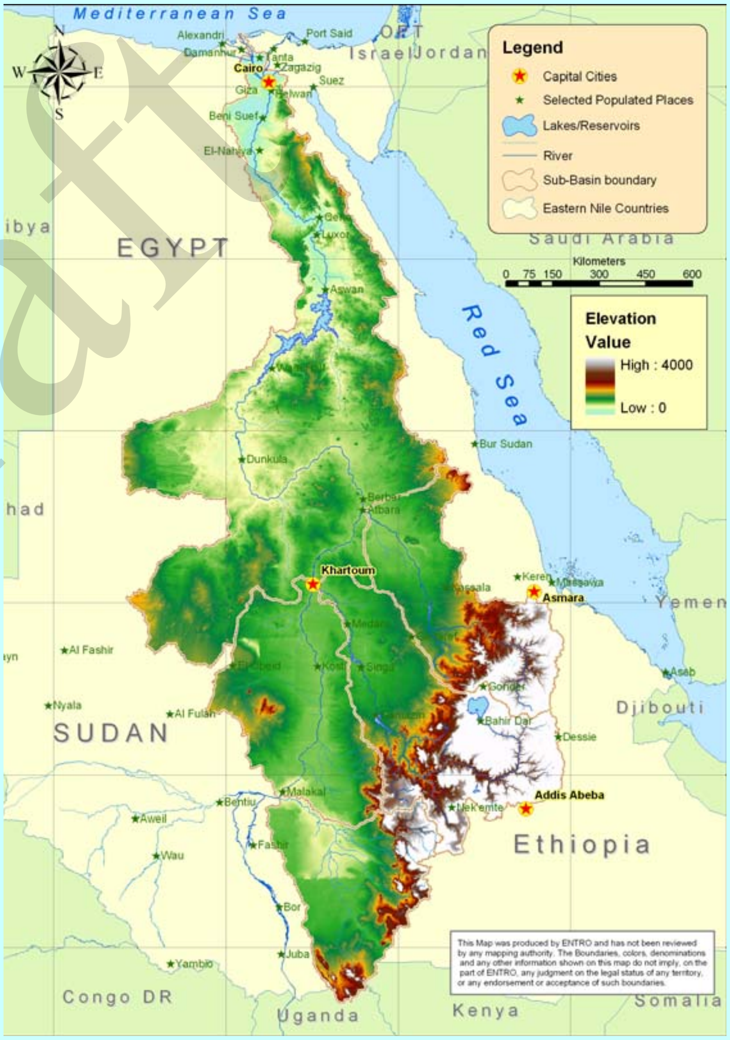
Multipurpose Development of the Eastern Nile, One–System inventory report on water resource related Data and information Sudan



ENTRO

(Eastern Nile Technical Regional Office)

By **Prof.Dr. Abdalla Abdelsalam Ahmed**
Khartoum, Sudan. 2006

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Preface

This is the final report which is prepared in response to the consultancy job requested by ENTRO within the Multipurpose Development Program of the Eastern Nile, One-System Inventory (Sudan). As a Consultant I have done my best to include all the required data. Therefore, the collection of the required data took longer time than it should be .However thanks to the Ministry of Irrigation and Water Resources and other Sudanese authorities who assisted us to obtain almost all the needed data and information. ENTRO knows the difficulties we faced in this respect, however their close follow up besides the appreciated efforts done by the National Coordinator lead to the success presented in this report. I would like here to state the valuable information supplied by the UNESCO Chair in Water Resources – Sudan. In this final report we tried our best to include all the comments and remarks pointed out by ENTRO during the draft stage of this report. I hope this final complete report will be meeting to high degree the TOR of this Project. I believe the report attempts to give general information and background related to the subject of the water resources and related issues of Sudan e.g. topography, climate, water resources, future development in irrigation and hydropower sectors,….. etc. Moreover; we tried to include even more information when we felt it is necessary for the programme. Nevertheless, we do believe nothing is 100%.

Prof. Abdalla Abdelsalam Ahmed
May 2006, Khartoum, Sudan

Acknowledgement

I would like to take this opportunity to thank ENTRO for giving me the chance to contribute to the Join Multipurpose Program through the preparation of this document about the Sudan water resources. In particular my thanks to Dr. Ahmed Khalid, Ass. Executive Director of ENTRO, and Dr. Salah Yousif the Chairman of the Water Resources Technical Organ and National Focal Coordinator of JMP, for their continuous support and help. My thanks to the Ministry of Irrigation and Water Resources and Metrological Authority for providing the relevant data. My thanks and appreciation to Eng. Isharga Sir Elkhatim for her help in pitting together the information in a form of Tables. My thanks also to Ms. Hala Abdelhalim for typing this manuscript of the report. In general, my thanks to all the UNESCO Chair in Water Resources staff, for the different kinds of help during the course of preparing this report.

Prof. Abdalla Abdelsalam Ahmed
May 2006, Khartoum, Sudan

Background Information

Sudan is the largest country in Africa and the ninth largest country in the world. It covers an area of 2,505,805 Km^2 located between latitudes 3^{0}N and 24^{0}N and longitudes 21^{0}E and 39^{0}E. It is about 2000 km long from North to South and 1800 km wide from East to West. In addition to the Red Sea which forms some 700 km of the northern part of its eastern borders, the country is bordered by nine African countries: Egypt and Libya in the North; Chad and Central Africa in the West; D.R. Congo ; Uganda and Kenya in the South; and Ethiopia and Eritrea in the East. Fig (1) shows the location of Sudan within the African continent. The vast area is mostly flat plain includes stretches of tropical forests, marshlands, mountains in the southern and central parts to savannah, stone and sand deserts and mountains in the north, east and west. The most remarkable feature of Sudan is the Nile River and its tributaries crossing the country from the south to the north. The diversity of the Sudan's geography and climate in particular is reflected in its people, who are multi-cultural, multi-ethnic, and multi-lingual.

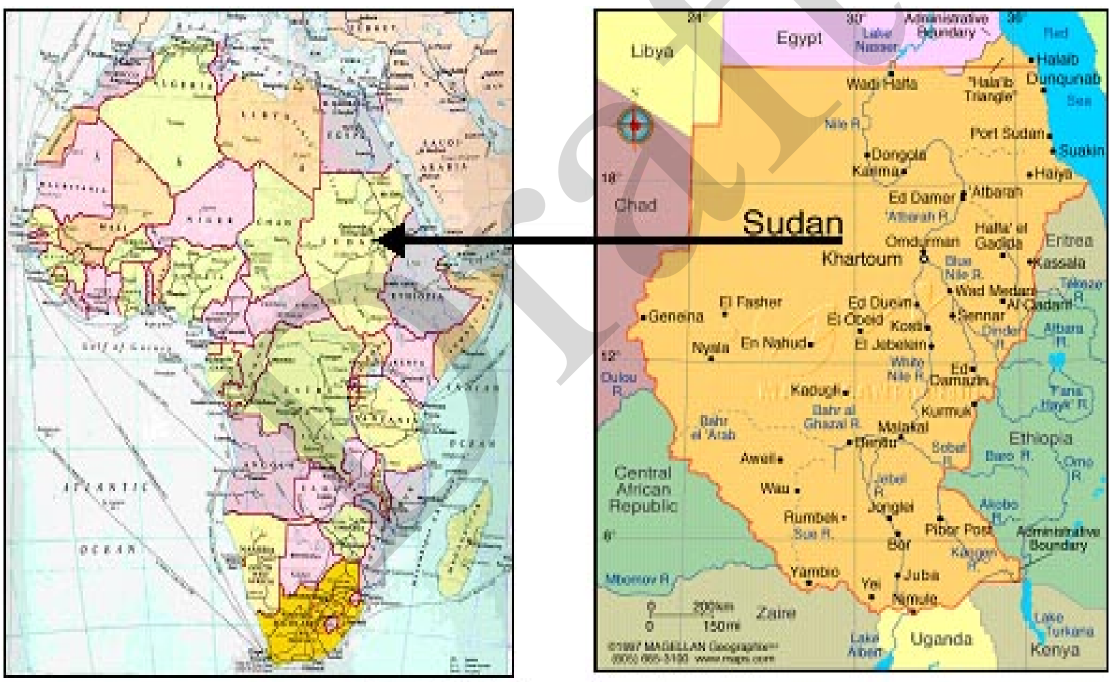
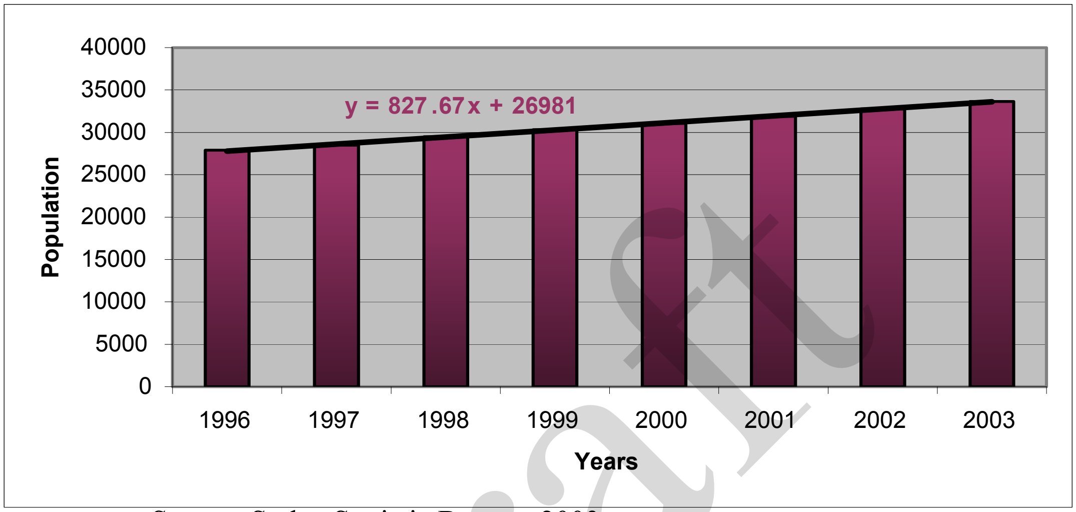


Fig. (1) Sudan Location

Based on the 1993 census the Sudan population in 2003 was estimated to be 33.72 million with an uneven distribution. The population density per km² is 14 persons. The average rate of the population is around 2.65% while the rate of growth in the capital Khartoum is amount to 6% per year due to other factors rather than the normal rate of growth. This explains the fact that about 25% of the Sudan's population lives in Khartoum. Fig (2) shows the population growth in the last 8 years (1996 -2003). However, the World Factbook estimates the population of Sudan as 39.148 million (July 2004) which is far more than that based on the 1993 census (11% more), which necessitate the importance of carrying out a new census as soon as possible. The Sudanese belong to about 700 tribes speaking more than 500 dialects and languages. About 80% of the population depends on agriculture or related activities for their livelihood. Cotton, oil seeds, gum Arabic and livestock are the main exports of the country. More recently petroleum has taken the lead in exports and now dominates the economy.



Source: Sudan Statistic Bureau, 2003

Fig (2) Growth in the population of Sudan (1996 – 2003)

Physical and Geographical Settings

The topography of Sudan and its neighbouring countries is a major controlling factor of its water resources availability and movement. It affects both the rainfall pattern, surface and groundwater movement. Most of the country is part of the Nile drainage area. Fig (3) shows the generalized topographical map of Sudan. Almost all the country is composed of a flat plain ranging in altitude from 200 m to 500 m above mean sea level (AMSL) and less than 2% of the surface area of Sudan lies below 200 m AMSL. This is confined to a narrow strip along the Nile River course in the Northern part of the country towards Egypt border.

On the other hand, only 3% of the area of the country has an altitude exceeding 1500 m. The high altitude areas include the Red Sea hills in the East rising to some 2700 m, the Imatong mountains on the Southern borders rising up to 3225 m, Nuba Mountains in the Southern part of Central Sudan rising to 1375 m and Jebel Marra in Western Sudan rising to 3500 m AMSL. The latter is considered by several observers to have a Mediterranean climate. This is confirmed by the fact that crops found in the Mediterranean climate zone grow successfully in the Jebel Marra area.

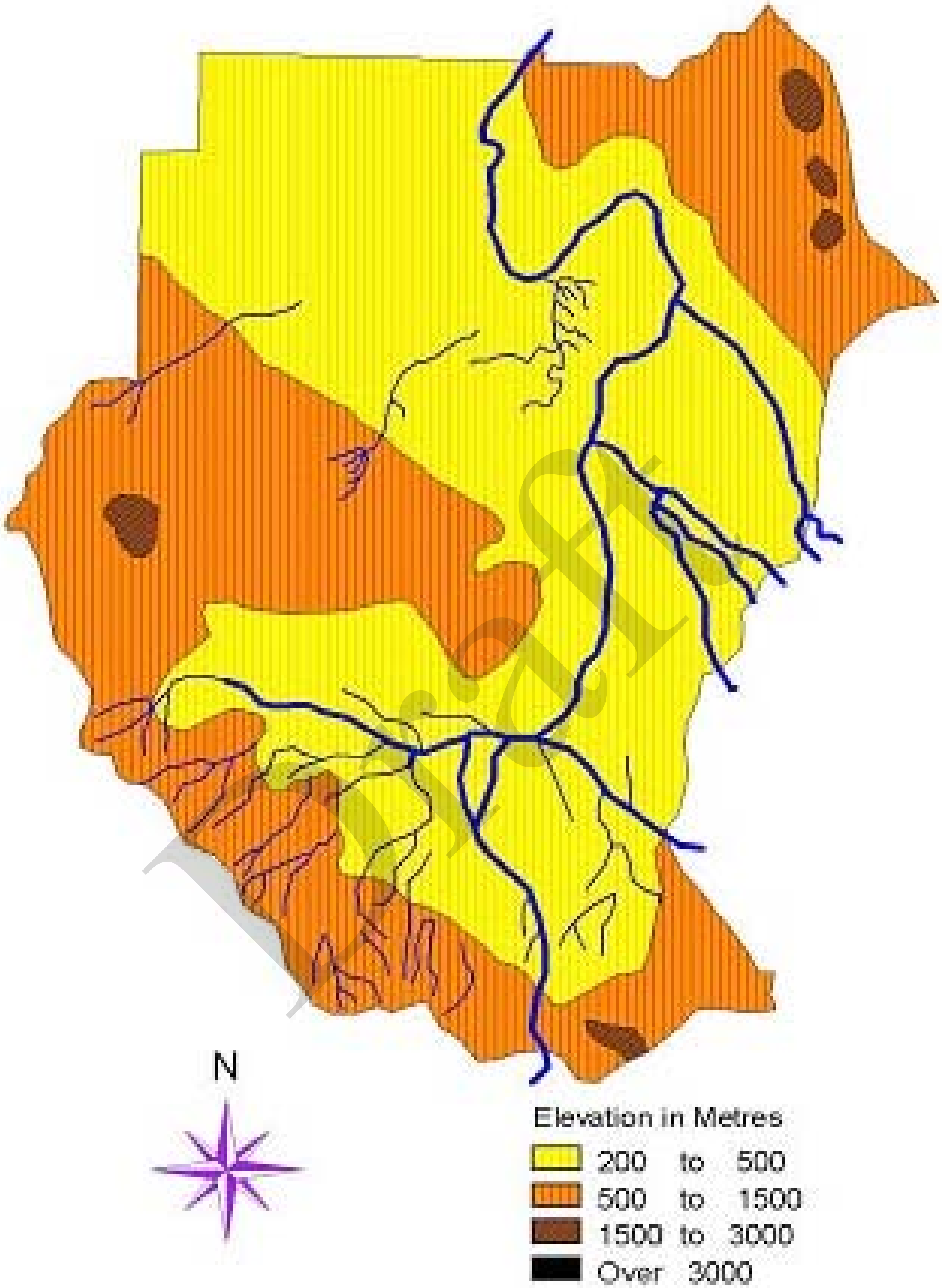


Fig (3) Topographical Map of the Sudan

Jebel Marra also represents a watershed divide line between the streams which flow west towards Lake Chad and those which flow east and south to meet the Nile Basin. The existence of the high mountains in Ethiopia and the Equatorial Lakes of the Upper Nile has great impact on the rainfall quantity, spatial and temporal distribution.
The low elevation of Sudan and the relatively high elevation in the west of the country, determine the drainage pattern of the Nile River, other seasonal streams and that of the groundwater. The Nile River crosses the country from south to north following the low level plain of central Sudan. The flow of the groundwater in the country also follows closely the surface topography.

Climate

The climate is of the tropical and subtropical type, which is a strongly influenced by the country's continental location. The rain falls is in summer with winter rainfall along the Red Sea. The rain depth and duration exhibit major variations across the country.
A large part of the North of the country falls within the Sahara Desert where the rain is infrequent and the total annual depth is less than 25 mm per year falling for only three months with the rest of the year virtually dry. The rain depth and the duration increase gradually towards the South to reach over 1000 mm. Only the Red Sea Coast line, which is separated from the rest of the country by the Red Sea hills, has a different rainfall pattern. It has its rainy season during winter with dry summer. The total annual rainfall and the length of the season can vary considerably from year to the other, and variation increases towards the North. There is also an indication of a decreasing trend in the rainfall in the country in the last 30 years. Fig (4) shows the retardation of the isohyets towards the south of the country.

The Temperature

The temperature is generally high particularly in the North of Sudan where it can reach 52^0C in summer. The main daily temperature during winter varies between 16^0C in the North and 29^0C in the South. The difference between the daily maximum and minimum temperature ranges between 18 and 24^0C in the desert area in the North, and 12 and 14^0C in the South of the country. It gives 28% in the North and 63% in the South. Some investigators classified the weather of Sudan to only two seasons: hot in the winter and very hot in the summer.
The variation in evapotranspiration across the country, from year to year and during the year is by far less than the variation in rainfall. Evapotranspiration variation across the country has a reverse pattern as that of the rainfall. It is highest in the north where it reaches 3000 mm per year and decreases steadily to almost half of this amount in the extreme South.

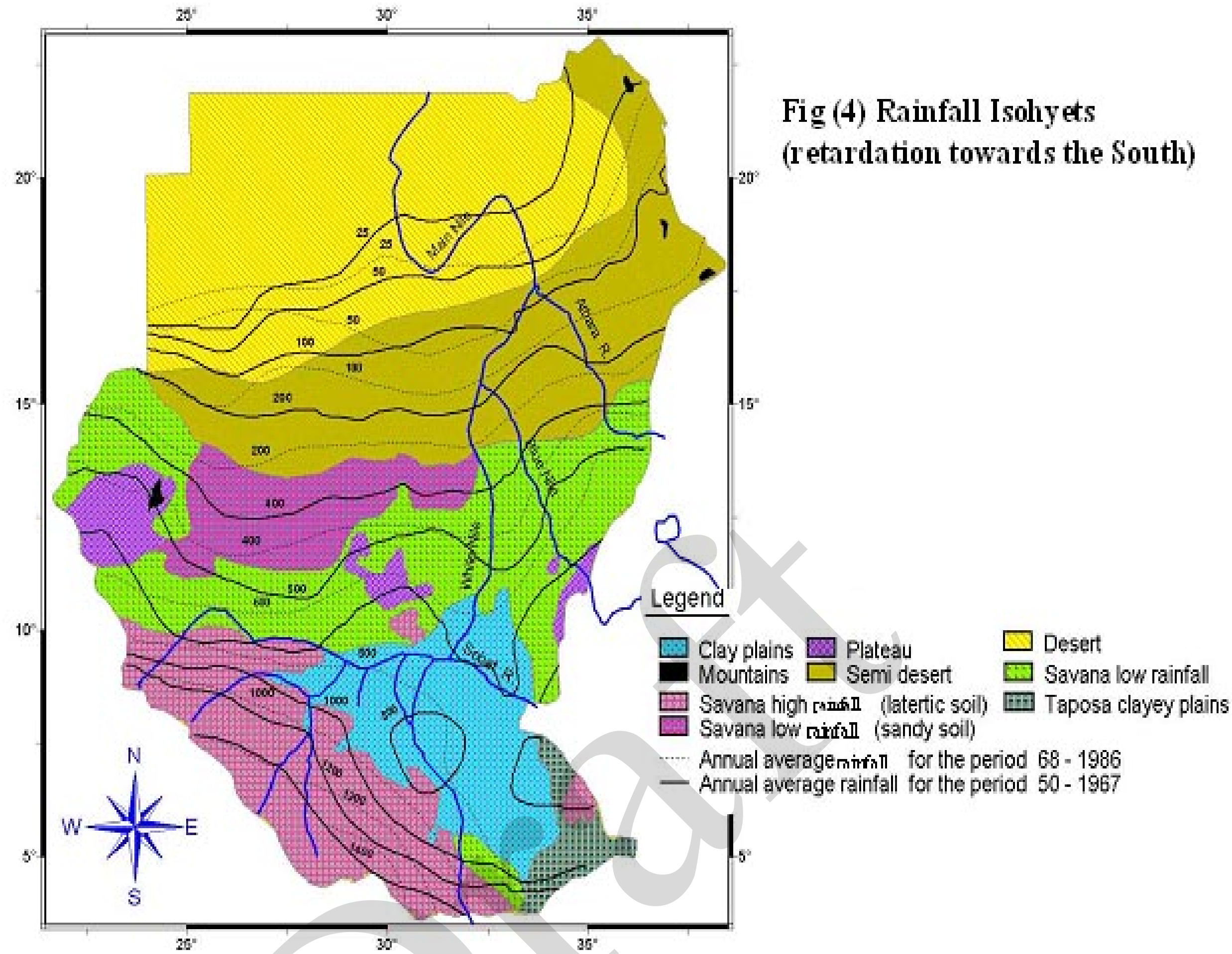


Fig (4) Rainfall Isohyets (retardation towards the South)

The spatial variation of evapotranspiration is mainly during the rainy season. Monthly variation is more pronounced in the North than in the South. The maximum evapotranspiration in the North occurs in May, and is about twice the minimum obtained in December. In the South, the maximum evapotransiration during March is only 50% higher than the minimum in July. Therefore, the deficit between rainfall and evapotranspiration is very large. It can be noticed that the only positive balance is found in the south of the country. Moreover, the rainy season is rather short and the rain falls on a hot pad of soil.

Rainfall

Rainfall in Sudan is mainly influenced by the seasonal movement of the sun and the associated Inter-Tropical Convergence Zone (ITCZ). The start of the rains coincides with the northward movement of the ITCZ, occurring in April in the far South of the Sudan, in about June in Central Sudan, and in July in Northern Sudan. During its further movement to the North, ITCZ weakens resulting in reduced rainfall towards the northern parts of the country. At the northern frontier of the country, rainfall events are rate . With the subsequent change of seasons, the ITCZ retreats southwards and brings the rainy season to a close. This occurs in August in the North of the Sudan, about September in Central Sudan, and

October in the far South. Accordingly, the annual rainfall is related to the length of the rainy season.
Another important factor which has influenced the distribution of annual mean rainfall of the country is the effect of topography. At any given latitude in Central Sudan, stations in the Nile valley may have less annual rainfall than those further West or East. Jebel Marra in the West gives a well marked local maximum, while along the eastern border with Ethiopia; rainfall isohyets lie parallel to the mountains, with increasing rainfall on the higher ground. In the North-East of the country a winter rainfall pattern results from the presence of the Red Sea. This generates local circulations which interact with the hills near the coast to produce rainfall. However, the maximum long term annual mean in this area is less than 100 mm so that water resources from rainfall are marginal at best, unless other means are used to harvest the rainwater. Table (1) shows Sudan rainfall zones.
In accordance with World Meteorological Organization (WMO) standards, meteorological stations in Sudan are classified as: Synoptic, Climatological, Agro-meteorological and Rainfall Stations. These stations are operated by the Sudan Meteorological Corporation (SMC). The SMC index lists a total of some 930 rain gauges.

