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ENVIRONMENTAL IMPACT ASSESSMENT AND ECONOMIC LOSSES FOR THE DELAY OF CONSTRUCTION PHASES OF COASTAL BREAKWATER, EGYPT

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ABSTRACT

Coastal breakwater structures cause problems including beach erosion on down-drift side. The construction phases of these structures affect the shoreline changes and sedimentation. A study at a sea resort located on the Northwestern Coast of Egypt was carried out whose objectives were to evaluate factors causing the problems, assess the environmental impact, and estimate the economic losses due to the delay of construction phases of the breakwater and proposing appropriate measures. Analyses of marine surveys during the period between 2010 and 2015 were carried out. The study concluded that there was erosion in the eastern zone led to a loss in the beach sand and sedimentation in the western zone due to the constructed lagoon used for maintaining the marine equipments. This sedimentation leads to difficulties in the entry and departure to and from the lagoon. The study revealed that the stopping of the implementation of the breakwater caused shoreline and morphology changes. In addition, the economic loss due to delay is more than 2.0 million USD, around 35% of the estimated original cost of the breakwater construction. The study recommended immediate start-up dredging in the western zone and the middle sector to facilitate the maneuvering of the marine equipments, which can speed up the execution process in order to in order to finalize the construction of the breakwater and to reduce economic and environmental losses.

Key words**:** Breakwaters; Dredging; Environmental impact, Lagoon; Marine survey; Sedimentation.

1 INTRODUCTION

1.1 Preamble

Shoreline engineering refers to any method of changing or altering the natural shoreline system in order to stabilize it. This may actually causes shoreline retreating. The shoreline is one of the earlier and rapidly changing features of the coastal zone that is dynamic in nature, which reacts to any changes in the coastal zone. Coastal erosion is one of the most important socio-economic problems that challenge the capabilities of states and local authorities. Whether it is due to natural or man-made reasons, coastal erosion causes significant economic losses, social problems and ecological damages [1]. Coastline movement due to erosion and deposition is a major concern for coastal zone management [2]. Consequently, considerable interest over the last five decades in the coastal changes observed along the Nile Delta (ND) coast leads to studies of coastal geomorphology, analysis of beach profiles up to the 6.0 m depth, aerial photography analysis, satellite image analysis, shoreline changes and dynamic factors on sediments transport [3]. Moreover, coastal projects have been undertaken to protect some parts of the coast through hard structures existence. These structures are jetties, groins, seawalls and shore-parallel breakwaters [4]. The main problem associated with these structures is that they induce beach erosion on down-drift sides. This may extend beyond the project area [5].

1.2 The study area

The Northwestern coast of Egypt extends from Alexandria to El-Sallum along the Mediterranean Sea for 520 km [6]. The special characteristics of this area make it very attractive for tourism and the tourists' activities.

Some beaches along this coast do not match recreational activities, because of the physical and morphological characteristics. For instance, the rip current problems that appeared due to the substantial development of the coastal regions of touristic villages and resorts in the last two decades.

The purpose for such development was to provide calm swimming conditions. However, due to natural complex coastal processes and irregular bathymetry, some villages suffer from irrelevant and dangerous swimming conditions that were caused by rip currents [7]. The study focused on a sea resort located at km 92 from the International Coastal Road on the Northwestern Coast of Egypt. The coordinates are $29^{o}\ 3^{\backslash}\ 46^{\backslash\backslash}$E - $29^{o}\ 4^{\backslash}\ 14^{\backslash\backslash}$E and $30^{o}\ 49^{\backslash}\ 18^{\backslash\backslash}$N - $30^{o}\ 49^{\backslash}\ 12^{\backslash\backslash}$N.

Figure 1: The general location of the study area.

1.3 Problem description

The project implementation plan was organized to start on 2010 and finish on 2012, ignoring the periods of extreme waves, storms and summer swells. Due to difficulties that face the execution company in the work in the project area during the last five years, the project is still under implementation and only around 60 % of its plan has been done. As a result of the delay of the implementation process of the submerged breakwater (SB) in the studied sea resort (SSR), shoreline changes have been occurred and the water depths of the bay have been changed. Hence, many problems associated with these changes, such as sedimentation in the bay as well as the artificial lagoon and the erosion at the east of the groin. Consequently, the implementation equipments have been restrained inside the artificial lagoon and couldn't drive through for finalizing its breakwater implementation. Therefore, the modifications of the original breakwater design must be done due to the morphological changes. This leads to additional cost and the area of the artificial lagoon and the bay must be dredged to discontinue the environmental losses.

1.4 The objectives

The study objectives are to evaluate factors inducing the problems and assess of the environmental impact on the shoreline and the bay and estimate the economic and environmental losses due to the delay of construction phases of the submerged breakwater on the bay and shoreline at the SSR, and then proposing appropriate measures to overcome these problems.

2 MATERIALS, METHODS AND DATA COLLECTION

2.1 Methodology

The following activities have been arranged to achieve the study objectives and evaluate the problems of the implementation delay of the breakwater on the bay in addition shoreline at the SSR and seeking solutions through the following aspects:

- Compiling the previous related studies; and
- Throughout, the period from April, 2008 to August, 2015 has been investigated the field survey, the measurements of shoreline position, hydrographic marine survey work, sea level variations, and waves. The Coastal Research Institute in Egypt (CoRI), in collaboration with the executing company, has obtained and tested these data. In turn, the contour maps have been prepared which is based on this hydrographic marine survey. The analysis of data therefore has been carried out.

