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Towards Smart Green Blue Infrastructure

Effect of Human Interventions on Hydro-Dynamics of Sidi-Abdel Rahman Bay "North Western Coast of Egypt"

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ABSTRACT

Sidi Abdel Rahman is the most precious coastal zone in the Egyptian North Coast. It is suffering from severe erosion. It has a variety of Coastal structures, including jetties, groins, revetments, and breakwaters; they were built to prevent coastal erosion. The study area involves tourism villages, located in Sidi Abdel Rahman Bay, which were subjected to fast erosion that got accelerated from May/June 2020 onward. This erosion led to the loss of approximately 40 meters of beach sand from the northern part of some beaches that are obviously redeposited southward. This may have been triggered by a number (or combination) of factors including climate-induced sea-level rise, and/or human-induced changes to sediment supply to the coast. This study aims to assess the shoreline changes during the interval between (2003-2021) in the study area of Sidi Abdel Rahman area. Also to evaluate the impact of the constructions of Marceillia and Hacienda resorts and the prediction of their future position. To achieve the aim of the study; Digital Shoreline Analysis System software (DSAS) had been used to illustrate the shoreline changes. Also, a 1D numerical model (LITPACK) was set up to predict the future position of the shoreline after 5 years. The results showed that urbanization and coastal structures caused significant erosion in the coastal area. Also, the results showed the amounts of sediment transport (accretion/erosion) in specific areas. The numerical model has shown that the area will suffer intensive erosion for around 1000 m distance with an average annual rate of 12m/year. The study recommends soft solutions as nourishment in addition to a set of hard protection measures of groins to eliminate erosion in this area.

Keywords: Erosion, DSAS, northern Egyptian coast, shoreline changes.

INTRODUCTION

Natural processes, human interventions, and coastal development have all contributed to ongoing changes in coastal zones. Almost all states along the coast must deal with the issue of coastal erosion. Coastal erosion and accretion have always existed and have contributed to the formation of present coasts Vos et al.[1] However, human activities have significantly accelerated coastal erosion.

There are no significant natural coastal erosion issues along Sidi Abdel Rahman bay. However, the beaches are not suitable for swimming due to the steeper slope of their surf zone and the formation of rip currents, which generate numerous troubles and major hazards for swimmers.

This situation pushed village owners to build coastal structures or construct artificial swimming pools and/or lagoons connected to the sea in order to establish suitable and safe places for swimming area.

Sidi Abdel Rahman has a special nature in terms of the predominance of coastal currents parallel to the beach over vertical currents on the shoreline, which requires the establishment of coastal facilities that calm the attacking waves the right way.

Since tourists have concerns about the natural qualities of the beach, the environmental condition of the beach is a major element in choosing a tourism location. The construction of coastal structures and dredging activities for tourism development, as well as the construction of ports and marinas, interfered with the coastal processes of this area. Changes in coastal processes may have a profound influence on the coastline. El-Masry[2]

Other solutions might include structures that protect the shoreline, those which disperse wave energy, and/or prevent shore slopes from sliding. Each solution entails an analysis of the present data from the site, the predicted land uses, the available money and time, and other consequences that may arise from any selection. Iskander[3]

Interventions on erosional beaches include the construction of shore protection measures such as groins, breakwaters, and revetments. It is claimed that these constructions transfer the issue to adjacent beaches. They interfere with parallel sediment transport Masria et al.[4], which causes sediment imbalance, up-drift deposition, and down-drift erosion Das[5]. While coastal protection structures serve to minimize erosion due to wave-induced pressures, some of these structures impede sand movement down the beach, making them problematic because they impact considerable erosion near to them. Masria et al.[4]. Beach erosion in Sidi Abdel Rahman Bay on the North Coast has been ongoing since the 1990sEl-Masry[2]. Erosion is a severe issue throughout the coastal region, especially at the Marassi resort.

The Ministry of Environment in Egypt identified turbidity in seawater near the Marassi resort in Sidi Abdel Rahman as a result of dredging for the new marina project. Despite a committee's investigation and assessment, the Environment Minister halted dredging efforts. However, erosion caused damage to surrounding beaches El-Masry[2].

Geographic information systems (GIS) and remote sensing (RS) have lately shown to be fairly useful for investigating the complete processes related to coastal erosion, accretion, and the impact of protective structures, and based on that, essential mitigation measures are provided Oliveira & Barboza[6] Mekonnen & Melesse[7]. DSAS is an ArcGIS extension that allows users to calculate coastal change rate statistics from several coasts at different periods Elstohey et al.[8] Bheeroo et al.[9]. This tool developed by the United States Geological Society has promoted shoreline change analysis in all coastal locations throughout the world Ogunrayi et al.[10]. This extension enables the creation of transects that are perpendicular to the baseline at the specified user spacing along the beach. It works by modeling transects from a theoretical baseline located a distance from the study's most recent shoreline and then estimating the convergence of every coastline with each transect Abou Samra & Ali[11]. In this manuscript, the Digital Shoreline Analysis System (DSAS) was used to calculate shoreline displacement rates during the interval between (2003-2021) in the study area of Sidi Abdel Rahman zone.

MIKE 21 SW is a state-of-the-art third-generation spectral wind-wave model developed by DHI Fonseca et al.[12]. The model simulates the growth, decay and transformation of wind-generated waves and swells in offshore and coastal areas. The simulation of hydraulics and hydraulic-related incidents in estuaries, coastal waterways, and seas is done using this comprehensive modelling system Warren & Bach[13]. The module used in MIKE 21 is LITPACK. LITPACK is one of the modules of MIKE 21 that solves hydraulic and sedimentation issues in the coastal areas Subiyanto & Supian[14]

The simulation used in this manuscript concerns the impact of groins on shoreline dynamics in Marceillia and Hacienda resorts. The modelling findings demonstrate that certain places will undergo abrasion, while others will experience accretion. There are many coastal protection measures that have positive and negative effects Schoonees et al.[15]. The methods referred to "hard" methods to harden the shore with long-term construction (bulkhead, seawall, revetment, breakwaters, sills or groins) or "soft" methods like beach nourishment. The" hard protection works", can be divided into three categories:

- Shore consolidation works;
- Transversal protection works (groins, dykes)
- Longitudinal work in the sea: breakwaters Anton et al.[16]

Coastal structures (hard works) based onshore consolidation works serve the primary goal of dissipating direct wave force Aliyari et al.[17]

It is essential that they do not cause erosion in their foundation area or along the front beach. These types of works hinder the natural beauty of the beaches as well as the way they are used by tourists. Transversal works, specifically groins, serve the primary aim of preventing the transport of sediments down the beach, resulting in the formation of upstream accumulations and erosion on the downstream side. Longitudinal works interfere with wave propagation by interfering with the incident energy flow. Parts of this energy are distributed broadly, while another is wasted in the building's mass, and the remaining energy is transferred through/over the dikes Anton et al.[16]

STUDY AREA

Sidi Abdel Rahman Bay (SARB) is located in the Egyptian northern Mediterranean coast (as shown in Figure1). The study area (SARB) is located 34 km east of Al Dabaa Nuclear Plant 20 Km west of Marina village's border between longitudes 28°48'23.16"E and 28°41'28.49"E and latitudes 30°57'21.56"N and 31° 0'13.35"N. The Sidi Abdel Rahman coastal area, located between Lazourdi Bay (E) and Hacienda Red (W) resorts, seems to be a complex system with coastline of advance and retreat zones that coexist in a sedimentary balance. The bay extends 8.60 km. from Marassi headland in the west to Lazourdi headland in the east.

