Journal of Coastal Research | 12 | 4 | 1044–1050 | Fort Lauderdale, Florida | Fall 1996

Reply

Reply to: Houston, J.R., 1996. Discussion of: Young, R.S.; Pilkey, O.H.; Bush, D.M., and Thieler, E.R., 1995. A discussion of the Generalized Model for Simulating Shoreline Change (GENESIS). *Journal of Coastal Research*, 11(3), 875–886. *This Volume.*

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INTRODUCTION

HOUSTON (1996) criticizes us for what he believes are two related shortcomings of our paper discussing the GENESIS shoreline change model (YOUNG *et al.*, 1995). He believes that we are incorrect in asserting that the use of GENESIS for the Folly Beach replenishment project is inappropriate, and he suggests that we should have provided more "evidence" from other projects that actual design parameters generated by GENESIS are incorrect.

We regret that Houston has not taken the opportunity to begin a much needed, sincere, point-by-point dialogue on the mathematical modeling of beach behavior for engineering purposes. Houston is criticizing a single paragraph in our detailed critical analysis of GENESIS. He has chosen to focus on a single, small issue in a larger debate. In the end, Folly Beach will be only one data point in a graph that charts the quality of service the U.S. Army Corps of Engineers delivers to our society. Furthermore, the real impact of GENESIS' use at Folly Beach will be realized in the sand volumes, renourishment costs and community impact over a decadal time frame, not the first year or two of the project.

HOUSTON (1996) presents a collection of before-and-after photographs purporting to demonstrate that the Folly Beach, South Carolina (Figure 1), replenishment project is performing as designed. He suggests that GENESIS predicted certain aspects of beach fill performance during the first year or two of monitoring. Much of Houston's argument in support of the success of GENESIS at Folly Beach is his assertion that the beach is still there. This, however, is not validation of any of the predictions made with the GENESIS model. Photos that show little beach in 1990 and a wider beach in 1995 have no bearing on whether design parameters that may have been generated from a GENESIS run were meaningful. Such photo comparisons are misleading, and short circuit a meaningful discussion of the model's shortcomings, including the extremely problematic geologic and oceanographic assumptions behind GENESIS.

We would also like to correct the accuracy of a statement that HOUSTON (1996) makes in the introduction to his discussion. He states that we "emphasize that [our] criticism is not an academic undertaking." This is an incorrect interpretation of our statement. We assert that the GENESIS *model* is not an "academic" undertaking in that it is used for very specific applied engineering purposes. If GENESIS were simply an academic undertaking, we would view it as one of many attempts to develop a better understanding of coastal processes. Instead, the model is now being widely used by the Corps to make critical decisions about the long-term management of beaches. In spite of the profound societal importance of such applications, the limitations of GENESIS are almost never heeded and to our knowledge, virtually never mentioned to the public.

In the following reply, we examine HOUSTON'S assertions that GENESIS worked and that the Folly Beach project is a success. A critical point to recall, however, is that we (HOUSTON'S discussion and this reply) are dealing only with the first two years of a beach with an eight-year nourishment interval and an overall 50-year plan for beach maintenance that was made on the basis of a GENESIS prediction. The true project performance and its impact on the community will not be evident for a decade or more.

DID GENESIS WORK?

The crux of the matter with respect to the use of GENESIS for the Folly Beach replenishment project is this: does GEN-

95041 received and accepted in revision 30 April 1996.

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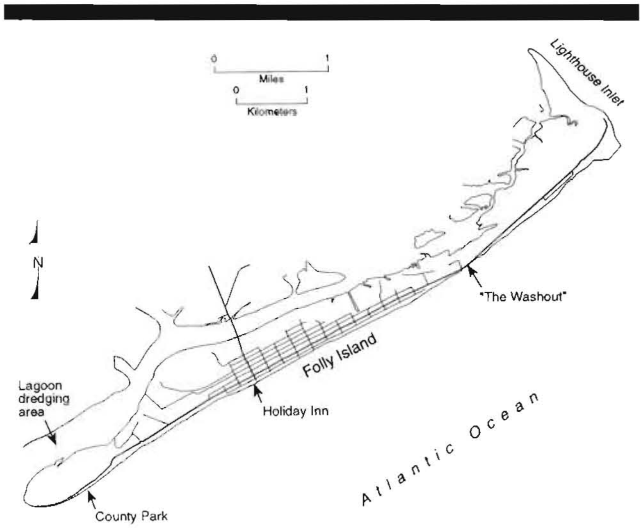


Figure 1. Index map of Folly Beach, South Carolina.

