PREDICTION OF CLOSURE DEPTH AT THE NILE DELTA COAST

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ABSTRACT

The Coastal Research Institute (CRI) in 1971 initiated a program to monitor changes in the nearshore zone of the Nile delta coast. A series of annual beach profiles covering the Nile delta coast have been obtained extending to 6.0 m depth. The analysis of these profiles for the last 20 years indicates the presence of a seaward limit (closure depth) beyond the 6.0 m depth. Contour maps available from different surveys covering the coast from Alexandria to Burullus for three periods 1920, 1976, 1984 up to 50.0 m depth were used for this study. Fifty profiles were plotted for the three periods and an average profile was calculated. Standard deviation procedure was applied against profiles for 4 subcells (Alexandria- West Rosetta- East Rosetta- Burullus) as defined early by Frihy et al (1991). Envelope including the data points is drawn indicating that the standard deviation is not constant. The closure depth is defined for the different cells using this method and compared with an analytical model based on wave and sediment characteristics developed by HALLERMEIER, (1981). Bimodal distribution of standard deviation of depth changes indicated a lack of closure for the Alexandria, East Rosetta and Burullus subcells. The standard deviation in depth at West Rosetta subcell decreases markedly at a mean depth of about 25.0 m after which it becomes effectively constant.

Key words : Beach profiles, closure depth, landward limit, seaward limit, Nile Delta, Egypt.

NOTATIONS

The following symbols are used in this paper:

H_s	The mean significant wave height,
H_e	The wave height which occurs only 0.137 % of the time,
σ_H	The standard deviation,
h_{cl}	The closure depth,
T_e	The wave period corresponding to H_e ,
g	The gravitational acceleration,
X_i	The water depth at each profile survey,
N	The number of data points,
μ	The mean water depth,
h_{ci}	The seaward bound,
T_s	The mean significant wave period,
γ	$(\rho_s - \rho)/\rho$
ρ	The density of water,
ρ_s	The density of sediment,
D	The grain size,
Z_1&Z_2	Dimensionless roots

INTRODUCTION

The closure depth is defined as the depth at which the dynamic forces in the sea can no longer produce a measurable change in it. Its position is not the location where sediment ceases to move, but the location of minimum depth where profile surveys before and after a period of wave action , a storm perhaps, coincides each other(ICCE,1992).

The closure depth enters in a number of applications such as placement of mounds of dredged material to reduce wave action, beach fill, placement of ocean outfalls and sediment budget calculations.

Several studies have dealt with the closure deep water limit. KOMAR et al(1972) showed that oscillatory ripple marks generated by surface waves have been observed on the interface of continental shelf sands to depths of 100m and as great as 200m during storms.

CERC (1973) suggested that waves can move bottom sediments over most of the continental shelf (to depths of 30 m to 130 m or more) during some time of the year. Geologic studies indicate that fine material has been winnowed from the surficial sediments over much of the shelf, SHEPARD (1963) and DIETZ (1963). HANDS (1980) measured a series of beach profiles from the east shore of lake Michigan ,showing a wide envelope of profile changes in the shallower water of the nearshore pinching out in the offshore. SILVESTER and MOGRIDGE (1970) noted that extreme waves can cause sand motion at water depths on the order of 100m , far out on the continental shelf and beyond usual estimates of the wave dominated bottom.

HALLERMEIER (1978) proposed an expression to calculate the closure depth on the open coast involving the annual wave statistics. He stated that the closure depth is the result of the largest waves eroding the beach which is exceeded only twelve hours per year. The extreme maximum wave height H_e ; which occurs only o.137 % of the time can be related to the mean wave height by the relation:

$$H_e = H_s + 5.6\ \delta_H \qquad (1)$$

where H_s is the mean significant wave height and δ_H is the standard deviation in annual wave heights The expression for h_{cl} is then

$$h_{cl} = 2.28\ H_e - 8.5\ (H_e^2 / g\ T_e^2) \qquad (2)$$

where h_{cl} is the closure depth
g is the gravitational acceleration,
T_e is the wave period corresponding to H_e , and
H_e is given by eq. no. 1

