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NUMERICAL MODELLING OF BEACH EROSION ALONG SOUTH WEST COAST OF INDIA DURING SOUTH–WEST MONSOON

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***Abstract*:** *Beach morphological models are being used as a predictive tool to solve many coastal engineering problems. Such models are scarce in the Indian scenario. The present paper presents results of a numerical modelling study carried out for predicting the beach profile under different wave conditions. The numerical model formulation is discussed in succinctly. The calibration and evaluation of model is carried out on monsoon season with intense wave and severe beach erosion condition, using comprehensive field data. Sediment transport criterion for developing bar/berm was evaluated on the actual field conditions. The model gives plausible results and is recommended for other coastal environmental conditions.*

Keywords: *Numerical model; Calibration; Beach profile; Model performance.*

INTRODUCTION

The hydrodynamics and associated sediment transport in the near-shore zone at microscopic level are highly complex. Beach morphological change models are being used as a predictive tool in coastal engineering projects. Such models are available in global scenario and only a few studies are available for Indian coast. Numerical modelling of beach erosion requires quantitative description of the relation between sediment transport rate and physical mechanism responsible for the transport. Many factors are causative for beach morphological changes and some factors are yet to be realised. Most of the models available are empirical and are derived from experiments carried out in laboratories. The monsoonal erosion and the subsequent build-up of the beach during the post-monsoon period have been already studied for some of the locations of the south–west coast of India (Kurian, 1988; Thomas, 1988; Shahul Hameed, 1988; Harish 1988; Shahul Hameed et al., 2007). The present work aims at numerical modelling study for beach profile changes in south-west coast of India utilising comprehensive field data. The model has been tested for the first spell of south west monsoon, which is well known for high wave activity and intense erosion along south-west coast of India. The model mainly focuses on the main morphological features of bars and berms.

OBJECTIVES AND PROCEDURE

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Model formulation

The main objective of the study is to investigate the morphological response of beach to monsoon waves and to find predominate factors which determine foreshore changes due to cross-shore transport on the basis of comprehensive field data. The numerical model to predict profile change is developed based on concept proposed by Larson and Kraus (1989). The model simulates wave induced sediment movement in surf zone and beach profile changes using empirical results derived from experimental data. The model is capable of predicting the formation and movement of geomorphologic features such as long-shore bars, troughs and berms. Cross distribution of sediments is computed from mass conservation equation.

$$\partial d/\partial t = \partial q/\partial x \qquad (1)$$

The model is made up of three separate modules: (1) Estimation of the wave height distribution across the beach profile, (2) Computation of sediment transport rate distribution across the beach profile and (3) Solution of sediment continuity equation across the beach profile.

Field measurement and analysis

The south-west coast of India borders the Arabian Sea and the Indian Ocean with the coastline more or less aligned in the NNW-SSE direction. Sea wall is constructed in many stretches of the coast. Kerala coast is micro-tidal regime with a tidal range less than 1m. Beach sites chosen for model calibration are Valiathura, near Trivandrum and Calicut (Figure. 1). Valiathura beach is almost straight in NW-SE orientation. The isobath are nearly straight parallel and shelf has an average width of 45km. The inner shelf (30/20 m. contour) is steep with a slope of about 0.002 (Thomas, 1988). This coast like other parts of west coast of India is under the spell of southwest monsoon during June-September.