2.2 Data collection

The CoRI carried out a monitoring of the changes of the Nile Delta coastal data on an annual basis. Field investigation took place through the interval between April, 2008 and August, 2015. The data is explained as follows:

2.2.1 Marine wave's data

The predominant wind direction in the study area is 22.5^{o} NW with a wind speed of approximately 3.75 m sec^{-1} [8]. The Egyptian coast is subjected to approximately 15 conventional storm waves that cause severe damage to the coast on annual basis [9]. The marine wave's induced-long-shore currents have a great importance in the shore operation analysis, which are considered the basis of hydrodynamic forces that cause shore-line and morphologic changes [5]. In the absence of sediment supply to the coast, the continued action of waves and currents this acts to induce beach erosion [10]. The wave climate data have been measured since 1994 [11] by using the Inter-Ocean S4DW directional wave-current meter device (S4DW) where it was installed in front of the navigation channel of the Dekhaila harbor in around 12 m water depth. The S4DW consists of an electro-magnetic current-meter with a pressure sensor. The signals were converted to wave measurements using a sampling frequency equals 2 samples/sec. The wave direction is to be derived from the two components of the wave orbital currents. A wave program utilizes the measured pressure information at a certain point to compute the statistics of the sea surface elevation by the use of Fourier transformation [4]. Information about the directional properties of the wave field is obtained from the phase differences observed between the surface elevation and the two components of the velocity [12 and 4]. Large wave events are increasing at a greater rate than mean wave heights [4]. The obtained data have been subjected to statistical analysis to get the percentage of occurrence of a certain wave height from a certain direction to get the wave roses.

2.2.2 Sea level data:

The Nile Delta coast has a typical micro-tidal semi-diurnal tidal regime with an average range of 40 cm [5 and 13]. The tide and ebb data have a great importance in studying coastal projects; especially the overlap areas between the sea and the estuaries or drains mouths, which represent the changes of water surface level with time. Therefore, the measured daily variations of the sea level at Rosetta City have been used during the period of January, 2015, and January, 2016.

2.2.3 Shore-line data:

The shoreline is one of the rapidly changing features of the coastal zone that is dynamic at the nature. It is also one of the earlier features reacts to a certain degree of changes in the coastal area. Analysis of the shoreline changes is fundamental to a broad range of investigations undertaken by coastal scientists, oceanographers, coastal engineers, and coastal managers [14]. Shoreline information is used in designing the coastal protection, calibrating and verifying numerical models, assessing sea-level rise, developing hazard zones, and formulating policies to regulate coastal development. Shoreline changes can be investigated by using field data measurements or satellite images [6] to indicate the maximum retreat of the shoreline through the year and to know the shoreline change of the study area.

2.2.4 Marine survey data:

The CoRI has initiated a program for beach profile survey in 1971. The profile lines are perpendicular to the coastline and extend approximately to 6.0 m water depth or up to about a distance of 1200 m from the fixed baseline. The beach levels and water soundings are adjusted to Mean Sea Level (MSL) datum using locally fixed benchmarks of known elevation. The hydrographic profile surveys have been undertaken in three parts. They are:

- The land survey that was conducted using a Nikon Total Station POWER Set 3010 and graduated staff;
- The surf-zone (the zone between the shoreline and water depth of ~1 m below MSL) that it was surveyed on foot during the land survey.

- The near-shore zone, from 1.0 m to 6.0 m depth that was surveyed using a small surveying rubber boat equipped with a global positioning system (DGPS) with an accuracy of ± 1.00 m in coordinates setting and an Echo-Sounder device model 205 Navigator to measure water depth with an accuracy of ± 0.10 m with 3.0 m interval. Both the echo-sounder and the DGPS were connected to a marine computer provided with a special program for data logging and maritime navigation that continuously records the seafloor depth with coordinates along the profile line. These data were corrected with respect to MSL during the marine survey.

3 RESULTS, DATA ANALYSIS AND DISCUSSION

3.1 Marine waves

The marine waves are considered the main hydrodynamic forces causing and generating marine currents which are responsible for the transport of sediment and thus erosion occurs at some areas and accretion occurs at others along the coast. The wave data have been studied to check the wave characteristics and directions. Consequently, the analysis of these data shows that the maximum wave height is approximately 6.85 m and peak wave period is about 7.0 sec during the year of 1994 [11]. Consequently, the predominant wave approach from the WNW and W, as shown in Figure 2, is responsible for generating the eastward-flowing long-shore current and morphological changes because of their long duration particularly in the winter. The Nile Delta coast is a typical wave dominated or perhaps more accurately termed wave- and current-dominated [15].

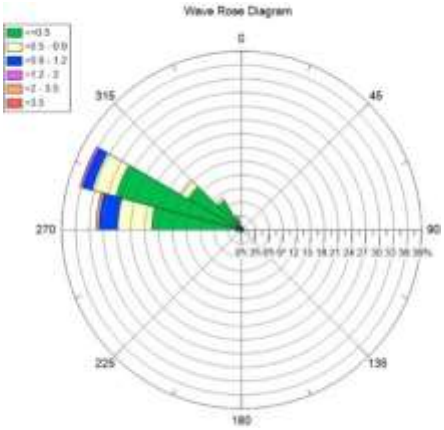

Figure 2: Rose waves of El-Dekhaila Harbor during 1994 [17].

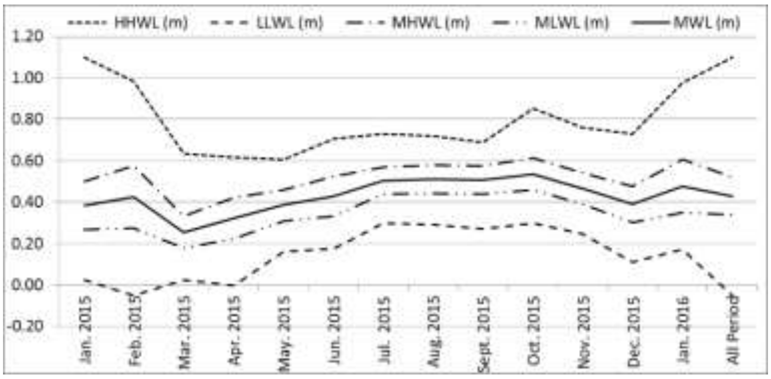

Figure 3: The measured daily variations of sea level at Rosetta City from Jan., 2015 to Jan., 2016 [16].