BIRKEMEIR (1985) utilizing numerous beach profiles taken at the U.S. Army Field Research Facility, evaluated Hallermeir's relationship and found it is held if the empirical coefficients were adjusted slightly for his field data:

$$h_{cl} = 1.75\ H_e - 57.9\ (H_e^2 / gT_e^2) \qquad (3)$$

with a good approximation to the data being given simply by

$$h_{cl} = 1.57\ H_e \qquad (4)$$

with an average error of 0.5 m

DATA COLLECTION AND ANALYSIS

The data base for this study has been established from the three surveys: i- during the period 1919/1922 by the Admiralty Survey Ship "Endeavour" on scales of 1:235, 410, ii-during the period from 1975/1976 by the Woods Hole Oceanographic Institution, by research vessel CHAIN and LE SUROOIT expeditions on scale of 1:100,000 and iii- during the year 1984 by the Shore Protection Authority (SPA) on scale of 1:100,000.

The three bathemetric maps (1919/1922, 1975/1976 and 1984) were matched to the same scale and carefully overlapped. The overlapping was carried out based on fixed points such as forts, towns and the meandering course of the Nile. A baseline is constructed on the matched three maps, which extends more or less parallel to the shoreline. Fifty profile lines bordering the coastal zone from Alexandria in the west to El-Burullus outlet in the east are selected roughly perpendicular to shore. They extend seaward from the baseline to the 50 m depth contour. Figure (1) shows the position of the beach profiles along the Nile Delta coast. The spacing between each two profiles is 2 km. The three sets of bathymetric data were transformed into a matched set of coastal profiles in the following way. Along each individual profile line, distances from baseline and their corresponding depths were calculated. A sample of these profiles is given in Figure (2), while the full set is shown in (Khafagy et al 1994).

Two methods have been used for the estimation of the seaward limit (the closure depth):

(1) the standard deviation method.It considers the determination of an average profile and then the deviations of depths from its mean value are calculated using the following equation:

$$\delta_H = (X_i - \mu)^2 / N \qquad (5)$$

where

δ_H is the standard deviation
X_i is the water depth at each profile survey,
μ is the mean water depth, and
N is the number of data points.

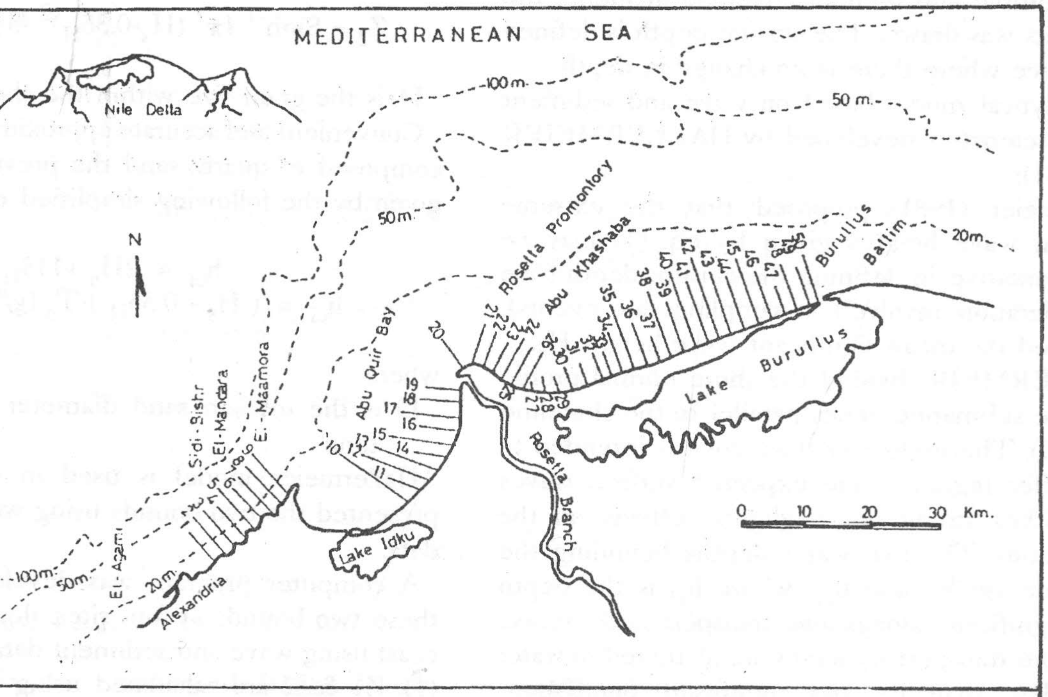

Figure 1. Map of the Nile Delta showing the position of beach profiles.

