Coastal Engineering Technical Note

DETERMINING LENGTHS OF RETURN WALLS

PROBLEM: In order for a coastal structure such as a seawall or a bulkhead to function effectively throughout its design life, its ends should be tied to adjacent structures or extended landward far enough to prevent flanking which could cause the loss of backfill and the possible failure of the structure. The distinction between seawalls and bulkheads is mainly a matter of the structure's purposes. The primary uses of seawalls are to resist wave forces, while the purpose of bulkheads is to retain fill. Presented here is a method of determining the length of return walls (also called wing walls or end walls) at the ends of vertically-faced coastal structures, primarily seawalls and bulkheads. This method was developed for use on Florida's shores, but the basic method can be used with locally-gathered data for design of return walls elsewhere.

SOURCE OF METHOD: The Florida method, developed by Walton and Sensabaugh (1979), combines methods of determining the post-storm profile of an unprotected beach and the local shoreline recession adjacent to the ends of a vertically-faced structure. The Florida method is based on extensive stereo-aerial photographic and ground surveys taken of Panama City Beach before and after Hurricane Eloise hit the coast between Fort Walton Beach and Panama City in September 1975. The method was created to provide design guidance for repair of concrete sheet-pile seawalls damaged in that storm. This CETN combines the Florida method with the method of determining the profile after long-term erosion, which is given in Chapter 5, Section II-8 of the Shore Protection Manual (SPM 1984).

THE SITE: The offshore profile at Panama City Beach exhibits a steeper shoreface and deeper offshore ramp than other sites along the western Florida coast, as shown in Everts (1978). Because of the depth nearshore, Panama City Beach is exposed to a higher-energy wave climate than other Florida Gulf shores, resembling sites on the US Atlantic coast. The beach material at

Panama City Beach is clean quartz sand with a median diameter of 0.3 to 0.4 mm. Prior to Hurricane Eloise, the dunes were well developed and, in most places, had not been damaged by encroaching buildings and parking lots. The seawalls and bulkheads along the beach generally were of uniform height, their tops being near 10 ft above mean sea level (MSL). Panama City Beach has a diurnal tide range of 1.3 ft.

THE STORM: Hurricane Eloise, with sustained windspeeds of at least 110 knots and gusts up to 135 knots, was a Category 3 storm on the National Weather Service Saffir/Simpson Scale (Burdin 1977). When it hit the coast, the 20-mile diameter eye was traveling at 23 knots, a relatively rapid pace.

Corps surveys indicate a surge of 15 to 16 ft above MSL where the damage was worst. Because of the absence of wave gages in the area, the storm's wave heights are unknown.

The seawalls and bulkheads were overtopped, but generally the dunes were not. Some seawalls and bulkheads were flanked. There was a 50-ft recession of the dune line, but the large volume of sand removed from the dunes produced a seaward movement of the MSL contour. The difference in sand elevation on the up- and downcoast sides of structures was small, implying that there was little longshore transport associated with the storm despite the large volume moved offshore.

FORMULATION OF THE METHOD: The Florida method's construction of a structure-free, poststorm profile was based on comparison of surveyed pre- and post-storm profiles from areas without structures. The effect of seawalls and bulkheads was evaluated by using stereo-aerial photogrammetry to make pre- and poststorm contour maps of beaches surrounding these structures. For each site, at least two points on the contour matching the elevation of the structure top were located: one in an area exhibiting no influence by structures and the other near the structure at the most landward point on the contour. The distances of the two points from a common baseline running parallel to the shore were measured, and the difference was considered to be the additional recession of the contour due to the presence of the wall. This added recession r' was plotted as a function of structure length, and a curve was drawn through the data points for design use, as shown in Figure 1.

