Proceedings of the Twenty-second (2012) International Offshore and Polar Engineering Conference
Rhodes, Greece, June 17–22, 2012

ISBN 978-1-880653-94–4 (Set); ISSN 1098-6189 (Set)

www.isope.org

A Study on The Use of Semi-Open Groin System for Protecting The North-West Coast of Egypt Along The Mediterranean Sea

Ayman M. Mostafa [1], M. Hasan [2] and Gamal Al-Sayed [2]
[1]Dept. of Irrig. & Hydr., Faculty of Engineering-Cairo University
Orman, Giza, Egypt
[2] Dept. of Civil Eng., Shoubra Faculty of Engineering, Banha University
Shoubra, Cairo, Egypt

ABSTRACT

This paper presents groins with a clear opening in their cross section as a tool for protecting the shore area. The opening allows water circulation and flushing in the near shore zone while protecting the swimmers from direct exposure to wave attack. The possible impact of the opening size and the internal properties of the groin on the shore line changes and water circulation have been investigated. The dominant wave/current conditions along the North-West coast of Egypt have been considered for various possible configurations of the semi-open groin to identify the appropriate design. Wind and wave data of Al-Daba Meteorological Station (DMS) have been adopted for the period 2000-2005. Attention has been given to the Egyptian Environmental Law 4/1994 and bathymetric survey of the bed contours has been prepared for Ras Al-Daba zone in the North-West coast of Egypt. A numerical model, namely known as Surface water Modeling System (SMS) ver.10, has been adopted in the simulation. The results of the model have been presented in convenient graphical formats and analyzed to select the appropriate configuration of the semi-open groin suitable. The results and analysis provide general guidelines for the use of semi-open groins in coastal resorts that can be applied to wide range of wave climate. It has also been found that semi-open groins can be of good help to provide safe swimming conditions with minimum impact on the shoreline if groins were properly studied. Wide gap spacing and permeable groins generally reduce the shoreline changes.

KEY WORDS: Groin; shoreline changes; coastal hydro-dynamics; Al-Daba Meteorological Station; Egyptian coast, safe swimming conditions.

INTRODUCTION

Coastal zones in many countries in the world are of major concern by the virtue of being multi-functional regions. Their use as harbors, fisheries, recreational areas, source of minerals, water supply and excess water disposal gives them a very special interest. The northern coast of Egypt along the Mediterranean Sea extends for approximately 1000 km from Rafah at the east to El-Sallum at the west. This study focuses on one of the most attractive summer resorts along the North-West coast of Egypt namely, Al-Daba – Ras Al-Hekma zone, as a pilot study for the use of new shore protection structures. A chain of tourist resorts, beautiful recreational beaches and many major projects have been recently constructed in this area. The coastline in this area faces several problems; one of the major problems facing the development in this area is continuous shoreline changes under the effect of sea waves and currents. Rip currents are also of major concern to swimmers due to the frequent drowning cases. Some resorts used surface piercing detached breakwaters for protecting the shoreline and swimmers, e.g., Marabella and Al-Nakhil resort of Egypt. In the latter cases, accretion was developed shortly after the construction of the breakwaters and the down drift zones suffered from shoreline erosion. The erosion has been dramatically increasing causing demolishment of large parts of the down drift beaches. Moreover, floats and debris are usually trapped behind surface piercing breakwaters while eddies are evident at the end sections. It is noteworthy that the latter cases violate the environmental laws of Egypt, but they could somewhat protect the swimmers from the risk of drowning.

Due to the increasing demand for safe swimming conditions with minimum impact on the shoreline while keeping acceptable water quality, new studies have been conducted to meet these requirements using appropriate coastal structures. The Shore Protection Authority of Egypt (SPA) conducted a study in 2002 for the development of the North-West coast of Egypt and introduced the use of perched beach as a possible alternative for providing safe swimming conditions along Al-Arab bay zone, located from Alexandria to Al-Alamin city (at station 120 Km along Alexandira-Matrouh road). However, none of the perched beach designs have been constructed to date. Only one design was approved by the Egyptian Environmental Affairs Agency (EEAA) at station 30 Km along Alexandria-Matrouh road, but it has not been constructed. Thus, the actual field effect of the perched beach is not well-known yet.

The Ministry Of Housing (MOH, 2000) in Egypt studied morphological and water components in El-Alemein marina resort using UNIBEST model for shoreline changes and DELFT2D-WAQ for water quality studies. It studied the use of groins, detached breakwaters and sand bypass / nourishment as protection measures for the erosion problems encountered. It was recommended to protect the shoreline using a system of groins combined with an initial amount of nourishment.

Submerged breakwaters were constructed along Alexandria promenade of Egypt over the past a few years to protect low sections of the promenade from flooding during severe storms in winter (El-Sharnouby and Soliman, 2010). A submerged breakwater system was installed to protect the beach of Miamy –Almontaza zone in Alexandria of Egypt in 2007-2008. The detached submerged breakwater has a total length of about 3 Kilometers. It was reported that natural sedimentation formed a beach with an average width of 100m in the leeside of the submerged breakwater, while no erosion observed for two years at any point and the seawall of the promenade remained untouched by waves even during severe winter storms. However, their results are based on actual field observations without sufficient technical supporting documentation, e.g., simulation using numerical models or laboratory experiments. Ahmed (2009) studied numerically the use of submerged breakwaters in protecting swimming beaches and seawalls from high waves using a coupled BEM-FEM model for the simulation of non-linear wave-structure interactions. Although the results of the latter study were not compared with actual field data due to the lack of such data during the study preparation, the results and conclusions made are consistent with the field observations reported by (El-Sharnouby and Soliman, 2010). It is also noteworthy that the BEM-FEM model was tested and compared with experimental data in many publications, e.g. Mizutani et al (1998) and Mostafa and Mizutani (1999).

