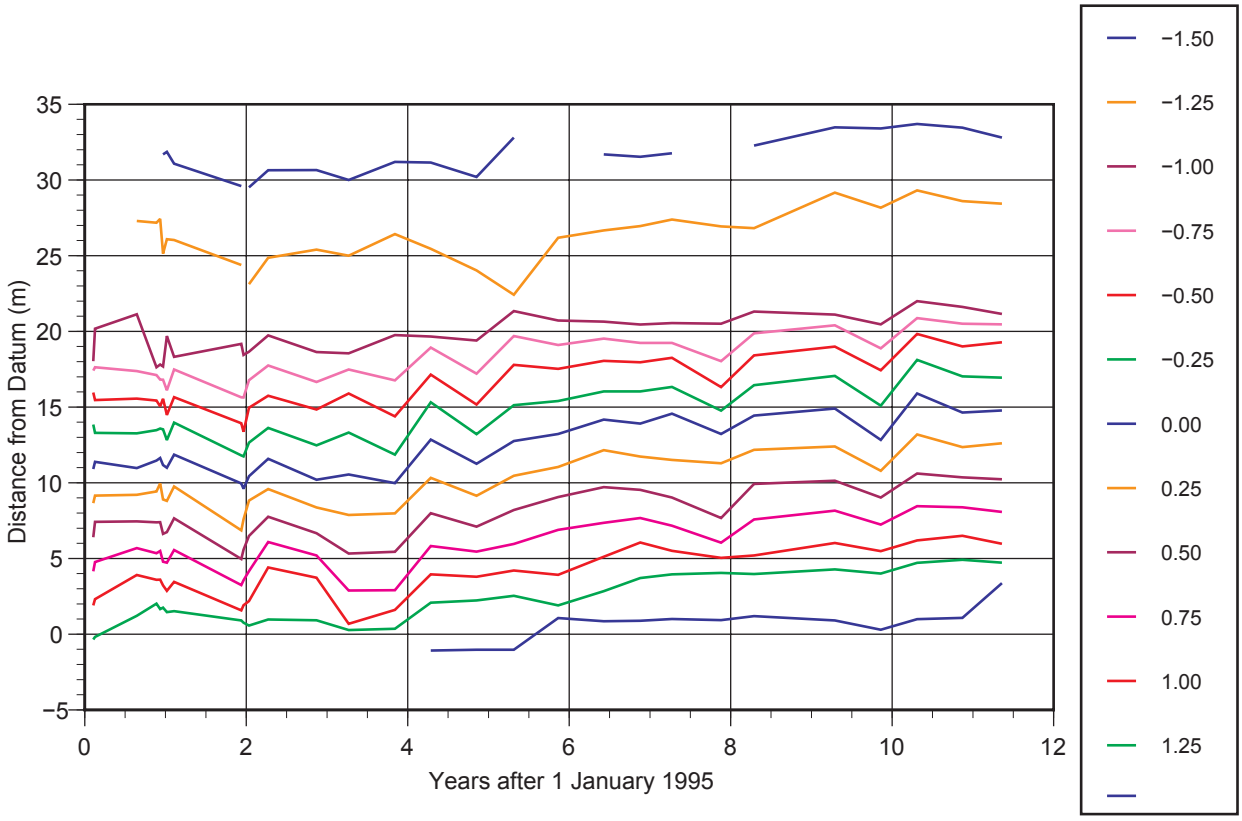
The photographs indicate that the dominant sediment type is sand with some small cobbles and pebbles.

Although no obvious relationships between ferry operations and beach change were able to be determined, it is apparent that the considerable variability in the profile ceased about the same time as fast ferry operations ceased. Slip beach has a considerable fetch into Queen Charlotte Sound to the north, and natural waves may be substantial. However, wave measurements at this site have indicated substantial wake events that continue for unusually long periods of time. Because of its unusual exposure, unusual wakes and, for the area, fine sediments, this location continues to be of particular interest.

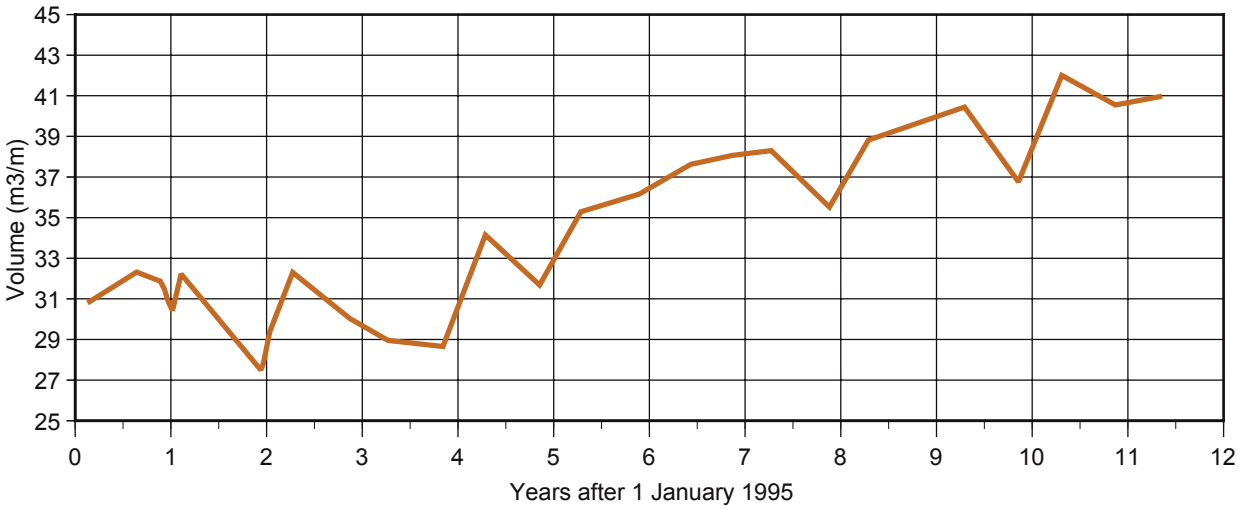


Profile 13: Slip Beach





Profile 13: Slip Beach



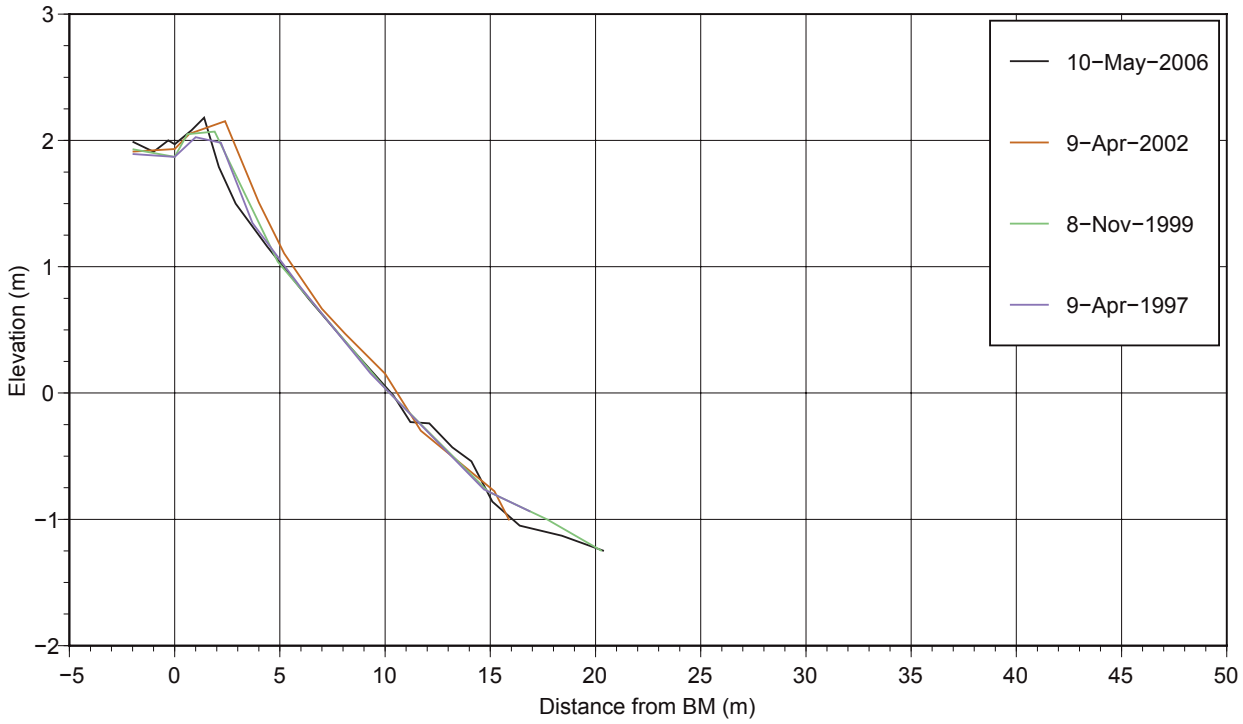
Date	Years after 1/1/95	Volume (m^3/m)
17-Feb-95	0.13	30.8
22-Aug-95	0.64	32.3
21-Nov-95	0.89	31.9
7-Dec-95	0.93	31.5
20-Dec-95	0.97	30.9
7-Jan-96	1.02	30.4
9-Feb-96	1.11	32.2
9-Dec-96	1.94	27.5
19-Dec-96	1.97	27.8
13-Jan-97	2.03	29.4
9-Apr-97	2.27	32.3
14-Nov-97	2.87	30.0
8-Apr-98	3.27	29.0
4-Nov-98	3.84	28.7
14-Apr-99	4.29	34.2
8-Nov-99	4.85	31.7
13-Apr-00	5.28	35.3
22-Nov-00	5.89	36.2
6-Jun-01	6.43	37.6
12-Nov-01	6.86	38.1
9-Apr-02	7.27	38.3
15-Nov-02	7.88	35.5
15-Apr-03	8.29	38.8
20-Nov-03	8.89	No data
15-Apr-04	9.29	40.4
8-Nov-04	9.86	36.8
20-Apr-05	10.31	42.0
11-Nov-05	10.87	40.5
10-May-06	11.36	41.0

Profile 13: Slip Beach

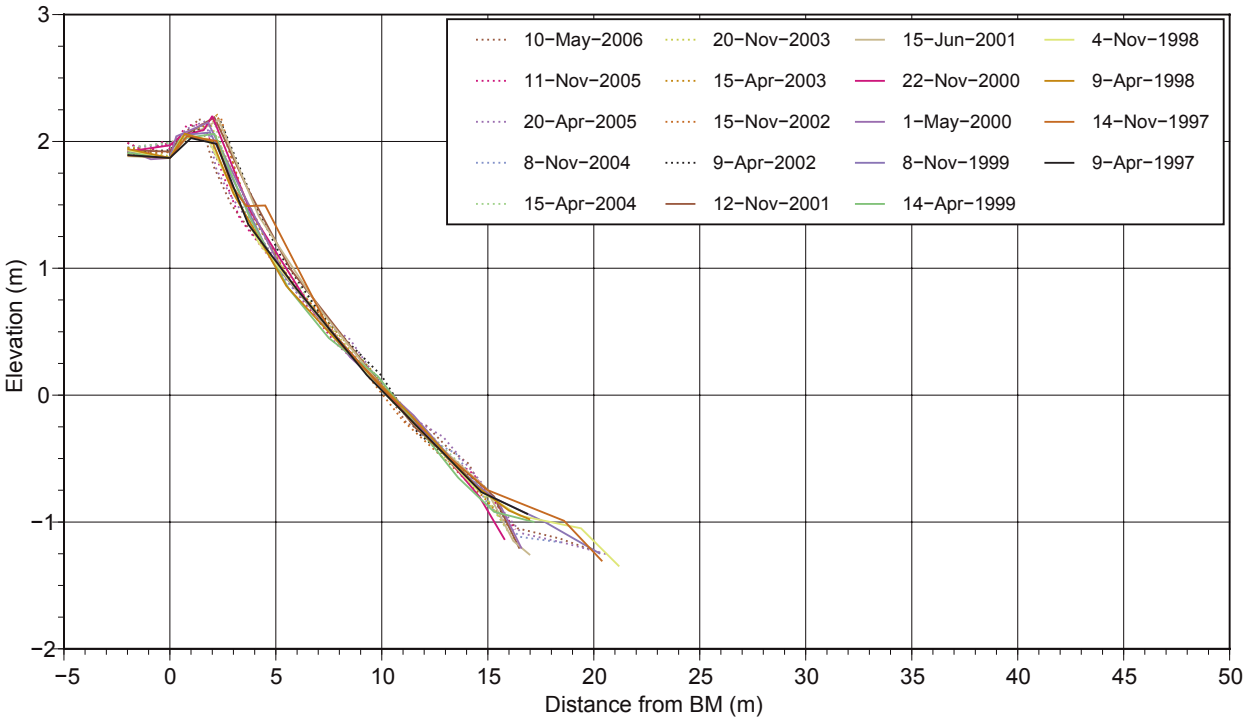
Profile 14 – Ngaionui Point

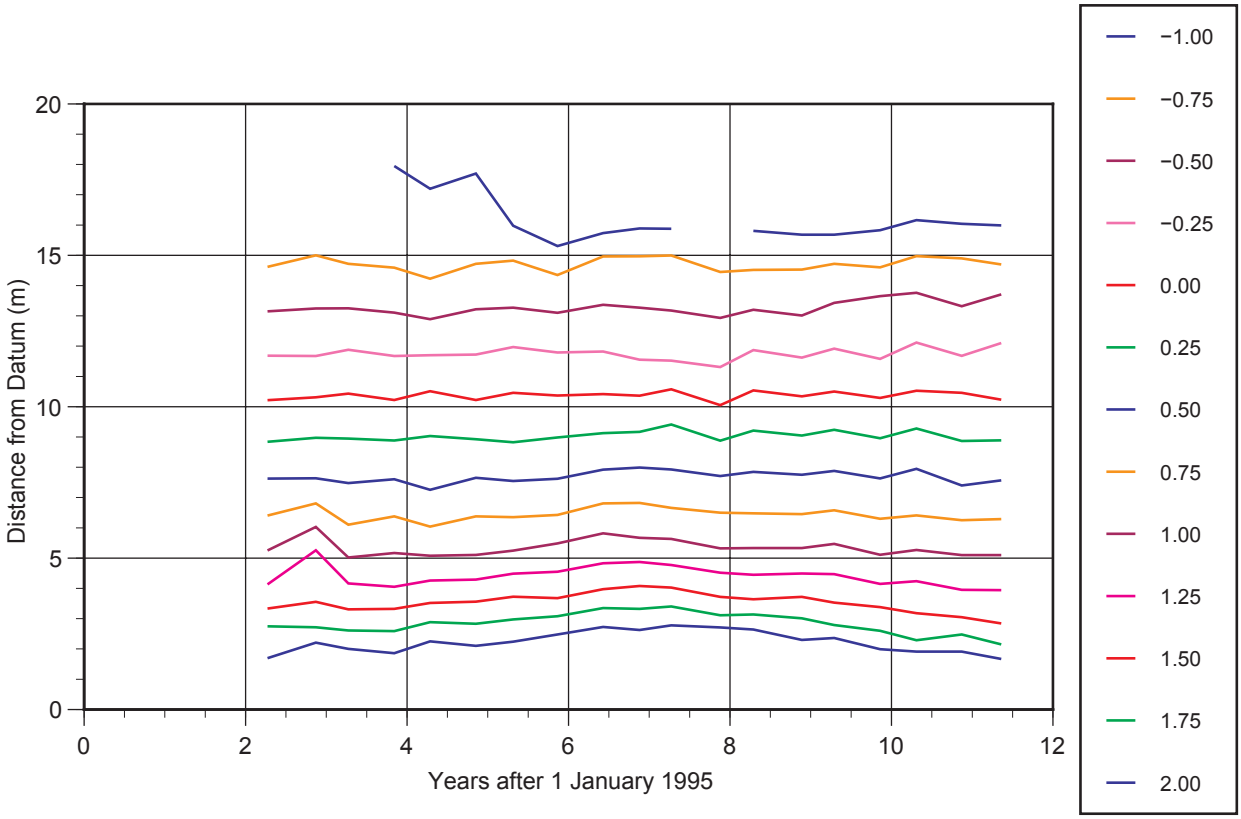
The beach on Ngaionui Point has shown surprisingly little change, particularly given its proximity to the sailing line of vessels in Tory Channel. It is most likely that significant change occurred when the fast ferry first started operation, and that the beach form has held since that time. There was a slow trend towards accretion up until about April 2002, and a very slow trend of erosion since that time, perhaps reflecting the start of a return to pre-fast ferry conditions.