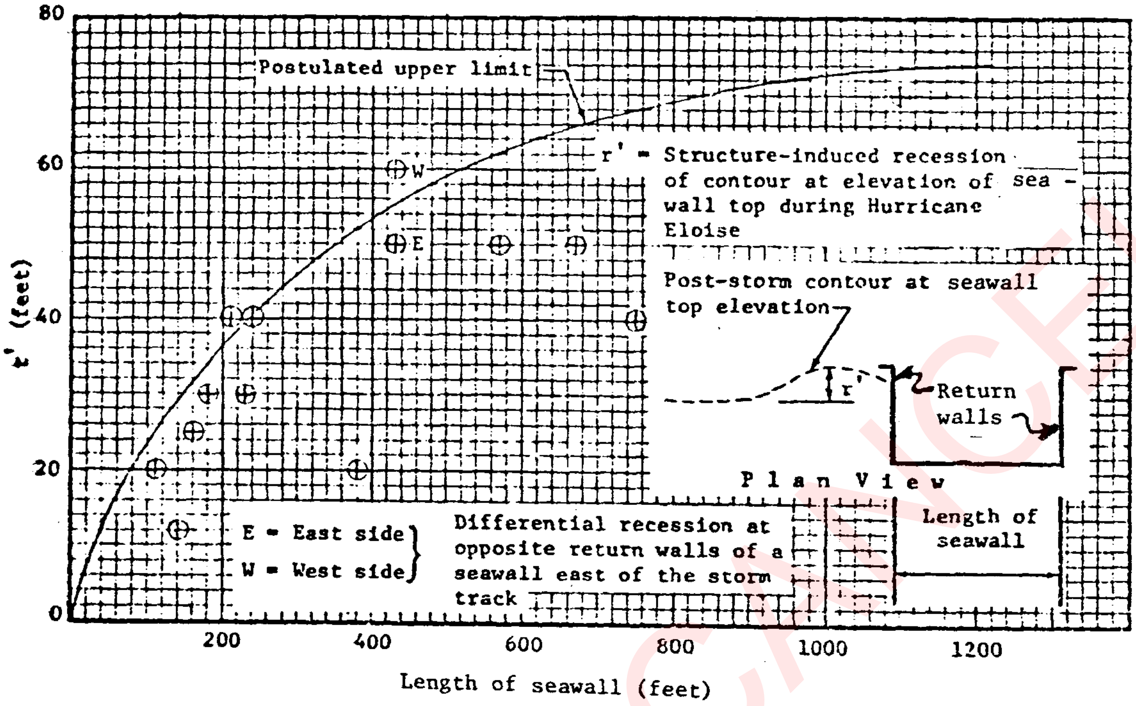

Figure 1. Structure-induced recession during storm

BASIC LIMITATIONS: Note that the Florida method is based on a single storm which might not represent the most severe conditions possible at other sites. The method requires the presence of dunes of the same material as the beach and will not produce a storm-damaged profile if dunes are absent, overtopped, or encroached by buildings. Figure 1 is based on data from only vertically-faced structures. Due to a lack of data, the effect of structure height on shoreline changes was unknown and was not taken into account in Figure 1.

DATA REQUIRED FOR RETURN WALL DESIGN: The primary requirement is accurate beach profiles to a depth where the profiles are not influenced by storms. Special attention to accuracy is needed to a depth below MSL, which is equal to one-half the design storm-surge elevation above MSL. Also needed are an estimate of the long-term shoreline recession, the design storm-surge elevation, and the structure's length and top elevation.

LONG-TERM PROFILE CONSTRUCTION: The equilibrium profile of the beach adjacent to the structure site at the end of the structure's design life can be predicted using the method described in the SPM and in Figure 2 for a shore