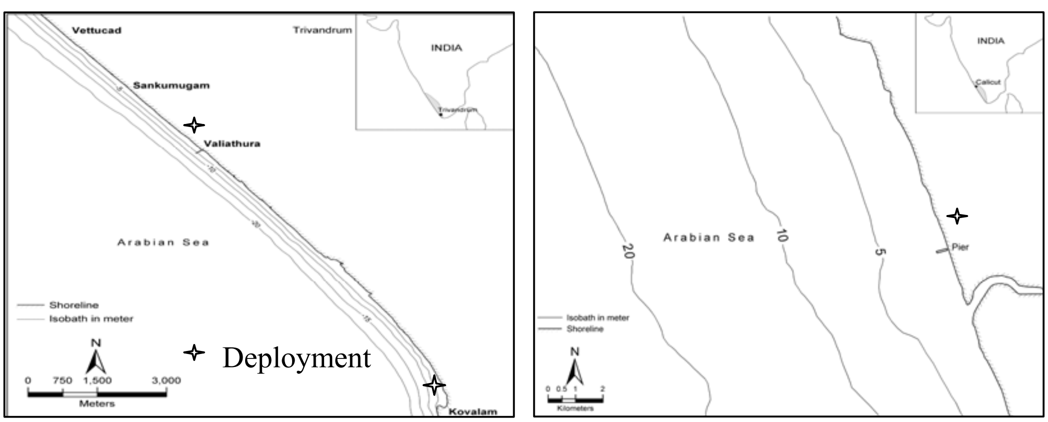


Fig. 1. Study area of numerical modelling (a) Valiathura (b) Calicut

The Calicut coastline is generally straight and oriented in NNW direction. The beach is comparatively wide, with a foreshore of moderate slope. Towards north the coastline is generally straight. The beach is generally wide and foreshore is moderately slope. The south of the coast is intercepted by two rivers Kadalundi and Beypore. Off Valiathura, the wave and current in the nearshore site were measured by deploying a Valeport wave guage and an Acoustic Doppler Current Profiler **(ADCP)** at a depth of 8m (Figure. 1) during 5 - 26 June 2005. The wave parameters like significant wave height (H_s), zero crossing period (T_z) and mean wave direction were derived from the instrument using appropriate software. The statistical parameters of measured wave data are given in the Table 1 .During the measurement period, wave characteristics vary considerably. In the beginning, the waves are of lower heights and higher periods, typical of swells from the SW-WSW directions. After a week the heights increased to the range 1.5 to 2.0m, but T_z is reduced to around 8 s to SSW direction. Latter half of the recording period is characteristic of intensified wave activity, with H_s mostly above 2 m ranging up to 2.78 m, T_z in the range 8-10 s and direction predominantly in the range of W- WSW. The intra monsoonal variation in wave characteristics as seen in earlier studies (Hameed et. al. 2007) is evident in the present results too.

Table 1. Statistic of input wave parameters of Valithura

Parameter	Min	Max	Mean	Standard Div.
Wave Height, H_s (m)	0.94	2.78	1.88	0.44
Wave Period, T_z (s)	6.8	9.8	8.28	0.75

At Calicut, the near-shore wave characteristics were measured at a depth of 3m during May-1980-1985 as part of a wave project conducted by CESS. A pressure type wave and tide telemetering system used for recording the waves. The wave parameters like, wave height (H_s), wave period (T_z), and wave direction recorded during July-1981 to August 1981 were taken for analysis and calibration processes and the statistical parameters relevant to the wave parameters are given in the Table 2.

Table 2. Statistic of input wave parameters of Calicut

Parameters	Min.	Max.	Mean	Standard Deviation
Wave Height, H_s (m)	0.13	1.53	0.93	0.32
Wave Period, T_z (s)	8	20.5	9.92	1.83

During this period wave characteristics vary considerably. The wave heights vary from very low value to high value. The standard deviation 0.32 indicates wide spreading of wave height. The significant wave heights (H_s) fall in the range 0.13–1.53. The wave period (T_z) shows rough sea condition and a typical characterization of monsoonal wave. Most of the time time short period waves are prevailing. The period varies from 8–20s. The wave direction varies from 235–300 ºN, the mean wave direction 260 ºN, which shows typical characteristics of south-west monsoon.

Beach profiles

Beach profile and sediment samples were collected twice, first on the day of deployment and second on the day of retrieval other during the retrieval of the equipments, to understand the changes occurred during this period by measuring the beach profiles at two times. The beach profiles were measured at 5m interval with respect to fixed bench mark using dumpy level and staff. The initial and final beach profile for the study period is given in Figure 2. At Calicut, the profile survey mainly used to carry out to locate the shoreline positions at regular interval. The beach profiles collected from July-August 1981 were taken for modelling study Figure 3. Both profiles shows are typical characteristics of the first monsoonal spell. The fair weather seaward berm is already eroded and the eroded sediment deposited as longshore bar just seaward of the shoreline. The final profile shows high erosion during this period with offshore movement of bar. The foreshore slope is derived from profiles. The foreshore slopes varies during the months of May, June and July.

