Coastal changes along Rosetta promontory

Abdel Moneim A. Badr, Farid A. Abdella and Ahmed I. El-Kolfat
Coastal Research Institute, El.Shallalat, Alexandria,Egypt

Rosetta promontory is subjected to severe erosion during the past 4 decades. This erosion has been increased since the construction of the High Aswan Dam in 1964. The length of the Rosetta promontory was reduced by about 5 km during the period from 1909 up to the year 2000. The shoreline changes astride Rosetta branch are depicted after analyses of 20 bathymetric profiles to water depths of 6m and extending about one kilometer from the shore. Comparison among these profiles in terms of changes in water depth and volumetric changes in bottom sediments, identifies areas of erosion and accretion. These changes are generally due to long-term sediment movement in which most of the accreted sediments come from eroded Rosetta tip as well as from offshore sources.

يتناول هذا البحث نتائج التغيرات طويلة المدى منذ عام ١٩٠٩ وحتى عام ٢٠٠٠ والتى طرأت على شواطئ دلتا نهر النيل (رشيد) خصوصا بعد انقطاع وصول طمي النيل الى البحر بعد إتمام إنشاء المرحلة الأولى للسد العالي ١٩٦٤ ومنذ ذلك الحين زاد معدل التآكل وحدوث حالة من عدم الاستقرار ويوضح هذا البحث حساب معدلات تآكل اللسان الشرقي والغربي لفرع رشيد . وأن كمية الرواسب المتحركة من مقدمة اللسان ناحية البحر قد ترسبت على طول الساحل الشرقى والغربى وعلى مسافة عشر كيلومترات شرقآ و غربآ.

Keyward: Nile delta, Rosetta promontory, Erosion, Accretion, Sediment, Shoreline

1. Introduction

The Nile Delta Coast is of particular interest to marine scientists and coastal engineers at this time because the last four decades sediment discharge of River Nile water into Mediterranean has been effectively prevented by the construction of the Aswan High Dam. In its present state, the Nile Delta can be considered as a non-stationary coastal marine system subjects to shore and bottom processes due to the action of waves, currents, winds and sea-level variations on sediments available for transportation.

It is of importance to consider the present Nile Delta Coast, that is, a feature that has developed through the coast retreat. The continental shelves of the world have been submerged by the rise of the sea level resulting from the melting of the Pleistocene continental glaciers. The sea level was approximately 120m lower during the Pleistocene – Holocene regression and rose to its present level about 20,000 years ago [1]. At the end of the Pleistocene, old Nile branches during their sediments directly northward to the beach existing at that time when the shelf was sub aerially exposed. Silts and clays were carried away by long-shore currents and were dispread seaward, while sand-size sediments were carried along parallel to the coast by littoral drift. With the subsequent rise, the sea advanced and the coast retreated. The Nile Delta was formed during thousands of years from the continuous discharge of large quantities of sediments into the Mediterranean Sea. The Greek historian Herodotus noted that there were seven active branches of the Nile, fig. 1 [2-4]. These branches had been silted up and replaced by the two present ones; the Rosetta and Damietta branches. These two marine branches developed the Rosetta and Damietta promontories, which progressed during Holocene times into the Mediterranean Sea [5].

The Rosetta promontory seems to have grown actively since the ninth Century and up to the 20th Century and extended seaward by 14km [6]. Since the beginning of the 20th Century dramatic erosion has occurred along some parts of the Nile Delta Coast [7-11].

The present paper aims to:

1. Describe the changes taking place in the Rosetta promontory, and

2. Estimate the volumetric changes of the accretion and erosion in near shore sediments astride Rosetta branch by analyzing the successive annual surveys for the periods 1988-1996 and 1990- 1996.

2. Techniques

2.1. Dynamic factors affecting the coast

The dynamic factors of the processes that influence the shape of the Nile Delta coast, and its offshore and near-shore areas are the same as those found in other deltas, except that they differ in intensity and magnitude.

After 1964 the Nile flow and the Nile sediment became partly unavailable to the coast. Therefore, the effect of the hydrodynamic factors may be increased on the coastal sediments.

Wind plays an important role in the processes that form the inland coastal areas. Waves and currents induced by them and to a lesser extend, those resulting from tides or winds are the primary agents causing transportation and deposition of coastal sediments and therefore changes in the coastal processes.

Most of the energy driving near-shore processes along delta coast comes from the Mediterranean Sea in the form of wind, waves, current and sea level variation.

The wave parameters were obtained from the statistical analysis of recorded data measured by a directional wave recording system termed Cassette Acquisition System (CAS), during 1986.

The direction and strength of wind play an active role in controlling the processes that form the inland coastal areas. Hourly measurement of wind speed, and direction at Rosetta during 2003, carried out by the (Auto Met Data Logger), measurement

Current in the coastal areas are important factors in the transporting sediment along the coast or in the on/offshore direction, they are also causing the mixing between the off-shore zone and the surf-zone.

Long-shore currents were measured between the breaker line and the shoreline (at water depth ranging between 1.3m &1.5m). The measurements were carried out at 2 local stations (west & east of Rosetta promontory), during 1995. It is speed and direction were calculated by measuring the time taken by the conical float with across, to travel between two point 20 meter a port, make on the shore by four poles.

The recorded data of water level changes were measured at Rosetta by use of STRIP chart water level recorded type DELTA, during 1994. The recorded are related to the zero survey level of the Egyptian survey authority.

