CHAPTER 97

The Effect of Seawalls on Long-Term Shoreline Change Rates for the Southern Virginia Ocean Coastline

David R. Basco[1]

Abstract

This paper examines the relationship between the off shore bathymetry, resulting wave climate, shore boundary conditions (i.e., seawalled versus dune/beach sections) and the shoreline response as represented by long-term shoreline change rates over 120 years for the southern Virginia ocean coastline in the United States. Along the tourist area of the City of Virginia Beach, the data supports the conclusion that a seawall's presence for over 50 years has produced no significant increase in the recession rate. The highest recession rate (3m/yr) occurs at the Sandbridge sector further south. Some now claim that the beach width is narrowing at Sandbridge as a result of recent seawall construction. This allegation completely ignores the root cause of the problem which is shown in this paper to be the steep offshore bathymetry and high wave energy in this region. If we neglect the offshore boundary conditions when making field studies of "hardfacing" versus dune/beach sections, we can reach completely erroneous results.

1.0 Introduction

Coastlines are either stable, accreting or receding when viewed on a long term basis relative to some *fixed* reference. For example, the City of Virginia Beach along the southern Virginia ocean coastline (Fig. 1) exhibits all three shoreline trends as described in detail below. There are numerous reasons for coastline recession, both natural and human-induced. Some form of shore protection

---

[1]Professor of Civil Engineering and Director of the Coastal Engineering Institute, Old Dominion University, Norfolk, VA 23529.

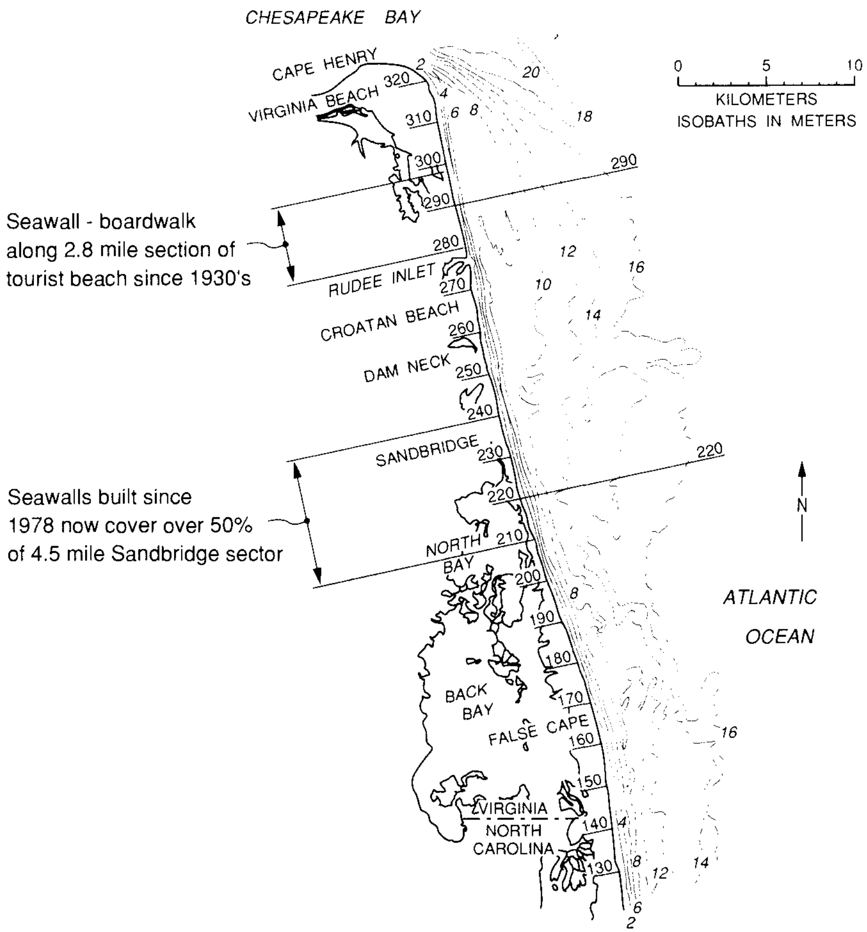

Fig. 1 Coastal Area and Bathymetry of the Study Region. (adapted from Wright et al., 1987)

measure is often undertaken when the shoreline recession threatens permanent resources (roads, bridges, buildings, etc.) and if the benefits exceed the costs over the design life of the project.