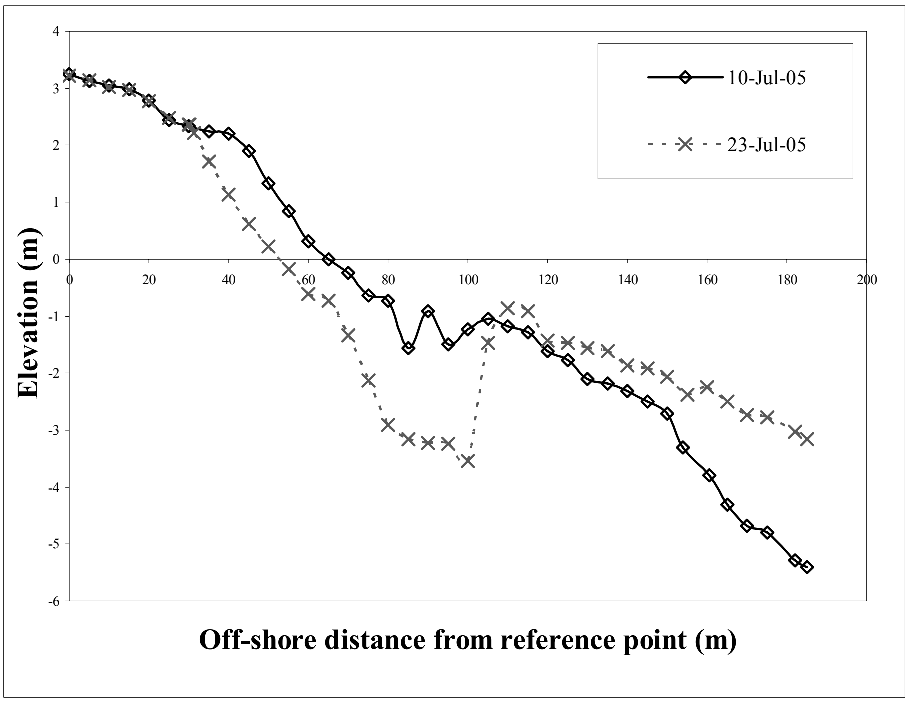


Fig. 2. Beach profile measured from Valiathura during the study period

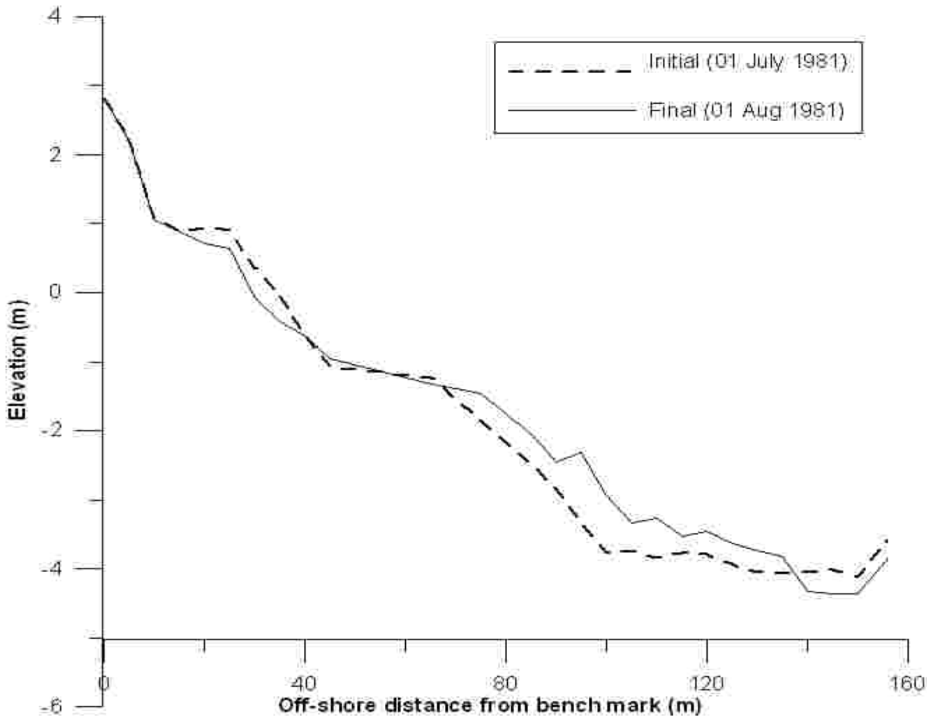
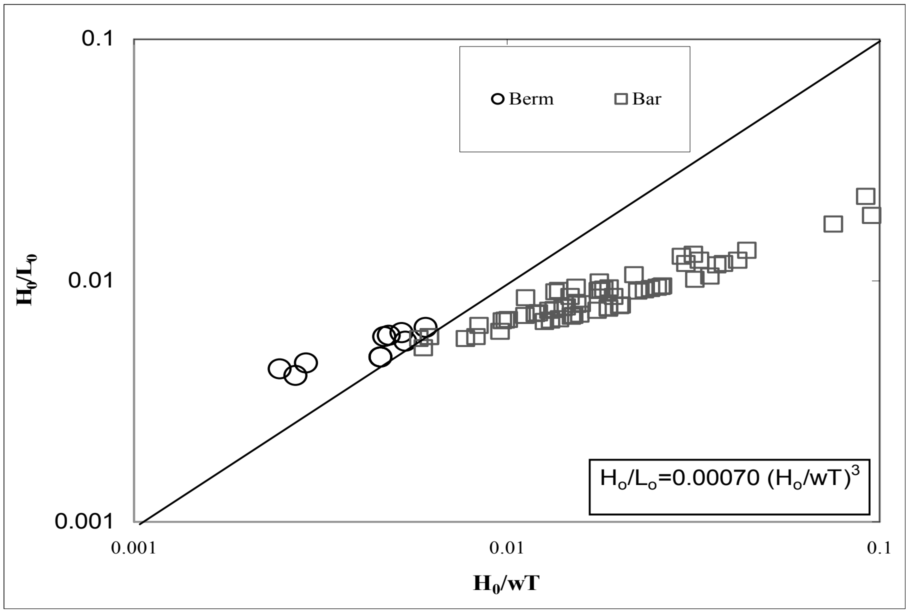