The use of groins for protecting the beach was applied in many places worldwide, but it still has the adverse impact of accretion /erosion as well as poor water quality at stagnation points. Semi-open and permeable groins could be one of the possible protection structures, which can be used to protect the shore from erosion with minor environmental impact, especially if attention is given to their design. Groins have several advantages; e.g., low cost, easy to construct, do not impair aesthetic amenity of the beach, effective control on erosion, retain sand on a beach and less adverse impact on the environment. Almost no reliable studies have been conducted on the use of semi-open groins along the Egyptian coast for protecting the beaches while limiting shoreline changes to a minimum. The internal properties of the groin, number, size and location of openings can be of paramount impact on the shore line changes and water circulation as well. This study focuses on the use of semi-open groins and tests the appropriate size of the opening located at the center of the groin as well as the internal properties of the groin. The impact of the various designs of the groin on the shoreline changes, wave height distribution and radiation stresses have been investigated and guidelines have been summarized.

STUDY AREA

This study considers an area located at station 150 Km along Alexandria-Matoruh road of Egypt for the application of the proposed groin. The beach is located near Al-Daba city and the shore is about 1500m long. The shoreline makes an angle of about 60 degrees with the West-East direction (see Figure 1). The prevailing wind/wave direction is North-North-West and makes an angle of about 22.5 degrees with the North direction (see Figure 2) as per the data of Al-Daba Meteorological Station along the North-West coast of Egypt (2000-2005). Thus, the prevailing wave direction makes an angle of 37.5 degrees measured clockwise from the normal to the shoreline and most waves approach the beach from the right-hand side direction of the groin.

SPA (2002) divided the North-West coast into number of cells based on the shape of the shore line and the main head lands. The cell is defined as a unit in which the long shore morphological interaction is anticipated to be relatively strong. The cell is bounded by physical boundaries, e.g., rock head lands or harbors, such that interruption of long shore current takes place. The main coastal cells are shown in Figure 3 and the study area is located in Cell 4.

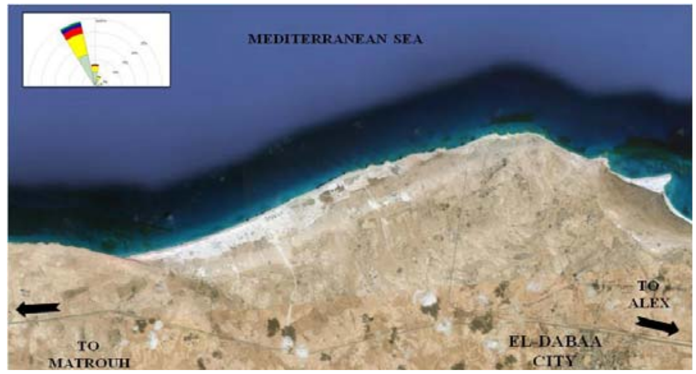

Figure (1): Satellite map of the project area on the North coast of Egypt.

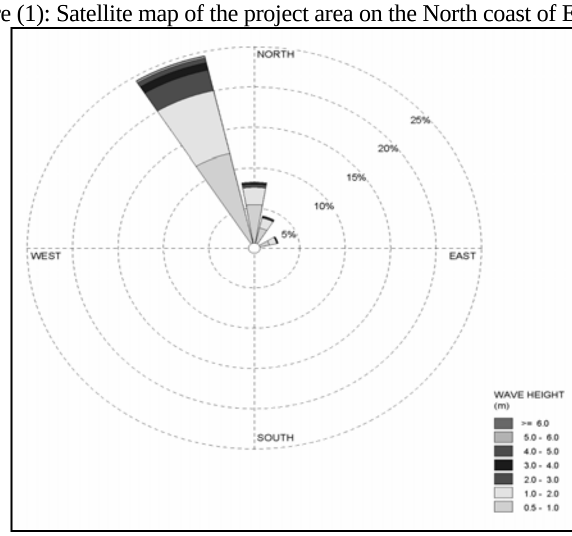

Figure (2): Deep water wave rose computed by SMB method using the data of Al-Daba Meteorological Station of Egypt (2000-2005).

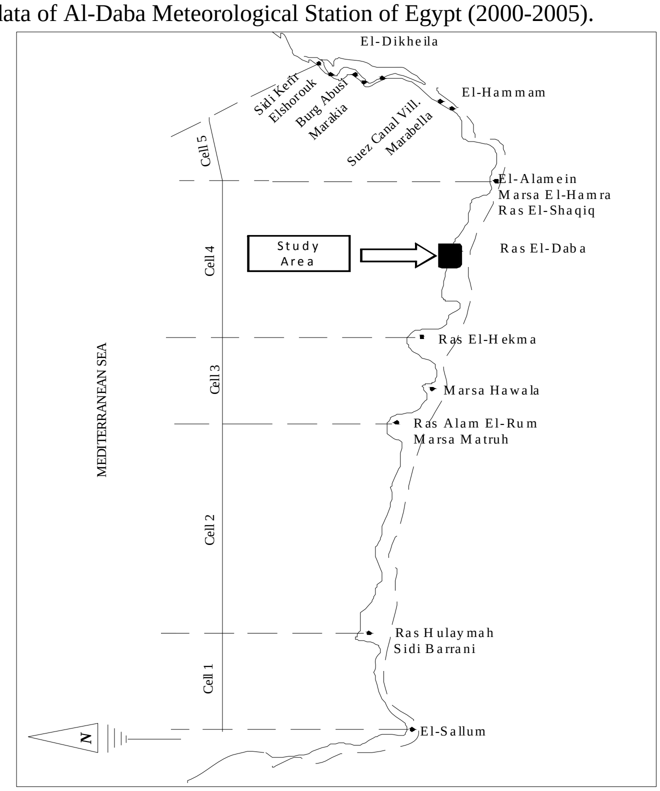

Figure (3): coastal cells along the North-West coast of Egypt as classified by SPA 2002.

Bathymetric survey recorded in 2000 has been made for the study area as measured from the MSL (Mean Sea Level=0) and presented in Figure 4-a. It can be seen that the bed levels go as deep as about 20m within 700m from the existing shoreline with an overall average slope of 1:35. On the other hand, the shore face is steep and the bed is about 3m deep shortly from the shoreline with an overall slope of 1:12 (Figure 4-b). It can be observed that the bed has a nearly uniform slope at bed levels less than 3m below MSL.

