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ANALYSIS OF WAVE OBSERVATIONS AND WAVE TRANSFORMATIONS IN ABU-QIR BAY, EGYPT

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ABSTRACT

Wave observations taken during 1986 in Abu-Qir Bay were statistically analyzed to calculate the wave parameters describing the sea state (significant wave height, wave period and predominant direction). On both sides of Rosetta promontory, the transformed wave parameters at break line (breaker height, breaker depth and crest angle) were calculated in terms of the predominant values of the significant wave height, period and direction using ACES software package. Breaker type and closure depth along Rosetta coast were also predicted. Generally, the wave effect in the bay was varying in intensity and direction in accordance with the prevailing wind. The average annual wave height and period are about 0.94 m and 6.5 s, respectively. Throughout the year, the predominant waves come from the NW direction (42%). Waves with significant height of about 4 m and period of about 11 s were infrequently observed during winter and summer gales. The wave characteristics at breaker line on both sides of Rosetta promontory are approximately similar. Generally, most of the waves along Rosetta coast break at about 1.7 m depth with a breaker height of about 1.5 m. The surf similarity parameter (ξ_0) was found to be equal 0.16, predicting that the spilling breaker predominates along Rosetta beaches. The closure depth (d_c) associated with the extreme wave conditions along Rosetta coast during 1986 was estimated to be equal 9.3 m, predicting a seaward limit of littoral transport to lie at about 0.5 km from the shoreline.

1. INTRODUCTION

Abu-Qir Bay (Fig. 1) is a semicircular shallow area with an average depth of less than 10 m and most of the bay has a gentle slope with a maximum depth of about 22m. The coastline of Abu Qir Bay extends between headlands of Abu Qir in the southwest and Rosetta in the northeast. A lot of activities are found in this area including industrial, commercial, fishing, army and tourism activities. The central area of Abu Qir Bay is occupied by three gas fields including complex of lighted platforms, submarine gas pipelines and wellheads. The pronounced seaward extending headlands of Abu-Qir and Rosetta have resulted in wave convergences and intense local erosion, with accompanying patterns of local accretion adjacent to these headlands. The erosion and accretion problems are more evident at Rosetta coast due to the more loose sediments that constitute its beaches. Shoaling in the exit of the Rosetta branch into the Mediterranean greatly affects fishing and navigation activities in the area.

Information on wave conditions in Abu Qir Bay is very important. Waves impact commercial shipping and recreation. In addition, nearshore waves derive sediment processes such as beach erosion and inlet shoaling. Accurate historical wave information is needed for engineering design, environmental impact assessment and hazard mitigation. Also, wave predictions are essential for military applications such as amphibious landings and mine warfare. Wave observations taken during 1986 in Abu-Qir Bay (Shereet, 2004) were statistically analyzed to obtain estimates of wave parameters describing the sea state, such as significant wave height, period and predominant directions. The estimated wave characteristics are then used to calculate the transformed wave parameters at break line on both sides of Rosetta promontory using ACES software package (Leenkencht et al, 1992). Breaker type along Rosetta coast was predicted according to Galvin (1968) formula. The depth of closure along Rosetta coast was estimated in terms of the extreme deep water significant wave height, wave period and sand specific gravity using Hallermeier equation (Hallermeier, 1981).

2. MATERIAL AND METHODS

The wind and wave data used in the present work have been collected by the Coastal Research Institute (CORI), Alexandria, Egypt (Shereet, 2004).

Wind data (speed and direction), taken during 1986 from a weather station at Rosetta headland, were sampled at 6 hours interval and calculated at 10 m above sea level. The collected wind data were then subjected to statistical analysis to get the percentage of occurrence of a certain wind speed moving towards a certain direction. In order to carry out this analysis, the wind data were divided into several classes such as 0 – 5 knots, >5 – 10 knots, >10 – 15 knots, >15knots in the eight cardinal directions (N,NE,E,SE,S,SW,W,NW). The analyzed wind data were then used to plot seasonal and annual wind roses for Rosetta area. Directional wave measurements were obtained using Cassette Acquisition System (CAS). It is portable, self-contained remote and recording system for sensing near-shore environmental parameters such as wave height, wave direction and wave period. It was fixed on the gas platform in Abu Qir Bay at 31^{o} 24$^{`}$ N latitude and 30°14$^{`}$ E longitude and the water depth at this location is18m Fig.1. The sensors of this system yield four daily recordings each 6.0 hours for about 34 minutes. The wave data are recorded on cassettes and analyzed by using a computer program, which gives the significant wave height, wave period and wave direction. The total number of wave measurements at Abu Qir during the year 1986 is 885 which corresponds to 885/4 ~ 221 day ≈ 7 months through this year.