2.2. Hydrographic survey

The Coastal research Institute has been conducting hydrographic surveys for the near-shore zone from of 20 cross-section from a point 14 km west of Rosetta branch to a point of 16 km east of Rosetta branch fig. 1. The spacing varies between the profiles from 0.5 km to 8 km depending upon the nature of the shoreline. The hydrographic profiles in serial numbers from west to east can be summarized as follows:

1-West Rosetta branch: 8 near-shore profiles and designate RHP 1 to 8, and,

2- East Rosetta branch: 12 near-shore profiles and designate WBP 9 to 20.

The near-shore profiles extend seaward from beach up to 6-meter depth or to 1 km from shoreline whichever is nearer to the coast. Beach profiles, are extend land ward from the mean low water level for some distance on the mainland (baseline). The soundings are taken every 10m up to a distance of 250m and then every 50m. Change in depth contour is highly affected by variations in the wave climate. Therefore, annual surveys were conducted at the same time of the year (October-November) for the periods 1988-1996 at the western side of Rosetta branch and 1990-1996 at the eastern one.

3. Results and discussion

3.1. Waves

Waves climate were studied, monthly and for the whole period on the main 16

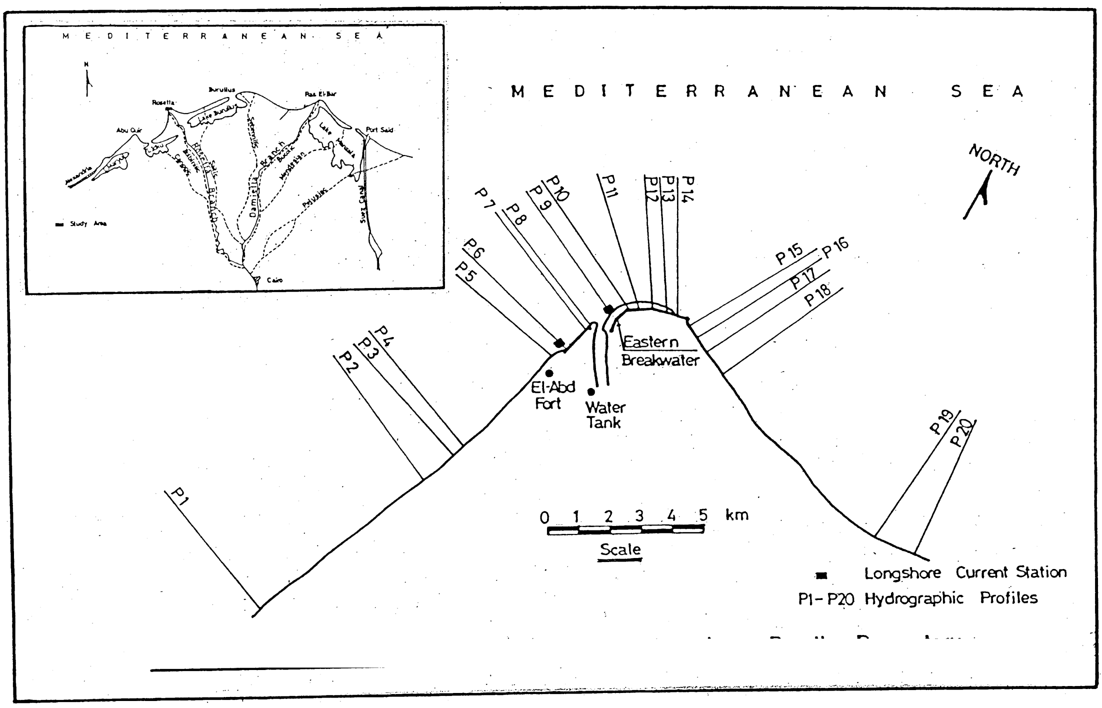


Fig. 1. General map of field measurements along Rosetta promontory.

direction (N,NNE.......NNW), from fig. 2, 3, we deduced the following.

1. The main wave direction is mainly from NW for all months with few exception, with a percent (39.4%) for the whole period.
2. The maximum wave height is observed during October, with a value 4.8m, from a NW direction.
3. The maximum average wave height is observed during June, (1.2m), and the minimum ones during September (0.68m).
4. The average wave height during the whole study period is 0.89m.

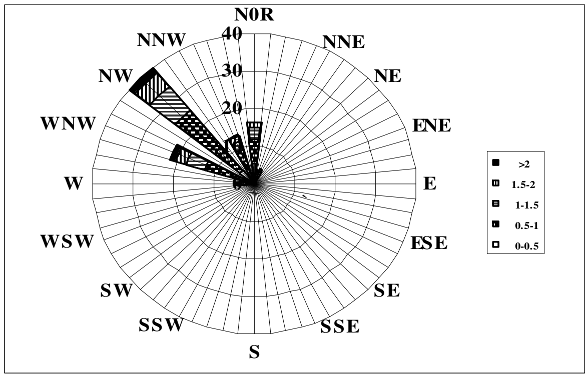


Fig. 2. Wave rose during 1986.

