CHAPTER 213

THE IMPACTS OF SHORELINE PROTECTION STRUCTURES ON BEACHES ALONG MONTEREY BAY, CALIFORNIA

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Abstract

As a result of severe coastal storm damage in recent years along the California coast and the continuation of development and redevelopment in hazard prone oceanfront areas, large numbers of coastal protection structures have been built. This same trend has been observed on the Atlantic and Gulf coasts as well. At present, fully 12%, or 130 miles of California's 1100 miles of shoreline have been armored. As the number of structures and their coastal frontage has increased, concern along the California coast and elsewhere has arisen in regard to the impacts of these protective structures on the adjacent beaches. Three Atlantic coast states (Maine, New Jersey, and North Carolina) have responded to this concern by establishing state-level policy which prohibits construction of any new "hard" protective structures.

Although considerable laboratory scale research has been carried out on this problem, field work has been extremely limited. A study along the central California coast was initiated in order to resolve some of the most critical questions regarding the impacts of protection structures on beaches. Based on 4 years of precise, biweekly, shore-based surveys in the vicinity of different types of seawalls along the shoreline of northern Monterey Bay along the central California coast, some consistent beach changes have been documented. All of the changes observed to date have been seasonal and are best developed in the fall and winter months during the transition from summer swell to winter storm conditions. The effects or changes documented include:

(1) Loss of summer berm sooner in front of seawalls and revetments

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relative to adjacent unprotected beaches with the onset of winter storm waves.
(2) No significant or consistent differences in the beach profiles at the contact between a vertical impermeable seawall and a permeable revetment despite the apparent differences in permeability and reflectivity.
(3) A lack of significant difference in matured winter profiles seaward of seawalls or revetments relative to adjacent unprotected beaches.
(4) Accelerated berm retreat and beach scour up to 150 m downcoast from seawalls due to a combination of end reflection and upcoast sand impoundment.
(5) Late spring/summer berm rebuilding independent of any protective structure, resulting in a continuous, uniform alongshore berm crest well seaward of the seawall.

Introduction

Much attention of coastal planners is focussed on the impacts of seawalls and revetments on beaches. A body of opinion exists that such impacts are adverse and promote erosion. Pilkey (1981) has asserted that building a seawall dooms the beach in front of it. Other researchers deny this, asserting that such claims are not based on an understanding of coastal processes (Dean, 1988). One reason for recent focus on seawalls is the increased development along our coastlines with a simultaneous increase in demand for coastal protection. Unfortunately, our knowledge of the long- and short-term effects of seawalls on beaches is limited. Planners and decision-makers are becoming more hesitant about granting permits or authorizing funding for such structures while the issue of impacts remains unresolved. One of the principal complaints of the decision-making community is that not only are they being told one thing by some scientists and something else by others, but they are frequently being told different things at different times by the same scientists.

Central to this dilemna is the lack of sufficient field data with which to resolve the claims. Most of our ideas are based on theoretical or laboratory models which have their own limitations. The coastal environment is extremely complex and does not readily lend itself to reductionism. In order to be manageable, mathematical models rely on a number of simplifying assumptions. In the study of seawalls and revetments, such assumptions as infinite length and perfect wave reflection have been used (e.g., Jones, 1975). Similarly, hydraulic models used by engineers (e.g., movable bed experiments conducted in wave tanks or basins) have serious problems with sediment and wave

scale. Even when near-prototype scale wave basins are employed, the waves used are usually monochromatic, or at best unidirectional spectra and three-dimensional processes are not accounted for; in general, reality is oversimplified. Furthermore, the results of such modeling are frequently not checked in the field.

For the most part, the lack of field results is a direct outcome of the large expense in both time and money that such studies require. A number of very good reviews of the seawall problem are now available. Dean (1986) and Everts (1985) have authored speculative synopses which are both comprehensive and well reasoned. Kraus (1988) has reviewed the literature concerning laboratory, field, and theoretical studies and provides an excellent critique. In October, 1986, Griggs and Tait (1988) began a study of beach response to four seawalls along northern Monterey Bay, California (Figure 1). Objectives included:

(1) How do beaches backed by seawalls change seasonally in response to changing wave climate compared to adjacent beaches without seawalls?
(2) What bearing does seawall design have on beach response?
(3) Does the position of the seawall on the beach profile (i.e. farther seaward relative to another structure) exert any effect on seasonal beach changes?
(4) Do seawalls exert alongshore control on beach development, cross-shore control, or both?

