Journal of Coastal Research	6	4	1023-1036	Fort Lauderdale, Florida	Fall 1990

DISCUSSION

Discussion of: Pilkey, O.H., 1990. A time to look back at beach replenishment (editorial), *Journal of Coastal Research*, 6(1), iii-vii. And, Leonard, L.; Clayton, T., and Pilkey, O.H., 1990. An analysis of replenished beach design parameters on U.S. east coast barrier islands, *Journal of Coastal Research*, 6(1), 15-36.

James R. Houston

Coastal Engineering Research Center
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199, U.S.A.

ABSTRACT

This paper discusses the editorial PILKEY (1990) and the paper LEONARD *et al.* (1990), on which the broad-reaching conclusions of PILKEY (1990) are based. The discussion shows that LEONARD *et al.* (1990) (in turn based on LEONARD, 1988) is extremely flawed and cannot be used to reach valid conclusions about beachfill performance.

ADDITIONAL INDEX WORDS: *Artificial beach renourishment, beach erosion, beach volume, beach replenishment, beachfill, coastal erosion, equilibrium beach, shoreline retreat.*

INTRODUCTION

Beachfill design is an evolving technology, and critical examination of beachfill performance can help evaluate weaknesses in present procedures and guide research to improve our understanding of processes. PILKEY (1990) raises several issues concerning beachfill performance, and his discussion is useful because it stimulates thought about our understanding of beachfills. The purpose of this discussion is to show, however, that the analyses on which PILKEY (1990) bases broad-reaching conclusions concerning beachfills are extremely flawed and cannot be used to reach valid conclusions about beachfill performance.

The foundation for the views of PILKEY (1990) is LEONARD *et al.* (1990), which is in turn a summary of LEONARD (1988). Serious quality problems of LEONARD *et al.* (1990) and LEONARD (1988) can be demonstrated by considering the first major conclusion in LEONARD *et al.* (1990), which is, nourished beaches erode at rates much greater than predecessor "natural" beaches (reported by LEONARD *et al.*, 1990, as, "Clearly . . . one of the most important conclusions of this study").

Figure 2 of LEONARD *et al.* (1990) shows data on which this conclusion concerning performance of nourished versus "natural" beaches is based. As is the case for much of LEONARD *et al.* (1990), insufficient information is given to determine how the data were obtained and used. LEONARD *et al.* (1990) do not even identify which 12 fills, of 43 fills listed in Table 1 of the paper, are plotted in Figure 2. LEONARD (1988) identifies the fills and lists pre- and post-fill erosion rates; however, she does not describe how the rates were determined or identify references used to obtain each specific rate. It appears LEONARD (1988) obtained information for these fills primarily using references given in PILKEY and CLAYTON (1989). It took considerable investigative effort by the present author using these references to discover that almost every pre- and post-erosion rate presented in LEONARD (1988) (and thus LEONARD *et al.*, 1990) is incorrect. The story of how rates were determined by LEONARD (1988) illustrates serious deficiencies in scientific rigor and quality control in LEONARD (1988) and LEONARD *et al.* (1990).

Table 1, from LEONARD (1988), lists beachfills with pre- and post-fill erosion rates. These rates are presumed to comprise the data set presented in Figure 2 of LEONARD *et al.* (1990).

LEONARD *et al.* (1990) purport to exclude a time period during a fill's initial adjustment to equilibrium in determining post-fill loss rates. "Figure 2; the post-emplacement rates illustrated by the figure do not include measurements made during the beaches' initial 'equilibrium' period." (LEONARD *et al.*, 1990). As will be presented in following paragraphs, post-fill rates of LEONARD *et al.* (1990) seldom (if ever) appear to exclude losses during the equilibrium period, as claimed. For example, losses of the 1977 Sandy Hook fill were tabulated by LEONARD (1988) and LEONARD *et al.* (1990) starting the first day the fill was placed.

ANALYSIS

Sandy Hook, New Jersey

Introduction The analyses LEONARD (1988) performs to obtain pre- and post-fill erosion rates for the 1977 Sandy Hook fill have many significant flaws. This fill, in fact, was hardly a designed beachfill. Instead, it was an emergency fill operation conducted by the U.S. National Park Service, whereby a reported 152,920 cu m of sand were carried by truck to the site during severe fall and winter storms. "...the fill was bulldozed into a high, narrow ridge to function as a barrier to overwash and flooding. The seaward slope of the fill was near vertical. The scarp acted as a barrier to uprush and kept the water and sediment in motion, thus transforming the attenuated foreshore into a continuous transport surface." (NORDSTROM *et al.*, 1979). LEONARD *et al.* (1990) report the emergency fill was a mere 250 m long.

Pre-fill The emergency fill was located (Figure 1) just downdrift (north) of a seawall and along the southern 250 m of a 1400-m long beach that NORDSTROM *et al.* (1979) reported had eroded at a rate of 8 m per year for 50 years with an average loss of 75,000 cu m per year. There were plans at the time to place a designed fill of 1,500,000 cu m along the 1400 m reach of eroding beach. The emergency fill's tiny length made it a finger of sand extending about 40 m into the surf zone along a coast which CALDWELL (1966) reported historic northerly littoral transport (380,000 cu m per year), more than twice the volume of the fill. Such a fill would be expected to be a feeder fill, eroding rapidly and supplying sand to the remainder of the 1400-m eroding beach. In fact, this is exactly what happened; NORDSTROM *et al.* (1979) reported winter storm waves attacking

Table 1. *Beachfill locations and pre- and post-fill erosion rates (from Leonard, 1988).*

Fill Location	Year	Pre-fill Erosion (cu m/yr)	Post-fill Erosion (cu m/yr)
Sandy Hook, NJ	1977	22,419	270,000
Atlantic City, NJ	1963	4,560	68,620
Atlantic City, NJ	1986	304,000	760,000
Ocean City, NJ	1952	304,000	1,540,915
Hunting Island, SC	1968	190,000	820,800
Canaveral Beach, FL	1974-75	25,553	27,868
Indialantic, FL	1980-81	13,934	91,260
Delray Beach, FL	1973	27,360	68,552
Bal Harbour, FL	1975	101,690	No value given
Miami Beach, FL	1976-82	123,090	80,000
Virginia Key, FL	1969	22,800	47,082
Key Biscayne, FL	1969	6,536	15,200

