

SPATIAL AND TEMPORAL PATTERNS OF COASTAL EROSION IN THE NIGER DELTA

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ABSTRACT

The coastline of the Niger Delta, which stretches some 395 km, consists largely of erodible barrier islands comprising sediments at different levels of densification and consolidation. Both long-term and short-term forces are exerted on the coastline leading to substantial temporal and spatial shifts in its configuration. By overlaying satellite imageries from Landsat TM, of two epochs (1963 and 1989/90), it was shown that large sections, up to 75% of the coastline are either eroding or accreting, with only about 25% of the entire length in relatively stable conditions. Anthropogenic activities which have influenced discharge and sediment transport, such as canals, river bed dredging, harbour protection works and impoundment in upstream dams and reservoirs are implicated as major causes of accelerated coastal erosion.

KEYWORDS: Coastline, Erosion, Sedimentation, Niger Delta

INTRODUCTION

The formation of the Niger Delta is attributed to the opening of the Atlantic Ocean (Allen 1965) and the outcome of an overwhelming constructive depositional process over the destructive erosional process. This has resulted in many years of incremental growth of the delta. Paleo-coastlines described by Allen (1965) delineate the coastline positions at various times, and provide a basis for gross estimates of progradational rates in different sections of the delta. However, because of the expression of time on geologic scale, progradational estimates from the paleo-coastline maps have not offered answers to problems of contemporary planning and development in the coastal areas. This is because environmental impacts on engineering projects are evaluated in terms that are relative to human life span and not geologic scale.

Short and medium -term erosion and sedimentation processes are evaluated in qualitative and quantitative terms (Ibe, 1986). Whereas the relative representation shows the location and relative intensity of the predominant process, the quantitative assessment provides not only the location but also the quantities of sediments eroded or deposited. A relative representation of erosion and sedimentation in the coastline of the Niger Delta is exemplified by NEDECO (1961). In this case, the intensity of

erosion and accretion were qualified by degree, as light or heavy. The quantitative assessment of erosion and accretion at a given location could be in terms of land area lost or gained, or volume of sediment eroded or deposited. Both the relative and quantitative representations of erosion and accretion could be complementary in places where data is inadequate (Abam and Beets, 1996).

This paper uses recent data from satellite imageries to investigate the pattern of coastline changes in terms of spatial and seasonal trends and appraises the contribution of anthropogenic influences on the sediment transport regime, in relation to the constructive and destructive processes along the coastline of the Niger Delta.

Factors Influencing Coastline Changes

In analyzing coastal erosion, it is helpful to recognize that there are long and short-term forces exerted on the shoreline. Whereas the long-term forces relate mostly to transgression and regression, the shoreline is constantly responding to the short-term forces causing the fluctuations that occur on an hourly, daily, monthly and seasonal bases and that are mostly evident to human observer.

Two of the long-term forces are sea level change and sediment supply. The short-term forces are largely due to tides and waves, and

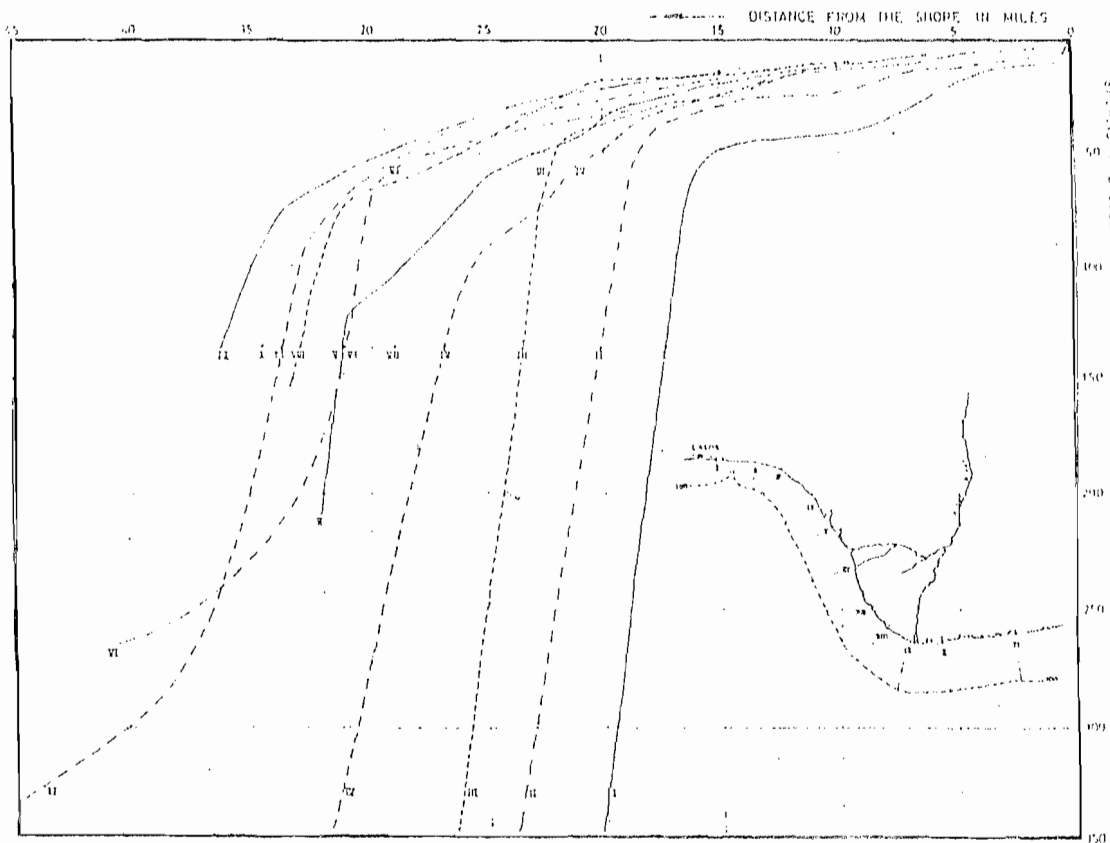


Figure 1: Slope of the continental shelf of the Nigerian coast t
(After NEDECO 1961)

anthropogenic activities. The waves in the coastal margins are largely wind induced but there is a substantial contribution by marine traffic especially within the estuaries. Wave heights vary with season and bathymetry. They are higher between July and October and in deeper sections

of the coastal margins. The wave heights in the western delta are expected to be higher than those of the eastern delta because of the steeper transition into the continental shelf in the former section (Figure 1). These factors had over time shaped coastal morphology and influenced coastal erosion and deposition.

