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Longshore Current in the Breaker Zone along the Rosetta Promontory, Egypt

A.M. AbdAllah*
Oceanography Department, Faculty of Science, Alexandria, Egypt.

S.H. Sharaf El-Din
Oceanography Department, Faculty of Science, Alexandria.

S.M. Shereet
Coastal Research Institute, Alexandria, Egypt.

Abstract

The longshore current regime along the Rosetta promontory was investigated using different theoretical models and through field measurements. Analysis of the longshore current observations on both sides of Rosetta promontory during the period from 1983 to 1998 showed that the maximum observed current speed during this period was 0.75 m/s, for the eastern side, and 0.76 m/s, for the western side, with an annual average speed of 0.36 m/s on both sides. The predominant longshore current flows southward along the western side and eastward along the eastern side of the promontory. Less frequently, this pattern reverses direction to northward for the western side and to westward for the eastern side under the effect of the less predominant NNE wave approach, particularly during winter and spring seasons. Predictions of longshore current along Rosetta promontory using: Longeut-Higgins [4], Galvin-Eagleson [5] and Komar [6] formulas show good agreement with observations.

Keywords: Beach Processes, Longshore Current, Rosetta promontory, Abu Qir Bay.

INTRODUCTION

Rosetta promontory is located on the eastern side of Abu Qir Bay (Fig.1) at about 60 km to the east of Alexandria city, Egypt. The promontory extends from about 2.4 km west Rosetta outlet to approximately 7.0 km east of it. Rosetta promontory is suffering from two main problems; the erosion problem on both sides of the promontory and the other, the siltation and shoaling problems in the Nile exit. This siltation problem can significantly affect the fishing activity in this area. In order to stop the shoreline retreat or at least to minimize it as much as possible two seawalls were constructed one on each side of the estuary. The western one has a length of 1500 m, while the eastern one has 3500 m length. These walls have been designed to stand a water depth of 8 meters in front of them.

