Paper from: *Hydraulic Information Management*, CA Brebbia and WR Blain (Editors).
ISBN 1-85312-912-7

Impact of upstream changes and coastal hydrodynamics on river basin characteristics in the Niger delta of Nigeria.

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Abstract

The Niger Delta, a sub-basin of the R. Niger, lies between latitudes $4^0 30'$N and 7^0N, and longitudes 5^0E and 9^0E. It covers an estimated land area of some 67,140km^2. Its climate is typically humid with total annual rainfall in excess of 2400mm annually.

The hydrology of the area is controlled by major and minor rivers, which have intricate links with a creek network that serves as transportation channels for sediments and other materials from the hinterland. During the wet season (July - October), about 119 x 10^9m^3 of water is discharged into the delta. Hydrodynamics that characterize the Delta include flooding of the coastal wetlands, coastal erosion, and saltwater intrusion into swampy freshwater and groundwater resources. The trapping of sediments within dams and other storages upstream has intensified loss of beaches, coastal land and other resources to the ocean.

This paper focuses not just on the impact of upstream changes and coastal hydrodynamics on the Niger Delta basin, some aspects of the socio-economy of the naturally fragile area is also discussed.

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1 Introduction

The Niger Delta, which is a major sub-basin of the R. Niger, lies between latitudes $4^0 30$`N and 7^0N, and longitudes 5^0E and 9^0E. (Figure 1). Its land area is some 67,140km^2 and currently has 5 States, (Rivers, Bayelsa, Delta, Akwa-Ibom and Cross River) as its constituent administrative divisions. Its climate is typically
humid with total annual rainfall in excess of 2400mm annually. Rainfall distribution also defines the double maxima characteristic of such areas. Temperature ranges between 27^0C and 30^0C.

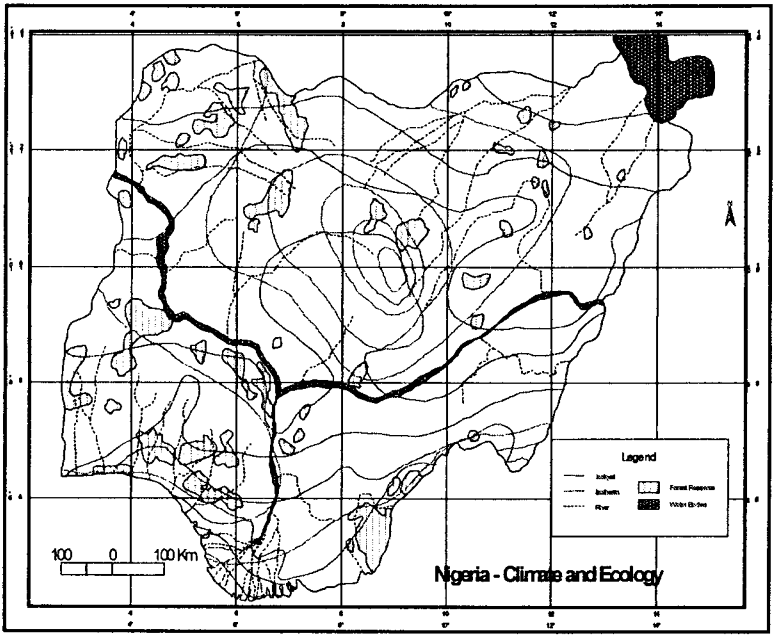

Figure 1: Map of Nigeria showing some climatic and ecological variables.

Total population is approximately $11.4x10^6$, and population densities averages 169.5 persons/km^2. but densities of 400/km^2 occur in some places. The main occupations traditionally are fishing, farming and other land-based activities such as hunting and fuel wood harvesting and selling. This is mostly the situation in the rural riverine areas from where the crude oil and associated gases that provide the bulk of Nigeria's economic wealth are exploited.

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The Niger Delta geologically, is a zone of active recent sedimentation. The Sombreiro-Warri Deltaic Plain sediments of early Holocene to late Pleistocene era are the oldest Quaternary sediments. They are principally coarse and fine sands with minor silt and clay in composition. These are overlain by sediments of the Mangrove swamp origin that vary from fine to medium sands in texture, the wooded back and freshwater swamps, and the meander belts which consist mainly of sand, silt and clay in different proportions.

Two hydrogeological provinces, namely, the coastal alluvial and the coastal sedimentary lowlands are identifiable. High water table, usually less than 2m characterizes the former, while the latter consist of unconsolidated and highly porous material. The high permeability and the shallow groundwater table enhance interactions between surface and groundwater in the region and that relationship also accentuates the risk of groundwater pollution particularly in the case of oil spills.

