Sediment-Related Problems in the Nile Basin: Emphasis on Sudan/South Sudan's Experience ------------Part 1

by

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Abstract

The growing awareness of the important role of alluvial sediment in water resources management has accentuated the need for better and more consistent information, yet such information still lags. In the Nile Basin, the problem of sediment management represents quite a challenge. In this paper, brief information on sediment transport and watershed management is reported. The difficulties and constraints in this field are reflected and discussed. Comments on sediment modelling in general and on the Nile Basin in particular are highlighted. Among several sediment modelling software packages, the SMS model has been selected for data analysis in the Nile Basin. The experience of Sudan/South Sudan (67% of the Nile Basin area-wise) in sediment management, which is very rich, is examined and explained. Management of sediment should work with nature, not against it, for ecological and economic sustainability. The paper concludes that sediment supply, transport and deposition are spatially and temporally variable; therefore, integrated sediment transport management in the Nile Basin requires a policy aimed at decreasing the adverse impacts of sedimentation for both U/S and D/S countries across the entire basin.

Keywords: Nile River Basin, Sediment, Problems, Rainfall, Flow, Canals, Reservoir, Capacity.

1.0- Introduction

This paper is the first part of a major study on sediment-related problems in the Nile Basin before the construction of the Grand Ethiopian Renaissance Dam (GERD). The second part will show the impact of GERD on sediment behaviour and its economic and environmental effects on the Nile Basin system.

Water is essential for the survival of individuals, populations, and nations. Water sustains animal and plant life and acts as a carrier and purifier of waste. Water underpins all life activities, domestic uses, food production, recreation, etc. All the uses of water described above are present in the Nile Basin. The Nile Basin encompasses areas ranging from those that receive some of the highest rainfall in Africa to areas with virtually no rainfall.

Africa's international rivers in general present a great management challenge, arguably greater than do the rivers of any other continent. The Nile River in Africa is at the forefront. There are several reasons for this: First, the highly variable climate, with extremes of precipitation and temperature, and considerable variability in river flow. Second, its water resources have profoundly affected its cultural and socio-economic conditions. Moreover, the Nile Basin is shared by 11 countries, making it the second river basin in the world, after the Danube River Basin (13 countries), in terms of the number of riparian countries. Rapidly growing populations in the Nile Basin remain predominantly agrarian and poor, and are highly vulnerable to water availability, including droughts and floods. Water has been and remains a primary factor in the location and production patterns of human settlements and in the structure and productivity of the economies of the Nile Basin countries.

In recent times, there has been recognition of the importance of basin-wide management of the Nile's waters. The need for basin-wide management has increased due to rapid population growth in the Nile Basin (over 300 million, with an annual growth rate of 3%). In addition, this growth has placed greater demands on watersheds, where land use practices, such as extensive clearing, increase the potential for erosion. Hence, a basin-wide approach to sustainable development is urgently needed, taking into account the present circumstances. Management of these multinational basins will require the sharing of information and, hence, enabling joint decision-making that benefits all residents of the Nile Basin. Management, development and planning of water resources within the Nile Basin, through assessment, monitoring, research, capacity building, and the collection and dissemination of data and information, are greatly needed.

The River Nile and its tributaries within Sudan are typically alluvial rivers. Flow in an alluvial river is basically similar to flow over an inclined plane. Its available energy is balanced by dissipation due to bed, side and internal friction, as well as by the energy required to transport the sediment load. On the other hand, the natural processes of erosion, transport and deposition of sediments have occurred throughout geological time and have shaped the landscape of the world in which we live. Erosion always causes serious damage to agricultural land by reducing soil fertility and crop productivity. Eroded soil is the largest pollutant of the surface waters in the world. Sediment affects water quality and its suitability for consumption and industrial use. Soil eroded from upland areas, e.g. the Ethiopian Highlands, from which 85% of the River Nile waters originate, is the source of most sediment transported by rivers to the reservoirs (Roseires, Sennar, Khashm El Girba and the Aswan High Dam (AHD)).

Problems associated with sediment deposition are varied; in stream channels, it reduces flood-carrying capacity, resulting in greater flood damage to adjacent properties. Reservoirs not only trap the incoming sediment load, but sedimentation also increases flooding risks, i.e. reservoir sedimentation results in a loss of storage capacity for flood control and/or irrigation. The upstream aggradation depends on the stream slope, the sediment size distribution and the water-level fluctuations in the reservoir. Streams with low slope carry large quantities of sediment, which may result in aggradation extending for kilometres upstream of the reservoir. Downstream of reservoirs, erosion usually occurs due to the action of the clear water released from the reservoir on the erodible channel bank and bed material, e.g. downstream of AHD in the Main Nile course in Egypt.

In this paper, problems of sediment management within the Nile Basin are highlighted. The impacts of sedimentation and mitigation measures are reviewed and discussed. Sudan's experience with sediment management is examined and discussed. Integrated sediment management within the entire Nile River Basin is found to be the best policy to minimise the adverse impacts of sedimentation.

2.0- Nile River Basin

Fig. (1) shows the general layout of the Nile Basin. The Nile River extends for some 6700 km through much of northeastern Africa. The setting is highly variable, ranging from tropical rainforest to desert and from mountainous terrain to areas near sea level. The basin spans many ranges and altitudes and exhibits wide climatic variation, with alpine extremes in mountain regions.

