PROTECTION MEASURES FOR THE NILE MIDDLE DELTA COASTAL ZONE STABILITY

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ABSTRACT

This paper studies the shoreline stability between Rosetta Branch and El Burullus in the Nile Delta. A one-dimensional numerical model has been applied to study shoreline stability and to investigate the suitability of a proposed soft protection measures. The model used to investigate the possibility of utilizing the dredged material from a nearby location to nourish and stabilize the eroded shoreline. Also the field data collected by Coastal Research Institute (CoRI) have been analyzed. Shoreline survey was used to get the shoreline behavior along the study area and to calibrate the 1-D model, the wave data were used as input for the model and to calculate the wave run up near the shoreline, the cross shore profiles were used to get the average berm level to check the wave overtopping. The efficiencyof using the sand nourishment was checked by using the 1-D model. The study results showed that using sand nourishment and sand dike is the optimum solution in terms of cost and efficiency comparing with the usual hard structures.

Key words:Nile Delta Coast, Sand nourishment, Flood protection.

1 INTRODUCTION

The coast of Nile Delta extends for 250 km between Rosetta and Damietta Branch characterized by its clayey and silty soil. The combined action of waves and currents had shaped sediments yield from the Ethiopian Plataue into a complex product of the sedimentary processes which have been occurred; since the Upper Miocene period some 10 million years ago. These sediments had been discharged into the Mediterranean sea by the old Nile tributaries, which have been silted up and replaced by the two present branches namely: Rosetta and Damietta, figure(1): (Nielsen, 1976), (El-Askary&Frihy, 1986) and (Frihy et al., 1991) . The Nile delta coast has three headlands known by Rosetta and Damietta promontories and El Burullus headland.

Since 1900 tothe present time the water flow and sediments carried out by Nile branch to the sea havebeen reduced due to: the climate changes, the regulation of the Nile River flow, the continuous use of water for permanent irrigation requirements and /or man interference with the shoreline. Consequently serious erosion has been taking place in Nile delta coast damaging its coastal zone environment. The erosion ratehas been accelerated since the completion of the High Aswan Dam in 1964 which trappedall the sediments transported by the River in its upstream side(Fanos et al., 1995).

The water quality of about 120 km in River Nile at Rosetta branch and five main drains located on its sides was examined,through several physico-chemical and bacteriological analyses. From the results of this study it could beconcluded that the water quality along the studied area inRosetta branch (120 km) is remarkably influenced bywastewater discharge from drains located on its sides regarding both physico-chemical and bacteriologicalcharacteristics. Agricultural and sewage wastes are the key factors in this environmental problem. However, self-purification and dilution concepts contributed to the gradual improvement recognized at the end of the branch particularly in summer season,(Safaa et al.,2012). Also, the water quality of the end of Rosetta branch was analyzed by CoRI. It was found that the coliform bacteria were between 40 & 70 so this area facing slightly eutrophication problem, (CoRI, 2013).

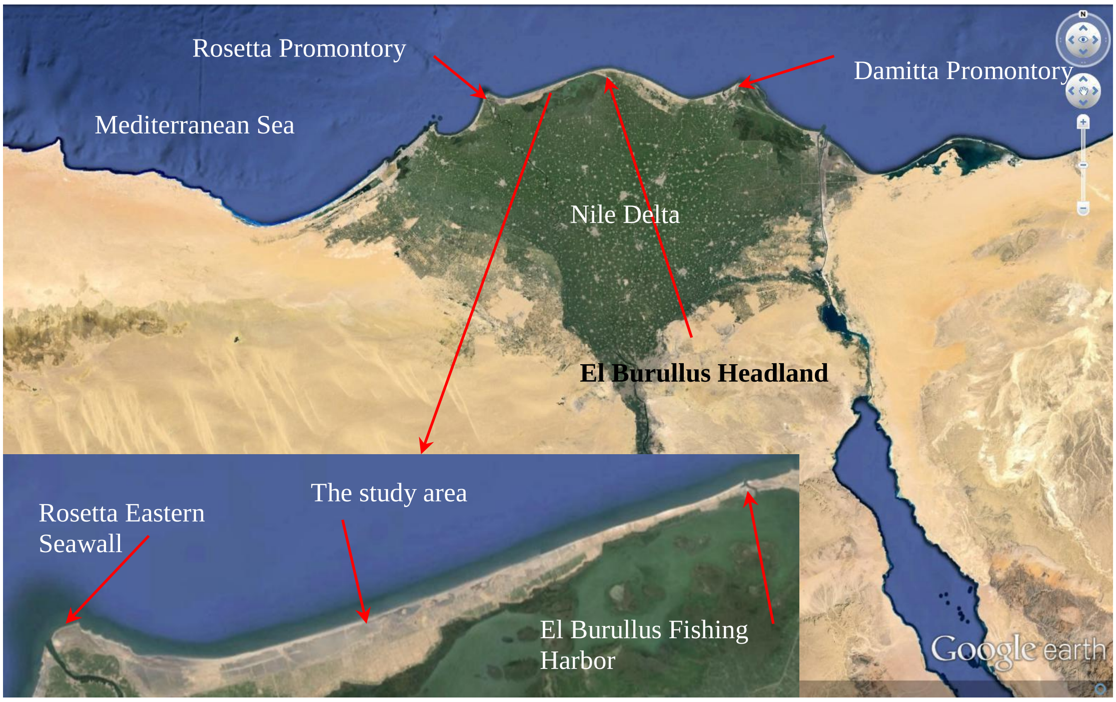


Figure 1. Location map of the study area

Many protective works, figure(2), have been implemented and/ or under construction since 1986 and up to the present time in attempt to stop or reduce the high rate of the shoreline retreat taking place along the study area which extends between the Eastern Rosetta Seawall in the west and the El Burullus Fishing port in the east. During the period from 1986 to1991, two Dolos revetments having length 1.5 and 3.5 km,figure (2-c), along the western and eastern sides of Rosetta promontory respectively, were executed in land (Fanos, 1999). The weight of the armor layers units is 4 tons. Due to wave and current actions and in the absence of the sediment supply, the land in front of these revetments had been eroded. These revetments have succeeded in reducing and stopping the reduction in the length of the promontory, but as their direct impact and due to the marine forces, erosion took place alongshore on their southern and eastern sides (El Sayed et al., 2007). In 1998, An extension of the eastern revetment by about 250 meters length and five rubble mound groins each of about 800-900 meters length have been constructed in land to protect a distance of about 4.5 km of the shoreline on this side, figure (2-c).

