Journal of Coastal Research	21	3	412–420	West Palm Beach, Florida	May 2005

Accretion and Erosion Patterns along Rosetta Promontory, Nile Delta Coast

Mohamed A.K. Elsayed†, Nazeih A. Younan§, Alfy M. Fanos††, and Khalid H. Baghdady§

†Department of Engineering Science and Mechanics
Virginia Tech,
Mail Code 0219
Blacksburg, VA 24061, U.S.A.
melsayed@vt.edu

§Civil Engineering Department
Alexandria University
Alexandria, Egypt

††Coastal Research Institute
Alexandria, Egypt

ABSTRACT

ELSAYED, M.A.K.; YOUNAN, N.A.; FANOS, A.M., and BAGHDADY, K.H., 2005. Accretion and erosion patterns along Rosetta Promontory, Nile Delta coast. *Journal of Coastal Research,* 21(3), 412–420. West Palm Beach (Florida), ISSN 0749-0208.

This study investigates the stability of the Rosetta Promontory shoreline on the Nile Delta over the period 1988–95, and especially the effect of the revetments constructed between 1986 and 1991 on the western and eastern parts of the promontory. A computer code is developed to calculate the volumetric changes along the promontory, and a numerical model, developed by the Danish Hydraulic Institute, is used to calculate the sediment transport. The results generated by this model are compared with those computed from beach profile data. The study shows that the shoreline along Rosetta Promontory is still unstable and that the revetments have not been efficient enough to stop erosion.

ADDITIONAL INDEX WORDS: *Shoreline, beach profile, volumetric changes, sediment transport.*

INTRODUCTION

The Nile Delta (Figure 1) has been developing since the Upper Miocene (NIELSEN, 1977) from a massive input of sediments. The old delta at that time comprised several branches that silted up, the flow becoming restricted to two active branches, Rosetta and Damietta. Each of these two branches developed a major promontory at its Mediterranean terminus.

FANOS *et al.* (1995a) studied the development of Rosetta Promontory and showed that between 1500 and 1900 AD, its eastern and western parts prograded respectively by about 11 and 8.5 kilometers into the sea. This accretionary phase reversed at about the beginning of the 20th century as a result of the construction of the Delta Barrage and other control works in the Nile itself. The length of the promontory was reduced by about 5 kilometers between 1900 and the present time. This phase has been marked by a general aggravation of erosion and deposition problems at Rosetta Promontory, at the delta mouth, and along the rest of the delta coast. These problems endanger the economic resources of the people living in Rosetta Promontory.

STANELY and WARNE (1998) confirmed this trend of a deltaic destruction phase over the past 150 years. They also attributed it to a combination of the disruption of the sediment flux caused by water regulation, ensuing erosive effects of coastal processes, and subsidence. This former deltaic depocenter has been altered to the extent that it is no longer a functional delta, but rather a subsiding and eroding coastal plain.

To control erosion at the tip of the promontory, two revetments 1.5 and 3.5 kilometers long were constructed between 1986 and 1991 on the western and eastern parts of the promontory, respectively. These revetments were designed for a deep-water wave height of 6.3 meters, with a return period of 20 years. In analyzing the effects of these revetments, the main goals of this paper are:

- to calculate the volumetric changes between summer 1988 and autumn 1995 for a better understanding of accretion and erosion patterns affecting Rosetta Promontory and
- to monitor the effects of the protection works on the promontory.

STUDY AREA

KADIB (1969) and MOBAREK (1972) compared the results of different surveying maps and showed that the shoreline of Rosetta Promontory retreated before the construction of the Aswan High Dam at an annual rate of about 18 m/y.

INMAN and JENKINS (1984) compared beach profiles along the Nile Delta coast and showed an average shoreline retreat along Rosetta Promontory of 160 m/y between 1964 and 1982.

SOGREAH (1984) and TETRA-TECH (1984) identified an accretionary phase on the promontory over a period from 1800 to about 1900. After the construction of the Aswan High Dam in 1964, the shoreline began to erode at a rate of around 150 m/y.

DOI:10.2112/03-0121.1 received 17 May 2004; accepted in revision 26 May 2004.

This study was part of a Master's of Science thesis carried out while the first author was a graduate student at Alexandria University, Egypt. The authors thank the reviewers for their invaluable suggestions.

