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EVALUATION OF EXISTING MARINA COASTAL PROBLEMS, WESTERN MEDITERRANEAN COAST, EGYPT

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ABSTRACT

El-Allamien Marina tourist center was built around an artificial lagoon, which has been connected to the sea through four dredged channels. Five jetties perpendicular to the shoreline of lengths varied from 350 to 1250 m, were constructed in the period from 1989 to 1993. Eight short groins of lengths varied from 150 to 400 m with artificial nourishment once has been implemented in the area between outlets of the artificial lagoon in the period from 2002-2003 to overcome the created problems. Along the 1800 m distance on the eastern side of the 5th jetty, three periodic operations have been carried out to mitigate the erosion that is still taking place. In a trial to get a solution for this problem, six months of intensive field measurements were conducted. Mathematical models SIMCOPRO, ImSedTran-2D and GENESIS, were applied to study waves, currents, sediment transport rate for the present time and forecasting, after using different proposed solutions. The overall study of hydrodynamic factors (waves and currents), sediment transport and geomorphology of the study area revealed that waves are breaking near the shoreline without permitting any surf zone for swimming and hence causing an increase of erosion rate. Current pattern shows a presence of strong rip and long shore current causing an offshore sediment transport and considered the most dangerous factors threatening the safety of swimmers in the near-shore zone. The study clarified that artificial sand nourishment is not an efficient protective measure. From the results of the analysis of these field data and those from applying the mathematical models, three solutions had been proposed. The recommended one is: to create a sloping beach 50:1, protected by a submerged breakwater parallel to the coast at water depth of 3-4 m, by the 8th groin from the west and the end part of the 2nd ridge in the east. This cell is filled with nourished sand to create the required beach. The study recommended that a monitoring program should be applied to follow up the developed beach during and after executing the work.

1. INTRODUCTION

The northwestern coast of Egypt is extending 600 km from Alexandria to El-Sallom. The coastal zone is distinct by white oolitic carbonate sand, clear blue water, mild weather and sun prevailing most of the year. All these privileges made this coast an attractive site to be developed rapidly for tourist and entertainment activities and for recreational uses. El-Allamien Marina large-scale recreation summer tourist center is one of these rapidly developing areas on this coast at km 94 road-mark on Alexandria Matrouh coastal road, (Fig. 1). On its eastern side, there exists El-Ahllam tourist village. The coast length of this center is about 12 km and it is expected to be extended to 15 km in the future, and its width is about 1.6 km inland. On the sea side there exists three rocky ridges (Liddell *et al*., 1991; Fig. 2). The beach and sea bottom are rocky covered by an oolitic sand layer with varying thickness resulted from the disintegrated rocky ridges and bottom. This rocky bottom made the slope of shore face and the near-shore zone to be steep while it became flatter in the offshore zone. These ridges and the steep slopes concentrated the wave energy on the shoreline, which caused negative impacts on the study area. Marina tourist center was constructed around an artificial lagoon, which is connected to the sea by four fabricated inlets. During the period from 1989 to 1993, five offshore rubble mound jetties constructed nearly perpendicular to the shoreline to stabilize these inlets, maintain continued water exchange and improve their navigation conditions.

Two jetties out of the five are used to control the navigation channel of the lagoon (exit no.3) and the other three jetties are constructed at west side of the other exits (exits no. 1, 2 and 4; Fig. 2). The length of these jetties varies from 350 to 1250 m (Fig. 2). The presence of these jetties created local erosion problems on their eastern side and accretion problems on their western side. A solution to mitigate erosion problem implemented but it is not effective along the eastern part of the Marina center near El-Ahllam village (Fanos, 2004). The present investigation aims to: present the history of El-Allamien Marina tourist center, its problems and attempt solutions with their impacts. Study the effect of the coastal processes (waves, currents and sediment transport) along the study area using numerical models, may lead to remedy solutions and recommend the proper solution.

2. HISTORY OF DEVELOPING MARINA RECREATIONAL CENTER

Marina recreational center was built around an artificial lagoon, which was in the past consists of three closed isolated natural hypersaline lakes and a sabkha. These lakes were separated from the sea by sand dunes extending along the shoreline. It is noticed that the western and middle lakes are small with their lengths and maximum width are about 375 & 350 m and 300 & 240 m respectively. While the eastern lake is large with length and maximum, width is 3500 & 750 m respectively (El-Saadek, 1988). The water in these lakes was stagnant with high concentration of salts. Field measurements during September and October 1987 showed that the average salinity of the eastern, middle and western lakes and the sabkha were: 70, 76, 78 and 119 $\%_o$ respectively. Whereas the average salinity of the Mediterranean Sea water in front of Marina recreational center is about 38.9 $\%_o$.

This large-scale project (Marina tourist center) has been carefully studied and designed based on sufficient field data and on the obtained results from a physical model, which began in 1987 in Suez Canal Research Center (El-Saadek, 1988). According to these studies four alternatives were proposed, which showed that deepening and connecting the three existing lakes and the sabkha to each other is the best solution for creating one long inner lagoon for recreation and yacht facilities. The total length of this lagoon is about 7 to 8 km connected to the sea by four openings, (Fig. 2). In order to provide entrance access for the vessels (yachts) and to ensure water circulation inside the lagoon four dredged channels with sufficient width and depth have been implemented to connect the artificial lagoon to the sea. These channels and their exits along the sea have been subjected to sedimentation processes. The same study indicated that the negative impact of the selected alternative was evaluated in the Environmental Impact Assessment (EIA) report prior to the implementation of this project. Periodical sand bypassing from accreted areas to the eroded ones on the down-drift side of beaches was also recommended as a proper mitigation measure ((El-Saadek, 1988; Frihy, 2001). Unfortunately, the responsible authority of this center has not follow up the instructions provided in the EIA report (Frihy, 2001). Moreover, the proposed monitoring plan to evaluate coastal changes during and after constructing the five jetties has not been executed.