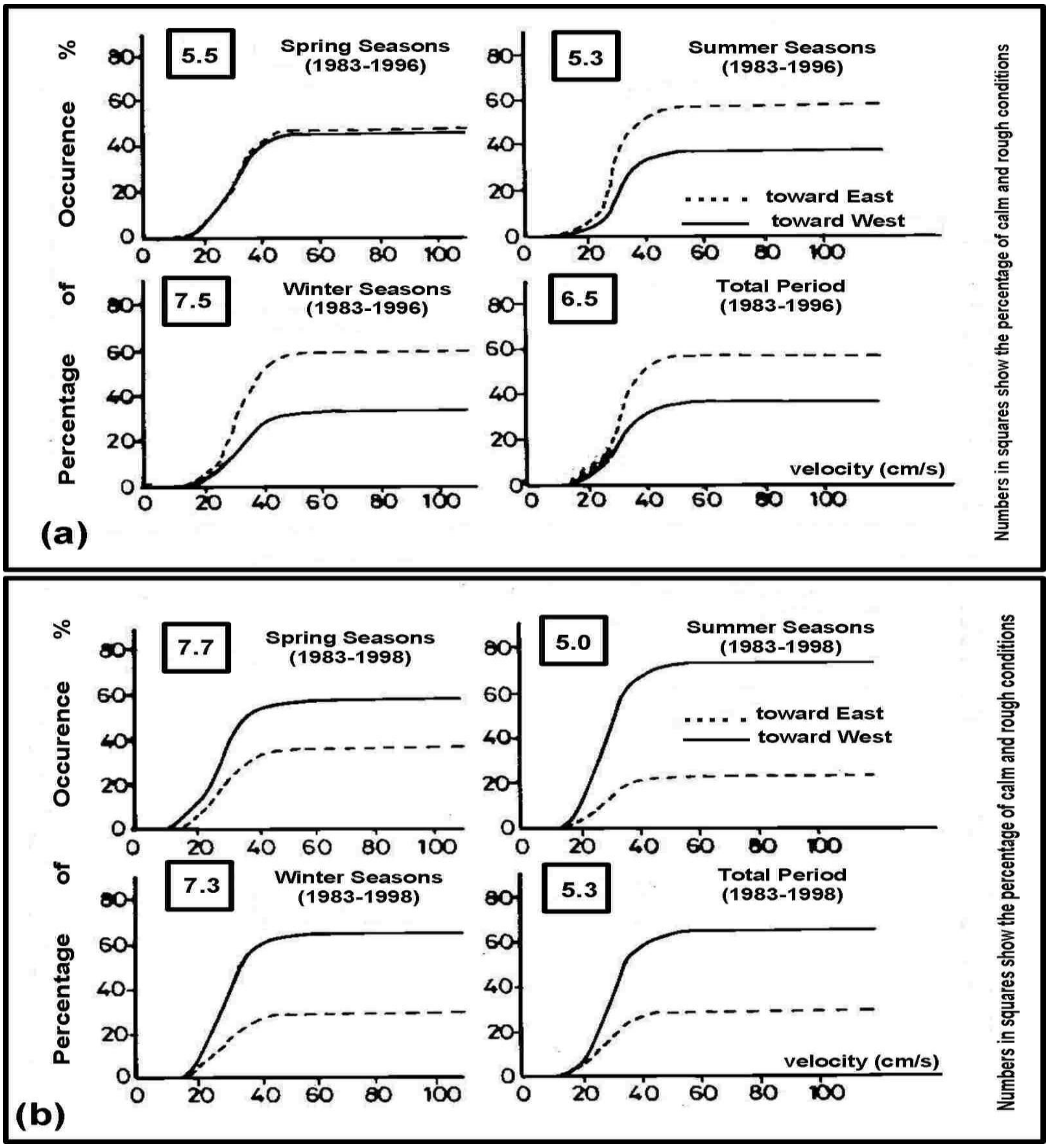

Figure 1. Longshore current (A&B) and wave(C) measurements stations off Rosetta coast.

Wave action along the Mediterranean coast of Egypt is seasonal in intensity and direction, and is strongly related to large-scale pressure systems over the Mediterranean and the north Atlantic [1]. Accordingly, they have indicated that wave climate was divided into three seasons. Winter extends from November to March, spring from April to May, and summer from June to October. The wave effect in Rosetta area is varying in intensity and direction in accordance with the prevailing wind. Hourly wind observations at Rosetta coast during 1986 indicate that the wind speed generally ranging from 0 to 13 m/s. The wind speeds in the winter months were generally higher than those recorded in spring and summer months. The winter season was characterized by winds coming from all directions but northerly and northwesterly winds were still more predominant. During the summer season, northerly winds predominate, while during the spring season the predominant directions of winds ranged between N and NW with some minor percentage from northeasterly direction [2, 3].Generally, winter and spring seasons are characterized by the occurrence of storms intervened by relatively longer calm periods [1]. Analysis of one-year records (1986) of directional wave observations at station C (Fig.1) off Rosetta coast at a depth contour of 18 m showed that the predominant wave directions were NW (42%) and WNW (25 %) and few have directions between NNW to NE and westerly directions. The annual mean significant wave height and period were 0.94 m and 6.5 s, respectively. About 87 % of all wave heights are less than or equal to 1.5 m while 13 % of them are greater than that value [2, 3].

Waves approaching the coast increase in steepness as water depth decreases. When the wave steepness reaches a limiting value, the wave breaks, dissipating energy and inducing longshore or littoral currents .The longshore current is a major and pervasive flow in the near-shore, and estimates of its velocity are needed in most coastal engineering projects involving sediment transport, such as navigation channel maintenance and shore protection. The aim of the present work is to study the littoral current regime along the Rosetta promontory by application of different theoretical models and through field measurements of this current.

MATERIAL AND METHODS

Littoral Current measurements

The longshore current data used in the present work have been collected by the Coastal Research Institute (CORI), Alexandria, Egypt [2]. Littoral current speeds were measured by conical floats designed especially for such measurements. This technique was applied because the available resources do not provide for other methods. Littoral current measurements were conducted at two stations: A is on the eastern side (from 1983 to 1996) and B is on the western side (from 1983 to 1998) of Rosetta promontory (Fig.1). Littoral current measurements were not available at both stations (A &B) during the period November 1985 to March 1988 and at station A during the winter months of 1996. Current measurements were done inside the surf zone in water depths ranging from 1.2 to 1.5 m, by following the movement of a conical float and measuring the time it took to travel a distance of 20 m in the longshore direction. The current speed is then calculated by dividing the distance traveled (20m) by the travel time. This process was repeated at both stations (A&B) two more times and the averages were computed. The direction of the longshore vector on the eastern side of Rosetta promontory (station A) is either to the west or to the east, while it is either to the south or to the north on the western side of the promontory (station B).