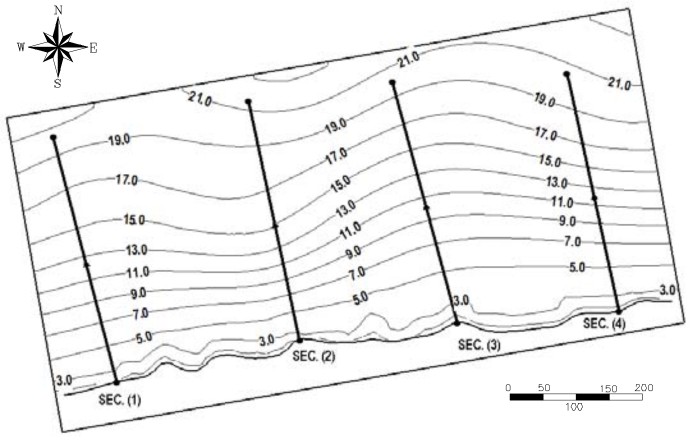

Figure (4-a): Bathymetric survey recorded in 2000 and location of transects at station 150 Km along Alexandria-Matrouh road of Egypt.

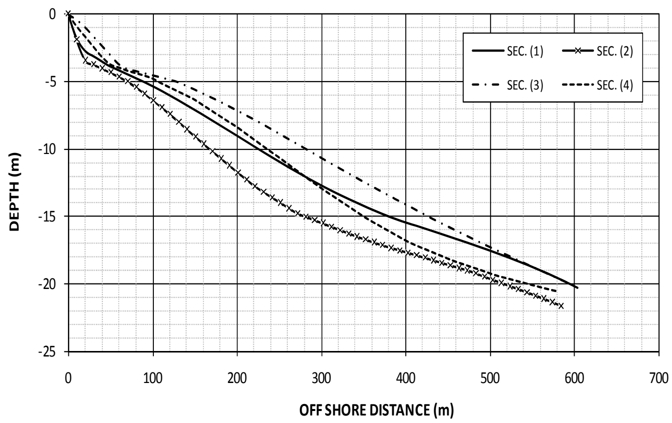

Figure (4-b): Bed levels at the selected transects surveyed in year 2000.

The wave data has been analyzed and input to the numerical simulation model, namely as Shoreline Modeling System (SMS) ver.10. SMS considers the existing shoreline as the baseline and the normal to it as a false North (direction=0 for the normal direction to the shoreline and angle is positive anti-clockwise). The distribution of the deepwater wave energy (m^2/Hz) versus the direction angle measured from the normal to the shore line during the occurrence of maximum incident wave height is shown in Figure 5-a. It can be observed that most of the wave energy is centered about the normal to the shoreline and the maximum is reached at about 10 degrees to the normal on the shoreline. Moreover, the spectral analysis of deepwater wave data during the period 2000-2005 is given in Table 1 as computed by SMS and presented graphically in Figure 5-b. The wave angle is zero at the normal to the shoreline and positive anti-clockwise. It can be noticed that large numbers of small waves generally occur in the study area. The largest deep water wave being observed is about 4.6m and approaches the groin from its left hand side direction, i.e., at an angle of 10.758 degrees (see Table 1). Also, the average height of the highest 10% of deep water waves is as high as 2.6m, while high waves as high as 2.4m and period of 8.6 sec approach the groin at angle of 12.4 degrees at relatively high frequency, i.e., see index 250 in Table 1.

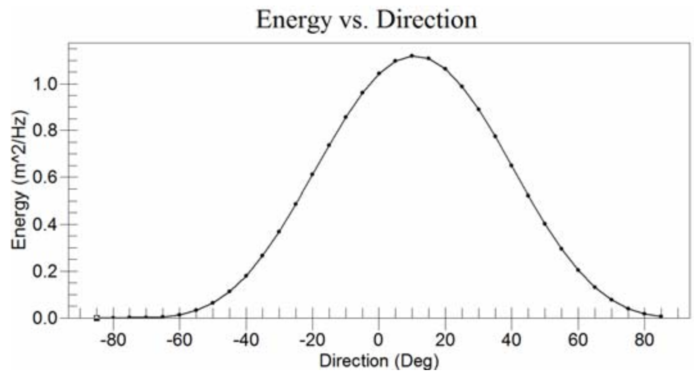

Figure (5-a): Wave energy distribution versus direction during the maximum incident wave height in deep water as per Al-Daba Meteorological Station data (2000-2005).

Table 1: Spectral analysis of wave data in Al-Daba Meteorological Station computed by SMS10 (2000-2005).

Index	Frequency of Occurrence	H_s (m)	T_p (sec)	Direction Angle (degrees)
10	10	0.125	3.842	-62.206
20	32	0.125	3.763	-39.289
30	66	0.128	3.771	-9.99
40	152	0.126	3.764	19.968
50	12	0.185	4.258	-62.206
60	180	0.321	4.932	-41.594
70	275	0.324	4.826	-9.399
80	510	0.304	4.744	18.837
90	29	0.548	5.812	-37.025
100	61	0.593	5.791	-8.588
110	135	0.588	5.792	16.986
120	68	0.696	6.356	-39.121
130	84	0.822	6.392	-11.593
140	185	0.815	6.368	15.874
150	3	1.066	7.487	-41.503
160	43	1.189	7.138	-15.297
170	134	1.194	7.117	14.52
180	9	1.613	7.73	-9.143
190	55	1.66	7.819	13.387
200	2	1.865	8.785	-36.05
210	4	1.84	8.132	-20.245
220	23	1.914	8.122	13.002
230	1	2.063	9.02	-36.05
240	9	2.339	8.571	-10.143
250	67	2.401	8.623	12.435
260	8	3.247	9.436	-13.981
270	26	3.317	9.423	11.593
280	2	4.077	9.93	11.593
290	6	4.596	10.21	10.758