The main branches of the Nile River, the Atbara, Blue Nile and White Nile systems, form the features of the Nile Basin. The White Nile originates from the Equatorial Lake Plateau (Burundi, Rwanda, Tanzania, Kenya, Zaire and Uganda), and the Blue Nile originates from the Ethiopian Highlands. The sources are located in humid regions, with an average rainfall of over 1000 mm per year. The arid region starts in Sudan, the largest country in Africa, which can be divided into three rainfall zones: the south of the country where rainfall ranges from 1200 to 1500 mm per year; the fertile clay plains where 400 to 800 mm of rain falls annually; and the desert in the north of the country where rainfall averages only 20 mm per year. Further north, in Egypt, precipitation falls to less than 20 mm per year.

The Nile Basin covers 10.3% of the African continent and spans 35% of the total area of 11 countries. Table (1) and Fig. (1) show the share and contribution of the 11 riparian countries to the Nile Basin.

Table (1) Nile Basin: areas and rainfall by country

Country	Total area of the country (km²)	Area of country within the basin (km²)	As % of total area of basin	As % of total area of country	Rainfall Min. (mm)	Rainfall Max. (mm)	Rainfall Mean (mm)
Burundi	27 834	13 260	0.4	47.6	895	1 570	1 110
Rwanda	26 340	19 876	0.6	75.5	840	1 935	1 105
Tanzania	945 090	84 200	2.7	8.9	625	1 630	1 015
Kenya	580 370	46 229	1.5	8.0	505	1 790	1 260
Zaire	2 344 860	22 143	0.7	0.9	875	1 915	1 245
Uganda	235 880	231 366	7.4	98.1	395	2 060	1 140
Ethiopia	1 100 010	365 117	11.7	33.2	205	2 010	1 125
Eritrea	121 890	24 921	0.8	20.4	240	665	520
South Sudan	644 329	588 000	18.9	91	800	1 610	1 100
Sudan	1 886 000	1 394 000	44.8	74	20	800	350
Egypt	1 001 450	326 751	10.5	32.6	0	120	15
Nile Basin	**8 914 000**	**3 112 369**	**100.0**	**35**	**0**	**2 060**	**615**

(Source: Ahmed and El Daw, 2004; Sudan / South Sudan split after Nile Basin Initiative figures)

3.0- Nile River Watershed

The Nile River has three distinct watershed regions (Fig. 2) from which it derives its flow: the Equatorial Lake Plateau in the south, the Sudd region in the centre, and the Ethiopian Highlands in the east. From the confluence of the Atbara River north to the Mediterranean, the Nile receives no effective inflow.