Four monitoring sites were initially selected with the objectives of observing different types of protective structures at different locations on the beach profile. Both vertical impermeable seawalls and sloping permeable revetments were monitored. These structures varied in their location from being placed at the base of the seacliff to as far as 75 m seaward on the beach profile. Precise biweekly shore normal surveys were carried out between October 1986 and May 1989. In addition, more frequent winter surveys were carried out at one site during the winter of 1989-1990. Profiles extended either from the seawall or back of the berm offshore as far as feasible using a field assistant in a wet suit (typically to 100 to 150 m offshore to depths of -1 or -2 m MSL).

The profile lines were spaced at 30 m intervals alongshore at locations were seawalls abutted unprotected beaches. A Leitz EDM and pole mounted prism reflector were used for surveys. Approximately 2000 individual profile lines have been surveyed.

The coast of California forms a marked contrast to the Atlantic and Gulf coasts of the United States where other researchers have

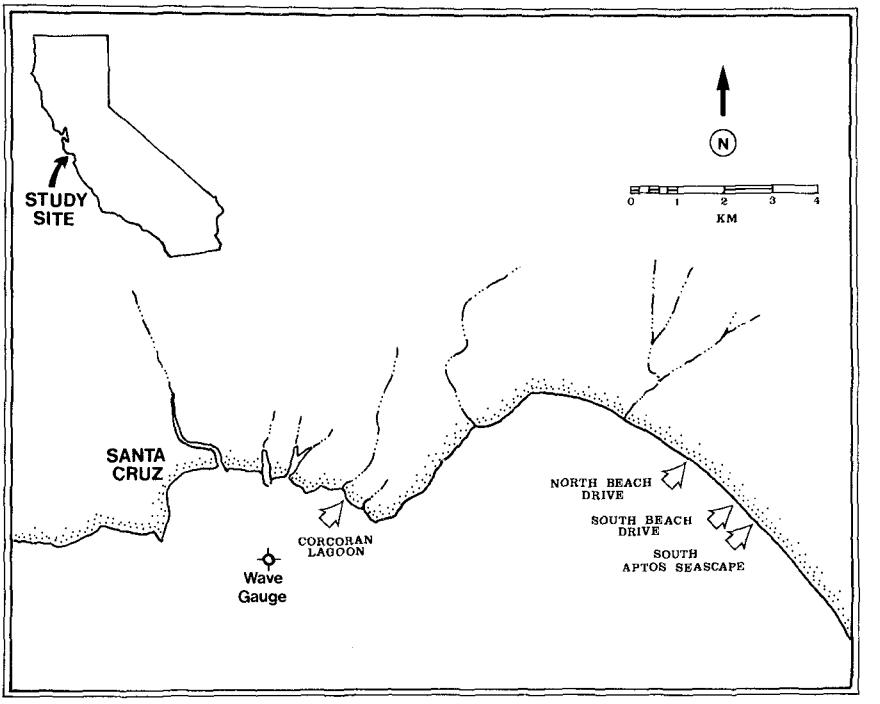

Figure 1. Location map of study area in Monterey Bay, California

carried out some post-hurricane seawall monitoring. The study area in Monterey Bay is fronted by a broad equilibrium beach (Figure 2) which, while undergoing seasonal variations in width, is not undergoing net erosion. The Atlantic and Gulf coasts are typically fronted by barrier islands which are migrating landward in response to sea level rise, and are also subject to hurricane overwash and breaching. Seawalls along these coasts attempt to fix the position of the shoreline on a coast which is otherwise retreating. The long term effects thus appear to be quite different due to basic difference in geomorphic and tectonic setting than the coastline of California.

Beach Response

Beach response is the morphological transformation of a beach due to gradients in sediment transport. Field studies show the response of a beach in front of a seawall to storm waves to be quite variable.The following beach responscs have been observed at seawalls (Figures 3 and 4):

Figure 2. South Aptos Seascape site where beach in front of and up and downcoast from concrete seawall were monitored.