Table (1) Sudan Rainfall Zones

Zone	Effect	Latitude	Remarks
South	I T C Z	3.5^{0}N-11.8^{0}N	21.8^{0}E – 35.15^{0}E
Central		11.8^{0}N-15.7^{0}N	21.8^{0}E-36.7^{0}E
North		North 15.7^{0}N	
Jebel Marra	Orography	12.8^{0}N	
North-East Sudan	Red Sea	18^{0}N-23.15^{0}N	35.5^{0}E-39.5^{0}E

The coverage of the network of the rainfall stations in Sudan has varied greatly since their erection. It was at peak in 1969, when 589 stations were operational with a national average density of one gauge per 4250 km² in 1986 and only 27 stations in 1996. Nowadays, the operating number of rain gauges is less than that of 1986.
The total average rainfall annually in Sudan is estimated to be 1000 billion m^3. (Ahmed 2003) produced Table (2) which verifies in a scientific way through zonation of the country climate the latter figure.
In Appendix 1, Tables (3, 4, 5, 6, 7, 8,) show the rainfall information in selected metrological stations for the period (1981 – 2000) in Sudan, while in Appendix 2, Tables (9, 10, 11, 12, 13, and 14) give the potential evaporation in the same gauging stations and period. Generally it can be notice that the rainfall and the potential evaporation data are well documented with very few places where there are No Records (NR). The latter represents less than 1% which gives good sign and confidence on the data collected in general.

Table (2) Average rainfall, land resources zones, distribution of persons per km ^{2} and length of cropping season

Zone	Area % to total area of Sudan	Persons per km^2	Mean Av. Rainfall Range (mm)	Mean length of crop growing season (days)	Amount of Rainfall in Billion m^3
Desert	44	04	000 - 200	000 - 50	100
Gos sands	10	22	200 - 800	050 - 150	100
Central clay Plains	14	38	200 - 800	050 - 150$^+$	140
Southern clay Plain	12	16	800 - 900	150 - 180	250
Ironstone plateau	12	14	800- 1400$^+$	150 - 240$^+$	330
Hills area and others	16	32	Variable	Variable	080
Total	100	Variable	Variable	Variable	1000

The Nile major Sub-basins

Eight major sub-basins within the Nile Basin were identified and selected on the basis of watershed drainage divides and sub-basin characteristics.

i- Lake Victoria Sub-basin

The Lake Victoria sub-basin is the area covering the lake surface itself and the catchment areas of all its tributaries. The outlet hydrological station is at Jinja. The lake's surface area is about 67,000 km^2 and occupies a large proportion of the entire sub-basin, (about 238,650 km^2). The average annual precipitation is high with a bimodal seasonal distribution with peaks in March–May and November–December. It amounts to 1,295 mm and is slightly higher over the lake surface than over the adjacent land area. It varies considerably across the sub-basin from 688 mm in the southeastern part of the basin to more than 2,550 mm over the northwestern part of the lake.

Runoff is very much a function of the catchments climate, soil, land-use/land-cover, and topographic characteristics of the watershed and of the channel network. The yearly mean accumulated observed flow at Jinja is 30.97 billion m^3, which is equivalent to 130 mm of average runoff over the whole catchment. Thus, the runoff/rainfall ratio is 0.10 or, in other words, only 10% of the total rainfall over the sub-basin is observed at the Jinja outlet. This relatively low runoff/rainfall ratio, compared to Europe and North America, is caused by the high evaporation rate from the lake's surface and by the moisture losses in a bimodal precipitation regime. Since the lake area does not differ considerably with the lake stage, it could be assumed that the hydrological cycle over the Lake Victoria Basin is without considerable anthropological impact. However, it can be pointed out that the outflow from Lake Victoria is controlled and therefore the yearly discharge or release at Jinja does not reflect the natural rainfall/runoff process in a particular year. The lake itself possesses huge storage. A difference of one meter in the lake level represents the volume generated by more than two years of average outflow.

ii- Equatorial Lakes Sub-basin

From the outflow of Lake Victoria at the Owen Falls dam, the **White Nile** flows into Lake Kyoga, then into Lake Albert and northwards into southern Sudan.
The average annual precipitation over the area is 1,198 mm, and the average yearly flow at Mongalla the outlet of Albert lakes amounts to 37.51 billion m^3.

iii- Sudd Sub-basin

To the north from Mongalla, the **White Nile** is known as the Bahr el Jebel and flows into a vast complex of channels, lakes and swamps in an enclosed basin. The entire area is very flat. From Mongalla to Malakal, the slope of the land averages only 10 cm/km.
The watershed area is about 139,425 km^2. The average annual precipitation over the area is 923 mm with a peak of over 1,470 mm in the southern part of the basin. Rainfall intensity decreases to the north where the annual average does not exceed 760 mm. Precipitation falls mostly in one season from April to October. This coincides roughly with the river flood period when the area is permanently flooded. Swamps expand in proportion to the magnitude of the inflow from the Mongalla and from local precipitation.
A comparison of the historical inflow data at Mongalla (37.51 billion m^3) and outflow data at Malakal (30.47 billion m^3) shows a negative balance of 7.04 billion m^3. Taking into account that the Sobat River contributes on average 13.66 billion m^3 of water yearly to the flow at Malakal, one can easily conclude that more than 20 billion m^3 of water is diverted, mostly by evaporation, evapotranspiration, and groundwater losses, not taking into account the local precipitation over this sub-basin.

iv- Bahr al-Ghazal Sub-basin

This sub-basin consists of a number of tributaries that run from the border of the Congo Basin to the Nile. This vast area is about 330,375 km^2. The peak of rainfall intensity in the south- western part produces over 1,550 mm of average annual rainfall, which decreases toward the northeast where the annual precipitation does not exceed 500 mm. The average annual precipitation over the entire area is 970 mm.
The catchment is divided into many tributaries with bank overflow and flooding. In this large area of very low slope, nearly all the basin runoff and precipitation evaporates, so only about 0.5 billion m^3 (out- flow from Lake No) leaves the basin annually.

v. Sobat Sub-basin

The Sobat River includes the discharge from two tributaries: the Baro River from the Ethiopian Highlands and the Pibor River from southern Sudan and northern Uganda. This sub-basin is about 186,275 km^2. Fig (6) shows the main features of the Sobat River catchment area. The rainfall regime tends to unimodal with a rainfall season from April to October. The highest rainfall intensity is over the Baro basin in the east of the sub-basin where the average annual precipitation almost reaches 2,000 mm. The lowest intensity is over the southeast over a tributary of the Pibor River, which joins Akobo River after it passes the Sudanese boarder, with an annual precipitation only slightly over 300 mm. The average annual precipitation over the entire sub-basin amounts to 1,057 mm. The Baro is the larger of the two and is highly torrential and seasonal. The Pibor is less seasonal.

Many of the tributaries of the Sobat tend to overflow and form swamps when they reach the flat plains of Sudan from the Ethiopian Highlands. The area of flooding and spillage into seasonal and permanent swamps is large and includes the Marchar Marshes. The losses are estimated as 30% of the Baro and 14% of the Pibor.

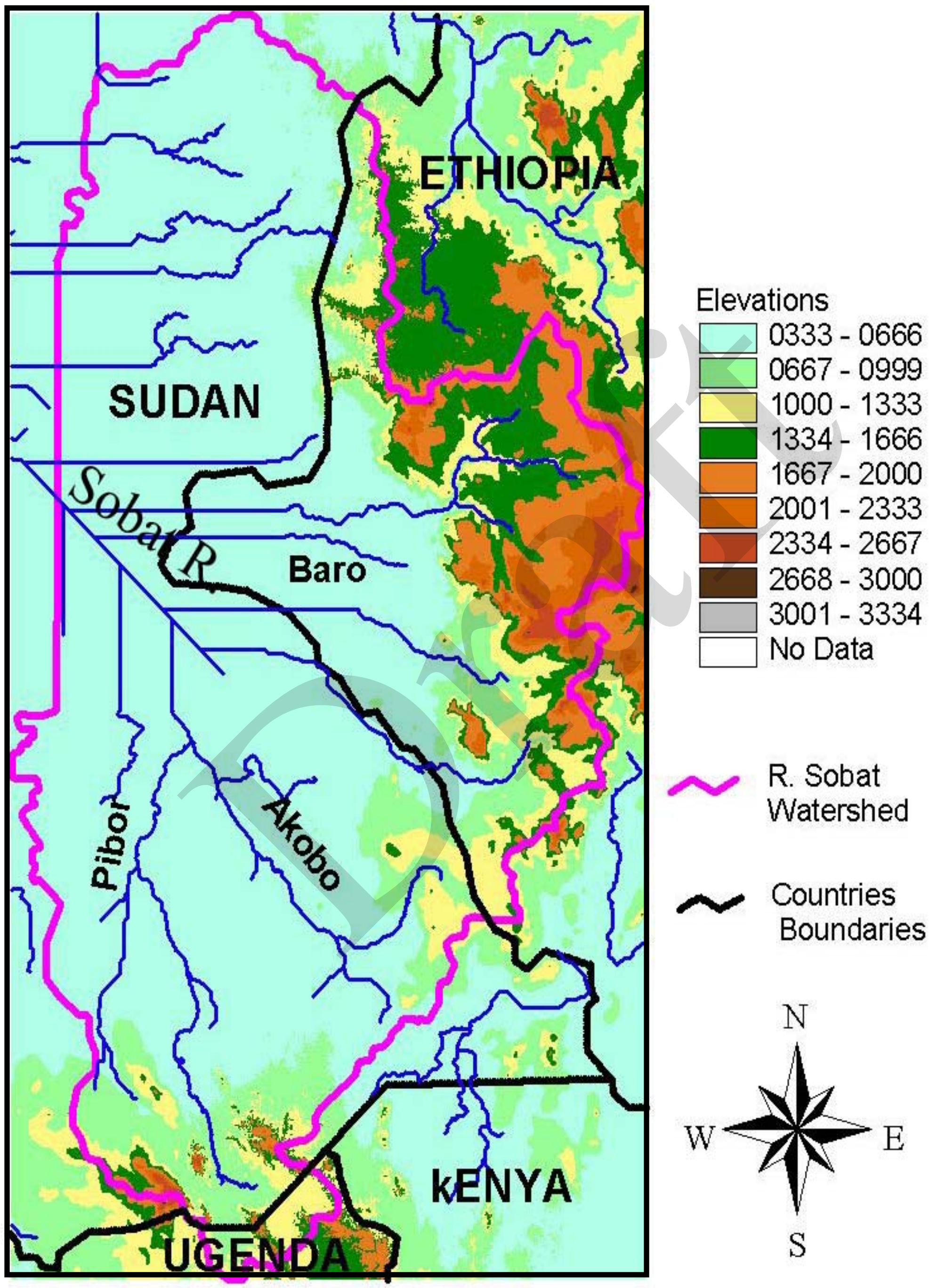


Fig (6) Sobat River Watershed

vi- Blue Nile Sub-basin

The source of the Blue Nile is the Little Abbay River in the Ethiopian Highlands. The Little Abbay flows into Lake Tana, which discharges into the Blue Nile and runs 900 km down through the highlands into Sudan. The area of the Blue Nile catchment is about 141,900 km2. Fig (7) shows the Blue Nile River catchment area and the main tributaries inside Ethiopia and Sudan. The Rosieres dam reservoir is located one hundred Km from the Sudanese-Ethiopian boarder. The average annual precipitation over the sub-basin is 1,346 mm, making it the highest among all the sub-basins of the Nile. The lowest rainfall is recorded over the eastern part of the sub-basin where the average annual precipitation does not exceed 800 mm. The highest values are over the southern part of the catchment (Ideas tributary) with the values exceeding 1,900 mm.

The average annual discharge of the Blue Nile at the Sudanese-Ethiopian boarder (Roseires station until 1965 and ElDiem afterward) is about 50 billion m^3. Therefore, the runoff/rainfall ratio over this basin is 25%, which is the highest among all the sub-basins in the Nile Basin.

From the Sudanese-Ethiopian boarder the Blue Nile flows north from humid to semi-arid conditions, Although there is a considerable additional runoff between the boarder and Roseires dam, however, usually little additional runoff north of Roseires is taken into consideration. The exceptions are the two tributaries, the Dinder and the Rahad. They join the main flow downstream of Roseires and have their headwaters in the Ethiopian Highlands.

The sub-basin watershed catchment area is about 121,175 km^2. The relatively high values (1,300 mm) of the average annual precipitation around the Sudanese-Ethiopian boarder decrease rapidly downstream. Around Khartoum the average annual precipitation is below 180 mm. The average annual precipitation over this sub-basin is 573 mm. Since the end of the 1950's, the area downstream Roseires become intensively irrigated and 70% of the Sudanese agricultural schemes have water from the Blue Nile system.

vii- Whit Nile Sub-basin

On the stretch from Malakal to Khartoum, the White Nile flows into increasingly semi-arid conditions. There are no permanent tributaries and it is only in years of very heavy precipitation that there is any addition of importance to the river flow. There are only losses. On average, there is a loss to evaporation of about 2 billion m^3 of the total discharge as measured at Malakal. The Jebel Aulia dam built forty kilometers upstream of Khartoum in 1937 to store water for later use in Egypt has added approximately a further 2.5 billion m^3 to the evaporation losses along this stretch. At Khartoum the White Nile joins the Blue Nile to form the Main Nile.

viii- Atbara Sub-basin

The Atbara River is the most northern tributary to join the Nile. Its headwaters originate in the north- western Ethiopian Highlands. The nature of the river is extremely torrential. The majority of the river discharge is derived upstream of the Khashm ElGirba reservoir. Downstream, the conditions change to semi-arid and then arid.

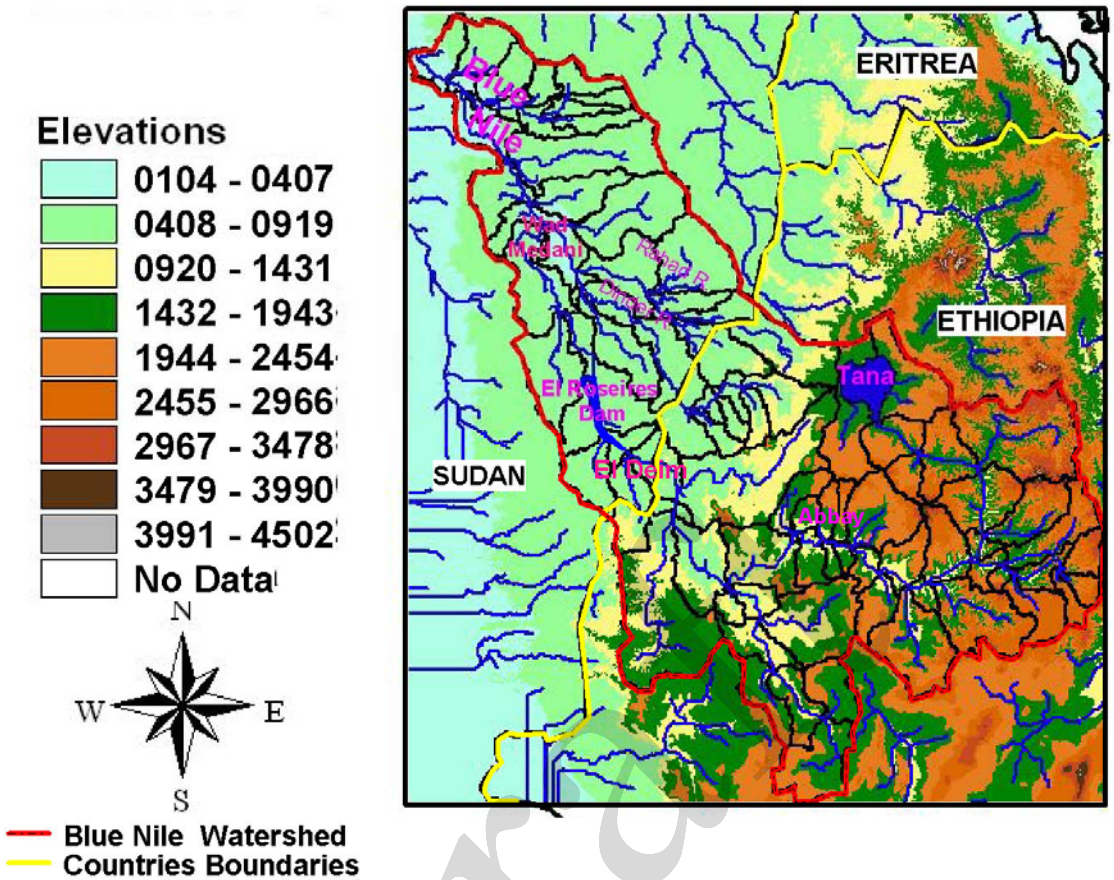


Fig (7) Blue Nile River Watershed and Roseires Reservoir

Fig (8) shows Atbara River catchment area and its main tributaries (Upper Atbara and Setit) and Gash ElGirba dam reservoir. The entire Atbara sub-basin is quite large. It is estimated as 166,875 km^2. The average annual precipitation over the area is 553 mm, the lowest among the Nile sub-basins. The relatively high value of more than 1,300 mm of annual rainfall over the Ethiopian Highlands decreases to less than 90 mm downstream at the junction of the Atbara River with the Main Nile. The average runoff/rainfall is estimated to be 12%.

ix- Entire Nile Catchment Basin

The entire Nile Basin area is simply the sum of all the sub-basins mentioned above (i - viii). The areas in which runoff are diverted to other river basins and arid areas where there is no rain at all are not counted. Hence, the entire Nile Basin corresponds to 1,527,500 km2. This figure is lower than those usually found in references to the Nile Basin area, which is usually estimated as 3.0 millions km^2. Therefore, the entire Nile catchment runoff/rainfall coefficient is estimated as 5.5%, which is very small compared to other international rivers and even to the African ones. The average annual flow of the Nile is estimated to be 84 billion m^3 , measured at Aswan High Dam.

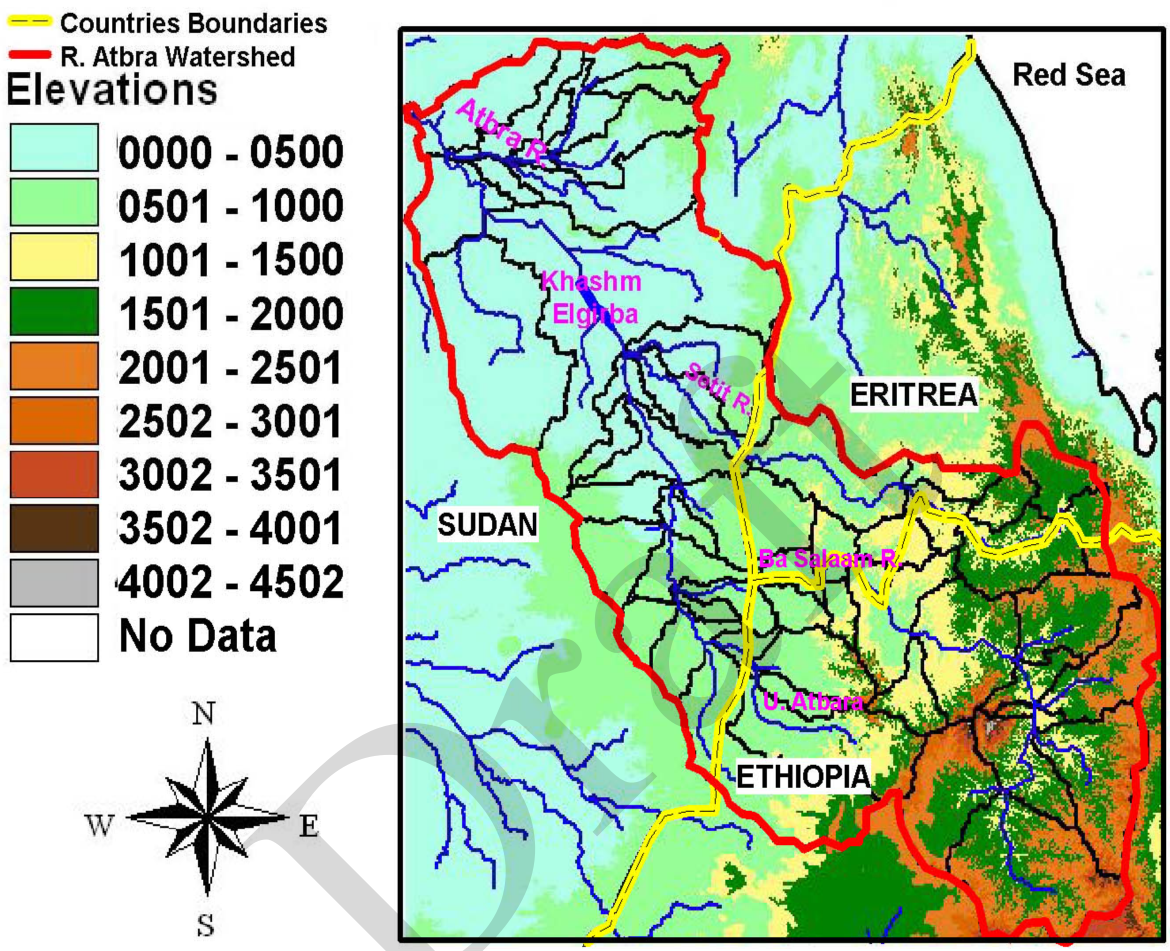


Fig (8) Atbra River Watershed and Gashm ElGirba Reservoir

Surface Water Hydrology and Measuring Stations

The major portion of Sudan surface water is mainly contributed by the Nile River and its tributaries; the Blue Nile, River Atbara and the White Nile. Fig (5)* (this is a size A0 submitted to ENTRO separately) shows detailed map of the River Nile and its tributaries. Moreover, the map explains the drainage system of the River Nile in Sudan. The Blue Nile contribution accounts for some 60% of the Nile total discharge. The flow pattern of the Blue Nile is highly seasonal. The annual flows of the Blue Nile for the last 50 years gives an average of 50 billion m³ annually.
The Atbara River contributes about 15% of the total discharge of the Main Nile and follows much the same seasonal pattern as the Blue Nile except that its discharge reduces to very low flows and sometimes to zero flow for almost four months of the year. The hydrograph of Atbara River gives an average of 12 billion m³ as stated by MIWR. The discharge of the White Nile does not follow the same

seasonal pattern as the Blue Nile and the Atbara. Half of the White Nile discharge is contributed by the outflows from the Sud (Bahr el Jebel, Bahr el Zeraf and Bahr el Ghazal). The other half of the White Nile discharge is contributed by the River Sobat which originates from the Ethiopian Highlands. Therefore, 85% of the Nile River waters come from the Ethiopian Plateau and 85% of that amount flows in three months (July-Sept.). The White Nile contributes about 25% of the Nile total discharge, average annual flow of the White Nile is about 27 billion m³. Other surface waters are the Non-Nilotic seasonal streams which are scattered in different parts of the country. The latter presents very important sources for domestic water uses in many parts of the country.
Water availability for irrigation in Sudan is strongly influenced by the temporal flow pattern of the Nile system and the very limited storage facilities available for regulation of its flow. Under the terms of the current agreement between Sudan and Egypt on the sharing of the Nile waters signed in 1959, Sudan is entitled to annual abstraction of up to 18.5 billion m³ of water from the Nile system (this as measured at Aswan in southern Egypt). While the same agreement gave Egypt 55.5 billion m³ and for evaporation in the Aswan High Dam reservoir 10 billion m³, i.e. the agreement divided the Nile waters 3:1 for Egypt and Sudan respectively, provided that the 10 billion m³ of the evaporation in AHD is subtracted from the total average which is 84 billion m³. The share of Sudan is equivalent to 20.5 billion m³ as measured at Sennar dam in central Sudan. Sudan is entitled to withdraw its share from the river system from anywhere and at any time during the year.