A newfishing port was constructed on the area west of El Burullus outlet. The port basin is protected from the west by constructing an inclined western jetty, yielding with the eastern jetty of El Burullus Lake an entrance width of about 120m, figure (2-b).

The study area is located between the Eastern Rosetta Seawall in the west and El Burullus Fishing port in the east. This area is suffering from flooding due to low berm leveland has 30m rate of erosion for 2.5km shoreline length down drift the groin system. Therefore, it can be considered as a closed cell and can be studied in an integrated scheme, figure (1&2).

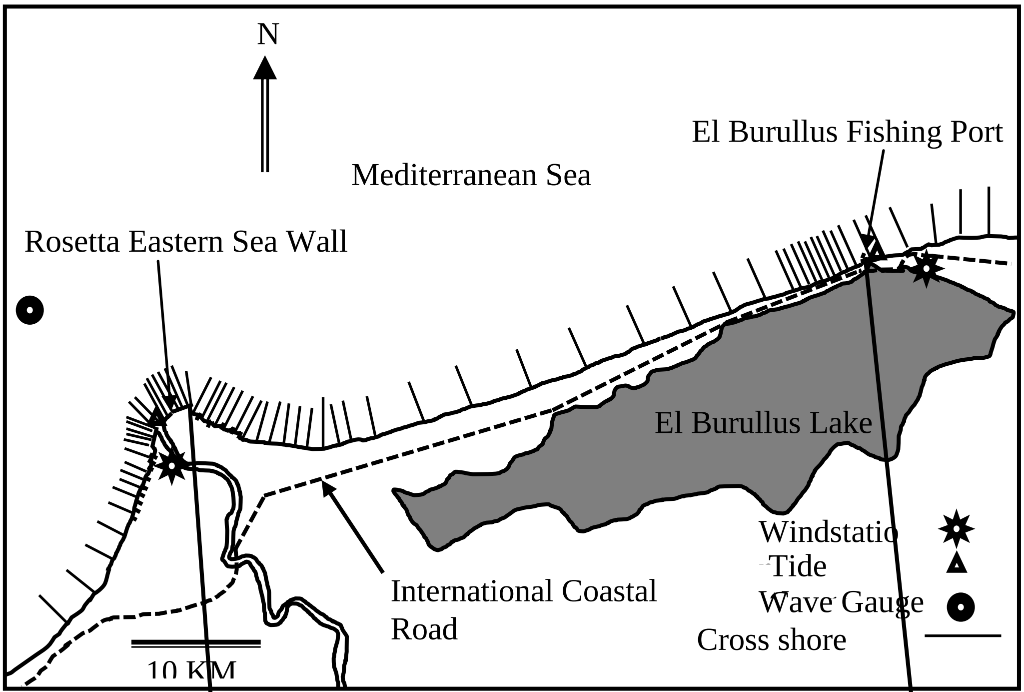


Figure (2-a): Field work along the study area

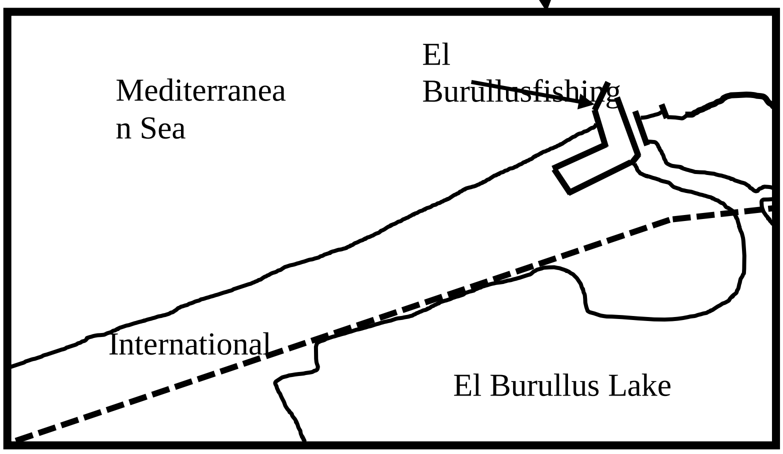


Figure (2-b): El Burullus fishing port

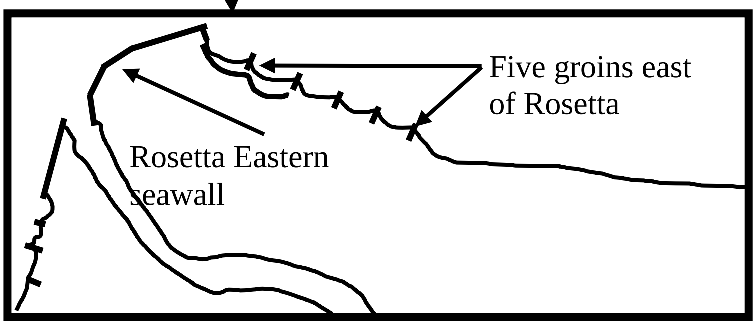


Figure (2-c): Coastal protection works at the eastern side of Rosetta promontory

Figure 2. Field work and main features along the study area

Population growth in the Nile Delta and limited agriculture resources force population to explore new land resources. Therefore, the precious land between the coastal road and shoreline presents a good asset. That is, protecting and developing north delta coast for agriculture, industry, and recreation will relief the dense delta population and add economic value. The study area is with 58 km shoreline with area of88million m^2.This area like the area located at west Rosetta is suitable for land use touristic, cultivation, natural gas plant and non-polluted industrial.

