CHAPTER 210

LONG-TERM BEACH RESPONSE TO SHORE STABILIZATION STRUCTURES ON THE OREGON COAST

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ABSTRACT

Increased development along the Oregon coast has led to heightened concern over beach erosion. As a result, more shore stabilization structures have been erected in recent years. A long-term field monitoring program, involving seven typical structures located on the central Oregon coast, was initiated in the spring of 1986 to quantify the effects of shore stabilization structures on the surrounding beach and adjacent properties. All structures are rip-rap revetments or seawalls. Volumetric changes of the subaerial beach at each site were examined at scales ranging from the entire beach surrounding the structure to the beach in the immediate vicinity of the structure. When the data coverage and site geometry permitted, a far field control section was utilized to compare the volumetric response of a portion of beach relatively uninfluenced by the presence of the structure with that of the beach on the two structure flanks. Measurements are presented for the seven structures over the observation period of ten years to document the long-term effects the structures are having on the fronting beach and adjacent unprotected properties. Ten years of monitoring has revealed that the structures at these seven sites are having no adverse impacts on the surrounding beach or adjacent properties. This can be attributed to the limited amount of wave attack that the structures have experienced. The structures are built high on the profile, and experience wave attack only during the most severe storms.

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INTRODUCTION

The structures selected for the monitoring program are located between Neskowin and Florence; spanning a distance of nearly 100 miles of the central Oregon coast. Structures were selected in locations such that the number of factors that could affect the long-term beach change were reduced primarily to the structure itself. As a result, the majority of the structures were chosen such that there were no headlands, jetties, or river mouths in the immediate vicinity, and the adjacent properties were unprotected for at least three structures lengths on either side of the structure. The structures are backed by dunes, sea cliffs, or bluffs; all common coastal environments in Oregon. Table 1 shows the characteristics and site codes (abbreviations) of the seven sites selected for the field monitoring program. The study was initiated to aid the Oregon State Parks Division and DLCD, which regulates the construction of coastal structures in their permit review process.

Table 1 Site and Structure Characteristics

Site	Site Code	Structure Type	D_{50}(mm)	Length (m)
Pacific Sands Motel	PSM	Timber Seawall	0.30	70
Gleneden	GE	Rip-Rap Revetment	0.53	40
Pacific Palisades	PP	Rip-Rap Revetment	0.31	300
Pacific Shores	PS	Rip-Rap Revetment	0.20	20
C&L Ranch	CL	Rip-Rap Revetment	0.20	25
San Marine	SM	Rip-Rap Revetment	0.22	150
Driftwood Shores	DS	Rip-Rap Revetment	0.21	30

DATA COLLECTION

Field data, in the form of multiple beach profiles, were collected intermittently from the fall of 1986 to 1990, and resumed in the winter of 1995. On average, the database contains fifteen surveys per site. An effort was made to obtain at least a winter and summer survey for each year. Numerous transects were measured with an EDM in order to monitor the topography of the beach surrounding each structure. Weather permitting, the surveys provided coverage at least five structure lengths on either side of the structure, and seaward to the swash zone. Transects were spaced on the order of 20 m to 30 m on planar beaches with little three-dimensionality in the longshore direction. For more three-dimensional beaches displaying cusps, transects were spaced accordingly to achieve an accurate representation of the beach.

ANALYSIS METHODS

The beach profile data were analyzed using contour plots, surface plots, contour of difference plots, and results from sand volume calculations. The profile data were interpolated to a uniformly spaced rectangular grid using MatLab codes, from which the plots and sand volume calculations were generated. To obtain the maximum use from the gridded data and explore all aspects of the structures effect on the surrounding beach, several scales were examined. A large scale (Scale I) was examined by considering the largest common area of beach covered in the field monitoring program. To reduce seasonal contamination and noise in the analysis, a intermediate scale (Scale II) was employed, defined as two structure lengths to either side of the structure and one structure length seaward. Finally, to concentrate on effects in the immediate vicinity of the structure, a scale consisting of the two structure flanks and beach immediately fronting the structure (Scale III) was examined. Each scale was divided into three sections; north, center, and south. When possible, the north and south survey sections were defined with the same sizes, thereby allowing a direct comparison between the two sections.