Remarks on the Nile Data in Sudan

Systematic gauging of the Nile within Sudan started at the beginning of the 20th century. However, the earliest flow data records of the Ministry of Irrigation and Water Resources started in 1964. For most of the stations on the Nile system in Sudan, an observer carries out stage readings. Discharges are then determined from rating curves which developed yearly, based on discharge Measurements.

Data problems in Sudan

There are some problems in data collection such as:
Different sources of data
Deterioration of Monitoring Network
Poor data Archiving
Different record length for each station
Missing data
In some cases shortage of equipment leads to loss of information and data, besides, the ODD measurements.

Some Techniques used to fill in the missed data
Arithmetic Mean
Used to fill in one-day missing data, by taking the average value of readings before and after that missing one?

Linear Interpolation

Adequate for application in the low flow seasons during the recession period, but in flood season it does not give satisfactory results due to high fluctuation in water level?

Correlation

The Correlation equation is used to fill in the missing values which has high Correlation coefficient

The Ministry of Irrigation and Water Resources (MIWR) of Sudan is responsible from collection, processing, storage and publication of river flow data. The records are being or have been obtained from a total of 263 sites. 130 stations are still in existence, but a large proportion of these measurements have been temporarily suspended because of the security situation in the South of the country. However there are 55 active gauging stations in the Nile River system, Out this number, 13 are primary stations (discharges and levels measurements) and 42 secondary stations where only water levels are measured. The available records are of widely varying types. They range from fully rated stations, where reliable records for more than eighty years have been maintained with few or no gaps, to stations where there are no stage records but the flow values have been estimated from occasional discharge measurements

At most of the stations on the Nile system, stage readings are carried out by an observer and rating curves are developed usually for each year separately, based on discharge measurements made in that year. Field procedures are adequate, but shortage of equipment sometimes leads to loss of data and to insufficient inspection of the sites. In the past, office procedures were principally manual; however, recently computerization has been introduced. It can be noticed clearly that the current practice of collecting the data is still traditional and involves high uncertainties. It is well known that any proper policy or planning depends firmly on the collected data, i.e. the quality of the data is highly important. Therefore, advance techniques should be introduced e.g. automatic gauging stations linked to computer centre.

The Nile River and its tributaries within the Basin are typically alluvial rivers. Flow in an alluvial river is basically similar to flow over an inclined plain. Its available energy is balanced by dissipation of energy due to bed; side and internal friction as well as the energy required transporting the sediment load. On the other hand, the natural processes of erosion, transport and deposition of sediments have occurred throughout geologic times and have shaped the landscape of the world in which we live. Erosion always causes serious damage to agricultural land by reducing fertility and productivity of soils. Eroded soil is the largest pollutant of the surface waters in the world, since sediments affect water quality and its suitability for consumption and industrial use. Soil eroded from upland areas, e.g. Ethiopia Highlands, from where 85% of River Nile waters come, is the source of most sediment transported by the rivers to the reservoirs; Roseires, Sennar, Gash el Girba, Aswan High Dam (AHD) in Egypt, and irrigated system.

Problems associated with sediments deposition are varied; in stream channels reduces flood carrying capacity, resulting in greater flood damage to adjacent properties. Reservoir not only trap the incoming sediment load but reservoir sedimentation also increases the flooding risks because of aggradations upstream of the reservoir i.e. reservoir sedimentation results in loss of storage capacity for flood control and/or irrigation. Upstream aggradations depend on the stream slope, the sediment size distribution and the water-level fluctuations in the reservoir. Streams with low slope carrying large quantities of sediment may result in aggradations many kilometers upstream of the reservoir. Downstream of reservoirs, erosion usually occurs as a result of the action of 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.

The sediment in dam reservoirs and in the irrigation channels creates a great problem and difficult situation for the water management in Sudan, as we can see in the coming sections of this report.

Sudan is an agricultural country and it will continue to be so for many years to come. Agriculture continues to be the most important production sector. A recent report from the Central Bureau of Statistics, 2003, shows that agriculture accounted for 39 % of GDP in 2001, and the share of industry and services had increased to 18% (including oil refinery) and services 43% of GDP. In agriculture, production of some traditional crops such as cotton and gum Arabic have declined, with livestock maintaining its dominant position accounting for about half of the GDP from the agricultural sector, especially during the period (1998-2001). However, from 2002 the share of livestock in the GDP was sharply declined due to the government marketing policy which canalized the livestock export in one body. At the same time, crops such as vegetables and fruits are growing in importance.

Being the largest country in Africa, makes Sudan water resources the most difficult issue due to the considerable variation and instability of the climate and its temporal nature. However, Sudan experiences a wide range of tropical climates, marked by a single summer rainy season for eight months towards the far south to almost zero in the extreme north. The Nile River and its tributaries is the main physical feature of the country. Other water resources are the non-Nilotic seasonal streams or (Khors) and the groundwater basins, which are scattered in the different parts of the country.

The available water resources are estimated to be 36.0 billion m^3 annually as reported by the Ministry of Irrigation and Water Resources(MIWR), if the share of Sudan from the swamp reclamation is added. Without the latter, the water resources of Sudan are estimated to be only 30 billion m^3 annually. The total groundwater storage capacity is estimated to be 564 billion m^3 by Salih et al, (1982), while Ali, (1998), estimated the average storage capacity as 15,756 billion m^3. These discrepancies in the figures require a comprehensive study to be carried out to evaluate the groundwater resources .

Sudan Water Resources and Nile River Basin

The rapidly growing populations in the Nile Basin remain predominantly agrarian and poor, and are highly vulnerable to water availability, droughts and floods. Water has been, and remains, a primary factor in the location, production patterns of human settlements and the structure and productivity of the Nile Basin countries economies. Saying this, Sudan represents 67% of the Nile Basin areawise and contributes to its flow annually with a considerable amount. Therefore, its water resources management will be directly affected by any activity in the Nile Basin.

Fig (9) shows the general layout of the Nile Basin as presented recently by the Secretariat of the Nile Basin Initiative (NBI). The Nile River; which is the longest river, in the world extends for some 6700 km through much of the Northeastern Africa. The setting is highly variable and ranges from tropical rain forest to desert and from mountainous relief to areas which are below sea level.

Recently, there has been recognition of the importance of Basin-wide management and development. The need for the Basin-wide management has increased by rapid population growth in the countries of the Nile Basin (over 300 million with rate growth of 3% annually). This has placed greater demands on watersheds, such as land use practices, extensive clearing, increase the potential for erosion. Hence, the basin-wide approach for sustainable development is highly needed taking all the present circumstances into account. Management on these multinational basins will require a sharing of information to enable joint decision making to the benefit of all residents of the Nile Basin.

Management, development and planning of the water resources within the Nile Basin through assessment, monitoring, research, capacity building, collection and dissemination of data and information are highly needed.

Table (15) shows the share and contribution of the 10 riparian countries to the Nile Basin. The Sud, situated in the south-central part of the country, is the largest swamp in the world. At peak flood, it covers an area of at least 30,000 km². Nile River has three main distinct regions from where it obtains its flow as indicated on Fig (10);, the Equatorial Lake Plateau in the South, the Sud (Bahr el Ghazal, Bahr el Jabel, and Bahr el Arab) region in the Center, 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 (11) shows the schematic diagram of the Nile River natural flows, while Fig (12) shows the hydrographs of the Nile system, while Fig (13) gives a long term average annual flow for the Blue Nile (1920 – 2000). Therefore, from the latter it is very clear that the long term average annual flow of the Blue Nile is amount to 50 billion m^3. Ahmed and Eldaw (2004) for the first time recognized what they called the Central Watershed, completely inside Sudan. Hence three watersheds for the Nile River (Southern Watershed, Central Watershed and Eastern Main Watershed) are clearly marked. This classification of the watershed has a meaningful impact from the technical, management, ecological, political and development points of views.

The total estimated annual inflow entering Lake Victoria from streams flow and rainfall is 118 billion m^3 while the evaporation is estimated to be 94.5 billion m^3, leaving only 23.5 billion m^3 to flow down the Victoria Nile. In the Sud the loss calculated as 33.9 billion m^3, leaving 15 billion m³ to flow into the White Nile. In the Aswan High Dam Reservoir, the losses are calculated to be 10.5 billion m^3, while the losses within Sudan downstream of Malakal are estimated to be about 7.0 billion m^3.

On the other hand, the remainder comes from Ethiopian Highlands via the Sobat (13.5 billion m^3), the Blue Nile (50 billion m^3), and Dinder River (3.0 billion m^3, Rahad River (1.0 billion m^3 and Atbara River (12 billion m^3). The White Nile is extremely well regulated with relatively constant contribution to the Nile River, due to the lakes and the swamps of the Sud. The flow from the Ethiopian Highlands is highly concentrated in the period from July to October, where 85% of the Nile River total flow occurs. In Appendix 3 Tables (16 to 25) show detailed information of the discharges of all the selected stations in the Main Nile and its tributaries inside Sudan for the period (1980 – 2000). However, Tables (26 and 27) give water levels for Wadi Halafa station on the Main Nile and Wadi Medani station on the Blue Nile for the same period (1980 – 2000), since there are no water discharge measurements in these two stations performed.

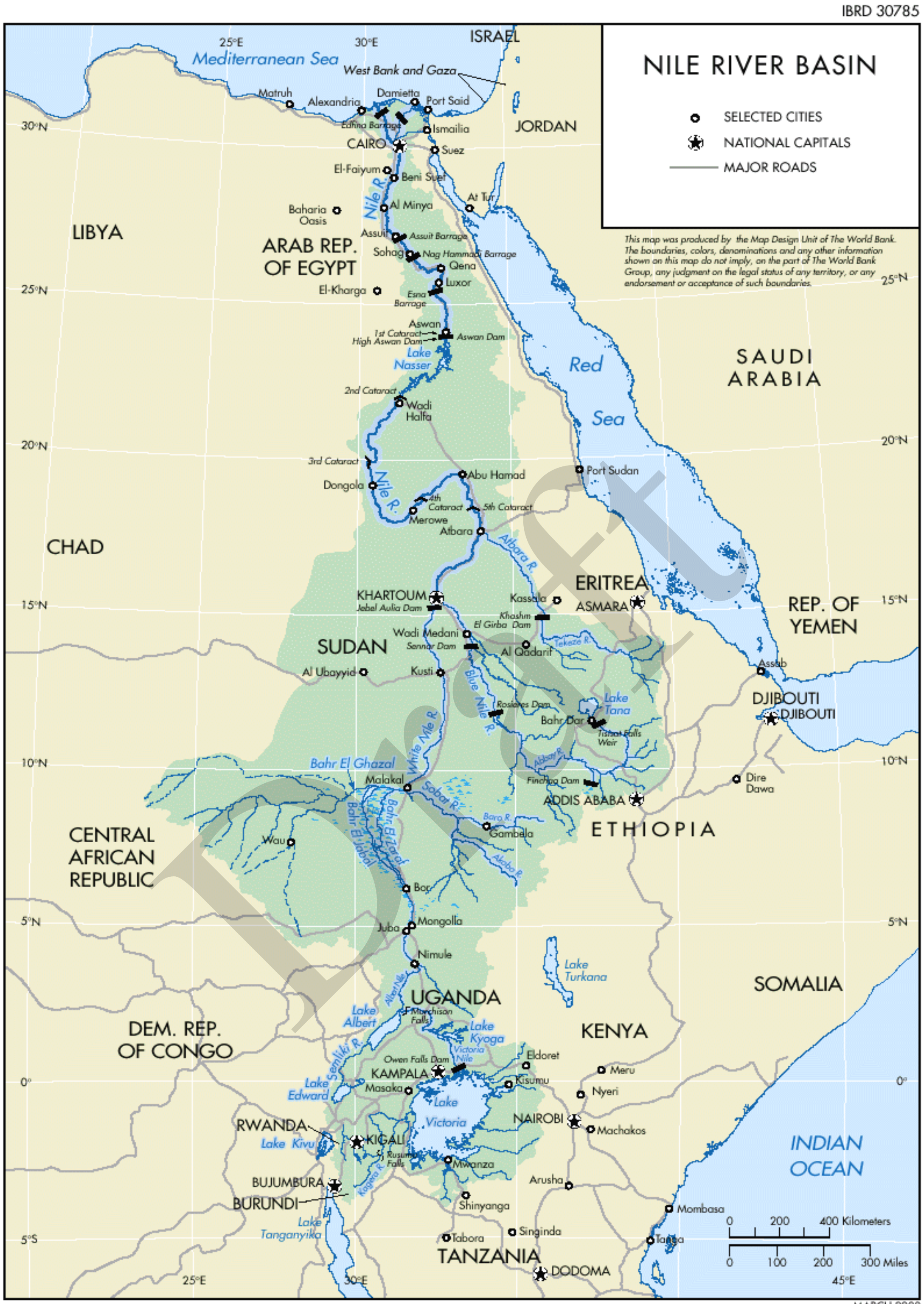


Fig (9) Nile River Basin

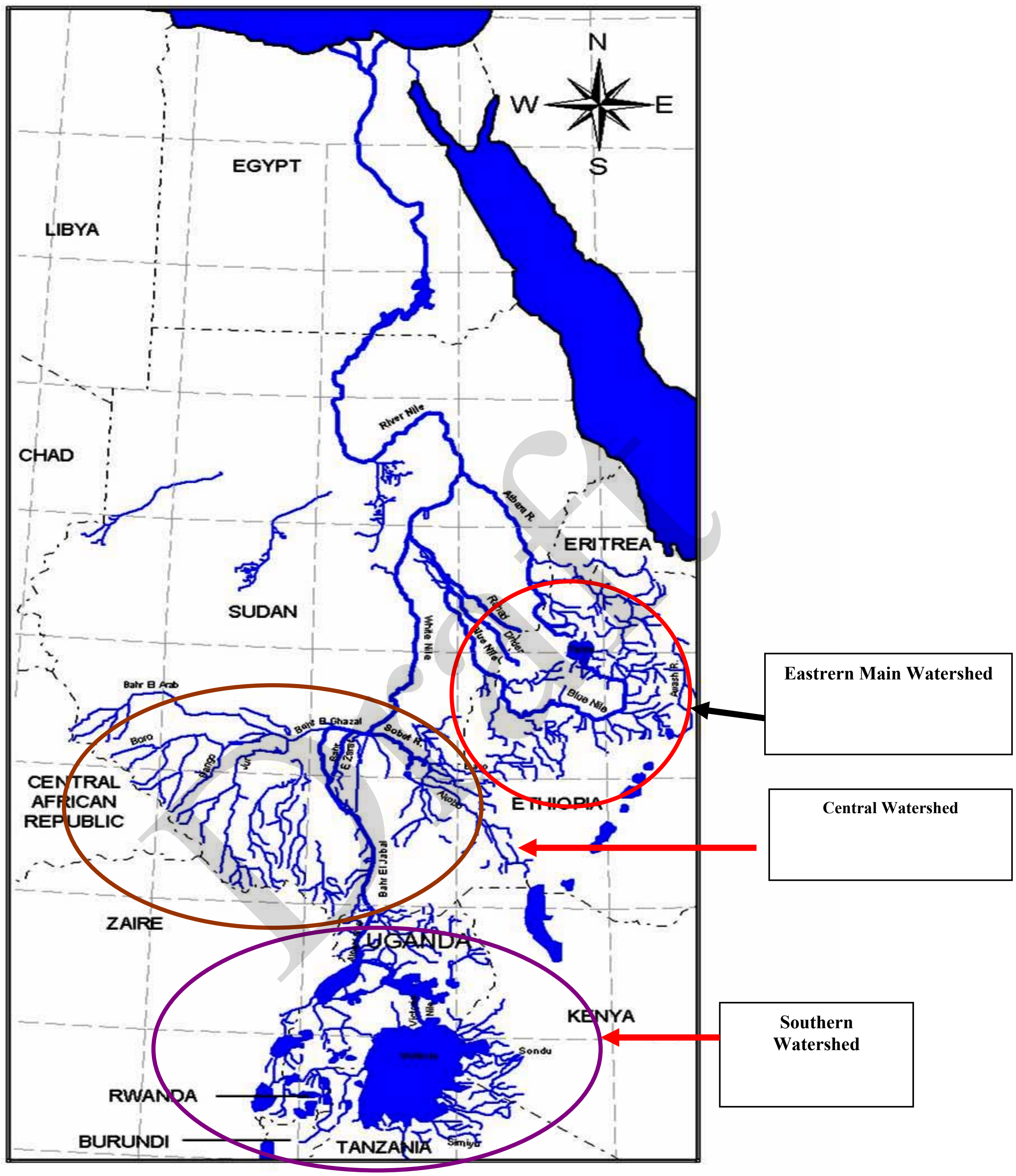


Fig (10) The Three major Watersheds of the Nile River

Table (15) Nile Basin: areas and rainfall by country

Country	Total area of the country (km^2)	Area of the country within the basin (km^2)	As % of total area of basin (%)	As % of country area (%)	Average annual rainfall in the basin area (mm)		
					Min.	Max.	Mean
Burundi	27834	13260	0.4	47.6	895	1570	1110
Rwanda	26340	19876	0.6	75.5	840	1935	1105
Tanzania	945090	84200	2.7	8.9	625	1630	1015
Kenya	580370	46229	1.5	8.0	505	1790	1260
Zaire	2344860	22143	0.7	0.9	875	1915	1245
Uganda	235880	231366	7.4	98.1	395	2060	1140
Ethiopia	1100010	365117	11.7	33.2	205	2010	1125
Eritrea	121890	24921	0.8	20.4	240	665	520
Sudan	2505810	1978506	63.6	79.0	0	1610	500
Egypt	1001450	326751	10.5	32.6	0	120	15
Nile basin	8889534	3112369	100.0	35.0	0	2060	615

Groundwater

Groundwater provides an important source of water supply in Sudan. About 80% of the inhabitants depend on groundwater for their domestic uses most of the year. The persistence of drought and the erratic nature of rainfall in Sudan over the past few decades has emphasized the importance of groundwater as a reliable source.

Major groundwater aquifers in Sudan cover about 50% of the surface area of the country. These aquifers fall under the following three main categories as discussed by:, Salama, (1987); Salih & Khadam, (1984); Salih & Khair, (1994) , Abdo, (2003) and many other sources:-

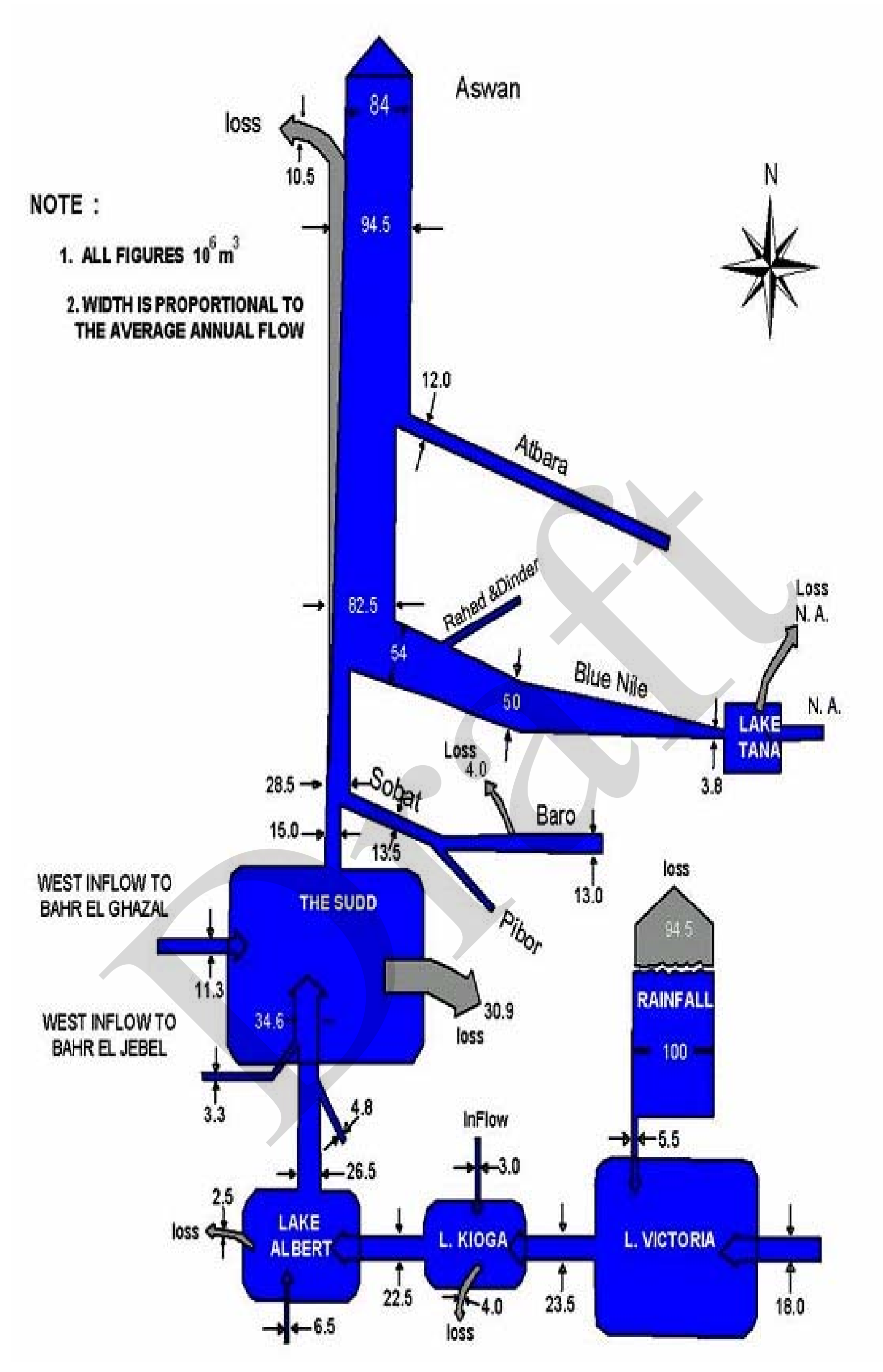
The Nubian Sandstone.