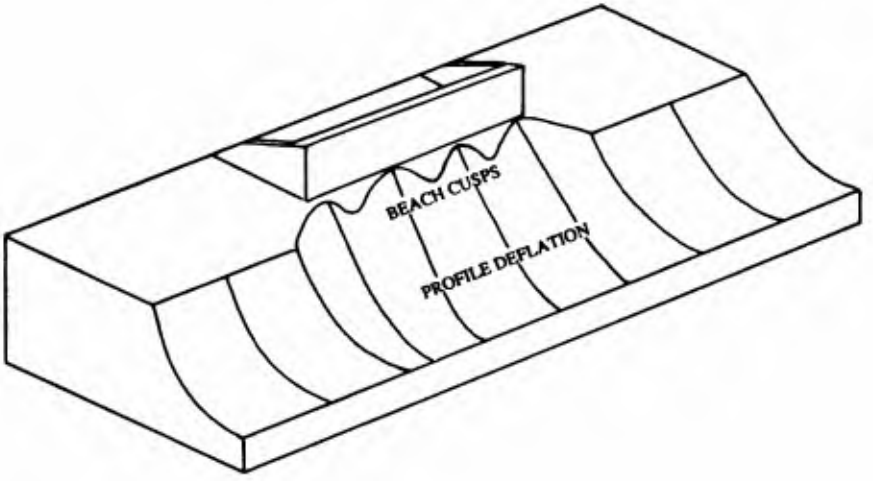

Figure 3. Types of beach response observed by Griggs and Tait (1988) before berm retreats past seawall.

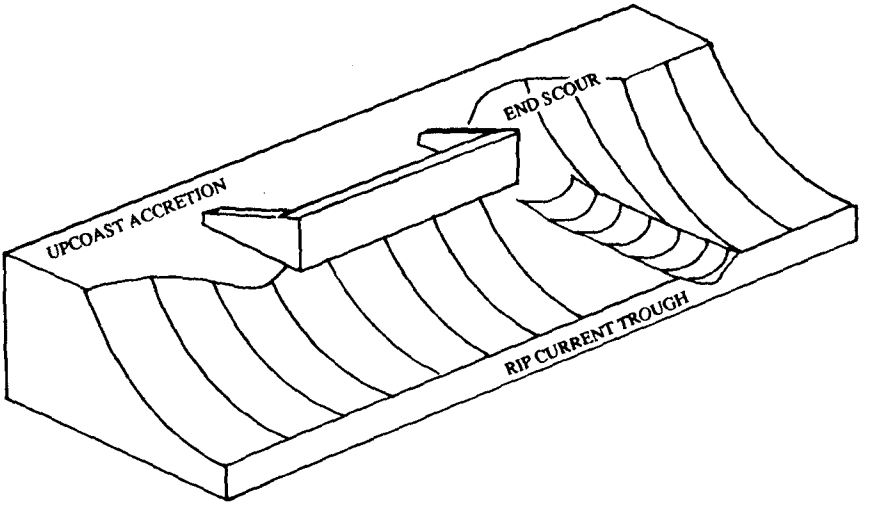

Figure 4. Types of beach response observed by Griggs and Tait (1988) after berm retreats past seawall.

Scour Trough- a linear trough or depression fronting a seawall
Deflated Profile- the lowering or erosion of the beach face
Beach Cusps- crescentic or semi-circular embayments on the beach face
Rip Current Trough- a trough or embayment crossing through the surf zone
End Scour- erosion of the unprotected beach adjacent to the end of a seawall
Upcoast Sand Accretion- the impoundment of sand on the upcoast or updrift end of a structure

Many of the types of beach response can be divided into two broad categories: "frontal effects" and "end effects. Scour trough, deflated profile, and cusping are all examples of "frontal effects". End scour, sometimes referred to as "flanking", and upcoast sand accretion are examples of "end effects". Rip current embayments appear to be a more complicated case, affecting both the profile in front of the wall and the profile alongside the wall. Any of the above may occur as a response to wave-seawall interaction. Or, beach response at a seawall may be indistinguishable from that on neighboring beaches which have not been modified by structures.

Results

A number of consistent beach changes related to the presence of seawalls and revetments have been recognized during the

course of four years of surveying. These are discussed below in a chronological fashion.

(1) SUMMER BEACH CONDITONS: At the start of each new season of monitoring (early fall) the beach at each of the monitoring sites had accreted to the point where the berm was well seaward of the seawall and there was no wave-seawall interaction. The summer berm was continuous alongshore with no deflection or difference in the vicinity of the seawall. Thus, although the summer berm varied somewhat each year in both its seaward extent and height, the beach/seawall system retained no memory of the previous winter conditions.