This approach was used primarily for analyzing the changes in sand volume. The volume of sand on the beach was calculated in reference to the 1929 NGVD mean sea level. Volumetric response, or the magnitude to which the sand volume is changing due to erosion and accretion events, was examined with the results of the volumetric calculations. The flanks on either side of the structure are typically considered the most susceptible to erosion; therefore, the sand volume of the north and south flanks, and the volumetric changes of the sand at these flanks over the observation period were of particular interest. Comparison of the sand volumes at these flanks with a far field control section, relatively uninfluenced by the presence of the structure, was an important analysis tool. The far field section provides a baseline to which volumetric responses close to the structure can be compared. The location of the far field section was always taken at the same distance from the bluff and defined with the same plan area as the flank section.

Contour and surface plots provide a means to observe seasonal changes at the sites, such as profile slope or formation of a berm or rip current embayment, as well as an indication of how the beach changes or adjusts in the vicinity of the structure. Figure 1 shows a contour and surface plot from Gleneden, obtained in June 1989. Contour of difference plots were used to show the specific areas of erosion and accretion between two sequential sets of beach profile data. They are useful in determining the degree to which the beach in the vicinity of the structure was responding to erosion and accretion events. Used in conjunction, this array of tools, contour and surface plots, contour of difference plots, and sand volume calculations, provide a detailed account of the long-term changes at the sites.

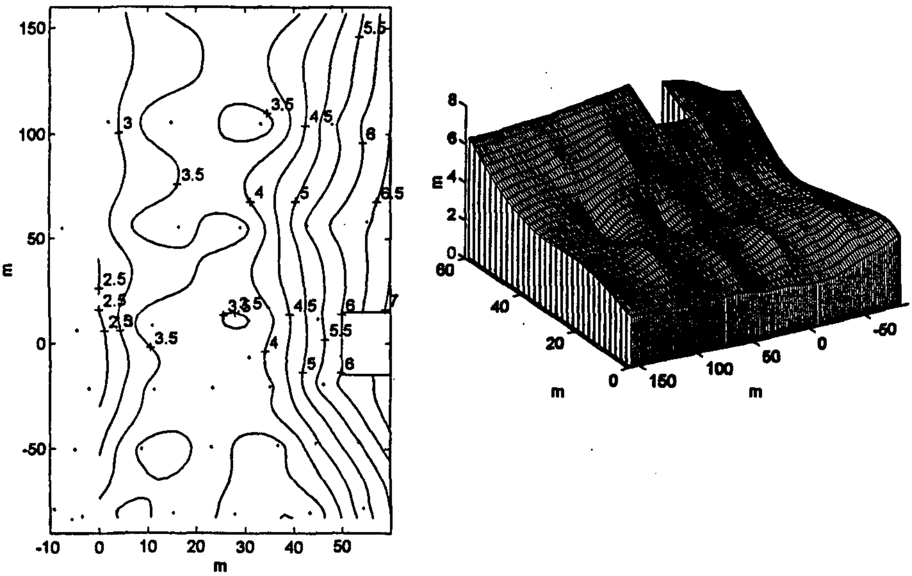

Figure 1 Contour and Surface Plot for Gleneden, June 1989

RESULTS

Analyses were undertaken by examining the contour and surface plots and the sand volume calculations for each site at of the aforementioned scales. One site will be analyzed in greater detail to illustrate the methodology and techniques used throughout the study to derive conclusions for all seven sites. A complete analysis of all sites is given in Hearon (1995) and Sturtevant (1987). Data for the remaining six sites will be presented in two forms, the volume of sand at Scale I over the observation period, and the results of the far field baseline comparison. Research has shown that the structure flanks are susceptible to erosion, therefore the results of the far field comparison are an effective indicator of structure induced impacts. The far field comparison data will be displayed in a normalized form, the volume of sand at the structure flank divided by the volume of sand in the far field control section ($V_{flank}/V_{far\ field}$). It is stressed that conclusions for each of the sites were derived by utilizing all analysis tools discussed in the previous section, and not solely from the data presented herein.

