THE DEMOCRATIC REPUBLIC OF THE SUDAN

THE WATER RESOURCES OF THE SUDAN

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GENERAL

The Sudan is the largest country in Africa covering A total area of 2,5 million square Kilometres. It is situated between latitudes 3° and 23°N and longitudes 21° 45" and 38° 30" E.

Th physiography of the country displays an extensive plain traversed throughout its length of 2000 kilometres from north to south by the River Nile and its tributaries. On the eastern side it is bounded by the Red Seahills rising up to altitude 2100 metres. On the western side lies the Jebel Marra massif with its peak altitude reaching.3089 metres.

The River Nile and its tributaries display the most prominent physical feature of the country. The origin of the White Nile is from the Equatorial lakes on the lake Plateau. On entering the Sudan it flows through rocky rapids extending for a length of 170 Kilometers and thereafter flowing through the swampy sudd region where huge losses are experienced. After it emerges from the swamps, it is Joined by Baher El-Ghazal on the west and by the Sobat on the east. At Khartoum the White Nile Joins the Blue Nile Which originates from the Ethiopian plateau. The Main Nile which Flows from Khartoum down to the high Aswan Dam Reservoir is joined on its way by River Atbara.

The fertile Central clay plains of the Sudan are enclosed by the Main Nile, the White Nile, River Atbara and the Blue Nile.

In the Jebel Marra area, and in the central plains of the Sudan there is a number of seasonal flashy streams. Originating from the Ethiopian Plateau there are the Gash and Baraka rivers. In the central region plains considerable runoff in the form of sheet flow and steamflow finds its way to the main courses of Bahr El Jebel, Bahr El Ghazal, the Sobat and the Mashar marches.

With regard to the climatic zones, the Sudan has predominantly a tropical continental climate with a maritime climate along the Red Sea coast.

The south westerly monsoons flowing from the Atlantic Ocean laden with moisture, are the source of rainfall in the Sudan. The extent of their inland penetration determines the annual volume and distribution of rainfall in the country.

The north third of the Sudan is almost a desert with an annual average rainfall of about 20 millimters. The rainfall increases steadily from north to south until it reaches isohytes 400mm. to 800mm. In the fertile central clay plains of the Sudan, and in the extreme south of the country the rainfall varies from 1200 to 1500 mm.

The number of population is approximately 15.7 million increasing at an annual rate of 2.8%. The annual per capita is of the order of 120 U.S. dollars. The country depends on agricultural and livestock production as the back-bone of its economy. More than 90% of the population are engaged in the agricultural sector which forms almost all the Sudan's exports. The main cash crop is cotton (about 60% of the country's exports) followed by Gum Arabic (about 10% of the exports) followed by Sesame 8% of the exports), and then comes the livestock products (7% of the exports), and finally groundnuts (6% of the exports).

Dura or sorghum, being the staple food in the Sudan, is cultivated in more than one third of the cropped area in the whole country. The productive

forests cover an area about 7 million feddans producing mainly Gum Arabic.

During the previous national development plan 1970/1977 a total sum of 280 million U.S. Dollars was earmarked for agricultural development in the Public sector. Investment in the irrigation development has been given top priority followed by mechanized rain-fed agriculture, livestock development and agricultural services. The considerable investment in irrigation development helps to utilize the Sudan's share of the Nile Waters, the available manpower, the available machinrey and the existing water resources in the already built reservoirs.

Pastures cover 34 million hectares, and the available livestock comprises 12 million cattle, 10 million sheep, 8 million goats and 2.5 million camels.

The cultivated land ranges from 6.7 to 7.1 million hectares of which about 1.72 million hectares are irrigated and the remainder are rainfed.

1. Water Resources and Needs

Assessment of the National Water Situation.

1. Adequacy of the Existing Systems for Collection of Data on the Quantity and Quality of Water Resources

1.1. The existing water resources network systems in the Sudan comprise the following :—

(a) The hydrological network of the River Nile and its tributaries.