The Quaternary-Tertiary aquifers(Um Rawaba and Gezira formations) and,

The Recent Alluvial Deposits, (rivers and wadi-fill aquifers).

Fig. (14) Shows the distribution of the main groundwater aquifers over the country. It should be mentioned that quantitative of the Sudan groundwater estimates are rather approximate.

Many other estimates are available in the literature but they are all based on preliminary studies and Limited scanty data. Therefore, considerable efforts are still needed in order to arrive at accurate figures. The UNESCO Chair in Water Resources of Sudan as an institute working in the field of water and related issues is taking the lead to establish an Encyclopedia of Sudan Groundwater within the coming months as a database for this important field



Fig(11) Schematic Diagram of the Nile River Natural Flows

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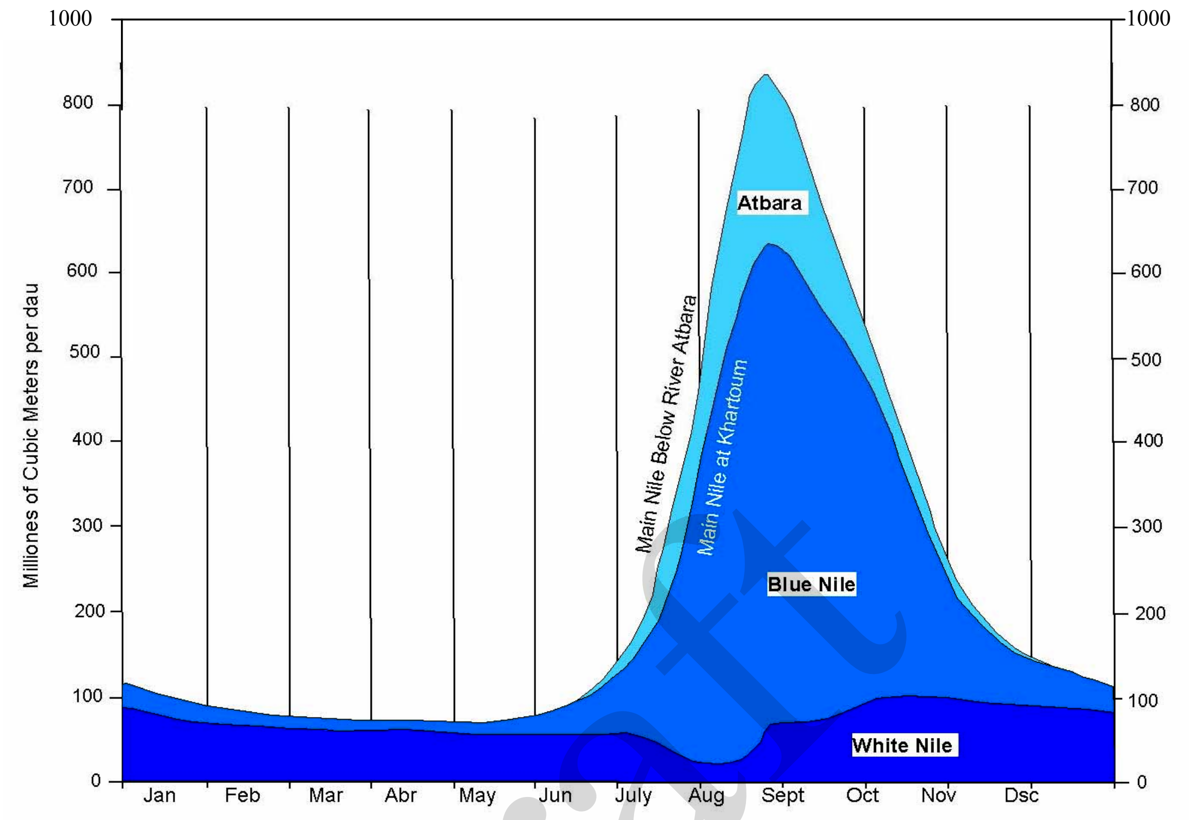

Fig (12) Hydrograph of the Nile System

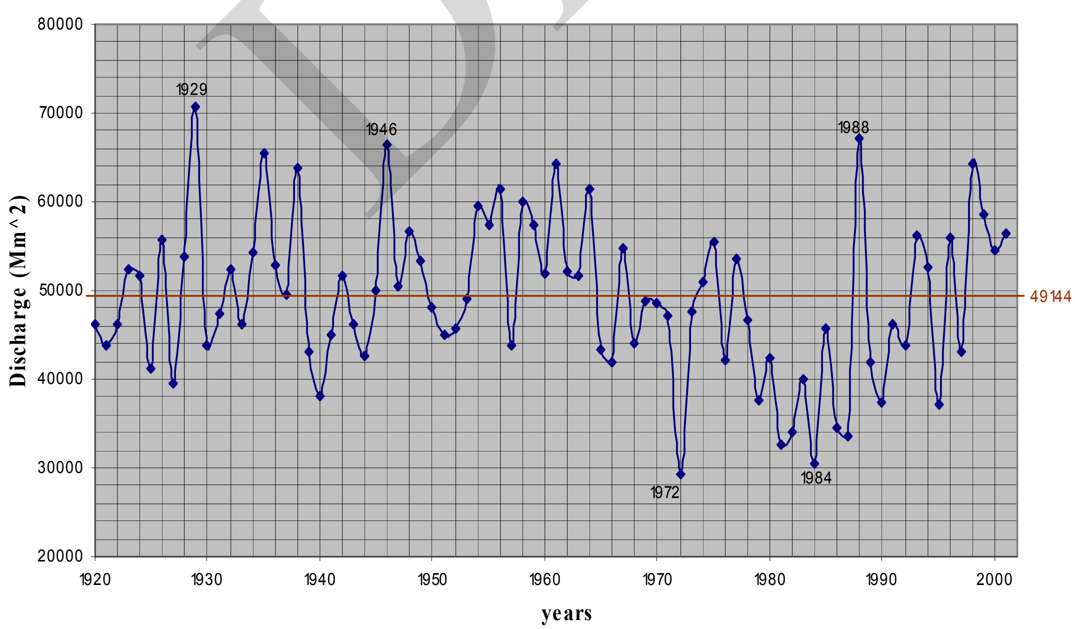

Fig (13) Blue Nile Hydrograph (1920 – 2001)

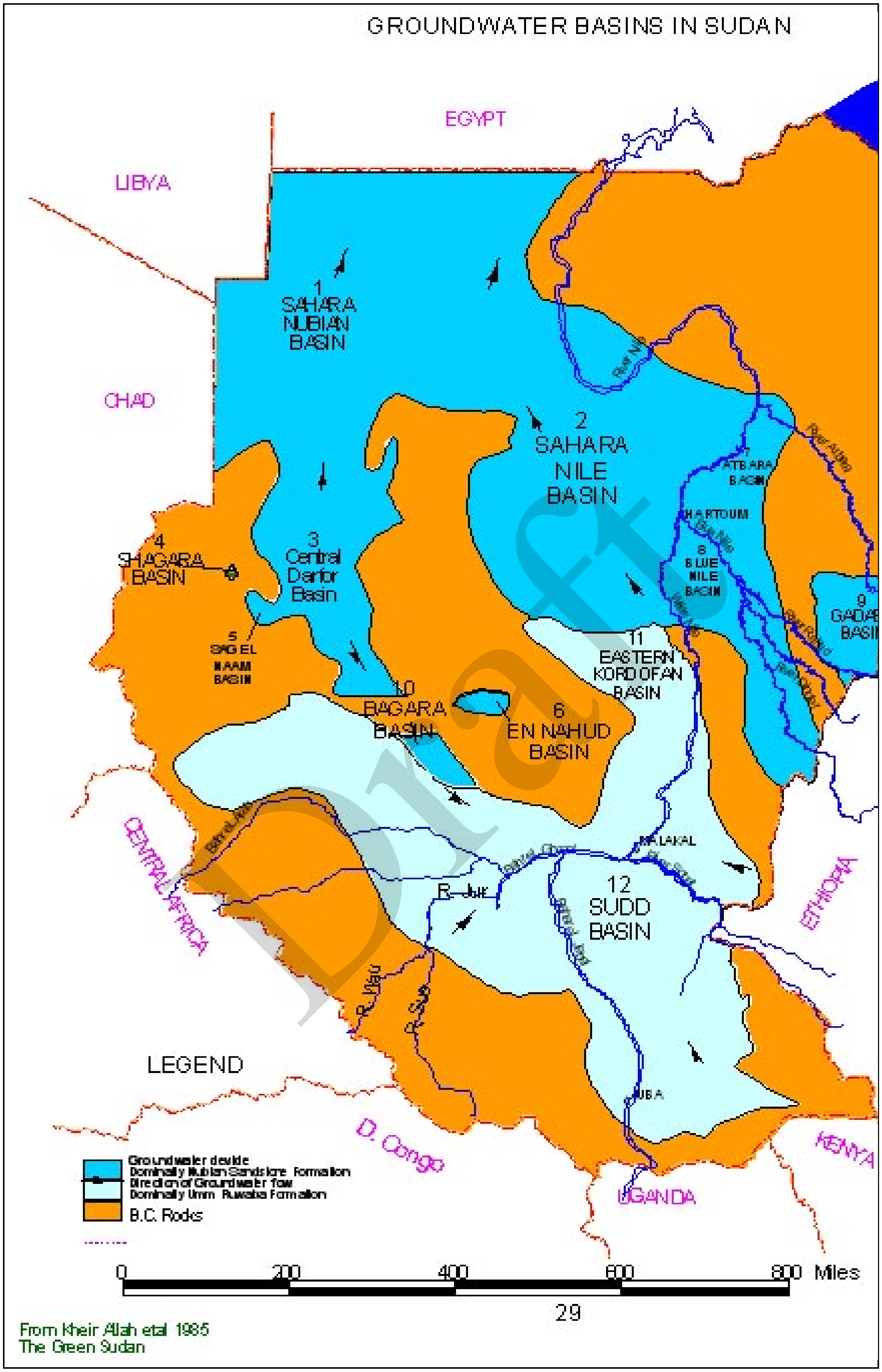

Fig (14) Groundwater Aquifers in Sudan

Non-Conventional Water Resources

i- Desalinated Water Resources

The treatment of desalinated water is a very recent phenomenon in Sudan with the construction of two plants commissioned in the year 2004 in Port Sudan. . The plants have a total capacity of 10,000 m^3 per day (the first one 2500 m^3/day and the other 7500 m^3/day).
The small plant takes the raw water from the Red Sea where the salt concentration is 42000 – 45000 pip. The plant is designed to work with a salt concentration of 45000 ppm. The big plant faced several difficulties because it was constructed a bit far from the Sea to take its raw water from deep wells. This is attributed to the high salt concentration (more than 65000 ppm). Although, the plant is new it requires maintenance, and the solution is to have raw water from the Red Sea.

ii- Treated Waste Water

Treated wastewater has been widely used in the world in recent years, especially in the Arab Gulf region. It is surprising to know that Sudan has an experience with treated waste water, which goes back to the fifties of the last century. The treated wastewater of Khartoum city was used to irrigate more than 200 ha of forest (south of the city).
The experience was very successful until recently, when the Khartoum authority unfortunately decided to remove the forest for the purpose of people settlement. It is widely believed now that the decision was not well thought of and that the negative impacts on the environment are evident regretfully, such wrong decisions and their negative effects are irrecoverable.

Water Demand and Management

Water is the great gift provided to humankind and to all living things. However, the Sudanese realize that their water resources are not abundant or unlimited as they believed. This is particularly after those years of drought, decades of desertification and shortage in water witnessed in the last thirty years. People from different backgrounds view water management differently. To those living in an arid country, it means drought, relief, irrigation, food, jobs, law and politics. To people living in humid areas, the emphasis is more on surface water. Their concern is waterworks, flood protection, navigation, hydropower, treatment plants and related issues.
In Sudan and many other countries, usually the emphasis goes to the supply side and little been done in the demand side of water management. No doubt any achievement in the demand side is of high value, especially in the arid country where most of the water resources consumed by agriculture. Only 10% of the irrigation water conserved by increasing the efficiency through good management means more production area, Ahmed (2003).
In Sudan the issue of water demand and management is not an easy question, since it has the local, national and regional interrelationship

i- Irrigated Agriculture

In Sudan water demand is a difficult area to tackle, not because the subject in itself is complicated, but because of the absent of the required data . Several studies have attempted to quantify and qualify the present water demand in Sudan to estimate the future requirements. It is believed that most African

countries suffer from similar situation as does Sudan , However, in Sudan more than 90% of the water resources is utilized in the agriculture sector while the domestic uses including the industry is about 8% and the other uses is 2%. Other than rain-fed agriculture which mainly depends on the quantity and distribution of the rainfall, the present water requirement for the irrigated area in Sudan amount to 20 billion m³ at present. Table(16) reflects the present and projected situation of the irrigated schemes areas in the Sudan. Most of the schemes cultivated by mixed crops or sugar cane while the method of irrigation varies from gravity irrigation from dam reservoir or using pumping stations and sometimes irrigation by flooding (recession).
Based on the main three crops; cotton, wheat and sugar cane El Awad and Ahmed (1998), calculated the total water required by 2025 to be 40 billion m³, On the other hand, conveyance efficiency in the irrigation systems in most of the Sudan irrigated schemes is reported to be 85% within the Central Clay Plain (CCP), (Ahmed et al, 1989). However, the irrigation efficiency at the farm field's level is about 70%. Hence, the overall irrigation efficiency is high, due to the nature of the soil where there is no seepage from the canals, nor is there any deep percolation at the farm fields. This CCP soil has a very low permeability; the irrigation is only through the cracks. The black cotton soil cracks when dry (exceed one meter) and they close when saturated with water, losses are through evaporation or evapotranspiration from vegetation.
Fig (15) shows in schematic representation the possible offtakes within the Nile River system in Sudan, while Fig (16) gives the locations of the existing and the proposed irrigated schemes within the same system.

ii- Hydropower

Hydropower is considered to be a clean and cheep source of energy, and besides it optimizes the use of the available water resources.
The present installed capacities for hydropower generation are 280 MW at Roseires dam, 15 MW at Sennar dam, 12.5 MW at Khash ElGirba dam and recently 30 MW in Jebel Aulia dam. Marlowe dam is going to add very recent in 2007, 1250 MW. The demand is usually in excess of the limited thermal and hydro-generation. However, in 2004 the total electricity production exceeded for the first time the capacity of the installed distribution network. The total capacity of the present distribution network is 875 MW while the production capacity from both thermal and hydro-generation is 1200 MW. The sharp increase in the power production is attributed to the thermal generation enhanced by the availability of oil and gas in recent years. However, Sudan has great hydropower potential from the Nile and its tributaries may exceed 9000 MW with a feasible power of nearly 5000 MW. Available energy may exceed 81000 GWh per year with a feasible energy of about 45000 GWh per year. Fig (17) shows the locations and magnitude of different hydropower opportunities (existing and potential in the River Nile system in Sudan. The most promising sites are on the Main Nile and the Southern rivers and streams. Running cost of hydropower, generation from a multi-purpose reservoir is always favoured over thermal generation. Hydropower does not consume water except for the evaporation losses from the resulting storage in the reservoirs. Moreover, the hydropower generation is safe from the environment point of view.
The demand for hydropower generation may at times conflict with agricultural and other water demands, especially when water is scarce during the long dry season.

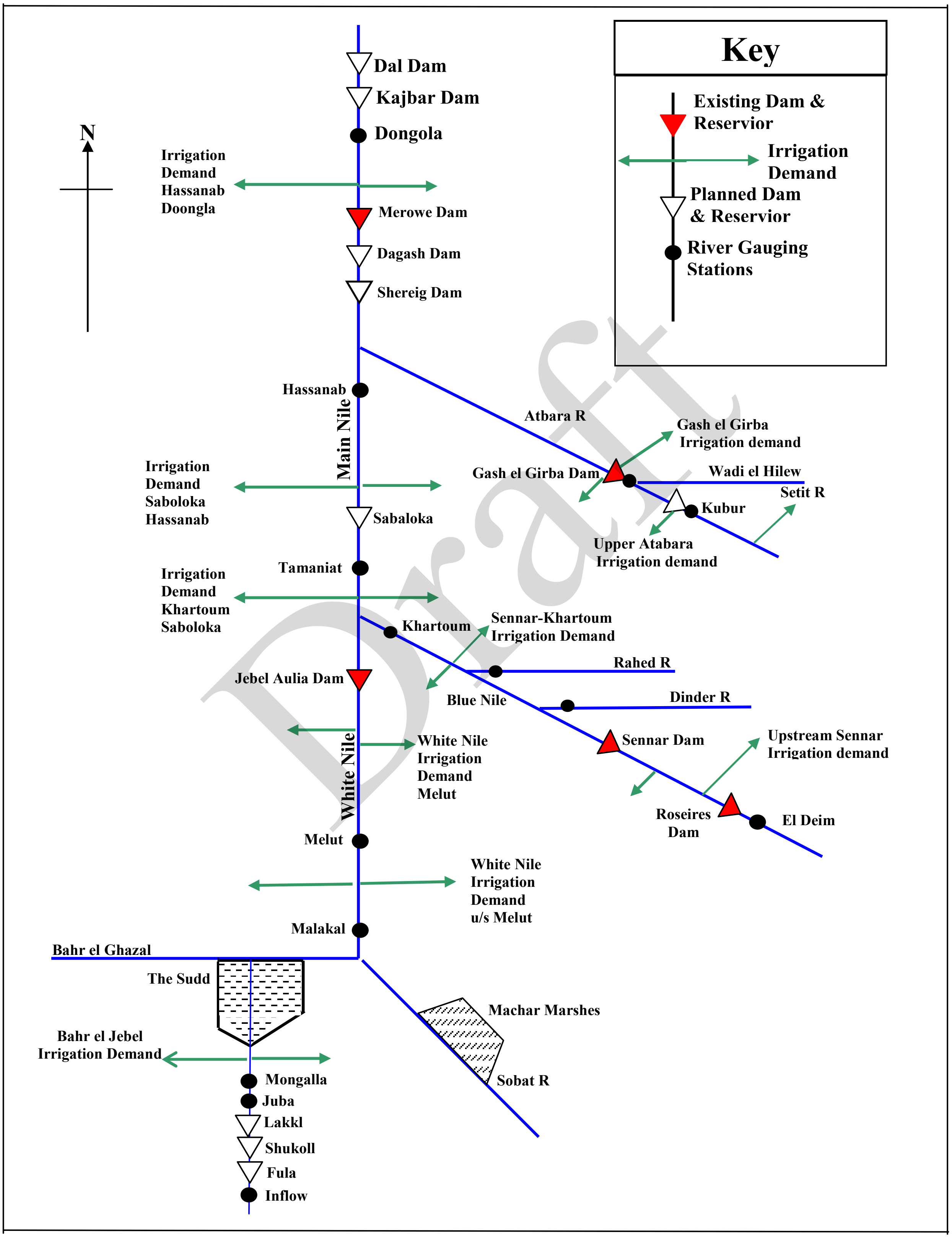
Key
Existing Dam & Reservior
Irrigation Demand
Planned Dam & Reservior
River Gauging Stations
N
Dal Dam
Kajbar Dam
Dongola
Irrigation Demand Hassanab Doongla
Merowe Dam
Dagash Dam
Shereig Dam
Hassanab
Main Nile
Atbara R
Gash el Girba Irrigation demand
Gash el Girba Dam
Wadi el Hilew
Setit R
Kubur
Upper Atabara Irrigation demand
Irrigation Demand Saboloka Hassanab
Sabaloka
Tamaniat
Irrigation Demand Khartoum Saboloka
Khartoum
Sennar-Khartoum Irrigation Demand
Rahed R
Jebel Aulia Dam
Blue Nile
Dinder R
Sennar Dam
Upstream Sennar Irrigation demand
White Nile Irrigation Demand Melut
White Nile
Roseires Dam
El Deim
Melut
White Nile Irrigation Demand u/s Melut
Malakal
Bahr el Ghazal
The Sudd
Machar Marshes
Bahr el Jebel Irrigation Demand
Sobat R
Mongalla
Juba
Lakkl
Shukoll
Fula
Inflow
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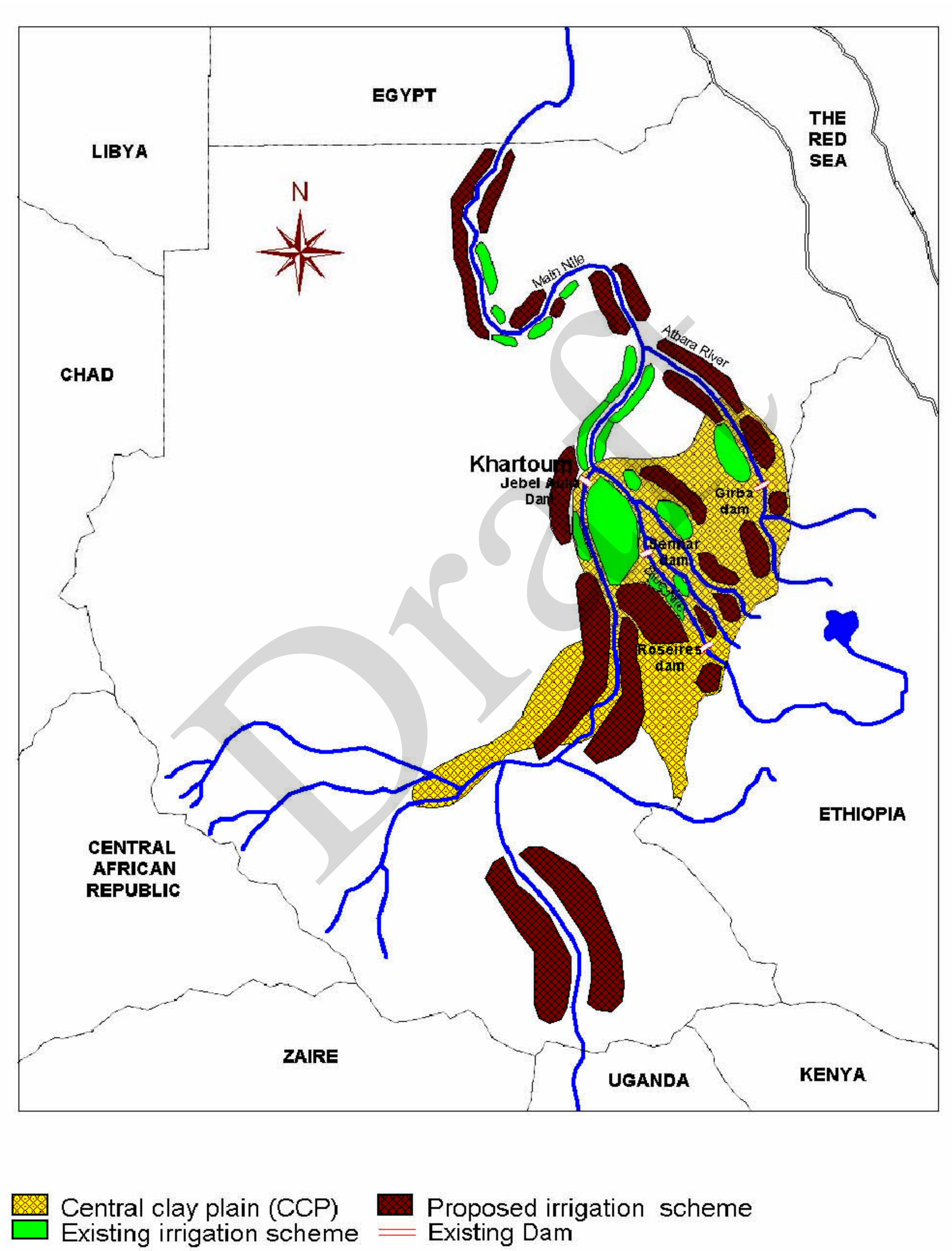
Fig (15) Schematic Map for the Existing and Potential Dams and Reservoirs and Irrigation Demand from the River Nile System – Sudan



Fig(16) Distribution of Existing and proposed Irrigation Schemes in Sudan

Table (16) Projected Irrigable Area in the Nile River System in Sudan

Nile Tributary	Project	Cultivated Area (1000 Feddans)		
		Year 2005	Year 2015	Year 2025
The Blue Nile Available Area is 6.271.5 million feddan	Gezira & Managel (m.c.)	2100	2100	2100
	Rahad (m.c.)	353	400	400
	El Souky (m.c.)	71	78	86
	Public Pumps (m.c.)	175	270	270
	Private Pumps (m.c.)	140	150	150
	Al gnaid Scheme (s)	83	83	83
	Sugar North West Sennar (m.c.)	35	45	45
	Abu Naama (m.c.)	30	35	35
	Al Slait,Waha and others(m.c.)	120	200	240
	Kenana II & III(m.c.)	-	1000	1000
	Rahad II (m.c.)	-	500	500
	South Dinder (m.c.)	-	200	315
Sub – Total		3107	5061	5224
The white Nile Available area is 1.791 million feddan	Public Pumps (m.c.)	410	600	750
	Private Pumps (m.c.)	60	160	260
	Kenana (s)	90	100	120
	Kenana (Crops) (m.c.)	14	40	80
	Hagar Asalaya (s)	36	42	46
	Sondos Scheme (m.c.)	110	110	110
	White Nile (s)	110	110	150
	Monagalla (s)		75	150
	Malakal Rice		40	40
	Fengco – Jongiel (m.c.)		20	40
	Other – South (m.c.)		100	150
Sub – Total		700	1147	1596
Atbara Available area is 1.361 million	New Halfa (m.c.)	450	500	600
	New Halfa (s)	42	42	42
	Upper Atbara (m.c.)		380	1000
	Upper Atbara (s)		60	100
Sub – Total		282	772	1492
Irritable area 2.860 million feddan	Public projects (m.c.)	103	151	228
	Private projects (m.c.)	208	920	1632
Sub -Total		311	1071	1860
Grand –Total		4740	8511	10950

M.C. = Mixed Crops, S = Sugar

NP: Total Available Area for Irrigation in the River Nile System in Sudan (12.283 million feddans = 5.16 million ha)

On the other hand, while water is in plenty during the flood season, reservoirs are kept at their minimum operating levels to minimize siltation and loss of capacity. Hence, the head available for hydropower generation is at its lowest, decreasing the efficiency and causing problems to the operation of the turbines. The situation is aggravated by the accumulation of silt and debris in front of the power intakes.