Sidi Abdel Rahman is Egypt's premier tourist destination on the north coast. It has highly precise weather requirements for activities in the outdoors, such as beach tourism. The study region has a semi-arid Mediterranean climate. The summer months of May through September are characterized by clear, sunny skies and an absence of precipitation.

The winter season, which lasts from October to March, is characterized by high winds and heavy rainfall El-Masry[2]. Temperature, sunlight hours, and precipitation all have a significant impact on visitors in this region. The average monthly air temperature in the summer and winter does not go too high. The lowest monthly average air temperature is 9°C in January and the highest monthly average is 31°C in July El-Masry[2].

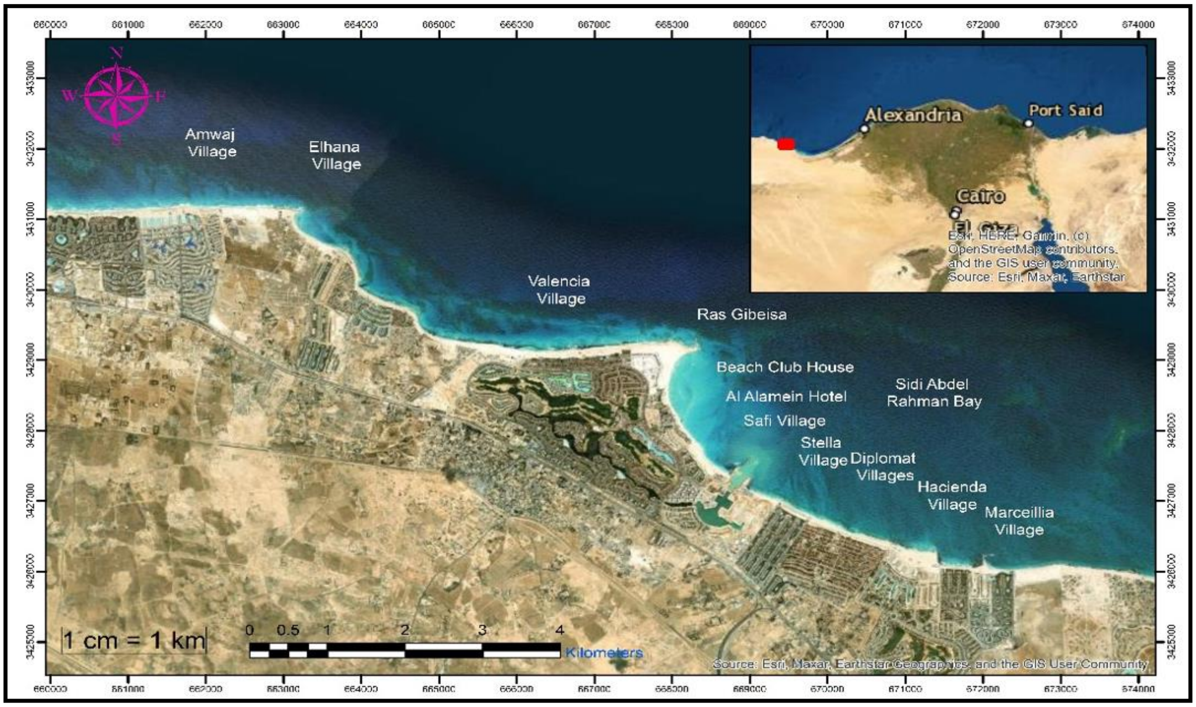

Figure 1: (SARB) The study area is located at Sidi Abdel Rahman Bay the northwestern coast of Egypt.

Study area Coastal topography

Figure 2: Study area zones.

Relation between (SARB) and neighbor's coasts

The nature of the beach in the region has been divided into five sectors, according to its geological properties as follows: Figure 2

1. Marassi western rocky headland (zone 1).
2. Western sandy bay between Marassi headland and Marina (zone 2).
3. Limestone rocks at the eastern Marassi coast (zone 3).
4. Sandy soil mixed with limestone (Diplomats and Stella) (zone 4).
5. Sand mixed with limestone at Hacienda, Loaloa and Marceillia (4) coast (zone 5).
6. Rocky limestone Eastern headland (west of Lazourdi village) (zone 6).

Coast of South Sidi Abdel Rahman Bay Land boundary

The coast of South Sidi Abdel Rahman Bay to the east of Marassi Marina is divided into several sections, which are from west to east (figure 1)

- Marassi East
- Safi village
- Stella Village
- Diplomats Village
- Hacienda
- Loaloa
- Marceillia beach
- Zahra village
- Boo Island front coast
- Lazourdi village northern coast

METHODOLOGY

The majority of coastal physical changes are strongly correlated with sediment transport. Monitoring the shoreline allows for the identification of both natural and human influences on nearshore sediment.

The shoreline changes are used as an indication of the change in sediment stability within the coastal zone. The Egyptian northern coast from Amwaj village to Marceillia village (about 15 km) is used to study the shoreline change and stability within the coastal zone. Data for this study have been collected from Google Earth satellite image extraction from 2003 to 2021 to identify the erosion and accretion zones for this part of the Egyptian Northern coast. Then the shoreline from different images was digitized and compared using DSAS.

To achieve the aim of this study Digital Shoreline Analysis System (DSAS), version 4.2, was utilized to figure the shoreline displacement rate. The coastline change rate statistics were calculated from the period (2003-2021) for the study area. The transects were created which are placed perpendicular to the baseline at the specified spacing along the shore. In this study, a theoretical baseline at a 15 km distance was created using ArcGIS 10.5 behind the shorelines. Modeling transects from the theoretical baseline were created and subsequently computing the convergence of every coastline with each transect. The program recorded shoreline changes by measuring the distance between the baseline and the shoreline locations.

DSAS tool created 1329 transects that are placed perpendicular to the baseline at 10 m spacing along the shore. Using this tool, statistics including all calculated distances was created. End Point Rate (EPR) statistical approach was utilized in this research to record coastline changes over 18 years.

To quantify the shoreline dynamics in the current study, the entire coastline was separated into villages, and each village change was examined using the (DSAS) method Zayoun & Ahmed[18], we got 4 main results, they are the net shoreline movement (NSM) and the endpoint rate (EPR) where NSM is the total distance between the youngest and the oldest shoreline in every transect in meter unit Alemayehu et al.[19] and EPR is the rate, which was calculated by dividing the net movement by the time elapsed in the oldest and the youngest shoreline in every transect in meters per year where a positive value indicates seaward movement (beach sediment accretion) and a negative value indicates landward movement (beach sediment erosion) of the shore-line Basiouny et al.[20]. Linear Regression Rate (LRR) was also applied in this study. The linear regression rate-of-change statistics can be calculated using a least-squares regression line to match all coastline points for a particular transect. By squaring the difference between each data point and the regression line and putting the results together, we can get the optimal location for the regression line Malik & Devi[21]. Shoreline Change Envelope (SCE) was estimated as the difference between the coastline farthest from and closest to the baseline. This helped to evaluate the overall change in shoreline movement across all shoreline positions Bagdanavičiūtė et al.[22].

The second phase of the study incorporates the 1D numerical model LITPACK (a subsidiary of MIKE ZERO suite) to assess the impact of the current envelope of wave climate and sediment characteristics on the stability of the shoreline. The Model was also implemented to evaluate the impact of the constructions of Marceillia and Hacienda resorts. Images from Google Earth have shown that the construction in front of these two resorts have been completed in October 2016 (figure 3). The model was calibrated and validated by comparing the model results with the actual shoreline changes acquired from Google Earth imagery during different time intervals.

Figure 3: The study area without any protection structures until October 2016 (Google Earth).