2.1. Statistical analysis of wave observations

The wave action along the Mediterranean coast of Egypt is seasonal in nature and the measured wave data are grouped according to the seasons. Three seasons with respect to atmospheric circulation pattern have been distinguished: winter season, which occurs from November to March, spring season, which extends from April to May and summer season, which cover the period from June to October (Hamed, 1983).

The aim of this analysis is to get the percentage of occurrence of a certain wave height from a certain direction (wave rose). A computer program has been developed by the Coastal Research Institute,Alexandria-Egypt (Shereet, 2004) to calculate the monthly and the seasonal of both wave statistics (mean and maximum wave height and period) and the percentage of occurrence of different wave height classes (0-50, >50-100, >100-150 cm….etc) for each of the main sixteen sectors (N, NNE, NE,….NNW), as well as the percentage of occurrence of the different wave period classes (3 - <4, 4 - <5, 5 - <6, 6 - <7 s…etc).

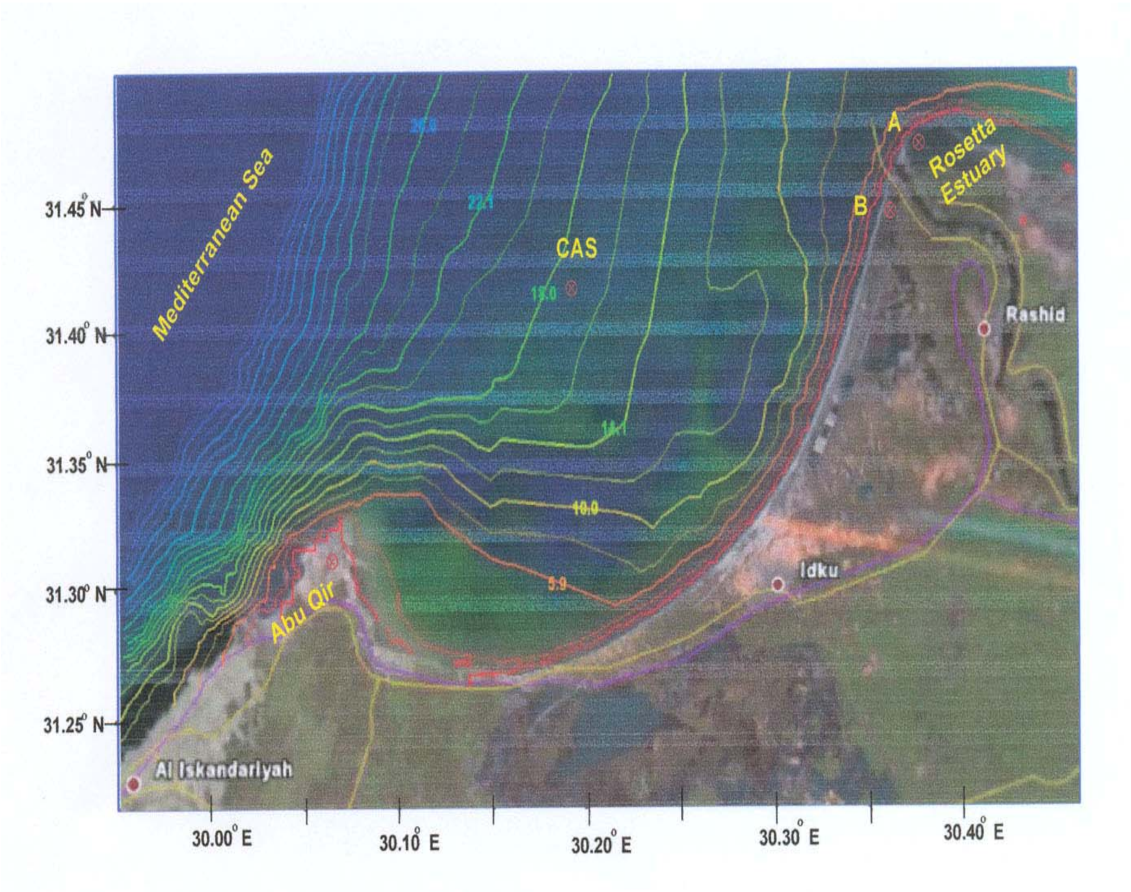

Fig. (1): Abu-Qir Bay, •- Location of the wave measurement arrays CAS.

