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DYNAMIC PROCESS ALONG THE EASTERN ZONE OF MARINA RESORT CENTRE ON THE NORTHWESTERN COAST OF EGYPT

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ABSTRACT

Marina resort centre lies on the western coast of Egypt overlooking the Mediterranean beach. Its beach situated in an open active area exposed to the combined action of waves and currents. Five jetties and eight groins and artificial sand nourishment have been implemented to protect the beach and guarantee safety of swimmers and keep connection of the Mediterranean Sea with the lagoon. Intensive measurement program (2007) was carried out along the eastern zone of Marina resort centre, including hydrographic profiles, tides, currents and surface sediment samples to provide a basis for possible protection process. In additions two fluorescent experiments using sand tracer were performed during winter and summer seasons along the study area in order to study the sediments transport quantitatively and qualitatively and their effect on the morphology of these beaches. The experiments revealed that erratic current governed the drifting of sediments eastward and offshore by induced long shore and rip currents. The study, indicated that the amount of artificial sand nourishment as proposed by Delft Hydraulics (2000), 0.08 x 10^6 m^3/yr is much lower than the calculated average sediment drift during this study, 0.24 x 10^6 m^3/yr. The hydrographic profiles shows that the beach face slope is very steep, hence permits the wave approach breaks close to the beach causing sever erosion and turbulent water conditions to the swimmers. Bottom relief deformation defined from profiles survey data indicates that significant erosion is taken place along most of the nearshore area and extends up to about 2.0 km offshore. To mitigate the problem of erosion and the presence of strong rip currents, the proposed scheme would improve the swimming conditions in the protected area in terms of wave height, current and also in terms of more gentle coastal profile. Therefore, it is recommended that, the proposed solution should put into consideration considerable reduction of wave energy and tompolo formation should be avoided. In addition the proposed solution includes the ridges as an engineering component in designing mitigation measure along this zone. A 2D mathematical and physical models should carry out to find the adequate adapting measures to get the attempt solution which might be perched beach method combined with submerged breakwater.

1. INRODUCTION

The northwestern coast of Egypt is extending 600 km from Alexandria to El-Sallum. Prior to 1960, the north western coastal region was given relatively little attention in the governmental plan of development. A few years ago the government has realized the importance of the coast development particularly in fields of tourism, agriculture and industry. The coastal zone is distinct by clear blue water, mild weather and sun prevailing most of the year. The beach and sea bottom are rocky covered by an oolitic carbonate sand layer with varying thickness resulted from the disintegration of the rocky ridges and bottom. All these privileges made this coast an attractive site to be developed rapidly for tourism and entertainment activities and for recreational uses. The rocky bottom made the slope of shore face and the near-shore zone to be steep while it becomes flatter in the offshore zone. The most prominent geomorphologic features are the existence of a series of unconsolidated carbonate ridges of Pleistocene age, which are native to this area (Fourtau, 1893; Shukri *et al*., 1956; Said *et al*., 1956; Butzer, 1960), (Fig. 1). These ridges progressively increase in elevation from ~ 10 m along the coast to ~ 100 m some 40 km inland. The seaward part of these ridges extends underwater down to a maximum depth of 20 m across the inner continental shelf of the Arabs Gulf between Alamein and Alexandria (Lindell *et al*., 1991). Marina tourist centre was constructed about 94 km west of Alexandria around an artificial lagoon, which is connected to the sea by four man-made inlets to create a safe water body for safe swimming activities. It extends 12 km along the shore and 1.6 km inland. This project was carefully designed based on sufficient data and tested using a physical model in the Suez Canal Research Centre (Saadek, 1998). In order to stabilize the inlets and maintaining continued water exchange, eight short groins (150 to 400 m length) were constructed with artificial nourishment to protect the beach, guarantee safety of swimmers and keep connecting the Mediterranean Sea with lagoons (Fig. 1). These structures unfortunately have created local erosion along the adjacent beaches on the down drift side. The continued erosion threatens as well a great portion of the setback condominiums.

The beach survey of 1991 and 1997 indicated that changes are significant at the up drift and down drift jetties (Fahmy, 1998). The estimated average erosion is 10 m/yr just east of the 5th jetty and accretion of 15 m at the up drift side of the 4th jetty. As the natural equilibrium of the coastline of this sector changes, a state of coastal imbalance appears for the present time in this area and has required on immediate protection. A solution to mitigate erosion problem implemented but it is not effective along the eastern part of Marina centre near El-Ahlam village (Fanos, 2004).

Several studies have been made for the coastal and nearshore beaches along the west coast of Alexandria (Coastal Research Institute, 1993 and Badr, 1998 & 2001, Delft Hydraulics, 2003, Frihy, 2001, Abo Zed *et al*., 2006, Frihy *et al*., 2007). In these studies hydrographic profiles, waves, tides, current, surface bottom samples and fluorescent sand tracers experiments were performed along the eastern side of El Alamien Marina Centre (Fig. 1). The objective of this paper is to delineate the coastal dynamic forces and to estimate the rate of sediment transport and direction of sediment drifting along the eastern side of Marine tourist centre (Zone A).