Three engineering options exist for shore protection: (1)natural defenses including strengthening dunes and beach renourishment; (2)sand trapping systems to widen beaches; and (3)coastal armoring; combinations are also possible. Coastal armoring includes seawalls, bulkheads and revetments, but all such coastal armoring structures will be referred to as "seawalls". Seawalls are usually constructed along developed shorelines experiencing a recessional trend *and* subject to storm-induced water level rise with accompanying wave energy. In many cases, recreational beaches are also present.

The degree to which a seawall affects the adjacent beach is the focus of much recent attention (e.g., Kraus and Pilkey, 1989, editors). Various allegations on the adverse effects of seawalls on beaches have been made and claimed as common knowledge (without reference). Statements such as "...the seawalls destroyed the beach"; "...bulkheads stir up wave action and increase erosion"; "...costly seawalls and jetties actually increase erosion"; "...bulkheading (does) more damage than it prevents"; "...bulkheads hasten the erosion of surrounding beaches"; etc. have been attributed to "coastal scientists". The most sweeping allegation of all is the claim that "...seawalls actually increase erosion and destroy the beach" (Pilkey and Wright, 1988). These allegations stem from an over emphasis on the land boundary conditions (i.e., "hardfacing" -vs- dune/beach "soft" boundaries) and consequently the almost total neglect of the *offshore* boundary conditions when discussing shoreline change. These allegations also stem from the "migration barrier beach paradigm" as discussed below.

In this paper, we examine the relationship between the offshore bathymetry, nearshore wave climate, type of landward boundary, and shoreline response as represented by long-term shoreline change rates based on over 127 years of survey records for the southern Virginia ocean coastline. Shoreline change rate data both before and after seawall construction are examined to determine if there is a discernable increase in long-term erosion rate in front of the seawalls. Shorter term variability and changes measured immediately after storms are also of concern but are not considered in this paper.

2.0 Boundary Conditions At Virginia Beach, Virginia

2.1 Offshore Boundary Conditions

The southern Virginia ocean coastline (Fig. 1) is all within the political jurisdiction of the City of Virginia Beach. It extends over 26 miles from Cape Henry at the north on the lower edge of the entrance to the Chesapeake Bay to the border of Virginia and North Carolina (latitude 36° 33').

2.11 Bathymetry. A three-dimensional, perspective plot of the nearshore bathymetry for over 6000m seaward to depths beyond -15m (MSL) is presented as Fig. 2. The off shore bathymetry is irregular. A relatively broad, flat region is found adjacent to the tourist part of the City (labeled Virginia Beach) resulting in the -9m contour almost 4000m seaward. This -9m depth contour gradually moves closer to shore as the beach profile steepens further south. At the section labeled Sandbridge (a subdivision of the City) the profile is the steepest with -9m being found only about 1200m offshore. Continuing further south, the profile again flattens and a large, permanent offshore bar feature is found at False Cape. Putting sections A & B together reveals the continued variability in nearshore bathymetry along the study region.

The -9m depth is approximately the "closure depth" for the existing wave climate and sand gain size in this area. Beach profiles in the northern end (e.g. Section 290) are flatter and those at Sandbridge (e.g. Section 220) are steeper that the equilibrium shape for the representative sand grain size. Tidal currents through the entrance to Chesapeake Bay are an important factor in shaping local bathrymetry as is the existing wave climate and its interaction with the tidal currents.