A major determinant of the state of the coastline is sediment supply. Very simply, if sediment supply to a shoreline exceeds sediment removal, net accretion will be expected. Sediment supply can be from inland sources such as semi-arid upstream catchments areas, rivers, long-shore sediment transport and from offshore sources. The work of Oyebande (1981) indicates that sediment supply to the Niger Delta is mostly from inland sources. Natural variability in sediment supply had been experienced due to long-term seasonal and climatic fluctuations providing additional sediment during wet cycles and deficits

associated with droughts. Land slides and bank failures are noted to have contributed to sediment supply to the coast.

The entrained sediment that constitutes the load of a river is carried in three main ways, bed load, suspended load and solution load. The greater part of the suspended load is carried off to the estuaries and the sea, where it exercises some influence on the coastline. Oyebande *et al* (1980) estimated the annual suspended sediment load carried during the pre-dam years (1915-1957) through the apex of the Niger Delta at Onitsha to be about 35 million tonnes. However, between 1956 and 1960, NEDECO (1961) recorded an annual sediment transport through the same location averaging 32.9 million tonnes. This sediment load was distributed between the western and eastern parts of the delta in the ratio 3:2 in approximate proportion to their prevailing discharge ratios.

Anthropogenic Factors Influencing Coastline Erosion

A major anthropogenic factor influencing coastal processes in the Niger Delta include the presence, within its hydrologic catchment area, of

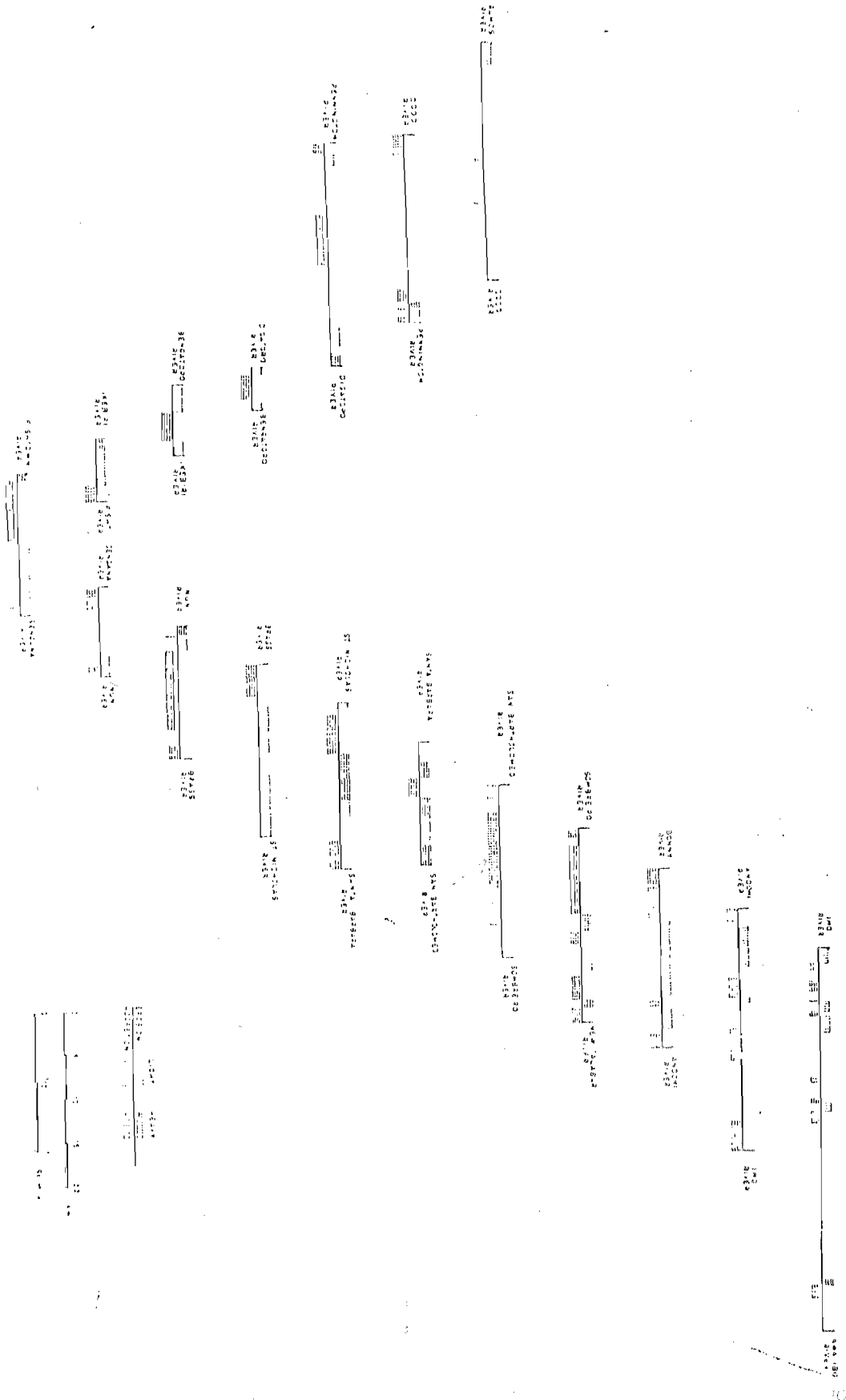


Figure 2: Erosion and sedimentation profile of the Niger Delta coastline by NEDECO 1961

Table 1: Distribution of erosion and accretion in the Niger Delta coastline between 1963 and 1990

River Estuary	Niger Delta Coastline			
	West		East	
	Erosion (km ²)	Accretion (km ²)	Erosion (km ²)	Accretion (km ²)
Benin	3.5	0.0	0.0	1.5
Escravos	1.02	0.5	0.0	3.5
Forcados	0.0	1.0	2.0	0.0
Ramos	0.2	0.15	0.1	0.05
Pennington	0.6	0.0	0.1	0.0
Dodo	2.25	1.7	0.3	0.1
Digitoru	0.15	0.0	1.0	1.3
Middleton	4.0	0.0	3.0	1.2
Nicholas	0.0	0.2	1.0	0.2
Nun	0.0	0.5	0.1	0.2
Brass	0.0	0.0	0.1	0.1
Santa Barbara	0.0	0.0	1.2	2.0
San Bartholomeo	0.0	0.0	0.0	0.0
Sombreiro	0.7	0.0	1.0	1.3
TOTAL	12.42	4.05	9.9	11.45