(2) EROSION OR RETREAT OF SUMMER BERM: During the transition from summer to winter (dissipative to reflective) beach state, the berm is usually cut back sooner in front of the seawalls monitored relative to the adjacent unprotected control beaches. Thus a flatter winter profile is attained sooner in front of the seawalls in contrast to the adjacent beach which will still have a relict summer berm. The difference in elevation between the beach in front of the seawall and the adjacent berm may vary from a few tens of centimeters to over a meter and the berm offset may be up to 12 m (Figure 5). The timing and extent of this premature berm erosion is controlled by the width of the initial summer berm fronting the seawall and the winter wave climate. The berm is typically lost first from those walls which are farthest seaward on the beach profile.

Figure 5. Example of winter berm erosion in front of rip-rap prior to berm removal on adjacent unprotected beach.

It is believed that this premature berm removal is due to wave reflection from the seawalls and revetments at high tide. Waves which overtop a berm of an unmodified beach will expend their energy over the width of the berm, depositing whatever sediment they carry. Waves colliding with a seawall before their energy is spent will be partially reflected and are still capable of scour. An issue of some controversy along the California coast is whether permeable revetments produce less reflection and beach scour and are, therefore, preferable to impermeable seawalls. Although several sites were studied where vertical impermeable concrete seawalls abut sloping permeable revetments, there was no consistent difference in the beach profiles at these sites over three years of monitoring (Figure 6) indicating that under the wave conditions experienced, that the difference in apparent permeability was not a significant factor affecting berm erosion.

(3) WINTER OR STORM PROFILE: As winter waves continued to erode both the seawall backed beach and the unprotected beach, the berm on the unprotected beach retreated until it was landward of the seawall (Figure 7). Once this winter state had been reached there was no significant difference in the profiles between the protected and the unprotected beaches (Figure 8).

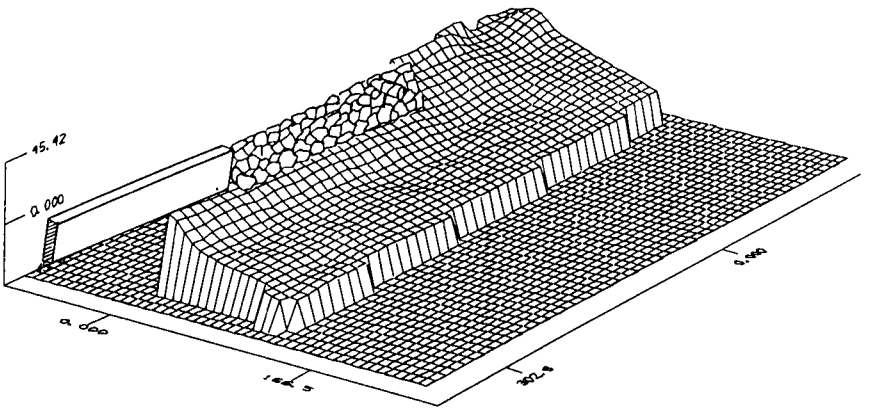

Figure 6. Uniform winter beach conditions at contact between permeable revetment and impermeable seawall.

Figure 7. Early winter conditions. Berm has retreated behind revetment leaving uniform planar beach in front of revetment and control beach.

There has been considerable controversy in recent years regarding whether or not seawalls are resonsible for beach scour. In 4 years of surveying (3 years of biweekly surveying and a year of storm surveying) we have never observed a scour trough directly fronting any of the seawalls studied. Relative to some of the more severe coastal storms of the past decade, however, the winter wave conditions during the four years of monitoring have been only of moderate height (maximum significant wave heights in the range of about 1.5 to 2 m).

(4) END EFFECTS OF SEAWALLS: Direct wave reflection from the end sections of seawalls was commonly observed. As a result of this increased wave energy at the downcoast or downdrift ends of seawalls, an arcuate zone of localized scour typically developed in the winter months which extended downcoast from 50 to 150 m (Figure 9). The downcoast extent of this impact depended upon wave height and wave period or the arrival of the next wave uprush which tended to override and dissipate the reflected wave. Additional factors which appeared to influence this end effect were the end geometry and permeability of the structure, the angle of wave approach, and tidal stage. The extent of end scour was consistently greater at a structure which offered the greatest angle to the incoming wave and which had the most reflective surface.