C&L Ranch (CL)

C&L Ranch provides an excellent open coast site. The structure is a 25-m long rubble mound revetment that protects and stabilizes the backing bluff. There are no headlands, jetties or river mouths in the vicinity. The bluff is shore parallel and unprotected for several structure lengths to either side. The land slide potential of the bluff is high. Evidence of several recent localized slides was observed during the 1995 data collection. Aerial photographs indicate that the beach and bluff line at C&L Ranch has changed little from 1965 to 1983.

The complete series of contour and surface plots indicates that the beach at C&L Ranch is very flat and planar throughout the year, exhibiting very little three-dimensionality. A summer berm was not observed in any of the surveys. The flat, dissipative beach at C&L Ranch is common on the central Oregon coast. A slight increase in sand elevation in the vicinity of the structure was observed in the majority of the contour and surface plots. The increased sand elevation was generally at the beach face junction of the flanks or at the seaward corners of the structure. The increased sand elevation at the seaward corners would generally extend several meters seaward of the structure. However, it cannot be concluded from this slight increase in sand elevation that the structure was retaining sand in its vicinity.

Figure 2 shows the volumetric responses of the north, south, and center sections for Scale I. The north and south sides of the structure are of equal area, but the center section is not of comparable size. The three sections all responded similarly to each other and to the total volumetric of Scale I shown in Figure 3. It appears as though the beach on the north side of the structure responded less sensitively to major erosion and accretion events than the beach on the south side of the structure. Similar to the total volumetric response of Scale I, all three sections of beach shown in Figure 2 displayed a balanced volumetric response fluctuating seasonally about a nearly constant mean and experienced a negligible net change in sand volume over the observation period. The volumetric response at Scale II was nearly identical to that of Scale I, showing seasonal fluctuation about a nearly constant mean.