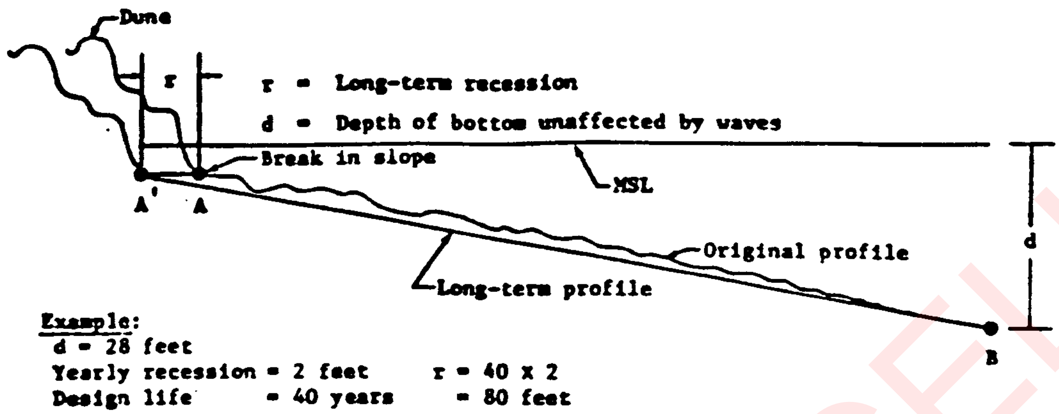

Figure 2. Construction of long-term profile

without a structure. This method assumes that the upper portion of the original profile is produced by, and is in equilibrium with, wave forces and that the profile, including the dune, migrates landward without changing. The first step is to identify the bottom of the original profile's upper portion by finding the point where the steep foreshore meets the flatter shoreface (see point A in Figure 2). Next, shift point A landward to A′, a distance equal to the predicted recession; then, at the new position, duplicate the portion of the original profile above point A. To construct the lower part of the long-term profile, find the point on the original profile below which the profile is not influenced by storms, point B; then, draw a straight line from point B to point A′. Figure 2 includes a numerical example.

STORM-INDUCED PROFILE CONSTRUCTION: The method of predicting the temporary effect of a storm on an equilibrium profile without a structure is illustrated in Figure 3. The equilibrium profile, called long-term profile is a portion of the long-term profile generated in Figure 2. Using the design storm surge, S the lower part of the poststorm profile is constructed by connecting the point on the long-term profile at a depth of 0.5 times S below MSL (point C in Figure 3) to a point at MSL (point D) spaced 4 times S seaward of the long-term profile's MSL contour (point E). To construct the upper part, a line is drawn from point D to a point spaced S above MSL (point F) in such a way that the area above the line (crosshatched area), representing erosion from the dunes, is equal to the area below the line (lined area), representing

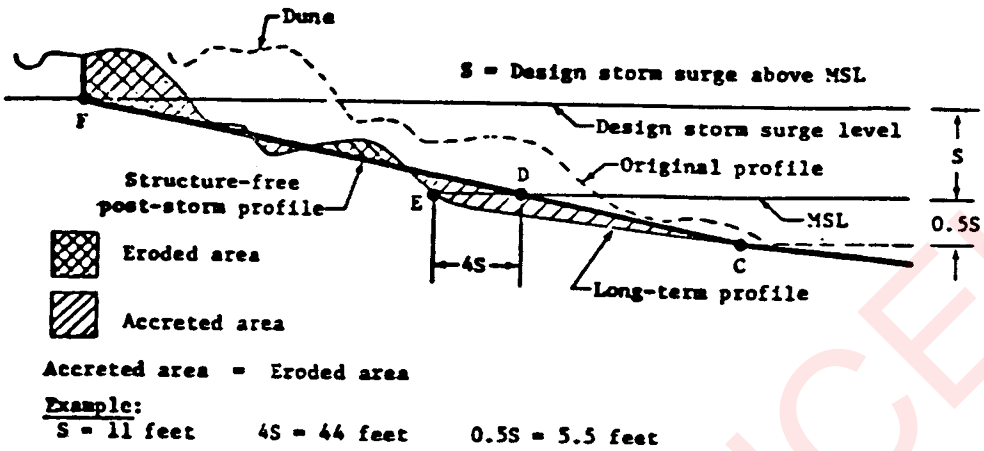

Figure 3. Construction of storm-induced profile

accreted area on the beach. Figure 3 illustrates the effect of an 11-ft surge.

STRUCTURE-INDUCED CHANGES: When struck by waves or overtopped by storm surge, a structure disturbs the pattern around it in respect to wave heights, longshore current, and erosion. This may prevent the formation of a protective offshore bar. The absence or seaward movement of a bar exposes the beach to higher waves and, coupled with the structure's amplification of wave heights by reflection, increases erosion in the structure's vicinity. Walton and Sensabaugh (1979) and Chapter 5, Section II-8, of the SPM discuss methods of predicting scour of the profile seaward of a vertical wall. There is no known method for constructing the scoured profile next to a return wall; but the Florida method locates the point where a horizontal line at the elevation of the structure's top intercepts the most severely receded poststorm profile induced by the structure (shown in Figure 1).