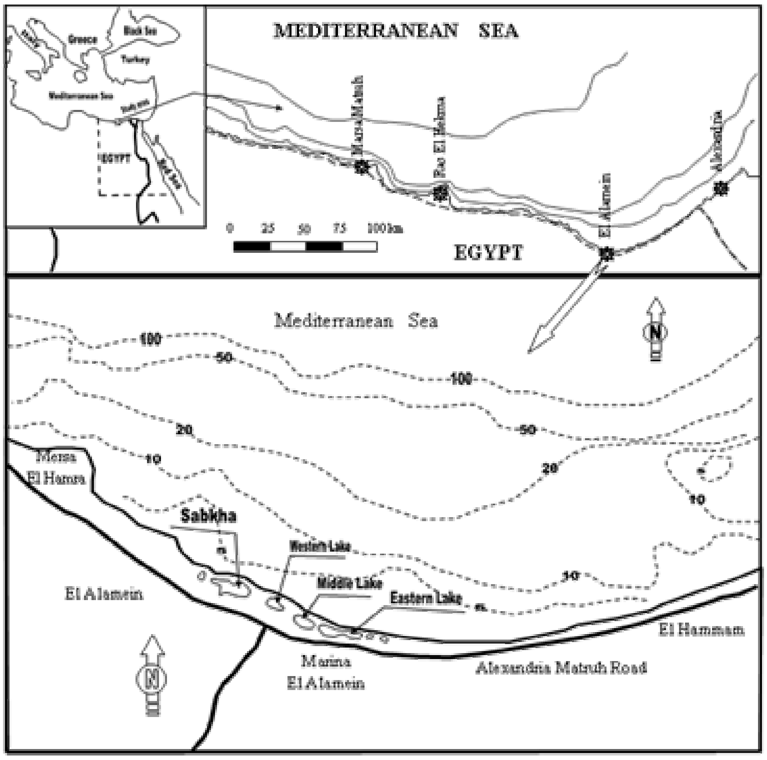

Fig (1): Location map of the study area shows the natural lagoons before recreation processes.

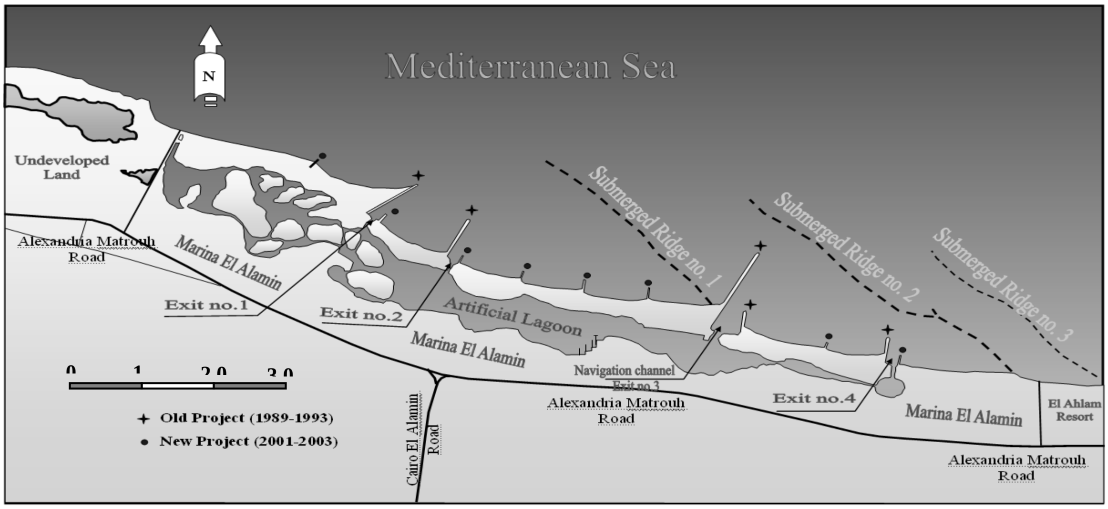

Fig. (2): Marina El Alamin Resort showing the ridges, the artificial lakes and the protection works.

3. COASTAL PROBLEMS AND PROTECTION WORKS

The four exits of the artificial lagoon have been subjected to sedimentation on the seaside due to the NW wave action and littoral sand drift by the predominant long-shore current from west to east. This sedimentation problem caused reduction to water speed and volume of water exchange between the lagoon and the sea, hence created stagnant water inside the lagoon with bad water quality and prevented the yachts from going in and out. In order to combat this problem and stabilize these exits one or two long jetties, (per exit) more or less perpendicular to the coast, were constructed during the period from 1989 to 1993. The five constructed jetties are of lengths varying between 350 and 1250 m. The navigation channel for the yachts is controlled by the 3rd and 4th jetties as shown in (Figs.2 and 3).

These jetties caused local erosion along their down-drift on eastern side and accretion on their up drift on the western side. Each jetty blocks the eastward sediment transport and causes sand accumulation on its western side. At eastern side of each jetty the long-shore transport develops but the sediments, supply from up drift is blocked in the west side by the jetty. Consequently, the coast erodes at the eastern side of the jetty. Re-orientation of the shoreline between the jetties and the leeside erosion east of the protection scheme is the classic response of a coast with a net long-shore transport directed to the east.

The two-shoreline surveys of 1991 and 1997, (Fig. 3), indicate that there is significant change along the beaches of Marina sea resort (Fahmy, 1988). The estimated average erosion is about 10 m/yr along the beach located just to the east of the 5th jetty and accretion of about 15m/yr at the up-drift side of the 3rd jetty (Frihy, 2001). As the natural equilibrium of the coastline has been altered, a state of coastal imbalance appeared in this area and required an immediate appropriate mitigation action. Regular sand nourishment operations planned to mitigate this erosion in the future. Continuous accretion processes on the up-drift side of the jetties resulting in sedimentation of the navigation channel, the exits of the lagoon and blocking large amounts of floating garbage, trash, debris, …etc. In addition, erosion processes on the down-drift side of the jetties resulted in loss of the sandy beaches and threatening a great portion of the summer sea resort buildings facing the sea. Delft Hydraulic Laboratory with the collaboration of Hydraulic Research Institute carried out computations on the long-shore sediment transport on the basis of a detailed wave climate from the British Meteorological Office (BMO) and shoreline orientation. The long-shore transport before the construction of the jetties estimated to be 140,000-160,000 m^3/yr just west of Marina village, to be 80,000-130,000 m^3/yr halfway of the village and to be 60,000-70,000 m^3/yr just east of the village (Delft Hydraulics, 2002). The gradient in the long-shore transport was explained by the curvature of the coast of this area, causing a difference in coastline orientation relative to the incoming waves.