3.2 Sea level Variation:

The information of the change in the sea level is of a great importance, especially in the case of port construction, protection works design, in the shoreline identification and in estimating the coastal flooding water on the coastal areas. The data of daily variations of sea level that measured during the period from January, 2015 to January, 2016 of the Rosetta City by CoRI [16], as demonstrated in Figure 3 that has been studied and analyzed. Consequently, the results of the analysis showed that the average sea level is about (0.40) m during the whole period. In addition, the highest level of the sea was (0.76) m above MSL during November, 2015, while the lowest level of the sea is estimated at 0.05 m less than zero sea level during February, 2015, Generally, the tide of the Egyptian coast is classified of half daily tide.

3.3 Submerged Breakwater, Shore-line and Marine survey :

The shoreline changes with time show the shoreline equilibrium and its behavior on erosion or accretion. Beach profiles are generally good indices to show the development and behavior of shoreline changes. Many factors affect the beach profile stability including wave characteristics, sediment characteristics both on the shore, in the breaker zone and in the offshore zone, various currents such as long-shore current, tide, and type of bottom profiles whether they are under-nourished, over-nourished and/or in equilibrium [18].

Figure 4: The shoreline of the area study in 26/6/2003 before the construction of WSR jetties.

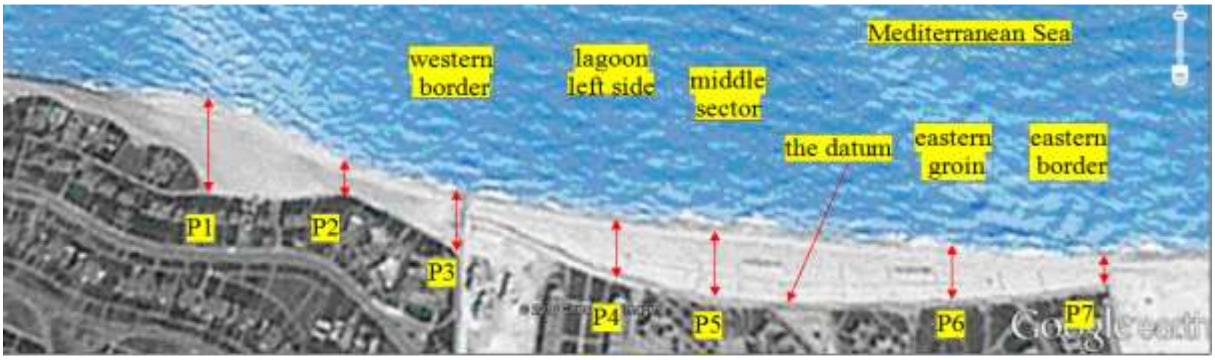

Figure 5: The shoreline of the area study in 7/2/2007 after the construction of WSR jetties.

The shoreline of the SSR was still stable up to 26/6/2003, as illustrated in Figure 4. While Figure 5 illustrates the shoreline changes in 7/2/2007 after the construction of long jetties and groins in the adjacent western sea resort (WSR), where erosion started to occur along the coast of the SSR and eastern coast of the WSR. Table 1 illustrates the values of shoreline positions relative to the alley of the SSR and the WSR as a datum. They are demonstrated in Figure 4, Figure 5, Figure 12, Figure 13, Figure 14 and Figure 15 of Google Earth satellite images. The values are estimated at seven profiles called; P1, P2, P3, P4, P5, P6 and P7, as shown in Figure 4. Profiles P1 and P2 are located in the WSR area. In addition, Profiles P3 and P7 are located at the western and eastern borders of the SSR respectively. Besides, the Profile P4 is located just at the western side of the artificial lagoon in the SSR that was constructed later in 25/9/2011. In addition, Profile P6 is located at the eastern groin in the SSR that was constructed later in 23/3/2012. The artificial lagoon and the eastern groin are illustrated on Figure 12. The values of erosion as mentioned in the profiles were -42.9, -23.1, -20.3, -19.3, -16.2, -3.9, -3.2 m at Profiles P1, P2, P3, P4, P5, P6 and P7, respectively. This means that erosion covers all the shoreline of the SSR due to shortage of sediments coming from the WSR from west to east. This is because of the construction of its long jetties in 2006.

This erosion caused failure of the SSR beach and its parallel alley, as well as, its concrete wall, as shown in Figures 6 and 7 in 20/10/2008. In addition, much of beach replenishment sand was later lost, as shown in Figure 8, thus the beach has become very steep and forming a scarp as shown in Figure 9. The beach texture is calcium carbonate.

Figure 6 and Figure 7: Beach erosion of the SSR causing failure of its parallel alley and its concrete wall in 20/10/2008.

Figure 8: The loss of beach replenishment sand. Figure 9: The beach became very steep forming a scarp

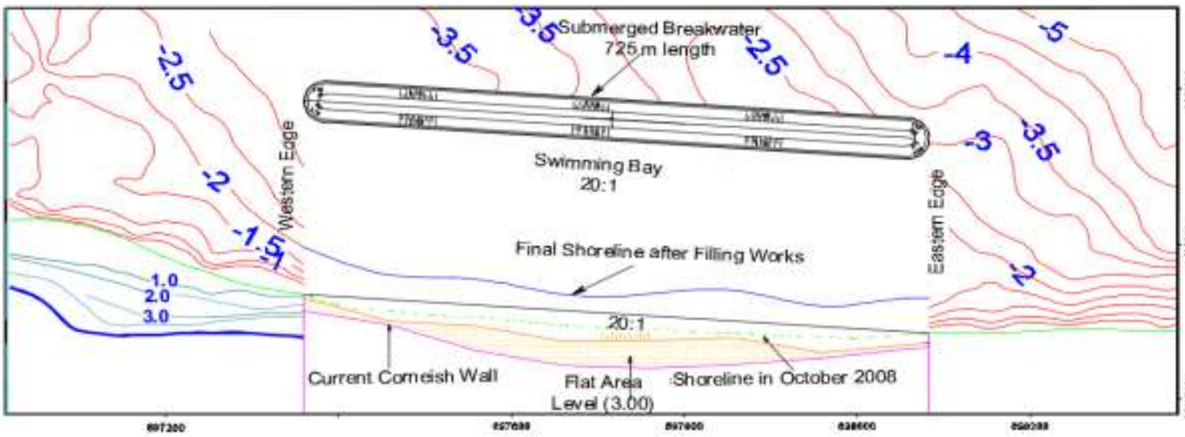

Figure 10: The layout of the designed submerged breakwater at the beach of the SSR in July 2009.