Fig. 3. Beach profile measured from Calicut during the study period

Evaluation of bar/berm criterion

A number of criteria have been developed for predicting the general response of a beach profile (a bar or berm profile) to incident waves (e.g. Dean, 1973; Sunamura and Horikawa 1974; Hattori and Kawakawa, 1981 and Larson and Kraus, 1989). The criteria proposed by Larson & Kraus (1989) is applied and evaluated in the field condition. The deep-water wave steepness 'H_o/L_o' (the ratio between the wave height and the wave length in deep water, a dimensionless parameter) appears in all criterion. The dimensionless parameters appearing in these criteria have distinct physical meaning. Other parameters appearing in these criteria are the sediment characteristics, such as average grain size or fall velocity and the beach slope. The dimensionless fall speed 'H_o/wT' is a measure of the time that sediment grain remains suspended in the water column. The deep water wave parameters were calculated from the measured wave data during the study period. The study show that, for both cases for most of the time, wave steepness (Ho/Lo) is less than fall speed parameter $(H_o/wT)^3$, which indicate seaward transport of the sediments is predominant and it is identical to the field signature. Hence this criterion can be applied to both coasts, which is well known for cross-shore transport during monsoon (Figure 4).



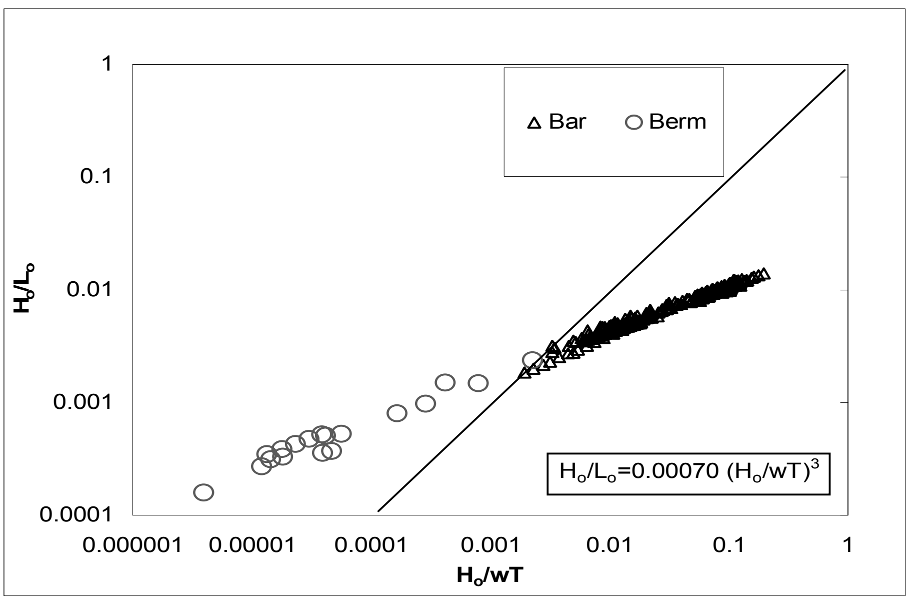


Fig. 4 Classification of bar and berm profiles by use wave steepness and dimensionless fall speed (a) Valiathura, (b) Calicut.

Model calibration

The process of calibration requires a detailed assessment of the local data and of field site characteristics to fully realise the potential of models. The numerical models need to be refined to match the site, and the decision-making leading to any modifications occurs during the calibration phase. The process of calibration also involves adjustment of empirical coefficients in the models. The empirical coefficient