Littoral current measurements (speed and direction) on both sides of the promontory were taken twice a day, once in the morning and again in the afternoon. The total numbers of the computed current values at station A are 8464, while they are 9924at station B. During the whole periods of longshore current observations, winds and waves were predominantly approaching the study area from NNW – N sector. Winds and waves from N – NE sector were also observed but with less frequent occurrence. The collected data of longshore current (speed and direction) have been subjected to statistical analysis to determine the probability distribution of the longshore currents in the different seasons of the year. A computer program was developed to carry out this analysis. It has been based on grouping the data into various groups i.e. from 1–10 cm/s, 11-20 cm/s…etc. The number and percentage of occurrence of each group were determined and the cumulative frequency distribution analysis was made to determine the percentage of occurrence of a certain speed from a certain direction as well as the maximum and minimum speed for each direction.

Longshore current prediction formulas

Many theoretical and semi-empirical formulas have been developed to predict the longshore current velocity at the mid-surf zone. They are based on simplified bottom topography, and a steady state of equilibrium. Four formulas are chosen depending upon the approach used in their derivation namely: the momentum balance, energy balance, continuity and radiation stress approaches. They are calibrated against the available field data. These formulae are as follows:

1-Longuet-Higgins [4] equation – SPM formulae:

$$V = 20.7\, m\, (g\, H_b)^{0.5} \sin 2 \propto_b \quad m/s \quad \text{---(1)}$$

2-Galvin – Eagleson [5] equation:

$$V = k\, g\, T\, m \sin 2 \propto_b \quad m/s \quad \text{--------- (2)}$$

where:

V is the current speed (m/s) at the mid-surf zone position, k is a dimensionless coefficient depending on the generation of the breaking wave and can range from about 0.6 to 1.1, but it has been assumed to be unity [4], g is acceleration of gravity, T is the wave period, m is the beach slope, $\propto_b$ is the angle between the wave crest and the bottom contour where breaking occurs and H_b is the breaker height.

3-Komar [6] equation:

$$V = 1.17\ (g\ H_b)^{0.5} \sin \propto_b \cos \propto_b \quad m/s \text{ ----------------------(3)}$$

The current speed V (m/s) can be estimated directly from the measured breaker height H_b (m)and breaker angle $\propto_b$, this equation is based on field and laboratory data and assumes that the longshore currents are generated from longshore component of the radiation stress.

4- Brebner – Kamphuis [7] equations:

(a) Energy balance:

$$V = \left(8\ H_0^{2/3}\ A\ (\sin \beta)^{1/3}\right) / T^{1/3} \qquad m/s \text{------------------ (4-a).}$$

(b) Momentum balance:

$$V = \left(14\ H_0^{3/4}\ A\ (\sin \beta\ )^{1/3}\right) / T^{1/2} \quad m/s \text{--------------------(4-b).}$$

where:

$A = \sin 1.65 \propto_0 + 0.1 \sin \propto_0$, H_0 is the deep water wave height and $\propto_0$ is the angle between wave crest and bottom contours in deep water, and $\tan \beta$ is the beach slope.

Equations (4-a) and (4-b) have the advantages that they contain deep-water equivalents of wave characteristics. Brebner – Kamphuis [7] pointed out that it is better to attempt to relate the current to the deep-water wave, which is easier to compute than the breaking wave. In the energy balance principle, the total energy of an incoming wave is assumed to be dissipated in the breaking wave, in the frictional resistance of the bottom, and in generating long shore current. The momentum approach considers the momentum is given to a volume of water put into motion in the direction of wave propagation when the wave breaks. The longshore component of this momentum provides energy of the longshore current.