The managers of the SSR started in 2008 to face the beach erosion problems by designing, in 13/7/2009, a submerged breakwater located at 250 m far from the shoreline and parallel to the shoreline with 725 m length. The designed submerged breakwater at the beach of the SSR in July, 2009 as illustrated in Figure 10 where the final shoreline after sand filling was designed to be a contour at 2.0 m below MSL. The implementation contract was made in 29/12/2009 with original cost of 6 million USD. The project implementation plan was organized to start on 2010 and finish on 2012, ignoring the periods of extreme waves, storms and summer swells.

Figure 11: The artificial lagoon for executing utilities.

Due to difficulties facing the execution company in work during the last five years it started to perform an artificial lagoon at 200 m east of the WSR on 26/2/2011, as shown in Figure 11. This Lagoon was completed on 25/9/2011 and used for maintenance operations of the implementation utilities. In addition, the execution company has implemented on 23/3/2012 a short groin at 100 m distance westward of the eastern border of the SSR beach, as shown in Figure 8. The execution company started the deployment and alignment of the breakwater materials in 23/3/2012 until it completely stopped the work on 11/9/2014 because of the aforementioned reasons. Since that date, the project is still under implementation and only around 60 % of its recommended works have been achieved.

Groins are intended to trap sand at the long-shore (surf-zone) current. If a groin is working correctly, more sand should be piled up on the up-drift side rather than the down-drift one. The problem with the groin is that it traps sand that it is probably flowing to a neighboring beach. Thus, if a groin on one beach is functioning well, it must be causing erosion elsewhere by “starving” another beach [19], which means that there was erosion at the eastern side of the SSR beach due to the construction of the aforementioned eastern groin. Besides, owing to the implementation of the aforementioned artificial lagoon, erosion has been occurred east lagoon at the middle sector the SSR beach. Furthermore, an accretion occurred west of the lagoon and extended westward at the WSR on 9/2/2013, as shown in Figure 12. The accretion is still increasing on 26/12/2013, 26/3/2014, and 31/1/2015, respectively, as shown in Figure 13, Figure 14 and Figure 15.

Shoreline changes are illustrated in aforementioned Figure 12, Figure 13, Figure 14, Figure 15, and Figure 16. Figure 16 shows shoreline changes on November, 2011, September, 2012, January, 2013, April, 2015, June, 2015 and September, 2015. As demonstrated in Table 1 and Figure 12 until Figure 16, the shoreline has changed corresponding to the implementation stages of the submerged breakwater as the following:

Table 1: The values of shoreline positions relative to the alley of the SSR and the WSR as a datum during the period from 2003 to 2015 through Google Earth satellite images.

Figure	Date	State	Profiles and its locations						
			P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**
			At AWSR (m)		At the western border of SSR (m)	Just at lagoon left side (m)	(m)	At eastern groin (m)	At the eastern border of SSR (m)
Figure 4	26/6/2003	*BCWJ	141.1	53.9	80.1	75.2	86.9	48.7	26.4
Figure 5	7/2/2007	**ACWJ	98.2	30.8	59.8	55.9	70.7	44.8	23.2
Accretion (+), Erosion (-)			**-42.9**	**-23.1**	**-20.3**	**-19.3**	**-16.2**	**-3.9**	**-3.2**
Figure 12	9/2/2013	***ACLRG	78.6	42.1	90.2	92.9	49.1	39.4	14.4
Accretion (+), Erosion (-)			**+19.6**	**+11.3**	**+30.4**	**+37**	**-20.6**	**-5.4**	**-8.8**
Figure 13	26/12/2013	****ACLRGB	101.5	62.4	127.4	110.1	52.8	43.2	10.1
Accretion (+), Erosion (-)			**+22.9**	**+20.3**	**+37.2**	**+17.2**	**+3.7**	**+3.8**	**-4.3**
Figure 14	26/3/2014	****ACLRGB	106.2	73.6	136.2	118.2	49.8	50.8	7.7
Accretion (+), Erosion (-)			**+4.7**	**+11.2**	**+8.8**	**+8.1**	**-3.0**	**+7.6**	**-2.4**
Figure 15	31/1/2015	*****ACLRGL	87.6	69.3	150.1	148.8	47.2	47.8	5.4
Accretion (+), Erosion (-)			**-18.6**	**-4.3**	**+13.9**	**+30.6**	**-2.6**	**-3.0**	**-2.3**

*__BCWJ__: Before Construction of adjacent Western sea resort Jetties.

**__ACWJ__: After Construction of adjacent Western sea resort Jetties.

***__ACLRG__: After Construction of Lagoon, Right part of submerged breakwater, and eastern Groin.

****__ACLRGB__: After Construction of Lagoon, Right part of submerged breakwater, eastern Groin, and Beginning of left part of the breakwater.

*****__ACLRGL__: After Construction of Lagoon, Right part of submerged breakwater, eastern Groin, and Left part of the breakwater.

Figure 12: The area study on 9/2/2013 after the construction of an artificial lagoon.