2.2. Wave at different

The predominant annual depths wave parameters (wave height, period and direction) computed at 18 m depth in Abu-Qir Bay during 1986 were used to determine the wave characteristics for deep water and at the breaker line off the two sites located on both sides of Rosetta promontory Fig. (1). These calculations were done using ACES software package (Leenknect *et al.,* 1992).

According to Galvin (1986), breaker type can be predicted using the surf similarity parameter (ξ_0), defined as

$$\xi_0 = m/(H_0 / L_0)^{1/2} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

where: m is the beach slope, H_0 and L_0: are the deep water wave length and height, respectively.

On a uniformly slopping beach, as the case with Rosetta beaches, breaker type is estimated by:

Surging / Collapsing $\xi_0 > 3.3$

Plunging $0.5 < \xi_0 < 3.3$ ……………. (2)

Spilling $\xi_0 < 0.5$

The closure depth (h_c), which is an important parameter in sediment transport and beach fill calculation, is defined as the offshore depth beyond which the depths do not change with time. This depth is generally deeper than that portion of the beach profile that change seasonally or due to storm and can be considered as the seaward limit of littoral transport. The depth of closure along Rosetta coast was estimated in terms of the extreme deep water significant wave height, wave period and sand specific gravity using Hallermeier equation (Hallermeier, 1981).

3. RESULTS AND DISCUSSION

3.1. Wind

The normal wind regime along the Mediterranean coast of Egypt is controlled by various atmospheric conditions that occur on a seasonal basis (Suez Canal Authority, 1965). Depending on the atmospheric circulation in the Eastern Mediterranean including the Egyptian coast, three seasons have been distinguished: a-Winter season occurs from November to March, b - spring season extends from April to May and c- Summer season which covers the period from June to October (Hamed, 1983).

During 1986, the mean monthly scalar wind speed has lower values in summer and higher ones in winter due to the frequent occurrence of storms during that season. Speeds average 2 knots in summer and spring and 4 knots in winter. The maximum mean scalar wind speed (8.5 knots) occurred in December while the minimum (1.5 knots) was in August. During the whole period of observation, the maximum wind speed recorded was 26 knots Fig. (2).

The annual wind rose at Rosetta coast Fig. (2) indicates that the wind was predominantly blowing from the north (with high frequency of occurrence) and north-west. Winds from all other directions occurred but with significantly low frequency of occurrence. Wind observations revealed that the winter season is characterized by wind coming from all directions but northerly and northwesterly winds are still more predominant than those from the other directions. During the summer season, northerly winds prevail, while during the spring season the predominant direction of wind ranges between N and NW with some minor percentage from northeasterly direction.

3.2. Wave statistics

Analysis of wave records in Abu-Qir Bay during 1986 showed that the wave effect in the bay was varying in intensity and direction in accordance with the prevailing wind. Wave characteristics in different seasons are as follow:

1-Winter season (November – March)

The significant wave height ranged between 0.0 and 4.19 m with an average of about 1 m. The maximum value of wave height (4.19 m) observed in November, 1986 with a wave period of 10.7 s Table (1) and from a northwesterly direction. The predominant directions of all waves during the winter season range between WNW (38%) and NW (20%) and few have directions between NNW to NE and westerly directions (Fig. 3). During this season, wave periods are generally less than 11 s (Fig. 3b) with an average value of 6.8 s (Table 1).

2-Spring season (April – May)

During this season, the maximum wave height (2.63 m) is significantly smaller than that in winter. It occurred in April, 1986 with a wave period of 9.1 s and approaching from WNW direction. The average wave height is also less than that calculated in winter, where it amounts 0.92 m (Table 1). The predominant directions of waves are between NW (38%), WNW (24%) and NNW (16 %) (Figs. 3a, 3b).The average wave period is 6 s, while the maximum period is 9.1 s (Table 1).

3-Summer Season (June – October)

The average significant wave height in summer is 0.92 m with a maximum height of 4.08 m recorded in October. This relatively large wave is approaching from northerly direction with a wave period similar to that observed in winter (10.7, Table 1). In summer, the predominant direction of all waves is NW (54%) with a smaller portion (19%) coming from the WNW direction (Fig. 3a, 3b). The wave period in summer had an average value of 6.1 s and a maximum of 10.7 s, which are similar to those observed in winter (Table 1).