(b) The hydrological network of the non-nilotic major rivers in the Country, namely Gash, Baraka and Jebel Marra seasonal streams.

(c) The hydrological network of the small rural streams scattered throughout the clay plains of the Sudan.

(d) The network of rain gauges.

(e) The meteorological and hydrometeorological network.

(f) The Agrometeorological stations.

(g) Water quality observations.

(h) Groundwater observations.

Following is an appraisal of the extent of adequacy of each of the above mentioned network systems :—

1.2. The Hydrological Network of the River Nile and its tributaries

1.2.1. The gauging of the River Nile in the Sudan started in 1869 after which the network of hydrological stations developed gradually at the rate indicated hereunder :—

Year	Number of stage observation Stations	Number of stage discharge Measuring Stations
1869	1	—
1900	5	3
1950	99	120
1975	130	145

1.2.2. The density of the network of the hydrological stations on the Nile and its major tributaries within the territorial boundaries of the Sudan is considered as adequate for the purpose of assessing the flow at the key points viz : near the frontiers, above and below the confluence of joining tributaries, above and below the storage reservoirs, at principal points of water abstractions and at sites of potential water resources development. As such, the density is not associated with the adopted standard minimum acceptable density of one station per 1000 — 2500 square Kilo-metres of catchment area, because most of the catchment areas of the Nile tributaries lie outside the Sudan borders. The principal tributaries of the Blue Nile, River Atbara, the Sobat and the White Nile have their headwaters and effective catchment areas in the Ethiopian and in the Equatorial Lakes Plateau. It is known that measures have been taken in recent years to establish and operate hydrological and hydrometeorological networks encompassing the drainage basins of the major tributaries of the Nile in Ethiopia and in the Equatorial Lakes Plateau.

However, the following table indicates the density of the network of the hydrological stations on the Nile and its major tributaries :—

River	No. of Stations	Catchment Area Mostly Lying Outside Sudan
Blue Nile	21	85,520 Km^2
White Nile and tributaries	203	1,538,000 Km^2
River Atbara and tributaries	10	123,000 Km^2
River Rahad ...	2	32,000 Km^2
River Dinder ...	2	18,160 Km^2
Main Nile	16	—

1.2.3. As for the density of suspended sediment sampling stations, it is considered fairly adequate in the Blue Nile, the Main Nile and River Atbara ; as it is in close conformity to the recommended criteria that 15% of the stream gauging stations should be equipped for sediment load measurements. There are three laboratories for the concentration and grain size analysis of the collected samples, one is located in Sennar on the Blue Nile, the other in Dongola on the Main Nile and the third at Showak on River Atbara.

1.3. The Hydrological Network of Non-Nilotic Major Rivers

1.3.1. In the Gash River, having its main drainage basin in Ethiopia, there are five gauging stations which are considered adequate.

1.3.2. In the Baraka river, it was not possible to find a suitable gauging site in Sudan. Ethiopia was approached to conduct joint hydrological studies of the Upper reaches of the Baraka basin.

1.3.3. In Jebel Marra region, where numerous seasonal Wadis flow, there are 32 stream gauging stations in a catchment area totalling 32,000 square kilometres and hence an average density of one station per 1000 square kilometres which tallies with the adopted standards.

1.4. The Hydrological Network of the Small Rural Water Streams

The existing hydrological network comprises only 44 stream gauging stations established on the 44 streams having a total annual flow of 756 mm3. They are scattered in the region bounded by latitudes 10° to 16° and includes the streams of the Red Sea region, the Savana Project, Darfur, Kordofan, Blue Nile and Kassala Provinces, the total area of which is of the order of 1.25 million square kilometres.

The existing network is being expanded continuously to attain 300 stations in the rural streams ultimately, noting that the rural water streams are scattered, accessible with difficulty during the rainy season and many of them lie in remote areas inhabited by wild animals.