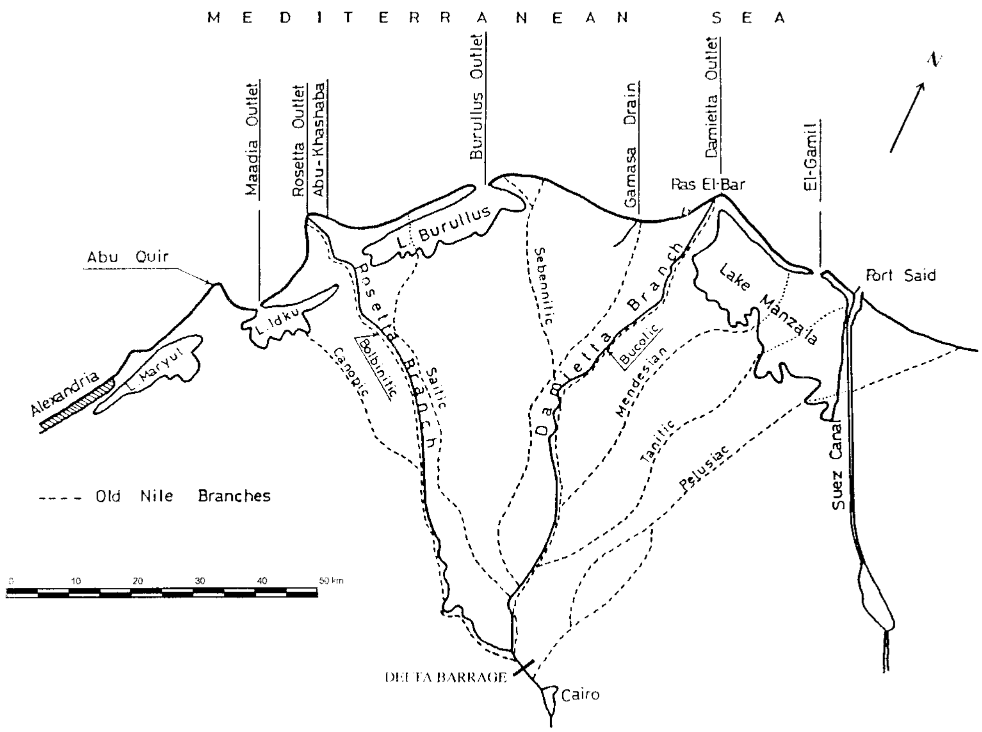

Figure 1. General map of the Nile Delta and the old distributary branches and outlets.

El-Serafy (1994) constructed a numerical model to simulate the shoreline changes for the period 1990–2025 and expected a future rate of erosion of 75–80 m/y. This is lower than the present yearly retreat (150 m/y) over the 1980–90 period given by Frihy *et al.* (1991).

Fanos *et al.* (1995b) studied the short- and long-term changes of the promontory using old maps, aerial photographs, satellite images, and shoreline profiles. The long-term changes deduced from this study showed that Rosetta Promontory was built at about AD 500–1000 when the waters of the Capnoic river branch and part of Sebennitic branch were diverted to the Rosetta branch (CRI, UNESCO, and UNDP, 1978). Both the western and eastern parts of the promontory advanced during the period 1500–1900 at a rate of about 25 m/y, whereas they retreated at an average rate of 50 m/y between 1900 and 1964. Starting from 1964, the rate of erosion increased tremendously to 125 and 170 m/y for the western and eastern parts of the promontory, respectively, between 1964 and 1982. The short-term studies that used the available profile data showed that:

- Remarkable erosion was taking place at the tip of the promontory along both its western and eastern parts. However, the shoreline comparisons also revealed significant accretion at Abu-Khashaba Bay (Figure 1) to the east of the Rosetta outlet. There was also minor accretion on the western side of the mouth.
- The total volume of the eroded and accreted sediments on the western part up to the 6-meter depth contour for the period 1980–90 was almost the same and amounted to 8.2 $\times 10^6$ cubic meters. On the eastern side, the eroded volume (20.6 $\times 10^6$ cubic meters) was much larger than the accreted volume (15 $\times 10^6$ cubic meters).

Fanos *et al.* (1995a) plotted 1919/1922 bathymetric maps (scale 1:235,410), 1976/1977 Chain survey maps (scale 1:100,000), and recent 1986 survey maps (scale 1:100,000) to the same scale. This comparison showed that maximum erosion took place at the tip of the promontory, with retreat values of 4.0, 3.5, 1.5, and 1.0 kilometers, respectively, for contours 0, 10, 15, and 20 meters over the period 1919/1922 to 1986. Within this period, the rate of erosion between 1976 and 1986 was particularly dramatic.

COASTAL PROTECTION WORKS

Western Revetment

Construction of the 1.5-kilometer-long western revetment started in 1986 and ended in 1991. An artificial embankment covered by dolos concrete blocks was established to facilitate the construction of the revetment. After removing the dolos blocks in 1988, the artificial embankment was subjected to erosion. The shoreline retreated about 70 meters at the northern end of the western revetment, whereas the southern end was stable over the period from April to October 1988. In 1990, the revetment was exposed to the sea after eroding all sediments in front of it. Over the period 1990–95, erosion continued in front of the western revetment and at its southern end for a distance of about 2 kilometers along the shoreline. Farther to the south of the western revetment, accretion

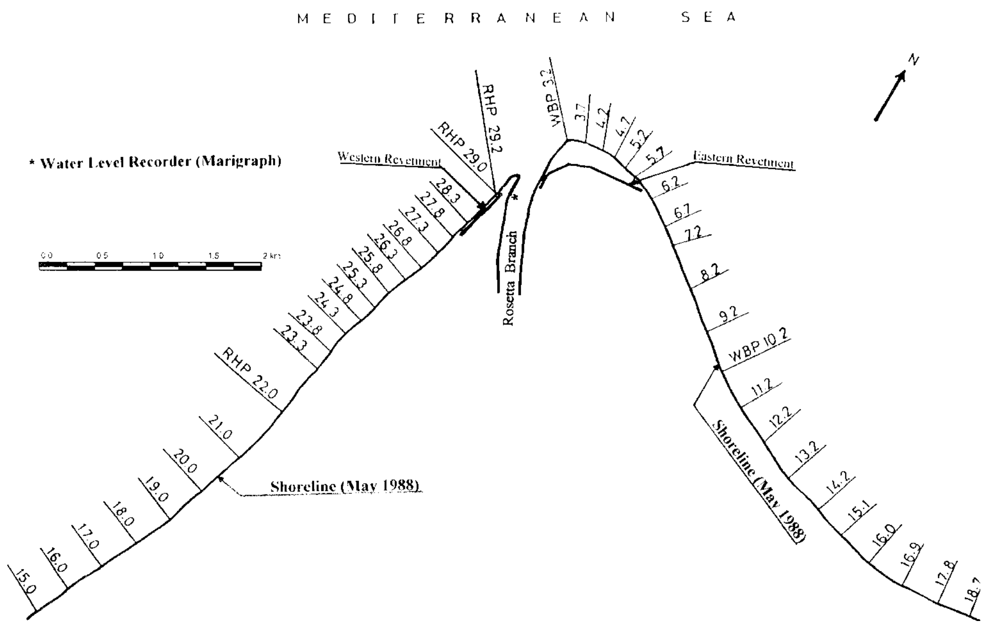

Figure 2. General layout of coastal profiles (after CRI, 1989).

was taking place because of the predominant long shore current (COASTAL RESEARCH INSTITUTE, 1996b).