Apparent changes at the very lower beach are probably the result of different survey placement. There have been no significant changes in sediments.

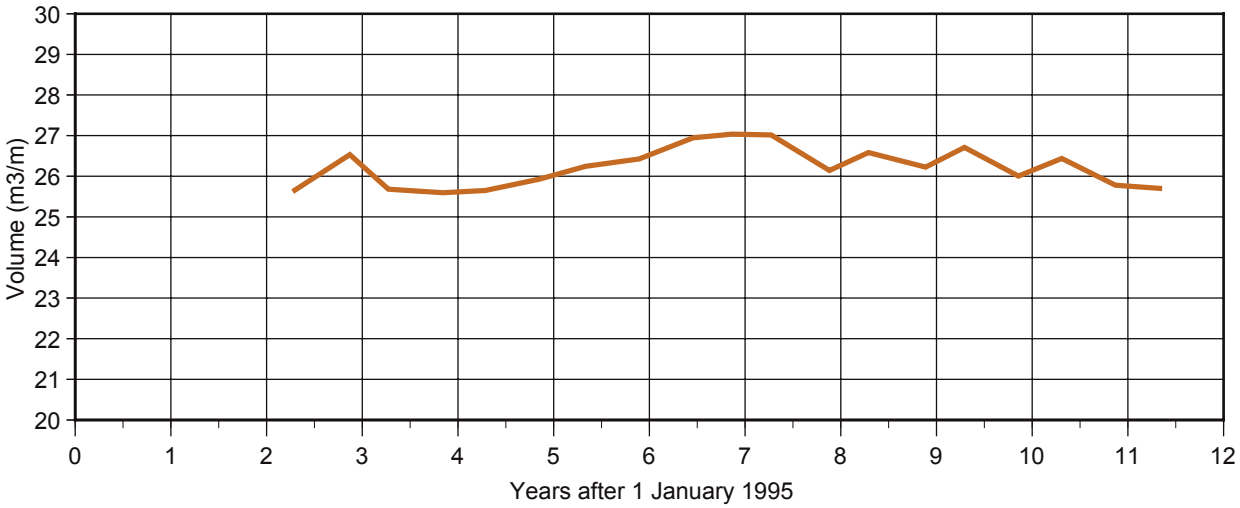


Profile 14: Ngaionui Point





Profile 14: Ngaionui Point



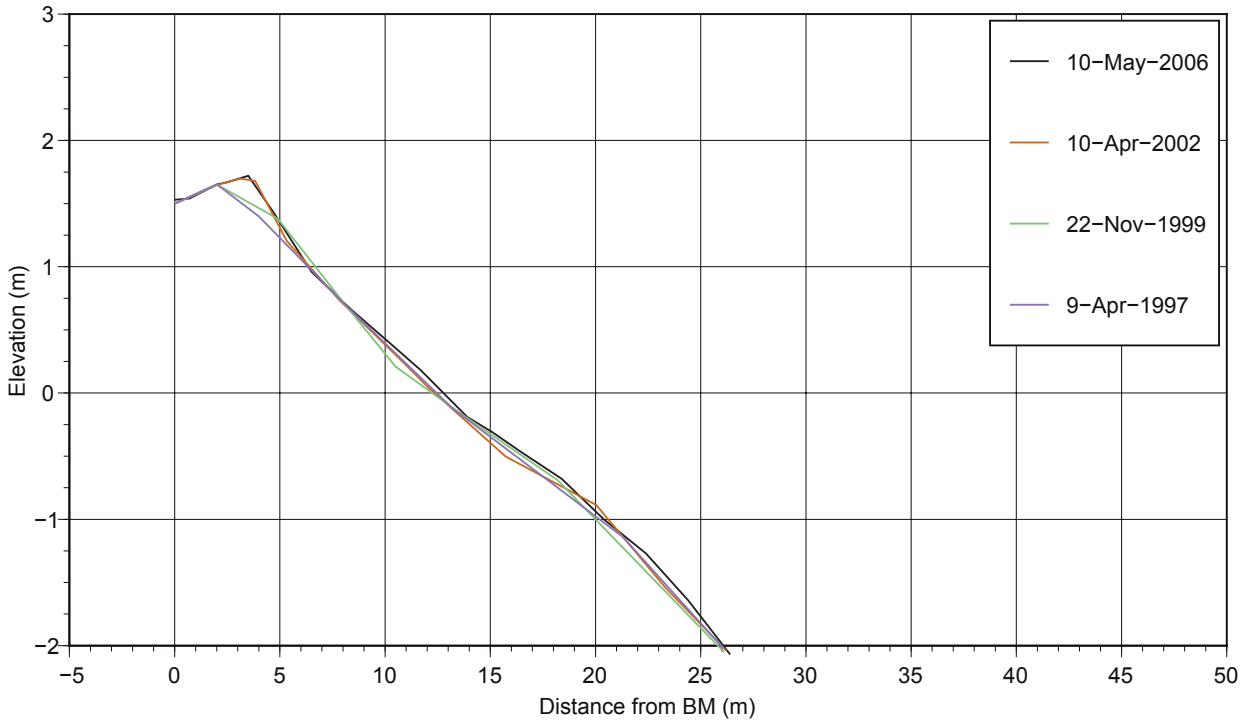
Date	Years after 1/1/95	Volume (m^3/m)
9-Apr-97	2.27	25.6
14-Nov-97	2.87	26.5
9-Apr-98	3.27	25.7
4-Nov-98	3.84	25.6
14-Apr-99	4.29	25.7
8-Nov-99	4.85	25.9
1-May-00	5.33	26.2
22-Nov-00	5.89	26.4
15-Jun-01	6.46	26.9
12-Nov-01	6.86	27.0
9-Apr-02	7.27	27.0
15-Nov-02	7.88	26.1
15-Apr-03	8.29	26.6
20-Nov-03	8.89	26.2
15-Apr-04	9.29	26.7
8-Nov-04	9.86	26.0
20-Apr-05	10.31	26.4
11-Nov-05	10.87	25.8
10-May-06	11.36	25.7

Profile 14: Ngaionui Point

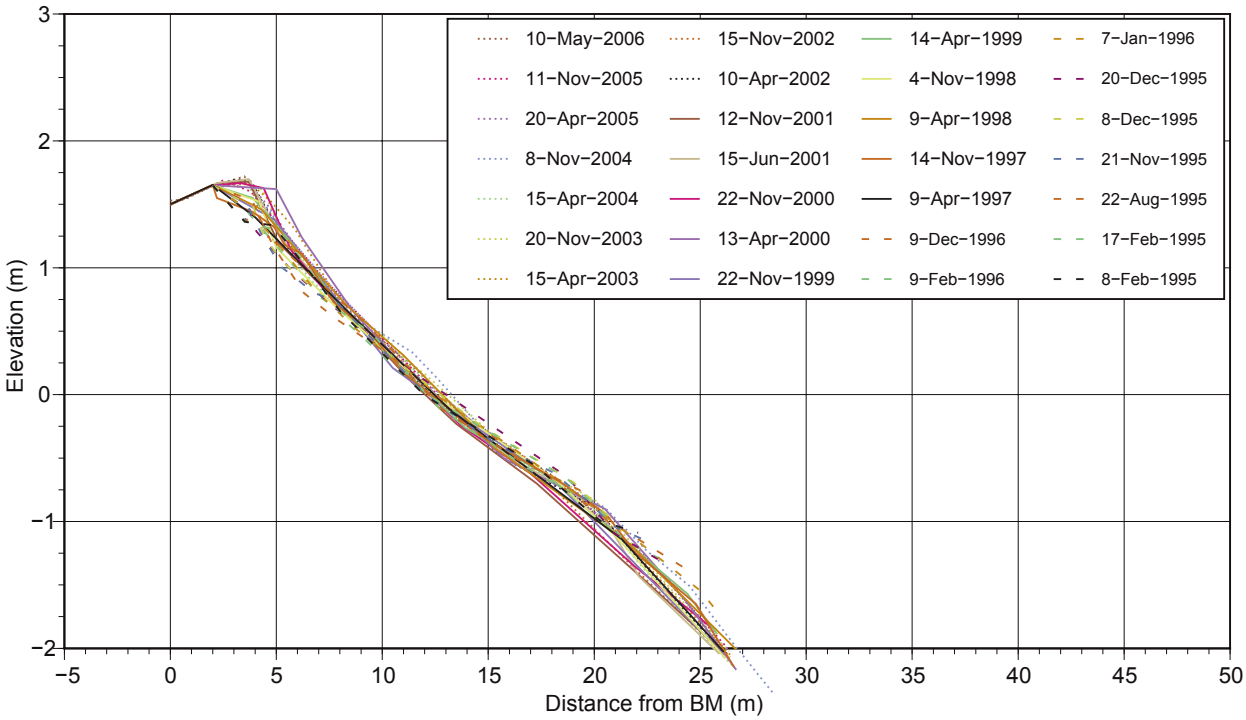
Profile 15 – Te Weka Bay

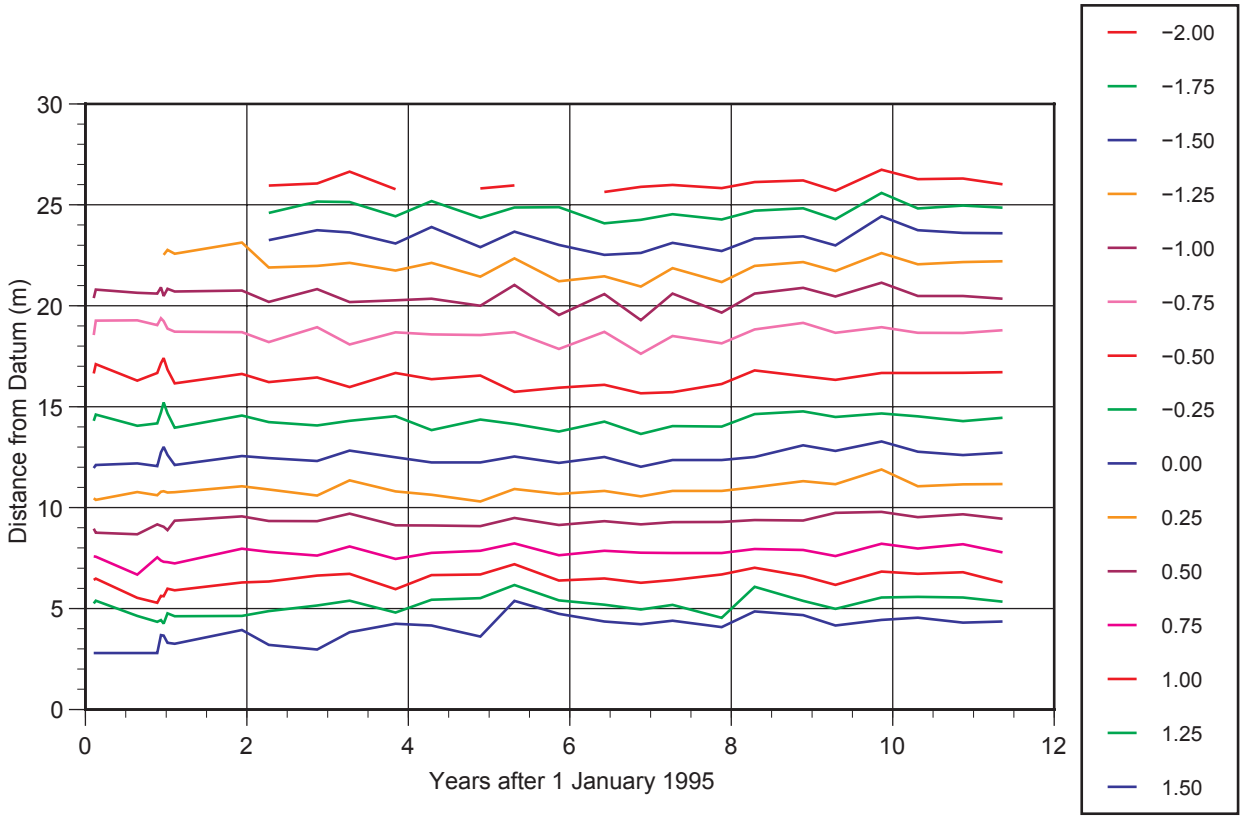
The Te Weka Bay profile, adjacent to the jetty, has been generally stable over the survey period, with very slight accretion, particularly on the upper beach. The development of an upper beach berm and the reduction in level of the middle beach during the period of fast ferry operation is evident (reaching a peak in April 2000). The berm has remained generally intact since that time

There have been no significant changes in sediment characteristics.