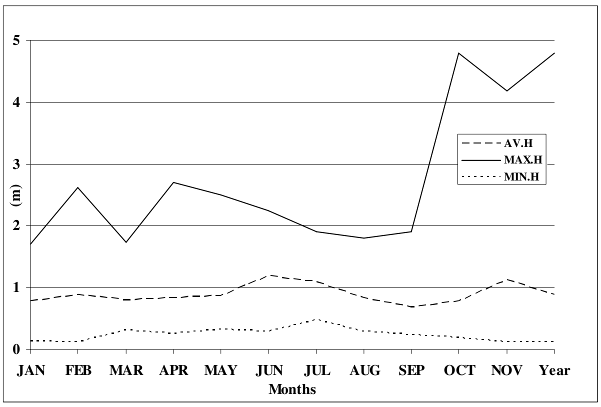


Fig. 3. The results of statistics wave data during 1986.

3.2. Wind

Wind speed and direction were studied monthly and for the whole period, the following was found:

1. The predominant wind direction was from NW with a percent 21.8% for the whole study period, fig. 4.
2. The maximum wind speed observed during December with a value of 15.4m/sec.from a W direction.
3. The maximum mean monthly wind speed is 6.2 m/sec during December, and the minimum ones is 4.7m/sec during October.

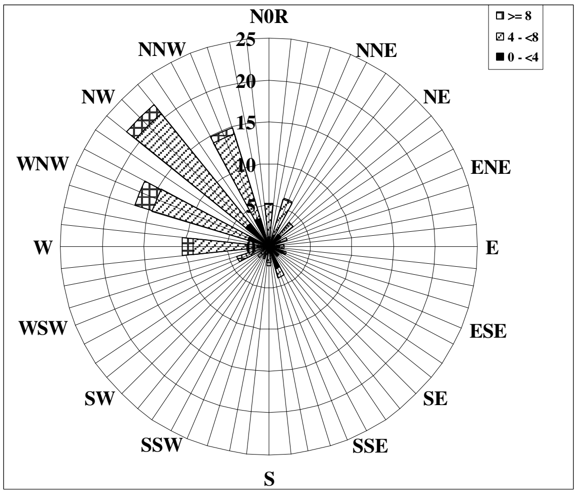


Fig. 4. Wind Rose of Rosetta during year 2003.

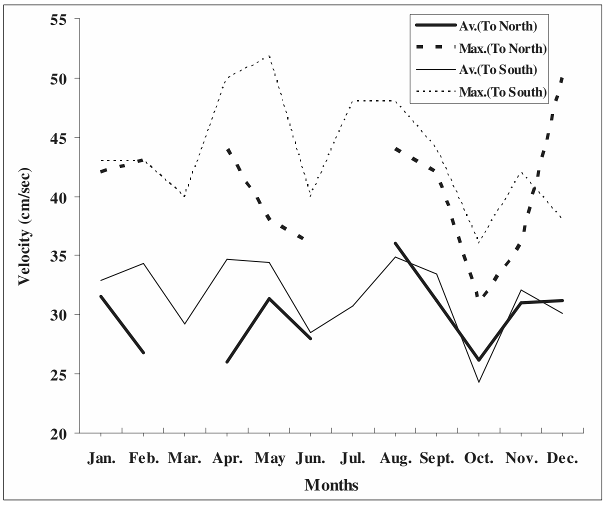


Fig. 5-a. The average & maximum longshore current velocity at western side of Rosetta promontory during year 1995.

4. The mean wind speed during the study period was 5.2m/sec.

3.3. Long-shore current

Current in coastal areas are important factor in the transport of sediments along coastline and in interchanging water and sediment between offshore and surf-zones.

The collected data for long shore current during 1995, have been subjected to monthly and yearly statistical analysis to determine the probability distribution of long shore currents & figs. (5-a, b, c and d), show the following.

2. The predominant direction of long-shore current in the study area is from North to South in the western side and from west to east in the eastern side of Rosetta promontory. This induce from the predominant wave direction and the shoreline configuration in the two stations except during March, September and, December in the eastern side in which the current reverses its direction.

3. As expected, littoral current velocity are higher during winter months than those in other months, due to the stormy waves prevailing during winter and swells in summer season.

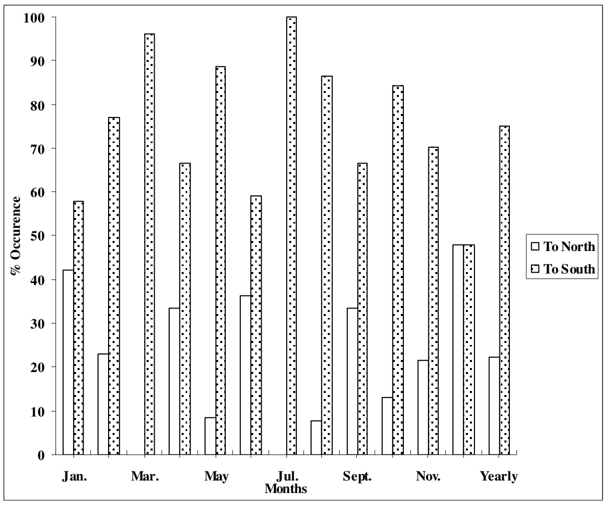


Fig. 5-b. The percentage of occurrence for longshore current direction at western side of Rosetta promontory during year 1995.