Eastern Revetment

The 3.5-kilometer-long eastern revetment was constructed during the period 1988–91. The land remaining after construction was finished in 1991 in front of the eastern revetment and land at its eastern end eroded over the period 1991–95 for a distance of 2.5 kilometers. Farther to the east, an accretion region formed because of the predominant long shore current, which is to the east (COASTAL RESEARCH INSTITUTE, 1996b).

DATA COLLECTION

Since 1978, the Coastal Research Institute of Alexandria has carried out beach profile surveys in Rosetta Promontory twice a year. The first survey, in April/May, is destined to highlight trends related to the winter season, whereas the second survey, in September/October, shows trends associated with the summer season. Forty-two profiles are surveyed on the western and eastern parts of Rosetta Promontory, as shown in Figure 2. The profiles are surveyed to depths of up to 6 meters or distances of up to 1,000 meters, whichever is nearer to the shore, because of limitations in the equipment used. A total of 16 surveys were carried out from 1988 to 1995. Each profile was corrected for tidal variation. The Coastal Research Institute provided the data used in this study and are described in COASTAL RESEARCH INSTITUTE (1989, 1993, 1995a, 1995b, 1995c, 1996a, 1996b).

COMPUTER CODE FOR DATA ANALYSIS

To calculate volumetric changes for the study area, computer code was developed to compute the erosion and accretion volumes for each of the two hydrographic profile survey data sets. The computations are carried out as follows.

- The profile is divided into three zones (see Figure 3): (1) Zone i is the shore zone, which gives the effect of runup and surges during storms. (2) Zone ii depths range from 0 to 2 meters. This zone corresponds approximately to the breaking zone (CRI, UNESCO, and UNDP, 1978). (3) Zone iii depths range from 2 to 6 meters.
- Volumes are calculated for the above-mentioned zones with the use of both elevation difference and distance between profiles.

NUMERICAL MODEL FOR PREDICTING SEDIMENT TRANSPORT

A numerical model developed at the Danish Hydraulic Institute was used to predict the sediment transport volumes along Rosetta Promontory. This model consists of the following elements.

- The Nearshore Spectral Wind-Wave (NSW) module of the MIKE21 numerical modeling system was used to calculate waves at selected points near the locations of the profiles. The basic equations in the model are derived from the conservation equation for the spectral wave action density. A parameterization of this equation in the frequency domain is performed, introducing the zeroth and first moments of the action spectrum as dependent variables. This leads to the following coupled partial differential equations:

$$\frac{\partial(c_{gx}m_0)}{\partial x} + \frac{\partial(c_{gy}m_0)}{\partial y} + \frac{\partial(c_\theta m_0)}{\partial \theta} = T_0 \tag{1}$$

$$\frac{\partial(c_{gx}m_1)}{\partial x} + \frac{\partial(c_{gy}m_1)}{\partial y} + \frac{\partial(c_\theta m_1)}{\partial \theta} = T_1, \tag{2}$$

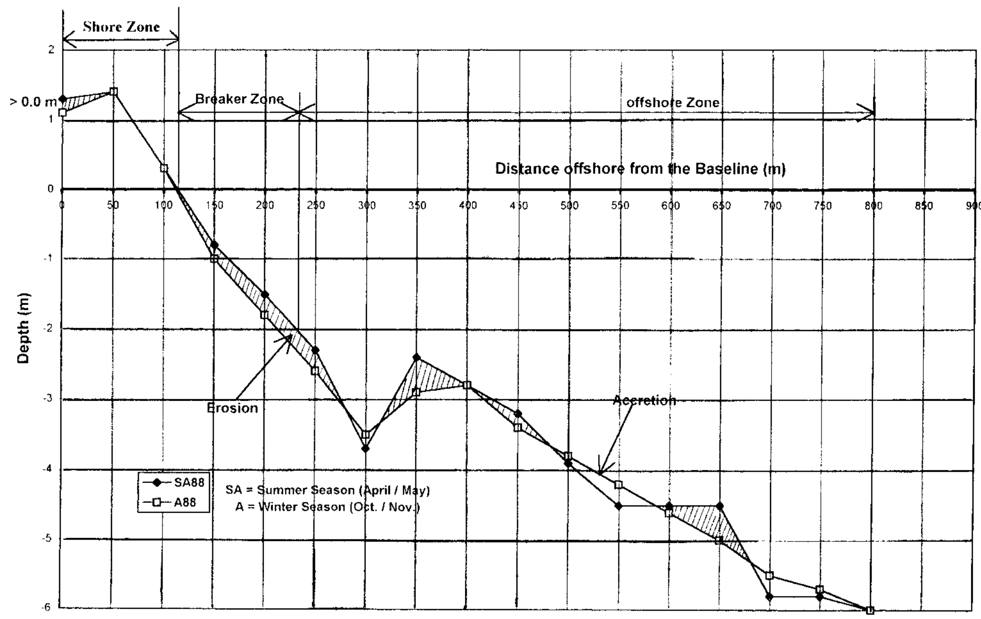

Figure 3. Volume calculations from the profile data.