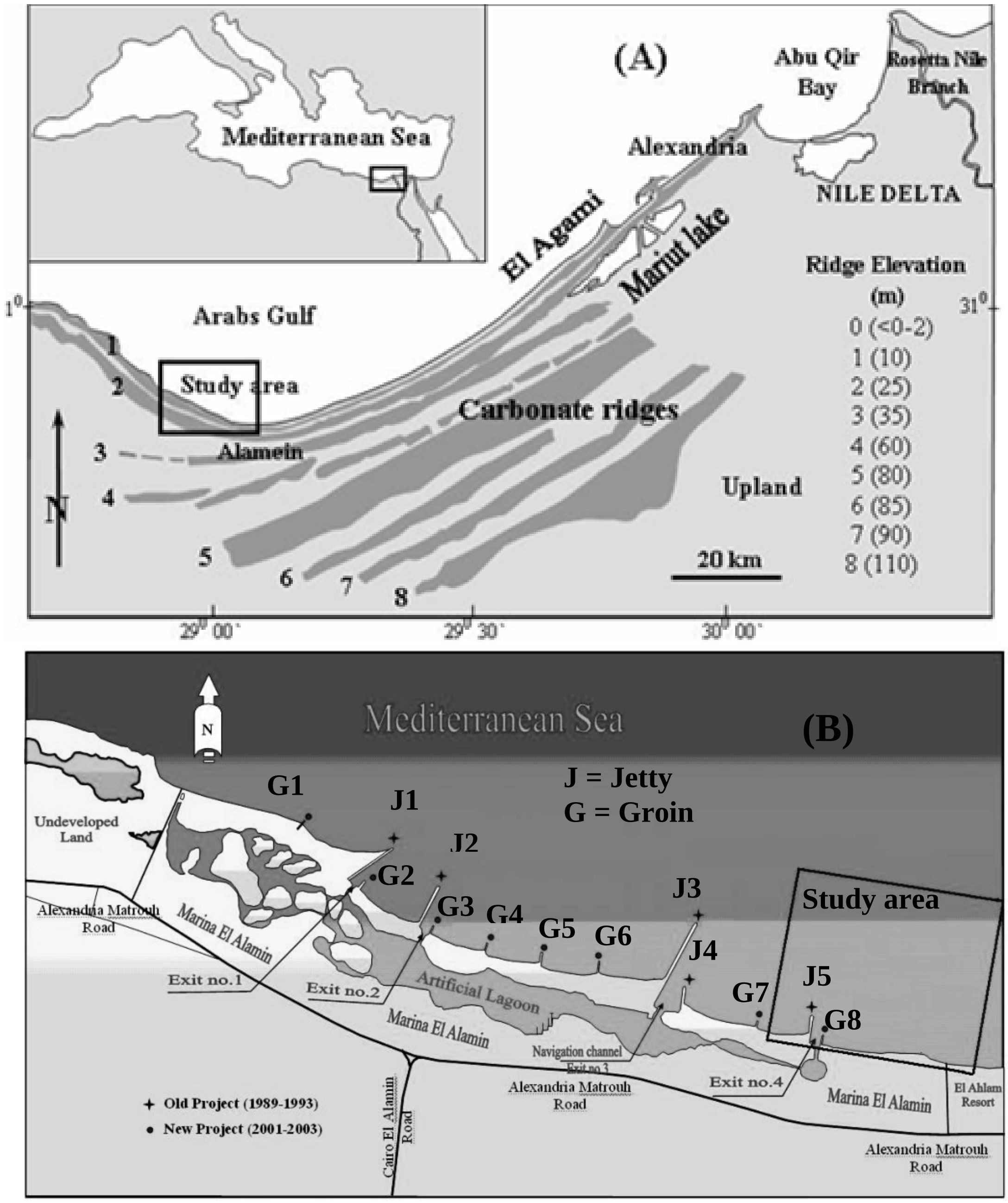


Fig. (1): (A) Map showing the location of the study area and the back-shore distribution of eight parallel carbonate ridges (B) El Alamien Marina Resort Center and the solid protection works have been built to stabilize the navigation entrance of the inland lagoon and to create safe beach to swimmers.

2. MATERIALS AND METHODS

In order to document the sea bed morphologies beach-near shore profiles have been surveyed at 31 stations along the length of the study area (numbered p1 through 31), profile lines extended approximately up to 5 km offshore or to a maximum depth 12 m depth contour (Fig. 2). They were surveyed perpendicular to the shore line with alongshore spacing 300 m a part along the west side (p1 to p6) and 100 m intervals for p7 to p31. Inland sounding were taken every 10 m to trace the details of the surf zone. The sounding and inland leveling of the profiles were surveyed with the use of total station, DGPS (GBX-PRO), Echo-Sounder (Navisound 205), onboard marine computer and rubber boat. The surveyed land elevations and water depths are referenced to Mean Sea Level (MSL), using local fixed benchmarks of known elevation and the hourly water level measurements recorded at Marina Resort. The profile survey was carried out twice in fair-weather in January 2007 and in May 2007.

The bottom relief deformation system astride the eastern zone of Marina centre has been studied by comparison of two bathymetry surveys between January 2007 and May 2007. These two bathymetry surveys were matched to the same scale and carefully overlapped. Every two successive surveys data for each profile (cross-shore distance and water depth) were compared to measure the vertical shift values of depth contours.

Seventy eight sediment samples from the surface layer of the sea bottom were collected over the study area, by a grab sampler. In the laboratory, samples are subjected to grain size analysis using stander ro-tap shaker at one-phi sieve intervals. The mean grain sizes (Mz) was calculated for each sample using the formula of Folk and Ward (1957).

The water level was recorded at Marina during the period from January 2007 to June 2007 by use of recorded tide gauge (Green Span) fixed in Marina port (Fig. 1). The recorded data was related to zero survey level of the Egyptian Navy Authority.

Magnitude and direction of currents beyond the breaker zone (near the surface and near the bottom) were measured along the study hydrographic profiles at 64 points, well distributed (every 200 m along 8 profiles) using direct reading current meter (Valeport).

In order to achieve the accuracy necessary for determining the direction of the longshore sediment transport, two fluorescent tracer experiments were performed at the eastern side of Marina tourist centre (Fig. 2) during 26 February and 9 July 2007. Fluorescent sand tracers with desired characteristics, particularly grain size, were used in tracer experiments along Marina beach. Two-release points were located and 10.5 kg of tracer sand were released at each drop point during each test. Tracer sands were released at the sea surf zone at the up-drift side of the sampling station distributed in a rectangular grid system. The length of tested location along the shore is 150 m and the width of the foreshore-inshore is 50 m. Sample stations were closest together near the release line and become progressively farther apart with distance from the release line. Series of grape samples were generally conducted every one hour. The time history of the position of the centre of gravity of the tracer as it moved along the beach is utilized to deduce the rate and direction of the sand movement on the beach. The thickness of the layer in motion (mobile bed layer) is measured by pressing plastic core tube on the bottom of the foreshore zone to observe the depth to which the dyed sand grains had been extended. Two series of samples were collected from the location test, 96 samples for each experiment were collected by volume sampler. In the laboratory, each sample was viewed under short-wave ultraviolet light and the number of tracer grains is tabulated. Tracer concentrations are expressed as the number of tracer grains per kilogram of sample. Values of tracer concentration were plotted at their respective stations and isopleths were constructed resulting in contoured patterns of tracer dispersion with time. The mean distance of transport is calculated from the tracer distribution by taking the first moment of the concentration in the longshore direction about the injection line. Dividing this mean longshore transport distance by the elapsed time between injection and sampling then yields a mean velocity for the sand transport.

