ROWES BAY RENOURISHMENT MONITORING REPORT #3

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EXECUTIVE SUMMARY

- Monitoring of the Rowes Bay renourishment project shows that in June 2001 ~13,800m^3 (61%) of the sand placed along the foreshore since late 1998 were still in the renourishment zone. This is a good result considering the effects of Cyclone Tessi in April 2000, and the unusual southwards longshore drift patterns that have persisted since late 1998.

- Since late 1998, natural longshore drift processes have carried ~4,700m^3 of sand south towards inner Rowes Bay, obstructing the mouth of the One Mile Creek drain, and forming a new berm landform along the beach face in front of the Rowes Bay caravan park. This has significantly improved the beach condition here.

- Longshore drift processes have moved ~4,000m^3 northwards out of the renourishment zone. This has contributed to the ongoing natural build-up of sand in this part of the foreshore.

- Taken together, these movements of sand along the beach face amount to a rate of sand loss from the renourishment site of ~3,400m^3/year. At this rate, the remaining renourishment sand will last about 4 years.

- The scale of the Rowes Bay renourishment needs to be increased beyond the relatively modest sand volumes so far placed on the foreshore. An addition of 50,000m^3 of sand could provide ~15 years of shoreline protection.

- Analysis of the morphodynamic process regimes is required to determine the most effective design for future beach renourishments in Rowes Bay. This should include an analysis of how to allow wave action to develop a berm landform on the beach face, and limit the development of the erosion scarp.

- Consideration should be given to the construction of a groyne near the north side of the mouth of One Mile Creek. This should be designed to trap sand moving south out of the renourishment zone, and would also help prevent the regular blocking of the creek mouth.

- Options for the on-going maintenance of the renourishment zone should be developed. In particular, attention should be given to developing systems that would take advantage of the natural longshore drift processes and reduce long-term reliance on imported sand to renourish the system.

- Monitoring of foreshore behaviour should continue, as this will provide the necessary data for future management of the site.

1. Introduction

This report documents monitoring of the Rowes Bay foreshore renourishment project from June 2000 to November 2001. Previous reports (*Rowes Bay Renourishment Monitoring Report #1*, March 1999; *Rowes Bay Renourishment Monitoring Report #2*, October 1999; and *Rowes Bay – Pallarenda Foreshore Response to Cyclone Tessi 3 April 2000*, June 2000) documented foreshore changes from late 1998, to mid 2000.

Details on the nature of the renourishment project and monitoring program are contained in the *Rowes Bay Monitoring Report #1*.

The purpose of the present report is to document results of the on-going profile monitoring and recent minor additions of renourishment sand to the site. This information will be interpreted in terms of the foreshore's future maintenance and renourishment needs.

2. Monitoring program

The initial renourishment of the Rowes Bay foreshore was carried out in October-November 1998 when ~16,000m^3 of sand was placed on the upper beach face and in the dune area. It was expected natural wave processes would move this sand along the beachface, and ultimately take the sediment out of the renourishment zone. Monitoring of this is necessary to establish where the sand moves to, and how fast this occurs. From this a better understand the natural processes can be gained, allowing more effective long-term management of the foreshore. Nine profile sites were established to monitor sand movement within (T30, T30.3, T30.5, T31, T31.6, T31.7, T31.8) and adjacent to (T29.5, T32) the renourishment area. The locations of these sites are shown in Figure 1, and dates of the 13 surveys so far are detailed in Table 1.

Table 1: Rowes Bay foreshore renourishment monitoring surveys 1998 - 2001

Date	Profile Sites	Notes	Report
Sept 1998	T29.5 – T32	Pre-renourishment survey	Monitoring Report #1
Nov/Dec 1998	T30 – T31.8	Post-renourishment survey	Monitoring Report #1
Mar/Apr 1999	T29.5 – T32	End of wet season survey	Monitoring Report #1
May 1999	T30, T31, T32	Dry season survey	Monitoring Report #2
Sept/Oct 1999	T30, T30.5 – T31.7, T32	Post-erosion event survey	Monitoring Report #2
Nov/Dec 1999	T29.5 – T32	Early wet season and post- renourishment survey	Cyclone Tessi Report
May/Jun 2000	T30, T30.5 – T31.7, T32	Post Cyclone Tessi survey	Cyclone Tessi Report
Jun 2000	T30, T30.5 – T31.8	Post-renourishment tape measurements	Monitoring Report #3
Oct 2000	T30, T30.5 – T31.7, T32	End of dry season survey	Monitoring Report #3
May 2001	T29.5 – T31.7, T32	Early dry season and pre- renourishment survey	Monitoring Report #3
Jun 2001	T30, T30.5 – T32	Post-renourishment survey	Monitoring Report #3
Oct 2001	T31, T32	Late dry season survey	Monitoring Report #3
Nov 2001	(T29.5 – T32)	Tape measurements of erosion scarp	Monitoring Report #3

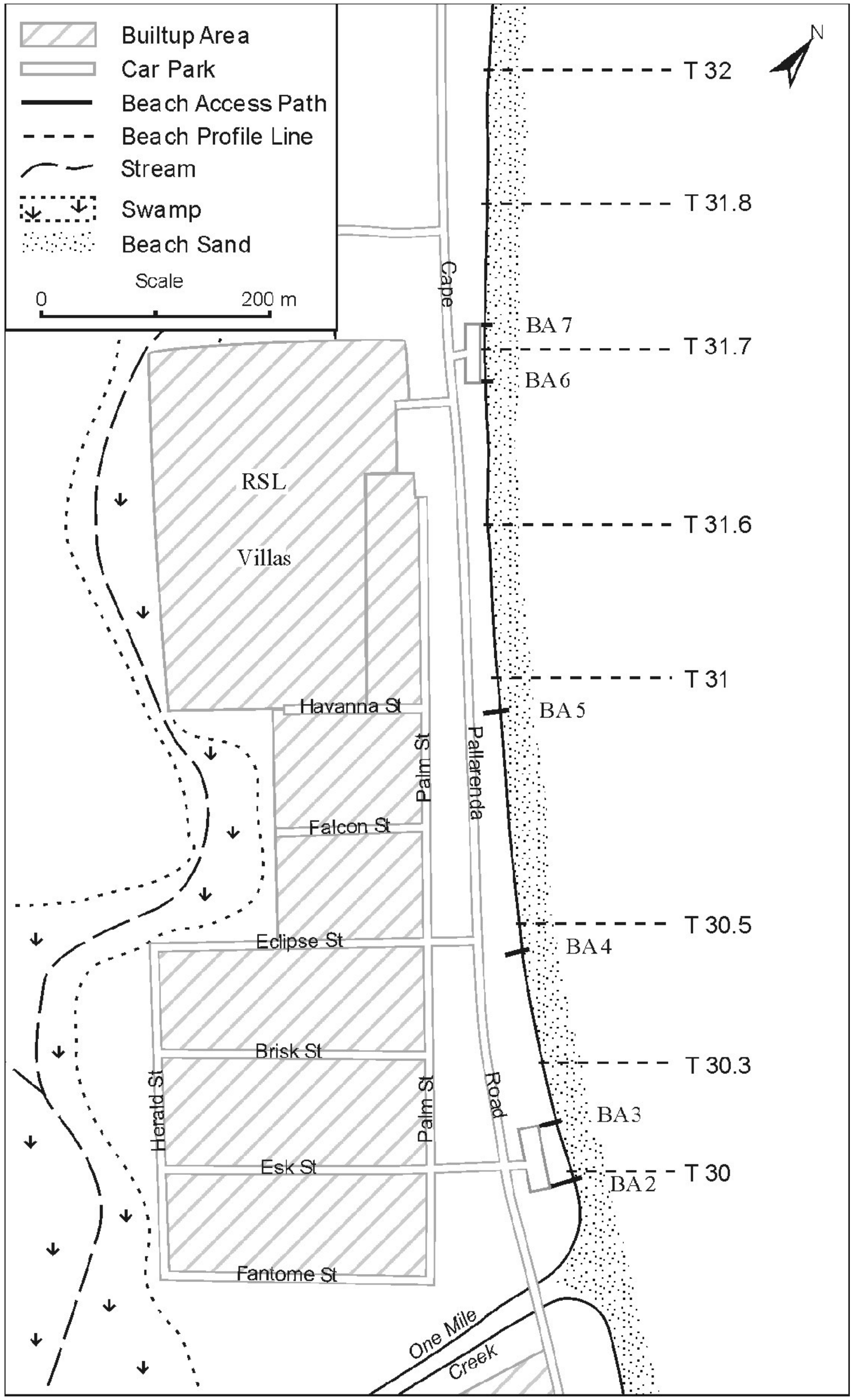

Figure 1: Location map of foreshore renourishment site, Rowes Bay.