The model was set up by importing the real shoreline position data, bathymetric profile data, and wave data (figure 4). The calibration and validation processes were undertaken to ensure the reliability and robustness of the model. These processes were carried out by comparing the model results with historical data of shoreline positions at different time intervals to fine-tune the model calibration parameters. The success of these processes shows the extent of the model's capability to predict future projections of the shoreline position.

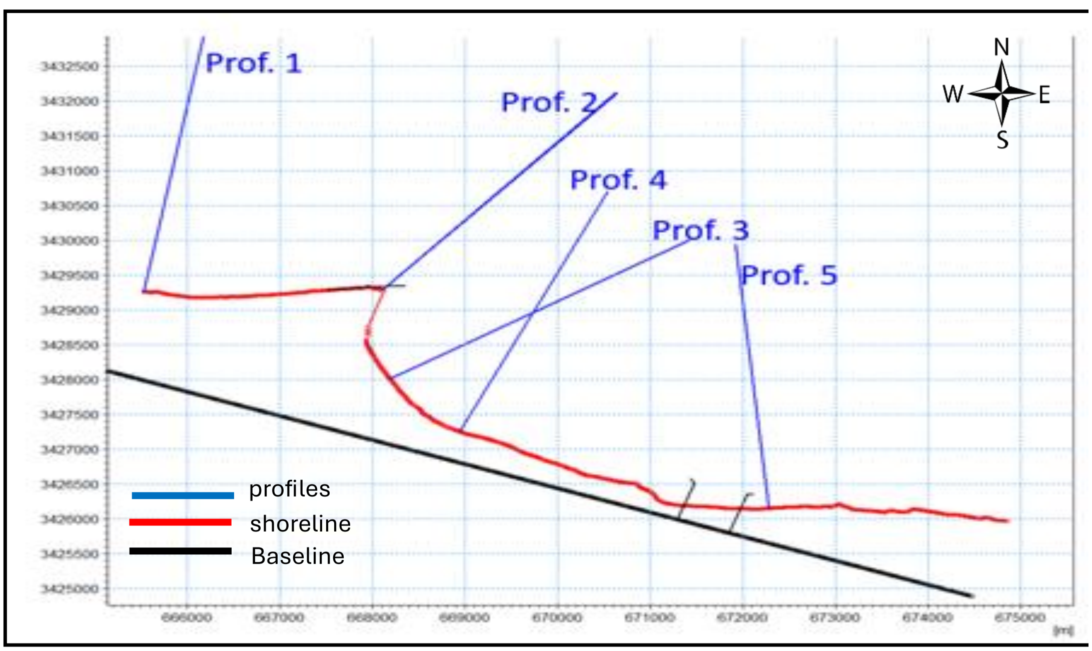

Figure 4: Illustrates the input data for the 1D model including the real shoreline position and bathymetric profile data.

RESULTS AND DISCUSSION

Since the 1990s, the western section of Sidi Abdel Rahman Gulf on the North Coast has suffered from erosion. Beach erosion and coastal retreat are two of the most significant challenges in the study region (Sidi Abdel Rahman). The coastline is an essential coastal geomorphological aspect for determining the state of a beach, particularly the issues connected with coastal erosion.

The following section discusses the beach sediment fluctuations overall the study area (loss/gain). Due to restrictions on access to the coast especially private tourism resorts, performing a study of shoreline evolution using just field data in the research region is practically unavailable nevertheless, by comparing historical and current satellite images, we can estimate the changes that have occurred.

The study Summarized the NSM, LRR, SCE and EPR data during the periods of the study. The results showed that the Sidi Abdel Rahman shoreline has active sediment movement, with a clear variation between erosion and accretion, as seen in the following results.

Shoreline change Calculation Methods

Shoreline change rates are calculated using methods that assess variations in coastline positions over time.

Rates are expressed in terms of distances of change per year. The most effective methods are the Endpoint rate (EPR), Shoreline Change Envelope (SCE), Net Shoreline Movement (NSM), and Linear Regression Rate (LRR).

Period 2003-2021

During this period, the shoreline indicates an equilibrium between accretion and erosion of the shoreline along the study area, the center (Ras Gibeisia) and the area to Amwaj village are dominated by severe erosion as shown in the following figures of the results:

1. End Point Rate (EPR)

Figure 5 illustrates the shoreline change rates in the study area at the north Marassi marina from Amwaj village to Valencia village showing the erosion with rates of -0.77 to -2.650, accretion of a rate of 0.00 to 2.40 between Elhana village and Valencia village. The study area of the north coast from Valencia village to Stella village shows erosion at the rate of 0.00 to -2.650 from Valencia village to the beach clubhouse, and accretion at the rate of 0.00 to 6.340 from the area of Al Alamein hotel to Stella village.

The study area of south Marassi marina from Stella village to Marceillia village shows erosion at the rate of 0.00 to -2.650 from Stella village to Diplomat villages, accretion at the rate of 6.34 to 11.96 at Hacienda village, accretion at the rate of 0.00 to 6.340 at Marceillia village.

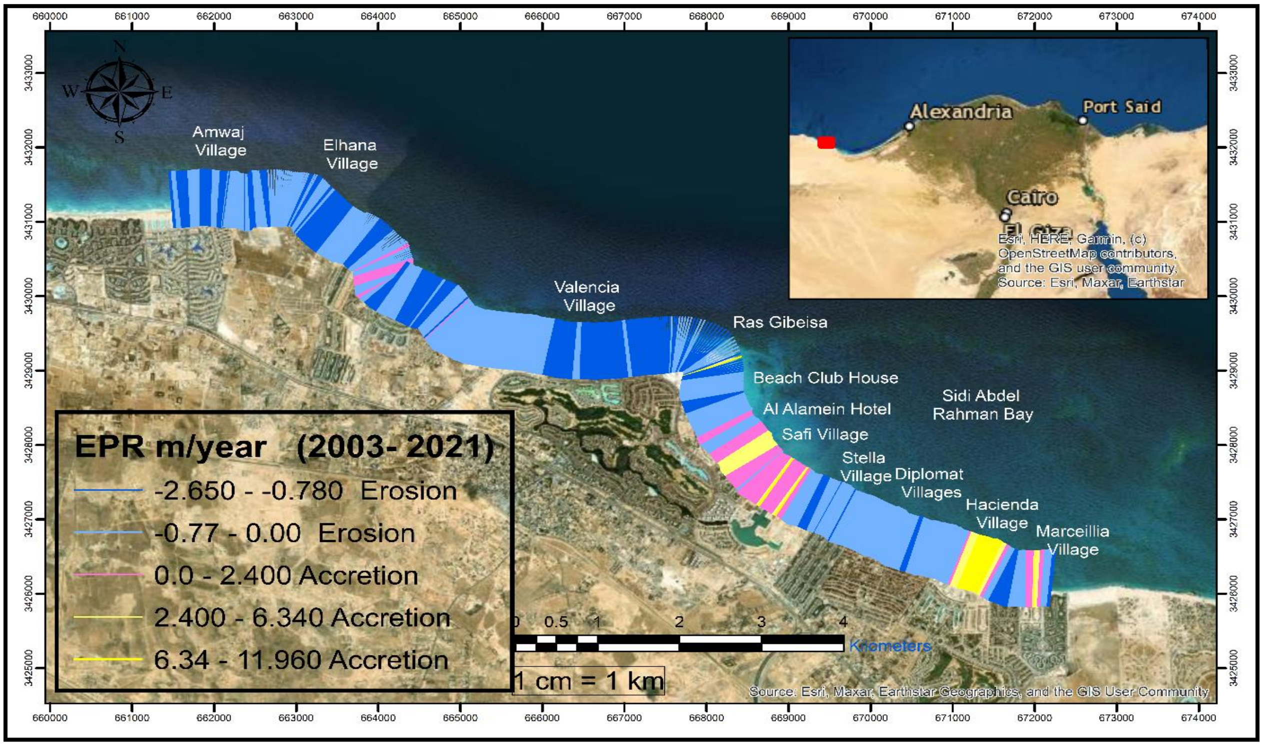

Figure 5: Shoreline changes by EPR for the study area.