Given the different climatic and ecological zones traversed by the R. Niger, vegetation types are also diverse. From the Niger Delta to the Savanna hinterlands, vegetation species display genetic variability, biodiversity and renewability. They all, however, are natural resources with local, national and international significance arising from their utilization for shelter, food and food items, clothing, fuel, medicines, tourism and commerce. They also play considerable roles in environmental sustenance by regulating water flows conditioning local climate and soil protection against erosion, among others. They thus impart stability and dynamism to the entire ecosystem within the Niger River system.

The tidal environment exerts a selection pressure on vegetation and only those that can adapt to periodic flooding and saline soil environment thrive. These include the red mangrove, *Rhizophora racemosa* and *Rhizophora mangle*, *Dalbergia acastaphyllum* and *Omocarpon vericosum* found in the estuaries. Special features of these plants include stilt roots and lenticels close to the ground level, which allow free passage of gases.

2 Hydrology and hydrodynamics

The R. Niger is of utmost importance in Nigeria as it is the most significant in the drainage of the entire country. It also traverses many ecological zones and acts as a vehicle for sediment transport and deposition. Its extensive system of major and minor tributaries also makes its impact felt in most parts of Nigeria. Indeed it has social, economic and political relevance in the country. Flow in the river as estimated from data of many gauging stations including Aboh, Onitsha, Idah, Shintaku, Lokoja and Baro ranges between 1,900m3/sec and 15,000m^3/sec at the Niger-Benue confluence. This implies that its discharge is approximately 40% of that of the Mississippi. Along with this considerable flow, some 2.62 x $10^9 m^3$ of sediments is transported. Only approximately 0.91 x $10^9 m^2$ or 35% that constitute the finer fractions reaches

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the sea. In essence, the bulk (1.7 x $10^9 m^3$ or 65%) of its sediment load is trapped in the Delta. As a result, it is a regular source of sediments particularly during seasonal flooding.

Figure 2 graphically shows variation in monthly discharge at 6 stations on the R. Niger. The stations northwards are Abaoh, Onitsha, Idah, Shintaku, Lokoja and Baro and covers about 600 km. The graph shows that the onset of rains brings about a steady increase in discharge at all stations. Expectedly, Aboh fringing the Niger Delta and Onitsha the closest to it have higher flows than the others in all months. Data used cover between 20 and 30 years. Although not illustrated, the drought years of the 1970s and 1980s are captured.

In respect of the Niger Delta, major and minor rivers that have intricate links with a creek network that serves as transportation channels for sediments and other materials from the hinterland control the hydrology. In response to tidal dynamics, these either experience fluxes or become sinks for nutrients, sediments and other materials. Characteristically, low tides bring about flow towards the Atlantic Ocean while high tides effect flow in the other direction.

On account of the general low-lying nature of a significant part of the Niger Delta and the prevailing high ground water table, more than 70% of the land area is wetlands that are submerged for different periods of the year. Deriving also from diversity in other ecological attributes, vegetation varies from freshwater to mangrove (saline) species. Each of these expresses to a large extent the biochemistry of the existing waters, sediments and soils. The uniqueness of each of these ecological units and indeed their sensitivity to modification and outright change are predicated on these innate characteristics.

The Niger Delta is naturally endowed with diverse natural resources. The most prominent of these are the vast reservoirs of crude oil and associated gas, which have become the mainstay of the national economy. The agents of impairment of the coastal and marine environment include domestic sewage, industrial effluents, petroleum hydrocarbons, dredged materials and garbage. These have degraded the aquatic resources for recreation and transportation. The effects of mineral oil mining are aggravated by rapid urbanization and industrialization in coastal settlements. Frequent oil spills have adversely affected fish stock, wildlife and the fragile mangrove ecosystem. In recent times, the situation has assumed such critical social and political dimension. Indeed, the restiveness that attended the environmental degradation of the area and its people over the years threatens the corporate existence of Nigeria as one country.