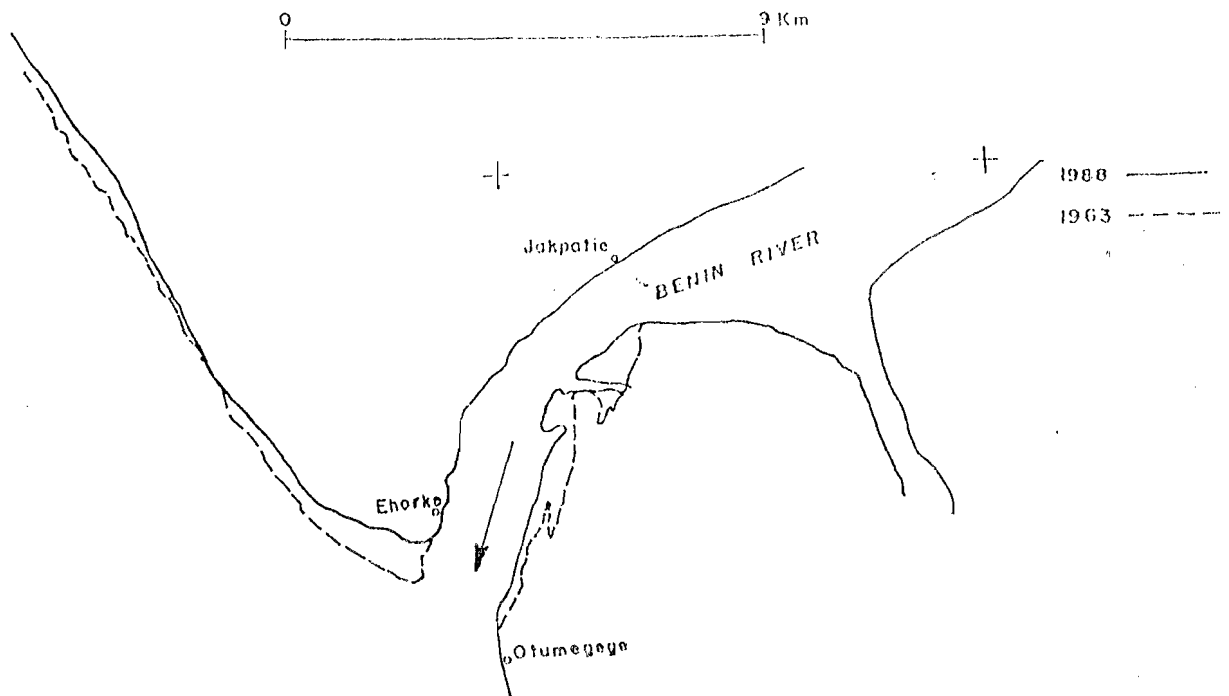


Figure 3: Coastline morphological changes of the Benin River estuary 1963-1988

large upstream dams and reservoirs which impound large quantities of coastline bound water and sediments. Other significant factors that could influence coastline erosion include harbour protection works (which introduce changes to the local hydrodynamics and consequently re-route sediments), dredging of riverbeds and estuaries, beach nourishment, urbanization and deforestation.

Due to the relatively low level of sediment-impacting activities in both the coast and inland

areas, the contributions of dredging, harbour works, deforestation and urbanization are not expected to be significant. The dam impoundments on the other hand, appear to have the most profound effect on the hydrological dynamics of the coastline. Collins and Evans (1986) estimated a 70% reduction in sediment load as a result of dam construction. Similarly, Oyebande *et al* (1980) estimated sediment retention in the Kainji reservoir of more than 70% of total sediment load. It also appears that with

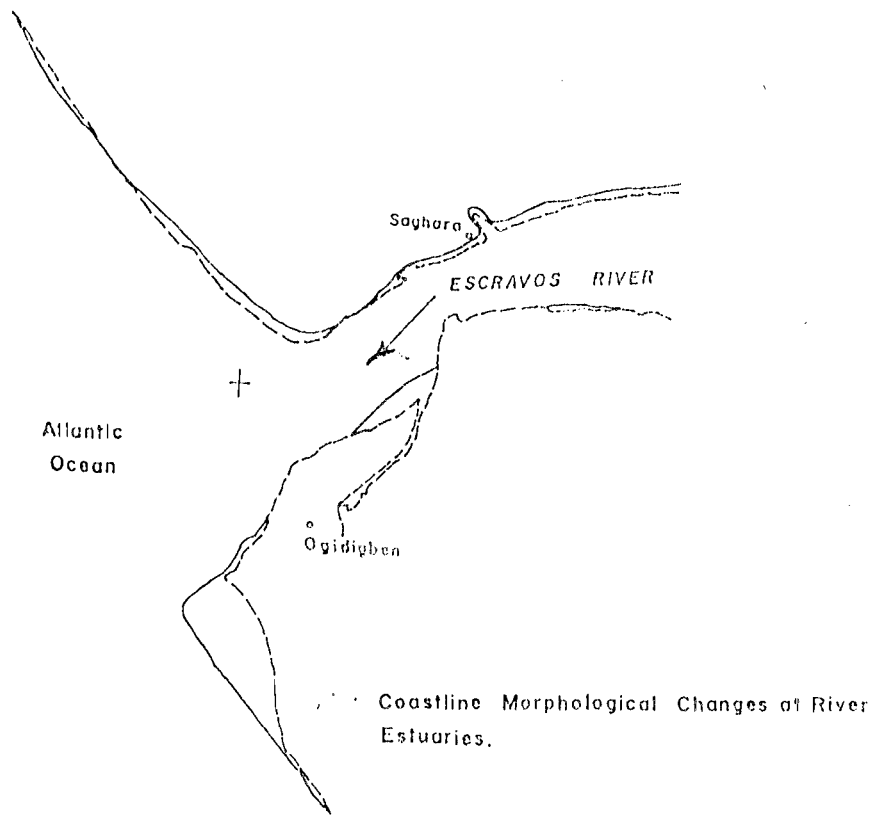


Figure 4: Coastline morphological changes of the Escravos River estuary 1963-1988

the completion of the proposed Lokoja Dam with a planned capacity of 68 km^3 , the deposition of silt in lower Niger will be substantially reduced.

Sediment entrapment in dams and reservoirs has caused an imbalance between the coastal constructive process encouraging sedimentation and the destructive hydraulic currents and waves that result in erosion. The Kainji and Jebba dams, which when combined control over 40% of the total reservoir impoundment in Nigeria, are believed to have disrupted the once natural sediment supply to the coastline and exacerbated coastal erosion (Abam, 1999). In places, this imbalance in coastal equilibrium has slowed the progradation of the Niger Delta.