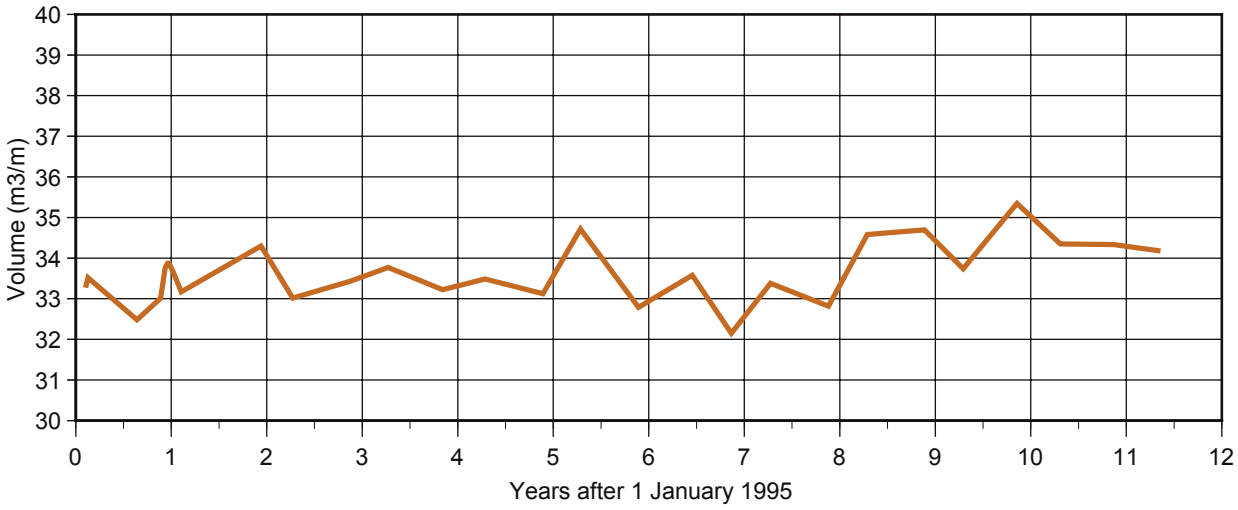


Profile 15: Te Weka Bay





Profile 15: Te Weka Bay



Date	Years after 1/1/95	Volume (m^3/m)
8-Feb-95	0.10	33.27
17-Feb-95	0.13	33.52
22-Aug-95	0.64	32.48
21-Nov-95	0.89	33.01
8-Dec-95	0.94	33.76
20-Dec-95	0.97	33.91
7-Jan-96	1.02	33.68
9-Feb-96	1.11	33.17
9-Dec-96	1.94	34.30
9-Apr-97	2.27	33.02
14-Nov-97	2.87	33.43
9-Apr-98	3.27	33.77
4-Nov-98	3.84	33.22
14-Apr-99	4.29	33.49
22-Nov-99	4.89	33.13
13-Apr-00	5.28	34.72
22-Nov-00	5.89	32.79
15-Jun-01	6.46	33.58
12-Nov-01	6.86	32.15
10-Apr-02	7.28	33.38
15-Nov-02	7.88	32.8
15-Apr-03	8.29	34.6
20-Nov-03	8.89	34.7
15-Apr-04	9.29	33.7
8-Nov-04	9.86	35.3
20-Apr-05	10.31	34.3
11-Nov-05	10.87	34.3
10-May-06	11.36	34.2

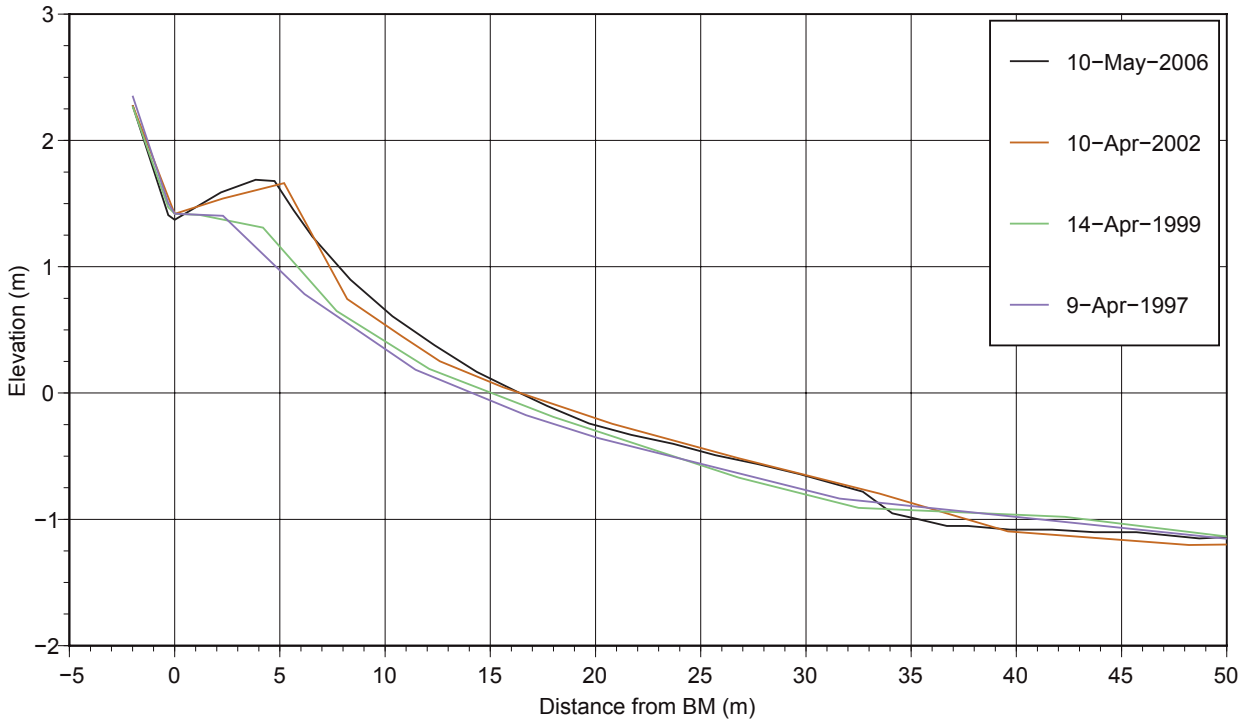
Profile 15: Te Weka Bay

Profile 16 – McMillan's Bay

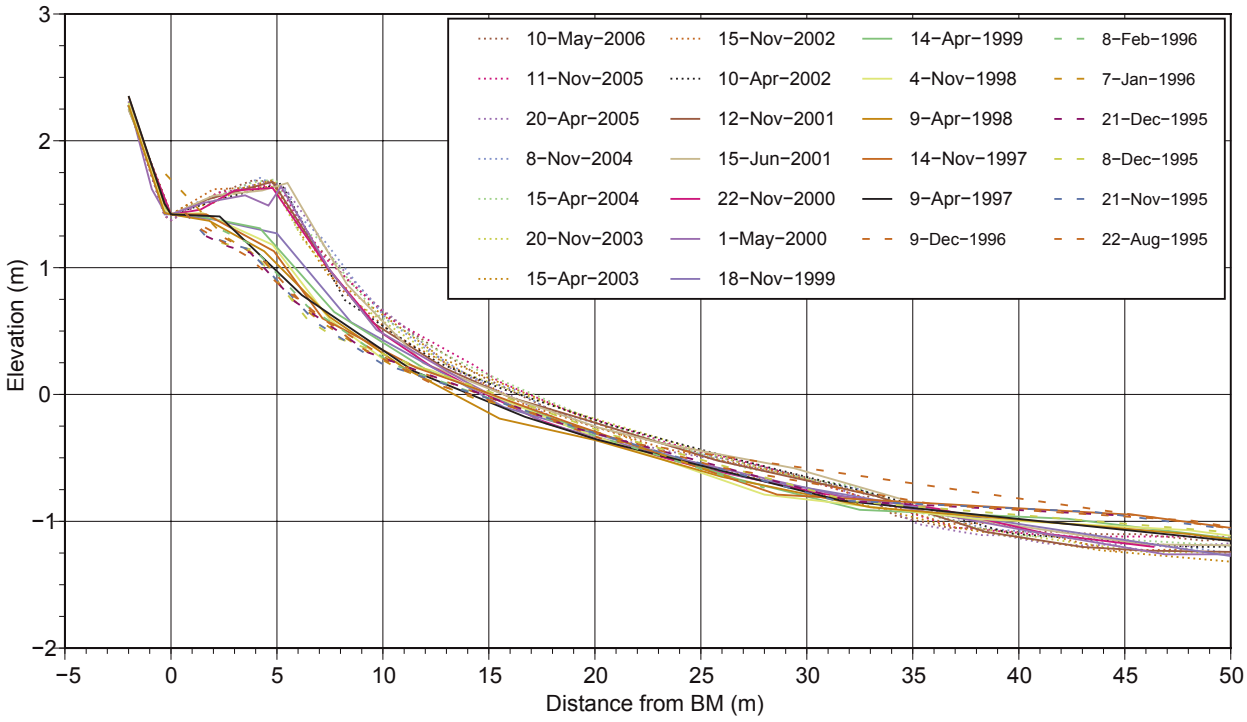
Up until November 1999 there had been a gradual accretion of the upper McMillan's Bay profile. The accretion was mainly comprised of gravels that were moving along the beach from the direction of Arrowsmith Point, although there had been some rise in the middle beach level, due to deposition of sand. Between November 1999 and May 2000 a major increase in the height of the upper beach berm occurred, with a very large deposit of gravel, again coming from the direction of Arrowsmith Point. This deposit has remained almost unchanged since that time. The middle beach has continued to build with the deposition of sand, although the rate of accretion slowed in 2000. The lower beach has been relatively stable, apparent changes probably being the result of minor differences in survey line.

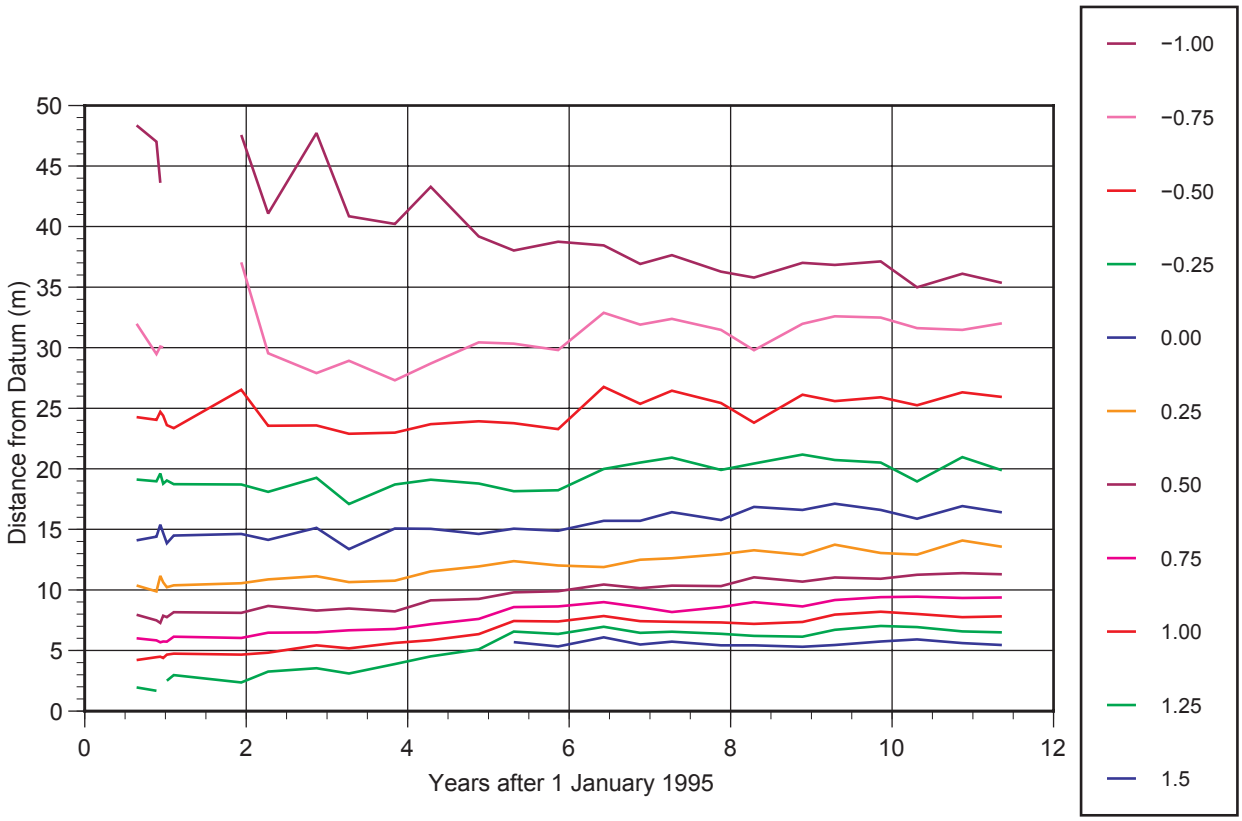
This profile line is clearly being influenced by longshore transport of gravels from west to east. It may also be that there is transport of sand either onshore or alongshore. It is most likely that the mechanism of accretion is the result of ferry generated wake waves. The rate of accretion dropped markedly about the time the fast ferry operation ceased, probably the result of a reduced ability of the waves to transport sediment.

McMillan's Bay is quite unusual in the context of the Tory Channel, being wide and with a relatively small slope. It has a wide 'surf' zone, unlike almost all other shorelines in the area.

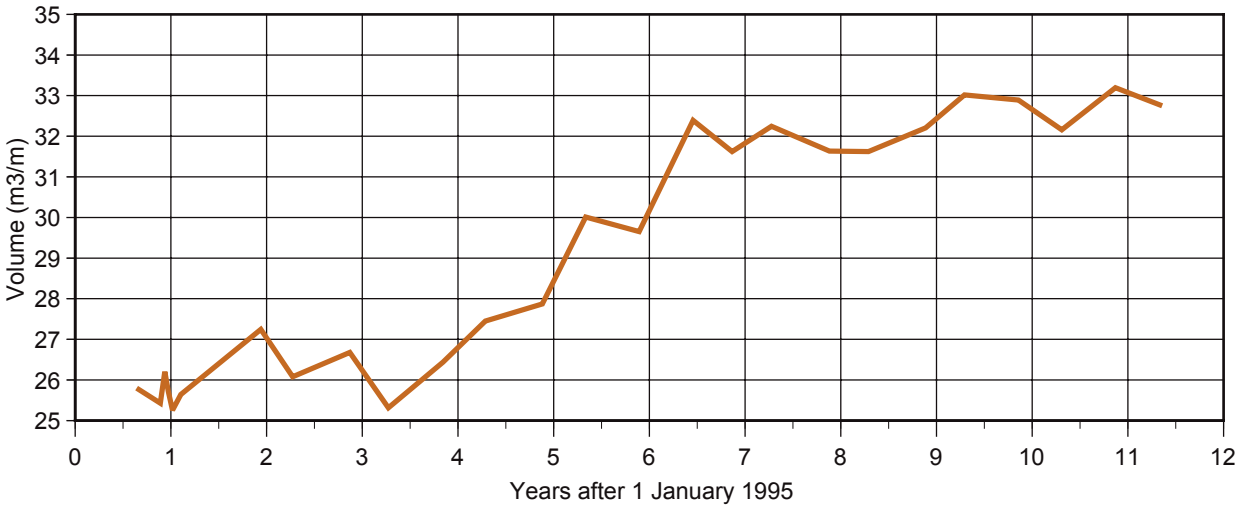


Profile 16: McMillan's Bay





Profile 16: McMillan's Bay



Date	Years after 1/1/95	Volume (m^3/m)
22-Aug-95	0.64	25.8
21-Nov-95	0.89	25.4
8-Dec-95	0.94	26.2
21-Dec-95	0.97	25.7
7-Jan-96	1.02	25.3
8-Feb-96	1.10	25.6
9-Dec-96	1.94	27.2
9-Apr-97	2.27	26.1
14-Nov-97	2.87	26.7
9-Apr-98	3.27	25.3
4-Nov-98	3.84	26.4
14-Apr-99	4.29	27.4
18-Nov-99	4.88	27.9
1-May-00	5.33	30.0
22-Nov-00	5.89	29.7
15-Jun-01	6.46	32.4
12-Nov-01	6.86	31.6
10-Apr-02	7.28	32.2
15-Nov-02	7.88	31.6
15-Apr-03	8.29	31.6
20-Nov-03	8.89	32.2
15-Apr-04	9.29	33.0
8-Nov-04	9.86	32.9
20-Apr-05	10.31	32.2
11-Nov-05	10.87	33.2
10-May-06	11.36	32.8