2.12 Wave Height Variation. The figures above are adapted from a recent report by the Virginia Institute of Marine Science (Wright et al., 1987) in which a computer model was used to transform ocean waves moving toward the shoreline from the northeast, east and southeasterly directions. The RCPWAVE code (Ebersole et al., 1986) was modified to include bottom friction, if desired. Fig. 3 is one example (Wright et al., 1987, p.61) for a deep water wave height of 2.1m and 8 sec period from the northeast and shows the three-dimensional perspective plot of wave height variation everywhere in the computational domain (60 x 160 grid with Δx=100m offshore and Δy=250m alongshore). The trends along the beach for

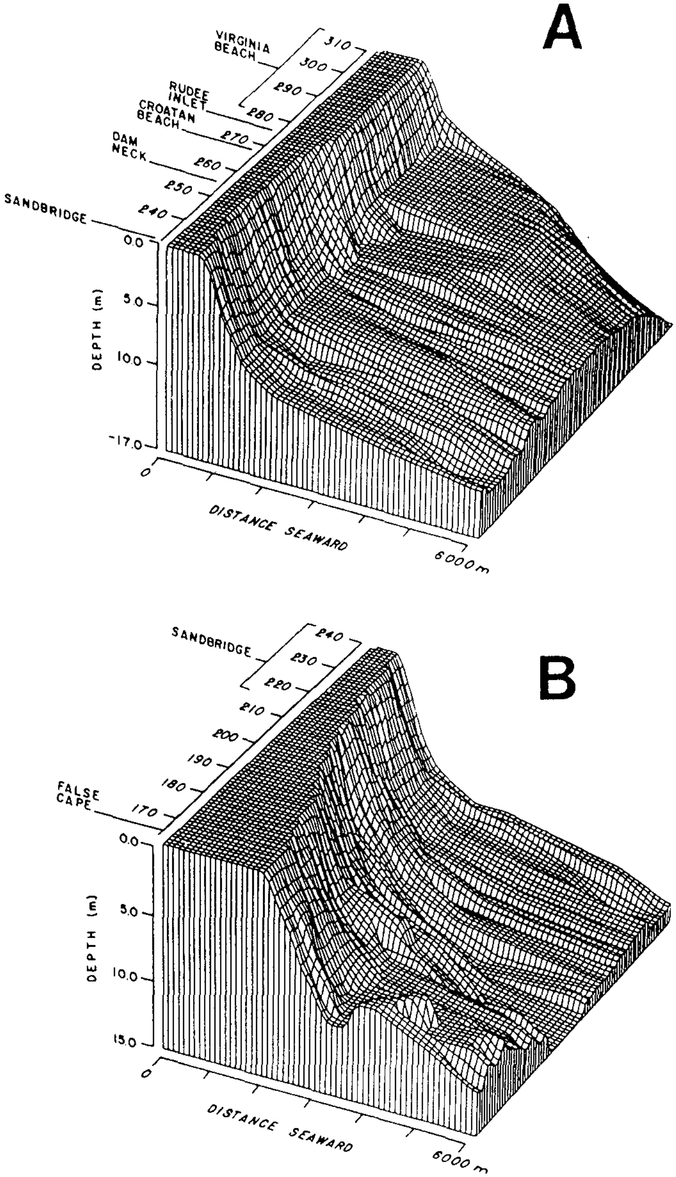

Fig. 2 The Study Region Bathymetry in 3-D Perspective and Split into a Northern (A) and Southern (B) Sector (adapted from Wright et al., 1987).