2. Shoreline Change Envelope (SCE)

Figure 6 illustrates the distance between the nearest and farthest shorelines with respect to the baseline in the study area at the north Marassi marina from Amwaj village to Valencia village ranges from 6.94 to 61.39 m. The distances at the study area of the north coast from Valencia village to Stella village range from 6.94 to 61.39 at the area of Valencia village to Ras Gibeisia and from the area from Al Alamein Hotel to Stella village, the area of Beach Club House to Stella village ranges from 61.39 to 212.17 m.

The study area of south Marassi marina from Stella village to Marceillia village shows distances ranging from 6.94 to 61.39 m at the area of Stella village to Marceillia village, the area of Hacienda village to Marceillia village ranges from 61.39 to 212.17 m.

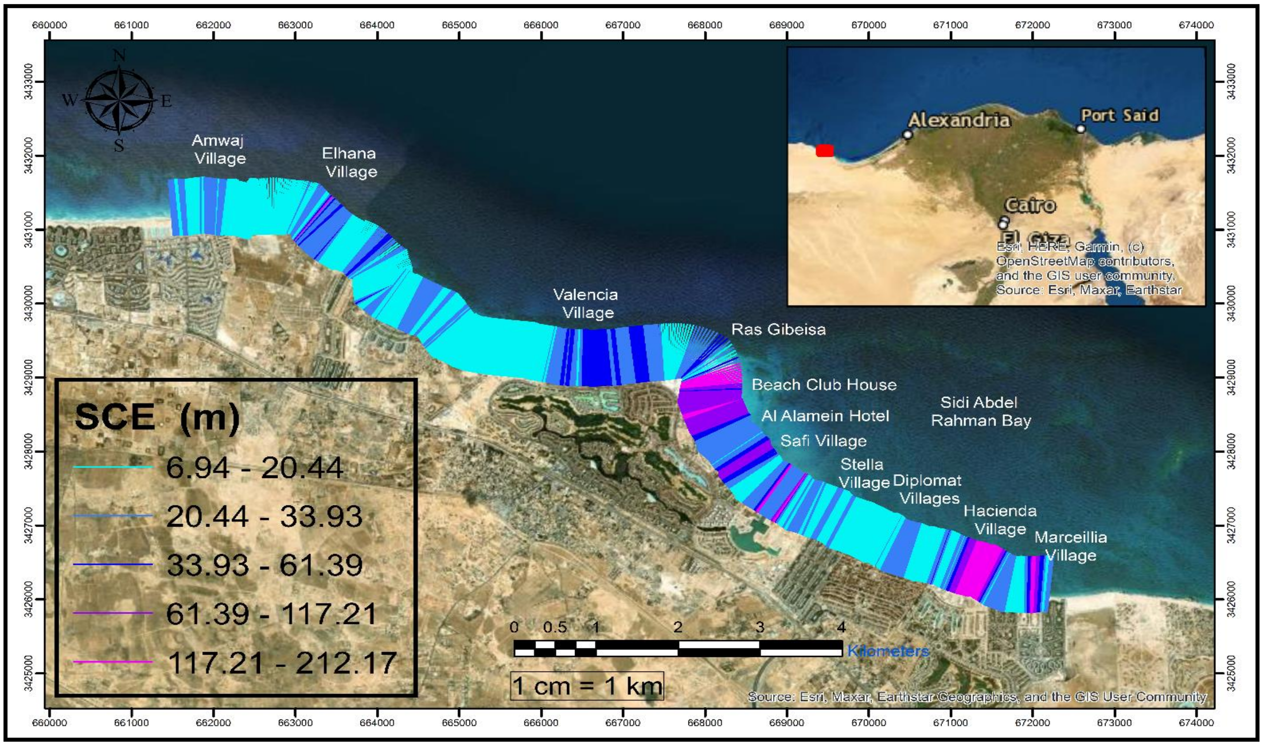

Figure 6: Shoreline change envelope(SCE) for the study area.

3. Net Shoreline Movement (NSM)

Figure 7 illustrates the shoreline change with respect to the distance between the oldest and the youngest shorelines, in the study area at the north Marassi marina from Amwaj village to Valencia village showing erosion at the rate of 6.78 to -47.08

The study area of the north coast from Valencia village to Stella village shows erosion at the rate of 6.78 to -47.08 from Valencia village to Al Alamein Hotel, accretion at the rate of 0.00 to 6.340 from the area of Al Alamein hotel to Stella village, accretion at a rate of 42.51 to 112.42 Safi village area.

The study area of south Marassi marina from Stella village to Marceillia village shows erosion at the rate of 6.78 to -47.08 from Stella village, Diplomat villages, and Marceillia village, accretion at the rate of 42.51 to 112.42 at Hacienda village.

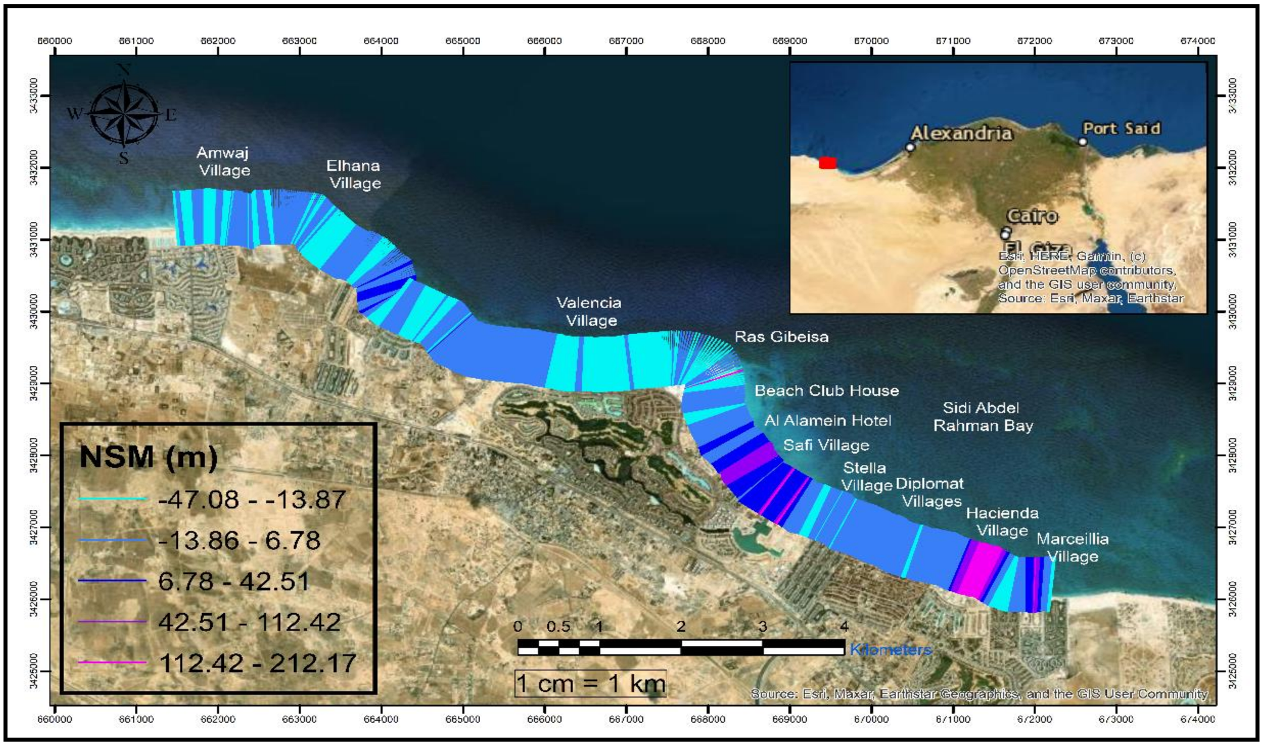

Figure 7: Shoreline change envelope (NSM) for the study area.