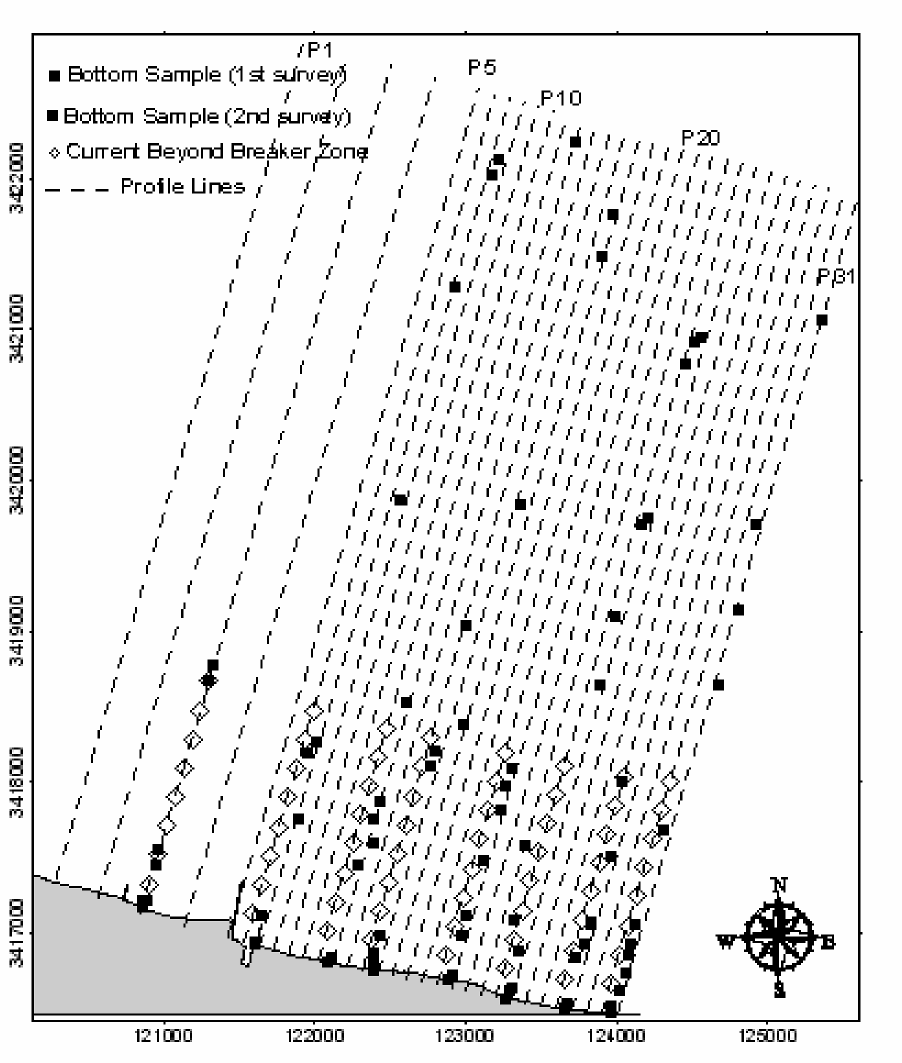


Fig. (2): Locations of hydrographic profiles, surface sediment samples and current measurements.

3. RESULTS

Two-D and 3-D high resolution bathymetry maps were generated from the beach-inner shelf profile data surveyed in January 2007 and in May 2007 using a linear interpolation triangulation method (Figs 3.1 and 3.2). Three submerged linear ridges are observed in the study area and extend offshore up to 5.0 km. These ridges are part of the submerged longshore carbonate ridges which now forms the shoreline and bedrock of the western coast of Alexandria. They progressively increase abruptly in elevation landward and reach maximum elevation of 2.1 m from seabed at ridge no.1. The crest level of the first inner ridge reaches 1.5 to 2.0 m below the mean sea-level. In contrast, the other outer ridges #2 to #3 have a low relief and their crests lies, respectively at 1.8 and 1.0 m below mean sea-level. Because of their low-crest level they are not effectively acting as a natural buffer for protecting the coastline from wave attack (Frihy *et al*., 2007). Ridge no.2 is more effective on the study area because it is extending from the offshore allover the coastal zone to shoreline ending just west of EL-Ahlam village. Profiles data revealed that the beach face slope is very steep between 1:8 and 1:10, while the nearshore one is somewhat flatter and ranging between 1:25 and 1:40. The steep beach face slope (Fig. 4) permits waves approach to break close to the beach causing sever erosion and turbulent water conditions to the swimmers.

3.1. Tides

The effect of tide variations is pronounced in delineating the shoreline as well as wave characteristics, breaking point, determination of current and bar formation. Tide influences to some extent, the sediment movement along the coast by shifting the level of attack of wave action and by governing the water flows in lagoons. The tidal regime along the coast is semi-diurnal with a mean range of approximately 0.36 m and highest water level 0.75 m, (in February 2007) above the survey authority datum. Whereas, the lowest water level is -0.003 m occurs in April 2007. The maximum water level for each region is due to the positive surges which cause the drawl of water towards the shore, whereas the minimum one is due to the appearance of the negative surge which cause negative drawl of the water away from the shore. This agrees with Manohar (1976) who concluded that storm surges during winter season and swell action during summer season may cause the increase of the water levels considerably and hence accelerate erosion along the coasts (El-Fishawi and Khafagy, 1991).

3.2. Waves

Water waves are the principal cause of most shoreline changes. Without wave action on a coast, most of the coastal engineering problems involving, littoral processes would not occur. Statistical distributions of wave characteristics along a given shoreline provide a basis for describing the wave climate of a coastal segment. Important wave characteristics affecting sediment transport near the beach are height, period and direction of breaking waves.

Wave action along the Mediterranean coast of Egypt is seasonally in intensity and direction and is strongly related to large scale pressure system over the Mediterranean Sea and north Atlantic (Nafaa *et al*., 1991). Wave climate in front of Marina was determined by Delft Hydraulics (2003) using 10 years offshore wind data (1988-1997). Wave data recording at 12 m depth in front of Ras El-Bar (2002-2004), are in fair agreement with the results given in Delft Hydraulics (2003). Accordingly, the predominant waves approach from the NNW, NW and WNW (84.4%) are responsible for generation of longshore eastward current (Fig. 5). The remaining portion of waves coming from N, NNE, ENE and NE generate an opposite directed longshore westward current. Maximum wave height and max significant wave height during the storms is of the order 6.6 m and 4.2 m approaching from N direction and took place during February, 2004 (Abo Zed, 2006). The wave energy during winter season is more effective than the summer and spring seasons (Naffaa, 1995).

3.3. Currents

As waves approach breaking, wave induced bottom motion in the water becomes more intense and its effect on sediment becomes more pronounced. Breaking waves create intense local currents (turbulence) that move sediment. Since wave crests at breaking are usually at a slight angle to the shoreline, there are usually longshore components of momentum in the fluid composing the breaking wave. This longshore component of momentum entering the surf zone is responsible for the longshore sediment transport.

The circulation pattern during the two periods (January and May 2007, Fig. 6) comprises circulation cells consisting mainly from longshore currents directed towards the east and rip currents directed offshore (Fig. 6). Current measurements have been carried out in relatively calm sea condition; therefore measured current velocity is small and fluctuated between 0.02 and 0.14 m/sec.

3.4. Sediment characteristics

The mean grain size ranges from 0.09 to 0.54 mm, with an average value of 0.33 mm. The spatial pattern of grain size revealed that, sediments near the shore up to a distance about 100 m are finer (0.25 – 0.39mm) than those in offshore zone (0.46- 0.54 mm). The values of carbonate content in these samples are varying from 43.02 to 99.4% with low specific gravity of 2.7 gm/cm^3, which makes the grain to be more active in the mobile layer. The grain size relationships combined with seabed morphology and hydrodynamic processes are used to provide information pertaining to delineate sediment transport direction (Frihy *et al*., 2007). Exclusively, the zone from the coastline up to 4 m depth is floored by relatively fine grained sediments, whereas coarse grained samples widely occur further offshore between > 4 and 12 m depth contour (Frihy *et al*., 2007)

3.5. Bottom Relief deformation

Changes in seabed relief given as absolute values of vertical shifts in depth contours (erosion or accretion) are obtained from analysis of beach profiles along the eastern side of Marina tourism centre. Spatial distribution of vertical shift values of erosion and accretion indicates that significant erosion is taken place along most of the nearshore area and extends up to about 2.0 km offshore (Fig. 7). In contrast, accretion is found at offshore zone (NE area) with some patches of eroded areas, with a positive vertical shift value of + 1.9 m. The sediments of this accretion are derived from areas of erosion located near the coast (borrowed sand). The negative vertical shift value of erosion therein shows a highest value of -1.6 m indicating active scoring of the seabed accompanied by sediment drift. The movement pattern indicates that most of sediments eroded from the coast move partly offshore and partly eastwards.