3. Methods

Beach profiles were measured at the 9 profile sites along the foreshore using dumpy level or total station surveying equipment. Full details on the locations of these sites were given in *Rowes Bay Renourishment Monitoring Report #1*. Foreshore profiles have been drawn and these are shown in Figures 2 – 10 (Appendix 1). Raw data from the surveys described in this report (Oct 2000 – Oct 2001) are shown in Appendix 2 below. Measurements were also made with a tape measure on two occasions (June 2000, and November 2001) when the state of the tides prevented more detailed surveys. These data are included in Table 2. Measurements from the profiles have been used to determine horizontal changes in the position of the erosion scarp (Table 2). Estimates of changes in sand volume have been measured from the profiles, and are documented in Tables 3 & 4.
The discussion below will refer to the main foreshore landforms present in Rowes Bay, the dune, erosion scarp, beach face and mudflats. These are described in more detail in the *Rowes Bay Renourishment Monitoring Report #1* pp 2-3 (March 1999).

4. Foreshore Changes June 2000 – May 2001

In June 2000 the beach was still showing the effects of Cyclone Tessi (3/4/2000). The cyclone had struck Townsville near the time of low tide, and as a result the foreshore had suffered only a small amount of wave erosion. However, the base of the erosion scarp had been eroded making the slope of this landform very steep. At site T31.7 the scarp was again close to the car park and some renourishment sand was subsequently placed here. Since then, there have been further small losses of sand along the whole the scarp, while the beach face has undergone more significant changes. These changes will be discussed below for each of the dune, scarp and beach face landforms.

4.1 Dune changes

As part of the 1998 renourishment program, an artificial dune landform was constructed along the foreshore between beach accesses #2 – #7. This was up to 14m wide and 0.75m high, and comprised about 4000m^3 of sand. It remains almost completely intact, with only minor losses of sand from the dune near Sites T31.6 and T31.7 (between beach accesses #5 – #7). This sand was replaced during the renourishments of May 2000 and June 2001.

4.2 Erosion scarp changes

The erosion scarp between the dune and beach face is the most obvious evidence of erosion along the foreshore. As noted in the *Rowes Bay Renourishment Report #1*, this landform was quickly re-established by wave erosion after the initial renourishment in late 1998.
From Table 2 it can be seen that scarp erosion is variable along the foreshore, with the greatest losses occurring at either end of the renourishment (sites T30 and T31.8). This may be due to flanking, which occurs in localised areas where the shore alignment is non-linear. Wave erosion is thus accentuated at either end of the renourishment where the newly placed sand protrudes from the normal beach alignment. Detailed interpretation of the spatial pattern of scarp erosion is complicated by the fact that there have been three top-up renourishments at various places along the foreshore in November 1999 (at T30.5, and T31.7), May 2000 (at T31.7), and June 2001 (between T31 – T31.8). However, it is clear
that the main problem area between T31 – T31.8 remains, as the erosion scarp here is only about 25m

Table 2: Distance from marker posts/pegs to top of erosion scarp (m).

	T29.5	T30	T30.3	T30.5	T31	T31.6	T31.7	T31.8	T32
Distance from road to marker	38	31	14	26	14	15	16	nd	32
Oct 1998	4.5	17.5	31	6.7	7.2	4	5	10.9	8.6
Dec 1998	4.5	*21.5*	*34*	*9.5*	*8.5*	*6*	*6.2*	*16.1*	8.6
Mar-Apr 1999	nd	21.5	34	9.5	8.3	6	6	16	8.5
Sep-Oct 1999	nd	21.5	nd	9.1	8.2	6	6	nd	7.8
Nov-Dec 1999	4.5	21.5	33	*9*	8.2	6	5.2	15.4	7.8
May 2000	nd	21.2	nd	8.9	7.7	6	5.2	nd	nd
Jun 2000	nd	21.2	nd	nd	7.7	5.6	*10.4*	13.4	7.2
Oct 2000	nd	19.5	nd	8.9	7	4.6	7.7	nd	7.2
May 2001	4.7	18	32.6	8.2	7	4.5	6.2	nd	6.8
Jun 2001	nd	18	nd	8.2	*14.4*	*10*	*13*	12.8	6.8
Oct-Nov 2001	nd	18	32.5	8.2	10.2	8	9.4	12.8	6.8
Maximum change Dec'98-Nov '01	+0.2	-3.5	-1.5	-1.3	-1.3	-1.6	-2.8	-3.3	-1.8

nd = no data.
Numbers in green are measurements made after renourishment sand was added at the site.
Numbers in red are measurements made after an erosion event at the site.

from the edge of the Pallarenda Road.

The temporal pattern of erosion shows that sand loss occurred along parts of the scarp in four events: king tides in August 1999; Cyclone Tessi in April 2000; king tides in the 2000 dry season; and king tides in the 2000/2001 wet season. However, erosion did not occur uniformly along the foreshore during each event. For example, during the 2000 dry season event, Sites T30 and T31.7 were significantly eroded, while sites T30.3 – T31.6 were largely unaffected.

Table 3 shows the volume of sand lost from the scarp since the renourishment program was initiated in December 1998. Three sets of figures are shown. Data from December 1998 – May 2000 summarises changes up to and including Cyclone Tessi. Data from May – October 2000 shows changes associated with the 2000 dry season erosion event, while the October 2000 – May 2001 shows changes to just prior to the most recent renourishment of June 2001. The data have been calculated from the beach profiles shown in Figures 2 – 10 (Appendix 1). Calculations involve measuring the area between successive profile lines, and averaging these changes along the foreshore between the profile sites. This gives an approximation of the volumes of sand being moved by wave action along the foreshore. In cases where changes are spread reasonably evenly along the foreshore (eg a after wave erosion event) a more accurate result should be possible. However, where the changes are more irregular (eg placement of isolated piles of renourishment sand), the results are less reliable. For example, in Table 3 the 900m^3 of renourishment sand placed in June 2000 at T31.7, shows as increase of >1000m^3 four months later, which is inconsistent with the erosion that had occurred during this time.

The data shows that since the initial renourishment of late 1998, ~5000m^3 of sand has been lost from the scarp, with the ~500m sector between sites T31 – T31.8 being worst affected. However, as will be seen below in Section 4.3, the eroded sand has not been totally lost from the renourishment zone.

Table 3: Volume of sand lost from the Rowes Bay erosion scarp Dec 1998 – May 2001.