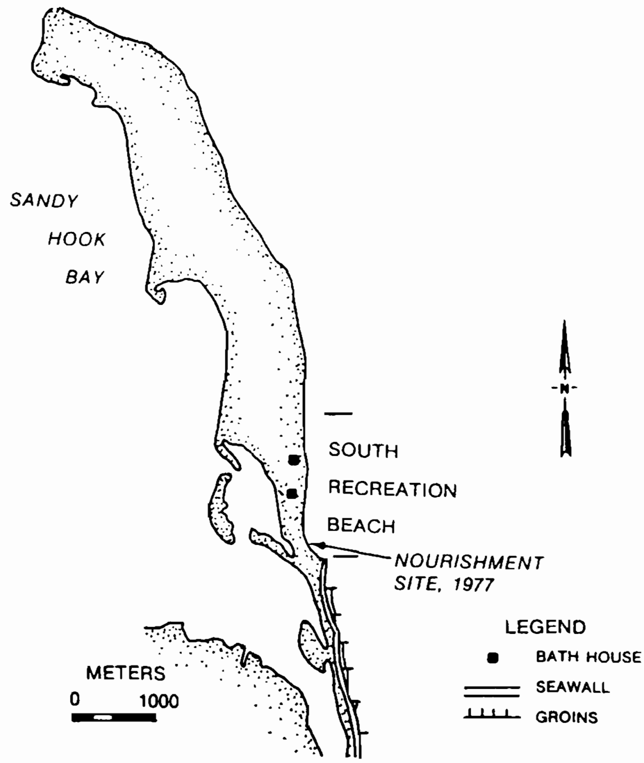

Figure 1. 1977 Sandy Hook Fill (adapted from Nordstrom *et al.*, 1979)

over 4.5 months removed 102,000 cu m of the fill from the original site and transported it north, with the beach at the southernmost bath house (Figure 1) gaining 10 m in width during the period. If this 10 m gain in width occurred along the entire 1150 m of beach north of the 250 m fill, the 1150 m of beach would have gained about 80,000 cu m of the 102,000 cu m "lost" by the 250 m long fill (using the same relationship between linear and volumetric losses as NORDSTROM *et al.*, 1979). In any case, the pre-fill erosion rate should be for the entire 1400 m eroding beach and not the 250 m feeder segment. Furthermore, LEONARD (1988) ignored the fact that erosion at the site had greatly intensified in years prior to the fill. NAKASHIMA *et al.* (1983) reported shoreline retreat for the 1400-m-long segment was 25 m per year between 1972 and 1977 (235,000 cu m per year) and 42 m (395,000 cu m) for a six month period before the 1977 fill (reason emergency fill was needed). Thus, in the six months prior to the fill, the "natural" beach lost 42 m along the entire 1400 m compared to the fill's loss of about 40 m along just 250 m (and NAKASHIMA *et al.*, 1983, report the storms that attacked the fill were the worst in six years). Finally, NAKASHIMA *et al.* (1983) estimated it would take 180,000 cu m per year to stabilize 250 m of the most critically eroding shoreline (location of the 1977 fill). These numbers dwarf the pre-fill erosion rate of 22,419 cu m used by LEONARD (1988).

Post-fill NORDSTROM *et al.* (1979) state 102,000 cu m of the fill placed starting September 26, 1977, was "lost" by February 18, 1978. Since this time period is 38 percent of a year, LEONARD (1988) divided 102,000 cu m by 0.38 and obtained a yearly post-fill loss rate of 270,000 cu m. Of course, this analysis is grossly in error because it assumes the whole year is comprised of storms that actually occur from late September to February. If erosion volume at almost any beach in the U.S. (even a beach that is stable in the long term) is measured during these months and divided by 0.38, the yearly erosion rate obtained will be remarkably in error. A good example of this can be seen in Figure 2 from EVERTS et al. (1974), which shows change in beach volume at Atlantic City, New Jersey, by month for a 10-year period when beaches had net accretion. Taking erosion volumes from Figure 3 for the period from the end of September through middle of February and dividing by 0.38 yields an erosion rate of about 775,000 cu m per year (loss of about 59 cu m per m for 5000 m beach). If instead, the same length of time is selected between the end of March and middle of August, using Figure 2 gives an *accretion rate* over 1,000,000 cu m per year. Considering a period of time in between, and using Figure 2 yields an erosion rate of zero. Thus, selecting a short time period and extrapolating rates to a year is not valid and can be manipulated (depending on months selected) to give almost any desired rate. If Sandy Hook has a similar seasonal loss of 59 cu m per m from the end of September to the middle of February, the 1400 m beach would be expected to seasonally "lose" about 80,000 cu m. Since most of the average loss at Sandy Hook of 235,000 cu m per year from 1972-1977 also occurred in winter, the net "loss" (approximately 80,000 plus 235,000 cu m) expected for the 1400-m eroding beach during the 4.5-month period the fill was monitored is much greater than the actual loss of 102,000 cu m (and, as shown earlier, as much as 80,000 cu m of this "loss" can be accounted for along the remainder of the 1400 m of beach). Thus, rather than the fill loss rate being 12 times greater than the "natural" erosion rate, as LEONARD (1988) and LEONARD *et al.* (1990) claim, it is not even apparent the fill eroded faster than the natural beach had been eroding. In fact, during a period of six months prior to the fill, the natural beach eroded more rapidly under less severe wave attack than did the fill after placement.

ATLANTIC CITY AND OCEAN CITY, NEW JERSEY

Pre-fill The analyses used by LEONARD (1988) to determine pre-fill erosion rates for the 1963 and 1986 Atlantic City and 1952 Ocean City fills are illustrative of quality problems that permeate LEONARD (1988) and, in turn, LEONARD *et al.* (1990). The 1986 fill covered the same area as the 1963 fill except an additional 700 to 800 meters of beach were nourished. Yet LEONARD (1988) has pre-erosion rates for the fills differing by almost two orders of magnitude! LEONARD (1988) sets the pre-erosion rate for the 1952 Ocean City fill equal to that of the 1986 Atlantic City fill despite the

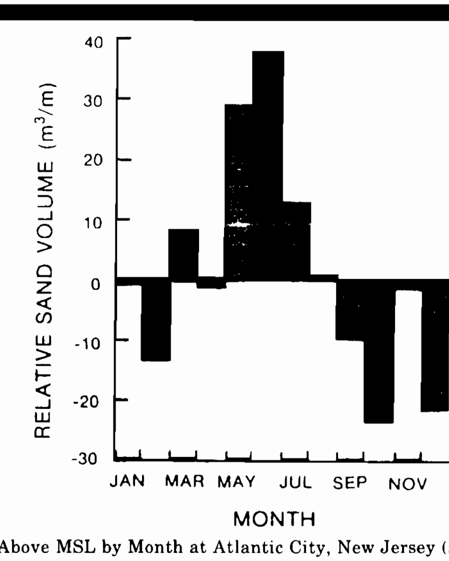

Figure 2. Change in Sand Volume Above MSL by Month at Atlantic City, New Jersey (adapted from Everts *et al.*, 1974)

two cities being on different barrier islands and having different shoreline orientations.