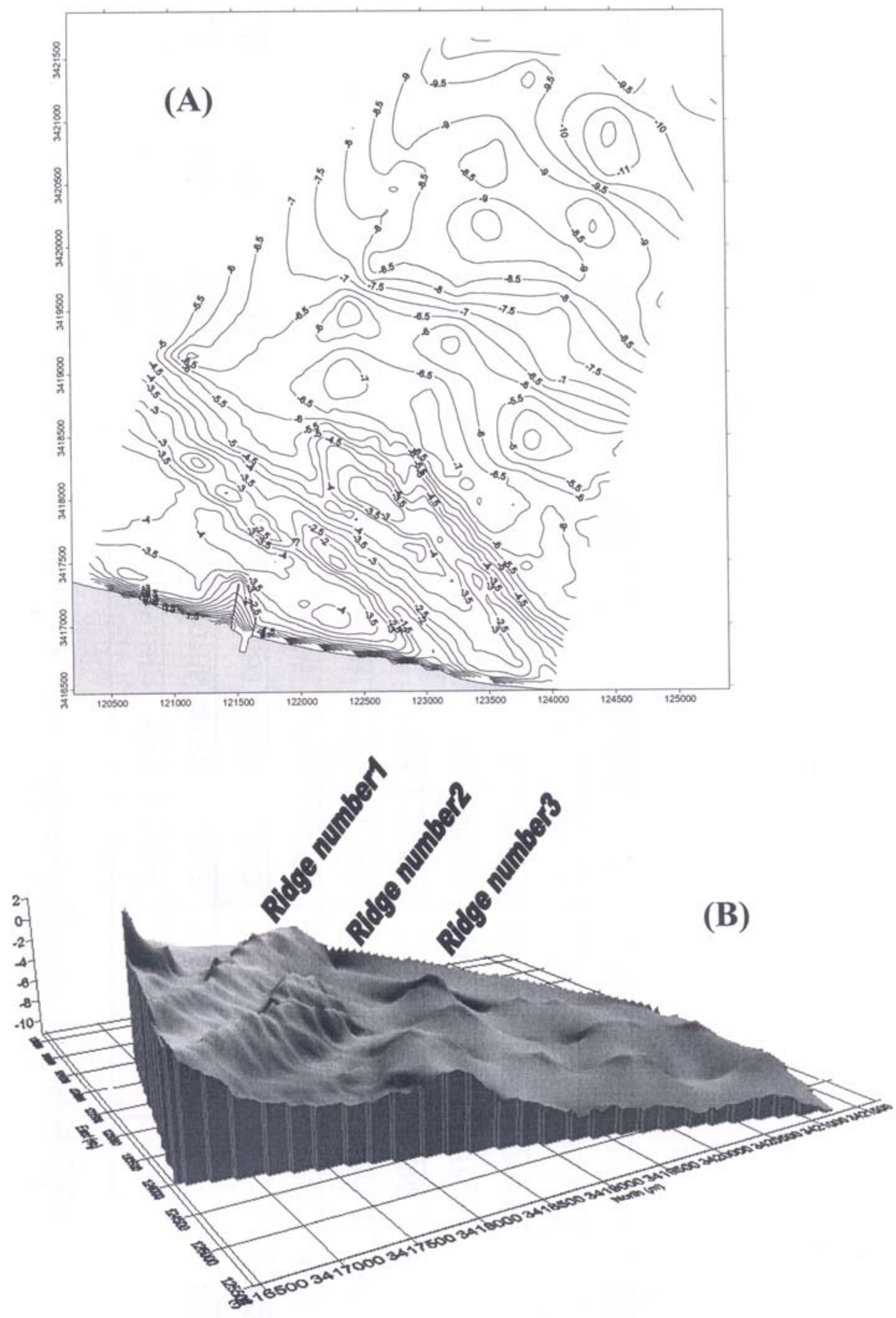


Fig. (3.1): Two-D and three-D bathymetric map generated from hydrographic profiles data, during January 2007.

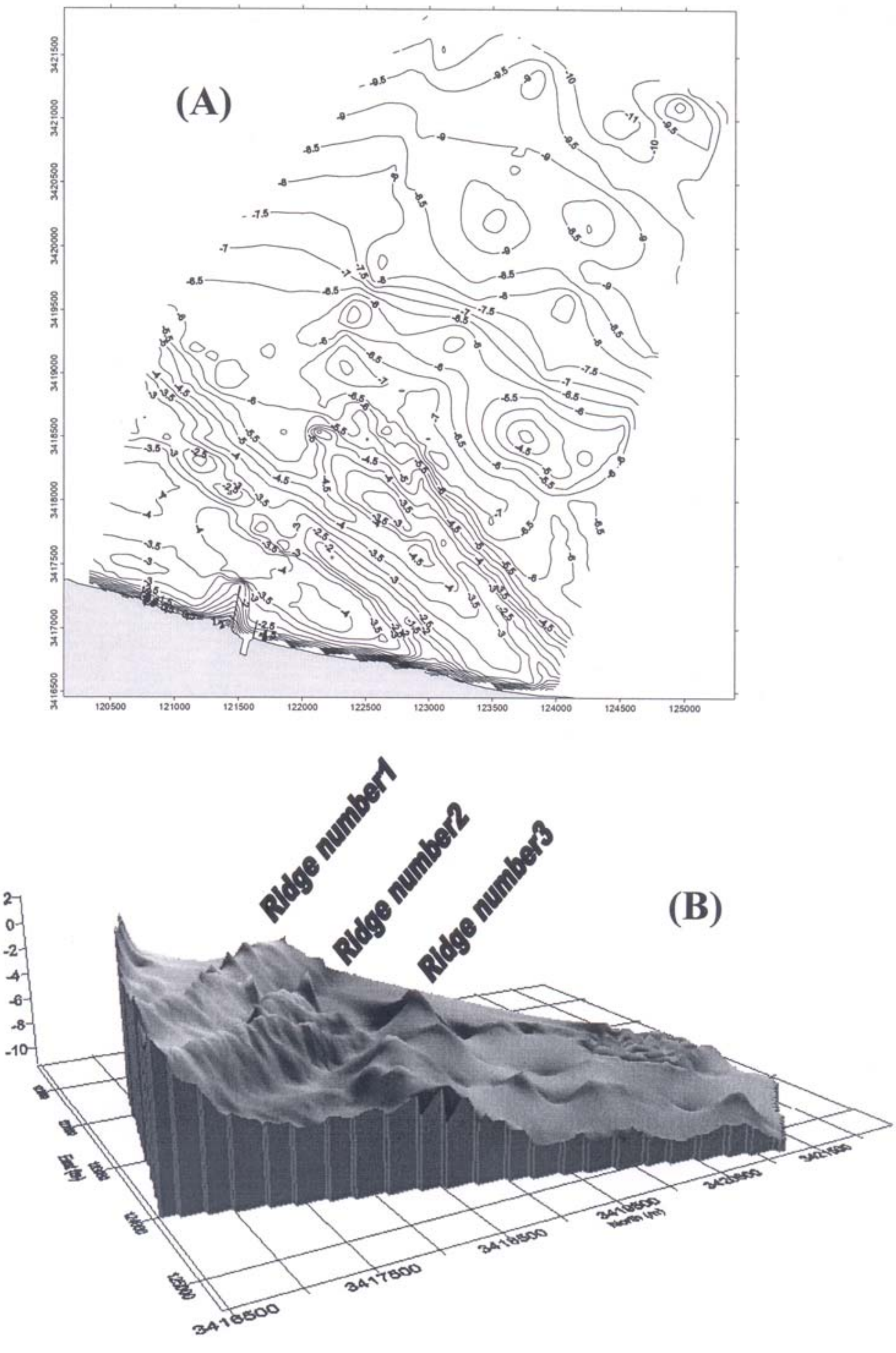


Fig. (3.2): Two-D and three-D bathymetric map generated from hydrographic profiles data, during May 2007.