Generally, about 87% of all wave height are less than or equal to 1.5 m and 13% is greater than that value Fig. (4). The average annual wave height is about 0.94 m (Table 1). Throughout the year, the predominant direction of all waves is the NW direction (42%) and part of it (25%) is approaching from the WNW direction (Fig. 3b). Most of the wave period values (59%) range between 5 and 8 s (Fig. 3b) with an annual mean period of 6.5 s. Also for all waves, about 80% of wave periods are less than or equal to 8 s Fig. 4. Wave energy, which is proportional to the square of wave height, is generally higher in winter than in the other two seasons due to the frequent occurrence of winter storms associated with strong winds of more than 25 knots. During this season, the maximum significant wave height (4.19 m) was observed in November, 1986 with a wave period of 10.7 s (Table 1) and coming from a northwesterly direction.

3.3. Wave transformation

According to Galvin (1968) wave breaking may be classified into four types as: spilling, plunging, collapsing and surging. Douglass (1990) showed that onshore winds cause wave to break in deeper depths and spill, whereas offshore winds cause waves to break in shallower depths and plunge.

Wave characteristics in deep water and at breaker depth off the points A, on the eastern, and B, on the western, side of Rosetta promontory (Fig. 1) are shown in Table 2. In the calculation done using ACES software package (Leenknect *et al,* 1992) the following parameters were used: the x-azimuth is 180^0, the average beach slope is 0.02 and the predominant wave parameters during 1986 at 18 m depth, which are: the significant wave height (0.94 m), the significant wave period (T_s = 6.5 s) and the significant direction (45^0 clockwise from the +ve x-azimuth). The angle between the wave crest and the 18 m contour line at the extent of point A is 12^0 and B is 15^0.

It is clear from Table (2) that the wave characteristics at breaker line on both sides of Rosetta promontory are approximately similar. Generally, most of the waves along Rosetta coast break at about 1.7 m depth with a breaker height of about 1.5 m. The surf similarity parameter (ξ_0) is estimated in terms of the deep water wave height (H_0 = 1.0 m), wave length (L_0 = 65.93 m) and bottom slope (m = 0.02) and applying equation 1. The computation yields ξ_0 = 0.16, indicating that the spilling breaker type predominate along Rosetta beaches. Spilling breakers differ little in fluid motion from unbroken waves (Divoky *et al.,* 1970) and generate less turbulence near the bottom and thus to be less effective in suspending sediments than plunging or collapsing breakers.

The closure depth (d_c) along Rosetta coast was estimated in terms of the extreme deep water wave height (H_0 = 4.58 m), wave period (T_s = 10.7 s) and sand specific gravity (2.65) using Hallermeier equation (Hallermeier, 1981). The calculation indicated that closure depth (d_c) associated with the extreme wave conditions along Rosetta coast during 1986 was estimated to be equal 9.3 m, predicting a seaward limit of littoral transport to lie at about 0.5 km from the shoreline.

4. SUMMARY AND CONCLUSIONS

Abu Qir Bay is a semicircular shallow area with an average depth of less than 10 m and most of the bay has a gentle slope with a maximum depth of about 22 m. Wind and wave data measured in this area have been collected in 1986 by the Coastal Research Institute (CORI), Alexandria, Egypt (Shreet, 2004). These data were statistically analyzed to obtain estimates of wave parameters (significant wave height, period and dominant directions) in Abu Qir Bay. The estimated wave characteristics are then used to calculate the transformed wave parameters at break line on both sides of Rosetta promontory using ACES software package (Leenknect *et al.,* 1992). Breaker type along Rosetta coast was predicted according to Galvin (1968) formula. The depth of closure(d_c) along Rosetta coast was estimated in terms of the extreme deep water significant wave height, wave period and sand specific gravity using Hallermeier equation (Hallermeier, 1981).

The mean monthly scalar wind speed during 1986, generally, has lower values in summer and higher ones in winter due to the frequent occurrence of storms during winter. Speeds average 2 knots in summer and spring and 4 knots in winter. During the whole period of observation, the maximum wind speed recorded is 26 knots**.** Generally, the wind is predominantly blowing from the north and north-west directions. The winter season is characterized by wind from all directions but northerly and northwesterly winds are still more predominant than those coming from the other directions. During the summer, northerly winds prevail, while during the spring season, the predominant directions of wind are ranged between N and NW with some minor percentage from northeasterly direction.