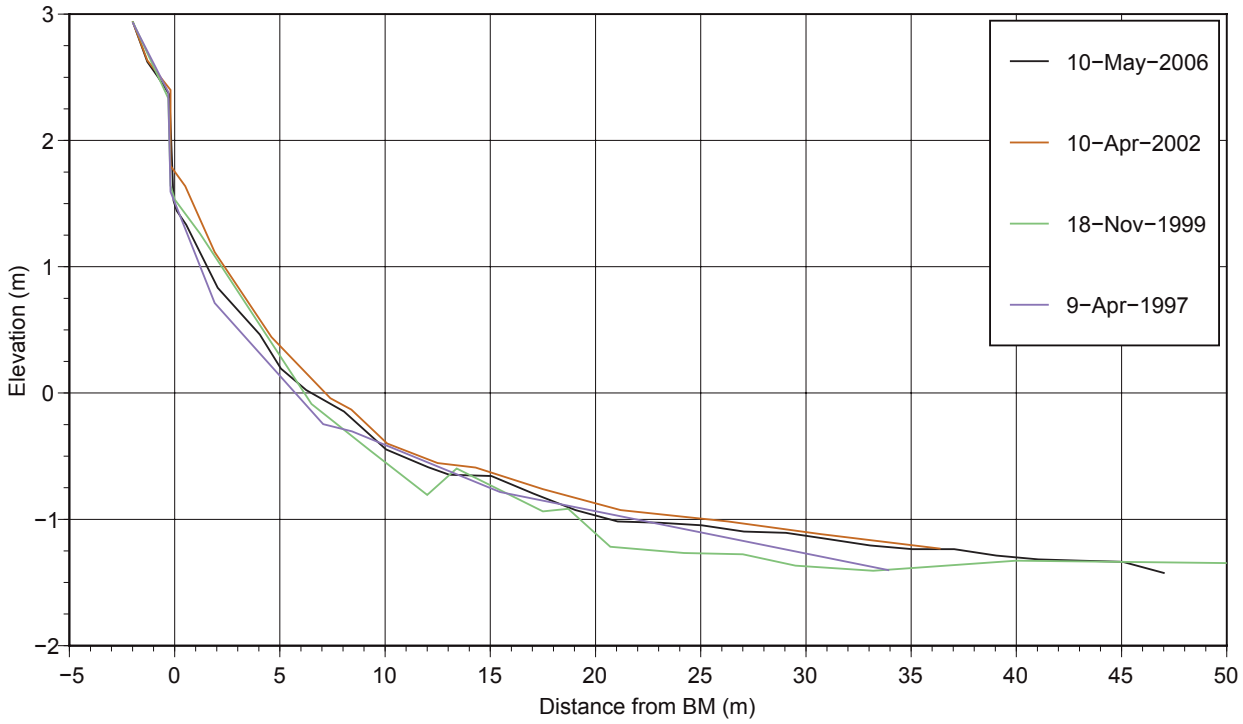
Profile 16: McMillan's Bay

Profile 17 – McMillan's Side

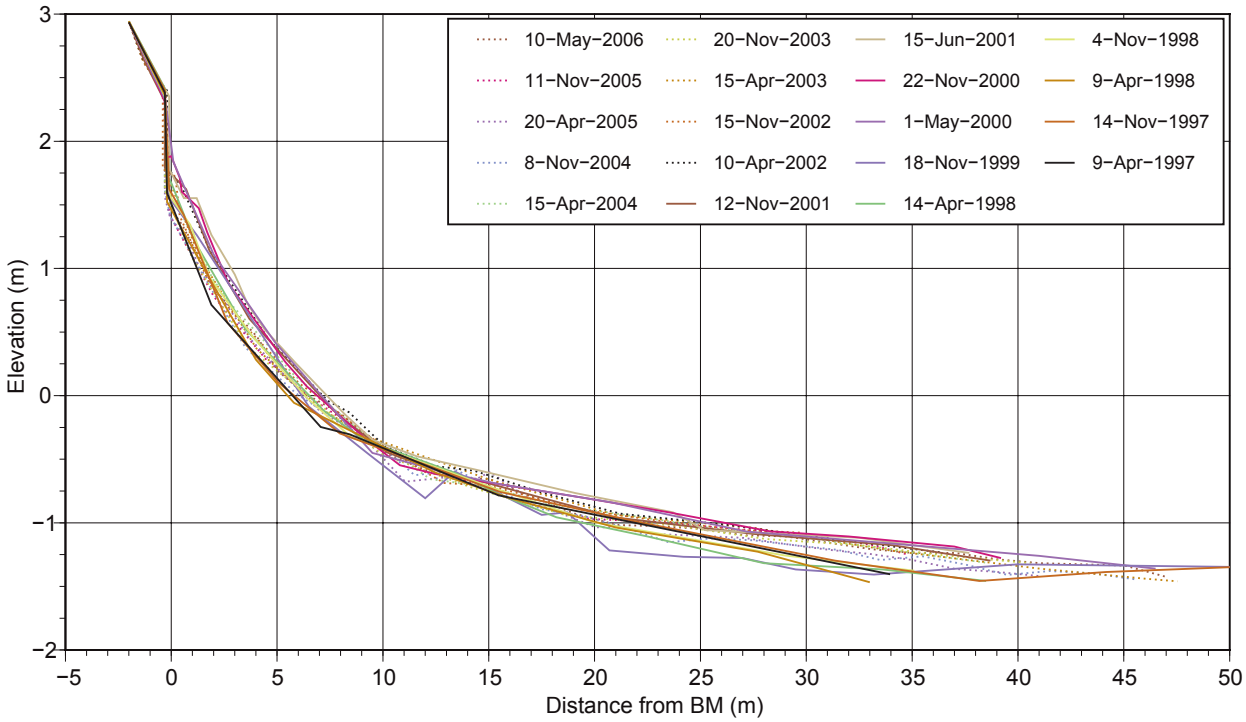
Between November 1999 and May 2000, at the same time as there was a major increase in the volume of the berm on Profile 16, there was a very significant deposition of sediment on the lower profile on Profile 17. Up until this time, the profile had been generally stable, with some accumulation on the upper beach, and perhaps some minor adjustments elsewhere on the profile line.

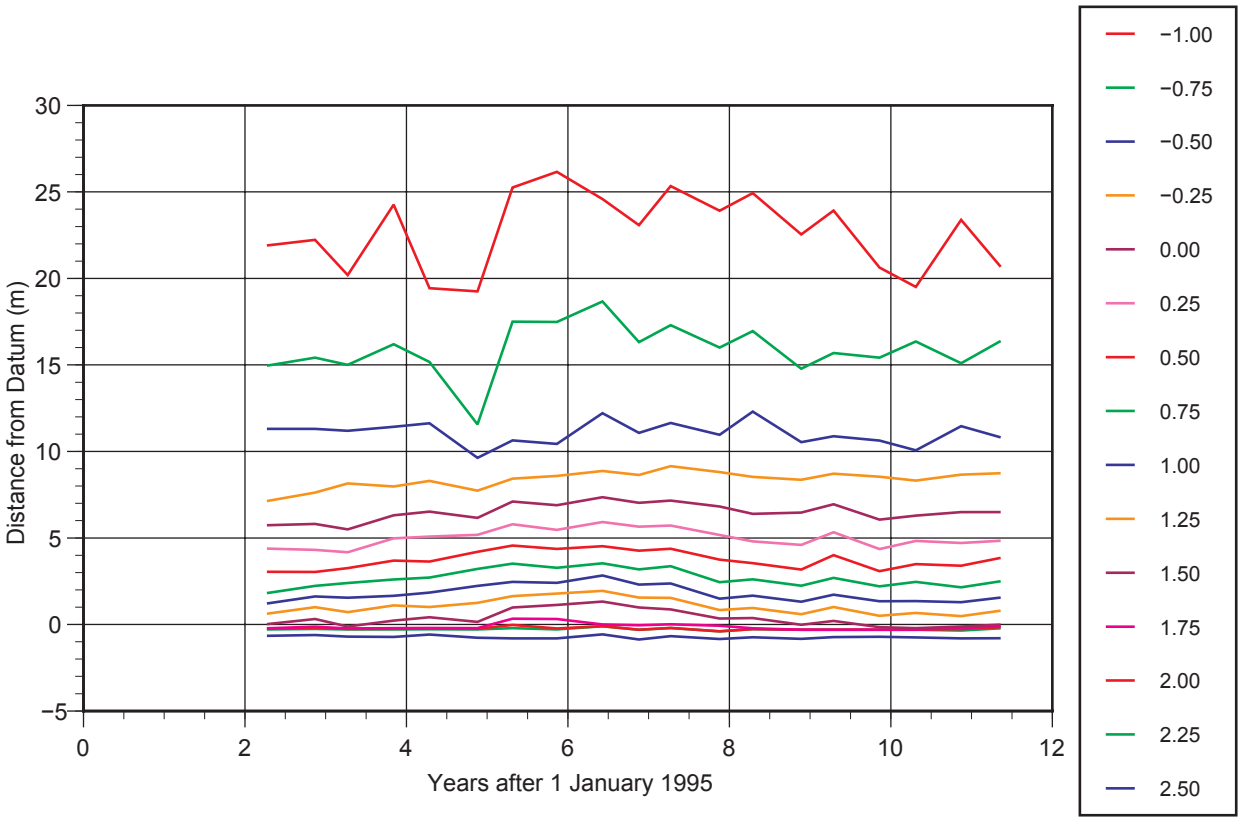
Beach volumes increased until 2001, with most of the accumulation on the lower profile. Since that time volumes have decreased, with most loss coming from the mid to upper beach. There is no indication of erosion at the upper beach scarp.

The reason for the major deposition between November 1999 and May 2000, reflected also on Profile 16, is unknown. However, there must have been a significant increase in sediment supply, perhaps a slip in the vicinity of Arrowsmith Point. After fast ferry operation ceased in 2000, there was a change from sediment accumulation to sediment loss. This occurred at the same time as a change from sediment accumulation to stability on Profile 16. Changes in this profile reflect changes in vessel operations, but there also appears to be a sediment supply control.

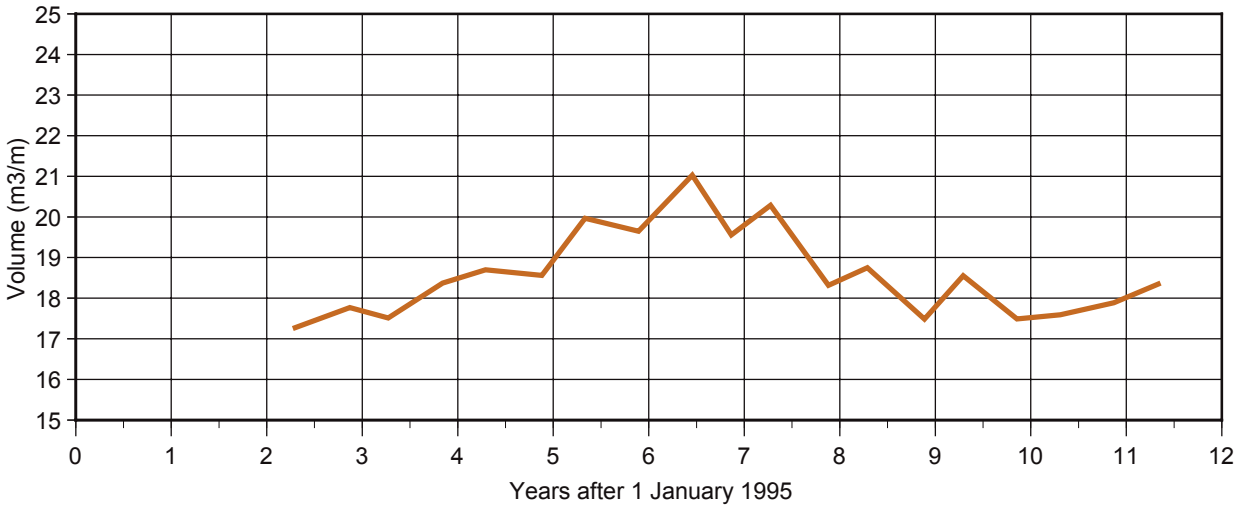


Profile 17: McMillan's Side





Profile 17: McMillan's Side



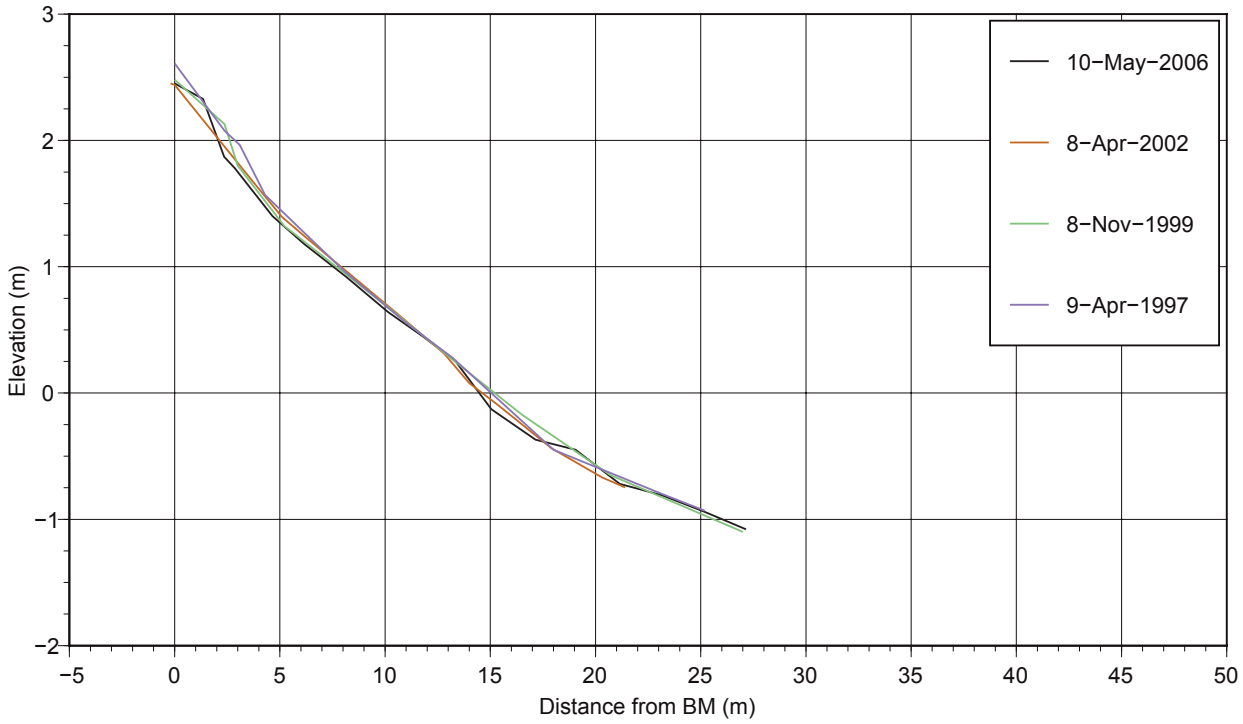
Date	Years after 1/1/95	Volume (m^3/m)
9-Apr-97	2.27	17.3
14-Nov-97	2.87	17.8
9-Apr-98	3.27	17.5
4-Nov-98	3.84	18.4
14-Apr-99	4.29	18.7
18-Nov-99	4.88	18.6
1-May-00	5.33	20.0
22-Nov-00	5.89	19.6
15-Jun-01	6.46	21.0
12-Nov-01	6.86	19.6
10-Apr-02	7.28	20.3
15-Nov-02	7.88	18.3
15-Apr-03	8.29	18.8
20-Nov-03	8.89	17.5
15-Apr-04	9.29	18.6
8-Nov-04	9.86	17.5
20-Apr-05	10.31	17.6
11-Nov-05	10.87	17.9
10-May-06	11.36	18.4