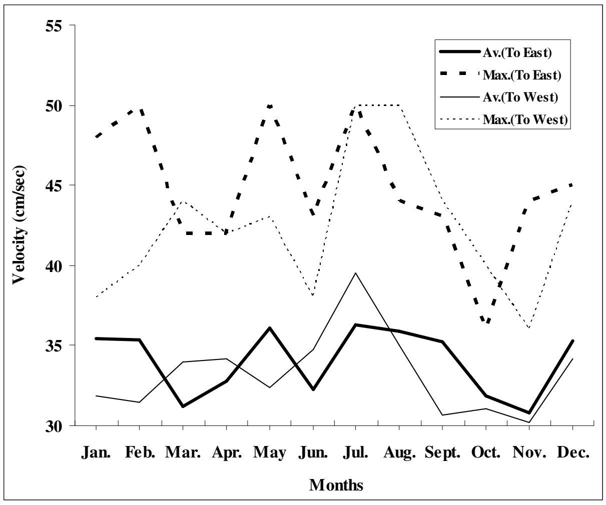


Fig. 5-c. The average & maximum longshore current velocity at eastern side of Rosetta promontory.

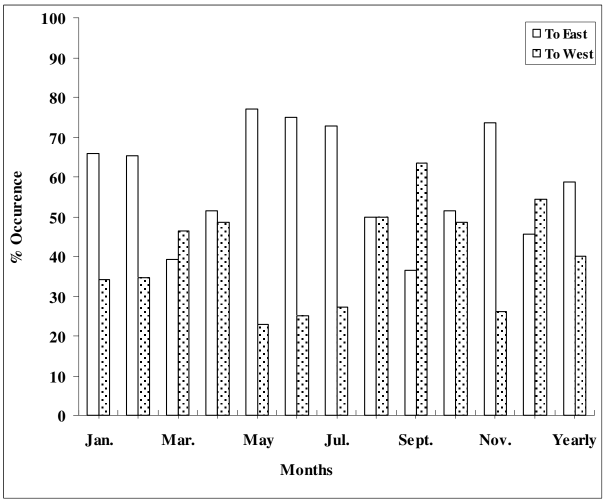


Fig. 5-d. The percentage of occurrence for longshore current direction at eastern side of Rosetta promontory during year 1995.

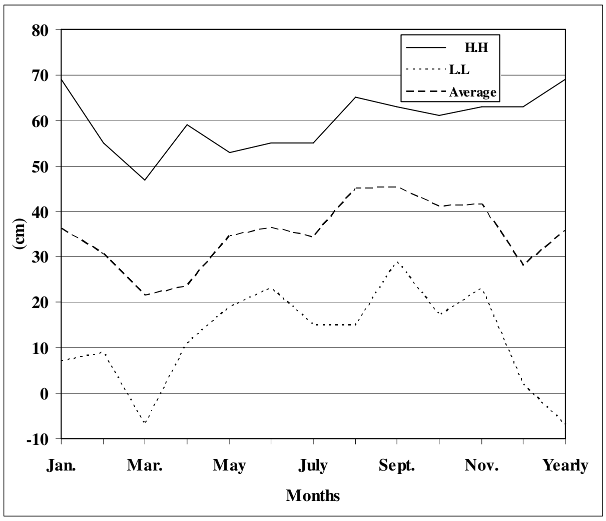


Fig. 6. The result of sea level change at Rosetta area during 1994.

3.4. Sea level variation

Statistical analysis of daily variation of sea level recorded (related to zero survey) at study area during 12 months, fig. 6, yield the following:

1. Maximum monthly mean sea level is 45.3cm (September), and minimum ones are 21.5cm (march).
2. The tidal range during the study period is 76cm.
3. The maximum water level was 69cm above the survey authority datum and it happened in January, while the minimum water level was -7cm and it happened in March.

3.5. Rosetta promontory and volumetric changes

The erosion of Rosetta promontory (located some 50 km to the east of Alexandria, started about the time of construction of the Aswan low Dam (1902). This has been well documented and thoroughly studied by many investigators [10, 12, 13].

Fig. 7 shows shore line positions at various times. The erosion rates for the western and eastern part of Rosetta headland for the periods 1909-1996 are illustrated in fig. 8. The old Rosetta lighthouse, which was 950m inland from the tip of the western part in 1889, became isolated in the sea in 1942.

Table 1
Decrease in maximum length (m/yr)astride Rosetta branch (1909 – 1996)

Period	Rate (m/yr)	
	Western side	Eastern side
1909 – 1926	21	21
1926 – 1941	17	17
1941 – 1964	39	30
1964 – 1971	86	107
1971 – 1981	250	135
1981 – 1987	42	116
1987 – 1990	33	67
1990 – 1994		150
1994 - 1996		150

reason for this erosion is the reduction in sediment supply through the Rosetta branch of the River Nile which, prior to dam construction, was estimated to be approximately $13x10^6$ m^3 of sand annually [6].