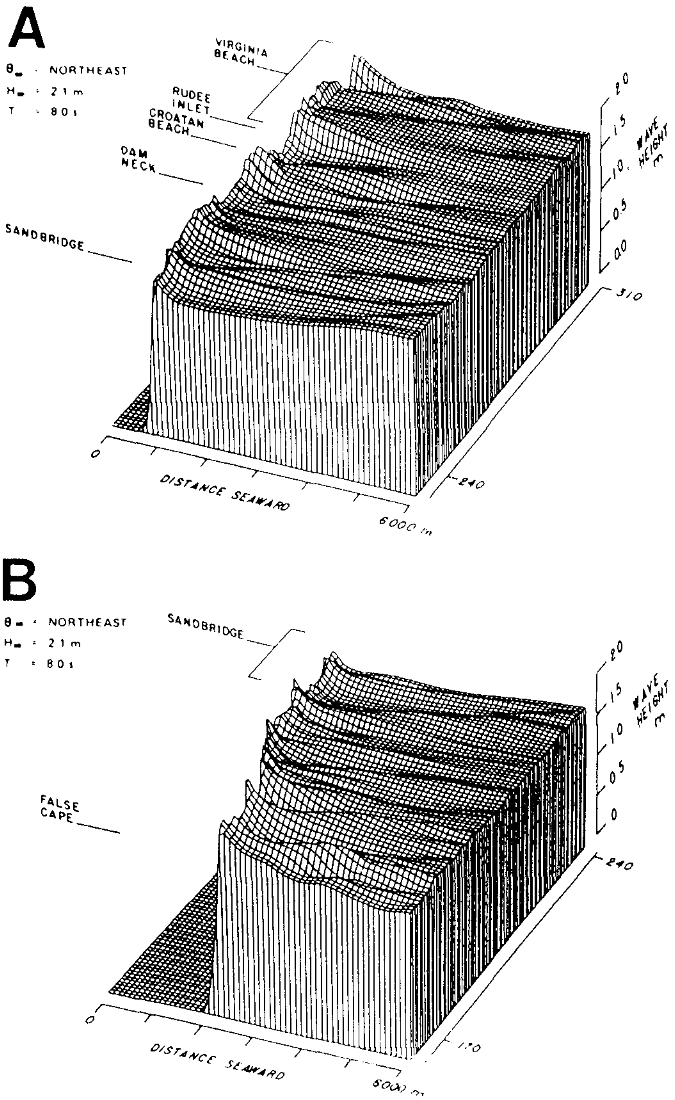

Fig. 3 Spatial Wave Height Variations for the Study Region As Predicted by the RCPWAVE Computer Code With No Bottom Friction. The Wave Conditions Are for a Typical Northeaster (adapted from Wright et al., 1987).

breaking wave height vary considerably but generally show H_b increasing along the Sandbridge sector relative to the northern and southern sectors. These results are with no bottom friction in the model.

Wright et al. (1987) considered the possibility for 55 different wave climate combinations (deepwater height, period, dominant direction) as measured in 1982 at the Corps of Engineers, Field Research Facility pier some 65 miles south of Virginia Beach. The computer model was run for these 55 cases, breaking wave height variations calculated along the coastline and then averaged together. The overall average breaking wave height calculated for the entire study region was 0.58m in 1982. The *relative* variation of breaking wave height along the shoreline from north(top) to south(bottom) when compared with the overall average is plotted in Fig. 4(rightside). These trends in breaker wave height are consistent with the variation in bathymetry. Higher wave energy at Sandbridge is expected because the deeper, offshore contours are closer to shore at Sandbridge.

2.2 Landward Boundary Conditions

The landward side of the shoreline consists of a sandy beach with natural and artificially created dunes, a small, stabilized tidal inlet and seawalls (with boardwalk) along some regions.

2.21 Seawalled Sections. Seawalls are found in two areas of Virginia Beach as shown in Fig. 1. Along the northern, tourist/resort beach, a seawall/boardwalk structure exists as illustrated in the Corps, Shore Protection Manual (1984), Vol II, p6-7) between Rudee Inlet and 49th Street. Private property seawalls further north extend the length of seawalled beach to about 2.8 miles. Some type of "hardfacing" structure with boardwalk has existed in this location since the 1930's*. Over 3 million people use this beach area during the three primary summer months of the tourist season.