Observed longshore current

Analysis of the longshore current observations on both sides of Rosetta promontory during the period from 1983 to 1996 (eastern side), and during 1983 to1998 (western side) revealed that, the long-term annual average speed of eastward/westward or northward/southward littoral current is in the range 34-37 cm/s with a mean value of about 36 cm/s. During the whole period of study, the maximum eastward/westward or northward/southward longshore current velocity is 67 – 75 cm/s. The longshore current predominantly flows eastward (55 %) along the eastern side, and southward (66.7 %) along the western side of the promontory (Figure 2). This observed pattern of the longshore current can be attributed to the predominant approach of waves from NW and WNW directions [3, 8]. Less frequently, this pattern reverses direction to westward (38.5 %) for the eastern side and to northward (28 %) for the western side of the promontory. This can be attributed to the effect of the less predominant NNE wave approach, particularly during winter and spring seasons [3, 8].The percentage frequency of calm and rough conditions during the spring and winter seasons is generally larger than those in the summer (Figure 2). This is due to the sharp fluctuations of wave conditions in these two seasons, which are characterized by the occurrence of storms intervened by relatively longer calm periods.

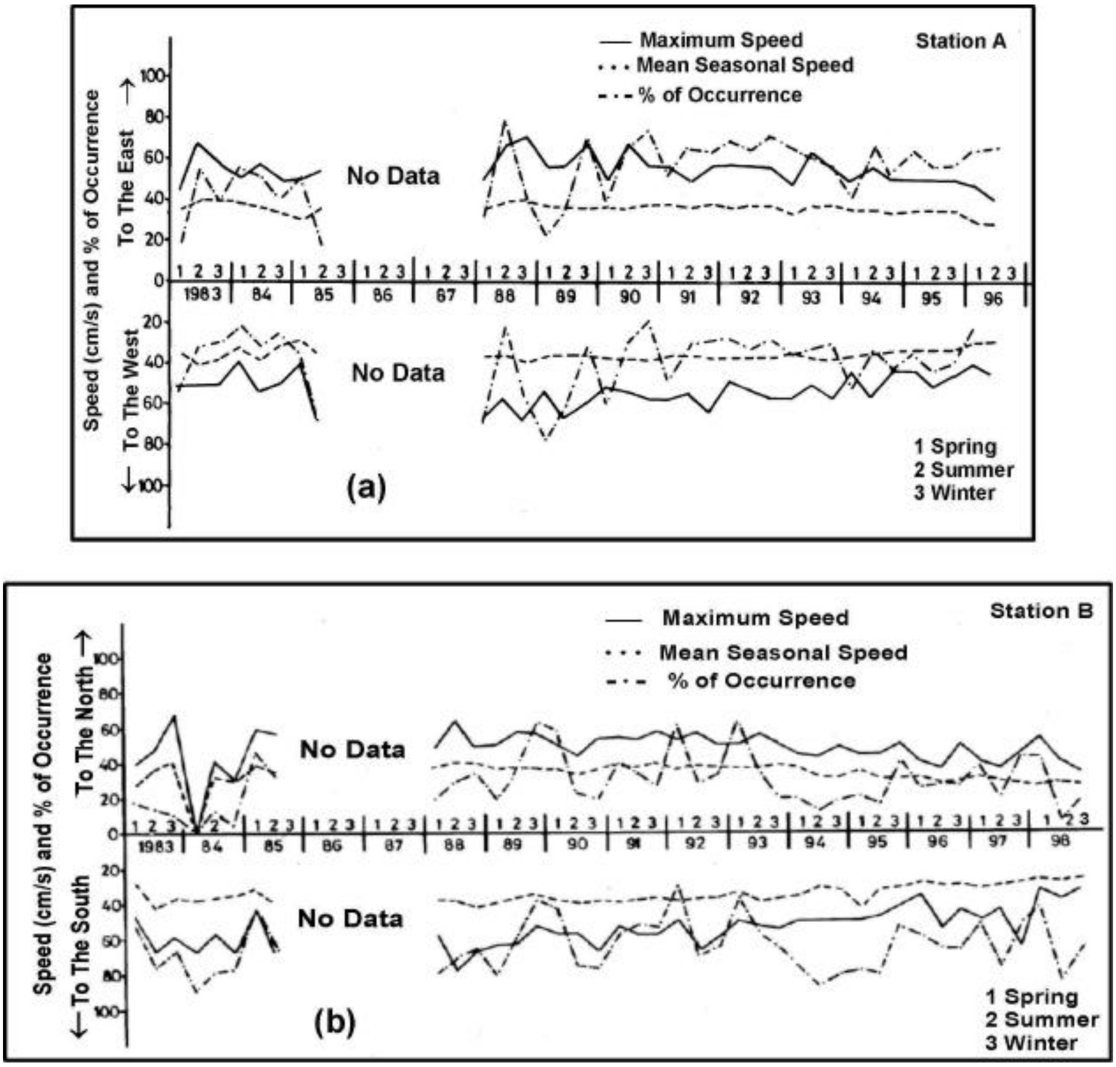

Figure 2. Long-term (seasonal and annual) mean cumulative frequency curves of long-shore currents: a- at station A east of Rosetta estuary during 1983-1996 and b- at station B westward of Rosetta mouth during 1983-1998.