The aim of this paper is to study the area between Rosetta promontory and El Burullus headland, with 58km shoreline length and proposing two solutions to overcome the coastal risks that threat the development in this coastal area, one for shoreline retreat and the other for coastal area flooding. Also, this paper illustrates a brief description of this study area, shorelineevolution, flooding hazards and the factors controlling the dynamic processes and environmentalparameters which affect this evolution.

2 METHODOLOGY

Shoreline and hydrographic survey data from 2004 to 2013, wave data from 1985 to 2005, tide data from1990 to 2000 as well as longshore current data from 1992 to 2004were used to study the behavior of the study area and to identify the coastal problems. GENESIS model is used to check the efficiency of the proposed solution for the shoreline retreat.

2.1The Main Dynamic Factors

2.1.1Waves

Wind waves are the principal driving force for the transport of sediments on thecoasts and the chief agent in near-shore coastal processes (erosion and/or accretion). Inorder to obtain a more complete description of wave climate; a directional wave recorderCAS (Cassette Acquisition System) has been used during the period from 1985 to 1990 (Elwany et al., 1988) and then followed by S4DW Directional Wave Meter up to 2005.These wave data have been subjected to statistical analysis and it is concluded that waves had significant wave height of 1.12 m and average peak wave period of 6.0 sec and coming from the NW. The maximum wave height is 5.5m with 13 sec corresponding wave period.The predominant wave directions are from WNW,NNW, N, and W ,figure (3), with a small portion of waves arrived from the NNE and NE especially inMarch and April (El Sayed et al., 2007). These wave data were used as main input forGENESIS model.

2.1.2 Longshore Currents

The longshore currents have been measured within the surf zone by floats on bothsides of Rosetta promontory. The predominant direction of the current on the eastern side of the promontory is from west to east, figure (3). Maximum and average current velocities are ranging between 80 & 90cm/sec and between 35 &40 cm/sec respectively (CoRI, 2004). These data of the longshore current were used to calibrate the sediment transport of the model and to know the behavior of the sediment transport direction in the study area.

2.1.3Water level variations, Sea level rise and Delta subsidence

The water level variations were recorded near the sea in the study area, figure (2-a). The collected data have been analyzed and it was found that thetide in the area is semi-diurnal. The tidal amplitude is small and ranging from 20 to 30 cm.Also it is noticed that the highest water level recorded is about 80 cm and the lowest waterlevel is -64 cm from the zero survey level (Fanos, 2001).

It was found that the local subsidence in Alexandria is about 0.4 mm/yr, (Stanley and Warne, 1993), while the rate of sea level rise in Alexandria during the period from1951 to1988 is 0.163 cm/yr (Sharaf El Din et al., 1989). The above data were used in calculating the wave run up near the shoreline.

2.1.4Field work

CoRI has been carried out field work especially intensive hydrographic survey, shoreline alignment,wave measurements, tideand wind data, figure (2),at the sensitive areas which are Rosetta and Damietta promontories and El Burullus headland located along Nile Delta Coast. The field data are analyzed to study the beach profile characteristics and shoreline changes. The following subsections give the details of the analysis and results for every subarea of the study area from 2004 to 2013. The subarea will be started from west to east,figure (3).