LEONARD (1988) apparently developed pre-fill erosion rates of 304,000 cu m per year for the 1986 Atlantic City and 1952 Ocean City fills using U.S. ARMY CORPS OF ENGINEERS (1985) or SORENSEN and WEGGEL (1985) (cited by PILKEY and CLAYTON, 1989), which in turn used CORPS OF ENGINEERS (1956). U.S. ARMY CORPS OF ENGINEERS (1956) mentions that earlier studies (not referenced of ". . . Atlantic City have indicated that 400,000 cubic yards may be accepted as a reasonable estimate of the annual rate at which material moves to the southwest from that locality." SORENSEN and WEGGEL (1985) note there is a northeast transport of 250,000 cu yd for a net of 150,000 cu yd per year to the southwest. LEONARD (1988) converts 400,000 cu yd to 304,000 cu m (LEONARD, 1988, uses a conversion factor with two significant figures—one cu yd equals 0.76 cu m—yet develops erosion rates (Table 1) with up to 7 significant figures). Of course, the southwest transport rate at Atlantic City is not the erosion rate for Atlantic City, and certainly not the erosion rate for Ocean City. In fact, CORPS OF ENGINEERS (1956) gives the pre-fill erosion rate at Ocean City of only 38,000 cu m per year, but LEONARD (1988) did not go back to this original reference and thus missed this important information. Even more confusing (and a good example of lack of consistency of logic within LEONARD, 1988) is why LEONARD (1988) assumed an estimate made prior to 1956 for the general area of Atlantic City was appropriate for the 1986 fill, but not the 1963 Atlantic City fill.

The remarkably low pre-fill erosion rate of 4560 cu m per year given by LEONARD (1988) for the 1963 fill at Atlantic City is not found in references cited. Although it is not certain how LEONARD (1988) obtained this pre-fill erosion rate, it appears to have been obtained by considering a rate that is neither a pre-fill rate nor a rate at the location of the 1963 beachfill. Figure 3 shows an area of Atlantic City monitored over a 10-year period (EVERTS *et al.*, 1974). Monitoring from 1962-1972 included surveys of profile lines 1 to 7. The 1963 fill extended only over profiles 1 to 3. Taking the years 1965-1969 (period of time between 1963 and 1970 fills), EVERTS *et al.* (1974) documented very convincingly that the 1963 fill eroded on profiles 1 to 3, moved down drift, and deposited on profiles 4 to 7 (which were experiencing erosion before the 1963 fill). This is a perfect example of down-drift nourishment of beaches. Thus, net erosion on profiles 1 to 7 over the period 1965-1969 was very small, and EVERTS *et al.* (1974) state it was 1/12th of the erosion rate of the fill area extending from profiles 1 to 3. It appears LEONARD (1988) took the fill length (profiles 1 to 3) of 1160 m, divided by 12, rounded to two significant figures, and multiplied by the loss rate of 47 cu m per m per year for the 1970 rather than 1963 fill (see next paragraph for similar fill mixup for post-fill erosion rates by LEONARD, 1988) to obtain a rate of 4,560 cu m per year. Thus the "pre-fill" erosion rate used by LEONARD (1988) and LEONARD *et al.* (1990) is actually a post-erosion rate (1965-1969) of the 1963 fill, uses a loss rate for the wrong (1970) fill, and covers a stretch of beach (profiles 1 to 7) about 5 times longer than the 1963 fill (profiles 1 to 3). The rate of erosion is quite small because the 1963 fill almost produced net stabilization of profiles 1 to 7 (erosion for beaches covered by profiles 1 to 3 and accretion for profiles 4 to 7). The actual pre-fill erosion rate for the 1963 and 1986 fills can be estimated by considering erosion at Atlantic City from January 1936 through April 1947 (Figure 4 from McCANN, 1981). Erosion over 11.25 years was approximately 142,000 cu m per year. This is greater than 30 times the pre-fill erosion rate for the 1963 fill given by LEONARD (1988).

Post-fill Post-fill erosion rates for the Atlantic City and Ocean City fills also are completely wrong. LEONARD (1988) confused a 1970 fill at Atlantic City with the 1963 fill. EVERTS *et al.* (1974) give the loss rate of the 1970 fill as 47 cu m per m per year along 1460 m, or 68,620 cu m per year. This is the rate used by LEONARD (1988) for the 1963 fill, and thus LEONARD (1988) analyzed the wrong fill. EVERTS *et al.* (1974) state the 1963 fill lost 65 cu m per m per year over its length of 1160 m, or about 75,000 cu m per year. A much more substantial error was made by LEONARD (1988) for the 1986 Atlantic City fill. The figure of 760,000 cu m per year used by LEONARD (1988) is based on loss in one year of the entire volume (760,000 cu m) placed in the 1986 fill. References cited by PILKEY and CLAYTON (1989) for this fill are a memo by the city engi-

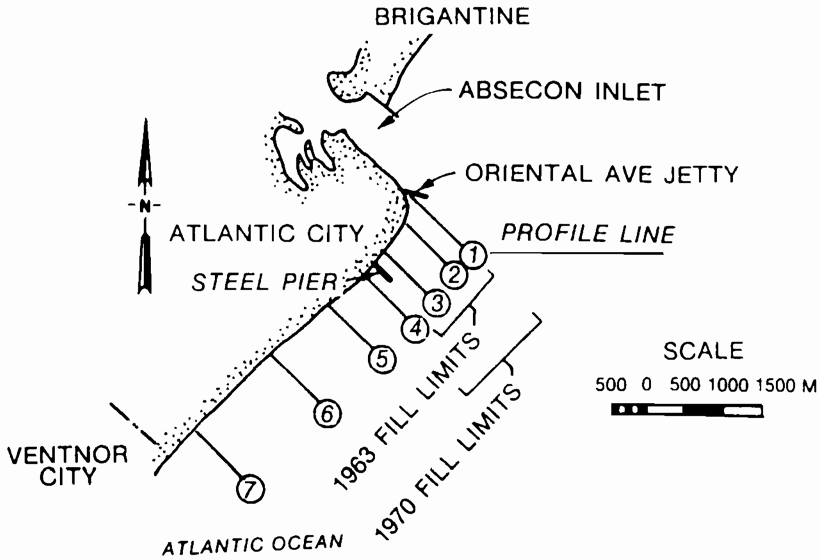

Figure 3. Locations of Profile Lines, Atlantic City, New Jersey (Everts *et al.*, 1974)

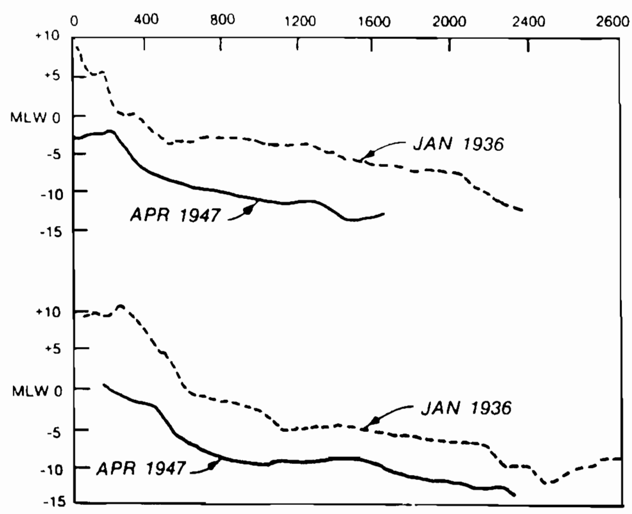

Figure 4. Profile Changes, Atlantic City (adapted from McCann, 1981)

neer soon after the fill was placed and newspaper articles in the New York Times and USA TODAY in January and February following fill placement. These references are good examples of types of references used by LEONARD (1988) and LEONARD *et al.* (1990) in their analyses. The problem with depending on such unreliable and inexpert references is obvious in this case because the fill did not disappear the first year. The beachfill was monitored after placement, and SORENSEN *et al.* (1989) present detailed measurements of fill performance over 18 months. They report, "After eighteen months the loss of beach sand fill volume from the berm/face sector varied between 24 and 48 percent for the six profile lines located in the fill area.