Profile 17: McMillan's Side

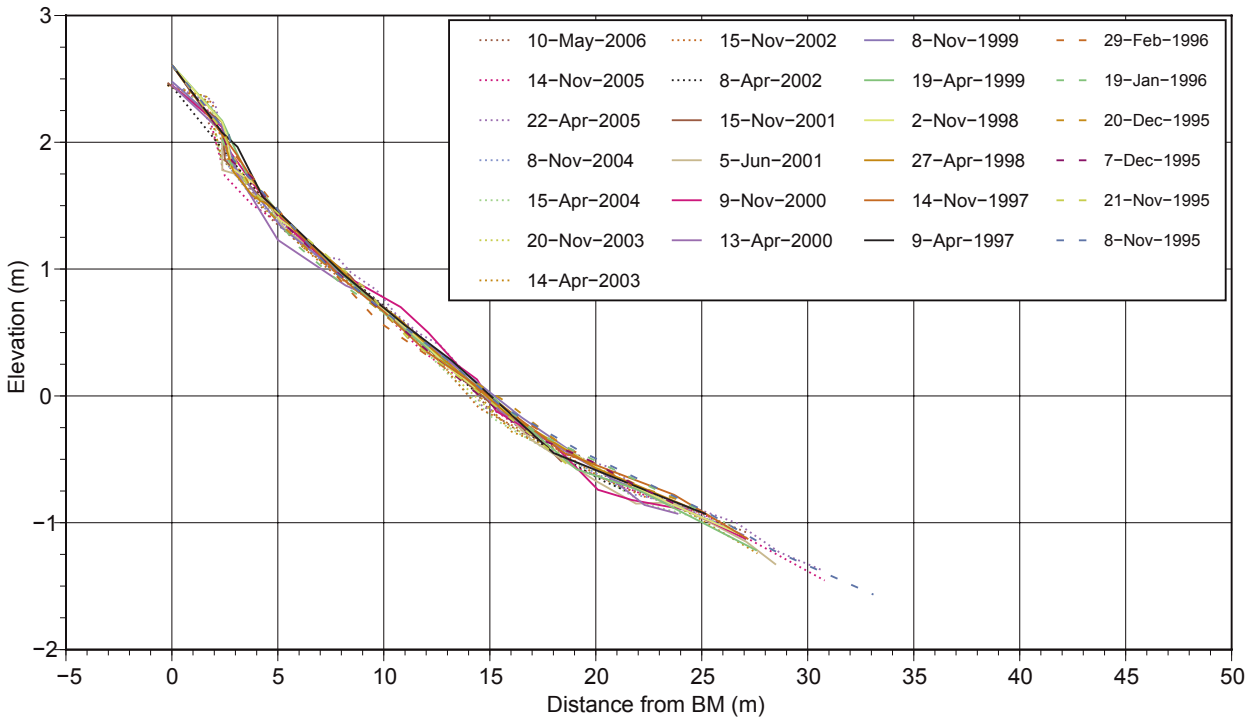
Profile 18 – Dieffenbach West

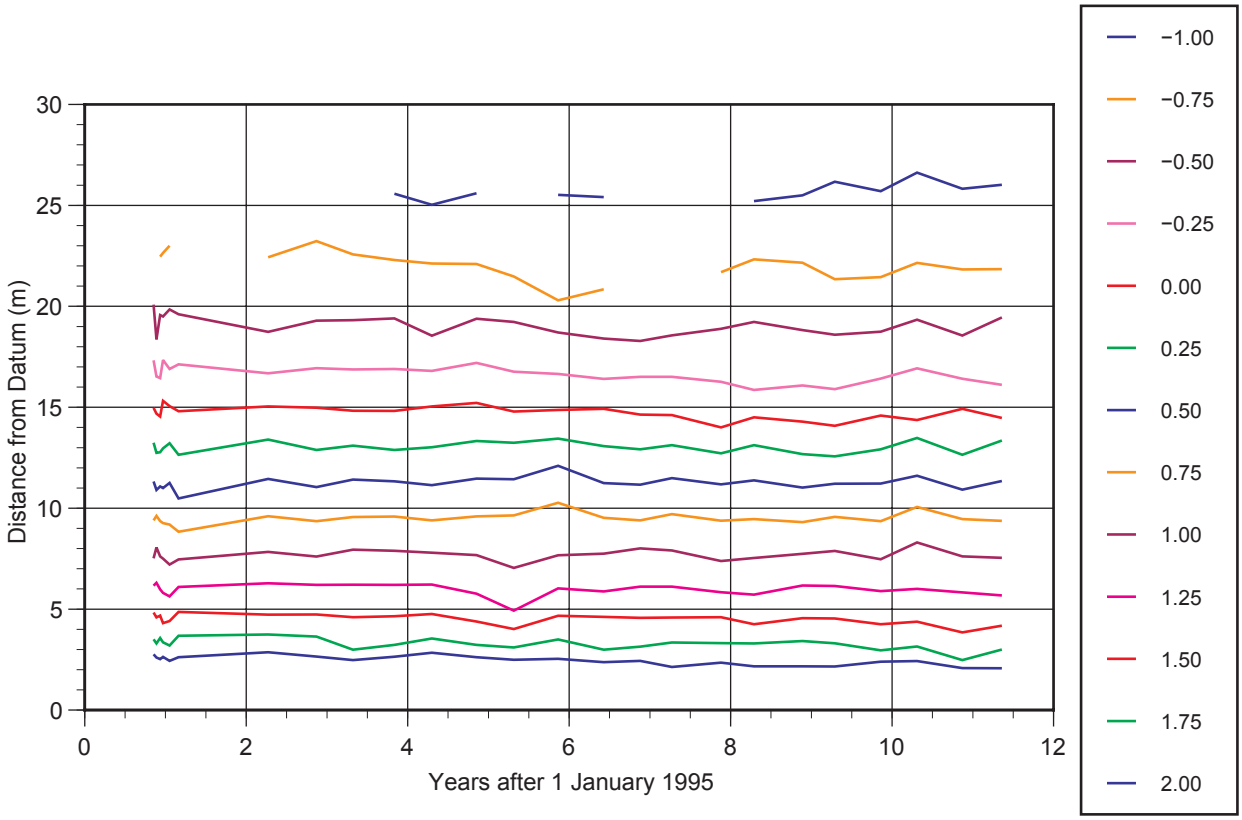
There has been no significant change in the profile shape or in sediment volume over the survey period. At time there is more sand on the beach, and it has been more persistent in recent times.

During 2000 a small cottage was built at the northern end of this beach, and in 2003 a boatshed was built and a minimal wooden seawall constructed adjacent to the profile line. The seawall does not appear to be affecting beach processes, but it is also not providing any significant protection to the land.

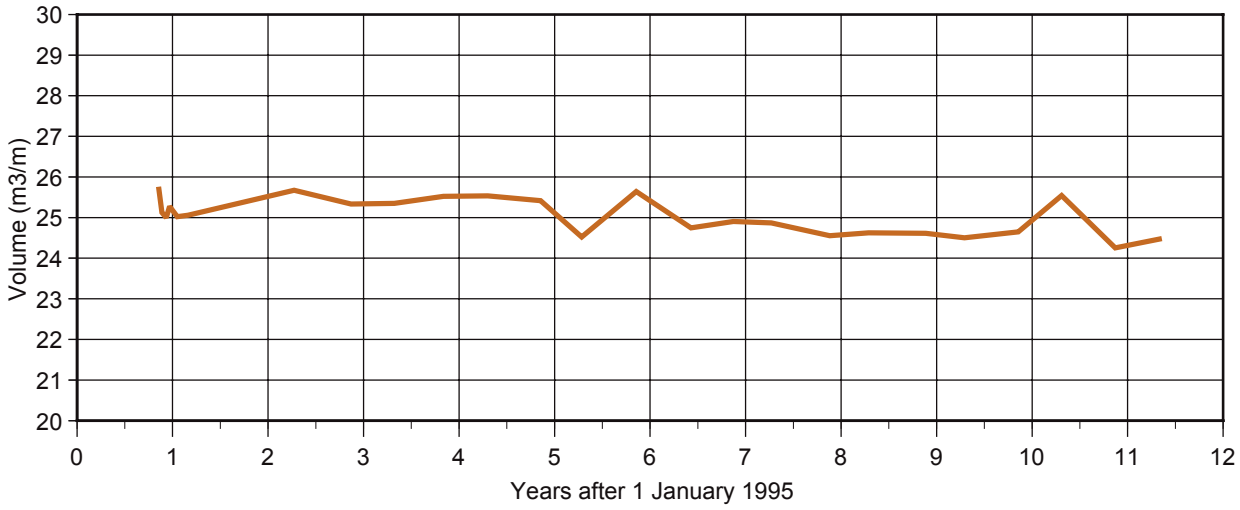


Profile 18: Dieffenbach West





Profile 18: Dieffenbach West



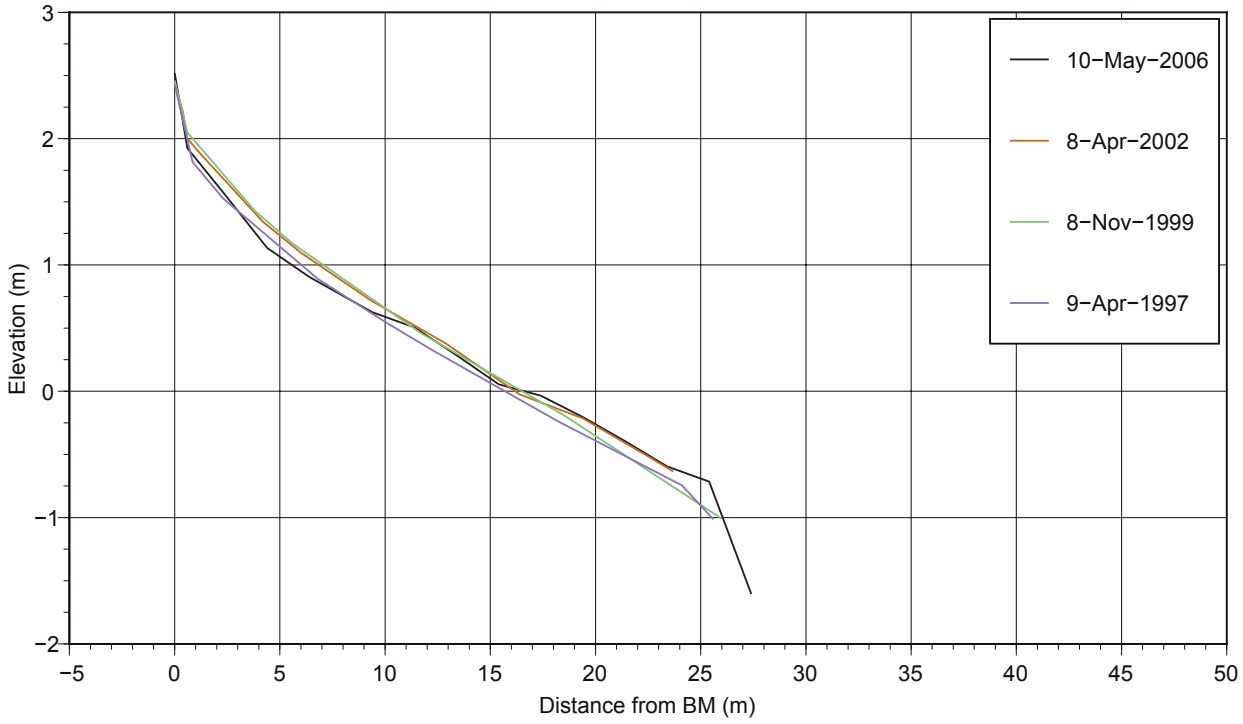
Date	Years after 1/1/95	Volume (m^3/m)
8-Nov-95	0.85	25.8
21-Nov-95	0.89	25.1
7-Dec-95	0.93	25.0
20-Dec-95	0.97	25.3
19-Jan-96	1.05	25.0
29-Feb-96	1.16	25.1
9-Apr-97	2.27	25.7
14-Nov-97	2.87	25.3
27-Apr-98	3.32	25.4
2-Nov-98	3.84	25.5
19-Apr-99	4.30	25.5
8-Nov-99	4.85	25.4
13-Apr-00	5.28	24.5
9-Nov-00	5.86	25.6
5-Jun-01	6.43	24.7
15-Nov-01	6.87	24.9
8-Apr-02	7.27	24.9
15-Nov-02	7.88	24.6
14-Apr-03	8.29	24.6
20-Nov-03	8.89	24.6
15-Apr-04	9.29	24.5
8-Nov-04	9.86	24.6
22-Apr-05	10.31	25.5
14-Nov-05	10.87	24.3
10-May-06	11.36	24.5