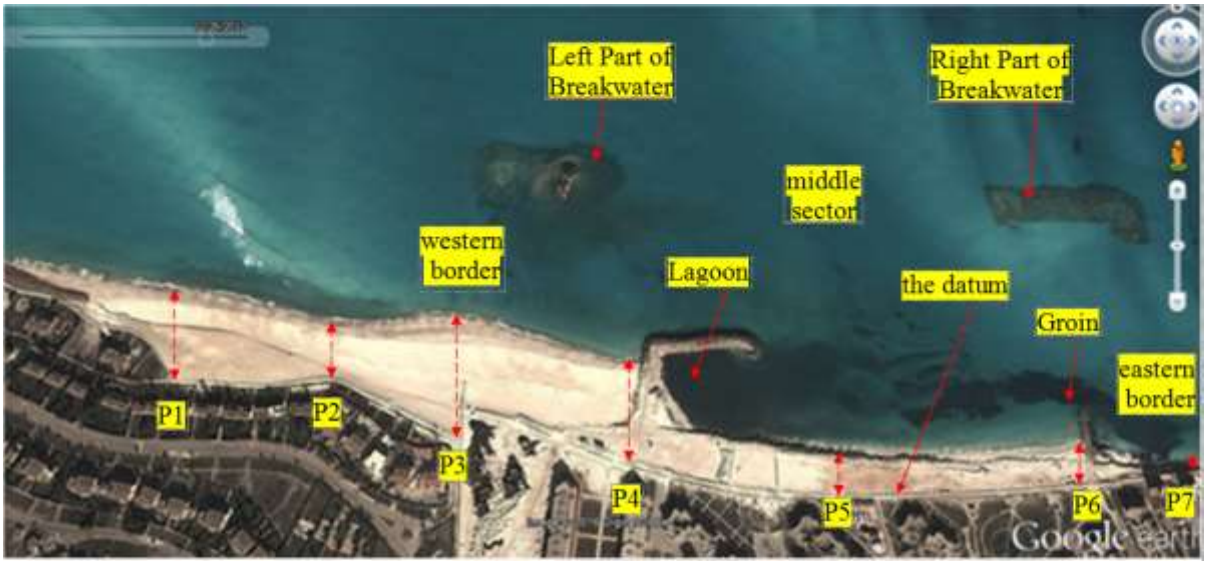

Figure 13: The study area on 26/12/2013.

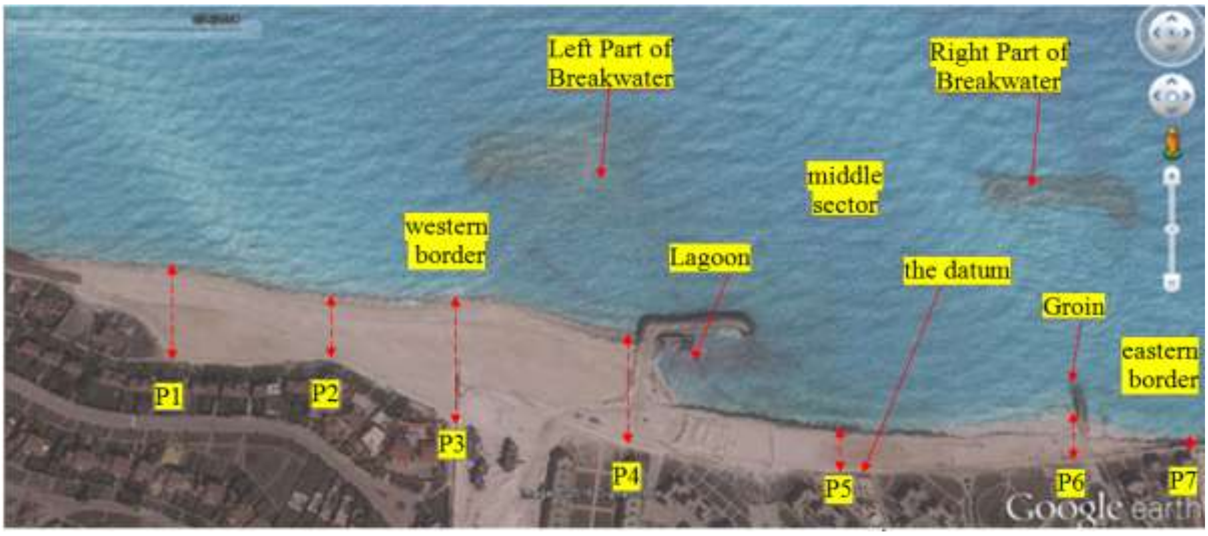

Figure 14: The study area on 26/3/2014.

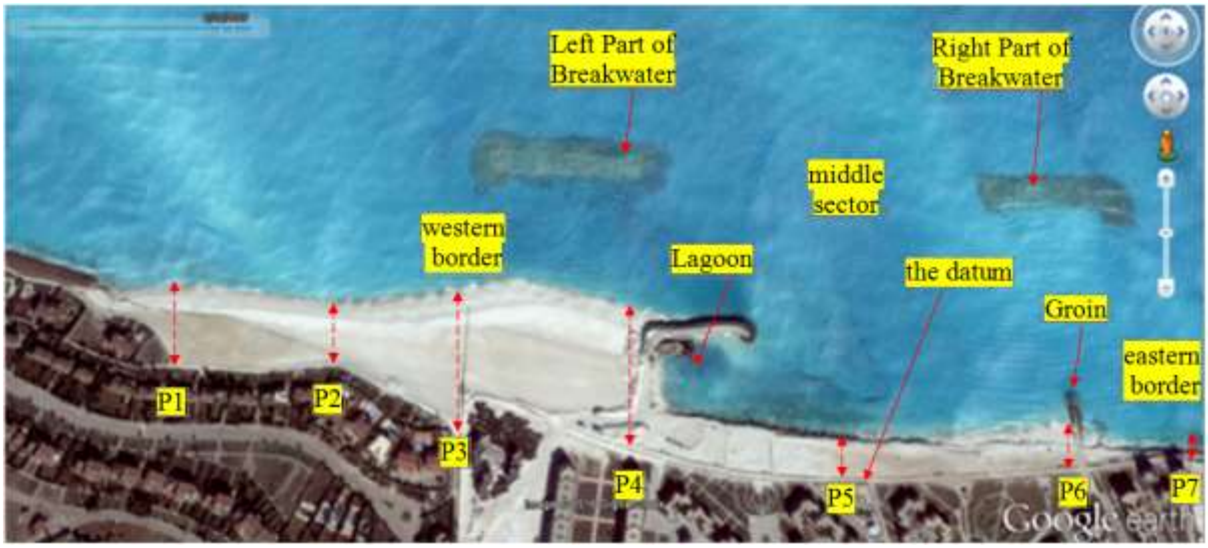

Figure 15: Google Earth satellite image on 31/1/2015.