4. Linear Regression rate (LRR)

Figure 8 illustrates the shoreline change rates in the study area at the north Marassi marina from Amwaj village to Valencia village showing the erosion at the rate of 0.00 to -4.65, accretion at a rate of 0.00 to 1.49 between Elhana village and Valencia village.

The study area of north coast from Valencia village to Stella village shows erosion at the rate of 0.00 to -0.63 at the area of Ras Gibeisa, Al Alamein House, and Safi village, erosion at the rate of -0.64 to -4.65 at Valencia village, accretion at the rate of 0.00 to 1.49 from the area of Alalamein hotel to Safi village, accretion at the rate of 1.49 to 4.87 at the area of Beach Club House to Stella village.

The study area of south Marassi marina from Stella village to Marceillia village shows erosion at the rate of 0.00 to -0.63 from Stella village to Diplomat villages, erosion at rate of -0.64 to -4.65 between Hacienda and Marceillia village, accretion at the rate of 0.00 to 1.49 at Marceillia village, accretion at the rate of 1.49 to 4.87 at Hacienda and Marceillia villages and accretion at the rate of 4.87 to 15.02 at Hacienda and Marceillia villages.

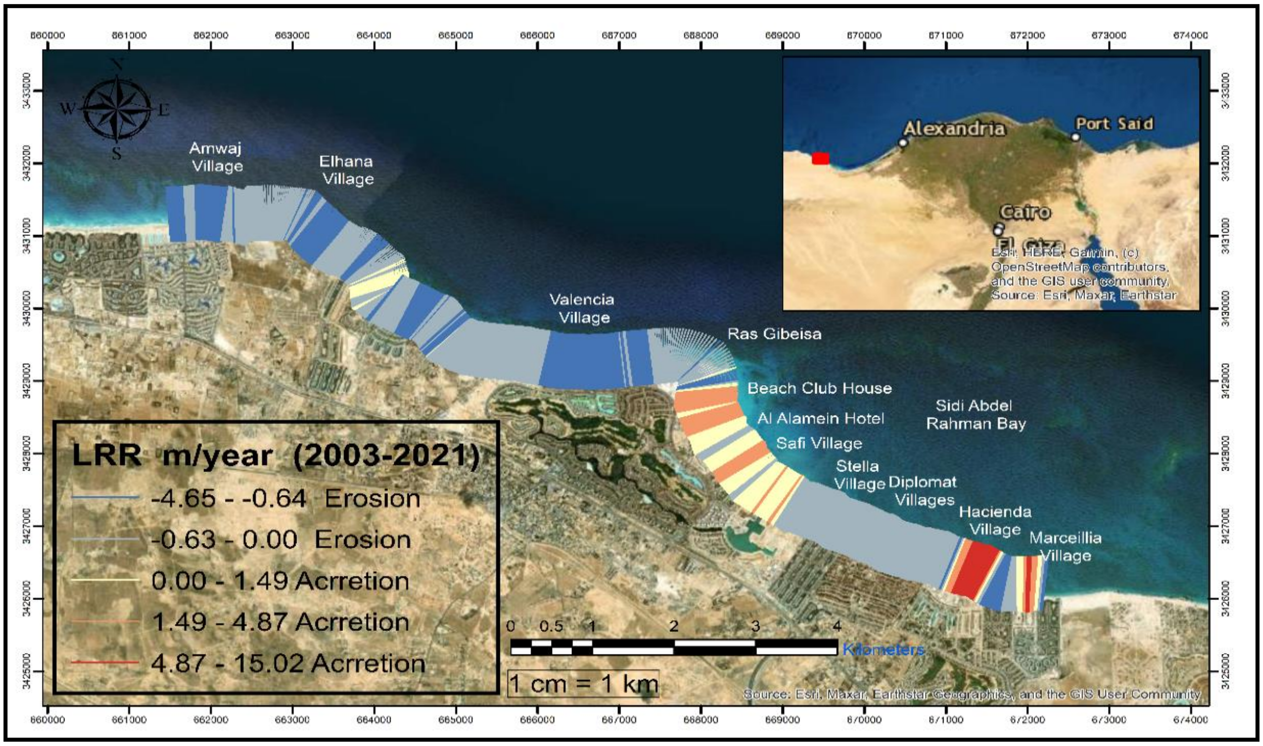

Figure 8: Shoreline change envelope(LRR) for the study area.

5. The 1D numerical model output

After importing the necessary data for setting up the numerical model, and to calibrate the parameters of the LITPACK model, the shoreline change that was deposited after the construction of Hacienda groin from the model were compared to the actual quantity from the Google Earth image between October 2016 to December 2020 (figure 9,10 and 11).

The calibration process was successful to the limit of dependency on the model to predict future shoreline projections. After the calibration, a validation process was carried out. The validation process incorporated the comparison of model results with the actual position of the shoreline from Google Earth imagery during the period between January 2021 to August 2021. This period was chosen to compare the impact of Marassi protection development during this time interval (figures 12,13 and 14). After the validation process, it is reliable to implement the model for future predictions for five years.

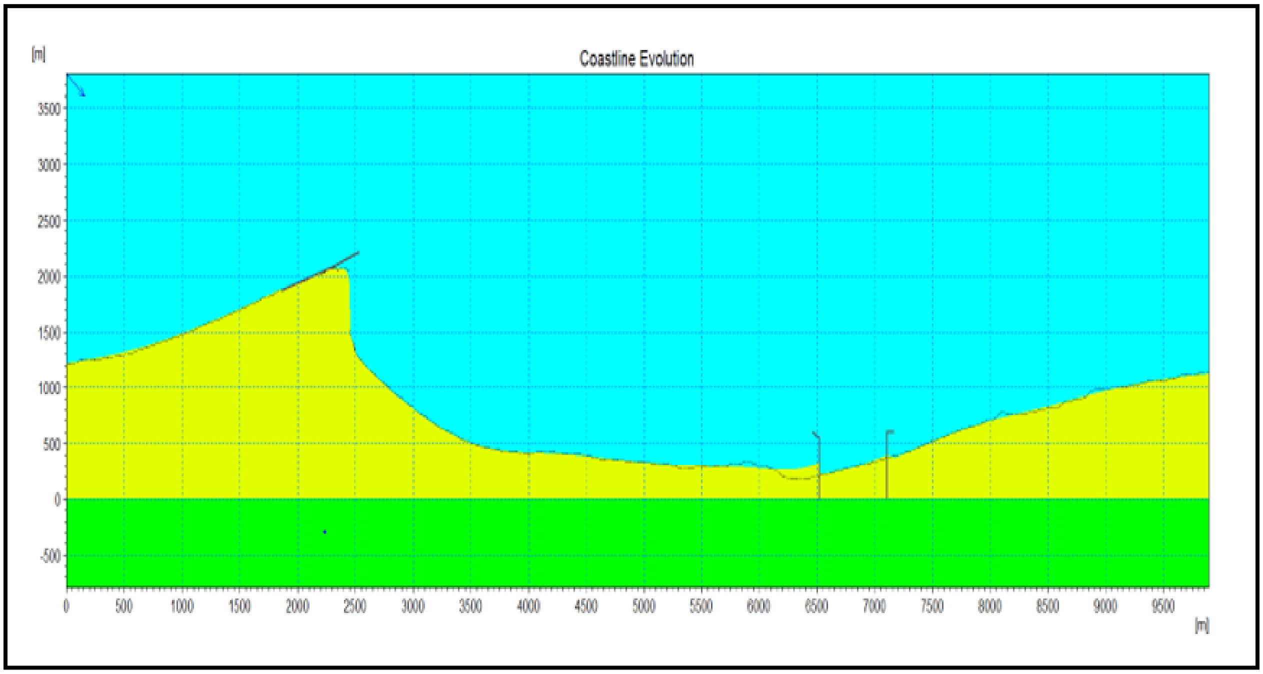

Figure 9: The shoreline changes due to the construction of Hacienda and Marciellia.