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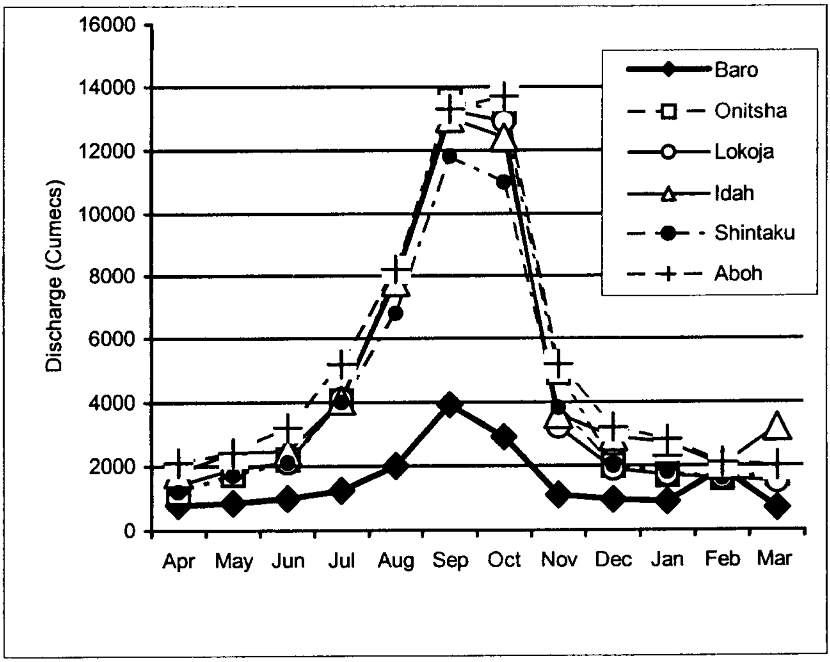

Figure 2: Monthly discharge at selected stations along R. Niger.

As already stated, the Niger-delta is mostly a flat, low-lying swampy sub-basin criss-crossed by a myriad of rivers and creeks. Its topography, geology and soil properties and heavy and frequent rainfall subject the area to severe annual flooding and erosion. It is known that the Niger-delta is subsiding as a result of both natural compactions of sediments and also due to oil, gas and water extraction. The rate of subsidence is as high as 7cm at Bonny during the last 10years. Superimposed on the subsidence is the accelerated sea-level rise (ASLAR) driven by the green-house warming which adds up to 30cm of sea-level rise in the next 3 decades. The implication of such changes at the coastline for the coastal zone could be grave for the natural resources and the inhabitants. A zone of 40km could be lost to the Ocean in the next two decades.

The Delta has its apex south of Onitsha some 375km from the ocean. The R. Niger bifurcates south of the Rivers Nun and Forcados. From there the depth expands to a 270km coastline using the considerable discharges of water and sediments in building up and progressively extending into the Atlantic Ocean. The seaward hydrodynamic zone of the Delta is completely tidal while those of the freshwater zone are determined largely by the discharge from the River Niger. The transitional/estuarine areas are

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dominated by tidal flows during the dry season and by freshwater during the wet or flood season of the River Niger system.

The Delta is the receptacle of the floodwaters of the Niger River system and stores much of the inflow for varying periods of time. During the wet season (July - October), about 119 x $10^9 m^3$ of water is discharged into the delta and constitutes the principal source of water. The run-off is distributed through a dense network of distributory rivers, creeks and estuaries the principal ones being the Forcados, Nun, Ase, Imo, Warri and the Sombriero comprising a well interconnected network that ensures rapid communication of pollutants such as oil-spills. The network also maintains a dynamic equilibrium between saline, estuarine and freshwater bodies through the complex groundwater system of pathways and reservoirs.

3 Upstream changes

The Delta also mirrors the impact of upstream water projects (dams and their reservoirs) as well as the prolonged 30-year drought of the Sudan and Sahel. This it does by the spontaneous decrease in river run-off soon after the construction of dams and reservoirs, which unfortunately coincided with the severe drought years (e. g 1971-73, 1983 - 84.) The discharge rate in the 1983-84 for instance, is observed to have dropped by 20% in the Niger Delta. In general the regulation by dams lowered the flood levels and reduced the capacity of flows to transport large volume of sediments during the wet season, which normally accounts for the bulk of the annual sediment transport. Also as a result of high evaporation rates and extensive nature of these shallow reservoirs, large volumes of their storages are lost to evaporation and to the Niger basin (though not to the global hydrological system). These losses in terms of the total annual inflow into the reservoirs amount to 20-30%. In addition, the dams retain the bulk of the sediments. As Nigeria's dams are traditionally over-designed they tend to retain over 70% of dissolved sediments intercepted by them.

Extreme construction and dredging of canals for transportation and communication in the many isolated riverine communities have contributed to anthropogenic impact in the Niger Delta. These structures often change the water flow pattern, disrupt sediment transport and deposition, and the level of salinity and could lead to destruction of fishing grounds and death of forests. The proposed dredging of the lower Niger has attracted much outcry from the general public and NGO's and the individuals as well as groups of stakeholders knowledgeable in environmental issues. The impact of the huge volumes of dredged materials, about $16 x 10^6 m^3$, covering approximately 600km along R. Niger from Baro in Kogi State, to Warri in the Niger Delta, on the aquatic and forest environments is expected to be severe as the conservative environmental assessments have indicated.