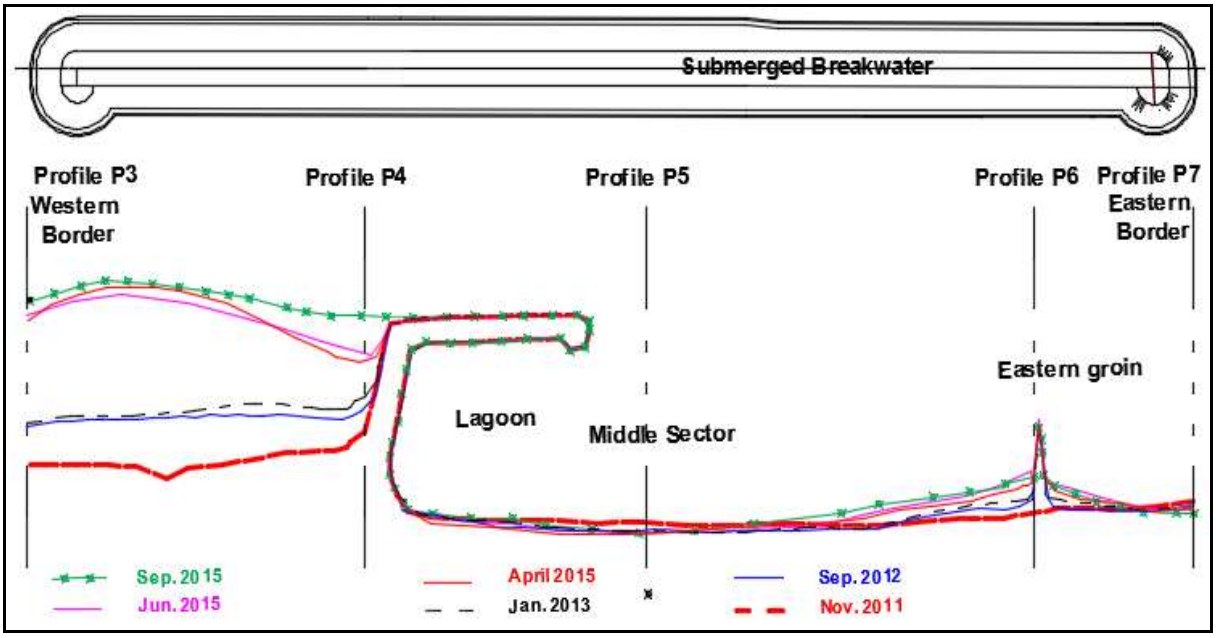

Figure 16: Shoreline changes of the SSR for November, 2011, September, 2012, January, 2013, April, 2015, June, 2015 and September, 2015.

For the period from November, 2011 to January, 2013:

At Profile P4 just west of the lagoon there was an accretion by about 22.3 m distance due to the construction of the lagoon, as shown in Figure 16. While, at Profile P5 at the middle sector, there was an erosion by about 2.2 m distance because of delaying the construction of this part of the breakwater. Furthermore, at Profile P6 at the west of the eastern groin, there was an accretion by 8.2 m distance due to the construction of the groin. Moreover, at Profile P7 at the eastern border of the SSR, there was erosion by about 3.8 m distance because of the groin has trapped sand flowing at the longshore current from west to east.

For the period from February, 2013 to December, 2013:

At Profiles P1, P2, P3 and P4 west of the lagoon there was an accretion by about 22.9 m, 20.3 m, 37.2 m and 17.2 m distance, respectively due to the construction of the lagoon, as shown in Table 1, Figure 12 and Figure 13. Besides, at Profile P5, there was an accretion by about 3.7 m distance. Furthermore, at Profile P6, there was an accretion by about 3.8 m distance due to the construction of the groin. Moreover, at Profile P7 at the eastern border of the SSR, there was erosion by about 4.3 m distance because of the groin has trapped sand flowing at the longshore current from west to east.

For the period from December, 2013 to March, 2014:

At Profiles P1, P2, P3 and P4 west of the lagoon there was an accretion by about 4.7 m, 11.2 m, 8.8 m and 8.1 m distance, respectively due to the construction of the lagoon, as shown in Table 1, Figure 13 and Figure 14. There is a Tombolo at Profile P3 due to the construction of the left part of the breakwater. Besides, at Profile P5, there was erosion by about 3.0 m distance due to delaying the construction of the middle part of the breakwater. Furthermore, at Profile P6, there it was an accretion by 7.6 m distance due to the construction of the groin. Moreover, at

Profile P7 at the eastern border of the SSR, there was erosion by about 2.4 m distance because of the groin has trapped sand flowing at the longshore current from west to east.

For the period from March, 2014 to January, 2015:

At Profiles P1 and P2 west of the lagoon there it was an erosion by about 18.6 m and 4.3 m distance, respectively due to the construction of the left part of the breakwater, as shown in Table 1, Figure 14 and Figure 15, which there is a Tombolo at Profile P3 due to the left part of the breakwater. While, at Profiles P3 and P4 west of the lagoon there was an accretion by about 13.9 m and 30.6 m distance, respectively, as shown in Table 1 due to the construction of the lagoon. On the other hand, at Profile P5 and Profile P6, erosion occurred by a distance about 2.6 m and 3.0 m, respectively due to delaying the construction of the middle part of the breakwater. The currents attached these parts across the non-implemented middle part of the breakwater. Furthermore, at Profile P7 at the eastern border of the SSR, there was erosion by about 2.3 m distance because of the groin has trapped sand flowing at the longshore current from west to east.