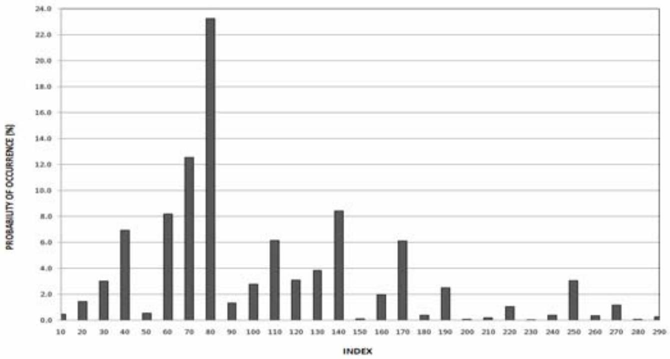

Figure (5-b): Graphical presentation of spectral analysis of wave data in Al-Daba Meteorological Station computed by SMS10 (2000-2005).

MODEL DESCRIPTION

SMS is a finite difference model originally developed by Brigham Young University (1985) in cooperation with the U.S. Army Corps of Engineers, Engineer Research and Development Center (ERDC), and the U.S. Federal Highway Administration (FHWA). The model adopts GENSIS II based on the one-line theory for sediment transport calculations (Hanson, 1987). It also adopts WABED model (Wave-Action Balance Equation with Diffraction) developed by Mase (2000) for the simulation of steady-state (time-dependent), half-plane, two-dimensional spectral wave transformation.

The input data consists of site specific wave climate data, morphological features and existing or planned structural information (such as groins, breakwaters, beach fills). The wave data, a set of wave events including deep water wave heights, periods, angles, corresponding closure depths and frequencies of occurrence for each wave direction per year, is obtained from either a wave history data or a wind climate study depending on the available type of data recorded by local meteorological stations. Another major input is the initial shoreline orientation and physical characteristics (such as median grain size in the surf zone, bottom slope or shape, berm height). The shoreline orientation is represented by an appropriate discretized shoreline. The last input data is the structural information such as the location and length of a groin or offshore distance of a detached breakwater. After all necessary input data is entered to the model, the shoreline is subjected to waves and its evolution in time is observed.

CASE STUDY

A study has been conducted on the use of semi-open groin for protecting a strip of the beach from severe wave attack while keeping reasonable flushing condition and minimum shoreline changes due to the groin. The study area is 1500m along the shore line and extends for about 700m normal to the shoreline (Figure 6). The groin has been considered at 1000m from the west boundary of the study area and 500m from the East one. The groin extends for 100m normal to the shoreline and the gap has its center midway along the groin. The average effective grain size of the soil on-site is 0.5mm and the average berm height has been computed and found to be 1m. The closure depth is 8m and the long shore sand transport calibration coefficients considered are K_1=0.4, K_2=0.4. The wave data and bathymetric survey described in the aforementioned sections have been used to run the model for the current configurations (see Table 2) and the results have been presented, analyzed and discussed. It is noteworthy that the current investigations have been focused on the effect of the size of the gap and permeability of the groin on the wave height, radiation stresses and shoreline changes. It is also considered that wave height less than 1.0m and radiation stresses less than 0.5m/sec represent favorable conditions for swimmers around the jetty. Thus, model output has been presented during the occurrence of maximum incident wave height (H=4.6m) to identify locations of high wave and/or radiation stresses. The impact of various groin configurations on the shoreline has been presented at the end of simulation period in year 2005.

Table (2) Input parameters for the case study.

Run-No.	Groin Length (m)	Groin permeability	Gap Spacing (m)	Note
1	-	-	-	No structure
2	100	0	0	No gap but variable permeability of the groin
3	100	0.2	0	
4	100	0.5	0	
5	100	0	5	Impermeable groin and middle gap of variable size
6	100	0	10	
7	100	0	15	
8	100	0	20	

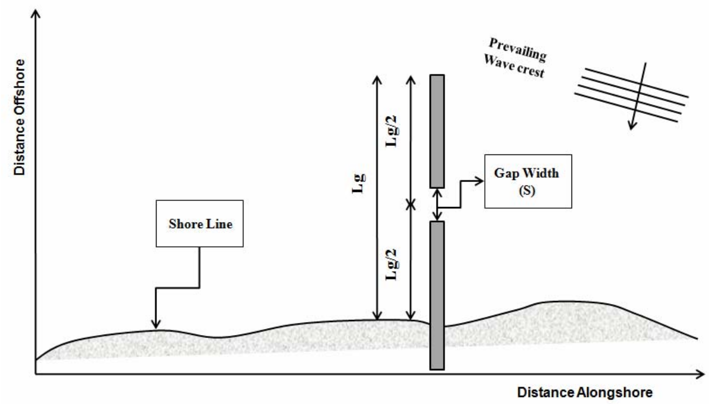

Figure (6): Definition sketch of study.

RESULTS

SMS model has been used to simulate the wave hydrodynamics around the groin for about 6 years to study the impact of the proposed groin on the shoreline and wave conditions at various time steps. Figure7-a shows the wave direction and height as the waves approach the groin during the occurrence of maximum incident wave height within the study period, i.e., H_i=4.6m. It can be observed that waves approach the shore normal to it due to refraction and shoaling (Figure 7-b) and wave height at the tip of the groin is about 2.5m and it decreases rapidly to about 0.5m high as it propagates along the groin. The waves affected by the groin are within 100m away from the groin on both sides, i.e., the same length of the groin, while the decay on the East side (up drift for the prevailing wave conditions) is slightly larger than that on the west side (down drift for the prevailing wave conditions). Figure 7-c shows two breaker lines, i.e., one in deepwater and the other in shallow water as well as breaking at the head of the groin itself. Moreover, rip current can be noticed on the up drift side and a rip head is formed offshore. The numerical results have showed that radiation stresses have been as high as 0.74m/sec.