ESIS have the ability to specifically predict that rehabilitating nine of the 43 deteriorating groins along the project reach will allow the amount of material required for initial construction to be reduced by more than 50 percent while maintaining the same nourishment interval (and providing a more favorable benefit/cost ratio) over the next 50 years? We argue (YOUNG *et al.*, 1995) that any reasonable assessment of the capabilities of numerical models of GENESIS' type will answer an emphatic "no."

We do not believe that HOUSTON has made the case that the groins have impacted the project to a significant degree. HOUSTON (1996) states that "*The groin field area that GENESIS predicted would improve project performance by holding sediment has indeed done so with sediment volume after a year being two percent greater than that initially emplaced. . . .*" We are at a loss to explain why Houston assumes that the volume of groin-trapped sand actually increased. The opposite is true. When the dredged sand emplacement was completed, the groin compartments were filled completely with replenishment sand, but within months the groins were exposed along most of their length. Clearly, the volume of sand actually held by the groins was immediately reduced. HOUSTON apparently is including shoreface sand in his sand volume estimates, but this is sand that is well away from any trapping influence of the groins.

On a less fundamental note, HOUSTON (1996) also touts the success of GENESIS in predicting the location of erosion hot spots. He notes "*GENESIS predicted the area* [near the "Washout;" see our Figure 1] *would experience much greater erosion than the remainder of the project . . . although the* [modeled] *hot spot area location . . . was spatially shifted somewhat from where it actually occurred.*" Maybe GENESIS did not predict the location of the hot spot! According to EBERSOLE *et al.* (1996) (the paper to which HOUSTON alludes in his section on Folly Beach performance), "the GENESIS model seems to predict the erosive zone to occur at a location that is several hundred meters southwest of the location of the actual hot spot. . . . ." (EBERSOLE *et al.*, 1996, p. 25). From the standpoint of community planning, that does not seem to us to be a useful model prediction. Other workers (HARRIS, *et al.*, 1995; SCHWAB *et al.*, 1995) have suggested that the hot spot at the Washout is related to a cross-shelf trough located on the adjacent shoreface, the position of which is controlled by the underlying geologic framework of Folly Beach. GENESIS, however, does not consider geologic control of shoreface evolution.

The hot spot in front of the Holiday Inn seawall on Folly Beach was correctly predicted by the Corps. It could hardly have been otherwise since: (1) this location has been a major erosion hot spot for decades; (2) the seawall protrudes far seaward of the general shoreline; (3) the last of the groins built by the Corps is just updrift of the Holiday Inn (making the hot spot prediction self-fulfilling); and (4) the shoreline downdrift has a strong setback from the shoreline position north of the Holiday Inn.

To the City of Folly Beach, the problem is that this hot spot prediction is not spelled out in the design document (USACE, 1991) referred to by HOUSTON (1996). The community had to hire a consulting engineer to discover (in other Corps documents) that the Corps had no intention of keeping sand in front of the hotel, and this was done at the last minute when it was too late to influence the project (Vicki Zick, Folly Beach City Administrator, *personal communication*; see also PILKEY and DIXON, 1996). According to Zick, Corps district officials assured the mayor that, once the project was complete he could invite people to "walk 150 feet seaward from the Holiday Inn and join him for a beer." The community considered a beach in front of the hotel, the only high rise building in the community and a business skirting on the edge of bankruptcy, to be the highest priority. HOUSTON'S arguments of hot spot predictive success, tucked safely away in the technical literature, ring hollow in the light of the lack of communication between the Corps and the community.