A promising hydropower generation project was initiated recently to utilize the potential hydropower of Sennar dam. The electricity will be generated during the flood period by using low head turbines. The feasibility study concluded that 120 MW can be obtained during the four to five months annually from Sennar reservoir on the Blue Nile River, (Ahmed et al 1998). A similar project for power generation using low head turbines has been proposed for Jebel Aulia reservoir to produce up to 45 MW.,

iii- Sudan Storage Capacity

One of the main limiting factors for the development of the irrigated sector in Sudan is the weak storage capacity. The reason is that about 85% of the Nile River waters flows in only three months (July – Sept.) and for the rest of the year the flow is very low, especially the Blue Nile where 70% of the irrigated area is located.

Table (28) shows the dam reservoirs in Sudan and their storage capacities. The dams are multi-purpose and their design capacity is 9084 Million m^3 while the present capacity is 6657 million m^3. The reservoirs are seriously affected by sedimentation, which has caused a reduction in the capacity by 30%. Plates (1.2) show the problems created by the sediment and debris in the reservoir and in front of the turbines in Roseires dam. However, Jebel Aulia dam is not directly used for irrigation, since its present operation is to keep high water levels in the upstream for the pump schemes to draw water for irrigation on both banks of the White Nile River. Moreover, its function is to regulate the downstream flow during the dry period of the year. Since the Jebel Aulia dam is not considered as a storage reservoir, the design storage capacity of dams in Sudan is 5,584 million m^3 and the present available storage capacity is 3,157 million m^3. The latter represents only 15% of the Sudan share in the Nile River waters according to 1959 agreement, while for example Egypt storage capacity is almost three folds its share in the Nile River waters (55.5 billion m^3), since the AHD storage capacity is 160 billion m^3. This limited storage capacity of Sudan has set back the irrigation sector since the sixties of the last century where the last large reservoir was constructed in 1966. Since then there has been no project implemented to increase the storage capacity However, recently the Government started to construct the Merowe dam in the Northern State on the Main Nile with a capacity of 11 billion m^3 for hydropower generation. The project to increase the height of the Roseries dam will increase its capacity from 3 to 7 billion m^3. This was envisaged at the time of the commissioning of the dam in 1964 but is still to be implemented. The author believes the Heightening of the Roseires dam is the most important project now in Sudan and by any means should be the top priority.

Any future development of the agriculture sector in Sudan depends greatly on this project to increase the dam height. .

There are several potential locations for hydropower generation on Atbra River, Main Nile and in the South suitable for dams, Dal, Setiet, Upper Atbara, (Akarib), Elsabalooga, Kajbar, Bedein, Wawoso, …etc. These projects should be implemented within the efficient utilization policy of the Nile River waters for national and regional benefits.

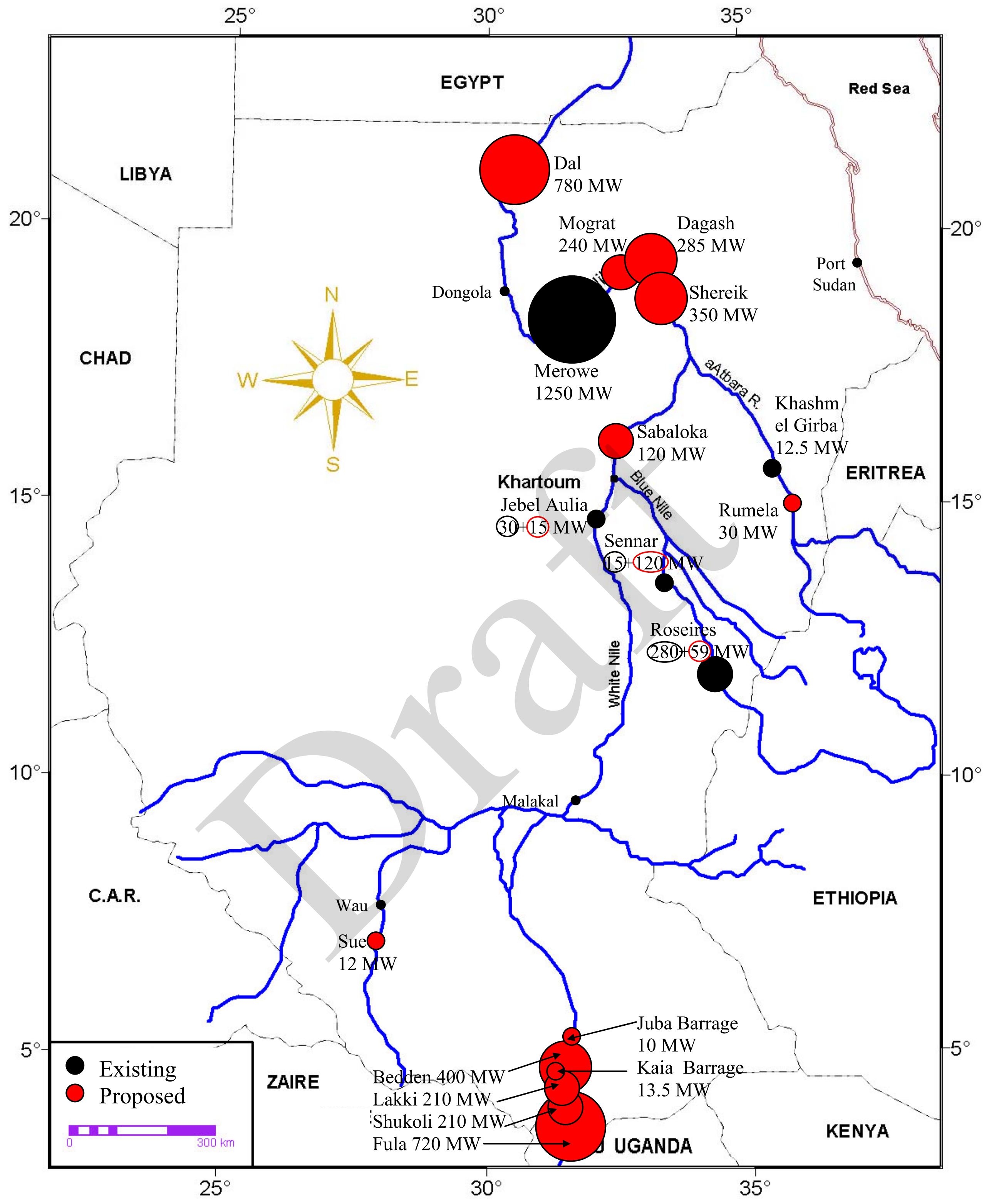


Fig (17) Existing and Proposed Hydropower Locations in River Nile System –Sudan, with Potential Estimation

Table (28) Sudan Water Storage Capacity

DAM	Date of commission	River	Ci Mm^3	Cg Mm^3	Vg Mm^3	Purpose of storage
Sennar	1925	Blue Nile	930	370	560	Irrigation & power
ElGirba	1966	Atbra River	1300	560	740	Irrigation & power
Roseires	1964	Blue Nile	3354	2227	1127	Irrigation & power
Jebe Aulia	1937	White Nile	3500	3500	-	Irrigation & power
TOTAL			9084	6657	2427	

C_i = original storage capacity, C_g = present storage capacity, V_g = Volume of sediment deposits., Source: Ahmed,1992

Plate(1) The Sedimentation Problem in Roseries Dam

Plate (2) Debris in front of Turbines U/S Roseries Dam

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Sedimentation and Aquatic Weeds

Information concerning the sediment load of the Nile is limited compared with the available water discharge data. Some measurements of suspended sediment load are available, but measurements of bed load are very rare. Intensive sediment measurements were started in 1988 and 1996 to quantify the sediment entering the Gezira and Rahad schemes respectively.

Measurements were taken on the Blue Nile (1954 and 1955 at Wad Alais) and on the Atbra (1954 at Butana Bridge and 1959 at Km 3) as part of the studies for Roseires and Khashm El Girba dams. Following construction of the two dams further sedimentation studies have been made (sediment load measurements and bathymetric reservoir surveys to estimate reservoir siltation). In 1973 measurements were conducted on the Upper Atbra and Setiet rivers just upstream of their confluence as part of the studies for the Upper Atbra Project. No data on the sediment load of the White Nile is available This is attributed to the fact that most of the sediment deposits in the swamp area in the south U/S , besides the mild bed slope of the White Nile river (less than 0.20 cm/km)

At present a limited number of sediment monitoring stations are operating. These are El Deim, Wad Alais and Sennar on the Blue Nile, Gawisi and Hawata on rivers Dinder and Rahad respectively. Furthermore, some stations are scattered on the Gezira and Rahad Schemes, and Hamdab on the Main Nile. Because of the limited data available for most of the locations, the estimates of sediment load and concentration may be subject to a wide range of error. The high sediment loads of the Main Nile, Blue Nile and Atbara rivers have a major influence on the design and operation of any river control and storage works on these rivers. The sediment which originates from Ethiopia Highlands is concentrated during the flood season, which lasts approximately from July to October. The highest sediment concentrations occur on the rising flood in late July to the first ten days of August. The Hydraulics Research Station (HRS) of MIWR carried out sediment concentration and discharge measurements in several locations of the Gezira Scheme canalization system. It concluded that 5% of the sediment settled in the main canals, 23 % in the major canals, 33% in the minor canals and 39% passed to the farm fields. Plates (3 and 4) show the serious problem of sedimentation in the irrigated schemes in Sudan.

From Table (28) we can easily notice the huge reduction in Sudan reservoir original capacities due to sedimentation. The Sennar lost 66%, Girba 60% and the Roseires 30%. It is clear that the sediment peak occurs before the peak of the flow by more than one week for Atbra River and about two weeks for the Blue Nile.

In Appendix 4 Tables (29 – 35) give some information of the monthly average sediment data for the period 1988 up to 2002 in the Blue Nile River.

Plate (3) Inadequate Sedimentation Clearance of Irrigation Canal in GS

Plate (4) Irrigation difficulties in GS due to Sedimentation

This is due to the fact that rainfall in Ethiopia Highlands falls on bare lands at the beginning of the rainy season in July, and brings high sedimentation load before the maximum runoff occurs in the area. Another serious problem is the aquatic weeds in the irrigation network. Growth of aquatic weeds aggravate the sedimentation rate while the sediment depositions furnish good environment to weeds to grow. About 60% of the O&M costs of the irrigation management in the Sudan irrigated schemes go to sediment and aquatic weeds clearance, Plate(5). Therefore, these two problems create many irrigation difficulties leading to reductions in crop yields and increasing the cost O&M. However, many approaches have been implemented to mitigate the problem with a reasonable success, (Ahmed 2003).

On the other hand, the hyacinth weeds in the White Nile started in 1957 in the Sud area in the South disrupting river traffic, inlet channels and river life. It is now spreading all over the equatorial lakes requiring regional and international efforts to combat it. However, both sedimentation and aquatic weeds required joint efforts between the Nile Basin countries. For example the problem of sediment, although it creates many difficulties and problems to Sudan, it has its negative impact on the Ethiopian Highlands, from where it originates, degraded the land by erosion, and reducing its productivity.

Plate (5) Aquatic Weeds Obstructing Water Flow in Irrigation Canal – Gezira Scheme

Sudan's Schemes Common Irrigation Management Problems

Major constraints hindering the efficient use of irrigation water in Sudan's schemes are:-

- Sediment and aquatic weeds have contributed to changes in water levels, canal discharge and equitable water distribution between farms, (Abdalla and Hamad, 2002).
- Excessive losses from irrigation system, especially at the field level; fortunately there are no percolation losses due to the type of soil.
- Diversity of crops within areas served by one canal.
- The mixing between continuous and night storage systems, (macro-network is continuous while micro-network is night storage).
- Lack of efficient irrigation water extension services.
- Poor maintenance of the irrigation structures.
- Poor land leveling
- Lack of adequate funds for maintenances and proper operation.
- Absence of a charging system for those who misuse the irrigation (up to the sixties there was a good system in this respect in the GS.
- Farmers role (or participation) in the irrigation system is not well defined in almost all the irrigation systems in Sudan. However, in the early days of the GS when Canal Regulation Rules were strictly applied by MIWR at the macro-level, and Rules and Regulations by SGB at the micro-level, every person working in the irrigation system management (from the General Manger to the Farmer) know his or her job and role.
- The introduction of crop intensification into the large Natural Irrigated Schemes (Gezira, Rahad, Gashm elGirba and Suki), in the late seventies, has had a negative impact on the irrigation systems. It placed enormous burdens on farmers and irrigation authorities alike and has often choked the logistical infrastructure, especially when lack of proper O&M is considered.
- No doubt the sediment process influences the aquatic weeds growth and vise versa. Several factors are influenced the sediment and aquatic

weeds processes in irrigated schemes of Sudan and can be summarized as follows: -

- Design and operation of the irrigation system.
- Absence of sediment exclusion and use of unsuitable excavation machines.
- The cross-section area of the canal and the hydraulic radius (R), where the wide and shallow cross-section means low R and deep and narrow means high R.
- Minimizing the sunlight that reaches the vegetation below the surface of water by deepening the canal and keeping high velocity in order to make water turbid in the canal. Therefore, the volume of weeds to be removed will be reduced.

Rainwater Harvesting

Freshwater is getting scarce in the world due to pollution and the increasing demand. The total population in the world is increasing, therefore, the need for food security and domestic water are steadily rising up. The gab between the supply and demand will soon become too great. Since the rainfall is the main source of the freshwater in the world, this part of report will discuss the impact of its harvesting in the agriculture production, rural development and satisfying domestic water use in Sudan. It is well known in the arid and semi-arid regions that the rainfed agriculture may consume over 90% of the water resources. Therefore, food security and settlement depend on the rainfall and its harvesting techniques used. The declining pattern of the rainfall in Sudan in the past five decades and its impact on the socio-economic of the country is noticeable. The traditional techniques adopted in Sudan, especially in the rural area proved that whenever supported by official efforts results in good agricultural production, community stability and development. However, better and more advanced technology and techniques should be made available to increase the efficiency of water resources utilization. The guidelines for the design and steps required to incorporate rainwater harvesting (RWH) in development plans are highly needed.

It is believed in Sudan that to increase the crop production and to provide drinking water for humans, animals as well as for domestic user and environmental purposes, water harvesting should be carefully implemented. In Sudan as in many other places in Africa, there is a very strong relationship between the arid, semi-arid areas and poverty, which is highly related to the availability of water and its uses. The possible solution of the latter situation is the rainwater harvesting. A number of RWH projects were implemented in the Western part of Sudan during the seventies, eighties and late nineties. The main objective has been to combat the effects of drought by improving crop production and increasing domestic water use. However, few of those projects have succeeded in combining technical efficiency with low cost and acceptability to the local farmers agro-pastoralists. This is partially due to the lack of technical “know–how” but also often due to the selection of an inappropriate approach with regard to the prevailing socio-economic conditions.

Water Quality of River Nile

Several areas and cities in Sudan depend on their drinking water on the Nile system. The watershed erosion and heavy sediment movement during floods seasons cause high turbidity and suspended solids in the Nile River water. For example at Khartoum, the turbidity has tremendously increased during the last decade. It was increased from 5000 NTU to above 20,000 NTU duringflood in 1999 to 2003. Water treatment plants at Khartoum abstracting raw water from River Nile have been affected by such heavy sediment load. Treatment plants being designed initially to treat raw water of maximum turbidity of 8000 NTU utilizing Alum salt as coagulant are now producing poor quality of water when maximum allowable dose of Alum (150 mg/l) is being utilized. Khartoum Water Corporation (KWC) has been applying many alternatives to overcome the problem of turbid water in piped water network.

The presence of sediment in the Blue Nile produces poor quality of water for domestic use with the following impacts: -

Accumulation of sediments at the dead ends of water network, which encourages after growth of microorganisms, and hence affects the health of consumers.

Clogging of pipe network and increasing the incidence of pipes burst and occurrence of cross connection pollutes drinking water. If chlorine is utilized for disinfections of such water of poor quality, chlorine oxidizes organic matter in water usually generating complex compounds leading to health hazards of consumers.

Utilizing a polymer of organic nature for treating water during the flood season. High dose of polymer (more than 5 mg/l) was used by KWC during the flood seasons (1999-2002), Accumulation of polymer residual in water may cause serious health risk for the consumers, if it is utilized over a long period of time.

Combination of inorganic salts are being utilized, (Alum + Poly Aluminum Chloride) producing better quality of water during flood season. However, the effects of both salts in combination over a long period of time have not being determined .

Annexes

Data collected :-

Monthly average Rainfall and Evaporation(1981-2000) i.e. twenty years for the following stations in mm.
Damazin
Khartoum
Dongola
Sennar
Karima
Khashim el Girba

Monthly average flows (1980 - 2000) i.e. twenty one years for the following stations in million m^3.

Blue Nile River
Elddeim
U/S Roseires
Wad Madeni (water levels only)
Khartoum
Sennar

Dinner River
El Giwasi

Rahad River
El Hawata

Main Nile
Atbara
Wadi Halfa (water levels only)
Dongola

Atbra River
Kubur
Khashim el Girba

White Nile River
Malakal
Jebel Aulia

Detailed Map for the Nile and its tributaries, (Fig (5) size A0 submitted to ENTRO Separately)

Although **sediment data** is rare however a reasonable one will be provided for some key stations in the Nile system within Sudan.

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This is a Ministry of Irrigation and Water Resources technical report reflecting the importance of the Main Nile river bank protection in the Northern part of Sudan. The report indicates in figures the agriculture areas affected by the floods damage and its negative impact on the livelihood of the local inhabitants. It suggests a number of mitigation measures to protect the river banks.

Adam, A. M., El Monshid B. F. and Ahmed S. E. (1994), "Bank Erosion of the River Nile in North Sudan" Proceeding of Khartoum Nile 2002 Conference, Comprehensive Water Resources Development of the Nile Basin: The Vision Ahead 29th January – 1st February 1994.

A paper describes the case study of the bank erosion of the River Nile in the Northern part of Sudan, where a serious phenomenon is observed. Mitigation measures are pointed out. The paper is a further study to the pervious one.

Adam, A. M., (1997), "Irrigation Funding Issues in Agricultural Schemes", (in Arabic), A Seminar on irrigation problems in the irrigated sector, Khartoum, Sudan, June, 1997.

The financing of the operation and maintenance represents one of the main obstacles facing the irrigation systems management in Sudan. This paper raised the main issues related to irrigation management funding in the Agricultural Schemes. It concluded that funding in time and space is the main problem facing the agricultural schemes management.

Ahmed A. A., (1992). "Sedimentation in Sudan multi purpose dam reservoir " 5th Symposium on River Sedimentation", Karlsruhi, Germany

A scientific paper discusses the performance of the four major reservoirs in Sudan regarding the sedimentation monitoring and its impact on their capacities reduction. The paper concluded that the losses in the reservoirs capacities ranging from 30% to 60%. The operation rules, the types of sediment and the flow characteristics are the main factors influencing the sedimentation rate in the reservoirs. Design mistakes in some of these reservoirs being one of the reasons aggravating the sedimentation problems.

Ahmed A. A., (2003). "Towards Improvement of Irrigation Systems Management", AWCOW Conference, Addis Ababa, Ethiopia.

A scientific paper reflects the present status of the irrigation systems in Sudan and its associated difficulties and constraints. Based on a thorough analysis of the irrigation systems performance in the last two decades and the long experience of the author, several suggestions to improve the irrigation management are highlighted and a number of mitigation measures is stated. However, the paper can be considered as a base for further irrigation management development.

Ahmed, S. E. & Saad M. B.(1992) "Prediction of Natural Channel Hydraulic Roughness" J. of Irrigation and Drainage Engineering, ASCE, Vol. 118, No 4.

An empirical formula to predict the natural channel hydraulic roughens is produced using measured data. The sediment and aquatic weeds and their effects are taken into consideration. The paper is based on an intensive analysis carried out during a PhD research programme.