depends on site and therefore need calibration so that predictions best match the data. It is desirable to relate empirical parameters in the model directly to physical quantities or assign them a constant value to minimise the degree of freedom in the calibration process. The number of parameters available for adjustment in the calibration process was thereby reduced with little loss of accuracy. To minimise the difference between measured and computed values, the model has been run for many cases in the present study. Calibrations of transport relationships are obtained by series of simulations. The main calibration parameter is transport coefficient, K in the transport rate equation (Larson and Kraus 1989). The other calibration coefficients are slope dependent coefficient, epsil (€) and empirical coefficient Gama (Ѓ). Transport coefficient K is an empirical constant, which governs the time response of the beach profile. The transport rate coefficient is calibrated and compared with field data. The effect of transport coefficient mainly depends on time. Calibration studies show that the model gives good results for transport rate coefficient (K) =$2x10^{-6}$ m^4/N for Valiathura and this best fit value is recommended for application.

The other calibration parameter is a slope dependent term (epsil, €) and mainly influences equilibrium bar volume (Larson and Kraus, 1989). The profile response to Epsil (€) is highly dependent on time and it has less effect on the initial stages of profile change. Based on the calibration study ἑ (epsil) was set to 0.00183 m^2/sec for study area. The third calibration factor is Gama (Ѓ), where Gama is the ratio between wave height and water depth. By calibration process the value of wave coefficient Gama (Ѓ) is set at 0.4 and it is found that the computed profile agrees with measured one. The calibrated results are shown in Figure 5

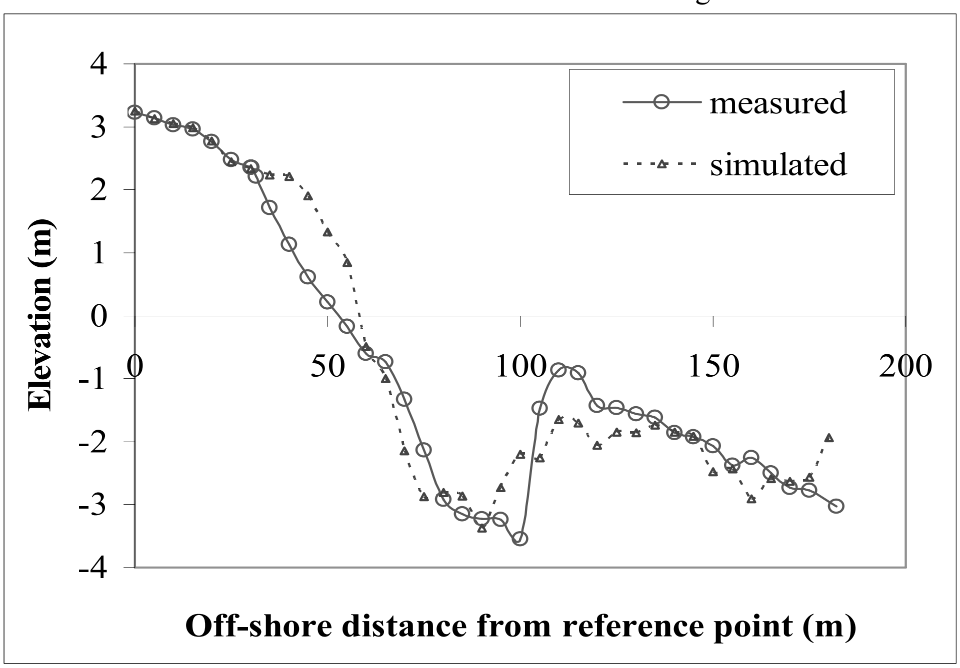


Fig. 5 Comparison of the calibrated model out put with the measured profile at Valiathura