EBERSOLE *et al.* (1996) suggest that the GENESIS model predicted that the sand transport for the "first year" would be to the southwest. This is how they explain their sand losses in regions 6 and 7 (their Figure 1). Our observations indicate that the net longshore transport of sand at the north end of the island has historically been to the northeast and not the southwest. The considerable shoal that developed at the north end of Folly Island at Lighthouse Inlet (Figure 1) immediately after the replenishment project is presumed by us to be due to the movement of beachfill to the northeast.

EBERSOLE *et al.* (1996) briefly review the use of GENESIS at Folly Beach. As is usually the case, we are not given enough information to adequately evaluate how GENESIS was used in the design of the project. There is no discussion of calibration, "verification," or data sources. They present us with the "results from the GENESIS model simulation of with-project conditions most like the project that was constructed in 1993" (EBERSOLE *et al.*, 1996, p. 24). They don't tell us how many runs were performed and why others were rejected. We are left with the impression that they have chosen the GENESIS run that most closely backed up the design criteria that had been settled upon without the use of GENESIS. Possibly the most successful aspect of the use of GEN-

ESIS on Folly Beach was the creation of a satisfactory cost-benefit ratio by halving the amount of sand required. This is exactly the problem with the use of GENESIS as an applied tool that our original paper (YOUNG *et al.*, 1995) was concerned about. It backs up one's judgment with what appear to be real numbers.

A DIFFERENT VIEW OF FOLLY BEACH

In the following section, we examine a number of statements (shown in italics) made by HOUSTON (1996) in his assertion that Folly Beach has behaved as designed. We have examined the history of the community–Corps of Engineers interaction during this project (PILKEY and DIXON, 1996) and we believe that enormous misunderstandings have occurred, some of which we note in this text. Houston's evaluation of beach success is done out of the community context which, we argue, is poor engineering.

The measured loss after one year was 81,000 cubic meters (only about 4 percent of sediment volume placed. . . .) . . . 96 percent of the fill sand was left after one year. . . .

The reason this loss is so small is that underwater shoreface sand is included in the total volume. From the standpoint of the Corps of Engineers, the beach was designed primarily to reduce property damage. The first sentence in Appendix 1 (Engineering Design and Cost Estimates) of the 1991 Folly Beach General Design Memorandum (USACE, 1991) is as follows: "The project is designed to reduce storm surge damages on Folly Island. . . ." From the community's standpoint, the replenishment project was wanted to improve the recreational quality of the beach. Underwater sand neither protects property nor improves recreational beach quality. According to the design documents, storm protection is furnished primarily by the berm, the elevation and width of which determines the size of the storm that the beach should withstand. Nothing in the design documents indicates that the district considered shoreface or underwater sand to be part of the storm protective function of the beach. Here on Folly Beach, with a relatively wide adjacent continental shelf, storm surge is an important feature of storms, further negating any effect the underwater sand might have on storm waves and surge.

The project also performed its primary task of storm-damage reduction with no damage to upland property experienced despite several severe storms. . . .

To our knowledge, there have been no severe storms since the beach was emplaced. (What is a severe storm?) The hurricanes of the summer of 1995 produced long wavelength swells of a type which, along this shoreline reach, are historically responsible for onshore transport of sand rather than substantial sand loss.

The Folly Beach replenishment project remains untested by an important storm (the March 12, 1996 Nor'easter that occurred during the writing of this article may have been the most important storm). This assertion is confirmed by South Carolina's annual beach status report (SCDHEC-OCRM, 1996), which was quoted in a Beaufort, South Carolina newspaper article:

> "Two mild winters and last year's uneventful summer have left South Carolina's beaches in their best shape in several years, according to the state's annual State of the Beaches Report. 'We've had two mild winters in a row and no major hurricane related problems,' said Bill Eiser, an oceanographer with the State Office of Ocean and Coastal Resource Management." (Beaufort Gazette, 1996).

This March 1993 storm ["Storm of the Century"] hit the project . . . with nearly hurricane-force winds.