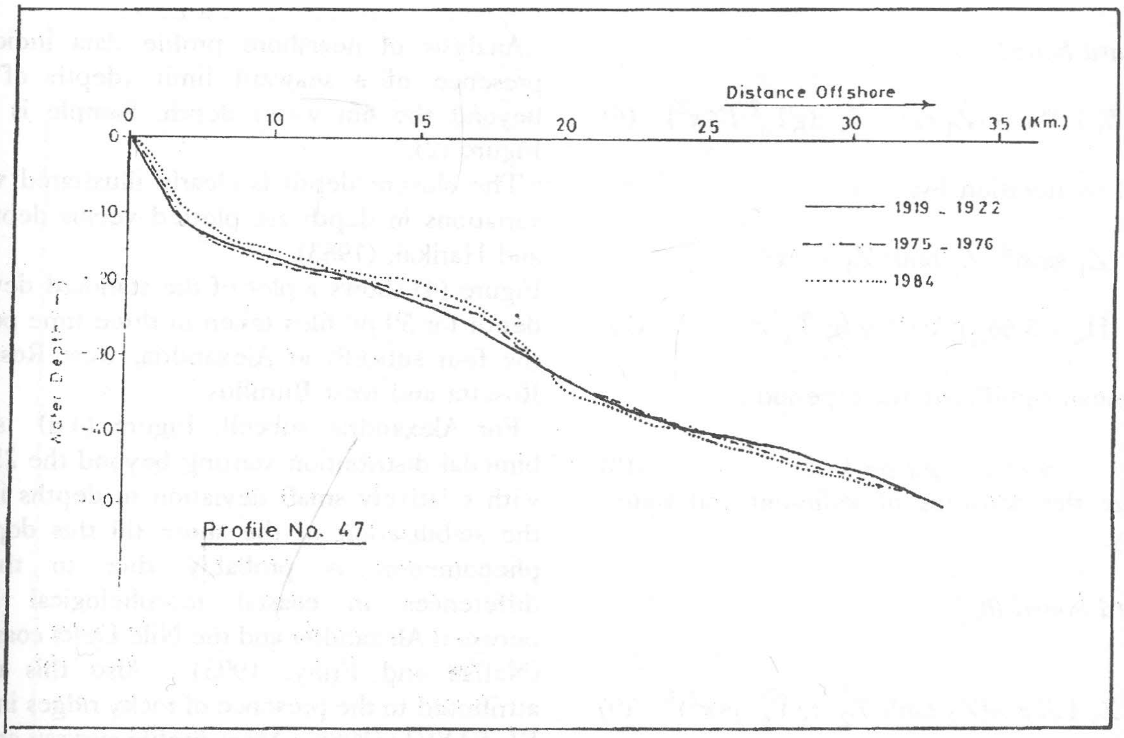

Figure 2. Sample of beach profiles.

The standard deviation was plotted against the average profile and then an envelope including the data points was drawn. The closure depth is defined at the place where there is no change in depth.

(2) Analytical model based on wave and sediment characteristics developed by HALLERMEIER (1981):

Hallermeier (1981) proposed that the extreme maximum wave heights given by eq. (1) may be unrepresentative in defining the closure depth (due to consideration involved in sampling rare events). So he used the mean significant wave height H_s.

HALLERMEIR divided the shore normal profile into three submarine zones parallel to the shoreline Figure (3). The middle or shoal zone is intended to be a buffer region where expected surface waves have neither strong nor negligible effects on the sand bottom. The two water depths bounding the shoal zone are h_{cl} and h_{ci} where h_{cl} is the depth where significant alongshore transport and intense on/offshore transport by waves are restricted to water depths less than h_{cl} and significant on/offshore transport by waves is restricted to water depths less than h_{ci}. The values of both the landward and seaward bounds are calculated as follows :

A. Landward bound h_{cl}

$$h_{cl} = Z_1 L/2\pi = (Z_1 \tanh Z_1)(gT_s^2 / 4\pi^2) \quad (6)$$

Z_1 is found by iteration by:

$$Z_1 \sinh^2 Z_1 \tanh Z_1 = 4\pi^4$$

$$(H_s + 5.6\delta_H)^2/0.03\, \gamma\, (g\, \bar{T}_s^2)^2 \quad (7)$$

where T_s mean significant wave period .

$$\gamma = (\rho_s - \rho)/\rho = 1.65 \quad (8)$$

ρ_s and ρ are the densities of sediment and water, respectively.