The potential coastal accretion that should have resulted from sediments entrapped in dams and reservoirs is estimated to be an average of 3 m across the 395 km stretch of the coastline, based on global reservoir sedimentation estimates (as in Mahmood, 1987), and discounting possible sedimentation on river beds and sand bars, flood plains, tidal swamps, river mouth and continental shelf.

The availability of these sediments for

constructive hydrological process leading to sustained progradation of the delta front should have resulted in the creation of new forest land contiguous to the beach ridge covering some 838.3 hectares.

Spatial and Temporal Coastline Changes

Locations in which erosion and accretion were prevalent on the Niger Delta coastline and the intensity of such phenomena were recorded by NEDECO (1961) as a segmented coastal profile (Figure 2). This figure indicates that large sections, up to 75% of the coastline are either eroding or accreting with only about 25% of the entire length in fairly stable conditions.

A dynamically active coastline was indicated by a beach profile monitoring exercise over a wide section of the Niger Delta covering Ugborodo, Escravos, Forcados, Brass and Bonny between 1991 and 1998 (Awosika, 1992). The profiles indicated seasonal transformations of the beach line in all the measurements. In Brass, for example, the profile suggested that accretion was largely in the dry months. In contrast, the profile in Bonny suggested that the bulk of the accretion in the beach was achieved in the wet season. Similarly, Oyegun (1991), with the aid of

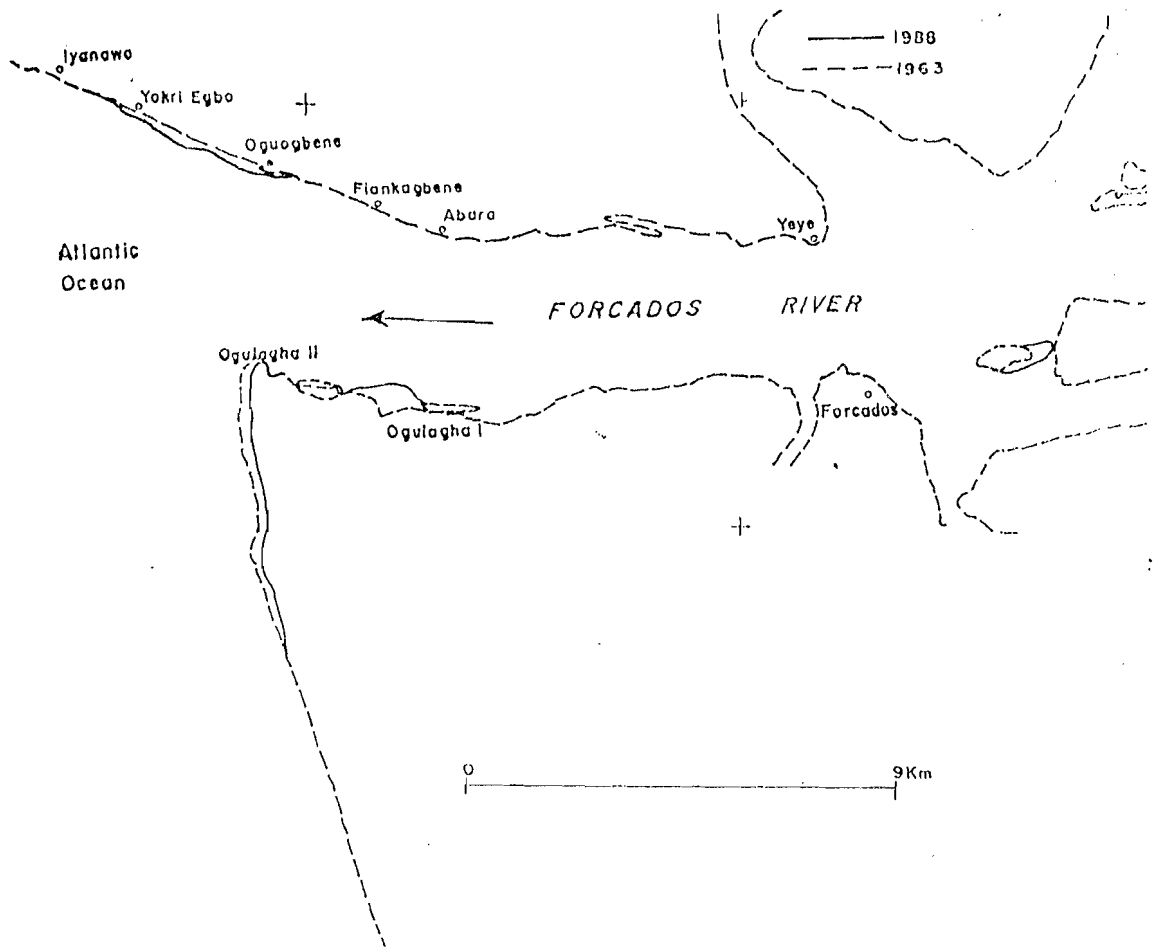


Figure 5: Coastline morphological changes of the Forcados River estuary 1963-1988