True enough. The beach in front of the Holiday Inn seawall was lost entirely and the dredge pipes were damaged as they came to rest on a rock revetment at the base of the wall. But to complete the story, Houston should have noted that the dredge contractor "repaired" the storm-caused beach loss by adding another 156,000 m^3 of sand (EDGE *et al.*, 1994). This short stretch of beach also received "repairs" after the February 1993 storm, when another 163,000 m^3 of sand was added (EBERSOLE *et al.*, 1996). These two "repairs," which disappeared completely in a few months, represent 15 percent of the total project volume (EBERSOLE *et al.*, 1996).

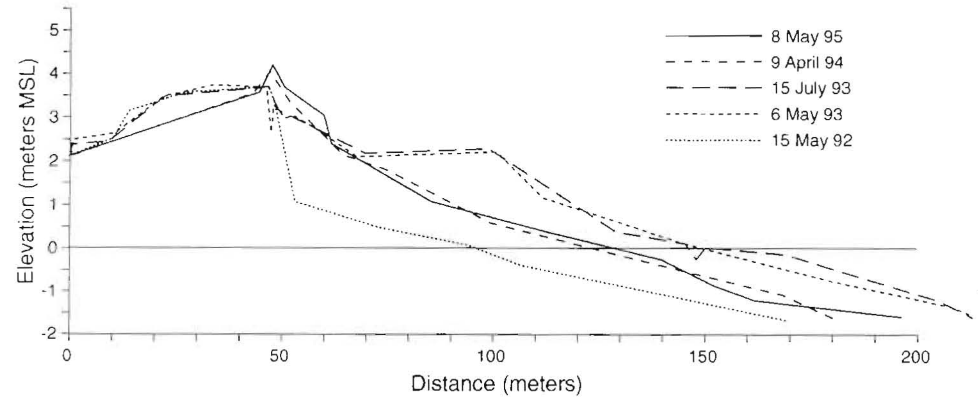
The photographs clearly show the dramatic beach improvement. . . .

Of course sand remains from the project; the community will continue to benefit from it for a few more years, barring any major storm events. Carefully selected photos from any beach project will show this. The really important question here, however, is the quality of design prediction and whether an eight-year nourishment interval is reasonable. The answer will determine the frequency of nourishment and the cost of holding the beach in place. The real predictive power of GENESIS (or lack thereof) needs examination over the next eight, 20, or 50 years, not the last one or two.

Plans for renourishment remain on the original design cycle.

The future of any beach replenishment project is a complex mixture of politics, economics and oceanography. HOUSTON'S view of the beach's future is based only on his (incorrect) assertion that the sand is behaving as predicted (and that over a mere year or two). Regardless of whether this is the case, the local view of the project is that future renourishment is unlikely, due to the present political climate, and to the changed economics of the project. The Corps of Engineers obtained sand from the lagoon behind the island using authorization that already existed for channel maintenance. The authorization was for a channel 2.7 m deep and 15 m wide but the eventual size of the dredged area was as much as 9.7 m deep and up to 183 m wide (PILKEY and DIXON, 1996). The borrow site behind the island can no longer be used because the U.S. Fish and Wildlife Service considered the source area to be too environmentally sensitive. Future sand will have to be obtained from offshore, which will raise the cost and create an entirely new benefit/cost situation.

The design subaerial-beach width for the Folly Beach project is 23 m with approximately 21 m of additional width added as an advanced fill. Before construction the designers predicted



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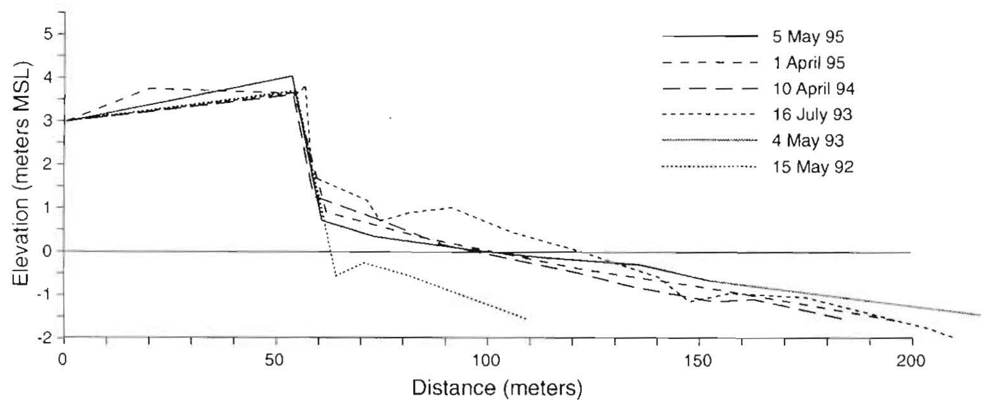