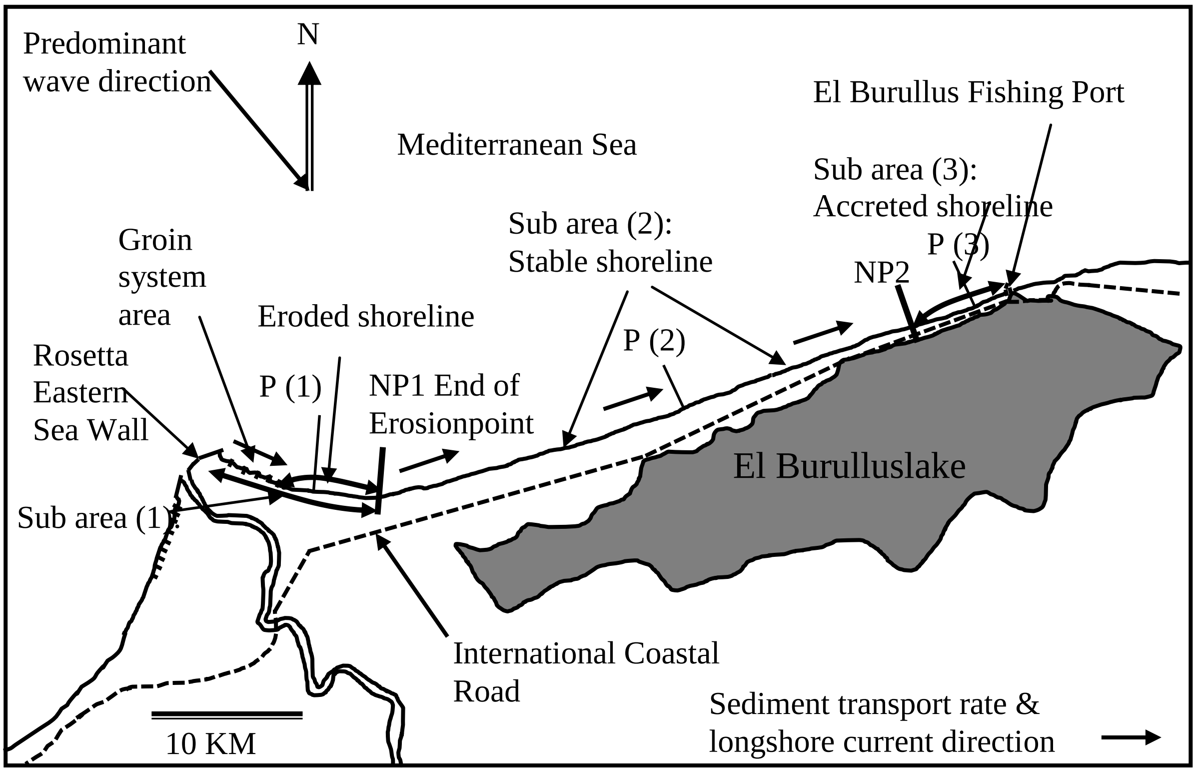


Figure 3. shoreline mode & profile location along the study area

3 RESULTS AND DISCUSSIONS

3.1ShorelineChange Analysis

3.1.1Subarea (1): from Rosetta eastern seawalltill NP1(end oferosion point), shorelineerosion mode

Starting from the west side, the eastern Rosetta revetment with 3.5km length, prevents shoreline retreat but allows water depth increase in front of the revetmentto reaches about 3.0m below mean water level. Also the down drift area of the revetment suffer from sever erosion. In 2003, a system of five groins was constructed to stop the erosion problem along 4.5 km east of the eastern revetment(250m length and 800-900m spacing). These groins nearly stopped the erosion within the protection area but they transport the erosion problem to the adjacent area eastward. The shoreline east of the system of groins is studied, the shoreline erodes by average rate of 30 m/year for a distance about 2.5 km, see figure (3) as a side effect of the coastal structures.Profile (1), figure (7), was taken as a sample of the profiles in this area. The shoreline, the cross of axe (0.0) and the profile, between 2008 to 2013 is retreated by nearly 30m/year which indicate the shoreline erosion. So two solutions were proposedto overcome this problem,one is for using sand nourishments and the second is for using seawall.

GENESIS numerical model is a powerful software packages for the purpose of engineering uses and research, it was developed jointly by the Department of the Army (Waterways Experiment Station, Corps of Engineers, Vicksburg, MS, USA) and the Department of Water Resources Engineering (Lund Institute of Technology, University of Lund, Sweden).This shoreline evolution model has demonstrated its predictive capabilities in numerous projects (Hanson, 1987).

This model wasused to calculate the sediment transport rate and the quantity of sand nourishment needed to stabilize the eroded area. The used input data are the measured shoreline for 2012 and 2013 for 12 km shoreline length including the eastern seawall, wave data at Edco 2002 andsediment characteristics data measured 2013.Figure (4) shows the model outputs for the shoreline change as the horizontal axe is the distance along the shoreline from the origin and the vertical axe shows the distance from the baseline, in a simple way it shows the coordinates of the shoreline in plan. The model calibrated using the measured shoreline in 2012 which was predicted after one year (predicted 2013 in the figure (4)) compared this with the measured ones in 2013. Figure(4) shows a good correlation between the measured and predicted one.It is proposed to use two techniques: first one is to construct seawall after the groins which will stop erosion in the down drift of it and will overcome the flooding problem there, second one is to using sand nourishment and sand dike. Figure (5), shows the effect of using the seawall along the eroded area. The shoreline retreat is stopped at the area of seawall but the erosion translated to the adjacent area for about 1500m down drift the seawall with average rate of 30m/year . The sediment transport rate from the model output at the eroded area is ranging from 300 000m^3 to 400 000 m^3. Many trials were done by using different of sand quantities for nourishment to get the optimum one. Figure (4) shows the shoreline after one year, (pred. 2013 after nourishment in the figure), will not be retreated after using 500 000m^3 sand nourishment.So, it is concluded that using 500 000m^3 sand nourishment every year will stabilize the eroded shoreline. The proposed solution which is sand nourishment is using worldwide as an example in Italy, Germany, the Netherlands, France, Denmark, Spain and United Kingdom.The uses of beach fill in the countries of the European Union are studied and discussed with respect to the general situation, project type and objectives, design and evaluation procedures, legal framework, and financial aspects. Significant differences were found among the investigated countries,(Hansona et al., 2002).

Shore Protection Authority (SPA)is a member in the committee of the dumping sea areas of thedredging sand. SPA in meeting with CoRI said that one millionm^{3}of sand every year has been dredging from the navigation channel of Egyptian Liquefied Natural Gas project at Edco city which located about 25km west of the study area, figure(6). So, it is recommended to use this dredging sand as nourishment for the above eroded area as it covers the needed quantities.