B. Seaward bound (h_{ci})

$$h_{ci} = Z_2 L/2\pi = (Z_2 \tanh Z_2)(g\bar{T}_s^2 / 4\pi^2)^5 \quad (9)$$

where

$$Z_2 = \text{Sinh}^{-1} \{\pi^2 (H_s - 0.3\delta_H)^2 / 8\gamma' g D\bar{T}_s^2\}^{0.5} \quad (10)$$

D is the grain size within the shoal zone

Convenient and accurate approximation for beaches composed of quartz sand the previous procedure is given by the following simplified equations :

$$h_{cl} \simeq 2H_s + 11\delta_H \quad (11)$$

$$h_{ci} \simeq (H_s - 0.3\delta_H)\, \bar{T}_s\, (g/5000D)^{0.5} \quad (12)$$

where

D is the median sand diameter within the shoal zone

Hallermeier model is used in this study as he presented the two bounds using wave and sediment data.

A computer program was developed to calculate these two bounds at four sites along the Nile Delta coast using wave and sediment data as given in table (1). Z1 &Z2 are calculated using Newton Raphson method .

RESULTS AND DISCUSSIONS

Analysis of nearshore profile data indicates the presence of a seaward limit (depth of closure) beyond the 6m water depth. Sample is given in Figure (2).

The closure depth is clearly illustrated when the variations in depth are plotted versus depth, Kraus and Harikai, (1983).

Figure (4) shows a plot of the standard deviation in depth for 50 profiles taken in three time periods for the four subcells at Alexandria, west Rosetta, east Rosetta and west Burullus.

For Alexandria subcell, Figure (4-a) shows a bimodal distribution starting beyond the 25m depth with relatively small deviation in depths indicating the stabilization of the shore till this depth. This phenomenon is probably due to the major differences in coastal morphological problems between Alexandria and the Nile Delta coastal zones (Naffaa and Frihy, 1993) . Also this could be attributed to the presence of rocky ridges in this area EL SAYED (1988) . More profile surveys are needed for this area.