The erosion of coastal areas astride Rosetta branch was calculated from the beginning of erosion in 1909 to 1996, fig 8. The area of erosion is estimated by comparing the shoreline of different dates and the rate of erosion for each period is obtained. The loss of coastal lands was about 2.6 and 16.5 $x10^6$ m^2 for the western and eastern sides of Rosetta branch, respectively. Its observed, that the rate of erosion ranged between 0.01-0.02 x 10^6 m^3/year and 0.01-0.1 x 10^6 m^3/year for the period of 1909- 1964, and then suddenly attained its value, of 0.07 x 10^6 m^2/year, and

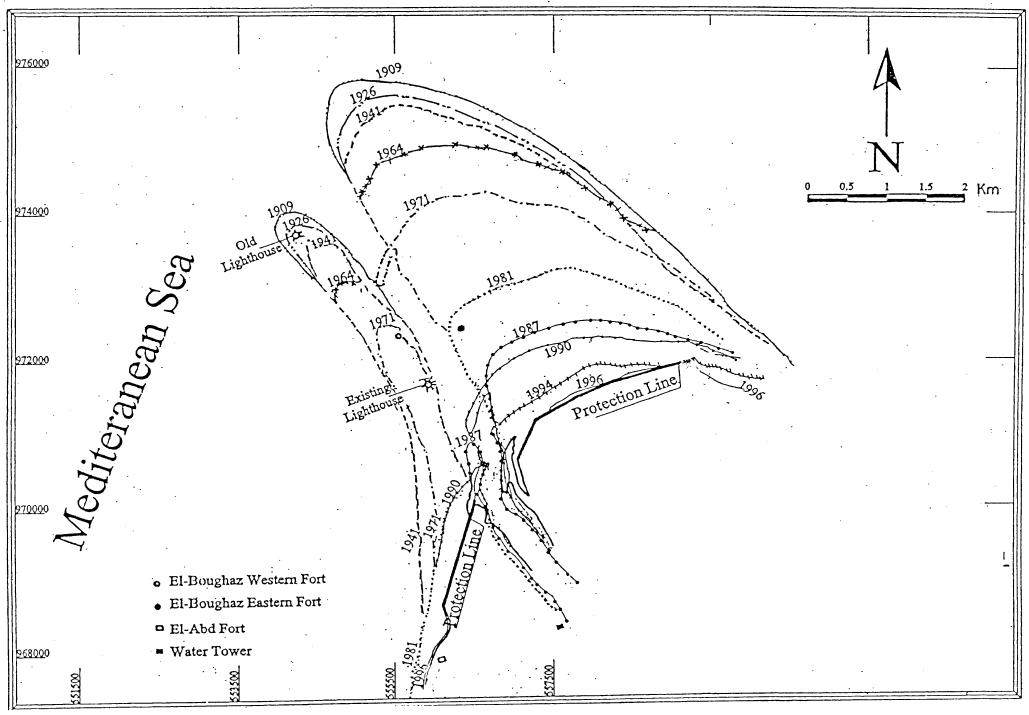


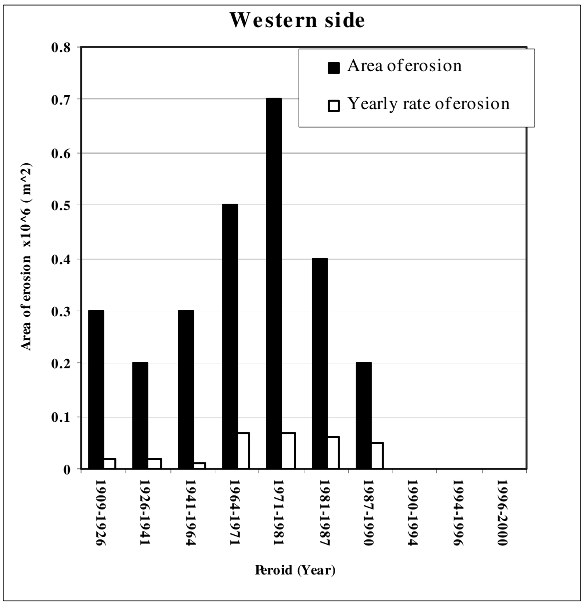
Fig. 7. Shore-line changes at Rosetta during the period from 1909 to May 2000.

0.53 x 10^6 m^2/ year for the period of 1964-1971 along the western and eastern sides of Rosetta branch, respectively.

Such highest rate of erosion can be related to the construction of the Aswan High Dam, closed off in 1964. The rate of erosion is gradually decreased from 0.42 x 10^6 m^2/year to 0.2 x 10^6 m^2/year along the eastern side of Rosetta branch and from 0.07 x 10^6 m^2/year to 0.05 x 10^6 m^2/year along the western one for the period of 1971-1990. Suddenly, an increase in the rate of erosion along the eastern side is observed (0.50 x 10^6 m^2/year), as a side effect, after the construction of Rosetta seawall as protective works in 1989-1991. This is because the sediments of the eastern part in front of the seawall is still exposed to the waves while the western part is protected by the western seawall which is acting with the waves and currents. The western side of Rosetta branch is protected by a seawall of 1.5km length and the northern end of the eastern one by a seawall of 3.5km length. The sea has reached the western structures and to date is performing well. The decrease in maximum length from the extremity of the point was estimated for western and eastern sides of Rosetta branch table (1) and, fig. 9. Rosetta headland shows shore retreat ranged between 21-39 m/year and 21-30 m/year along western and eastern sides for the period 1909-1964. It tended to greatly increase after the construction of the Aswan High Dam.

