CHAPTER 130

Statistical Variations in Beach Parameter Change Rates for Walled and Non-Walled Profiles at Sandbridge, VA

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Abstract

It has been argued that seawalls have a detrimental effect on the adjacent beach. These effects may only be noticeable over a period of years or may be short-term effects associated with storms or with seasonal transitions of the beach. Many theories on beach and seawall interaction have been speculative and have lacked actual field or laboratory evidence for their basis. This study uses four years of monthly and post-storm beach profile data to examine what influences the seawalls at Sandbridge, Virginia (USA) have on the adjacent beaches. Long-term effects of the seawalls are analyzed using fourteen years of profile data. Five parameters are defined to describe the subaerial beach profiles. Changes in the profile parameters in time are quantified using three methods of analysis.

1. Introduction

Sandbridge, Virginia is the site for an ongoing investigation of seawall and beach interaction. The study area lies on the east coast of the United States. Sandbridge is located south of the Chesapeake Bay and north of the Virginia-North Carolina border, as depicted in Figure 1. The beach is used by local property owners, residents and tourists as a recreational area.

In August 1990 the Civil and Environmental Engineering Department at Old Dominion University (ODU) began a beach monitoring program at Sandbridge, Virginia. The purpose of the monitoring program was to examine the effects of seawalls on the adjacent beach. The monitoring program involves surveying 28 beach profiles at seawalls and dunes out to mean low water. Surveys are conducted once a month and after significant coastal storms. Results of the two year study may be found in Basco et al. (1992) and Bellomo (1993).

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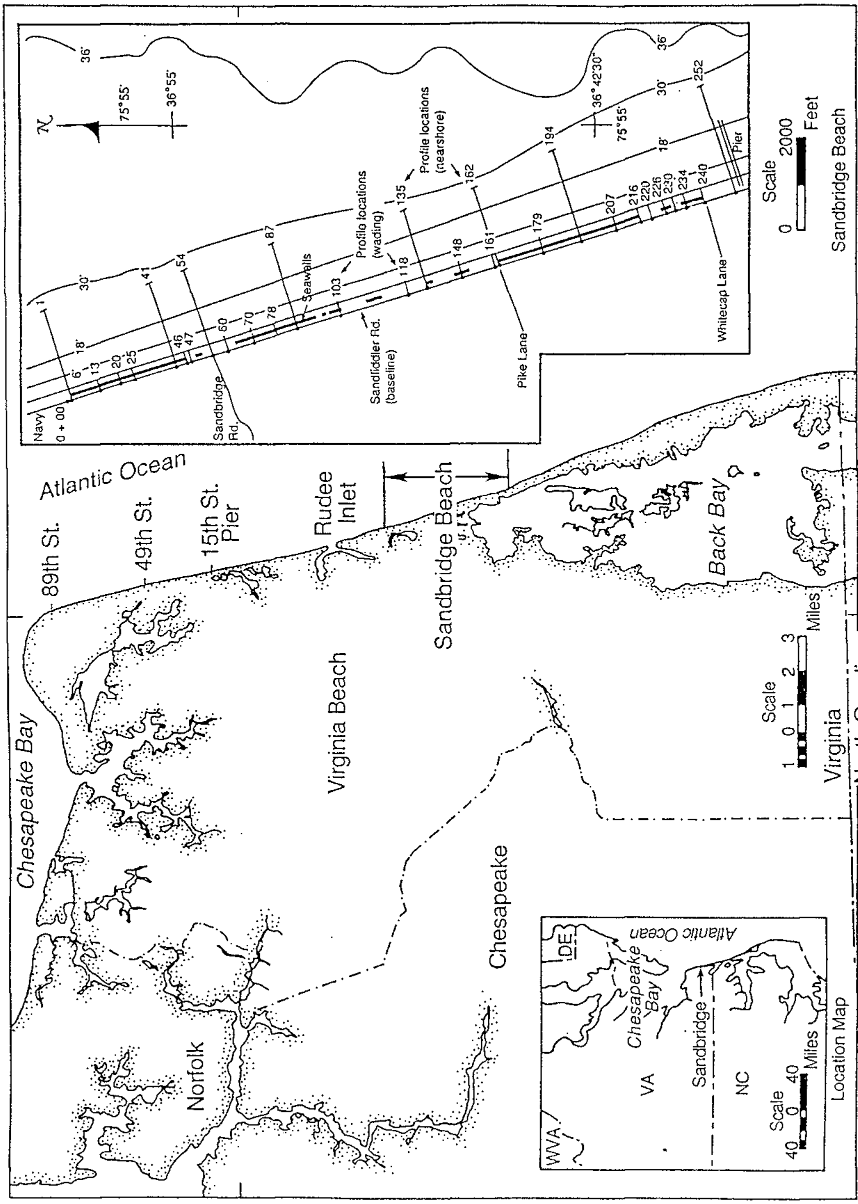

Figure 1. Location Map

The City of Virginia Beach began survey work at Sandbridge in 1980 with profiles at roughly 305 m intervals. Most profiles extend only out to wading depths, however some nearshore profiles (i.e. to depths of -8.0 meters) have been taken. The time between City surveys varies over the past 14 years. The Virginia Institute of Marine Science has also sponsored survey work at Sandbridge.