Much of this sand moved offshore as post-fill beach slope adjustment occurred... some of the sand also moved downcoast to nourish beaches adjacent to the fill area." Assuming the whole fill of 760,000 cu m was initially placed on the berm/face (this over predicts losses), and the average "loss" was 36 percent over 18 months, the yearly loss rate is only about 180,000 cu m. Since the 18 months covered two winter and only one summer season, loss really should be calculated as occurring over two years, giving a loss rate of about 135,000 cu m per year (including slope adjustment). This is less than 20 percent of the post-fill loss rate given by LEONARD (1988).

The post-fill loss rate used by LEONARD (1988) for the 1952 Ocean City fill is not in references cited by LEONARD (1988). The major reference cited by PILKEY and CLAYTON (1989) for Ocean City fills is U.S. ARMY CORPS OF ENGINEERS (1985), which obtained its information from U.S. ARMY CORPS OF ENGINEERS (1956). U.S. ARMY CORPS OF ENGINEERS (1956) described a detailed monitoring study and gave a loss of 95 percent of the 1,950,000 cu m fill in 31 months (covering three winter seasons). This is a yearly rate of about 715,000 cu m, or less than half the figure used by LEONARD (1988). Again, adjacent beaches gained nearly all sand "lost" by the fill. ("The data collected from the periodic surveys are fairly conclusive that this fill material was ultimately deposited in the beach zone to the north and south of the fill limits; therefore the fill material, although only partially effective in the area where it was initially placed, subsequently benefited adjacent shore segments," U.S. ARMY CORPS OF ENGINEERS, 1956). Furthermore, U.S. ARMY CORPS OF ENGINEERS (1985) and WEGGEL *et al.* (1988) report Ocean City's shoreline position has been stable through placements of fill from 1952 through 1984. The beach along which the 1952 fill was placed has lost fill material at a rate of about 92,000 cu m per year for this extended period (U.S. ARMY CORPS OF ENGINEERS, 1985). This loss rate of fill over an extended time period is much less than the pre-fill loss rate given by LEONARD (1988) (shown previously to be erroneous).

HUNTING ISLAND, SOUTH CAROLINA

Pre-fill The pre-fill rate used by LEONARD (1988) for Hunting Island agrees with U.S. ARMY CORPS OF ENGINEERS (1964) and WALTON (1977).

Post-fill Once again, the post-fill loss rate in LEONARD (1988) was obtained incorrectly by taking a short period of time that included the year's storm events and extrapolating results such that a year was comprised only of the winter storm season. In addition, LEONARD (1988) made a significant error by including in fill losses the erosion of "natural" beach not covered by the fill. Erosion (410,000 cu m) for the fill's first six months (fill placed in December) was taken from WALTON (1977) by LEONARD (1988) and doubled to obtain the loss rate of 820,000 cu m per year (clearly an initial time period to account for equilibrium adjustments was not excluded, as claimed by LEONARD *et al.*, 1990). However, WALTON (1977) shows total loss over 18 months was only 590,000 cu m (less than the yearly loss rate given by LEONARD, 1988), with 410,000 cu m lost the first 6 months and 180,000 cu m the next 12 months. The loss rate from WALTON (1977) based on the entire 18 months is 320,000 cu m per year, less than 40 percent of the rate in LEONARD (1988). Furthermore, the 590,000-cu-m loss (18 months) was not just for the fill, which extended over 3050 m of beach, but for most of Hunting Island, extending over a distance of 6525 m. In addition, WALTON (1977) is based on BERG and ESSICK (1972), but WALTON (1977) was in error concerning dates various losses occurred. BERG and ESSICK (1972) show the actual loss over 18 months was 650,000 cu m and this was composed of a 345,000 cu m loss along the 3050-m-long fill (loss rate of 230,000 cu m per year), 445,000 cu m loss along 2775 m of "natural" beach to the south of the fill (loss rate of 297,000 cu m per year — that is, loss of "natural" beach was greater than loss of fill), and a 140,000 cu m gain along 700 m of beach to the north of the fill (sand moving alongshore from the fill). Thus, much of the loss is not fill loss, but "natural" beach loss at a higher rate than fill loss. The actual post-fill erosion rate of the fill of 230,000 cu m per year is less than 30 percent of the post-fill rate given by LEONARD (1988) and very similar to the pre-fill estimate of 190,000 cu m per year (easily within the accuracy of the estimate and variation in wave climate from year to year). In any case, the erosion rate for the natural beach was greater than for the fill beach!

CANAVERAL BEACH, FLORIDA

Pre-fill Both pre- and post-fill erosion rates given by LEONARD (1988) for the 1974-1975 Canaveral Beach fill are much too low, and neither number is found in references (FLORIDA DIVISION OF BEACHES AND SHORES, 1985; UNIVERSITY OF FLORIDA, 1976; and HUSHLA, 1982) cited for Canaveral Beach by PILKEY and CLAYTON (1989), LEONARD (1988), or LEONARD *et al.* (1990). The time period of analysis must be carefully chosen to determine a reasonable pre-fill erosion rate for the 1974-1975 Canaveral Beach fill. UNIVERSITY OF FLORIDA (1976) notes Canaveral Beach changed from an area of high accretion to one of severe erosion following cutting of the Port Canaveral channel in 1952 and construction of jetties on the north boundary of Canaveral Beach. UNIVERSITY OF FLORIDA (1976) says, "Canaveral channel and jetties... are considered littoral barriers to the south beaches" and cites studies by "Walton, COEL, U. of Fla" and "U.S. Army Corps of Engineers" which estimate a net annual southerly littoral drift of 180,000 to 270,000 cu m per year. If the Canaveral channel and jetties were complete littoral barriers, the pre-fill erosion rate would approximate the net littoral drift and thus be much greater than the rate used by LEONARD (1988). LEONARD (1988) likely determined a pre-fill erosion rate by considering a period that included time before construction of the Port Canaveral channel and jetties. Such an analysis is clearly wrong, since UNIVERSITY OF FLORIDA (1976) notes the long-term shoreline *accretion* rate at Canaveral Beach was about 3.4 m per year before jetty construction, and this reversed to a severe erosion rate of about 4.3 m per year just before (1965-1971) fill placement in 1974-1975. DEAN (1987) says erosion was 4.6 m per year from 1955-1974. Lumping time periods before and after 1952 completely distorts presently existing erosion problems at Canaveral Beach. For example, HUSHLA (1982) shows Canaveral beach gained in area from 1943 to 1973 because accretion before 1952 more than compensated for erosion after 1952. DEAN (1987) determined a pre-fill (and post-construction) erosion rate for 1955-1974 of 120,000 cu m per year. Similarly, HUNT (1980) gives the volumetric erosion rate from 1958-1965 as about 220,000 cu m per year for the 3380 m of beach of the 1974-1975 Canaveral Beach fill. This is more than eight times the rate given by LEONARD (1988).