The short-term change has been studied by analyzing the 20 nearshore hydrographic profiles, covering the Rosetta promontory. They are used to follow up the movement of the different contour lines as well as to calculate the volumetric changes taking place. The complete analysis of the profile data shows that remarkable erosion is taking place on the tip of Rosetta promontory along its both western and eastern parts. The results of volumetric changes of Rosetta promontory are summarized as follows:

1. Volumetric changes during 1988-1996 along the western side of Rosetta branch. Each two annual surveys for each profile were drawn together to make the comparison easy, fig. 10. Established volumetric changes based on 2 years of surveys are given for the



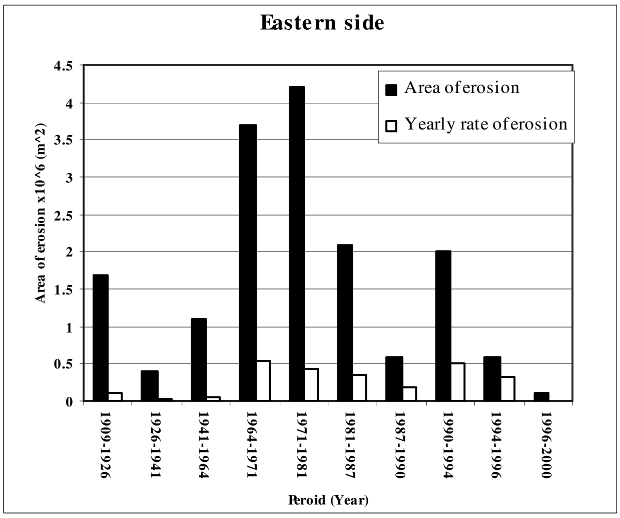


Fig. 8. Area of erosion and erosion rate astride Rosetta headland.

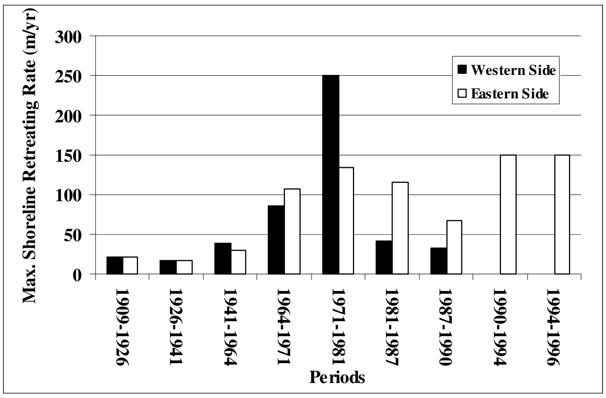


Fig. 9. maximum shoreline retreating (m.yr) astride Rosetta branch, 1909-1996,

different zones of 0 to -2, -2 to -4 and -4 to -6m depths beside the gross volume. The analysis of the coast on the basis of hydrographic surveys (8 profiles) during 1988-1996 indicate that western side of Rosetta headland is subjected to erosion whereas accretion is common along the coast towards El Maadia. With its protruding position and consequently wave refraction effect, the maximum annual erosion of the western side of Rosetta headland of the order of 3.75 million cubic meters is found. The source for accreted sediments from a point 12km west of Rosetta branch may be related mostly to the areas of the inner shelf and partly to the eroded sediments from Rosetta headland which move south ward, fig. 11. The movement pattern [11, 14, 15] indicates that most of the sediments eroded from the Rosetta headland moves offshore whereas sediments eroded from the western side move partly offshore and partly southwards. The average predominant direction of littoral current along the western side of Rosetta branch is from north to south (31.63 cm/sec.75.1 %), fig. 5. This trend of the littoral current (southwards) is mainly responsible for sediment transport from Rosetta headland to point 12km west of Rosetta branch.

2. Volumetric changes during 1990-1996 along the eastern side of Rosetta branch. The study of the eastern coast of Rosetta branch on the basis of hydrographic surveys (12 Profiles) during 1990-1996 indicates that its subjected to erosion whereas accretion is common along the coast towards El-Burullus. The maximum annual erosion of the eastern side of the order of 1.62 million cubic meters is found [14-17]. The movement pattern indicates that most of sediments eroded from the Rosetta headland moves offshore whereas sediments eroded from the eastern side move partly offshore and partly eastwards. The source for the accreted sediments from a point 16km east of Rosetta branch may be related to the areas of the inner shelf and partly to the eroded sediments from Rosetta headland which move eastwards, fig. 11. The accumulation of accreted sediments at 16 km east of Rosetta branch is transported by the average predominate direction of the littoral current [eastwards; 50 cm/ sec (58. 69%)].