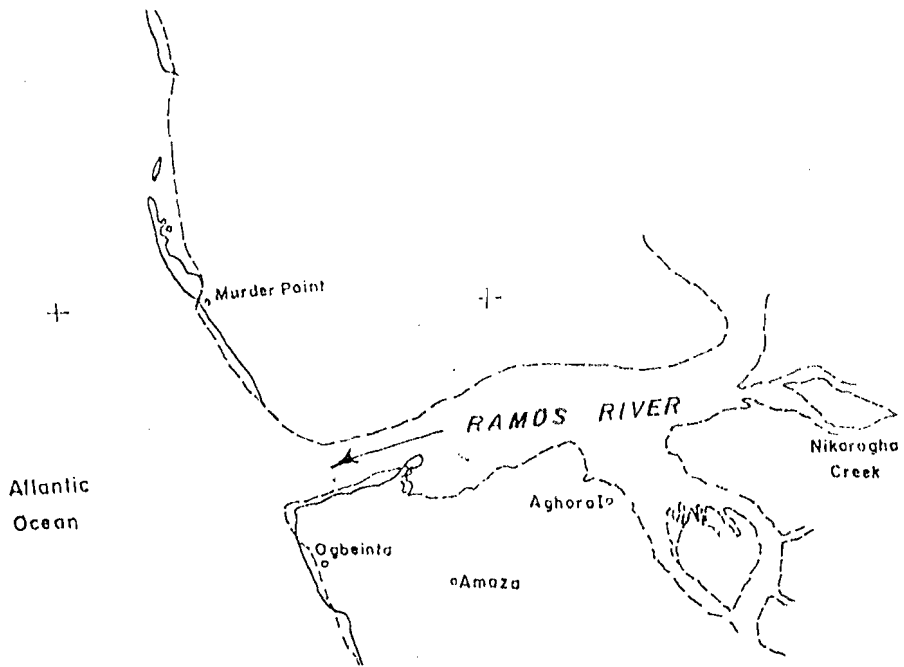


Figure 6: Coastline morphological changes of the Ramos River estuary 1963-1988

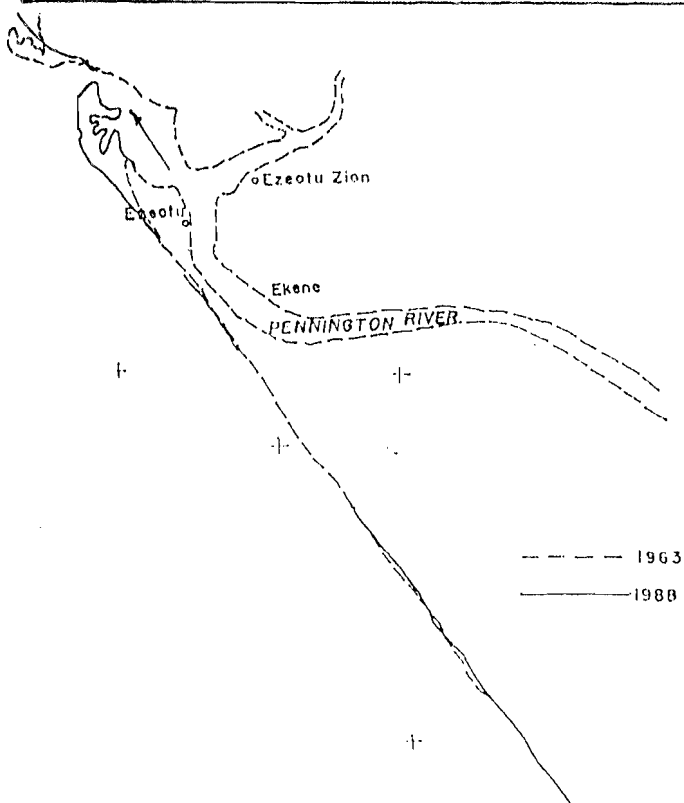


Figure 7: Coastline morphological changes of the Pennington River estuary 1963-1988

graduated pegs emplaced perpendicular to the shoreline in Forcados area, determined that the magnitude and frequency of beach changes are greater in the wet season than in the dry season. The cause of this variation in the predominant process at the different locations is not yet determined. Certainly, an appreciation of the combination of processes in the near-shore bathymetry, wave climate, sediment load and transport could provide better understanding.

The observed pattern of coastline development recorded by NEDECO (1961) and Awosika (1992) contrast with that reported by Whiteman (1982) which is essentially that of a prograding delta, where sedimentation was continuous. The presence of strong erosional stress in some sections of the coast suggests that there is not enough sediment reaching them to sustain existing hydrodynamic balance between coastal erosion processes and constructive river hydrological processes.

Maps of sections of Nigeria coastline generated from a comparison of the satellite imageries from Landsat TM data sets (Figures 3 to 14) between 1963 and 1990 reveal significant changes. The Benin River estuary for example (Figure 3) shrunk in width due to accretion on its south bank, resulting in the expansion of an existing sand bar.

However, the shoreline north of the river mouth, which is exposed to direct wave action, is receding. Similarly, the coastline north of Escravos River estuary (Figure 4) is experiencing erosion, while sedimentation is taking place on the coastline south of the estuary.

The Forcados River estuary (Figure 5), on the other hand, is showing a very dynamic behaviour characterized by rapid shallowing in its mainstream and extensive erosion at the shoreline south of the estuary. Being a major distributary of the Niger River system, significant sediment load is transported by this river. However, the interaction of the discharge at the coastline with near shore hydrological processes - waves, long-shore and rip currents - result in substantial redistribution of the sediment load. Significant accretion has occurred in the coastline north of the Ramos River (Figure 6), while the coastline south of the estuary continues to be eroded. Also, significant land gains have been recorded immediately south of the Pennington River estuary (Figure 7). The coastline bordering the Dodo River estuary (Figure 8) has also been significantly transformed. Similarly, land gains

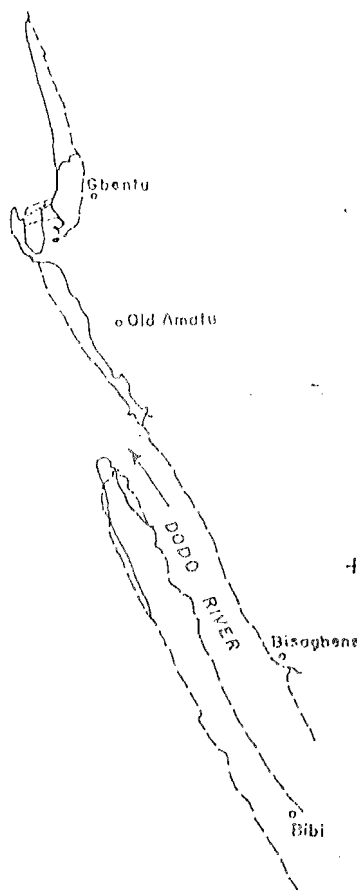


Figure 8: Coastline morphological changes of the Dodo River estuary 1963-1988

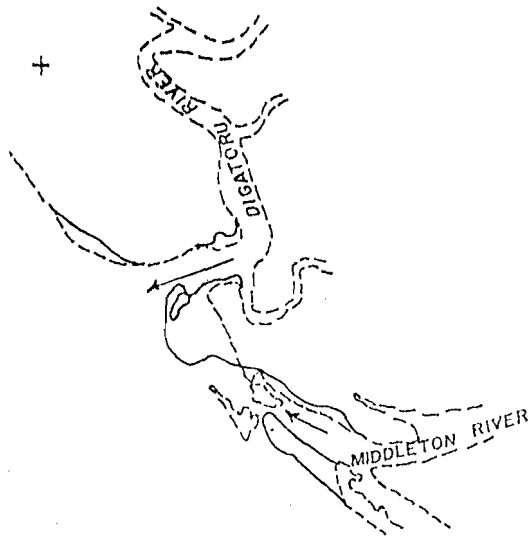


Figure 9:
Figure 9: Coastline morphological changes of the Digitoru and Middleton Rivers estuary 1963-1988