Shoreline sector (length in metres)	Sand volume loss along scarp (m^3) 12/98 – 5/00	Loss/m	Sand volume changes along scarp (m^3) 5/00 – 10/00	Change/m	Sand volume loss along scarp (m^3) 10/00 – 5/01	Loss/m
T30 – T30.5 (231m)	-393	1.7	-451	2.0	-508	2.2
T30.5 – T31 (221m)	-464	2.1	-88	0.4	-33	0.15
T31 – T31.6 (137m)	-411	2.95	-62	0.45	-27	0.2
T31.6 – T31.7 (157m)	-699	4.45	385*	2.45	-267	1.7
T31.7 – T32 (252m)	-907	3.6	642*	2.55	-733	2.9
TOTALS (998m)	*-2874*	*2.9*	*426**	*0.4*	*-1568*	*1.57*

* 900m^3 of renourishment sand placed along ~60m of the erosion scarp at Site T31.7 in June 2000.

In the current sand-starved state of the foreshore in Rowes Bay, the scarp landform is particularly susceptible to erosion during both cyclones and king tide events. Erosion is not balanced by subsequent build up of sand as happens further north in the Rowes Bay – Pallarenda embayment where wave and wind processes are able to naturally re-establish the foreshore after erosion events.

4.3 Beach face changes

The beach face is a dynamic landform, worked by waves twice a day as the tides rise and fall. Sand is moved both up and down the beach face, and along the shore by longshore drift processes. South-easterly wind-driven waves will move sand northwards towards Pallarenda, while waves formed by north, northeast, and easterly winds will to move sand southwards towards the mouth of One Mile Creek and inner Rowes Bay. Thus, the sand on the beach face can be highly mobile.

Table 4: Sand volume changes along the Rowes Bay beach face Dec 1998 – May 2001.

Shoreline sector (length in metres)	Sand volume loss along beach face (m^3) 12/98 – 5/00	Loss/m	Sand volume changes along beach face (m^3) 5/00 – 10/00	Change/m	Sand volume changes along beach face (m^3) 10/00 – 5/01	Change/m
T30 – T30.5 (231m)	-46	0.2	-1479	6.4	2930	12.7
T30.5 – T31 (221m)	-795	3.6	121	0.55	-66	0.3
T31 – T31.6 (137m)	-727	5.3	-75	0.55	-76	0.55
T31.6 – T31.7 (157m)	-141	0.9	-424	2.7	-149	0.95
T31.7 – T32 (252m)	-264	1.0	-365	1.45	443	1.76
TOTALS (998m)	*-1973*	*1.98*	*-2222*	2.22	3083	3.09

Table 4 shows the changes that have occurred on the beach face since December 1998. Until October 2000 the main pattern was erosion, with a total of ~4,200m^3 of sand being lost from the beach face. However, since then a considerable volume of sand has built up, particularly at the southern end of the renourishment near sites T30 and T30.3. As can be seen on Figure 2, this has created a significant berm landform on the upper beach face. Wave action, even during king tides, does not overtop this feature, which thus provides important protection for the erosion scarp behind (see Section 10 below).

4.4 Mudflat changes

Detailed analyses of mudflat changes have not been carried out, as the changes are small, and the sediments involved are largely unrelated to the sands on the beach face. From Figures 2 – 10 it can be seen that the elevation of the mudflats typically varies by only ±0.2m, and there is no clear pattern to these changes. The mudflats are comprised of very fine sands that are noticeably different from the coarser sands on the beach face. This is typical of beaches on meso-tidal low energy coasts, where there is very little on-shore/off-shore transfer of sediment between the beach face and mudflats. From this it is assumed that renourishment sand added to the upper shore face in Rowes Bay has not been significantly lost to the mudflats.

5. Foreshore changes June – November 2001

In June 2001 a further renourishment of the foreshore was carried out as detailed below in Section 6. Beach profiles were surveyed shortly after the sand was placed, and these are shown in Figures 3-10. Along most of the newly renourished foreshore the position of the erosion scarp was 5-7m seaward of its May position. No detailed calculations have been made from these data as there were anomalous bulges in the foreshore alignment at sites T30.5, T31, and T31.7, which would have resulted in an over-estimate of the sand volume.

The most recent observations of the foreshore condition were made in October and November 2001 (see Tables 2 & 5, and Figures 6 & 10). By this time the shoreline had established a more stable post-renourishment orientation. The scarp had moved back up to 4m, with the eroded sand being added to the beach face (see for example Figure 6). Table 5 shows the height of the scarp, which averages 1.1m, and continues to present some problems at the beach access points.

Table 5: Height (m) of erosion scarp along Rowes Bay foreshore in November 2001.

T29.5	T30	T30.3	T30.5	T31	T31.6	T31.7	T31.8	T32
0.2	1.7	1.3	0.6	1.6	1.0	1.2	0.3	0.2

6. Top-up renourishments

As noted above there have been a number of top-up renourishments since the initial 16,000m^3 of sand were added in November 1998. In November 1999, after erosion caused by the king tides of the preceding dry season, ~2,800m^3 was placed in front of the scarp at sites T30.5, and T31.7 (Figures 5 & 8). In May 2000, after the Cyclone Tessi erosion event, ~900m^3 of sand was placed at Site T31.7 (Figure 8). In June 2001, a further ~2800m^3 of sand was placed in front of the erosion scarp from 60m south of Site T31 to 90m north of Site T31.7 (Figures 6 – 8). These bring the total volume of sand added to the Rowes Bay foreshore since the Cyclone Sid erosion event of January 1998 to 22,500m^3.

7. One Mile Creek mouth and inner Rowes Bay

The mouth of One Mile Creek is situated just outside the renourishment area, about 100m southeast of Site T30 (see Figure 1), and beyond this is the inner Rowes Bay foreshore. Observations from aerial photographs taken over the last 40 years show that sand often built up across the mouth of the creek. During flood events, the creek would break through the beachface, and form a small bar and delta system on the mudflats. However, more often the sand across the creek mouth had to be cleared with heavy machinery. This southwards movement of sand only reached as far as the creek mouth and did not extend further south into inner Rowes Bay. The beach here showed no significant build-up of sand from the 1940s to the late 1990s.

Since the renourishment project commenced in late 1998, sand has continued to move south and build-up across the mouth of the creek. On at least two occasions this has been artificially cleared, most recently in May 2001 when a substantial quantity of sand was moved by bulldozer back towards the renourishment zone.

Since late 1998, the movement of sand has extended much further southwards than usual, forming a new berm along ~200m of the inner Rowes Bay beach face. A considerable quantity of sand is now stored in the foreshore landforms south of Site T30. Preliminary estimates suggest there may be ~2,400m^3 of sand in the berm south of Site T30; ~1,000m^3 in the bar and delta complex at the mouth of One Mile Creek; and ~1300m^3 in the berm on the inner Rowes Bay beach face. This 4,700m^3 of sand has probably been derived from sediment eroded from the renourishment site.

Movement of sand south along the Rowes Bay beach face is not unusual. While the dominant longshore drift is to the north (driven by the prevailing southeasterly winds), smaller amounts of southward sand movement occurs when winds are from the north, northeast, and east (ie sea breezes and wet season winds). This sand is usually moved back to the north by the stronger and more persistent southeasterly waves. However, the inner parts of Rowes Bay are protected from the southeasterly waves by Kissing Point, and sand moved south is not moved back to the north. This southward movement of sand has been responsible for the persistent closing of the One Mile Creek mouth ever since it was constructed in 1961. The northern boundary of this inner Rowes Bay protected zone probably varies as wave directions shift, but it seems to lie somewhere in the region of Site T30.3 south to the mouth of One Mile Creek.

The build-up of sand in the berm along the inner Rowes Bay beach face since 1998 has been unusual, and indicates that southwards longshore drift has been more effective than usual. This may be due to the extra sand in the renourishment project area providing a ready source of sediment to be moved, or prevailing winds since late 1998 may have favoured more north, northeast and east directions. Such a shift in wind directions may be related to the persistent La Niña weather patterns that have been experienced since mid 1998.