Contour map were obtained from measured hydrographic marine survey, using spatial interpolation of bed levels by using the "Kriging" interpolation method by using Golden Software SURFER 11.0 computer program, as shown in Figures 10, 17, 18, and 19 for the bay and shoreline on July, 2009, November, 2011, January, 2013 and September, 2015, respectively.

On Figure 10 on July, 2009, at the design date of the submerged breakwater, the bed levels of the submerged breakwater site varied between -3.0 to -3.5 m below the MSL. While on November, 2011, after the construction of the artificial lagoon, the bed levels became -3.8 to -4.4 m below MSL, especially in both the west and middle sector of the breakwater, as shown on Figure 17. This means that the site organized to construct the breakwater has been changed during the period from 2009 to 2011 because of erosion due the construction of the long jetties of Marina Sea Resort.

On the Figures 17 and 18, the swimming bay that it is located between the submerged breakwater and the beach is exposed to sedimentation during the period from November, 2011 to January, 2013. The bed levels of the west sector of the site of the submerged breakwater have been changed from -4.4 below MSL to -3.6 below MSL, besides, the bed levels of the bay at the west sector, which have been changed from -4.2 below MSL to -2.4 below MSL due to the construction of the lagoon. While, the bed levels of the right sector have been also changed from -3.4 below MSL to -2.4 below MSL, besides, the bed levels of the bay at the right sector have been changed from -3.0 below MSL to -2.4 below MSL due to the construction of the right part of the breakwater. In addition, the bed levels of the middle sector of the site of the submerged breakwater have been changed from -4.2 below MSL to -3.4 below MSL. Besides, the bed levels of the bay at the middle sector have been changed from -3.8 below MSL to -2.6 below MSL due to the construction of the lagoon and the right part of the breakwater.

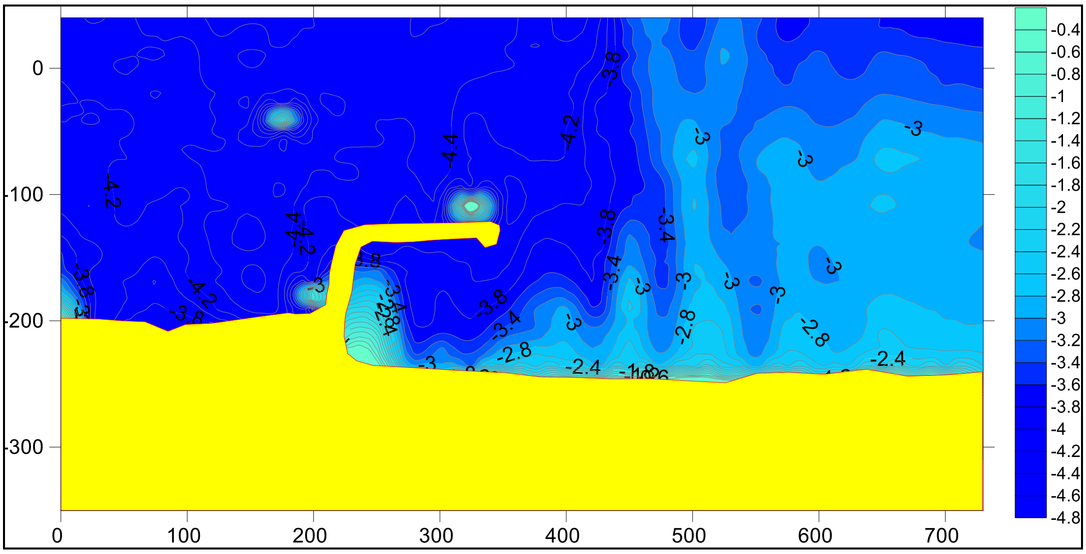

Figure 17: Contour map (Bathymetry) of the study area (Bay and Shoreline) on Nov., 2011

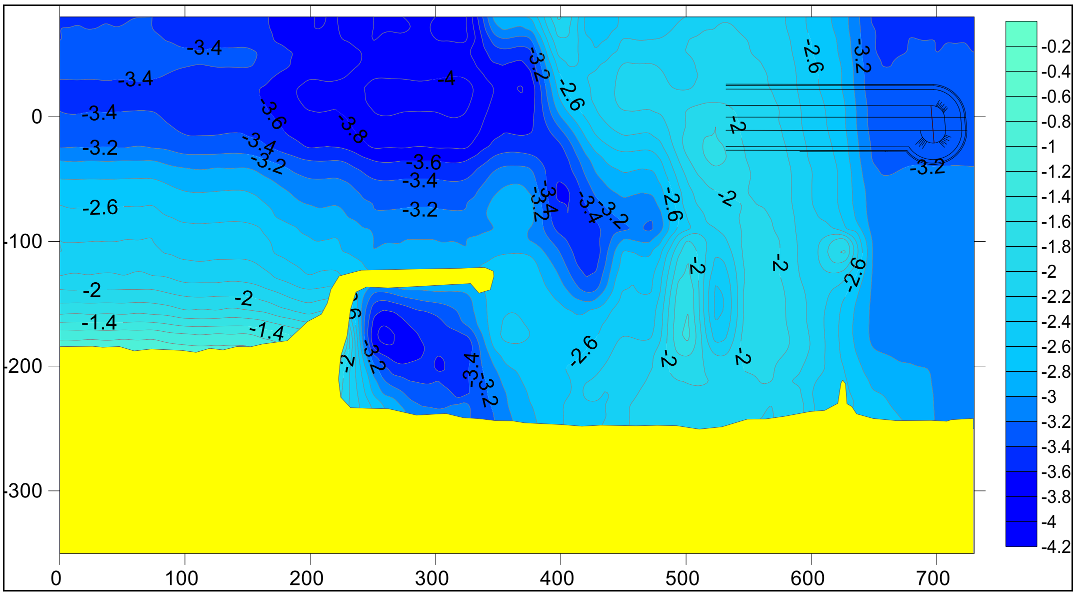

Figure18: Contour map (Bathymetry) of the study area (Bay and Shoreline) on Jan., 2013