There are currently 2,350 profile-surveys at 53 locations collected during the last 14 years in the data base. Four of the profiles have had a seawall built during the period they were surveyed. Seven non-wall profiles have been surveyed before the boom in seawall construction in 1989.

The U.S. Army Engineer Waterways Experiment Station's Coastal Engineering Research Center (CERC) is sponsoring this study. This paper presents the preliminary results of what will be a five year study. They are also supporting two other beach and seawall interaction studies on United States beaches with one on the California coast and the second located at the eastern shore of Lake Michigan. It is anticipated that from the results of long-term field monitoring at three different locations, some facts will become clear regarding seawall and beach interaction.

2. Literature Survey

The Journal of Coastal Research (1988) Special Issue Number 4 entitled, "The Effects of Seawalls on the Beach", was specifically devoted to this topic. Included was a literature review by Kraus (1988) of beach and seawall interactions. Kraus concluded that there were no adverse effects of a seawall on the adjacent beach if a sediment supply exists.

Griggs et al. (1994) have described the results of seven years of monitoring beach and seawall interactions at Monterey Bay, California. They concluded that there were no significant long-term effects of the seawalls on the adjacent beach and the summer rebuilding of the beach was not influenced by the seawall. They found no difference between the winter profiles of the walled and non-walled beaches. At Monterey Bay the shoreline is stable and a steady sediment supply exists. This is different than at Sandbridge where a long-term, erosional trend exists.

3.0 Study Area Characteristics

Sandbridge, Virginia is quite literally a 'sand bridge' that is 7.7 km long and about 250 m wide at its narrowest point. Sandbridge separates the Atlantic Ocean to the east and the freshwater estuary Back Bay to the west. The long-term shoreline recession rate has been shown to vary linearly at Sandbridge from 1.1 m/yr at the north end, to 2.9 m/yr at the south end (Everts et al., 1983).

There are 4738 m of seawalls in 15 different sections along the Sandbridge shoreline. This is 62% of the oceanfront. The seawalls were built to protect septic tanks, driveway concrete slabs, and other property at ground level. The majority of the homes in the area are on piles above the one percent chance storm surge elevation. Most of the walls are made of steel sheet-piles with others being constructed of timber. Short stretches of concrete and asphalt rubble revetments also exists along the Sandbridge shoreline.

Seawalls along the southern portion of Sandbridge have their base located within the tidal range during the summer months and below mean low water during the winter months. Seawalls along the middle and northern portion have their base above mean high water during the summer and within the tidal range during the winter months. The mean tidal range is 1.04 meters.

4.0 Parameter Definitions

To quantify profile "change" we have adopted five parameters as depicted in Figure 2. There are three section volume parameters, namely: landward volume (V_L), seaward volume (V_S), and total volume (V_T), each carrying units of m^3/m. The area between the profile and the MLW line is calculated using the trapezoidal rule. To obtain a volume, this area is then multiplied by a unit length parallel to the beach. The different volumes (landward, seaward, and total) are calculated using different right and left hand boundaries. Landward volume is bounded on the left by the survey baseline. For a walled profile, the right hand boundary for landward volume is the wall itself. However, for a dune/beach profile, an imaginary partition is used as the landward right hand boundary. This imaginary partition is located at the same distance from the baseline as the nearby seawalls. Seaward volume is bounded on the left by the imaginary partition or seawall, and on the right by the intersection of the profile and the MLW line. The total volume is simply the sum of the landward and seaward volumes.

The berm elevation (E_B) is measured in meters above the vertical datum. It is simply defined as the elevation of the profile at the seawall or imaginary partition, as shown in Figure 2. The shoreline position (P) is also shown in Figure 2. It is defined as the distance from the baseline, to where the profile intersects the MHW line.

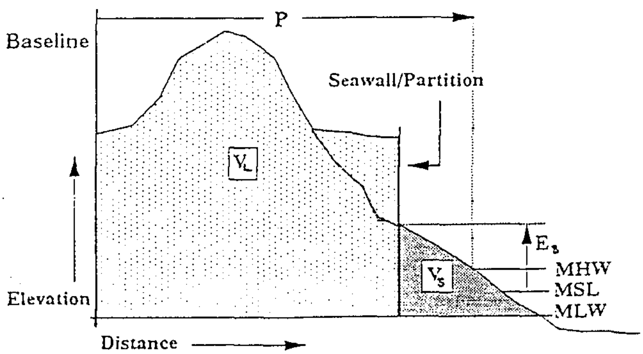

Figure 2 Definition Sketch

5.0 Methods of Analysis

Three basic methods have been devised to analyze changes in the profile parameters: (1) Individual Profile Method, (2) Simple Average Method and (3) Weighted Average Method. Each method uses an increasing number of profiles in their procedures and is useful in studying different topics of bcach and seawall interaction. Linear regression was used to find the parameter rate of change for each method.