Figures 8a and 8b show the case of a small gap in the middle section of the groin having a width of $0.05L_g$. It can noticed that some waves cross the gap from the up drift to the lee of the groin due to the effect of wave diffraction and the wave height at the down drift side is slightly higher than the case of the no gap in the groin. Also, some current cross the gap to the lee ward of the groin and interact with the wave-induced current causing some turbulence.

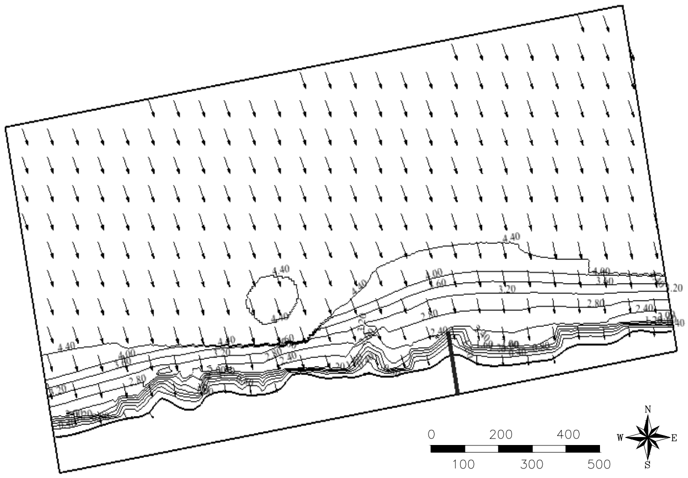

Figure (7-a): Computed wave height (m) and direction in the near shore zone during the occurrence of maximum incident deepwater wave height along the study area (H_i=4.6m, L_g= 100m, P=0.0 and S/ L_g=0).

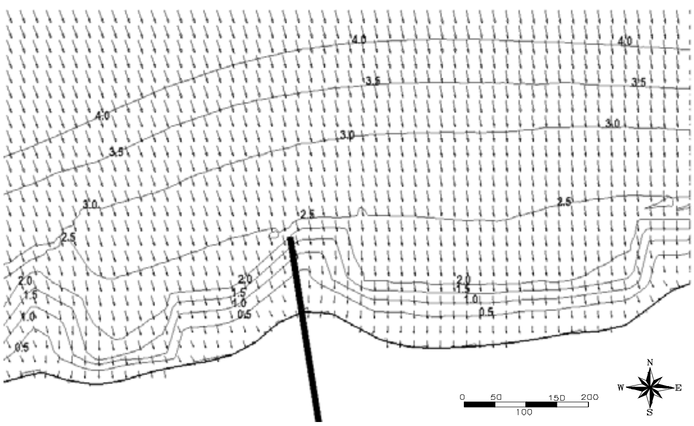

Figure (7-b): Computed wave height (m) and direction in the vicinity of the groin during the occurrence of maximum incident deepwater wave height (H_i=4.6m, L_g= 100m, P=0.0 and S/ L_g=0).

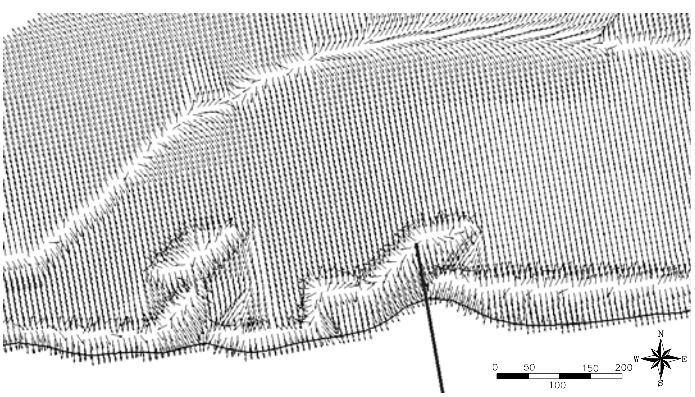

Figure (7-c): Computed radiation stress (m/sec) during the occurrence of maximum incident deepwater wave height in the vicinity of the groin (H_i=4.6m, L_g=100m, P=0.0 and S/ L_g=0).

Figures 9 through 11 show the cases of larger gaps varying in size from S/L_g=0.10 and 0.20 and almost the same trend can still be observed, i.e., slight increase in wave height, more currents crossing the gap and less turbulence inside the gap. It is intuitive that the offshore zone of the groin is almost unaffected by the gap in the groin, but the effect of the gap is evident on the lee ward of the groin. It can be observed that the case of large gap (S/L_g=0.2) shows minor impact of the groin in protecting its leeward from waves and the waves on both sides of the groin have nearly equal heights.

Figure (8-a): Computed wave height and direction during the occurrence of maximum incident deepwater wave height in the vicinity of the groin (H_i=4.6m, L_g= 100m, P=0.0 and S/ L_g=0.05).

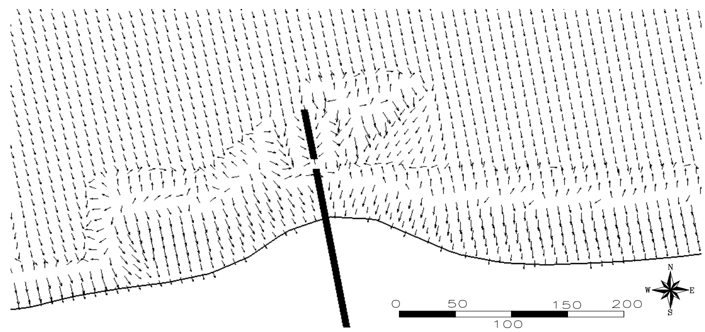

Figure (8-b): Computed radiation stress (m/sec) during the occurrence of maximum incident deepwater wave height in the vicinity of the groin (H_i=4.6m, L_g= 100m, P=0.0 and S/ L_g=0.05).