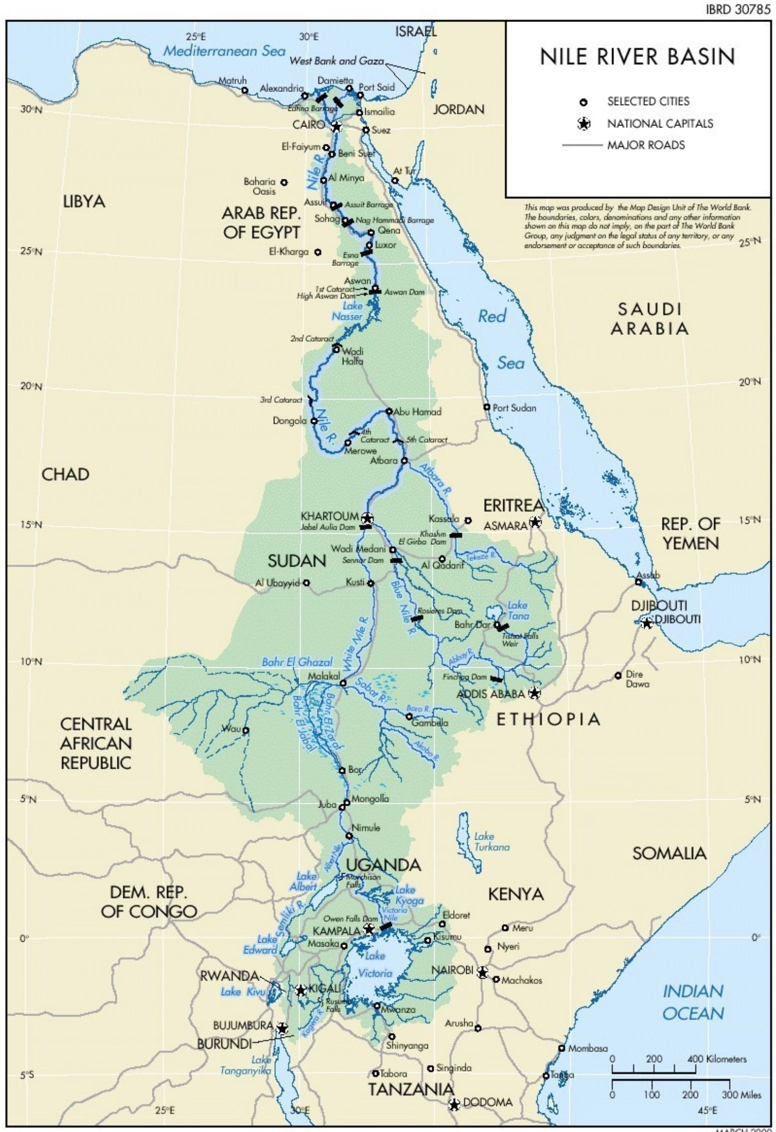


Fig. (1) Nile River Basin Watershed

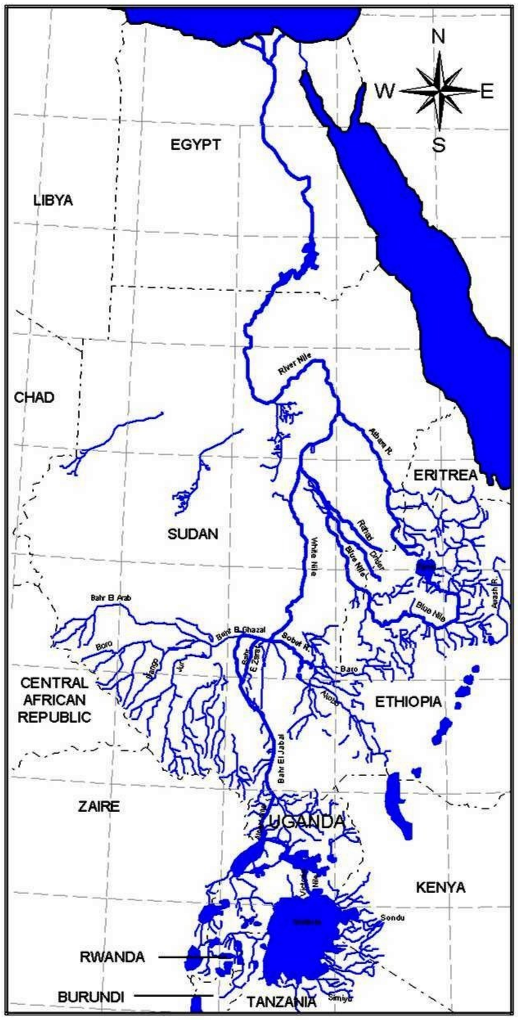


Fig. (2) Nile River: Three Main Distinct Regions Watersheds, after Ahmed and El Daw, 2004

Therefore, a regional team comprising experts and scientists has been formed, with technical support from the Flemish counterparts and under the auspices of the UNESCO Cairo Office to study sediment transport, watershed management and related issues in the Nile Basin. Besides national and regional capacity building, the research programme aimed:

- To exchange experience, ideas and information and to foster common understanding and cooperation in the field of sediment and related issues.
- To raise the level of awareness of policy makers, stakeholders and the public at large on various problems related to sediment transport and watershed management.
- To study the interaction between land use and the sedimentation problem.
- To gain experience in using hydrological models (the SMS model) as an effective tool in studying the selected case study in each country, and to try to relate this to watershed management.
- To find ways and means to reduce the negative impacts of sedimentation on the reservoir capacity and irrigation systems, hence increasing crop production and hydropower generation and enhancing socio-economic development.

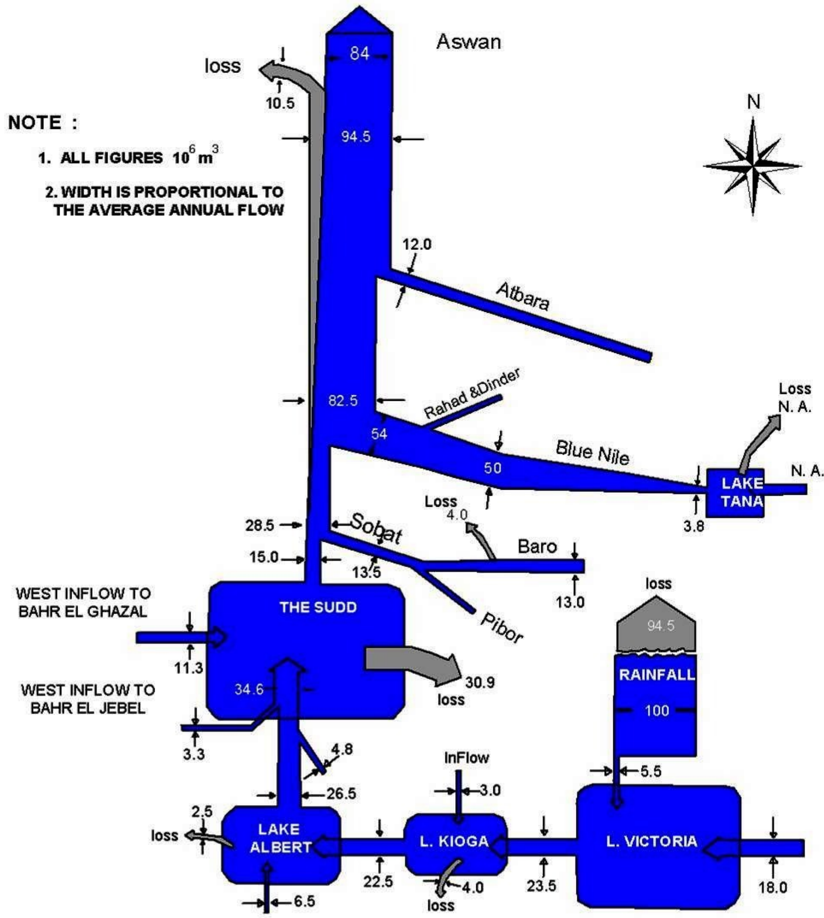


Fig. (3) Schematic Diagram of the Nile River Natural Flows

4.0- Blue Nile System Watershed

The Blue Nile system watershed (Fig. (2)) is almost entirely within Ethiopia, except for a relatively small contribution from Sudan near the border. Sudan's seasonal streams flow into the Blue Nile itself and into its two main tributaries (the Dinder and Rahad rivers). The Ethiopian plateau is the main source of the sediment in the Blue Nile system. It is believed that the total contribution of more than 11 seasonal streams in Sudan is relatively small (about 5 billion m³) compared to the Blue Nile flow; however, their sediment concentration is about 10 times that from the Ethiopian Highlands. The main streams in this area are: Khor Dunya, Khor Tumat, Khor Famaka, Khor El Gana, Khor Uffat, Khor Sereifa, Khor Zagholi, etc.