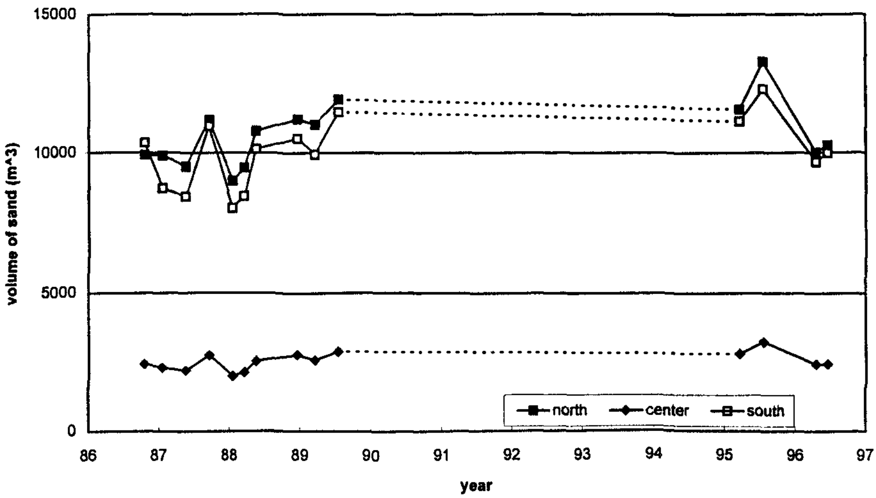

Figure 2 C&L Ranch Section Sand Volumes, Scale I

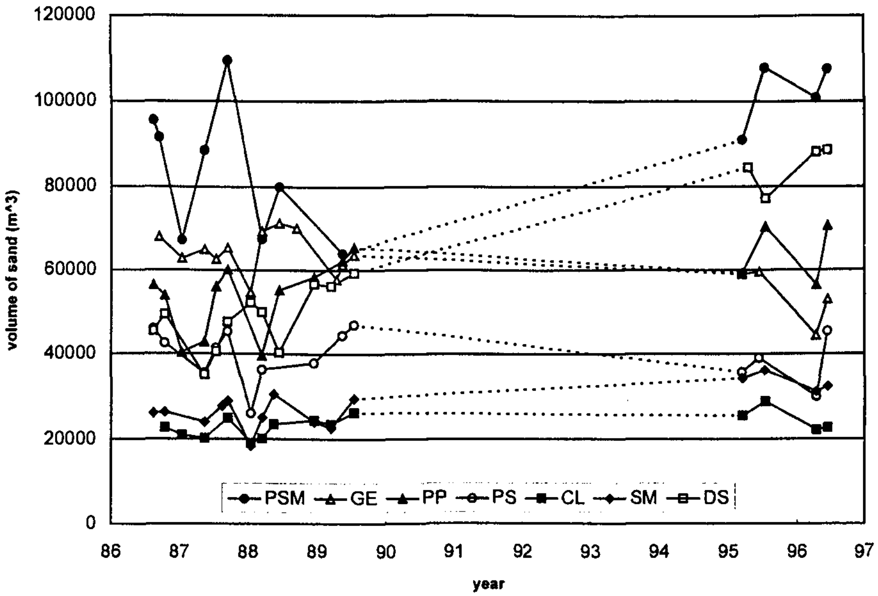

Figure 3 Total Sand Volumes at Each Site, Scale I

Far field sections were used both to the north and south of the structure. Figure 4 shows the comparison of the north far field and the north flank of the structure. The volumetric responses of the two areas were remarkably similar. The sensitivity to erosion and accretion events was approximately the same for both the north flank and the north far field. The north flank experienced a slight net gain in sand volume over the observation period, whereas the north far field section experienced a slight net loss. As Figure 5 indicates, the volumetric response of the south far field and the south flank of the structure were reasonably similar. The south far field section appeared too be slightly more sensitive to erosion and accretion events than the south flank. Both far field and the flank experienced a moderate net loss in sand volume over the observation period. Each of the structure flanks and corresponding far field volumes displayed a balanced volumetric response and negligible net change in sand volume over the ten year period.

The beach at C&L Ranch was very stable. The volumetric response of the beach followed a pattern of fluctuation between summer accretion and winter erosion. Erosion events were followed by periods of comparable recovery. The volumetric response of the beach was very similar for Scale I and Scale II, indicating the absence of seasonal features such as berms. The far field baseline comparison indicated that the structure flanks are responding similarly to the beach uninfluenced by the structures presence. The south flank appeared to be more stable than the south far field, and the north flank experienced a net gain in sand volume over the observation period, whereas both far field sections experienced a slight net loss.