Accordingly, Delft Hydraulic Laboratory proposed the construction of 8 groins ranging from 100 to 400 m in length (Fig. 3). This solution had been implemented in the whole study area of the artificial lagoon during the year 2003. A quantity of 400,000 m^3 of coarse sand from the desert was conjunct once in 2004 between the constructed groins in the area bounded by the 1st and the 5th jetty and gave good results. In addition, three periodic artificial nourishment operations by an amount of 80,000 m^3/year have been carried out along the stretch from the eastern side of the 8th groin on the exit no 4 to the borders with El-Ahllam tourist village with a total distance of 1800 m alongshore. Unfortunately, erosion is still taking place in this zone up to the present time and reaching to the underlying rocks in this zone (Fig. 4).

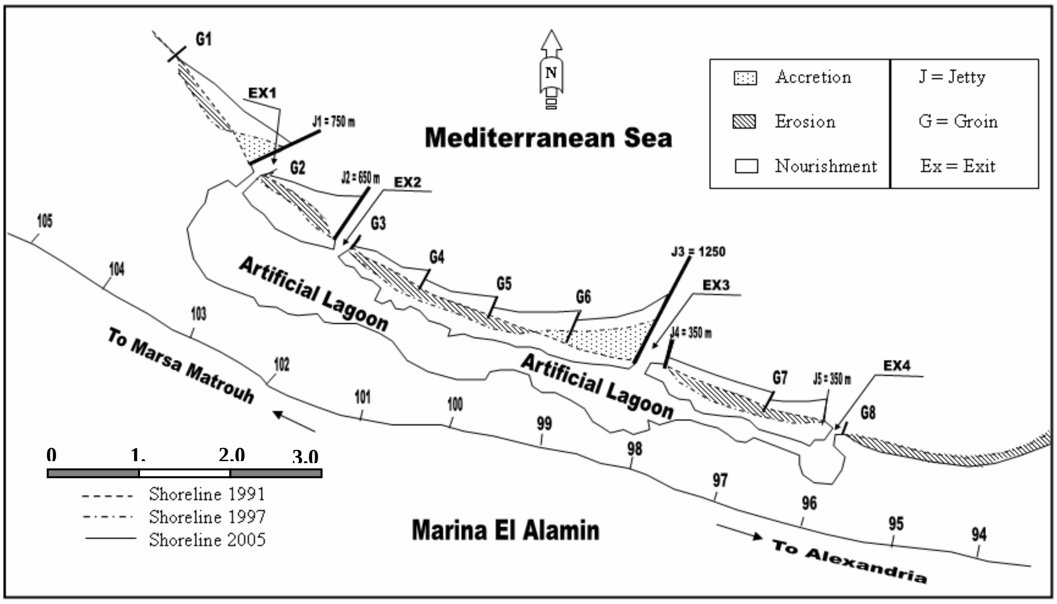

Fig. (3): Protection Works and Shoreline Evolution along the study area.

Fig. (4): The shoreline east of Marina resort shows the underlying rocks.

4. FIELD WORK AND DATA COLLECTION

The present severe erosion of the artificial nourished sand delivered yearly to the eastern zone (1800 m) and the native sand, caused the loss of the sandy wide beaches and threatened the sandy beach and all the infrastructure along this stretch. In a trial to get a solution for this problem Coastal Research Institute (CoRI), started intensive field study for a period of six months (January 2007 to July 2007). The study area extends from 1.5 km in the west side of the 5^{th} jetty to a distance of about 2.4 km was covered by 31 hydrographic profiles. The profile lines are 300 m apart along the west side of the fifth jetty and 100 m a part for the eastern 2.4 km. They were surveyed nearly perpendicular to the shoreline and extending up to 12 m depth, about 5 km offshore. Sounding and inland leveling of the profiles are surveyed with the use of total station, DGPS, Echo Sounder and marine computer. Sounding are corrected with respect to the mean sea level. The profiles were surveyed twice; the first one was during January 2007 and the second one during May 2007.

The currents were measured near the surface and near the bottom at 32 points well distributed on the study area using direct reading current meter.

Delft Hydraulics (2002) used 10 years wind offshore wind data (1988-1997) recorded in front of the study area to study wave climate along that stretch (Delft Hydraulics, 2003). Also, wave characteristics recorded at Damietta in a water depth of 12 m for a year of 2002/2003 by Coastal Research Institute will be used in that study.

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 standard 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).

5. DATA ANALYSIS AND RESULTS

Contour map for the study area developed from the hydrographic profile data (Fig. 5).It shows that there are two submerged ridges no. 2 and 3, extending along the study area (1800 m). Ridge no2 is more effective on the study area because of its extension from the offshore all over the coastal zone to the shoreline ending just west of El-Ahllam village. Its crest is about 1.5 m under the mean sea level (MSL), inclined on both eastern and western sides to a water depth of about 4m below MSL. The present contour map configuration formed two channels on both sides of the ridge. The longitudinal alignment of this ridge is making an angle of 35^{o} with the shoreline, (Fig. 5). Ridge no. 3 might affect on the waves coming from the NE direction. In addition, the developed map shows that the contour lines are parallel to the shoreline in the near shore zone in front of the study area and then they became irregular, complicated and inclined to be parallel to the ridge no.2, i.e. making an angle of 35^{o} with the shoreline (Fig. 5). Profiles data revealed that the beach face slope is very steep between 1:8 and 1:10, while the near-shore one is somewhat flatter and ranging between 1:25 and 1:40. The steep beach face slope causes waves approach to break close to the beach causing severe erosion and turbulent water conditions to the swimmers.

Current pattern revealed that there are circulation cells consisting of long-shore currents directed towards the west and rip currents directed towards the offshore, (Fig. 6). The measured current velocity is small and fluctuated between 0.02 and 0.13 m/sec., because the measurements have been carried out in relatively calm sea condition.

Wave rose (Fig.7) indicated that the predominant direction of the waves is coming from the north-westerly sector with the highest offshore waves in the period 1988 to 1997 are in the order of 5.5 to 6.0 m. The highest waves during the winter season are approaching from the NNW and WNW directions. In addition, a small percentage of waves are coming from N to ENE sector.

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 100m are finer (025 – 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). Generally, 50% of the sediments have been displaced seaward by both cross-shore current and downslope by gravity processes. 50% of the sediments are also directed eastward by wave-induced longshore and offshore currents (Frihy *et al*., 2007).