where $m_0(x, y, \theta)$ is the zeroth moment of the action spectrum; $m_1(x, y, \theta)$ is the first moment of the action spectrum; C_{gx} and C_{gy} are components in the x- and y-direction, respectively, of the group velocity C_g; C_θ is the propagation speed representing the change of action in the θ-direction; x and y are Cartesian coordinates; θ is the direction of wave propagation; T_0 and T_1 are source terms. The moments $m_n(\theta)$ are defined as:

$$m_n(\theta) = \int_0^\infty \omega^n A(\omega, \theta)\, d\omega,$$

where ω is the absolute frequency and A is the spectral wave action density. The propagation speeds C_{gx}, C_{gy}, and C_θ are obtained with linear wave theory. The left-hand side of the basic equations takes into account the effects of refraction and shoaling. The source terms T_0 and T_1 take into account the effect of local wind generation and energy dissipation from bottom friction and wave breaking. The effects of currents on these phenomena are included.

- The LITDRIFT module of LITPACK is a one-dimensional numerical modeling system for calculating long shore sediment transport. This module consists of two major elements: (1) a hydrodynamic model and (2) a sediment transport model (STP).

The hydrodynamic model includes a description of wave propagation, shoaling, and breaking; calculations of the driving forces resulting from radiation stress gradients; momentum balance for the cross-shore and long shore direction, giving the wave setup and the long shore current velocities. It is assumed in the model that the contours are uniform and straight. Having computed the long shore current by the hydrodynamic module, sediment transport calculations were carried out by the STP module. After sediment transport calculation with the selected points, the transport is interpolated and integrated across the profile. The transport is assumed to vary linearly between the selected calculation points. The sediment transport capacity is converted from solid transport to volume by introducing the porosity

$$QS_{\text{volume}} = \frac{QS_{\text{solid}}}{(1 - \text{porosity})}. \qquad (3)$$

Detailed descriptions of the numerical models are given in the reference manuals (LITPACK, 1996; MIKE21, 1996).

DATA USED IN THE NUMERICAL MODEL

Wave Data

The available wave data are wave measurements obtained at a depth of 18 meters over the period 1985–90 off Abu-Quir station, 60 kilometers west of Rosetta Promontory (Figure 1). A relationship between deep-water wave climate and near-shore wave climate is established by applying various wave conditions in deep water and calculating the corresponding wave climate at Abu-Quir station with the NSW module. The wave climates at six locations are obtained with the relationship between deep water conditions and Abu-Quir station. Figure 4 shows the locations of the wave climate points used to calculate long shore sediment transport. Table 1 gives the annual average frequency of wave climate off Abu-Quir station over the period 1985–90.

Bathymetry

Six profiles were selected to calculate the sediment transport rate. The six selected profiles cover both the western and the eastern sides of the study area. The profiles were taken

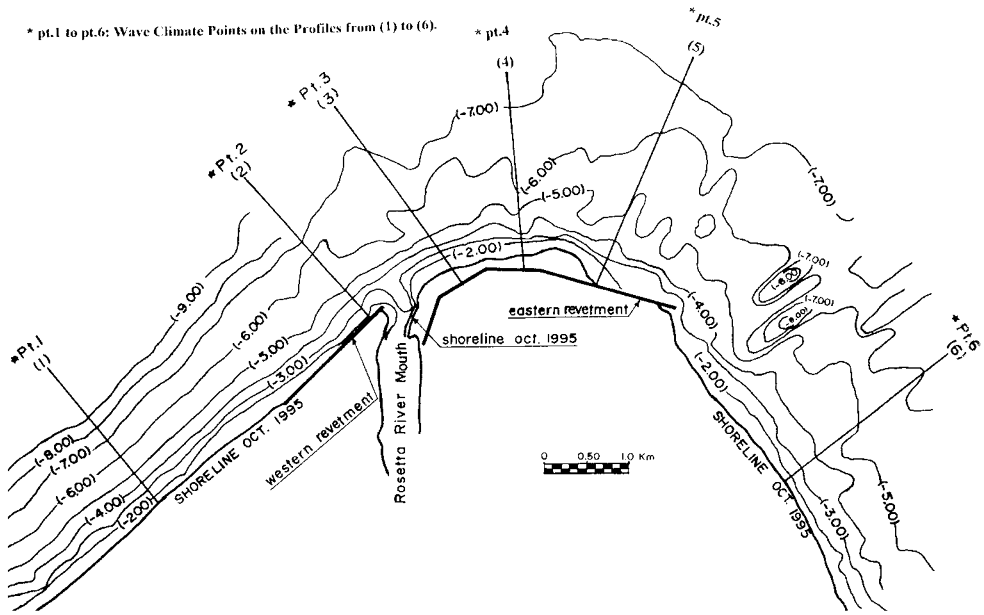

Figure 4. Locations of the predicted wave climate points and coastal profiles for the numerical model.

from a bathymetric survey by the Egyptian Shore Protection Authority (SHORE PROTECTION AUTHORITY, 1995).

Grain Size

The Coastal Research Institute of Alexandria measures the grain size distribution along the profiles, and the data concerning the bottom samples are given in COASTAL RESEARCH INSTITUTE (1996b). The mean grain size of the coastal sediments along Rosetta Promontory shows a tendency to decrease seaward. It averages from 0.15 to 0.27 millimeter for beach sediments and from 0.10 to 0.17 millimeter for sediment samples from 0 to 6 meters depth.