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4 Anthropogenic activities

Over-abstraction of groundwater in coastal/estuarine cities such as Port Harcourt and Warri may result in the lowering of the water table/ piezometric level and hence reversal of the hydraulic gradient at the groundwater-seawater interface. If this happens, the saline water intrusion at the interface will extend the zone of contamination.

The most probable agent of change as at now is oil prospecting/mining. It is to be noted that activities undertaken in the search and production of oil have already been implicated in some areas where oil-spills have been recorded over the years. Gas flaring regarded as another "safety measure" put in place by all the oil prospecting companies in the Niger Delta field in the absence of a more cost-effective measure is another source of impact that has become worrisome. Incident of acid rain and its deleterious effects on both the human and physical environments have been recorded.

Considerable alteration has been brought to bear on both the flow and sediment load and mode of deposition of R. Niger as a consequence of hydrological engineering activities over the years. For example, mean annual flow at Lokoja progressively decreased to 166,000 MCM in the 1970's and 138,000 MCM in the 1980's. Coastline and riverbank erosion have also had significant impact on the Delta over the years. From the hinterlands other erosion types, gully sheet and rill also add to the sediment load. River bank erosion alone has been implicated in the loss of an estimated 400 ha of land annually in the Niger Delta. This implies that 40% of the area currently inhabited in the Delta will be lost in 30 years.

5 Some existing change indicators

Apart from the changes in the Niger Delta induced by pattern of sediment deposition, one other characteristic that mirrors variability in basin components is water chemistry. It is also to be noted that although natural factors are involved, changes attributable to human activities are more significant. Such activities include use of agrochemicals in both rain-fed and irrigated agriculture, mishandling of wastes of diverse origin.

Table 1 exemplifies the chemistry of the waters of the R. Niger. Between Warri, within the Niger Delta and Baro in the Savannah ecological zone some 600 km away, a picture of the variability existing in water chemistry is presented. For example, it is only in the Niger Delta that acidic surface waters exist. While the other four locations Onitsha, Umutu Anam, Ajaokuta and Baro, have waters with pH greater than neutral, i.e. pH 7.0, Warri has pH 6.6, which is acidic. The electrical conductivity and dissolved solids of the waters in the Niger Delta is also approximately 15 times that of the other areas. In addition, it is only within the Niger Delta that salinity is detectable and measurable. This is further borne out by higher concentrations of other

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acidity and salinity enhancing chemical variables such as (Cl), sodium (Na) and manganese (Mn).

Table 2 also presents spatial variability in river sediment chemistry along the lower stretches of R. Niger. In general, the Niger Delta typified by Warri, has significantly higher concentration of most of the variables. Noteworthy are Na, Cl, NO_3, Fe and Zn. The data presented for all the locations including Warri are results of a recent (1999-2000) unpublished study along the lower Niger River. The situation in areas where oil-related activities, particularly oil spillage have been recorded is more worrisome. In 15 separate studies covering more than 300 villages, health and other environmental problems, which include thick oil films on both surface and groundwater, and respiratory problems have indeed been identified.

The level of concentration of sulphate (SO_4) and iron (Fe) in both the water and sediments of the Niger Delta predisposes the environment to intense acidification. Already, a large proportion of the soils of the area has been identified as potential acid sulphate soils that are difficult to manage (Balogun and Oyebande, 1993). The role played by Fe and SO_4 in the evolution of full blown acid sulphate soils is expressed in a reaction in which the iron-sulphur bacteria, Thiobacillus theooxidans, oxidize ferrous sulphide as pyrite, FeS2. This produces sulphuric acid and soluble iron (e.g. Foscolos and Kodama, 1981), as shown below:

$$4\ FeS_2 + 150_2 + 2H_2O \rightarrow 2Fe_2\ (SO_4)_3 + 2H_2\ SO_4 \qquad (1)$$

The other environmental factors required to speed up the process of acid sulphate soils, viz: conducive temperature, rainfall distribution pattern, a permanently highly reducing environment and high organic matter content exist in good measure within the Niger Delta, particularly the mangroves.