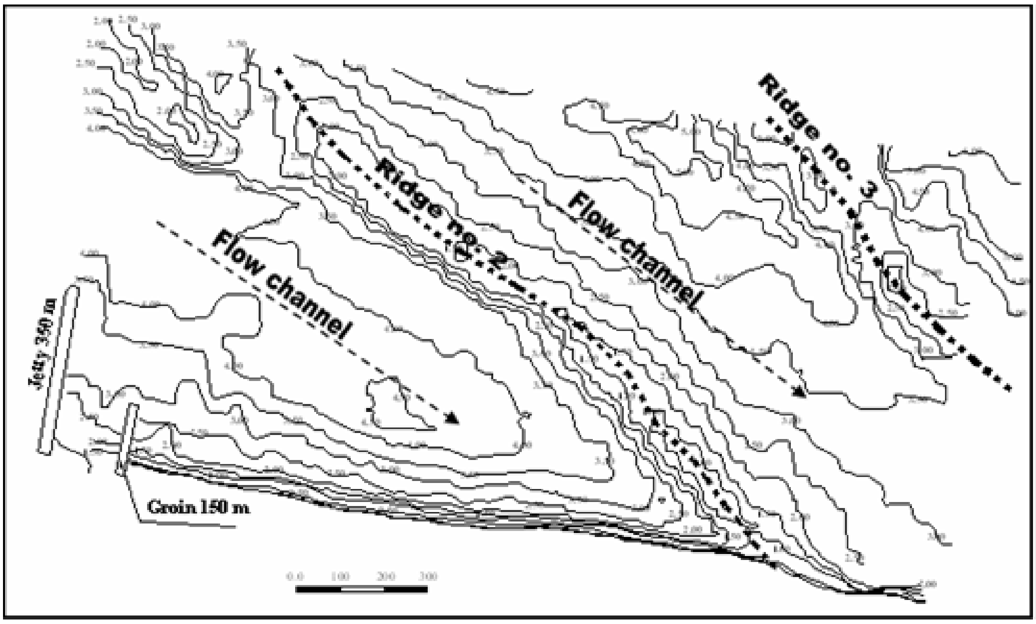

Fig. (5): Contour map of the eastern zone of Marina Center during May 2006.

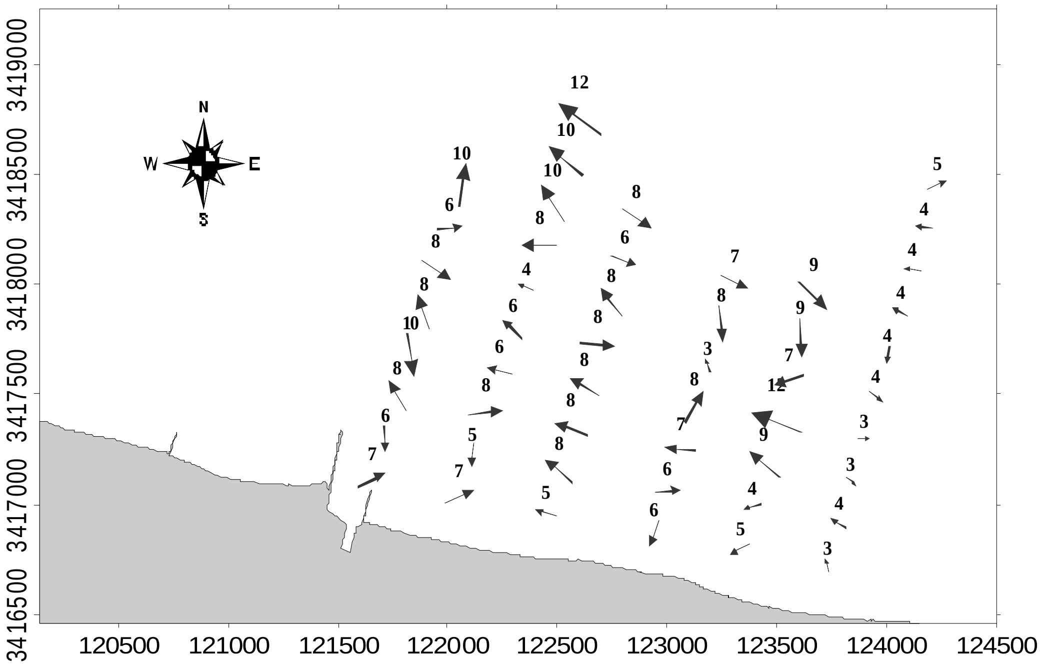

Fig. (6): Near surface current pattern in front of the study area from field measurements conducted during May 2007.

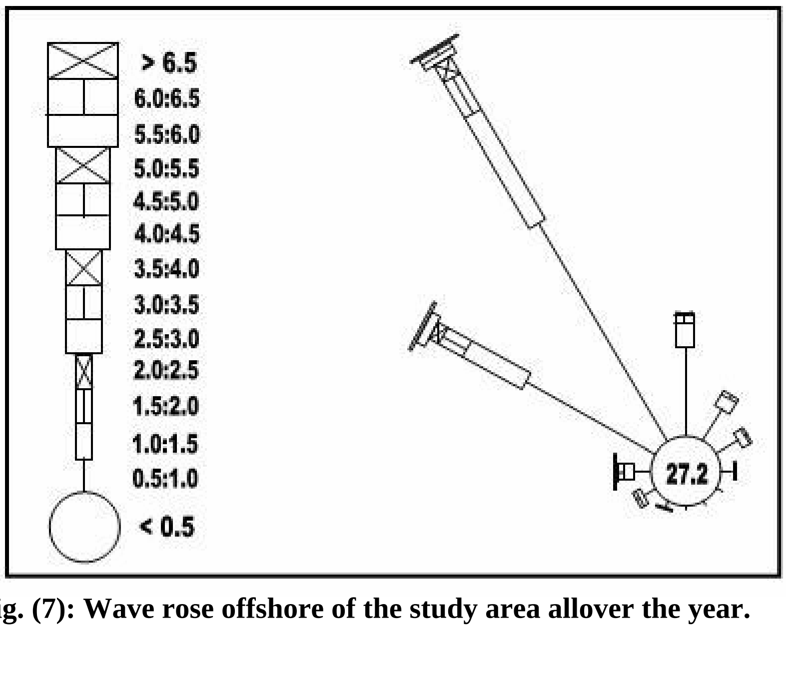

Fig. (7): Wave rose offshore of the study area allover the year.