Ahmed S. E. and Elawad. O. M. A. (2002) "Environmental Impact of the Alluvial Nature of the Nile on Irrigated Agriculture in Sudan" Presented in Addis Ababa Nile 2002 Conference.

A paper reported the environmental impact of the river Nile as an alluvial river on the irrigated agriculture in Sudan. The paper concentrated on the sediment behavior in the canalization systems. Moreover, the aquatic weeds is studied in connection to the sediment behavior.

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Gismalla, Y.A., (1998) Sediment Monitoring Programme (Blue Nile System), Ministry of Irrigation and Water Resources, Sudan.

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Gismalla, Y.A., (1999), Sediment Monitoring Programme (Blue Nile System), Ministry of Irrigation and Water Resources, Sudan.

Annual technical report produced by the HRS – MIWR describes the situation of the sediment programme in the Blue Nile system, 1999.

Gismalla, Y.A., (2002) Sediment Monitoring Programme (Blue Nile System), Ministry of Irrigation and Water Resources, Sudan.

Similar technical report as above in (12) for the year 2002 on sediment monitoring Programme.

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The Hydraulics Research Station is playing a major role within the MIWR, especially in the (HRS) field of researches and studies in the water resources management and development and the related fields. The River Nile Bank erosion is one of the projects which was carried out by the HRS staff. Therefore, very good literature is available in the library of the HRS in Wad Medani, Sudan.

Hussein, A.S., Ahmed, A. A. and Ahmed S. E. (1986) "Sedimentation Problems in the Gezira Scheme" Proc. Internal Conf. on Water Resources Needs and Planning in Drought Prone Areas, Khartoum.

The paper discusses the sedimentation problems in the irrigation schemes. The paper seeks to find mitigation measures to deal with the irrigation difficulties. It indicates the important of the sediment management in the irrigation system in Sudan and in particular in the Gezira scheme.

Hussein, A.S. (1993) "Upstream Soil Erosion Impact on Downstream; A case study Sudan Gezira Scheme presented at the workshop on, Environmentally sound management of the Upper Nile watershed.

A scientific paper deals with the impact of sediment distribution in the irrigation canalization system. The paper concentrates on the source of the sediment from the watershed in the upstream catchment, especially in Ethiopia. The paper attempts to link the erosion process in the upstream watershed and the sediment distribution impact on the irrigation system management, especially in the Gezira Scheme.

Hussien A.S. & Yousif, D.M. (1994), "prediction of Settling Performance for Very fine Sedimentation" Proceeding of the International Conference on Utilization and Management of Water Resources in Africa.

Based on experimental information provided by in the Hydraulics Research Station laboratory an intensive analysis was carried out to study the performance of the very fine sediment in the irrigated schemes. Hence, the prediction of the settling performance of the fine sediment is discussed and reported. It is concluded that about 40% of the sediment enters the Sudanese irrigation systems is considered as very fine one.

Lates E. M. and El Monshid, B.F. (1986) "The influence of the Hydraulic Operation of Pump station energy Dissipaters on the Pattern and Size of Downstream Scouring in the main Irrigation Cannel" Proceeding of the International Conference on Water Resources Needs and Planning in Drought Prone Areas.

The phenomenon of the scour downstream the hydraulic structures is considered as one of the serious problems endangering the safety of the irrigation systems. The paper discusses the impact of the energy dissipaters on the pattern and size of the downstream scour of the hydraulic structures, especially in the main canal of the Gezira Irrigated scheme.

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A paper highlights the environmental impact of the Blue Nile sedimentation on the reservoirs and irrigation canals. It reflects the negative impacts of the sedimentation on the Sudan economy in general and the irrigated area in particular. The social and environmental issues are also tackled in this paper.

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Osman, M. A. & Thorne, C. R. (1988) "River Bank Stability Analysis", American Society of Civil Engineering, Journal of Hydraulics, Feb. 1988.

A scientific paper concentrated on the main factors influencing the River banks stability based on the above thesis (published 1985).

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PhD thesis on Reservoir Sedimentation control, where an empirical formula is produced to calculate and predict the amount of sediment deposition in the reservoir. It is believed that this thesis is a good piece of work in the reservoir sedimentation field.

Teg-Elsir, A. Osman, E. H., 1986,"Sediment Transport in Relation to Reservoirs" International Conference on Water Resources Needs & Planning in Drought Prone Areas, Khartoum Dec. 1986, PP 281.

A scientific paper describes the relation between the sedimentation and the operation rules govern the reservoirs.

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Yousif, D. M., (1994), "Fall Velocity of very Fine Sediment in Turbulent Flow", Proceeding of Khartoum Nile 2002 Conference: Comprehensive Water Resources Development of the Nile Basin: The Vision Ahead.

A paper discusses the performance of the fine sediment in the turbulent flow. It concludes that the fine sediment will be in suspension in the turbulent flow zone. However, the bulk of the sediment enters the irrigation systems in Sudan is considered as wash load. Moreover and because the sediment is very fine about 39% passes to the farm fields.

Appendix 1

Rainfall Data

Note:
Source of Data : Meteorological Authority, Ministry of Aviation, Sudan, 2006

TR=Rainfall less than or equal to 0.1 mm, NR=No Record

Table (3) El-Damazin Station Monthly Rainfall in mm

LAT. 11 49 N LONG. 34 24E ALT. 470 M. ABOVE M.S.L.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1981	0	0	0	4	15.9	80	239	197.8	170.3	60.8	0	0
1982	0	0.1	0	2.6	27.4	95.6	132.9	278.8	55.2	52.9	0	0
1983	0	0	0	0	12.5	139.4	266.6	158	59	53.7	0	0
1984	0	0	0	0	49.4	53.1	191.3	112.3	138.7	26.9	0	0
1985	0	0	0	0	81.9	80.5	138.8	90.3	84.3	21.2	0	0
1986	0	0	0	1	15.3	80.7	213.9	167.8	66.8	28.1	0	0
1987	0	0	0.5	9.9	56.5	139.7	97.2	115	88.4	43.2	0.2	0
1988	0	0	5.2	0	56.4	70.5	211.8	151.8	195.1	35.9	0	0
1989	0	0	24.5	2	38.2	180.1	235.8	181	95.9	8.7	0	0
1990	0	TR	0	1.5	28.6	137.3	176.7	220.5	69.5	6.7	0	0
1991	0	0	0	27.3	101.2	116.2	180	220.2	45.7	7.9	0	0
1992	0	0	0	TR	11.8	128.2	80.9	161.8	160.9	37.6	1.1	0
1993	0	0	0	9.7	39.5	205.7	197.5	223.2	179.6	33	4.5	0
1994	0	0	0	TR	108.6	89.9	312.3	196.5	134.3	32	0	0
1995	0	0	3.5	10.3	82.3	92.8	64.2	159.3	173	49.2	0	0
1996	0	0	1.7	70.7	103.8	153.2	150.4	152.6	122.7	24.1	0	0
1997	0	0	0	17	49	177	167.8	101.8	200.5	39.9	24.7	0
1998	0	0	TR	33.1	15.5	53.7	190.9	204	261	61.7	0	0
1999	0	0	0	23.5	75.7	165	230.7	129.1	213.1	62.2	0	0
2000	0	0	0	8	58.8	99.1	232.4	182	46	TR	0	0

Table (4) Sennar Station Monthly Rainfall in mm

LAT. 13 33 N LONG. 33 37E ALT. 420 M. ABOVE M.S.L.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1981	0	0	0	0.7	19.9	18.2	135.1	138.2	104.6	6.6	0	0
1982	0	0	0	0	5.4	28.2	51.7	105.4	36.2	2.4	0	0
1983	0.8	0	0	0	6.8	122.9	71.1	88.9	54.3	0	0	0
1984	0	0	0	0	77.9	11.5	14	10.9	60.4	0	0	0
1985	0	0	0	0	20.7	50.2	76.3	149.4	111.3	3.8	1.7	0
1986	0	0	0	0	3.4	98.5	146.7	75	94.5	43	0	0
1987	0	0	0	0	31.4	0.8	110.1	208.2	36.3	29.4	0	0
1988	0	0	0	0	10.2	106.1	141.9	152.9	146.5	23.1	0	0
1989	0	0	0	0	19.3	47.5	28.8	327.2	137	7	0	0
1990	0	TR	0	0	TR	9.8	97.9	12.4	151.6	36.6	0	0
1991	TR	0	0	17.5	57.6	7.6	68.7	75.4	12.1	5.4	0	0
1992	0	0	0	0	7.2	56.2	151	155	46	1	TR	0
1993	0	0	0	10.7	72.6	16.1	131.3	223.4	72.1	TR	TR	0
1994	0	0	0	2.7	2.5	33	154.5	177.5	51.1	61.7	TR	0
1995	0	0	1.1	0.7	24.2	13.2	138.6	198.4	71	12.8	0	0
1996	0	0	2.1	0.7	123.4	41.6	67.3	240.5	77.2	11.8	0	0
1997	0	0	0	0.3	11.7	21.2	43.6		80.5	23.7	4.5	0
1998	0	0	0	TR	4.1	8.1	15.7	161.2	116.9	20.5	0	0
1999	0	0	0	1.3	1.3	5.1	124.7	190	96.1	17.3	0.5	0
2000	0	0	0	TR	18.4	71.8	223.6	147.7	42.7	46.7	0	0

Table (5) Khartoum Station Monthly Rainfall in mm

LAT. 15 36N LONG. 32 33E ALT. 380 M. ABOVE M.S.L.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1981	0	0	1.4	0	1.2	1.7	86.9	30.7	12.9	6.3	0	0
1982	0	0	1.6	0	5	0	9.4	46.9	39.8	0	0	0
1983	0.6	0	0	0	1.1	46.5	23.2	6.8	5.8	0	0	0
1984	0	0	0	0	1.4	0	0	0	3.3	0	0	0
1985	0	0	0	0	9.1	3.1	16.4	0.3	9.9	0	0	0
1986	0	0	0	0	0	0	9.1	21.9	16.3	10.4	0	0
1987	0	0	0	0	21.1	23	22	48.9	0	0.6	0	0
1988	0	0	0	0	0	0	65.9	301.4	46.3	1.9	0	0
1989	0	0	0	0	5.8	1.3	0	24.7	48	0	0	0
1990	0	0	0	0	TR	0	2	0	2.4	TR	0	0
1991	0	0	0	TR	2.3	0	4.3	37.7	TR	0.5	0	0
1992	0	0	0.6	0	10.8	4	6.9	89	36.6	TR	0	0
1993	0	TR	TR	TR	3.8	TR	1	33.4	TR	1.6	0	0
1994	0	0	0	0	12.7	0	51.3	48	100.2	19.4	0	0
1995	0	0	0	0	0	0.3	83.9	52.9	45.9	11.4	0	0
1996	0	0	0	0	19.2	0.4	32	44	91.9	0.5	TR	0
1997	TR	0	TR	TR	TR	3.1	50.9	50	9.2	42.2	TR	0
1998	0	0	TR	0	0	0	TR	21.3	85.3	4	0	0
1999	TR	0	0	TR	TR	1.9	26.9	47.3	25.5	29	0	0
2000	0	0	0	TR	TR	TR	1.4	8.5	15.3	34.8	0	0

Table (6) Kashem Elgirba Station Monthly Rainfall in mm

LAT. 15 19 N LONG.35 36E ALT. 450 M. ABOVE M.S.L.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1981	0	0	0	5.5	12.2	18.9	36.5	123.2	132.7	5	0	0
1982	0	0	0	0	10.6	27.3	65.3	143.5	13	6.1	0	0
1983	0	0	0	0	9.3	36.3	28.2	30.4	65.5	0	0	0
1984	0	0	0	0	0.5	0.1	21.2	1	19	0	0	0
1985	0	0	0	0	67	48.5	33.5	39.1	26	1.5	15	0
1986	0	0	0	0	0	18.1	45.8	50.4	37.7	20.3	0	0
1987	0	0	0	0	39.9	11.4	11.9	14.2	0	1.4	0	0
1988	0	0	0	0	6	10.2	34.2	145.1	19.3	16.2	0.6	0
1989	0	0	0	1	8.7	9.6	4.5	36.8	13.8	1	0.8	0
1990	0	TR	0	0	4	4.6	7.7	0.2	16.7	TR	0	0
1991	0	TR	TR	2.4	3.2	3	10.6	38	TR	4.8	0.5	0
1992	0	0	TR	1.2	1.6	41.7	28.5	104.6	36.5	1.5	TR	0
1993	0	0.1	TR	15.6	20.1	75	185.7	197.3	47.1	3	0	0
1994	0	0	0	0	30.3	6.2	109	101.5	45.3	0.4	0	0
1995	0	TR	TR	10	3.2	19.2	123.1	65.9	25	0	0	0
1996	0	0	0	TR	13.9	21.3	10.6	221.7	38	5.5	TR	0
1997	0	0	0	1	3	10.5	105.5	152.8	14.2	14.1	0	0
1998	0	0	0	2.6	0.8	2	26.8	93.6	57.2	0.8	0	0
1999	3.4	0	0	1.8	13.8	49.5	125.7	99.4	93.6	29.9	0	0
2000	0	0	0	10	6.8	2.7	41.3	93.2	78.6	1	0	0

Table (7) Karima Station Monthly Rainfall in mm

LAT. 18 33N LONG.31 51E ALT. 250 M. ABOVE M.S.L.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1981	0	0.2	0	0	0	0	0	0	4.5	0	0	0
1982	0	0	0	0	0	0	0	1	0.9	3	0	0
1983	0.1	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0.2	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	1	20	2	0	0	0
1987	0	0	0	0	2	0	0	10	1	0	0	0
1988	0	0	0	0	0	0	0.6	29	0	0	0	0
1989	0	0	0	0	0.6	1.6	0	1.6	8.7	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	TR	TR	0	6	0	15.7	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0
1993	0.7	0	0	0	10.7	TR	0	0	0	0	0	0
1994	0	0	0	0	0	0	32.7	10.9	0	0.6	0	0
1995	0	0	0	0	0	0	0	0	1	0	0	0
1996	0	0	0	0	0	0	0	0	0.3	0	0	0
1997	0	0	0	0	2.2	0	0	10.8	1	0	0	0
1998	0	0	0	0	0	0	1	0	2.7	0	0	0
1999	0	0	0	0	0	0	6.4	51.2	5.5	0	0	0
2000	0	0	0	0	0	0	0	0	2	0	0	0

Table (8) Dongola Station Monthly Rainfall in mm

LAT. 19 10 N LONG. 30 29E ALT. 228 M. ABOVE M.S.L.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1981	0	0	0	0	0	0	0	0	2	0	0	0
1982	0	0	0	0	0	0	0	0	0	7	0	0
1983	1.2	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	1	0	0	0.4	0	0	0	0
1988	0	0	0	0	0	0	0	32.5	1	0	0	0
1989	0	0	0.3	0	0	0	0	0	1	5.8	0	0
1990	0	TR	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	2	0	0	0	0	0	TR	0	0
1992	0	0	TR	0	0	0	0	13	0	TR	0	0
1993	TR	0	0	0	4.8	0	0	4.8	0	0	0	0
1994	0	0	0	0	0	61	7.2	6	0	0	0	0
1995	0	0	0	0	0	0	TR	0	TR	0	0	0
1996	0	0	0	0	TR	0	0	NR	NR	NR	NR	NR
1997	0	0	0	0	0	0	4.5	1	0	0	0	0
1998	0	1.4	TR	0	0	0	0	17.7	4	TR	0	0
1999	0	0	0	TR	0	0	9	TR	1	TR	0	0
2000	0	0	0	0	0	TR	0	1.3	0	0	0	0

Appendix 2
Evaporation Data

Table (9) El-Damazin Station monthly mean Evaporation in mm

LAT. 11 49 N LONG. 34 24E ALT. 470 M. ABOVE M.S.L.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	12.8	16.2	18	18.3	13.6	8.1	4.4	3.4	3.8	5.1	10.7	10.7
1981	13.4	NR	18.4	19	12.9	10.2	4.3	3.1	2.9	4.5	9.7	10.7
1982	11.9	13.9	17.7	16.3	12.8	9.3	5.5	NR	3.4	5.3	9.5	11.2
1983	12.5	15.5	17.9	19.6	15.6	8.2	4.4	3.3	3.1	5.3	11	12.1
1984	12.9	16	19	18.9	11.7	8.7	8.5	NR	4.5	7.7	11.8	12.9
1985	14.3	17.5	19.3	17.7	8.2	NR	4.3	3.9	4.5	6.5	11.8	12.3
1986	13.4	14.9	18.9	17.1	15.8	9.9	4.6	3.4	3.6	5.3	10.9	12.3
1987	12.1	11.8	17.5	18.5	12	7.2	6.1	4.3	5	7.8	12.5	12.8
1988	13.1	14.6	10.3	18.1	15.4	8.7	5.5	3.1	3	4.9	11.1	11.2
1989	12.6	14.4	14.4	14.4	107	7.6	4.4	4	3.2	5.5	9.8	10.8
1990	12.4	NR	18.3	17.4	14.7	10.2	5.2	4.1	4.9	7.2	11.4	12.9
1991	12.8	15.4	17.9	15.2	10.7	8.9	6.9	4.6	5.4	7	11.6	12.7
1992	13.4	16.4	19.5	9.8	14	9.8	6.7	6	4.2	5.7	9.4	11.6
1993	13.7	15.6	18.7	17	15.1	8.6	5.4	4.6	5.6	7.7	11.2	14.7
1994	16.4	19.5	21.6	25.9	18.3	10.1	7.4	3.7	4.3	7.6	11.1	12.2
1995	13.2	17.1	17.2	20	16.8	13.1	7.7	5.8	4.5	6.2	10.6	11.9
1996	12.4	13.8	16.8	19.8	13.4	9	7.2	4.8	4.6	6.9	10.1	10.1
1997	11.4	15.7	17.5	NR	11.3	11.7	8.3	3.5	4.7	5.5	8.9	12.6
1998	13.4	15.4	18.8	18.5	14	11	6	3.7	3.7	4.5	13.9	9.9
1999	11.7	17.1	19.2	19.7	14	10.5	5.1	3.5	3.5	7.1	7	10.5
2000	12.5	15.7	19.4	15.2	11.5	10.9	5.3	3.1	3.7	5.7	10.5	12.5

Table (10) Sennar Station monthly mean evaporation in mm

LAT. 13 33 N LONG. 33 37E ALT. 420 M. ABOVE M.S.L.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	11.8	16.7	16.9	19.6	17.0	12.4	7.3	5.4	9.1	12.0	15.0	13.7
1981	16.5	15.9	19.4	22.2	19.9	20.1	10.2	10.5	5.9	10.7	14.5	12.0
1982	13.1	15.8	20.0	20.5	17.4	17.5	13.8	8.9	10.5	11.4	13.3	12.7
1983	14.3	17.3	18.3	20.7	18.4	13.7	10.2	7.1	8.5	11.1	11.3	9.6
1984	11.0	13.2	19.2	20.9	15.9	14.7	14.2	12.3	10.8	13.6	15.3	13.5
1985	14.0	17.1	18.3	19.3	14.3	13.7	9.2	10.1	7.0	10.4	11.9	11.3
1986	12.4	13.6	16.9	16.7	18.1	13.6	7.1	5.9	5.7	8.8	12.4	12.2
1987	11.4	11.9	14.5	20.1	16.5	13.4	11.3	6.4	7.4	11.6	13.5	11.6
1988	11.4	14.3	19.5	20.4	18.9	12.4	6.9	4.6	3.5	6.2	12.0	11.5
1989	12.3	14.5	15.5	17.4	14.8	14.3	11.9	6.1	4.7	8.3	11.7	10.7
1990	11.9	14.5	18.6	18.9	15.4	17.8	11.0	12.9	9.6	8.9	11.7	10.7
1991	11.9	NR	15.6	16.6	13.7	14.6	NR	5.9	NR	9.6	12.3	10.5
1992	10.8	12.4	15.9	18.2	15.7	12.8	6.8	3.9	5.6	8.2	12.9	10.8
1993	11.6	13.2	18.1	17.7	9.1	12.7	8.4	6.3	5.0	9.2	11.8	11.2
1994	10.7	13.4	15.0	18.9	18.4	16.5	9.2	5.9	7.3	10.4	15.4	12.7
1995	12.1	15.7	18.0	20.5	17.6	16.4	8.3	7.0	6.9	10.4	13.7	11.8
1996	11.0	14.9	18.1	19.3	13.3	14.1	11.6	6.3	5.8	10.5	12.6	12.1
1997	11.7	17.9	18.5	18.0	15.1	14.5	8.9	8.5	9.7	10.6	11.5	12.3
1998	12.7	14.4	19.4	21.3	18.0	17.5	9.9	5.6	5.1	7.9	13.3	13.1
1999	12.0	17.1	17.9	204.0	17.3	15.7	7.9	4.9	4.8	6.4	11.5	11.5
2000	13.6	17.5	21.1	19.2	16.9	17.7	10.8	6.5	6.6	9.2	12.5	12.7

Table (11) Khartoum Station monthly mean evaporation in mm

LAT. 15 36N LONG. 32 33E ALT. 380 M. ABOVE M.S.L.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	14.3	18.9	20.2	22.2	21.5	20.1	12.4	13.4	13.2	14.7	20.1	16.5
1981	18	21.4	21.4	24.7	23.4	NR	10.3	15.8	15.3	15.7	20	16.3
1982	14.1	10.3	19.4	22.1	22.8	20.2	18.1	13.7	15.7	16.8	17.6	15
1983	14.7	19.1	21.2	25.4	16.8	18.5	16.8	17.1	19.2	16.2	18	11.1
1984	15.7	18.3	17.5	24.4	22.9	21.3	17.6	17.3	17.7	20.2	18.8	15.7
1985	16.2	20.2	22.9	22.5	18.9	19.5	15.6	16.5	16.7	20.2	12.2	9
1986	16.4	18.7	23.4	20.6	24.3	19	15.4	14.9	14.2	18.6	17.4	16
1987	11.7	19	21.3	25.7	19.1	19.2	20.2	15.1	17.2	20.4	19.2	17.5
1988	16.8	18.7	25.9	22.1	23.9	22.3	13.8	9.9	12.3	18.7	18.2	16.2
1989	15.3	16.4	19.1	20.4	21.8	20.3	21.8	16.7	16.1	19.2	20.1	13.6
1990	15.6	16.1	19.1	24.1	22.2	20.8	17.7	18.5	18.8	19.7	18.7	15.3
1991	17.1	18.8	21.3	21.2	22	19.6	17.2	15.3	19.9	20.3	19.5	18
1992	16.1	19	21.1	21.5	25.5	24.5	20.7	19	15.8	17.9	18.5	14.6
1993	15.4	18.8	24.5	23.4	21.7	23	20.8	18.2	19.7	20.9	20.1	16.8
1994	17.7	21.1	21.8	26.8	24.5	21.5	17	13.5	12.3	15	19.8	15.3
1995	15.7	16.9	21.5	22.1	17.7	20.5	13.2	10.8	13.1	16.6	16.4	13.9
1996	12.9	16.8	20.2	24	20.1	14.4	17.6	15.1	13.1	17.2	16.5	15.8
1997	14.6	18.9	20.5	22.9	21.9	21	15.2	14	16.9	15.6	17.7	16.8
1998	15.2	18.1	22.2	25.6	24	23.8	20.7	13.5	11.5	15.9	18.3	16.7
1999	16.2	20.9	22.9	26.3	26.8	25.5	18	14.3	15.9	16.3	21.2	17.5
2000	20.9	24.6	28.3	26.5	25.9	26.5	26.6	23.7	20.5	23.3	22.1	19.5