RESULTS OF THE ANALYSIS

Volumetric Calculations

Western Rosetta Promontory

During the period 1988–95 for all profiles from the shoreline to a depth of 6 meters, the eroded and accreted volumes were 32.2×10^6 cubic meters and 34.9×10^6 cubic meters, respectively, with a net accretion value of 2.7×10^6 cubic meters and a total gross sediment volume of 67.1×10^6 cubic meters. Figure 5 gives the net volume of sediments for the western side of Rosetta Promontory.

Table 1. *Annual average frequency of wave climate off Abu-Quir station over the period 1985–1990.*

Wave Direction (degrees)	Wave Height (m)				
	0–0.5	0.5–1.0	1.0–1.5	1.5–2.0	>2.0
270–292.5	1.75	5.33	3.72	2.48	2.57
292.5–315	3.67	11.17	8.7	5.82	3.77
315–337.5	2.92	10.92	8.93	4.78	4.54
337.5–0	3.29	4.6	1.57	0.67	1.17
0–22.5	2	2.31	0.53	0.23	0.05
22.5–45	1.43	0.55	0.21	0	0
45–67.5	0.32	0	0	0	0

Eastern Rosetta Promontory

Over the period 1988–95, the eroded and accreted volumes were 51.3×10^6 cubic meters and 45.9×10^6 cubic meters, respectively, with a net erosion value of 5.4×10^6 cubic meters. The total gross volume of sediments was about 97.2×10^6 cubic meters, which was much larger than the net volumes. Figure 6 shows the net volume of sediments for the eastern side of Rosetta Promontory.

Long Shore Sediment Transport Calculations

With the calculated wave climates at the six selected points, the selected profiles, and the grain size distribution along the profiles, the numerical model was used to simulate the annual net sediment transport for both sides of Rosetta Promontory.

The calculated annual net drift for the eastern side of Rosetta was 0.9×10^6 cubic meters and 1.5×10^6 cubic meters for the western side of Rosetta.

Rosetta Subzones

Rosetta Promontory was divided into four subzones, regions (A, B, C, and D). Figure 7 shows the subzones of the study area, and Figure 8 shows the yearly average net depths over the period 1988–95 for each subzone.

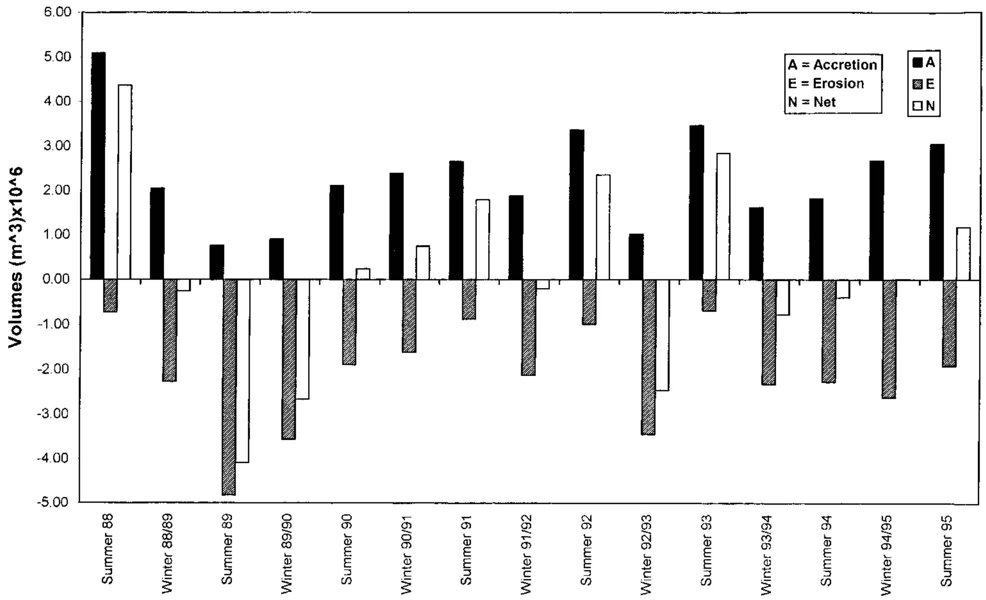

Figure 5. Net volume of sediments along the western side of Rosetta Promontory for 0–6 meter depths over the period 1988–95.

Shoreline Changes

Shoreline changes calculated over the study period (1988–95) are shown in Figure 9.

DISCUSSION

Western Rosetta Promontory

The temporal variation of the net volumes for different seasons over the period 1988–95 is given in Figure 5. The seasonal variation in the volume of sediments is a result of the local conditions in the study area. The large accretion value in summer 1988 was due to an artificial sediment recharge covered by dolos blocks to form an embankment aimed at facilitating the construction of the revetment. In contrast, the large erosion volumes recorded over the period from winter 1988/1989 to summer 1990 were due to erosion of this artificial embankment after the protective structures were constructed and the temporary dolos blocks removed. Between