Parking lot of Holiday Inn

Figure 2. Two typical profile series across Folly Beach to wading depth. These stadia rod and level profiles are from College of Charleston Department of Geology studies. A total of 28 profile stations, all established by the South Carolina Coastal Council, were occupied along the entire length of the island.

after a year the project would have a 44-m average subaerial-beach width. The measured average subaerial-beach width after a year was 43 m.

Houston's use of the term subaerial beach is somewhat misleading because it includes the storm berm. The storm berm was vegetated and the community established a fine of $200 for walking on it. At the county park at the south end of the island, a sign notes that penalties up to $1000 will be assessed for damaging the vegetation. The point is that the actual recreational subaerial beach is only about half of the design beach. As noted earlier, the predicted beach widths were not available to the community before sand emplacement. They are not in the General Design Memorandum referenced by HOUSTON, although they could perhaps be obtained by using some of the very small scale cross sectional diagrams with large vertical exaggeration. Good engineering design requires that the customer be part of the picture, and these numbers were unknown to Folly Beach officials (VICKI ZICK, *personal communication*).

We have profiled to wading depth all 28 of the South Carolina Coastal Council bench marks (mentioned by EBERSOLE *et al.,* 1996) in May of 1992 (pre-project), 1993, 1994, and 1995. This was accomplished using a standard rod and level system. As shown in Figure 2, by May of 1995, only 14 percent (or 283,000 m^3) of the original volume of replenishment remained above low tide wading depth.

For reasons that are not clear, our volume measurements differ significantly from those of EBERSOLE *et al.* (1996), even after correcting for the fact that their profiles are longer and extend to a depth of around 5.5 m. EBERSOLE *et al.* (1996) point out that they believe there are possible errors in the comparison of repeated profiles. Apparently EBERSOLE *et al.* used before and after profiles made by the dredging contractor (using a combination of level onshore and fathometer off-