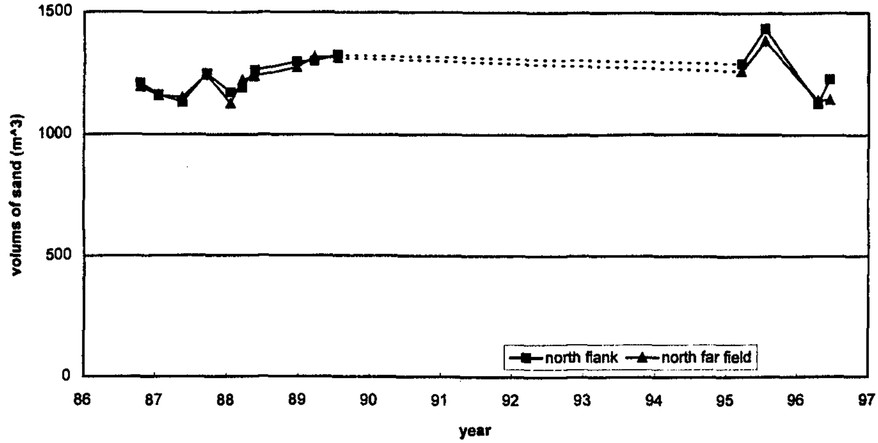

Figure 4 C&L Ranch North Far Field Comparison

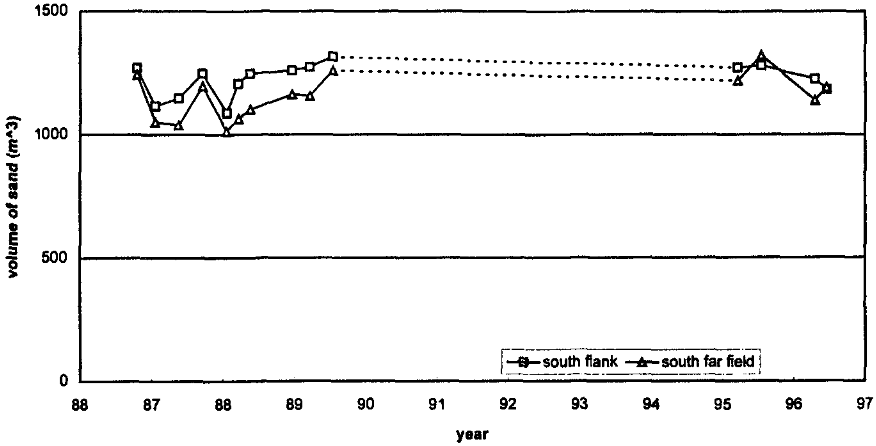

Figure 5 C&L Ranch South Far Field Comparison

Pacific Sands Motel (PSM)

Pacific Sands Motel, located in Neskowin, is the northern most site considered in this study. The structure is a timber seawall fronting the Pacific Sands Motel. The seawall is constructed of railroad ties with limited steel lateral supports and a 4 cm x 25 cm timber cap. The upper portion of the beach is characterized by low dunes with non-continuous low bluffs to the south of the structure. Proposal Rock, located to the south of the structure, is the predominate morphological feature in the area. Evidence suggests that Proposal Rock has a considerable influence on the beach processes at the site, mainly in the formation of a rip current embayment. Concentrated foot traffic at the north end of the seawall results in lower a local dune elevation and sparse vegetation at the foot path, making it difficult to separate structure induced flank erosion from foot traffic induced erosion. Aerial photographs for Pacific Sands Motel show that the coastline has not changed much since the mid-1960's.

Examination of the contour and surface plots reveal that during the summer, generally May through September, when the beaches are subjected to low wave energy, the beach at PSM is characterized by a well defined berm and cusps. The berm is often altered by a rip current embayment formed by the presence of Proposal Rock. During periods of high wave energy, typically November through April, the beach becomes very flat in order to dissipate the increased wave energy. The seawall and dunes are most susceptible to wave attack during these periods.

Figure 3 gives the results of the sand volume calculations for Scale I. Profile data for January 1989 and February 1988 were not used in the Scale I calculations due to insufficient range of coverage. The volume of sand fluctuates between winter lows and summer highs about a slightly increasing mean. The beach experiences a sizable net gain in sand volume over the observation period. The volumetric response of Scale II was very similar to that of Scale I.

Comparison of the volume of sand at the structure flanks with far field control sections, in plots similar to Figures 4 and 5, indicates that the flanks responded less sensitively to seasonal erosion and accretion. This data is presented in a normalized form in Figures 6 and 7. The north flank contained a greater volume of sand than the far field section throughout the observation period. A portion of the north far field control section is located landward of the mean dune line. The dune line tends to migrate seasonally, and at the time of the April 1988 survey the dune line had receded several meters. This results in the +2.40 spike in the V_n/V_{nff} data indicating a much larger volume at the north flank in comparison to the north far field. As shown in Figure 7, the volume of sand at the south flank deviates only slightly from that of the south far field. Sand volumes at the south flank are greater than those of the south far field section over the vast majority of the observation period. The results of the far field baseline comparison indicate that the structure flanks appear to be more stable than far field control sections partially because the seawall tends to stabilize the position of the dune line at its flanks. Overall, the south side of the structure was very stable, and although the north side occasionally underwent large volumetric changes, it was fairly stable over the long-term.

Gleneden (GE)

The Gleneden site is located in the town of Gleneden. The structure is a rubble mound revetment approximately 40 m long. The beach is backed by bluffs approximately 10 m in height. The revetment has two well defined flanks as the structure extends several meters from the bluff. This site provides a good open coast scenario, as the beach extends several miles in either direction without any significant obstructions. A beach access is located approximately 90 m to the south of the structure. A cut, several meters in width, was excavated through a low section of the bluff and partially paved to create this access. The access is significant to the site because a great deal of the storm water runoff from the neighborhood is discharged onto the beach at this point. Depending on the time of year, high flows associated with this runoff scour a creek through the beach face. A considerable volume of sand can be removed through this hydrologic process. Aerial photographs of Gleneden indicate that the coastline has changed little from 1963 to 1983.