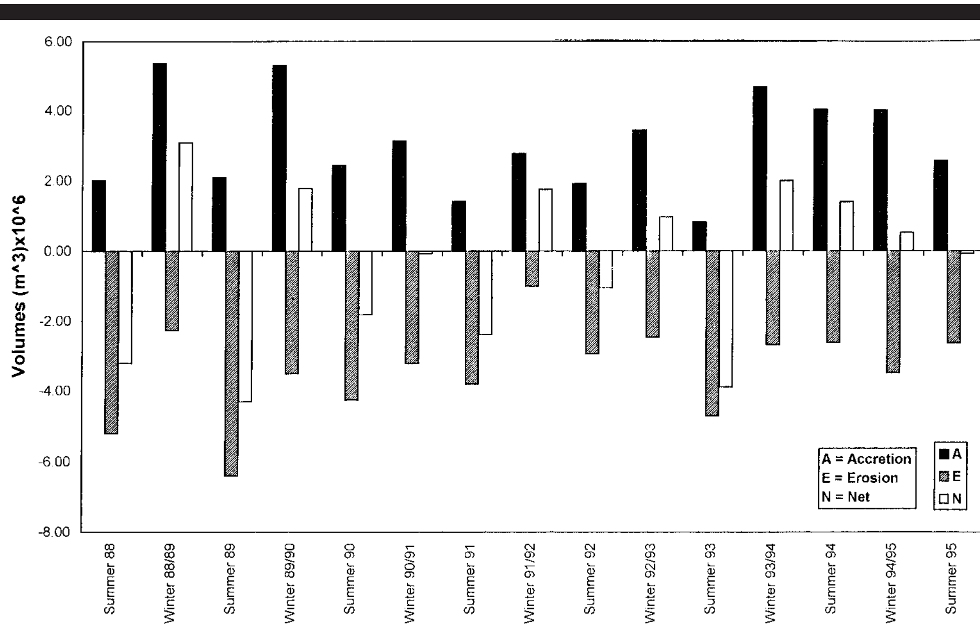

Figure 6. Net volume of sediments along the eastern side of Rosetta Promontory for 0–6 meter depths over the period 1988–95.

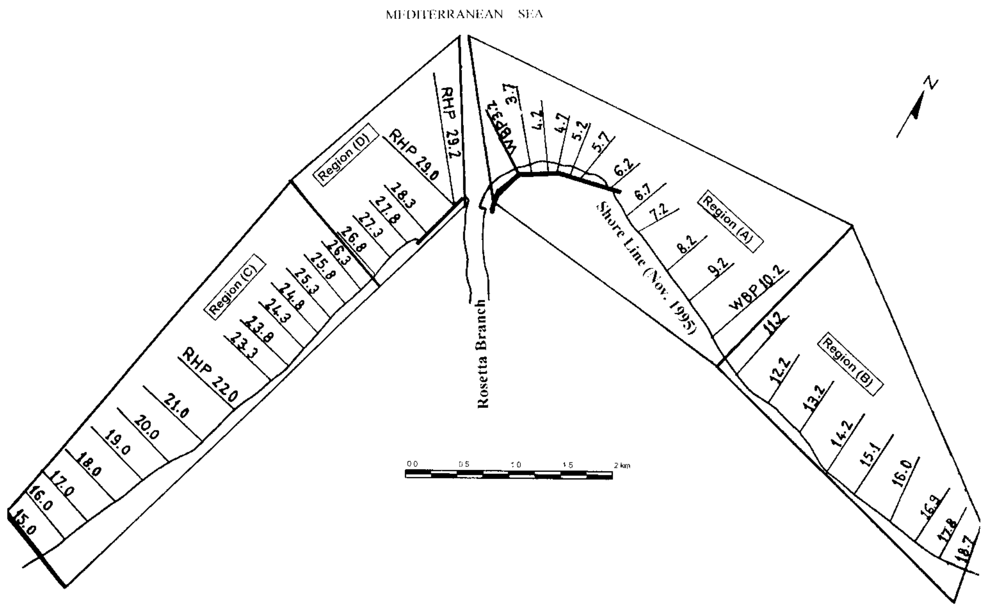

Figure 7. Rosetta Promontory subzones.

winter 1990/1991 and summer 1993, accretion exceeded erosion because of dredging of the Rosetta outlet, which released fine sediments transported in suspension southward by the long shore currents.

Eastern Rosetta Promontory

The temporal variation of the net volumes for different seasons over the period 1988–95 is given in Figure 6. The seasonal variation in the volume of sediments is due to the local conditions in the study area, such as excavation for the construction of the revetments and their interactions with waves and currents and subsequent deposition of dredged sediments transported to the east by long shore currents.

Rosetta Subzones

According to the analysis of the results, Rosetta Promontory can be divided into four subzones with respect to the type of motion (accretion or erosion), as shown in Figure 7. The yearly average net depth change for depth ranges of 0–2, 2–

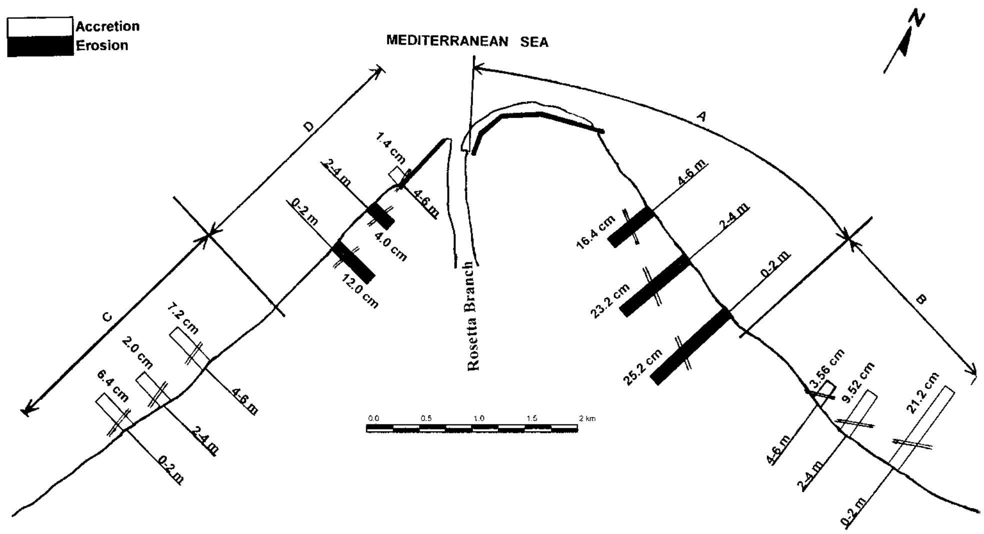

Figure 8. Yearly averages of net depth change over the period 1988–95 for Rosetta Promontory subzones.