Table (12) Kashem Elgirba Station monthly mean evaporation in mm

LAT. 15 19 N LONG.35 36E ALT. 450 M. ABOVE M.S.L.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	11.7	15.7	18.6	21.2	21.2	16.1	10.6	11.1	10.9	13.4	13.6	12.1
1981	NR	14.5	16.9	20.2	18.2	18.3	12.5	13.5	7.9	12.0	13.4	13.3
1982	NR	NR	18.8	20.6	20.1	19.5	17.0	9.8	11.0	12.8	13.4	12.6
1983	11.4	14.0	17.9	20.1	18.5	19.1	15.4	12.3	12.1	13.1	14.0	10.5
1984	10.7	12.3	17.0	22.9	21.3	23.2	18.0	16.0	13.9	15.4	13.7	11.5
1985	12.2	15.0	18.6	20.2	15.7	16.7	14.7	12.8	10.9	14.3	13.2	10.3
1986	11.4	14.2	17.7	18.3	20.9	19.9	14.5	13.9	11.1	12.2	14.9	11.8
1987	11.1	15.9	18.4	20.0	15.1	15.8	15.2	11.3	13.9	13.0	13.2	12.5
1988	11.7	14.7	19.2	20.3	19.1	19.0	12.4	5.8	6.1	9.3	11.4	10.5
1989	10.2	12.2	15.5	16.6	17.0	19.8	17.7	11.1	10.5	12.3	13.2	11.8
1990	12.5	16.1	18.6	21.7	18.9	20.1	16.2	17.1	12.8	14.0	13.6	21.1
1991	11.7	14.1	17.7	20.1	18.1	20.5	16.5	12.9	15.4	15.2	14.2	13.5
1992	13.6	17.1	19.7	22.5	22.2	22.5	14.8	8.0	6.9	11.1	12.1	12.2
1993	13.7	14.9	20.8	21.5	18.4	20.4	15.4	10.1	8.9	11.9	12.5	11.3
1994	12.7	16.2	19.3	23.1	21.9	22.8	8.9	7.9	10.5	13.0	15.5	12.2
1995	11.8	15.6	21.0	21.0	20.1	20.1	12.2	9.3	10.1	9.2	13.8	10.1
1996	13.7	17.2	21.0	21.7	18.1	17.2	11.9	10.2	8.7	12.9	14.3	12.3
1997	12.9	14.9	18.6	21.8	19.1	19.7	11.6	9.7	11.3	12.4	14.1	12.3
1998	13.3	15.4	18.6	21.3	19.9	21.6	12.1	7.8	7.9	10.9	13.9	12.6
1999	11.5	14.3	16.1	20.5	21.1	20.6	10.9	8.2	8.8	10.2	13.6	11.6
2000	12.4	13.9	17.5	18.2	19.5	20.4	15.7	12.4	9.3	12.0	13.8	12.4

Table (13) Karima Station monthly mean evaporation in mm

LAT. 18 33N LONG.31 51E ALT. 250 M. ABOVE M.S.L.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	14.6	14.7	19.5	25.5	24.3	24.3	20.6	21.3	23.4	21.7	16.6	12.6
1981	13.3	16.7	18.8	22.0	24.2	22.6	19.6	21.2	21.7	20.6	15.0	13.8
1982	12.7	13.1	18.9	19.6	23.8	21.9	19.1	19.6	23.7	18.9	14.2	12.1
1983	10.7	16.2	16.3	21.5	22.5	24.3	21.7	20.8	21.3	21.3	14.6	13.0
1984	13.1	18.6	20.5	25.4	24.9	20.3	19.0	21.4	23.0	20.8	16.3	12.9
1985	14.4	16.6	20.3	21.9	22.7	22.0	18.8	21.3	23.3	22.3	14.7	12.2
1986	12.7	15.5	20.9	17.5	18.9	21.1	19.2	20.5	19.7	18.3	15.2	12.1
1987	12.7	14.9	16.6	20.4	18.7	18.4	15.9	17.9	25.3	18.6	16.5	13.1
1988	13.5	14.8	23.0	22.3	23.5	21.1	20.6	14.3	14.9	19.5	16.0	12.8
1989	12.6	13.9	16.7	20.2	17.7	19.1	15.4	19.8	19.5	15.9	16.1	12.8
1990	14.9	13.2	14.4	25.3	22.3	20.7	17.8	19.0	23.0	19.5	16.0	14.2
1991	12.3	14.6	16.1	18.6	18.2	18.4	17.5	17.5	20.5	14.3	17.3	12.7
1992	12.8	15.3	20.1	23.2	21.5	22.1	18.1	19.8	22.3	20.7	17.1	12.9
1993	14.6	16.2	21.3	20.9	23.0	22.5	25.4	21.9	22.8	21.8	23.0	15.0
1994	16.0	21.0	21.9	28.4	19.8	29.0	23.7	24.0	24.8	26.2	23.9	20.9
1995	20.8	23.0	25.4	28.9	29.4	29.5	27.4	25.6	26.3	28.5	18.3	14.6
1996	18.7	19.0	21.7	25.4	24.8	24.8	22.8	23.5	22.9	22.5	16.5	15.9
1997	11.3	18.7	22.2	26.1	23.2	24.8	22.7	20.5	26.5	22.7	19.6	15.4
1998	14.0	16.7	19.8	24.5	26.2	26.5	22.1	20.6	22.0	24.3	19.2	15.9
1999	15.8	20.4	21.2	26.9	25.3	25.3	19.1	18.0	23.6	22.2	18.4	18.2
2000	16.7	19.6	24.2	25.5	25.9	24.7	21.2	23.6	22.7	24.8	18.8	14.3

Table (14) Dongola Station monthly mean evaporation in mm

LAT. 19 10 N LONG. 30 29E ALT. 228 M. ABOVE M.S.L.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	13.3	14.3	18.1	24.3	24.8	22.2	19.9	22.0	26.3	24.8		14.1
1981	14.5	16.0	18.2	22.3	24.9	24.2	22.2	26.1	22.2	20.9	16.2	14.6
1982	12.8	13.6	19.8	20.1	22.5	21.5	21.6	23.0	27.7	20.1	14.3	10.7
1983	11.1	14.3	16.5	19.1	22.0	24.0	21.4	24.6	25.9	23.6	16.2	11.7
1984	13.4	18.2	20.4	24.0	25.8	22.4	20.6	22.8	24.0	22.6	15.1	12.4
1985	13.1	14.6	15.7	18.2	20.2	24.7	19.5	19.9	26.7	20.1	16.9	14.3
1986	14.5	17.3	20.3	19.7	21.7	24.7	20.8	25.3	25.5	24.6	17.3	15.4
1987	16.0	17.3	20.9	21.6	21.6	24.9	23.9	23.6	27.1	24.0	23.1	16.7
1988	16.1	17.2	25.9	24.5	24.6	25.0	23.3	18.7	26.1	24.1	20.6	14.9
1989	16.0	14.5	19.2	20.0	24.2	25.5	23.0	24.7	27.2	22.1	16.2	12.0
1990	13.7	13.0	18.4	22.9	25.3	24.9	20.9	24.5	24.7	23.0	17.7	14.9
1991	12.5	15.3	17.2	22.6	25.3	23.7	20.6	21.1	24.6	22.3	16.6	11.3
1992	11.0	13.8	19.4	22.5	23.4	24.3	24.5	23.4	26.3	21.8	17.0	11.7
1993	12.9	14.2	19.8	21.0	24.7	25.0	23.2	19.1	20.4	22.8	18.1	14.5
1994	16.2	17.1	20.0	26.7	27.3	27.0	23.6	23.4	21.1	23.3	17.4	14.0
1995	14.4	15.2	21.1	24.6	26.1	27.1	25.3	25.8	25.7	24.8	17.5	13.9
1996	13.1	16.6	21.2	21.7	27.9	26.2	25.8	25.1	NR	NR	NR	NR
1997	12.7	15.0	17.8	22.9	23.5	29.6	23.3	23.0	26.3	22.2	17.5	13.2
1998	12.6	14.9	18.7	23.2	26.0	24.1	22.0	25.1	24.7	24.9	19.6	15.8
1999	15.0	20.4	19.7	25.2	28.4	28.2	22.8	25.1	26.7	25.1	19.2	15.1
2000	14.9	19.0	23.2	26.0	26.8	27.3	27.1	27.6	27.6	24.6	17.7	12.9

Appendix 3
Water Discharges Data

Table (15) Blue Nile River Discharges- Eddeim Station (1980-2000)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	560.70	333.16	267.87	254.70	458.72	1297.60	7603.60	15119.50	9121.00	4630.90	1786.20	994.36
1981	621.72	424.48	324.47	231.30	476.78	1106.50	6111.64	3342.51	11732.20	5336.02	1842.90	968.38
1982	504.75	332.83	240.75	248.50	323.69	1076.20	4329.46	10933.43	7789.50	5490.47	1859.10	961.04
1983	555.15	318.80	195.68	125.30	429.98	1102.00	3923.90	13273.00	10920.00	5885.00	2191.30	1017.34
1984	321.59	212.46	151.01	224.90	290.37	1862.50	6287.55	9806.00	7292.50	2517.42	976.80	574.41
1985	543.05	338.14	294.22	305.80	739.27	1427.00	6127.39	15448.90	13228.80	4559.82	1743.60	984.35
1986	419.22	245.09	353.59	308.40	195.88	1429.40	6693.04	10207.05	8714.50	3780.81	1377.80	732.51
1987	370.58	330.66	396.92	220.80	812.83	2472.70	4735.73	10165.71	6815.00	4220.88	1931.70	1027.95
1988	764.81	453.18	370.30	431.30	273.25	2308.90	12600.68	19782.52	14994.10	10354.35	3285.10	1502.27
1989	836.92	494.35	353.79	273.10	448.38	1313.40	6101.19	12324.58	10522.70	5317.65	2345.10	1487.23
1990	511.81	296.44	262.51	332.90	289.97	803.70	4712.24	12788.48	9791.50	5099.97	1660.70	869.78
1991	682.70	458.13	323.94	252.40	636.62	1560.70	8462.06	14642.00	11174.10	4733.13	2077.60	1206.39
1992	924.55	529.57	365.85	678.60	636.40	1441.90	4239.80	11905.10	10310.70	7888.69	3270.60	1656.65
1993	924.59	513.29	360.74	700.93	1130.49	3240.97	8516.36	15271.00	12774.46	7737.06	3352.56	1575.50
1994	899.73	486.48	353.77	277.19	744.34	1974.17	8397.61	18072.99	13496.38	4500.94	2189.49	1118.07
1995	516.75	302.27	274.41	353.86	547.75	1445.01	5278.94	13197.53	8840.89	3843.08	1628.69	897.00
1996	563.93	318.92	342.22	509.75	1350.35	4056.92	10282.55	17300.00	11526.29	6039.20	2354.97	1379.68
1997	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1998	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1999	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table (16) Blue Nile River Discharges- Roseries Station (1980- 2000)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	7610.13	14973.70	8989.20	4628.20	1784.97	996.14	562.82	311.45	265.62	249.48	485.69	1065.24
1981	6170.72	13800.60	11573.10	5230.20	1836.45	967.92	611.82	340.16	320.27	215.82	319.28	1028.61
1982	4354.00	10916.70	7652.70	5253.90	1802.79	935.35	499.36	308.09	239.48	246.51	421.94	1088.01
1983	3970.87	14592.60	10117.80	5682.60	2088.90	1009.80	552.72	306.90	190.38	123.75	291.65	1823.58
1984	6242.90	8644.70	7207.20	2451.54	955.35	563.81	317.39	195.03	149.09	227.70	730.03	1395.90
1985	6030.10	15287.60	12780.90	4537.30	1718.64	969.61	536.18	311.85	290.07	294.03	1441.64	1415.70
1986	6626.10	10107.90	8627.90	3756.06	1375.11	732.50	414.32	248.89	350.56	305.91	804.67	2448.27
1987	4683.64	10058.40	6741.90	4178.00	1912.68	929.71	507.67	362.93	392.44	218.79	271.66	2095.83
1988	12467.10	19711.90	14790.60	10019.80	3155.13	1490.84	766.76	424.51	366.50	418.77	435.50	1148.40
1989	6281.50	12059.20	10652.40	4791.70	1665.18	1103.65	838.13	448.67	349.37	270.27	287.06	795.66
1990	4665.12	12660.60	9693.60	5049.00	1644.09	861.09	506.69	284.20	259.89	329.57	630.26	1545.09
1991	8377.40	14495.60	11062.40	4685.80	2056.83	1194.33	675.87	439.90	320.71	249.88	630.04	1427.48
1992	4197.40	11786.00	10207.50	7809.80	3237.96	1640.09	915.31	508.60	357.19	693.89	1119.21	2928.11
1993	8397.10	15118.90	12662.30	7723.40	3318.43	1564.48	890.07	481.33	349.84	274.31	722.28	1921.16
1994	8246.40	17742.40	13272.60	4439.00	2165.23	1104.49	511.18	299.11	267.46	346.68	535.35	1411.74
1995	5158.07	12962.60	8733.40	3793.66	1610.56	886.98	558.03	315.23	348.80	482.74	1364.25	4022.60
1996	10382.90	16870.80	11267.30	5782.30	2279.06	1343.65	848.20	419.25	598.72	533.35	876.91	2713.61
1997	8249.30	12053.40	7005.10	4896.70	4064.80	1734.15	916.40	585.19	511.80	626.17	824.93	1668.97
1998	8467.20	18778.20	15581.10	11413.10	3952.02	1952.64	1154.79	702.84	453.03	306.55	858.73	2235.77
1999	8565.20	16832.90	12098.20	11628.00	3953.30	1917.52	1086.49	820.97	278.67	589.72	830.61	2317.94
2000	7758.00	18096.40	10827.80	9174.60	3948.25	1840.79	894.51	457.79	749.88	797.71	938.29	2705.23

Table (17) Blue Nile River Discharges- Sennar Station (1980- 2000)

year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	297.59	264.047	317	486	627	671.087	6165.83	14640.22	7126.191	2533.814	636	254
1981	223	224	244	400.33	589	539	4387	12710	9910	3036	703	240
1982	218	182	228	686	585	657	3237	9751	4469	4094	618	296
1983	217.956	209.805	265.1	497.086	701.41	757.769	2589.65	11733.259	7456.46	3743.788	957.389	285.793
1984	225.492	214.307	350.447	447.621	451.598	1158.114	4801.975	7118.134	3766.361	1284.347	165.672	163.075
1985	219.07	330.05	288.72	321.42	664.21	1010.57	4468.58	13388.79	11523.62	1284.35	629.26	256.47
1986	250.30	247.90	299.48	495.73	497.97	874.36	5198.68	9426.67	6008.22	2243.85	349.31	172.27
1987	284.34	307.22	620.92	412.23	682.10	2584.39	3292.86	8867.56	3658.00	2729.52	820.23	215.62
1988	181.15	177.93	352.00	581.91	615.22	1408.98	6781.64	19046.23	14666.94	7203.92	1897.80	496.37
1989	233.61	205.58	369.28	640.42	937.43	1241.82	5155.16	10878.24	8677.68	3928.54	976.57	404.79
1990	275.47	229.08	435.33	829.83	645.26	350.88	3239.36	11840.56	8308.15	3361.11	552.96	175.71
1991	124.61	122.19	250.02	575.85	619.05	924.77	6524.78	13731.74	9889.52	2070.29	923.14	249.43
1992	213.00	185.00	294.00	748.00	551.00	836.00	2779.00	11481.00	8622.00	6310.00	1939.00	475.00
1993	220.00	140.00	255.00	554.00	1015.00	2911.00	6907.00	15475.00	11934.00	4940.00	2229.00	502.00
1994	221.00	187.00	455.00	789.00	870.00	1292.00	6530.00	17543.00	13422.00	1967.00	860.00	225.00
1995	188.00	221.00	310.00	397.00	626.00	757.00	3866.00	13346.00	6349.00	2248.00	399.00	189.00
1996	229.00	263.00	303.00	518.00	1132.00	3361.00	9262.00	17446.00	9635.00	4526.00	1258.00	396.00
1997	230.00	219.00	513.00	927.00	1276.00	2871.00	7419.00	11656.00	4352.00	3967.00	3874.00	1152.00
1998	332.00	317.00	407.00	765.00	1167.00	1340.00	7498.00	19812.00	16958.00	9549.00	3605.00	1347.00
1999	586.00	374.00	517.00	647.00	1253.00	2085.00	7533.00	16810.00	10426.00	10702.00	3242.00	1349.00
2000	587.00	334.00	606.00	987.00	1324.00	1758.00	6298.00	16394.00	9428.00	7253.00	3369.00	1257.00

Table (18) Blue Nile River Discharges- Khartoum Station (1980- 2000)

year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	530.46	395.33	517.84	921.75	1226.37	706.78	4402.69	16802.04	10734.89	3139.57	1489.34	842.93
1981	692.08	417.77	536.94	1068.58	781.56	639.54	2840.64	12865.49	12883.67	4747.14	1377.32	1410.74
1982	1064.37	676.57	662.56	1403.18	778.75	725.75	2217.21	9046.86	2831.44	4989.40	1126.89	1114.09
1983	418.45	353.56	579.29	847.70	580.39	576.38	1258.02	9958.31	9544.23	4065.04	1662.12	639.03
1984	757.82	455.44	485.52	768.45	526.34	517.37	2481.45	5325.07	1776.06	1137.50	577.30	416.32
1985	456.25	307.40	501.66	618.53	692.06	890.39	2612.57	12282.05	13238.69	1137.50	1362.71	902.36
1986	680.84	471.12	539.29	1157.59	862.80	539.97	3847.22	9599.00	7167.08	2965.00	1336.91	605.81
1987	606.21	514.05	532.73	1046.88	1028.21	2585.39	2970.11	9584.72	5715.08	3821.31	1679.02	866.77
1988	477.28	322.43	552.61	736.19	454.97	775.73	4821.26	22344.67	22135.18	10363.68	3179.93	1408.08
1989	1456.19	744.07	584.77	1406.27	1412.74	1183.91	4070.20	10437.38	10558.57	5187.79	1837.21	1027.67
1990	724.46	504.56	414.23	1440.42	1037.89	474.06	1825.74	10307.77	9412.63	4033.59	1109.46	771.98
1991	317.88	218.12	338.42	573.09	461.07	512.29	3370.16	15680.23	14831.45	1726.86	949.03	720.28
1992	518.97	331.49	412.67	966.92	514.47	526.90	1249.07	12794.36	12422.34	6147.19	1866.72	779.67
1993	344.42	190.05	235.20	876.95	809.05	2255.18	5079.11	15878.63	15041.58	6034.06	2460.53	976.39
1994	824.95	654.77	753.71	1427.69	1068.27	708.66	4533.74	17265.81	15723.44	4650.34	2073.50	1331.72
1995	429.42	61.75	180.54	380.15	491.51	135.12	1775.33	13504.22	7452.88	2626.28	581.57	216.19
1996	232.96	15.69	121.64	399.77	811.48	2194.90	7443.76	17243.00	12733.65	5476.30	1537.06	630.43
1997	595.69	263.68	397.94	1151.32	891.72	1830.93	5439.49	13044.44	4346.58	5476.30	4158.92	1134.96
1998	610.23	417.93	464.30	1006.22	941.55	737.46	4269.36	16823.43	17890.40	3587.44	4324.69	1612.13
1999	434.10	205.09	116.94	612.38	680.34	1395.82	5643.57	16461.66	13155.01	12162.65	4836.84	2315.89
2000	1202.81	577.82	1035.63	1720.78	1147.84	1219.31	4099.30	15105.71	10507.35	7515.99	3755.24	1240.29

Table (19) Dinder River Discharges- Giwasi Station (1980- 2000)

year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	0.00	0.00	0.00	0.00	0.00	0.00	270.81	847.55	657.40	211.28	0.00	0.00
1981	0.00	0.00	0.00	0.00	0.00	0.00	333.33	686.17	956.30	220.90	0.00	0.00
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	580.14	296.30	176.56	0.00	0.00
1983	0.00	0.00	0.00	0.00	0.00	0.00	59.05	582.06	774.90	170.70	0.00	0.00
1984	0.00	0.00	0.00	0.00	0.00	0.00	8.69	91.28	196.20	12.00	0.00	0.00
1985	0.00	0.00	0.00	0.00	0.00	0.00	215.05	1125.73	1112.00	339.79	0.00	0.00
1986	0.00	0.00	0.00	0.00	0.00	74.80	123.59	424.57	452.12	205.82	0.00	0.00
1987	0.00	0.00	0.00	0.00	0.00	0.00	142.26	688.18	538.90	298.10	8.60	0.00
1988	0.00	0.00	0.00	0.00	0.00	0.00	288.20	1591.32	1773.00	999.24	132.40	0.00
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.00	778.94	893.30	422.75	0.00	0.00
1990	0.00	0.00	0.00	0.00	0.00	0.00	194.04	895.38	521.80	235.61	0.00	0.00
1991	0.00	0.00	0.00	0.00	0.00	0.00	289.95	514.00	648.15	93.39	0.00	0.00
1992	0.00	0.00	0.00	0.00	0.00	0.00	31.24	546.66	661.60	342.64	56.90	0.00
1993	0.00	0.00	0.00	0.00	0.00	0.00	43.46	640.82	632.47	276.79	12.44	0.00
1994	0.00	0.00	0.00	0.00	0.00	0.00	403.79	917.53	1391.35	264.78	25.03	0.00
1995	0.00	0.00	0.00	0.00	0.00	13.47	219.12	684.66	418.83	122.87	0.00	0.00
1996	0.00	0.00	0.00	0.00	0.00	0.00	197.89	598.32	814.77	248.33	1.61	0.00
1997	0.00	0.00	0.00	0.00	0.00	0.00	80.84	527.82	373.71	101.77	53.99	0.00
1998	0.00	0.00	0.00	0.00	0.00	0.00	197.34	779.50	867.09	615.66	150.25	16.74
1999	0.00	0.00	0.00	0.00	0.00	0.00	220.15	832.02	861.25	985.47	177.34	191.09
2000	0.00	0.00	0.00	0.00	0.00	0.00	72.35	583.11	469.10	294.13	116.89	0.00