The weighted average method (WAM) used only 28 profile locations surveyed by ODU since August of 1990. The 28 profiles were separated into two categories, wall and non-wall profiles. Each wall profile was assigned a representative length of seawall along the beach. One wall profile is said to represent the conditions along this particular length of shore. The wall profile parameter is multiplied by the representative length. This is done for each wall profile. The sum of the representative lengths equals the total length of seawalls at Sandbridge, 4738 m. All of the weighted profile parameters were added together and then divided by 4738 m. The result is a single set of five weighted parameters (V_S,V_L,V_T,P, and E_B) that represent all the wall profiles at Sandbridge. The same scheme was used with the dune profiles but with different representative lengths totaling 2953 m of non-walled beach.

For the simple average method (SAM) Sandbridge was divided into three reaches. The reasons for the division were due to differences in the baseline elevation and erosion rates along the Sandbridge shoreline. ODU profiles 1 to 54 were placed into the northern section, profiles 60 to 161 into the middle section and profiles 162 to 252 into the southern section. For each section the profiles were sorted again into wall and non-wall profiles. The data base has now been sorted into six categories. For each category, every profile had their parameters averaged together. The outcome is five parameters for a particular survey date representing either wall or dune profiles for each section.

For the individual profile method (IPM), the parameters were calculated for all surveys of a particular profile. This allows the profile history to be analyzed beyond the four years of ODU monitoring. The most significant benefit of the IPM was that parameter rates of change could be looked at before and after wall construction. An individual spreadsheet for each profile was created and contained the five parameters for every date that the profile was surveyed.

Seasonal variations of the profile parameters were studied using the results of the WAM. Seasonal trends can be mathematically modeled as a sinusoidal wave with a wave length of one year. The equation for the seasonal sine wave is given by:

$$Y = b + m(t) + (a)\sin(-2\pi(t-t_o)/365) \qquad (1)$$

where:
- Y = parameter value (V_S,V_L,V_T,P, or E_B)
- b = parameter starting value, constant, at October 1990
- m = slope of best fit linear regression line
- t = time in number of days since January 1, 1900

a = amplitude of sine wave
t_0 = start date October 1990

Linear regression was used to find the values of b and m. The amplitude, a, was found by using a value of the amplitude that gave the least variance between the measured WAM values and the predicted sine wave values, Y. Four years of WAM survey data were utilized in the analysis (October, 1990 to September, 1994). All values in the seasonal variation plots were subtracted by the parameter's linear regression intercept at October 1990. By using the "difference" values discrepancies between wall and dune profiles are more easily seen.

6. Beach and Seawall Interaction Hypotheses

To prove if the seawalls at Sandbridge are adversely affecting the adjacent beaches, three basic hypothesis were tested. The first hypothesis is that seawalls delay the recovery of the beach transition from winter to summer seasons. This hypothesis will be accepted or rejected by studying the weighted average volume seaward of the dune and wall profiles.

The second hypothesis is that the volume of sand in front of the walls erodes faster than the volumes in front of the partition for the dune profiles. This hypothesis will be accepted or rejected by comparing the rates of loss of volume seaward for the wall and dune profiles.

The third hypothesis is that the dune landward volumes are eroding at a faster rate because of sand being held back by adjacent seawalls. The volume of sand behind the wall is removed from the littoral system. This hypothesis will be tested by comparing the volume landward loss rates before and after seawall construction at the dune profile locations.

7.0 Results

7.1 Weighted Average Method

Results of the weighted average method are included in the plots of the seasonal variations in Figures 3 through 9. The solid dots represent the measured weighted average parameter difference. The heavy, solid line is the linear regression slope of the parameter rate of change using data from October, 1990 to September, 1994. The values of these four year, WAM slopes are summarized in Table 1. Also included in Table 1 are parameter rate of change using one, two and three years of data. There is some variability in the value of the parameter rate of change with an increasing number of years. The cause of this variability is that some winter seasons had more severe storms and some summers resulted in more beach recovery. By using the longest time span available, such inconsistencies are reduced. Parameter rate of change tends to decrease as the number of years used increased, except for the dune landward volume.

The null-hypothesis at the 95% confidence level was used to determine that the four year shoreline recession rate was statistically higher for the dune profiles. The volume seaward erosion rate was also statistically higher for the dune profiles. Berm elevation recession rates were found to be statistically the same for the wall and dune profiles.