There should be established also 10 index catchments for the rural streams each covering an area in the range of 1500 to 2000 square kilomerets.

1.5. The Network of Rain Gauges

The existing network comprises 1200 ordinary rain gauges and about 27 autographic rainfall recorders. The rainfall stations are concentrated in the agricultural schemes and in towns lying near the railway lines whereas the density is very low in many other regions. The density of the network in the Gezira scheme and in Jebel Marra area is of the order of one station per 20 to 30 square kilometres and in other areas the density is as low as one station per 25,000 square kilometres. Steps are underway to intensify the network in accordance with the universally adopted standards so that there should ultimately be 3200 stations of which 2600 should have ordinary rain gauges and 600 recording gauges.

1.6. The Meteorological and Hydrometeorological Network

The existing network comprises 48 first order stations and 41 part time second order stations installed mainly in big towns. The spatial distribution of the observing stations is fairly adequate compared to 44 proposed by W.M.O. as minimum. In accordance with the general standards there should be as average a meteorological network having 120 hydrometeorological stations, 120 first order and 120 second order meteorological stations.

1.7. The Agrometeorological Stations

The Agro-Climatological section of the Sudan meteorological service was established in 1957 to measure the parameters needed to determine the consumptive use by the crop factors and Penman's method. Observations are now undertaken systematically in two principal agro-met stations and 12 ordinary agro-met stations representing different agricultural and climatological zones in the Country.

Some soil moisture measurements on a limited scale have been incorporated in the agricultural research stations on a limited scale using neutron probes and gamma probes.

1.8. Water Quality Observations :-

Comprehensive surveys of rivers and storage reservoirs for the determination of the chemical and hydrobiological characteristics undertaken by the hydrobiological research unit, the fisheries department and the Ministry of Health are not performed on systematic routine schedules with the exception of the samples collected and analysed monthly from the Blue Nile and the White Nile near their confluence.

Samples from boreholes in the various parts of the Country are analysed whenever a borehole is drilled. Surveys are conducted from time to time to study the environmental effects of the Roseires, Sennar, Khashm El Girba, Jebel Aulia and El Sad El Ali reservoirs and the invasion of water hyacinth on the environmental factors.

1.9. Groundwater Observations :-

These observations are conducted in regions in which groundwater development is being initiated such as Jebel Marra, Sag El Naam, Tokar and also for water supply in the various Provinces. The density of network is being built up gradually. The number of boreholes and wells existing up to 1976 is 3,916.

2. Assessment of Water Supplies and Demands :-

The water resources in the Sudan comprise the rainfall, Nile Waters, rural waters from seasonal small streams, and groundwater reserves.

2.1. Rainfall :-

The rainfall zones in the Sudan are as follows :—

(a) The desert zone north of latitude 17° covering an area of 73 million hectares and having annual rainfall of less than 75 mm.

(b) The semi desert zone north of latitude 15° covering an area of 50 million hectares and having annual rainfall of 75 to 300 mm.

(c) The Savanna zone lying between latitudes 9° and 15° covering an area of 69 million hectares and having annual rainfall of 300 to 800 mm.

(d) The zone comprising the Savanna, the flood plains the Equatorial forests south of latitude 9° covering an area of 60 million hectares, of which 35 million hectares are forest and savanna and the other 25 million hectares are flood plains.

2.1.1. Evapotranspiration :-

As for the potential evapotranspiration in the Sudan the annual P.E. varies from 828mm in Nagishot to 1907mm in Kassala — In most regions the value exceeds 1450mm which corresponds to about 4mm per day.

The areas where P.E. is less than 1450 mm. are confined to high elevation regions.

Considering the year as a whole the annual water deficit is above 600mm over the major part of the Country and in the northern part it exceeds 1600mm. Accordingly the water surplus is practically nill for the country except at the extreme south, and as such, the moistrue index according to Thornwaite is negative for all the country, with its magnitude increasing from south to north. In the extreme northern parts the index is near to — 60 ; in the central parts varies from — 40 to — 50 ; below latitude 12° N varies from — 20 to — 40 ; and in the extreme south having a positive value of around + 20.

