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# Breaking Waves on a Macrotidal Barred Beach: A Test of McCowan's Criteria

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**ABSTRACT**

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The location of the breakpoint on a macrotidal beach can vary in a discontinuous manner due to the presence of longshore bars. A number of studies have examined controls on the water depth at which breaking occurs. Here we extend those analyses to test predictions of the location of the breakpoint on a barred profile. Observations of breakpoint position and corresponding wave parameters are reported from Gibralter Point on the North Sea coast of eastern England. The results continue to support the theoretical analysis of McCowan (1894) and suggest that a value of 0.78 for the ratio of the wave height to the water depth at the breakpoint can be used to model breaker location to +/− 5 m on a 300 m wide intertidal profile.

**ADDITIONAL INDEX WORDS:** *Breaking waves, breaker parameter, barred beaches.*

## THEORY

The location of the breakpoint in nearshore models is important because it can control not only the hydrodynamics of wave reflection, energy dissipation and nearbed currents in the shorenormal sense, but also the generation and maintenance of longshore currents, cell circulations and edgewave systems. The breakpoint can reasonably be assumed to be constant for given wave conditions on tideless or microtidal beaches, but the problems become more complex when significant tidal variations in the still water level are present. Again a sinusoidal variation in the location of the breakpoint may then be a reasonable assumption when the nearshore and beach bathymetry is planar, but in reality the interaction of the breaking wave with nearshore bars will produce a complicated step function as the breakers move from one bar to another during the tidal cycle.

The location of the breakpoint was defined theoretically by McCOWAN (1894) who used solitary wave theory, and assumed that instability is reached when the particle velocity at the crest equals the wave celerity and that the crest angle is then 120° to demonstrate that:

$$B_o = \frac{H_b}{h_b} = 0.78 \qquad \text{Eq. 1}$$

where the breaker parameter, $B_o$, is defined simply as the ratio of the wave height, $H_b$, to the water depth, $h_b$, at the breakpoint. A range of other $B_o$ values have been derived theoretically (BOUSSINESQ, 1872: 0.73; RAYLEIGH, 1876: 1.0; GWYTHER, 1900: 0.83; DAVIES, 1951: 0.83; PACKHAM, 1952: 1.03; YAMADA, 1957: 0.83; LAITONE, 1959: 0.73; and LENNAU, 1966: 0.83), and from field observations (SVERDRUP and MUNK, 1946: 0.78), Laboratory experiments (IPPEN and KULIN, 1955 and KISHI and SAEKI, 1967) suggested that the $B_o$ value may increase considerably on steeper bed slopes. BOWEN *et al.* (1968) conducted a number of laboratory experiments in which plunger-generated waves were incident upon plane concrete beaches and confirmed the dependence of $B_o$ on beach gradient, and these empirical results received recent theoretical support fron New et al. (1985) who used a numerical method to extend the overturning wave model of LONGUET-HIGGINS and COKELET (1976) into shallow water. The *Shore*

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*Protection Manual* (1984) reviews recent results and utilises the experiments of WEGGEL (1972) to show that:

$$B_o = b - \frac{aH_b}{gT^2} \qquad \text{Eq. 2}$$

where T is the wave period, g is the gravitational acceleration and both a and b are functions of the beach gradient, m:

$$a = 43.75(1 - e^{-19m}) \qquad \text{Eq. 3}$$

$$b = \frac{1.56}{(1 + e^{-19.5m})} \qquad \text{Eq. 4}$$

DYER (1986) also relates the breaker parameter to the beach gradient through the rather simpler expression:

$$B_o = 0.72(1 + 0.64m) \qquad \text{Eq. 5}$$

giving values in the range 0.72 to 1.18 which are in general agreement with the predictions of Eq. 2. In the present paper we use the original McCOWAN criteria with $B_o = 0.78$ to extend these analyses and to predict the location of the breakpoint throughout the tidal cycle on a wide, barred, intertidal beach profile. We then test the predictions with field observations over a number of tidal cycles.

## METHOD

The experiments were conducted at Gibraltar Point (Figure 1) on the North Sea coast of eastern England. The profile was surveyed using standard techniques (Figure 2) and exhibits two shore-parallel bar systems. The tidal range at the site varies from 3.0 m on neaps to 6.1 m on spring tides, and the beach consists of well sorted fine to medium quartz sand. Poles were marked to enable visual observations of wave height, and set in the beach at twenty metre intervals during low water. Measurements were made by telescope from the shore at twenty minute intervals over a a number of tidal cycles and the wave height and water depth at the breakers, the mean wave period and position of the breakpoint were recorded. When waves were breaking between poles, the height and depth data were supplemented by measurements obtained with a hand held staff.