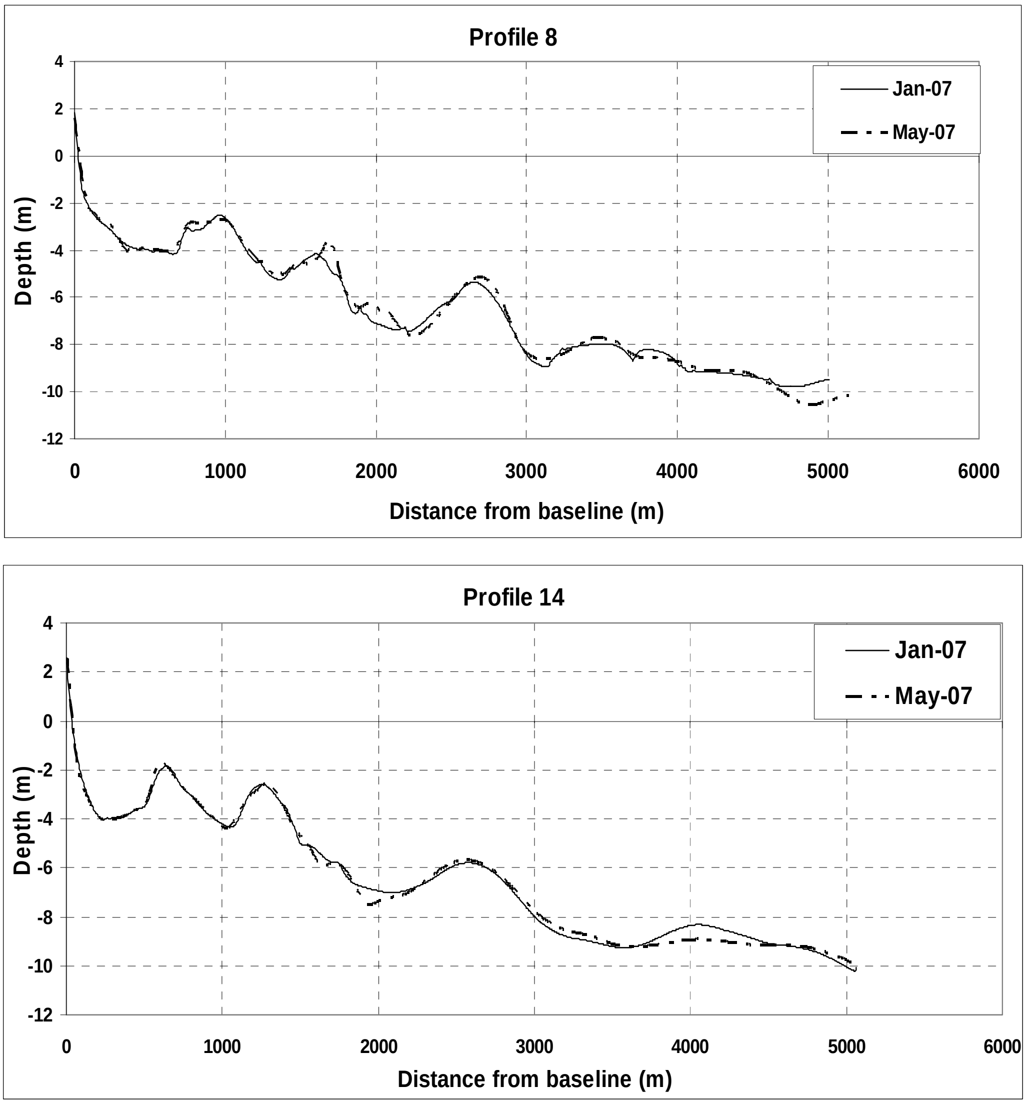


Fig. (4): Examples of hydrographic profiles shows the very steep slope of the beach face during the two surveys, January and May 2007.

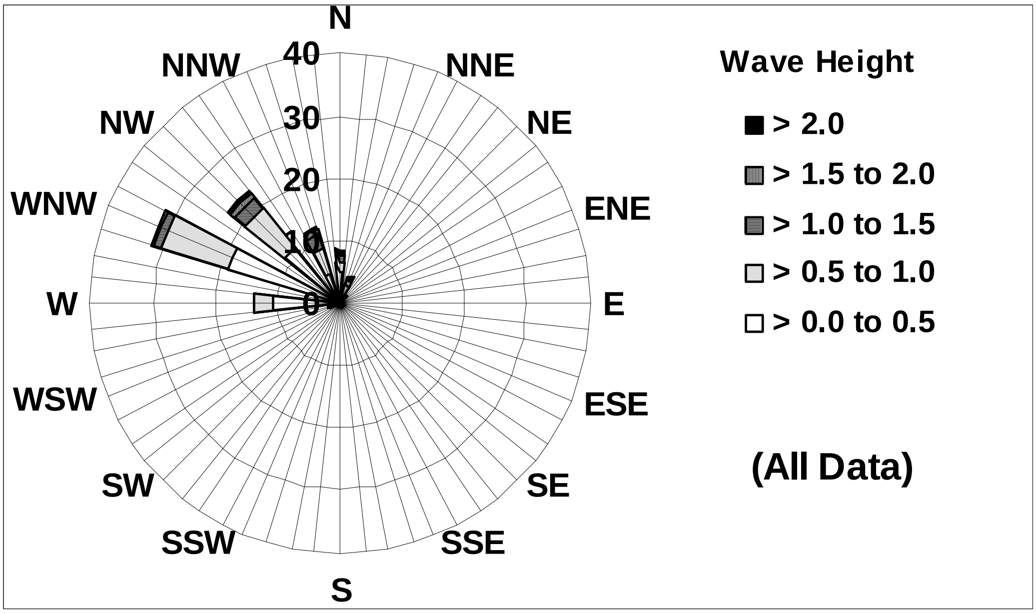


Fig. (5): All data wave rose at Ras El Bar (June 2001 to June 2004).