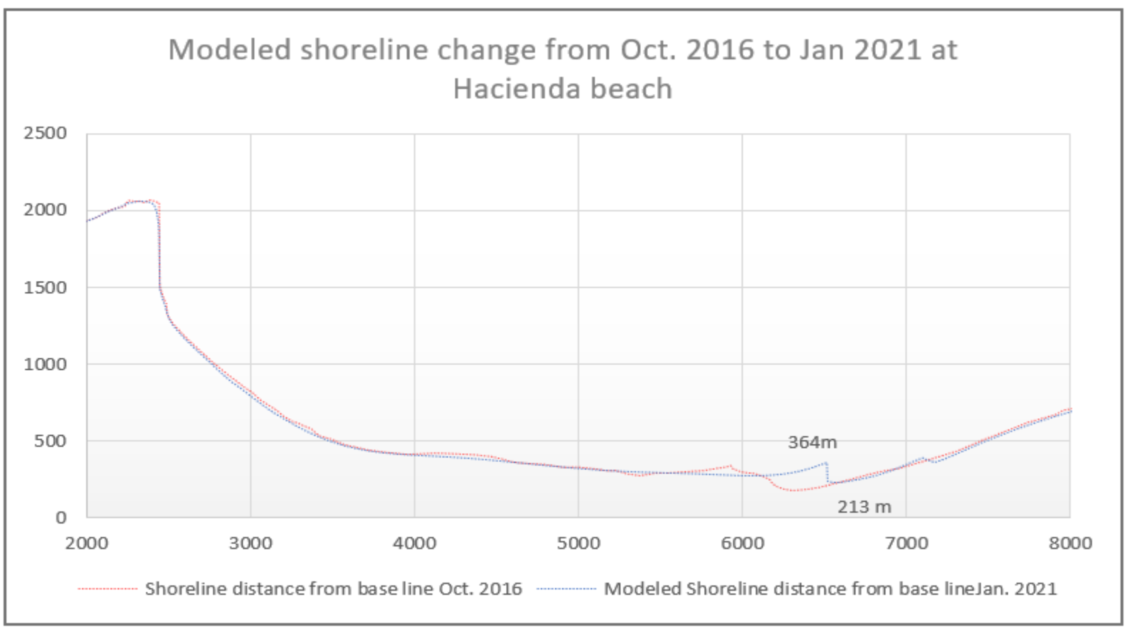

Figure 10: The shoreline changes during the period between October 2016 to January 2021 from the numerical model.

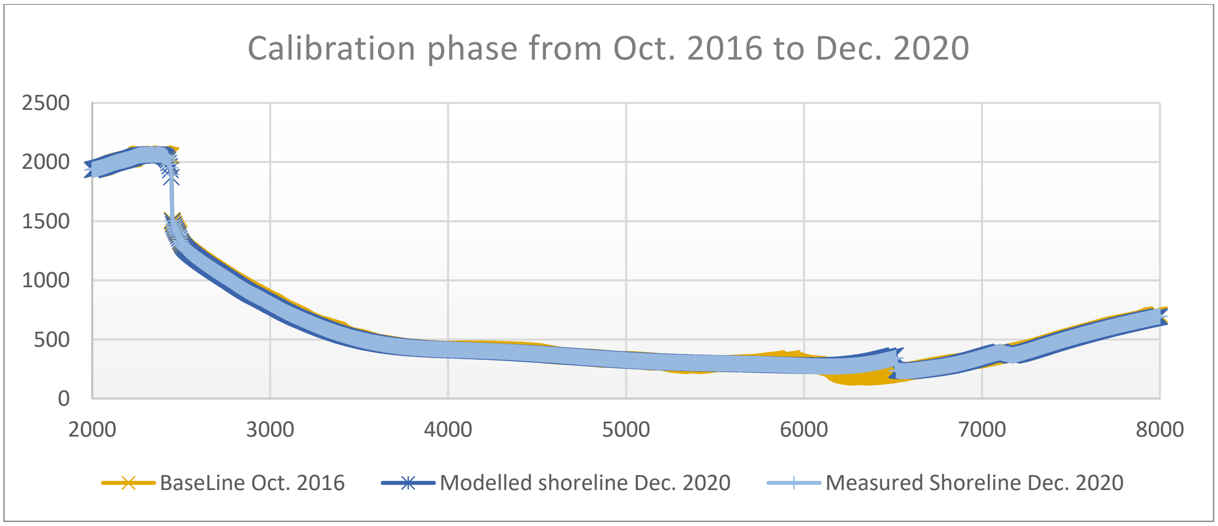

Figure 11: Results of the calibration process between Oct. 2016 to Dec. 2020.