Further south at Sandbridge, seawall construction began in 1978 to protect private property of individual lot owners as year-around residents or renters. Construction

---

*An 1887 photograph of the Princess Anne Hotel at the tourist beach location showed an extensive length of vertical pile seawall about 5-6ft in elevation above the beach face.

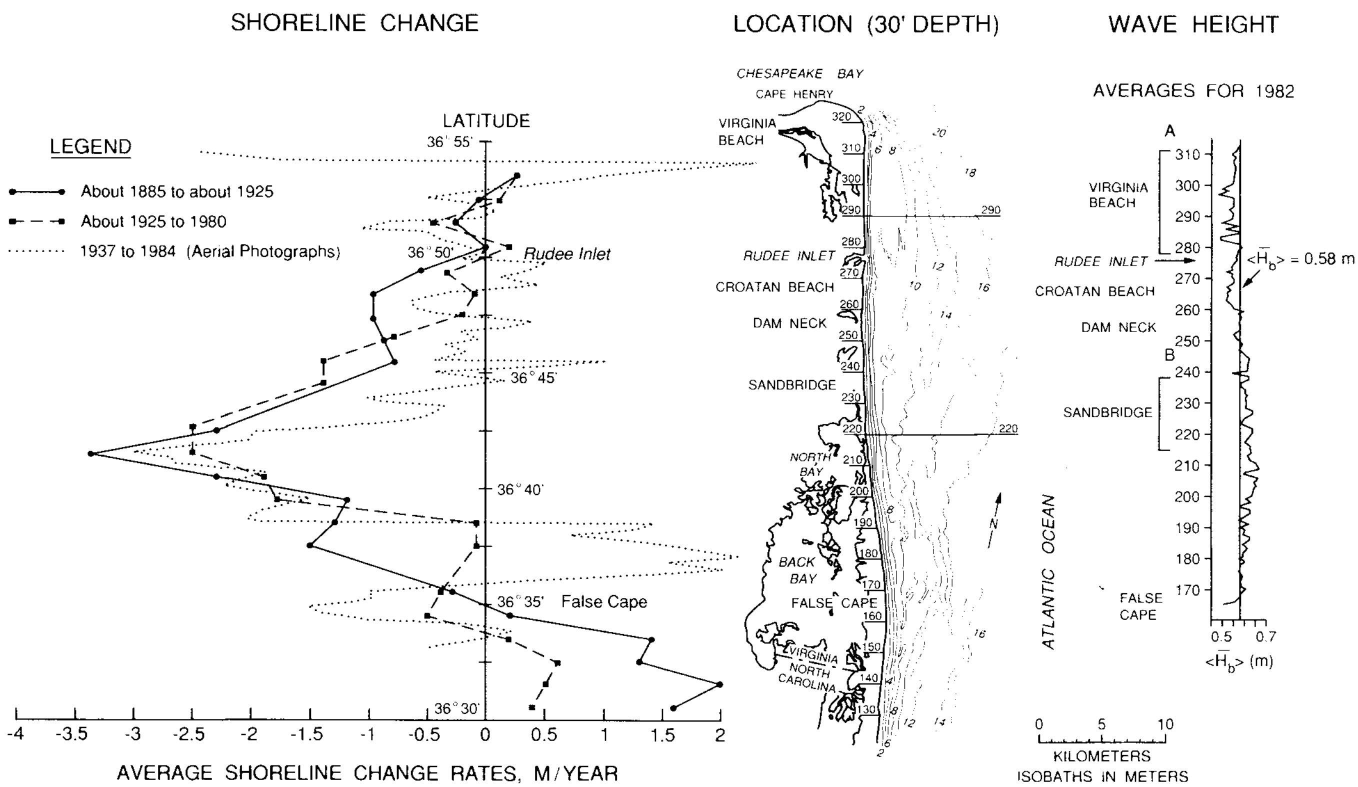

Fig. 4 Composite of Shoreline Change Rates(left), Bathymetry(center) and Breaking Wave Heights(right) and Their Variation Along the 25-mile Atlantic Ocean Coastline of the City of Virginia Beach, Virginia

has accelerated in recent years so that presently, over 50% of the 4.5 mile stretch has vertical, sheet-pile (steel, timber, concrete) bulkhead protection.