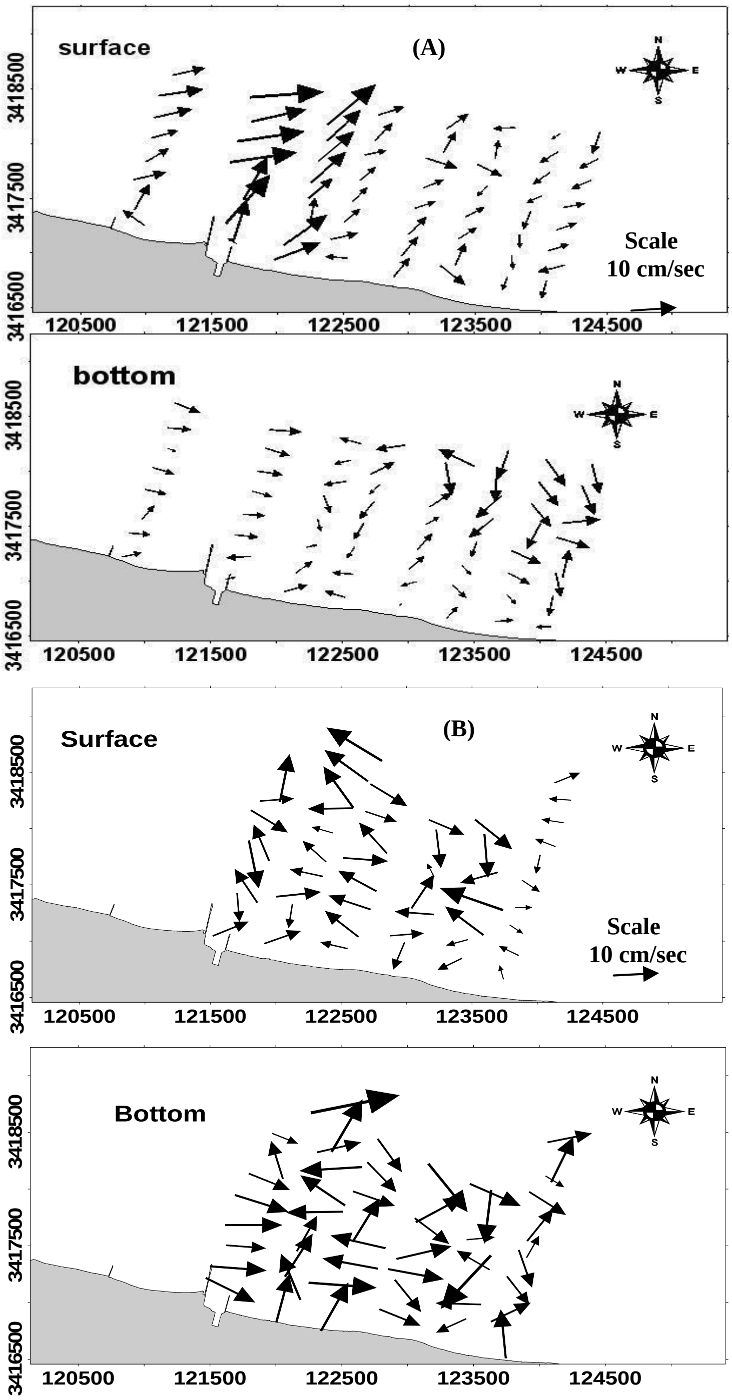


Fig. (6): Horizontal current distribution near surface and near bottom, during (A) January 2007 and (B) May 2007.

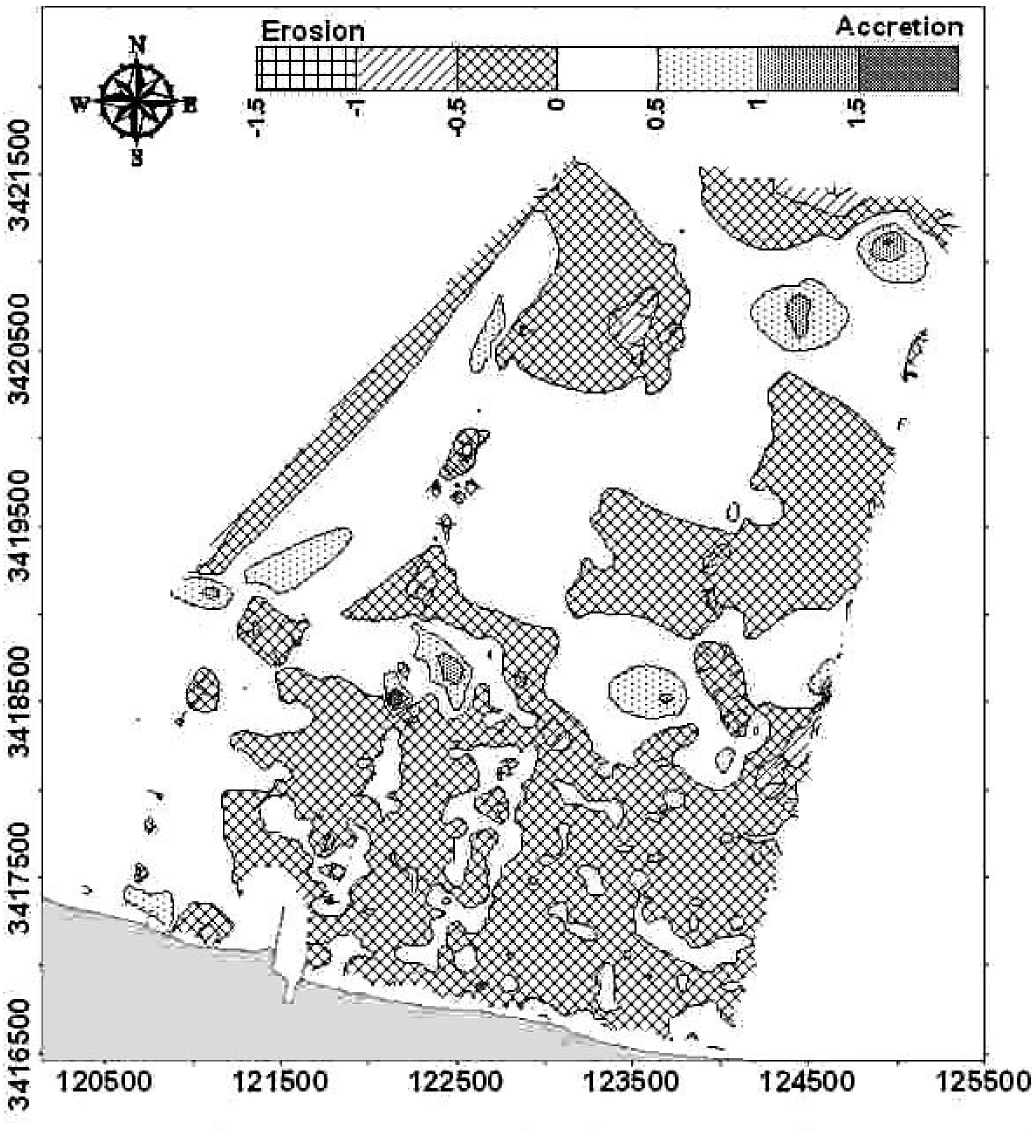


Fig. (7): Bottom relief deformation along the eastern zone of Marina Center (2007).