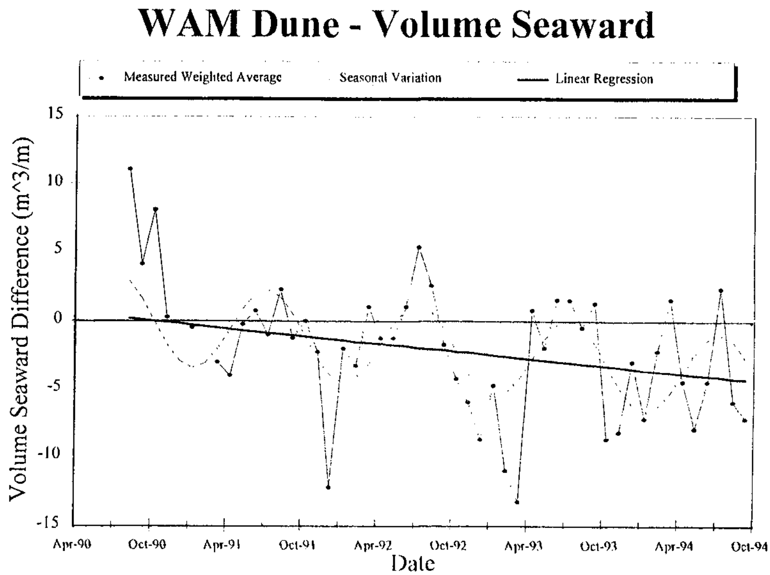

Figure 3 Dune Volume Seaward Seasonal Variations

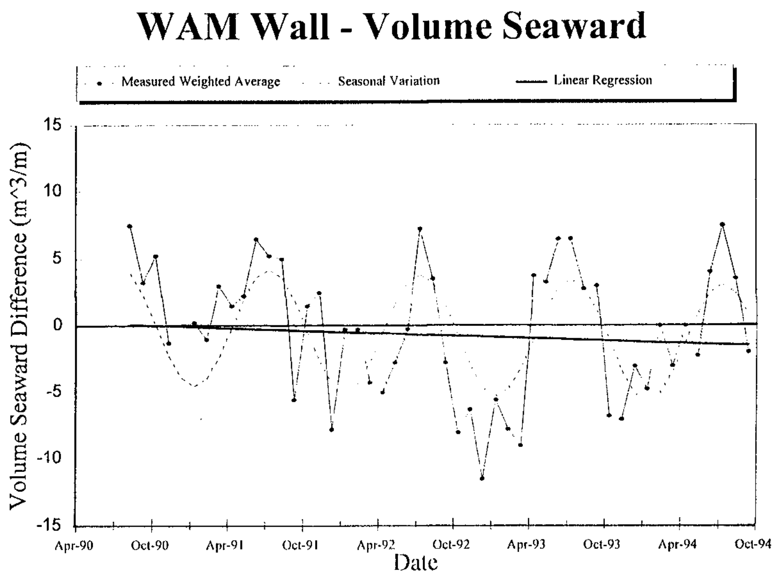

Figure 4 Wall Volume Seaward Seasonal Variations

The amplitude of the seasonal sine wave is larger for the wall profiles than for the dune profiles. This amplitude is one-half of the active volume of sand that builds in the summer and is removed in the winter. Active volumes for the dune and wall profiles are 6.2 m^3/m in Figure 3 and 8.9 m^3/m in Figure 4, respectively. The active seasonal volume of sand landward of the partition is 4.0 m^3/m for the dune profiles as shown in Figure 5. Fluctuations in the seasonal berm elevation and shoreline position were found to be larger for the wall profiles than the dune profiles (see Figures 6, 7, 8 and 9).

These results suggest that the walls produce more seasonal variations causing lower winter profiles and more sand piled up in front of the walls in the summer than the duned sections. Dune and wall parameters reached their transition from winter to summer profiles in April and from summer to winter profiles in October. Volume seaward for the wall recovered before the dune in 1991 and simultaneously in 1993 and 1994. The dune recovered before the wall in 1992. Dune profiles achieved their winter profile before the wall in 1991 and simultaneously in 1990, 1992, 1993 and 1994. There is no evidence that walled sections recover at a later time than the duned sections.