While this movement of sand south constitutes a loss of sediment from the renourishment zone, it has not been entirely lost from the foreshore, and the build-up of sand in inner Rowes Bay has significantly improved beach amenity and erosion protection in that part of the bay.

The southwards sediment movement poses two problems: sand is lost from the renourishment zone; and the mouth of One Mile Creek is blocked by the build-up of the berm and sand bars. It should be possible to design a small groyne structure that would be placed north side of the creek mouth. This would act as a trap to sand moving south out of the renourishment zone, and would limit the movement of sand into the creek mouth. The sand that builds up on the north side of the groyne could be readily recycled back into the renourishment zone. This would reduce the on-going need for fresh sand, and there should be no further need for regular clearing of the mouth of One Mile Creek.

8. Sand movement to the north

It was anticipated that longshore drift processes would ultimately move sand north out of the renourishment zone. It was hoped that monitoring of Site T32, which is 120m north of the renourishment zone, would provide some indication of this process. Surveys of Site T32 from 1982 to 1998 showed the beach face here was essentially stable, showing no long-term pattern of sand erosion or build-up. From Table 4, and Figure 10 it can be seen that sand has recently begun to build up on the beach face at this site, particularly since October 2000. These preliminary data indicate that some sand from the renourishment site may indeed be moving northwards, although it is not possible to quantify the volume of sediment involved.

Initial estimates in the *Rowes Bay Renourishment Monitoring Report #1* suggested that longshore drift could move ~1,500m^3/year. More recent calculations, based on erosion rates over the last 50 years which included the Cyclone Althea and Cyclone Sid events, indicate that the long-term nett rate of longshore drift to the north could be as much as ~3,300m^3/year.

9. Summary of foreshore changes

The Rowes Bay foreshore renourishment project has been in place for nearly three years. In that time the site has been affected by a number of erosion events, including Cyclone Tessi, and wave attack during several king tides. In addition, the normal wind patterns may have been disrupted by a persistent La Niña weather pattern. Given the monitoring data described in this report, it is now possible to develop a preliminary beach sediment budget that quantifies both the inputs of sand to the system, and the fate of sand lost from the foreshore. This will provide a basis from which to assess the success of the project, and provide recommendations for the future maintenance of the foreshore.

9.1 Rowes Bay foreshore sediment budget

The Rowes Bay foreshore is today an uncomplicated sediment system where sand is confined to the upper intertidal zone on the beach face and dunes, and there are no natural inputs of sand. This allows for a relatively simple accounting of the foreshore sediment budget, which quantifies the volumes of sand moving through the system since the renourishment project began. This is shown in Table 6. It has been complied from records of renourishment sand volumes, Tables 3 & 4 and data in Section 7. Numbers are rounded to the nearest 100m^3.

As noted above, sand lost to the north cannot be directly measured. It has been assumed that as all other movement directions can be accounted for, the sand ‘missing’ in the sediment budget (4,000m^3) can only have been lost to the north.

9.2 Processes of change

Wave processes cause two different effects along the Rowes Bay foreshore: irregular erosion of the scarp and dune; and day-to-day movement of sand on the beach face.

Erosion of the scarp and dune landforms occurs occasionally during high-energy events such as cyclone wave attack during king tides, and eroded sand is immediately redeposited on the beach face. Large amounts of sand are moved in a short time by these high-energy events.

Low-energy wave processes work the beach face twice a day as the tide rises and falls, causing longshore drift of sediment which redistributes sand north and south along the beach face. Over periods of weeks and months, these day-to-day processes can move large volumes of sand. Effective management of the foreshore requires that sufficient sand be supplied both in the scarp and dune landforms to accommodate the irregular high-energy events, and on the beach face to accommodate the day-to-day wave processes.

Table 6: Rowes Bay foreshore sediment budget November 1998 – June 2001

***RENOURISHMENT INPUTS*:**	November 1998	Dune	4,000m^3	
		Scarp	5,600m^3	
		Beach face	6,400m^3	
	November 1999	Scarp	2,800m^3	
	May 2000	Scarp	900m^3	
	May 2001	Scarp	2,800m^3	
		TOTAL INPUTS		**22,500m^3**
***SAND REMAINING*:**	June 2001	Dune	4,000m^3	
		Scarp	4,400m^3	
		Beach face	5,400m^3	
		TOTAL REMAINING		**13,800m^3**
***SAND LOST*:**	June 2001	To south	4,700m^3	
		To north (?)	4,000m^3	
		TOTAL LOST		**8,700m^3**
***AVERAGE RATE OF LONGSHORE DRIFT*:**		To south	1,800m^3/yr	
		To north	1,550m^3/yr	

9.3 Rates of change

From Table 3, the average rate of scarp erosion over the 31 months of the renourishment project has been ~1,950m^3/year. However, as discussed above, the real rate of change along the erosion scarp is irregular. A high-energy wave event could erode this amount of sand in just a few hours. While this rate of erosion is significant, the sand removed is redeposited directly on the beach face and so is not immediately lost from the system.

The rate of sand movement (longshore drift) on the beach face is shown in Table 6. There are two components to this, one northwards at ~1550m^3/year, and the other southwards at ~1,800m^3/year. Wave processes work the beach face twice a day, and thus these average rates probably give a realistic picture of changes on the beach face. The nett southwards movement of sand has been unusual, and this may be related to prevailing wind directions over the last three La Niña-dominated years (see Section 7). The total rate of sand loss from the system has been ~3,400m^3/year, which is consistent with expectations (see Section 8).

10. Conclusions

The Rowes Bay renourishment project has been in place for three years, and a good database of beach profile information is now available from which to judge the success of these works. The foreshore sediment budget calculations show that over 60% of the sand placed here since late 1998 is still in the renourishment zone. The beach has withstood the effects of a Category 2 tropical cyclone, and several other high-energy wave events. In addition, day-to-day weather conditions over the last three years have been unusual, favouring much stronger than normal southwards longshore drift processes. Given these departures from usual conditions, the project has stood up well, and has provided important erosion protection and improved beach amenity value to the foreshore.

It is important to re-state that beach renourishment cannot permanently solve a coastal erosion problem. Natural sediment movement processes continue, and sand is thus constantly moved through the system. It is also clear from the analysis presented above, that the volumes of sand placed in the renourishment zone so far are small when compared to the rates at which natural processes move sediment in this system. At current rates of erosion, <7 years supply has been added to the system. The small-scale renourishments to date have demonstrated the value of this method of beach restoration, but much larger volumes of sand are required to provide longer-term protection for the foreshore.

Scarp erosion is a significant contributor to the erosion problem, and some means of protecting this landform from frequent wave attack would help reduce the rate of sand loss. Observations at Site T30 (Figure 3) at the southern end of the renourishment zone suggest that a berm landform on the beach face provides good protection for the erosion scarp. This is a natural element of the beach face further north towards Pallarenda. It is a dynamic feature, subject to erosion during high-energy wave attack, but it naturally reforms if the system is not starved of sand. Future renourishment in Rowes Bay should be designed to allow such a landform to develop on the beach face. This would require analysis of the bay's wind, wave, and tidal process regimes, and their interactions with the beach morphodynamics. Considerably more sand than has so far been used would be necessary, and there needs to be a commitment to on-going maintenance and top-ups of sediment to the system.

11. Recommendations

1. Analysis of the morphodynamic process regimes is required to determine the most effective design for future beach renourishments in Rowes Bay. This should include an analysis of how to create the conditions necessary for wave action to develop a berm landform on the beach face.