The beach at Gleneden is characterized by a well defined berm and cusps in the low wave energy summer months (Komar and McDougal, 1988). A berm of some magnitude usually formed in the early spring and remained until October, however, a slight berm was often present through most of the year. A dominant reflective profile at Gleneden can be partially attributed to the presence of coarser sands on the beach (Shih and Komar, 1994).

The results of the sand volume calculations for Scale I are given in Figure 3. Profile data from January 1989 were not incorporated into the Scale I analysis due to lack of data range in the cross-shore direction. The volumetric response of the beach in Scale I shows the typical pattern of winter erosion followed by summer accretion or recovery. A sizable net loss in sand volume over the observation period had occurred primarily as a result of the severe erosion in May 1996. Recovery from this erosion event indicated from the July 1996 volume was significant, however, this data point probably does not represent full recovery. Oregon experienced a late summer in 1996, and beaches commonly experience accretion well into October.

Due to the drainage area located to the south of the structure, only a north far field control section was utilized for the baseline comparison. Normalized far field comparison data shown in Figures 6 and 7 indicate that the sand volume at the flanks was similar to that of the north far field section throughout the observation period. On average, both the north and south flanks of the structure contained greater volumes than the far field section. During the most severe erosion event recorded over the ten year monitoring period, May 1996, both flanks retained over 10% more sand than the north far field section. This is an indication that the flanks are more stable than the far field control section, and appear to be less sensitive to seasonal fluctuations. Although the beach at Scale I and the far field control section experienced significant net losses in sand volume, the north and south flanks of the structure were not impacted as severely by comparison. The north flank actually recorded a slight net gain in sand volume.

Pacific Palisades (PP)

Pacific Palisades is located just south of Lincoln Beach. The site is on the north side of Fishing Rock, a rocky point of land jutting out approximately 150 m into the ocean. Fishing Rock is not considered a littoral cell boundary, but it does inhibit longshore sediment transport and has a substantial effect on the beach processes at the site. The bluff line north of Fishing Rock forms a crescent shape, indicative of a hooked beach. A rubble mound revetment follows the curve in the bluff for approximately 300 m. The rubble blends into the bluff face and there are no discernible flanks on either end of the structure. The south end of the structure essentially extends to the base of Fishing Rock. The analysis of Pacific Palisades was limited to investigations of Scale I and Scale II. A far field investigation was not feasible considering the crescent shaped backing bluff and the lack of identifiable flanks. Aerial photographs indicate relatively little change in the coastline from 1962 to 1983.