Post-fill Using aerial photography, HUSHLA (1982) concluded 30 percent of the area of the 2,077,000 cu m Canaveral Beach fill placed in 1974-1975 was lost in 5 years. If volume loss is assumed to be proportional to area loss (not necessarily true, but likely the right order of magnitude), approximately 625,000 cu m was lost over 5 years, or 125,000 cu m per year ("lost" to the fill area, but DEAN (1987) reports the beach down drift from the fill accreted along a 5 km reach at a rate of about 2 m per year from 1974-1986). The rate of 125,000 cu m per year is about 5 times the post-fill rate given by LEONARD (1988).

INDIALANTIC, FLORIDA

Pre-fill It appears the pre-fill erosion rate given by LEONARD (1988) for Indialantic is based on aerial photography presented in HUSHLA (1982) of land area loss at Indialantic between 1940 and 1980. If land area loss is converted to a shoreline erosion rate and then a volume loss (assuming loss of about 8.2 cu m per m for each 1 m of erosion—DEAN, 1987), one obtains an erosion rate of about 19,000 cu m per year, similar to that of LEONARD (1988). However, PHLEGAR and DEAN (1989) note Indialantic has a "...poorly known background erosion rate" and erosion rates determined by the Florida Department of Natural Resources "...vary significantly over this area of the coast." They show a range of possible background erosion rates at Indialantic can produce everything from accretion of about 10,000 cu m per year to erosion of about 70,000 cu m per year. DUANE (1968) estimated fill requirements of 68,000 cu m per year. HUNT (1980) presents the average annual erosion rate for Indialantic for 1928-1965 based on profile measurements in 1928, 1958, and 1965, as about 50,000 cu m per year. This is over 3 times the pre-erosion rate given by LEONARD (1988).

Post-fill LEONARD (1988) appears to have obtained a post-fill erosion rate for Indialantic by considering only first-year losses. Fill volume was taken from STAUBLE *et al.* (1984) to be 195,000 cu m. Several different volumes for this fill have appeared in the literature, but the volume reported by STAUBLE *et al.* (1984) is based on profile measurements. Since HUSHLA (1982) states about half the fill was lost in a year (about 90 percent of this first year loss was lost in the first two months—again there is no indication LEONARD, 1988, considered an adjustment period), LEONARD (1988) appears to have divided 195,060 cu m by two. However, monitoring lasted a little less than a year (342 days). Instead of dividing the loss by this fraction of a year, LEONARD (1988) appears to have erroneously multiplied (both the volume and fraction of a year truncated to three significant figures). The result is the rate of 91,260 cu m per year cited by LEONARD (1988). Actually, the fill stabilized after the first year loss, volume of the fill increased over the next two years (PHLEGAR and DEAN, 1989), and the fill remained in place until storms at the end of 1984. STAUBLE (1990) continued measurements along one fill profile until 1987 and found the fill partially recovered in the summer of 1985 and by mid-1987 (6.5 years after fill), about 18 percent of the fill's volume still remained. This represents a loss of about 25,000 cu m per year, or less than 30 percent of the post-fill rate used by LEONARD (1988).

DELRAY BEACH, FLORIDA

Pre-fill The pre-fill erosion rate for Delray Beach was taken by LEONARD (1988) from U.S. ARMY CORPS OF ENGINEERS (1972). This is one of the few cases where a pre- or post-erosion rate used by LEONARD (1988) agrees with a rate presented in a cited reference. U.S. ARMY CORPS OF ENGINEERS (1972) is based on U.S. ARMY CORPS OF ENGINEERS (1967), which made rough estimates of erosion losses along the entire east coast of Florida prior to 1961. However, PHLEGAR and DEAN (1989) note the erosion problem at Delray Beach worsened in the 1960's. "A reduced littoral drift environment exists at Delray Beach due to South Lake Worth Inlet in combination with shoreline defense structures just north (updrift). Vertical seawalls, concrete block revetment, and coral rip rap were installed in the 1960's to prevent further damage and erosion. Erosional pressure was thus simply being forced further south." Again, LEONARD (1988), when developing pre-erosion rates, did not consider whether changing conditions worsened these rates. The 1973 fill was placed in response to an accelerated erosion rate likely considerably larger than that given by LEONARD (1988).

Post-fill The post-fill loss rate for the 1973 fill at Delray Beach given by LEONARD (1988) was taken from STROCK (1984). Unlike all other post-fill rates used by LEONARD (1988), this rate is a linear regression of the loss rate over about 5 years. The loss rate obtained by dividing actual losses over 5 years by 5 is approximately 94,000 cu m per year (STROCK, 1981, 1983), or about fifty percent larger than the rate used by LEONARD (1988). The high loss rate at Delray Beach was expected, since the fill's average sand grain size of 0.23 mm was much smaller than the native size of 0.48 mm (STROCK, 1981). STAUBLE *et al.* (1984) give a required renourishment factor greater than 10. CAMPBELL and HOWARD (1989) show the three fills at Delray Beach (1973, 1978, and 1985) have had extremely predictable loss rates and satisfactory performances. LEONARD *et al.* (1990) give the 1973 Delray fill a half life of 1 to 5 years, even though LEONARD (1988) gives a half life greater than 5 years. The short half life given by LEONARD *et al.* (1990) is a result of placement of the 1978 fill occurring just less than 5 years after the 1973 fill. However, an average of 70 percent of the 1973 fill was still in place when the small 1978 fill was placed. A 1985 fill was placed to build the fill out much beyond the original extent of the 1973 fill. After 13.5; years, 68 percent of all fill material placed in the three fills remains (CAMPBELL and HOWARD, 1989).

BAL HARBOUR, FLORIDA

Pre-fill Pre- and post-fill erosion rates for Bal Harbour given by LEONARD (1988) are much too large and not found in references cited by LEONARD (1988), LEONARD *et al.* (1990), or PILKEY AND CLAYTON (1988). U.S. ARMY CORPS OF ENGINEERS (1975, 1984) give the pre-fill erosion rate at Bal Harbour of 9.41 cu m per m of beach per year. The length of the Bal Harbour fill was about 1370 m. Thus the pre-fill erosion rate was approximately 12,900 cu m per year. The rate given by LEONARD (1988) is almost eight times as large.

Post-fill LEONARD (1988) omits a post-fill erosion rate for Bal Harbour, but says only the Miami Beach fill had a lower post-fill than pre-fill erosion rate. Thus the post-fill erosion rate for Bal Harbour, according to LEONARD (1988), must be greater than the pre-fill rate or at least 101,690 cu m per year. However, the only source of post-fill erosion rates for Bal Harbour is U.S. ARMY CORPS OF ENGINEERS (1987), which reported there was accretion along part of the fill and erosion on part from 1983 to 1987, with net erosion of about 6700 cu m per year. The rate given by LEONARD (1988) is at least 15 times greater than this measured rate. Moreover, the actual post-fill erosion rate is lower than the pre-fill erosion rate.