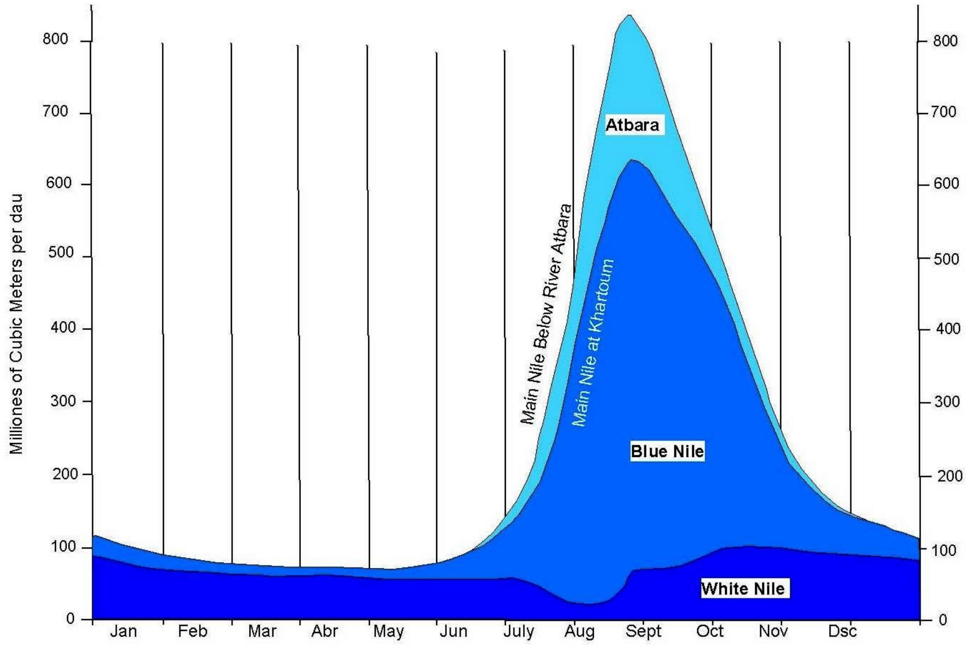


Fig. (4) Hydrograph of the Nile System

It is well known that in any watershed, the extent of erosion, degradation and sediment yield is linked to a complex interaction among topography, geology, climate, soil, vegetation, land use and man-made developments. Erosion in the Ethiopian Highlands is characterised by the detachment and entrainment of solid particles from the land surface or from the stream bed and banks as water flows downwards. Particles detached by weathering or rock fracturing are usually angular. Abrasion of sediments during multiple cycles causes sediments to become more rounded as they travel long distances over geological time. The total area of the Blue Nile watershed is estimated to be 201,346 km². Table (2) shows the estimated watershed areas of the Blue Nile River and other Nile River tributaries inside Ethiopia. Ten rainfall stations are distributed throughout the Blue Nile watershed in the Ethiopian Plateau. The stations give a reasonable representation of the watershed. The rainfall data collected cover the period (1987-1998). The occurrence of rainfall on the Ethiopian Highlands has a well-defined pattern, but the amount that falls each year varies erratically.

Before the 1960s, there was an absence of reliable records of rainfall and flows. The rainfall data are used for analysis and discussion, utilising the runoff flows into the Blue Nile and sediment concentration. Before the construction of Roseires Dam in 1964, only two flow stations with records were available: Roseires station (erected in 1905) U/S of the dam, and Wad Elais station D/S of the dam location.

Table (2) Catchment Areas of the Nile system in Ethiopia

River	Basin area (km^2) 10^3	Annual Runoff (m^3 × 10^9)	Flow at catchment Outlet in Sudan (m^3 × 10^9)
Blue Nile	201.346	52.60	48.74
Tekeze – Angereb	112.400	19.76	11.95
Baro – Akobo	74.102	11.89	NA
Total	**387.850**	**72.12**	**NA**

5.0- Methods of Sediment Measurement

The common method used in Sudan for sampling is dip sampling, whereby a suspended-sediment sample is collected by dipping a bottle into the turbulent flow just downstream of hydraulic structures in irrigation canals or dams (the location may affect the final results).

The collected water samples are analysed to determine two parameters:

- Sediment concentration
- Sediment grain sizes (size distribution)

Sieve analyses and hydrometer tests are used to measure the grain size distribution.

- Sieve analyses: used to determine the grain size distribution of sand and the relatively coarser sediment particles (diameter > 75 microns).
- Hydrometer test: used for defining the grain size of the sediments finer than 75 microns. The hydrometer procedure depends on Stokes' equation for the terminal velocity of a falling sphere.

This simple method for measuring sediment concentration has proven to be excellent when compared with the most sophisticated samplers in this field, e.g. US depth-integrating samplers (Hussein A. S., 2002).