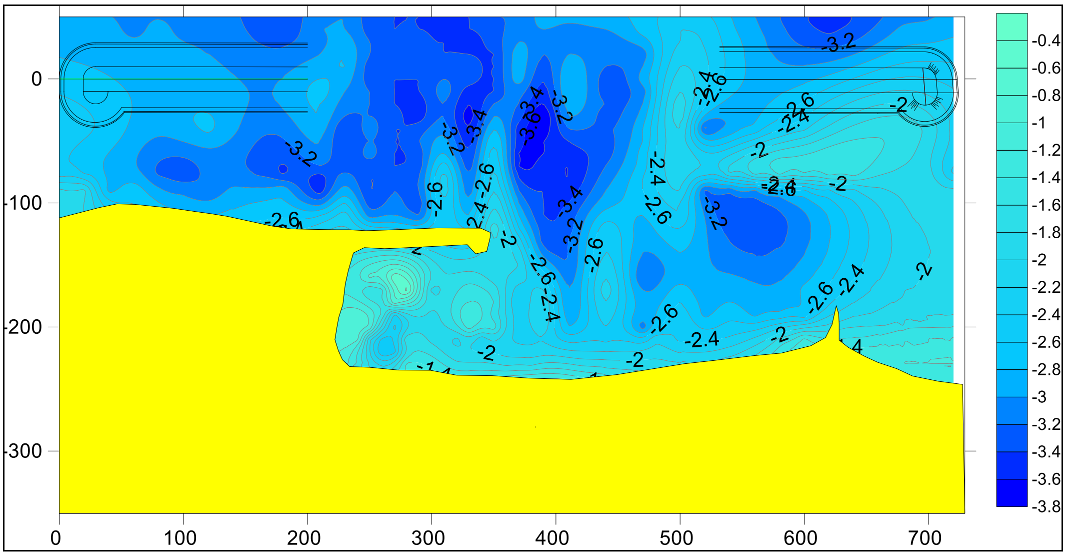

Figure19: Contour map (Bathymetry) of the study area (Bay and Shoreline) on Sep., 2015

On the other hand, after the construction of the left part of the breakwater during the period from December, 2013 to September, 2014, as shown on Figure 19, the bed levels of the middle sector of the site of the submerged breakwater that it have been changed from -3.8 to -3.4 m below MSL. Besides, the bed levels of the bay at the middle sector have been changed from -3.2 below MSL to -2.6 below MSL due to the construction of the lagoon and the right part of the breakwater. Furthermore, the shoreline has moved about 60 m seaward west of the lagoon and bed levels of the bay at the west sector have been changed from -2.2 below MSL to +0.4 above MSL due to the construction of the lagoon that prevented sand going from west to east. On the other hand, the bed levels of the bay at the right sector have been changed from -2.4 below MSL to -3.2 below MSL due to the currents coming across the non-implemented middle part of the breakwater. In addition, the bed levels of the lagoon have been changed from -3.4 below MSL to -1.4 below MSL due to work stopping because of the aforementioned reasons.

This means that the area is subjected to sedimentation, especially at the part facing the artificial lagoon as well as, the maneuvering path of the marine equipment used in executing the submerged breakwater. Accordingly, major difficulties in the departure and entrance operations of these utilities are facing the execution company now. Therefore, many difficulties are facing the executive company to complete the project implementation.

The required dredging quantity allowing the marine utilities to continue the implementation was calculated around 52500 m^3 for only the necessary required area of the maneuvering path to complete just the middle sector of the breakwater. Considering the price of dredging 10 USD /m^3, the cost of this work exceeds 0.5 million USD. On the other hand, the losses due to the delay of ending the project as in the scheduled plan on 2012 and the losses of sand replenishment of the beach reach to 0.5 million USD. In addition, the losses due to the operation delay and the resort usage reach to 1.0 million USD for the period from 2012 to 2016.

4 CONCLUSIONS AND RECOMMENDATION

The implementation plan of the submerged breakwater project of the studied sea resort (SSR) was scheduled to start on 2010 and end on 2012, ignoring the periods of extreme waves, storms and summer swells. Due to difficulties facing the execution company during the last five years, the project is still under implementation and only around 60 % of its recommended work has been achieved. As a result of the delay, the shoreline positions and the bay water depths were changed. These led to many problems, such as sedimentation in the bay and the artificial lagoon, and erosion at the east of the groin. Consequently, the implementation equipments have been trapped inside the artificial lagoon without the ability to function their required activities to finalize the breakwater implementation. Therefore, modification of the original breakwater design is required to be carried out due to the morphology changes that lead to additional cost. In addition, the area of the artificial lagoon and the bay are required to be dredged to stop the economic and environmental losses.

The study revealed that the delay of the implementation of the submerged breakwater for 4 years due to the difficulties facing the execution company in the project area leads to economic losses roughly 2.0 million USD that represents around 35% of the estimated original cost. The study indicates that sedimentation is prevailing in the western side due to the construction of a small lagoon used for maintenance operations of the implementation equipments. In addition, the study revealed that the area was subjected to severe erosion in the eastern zone and its adjacent area with loss on sand from the beach of the studied sea resort (SSR).

Finally, the study recommends an immediate dredging of the maneuvering path to allow the marine equipments to continue implementation breakwater, and indicates that it is very significant to start in dredging works at the western zone and the middle sector of the breakwater to facilitate the maneuvering of the marine equipments and accelerate the implementation process to minimize the economically and environmentally losses.

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