2.22 Rudee Inlet. An extremely small water body (Lakes' Rudee and Wesley) is open to the Atlantic Ocean through Rudee Inlet which was fixed in position by two, very short, rock jetties in 1953. Inlet bypassing from south to north and channel maintenance by fixed and floating dredging plant (hydraulic cutterhead and jet-pump systems) occurs each year averaging about 100,000cy per year. The short length of the jetties permits natural inlet bypassing in both directions and results in an accretional beach for less than 500 ft on *both* sides of the inlet. Consequently, these natural and artificial sand transport systems and the small scale of the tidal flows and jetties produce only local, minor changes along the landward boundary at this location.

2.23 Beach Renourishment. Since 1951, over 10.6 million cy of sandy material (including Rudee Inlet bypassing) has been deposited on the resort strip between Rudee Inlet and about 45th street. The average amount per year (0.27 M cy) is about 5 percent of the total active sand volume (envelope between erosional and accretioned profiles out to the closure depth) in this region. Net sediment transport to the north has changed the shoreline position in this region over the last 40 years as discussed below. Most references consider Sandbridge a nodal point for net sediment transport direction.

3.0 Shoreline Movements

3.1 Long-Term Average Shoreline Change Rates

3.11 Cartographic Information. Federal government surveys and resulting cartographic information has been used by Everts et al., (1983) to calculate the long-term average shoreline change *rates* in m/yr for 122 years of data as shown in Fig. 4 (far left side). The vertical scale (latitude) coincides with the shoreline location with Cape Henry at the top and the Virginia/NC border at the bottom. Accretion is to the right of zero and recession rates are shown to the left of zero (stable shoreline position) on the horizontal axis.

For a 67 year period between 1858-1925, the solid line reveals some accretion in the far north, a slightly receding shoreline along the tourist beach to Rudee Inlet, considerably recession exceeding 3 m/yr at Sandbridge and then the reverse trends with considerable accretion (2m/yr) further south at False Cape and beyond the border.

For the next 55 year averaging period (1925-1980) as shown by the dashed line, the trends are very similar or less extreme in all locations. Further refinement by Everts et al., (1983) for the north end above Rudee Inlet using 10-15 years averaging intervals between 1925-1980 reveals increasing accretional rates with time and reflects the last 40 years of beach renourishment with net northerly drift.

3.12 Aerial Photographs. Dolan(1985) used historical aerial photographs between 1937 and 1984 (47 years) to determine long-term average change rates along this same coastline. These results are shown as the fine dotted line in Fig. 4 (far left side). The overall patterns are generally similar. Additional accretional reachs below Rudee Inlet and above Sandbridge may be due to some southerly movement of renourishment materials since 1952. The location and magnitude of the highest recessional rates at Sandbridge are confirmed by these results. The greatest differences in change rates between the mapped and photographically deduced data are found in the False Cape region. No explanation is offered for these discrepancies.

3.2 Short Term and Storm Effects

The results above are for average shoreline movement over very long time intervals. Shorter term "average" variability, seasonal changes and those occurring immediately after storms are also of concern. A study has recently begun at Sandbridge with the goal to investigate shorter term and storm term related effects of seawalls and beaches (Basco, 1990a).