2. Consideration should be given to the construction of a groyne near the north side of the mouth of One Mile Creek. This should be designed to trap sand moving south out of the renourishment zone, and would also help prevent the regular blocking of the creek mouth.

3. The scale of the Rowes Bay renourishment needs to be increased beyond the relatively modest sand volumes so far placed on the foreshore. An addition of 50,000m^3 of sand could provide ~15 years of shoreline protection.

4. Options for the on-going maintenance of the renourishment zone should be developed, in particular assessing means of reducing long-term reliance on imported sand to renourish the system.

5. Monitoring of foreshore behaviour should continue, as this will provide the necessary data for future management of the site.

Appendix 1: Figures 2 – 10

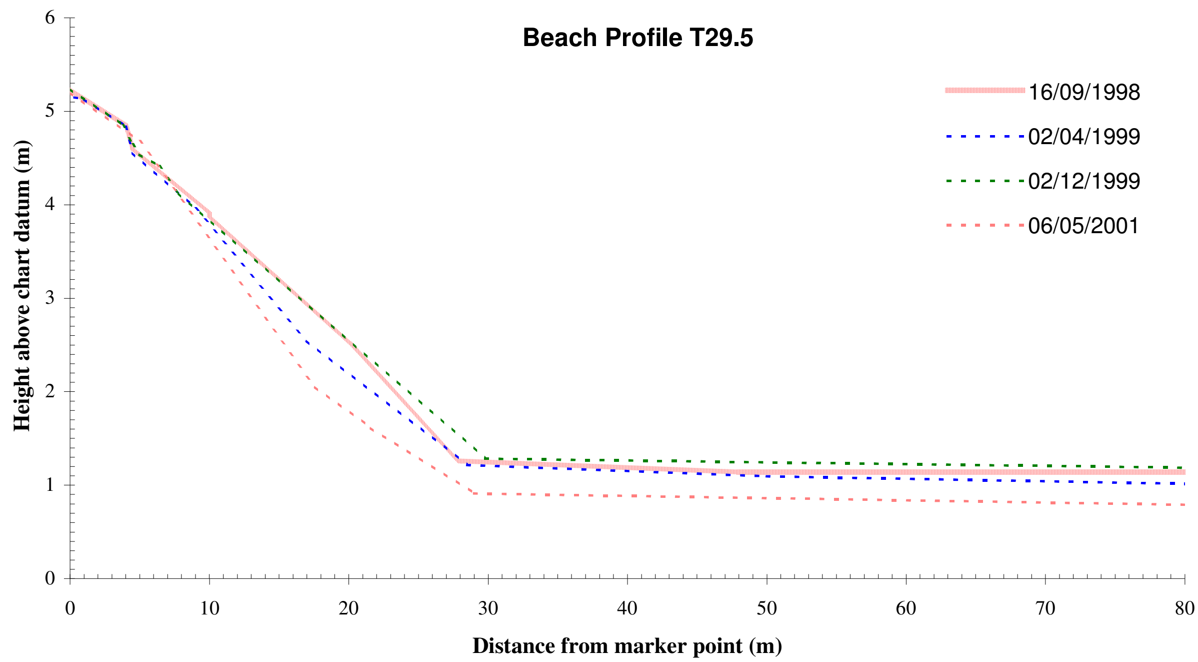

Figure 2: Beach profile at TCC marker point T29.5

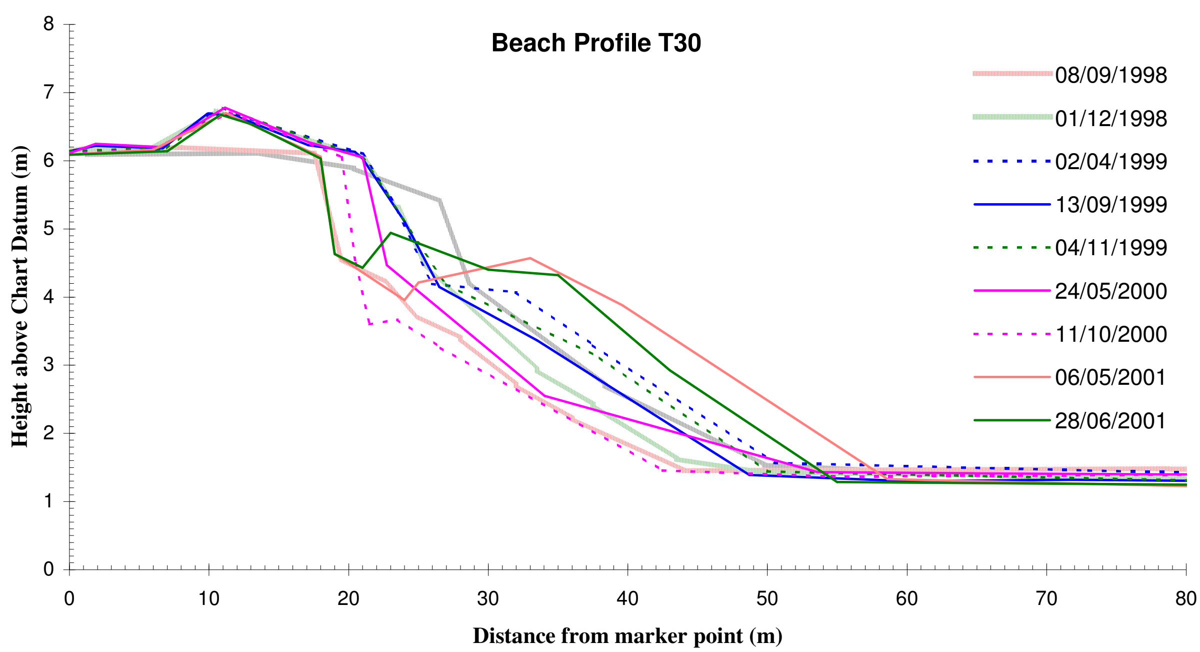

Figure 3: Beach profile at TCC marker point T30

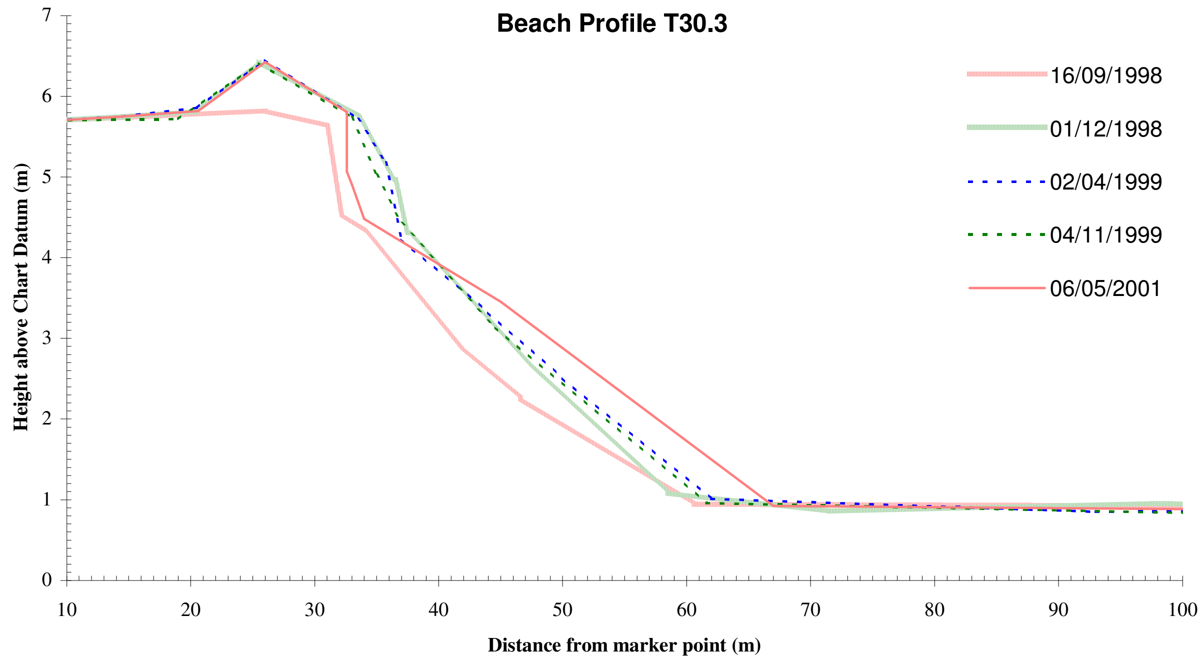

Figure 4: Beach profile at TCC marker point T30.3

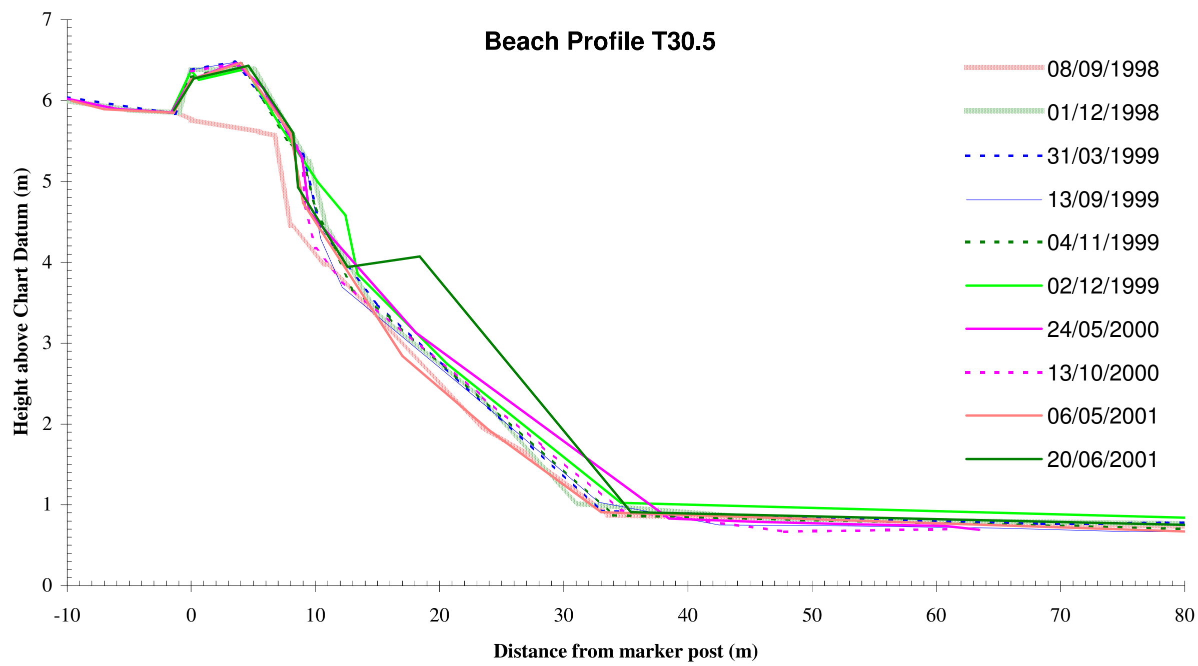

Figure 5: Beach profile at TCC marker post T30.5

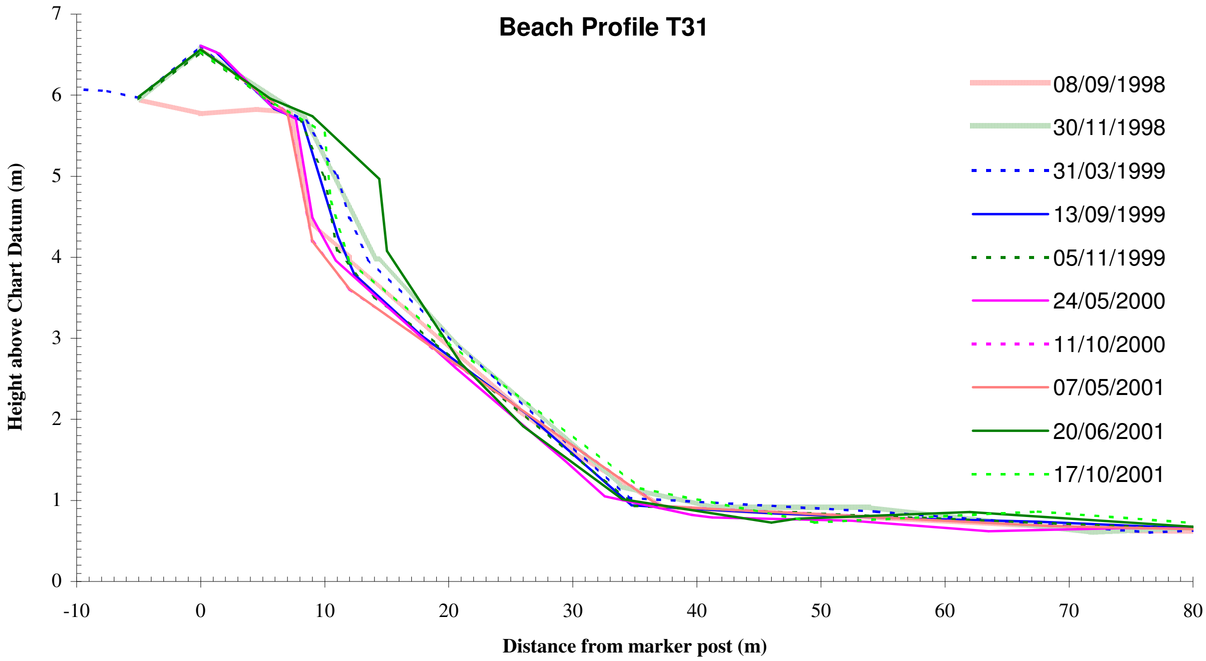

Figure 6: Beach profile at TCC marker post T31

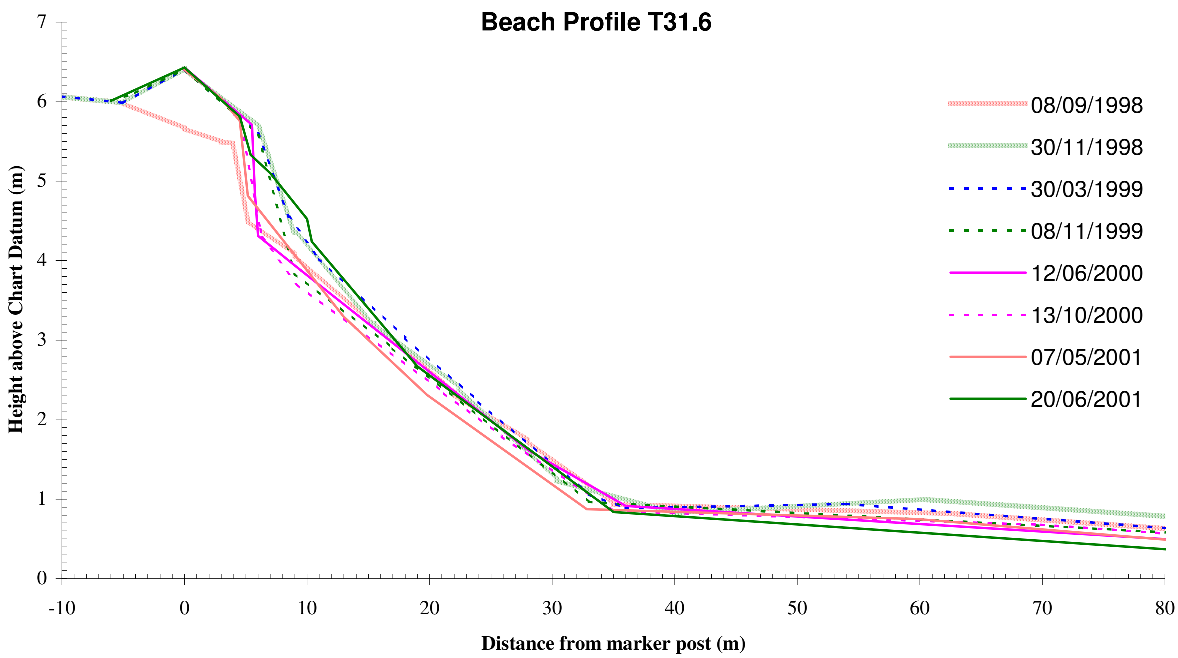