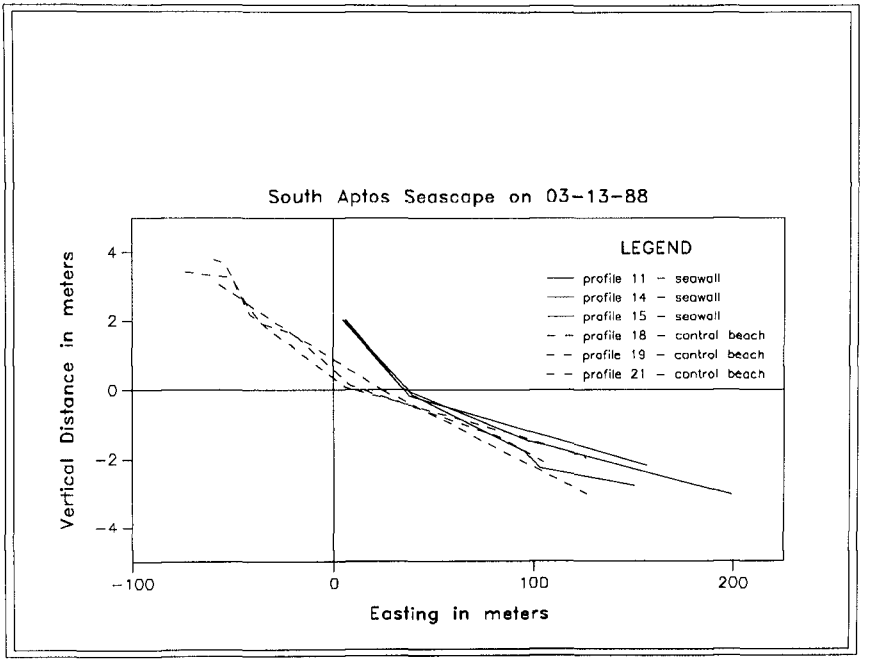

Figure 8. Winter profiles at Aptos Seascape site showing similarity in beach fronting seawall (profiles 11-15) and control beach (profiles 18-21).

Upcoast sand accretion counteracted the modest increased scour at the downcoast end of the structures. The significance of this groin effect or upcoast accretion is dependent upon the location of the seawall on the beach profile and the winter position of the berm crest relative to the seawall.

(5) RECONSTRUCTION OF SUMMER BERM: With the change from winter to spring and summer wave conditions, the berms in the study area begain to rebuild during May and June, a process which continued into July and August. Sequential biweekly surveys of this accretionary phase indicate that the berm on the unprotected beach advances seaward until it reaches the seawall, and then the berm in front of both seawall and adjacent beach advance together (Figure 10). Thus, while the winter erosional phase of the seasonal beach cycle was influenced to some degree by the presence of the seawall, this was not the case for the summer accretionary or rebuilding phase. At the end of this reconstruction phase a uniform alongshore berm crest exists well seaward of the seawalls.

Figure 9. Localized scour adjacent to downcoast end of seawall.

Discussion

Overall, relatively little field research has been conducted on the problem of beach-seawall interactions. The few studies to date indicate that beach response can be variable with a number of processes at work and with the factors controlling the type and magnitude of beach response interdependent (Tait and Griggs, 1990). Kriebel et al (1986), for example, noted the presence of a scour trough in front of a vertical impermeable seawall during hurricane conditions. In this study, on the other hand, we never encountered a trough in front of any of the seawalls or revetments monitored, but instead observed a more rapid retreat of the summer berm. We have observed downdrift scour, yet Kriebel et al (1986) observed no flanking in a downdrift area where it was expected. Both of these studies, however, found that beach recovery was approximately as rapid in front of seawalls as it was on adjacent natural beaches.