Profile 18: Dieffenbach West

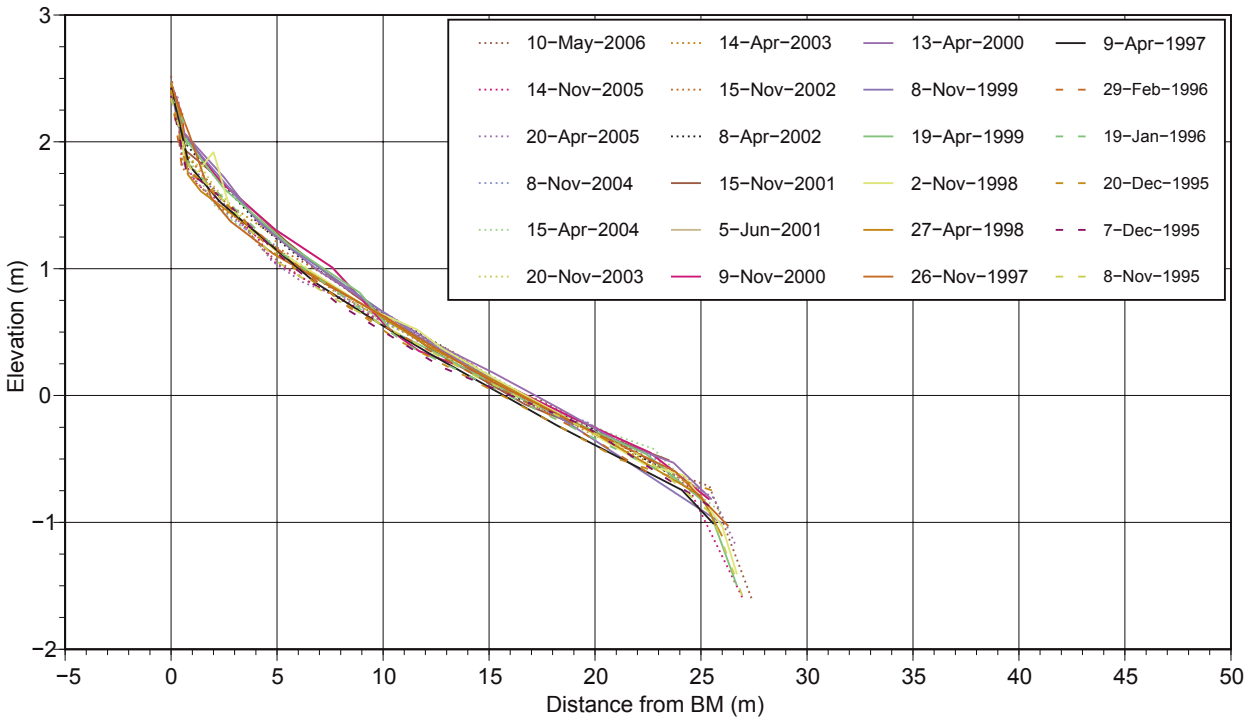
Profile 19 – Curious Monkey

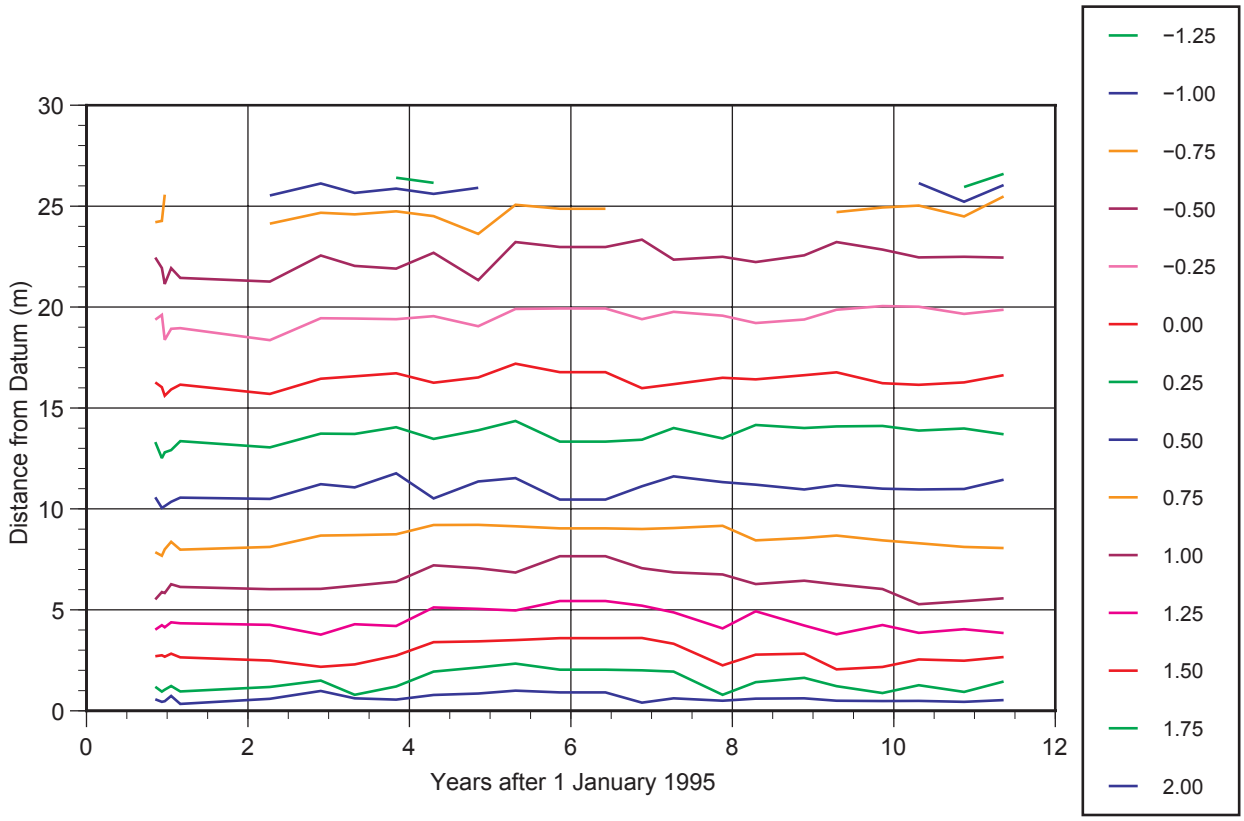
Overall the beach has been stable since 1997. However, there was slow accretion through to the end of 2000, and slow erosion since that time, the change coinciding with fast ferry operation ceasing. The lower beach, however, has remained at an accreted position.

There have been no notable changes in sediment characteristics.

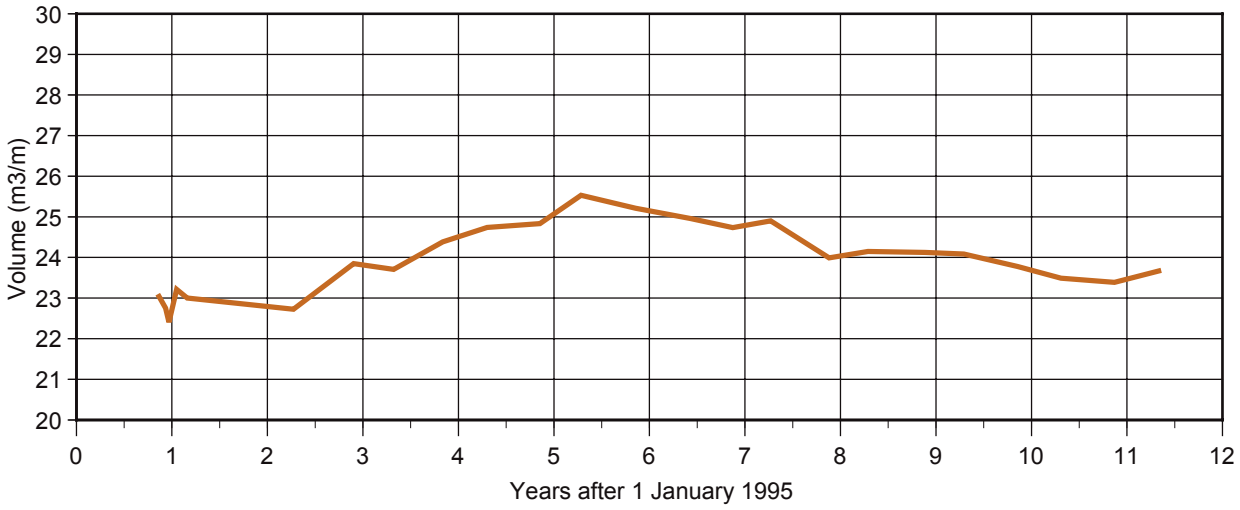


Profile 19: Curious Monkey





Profile 19: Curious Monkey

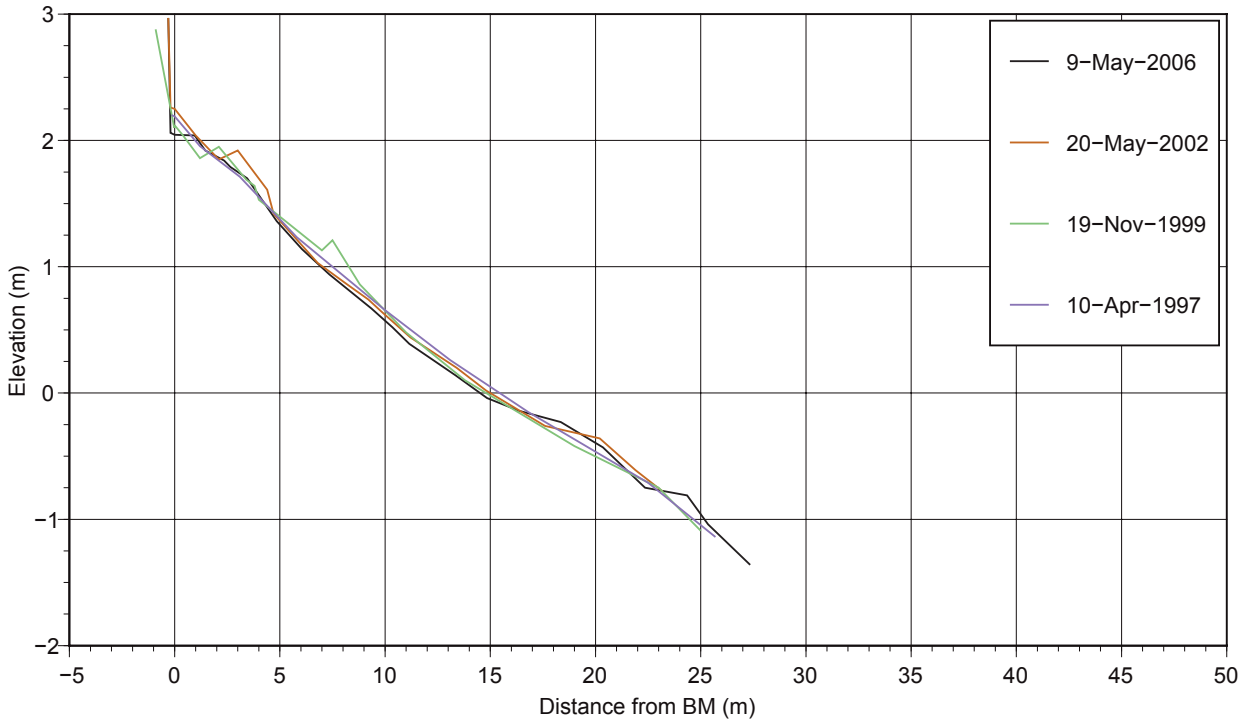


Date	Years after 1/1/95	Volume (m^3/m)
8-Nov-95	0.85	23.1
7-Dec-95	0.93	22.8
20-Dec-95	0.97	22.4
19-Jan-96	1.05	23.2
29-Feb-96	1.16	23.0
9-Apr-97	2.27	22.7
26-Nov-97	2.90	23.8
27-Apr-98	3.32	23.7
2-Nov-98	3.84	24.4
19-Apr-99	4.30	24.7
8-Nov-99	4.85	24.8
13-Apr-00	5.28	25.5
9-Nov-00	5.86	25.2
5-Jun-01	6.43	25.0
15-Nov-01	6.87	24.7
8-Apr-02	7.27	24.9
15-Nov-02	7.88	24.0
14-Apr-03	8.29	24.1
20-Nov-03	8.89	24.1
15-Apr-04	9.29	24.1
8-Nov-04	9.86	23.8
20-Apr-05	10.31	23.5
14-Nov-05	10.87	23.4
10-May-06	11.36	23.7