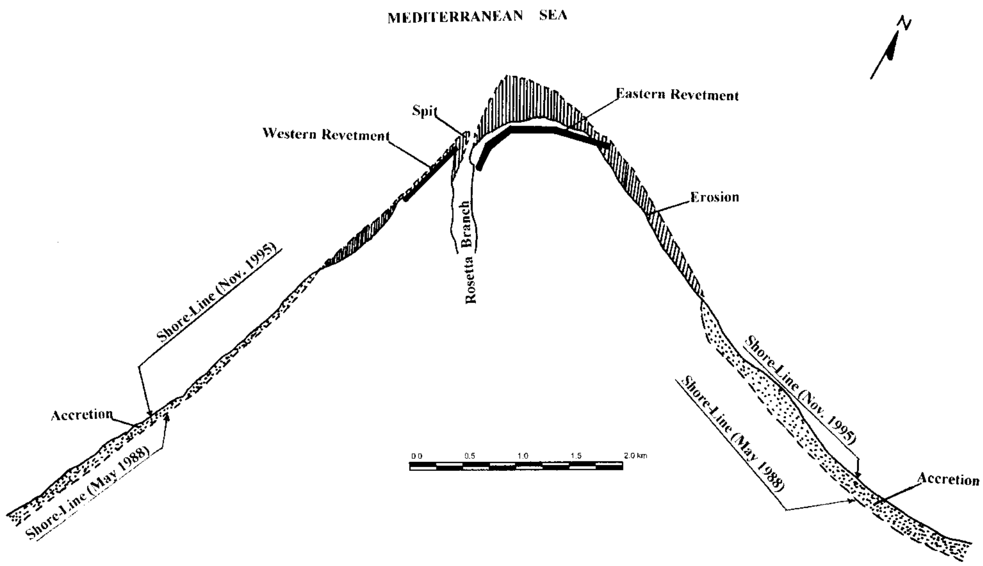

Figure 9. Comparison of shoreline changes over the period 1988–95 for Rosetta Promontory.

4, and 4–6 meters of each subzone over the period 1988–95 are given in Figure 8. We observed that:

- In region A, the erosion depths are 25.2, 23.2, and 16.4 centimeters for depth ranges of 0–2, 2–4, and 4–6 meters, respectively. Therefore, the erosion depth for the breaker zone is greater than the erosion depths of the other two zones because the maximum effect of the waves is in the breaker zone.
- In region B, the accretion depths are 21.2, 9.5, and 3.6 centimeters for depth ranges of 0–2, 2–4, and 4–6 meters, respectively. Hence, the largest accretion depth was in the breaker zone because of the predominant littoral drift.
- In region C, the accretion depths are 6.4, 2.0, and 7.2 centimeters for depth ranges of 0–2, 2–4, and 4–6 meters, respectively. So, the largest accretion depth was in the 4–6 meter zone because of the on/offshore movement of the sediments.
- In region D, the erosion depths are 12.0 and 4.0 centimeters for depth ranges of 0–2 and 2–4 meters, respectively, whereas the accretion depth is 1.4 centimeters for 4–6 meters depth because the eroded sediments were moved offshore by currents beyond the breaker zone.

Shoreline Changes

The resultant change of the Rosetta Promontory shoreline during the study period is given in Figure 9. It can be noticed that, erosion was taking place at the end of the construction of the revetments, followed by accretion. Overall, however, the revetments are not adequate in resolving the erosion problem of Rosetta Promontory because they protect a limited stretch of the shoreline. The consequence of these revetments is the classic downdrift transfer of the erosion problem.

Calculated versus Predicted Volumes

A comparison between the computer-calculated volumes and the predicted volumes from the numerical models showed that:

- The calculated annual net drift for the eastern side of Rosetta was 0.53×10^6 cubic meters for 0–2 meters depth, which is approximately the breaker zone (CRI, UNESCO, and UNDP, 1978). The predicted annual net drift amounted to 0.9×10^6 cubic meters.
- The calculated annual net drift for the western side of Rosetta was 0.26×10^6 cubic meters for 0–2 meters depth, whereas the predicted annual net drift was 1.5×10^6 cubic meters.

Thus, the predicted and computed values are not in good agreement. The difference between the calculated and the predicted volume is attributed to the following factors. (1) The numerical model assumes parallel and straight contour lines. (2) The western revetment was exposed to the sea (*i.e.,* no land in front of it) and the model does not take into account the effect of diffraction. (3) The shape of the promontory could give rise to some zones of separation and associated circulation currents. Easterly wave-induced and tidal currents might separate on the east side of the promontory because of large changes in coastal orientation. These processes are highly two-dimensional, and it would require a two-dimensional model such as MIKE21 to investigate them in detail.

CONCLUSIONS

The main findings of this study are summarized as follows.

- Rosetta Promontory can be divided into four subzones according to type of motion (accretion or erosion).