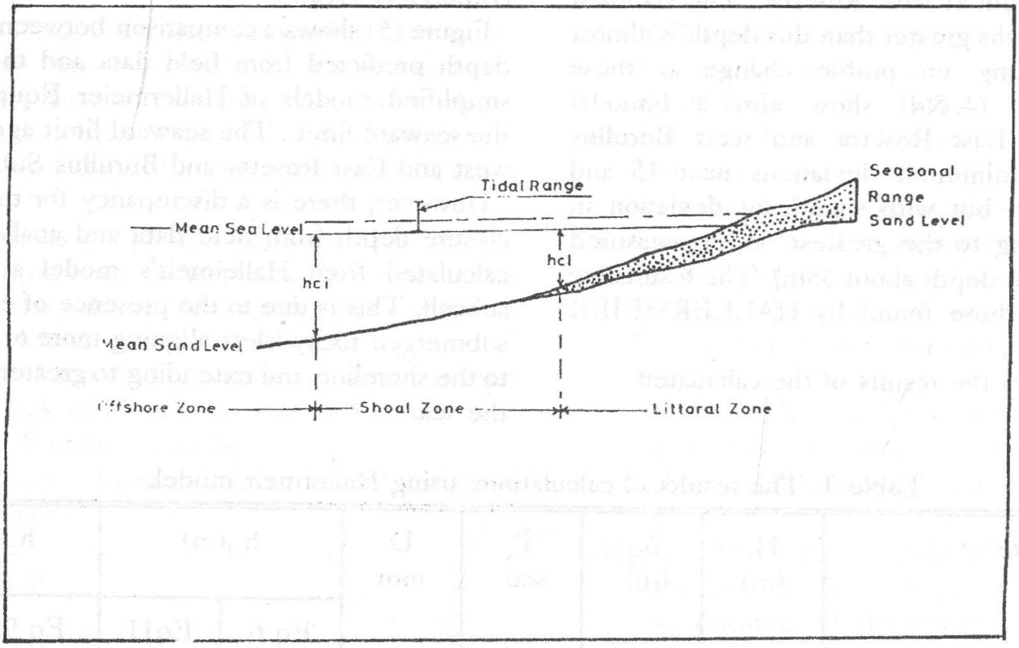

Figure Proposed Annual Zonation of Seasonal Sand Beach Profile (After Hallermeier, (1981).

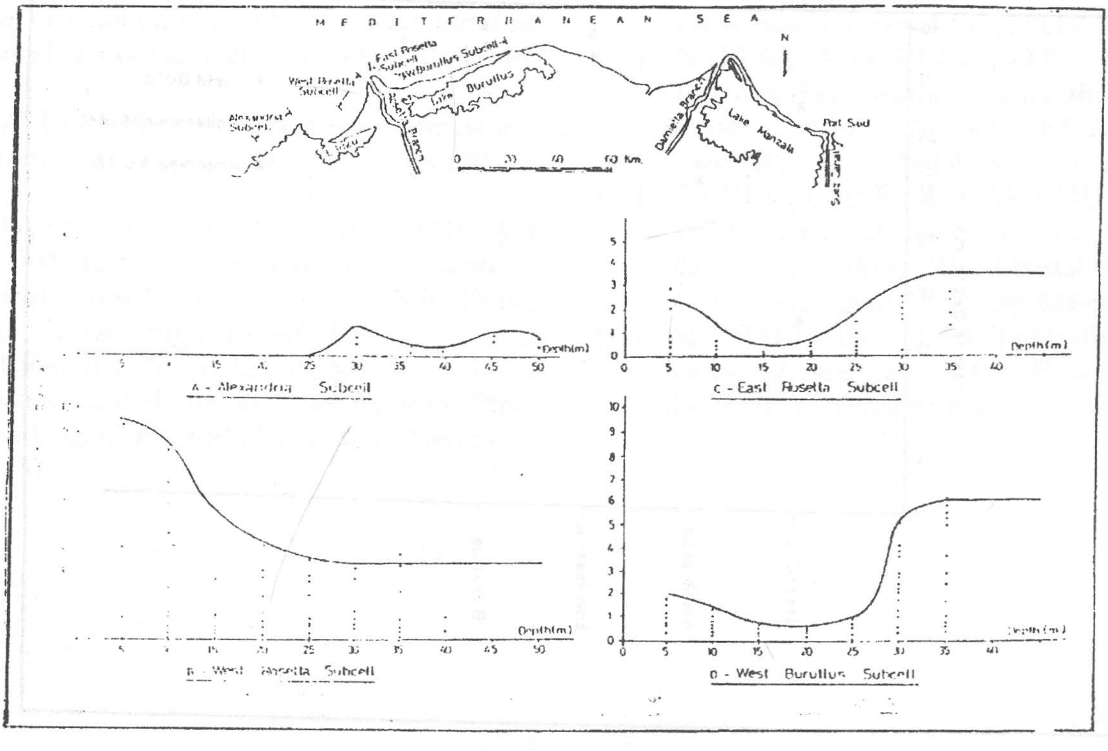

Figure 4. Standard Deviation of Depth Versus Average Depth for Different Subcells.

From figure (4b) it is apparent that the closure depth is about 25m at west Rosetta . The standard deviation for depths greater than this depth is almost constant indicating no profile change at these depths. Figures (4c&d) show also a bimodal distribution for East Rosetta and west Burullus subcells with minimum deviations near 15 and 20m,respectively, but with significant deviation in depths continuing to the greatest depth measured (expected closure depth about 35m). The results are consistent with those found by HALLERMEIER equation Eq(11) .

Table (1) shows the results of the calculated landward and seaward limits using Hallermeir model (Eq.6,11 & 9,12).

Figure (5) shows a comparison between the closure depth predicted from field data and that from the simplified models of Hallermeier Equation 12 for the seaward limit . The seaward limit agrees well for west and East Rosetta and Burullus Subcells.