Figure 7: Beach profile at TCC marker post T31.6

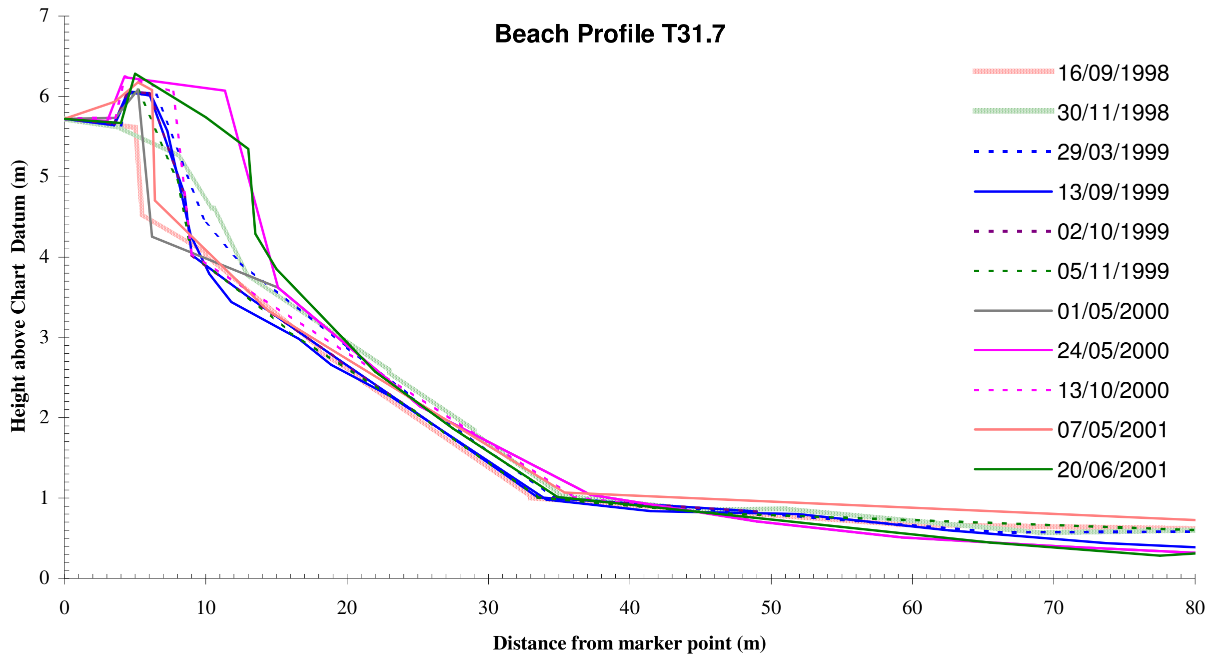

Figure 8: Beach profile at TCC marker point T31.7

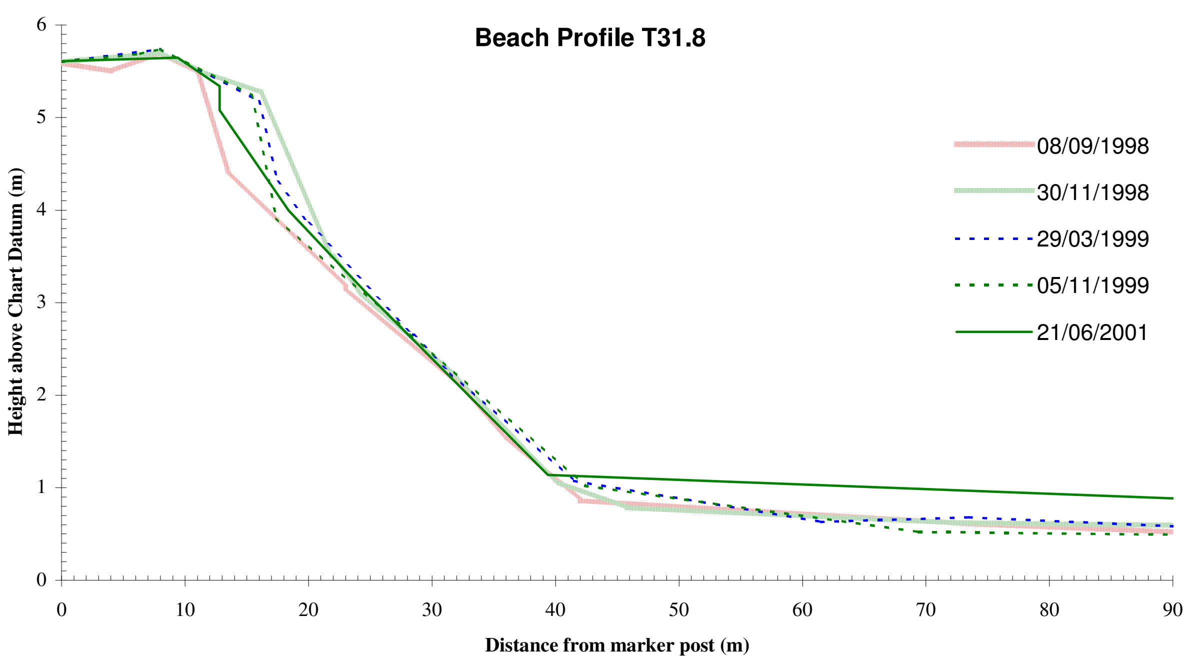

Figure 9: Beach profile at TCC marker post T31.8

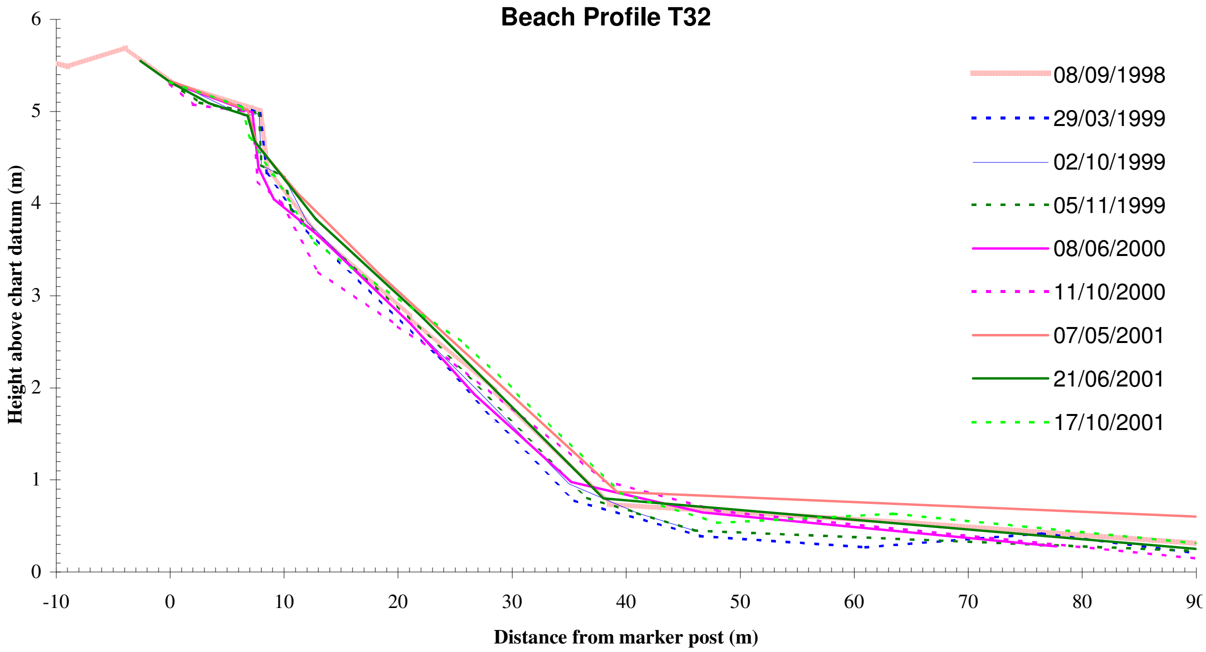

Figure 10: Beach profile at BPA marker Post T32

Appendix 2: Profile raw data

Profile T29.5

06/05/2001

Distance	Height
-3.2	5.28
-1.4	5.255
-0.2	5.252
0	5.2
5	4.68
17.6	2.05
21.6	1.612
29	0.912
109.6	0.722

Profile T30

11/10/2000		06/05/2001		28/06/2001	
Distance	Height	Distance	Height	Distance	Height
0	6.11	0	6.09	0	6.09
6	*6.165*	6	6.165	7	6.14
11.5	6.71	11.2	6.697	10.8	6.676
19.5	6.05	18	6.06	13	6.54
20.5	4.495	19	4.63	18	6.03
21.5	3.6	24	3.955	*19*	*4.63*
23.5	3.67	25	4.215	21	4.43
26.6	3.256	33	4.57	23	4.94
42.5	1.456	39.6	3.88	30	4.4
54.6	1.366	58.6	1.33	35	4.32
90.6	1.406	107.6	1.095	43	2.925
137.6	1.306			55	1.285
146.6	1.576			113	1.195

Profile T30.3

06/05/2001		13/10/2000		06/05/2001		20/06/2001	
Distance	Height	Distance	Height	Distance	Height	Distance	Height
0	6.06	0	6.36	-9.6	5.995	-1.4	5.88
9	*5.7*	*3.58*	*6.46*	-7	5.891	0.2	6.27
14.5	*5.75*	*5.75*	*6.16*	-1.4	5.847	4.6	6.43
20.6	5.817	8	5.61	0	6.26	8.2	5.6
26	6.425	8.94	5.28	4	6.466	8.6	4.927
32.6	5.807	9.14	4.69	8	5.591	12.6	3.94