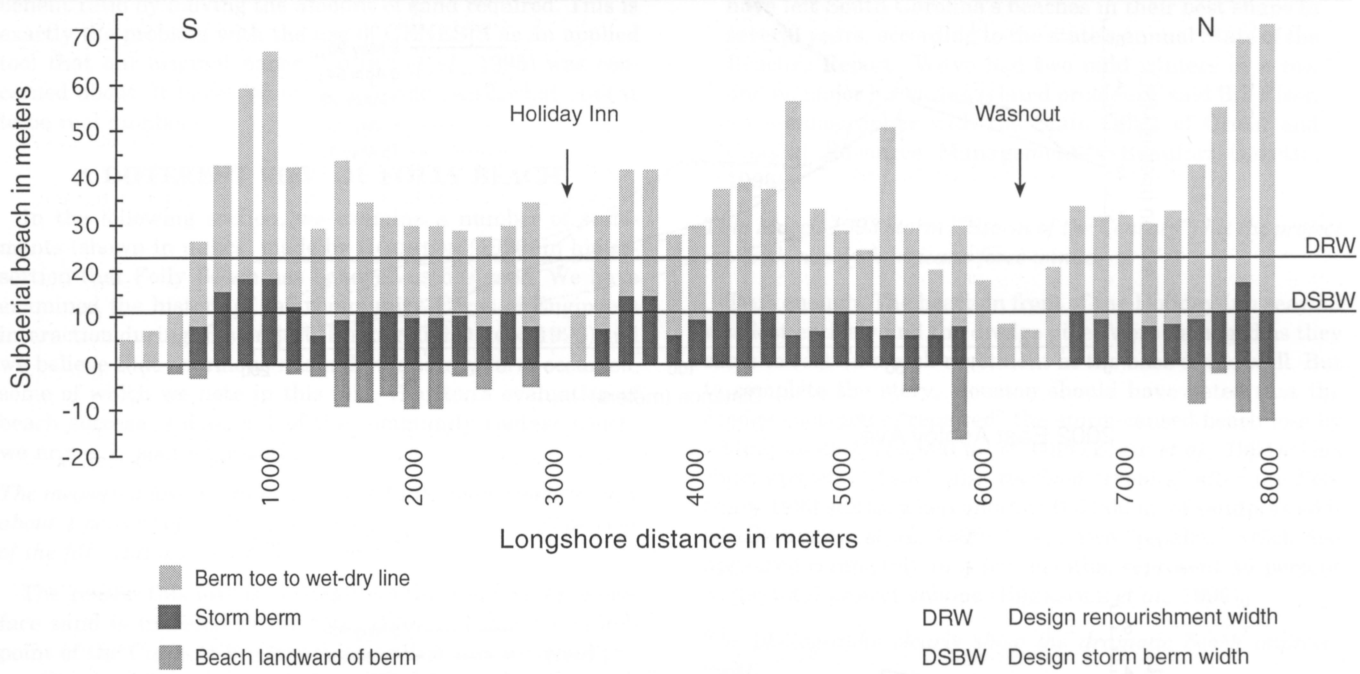

Figure 3. This graph shows measurements of dry beach width made in early February, 1996 on the Folly Beach subaerial beach. Wet/dry line measurements were made at intermediate tide levels after a period of several weeks of calm weather. The wet/dry line is generally accepted as a reasonable approximation of mean high water (MHW) (Dolan *et al.*, 1980; Crowell *et al.*, 1991), and our mean subaerial beach width is similar to the numbers reported by Houston. See text for further explanation.

shore) making it difficult to make a direct comparison with their later profiles which used a mobile survey cart and different base stations. In addition, some of their profiles begin well behind the seawall, making it impossible to make direct comparisons of their volumes with ours. Their profiles exhibit much more temporal variation in shape and volume changes than ours do.

In February 1996 we made a number of measurements of visible beach width at Folly Beach. This was done at a time of intermediate tide levels, during calm weather after several weeks of relatively calm weather. Measurements were taken at 56 locations along 8,600 m of shoreline; the data are summarized in Figure 3. The average width of the subaerial beach (seawall toe to the wet/dry (MHW) line) is 35 m and the dry beach width (seaward toe of berm to wet/dry line) is 24 m. These numbers are closely in line with what Houston says the project should be if the design predictions were correct and if GENESIS correctly predicted beach behavior. There is more to the story, however, than this simple measure of beach width.

Along several sections of the beach, the 4.6 m wide, 2.7 m above MSL storm berm is separated from the seawall by an expanse of dry, pre-project beach. This occurrence is shown in Figure 3 by the bar segments plotted below the abscissa. These isolated areas were created as a result of the need to keep the storm berm in a relatively straight line instead of following the original rather sinuous line of seawalls. HOUSTON'S definition of subaerial beach width apparently includes this segment, landward of the storm berm (EBERSOLE *et al.*, 1996), but since the project's storm protection function would be gone when the storm berm is destroyed, it makes no sense to include this portion of the beach, landward of the storm berm. Omitting this beach segment, the average subaerial dry beach width from the back of the berm to the wet/dry line is 32 m, not 43 m as HOUSTON claims.

Another, and perhaps the most important problem with HOUSTON'S assertions that the beach has worked perfectly is that his numbers involve island-wide averages of beach quality. All replenished beaches disappear unevenly along their lengths. Evaluating beach success must take this into account. Beach condition must also be considered from the community's standpoint: where are the problem erosion areas to begin with and what is their condition now? Averaging total project beach width numbers can hide a realistic view of the beach from the community's perspective.