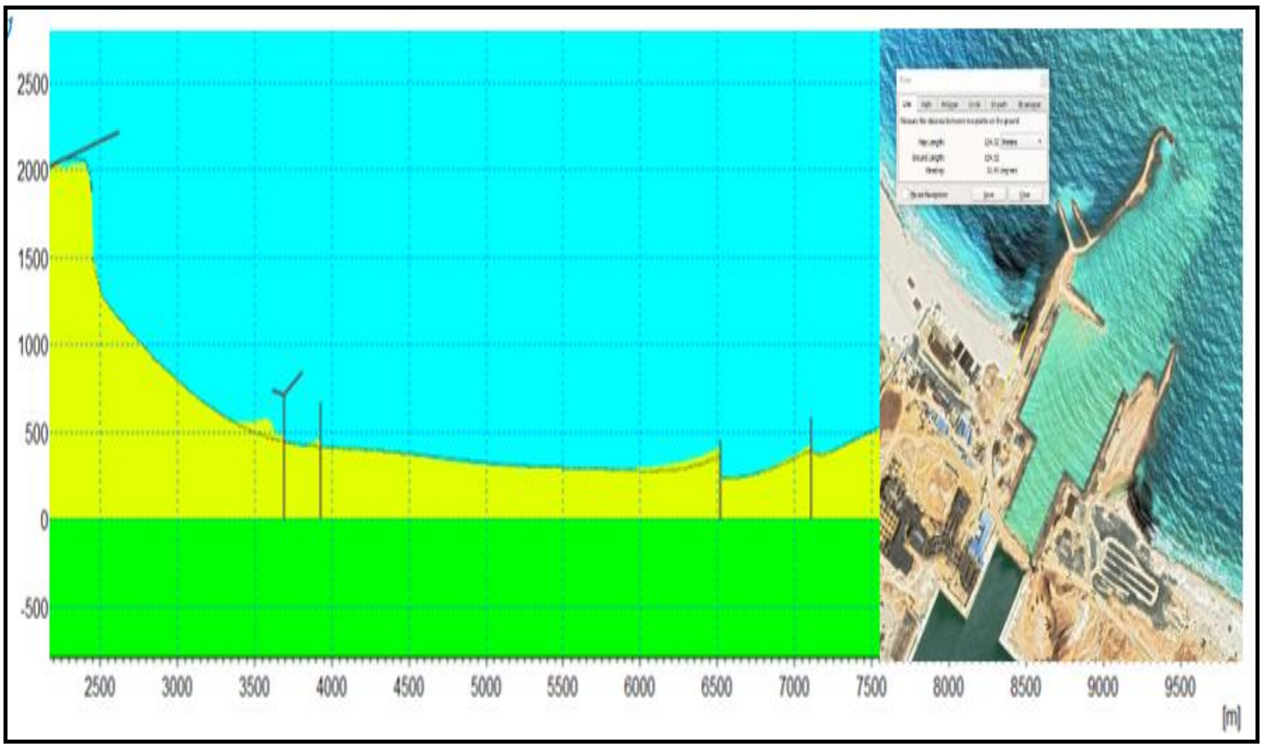

Figure 12: The result of the numerical model after the completion of Marciellia and Hacienda protections and also during the construction of Marassi coastal development during the period between Jan. 2021 to Aug. 2021.

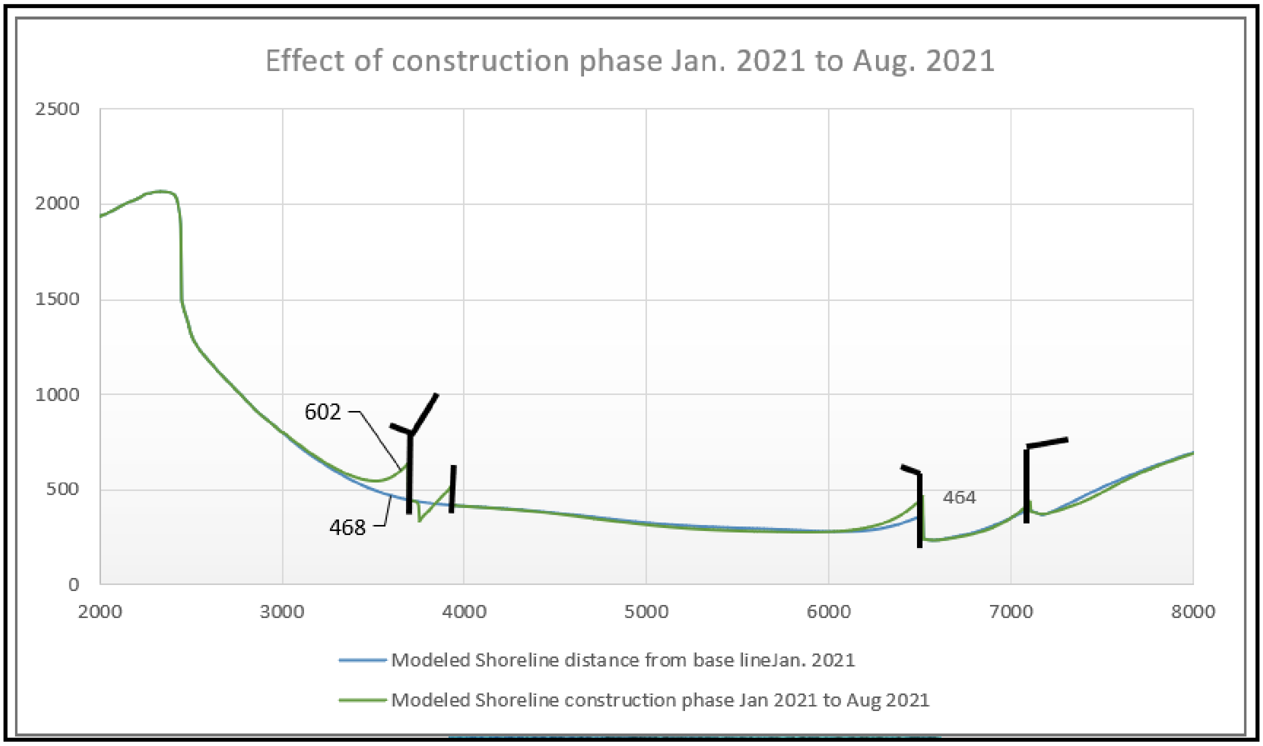

Figure 13: A chart for visualization of numerical model output after the construction of Marassi coastal development.

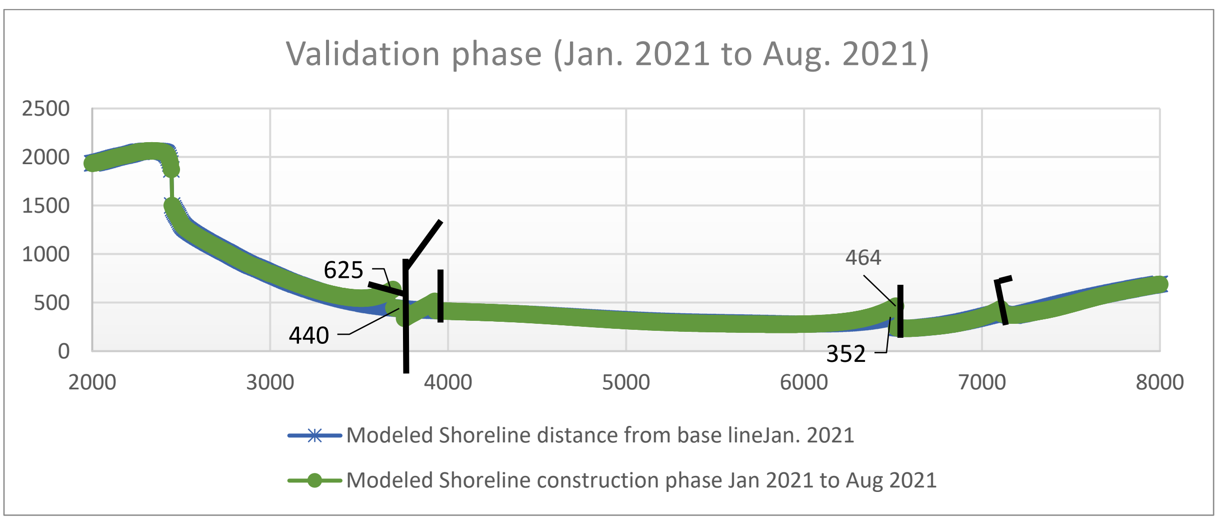

Figure 14: Results of the validation process after the construction of Marassi development between Jan. 2021 to Aug. 2021 development.

The model was implemented to predict the shoreline position after 5 years without any further developments. The results of the prediction simulation indicated that the shoreline position after the construction of the Marassi protections was obviously impacted. The shoreline will suffer severe erosion for a distance that extends for around 1000m with an average annual rate of 12m/year that starts with a high rate and decreases gradually till stability (figures 15 and 16).