3.6. Littoral drift rate along the study area

Delft Hydraulics (2003) predicted the net longshore sediment transport capacity at the study area, using UNIBEST model, ranging between 0.05 x 10^6 m^3/yr and 0.10 x $10^6 m^3$/yr (Fig. 1)

In order to study the coastal processes accompanying erosion and to develop predictive models, precise measurement of the sediment transport is required. After releasing the fluorescent grains into the movement system, they mix evenly throughout the system during a suitable interval of time. The behavior of tracer concentration would represent the grain dispersion and drift. The bulk volume sand transport rate along the study area is given by Komar & Inman (1970) equations:

$V_i = Y/t$ …….. (1)

$S_I = V_i * b*X_b *1440$…… (2)

Where:

V_i = Velocity of sand transport (m/min);

Y = Distance between injection line and centre of gravity (m);

t = Elapsed time between injection and sampling (min);

b = Thickness of the layer in motion (m);

X_b = Width of the surf zone or beach face (m); and

S_i = Bulk volume sand transport rate (m^3/day)

The measured instantaneous transport at the annual rate of both offshore and eastward drift for 50 %, are 0.28 x 10^6 m^3 and 0.20 x 10^6 m^3 during winter and summer, respectively (Table 1; Figs 8.1 and 8.2). The calculated velocity for sand grains in motion ranged between 0.64 m/min and 0.75 m/min with an average of 0.70 m/min (1.17 m/sec). This high magnitude of velocity means that the bulk of the sand load travels along the coast at a fast rate. The seaward (50 %) and eastward (50 %) sediment transport along the east side of Marina beach (Study area) is mainly responsible for sever coastal erosion (Figs 8.1 and 8.2). On the other hand, the portion of sediments transported to the eastward cause sedimentation at El-Ahlam village (during summer months), then afterwards it might be transported again to both offshore and eastward direction.

3.7. Discussion and Conclusions

Between, 1988 and 1995, a large recreation centre of Marina was constructed near El Alamien city about 94 km west of Alexandria. It extends 12 km along the shore and 1.6 km inland. In order to create a safe water body for swimming activities, a recreational lagoon is made connected to the Mediterranean Sea by four man-made inlets. In order to stabilize the inlets and maintaining continued water exchange, five jetties and eight groins have been constructed to defend the beach, guarantee safety of swimmers and keep connecting the Mediterranean Sea with the lagoon (Fig. 1). These structures unfortunately have created local erosion along the adjacent beaches on the down drift side (Fig. 9). The continued erosion threatens as well a great portion of the setback condominiums. As proposed by Delft Hydraulics study (2003) beach nourishment of the eastern sector (Study area) have been undertaken in early summer beginning of 2004 until present with an annual amount of 0.08 X 10^6 m^3 /yr terrigenous sand (Fig. 10). Unfortunately, nourishment sand was not enough to compensate the amount of eroded sediments. The study of hydrographic profiles revealed that the beach face slope is very steep between 1:8 to 1:10 (Fig. 4). This steep beach face permits wave to approach and break close to the beach resulting in a sever erosion and turbulent water condition to the swimmers. These results coincide with the results of the bottom relief deformation, which indicated that significant erosion is taking place along most of the nearshore area and extends up to about 2.0 km. In addition Hydrographic survey shows the presence of three submerged longshore ridges extending along most of it. Ridge no.2 is more effective on the study area because it is extending from offshore allover the coastal zone and ending just west of El-Ahlam village. These ridges formed two channels on both side of the ridges and hence increased the speed of rip current, hence increasing the rate of the offshore sediment transport. Two sand tracer experiments were performed during this study during February and July 2007. The study estimated that, the average annual drift rate 0.24 x 10^6 m^3/yr with 50% directed offshore and 50 % directed eastward direction. The results are in a good agreement with those derived from Abo Zed, 2004, who determined the sediment transport rate during 2004 in the surf zone (between Jetty 1 and Jetty 2) by 0.18 X 10^6 m^3/yr, directed to offshore (50 %) and east direction (50 %).

The overall study of the hydrodynamic factors (waves, currents, tide) and erosion/accretion pattern shows that the study area is characterized by offshore and eastern sediment transport. In addition, the study, clarified that the amount of artificial sand nourishment as proposed by Delft Hydraulics (2003), 0.08 x 10^6 m^3/yr is much lower than the calculated average during this study (2007), 0.24 x 10^6 m^3/yr. Hence, the periodic sand nourishment by 0.08 x 10^6 m^3/yr (Fig. 9) which costs more than 2 million LE is not an efficient protective measure (Fig. 10).

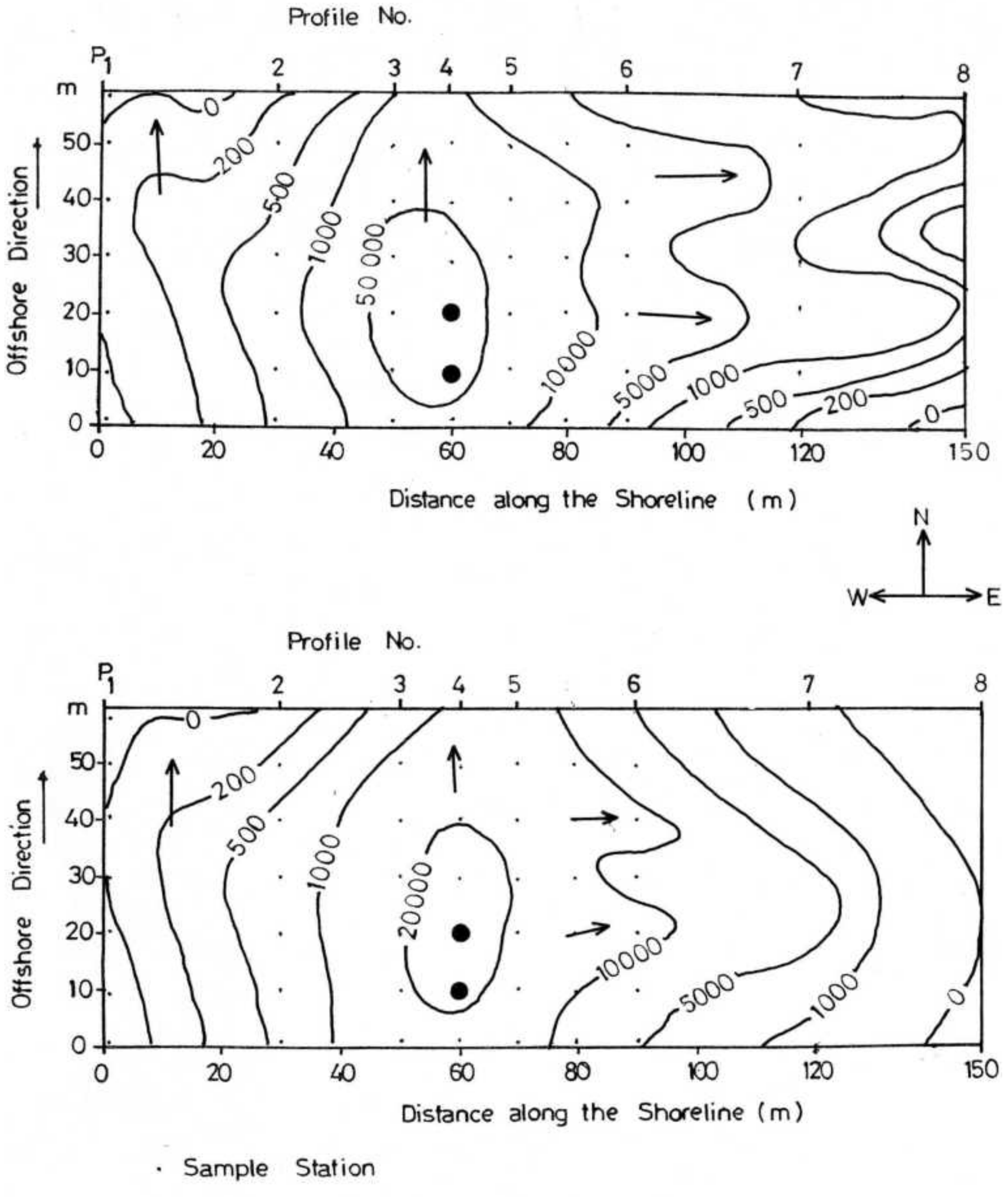
To mitigate the problem of erosion and the presence of strong rip currents, the proposed scheme would improve the swimming conditions in the protected area in terms of wave height and current and also in terms of more gentle coastal profile. Therefore it's recommended the proposed solution should put into consideration a considerable reduction of wave energy and tompolo formation should be avoided. In Addition the proposed solution should include the ridges as an engineering component when designing mitigation measure to stop beach erosion of this zone. The solution could be perched beach method combined with submerged breakwater.