Figure 3 shows that along 60 percent of its length, the protective storm berm is either missing or has been significantly reduced in size. We interpret this to mean that along much of the community, the berm cannot withstand the five-year design storm. The shoreline segments where the storm berm is in the best condition, at the north and south ends of the island, is where the community's beaches were in the best condition before the project began.

As we have noted elsewhere (PILKEY, 1993), in order to evaluate the success of a replenished beach or the success of the model that predicted its behavior, one must consider what the community's problem was before the beach was pumped in. If the replenished beach did not solve this problem as predicted, the beach was less than successful. It is also important to view these long-term projects over the appropriate long-term time scale. Reviewing a year of beach behavior for a beach with an eight-year nourishment interval as HOUSTON has done is simply misleading.

HOW TO EVALUATE GENESIS

HOUSTON (1996) criticizes us for not providing more discussion of practical engineering applications of GENESIS. That is, why not criticize the application of GENESIS on a project-by-project basis. We consciously avoided this because we believe this is a nearly impossible task. To do this we need much information that is not available. How was the model calibrated? What were all of the data sources? How was the model "verified?" How many times was the model recalibrated or "reverified?" The analysis of shoreline change at Lakeview Park in Lorain, Ohio (HANSON and KRAUS, 1991), is widely hailed as an example of a successful application of GENESIS (*e.g.*, National Research Council, 1995). However, the model required adjustments during *both* the calibration and "verification" stages. Without detailed examination of the internal workings of the model run, one cannot distinguish between a truly successful application of a model based on physical principles from a model application where "adjustment of empirical coefficients" is used to come up with "reasonable" answers. Given the statement by EBERSOLE *et al.*, (1996) (which we quoted above) regarding the comparison of GENESIS predictions with the actual Folly Beach project, we suspect this is what happened at Folly Beach, too.

It is obvious that arguing over GENESIS on a case-by-case basis becomes an exercise in opinionated futility. The model must be able to stand on its own, assumption by assumption, and we must make sweeping evaluations of its validity, reasonableness and utility for non-stochastic prediction. If even a single important assumption is wrong or a single process is poorly understood, the model will not work for engineering purposes. As we argued in YOUNG *et al.* (1995), we believe that it is a simple matter to demonstrate that the geologic and oceanographic underpinning of GENESIS is missing.

BEACH PROJECTS NEED MONITORING

Hardly a paper is written about beach replenishment that does not mention the need for monitoring, and bemoan the fact that it hasn't been carried out in the past. The aforementioned NRC report is only the latest to do this. The Ebersole *et al.* paper and Houston's discussion of our paper (the subjects of this discussion and reply) illustrate very clearly ways that monitoring should not be carried out. The problems are:

(1) The assertion of likely project success on the basis of a one-year report. EBERSOLE *et al.* (1996) produced a one-year progress report for a beach with an eight-year nourishment interval. With the vagaries of storm occurrence and other local factors, a one-year or "one-eighth of the nourishment interval" report is nearly useless.

(2) The inclusion of underwater sand in the volume total which leads to the conclusion (by EBERSOLE *et al.*, 1996 and HOUSTON'S discussion) that 96 percent of the beach was still present after one year. This sand does not create a recreational beach nor does it impact appreciably on storm damage mitigation (the stated purpose of the project).

(3) The presence of undocumented claims that the beach has withstood a number of "severe" storms.

(4) Evaluating beach loss on the basis of project-wide averages of beach width.

(5) Not considering whether the project has solved the community's original erosion problem. The beach's success is measured by the Corps using parameters which the community was not informed about. The expectations concerning beach width as related to nourishment interval, so clearly stated by HOUSTON in his discussion (42 m subaerial beach width now, 21 m beach width when nourishment will be needed) are not in the General Design Memorandum for the project.

CONCLUSIONS

We believe that GENESIS predictions are not performing well at Folly Beach. Model predictions of sand retention by groins leading to halving the amount of sand used for the project and predictions of erosion hot spots and sand transport directions have been in large part wrong. The 1993 Folly Beach project itself has been a failure in many ways. It is now, for all practical purposes, beyond the nourishment interval that was predicted by the Corps to be eight years. At least this is true for more than half of the community's shoreline, the same half that was having the most erosion trouble before the project.