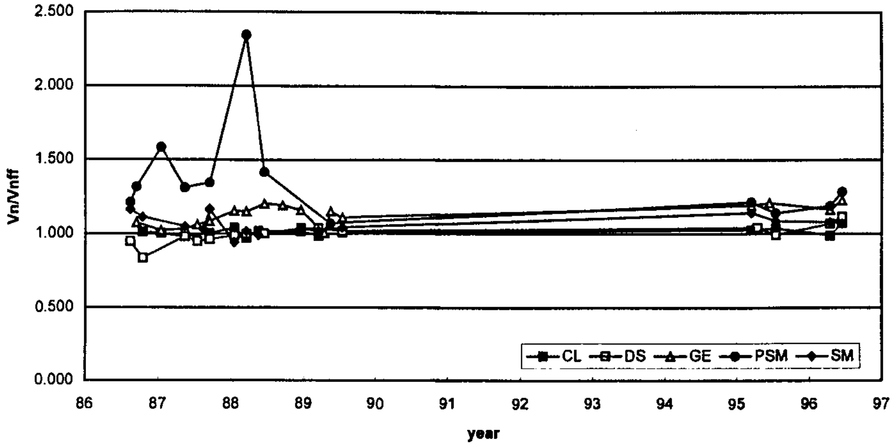

Figure 6 Normalized North Far Field Comparison

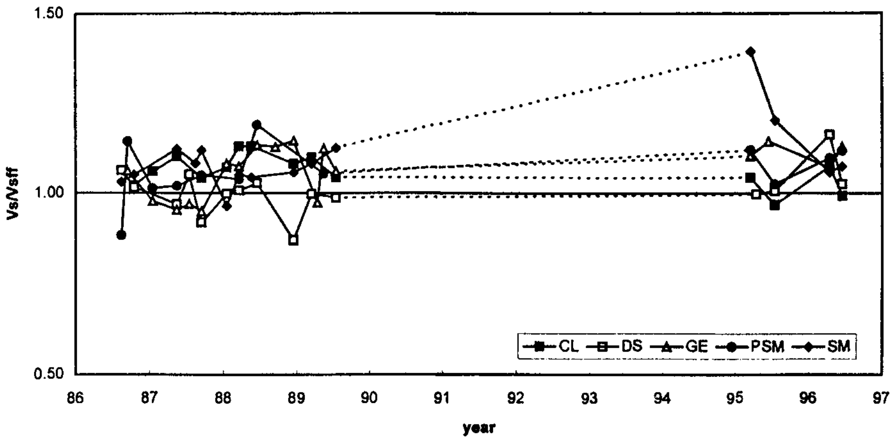

Figure 7 Normalized South Far Field Comparison

When the beach at Pacific Palisades was subjected to low energy waves, usually May through October, the beach was typified by a well defined berm, cusps, and a rip current embayment. The rip current embayment, present throughout most of the year, was most likely caused by Fishing Rock. The sand volume of the beach at Scale I, shown in Figure 3, fluctuates seasonally about a nearly constant mean. The beach experienced a slight net gain in sand volume over the observation period.

Pacific Shores (PS)

Pacific Shores is a sea cliff backed site located approximately three miles south of Newport. The dominant morphological feature at the site is a section of the sea cliff that protrudes further seaward than the adjacent cliffs on either side. This protruding section of cliff, which is probably subjected to wave attach on a regular basis, is composed of an erosion resistant material. The cliff line south of the protrusion, where the structure is located, forms a crescent shape similar to that of Pacific Palisades. The original structure selected for the field monitoring program was a rubble mound revetment measuring approximately 20 m in length. However, since the initiation of the study in 1986, a new 140 m long rubble mound revetment has been constructed immediately north of the original structure. The newer structure was probably built in response to localized land slides which occur at the site. The two structures were not joined together, thus leaving a 15 m gap of unprotected sea cliff between them. The addition of this enormous new structure during the observation period and in such close proximity to the original, smaller, structure made for a complicated analysis. Aerial photographs show that parts of the southern portion of the protruding cliff have been eroded since 1965. It is also possible that parts of the cliff were removed as part of the construction of the newer structure.

The complete chronology of contour and surface plots suggests the beach at Pacific Shores was very flat and planar throughout the year. A summer berm was not present, and there was no evidence of a rip current in any of the surveys. The contour plots did not indicate a trend of sand accumulating in front of any part of the structure. The volumetric response of the beach at Scale I, shown in Figure 3, followed a typical pattern of summer accretion and winter erosion, with the exception of 1989 when the beach experienced a prolonged period of accretion. Ten years of monitoring yielded a negligible net change in sand volume. A far field comparison was not feasible due to the addition of the new structure and the geometric nature of the backing bluff.

San Marine (SM)

San Marine is located between Walport and Yachats. The beach is backed by a low bluff, which is very irregular, containing several indentations and moderately protruding areas along a lengthy front. These are rather small scale features on the bluff, which is essentially shore parallel. The structure is a rubble mound revetment that measures approximately 150 m in length. The bluff line position is several meters further seaward at the structure. The bluff appears to be fairly stable with respect to slides. Aerial photographs for San Marine indicate that the coastline and the bluff were remarkably stable from 1962 to 1983. Several of the unique and irregular features in the bluff, which is composed of an erodable material, are present in both the 1965 and 1983 photos. This suggests that waves seldom reach the bluff line.

The beach at San Marine was very flat and dissipative throughout the year. The majority of the Scale I contour and surface plots indicate a slight rise in elevation near the structure flanks. This slight rise may be attributed to the fact that the bluff is recessed several meters on either side of the structure.

Seasonal fluctuations about a slightly increasing mean are apparent in the volumetric response of the beach at Scale I, Figure 3. The beach at San Marine experienced a considerable net gain in total sand volume over the observation period. This can be attributed to significant recovery following the winter erosion events.