5.1 NUMERICAL MODELS

In order to get a complete picture for the distribution of currents, waves and sediment transport on the study area two mathematical 2-Dmodels (SIMCOPRO (SIMulating COastal PROcesses) and ImSedTran) have been applied. These models are taking into consideration the effect of shoaling, refraction, diffraction, and breaking phenomena. The input data to these two models are:

- The contour map developed from the hydrographic profiles.
- The shore-line data and the present protection structures.
- The wave data concluded from wave roses.
- Sediment characteristics and their spatial distribution in the study area.

The used models have been verified using the available data and its results showed good simulation with the measured ones. Then the models were applied to fill the gaps of the missed data by using the available ones.

5.1.1 ImSedTran-2D model

This model (Iskander, 2005) gives the distribution of the waves on the study area and determines their breaking characteristics taking into consideration the effect of the existing ridges beside the contour lines. The model is using Kraus, 1984 and Noda, 1972 equations to get the wave distribution and characteristics on the study area. The statistical analysis of waves recorded at Damietta (2003-2004) are chosen to be used for representative wave characteristics of mathematical models: wave heights 1.19, 4.45, 2.51 and 4.31 m with wave periods of 6.8, 8.9, 8.7 and 8.3 sec and their direction makes an angle of 310, 314, 0.60 and 52.8 degrees with the north. Model results (Fig. 8) revealed that the offshore waves twisting through their path to the coast trying to approach perpendicular along the shoreline. waves height are reduced due to the dissipation of wave energy by about 80% of their original energy due to the effect of the ridge (wave breaking) and shoaling of bottom contours. The results indicated that the breaking depth is ranging between 1 and 3 m, while breaking wave height is ranging between 0.78 and 2.3 m depending on the deep water wave height, wave period and wave direction. In addition, storm waves are breaking above ridge no. 2, then the wave reformed then break again near the shoreline due to the steep slope of the beach face. The reformed waves break at a distance ranging between 70 and 100m from the shoreline i.e. in a water depth of about 2 m. The predominant significant offshore wave height of 1.19 m, generally, breaks at a distance ranging from 50 to 70 m from the shoreline i.e. at water depth from 1 to 1.5 m.

5.1.2 SIMCOPRO (Simulating Coastal Processes) model

The model, (El-Sayed, 2004) is a multi-purpose one to determine the distribution and characteristics of the waves, the currents and the amount of moving sediments. This model is using Dalrymple, 1988; Horikawa, 1978; Longuet-Higgins and Stewart, 1964 equation for the waves and current simulation while the sediment quantities is determined by equation of Van-Rijn, 1988. The current distribution was determined by the 1st part of this model and a sample of these results is shown in Figure (9). Current distribution is affected by the waves, the irregular bottom contours and the alignment of the existing ridge. The long-shore current inside the breaking zone was generally directed from west to east for all wave characteristics mentioned above with variable magnitude. The current velocity vary from 0.15 to 0.50 m/sec, from 0.15 to 0.7 m/sec and from 0.25 to 0.9 m/sec for the wave heights 1.19 m coming from NW, 2.51 m coming from N and 4.31 m coming from NE respectively. The currents beyond the breaking zone are fluctuated to different directions (Fig. 9). At

4m water depth zone, current velocities are varying from 0.09 to 0.4 m/sec, from 0.2 to 0.6 m/sec and from 0.38 to 0.8 m/sec for the different wave conditions mentioned above. Also a strong current of about 0.4 m/sec is moving to the off-shore direction (parallel to the 2nd ridge), which might transport part of the eroded sand to the offshore direction. This explains the existence of some of the nourished sand at offshore area. In the eastern side of the study area, circulation cells characterized by a presence of strong rip currents with speed ranging from about 0.31 to 0.4 m/sec. These rip currents are causing troubles and serious hazards to the swimmers.

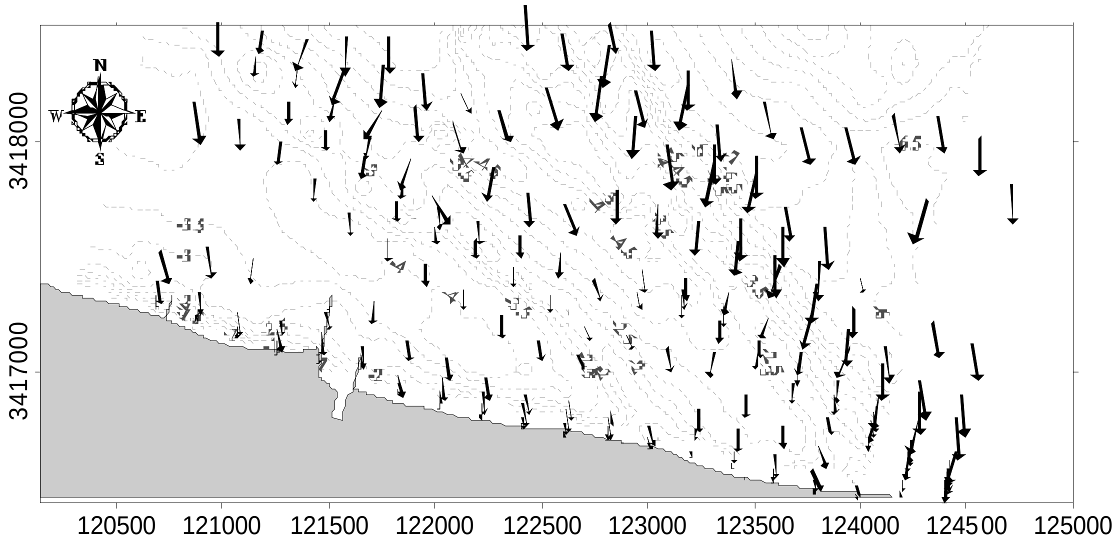

Fig. (8): Nearshore distribution of the maximum northern wave of H_{max}= 2.51 m, T= 8.7 sec which measured at 12.0 m water depth.

Fig. (9): Distribution of the developed wave induce currents along the study area due to the maximum northern wave of H_{max}= 2.51 m, T= 8.7 sec which measured at 12.0 m water depth

5.1.3 Shoreline change model

Shoreline measurements during the period from 2004 to 2006 (Fig. 10) indicated that the whole shoreline was subjected to erosion with maximum value of 30 m except a small zone located east of the 8th groin where accretion is taking place. This might be due to the reversed long-shore current (Fig. 9) and the great amount of nourishment sand conjunct to that area yearly (thee times; 2004 to 2006). During the period from 2006 to 2007 the shoreline retreat (subjected to erosion) along the whole area with maximum value of 15 m (Fig. 10). Mathematical model GENESIS, was calibrated using the data of the two shore-line surveys during 2007 in iteration manner to get good coincidence between the measured and the predicted ones (Fig. 11). Then the model was run to predict the shoreline after one year, i.e. at January 2008. The predicted shoreline shows that the eastern zone near El-Ahlam village is still accreted and the erosion exist along most of the study area of Marina center (Fig. 11) .