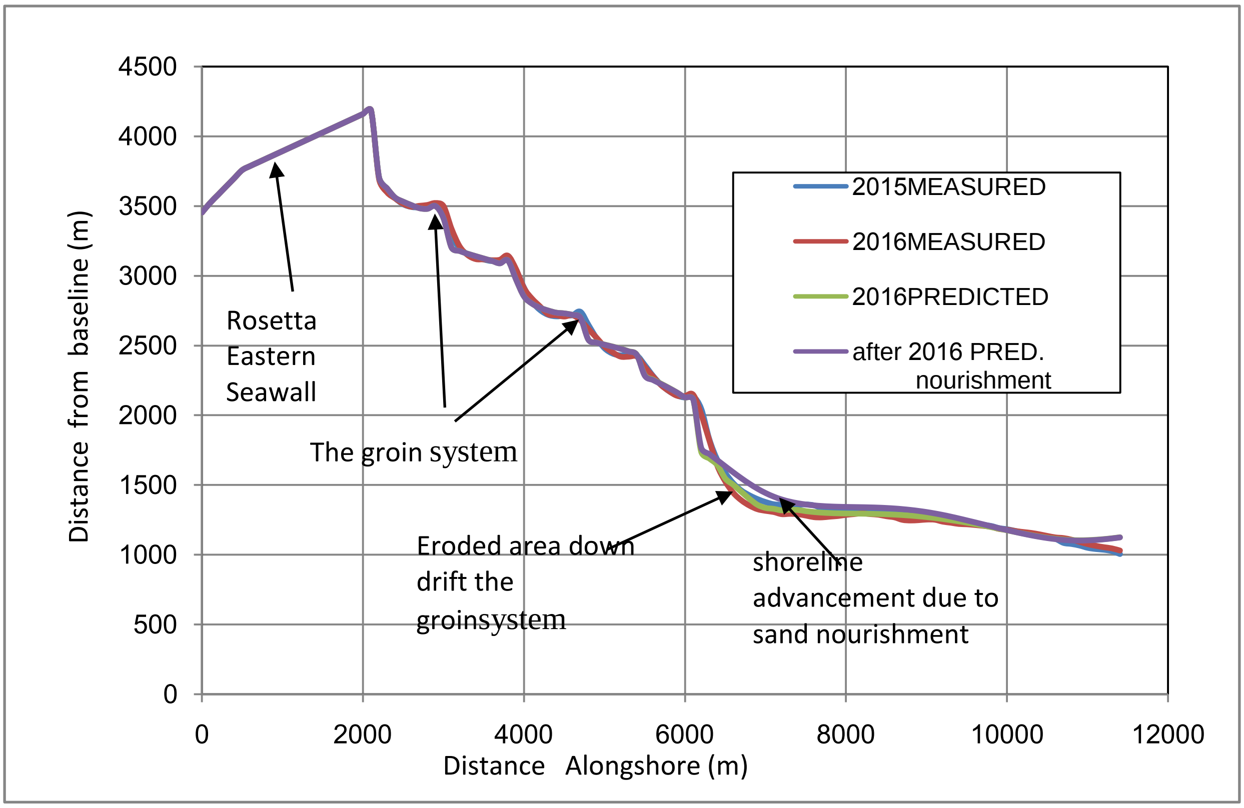


Figure 4. Shoreline change along the study area

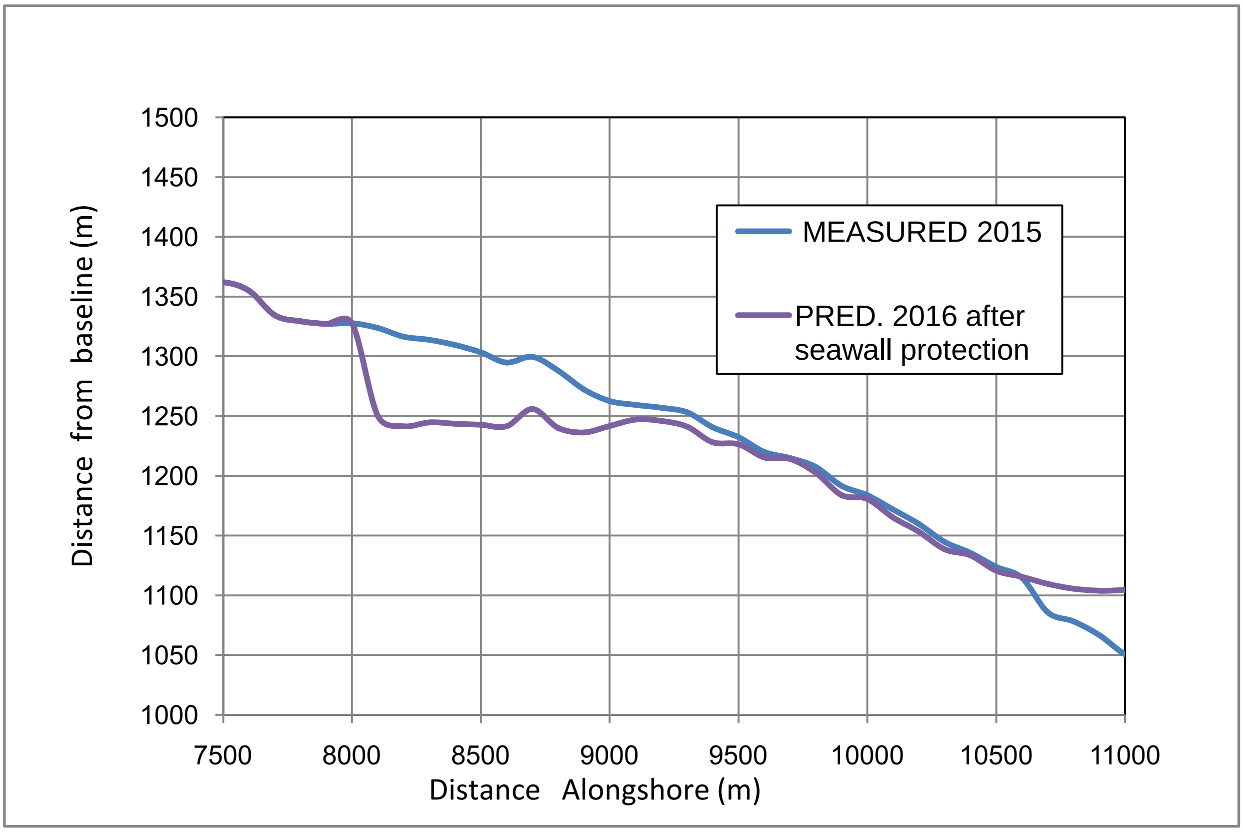


Figure 5. Shoreline change along the study after using seawall for protecting the erosion area of the groin system down drift