MIAMI BEACH, FLORIDA

Introduction Pre- and post-fill erosion rates for Miami Beach given by LEONARD (1988) are not found in references cited by LEONARD (1988), LEONARD *et al.* (1990), or PILKEY AND CLAYTON (1988). LEONARD (1988) and LEONARD *et al.* (1990) give the length of the Miami Beach fill as 10.5 miles (16,900 meters). However, this length of beach would include fills at Haulover Park (1.2 miles or 1930 m) and Bal Harbour (0.85 miles or 1370 m) (Figure 5). Thus, LEONARD (1988) and LEONARD *et al.* (1990) consider the Bal Harbour fill both as a separate fill and part of the Miami Beach fill.

Pre-fill LEONARD (1988) gives the 1370-m long Bal Harbour fill a pre-fill erosion rate of at least 101,690 cu m per year (74.2 cu m per m of beach per year), whereas the entire 16,900-m long Miami Beach fill (which included the Bal Harbour fill) had a pre-fill erosion rate of only 123,090 cu m per year according to LEONARD (1988). Thus, the 15,530-m long portion of the Miami fill that excludes the Bal Harbour fill had a pre-fill erosion rate according to figures of LEONARD (1988) of only 21,000 cu m per year (1.4 cu m per m per year). LEONARD (1988) and LEONARD *et al.* (1990) apparently saw no inconsistency in a pre-fill erosion rate of 74.2 cu m per m per year at Bal Harbour and a 1.4 cu m per m per year for beaches on either side of Bal Harbour (Figure 5). Of course, the reason erosion rates are so different is LEONARD (1988) has incorrect rates for both the Bal Harbour and Miami Beach fills. U.S. ARMY CORPS OF ENGINEERS (1975, 1984) give a pre-fill erosion rate for the entire 16,900 m shown in Figure 5 of about 157,000 cu m per year, for 14,970 m (excluding Haulover Park) of about 142,000 cu m per year, and for 13,600 m (excluding Haulover Park and Bal Harbour) of about 128,000 cu m per year. The pre-fill rate of 123,090 cu m per year given by LEONARD (1988) does not match any of these rates.

Post-fill The post-fill erosion rate at Miami Beach is believed to be less than the pre-fill rate, but a quantitative loss rate could not be found in references cited by LEONARD (1988), PILKEY and CLAYTON (1989), LEONARD *et al.* (1990), or PILKEY (1990). Origin of the post-fill erosion rate given by LEONARD (1988) is unknown. Again, LEONARD (1988) and LEONARD *et al.* (1990) do not explain where they obtained pre- and post-fill erosion rates by giving specific references.

VIRGINIA KEY AND KEY BISCAYNE, FLORIDA

Pre-fill The Virginia Key and Key Biscayne, Florida, beachfills were placed and monitored at the same time. Pre-fill rates used by LEONARD (1988) are not consistent for the two fills, since they were based on different time periods and depths of profiling. In addition, minimum possible erosion rates were selected for both by LEONARD (1988). The pre-fill rate of about 23,000 cu m per year used by LEONARD (1988) for Virginia Key came from UNIVERSITY OF FLORIDA (1972), which was based on U.S. ARMY CORPS OF ENGINEERS (1961). The rate was based on profile erosion measured from 1919 through 1960. However, this rate was for the "inner profile" extending only about 230 m to a depth of 2.4 m. U.S.

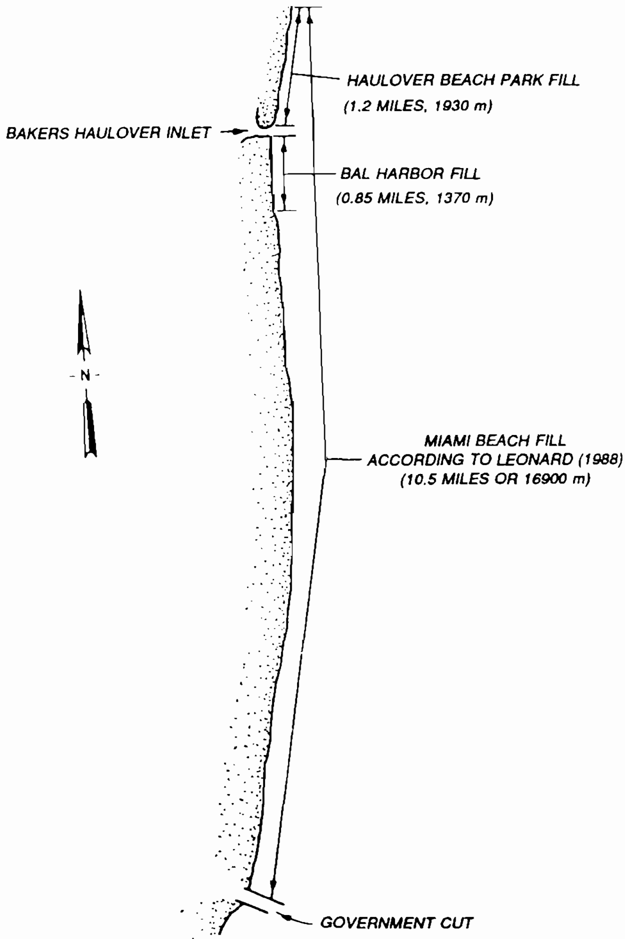

Figure 5 Miami Beach, Bal Harbor, and Haulover Beach Park Fills.

ARMY CORPS OF ENGINEERS (1961) believed this erosion rate was representative of erosion a fill might experience. Erosion for the same period along the entire profile length out to a depth of 5.5 m was about 61,000 cu m per year (U.S. ARMY CORPS OF ENGINEERS, 1961). Thus the pre-fill erosion rate at Virginia Key could vary from about 23,000 to 61,000 cu m per year, depending on the depth to which losses are considered. For Key Biscayne, LEONARD (1988) did not use rates given in U.S. ARMY CORPS OF ENGINEERS (1961, 1972) for the period 1919-1960. Instead, LEONARD (1988) determined an erosion rate by considering just the period 1960-1969, when profiles were measured only to a distance of 105 m to a depth of 1.1 m. U.S. ARMY CORPS OF ENGINEERS (1972) notes these profiles were too short to quantify the erosion, and thus used the 1919-1960 profiles for beachfill design. The pre-fill erosion rate on the inner profile for 1919-1960 (extending to a depth of only 1.5 m, about 170 m offshore) was about 11,000 cu m per year. The erosion rate on the complete profile to a depth of 5.5 m was about 44,000 cu m per year. Thus the pre-fill erosion rate for Key Biscayne falls between about 11,000 to 44,000 cu m per year and is much larger than the 6536 cu m per year used by LEONARD (1988). LEONARD (1988) was inconsistent in using the

1919-1960 profiles for Virginia Key and a different time period and depth of measurement for Key Biscayne.