32.6	5.066	10	4.173	9	4.731	18.4	4.072
33	4.905	12.2	3.756	17	2.841	35.4	0.907
34	4.482	23.5	2.33	24	1.921	108.4	0.652
45	3.452	28.3	1.721	33	0.911		
67	0.922	34.6	0.934	86	0.641		
141	0.837	47.8	0.67				
		61.2	0.7				

Profile T30.5

13/10/2000		06/05/2001		20/06/2001	
Distance	Height	Distance	Height	Distance	Height
0	6.36	-9.6	5.995	-1.4	5.88
3.58	*6.46*	-7	5.891	0.2	6.27
5.75	*6.16*	-1.4	5.847	4.6	6.43
8	5.61	0	6.26	8.2	5.6
8.94	5.28	4	6.466	8.6	4.927
9.14	4.69	8	5.591	12.6	3.94
10	4.173	9	4.731	18.4	4.072
12.2	3.756	17	2.841	35.4	0.907
23.5	2.33	24	1.921	108.4	0.652
28.3	1.721	33	0.911		
34.6	0.934	86	0.641		
47.8	0.67				
61.2	0.7				

Profile T31

11/10/2000		07/05/2001		20/06/2001		17/10/2001	
Distance	Height	Distance	Height	Distance	Height	Distance	Height
0	6.57	0	6.55	-5	5.98	0	6.54
7	5.78	3.8	5.885	0	6.56	5	5.985
9	4.195	5.8	5.783	5.6	5.957	10	5.53
12	3.61	5.9	5.153	9	5.74	10.5	4.685
18.5	2.905	6	4.77	14.4	4.965	12	3.95
37	0.93	12.6	4.438	15	4.08	20	2.945
68.5	0.685	32.6	1.063	21	2.69	24.5	2.423
143.5	0.44	48.6	0.678	26	1.915	35.5	1.148
		56.6	0.868	34	1.015	49.5	0.728
		94.6	0.498	46	0.725	67.5	0.863
				48	0.775	94.5	0.558
				62	0.855	119.5	0.663
				94	0.535		

Profile T31.6

13/10/2000		07/05/2001		20/06/2001	
Distance	Height	Distance	Height	Distance	Height
0	6.41	0	6.4	-6	6.01
3.2	6.009	3	6.038	0	6.43