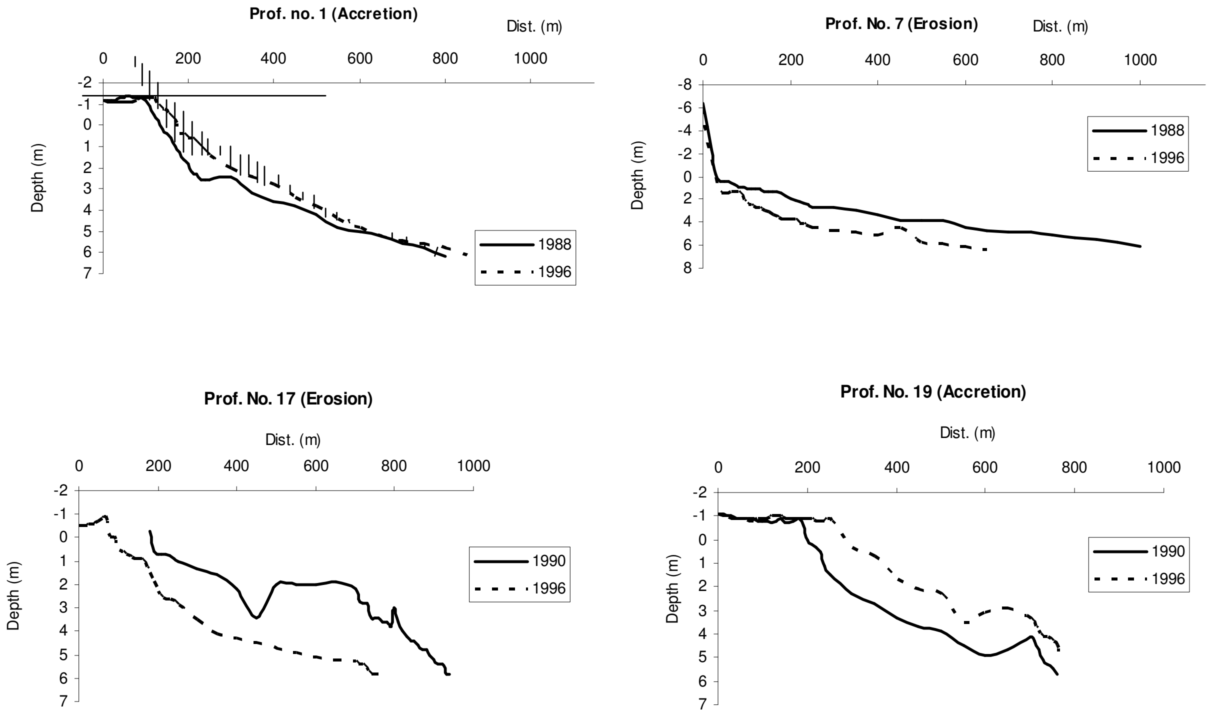


Fig. 10. Accretion and erosion profiles astride Rosetta branch.

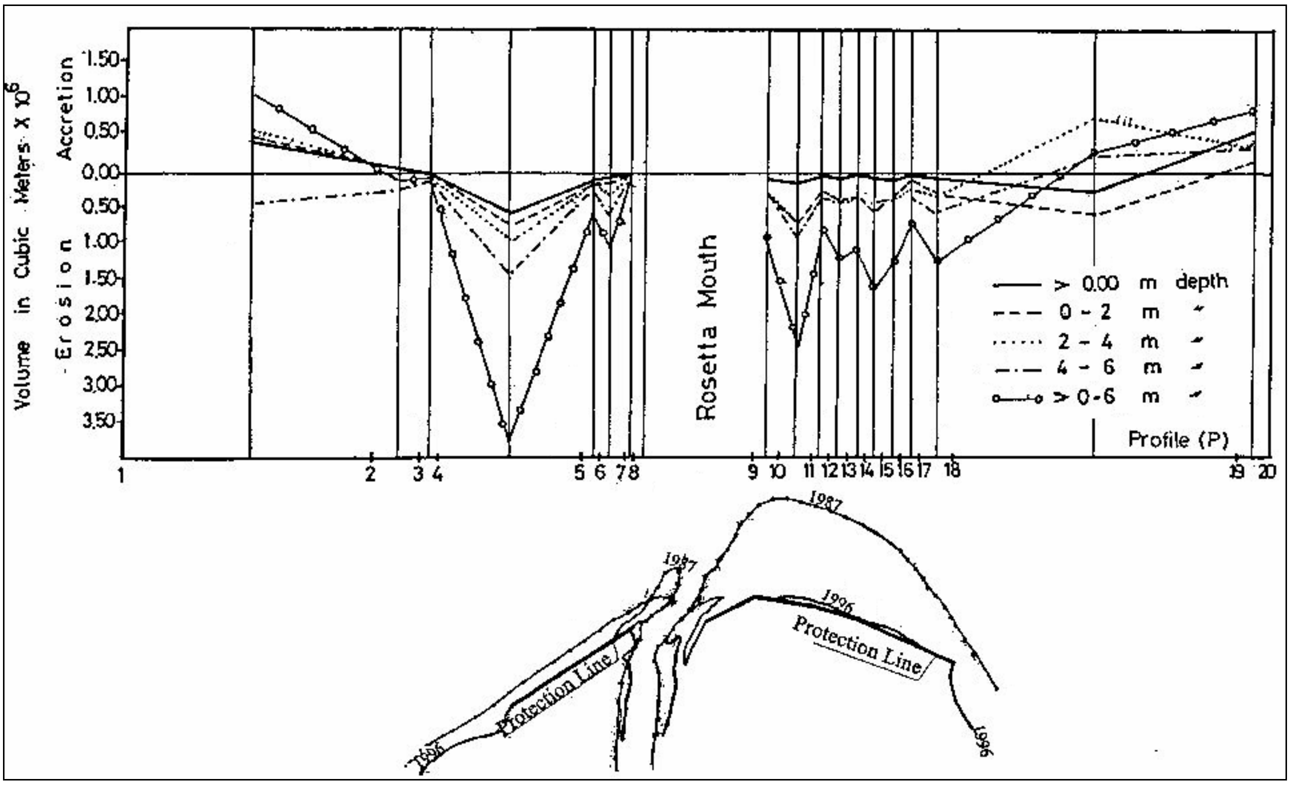


Fig. 11. Estimation of accretion and Erosion astride Rosetta branch during 1988-1996.