2.2. The Supply from the River Nile and its Tributaries

The major hydrological characteristics can be summarised as follows :—

2.2.1. The total annual average supply of the Blue Nile is 50.7 milliards and the daily discharge fluctuates between 11mm^3/day in April to 535 mm^3/day in August.

2.2.2. The total annual average supply of the Rahad tributary is 1.09 milliards flowing from July to November.

2.2.3. The total annual average supply of Dinder tributary is 3 milliards flowing from June to December.

2.2.4. The total annual average supply of River Atbara is 12 milliards of which 7 milliards come from Setit tributary and 5 from Atbara branch. The flow is between June to February.

2.2.5. The total annual average supply of the White Nile system as at Jebel Aulia Dam is 30.9 milliards, with the daily flows fluctuating from 54 mm3/day in April to 114 mm3/day in November.

2.2.6. The total annual average supply of Bahr El Ghazal basin system is 14 milliards, but this supply is substantially lost in Swamps, save for 0.5 of a millird only which reaches the White Nile. These swamps cover an area 40,000 Square kilometres and are subjected to a rainfall of 900 mm. and evaporation rate of 1200 mm. annually.

2.2.7. The total annual average supply of Bahr El Jebel Basin is 29 milliards at Mongalla, but due to huge losses in the Bahr El Jebel Swamps, the volume reaching Malakal is only 14.7 millirds. The Bahr El Jebel swamps cover an area of 7,000 Square kilometres.

2.2.8. The total annual average supply of the Sobat Basin at Malakal is 13.7 millirds with the daily discharge fluctuating between 8 mm3/day in April to 66 mm3/day in November. The total water losss deue to spillage into swamps in this bain amount to 4 milliards annually in the Baro tributary and another 4 milliards in the Machar marshes which cover an area of 20,000 Square Kilometres and having annual rainfall of 800 mm.

2.2.9. The Main Nile receives its supplies from the Blue Nile, The White Nile and River Atbara, the details of which have been indicated above.

2.2.10. From the aforementioned review, it can be concluded that there is remarkable fluctuation between the flood and low season discharges in the Blue Nile, the Atbara and consequently the Main Nile, whereas the corresponding fluctuation in the White Nile is much less.

Henceforth storage reservoirs in the River Atbara and Blue Nile were inevitable.

It can also be seen that there are huge losses in the swampy regions of the Upper Nile system in the Sudan amounting to 42 milliards annually, and there is need to minimize these losses and utilize the water yields derived from these swamps for agricultural development in the downstream reaches.

2.3. The Water Consumption and Demand from the Nile System

The Sudan's share of the Nile Waters, according to the 1959 Nile Water Agreement between Egypt and Sudan is 18.5 milliards at Aswan (20.35 milliards at Sennar), and the corresponding share for Egypt is 55.5 milliards. The present consumption in the Sudan from the Nile waters including consumption by projects under construction is as follows :—

The River System	The annual consumption in milliards	The irrigated Area in hectares
1. The Blue Nile System ...	11.977	1,246,535
2. The White Nile System ...	2.840	260,395
3. The Atbara System ...	1.839	156,237
4. The Main Nile System ...	1.603	176,396
TOTAL ...	18.259	1,839,563

From the above table, the remaining share of the Sudan is about 2.091 milliards, this amount is not adequate to meet the water demand of irrigation development stipulated in the prospective short and medium term plans for the country, which comprises the following areas :—

River System	Required annual consumption in milliards	Proposed irrigated areas in hectares
1. Atbara (Upper Atbara & Setit)	2.190	260,815
2. Blue Nile (Kenana South of Khartoum Rahad II ...	4.800	596,388
3. White Nile ...	2.300	117,597
TOTAL ...	9.290	974,800

In addition there are 630,000 hectares of irrigable areas which can be irrigated from the Blue Nile in the long term plans, and which require about another 5 milliards.