4.6	5.724	4.5	5.756	4.5	5.815
6.2	4.389	5.15	4.815	5.4	5.33
6.3	4.291	13	3.293	7	5.1
9.2	3.699	19.8	2.311	10	4.525
21.2	2.334	32.8	0.876	10.4	4.24
25.9	1.789	59.8	0.751	19	2.67
35	0.849	87.8	0.391	35	0.84
69.9	0.679	109.8	0.251	83	0.34
99.4	0.359	125.8	0.411		

Profile T31.7

13/10/2000		07/05/2001		20/06/2001	
Distance	Height	Distance	Height	Distance	Height
0	5.72	0	5.72	0	5.72
3.6	*5.734*	3.6	5.936	4	5.67
4.3	6.247	5.2	6.173	5	6.28
7.7	6.055	6.2	6.078	10	5.74
9	4.045	6.4	4.703	13	5.345
36	1.015	13	3.57	13.5	4.29
49	0.745	14.4	3.333	15	3.85
		35.4	1.068	22	2.57
		126.4	0.373	27.5	1.865
				34.9	1.013
				65.5	0.445
				77.5	0.285
				89.5	0.415

Profile T31.8

T31.8 2001	
Distance	Height
	21-06-2001
0	5.61
9.4	5.648
12.8	5.338
12.8	5.08
18.4	3.993
24.4	3.143
39.4	1.138
97.4	0.848

Profile T32

11-10-2000		07-05-2001		21-06-2001	
Distance	Height	Distance	Height	Distance	Height
0	5.3	0	5.33	-2.6	5.546
2	5.075	6.8	5.016	0	5.32
5	5.025	7.6	4.635	3.4	5.091
7.2	4.99	11.2	4.109	6.8	4.953
7.7	4.24	18.4	3.227	7.4	4.676
9.7	*4.01*	39.2	0.869	12.8	3.828
13	3.26	111.2	0.489	12.8	3.828
20	2.665			22	2.781
25	2.26			38	0.801
38	0.995			94	0.211
48	0.665				
104	-0.025				

17-10-2001			
Distance	Height		
0	5.32	Contd.	
6.3	5.043	39.5	0.858
7	4.71	48	0.533
9	4.315	63.5	0.633
12.7	3.577	96.5	0.233
26	2.465		
30.5	1.938		