## RESULTS AND ANALYSIS

The observed wave heights were used with Eq. 1 to predict the water depth at the breakpoint, and this was used to predict the location of the breakpoint on the profile throughout the

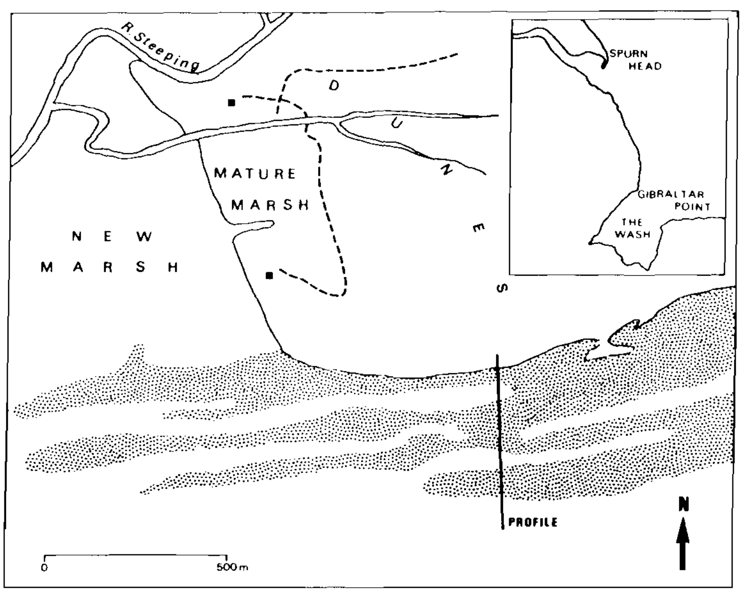


Figure 1. Location of the experimental site at Gibraltar Point on the English coast of the southern North Sea.

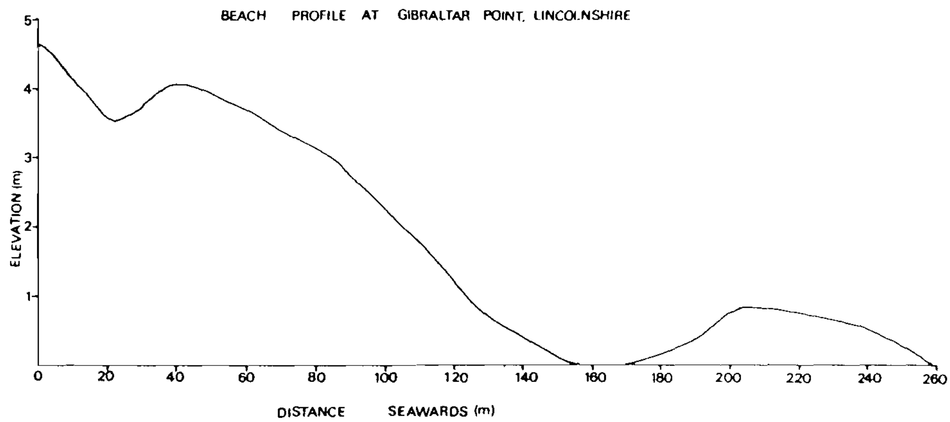


Figure 2. Intertidal profile at the experimental site.

tidal cycle. The predictions are compared with the corresponding observed breakpoint locations in Figure 3. There is clearly a good comparison between the results and predictions based upon McCowan's criteria with $B_o = 0.78$ and, in general, the accuracy is to within +/−

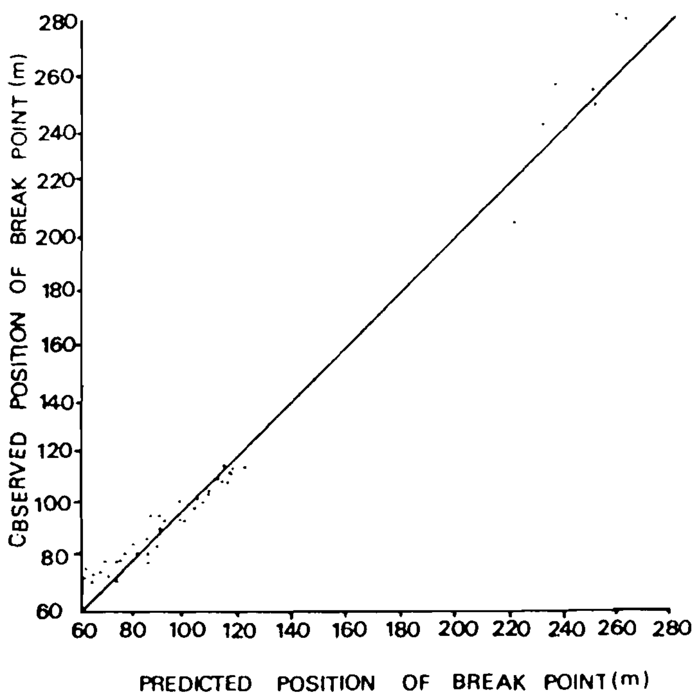


Figure 3. Comparison of the observed breakpoint positions with the predicted positions using McCowan's criteria and breaker parameter value of $B_o = 0.78$.

5 m over the 300 m intertidal profile. However a number of further points are apparent from the data. Firstly the waves only break on the outer bar for the first one to one and a half hours of the tidal cycle, and they then move to the inner bar with little evidence of waves breaking above the trough between the bars. Secondly the waves do not appear to break only on the crests of the bar, but instead break at the appropriate value of $B_o$ over the whole of the seaward slope of the inner bar. This may of course simply indicate that the waves which occurred during the field measurements are not of the size and period which is responsible for the formation of these bars. Finally, although the more sophisticated versions of the breaker parameter (Eq. 2 and Eq. 5) have been formulated to include the influence of bed slope on $B_o$, the present results suggest that the original analysis can be extended to predict breakpoint position within less than 5% with the simple value $B_o = 0.78$. The results suggest that this approximation is adequate because natural, macrotidal beaches have very low gradients even when a barred profile is developed.

## CONCLUSIONS

The results reported here suggest that a value of $H_b/h_b = 0.78$ provides reasonable predictions for the complex changes in the location of the breakpoint on a barred, macrotidal beach profile.

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