Annual sediment transport rate have been studied using GENESIS model (Fig. 12). The study revealed that 93% of sediment transport (57000 m^3) is moving towards the east and about 7% (4000 m^3) is moving towards the west. Consequently, the net sediment transport is 53000 m^3 directed towards the east. Therefore, the study area in front of Marina is marked by erosion, whereas El-Ahlam tourist village, which located to the east is marked by accretion during summer and autumn months, then it eroded again during winter months.

5.2 PROPOSED CORRECTIVE MEASURES

The overall study of hydrodynamic factors (waves and currents), sediment transport and geomorphology of the study area revealed that the area is characterized by: i – Waves are breaking near the shoreline without permitting any surf zone for swimming and hence causing the increase of erosion rate. ii – Presence of strong rip and long-shore currents create offshore sediment transport and considered the most dangerous factors threatening the safety of swimmers in the near-shore zone. iii- The study indicated that artificial sand nourishment is not an efficient protective measure. iv- In order to overcome these problems, the proposed solution will be depending on the results of the present study and those came up from the impact of the previous protection works implemented in the neighbor area, northwestern coast of Egypt. The attempt solutions could be one of the following:

1. Using detached breakwater whether emerged or submerged in water depths 3-4m as it was executed along the beach of Marabella tourist village. The solution created erosion in the down-drift side and accretion in the up-drift side. In addition, the beach is also suffering from accumulated pollution problem.
2. Using the transition groin system with artificial sand nourishment between the groins. It is implemented along the western side of exit 4, and the impact was creating severe erosion problem along the eastern side of exit 4. Also accretion problem at the western side of the groins and pollution problems along most of marine coast. In addition, the nourishment sand will be lost in small period due to the combined action of currents (rib and longshore currents) and waves approach to the coast from open sea with full energy. Hence, the needed refill quantities will be huge and should repeat within short period to compensate the eroded sand.
3. Using perched beach method by creating a flat wide gradually sloping beach in order to reduce the combined action of waves and currents at offshore zone (far away from the shore-line) and thus reducing their energy and creating surf zone suitable for swimming and recreational conditions. This protection solution can be achieved by adapting the following measures:

a. Construct a submerged breakwater at water depth 3 to 4 meter more or less parallel to the shore-line. The crest of the breakwater is one meter below the mean sea level (MSL) and is extending longitudinally from the 8th groin in the west to the end of the ridge no2 in the east. (total length is about 1800 m). Its crest is 12 meter wide, side slope of 5:1 or 7:1 on the seaside and 3:2 on the shore side and its inner edge is about 100 meters from the existing shoreline (zero contour).
b. Create the planned beach with gentle slope 50:1 using artificial sand nourishment along the perched beach bounded by the submerged breakwater and the 8th groin in the west and the end of the 2nd ridge in the east. The nourishing sand could be brought from the desert or from the offshore.
c. Cross light groins could be used to divide the perched beach into small compartments obstacle the channel flow to reduce the quantity of sand losses by littoral drift. The groins will be extending from the shoreline to the submerged breakwater (Fig. 13) and inclined towards the offshore direction by the same slope of the created beach.

In the present overview, the choice of the optimum solution is determined according to the results coming from the results of the present study, running of the mathematical models and previous works implemented. They recommended the protection works plan mentioned in part C (Fig.13).

6. SUMMARY AND CONCLUSION

El-Alamein Marina tourist center was built around an artificial lagoon connected to the sea through four dredged channels to provide access for vessels and ensure water circulation. During the period from 1989 to 1993, five jetties with lengths varying between 300 and 1300 m have been built to stabilize these channels. The jetties caused a quick shoreline changes with accretion on their western side and erosion on their eastern side. In 2003, eight groins of lengths varied between 100 and 400 m with sand nourishment had been implemented one time. They succeeded to combat the problems created between the jetties and severe erosion created along the eastern side of Marina center. During the period from 2004 and 2006 three times of yearly periodical sand nourishment conducted along the eastern side of Marina center failed to mitigate the erosion processes. Six months of intensive field measurements were conducted. Mathematical models SIMCOPRO, ImSedTran-2D and GENESIS, were applied to study waves, currents, sediment transport rate for the present time (available data) and for future, after using different proposed solutions. The results coming from mathematical models coincide with the results shown in nature from executing protection works at some villages on the northwestern coast of Egypt (Marina center and Marabilla). The study recommended creating perched beach method mentioned above in the Proposed Corrective Measures. In addition, the study recommended that a monitoring program should be applied to follow up the developed beach during and after executing the work.