6.0- Nile River Sediment

The sediment carried annually by the Nile River averaged 110 million tons as measured at Aswan. However, in recent years (1990s) the average sediment increased to about 140 million tons, indicating the seriousness of land degradation in the watershed (upstream) of the Blue Nile and Atbara River. The White Nile carries relatively little silt, or a negligible amount of sediment, because most of it is deposited in the swamps and marsh areas in the southern part of Sudan. This phenomenon is studied in this project, which aims to improve land use (land conservation) and water utilisation. The amount of sediment carried by the River Nile (140 million tons) is compared to 150 million tons for the Mississippi, 250 million tons for the Colorado and 2000 million tons for the Yellow River in China. The main sediment source in the River Nile system is the Blue Nile and its tributaries (the Dinder River, the Rahad River and the Atbara River). Before the construction of the Roseires Dam in 1964, the estimated annual suspended load of the Blue Nile was 70 million m³, equivalent to 185 million tons measured at the Roseires station. The average sediment concentration is about 4000 ppm, with maximum values sometimes reaching 6000 ppm. However, over the last ten years, the maximum sediment concentration increased to about 8500 ppm (45% sand, 15% silt, and 40% clay). The Blue Nile system contributes 65% of the River Nile flow (50 billion m³ from the Blue Nile plus 5 billion m³ from its tributaries, the Dinder River (3.5 billion m³) and the Rahad River (1.5 billion m³)) annually. In Sudan, 70% of the irrigated area (1.4 million hectares) draws water from the Blue Nile. The large amount of sediment which is carried annually by the river creates serious sedimentation problems in the reservoirs and irrigation difficulties throughout the canal network in the irrigated schemes, e.g. the Gezira Scheme (the largest scheme in Sudan, 1.0 million ha), the Rahad Scheme (0.12 million ha) and other Blue Nile irrigated schemes (0.28 million ha).

7.0- Blue Nile Water Flows and Sediment

Fig. (5) gives a clear picture of the Blue Nile flow trend over the last eight decades (1920-2001), with an average flow of 49,144 million m³ annually. The latter figure does not include the flows of the two main tributaries, the Dinder and Rahad rivers, and seasonal streams (Khors) inside Sudan. It is observed that very high sediment concentration was recorded D/S of the Roseires Dam. The sediment load in 2002 was exceptionally high; this might be attributed to the flushing D/S of the dam. On the other hand, the amount of sediment entering the Gezira Scheme irrigation networks is huge, despite the limited period (July-September); 20% of the total sediment carried by the Blue Nile is estimated to pass annually into the irrigation system networks. The latter represents 70% of the total irrigated area in Sudan.

8.0- Sediment Transport Modelling

Despite extensive research efforts, knowledge of erosion and sediment transport models is diverse and inconsistent. Functionally, models can be classified into five major categories: watershed, stream, reservoir, estuarine and coastal sedimentation models. Ahmed and El Daw (2002) reviewed many computer sedimentation models and concluded that no single model is usable under all conditions. Therefore, making proper selection and use of models that best fit particular circumstances is always a critical and troublesome question.

It is very important here to briefly summarise some of the findings about the sediment models in general, including the SMS (Surface Water Modelling System) model:

a. Mathematically: Almost all the models simulate a boundary value problem.

b. Hydraulically: All models include four major model components: equation of motion for water; continuity equations for water and sediment; one or more sediment transport functions.

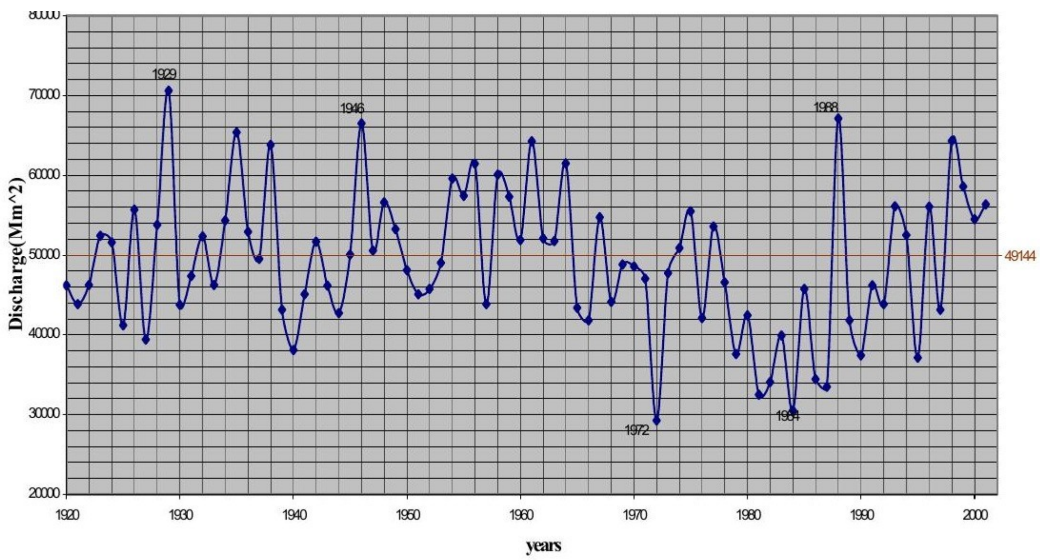


Fig. (5) The Blue Nile annual flows (1920 - 2001)

c. Most models solve their boundary value problems and partial differential equations with the explicit finite-difference technique.

d. Most models have greatly simplified their flow problems by considering unsteady problems as steady ones (SMS uses both).

e. Most models are uncoupled in the sense that they solve the flow equations first and consider the sediment factors later.

f. All models may have different sediment distribution assumptions.

g. Only a few models, in limited ways, can model bank erosion, armouring effects of channel geometry and morphology changes (SMS considers all of them).

h. All models may produce significantly different results, even when run with the same set of inputs.

i. Most of the existing stream sedimentation models are an amalgamation of three major modules: water routing, sediment routing and special function.

j. Most models use the following methods for water routing: finite difference method; finite element method; method of characteristics.

k. Most models, at present, use sediment transport functions which are not applicable to wash load or unsteady flow conditions (SMS considers unsteady conditions).