Analysis of wave records in Abu-Qir Bay during 1986 showed that the wave effect in the bay is varying in intensity and direction in accordance with the prevailing wind. Generally, during 1986 about 87% of all wave height are less than or equal to 1.5 m and 13% is greater than that value. The average annual wave height is about 0.94 m. Throughout the year, the predominant direction of all waves is the NW direction (42%) and part of it (25%) is approaching from WNW direction. Most values of the wave period range between 5 and 8 s (59%) with an annual mean period of 6.5 s. Also for all waves, about 80% of wave periods is less than or equal to 8 s. Relatively high waves with significant wave height of about 4m and period of about 11s are infrequently observed during summer and winter gales The wave characteristics at breaker line on both sides of Rosetta promontory are approximately similar. Generally, most of the waves along Rosetta coast break at about 1.7 m depth with a breaker height of about 1.5 m. The surf similarity parameter (ξ_0) is found to be equal 0.16, predicting that the spilling breaker predominates along Rosetta beaches. The closure depth (d_c) associated with the extreme wave conditions along Rosetta coast during 1986 is estimated to be equal 9.3 m, predicting a seaward limit of littoral transport to lie at about 0.5 km from the shoreline.

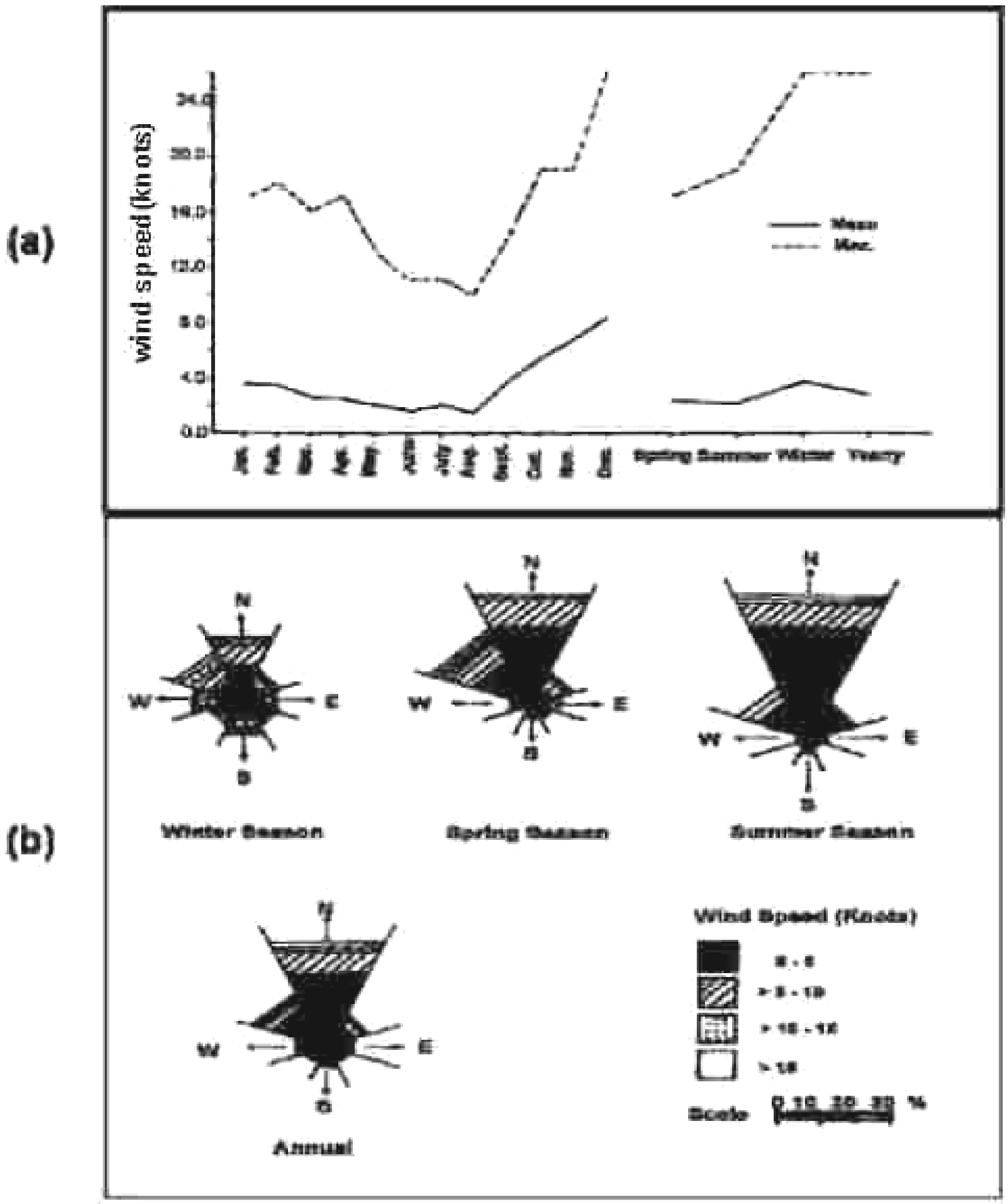

Fig. (2): a- Mean and maximum: monthly, seasonal and annual wind speed, b-Seasonal and annual wind rose diagrams (Rosetta area, 1986).

Table (1): Mean and maximum: monthly, seasonal, annual wave height and period (Abu Qir Bay, 1986).

Period	Wave height (cm)		Wave period (seconds)		Number of records
	Maximum	Mean	Maximum	Mean	
January	170	83	10.7	7.8	49
February	262	101	10.7	7.1	76
March	173	83	8.4	5.8	38
April	263	88.5	9.1	6	113
May	205	93	9.1	6.1	85
June	225	129	8	4.7	35
July	191	112	8	6.6	108
August	154	87.7	8	6.2	118
September	180	71	10.7	5.8	116
October	408	85.5	10.7	6.5	94
November	419	127	10.7	6.2	53
December	-	-	-	-	-
Winter	419	100.1	10.7	6.8	216
Spring	263	90.1	9.1	6	198
Summer	408	91.8	10.7	6.1	471
Annual	419	93.5	10.7	6.5	885