Post-fill Post-fill erosion rates given by LEONARD (1988) for Virginia Key and Key Biscayne do not agree with references (UNIVERSITY OF FLORIDA, 1972, and WALTON, 1977) cited by LEONARD (1988) and PILKEY and CLAYTON (1989). Both references give the post-fill erosion rate for Virginia Key as approximately 38,000 cu m per year. LEONARD (1988) gives a rate of 47,082 cu m per year, because it was mistakenly assumed the monitoring period was a year rather than the actual 15 months. Both UNIVERSITY OF FLORIDA (1972) and WALTON (1977) clearly give 15 months as the period the material was lost and present the loss rate of approximately 38,000 cu m per year. The post-fill loss rate used by LEONARD (1988) for Key Biscayne is not found in UNIVERSITY OF FLORIDA (1972) or WALTON (1977). WALTON (1972) gives a loss rate for Key Biscayne of zero over the 15-month period. UNIVERSITY OF FLORIDA (1972) uses three methods to analyze the monitoring data for Key Biscayne. The most accurate method judged by UNIVERSITY OF FLORIDA (1972) gave an accretion rate over the 15 months of about 3000 cu m per year. The other two methods gave annual rates of about 2,000 cu m (accretion) and 700 cu m (erosion). These rates are all much less than the erosion rate of 15,000 cu m per year given by LEONARD (1988). The post-fill erosion rate at Virginia Key of 38,000 cu m per year fits well within the pre-fill erosion rate of 23,000 to 61,000 cu m per year. The post-fill erosion rate of 700 cu m per year to accretion of 3000 cu m per year for Key Biscayne is much lower than the pre-fill erosion rate of about 11,000 cu m to 44,000 cu m per year. Therefore, the erosion rate of the nourished beach at Virginia Key was similar to that of the "natural" beach and the erosion rate of the nourished beach at Key Biscayne was less than that of the "natural" beach.

CONCLUSIONS

Table 2 presents pre- and post-erosion rates given by LEONARD *et al.* (1990) and those presented in this discussion.

Only one of the twelve fills has post-fill erosion rates significantly greater than pre-fill rates. The pre-fill rate at Ocean City, New Jersey, is low because the beach has been largely stabilized by structures. Whenever large fills extending beyond structure protection have been placed at Ocean City, subsequent erosion of the fills have been large. The shoreline was stable from 1952 through 1984 through placements of fill averaging 92,000 cu m per year.

Almost all pre- and post-fill erosion rates given by LEONARD (1988), and used by LEONARD *et al.* (1990), are wrong and often considerably different than documented rates cited in references. LEONARD (1988) makes a wide variety of systematic errors. Sometimes LEONARD (1988) determines yearly erosion rates by extrapolating measurements made only over a few months. This method neglects the fact that erosion is seasonal, and that one can conclude a beach is rapidly eroding, accreting, or stable by selecting particular periods of time extending over a few months. Pre-erosion rates used by LEONARD (1988) sometimes are taken during periods that neglect changes that have caused increased erosion (often this increased erosion is the reason the fill is needed). Quite often, LEONARD (1988) chose pre- and post-erosion rates by misinterpreting data given in references or relying on popular press accounts, even when measurements were available.

LEONARD (1988) and LEONARD *et al.* (1990) do not show where they obtained pre- and post-fill erosion rates by providing references keyed to rates or explaining how they developed rates from more basic data. Thus, considerable effort is required to determine how they obtained rates. One is led to believe when reading LEONARD *et al.* (1990) that all required information to confirm rates is given by LEONARD (1988). This is definitely not the case. Furthermore, it is remarkable that LEONARD (1988) manipulates data and comes to broad-reaching conclusions without providing documentation showing where or how data were obtained.

Since almost all rates given in Figure 2 of LEONARD *et al.* (1990) are wrong, and there are a wide variety of errors indicative of lack of understanding of proper use of statistics, cursory reading of references, and limited familiarity with coastal processes, there is no reason to believe data presented throughout LEONARD *et al.* (1990) are correct. In order for

Table 2. *Comparison of pre- and post-fill erosion rates from this discussion from Leonard (1988).*

Fill Location	Year	Pre-fill Erosion (cu m/yr) This discussion	Pre-fill Erosion (cu m/yr) Leonard (1988)	Post-fill Erosion (cu m/yr) This discussion	Post-fill Erosion (cu m/yr) Leonard (1988)
Sandy Hook, NJ	1977	235,000	22,419	*	270,000
Atlantic City, NJ	1963	142,000	4,560	75,000	68,620
Atlantic City, NJ	1986	142,000	304,000	135,000	760,000
Ocean City, NJ	1952	38,000	304,000	715,000	1,540,915
Hunting Island, SC	1968	190,000[1]	190,000	230,000	820,800
Canaveral Beach, FL	1974-75	120,000-220,000	25,553	125,000	27,868
Indialantic, FL	1980-81	0-70,000	13,934	25,000	91,260
Delray Beach, FL	1973	*	27,360	94,000	68,552
Bal Harbour, FL	1975	12,900	101,690	6,700	No value given
Miami Beach, FL	1976-82	159,000	123,090	*	80,000
Virginia Key, FL	1969	23,000-61,000	22,800	38,000	47,082
Key Biscayne, FL	1969	11,000-44,000	6,536	0-700	15,200

*Unknown
[1]Agrees with LEONARD (1988)

LEONARD *et al.* (1990) to be credible, all data used must be presented explicitly, the source of each piece of data must be given by citing references keyed to the data, and methods used to manipulate the data must be presented in detail. Without this information, all data presented by LEONARD *et al.* (1990) are suspect, and conclusions of LEONARD *et al.* (1990) and PILKEY (1990) are built on foundations of sand.

The idea that performance data from beachfills should be evaluated to improve our understanding of fills is a good one and the author encourages reexamination of data on fill performance at locations around the world. However, as was shown in this paper, great care should be taken to properly analyze data before conclusions are made.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the Office, Chief of Engineers, U.S. Army Corps of Engineers (CE) for authorizing publication of this paper. Help in obtaining references was provided by Mr. Stephen Wagner, Coastal Engineering Research Center (CERC), Dr. Donald Stauble (CERC), Maj. James Marino (CERC), Mr. Jeffery Gebert, Philadelphia District (CE), and the Jacksonville District (CE).

LITERATURE CITED

BERG, D.W. and ESSICK, M.G., 1972. Case Study Hunting Island Beach, South Carolina. *Proceedings, Seminar on Planning and Engineering in the Coastal Zone*, Coastal Plains Center for Marine Development Services, Seminar Series No. 2, Charleston, SC.

CALDWELL, J.M., 1966. Coastal Processes and Beach Erosion. *Journal of Coastal Research*, 53 (2), 142-157.

CAMPBELL, T.J. and HOWARD, E., 1989. Comparing Alternate Borrow Sands for Beach Restoration. *Proceedings, Beach Preservation Technology 89*, Tampa, Florida, pp. 59-66.

DEAN, R.G., 1978. Coastal Sediment Processes: Toward Engineering Solutions. *Proceedings, Coastal Sediments '77*, American Society of Civil Engineers, pp. 1-24.