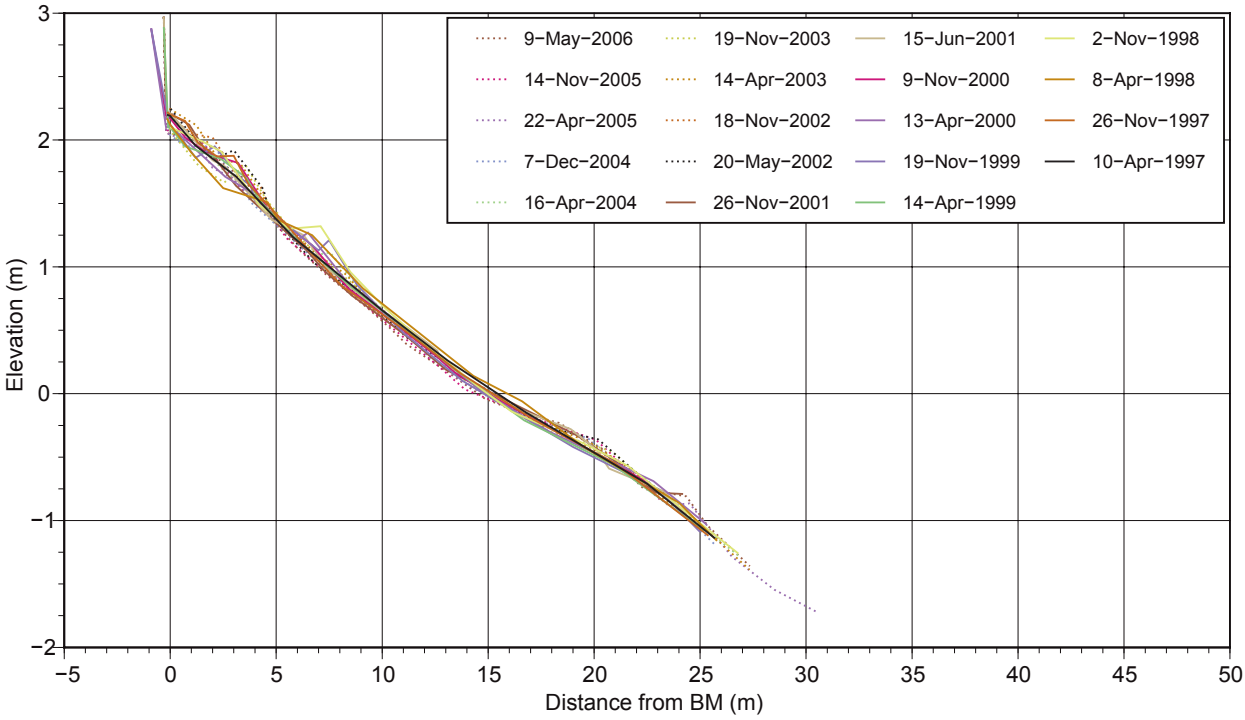
Profile 19: Curious Monkey

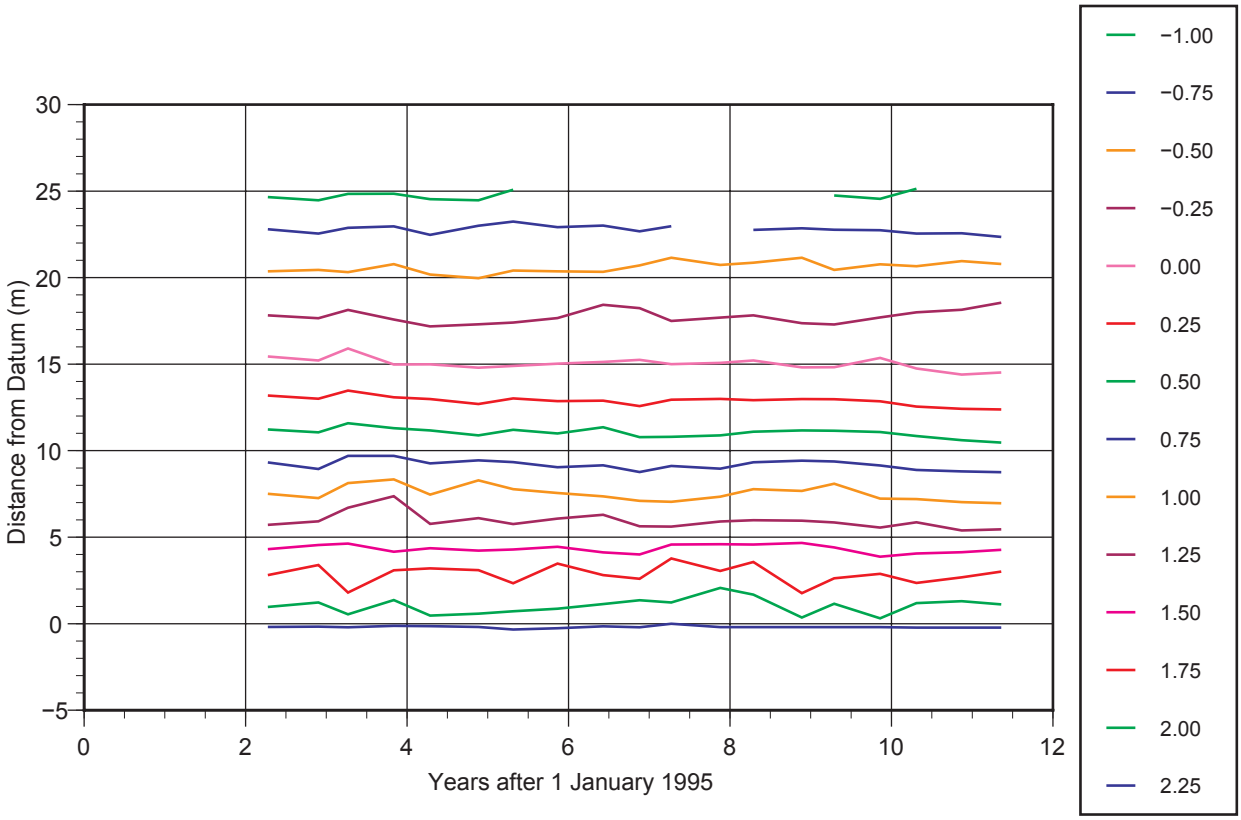
Profile 20 – Patten's Passage

There is considerable variability on the upper and middle beach, but overall stability, although volume data indicates that there may have been some minor erosion since 2003. Small berms build and are removed on the upper beach, with no particular seasonal pattern. Sediments are gravels and sands, and there is frequent banding, but no significant trends are obvious.

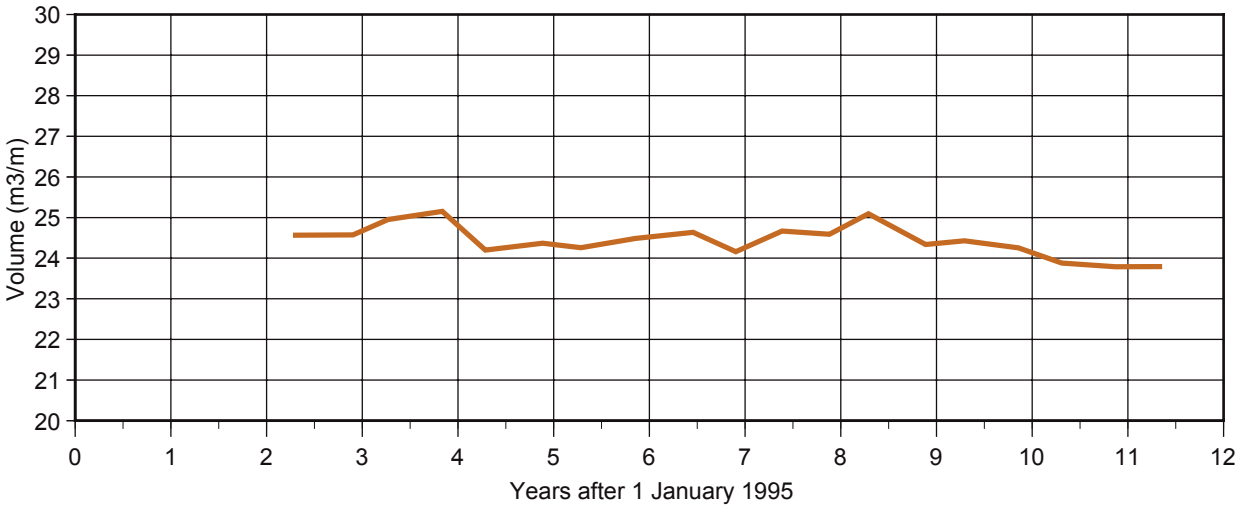


Profile 20: Patten's Passage





Profile 20: Patten's Passage

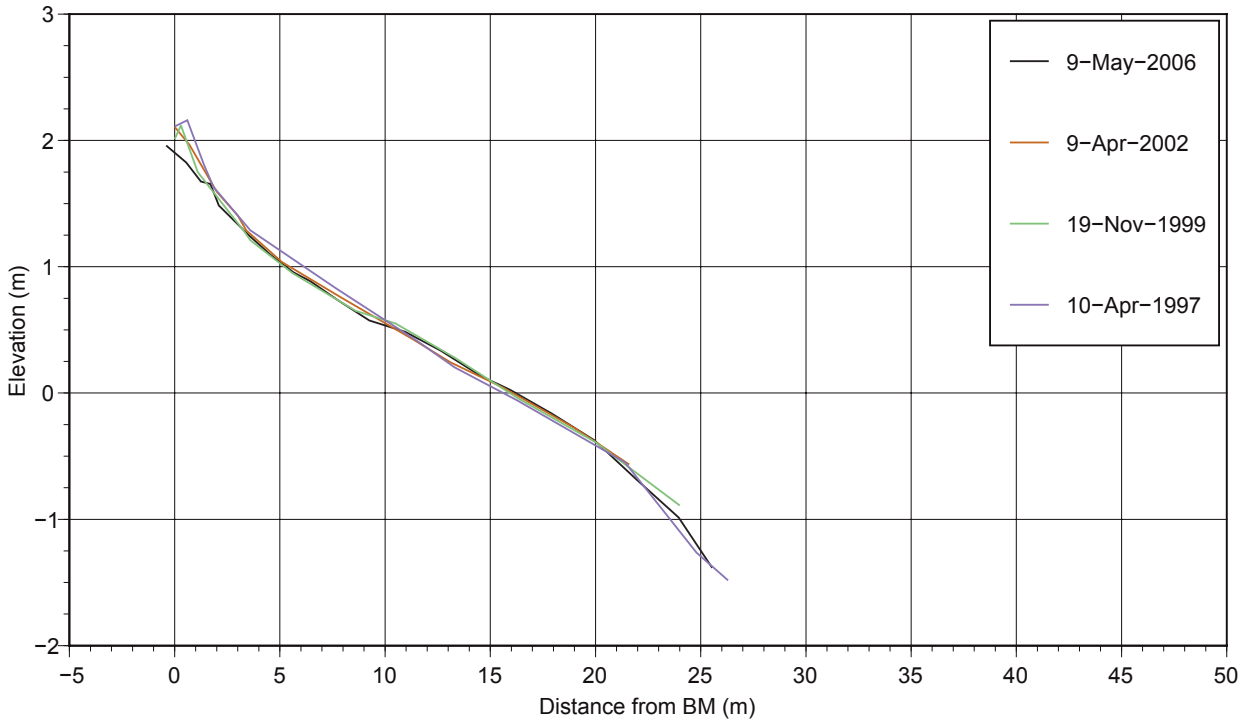


Date	Years after 1/1/95	Volume (m^3/m)
10-Apr-97	2.28	24.6
26-Nov-97	2.90	24.6
8-Apr-98	3.27	25.0
2-Nov-98	3.84	25.2
14-Apr-99	4.29	24.2
19-Nov-99	4.88	24.4
13-Apr-00	5.28	24.3
9-Nov-00	5.86	24.5
15-Jun-01	6.46	24.6
26-Nov-01	6.90	24.2
20-May-02	7.39	24.7
18-Nov-02	7.88	24.6
14-Apr-03	8.29	25.1
19-Nov-03	8.89	24.3
16-Apr-04	9.29	24.4
7-Dec-04	9.86	24.3
22-Apr-05	10.31	23.9
14-Nov-05	10.87	23.8
9-May-06	11.36	23.8

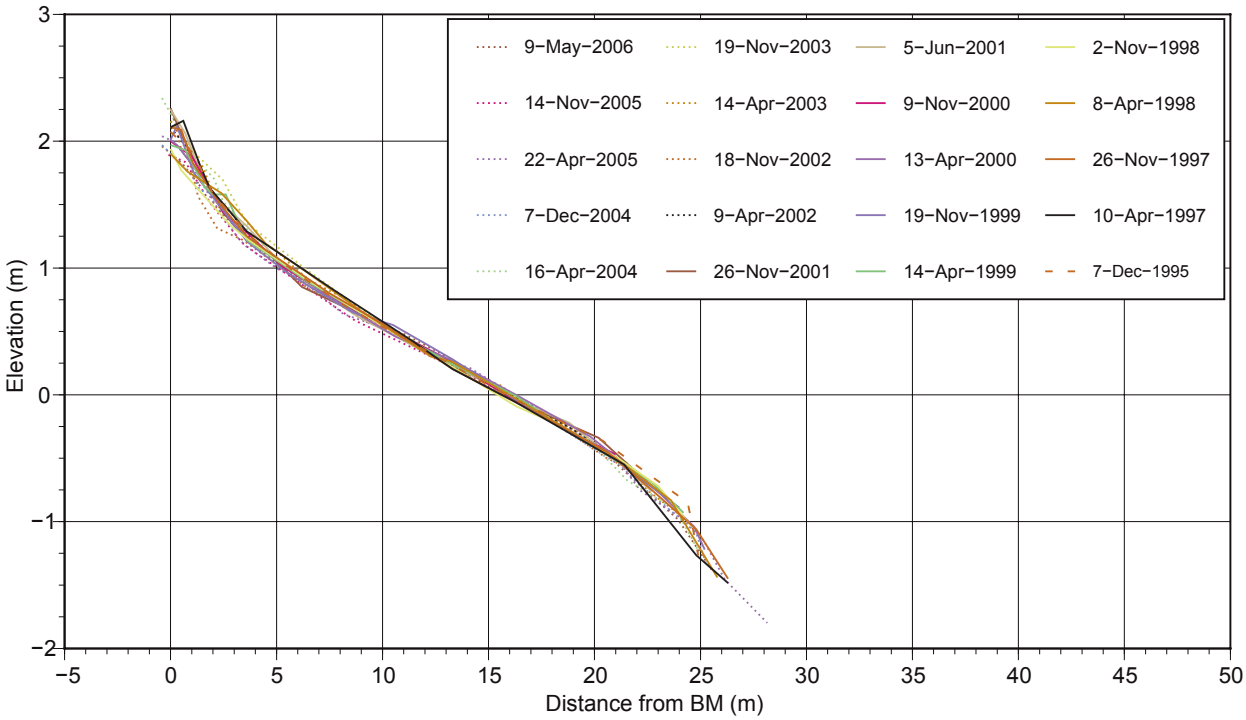
Profile 20: Patten's Passage

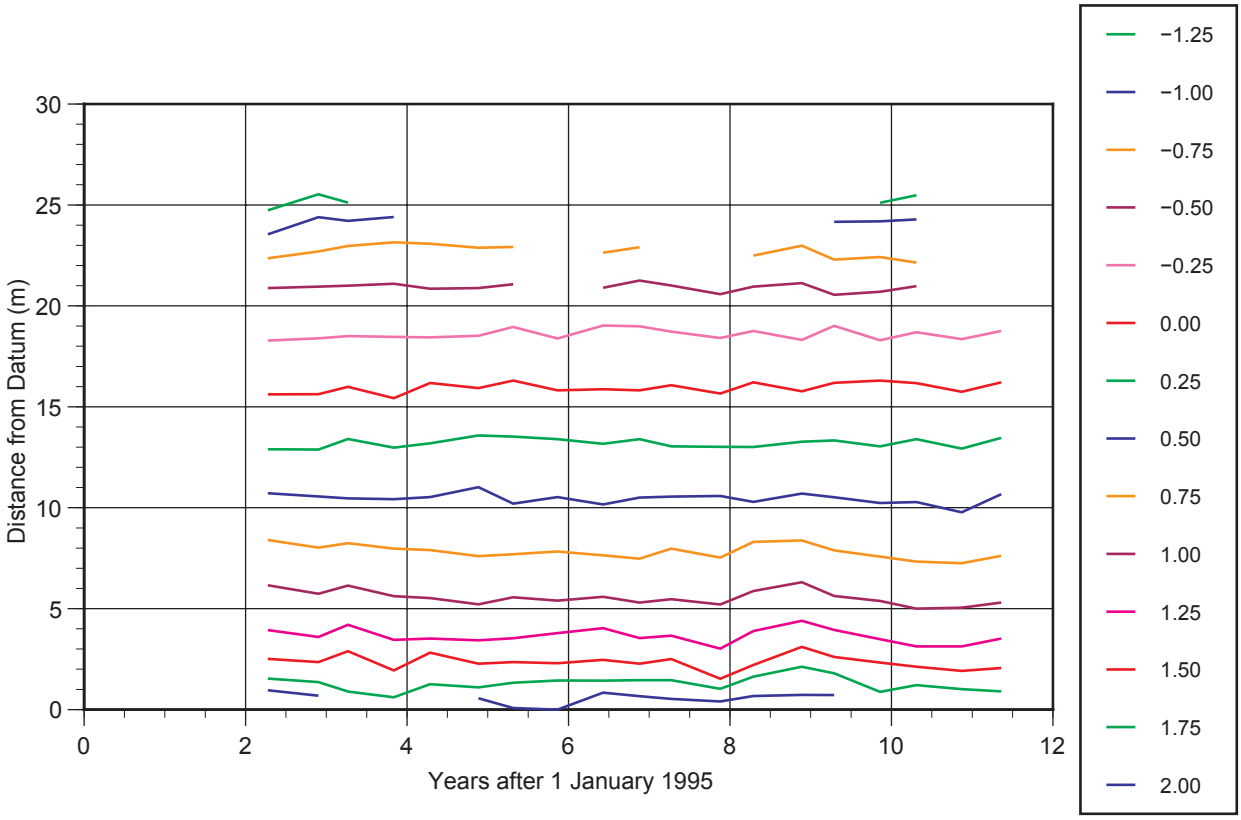
Profile 21 – Blumine Island

Blumine Island has a similar aspect to the Patten's Passage profile. There have only been minor changes across the profile, although there has been up to 15 cm of level variability at the extreme upper beach. There is no indication of seasonality, and no indication of sediment characteristics changing. Beach volumes have been stable.