It is evident that the area is indeed a receptacle for upstream fluxes of materials from diverse sources. For example, wastes generated from domestic, industrial and agricultural (irrigated farmland in particular) sources usually end up in the river. These constitute a potent source of contamination not only at the point of use but also in areas many kilometers away downstream. This leads to eutrophication with dire consequences for aquatic lives. Natural processes such as flooding and erosion also exacerbate the changes in drainage basin characteristics.

In terms of health and socio-economy, the most worrisome of the anthropogenic forcing are the frequent oil spill and the continuous gas flaring. The combined effect of these takes a great toll on the environment. A 1998 oil spill which covered approximately 790km, 7 coastal States (Akwa Ibom, Cross River, Bayelsa, Rivers, Delta, Ondo and Lagos), and affected more than 1000 communities within the Niger delta vividly mirrors the immense toll the phenomenon takes on the human and physical environment. The effect of gas flaring though surreptitious is devastating in both the medium and short term. In fact its wider spatial coverage makes it particularly devastating on human health. Instances of respiratory diseases within communities have been linked

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to inhaling of soot-laden air in the immediate environment of gas flares.

Table 1: Spatial variability in some quality parameters of the waters of the River Niger.

Water Quality Parameter	Warri	Onitsha	Umutu Anam	Ajaokuta	Baro
Temp. (oC)	31.10	31.30	30.40	31.40	33.60
PH	6.60	7.45	7.80	7.20	7.20
Cond (us/cm)	91.60	6.00	6.30	5.90	5.90
Total Dissolved Solid (TDS)	45.60	3.00	3.15	3.00	3.00
Dissolved Oxygen, DO (mg/l)	5.20	7.20	7.00	7.00	7.00
Salinity (%)	0.30	0.00	0.00	0.00	0.00
Fluorine, F (mg/l)	4.39	1.16	1.18	1.43	1.15
Chlorine, Cl (ug/g)	10.48	3.92	3.71	5.23	4.28
Sulphate, SO4 (ug/g)	3.73	0.00	0.00	0.00	0.00
Sodium, Na (ug/g)	6.55	3.96	3.49	3.49	3.86
Potassium, K (ug/g)	6.26	3.35	2.59	3.36	2.69
Calcium, Ca (ug/g)	0.40	0.62	0.53	0.46	0.45
Magnesium, Mg (ug/g)	1.56	1.32	1.22	1.62	1.49
Manganese, Mn (ug/g)	0.06	0.03	0.02	0.04	0.05

Table 2: Spatial variability of some sediment physico-chemistry parameters along the lower Niger River

Parameter	Warri	Onitsha	Umutu Anam	Ajaokuta	Baro
Lead, Pb (mg/l)	2.227	0.560	0.200	0.178	0.360
Cadmium, Cd (mg/l)	0.210	0.000	0.000	0.154	0.000
Nickel, Ni (mg/l)	0.450	0.200	0.130	0.210	0.280
Iron, Fe (mg/L0	222.70	39.500	40.300	39.200	28.200
Copper, Cu (mg/l)	1.690	3.510	2.350	2.150	0.960
Zinc, Zn (mg/)	1.240	2.190	1.880	1.560	1.400
Sodium, Na (ug/g)	2.550	0.620	0.920	1.790	0.860
Potassium, K (ug/g)	1.660	0.570	1.030	1.400	1.600
Calcium, Ca (ug/g)	0.580	0.540	0.900	0.750	0.650
Magnesium, Mg (ug/g)	1.380	0.490	0.223	0.310	0.290
Manganese, Mn (ug/g)	0.500	0.400	0.223	0.220	0.190
Chlorine, Cl (ug/g)	37.120	29.740	1.750	9.320	6.090
Nitrate, NO_3 (ug/g)	334.80	58.280	3.640	3.620	0.000
Sulphate, SO_4 (ug/g)	665.60	393.340	7.990	22.910	11.520

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Impact arising from the trapping of sediments within dams and other storages upstream is the distortion of the natural equilibrium in sediment removal and deposition. This also intensifies loss of beaches and other coastal land to the ocean.

6 What to do

Both natural processes and man-induced factors upstream and within the Niger Delta itself are responsible for the change in the characteristics of the Niger-Delta sub-basin. Attempts at prevention and management of the impacts must include:

- understanding the why, what and how of the natural processes involved
- factoring the knowledge acquired into feasible mitigative and control and management options, and
- taking deliberate steps to protect the Niger delta from man and the aftermath of developmental activities,
- ensuring stricter compliance with environment-protecting legislation such as the mandatory environmental impact assessment (EIA) study prior to the take-off of any project that can impact the environment, and
- more effective and efficient management of upstream reservoirs and dams.
- intensification of continuous multi-disciplinary studies

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