However, there is a discrepancy for the predicted closure depth from field data and analytical results calculated from Halleimeir's model at Alexandria subcell. This is due to the presence of emerged and submerged rocky islets aligning more or less parallel to the shoreline and extending to greater depths into the sea.

Table 1. The results of calculations using Hallermeir model.

Site	H_s (m)	δ_H (m)	$\bar{T}_s$ sec	D mm	h_{cl}(m)		h_{ci}(m)	
					Eq 6	Eq11	Eq 9	Eq12
Alexandria	0.51	0.13	6.4	.11	2.6	2.5	14.4	13.9
West Rosetta	1.21	0.72	6.13	.11	8.3	10.3	19.8	25.7
East Rosetta and Burullus	1.05	0.26	8.2	.11	5.12	4.96	29.8	33.6

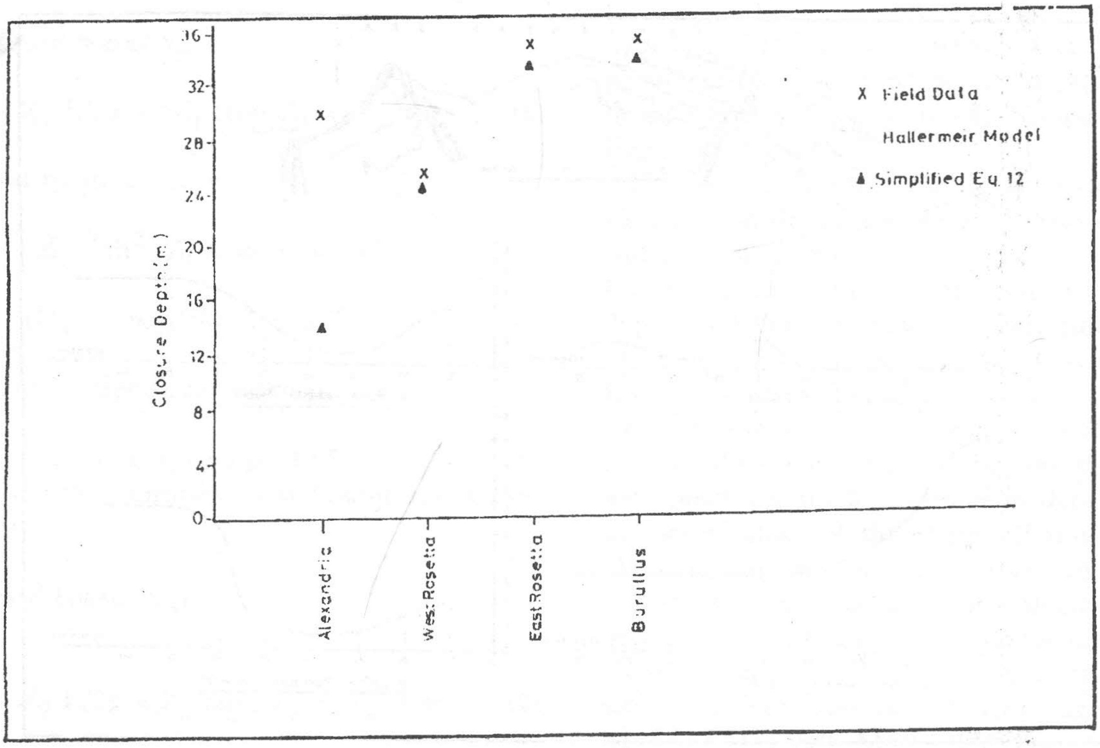

Figure 5. Comparison between field Data and Hallermeier Model.

CONCLUSIONS

The Nile Delta coast from Alexandria to Burullus was divided into 4 subcells (Alexandria, west Rosetta, East Rosetta, Burullus). The closure depth was determined from 50 beach profiles taken every 2 km up to 50 m depth for three periods 1920, 1976, 1984.

Standard deviation plotted against average profile indicate the presence of closure depth at about 25m at west Rosetta subcell. This result agrees well with HALLERMEIER model. However, bimodal distribution of standard deviation of depth change indicates a lack of closure for the Alexandria, East Rosetta and Burullus subcells.

Expected closure depth is 35m for East Rosetta and Burullus subcells.

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