Table (20) Rahad River Discharges- El Hawata Station (1980- 2000)

year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	0.00	0.00	0.00	0.00	0.00	0.00	237.82	450.82	359.00	138.29	8.50	0.00
1981	0.00	0.00	0.00	0.00	0.00	0.00	242.93	406.27	505.40	240.47	8.80	0.00
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	123.40	172.50	103.40	6.10	0.00
1983	0.00	0.00	0.00	0.00	0.00	0.00	70.40	239.60	343.60	110.97	39.50	0.00
1984	0.00	0.00	0.00	0.00	0.00	0.00	59.00	117.50	117.40	44.80	0.00	0.00
1985	0.00	0.00	0.00	0.00	0.00	0.00	173.86	451.56	482.10	161.60	45.20	0.00
1986	0.00	0.00	0.00	0.00	0.00	22.53	143.74	321.06	436.50	121.01	40.00	0.00
1987	0.00	0.00	0.00	0.00	0.00	0.00	135.52	345.99	179.14	133.56	17.56	0.00
1988	0.00	0.00	0.00	0.00	0.00	0.00	342.64	684.91	653.00	614.90	189.93	0.00
1989	0.00	0.00	0.00	0.00	0.00	0.00	151.17	299.58	339.30	190.45	0.00	0.00
1990	0.00	0.00	0.00	0.00	0.00	0.00	119.10	252.84	230.40	85.80	0.00	0.00
1991	0.00	0.00	0.00	0.00	0.00	0.00	194.01	372.00	353.00	63.26	0.00	0.00
1992	0.00	0.00	0.00	0.00	0.00	24.63	165.92	410.50	452.80	294.85	44.83	0.00
1993	0.00	0.00	0.00	0.00	0.00	0.00	92.45	366.23	391.09	223.04	24.84	1.69
1994	0.00	0.00	0.00	0.00	0.00	0.00	261.22	427.27	468.09	149.55	24.50	3.42
1995	0.00	0.00	0.00	0.00	0.00	42.95	150.18	389.29	388.66	97.12	0.00	0.00
1996	0.00	0.00	0.00	0.00	0.00	0.00	77.19	296.31	331.80	136.73	12.38	1.13
1997	0.00	0.00	0.00	0.00	0.00	0.00	216.28	351.84	328.98	158.21	80.98	5.94
1998	0.00	0.00	0.00	0.00	0.00	0.00	114.40	393.14	428.71	329.91	52.65	11.24
1999	0.00	0.00	0.00	0.00	0.00	0.00	234.63	396.36	442.57	445.00	91.03	27.72
2000	0.00	0.00	0.00	0.00	0.00	0.00	157.43	336.80	367.95	228.45	58.81	7.50

Table (21) Main Nile River Discharges- Dongola Station (1980- 2000)

year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	2700.00	1870.00	1840.00	2750.00	2930.00	2120.00	4250.00	19400.00	15900.00	5800.00	4220.00	2880.00
1981	2700.00	2270.00	1890.00	2690.00	2480.00	2190.00	3420.00	16500.00	17100.00	10300.00	4170.00	3260.00
1982	2100.00	1540.00	1700.00	2920.00	2310.00	2180.00	2660.00	10500.00	10600.00	7420.00	4000.00	3020.00
1983	2700.00	2310.00	1750.00	2600.00	2510.00	1850.00	4920.00	11200.00	14400.00	7070.00	4620.00	2760.00
1984	1750.00	1490.00	1690.00	2190.00	2350.00	2180.00	5760.00	9260.00	5800.00	4200.00	2350.00	1870.00
1985	2270.00	1730.00	1640.00	2380.00	2720.00	1540.00	5280.00	14300.00	19500.00	6600.00	3620.00	2990.00
1986	1730.00	1730.00	1380.00	1840.00	2420.00	2930.00	4730.00	13000.00	13400.00	6300.00	3190.00	2040.00
1987	2060.00	1570.00	1660.00	2400.00	1850.00	1620.00	7490.00	9890.00	9420.00	4940.00	3360.00	2330.00
1988	3270.00	2060.00	1740.00	2460.00	2990.00	2090.00	5010.00	25200.00	24600.00	13800.00	7200.00	3460.00
1989	2450.00	1710.00	1480.00	2880.00	3020.00	1460.00	2500.00	13300.00	15700.00	8750.00	4280.00	2760.00
1990	1840.00	1190.00	1390.00	2200.00	2250.00	1870.00	5670.00	11900.00	13400.00	6710.00	3130.00	2260.00
1991	2650.00	1940.00	1930.00	2810.00	2650.00	1910.00	4150.00	16300.00	18200.00	6040.00	4040.00	3030.00
1992	2600.00	2150.00	2120.00	2690.00	3030.00	3920.00	7250.00	13900.00	16900.00	9310.00	5240.00	3360.00
1993	2380.00	1670.00	1620.00	2370.00	2840.00	2150.00	5780.00	17700.00	19200.00	10400.00	5450.00	3780.00
1994	2390.00	1760.00	1910.00	1820.00	2590.00	1900.00	3870.00	22400.00	24400.00	8680.00	3430.00	2780.00
1995	2260.00	1790.00	1880.00	2150.00	2790.00	3240.00	10500.00	17600.00	13700.00	5750.00	3140.00	2330.00
1996	2760.00	2340.00	2270.00	2930.00	3020.00	2900.00	7160.00	20100.00	19000.00	10100.00	4120.00	3020.00
1997	2700.00	2070.00	2060.00	2590.00	3140.00	2210.00	5370.00	16000.00	9460.00	5820.00	6850.00	4210.00
1998	2890.00	2490.00	2390.13	2550.00	2850.00	2850.00	7070.00	23600.00	32200.00	16800.00	9300.00	4350.00
1999	3140.00	2700.00	2570.00	3220.00	2870.00	2690.00	5260.07	21500.00	22000.00	14200.00	8199.88	4530.00
2000	2930.00	2170.00	2090.00	2390.00	2860.00	2460.00	6740.00	19800.00	17300.00	9970.00	6540.00	3750.00

Table (22) Atbara River Discharges- Kashim ElGirba Station (1980- 2000)

year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1981	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1982	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1983	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1984	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1985	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1986	0.00	0.00	0.00	0.00	0.00	32.69	2254.13	4080.12	2437.28	313.28	6.10	0.00
1987	0.00	0.00	0.00	0.00	9.97	432.56	1116.40	3498.99	509.47	33.55	4.95	0.00
1988	0.00	0.00	0.00	0.00	0.00	0.83	4144.97	10084.11	3462.14	1476.72	49.11	18.47
1989	0.00	0.00	3.96	13.47	13.59	23.59	1881.32	3269.26	1016.27	1476.72	11.01	0.00
1990	0.00	0.00	0.00	0.00	0.00	0.00	1541.04	1804.86	1103.13	328.75	0.00	0.00
1991	0.00	0.00	0.00	0.00	0.00	1.79	2183.10	4728.57	1087.12	78.63	0.00	0.00
1992	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1993	0.00	0.80	6.15	9.22	37.54	667.35	2225.81	3501.24	2069.52	430.05	21.82	0.00
1994	0.00	0.00	0.00	0.00	0.00	6.12	3355.31	7785.25	4550.92	260.08	8.12	0.00
1995	0.00	5.92	9.07	11.88	17.08	27.68	2873.42	5425.37	1481.55	0.00	0.00	0.00
1996	0.00	2.76	4.22	12.19	15.94	1110.59	2339.64	6207.69	2418.79	378.96	3.47	3.73
1997	2.38	0.00	5.00	9.97	10.24	459.47	2331.47	2895.62	345.54	378.96	111.23	0.00
1998	13.93	14.73	12.35	6.93	16.42	21.09	2841.68	11083.50	6009.16	342.91	122.82	2.41
1999	0.00	0.00	6.44	7.50	7.60	0.00	2770.97	7562.81	5364.65	2353.70	226.30	18.48
2000	0.00	0.00	5.11	17.69	85.11	0.00	2532.63	7055.57	2213.24	1038.73	144.69	0.00

Table (23) White Nile River Discharges- Malakal Station (1980- 2000)

year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	2667.23	2167.22	2038.85	1868.84	2092.99	2473.51	2905.20	3246.38	3336.72	3644.28	3595.42	3171.76
1981	2093.18	1631.12	1648.22	1514.68	1585.38	1796.23	2259.84	2646.58	2923.26	3198.73	3046.50	2813.82
1982	2126.25	1653.16	1664.42	1492.21	1598.04	1833.81	2345.79	2644.77	2637.44	2923.20	2841.02	2441.67
1983	2026.00	1580.72	1605.77	1480.12	1554.41	1818.52	2424.41	2871.38	3106.25	3446.74	3414.38	3551.02
1984	2737.32	1845.52	1678.61	1515.59	1595.31	1890.31	2338.34	2607.32	2668.42	2841.37	2545.11	2005.49
1985	1778.32	1451.52	1464.81	1461.75	1707.20	2133.02	2630.54	2903.95	2991.59	2841.37	3160.36	2850.37
1986	1955.52	1504.83	1573.62	1480.95	1518.60	1670.42	2356.81	2700.26	2805.20	3212.66	2747.83	2029.31
1987	1677.16	1388.17	1464.82	1378.58	1466.60	1930.11	2390.28	2718.15	2827.61	2990.34	2916.20	2638.42
1988	1893.58	1535.66	1582.37	1390.50	1525.26	2073.98	2675.01	3050.51	3300.95	3777.39	3668.07	3843.77
1989	3701.01	2220.27	1804.36	1650.46	1760.13	2086.11	2584.10	2989.61	3162.59	3408.49	3346.37	3140.73
1990	2484.32	1816.10	1841.75	1637.51	1755.43	2048.28	2654.32	2957.28	2982.13	3150.06	3094.75	2898.80
1991	1967.01	1489.52	1550.84	1538.44	1926.82	2358.65	2861.32	3225.59	3351.45	3613.66	3570.22	3608.77
1992	2930.26	2129.86	1903.46	1695.77	1948.63	2150.65	2656.75	2973.80	3117.59	3368.94	3350.79	3492.16
1993	3393.32	2520.37	2115.85	1867.31	2073.19	2308.26	2879.33	3149.79	3186.63	3391.34	3295.71	3184.79
1994	2236.22	1689.10	1697.05	1547.53	1795.18	2206.06	2724.41	3099.93	3187.05	3519.22	3402.12	3254.46
1995	2393.90	1630.65	1594.17	1535.72	1685.52	1912.73	2502.92	2863.23	3025.36	3284.67	3223.60	3061.74
1996	2367.43	1834.91	1736.01	1701.27	2029.81	2426.65	2866.59	3190.21	3412.77	3703.62	3580.96	3776.97
1997	3643.97	2500.35	1947.79	1756.13	2103.39	2409.74	2820.05	3074.02	3092.01	3703.62	3221.86	3274.07
1998	3060.20	2145.49	2167.78	1912.63	1989.41	2297.38	2940.43	3337.75	3512.32	3254.00	3769.23	3878.05
1999	3401.21	2246.17	1928.19	1686.45	2134.16	2607.15	3030.29	3273.04	3299.46	3596.53	3493.80	3576.84
2000	3353.20	2248.20	1899.49	1690.99	1989.20	2403.63	2857.78	3110.82	3160.63	3364.06	3257.92	3304.45

Table (24) White Nile River Discharges- Jebel Awlia Station (1980- 2000)

year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	2005.00	1720.00	2080.00	3000.00	3020.00	1915.00	1700.00	1820.00	1840.00	2800.00	2770.00	2455.00
1981	2345.00	1559.00	1985.00	2995.00	2027.00	1540.00	1303.00	1208.00	1876.00	3320.00	2521.00	2779.00
1982	2469.00	1818.00	2113.00	2769.00	1845.00	1901.00	1490.00	1136.00	1571.00	2565.00	1799.00	2689.00
1983	1753.00	1541.00	2338.00	2622.00	1934.00	1679.00	1588.00	1053.00	1559.00	2562.00	2904.00	2127.00
1984	2953.00	1954.00	2109.00	2978.00	2183.00	1663.00	1355.00	1459.00	1119.00	1784.00	2340.00	1874.00
1985	1910.00	1336.00	1948.00	2227.00	2187.00	1856.00	1525.00	1397.00	1487.00	1784.00	2435.00	2319.00
1986	1828.00	1445.00	1763.00	2562.00	2110.00	1476.00	1128.00	963.00	1612.00	2064.00	1833.00	1973.00
1987	1651.00	1256.00	1565.00	2321.00	1990.00	1690.00	1276.00	822.00	1480.00	2072.00	2170.00	2250.00
1988	2038.00	1521.00	2191.00	2433.00	1582.00	1706.00	1353.00	1175.00	2518.00	2397.00	2958.00	2568.00
1989	3099.00	2049.00	2241.00	2994.00	2348.00	1809.00	1642.00	1180.00	1518.00	2616.00	2264.00	2354.00
1990	2157.00	1572.00	1777.00	2992.00	2188.00	1676.00	1156.32	331.31	2344.00	2216.00	2133.00	2499.00
1991	1854.00	1499.46	2101.44	2601.78	2116.67	2023.73	909.29	1906.18	2583.98	2179.02	2584.38	3222.26
1992	2427.46	1893.64	2145.75	3164.19	2073.00	1875.00	1369.00	895.00	2044.91	2481.46	2489.94	2614.87
1993	2397.10	2189.84	2543.61	3215.27	2293.22	1782.57	1367.98	1718.07	2666.49	2240.32	2191.27	2748.15
1994	1994.49	1652.86	1689.87	2474.90	2097.09	1300.44	327.77	2161.80	2570.52	2556.02	2325.06	2508.95
1995	2380.41	1629.98	1843.81	2343.03	2462.32	1678.86	842.20	1654.22	2032.37	2155.35	2287.85	2261.78
1996	2389.69	1599.98	2095.31	2551.13	2614.23	2009.07	1381.42	1942.12	2631.01	2214.64	2674.82	2675.46
1997	2966.80	2064.95	2451.90	3021.51	2323.86	2151.57	1264.55	1965.66	1514.01	2214.64	2454.64	2525.69
1998	2433.02	1861.26	2080.57	2875.21	2529.26	1894.50	1399.37	1636.05	2746.35	2411.30	2876.28	2701.10
1999	2614.30	2280.59	2170.17	2986.75	2555.89	2280.55	1166.41	2289.20	2301.07	2390.74	2830.63	2621.96
2000	2586.40	2149.32	2586.96	2861.15	2014.96	1862.96	636.99	2018.15	2064.41	2229.48	2349.50	2386.68

Table (25) Upper Atbara River Discharges- Kubur Station (1980- 2000)

year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1981	10.77	5.12	0.78	0.00	0.00	122.11	1136.04	2071.30	1687.43	420.12	58.49	23.75
1982	11.89	6.66	0.00	0.00	0.00	52.24	351.78	1347.39	742.44	333.12	52.04	13.56
1983	5.63	0.92	0.00	0.00	0.00	33.32	291.55	1877.74	1350.68	183.93	35.54	12.27
1984	1.86	0.12	0.00	0.00	0.00	29.66	541.80	692.77	343.79	62.18	6.11	0.35
1985	0.00	0.00	0.00	0.00	0.00	207.94	1119.54	1609.31	2334.88	62.18	41.02	14.68
1986	4.07	0.62	0.00	0.00	0.00	46.46	923.88	1848.81	1983.16	325.51	43.44	14.15
1987	6.29	2.06	0.00	0.00	0.00	174.06	644.19	1748.81	580.04	249.71	35.14	9.19
1988	5.04	NA	0.00	0.00	0.00	NA	NA	NA	NA	NA	NA	NA
1989	11.94	6.66	4.30	0.39	3.20	102.38	771.43	2199.89	1203.38	292.81	39.37	13.64
1990	7.34	2.99	0.70	0.00	0.00	2.40	532.26	945.30	927.72	222.38	30.08	12.79
1991	0.00	0.00	0.00	0.00	0.00	78.85	763.82	2843.60	1211.78	195.86	64.76	36.58
1992	118.71	85.49	0.00	0.00	0.00	881.05	1933.65	5926.87	3432.14	1073.04	259.20	149.68
1993	0.00	0.00	0.00	0.00	45.19	637.69	1862.90	3908.87	1588.87	784.83	423.74	129.70
1994	88.97	0.00	0.00	0.00	0.00	266.52	1955.91	9592.45	6217.78	2117.08	547.36	310.52
1995	231.00	172.00	163.17	10.01	103.16	364.78	2052.03	6783.11	6379.00	4342.78	845.46	346.82
1996	375.07	26.58	0.00	23.13	127.91	288.00	2750.05	7279.26	3948.58	2283.84	697.64	398.10
1997	0.00	0.00	0.00	0.00	0.00	207.94	1119.54	1609.31	2334.88	2283.84	41.02	14.68
1998	4.07	0.62	0.00	0.00	0.00	46.46	923.88	1848.81	1983.16	325.51	43.44	14.15
1999	6.29	2.06	0.00	0.00	0.00	174.06	644.19	1748.81	580.04	249.71	35.14	9.19
2000	5.04	1.44	0.00	0.00	0.00	NA	NA	NA	NA	NA	NA	NA

Table (26) Main Nile River Average Gauge- Wadi Halfa Station (1980- 2000)

year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	61.17	60.85	60.24	59.58	59.14	58.56	57.40	58.18	61.18	62.09	62.20	61.94
1981	61.58	61.14	60.55	62.81	59.46	58.66	57.39	57.61	59.87	61.63	61.89	61.56
1982	61.11	60.75	60.12	59.46	58.97	58.12	56.66	56.33	57.70	58.20	58.45	58.03
1983	57.46	56.90	56.12	55.47	54.90	53.88	52.39	51.84	54.21	55.44	55.74	55.60
1984	55.12	54.66	54.01	53.19	52.63	51.76	49.90	49.72	50.36	50.32	49.90	49.15
1985	48.38	47.86	47.14	46.27	45.34	43.93	42.24	42.87	47.26	50.09	50.12	49.82
1986	49.47	48.95	48.06	47.26	46.59	45.35	43.23	43.55	46.78	48.29	48.45	47.95
1987	47.45	46.85	45.77	44.85	44.02	42.80	41.07	40.32	42.01	44.05	44.32	44.09
1988	43.66	43.18	42.38	42.49	41.04	38.89	38.59	41.17	48.36	52.50	54.28	54.75
1989	54.59	54.50	54.02	53.35	52.92	52.05	50.23	50.89	53.38	55.26	55.72	55.63
1990	55.42	55.08	54.50	53.67	53.10	52.03	50.34	50.04	52.13	53.90	54.32	53.12
1991	53.67	53.15	52.42	51.79	51.28	49.73	48.25	49.46	53.17	55.14	55.25	55.16
1992	55.01	54.71	54.00	53.31	52.83	51.91	50.25	50.25	53.52	55.43	56.41	56.60
1993	56.61	56.32	55.86	55.30	54.75	53.91	54.26	54.41	57.59	59.62	60.22	60.34
1994	60.30	59.92	59.18	58.49	58.02	57.05	55.77	56.98	60.85	63.02	63.14	62.98
1995	62.88	62.54	62.00	61.31	60.80	59.89	58.69	59.01	61.30	62.21	62.12	61.91
1996	61.77	61.52	60.98	60.29	59.70	58.83	58.38	59.80	62.67	64.25	64.49	64.45
1997	64.37	64.71	63.62	63.22	62.89	62.04	61.41	62.01	63.48	63.80	64.11	64.39
1998	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1999	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table (27) Blue Nile River Average Gauge- Wad Madani Station (1980- 2000)

year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	10.40	10.31	10.24	10.52	11.08	11.22	14.46	18.06	15.83	13.24	10.92	10.11
1981	9.98	10.07	10.10	10.45	10.57	11.18	13.34	17.46	15.39	13.42	11.20	10.18
1982	10.15	9.97	9.93	10.67	10.28	10.57	13.19	16.40	14.48	13.94	10.82	10.15
1983	9.93	9.95	9.84	9.96	10.38	10.55	12.18	16.98	16.39	14.56	11.14	9.83
1984	9.36	9.65	9.99	10.09	10.18	10.82	14.02	15.81	13.81	11.95	9.48	9.79
1985	9.81	9.92	9.97	9.85	10.82	11.35	13.95	17.92	17.38	11.95	11.28	10.49
1986	10.23	10.15	10.10	10.40	10.44	10.55	14.50	16.71	15.28	13.15	10.91	9.89
1987	9.88	10.14	9.87	10.14	10.46	12.65	13.43	16.04	14.06	13.55	11.32	9.81
1988	9.94	9.62	9.93	10.10	10.10	11.55	15.25	19.71	19.12	16.01	12.91	10.97
1989	10.48	10.18	10.20	10.54	10.86	11.39	13.51	16.52	17.05	14.48	11.88	10.31
1990	9.78	9.83	9.96	10.30	10.49	10.73	12.67	17.38	17.20	14.19	11.34	9.94
1991	9.75	9.04	9.81	10.35	10.50	11.34	15.19	18.37	NA	NA	NA	NA
1992	NA	NA	NA	NA	NA	11.80	13.10	17.53	17.10	15.62	NA	NA
1993	NA	NA	NA	NA	NA	13.47	15.31	18.78	18.15	15.14	13.36	11.13
1994	10.81	10.78	NA	NA	NA	NA	NA	19.07	18.65	14.01	12.16	11.16
1995	10.21	10.31	NA	NA	NA	11.33	14.14	17.87	16.18	14.70	12.78	11.38
1996	11.14	10.88	10.96	11.28	11.85	NA	16.25	18.91	17.34	15.25	12.86	11.19
1997	10.71	10.56	10.89	11.64	12.16	13.13	15.21	17.25	14.26	15.25	14.10	11.52
1998	9.94	9.77	10.36	11.14	11.23	11.76	15.14	19.24	19.02	13.88	14.25	11.93
1999	10.68	10.43	10.68	10.81	11.77	12.71	15.50	18.48	17.31	17.23	13.98	12.24
2000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Appendix 4
Sediment Data

Table(29) Sediment Data for Blue Nile D/S Sennar 2002

Month	S.S. Conc. (ppm)	QQ Mm3/month
July	217737.47	5643.13
August	153549.2	12398.28
September	9739.2	5230.33
October	2291.42	160.76

S.S. Conc. = Sediment Concentration in ppm, QQ= Water Discharge in Million M^3 Cubic metre per Month

Table(30) Sediment Data for the Blue Nile D/S Sennar 2001

Month	Qw Mm^3/month	Qs 10^3 Tons/month
June	4194.39	4848.6
July	8193.87	53091.20
August	19119.55	81350.27
September	10905.36	20958.27
October	2587.69	935.93

Qw= Water Discharge in Million M^3 per month, Qs= Sediment Load in Tons per Month

Table(31) The Blue Nile Sediment Data @ Senner 1996

Month	SEDIMENT CONC. (PPM)	SEDIMENT DISCHARGE (m3/month)
July	109027	22295541
August	65276.24	16515919.1
September	43065	8544405

Table(32) The Blue Nile Sediment Data @ Sennar 95

Month	SEDIMENT CON. (PPM)	SEDIMENT DISCHARGE (m3/month)
July	73346	14913759
August	80321	2869050
September	24210	3314250
October	15830.67	129166.67

Table(33) The Blue Nile Sediment Data @ Sennar 93

Month	SEDIMENT CON. (PPM)	SEDIMENT DISCHARGE (m3/day)
July	121261.67	7726595
August	61369.67	13314861.67
September	49950	8365701.43
October	26877	279753

Table(34) SENNAR-BLUE NILE-SEDEMENT-Jul. 1992

Month	Washed Load(ppm)	Susp. Sand (ppm)
July	31017.22	3401.39

Table(35) SENNAR-BLUE NILE-SEDEMENT-Aug-Sep. 1988

Month	Washed Load(ppm)	Susp. Sand (ppm)
July	114904.08	8884.08
August	98217.67	6312.58