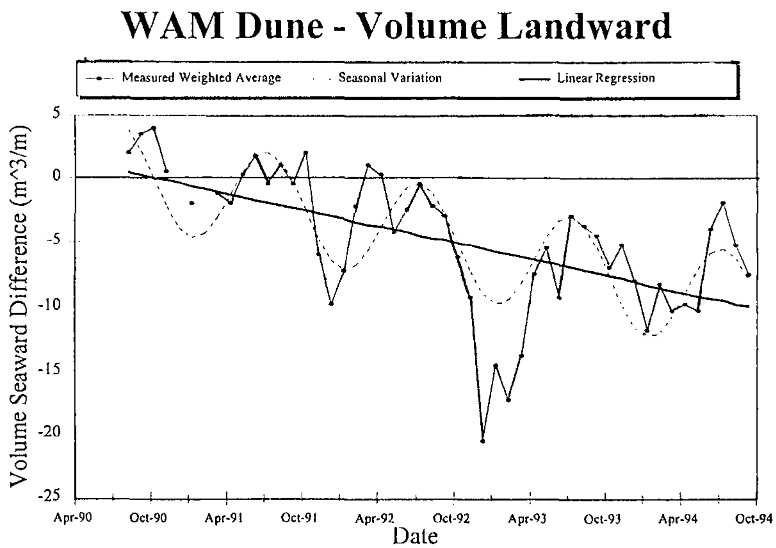

Figure 5 Dune Volume Landward Seasonal Variations

7.2 Simple Average Method Results

Results from the simple average method are listed in Table 2. Column one is the section number and column two is the profiles used in that section. The third column is the percent of shoreline that is fronted with seawalls in that section. Column four is the profile parameter type. This table includes the parameter rate of change for each of the three sections in the last five columns.