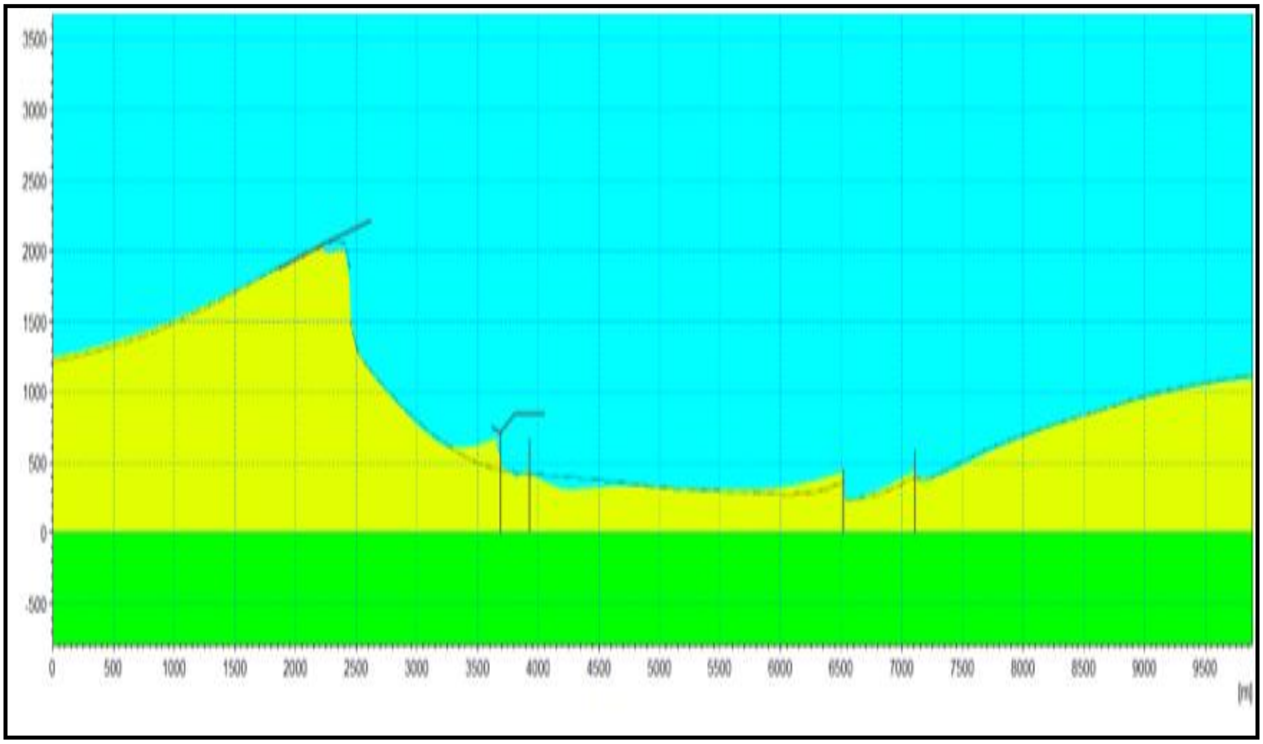

Figure 15: The numerical model output after the future simulation for 5 years.

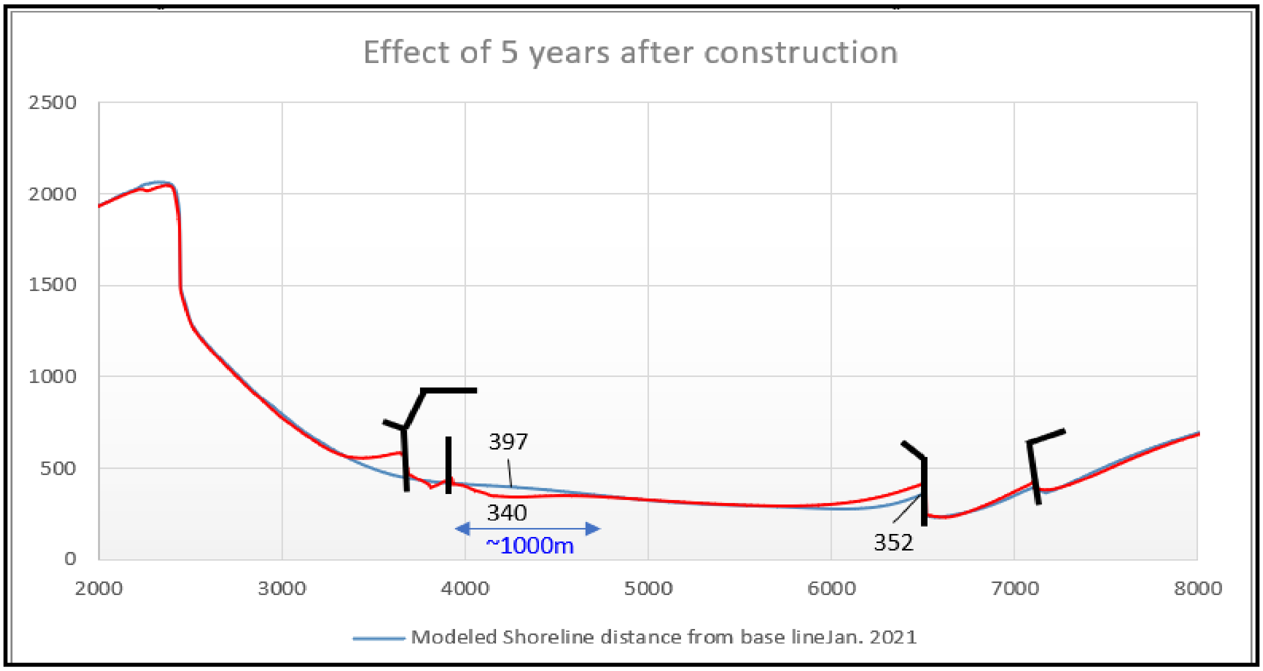

Figure 16: The numerical model output after the construction of Marassi coastal development for five years.

CONCLUSIONS & RECOMMENDATIONS

The shoreline location is an important indication of study because it represents beach vulnerability tendencies to erosion, which has ramifications for tourist development and related recreational activities.

Sidi Abdel Rahman Bay is a changing location with a variety of natural and manmade factors that contribute to erosion, thus increasing the need for the construction of several effective types of coastal defense along this coast. During the study period, the beach eroded in several portions.

Urbanization has a significant side effect on the shoreline. This study examines shoreline stability in the Northern Egyptian coastal zone. The study examines how human interventions affect this stability. The methodology is based on combining all accessible connected studies in coastal engineering. Along with Google Earth images, DSAS is used to determine the stability of sediment in the coastal zone and its impact on coastal zone sustainable development.

The study showed that there is erosion in the area starting from Ras Gibeisa to Amwaj village. The results also identified two regions with maximum erosion rates, which are Ras Gibeisa and Valencia Village. While there is accretion in the area of Safi village to the beach clubhouse and this is because of Ras Gibeisa headland which acted as a natural protection method.

Another area of erosion is the area of Stella, diplomat villages and maybe that is because of the groins constructed in front of Marassi while there is clear accretion in the hacienda village coast because of that constructed groin.

The second phase of the study implemented 1D numerical modeling (MIKE Litpack tools) to predict the shoreline position of the study area for 5 years. The model included the protection measures of Marciellia, Hacienda and Marassi development. The Model was set up using Bathymetry data through bathymetric profiles, wave data and original shoreline. The model was calibrated and validated by comparing the model results with the actual shoreline position from Google Earth Images. After the calibration and validation, the future prediction simulation was set up. The results of the simulation indicated that the shoreline of the study area is thoroughly impacted by the new development and intensive erosion is initiated in the area and reached a distance of around 1000m with an annual rate of 12m/year.

Finally, changes in both natural and human activities caused the shoreline to change; consequently

, the study suggests:

1. Regular and ongoing shoreline analyses to know and predict coastal changes.
2. The appropriate choice of the suitable hard protection structure in the area of the eroded beaches whether the usage of a set of groins or breakwater
3. Also the study suggests that a nourishment scheme can be employed with the hard structure protection in the placement of borrowed suitable particle size sand directly onto the eroded beaches.
4. We recommend for future studies to use the 2D mathematical models to assess the optimum solution to mitigate the significant erosion in front of the study area.

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