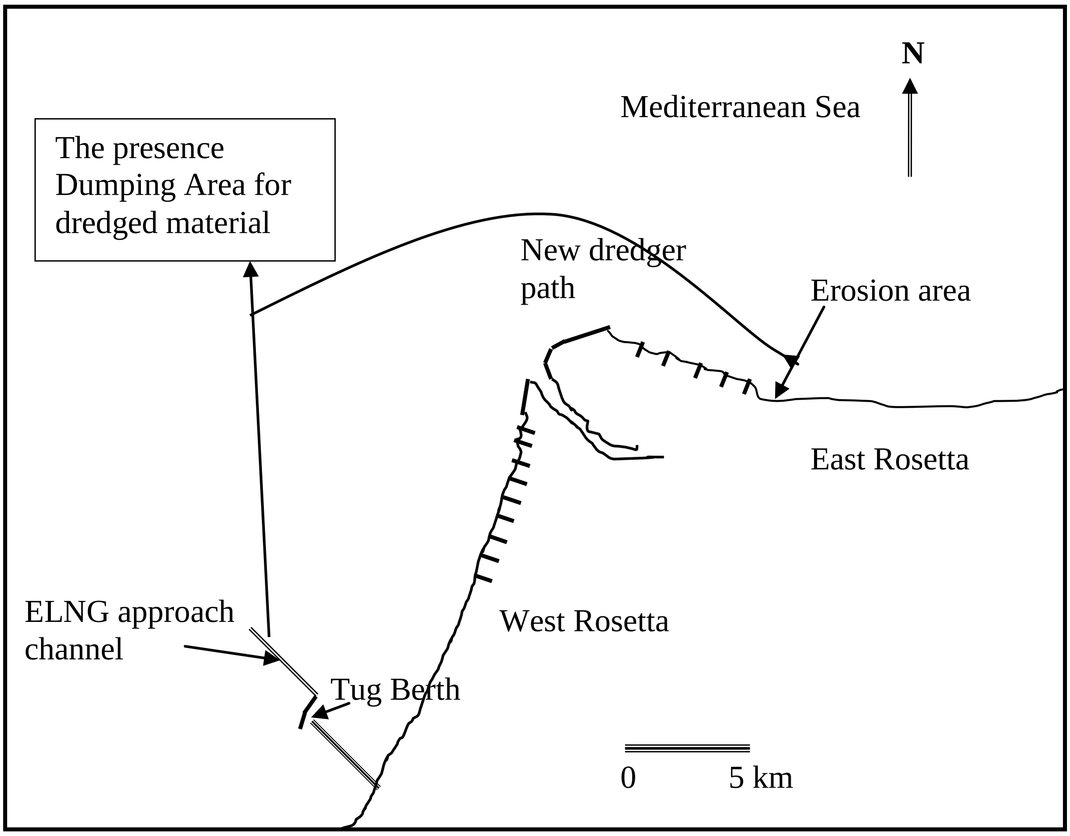


Figure 6. ELNG approach channel & the new dumping area of the dredged material

3.1.2Subarea (2): shoreline from NP1 toNP2, shoreline stable mode

This shoreline is located between the ends of shoreline erosion (NP1) to the start of accretion shoreline (NP2), figure (3). The shoreline of this area is nearly straight line with angel of 72 degree measured from north toward east, taking the perpendicular of wave direction.The shoreline of this sub area is fluctuated between erosion and accretion with rate ranging from 2 to 6 m/year. It is almost stable.Profile (2), figure (7), was taken as a sample of the profiles in this area. The shoreline, between 2007 to 2012,is nearly at the same point which ensures the stability of shoreline.

3.1.3Subarea (3): shoreline from NP2 to El Burullusfishing port, shoreline accretion mode

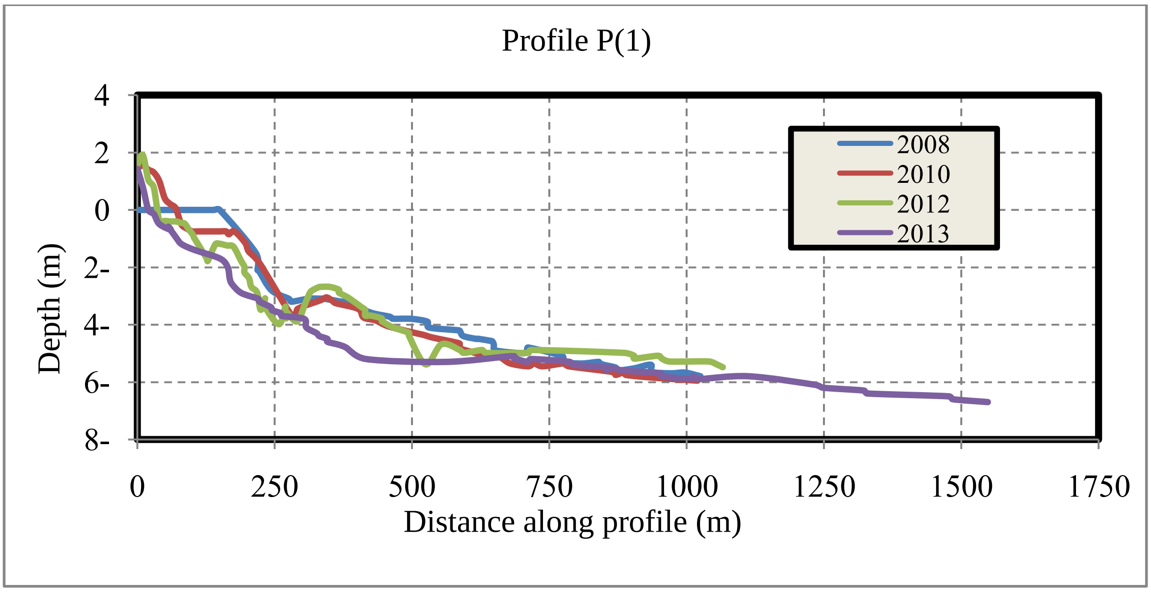
This shoreline is located up-drift of the El Burullus fishing harbor, with 2.5 km length. The shoreline of this area likes the previous one taking the perpendicular of wave direction.The shoreline of this sub area is in accretion mode with average rate about 7.0 m/year, figure(3).The western jetty of the port is blocking the sediment movements.Profile (3), figure (7), was taken as a sample of the profiles in this area. The shoreline, between 2004 to 2012, is advancedby nearly 6m in the sea which compatible with the shoreline analysis.