Thus it is evident from the prospective plans that the extra Nile water needed for the short and medium term plan is of the order of 9.29 — 2.091 = 7.199 milliards.

2.4. Projects of the Control and Increase of the Nile Yield to Meet the Envisaged Demand

These proejcts comprise the reclamation of the Upper Nile swamps and the provision of storage works to make available adequate water supplies during the dry season for further development. A brief account is given hereunder :—

2.4.1. As for the Behr El Jebel and Behr El Zarfe Basin

Steps are in hand to commence the implementation of the first phase of Jonglei diversion canal to provide an extra annual yield of 4.7 milliards. The future second phase of this Project which will provide another 4.3 milliards of extra water is tied with the storage in the Equatorial Lakes where extensive hydrological studies are currently in progress to formulate the optimum conservation and storage works. The plans also include the control of the torrents and other tributaries of Behr El Jebel as well as the run of of the eastern plains such as the Pengko plain which is estimated as 1.5 milliards covering 2.94 million hectares.

2.4.2. Over-year storage or annual storage on *River Baro* together with the training and banking of 23 kilometres of this river to equalize its flows and to provide an extra annual yields of 4 milliards presently lost by spillage in swamps.

2.4.3. The diversion of the 4 milliards now lost in *the Machar Marshes* through a canal from Machar, Adar to Melut on the White Nile.

2.4.4. The construction of storage reservoirs and diversion canal to conserve about 7 milliards out of the 14 milliards currently lost in the swamps of *Behr El Ghazal* basin which encompasses about 14 major streams beside other minor tributaries.

2.4.5. On the Blue Nile, due to the shortage of dry season flows to meet irrigation and power demands despite the existing storage of 0.932 milliards in Sennar Dam reservoir and 3.024 milliards in Roseiris Dam reservoir, it is deemed necessary to provide an extra storage by heightening the Roseiris Dam to its ultimate capacity of 7 milliards.

Long term plans take into account the feasibility of storage in Lake Tana to augment the summer flows.

2.4.6. With respect to River Atbara, studies are nearing completion to construct two dams on Upper Atbara and Setit to store 1.6 milliards for the irrigation of 260,000 hectares and generation of 20 MW of hydropower.

2.4.7. Along the Main Nile there are five natural cataracts suitable for the generation of hydropower amounting to about 700 *MW*.

2.5. Water Demand and Supply in Non-Nilotic Rivers

2.5.1. *The River Gash*

The Gash orginating from Ethiopia has an annual flow varying from 200 to 800 MM3 in the Sudan and irrigates an annual average area of about 26,000 hectares out of the total delta area of 295,000 hectares. Studies are in hand to formulate training conservation and control projects for the increase of the irrigated area.

2.5.2. The River Baraka

It originates in Ethiopia and its flow reaches the Sudan in spates. Embankments have been constructed to direct its flows which irrigate an average annual area of 30,000 hectares out of the total delta area of 255,000 hectares.

2.5.3. Jebel Marra Water Resources

The annual rainfall in this region lying in the Western Sudan varies from 600 mm. to 1,000m. The annual discharge of the streams is 75 mm 3 in the Piedmont zone and 255 mm3 in the lower valleys.

The groundwater resources amount to 250 mm3 annually. The total arable area is 270,000 hectares, which can be rainfed. The area irrigable from streams is of the order of 5,000 hectares in the piedmont zone. The groundwater reserve suffices for the irrigation of 34,000 hectares. The irrigation of more areas necessitates the construction of dams which incur high capital cost.