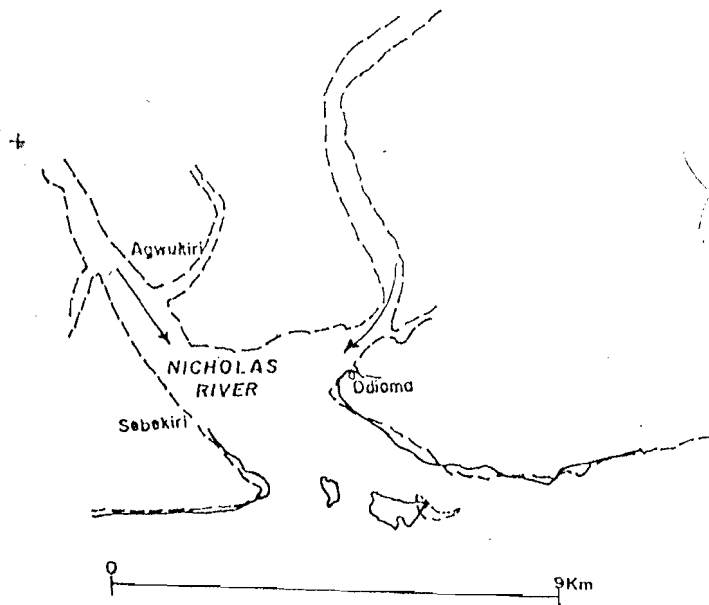


Figure 10: Coastline morphological changes of the Nicholas River estuary 1963-1988

have been recorded just before the Digitoru River (Figure 9). The coastline of the Nicholas River estuary (Figure 10) has visibly changed within the last 27 years.

Significantly, the coastline between Nun and Brass Rivers (Figure 11) has remained fairly stable. The entrance of the Santa Barbara River to the Atlantic Ocean (Figure 12) witnessed considerable alteration through erosion. In contrast, the neighbouring San Batholomeo coastline has been fairly stable.

The coastline modification at the Bonny River entrance is dramatic (Figure 13). In this case,

some sections have gained land, while others have suffered erosion. This indicates that, although erosion may be the dominant geomorphic process, sedimentation may also occur in some locations. Table 1 summarizes the distribution of erosion and accretion on the coastline of the Niger Delta. This summary considers the morphological activities of erosion and accretion to the east and west of the river mouths that discharge into the Atlantic ocean.

The similarity in the pattern and distribution of erosion and sedimentation at the coastline between these recent observations and those of NEDECO (1961) suggests that the medium to long-term trends that existed between 1951 and 1959, at the time of NEDECO field surveys, are still operational. Although the trends may remain unchanged, it is quite probable that the rates of erosion and sedimentation have changed, since these depend largely on sediment availability among other factors. The aggregate response of the coastline in the long-term is what determines whether the delta is prograding or receding.

An important influence on coastal erosion and sedimentation is the nature of the drainage basin. The significantly reduced intensity of coastline modification of Sombreiro River (Figure 14) can be explained by the structure of the drainage basin. An inspection of the drainage zones in the Niger Delta reveals drainage lines of limited extent and catchment size in the eastern Niger Delta, suggestive of constraints in sediment supply. This further implies that accretion would largely be low in qualitative terms, as indicated by NEDECO (1961). This deduction is strengthened by the skewed discharge and sediment distribution in favour of the western delta between 1953 and 1984. This discharge distribution between Nun and Forcados is presently in favour of River Nun, according to a recent measurement of discharge, which revealed a 56% of the Niger River discharge through River Nun at peak flood (NDES, 1998).

Coastline modification arising from short-term trends can be misleading if not interpreted with long-term trends in perspective. Two coastline segments, where short-term trends have caused significant changes are the Ondo mud-flat coast and Bonny River sections of the Niger Delta coastline.

The Western Niger Delta Coastline at Ondo State

Using aerial photographs of the western coastline of Nigeria, taken between 1973 and 1981,

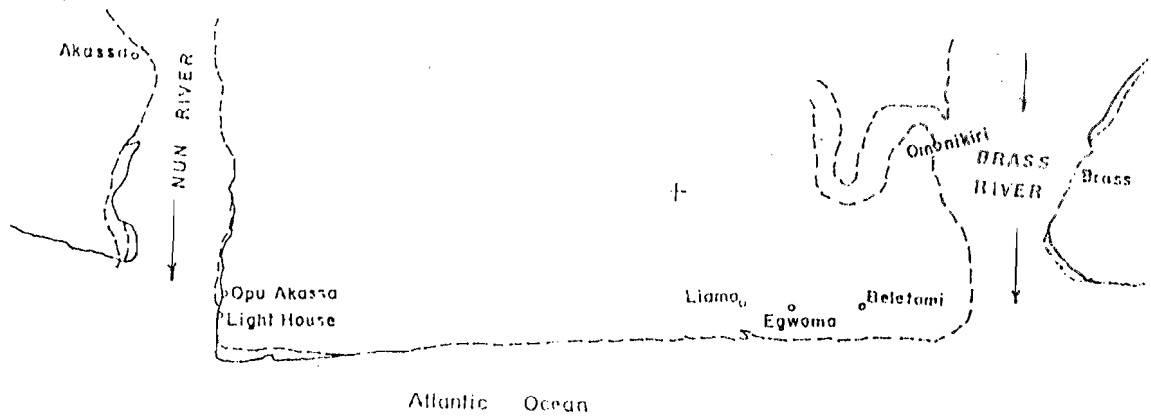


Figure 11: Coastline morphological changes of the Nun and Brass Rivers estuary 1963-1988