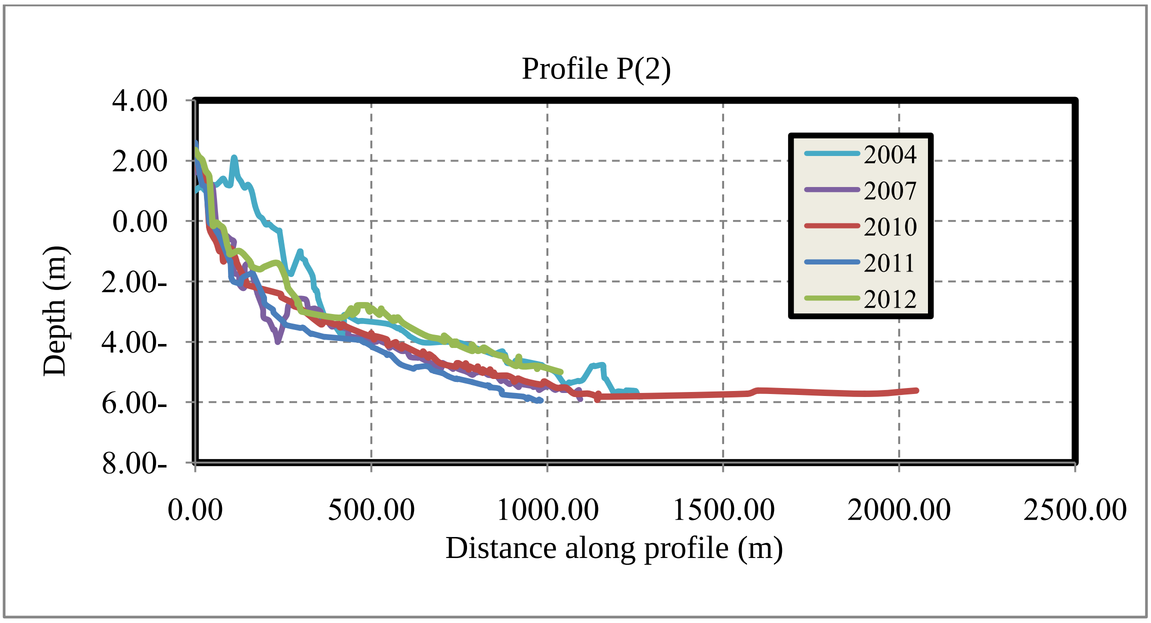
3.2 Flooding Analysis

The cross shore profiles were studied to get the information about the berm level. The average berm level is about 1.45 m. Figure (7) shows samples of the cross shore profiles showing the berm level changes with time from 2004 to 2012.Going to the land, most of the land areas could be classified as low land bounded by the shoreline and the international coastal road. The width of this area is ranging from 430m to 2200m. So there is a need to check the sea water overtopping the berm level.

The maximum water level is (average sea level 0.36 + storm surge for high waves 0.9 + wave run up 0.70) 1.96 m without sea level rise. After 100 year the maximum water level is about = 1.96+0.16m (The predicted sea level rise rate is about 0.16 mm/year.)= 2.12 m.

The average berm level (1.45m) is less than the maximum water level reaching it (2.12m). So the land area back the berm level is subjected to sea water flooding.





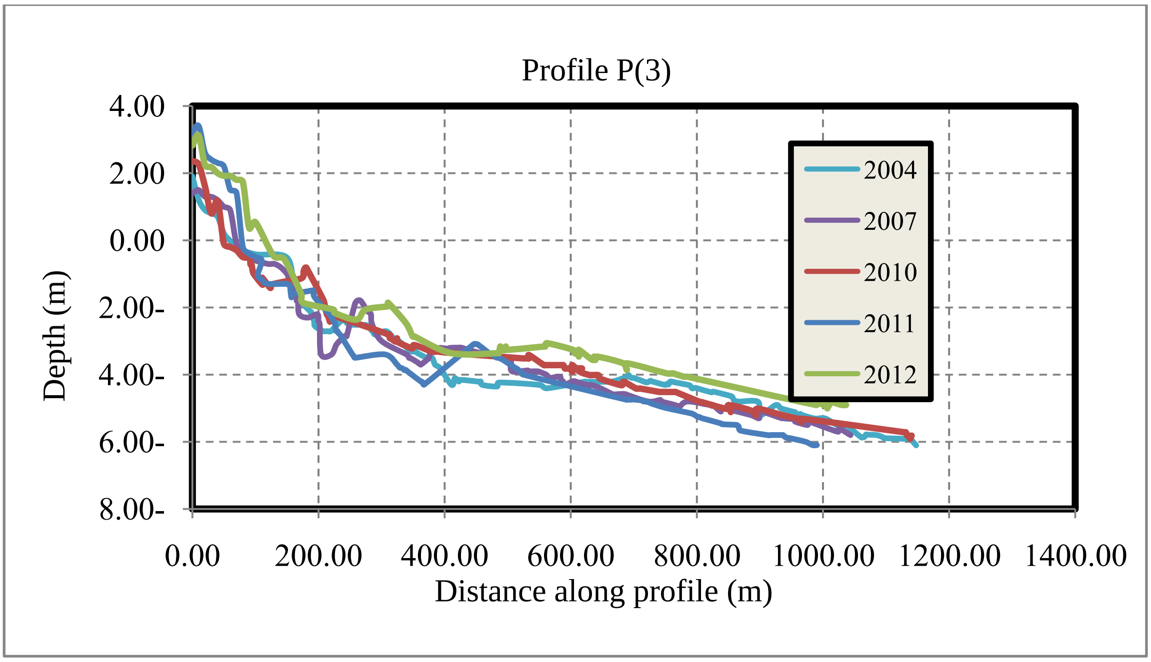


Figure 7. Selected Profiles of the Study area (P1,P2,P3)