Therefore, the predominant current direction reflects the cause of the accretion on both sides of the promontory tip while the reverse currents are the cause of spit formation on both sides of Rosetta Nile branch. Thus the predominant current are from a northerly and westerly directions, causing a large littoral transport to south and east, computed to about 1.07 and 1.19 million cubic meters along the western and eastern sides of Rosetta branch, respectively.

4. Summery and Conclusions

Rosetta promontory has been dynamically unstable for the last century long and short term studies showed that, in the absence of the Nile sediments after the closure of the River Nile by the High Aswan Dam in 1964, this shore become severely undernourished. The loss of coastal lands was about $16.5x10^6$ and $2.6x10^6$ m^2 on the eastern and western sides of Rosetta branch for the period of 1909-2000, respectively the rate of erosion attained its maximum value of 0.53×10^6 m^2/ year after the construction of the Aswan High Dam in 1964.

Depending upon the volumetric changes (accretion or erosion), Rosetta headland extends from a point 14 km west of Rosetta branch to a point of 16 km east of it where erosion is predominant. The nearshore sediments of Rosetta headland are subjected to maximum erosion of the order of 3.75 million cubic meters on the western side during 1988-1996 and 2.49 million cubic meters on the eastern side during 1990-1996. The volume of sediments in the motion within the breaker zone is small as compared to the volume in motion beyond the breaker zone. This shows the importance of extending the surveys of the main profile offshore. The source for the nearshore accretion sediments from a point 12 km west and 16 km east of Rosetta branch may be related mostly to the sediments of inner shelf areas and partly to the eroded sediments from Rosetta tip which generally move southwards and eastwards, respectively.

References

[1] K.O. Emery, Relict Sediments on the Continental Shelves of World. Am. Assoc. Petr. Geol. Bull., Vol. 52, pp. 445-464 (1968).

[2] O.E. Frihy, A.M. Fanos, A.A. Khafagy, and P.D. Komar, Patterns of Sediments Transport Along the Nile Delta Egypt. Coastal Engineering, Vol. 15, pp. 409-429, Elsevier Science publishers B.V., Amsterdam, (1991).

[3] R. Said, The Geological Evolution of the River Nile. New rock: Springer- verlag, 151P (1981).

[4] V. Coutellier and D.J. Stanley, Late Quaternary Stratigraphy and Paleography of the Eastern Nile Delta, Egypt. Marine Geology, pp. 257-275 (1987).

[5] M.A. El-Askary and A.A. Badr, Foreshore Sediments of the Nile Delta Promontories: A Correlation Study. N. Jb. Geol. Paläont. Mh., 8, stuttgart, pp. 461-472 (1996).

[6] CORI /UNESCO/UNDP, Costal Protection Studies, Final Technical Report, 182 (1978).

[7] O. Orlova and V.P. Zenkovich, Erosion of the Shores of the Nile Delta. Geoforum, Vol. 18, pp. 68-72 (1974).

[8] D.L. INMAN and S.A. Jenkins. The Nile Littoral Cell and Man's Impact on the Coastal Zone of the Southeastern Mediterranean. SID Reference Series, 31, Scripps Institute of Oceanography, Vol. 43 pp. (1984).

[9] S.E. Smith, and A. Abdel Kader, Coastal Erosion Along the Egyptian Delta. Journal of Coastal Research, Vol. 4 (2) pp. 245-255 (1988).

[10] N.M. El-Fishawi and A.A. Badr, Volumetric Changes of Near-Shore Sediments Between Rosetta and Burullus, Egypt. IN QUA, Spain, Vol. 11, pp. 39-42 (1989).

[11] M.A. El-Askary and O.E. Frihy, Depositional Phases of Rosetta and Domietta Promontories on the Nile Delta Coast. Journal of Africa Earth Sciences Vol. 5, pp. 627-633 (1986).

[12] E.V. NIELSEN, Shore Evolution. CRI/ UNDP/ UNESCO, Proceedings Seminar

Nile Delta Coastal Processes, pp. 15-59, (1977).
[13] N.M. El-Fishawi, and A.A., Badr, Erosion and Flooding as Related to Recent Sea Level Rise, Nile Delta Coast, Egypt. Medcoast 95, 24-27, Tarragona, Spain, pp. 1229-1239 (1995).
[14] M. Manohar, Dynamic Factors Affecting the Nile Delta coast. Proc. Sem. Nile Delta sed. UNDP/UNESCO/ASRT, Alex. 25-29 1975, pp. 104-129 (1976).
[15] A.A. Badr, and M.F. Lotfy, Tracing Beach Sand Movement Using Fluorescent Quartz along the Nile Delta promontories, Egypt. Journal of Costal Research. Vol. 15 (1) pp. 261-265 (1998).
[16] A.M. Fanos, A.A. Khafagy, and Sharaf El Din, Coastal Changes Along the Egyptian Mediterranean Coast, International Seminar Management, 11-14 December 1989, Cairo, Egypt (1989).
[17] N.M. El-Fishawi, A.A. Khafagy and A.A. Badr, Coastal Erosion as Indicated by Fluorescent Sand Experiments, Rosetta Coast, Egypt. MMBSS News-Leter (13), INQUA, Spain, pp. 21-28 (1991).

Received May 30, 2004
Accepted October 21, 2004