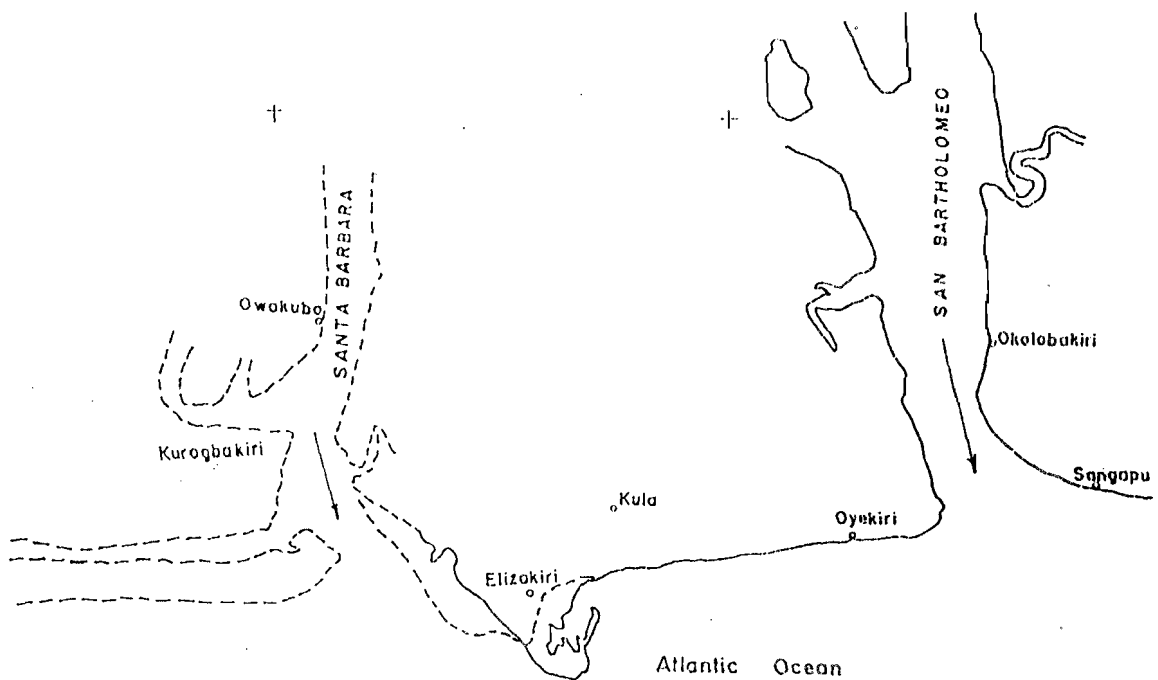


Figure 12: Coastline morphological changes of the Santa Barbara and San Bartholomeo Rivers estuary 1963-1988

Ebisemiju (1988) estimated a shoreline retreat of 257m to 308m, giving an annual rate of 20-39m for the period. Further field measurements between March 1984 and February 1985 revealed both temporal and spatial variations in the rates of erosion in the area, with shoreline retreat varying from 16m to 27m. The highest rates of erosion were recorded between July and September, which seems to correlate with the normal increase in sea level. Several fishing villages along the mud coast in the western axis of the Niger Delta were forced to abandon their locations due to flooding and erosion. Some of the creeks that once terminated some distances inland (beyond the mud coasts) are now connected to the ocean through the Jirinwo and Odojado canals.

Eye witness accounts of the coastal erosion phenomenon, traced it to the construction of canals by an oil prospecting company. The canal link soon served as a channel for inland movement of the undissipated wave energy of the ocean. In the process, erosion became accelerated and uncontrolled. Large hectares of tropical forest and agricultural lands, including those inhabited by the people were lost to the ravaging erosion.

Reduced sediment supply to the Mahin areas has also been partly blamed for the accelerated coastal erosion problems in this area (Ibe, 1986). The overall sediment supply to the area has been reduced from the east by dam impoundments, and from the west by the eastern mole of Lagos