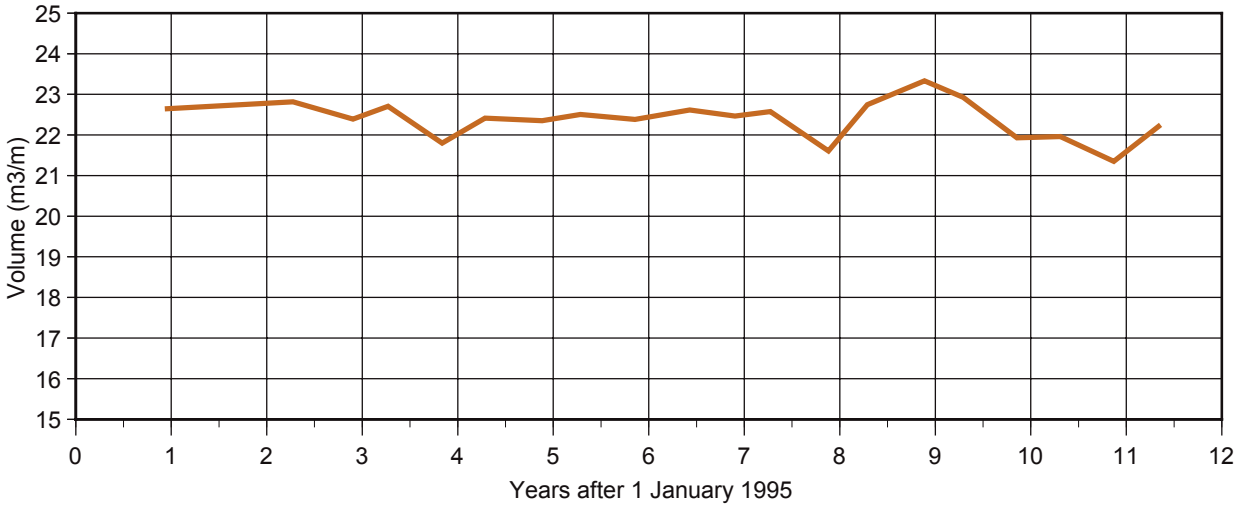


Profile 21: Blumine Island





Profile 21: Blumine Island



Date	Years after 1/1/95	Volume (m^3/m)
7-Dec-95	0.93	22.6
10-Apr-97	2.28	22.8
26-Nov-97	2.90	22.4
8-Apr-98	3.27	22.7
2-Nov-98	3.84	21.8
14-Apr-99	4.29	22.4
19-Nov-99	4.88	22.4
13-Apr-00	5.28	22.5
9-Nov-00	5.86	22.4
5-Jun-01	6.43	22.6
26-Nov-01	6.90	22.5
9-Apr-02	7.27	22.6
18-Nov-02	7.88	21.6
14-Apr-03	8.29	22.7
19-Nov-03	8.89	23.3
16-Apr-04	9.29	22.9
7-Dec-04	9.86	21.9
22-Apr-05	10.31	22.0
14-Nov-05	10.87	21.4
9-May-06	11.36	22.2

Profile 21: Blumine Island

6. Summary of beach changes and the effects of vessel wakes

This summary is divided into three sections, comprising those sites that are conceivably influenced by vessels travelling in Tory Channel and Inner Queen Charlotte Sound (on the ferry sailing route), those sites in the outer Queen Charlotte Sound, and the Picton foreshore site, which is possibly influenced by vessels moving within the port area.

a) Picton foreshore

There is no indication that this site is affected by vessel operation, with the beach being relatively stable despite being highly modified. However, I do not have data on the timing and extent of any renourishment programmes.

b) Sites in outer Queen Charlotte Sound

There are five profiles located at sites in the outer Queen Charlotte Sound: Double Bay, Long Island, Clark Point, Patten's Passage and Blumine Island. The sites in outer Queen Charlotte Sound are not influenced by ferry traffic, although some are on the sailing line of larger vessels using Shakespeare Bay. All five sites have remained very stable over the survey period since April 1997, showing only minor adjustments in beach shape, beach volume and sediment composition. It is interesting to note that even sites with considerable exposure to reasonably high energy, show little change.

c) Sites in Tory Channel and inner Queen Charlotte Sound

Many of the sites on the ferry route have exhibited change. However, trends or seasonality consistent between sites is not apparent. It is possible to make tentative links between the changing beach shape and vessel operational regimes at individual sites. Sites seem to be primarily influenced by the local factors, particularly with respect to sediment supply.

Two sites have demonstrated consistent erosion. Blackmore's at Waikawa has been stripped to bedrock, and therefore no further erosion is likely. Bob's Bay is located on the route, but at a position where ferries are likely to be operating relatively slowly as they arrive in, or leave, Picton. There has been a consistent erosion trend across the

whole profile. The particular circumstances that lead to erosion at this site are not understood, although the high number of boats of all types passing this point may be a factor.

A number of profiles exhibit no significant change. These are Ngaionui Point, Te Awaiti, Te Weka Bay and Tipi Bay in Tory Channel, and Dieffenbach West and Curious Monkey on the eastern shore of inner Queen Charlotte Sound. The Curious Monkey site showed a change from minor accretion to minor erosion coinciding with fast ferry operation ceasing. Ngaionui Point, a site very close to the vessel travel line, particularly on the Wellington to Picton journey, shows a change from minor accretion to minor erosion in 2002, perhaps indicating a slow return to pre fast ferry morphology.

Profile 2, The Snout at Picton Point, indicates accretion at the top of the profile and significant erosion at the bottom, and therefore a steepening of the beach profile. The deep water channel is clearly cutting into the shoreline at this point. The reason may be related to vessel traffic, or may be entirely natural.

Ngaionui Bay and Slip Beach show a trend of beach building. Ngaionui Bay has had considerable sediment removed by the residents, but it is clear that sediment accumulation is occurring. In Ngaionui Bay this appears to be the result of ferry traffic, although there is probably a sediment surplus in the bay due to a slip that occurred some years ago.

McMillan's Bay and McMillan's Side, were relatively stable with a small amount of accretion until an event in 1999/2000 when a large amount of sediment accumulated on both profiles. The accretion trend continued until the beginning of 2001, after which time there was stability on the McMillan's Bay profile and erosion on the McMillan's side profile. It is probable that the accretion related to a mass movement event towards Arrowsmith Point, and significant sediment transport capability due primarily to fast ferry operation, although I have no direct evidence for this.

Moioio Island is an unusual case, being a beach adjacent to a major landslide, and being towards the back of the island, not directly facing the vessel track. Seasonality was evident when the fast ferries were operating seasonally. Both profiles show that the beach is extending into the deep water channel over time (a process that takes a lot of

sediment), and generally accreting. Although Profile 6 shows considerable variability, Profile 7 has been accreting throughout the survey period, but the rate increased about the time fast ferry operation ceased in 2000. These profiles are almost certainly influenced by changes in ferry operations, being almost completely sheltered from natural wind generated waves. However, the sediment supply from the landslide (which may be affected by vessel wakes) is likely to dominate the beach behaviour.

At the time of the last summary report in 2002 it was concluded that with the exception of Bob's Bay near Picton, the beaches on the ferry route are accreting (or are stable) as opposed to eroding, although it is equally clear that local circumstances (particularly sediment supply) play a very significant role. This conclusion is still generally supported, although on some profiles change from accretion to stability (McMillan's Bay), accretion to minor erosion (Ngaionui Point, McMillan's Side, Curious Monkey), or in the case of Moioio Island 1, an increase in the rate of accretion, occurred at about, or soon after, the time fast ferry operation was restricted to 18 knots in December 2000. Although a definitive conclusion may never be possible, the results support the understanding that the fast ferry wakes resulted in sediment building up at the top of the beach on most beaches along the ferry route.

7. Recommendations

The beach monitoring programme has been underway for over 10 years, and has been through a range of vessel operation changes. Beach monitoring requires a long term commitment to provide value, and it is now possible to assess the usefulness of the programme. The value of the monitoring programme comes in understanding how beaches of the region function, both in response to vessel wakes and in response to natural events. Having these data should be of value to the Marlborough District Council in relation to the requirements under Section 35 of the Resource Management Act (1991).

Profiles in the outer Queen Charlotte Sound, off the ferry route, were established to provide an element of control, and in response to the possibility of significant boat traffic using port facilities in Shakespeare Bay, using the northern entrance to Queen Charlotte Sound. These profiles have been very stable, and unless driving forces change (such as a significant change is vessel traffic, or significant sea level change),

they are likely to remain stable. With respect to the purpose of this monitoring programme these sites could probably now be abandoned, or the frequency of survey reduced. It is reasonable to conclude that beaches unaffected by vessel wakes, including those subject to relatively high wave energy, are very stable.

Profile 5 (Blackmore's at Waikawa) was established at the request of Council. This site demonstrated erosion, but is now stripped to bedrock, but it is unlikely that the reason for the loss of sand is ever going to be known. As previously noted, I see no good reason for maintaining this site.

Profile 1 (Picton Foreshore) does not seem to be changing, and certainly not with respect to vessel traffic. In terms of the purposes of this monitoring programme, continued monitoring is probably unnecessary, although there may be other reasons to continue. If this site is continued, provision of other data, such as the dates and amounts of maintenance nourishment or other construction or maintenance activity, are required.

Other sites in Tory Channel and inner Queen Charlotte Sound continue to provide good data. With seasonal operation no longer being a factor, and distinct seasonality of behaviour not being observed since fast ferry seasonal operation ceased, it is possible that the frequency of data collection could be reduced to once a year. Although beach behaviour has generally been established, it is recommended that the monitoring of beaches along the ferry route be continued, at least until changes to the Coastal Plan involving the regulation of vessel operations are well established and tested.

The Bob's Bay profile has been continuously eroding. Erosion may be caused by all vessel wakes in the high traffic area near Picton (including the many small boats that pass quite close to the shore at this point), but may be entirely natural. Should erosion at this site be of particular concern, another profile towards the southern end of the bay should be established, to determine if the whole beach is eroding or if sediment is being redistributed within the embayment. In the longer term, some process studies could be considered.

In summary, the following changes to the monitoring programme could be considered:

1. *Abandoning or reducing the frequency of survey of the profiles in outer Queen Charlotte Sound, Blackmore's at Waikawa and Picton foreshore*. The disadvantage of reducing the frequency is that if profile markers are lost, they will be harder to reinstate in the future.

2. *Reducing the frequency of surveys on other profiles to one per year*, with provision for extra surveys should there be significant events such as a major storm or the introduction of a new vessel with considerably different wake characteristics. The disadvantage, is the increased difficulty of reestablishing lines if markers are lost.

3. *Establish a second profile towards the other end of the beach at Bob's Bay*, should the continued erosion be of particular concern.

4. *Supply more consistent profile photographs*. The surveyors should be asked to take a set of photographs with them, and make these the standard for composing all future photographs of the same profile.

5. *Establish quality vertical control for profile benchmarks*. The survey lines have never had very good vertical control. The zero datum level used has been established independently for each profile, sometimes from water level measurements and assumed tidal curves, and sometimes for consistency with data sets collected by other groups (such as Kirk and Single). It would be very useful if the profiles were able to be tied together. RTK-GPS technology is now available to enable this to be done, although the topography of the area will make the task difficult. Undertaking such a survey would have the additional benefit of enabling survey lines to be accurately reconstructed should permanent marks be lost.

I am happy to discuss these recommendations with Council staff.

Appendix 1

Survey Benchmarks as at May 2006

Levels used in this report are in BOLD

Pr	Name	Peg	Dist	Ayson RL	KP RL	Kirk RL	SL RL	Notes
1	Picton Foreshore	Seawall	6.87				**2.440**	Top of wall
1	Picton Foreshore	C	0.00				**2.550**	C" hole in grey stone
2	The Snout at Picton Point	IT	-1.00	10.34			**3.293**	
2	The Snout at Picton Point	W	0.00	10.00			**2.950**	
3	Double Bay	W	-1.50	10.74			**2.720**	
3	Double Bay	IT	0.00	10.00			**1.980**	
4	Ngaionui Bay (C Thomas)	W	-2.00	10.36			**2.730**	
4	Ngaionui Bay (C Thomas)	IT	-2.5	10.02			**2.39**	
4	Ngaionui Bay (C Thomas)	IS	0.60	10.07			**2.44**	
5	Blackmore's at Waikawa	Nail	0.00	10.00			**1.900**	In round post
6	Moioio Island 2	W	-2.00		0.33		**1.740**	Based on Kirk and SL Difference
6	Moioio Island 2	0IS A	0.00		0.00		**1.410**	KP Peg
7	Moioio Island 1	W	-2.00	10.36		1.70	**1.700**	
7	Moioio Island 1	IT	0.00	10.00		1.34	**1.340**	
8	Bob's Bay	W	-2.00	11.19		2.96	**2.959**	
8	Bob's Bay	IT	0.00	10.00		1.77	**1.769**	
9	Te Awaiti	W	-6.00	10.87		2.01	**2.006**	
9	Te Awaiti	IT	0.00	10.00		1.13	**1.133**	
10	Tipi Bay	W	-2.50	10.65		2.19	**2.188**	
10	Tipi Bay	IT	-1.5	10.02		1.56	**1.56**	
11	Long Island	W	0.00	10.00			**2.840**	
11	Long Island	IT	-2.50	9.30			**2.140**	
12	Clark Point	IT	0.00	10.00			**1.620**	
12	Clark Point	OISA	2.20	9.75			**1.373**	Biol peg
12	Clark Point	W	6.50					Biol peg
13	Slip Beach	IT	-0.55	10.25		1.74	**1.740**	
13	Slip Beach	W	-0.10	10.51		2.00	**2.000**	

Pr	Name	Peg	Dist	Ayson RL	KP RL	Kirk RL	SL RL	Notes
14	Ngaionui Point	W	-2.00	10.52			**2.386**	
14	Ngaionui Point	IT	0.00	10.00			**1.870**	
15	Te Weka Bay	IT	0.00	10.00		1.50	**1.498**	
15	Te Weka Bay	Wood board	2.00	10.15		1.65	**1.648**	Kirk datum
16	McMillan's Bay	W	-2.00	11.49		2.91	**2.908**	
16	McMillan's Bay	Wood Peg	-0.30	10.32		1.74	**1.738**	Kirk peg
16	McMillan's Bay	IT	0.00	10.00		1.42	**1.418**	
17	McMillan's Side	IT	-2.00	11.15			**2.938**	Based on Kirk and SL Difference
17	McMillan's Side	W	-1.3	11.48			**3.263**	
18	Dieffenbach West	OIS A	0.00	-0.09			**2.520**	Reestablished after disturbance
18	Dieffenbach West	W	-0.2	-0.04			**2.570**	Reestablished after disturbance
19	Curious Monkey	W	-1.00		1.10		**3.620**	
19	Curious Monkey	OIS A	0.00		0.00		**2.520**	KP peg
20	Patten's Passage	IT	-1.10	10.85			**3.488**	KP peg
20	Patten's Passage	W	0.00	10.00			**2.640**	KP peg
21	Blumine Island	W	-0.40	0.45			**2.66**	KP peg
21	Blumine Island	Railway iron	3.60		0.23		**2.440**	KP peg

Appendix 2

Profile Photographs

Photographs are taken looking alongshore from both sides of the profile line, looking back towards the profile line. The profile line is approximately 20m from the camera, and appears in all photographs.