Beach response to seawalls appears to be variable because of the number of factors involved; furthermore, these factors are interrelated, and each factor influences other controlling factors. Attempts to assess the potential impacts of a seawall on a beach should be site specific. The following basic controls appear to be important in governing seawall-beach interactions (Tait and Griggs, 1990):

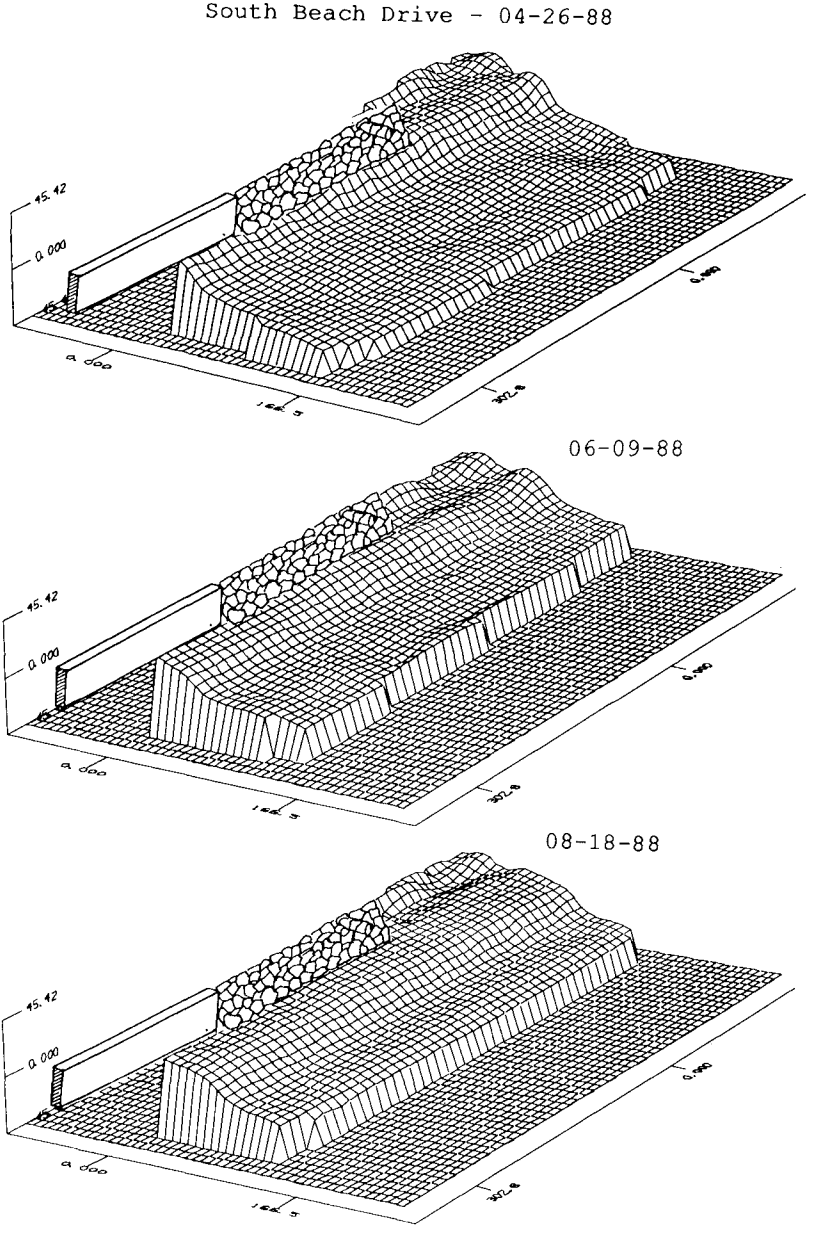

Figure 10. Spring/summer berm reconstruction with no seawall effect.

(1) Longterm shoreline trends
(2) Position of seawall on the beach profile
(3) Coastal Geomorphology
(4) Sediment supply/beach width
(5) Offshore gradient/width of surf zone
(6) Wave energy and exposure
(7) Seawall design (height, permeability, slope)
(8) Length of seawall

More studies are needed, particularly on the Atlantic and Gulf coasts where the beach/seawall controversy has reached a peak. Most of the processes and controls involved in beach/seawall interaction have not been measured in the field. Measurements of parameters such as suspended sediment concentration, sediment transport, nearshore current fields, and beach water table levels in the vicinity of seawalls are necessary before beach/seawall interactions can be predicted with any confidence. Kraus (1988) makes some excellent suggestions for future seawall studies and monitoring programs. To underscore the speculative nature of the processes currently being associated with beach/seawall interactions, Dean (1986) points out that a rational argument, based on momentum flux considerations, can be advanced to show that increased wave reflection at a seawall actually reduces sediment transport.

Acknowledgements

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