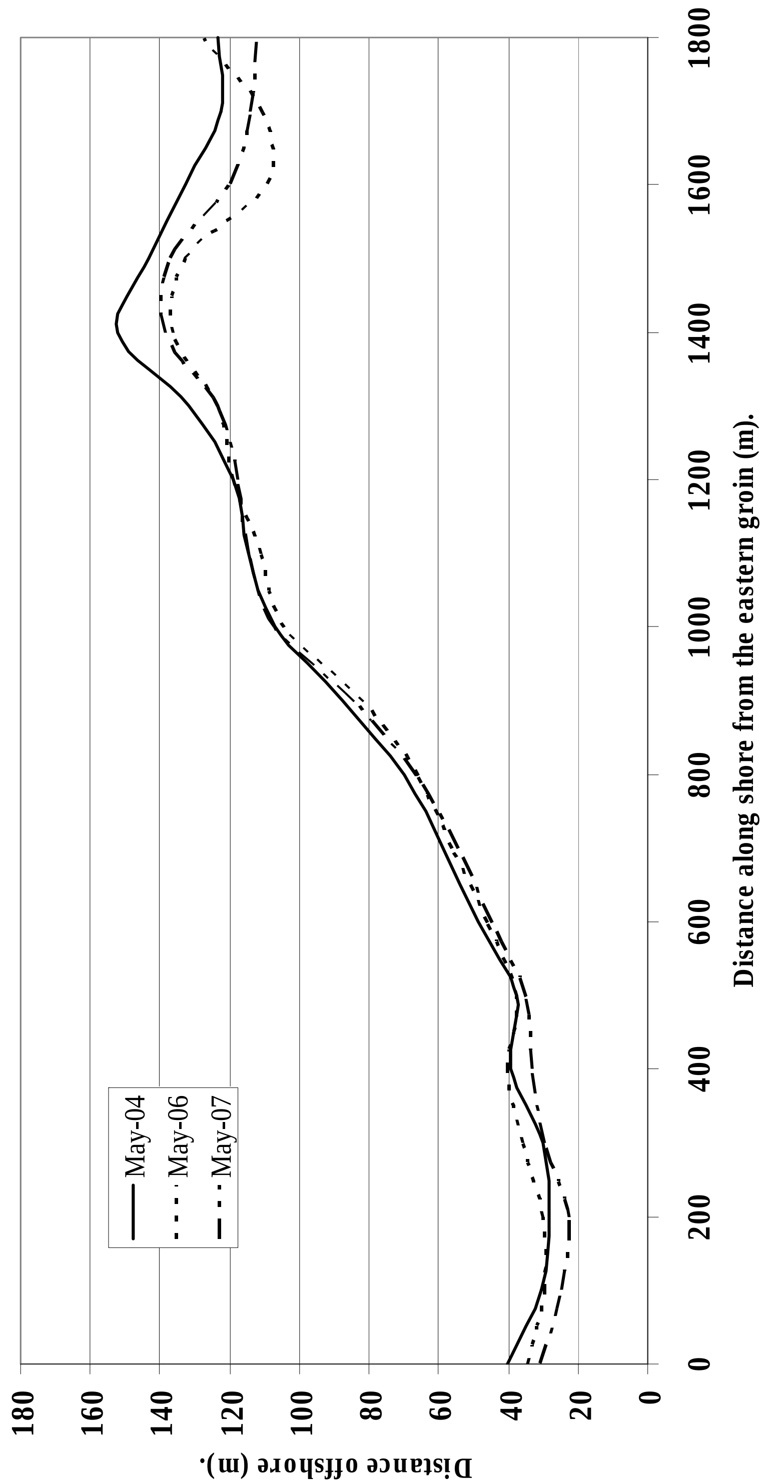

Fig. (10): Measured shoreline changes at the eastern part of Marina resort during the period from May 2004 to May 2007.

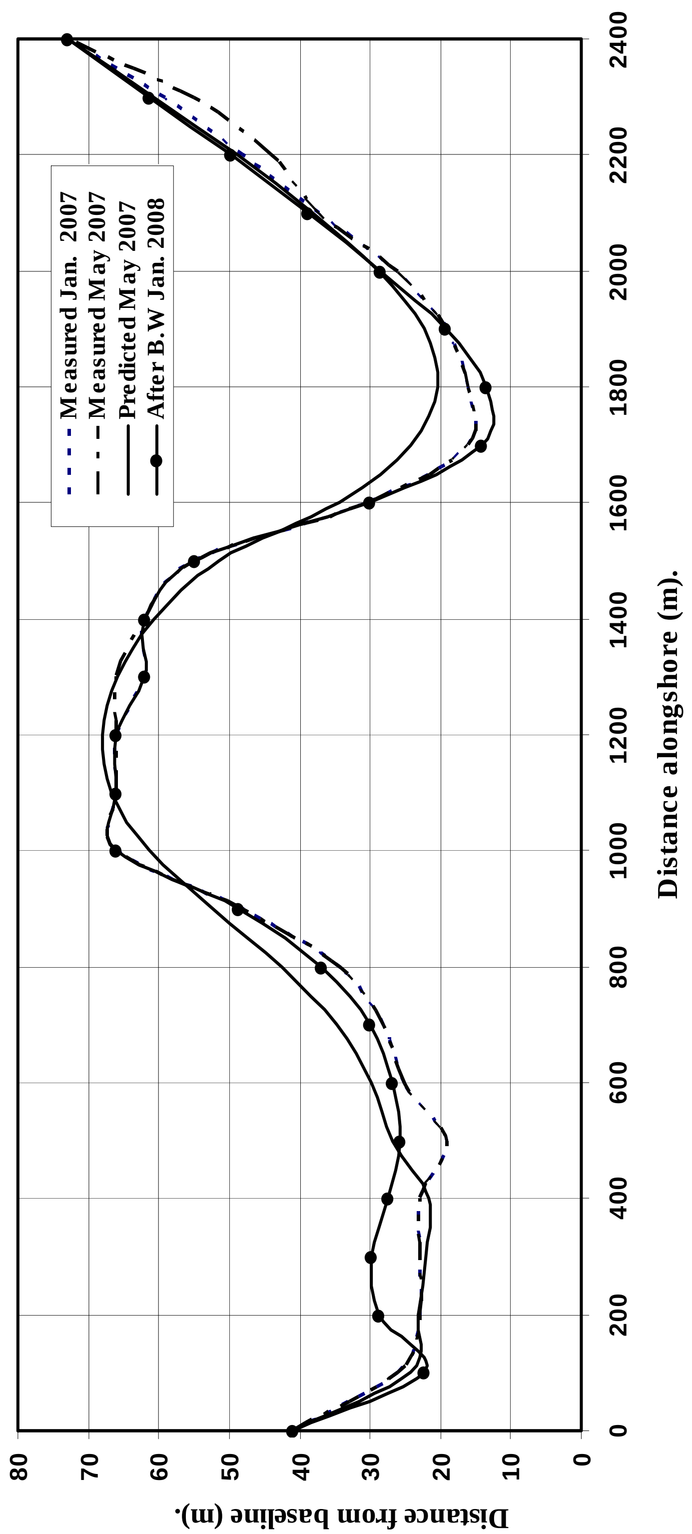

Fig. (11): Predicted shoreline changes at the eastern part of Marina resort calculated from Genesis model.