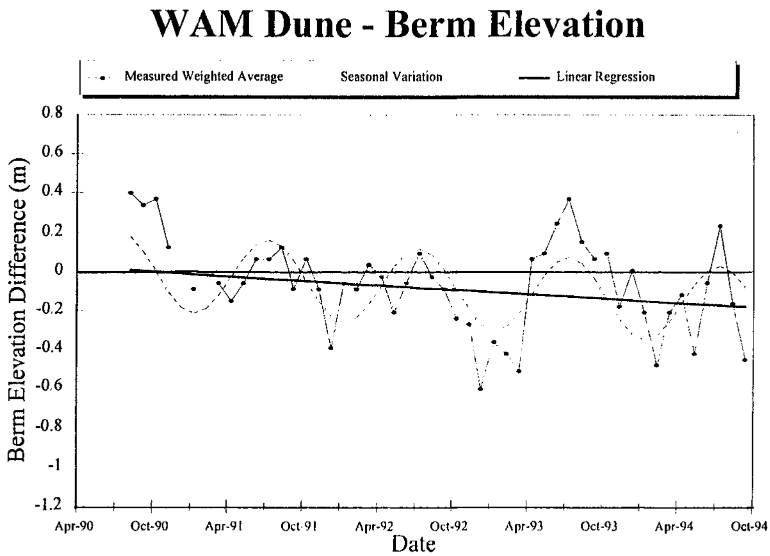

Figure 6 Dune Berm Elevation Seasonal Variations

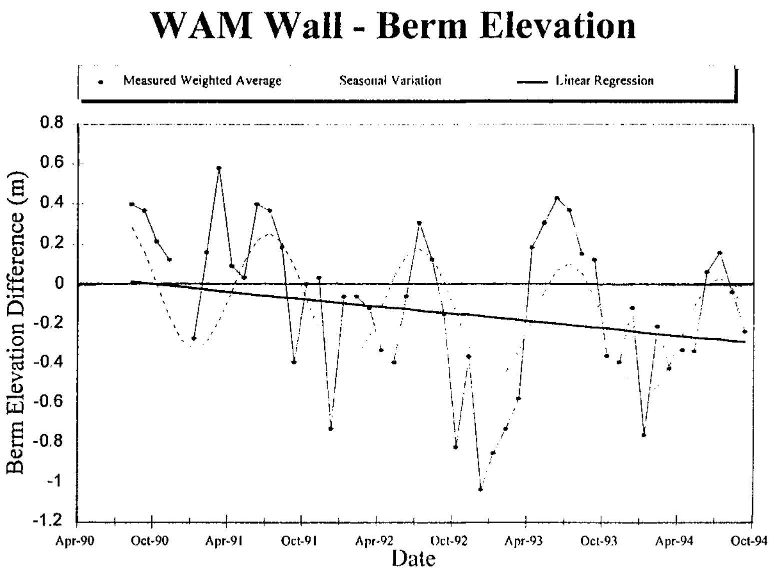

Figure 7 Wall Berm Elevation Seasonal Variations

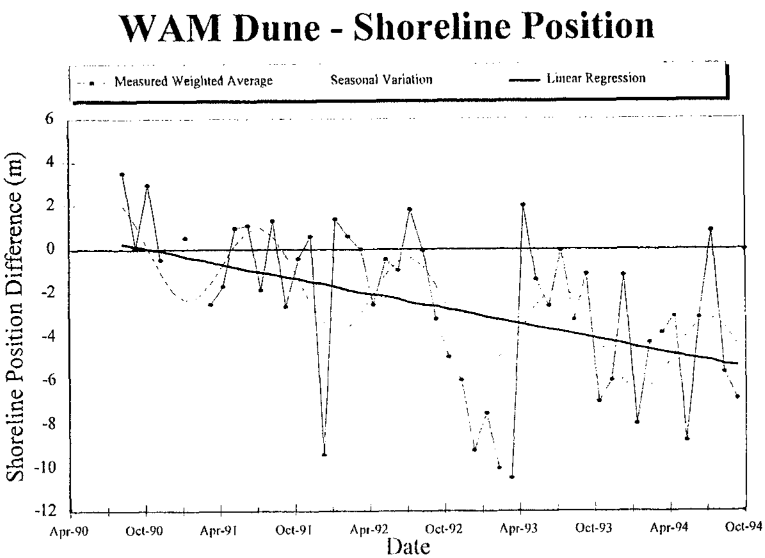

Figure 8 Dune Shoreline Position Seasonal Variations

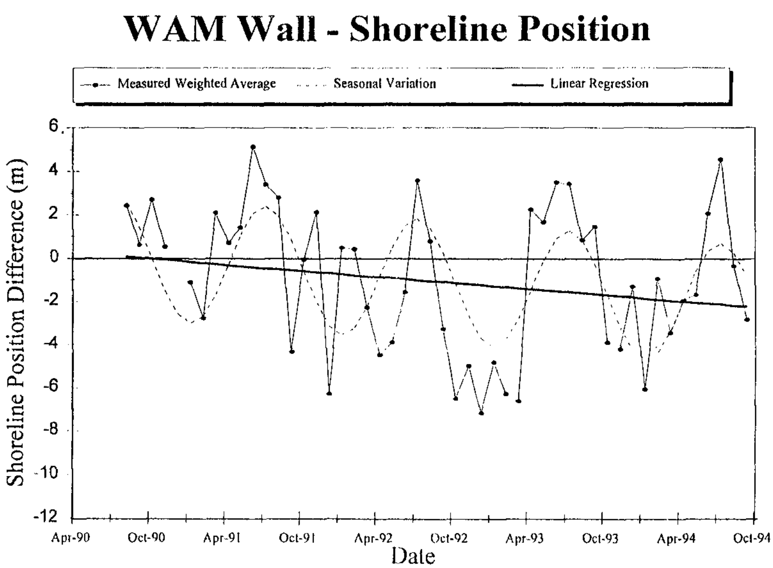

Figure 9 Wall Shoreline Position Seasonal Variations

WAM Beach Parameter	Wall	Dune	Difference
V(t) change rate (m^3/m/yr) - 1 Year	0.14	-7.41	7.55
2 Years	-5.45	-5.18	-0.27
3 Years	-2.74	-5.00	2.26
4 Years	-1.71	-3.64	1.93
V(s) change rate (m^3/m/yr) - 1 Year	-0.21	-4.70	4.49
2 Years	-2.93	-1.88	-1.05
3 Years	-0.94	-1.14	0.2
4 Years	-0.39	-1.10	0.71
V(l) change rate (m^3/m/yr) - 1 Year	0.33	-2.54	2.87
2 Years	-2.60	-3.31	0.71
3 Years	-1.81	-3.86	2.05
4 Years	-1.33	-2.55	1.22
E(b) change rate (m/yr) - 1 Year	-0.07	-0.21	0.14
2 Years	-0.27	-0.13	-0.14
3 Years	-0.09	-0.03	-0.06
4 Years	-0.08	-0.05	-0.03
P change rate (m/yr) - 1 Year	-0.40	-2.25	1.85
2 Years	-2.51	-1.59	-0.92
3 Years	-0.90	-1.50	0.6
4 Years	-0.57	-1.38	0.81

Table 1. Weighted Average Method Parameter Rate of Change

Location	**Profiles Used**	**Percent Walled**	**Profile Type**	**Parameter**				
				V(t) (m^3/m/yr)	V(s) (m^3/m/yr)	V(l) (m^3/m/yr)	E(b) (m/yr)	P (m/yr)
Section 1	1 to 54	79.5 %						
North			Wall	-2.6	1.9	-4.5	0.0	0.6
			Dune	-4.4	0.4	-4.8	-0.1	-0.8
Section 2	60 to 161	43.6 %						
Middle			Wall	0.7	0.8	-0.1	0.0	-0.2
			Dune	-0.4	-2.1	1.7	-0.1	-0.7
Section 3	162 to 252	73.3 %						
South			Wall	-4.6	-2.9	-1.7	-0.3	-1.7
			Dune	-4.6	-2.1	-2.5	-0.2	-1.5

Table 2 Simple Average Method Parameter Rate of Change
from Oct. 1990 to Sep. 1994

The time span used in the regression analysis was from October 1990 to September 1994.

Section 3 experienced the largest total volume decrease of the three sections. Volume seaward loss and shoreline retreat were the highest for walled profiles in Section 3. The higher parameter change rates in Section 3 are due to the seawalls being located closer to the surf zone than the seawalls in Section 1 and 2.