9.0- Results and Discussion

In the FRIEND/Nile project's first phase for the Nile Basin (started in 2002), data were collected, classified, and verified, and data gaps were identified. Several methods were used to fill the gaps, e.g., the arithmetic mean, normal ratio and weighted average methods. Different techniques and methodologies were used to analyse the data. One of the important tools for data analysis is the SMS model. It can be concluded from Fig. (4) that more than 80% of the Blue Nile flow occurs during the period July-October, with a peak in August. On the other hand, during the dry season (Jan-April), the flow can be as low as 10 million m^3/day. Such a situation makes it difficult to use the Blue Nile water efficiently. At the same time, it creates operational difficulties either in the reservoirs or in the irrigation systems. The Blue Nile flow gives the impression that it follows a normal distribution curve with its centre in August (Fig. 4). High variations in the total annual discharge with time can be easily noticed (Fig. 5). It is hard to observe any stability in any period. If the average of the Blue Nile is around 50 billion m^3 annually, some years recorded very high flows: 1929 (71 billion m^3), 1946 (66 billion m^3), 1988 (68 billion m^3) and 1998 (65 billion m^3). In contrast, some years show very low annual total discharge: 1972 (29 billion m^3), 1981 (32 billion m^3) and 1984 (30 billion m^3). There is no evidence to show how the alternating floods and droughts in the Blue Nile system occur. It can also be observed that while the seventies and eighties show a declining flow trend in the Blue Nile, the nineties show an increase. Therefore, it is highly recommended to investigate this phenomenon deeply.

Fig. (6) gives an overall picture of the annual rainfall pattern in the Eastern Highlands and Midlands of Ethiopia, where most of the Blue Nile and Atbara River watersheds are located. It indicates a decline in rainfall in the last two decades. This finding contradicts what we can conclude from Fig. (5). Data from the 10 rainfall gauging stations are used to measure the total annual rainfall in the catchment area. The Kriging method is used to interpolate rainfall in the Blue Nile catchment area, and hence the total rainfall amount is calculated for the catchment. Figs. (7 & 8) compare the discharge, the total amount of rainfall in the watershed and the sediment concentration for the Blue Nile and Atbara River. The peak of the average discharge (513 million m^3 per day) comes about three weeks after the peak of the sediment concentration (5660 ppm), while the peak of the total rainfall (2123 million m^3 per day) comes one week before the peak of the discharge. From a technical point of view, this sequence of events is quite sound, systematic and logical. This is attributed to the relationship between the start of rainfall and the topsoil in the catchment area being bare and loose, making it easier for the runoff to carry it into the river channel.

The time lag between these peaks depends entirely on rainfall intensity, duration and the condition of the catchment area. Sediment levels start to rise from mid-June to reach the maximum by the end of August and the beginning of September. Hence, they decline towards the end of the rainy season, after October.

On the other hand, if we consider the water discharges measured at El Deim at the border of Sudan with Ethiopia (just after the Blue Nile leaves Ethiopia to Sudan) as runoff of the Blue Nile catchment (watershed), the total average runoff coefficient is about 20% compared to the total average runoff coefficient for the Atbara River, which is about 14%. Although it is difficult to verify these figures, they look a bit low, since the calculations are complex and may encounter many errors.

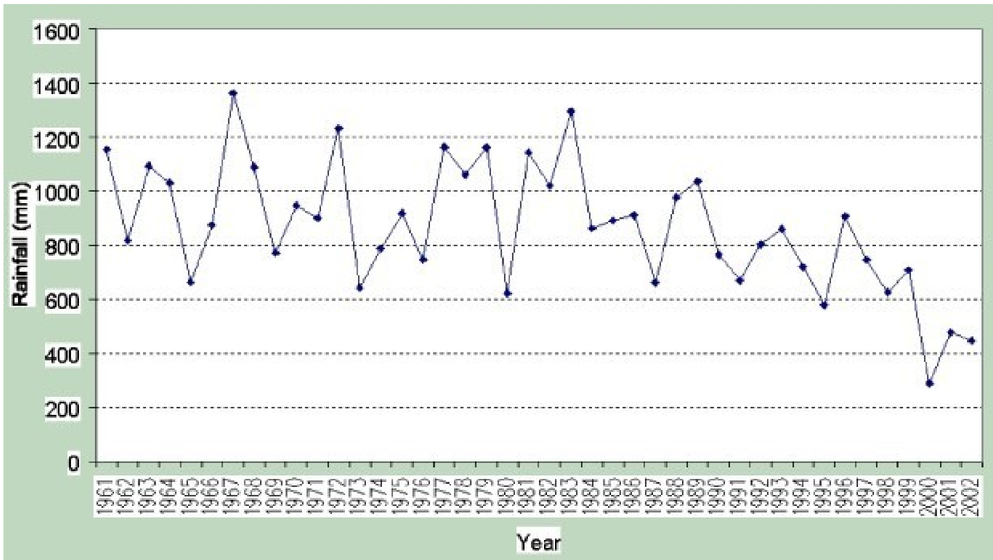
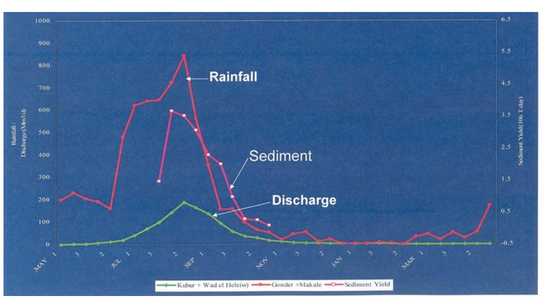


Fig. (6) Rainfall Pattern in Eastern Highlands and Midlands of Ethiopia (1961 – 2002). Source: USGS/EDC

Nevertheless, the Blue Nile runoff coefficient is higher than that of the Atbara River. This can be attributed to several reasons:

- The Atbara River catchment area is north of the Blue Nile; therefore, it is drier with less green cover.
- Higher sediment concentration in the Atbara River compared to the Blue Nile.
- The Blue Nile contributes 65% of the flow of the Nile system, while the Atbara River contributes only 16%.