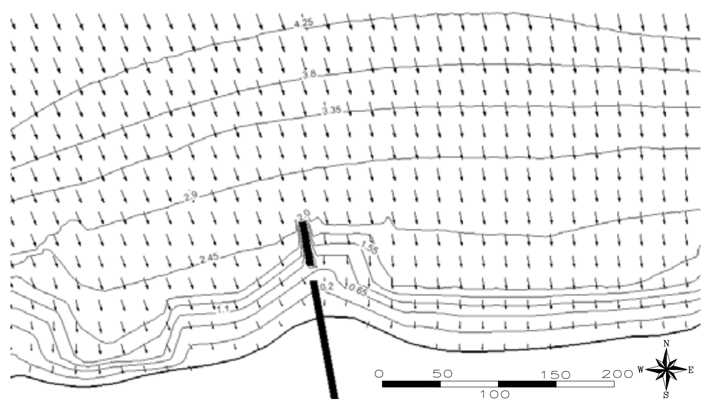

Figure (9-a): Computed wave height and direction during the occurrence of maximum incident deepwater wave height in the vicinity of the groin (H_i=4.6m, L_g= 100m, P=0.0 and S/ L_g=0.10).

Figures 10-b and 11-b show large variation in the radiation stresses in the zone of the gap especially in the leeward of groin. This could be due to the interaction between diffracted waves crossing the gap and waves propagating on the leeward side of the groin. It can be judged that gaps in the groin larger than S/L_g=0.15 allow large waves in the leeward of the groin and almost provide less protection for swimmers.

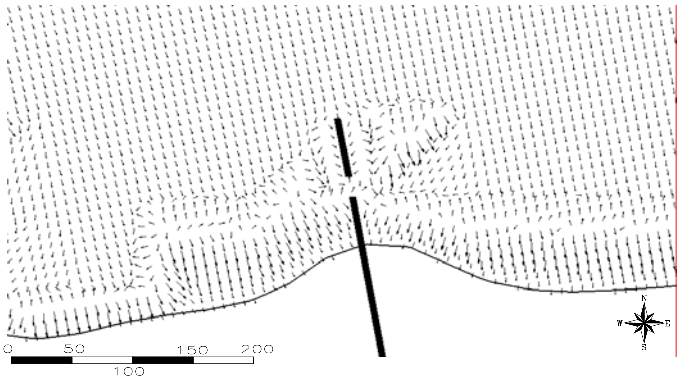

Figure (9-b): Computed radiation stress (m/sec) during the occurrence of maximum incident deepwater wave height in the vicinity of the groin (H_i=4.6m, L_g= 100m, P=0.0 and S/ L_g=0.10).

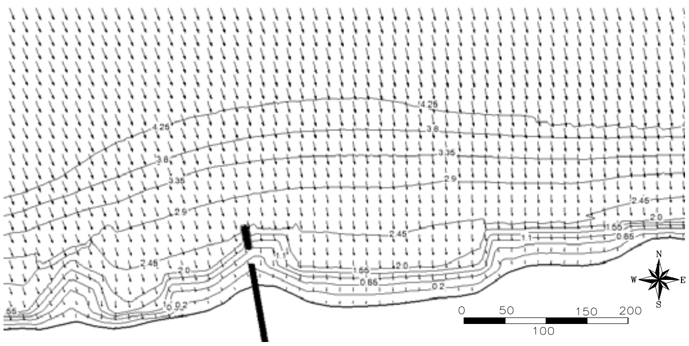

Figure (10-a): Computed wave height and direction during the occurrence of maximum incident deepwater wave height in the vicinity of the groin (H_i=4.6m, L_g= 100m, P=0.0 and S/ L_g=0.15).

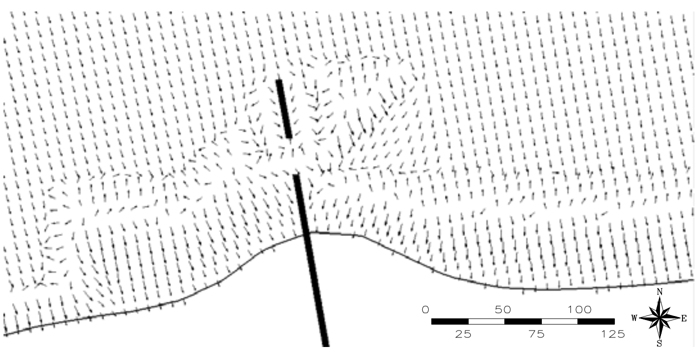

Figure (10-b): Computed radiation stress (m/sec) during the occurrence of maximum incident deepwater wave height in the vicinity of the groin (H_i=4.6m, L_g= 100m, P=0.0 and S/ L_g=0.15).

Investigations have also been made for the effect of groin permeability on the wave height and radiation stresses in the vicinity of the groin. The results have been presented in Figures 12-13 during the occurrence of maximum incident wave height as a sample output of the simulation results during the period 2000-2005. It can be seen that the larger the permeability of the groin is, the less the protection of the leeward zone from wave attack becomes. It is also noticed that some current cross the groin from one side to the other due to the permeability of the groin. Also the wave heights on both sides of the groin are almost the same for the case of P=0.5 (Figure 13). The effect of the permeability is more evident in case of P=0.5 (Figure 13) than the case of P=0.2 (Figure 12). It can be stated that the permeable groin provides good circulation of flow while keeping reasonable protection of the groin on the leeward side from wave attack. It is also anticipated that the current carries sediments through the groin as the current passes the groin. Thus, the impact of the groin on shoreline changes becomes less as the groin has larger permeability.

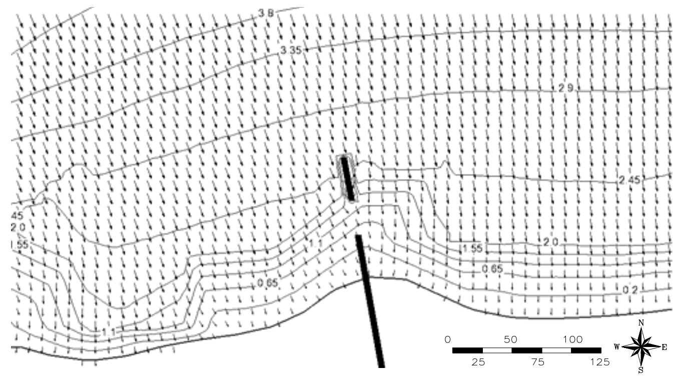

Figure (11-a): Computed wave height and direction during the occurrence of maximum incident deepwater wave height in the vicinity of the groin (H_i=4.6m, L_g= 100m, P=0.0 and S/ L_g=0.20).