- The computations of the yearly average net depth change for depth ranges of 0–2, 2–4, and 4–6 meters for each subzone over the period 1988–95 show two distinct regions of erosion and accretion, on both the east side and west side of the promontory.
- The Rosetta Promontory shoreline is unstable.
- The revetments are not sufficient to overcome the problem of erosion because they protect a limited reach of the promontory.
- The main consequence of these revetments is that of transferring the problem of coastal erosion downdrift.
- Further investigations should be carried out to envisage more appropriate solutions to the erosion problem affecting Rosetta Promontory. Both hard solution (groin, breakwater) and softer alternatives (beach nourishment) should be considered.
- A reestablishment of some degree of the natural hydrologic conditions affecting the Nile River and Delta would be the only possible way for the deltaic system to assure an adequate sediment input to the deltaic plain. Such a sediment input is necessary to mitigate subsidence and offset coastal erosion (STANELY and WARNE, 1998). As these workers have suggested, for the Nile Delta to become a functional Delta once again, it is necessary to reduce, substantially, anthropogenic impacts.

LITERATURE CITED

COASTAL RESEARCH INSTITUTE, 1989. Shoreline Changes of Rosetta Promontory. Alexandria, Egypt: Coastal Research Institute Progress Report 3.

COASTAL RESEARCH INSTITUTE, 1993. Shoreline Changes of Rosetta Promontory during September, October and November 1990. Alexandria, Egypt: Coastal Research Institute Progress Report 7.

COASTAL RESEARCH INSTITUTE, 1995a. Shoreline Changes of Rosetta Promontory during April, May and June 1994. Alexandria, Egypt: Coastal Research Institute Progress Report 14.

COASTAL RESEARCH INSTITUTE, 1995b. Shoreline Changes of Rosetta Promontory during October, November, December 1994, and January 1995. Alexandria, Egypt: Coastal Research Institute Progress Report 15.

COASTAL RESEARCH INSTITUTE, 1995c. Shoreline Changes of Rosetta Promontory during April/June 1995. Alexandria, Egypt: Coastal Research Institute Progress Report 16.

COASTAL RESEARCH INSTITUTE, 1996a. Shoreline Changes of Rosetta Promontory during September, October and November 1995. Alexandria, Egypt: Coastal Research Institute Progress Report 17.

COASTAL RESEARCH INSTITUTE, 1996b. Report on changes of Rosetta estuary outlet and evolution of Rosetta Promontory. Alexandria, Egypt: Coastal Research Institute Progress Report 18.

[CRI, UNESCO, and UNDP] COASTAL RESEARCH INSTITUTE; UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION, and UNITED NATIONS DEVELOPMENT PROGRAMS, 1978. Coastal protection studies. Final Technical Report I and II. Cairo, Egypt: UNDP.

EL-SERAFY, S.Y., 1994. Morphological Changes of the Nile Sub-delta Rosetta. Braunschweig, Germany: Technical University Carolo-Wilhelmina of Braunschweig, Doctoral thesis, 90p.

FANOS, A.M.; NAFFAA, G.M.; GEWILLI, M.Y., and ALI, M.M., 1995a. Long and short term changes of Rosetta Promontory, Egypt. *Proceedings of the International Conference on the Mediterranean Coastal Environment.* Tarragona, Spain: MEDCOAST.

FANOS, A.M.; NAFFAA, G.M.; GEWILLI, M.Y., and ALI, M.M., 1995b. Erosion of Rosetta Promontory, the Nile delta, Egypt. International Conference on Coastal and Port Engineering in Developing Countries. September, 1995, Rio de Janeiro, Brazil.

FRIHY, O.E.; NASR, S.M.; AHMED, M.H., and ELRAEY, M., 1991. Temporal shoreline and bottom changes of the inner continental shelf of the Nile delta, Egypt. *Journal of Coastal Research,* 7(2), 465–476.

INMAN, D.L and JENKINS, S.A., 1984. The Nile littoral cell and man's impact on the coastal zone of the south-eastern Mediterranean. *Proceedings of the 19th Conference in Coastal Engineering,* Houston, Texas: ASCE, pp. 1600–1617.

KADIB, A.A., 1969. Sand movement along a portion of the northern coast of United Arab Republic. *22nd International Navigation Congress,* Section 2, pp. 273–287.

LITPACK, 1996. *Littoral Drift, LITDRIFT: Long Shore Sediment Drift,* Release 2.1, *User's Guide and Reference Manual.* Copenhagen, Denmark: Danish Hydraulic Institute.

MIKE21, 1996. *Near Shore Spectral Wind-Wave Module,* Release 2.4, *User's Guide and Reference Manual.* Copenhagen, Denmark: Danish Hydraulic Institute.

MOBAREK, I.E., 1972. The Nile Delta coastal protection project. *Proceedings of the 13th Coastal Engineering Conference*, Houston, Texas: ASCE, pp. 1409–1426.

NIELSEN, E.V., 1977. Shore evolution. *In:* COASTAL RESEARCH INSTITUTE; UNITED NATIONS EDUCATIONAL, SCIENTIFIC, AND CULTURAL ORGANIZATION; and UNITED NATIONS DEVELOPMENT PROGRAMS (eds.), *Proceedings of the Seminar on Nile Delta Coastal Processes.* Cairo, Egypt: Academy of Scientific Research and Technology, pp. 15–59.

SHORE PROTECTION AUTHORITY, 1995. Rosetta Promontory Monitoring Survey. Cairo, Egypt: Shore Protection Authority Report 18.

SOGREAH, 1984. Coastal Protection of Rosetta Shoreline. Cairo, Egypt: Ministry of Public Works Report For Shore Protection Authority.

STANELY, D.J. and WARNE, A.G., 1998. Nile delta in its destruction phase. *Journal of Coastal Research,* 14(3), 794–825.

TETRA-TECH, 1984. Shore Protection Master Plan for the Nile Delta Coast. Cairo, Egypt: Ministry of Public Works Report For Shore Protection Authority.