3.3 ProposedFlood Protection:

Many coastal protections could be proposed to overcome the seawater flooding. These solutions are classified as hard and soft structures. Hard structures like berm revetment using stone armor layer or making it by using sand bags. The hard structures will change the behavior of the nearshore stability to erosion one. Also the cost will be about 2120 million L.E. for 53 km shoreline. These hard structures used tobe built in the eroded area but our area is mostly stable. Soft solution like sand dike it could be built near the shoreline as nourishing dunes or far away the shoreline in land. The sand dike near the shoreline will be subjected to sea waves attack so it needs regular feeding but the sand dike in land will be stable but we can't use the area between the shoreline and the dikeas it will be subjected to sea water flood.

Sea dikes have been used over the world for flooding protection. As in Vietnam, the Mekong River delta plays an important role in the Vietnamese economy and it has been severely impacted during this century by a series of unusually large floods. To mitigate this impact, a large number of engineering structures, primarily dikes and weirs, have been built in the delta in recent years and are still being built, mainly to control floods and saltwater intrusion, (Thi Viet Hoa Lea et al., 2007).Also in The Netherlands, large parts of the Netherlands are below sea level. Therefore, it was important to have insight into the possible consequences and risks of flooding. So an analysis of the risks due to flooding of the dike ring area South Holland in the Netherlands was executed, (Sebastiaan N. Jonkmanet al., 2008)

A sand dike is proposed to protect the area from flood risk, figure(8). This dike will be executed about 100m from the shoreline. The length of this dike is about 53km length need about 0.85 million cubic meter of sand. The surface of this dike will be cultivated by especial plant to keep the sand. The dike outline is nearly like the existing dike in some placesin nature. The cost of this dike is about 170 million L.E. The used area is about 88million m^2 so the excess cost for square meter of the land is about 1.93 ≅ 2.0 L.E./m^2 .This measure is suitable for any land use tourism, cultivation, natural gas plant and industry.

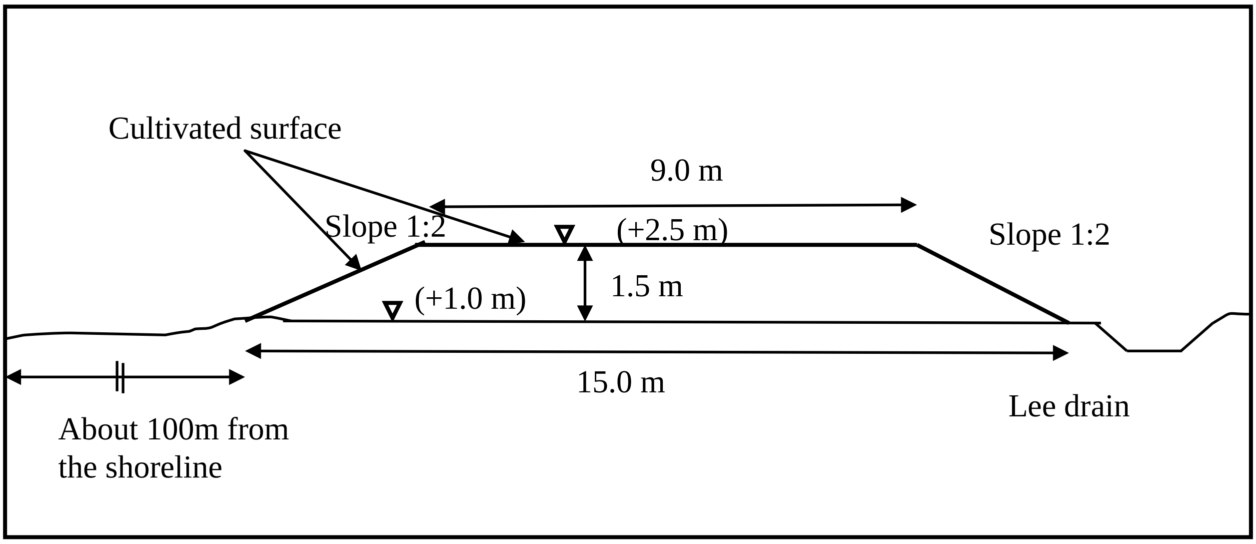


Figure 8. The proposed measure for flooding protection

4 CONCLUSIONS

The coastal area between Rosetta eastern revetment and El Burullus fishing harbor with 58 km length along the Nile Delta Coast of Egyptis studied for providing a suitable area for development projects in the middle sector of the Nile Delta. The shoreline stability is studied and a soft protection measures are proposed by using GENESIS model for the erosion area which located down drift the groin system. Thedredged sand from the navigation channel of Egyptian Liquefied Natural Gas project at Edco city about 25 km from the erosion area will be used as a nourishment sand to stabilize the eroded shoreline. Also, the flooding hazards have been studied and it was concluded that most of the study area suffers from flooding threats. So, a low cost coastal protection, sandy dike, is proposed to overcome the impacts of wave storms and sea level rise due to climate changes. These protections will cost about 2.0 L.E. / m^2 of the study area.

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