Far field control sections were defined both to the north and south of the structure. Normalized results of the far field comparison, shown in Figures 6 and 7, indicate that the volume of sand at the north flank deviates little from the volume of sand at the far field control section. A trend a increasing volume in the south flank in comparison to the south far field is apparent in Figure 7. This trend can be attributed to a volumetric response about an increasing mean for the south flank, and a volumetric response about a nearly constant mean for the south far field section. Volumes for both the north flank and the north far field section fluctuated about an increasing mean. A gain in net volume over the observation period and the stability of the bluff indicated in the aerial photos suggest that the structure is having no adverse affect on the surrounding beach or adjacent properties.

Driftwood Shores (DS)

Driftwood Shores, the southern most site included in this study, is located at Heceta Beach just north of Florence. The structure is a low rubble mound revetment measuring approximately 30 m in length. There are large dunes to the south of the structure and the area north of the structure is more similar to low hills with heavy vegetation than dunes. The structure is located at a low point in the dune. The backshore area behind the dune is actually lower than the structure and many parts of the upper profile. A house is situated several meters behind the structure. The house is not built in the backshore depression, but is very low relative to the other houses in the vicinity.

The beach exhibits a great deal of local three-dimensionality. The small scale three-dimensionality of the upper portions of the beach appears to be aeolian dominated. The complete chronology of contour and surface plots indicates that the beach was reasonably flat and dissipative during much of the year. The dunes to the south were evident in several of the surveys, but absent in the majority. It was likely that the dunes migrated back and forth in the cross-shore direction during the observation period. There were no typical summer profile features evident in the contour and surface plots, although it was generally in the summer months when the south dunes were present in the contour and surface plots.

The volumetric response of the beach at Scale I, contained in Figure 3, shows seasonal fluctuation about an increasing mean, and a dramatic net increase in sand volume over the observation period. Driftwood shores was the only site which experienced accretion during the May 1996 period. The beach appeared to be gaining sand volume during the active portion of the study, 1986 through 1990, but the most substantial net gain in sand volume occurred between 1990 and 1996. Results from plots similar to Figures 4 and 5 show that the flanks responded nearly identical to the far field section over the ten year period. As indicated in Figures 6 and 7, the flank volumes deviated little from the respective far field volumes throughout the study. Similar to the volumetric response at Scale I, both flanks experienced a considerable net gain in sand volume.

CONCLUSIONS

All seven sites on the Oregon coast behaved in a similar manner. The volumetric response of the beach at each of the sites fluctuated seasonally between low sand volumes in the winter and higher sand volumes in the summer. Considerable recovery following periods of erosion resulted in net gains in sand volume over the observation period at Scale I for three sites (PSM, PP, DS), negligible changes at three site (PS,CL, SM), and a significant net loss in sand volume at only one site (GE).

The structure flanks at each site, including Gleneden, were stable over the observation period.. Sand volumes at the structure flanks deviated little from those of the far field control sections used in the baseline comparison. The average $V_{flank}/V_{far\ field}$ value for all seven sites, regardless of north or south flank, was 1.094 with a coefficient of variance of 0.102. This indicates that the structure flanks were retaining greater volumes of sand over the observation period than the far field control sections. In general, the structure flanks experienced negligible net changes in sand volumes, and often slight net gains in sand volume over the observation period.

There were no significant negative effects caused by the structures at any of the seven sites. This can be attributed to the lack of wave attack that these structures experience (Ruggiero et. al., 1997) The structures were built high on the profile against the base of the bluff or dune. Each site has a wide buffer beach fronting the structure which dissipates the high wave energy found on the Oregon coast and prevents waves from reaching the structure or bluff except during the most severe storms. The structures tend to serve as bluff retention and stabilization structures as much as shore protection structures. Structures built against bluffs appear to be doing an excellent job supporting the bluff and preventing landslides, which can be brought about by undercutting of the bluff or cliff by wave action, but many other non-beach process related factors are also recognized (Komar and Shih, 1994).

When examining the long-term effects of seawalls on beaches, the analysis must be site specific. Susceptibly to wave attack should be considered when permitting or building a shore stabilization structure on the central Oregon coast.

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