7.3 Individual Profile Method Results

The parameter rates of change for each of the 28 profiles are provided in Table 3. Volume seaward and landward for profiles 1, 25, 161 and 252 have been plotted in time and are shown in Figures 10, 11, 12, and 13, respectively. Dune profile 1 is at the north end of Sandbridge and dune profile 252 is at the south end. These profiles have been regularly surveyed since October 1980 and have been the least affected by road maintenance, beach bulldozing and home construction. Both profiles show a significant increase in the loss rates of all parameters (V_T, V_S, V_L, E_B and P) after the construction of nearby seawalls in 1989. Profile 1 and 252 can be considered as control profiles in this study. The other dune profiles surveyed back to 1980 have seawalls to the north and south of them and have been modified by man. These other profiles have mixed results. The plot of dune profile 161 has a decrease in sand loss after a seawall was built 30 m to the south.

Profile 25 has been surveyed since 1980 and changed to a wall profile in the fall of 1988. Volume landward has a decreasing rate due to sand mechanically removed in the spring of 1994. The amount of sand decreased in front of the seawall after construction but has been increasing since then.

8.0 Conclusions

The hypothesis that erosion in front of the seawalls is greater than that on adjacent non-walled beaches was statistically found to be false. The hypothesis that seawalls inhibit the recovery of the beach after the winter storm season was also found to be false at Sandbridge. There is support for the hypothesis that the landward dune volume is eroding at a faster rate due to seawall construction on adjacent beaches. Complete details can be found in Hazelton (1994).

The seawalls at Sandbridge are performing exactly as they were intended to perform. They are protecting the infrastructure behind them from damage due to wave action. They were never intended to save the beach from erosion. The shoreline was receding well before the seawalls were constructed but now people have a reference point from which to judge the amount of retreat.

What is of concern in this study is the additional erosion caused by coastal armoring above the historic background erosion rates. The adverse effects of coastal armoring can be mitigated by nourishing the beach suffering from the increased erosion with sand so that the armoring has a neutral effect on the beach

Profile No.	Profile Type	Dates Used in Regression	No. of Years Used	No. of Survey Points	Volume Total (m^3/m/yr)	Volume Seaward (m^3/m/yr)	Volume Landward (m^3/m/yr)	Berm Elevation (m/yr)	Shoreline Position (m/yr)
1 before	Dune	10/80 to 7/88	8	24	0.3	-0.5	0.8	0.0	-0.1
1 after	Dune	7/89 to 6/94	5	54	-11.4	-2.3	-9.0	-0.1	-1.4
13 before	EOW	5/91 to 4/93	2	26	-13.4	-1.0	-12.4	-0.3	-3.7
13 after	Wall	5/93 to 4/94	1	12	-23.8	-16.1	-7.6	-0.9	-9.7
20	Wall	10/90 to 9/94	4	49	1.1	-0.1	1.2	-0.1	-0.8
25 before	Dune	10/80 to 9/88	8	24	0.5	0.7	-0.2	0.1	0.0
25 after	Wall	10/90 to 9/94	4	52	-1.8	2.5	-4.4	0.1	1.0
41	Wall	10/90 to 9/94	4	53	2.7	2.0	0.7	0.0	0.6
46	EOW	10/90 to 9/94	4	50	6.1	2.6	3.6	0.0	0.8
47	Dune	10/90 to 9/94	4	49	-4.7	2.3	-6.9	-0.0	0.4
54	Dune	10/90 to 9/94	4	51	-4.0	-0.6	-3.4	-0.1	-1.7
60 before	Dune	10/80 to 7/85	4	17	-11.3	-6.2	-5.0	-0.5	-1.3
60 after	Dune	10/90 to 9/94	4	50	-6.1	-0.1	-6.0	-0.1	-1.3
70	Wall	10/90 to 9/94	4	51	-0.6	1.0	-1.7	-0.1	-0.1
74 before	Dune	10/80 to 9/88	7	30	-11.4	-10.6	-0.8	-0.4	-2.0
74 after	Wall	7/89 to 7/93	4	9	0.3	0.6	-0.4	0.2	0.5
78	Wall	10/90 to 9/94	4	53	3.9	1.6	2.2	-0.1	0.4
87	Wall	10/90 to 9/94	4	51	0.5	0.9	-0.4	0.0	0.0
103	EOW	10/90 to 9/94	4	48	-0.5	-2.1	1.6	0.0	-1.1
118	Dune	10/90 to 9/94	4	49	-14.6	-5.7	-8.9	-0.1	-2.8
135 before	Dune	10/80 to 9/88	8	24	4.3	1.4	2.9	0.1	1.1
135 after	Dune	10/90 to 9/94	4	53	6.1	1.3	4.8	0.1	-0.1
148	Wall	10/90 to 9/94	4	50	1.3	0.8	0.6	0.1	0.0
161 before	Dune	10/80 to 10/88	8	50	-4.6	-2.0	-2.6	-0.1	-1.0
161 after	Dune	10/90 to 9/94	4	54	-1.1	-0.7	-0.4	-0.0	-0.7
162	EOW	10/90 to 9/94	4	48	0.3	-0.6	0.9	0.0	-0.5
179	Wall	10/90 to 9/94	4	48	-4.9	-4.2	-0.7	-0.2	-2.1
194 before	Dune	10/88 to 9/89	1	18	-16.0	-1.2	-14.9	0.5	4.5
194 after	Wall	10/90 to 9/94	4	52	-3.2	-2.1	-1.1	-0.3	-1.7
207	Wall	10/90 to 9/94	4	49	-3.4	-2.2	-1.1	-0.2	-1.3
216 before	Dune	9/85 to 8/90	5	29	-7.6	-3.7	-3.9	-0.2	-2.6
216 after	EOW	10/90 to 9/94	4	53	-4.1	-1.3	-2.8	-0.2	-2.6
220 before	Dune	9/85 to 9/89	4	42	-16.4	-6.8	-9.6	-0.2	-3.0
220 after	Dune	10/90 to 9/94	4	53	-1.3	0.2	-1.5	-0.0	-1.1
226	Wall	10/88 to 9/94	6	66	-3.9	-4.3	0.4	-0.2	-2.5
230	Dune	10/88 to 9/94	6	68	-7.8	-3.9	-4.0	-0.1	-2.2
234	Wall	10/90 to 9/94	4	49	-6.1	-2.7	-3.4	-0.1	-1.8
240	EOW	10/90 to 9/94	4	50	-6.6	-3.2	-3.4	-0.2	-1.9
252 before	Dune	10/80 to 9/88	8	47	-2.1	-2.9	0.9	0.1	-1.6
252 after	Dune	10/90 to 9/94	6	59	-7.6	-5.7	-1.8	-0.3	-2.8