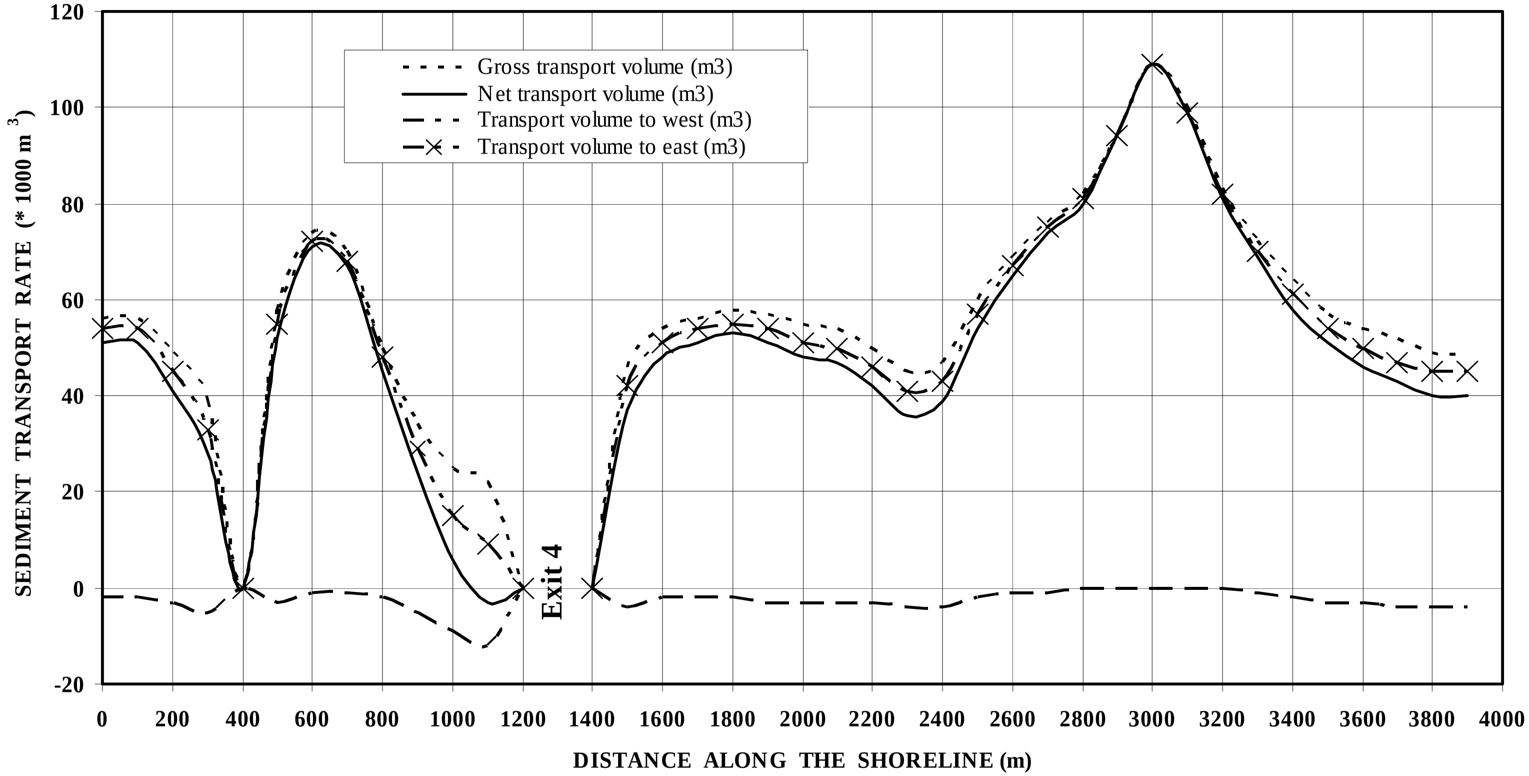

Fig. (12): Sediment transport rate along the shoreline at Marina resort for one year simulated period.

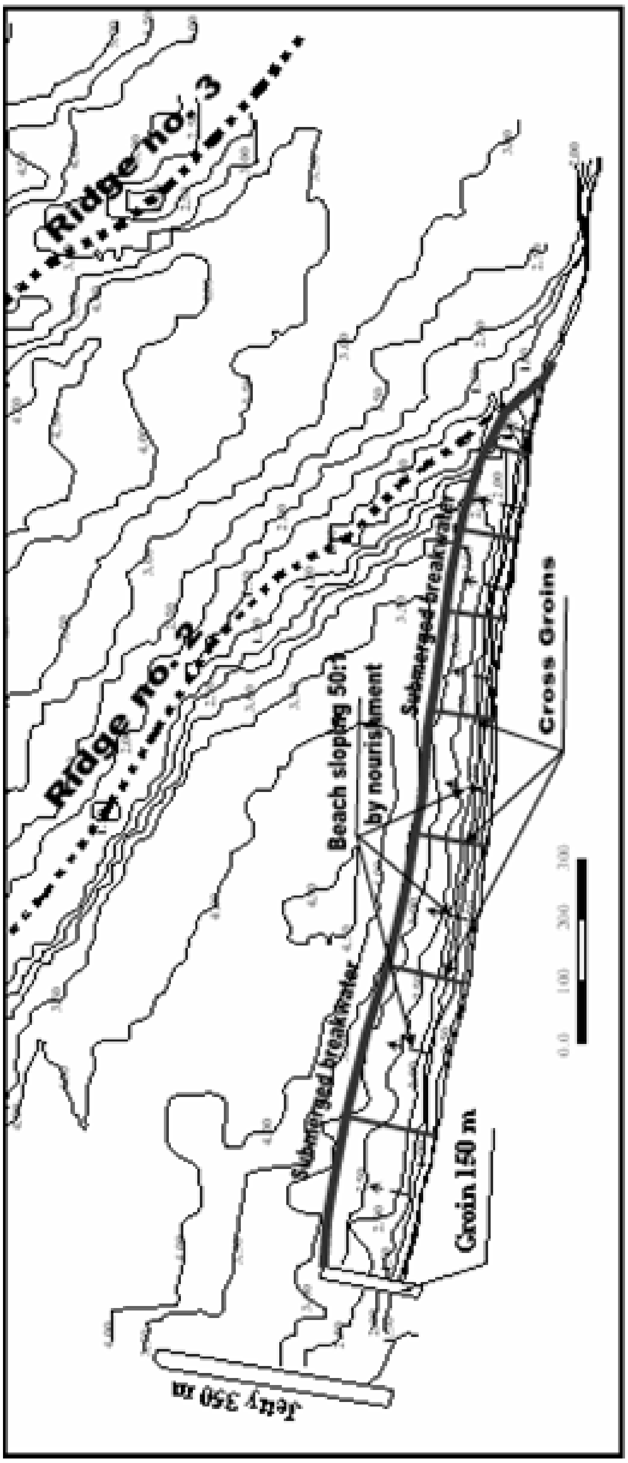

Fig. (13): General layout of the proposed solution to protect the study area.

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