Along Rosetta coast, the variations with time of the maximum current speed and the percentage of occurrence of the littoral current in a definite direction (E-W or N-S directions) are more significant than the fluctuations of the seasonally average current speed (Figure 3). On the eastern side of the Rosetta mouth, the long-term (1983-1996) seasonally averaged eastward flowing currents are 35.4, 36.1 and 36.9 cm/s, while those flowing westward are 35.5, 36.1 and 36.6 cm/s for spring, summer and winter, respectively. The maximum speeds of the eastward flowing longshore current are 75, 67 and 71 cm/s, while those flowing westward have the same value of about 67 cm/s for the three seasons, respectively (Figure 3). On the western side of Rosetta promontory, the long-term(1983-1998) seasonally averaged speeds of southward flowing current are: 35.7, 34.2 and 34.3 cm/s, and those for the northward flowing current are: 34.2, 34.6 and 33.6 cm/s for all spring, summer and winter, respectively (Figure 3). Also, the maximum speeds of the southward flowing current are: 57, 67 and 67 cm/s, while those flowing northward are: 59, 63 and 67 cm/s for the three seasons, respectively (Figure 3).

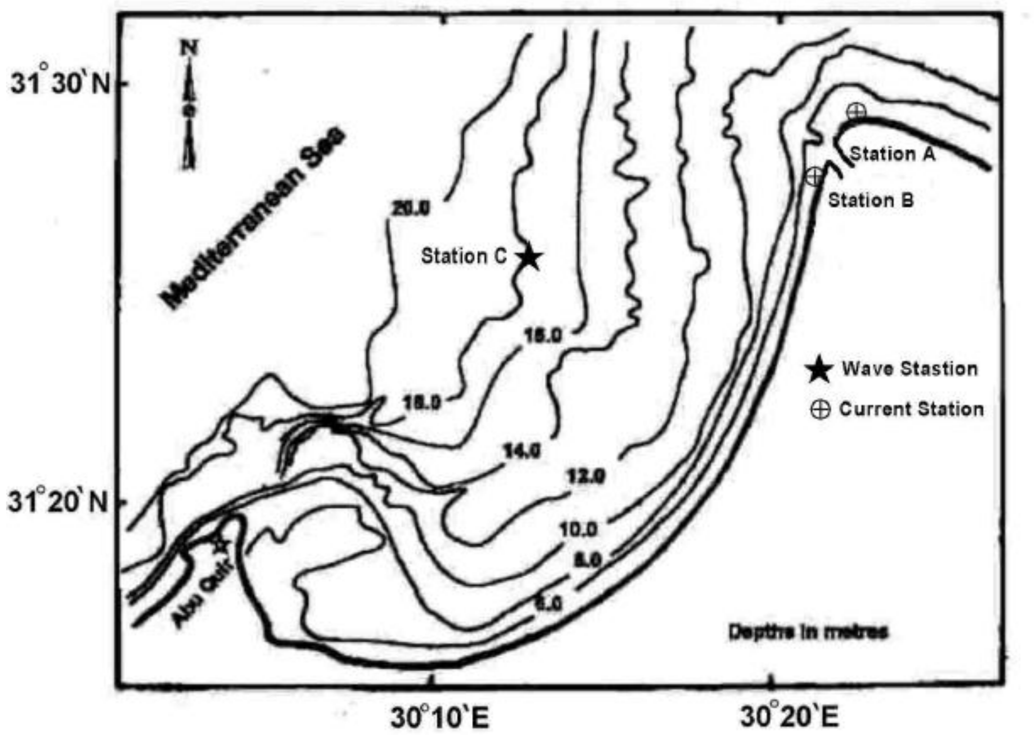

Figure 3. Seasonal variation of longshore current speed (maximum&mean seasonal) and their percentage of occurrence: a- at station A (eastward or westward, 1983-1996) and b- at station B (northward or southward, 1983-1998).