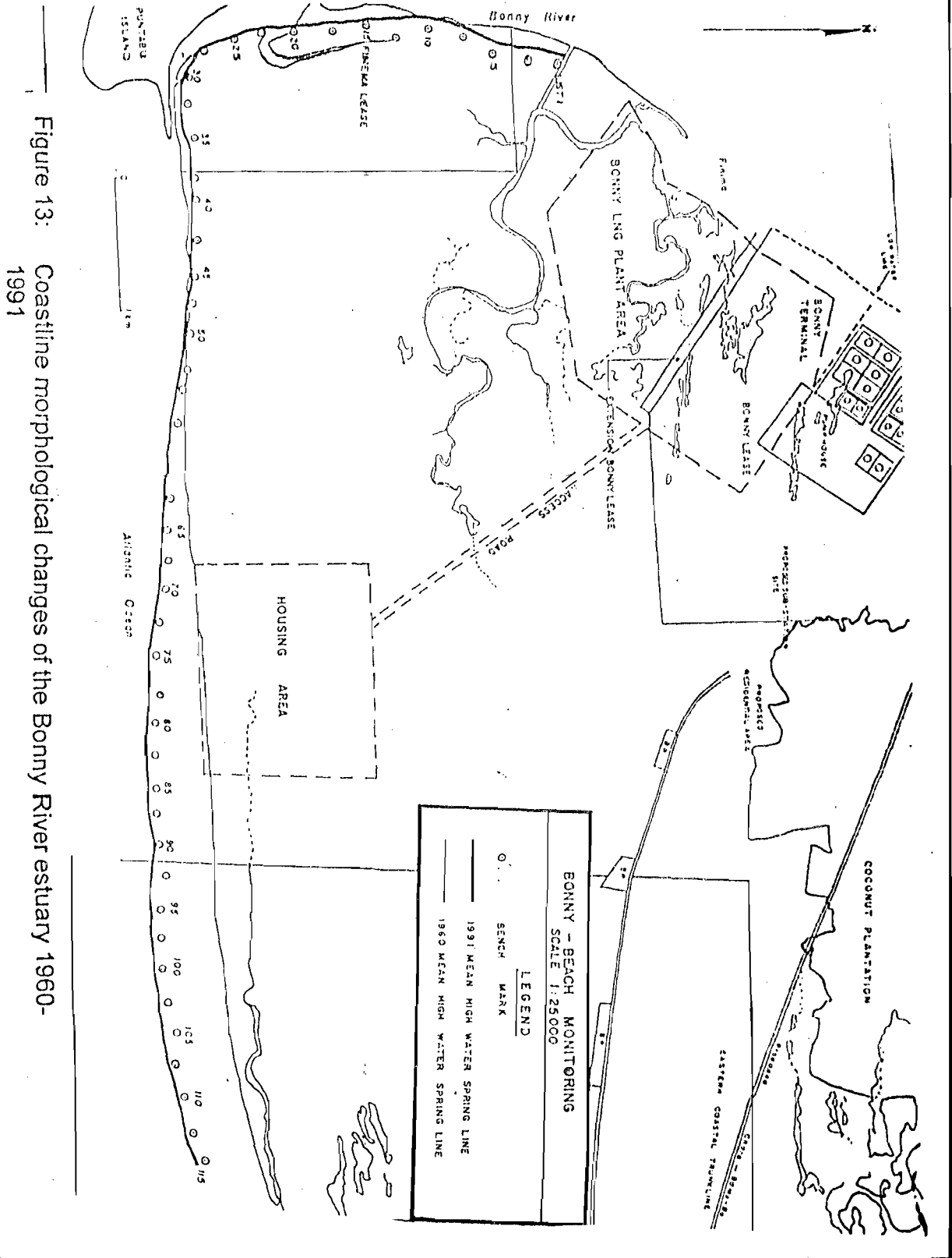


Figure 13: Coastline morphological changes of the Bonny River estuary 1960-1991

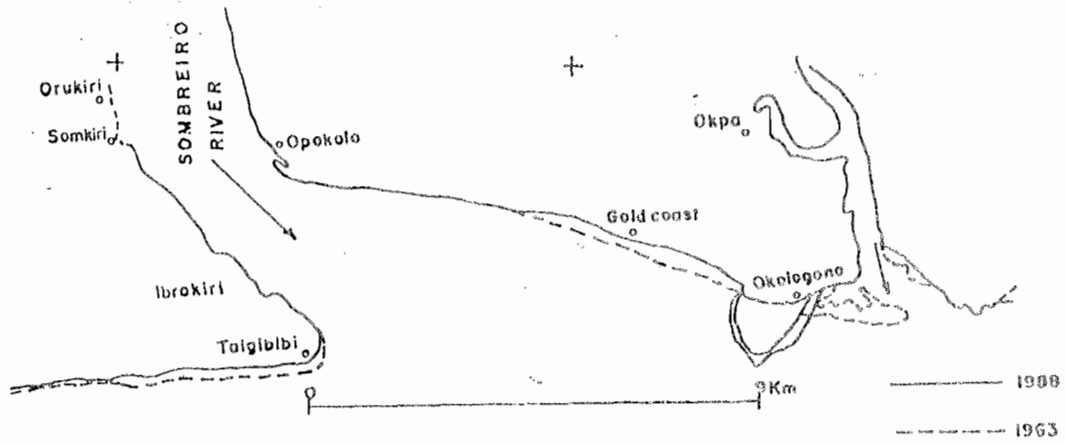


Figure 14: Coastline morphological changes of the Sombreiro River estuary 1963-1988

harbour. The shortage in sediment supply rapidly resulted in the denourishment of the coast. Consequently, an imbalance that exacerbated the destructive process was created between forces of accretion and the destructive forces of waves, tide and currents.

The Eastern Niger Delta Coastline at Bonny

The Bonny estuary is a deep ocean access that has attracted major investments including the Nigeria Liquefied Natural Gas. The concern for the stability of the coastline compelled the company to commission a beach-monitoring programme. Four beach monitoring surveys were consequently carried out over a period of one year.

One of the specific features of this coastline is the frequent change in the location of Oputanbe Island, off the south-western part of Bonny Island (Figure 13). This Island, which is marginally above High Astronomical Tide, displays a mobile character. The Island was initially located farther from the shore, however at the time of the surveys, it had been drastically re-shaped and moved closer to the beach.

An account of the behaviour of the island by indigenes, indicated that "once every seven years", this island unites with the land, however the connection is breached during storms in the wet season.

The migration of the island towards the shore exerts an impact on the current pattern by creating eddy currents, which in turn affect the beach. In the process the existing coastline configuration is adjusted by erosion and sedimentation processes. Although erosion was

taking place west of the residential area, the foreshore part of the residential area and further eastern areas, had gained some 15 meters per year towards the sea.

Over an extended period, these processes have induced drastic changes in coastline configuration. Such a change is also evident in Figure 14, which effectively compares with the shoreline position between 1957/60 and 1992 along with details of the causative processes. The foreshore had expanded considerably with widespread growth of new shrubs and trees in the areas. The actual fresh water forest extends to a distance approximately 400 meters from the beachhead. The beach has a very gentle slope that causes the waves to break far offshore.

CONCLUSIONS

A close observation of the Niger Delta coastline confirms that dynamic hydrological processes have indeed affected the beach in both positive and negative ways.

Reduction of the sediment supply feeder function of the upstream river systems due to impoundments at upstream dams and the structure of the drainage pattern, combined with the rise in mean sea level has changed the sediment distributive forces at the coast into destructive forces. The pre-dam long-term coastline modification trend is still operational. Short-term trends are only super-imposed on the long-term trends. However, the rates of erosion and sedimentation have changed.

REFERENCES.

- Abam, T. K. S., 1999. Impact of dams on the hydrology of the Niger Delta. *Bull of Engineering geology and the Environment* 57:239-251
- Abam, T.K.S and Beet, C., 1995. Hydrology of the Niger Delta: Niger Delta Environmental Surveys Sponsored by Euro-consult/SPDC (50 pages).
- Allen, J. L., 1965. Late Quaternary Niger Delta and adjacent areas sedimentary environment and lithofacies *AAPG Bull* 49:54-60
- Awosika, L. F., 1992. Coastline erosion in West Africa: causes, effects and response options. International symposium on rational use of coastal zone, Bordeaux, France.
- Collins, A. and Evans, G., 1986. The influence of fluvial sediments on coastal erosion in west and central Africa. *Shoreline Management* 2 : 5-12.
- Ebisemiju, F.A., 1988. Human impact on Marine processes in the Western Niger Delta, Nigeria. In proceedings of policy seminar on environmental issues and management in Nigerian, Benin, p239-251.
- Hanson, H. and Lindh, G., 1993. Coastal erosion and escalating environmental threat. *Ambio*, 22: 189-195
- Ibe, A. C., 1986. Coastline erosion in Nigeria. University of Ibadan press, 217 p
- Mahmood, K., 1987. Reservoir sedimentation Impact, extent and mitigation. World Bank Technical Paper, 71, Washington D.C.
- Niger Delta Environmental Survey, 1995. Phase I Report. Vols.1 to 4
- Niger Delta Environmental Survey, 1998. Discharge measurement at the Niger River bifurcation into Nun and Forcados Rivers, p112-119.
- NEDECO, 1961. Waters of the Niger. The Hague, 398p.
- Oyebande, I., Sagua, V.O. and Ekpeyong, J. L., 1980. The Effect of Kainji Dam on the Hydrological Regime, Water Balance, and Water quality of River Niger, IAHS-AISH publication 130: 221-338.
- Oyebande, I., 1981. Sediment transport and river basin management in Nigeria: Tropical Agricultural Hydrology. Ed. By R Lal and E. W. Russell. John and Sons.
- Oyegun, C. U., 1991. Spatial and seasonal aspects of shoreline changes at Forcados beach, Nigeria. *Earth Surface processes and Landforms*, 16: 293-305
- Oyegun, C. U., 1990. The management of coastal zone erosion in Nigeria. *Ocean and shoreline management*, 14:215-228.
- Whitman, A.J., 1982. Nigeria, its petroleum geology, resource and potential, vol. 1, pp168, Graham and Trotman, London.
- World Bank, 1995. Defining an environmental development strategy for the Niger Delta, Vols. 1 &2.