The calibration study was simultaneously carried out for Calicut, having different environmental conditions compared to Valiathura. Predictions of the model are examined by number of cases. The model gives plausible results (Figure 6) for K=$0.5x10^{-6}$ m^4/N, epsil=0.0280 m^2/sec and gamma= 0.8.

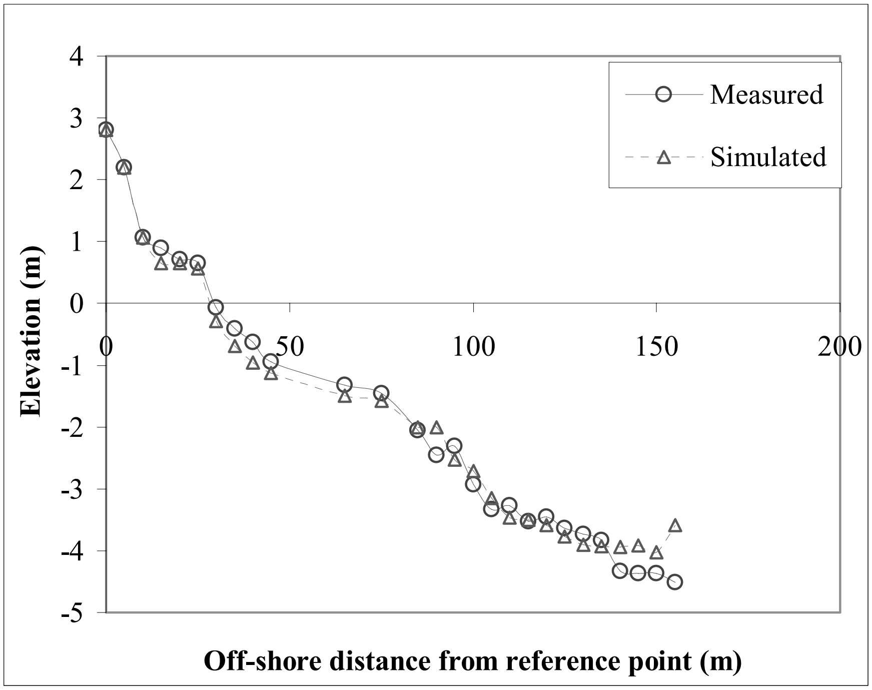


Fig. 6 Comparison of the calibrated model out put with the measured profile at Calicut

Model performance

Coastal engineers and policy makers are not concerned about the internal processes of the particular model they use but are concerned about the credibility and performance of the model. The performance of numerical models is used to establish the credibility of the model. It depends on mathematical stability of the model as well as the quality of the model. The performance of the model can be evaluated by calculating the parameters like, bias, correlation coefficient, and RMS, from the model simulations. 'Bias' measures the difference in central tendencies of the predictions and observations. The correlation coefficient measures the linear relationship between the two variables and Root mean square (RMS) error gives a measure of the differences between the predicted and observed values. The model performance calculated from model results gives best results in both locations (Table 3).

Table 3 Model performances

Locations	**Statistical parameters**		
	Bias	**RMS**	**Correlation ffi i t**
Valithura	0.05	0.60	0.96
Calicut	0.02	0.28	0.99

CONCLUSION

A numerical model study of beach morphological changes at two locations along the South West coast of India under intense wave conditions with large erosion and bar formation were carried out. A profile change model is proposed, calibrated and evaluated with comprehensive field data. The sediment transports at the surf zone were estimated by numerically solving the sediment transport balance equation across the shore. A criterion proposed by Larson and Krauss (1989) to delineate bar and berm profile were effectively evaluated with field data. The calibration processes were carried out by varying the parameters at different environmental conditions. The results fairly match with measured data. The model can be used for other coastal locations subject to its validation.

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