By May 1995, only 14 percent of the original nourishment sand remained above wading depth. In February 1996, along 60 percent of the community, the storm berm was gone or was narrower than its design width. Community officials were not informed of hot spots and other beach behavior expectations, such as the fact that most of the sand would quickly move underwater to the shoreface. The Corps used a one-time only dredging source area and failed to inform the community that the next project would likely be much more expensive. As a result, community officials now believe that they will not be able to renourish the beach in the future. Folly Beach has not been served well by the Corps or by GENESIS.

LITERATURE CITED

BEAUFORT GAZETTE, 1996. Beaufort, South Carolina, 7 April 1996, p. 1.

CROWELL, M.; LEATHERMAN, S.P., and BUCKLEY, M.K., 1991. Historical shoreline change: Error analysis and mapping accuracy. *Journal of Coastal Research*, 7(3), 839–852.

DOLAN, R.; HAYDEN, B.P.; MAY, P., and MAY, S., 1980. The reliability of shoreline change measurements from aerial photographs. *Shore and Beach*, 48(4), 22–29.

EBERSOLE, B.A.; NEILANS, P.J., and DOWD, M.W., 1996. Beach-fill performance at Folly Beach, South Carolina (1 year after construction) and evaluation of design methods. *Shore and Beach*, 64, 11–26.

EDGE, B.L.; DOWD, M.; DEAN, R.G., and JOHNSON, P., 1994. The reconstruction of Folly Beach. *Coastal Engineering 1994*. New York: ASCE, pp. 3491–3506.

HANSON, H. and KRAUS, N.C., 1991. Numerical simulation of shoreline change at Lorain, Ohio. *Journal of Waterway, Port, Coastal and Ocean Engineering,* 117, 1–18.

HARRIS, M.S.; GAYES, P.T.; DONOVAN-EALY, P.; NELSON, D.D.; YORK, L.L.; GIELSTRA, N.; KINDINGER, J.; FLOCKS, J., and KRANTZ, D.E., 1995. Geologic framework influences on the modern coastal morphology and processes along the South Carolina coast. *Geological Society of America, Abstracts with Programs,* 27(6), A–78.

HOUSTON, J.R., 1996. Discussion of: YOUNG, R.S., PILKEY, O.H., BUSH, D.M., and THIELER, E.R. A discussion of the Generalized Model for Simulating Shoreline Change (GENESIS), *Journal of Coastal Research* 11(3), 875–886. *Journal of Coastal Research,* this volume.

NATIONAL RESEARCH COUNCIL, 1995. *Beach Nourishment and Protection.* Washington: National Academy Press, 334p.

PILKEY, O.H., 1993. Can we predict the behavior of sand: In a time and volume framework of use to humankind? *Journal of Coastal Research* 9(1), iii–iv.

PILKEY, O.H. and DIXON, K.L., 1996. *The Corps and the Shore.* Washington: Island Press, 256p.

SCDHEC-OCRM, 1996. *South Carolina's Annual State of the Beaches Report.* Charleston, South Carolina: South Carolina Department of Health and Environmental Control, Office of Ocean and Coastal Resource Management, 72p.

SCHWAB, W.C.; TWICHELL, D.C.; RODRIGUEZ, R.W.; THIELER, E.R., ALLISON, M.A., and GAYES, P.T., 1995. Linear rippled scour depressions in the nearshore: Possible indicators of cross-shelf sediment transport? *Geological Society of America, Abstracts with Programs,* 27(6), A-77.

U.S. ARMY CORPS OF ENGINEERS, 1991. *General Design Memorandum, Folly Beach, South Carolina Shore Protection Project Charleston, SC.* Charleston District, May 1991.

YOUNG, R.S.; PILKEY, O.H.; BUSH, D.M., and THIELER, E.R., 1995. A discussion of the Generalized Model for Simulating Shoreline Change (GENESIS). *Journal of Coastal Research,* 11(3), 875–886.