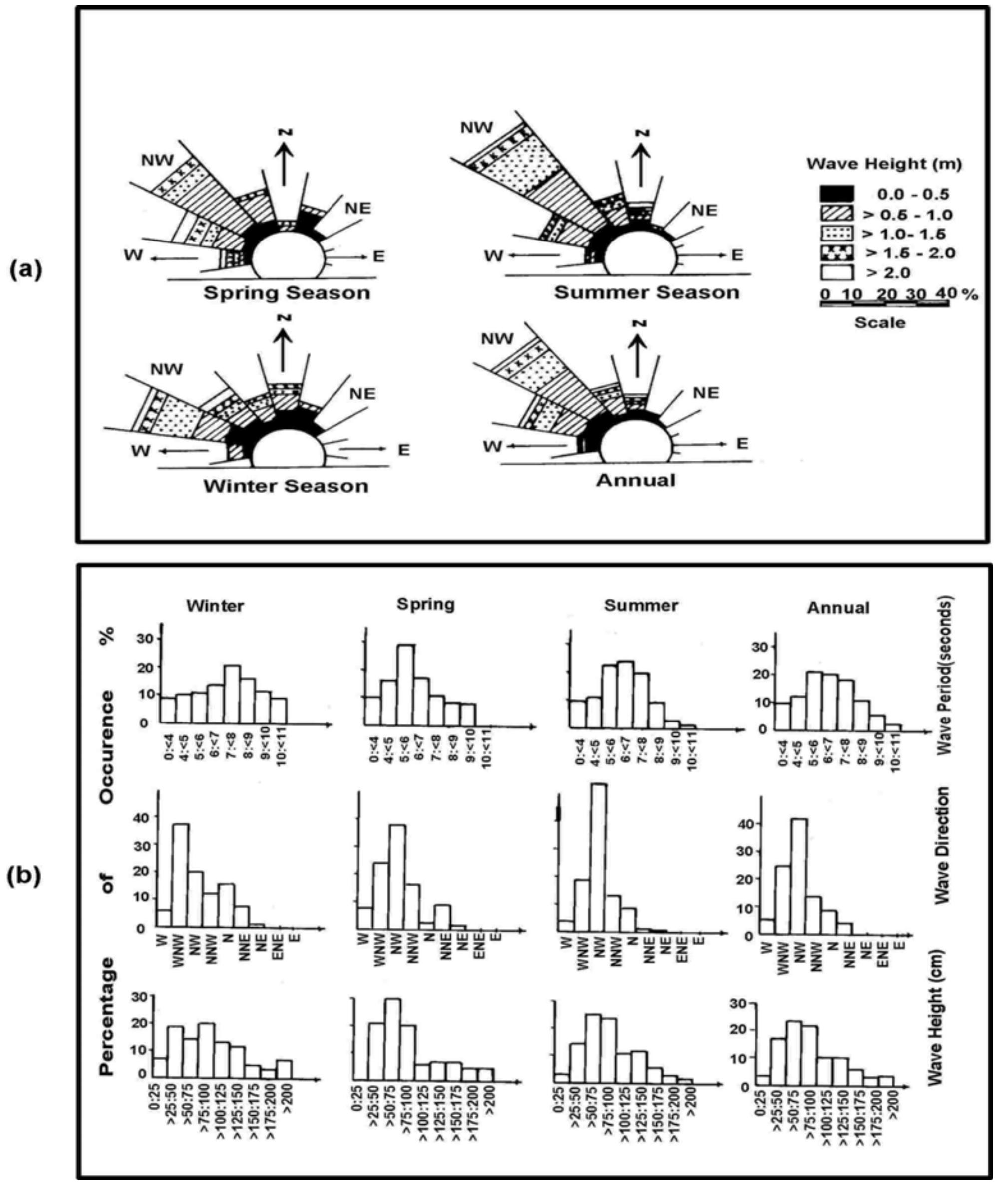

Fig. (3): Seasonal and annual: a- Wave rose diagrams, b- Histograms of wave height, Wave direction and wave period (Abu Qir Bay, 1986).

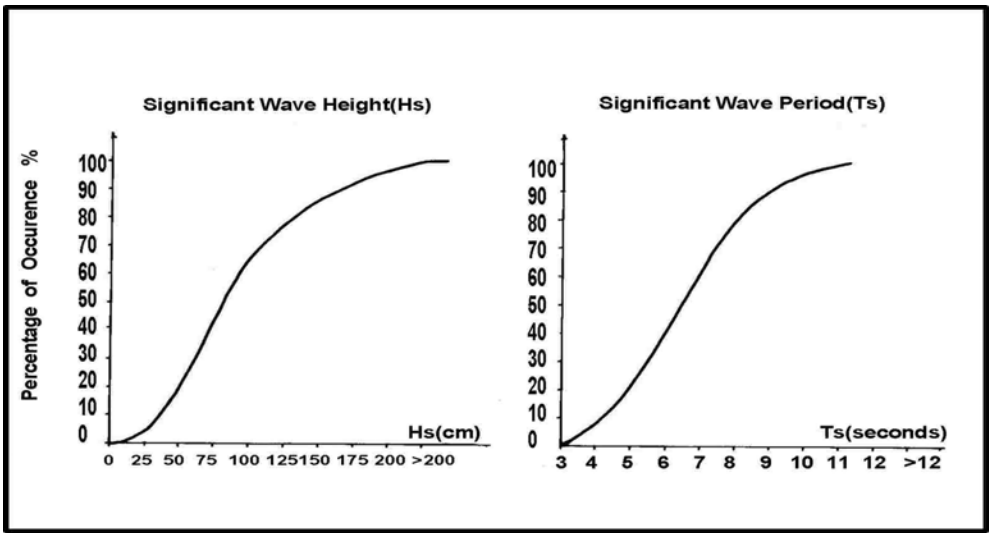

Fig. (4): Cumulative significant wave height and period distributions (Abu Qir Bay, 1986).

Table (2): Wave characteristics in deep water and at breaker depth off the points A, on the eastern, and B, on the western, side of Rosetta promontory (Rosetta area, 1986).

Parameter	Deep water	off point A	Off point B	units
Wave height (H)	1.0	---------	---------	m
Crest angle (α)	12.67	4.89	6.1	deg
Wave length (L)	65.93	25.64	25.64	m
Celerity(C)	10.14	3.94	3.94	ms^{-1}
Group velocity (C_g)	5.07	3.74	3.74	ms^{-1}
Energy density (E)	1261.7	1673.49	1655.51	Joul m^{-2}
Breaker height (H_b)	---------	1.48	1.48	m
Breaker depth (d_b)	---------	1.67	1.68	m

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