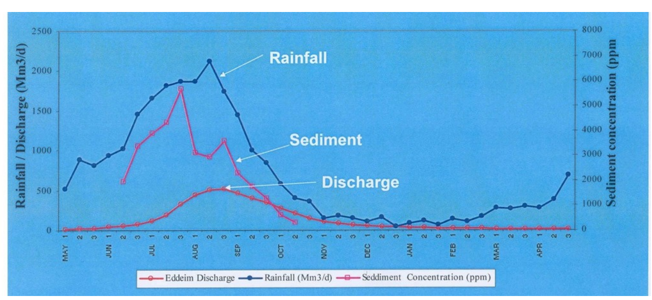
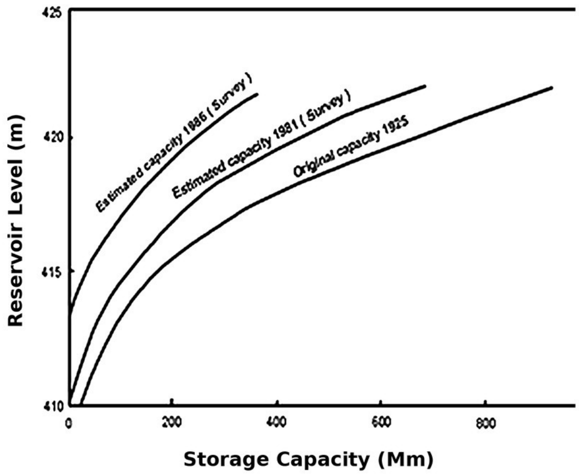


Fig. (7) Comparison of Rainfall, Discharge and Sediment Yield in the River Atbara (left) | Fig. (8) Comparison of Rainfall, Discharge and Sediment Yield in the Blue Nile (right)

These low runoff coefficients indicate how serious the problem is and how difficult it is. Deforestation and degradation of the Ethiopian Highlands have a clear negative impact on the whole system. In Sudan, where these rivers run, the situation is even worse. The problem has been reflected downstream as sediment deposition in reservoirs and irrigation canalisation networks, causing flood risks, crop damage, pump intake blockage, low production, and difficulties with hydropower generation.



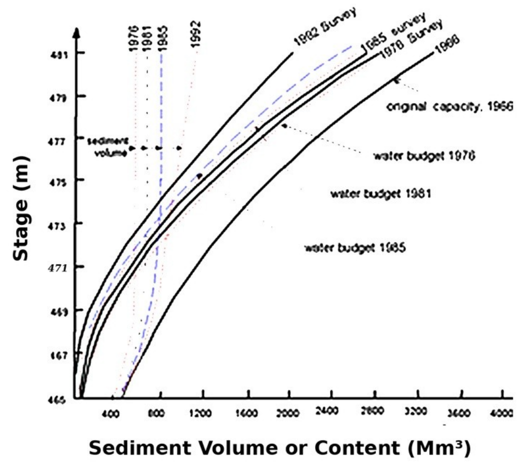


Fig. (9) Sediment Volume and Content of Sennar Dam (left) | Fig. (10) Sediment Volume and Content of Roseires Dam (right)

9.1- Reservoir Sedimentation and Potential Mitigation Measures

There is no doubt that the most effective sediment control is by conservation of the catchment area of the river, mainly by green cover (afforestation). Other control measures to improve sediment management in Sudan are: dredging, operational management rules, sluicing (flushing) and trapping.

Sennar Dam was constructed in 1925 on the Blue Nile, as the second dam in the Nile River system after the Old Aswan Dam in Egypt in 1902. The Sennar reservoir's original capacity was 930 million m³ (1925). Because of its good design and implementation of proper operational rules throughout the first 56 years (1925-1981), the reservoir was almost protected from sedimentation, i.e. the reservoir was well kept with negligible sedimentation (Fig. 9). The rate of sedimentation in that period had never exceeded 0.5% per year (4.6 million m³) with respect to the original capacity. Therefore, only a 28% reduction in reservoir capacity occurred over that long period (56 years). In contrast, during the period 1981-1986, sedimentation increased drastically at a rate of 80 million m³ (9.5%) per year, i.e. a reduction of 400 million m³ (43%) in only 5 years. However, the Sennar Dam (after 100 years) has lost 71% of its original reservoir capacity (660 million m³). In addition to the general increase in sediment load over the last two decades, the main reason for the poor situation during the above-mentioned period (1981-1986) is the change in operational rules to meet the irrigation requirements of the agricultural schemes upstream and downstream of the dam. Now, the Sennar reservoir is no longer used to store water but to regulate river flow and generate hydropower from a limited-capacity station (15 MW).