Estimated longshore current

During 1986, wave observations in an area having a water depth d = 18 m off Rosetta coast (station C in Figure 1) showed that, waves are predominantly (42%) approaching the study area from the NW direction. In this region, the study also revealed that, the annual mean significant wave height (H_s) and significant wave period (T_s) are 0.94 m and 6.5 s, respectively [2, 3]. Wave crests approaching Rosetta coast from the predominant direction (NW) will make with the 18 m contour line off station A (eastward of Rosetta mouth) an angle α_1=12° , while off station B (westward of the mouth) they will make an angle α_2=15° . These values of wave parameters at 18 m depth (H_s, T_s, α_1 and α_2) were used to calculate the deep-water wave parameters: H_o (deep-water wave height), α_{o1} and α_{o2} (deep- water angles of approach) using the wave transformation module in the ACES software package [9]. The model was also used to calculate the breaker height (H_b), the angles α_{b1} and α_{b2} that the wave crests make with the contour line at breaker depth (d_b). On both sides of Rosetta promontory, the sea bottom gently slopes down seaward. Beach slope measurements conducted by the Coastal Research Institute (CORI), Alexandria, Egypt [2] have indicated that the average beach slope (m or tanβ) along Rosetta coast equals 0.02.

The longshore current speeds (V) at station A (on the eastern side of the Rosetta mouth) and station B(on the western side) have been estimated using , as previously mentioned, equations 1 ,2, 3 and 4(a and b). The model results of wave parameters and beach slope used in the evaluations of these equations are as follows:

H_b = 1.3 m, α_b = 5° on the eastern and 6.3° on the western side of Rosetta mouth, tan β = 0.02,

T = 6.5 s, H_0 = 1.001 and αo = 12.677^0 on the eastern and 15.9^0 on the western side.

As mentioned previously, the long-term average value of the observed longshore current on both sides of Rosetta promontory equals 0.36 m/s. This value is clearly close to those values given by [4] and [5] for the western side of Rosetta mouth (Table 1). On the eastern side of Rosetta mouth, the Kumar [6] equation gave the best fit; it had a very good agreement with observations. Brebner-Kamphuis [7] equations gave estimates of longshore current, which differ significantly from the observed values.

Table 1. Estimated Longshore Current Speeds (V) on both sides of the Rosetta Promontory.

Equations	Station A (eastern side) V(m/s)	Station B (western side) V(m/s)
1-LonguetHiggins[3]	0.26	0.32
2-Galvin- Eaglassen [4]	0.24	0.31
3-Komar [5]	0.36	0.46
4-a-Berbner- Kamphuis [6]	0.56	0.70
4-b-Berbner- Kamphuis [6]	0.44	0.55

CONCLUSIONS

Analysis of longshore current observations on both sides of Rosetta promontory during the period from 1983 to 1998 revealed that the maximum value of the observed current during this period was 0.75 m/s, for the eastern side, and 0.67 m/s, for the western side, with an average of 0.36 m/s for both sides of the promontory. The predominant longshore current flows southward (66.7 %) along the western flank and eastward (55 %) along the eastern side of the promontory. The predominant NW and NNW wave approach characterizing the Rosetta coast [7, 8] is responsible for this observed pattern of longshore current. Less frequently, this pattern reverses to northward (28 %) for the western side and westward (38.5 %) for the eastern side under the effect of the less predominant NNE wave approach, particularly during winter and spring seasons. The calm and rough periods during the spring and winter seasons are generally longer than those in the summer due to the sharp fluctuation of wave conditions resulting from the occurrence of storms intervened by relatively longer calm periods.

Estimation of longshore currents along Rosetta promontory has been done using several models: Longuet-Higgins [4], Galvin-Eagleson [5], Komar [6] and Brebner – Kamphuis [7] formulas. The results of these models were compared with observations and it was found that the first three models are recommended for any longshore current estimates in this area.

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