4.0 Boundary Conditions and Shoreline Response

4.1 Virginia Beach, Virginia

Fig. 4 compares the (*i*)variability of offshore bathymetry and seawall locations (center)(*ii*)the variability in breaking wave height (far right) and the (*iii*)variability of long-term shoreline change rates (far left) on the same vertical scale. We must consider *both* the offshore and the landward boundary conditions when discussing shoreline change. For Virginia Beach, Virginia there exists a strong cause-effect relationship between offshore bathymetry (*i.e.*,profile steepness), breaking wave height variation, and long-term shoreline response.

For the tourist section above Rudee Inlet, a comparison of pre-seawall recession rates (67 years, 1858-1925) and post-seawall recession rates (55 yrs, 1925-1980) allows us the opportunity to tentatively conclude that a seawall/boardwalk for over 50 years has produced no *significant* change in long term shoreline trends. This conclusion admits some shorter term variably in the data, accuracy of rate estimates and beach renourishment.

At Sandbridge, seawalls have only existed for a relatively short time period. About 90% of the total coverage (2.3 miles) had been constructed since 1986. One thing is clear, however. Seawalls are not responsible for over 130 years of steady shoreline recession of about 3m/yr. To argue now that the beach width is narrowing at Sandbridge as a result of the recent acceleration of seawall construction is to completely ignore the root cause of the problem.

4.2 General

Attempts to develop generalized boundary conditions landward, seaward and along the bottom that influence shoreline position and adjacent subaerial beach response are underway. Weggel has suggested a classification system (Weggel, 1988, p.36) involving six seawall "types" which depend on the *location* of the seawall with respect to the shoreline. During storm surge events on some coasts, all six "types" or locations could be realized when variable water levels are experienced.

The subsurface boundary is only of recent interest. Drain pipes to artificially lower the water table have produced stable or accretional shorelines in some locations that were previously recessional. More study is needed of the local water table effects on shoreline change rates.

5.0 Barrier Beaches and Adjacent Back Bay Systems

5.1 Barrier Beach Migration Paradigm

Barrier beaches are nature's mechanism for protecting the bays, lagoons, and estuaries that lie behind them. The reduced wave energy environment permits the retention of cohesive sediments and grasses to survive in the tidal marsh areas. Since the 1950's, coastal geologists have done a outstanding job of explaining the migrating nature of barrier beach systems. These educational efforts have influenced public policy regarding development on migrating barrier islands. In short, the beach migration paradigm says:

> 'Let the barriers migrate landward. All efforts to stabilize migration are "economically unsound" in the long run when *only* the value of property built *on* the barrier is considered. The gonvernment should not subsidize an "economically unsound" policy'.

The first *road* built on a migrating barrier island becomes a fixed reference line to measure shoreline movements. Barriers migrating landward (transgression) create recessional shoreline movements. Simply put, the distance from the shoreline to the reference line (e.g. road centerline) decreases each year. Efforts to maintain the road at its fixed position result in shrinking beach widths when the road gets close enough to the shoreline. Is the road "... increasing erosion and destroying the beach"?

The presence of the road permits easy access by car, development for commercial, residential and recreational use and when economical, seawall construction to protect upland resources including public facilities. The distance from the shoreline to the seawall (new reference line) continues to *decrease* each year. Is the "... seawall increasing erosion and destroying the beach"?

As shown in this paper, some coastlines are receding at some locations due to offshore boundary conditions causing wave energy focusing and excess erosional stress. Not all coastlines are potected by barrier islands. And, as conclude by Leatherman, 1988 (p.63):

> " Overwash is *not* the dominant process by which *most* barriers move landward since the amount of sediment transported by this means is too small. Inlet formation, when tidal currents cut a channel below sea level, moves far greater quantities of sediment into a lagoon over the long term and is the major process for barrier migration" (p.63).

It is thus clear to the writer that much blame placed on sewwalls for shrinking beach widths and disappearing beaches is ill-founded.