LOCATING THE STRUCTURE-INDUCED PROFILE: As illustrated in Figure 4, the first step in locating the structure-induced profile is to locate the structure on the structure-free, poststorm profile constructed in Figure 3. Next, draw a horizontal line landward from the top of the wall and locate the intersection of the horizontal line with the profile (point G). Given the length, 300 ft, enter Figure 1 and find the additional recession caused by the structure r',

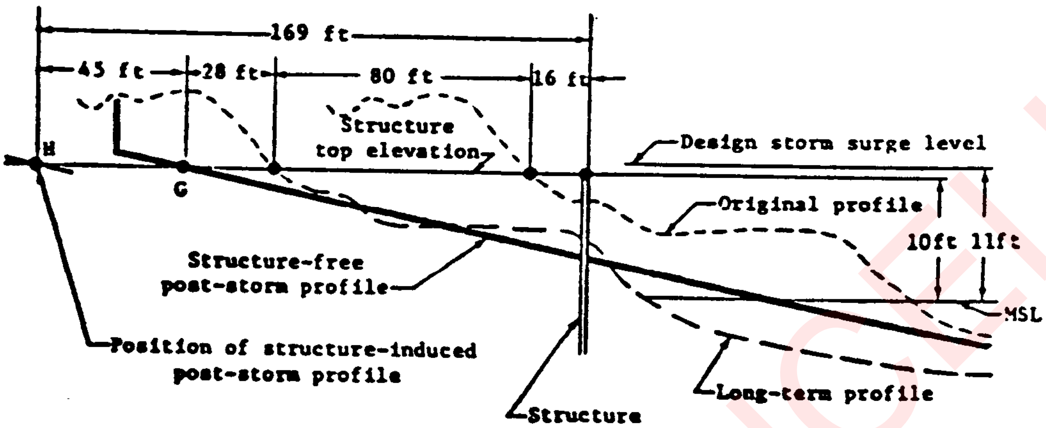

Figure 4. Determination of Return Wall Length

in this case 45 ft. In Figure 4, plot this additional recession along the horizontal line landward of point G and thereby locate the structure-induced, poststorm profile at point H.

RETURN WALL LENGTH: Return wall length is determined by measuring the horizontal distance from the top of the structure to the structure-induced profile at point H, as shown in Figure 4. Notice that the length (169 ft) consists of four components: (1) the distance from the structure to the original profile (16 ft), (2) the recession of the profile due to long-term erosion (80 ft), (3) the recession due to storm erosion (28 ft), and (4) the recession due to structure effects (45 ft). If the length of the return wall is uneconomical due to the long-term erosion component, the return wall could be constructed in stages, adding length as it becomes necessary. With stage construction, the initial length would include components (1), (3), and (4), plus some fraction of (2).

ADAPTATION TO OTHER COASTS: Where local pre- and poststorm profiles are available for comparison, the method of predicting the structure-free, poststorm profile can be modified to fit local conditions by changing the proportions of S used to locate points C and D, the end points of the profile's lower part. Pre- and poststorm stereo-aerial photographs would be necessary to use Florida's procedures for measuring structure effects. If a reliable baseline exists along the shore, the additional recession of profiles near structures could be measured from comparison of poststorm profiles surveyed within and outside the influence of the structures. A safety factor, neglected by the Florida method, may be chosen based on local experience and incorporated into the local design method.

ADDITIONAL INFORMATION: Florida Sea Grant Report 29, "Seawall Design on the Open Coast," provides additional technical guidance. A single free copy of this report may be obtained by writing: Sea Grant Marine Advisory Program, G022 McCarty Hall, University of Florida, Gainesville, Florida 32611; or by calling (904) 392-1771. Give the report name and number.

REFERENCES:

Burdin, W. H. April 1977. "Surge Effects from Hurricane Eloise," Shore and Beach, Vol 45, No. 2, pp 2-8.

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Walton, T. L., Jr., and Sensabaugh, W. June 1979. "Seawall Design on the Open Coast," Sea Grant Report No. 29, State University System of Florida, Sea Grant College Program.