Table (1): Percentage of occurrence and drift rates for each direction of sediment movement along east side of Marina tourism centre (winter and summer 2007).

Date	D_{50}	Grain velocity (m/min)	Thickness of mobile layer (m)	Drift rate			Littoral Current	
				X10^3 m^3/day	X10^3 m^3/month	X10^6 m^3/year	Velocity cm/sec	Dir. To
26/02/2007	0.20	0.75	0.015	0.76	22.84	0.28	30	E
09/07/2007	0.23	0.64	0.012	0.55	16.46	0.20	25	E
Average	0.22	0.70	0.013	0.66	19.65	0.24	27.5	E

Table (2): Drift rates from each direction.

Location	Annual drift rate x10^6(m^3/year) from								Total drift rate X10^6 m^3/year
	E to W		W to E		Onshore to offshore		Offshore to onshore		
	%	S_i	%	S_i	%	S_i	%	S_i	
26/02/2007	-	-	50	0.14	50	0.14	-	-	0.28
09/07/2007	-	-	50	0.10	50	0.10	-	-	0.20
Average			50	0.12	50	0.12	-	-	0.24



10.5 kgs. Of Fluorescent Sand Were Released at Each Drop Point

- Drop Point.

Fig. (8.1): Dispersion of fluorescent sand across foreshore – inshore area along the eastern zone of Marina Resort Center during February 2007.

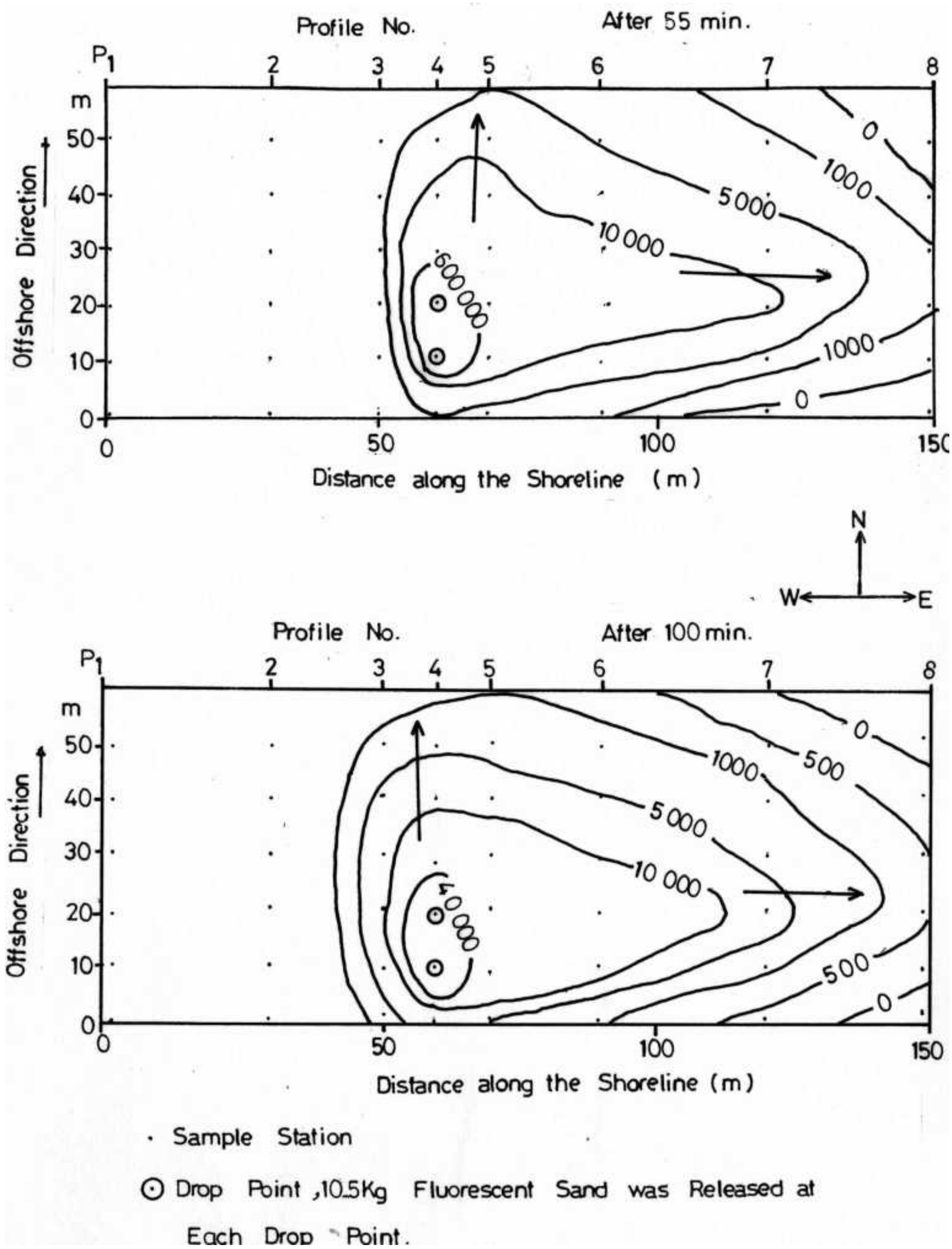


Fig. (8.2): Dispersion of fluorescent sand across foreshore – inshore area along the eastern zone of Marina Resort Center during July 2007.

Fig. (9): The shoreline east of Marina resort shows erosion problem.

Fig. (10): Sand nourishment along the eastern zone of Marina center.

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