Table 3. Individual Profile Method Results

Non-Wall Profile No. 1 Sand Volume

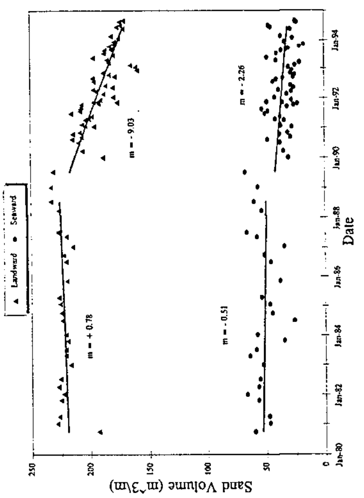

Figure 10 Non-Wall Profile No. 1

Wall Profile No. 25 Sand Volume

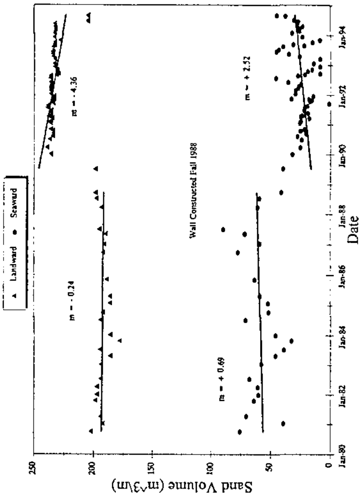

Figure 11 Wall Profile No. 25

Non-Wall Profile No. 161 Sand Volume

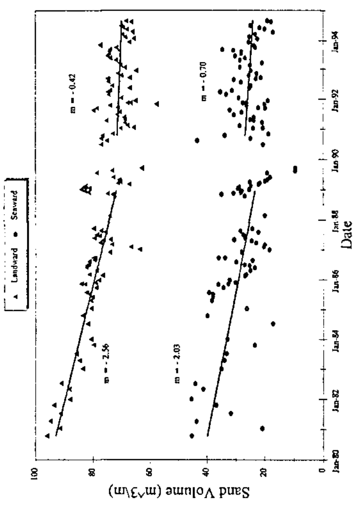

Figure 12 Non-Wall Profile No. 161

Non-Wall Profile No. 252 Sand Volume

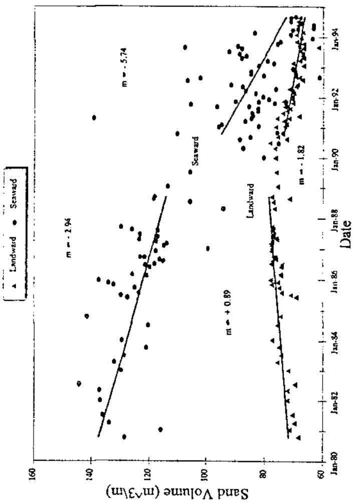

Figure 13 Wall Profile No. 252

(Dean, 1986). Even with this mitigating nourishment, the historic background erosion will continue to erode the beach and the shoreline will eventually reach the seawall and no beach will exist.

Seawalls and beaches can only coexist with periodic beach nourishment for a beach experiencing high rates of historic erosion. A nourishment project has been planned for Sandbridge in the spring or summer of 1997. The seawalls can continue to provide protection to homes during periods of high waves and storm surges and tourist can also enjoy the wide summer beach. Subaerial beach monitoring at Sandbridge will continue until a nourishment project is completed after which full profile monitoring to closure depth will take place.

Acknowledgments

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