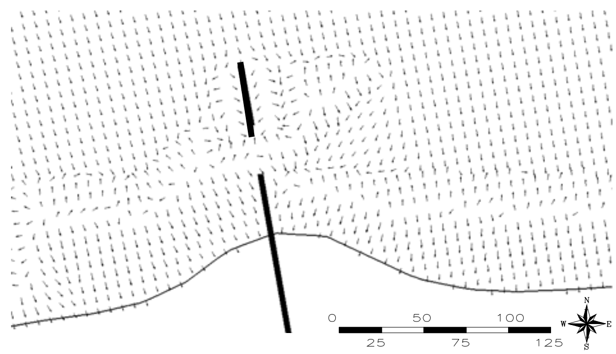

Figure (11-b): Computed radiation stress (m/sec) during the occurrence of maximum incident deepwater wave height in the vicinity of the groin (H_i=4.6m, L_g=100m, P=0.0 and S/L_g=0.20).

Investigations have been made for the impact of the gap width on the shore line changes in the close vicinity of the groin. It is noteworthy that most of coastal protection structures, e.g., breakwaters and groins, have been recently rejected by the EEAA due to their adverse impact on the shoreline that usually extends to the surrounding villages. Some villages even suffer from nearly complete erosion of their sand beach due to the construction of detached breakwaters on the up drift side, e.g., Marabella and Suez Canal resorts.

Figure 14 shows the shoreline changes along the shoreline due to various size of the gap while the groin is impermeable and using the wave data 2000-2005. It also shows the case of no groin is constructed for comparison with the case of the groin. It can be seen that considerable changes have occurred in the shoreline very close to the groin, but the changes due to the groin are limited to some distances away from the groin. The latter distance is called the effective length of the groin on the shoreline. Of course, the shoreline away from this length is still affected by direct wave attack, but without being affected by the groin. It can be seen that accretion occurs at the up-drift side and scour develops on the down drift one. It should be remarked that the prevailing wind direction is at the right hand side of the groin while the direction of occurrence of maximum wave height is at its left hand side. The case of no groin shows that the location of the groin could be subject to scour if the groin were not constructed. However, scour increases on the down-drift side, but accretion takes place on the up-drift side after the jetty is constructed.

Figure 15-a shows that the erosion is generally slightly larger than accretion. The maximum scour depth varies from 0.16 L_g for the case of no gap to as small as 0.06 L_g if S=0.15 L_g. Also noticed is that the maximum scour and deposition depths are almost equal in case of S=0.15L_g. On the other hand, the variation of maximum scour/deposition depth varies almost linearly against the gap width. However, this result could not be generalized for all cases unless further investigations are made to confirm the relation. It can also be noted that the shoreline

Figure 15-b shows the variation of the length of the affected zone of the groin versus the gap width. It is clear that the up drift is much more impacted by the groin as compared with the down drift for the cases investigated in this work. The up drift is affected up to twice the length of the groin in case of no gap and the length is about 1.1 L_g in case of gap width equals 0.15 L_g. The variation of the effective length on the down drift varies slowly as the gap width varies, i.e., varies from 1.2 to 1.1 as S/L_g varies from 0 to 0.15. It is noteworthy that the variation of the effective length is nearly linear with the gap width in this study.

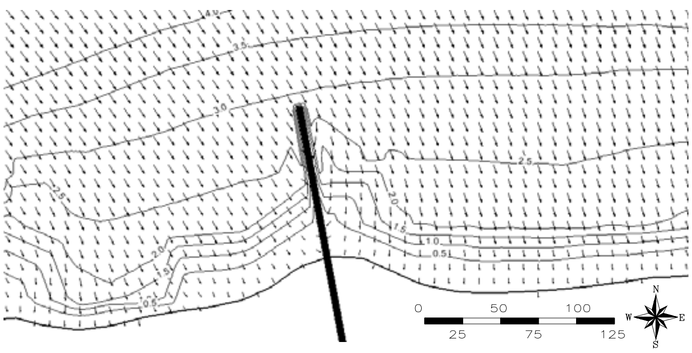

Figure (12): Computed wave height and direction in the vicinity of the groin during the occurrence of maximum incident deepwater wave height (H_i=4.6m, L_g=100m, P=0.2 and S/ L_g=0).

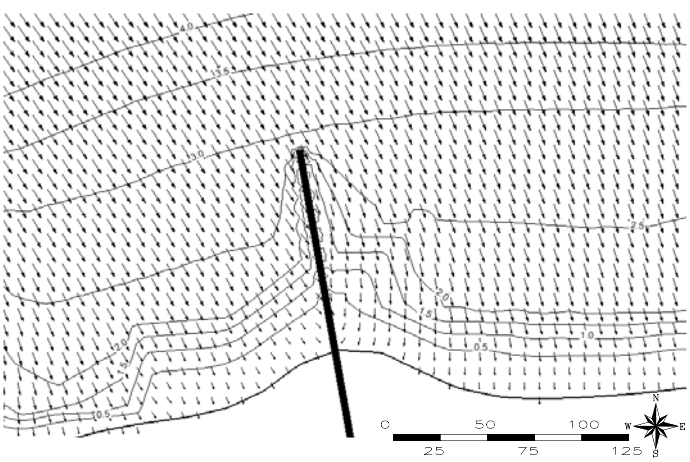

Figure (13): Computed wave height and direction in the vicinity of the groin during the occurrence of maximum incident deepwater wave height (H_i=4.6m, L_g= 100m, P=0.5 and S/ L_g=0).

