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REPLY

Reply to: Houston, J.R., Rejoinder to: Pilkey, O.H., Young, R.S., Thieler, E.R., Jacobs, B.S., Katuna, M.P., Lennon, G. and Moeller, M.E., 1996. Reply to Houston, J.R., A discussion of the Generalized Model for Simulating Shoreline Change (GENESIS). *Journal of Coastal Research*, 12(4), 1044–1050; *Ibid.*, 14(3), 1170–1173.

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INTRODUCTION

In his rejoinder to our reply (PILKEY *et al.*, 1996) of his discussion of YOUNG *et al.* (1995), HOUSTON (1998) states that we "provide virtually no concrete criticism that GENESIS developers can address" (p. 1173). On the contrary, we believe that we offered very fundamental criticisms of GENESIS that need to be answered. In this reply to HOUSTON (1998), we reiterate eight criticisms of GENESIS that form the basis of the criticism in our original paper (YOUNG *et al.*, 1995). If deterministic numerical models used in beach design are to have credibility, it is essential that fundamental criticisms such as ours be addressed. We ask that Houston respond to these questions as the first step in a dialogue between model proponents and critics. Such a dialogue, centered around the widely used GENESIS shoreline change model (HANSON and KRAUS, 1989; HANSON, 1989), should be useful for coastal managers who see model applications on an almost daily basis and who apply models with little understanding of how they work. We feel that our criticisms are fair, objective, and worthy of a response.

The same eight questions apply to most models used to predict beach behavior, including SBEACH (LARSON and KRAUS, 1989).

EIGHT QUESTIONS

Wave Parameters

Mean wave height and direction are critical for modeling of beach behavior. Yet, as pointed out in the GENESIS technical manual (HANSON and KRAUS, 1989), good wave data are rarely available. Two waves of the same height, period, and direction do not necessarily have the same effect, depending on beach state, sediment sorting, sand supply, and other factors. Assuming good wave data *were* available, *how do you know which average wave characteristics are useful in a GENESIS model run to predict the behavior of a given beach?*

Shoreface Character

The GENESIS model assumes that the shoreface is composed of a thick, homogeneous layer of sand. It also assumes a shoreface surface based on an equilibrium profile shape. Recent studies, of East Coast shorefaces (RIGGS *et al.*, 1995; THIELER *et al.*, 1995; 1998; SCHWAB *et al.*, 1997), however, indicate increasingly that most shorefaces are sediment-starved, and that shoreface shape is controlled by a widely varying geologic framework ranging from modern inlet-fill to well-indurated Tertiary limestone. In addition, the concept of profile of equilibrium has been called into question (PILKEY *et al.*, 1993; RIGGS *et al.*, 1995; THIELER *et al.*, 1995). Even on relatively sand rich shorefaces, offshore bars are responsible for variations in the volume of sand transported on the upper shoreface (WRIGHT and SHORT, 1983; HOLMAN, 1995); shell lags, organic mats, and even wave-induced stresses may inhibit sand transport in fairweather and delay the onset of sediment transport during storms (WRIGHT, 1989; WRIGHT *et al.*, 1991; 1994; 1997). *How do you rationalize the GENESIS assumption of a smooth equilibrium profile without geologic control, offshore bars, or sediment variability?*

Closure Depth

GENESIS assumes a closure depth (or depth beyond which no sediment is transported in significant volumes). We find

no oceanographic basis for the existence of a closure depth. Rather the geologic literature is full of data suggesting significant sediment transport from shallow into deep water and *vice versa* (see NUMMEDAL, 1991; PILKEY and FIELD, 1972 as examples). Current-meter studies (WRIGHT *et al.*, 1991) indicate such a dividing line between the shoreface and the inner shelf does not exist. The seaward transport of beach nourishment sediment has been observed to depths well beyond the design closure depth at a number of beaches (PEARSON and RIGGS, 1981; THIELER *et al.*, 1994; REED and WELLS, in press). At Folly Beach, South Carolina, the subject of much of the rejoinder in question (HOUSTON, 1998), substantial quantities of nourishment sediment are being transported onto the inner shelf beyond the presumed closure depth (THIELER *et al.*, in press). *What is the field evidence for the existence of a closure depth, as used in GENESIS, as a limit of significant offshore sediment transport?*

Mean and Combined Flows

WRIGHT *et al.* (1991) note the existence of at least five different types of mean flows on the shoreface. These currents often interact with wave-induced currents and are responsible for sediment transport, onshore and offshore, even in fair weather (SWIFT, 1976; GRANT and MADSEN, 1979; CACCHIONE and DRAKE, 1990; PILKEY *et. al.*, 1993; WIBERG *et al.*, 1994). None of these currents are considered in GENESIS. *Because mean and combined flows are not considered in GENESIS, how do you discount their importance in sediment transport?*

Uncertainty

GENESIS is a deterministic model. Output quantities are provided without error bounds. Yet, model users need to know the possible errors or uncertainties in the model output. It is in the public's interest to be made aware of the scientific uncertainty of projects funded by public monies. This is especially true because the durability of coastal engineering projects like beach nourishment is often determined in large part by randomly occurring, but inevitable, storms (LEONARD *et al.*, 1990). Further, the nearshore oceanographic system is extremely complex and exhibits chaotic behavior. *How can GENESIS provide useful answers for coastal managers if the error bounds of the model output are unknown?*

Averages

GENESIS model parameters and results rely heavily on averaged values. Averaging, however, removes extreme events from either end of the spectrum and extreme events are certainly, on some beaches, responsible for most of the rapid and large changes. The use of averages denies the significance of the natural variability of the nearshore system (NICOLIS and NICOLIS, 1991). *How do you justify the widespread use of average values (e.g., wave characteristics, grain size, nearshore slope) in GENESIS?*

Storms

Storms and storm-related processes are important, if not critical, in the evolution of most beaches. Storm processes are numerous, including overwash, eolian transport, nearshore and inner shelf sediment transport by up- and down-welling, rip currents, storm surge ebb, *etc.* Storms of different intensity and from different directions can have widely varying impacts on the same beach. *How can a model such as GENESIS omit a realistic storm climate in predicting beach behavior?*

Field Data

The successful use of any model of earth surface processes requires good input data. As pointed out repeatedly by the GENESIS technical manual (HANSON and KRAUS, 1989), however, adequate data from a given field site are rarely available. Model-required data such as mean wave characteristics, groin permeability, nearshore bathymetry, shoreface sediment characteristics, and closure depth are difficult to obtain. Even if the model was able to represent reality accurately, the problem can be summed up in the old adage, "garbage in, garbage out." *In view of the great uncertainties concerning all input data and boundary conditions that might affect a GENESIS model run, how can one expect a physically reasonable answer from the model?*

CLOSURE

These eight questions are a distilled reiteration of the original criticisms of the GENESIS model from YOUNG *et al.* (1995). Although that paper has been much discussed within the pages of this journal, the fundamental questions of model usefulness and accuracy have never been answered or discussed. We desire a meaningful dialogue regarding the evidence behind coastal modeling assumptions and we believe these eight questions are a good place to start.

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