Roseires Dam, constructed in 1964 on the Blue Nile, was the largest reservoir in Sudan and the second largest in Africa after the Aswan High Dam, with an initial capacity of 3.3 billion m³. Roseires Dam is located about 200 km upstream of Sennar Dam (Sir Alexander Gibb & Partners and Merz & McClane, 1987). Fig. (10) shows the sediment volume and the content of the Roseires reservoir in the period (1964-1992). In the first ten years, the drop in capacity was 550 million m³ at a rate of 55 Mm³ per year. In the second period (1976-1981), the reduction in capacity was 100 Mm³ at a rate of 20 Mm³ per year. In the period (1981-1985), the reduction in its capacity was 120 Mm³ at a rate of 30 Mm³ per year. However, a drastic increase in sedimentation occurred in the period (1985-1992) at a rate of 60 Mm³ per year, resulting in a reduction of 427 Mm³ of the reservoir capacity. This may be attributed to the drought period (the 1980s) and the food security policy adopted in Sudan. This is aimed at increasing the irrigated area without taking any mitigation measures regarding the negative consequences on the reservoirs and the irrigation canal networks. Furthermore, intensive irrigation usually occurs during the period of high sediment content (July-August).

The reservoirs on the Blue Nile are seriously affected by sedimentation. This problem is irrecoverable and persists to this day. Plates (1, 2) show the magnitude of the sediment and debris problem in front of Roseires Dam. Unfortunately, there has been no survey of the reservoir in the last 11 years (1992-2003) [as of the time of this study, prior to the 2012 heightening of Roseires Dam]. However, the sedimentation rate is expected to be lower than in previous years because the reservoir has reached a stable regime. Now the storage capacity is less than 2.1 billion m³, and more than 36% (1.2 billion m³) has been lost from the original capacity. One can say there is a huge gap between what was estimated by the designer (Sir Alexander Gibb & Partners) before the construction of Roseires Dam in 1964 as a rate of sedimentation (15 Mm³ per year) and what has actually happened in the reservoir since then, where the average sedimentation rate is 43 Mm³ per year (Ahmed, 1992). However, sediment deposition in the reservoir is expected to increase, making the situation more complex and serious. It can be argued, without hesitation, that the dam designer's approach to the sediment issue, in the first place, has not been based on a solid scientific basis, resulting in an unsuccessful design where the deep sluice gates are located only in a narrow channel. This leaves part of the dam width without any flushing mechanism. Therefore, it is very important to consider how to manage sedimentation, e.g. to change the present reservoir operation policy and implement an efficient flushing system. Moreover, it is essential to consider intensive work in collaboration with the Ethiopian Authority for proper watershed management and conservation. This area requires wide studies and deep investigations.


Plate (1) Delta Formation Upstream, Roseires Dam (left) | Plate (2) Debris in the Reservoir Upstream, Roseires Dam (right)

9.2- Irrigation Networks Sedimentation

One of the well-known problems in Sudan associated with operation and maintenance (O&M) of irrigation systems is sedimentation. It has serious negative impacts, such as reduced irrigated areas and lower crop productivity. Moreover, this results in increasing costs of operation and maintenance of the irrigation system (Ahmed and Ahmed, 1993).

Normally, sediment is deposited in irrigation canals during low-velocity flow. An important point to consider from this monitoring program, carried out by the Ministry of Irrigation and Water Resources, is that almost 97% of the sediment entering the irrigation systems is smaller than 63 microns, i.e. predominantly silt and clay. However, the soil formed (by the silt and clay) at the bed and banks of the canals furnishes a good environment for the growth of aquatic weeds. This slows down the flow velocity, which promotes high sediment deposition in the irrigation canals. The proportion of sediment entering the canals increases as we move downstream in the irrigation networks.

Plates (3, 4, 5) give insight into the serious problem facing these irrigated schemes. Plate (6) shows an example of poor sediment clearance in one of the irrigation canals in the Gezira Scheme using an unsuitable excavation machine. The approximate distribution of sediment deposition according to recent studies carried out in the Gezira Scheme gives the following results:

i- the Main Canal 5%, ii- Major Canals 25%, iii- Minor Canals 33%, and iv- the Fields 37%.


Plate (3) Sedimentation and Aquatic Weeds in Irrigation Canals (left) | Plate (4) Sedimentation Problem in Gezira Scheme Canalisation System (right)

The common practice of sediment control in Sudan's irrigated schemes is to restore the original design of the canal cross-section by dredging or clearing sediment deposited along its course. This practice is very expensive and time-consuming. Therefore, the following solutions are suggested:

- To change the present practice
- To change the irrigation practice
- To introduce sediment excluders or settling basins.

However, the author believes further studies and investigations are required to address the sedimentation problem in irrigation canal networks.

Plate (5) Irrigation difficulties in Gezira Scheme due to Sedimentation (left) | Plate (6) Poor Sediment Clearance of Irrigation Canal in Gezira Scheme (right)

10.0- Conclusions

This paper highlights a wide spectrum of sedimentation issues in the Nile River system within the Nile Basin, with emphasis on Sudan's experience. It is also an attempt to relate the whole issue to upstream watershed management and downstream sediment control and management. Attempts to analyse the collected data using several different methods and techniques are highlighted and presented. Sediment analysis is attempted using the SMS model. However, it is too early to present firm conclusions without sufficient sediment data.

There is no doubt that the sedimentation in the reservoirs and the irrigation systems within the Nile Basin has environmental and socio-economic impacts. Therefore, suitable sedimentation management is a key factor for sustainable water resources management. Moreover, it is very important to evaluate the environmental impacts of sediment management properly and mitigate them as much as possible.

It can be concluded that the sedimentation rate in the last decade (1990s) increased rapidly, indicating that severe and widespread land degradation is occurring in the catchment area of the Blue Nile system. Therefore, integrated sediment management is recommended as the best policy to minimise the adverse impacts of sedimentation within the entire Nile Basin.

11.0- References

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