DEAN, R.G., 1987. Coastal Sediment Processes: Toward Engineering Solutions. *Proceedings, Coastal Sediments '87*, American Society of Civil Engineers, pp. 1-24.

DUANE D.B., 1968. Sand Inventory Program in Florida. *Shore and Beach*, 36 (1).

EVERTS, C.H.; DEWALL, A.E., and CZERNIAK, M.T., 1974. Behavior of Beach Fill at Atlantic City, New Jersey. *Proceedings, Fourteenth Coastal Engineering Conference*, American Society of Civil Engineers, pp. 1370-1388.

FLORIDA DIVISION OF BEACHES AND SHORES, 1985. *Beach Restoration: A State Initiative*. Florida Department of Beaches and Shores and the Restore Our Coast Task Force.

HUNT, S.D., 1980. Port Canaveral Entrance. *Glossary of Inlets Report No. 9*, Florida Sea Grant College, Report No. 39.

HUSHLA, F.L., 1982. Evaluating the Performance of Beach Nourishment in Brevard County, Florida Through the Use of Aerial Photography. M.S. Thesis, Florida Institute of Technology, Melbourne, Florida.

LEONARD, L.A., 1988. An Analysis of Replenished Beach Design on the U.S. East Coast. Masters Thesis, Department of Geology, Duke University, Durham, North Carolina.

LEONARD, L., CLAYTON, T., and PILKEY, O., 1990. An Analysis of Replenished Beach Design Parameters on U.S. East Coast Barrier Island. *Journal of Coastal Research*, 6 (1), 15-36.

MCCANN, D. P., 1981. Beach Changes at Atlantic City, New Jersey (1962-73). *Miscellaneous Report No. 81-3*, Coastal Engineering Research Center, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.

NAKASHIMA, L.D.; MCCLUSKEY, J.M.; GARES, P.A., and PSUTY, N.P., 1983. Short-term Protection on a Rapidly Eroding Beach. *Proceedings, Coastal Zone 83*, American Society of Civil Engineers, pp. 682-696.

NORDSTROM, K.F.; ALLEN J.R.; SHERMAN, D.J., and PSUTY, N.P., 1979. Management Considerations for Beach Nourishment at Sandy Hook, NJ, USA. *Coastal Engineering*, 2, 215-236.

PHLEGAR, W.S. and DEAN, R.G., 1989. Beach Nourishment Performance Predictability. *Proceedings, Beach Preservation Technology 89*, Tampa, Florida, pp. 75-86.

PILKEY, O.H., 1990. A Time to Look Back at Beach Nourishment. Editorial, *Journal of Coastal Research*, 6 (1), iii-vii.

PILKEY, O.H. and CLAYTON, T.D., 1989. Summary of Beach Replenishment Experience on U.S. East Coast Barrier Islands. *Journal of Coastal Research*, 5 (1), 147-159.

SORENSEN, R.M., and WEGGEL, J.R., 1985. Evaluation of Beach Behavior and Coastal Structures Effects at Atlantic City, NJ. *Fritz Engineering Laboratory Report No. 200.85.811.1*, Lehigh University, Trenton, New Jersey.

SORENSEN, R.M.; WEGGEL, J.R., and DOUGLASS, S.L., 1989. *Monitoring and Evaluation of 1986 Beach Nourishment Atlantic City, New Jersey.* Coastal and Marina Engineering Consultants, Inc., Haddon Heights, New Jersey.

STAUBLE, D.K., 1990. State-of-the-Art Report on Beachfill Design. *Technical Report No. 90-*, Coastal Engineering Research Center, U.S. Army Corps of Engineers, Waterways Experiment Station, VIcksburg, Mississippi.

STAUBLE, D.K.; HANSEN, M., and BLAKE, W., 1984. An Assessment of Beach Nourishment Sediment Characteristics. *Proceedings, Nineteenth Coastal Engineering Conference*, American Society of Civil Engineers, pp. 1471-1487.

STROCK A.V. and ASSOCIATES, INC., 1981. *City of Delray Beach—36 Month Follow-up Study.* A. V. Strock and Associates, Inc., Deerfield, Florida.

STROCK A.V. and ASSOCIATES, INC., 1984. *City of Delray Beach—60 Month Follow-up Study.* Deerfield Beach, Florida: A.V. Strock and Associates, Inc.

U.S. ARMY CORPS OF ENGINEERS, 1956. Behavior of Beachfill at Ocean City, New Jersey. *Technical Memorandum 77*, Beach Erosion Board, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.

U.S. ARMY CORPS OF ENGINEERS, 1961. *Beach Erosion Control Report on Cooperative Study of Virginia Key and Key Biscayne, Florida.* Jacksonville District, U.S. Army Corps of Engineers, Jacksonville, Florida.

U.S. ARMY CORPS OF ENGINEERS, 1964. Hunting Island Beach, South Carolina. *House Document No. 323, 88th Congress, 2nd Session*, Cooperative Report submitted by the Chief of Engineers.

U.S. ARMY CORPS OF ENGINEERS, 1972. *Study Report to Determine Behavior of Project Fill for Beach Erosion Control Virginia Key and Key Biscayne, Florida*, Department of Coastal and Oceanographic Engineering, University of Florida, Gainesville, Florida

U.S. ARMY CORPS OF ENGINEERS, 1975. *General Design Memorandum, Dade County Beaches, Florida.* Jacksonville District, U.S. Army Corps of Engineers, Jacksonville, Florida.

U.S. ARMY CORPS OF ENGINEERS, 1984. *General Design Memorandum, Addendum ii (First Renourishment), Dade County, Florida, Beach Erosion Control and Hurricane Surge Protection Project*, Jacksonville District, U.S. Army Corps of Engineers, Jacksonville, Florida.

U.S. ARMY CORPS OF ENGINEERS, 1985. *Great Egg Harbor and Peck Beach, Ocean City, NJ: Beach Erosion-Navigation Study*, Philadelphia District, U.S. Army Corps of Engineers, Philadelphia, Pennsylvania.

U.S. ARMY CORPS OF ENGINEERS, 1987. *General Design Memorandum, Addendum IV (Nourishment of Beach Segment Between 96th Street to Haulover Inlet), Dade County, Florida, Beach Erosion Control and Hurricane Surge Protection Project.* Jacksonville District, U.S. Army Corps of Engineers, Jacksonville, Florida.

UNIVERSITY of FLORIDA, 1976. Report on Monitoring of A Beachfill South of Canaveral Jetties, Brevard County, Florida. *Report No. 76/010*, Coastal and Ocean Engineering Laboratory, University of Florida, Gainesville, Florida.

WALTON, T.L. Jr., 1977. Beach Nourishments in Florida and on the Lower Atlantic and Gulf Coasts. *Technical Paper No. 2*, University of Florida, Gainesville, Florida.

WEGGEL, J.R.; DOUGLASS, S.L., and SORENSEN, R.M., 1988. An Engineering Study of Ocean City's Beaches, New Jersey, USA. *Proceedings, Twenty-first Coastal Engineering Conference.* American Society of Civil Engineering, pp. 2867-2881.