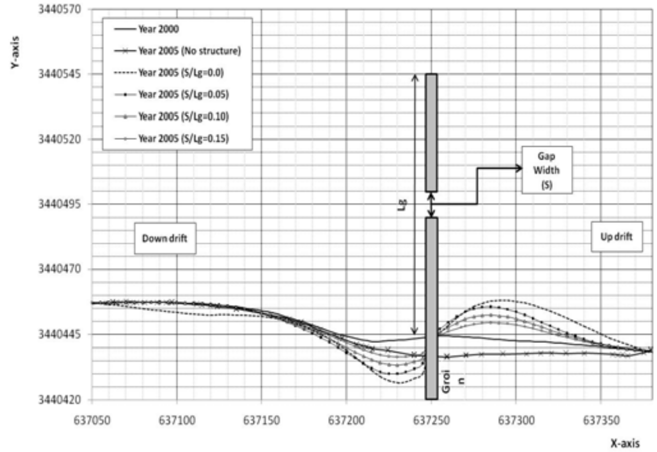

Figure (14): Computed shoreline changes along the coast for various gap widths during the period 2000-2005 (L_g=100m, P=0.0).

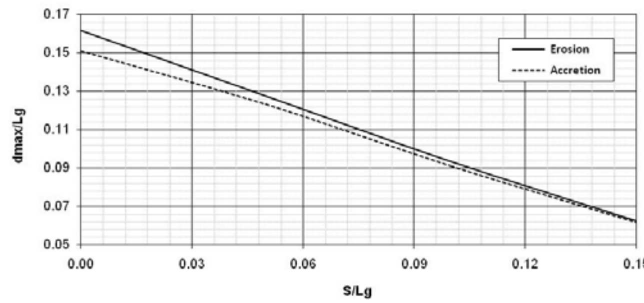

Figure (15-a): Computed maximum depth of erosion/accretion along the shoreline for various gap width during the period 2000-2005 (L_g= 100m, P=0.0).

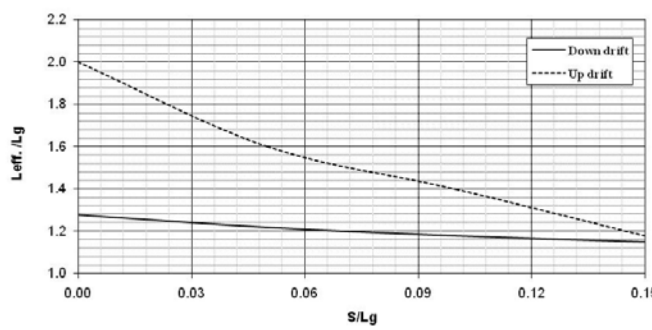

Figure (15-b): Computed effective length along the shoreline for various gap width during the period 2000-2005 (L_g= 100m, P=0.0).

CONCLUSIONS AND RECOMMENDATIONS

A study has been conducted to investigate the case of semi-open groin on the wave height, currents and shoreline changes in the vicinity of the groin. This investigations aim at providing some guidelines for the design of the groin if safe swimming conditions are sought and shoreline changes are of major concern. The followings have been concluded:

- Groins can be a good tool to provide safe swimming conditions along the North-West coast of Egypt if they are properly designed and studied.

- The permeability of the groin allows the flow of water across the groin and better flushing in the leeward of the groin. It also reduces the shoreline changes due to the construction of the jetty.

- The gap in the groin also allows better circulation of water between both sides of the groin and reduces the shoreline changes. It has been found that gaps larger than 0.15 of the groin length have almost the same impact of a single groin (the onshore part), while the offshore part becomes of minor impact on the shoreline changes.

- It is found that the maximum scour and deposition depths are almost equal in case of $S>0.15\ L_g$ for the cases investigated.

- The effective length on the up-drift side is much more than that on the down-drift for the cases investigated in this work. The up-drift is affected up to twice the length of the groin in case of no gap and the length is about $1.1\ L_g$ in case of gap width equals $0.15\ L_g$.

- The variation of the effective length on the down-drift varies slowly as the gap width varies. The effective length varied from 1.2 to 1.1 as S/L_g varies from 0 to 0.15. It is noteworthy that the variation of the effective length is nearly linear with the gap width in this study.

REFERENCES

Ahmed, M. T. (2009). “The Use of Submerged Cells in Controlling the Wave Conditions in Coastal Zones”, Master Thesis, Cairo University, Giza, Egypt.

El-Sharnouby, B. and Soliman, A., (2010). “Integration for a Better Future: Shoreline Response For Long, Wide, and Deep Submerged Breakwater of Alexandria City, Egypt”, 26th International Conference for Seaports & Maritime Transport, Alexandria, Egypt.

Hanson, H., (1987), “GENESIS: A generalized shoreline change numerical model for engineering use”, Ph.D. Thesis, University of Lund, Lund, Sweden.

Kamphuis, J.W., (1991), “A Longshore Sediment Transport Rate”, Journal of Waterway, Port, Coastal and Ocean Engineering, ASCE, Vol.117, pg.624-640.

Larson, M., Hanson, H., Kraus, N.C., (1997), “Analytical Solutions of One-line Model for Shoreline Change Near Coastal Structures”, Journal of Waterway, Coastal and Ocean Engineering, Vol.123, No. 4, pg.180-191.

Mizutani, N., Mostafa, A., and Iwata, K. (1998). "Nonlinear Regular Wave, Submerged Breakwater and Seabed Dynamic Interaction," Coastal Eng., Elsevier, Vol.33, pp.177-202.

MOH (2000). “El-Alamein Marina Resort Erosion Study” A report prepared by Delft Hydraulics to the Ministry of Housing, Utilities and Urban Communities of Egypt.

Mostafa, A.M. and Mizutani, N. (1999). "Stability and Local Scour of a Fine Sandy Bed Around Caisson-Type Breakwater Subject to Nonlinear Waves," Proc. of Coastal Structures'99, ASCE, Santander, Spain, Vol.1, pp.193-202.

Shore Protection Authority (2002). “Integrated Development of Egypt’s Northwestern Coastal Zone, Development of Near Shore Water Conditions” A report prepared by Delft Hydraulics to the Ministry of Water Resources and Irrigation of Egypt.