5.2 Loss of Tidal Marshes in Back Bay Systems

We need to consider the barrier island *and* the estuarine-bay-lagoon-system behind the migrating island as an integrated whole. Since the 1950's a wetlands value paradigm for public policy has evolved that says in short:

> 'America's wetlands are diminishing. Alterations must be monitored and any losses mitigated to conserve existing wetlands. The government is opposed to all destruction of coastal marshes.'

Basco (1990b) discusses the conflict produced by migrating barrier islands that shrink wetlands and calls for an expanded, elevated and shifted new paradign for public policy decisions that includes the total value of whats *behind* and *on* the moving barrier islands in the coastal zone.

6.0 Conclusions

No discernable increase in long-term average shoreline change rate has occured over a 2.8 mile stretch of Virginia Beach when considering data prior to seawall construction (1858-1925) and in subsequent years (1925-1980) when seawalls have existed. The long-term average change rate in this tourist/resort strip area of the city is about 0.4m/yr recession.

At Sandbridge, fourteen miles south, the 127 year data average (all sources) is about 3m/yr recession. This is attributed to offshore boundary conditions producing an excess erosional stress and a nodal point for sediment transport at this location. Recent seawall construction at Sandbridge (since 1978) provides a new reference line to measure shrinking distances from the shoreline to the seawall. The presence of the seawall is not responsible for a long-term average shoreline change rate of -3m/yr. Only long-term data at this location will provide the necessary evidence to determine if the walls create a recession rate exceeding -3m/yr. Little is known about the proper averaging time necessary to remove short-term variability from the long-term trend.

If we neglect the offshore boundary conditions when making field studies of "hardfacing" sections of coastlines versus "soft" sections and erosion rates, we can reach completely misleading results. As a positive first step toward understanding how seawalls and beaches interact, the science and coastal engineering community must insist upon more complete documentation of field studies when reported in the literature and at conference proceedings.

References

Basco, D.R. (1990a) "The Interactions of Seawalls and Beaches at Sandbridge Beach, Virginia", Research Proposal for USAE, WES, CERC, Vicksburg, MS.

Basco, D.R. (1990b) "On the Loss of Estuarine Bay Areas Due to Barrier Island Migration", Proceedings, *The Coastal Society*, Oct. (in press).

Dolan, R.H. (1985) *Sandbridge Beach and Back Bay Virginia*, Tech Report, Coastal Research Assoc., Inc., Charlottesville, VA, 120p.

Ebersole B.A., et al. (1983) *Regional Coastal Processes Numerical Modeling System, Rept. 1, RCPWAVE,* Tech Rept. CERC-86-4, WES, Vicksburg, MS March, 150p.

Everts, Craig H., et al. (1983) *Shoreline Movements: Cape Henry, Virginia to Cape Hatteras, North Carolina, 1849-1980*, Rept. No.1, Tech. Rept, CERC-83-1, WES, Vicksburg, MS, July, 123p.

Kraus, N.C. and O.H. Pilkey (editors), (1988) "The Effects of Seawalls on the Beach", *Journal of Coastal Research,* Spec.Iss., No.4, Autumn.

Leatherman, S.P. (1988) *Barrier Island Handbook,* Laboratory, for Coastal Research, U. of Maryland, College Park, MD, Third Edit, 92p.

Pilkey, O.H. and Wright, H.L.,III; (1988) "Seawalls Versus Beaches", *Journal of Coastal Research,* Spec. Iss. No.4, pp.41-66.

Shore Protection Manual (1984), USAE, Vol.II, US Govt. Printing Office, Washington, DC.

Weggel, J.R. (1988) "Seawalls: The Need for Research, Dimensional Considerations and a Suggested Classification", *Journal of Coastal Research*, Spec. Iss. No.4, pp.29-39

Wright, L.D., et al. (1987) *Shoreline and Beach Dynamics of the Coastal Region from Cape Henry to False Cape, Virginia*, Virginia Institute of Marine Science, Tech. Rept., September., 105p.