2.6. Rural Surface Water Resources

2.6.1. During the last three decades measures have been taken to harness many of the seasonal rural streams by the construction of small dams, hafirs (ponds) for drinking purposes by people and animals and for small scale agricultural development (crops and livestock) as well as for the replenishment of groundwater aquifers. During the period 1947 to 1975 about 800 hafirs have been constructed having a total storage capacity of 19 million cubic metres. In addition about 30 small embankment dams have been constructed having a total storage capacity of 23.3 Million cubic metres. Allowing 40% for evaporation and 10% for seepage the net utilized water from hafirs and small dams can be estimated as 20 million cubic metres which conserve a rural land area of about 8.4 million hectares and serve about 3 million people assuming that one water point is surrounded by an area of 100 Square Kilometres without exhausting the pasture lands and that the rate of domestic consumption per capita is about 4 gallons per day. There are also 900 superficial wells giving a net annual yields of 1.2 mm3.

2.6.2. As for the future rural surface water supply and demand in the semi desert and the Savannah zones in the Sudan, the extra required number of water points is estimated as 126 mm3 which have to be attained by the provision of 7200 water points, each producing 35,000 m3 gross capacity in addition to 974 hand dug wells yielding 11mm3 annually.

2.6.3. The major rural surface water projects currently under study comprise the first and second phase of the Savannah project the Southern Darfur development project, and the Red Sea region development project.

2.6.4. Steps are being taken to minimize the water losses in hafirs and small dam reservoirs using plastic membrane asphalt, butyle rubber and earth compaction.

2.7. Rural Groundwater Resources

2.7.1. The groundwater investigations and development are still in the early stages. The water bearing geological formations in the Sudan comprise the following :—

(a) The Nubian series mainly north of latitude 10° covering an area of 704,000 square kilometres (28.1% of country). The water in this series is suitable for man, animals, agricultural and industrial purposes. The soluble salts vary from 200 to 500 p.p.m. on the average.

(b) The Um Ruba series south of latitude 14° covering an area of 515,000 square kilometres (20.5% of country area). The soluble salts range from 400 to 650 p.p.m.

(c) The Basement complex comprising mainly the Nuba and Red Sea hills is generally non-water bearing except where there are faults covers 1,077,000 square kilometres (42.3% of Sudan).

(d) The rocks cover 228,000 square kilometres (9.1% of country). The soluble salts vary from 1500 to 3,000 p.p.m.

2.7.2. Ground Water Basins in Sudan Nubian Basins

	Under flow Recharge		Storage Capacity	Abstraction action M M³ per year	% age of Abstraction to recharge	Percentage of total country area
	M M³ per year					
1. Sahara Nile Basin ...	3.65	136.0	5500	7.4	5.44	—
2. Sahara Nubian Basin	20.6	20.6	9740	1.2	5.82	—
3. Central Darfur Basin ...	12.8	47.6	794	8.6	11.82	—
4. Nahud Basin	1.5	15.4	136	2.5	16.50	26.4
5. Sag El Naam Basin ...	1.3	14.8	134	1.5	9.9	—
6. Lower River Atbara Basin	3.65	23.0	240	0.5	1.9	—
UMM RAWABA BASINS						
1. Sudd Basin	50.8	341.0	11000	1.9	0.54	16.8
2. Eastern Kordofan ...	2.3	15.8	1710	4.5	28.3	—
NUBIAN UMM RAWABA						
1. Baggara Basin	22.7	154.6	7110	12.0	7.7	8.4
2. Blue Nile Basin ...	10.4	71.0	2270	21.5	30.	—
NUBIAN/BASALT						
1. Gedaref Basin	6.1	41.7	700	4.2	10.14	1.1
2. Shagara Basin	1.0	1.09	4.54	0.7	64.72	—
ALLUVIAL BASINS Darfur :- Nyala - Azum Kutum — IBRA ...	45.0	500.0	—	80	—	—
Kordofan :- Abu Gibaiha Kassala :- Gash Red Sea :- Arbaat Khor Baraka		Irrigation				

2.7.3. The Utilization of Groundwater for Agricultural Development :-

The potential irrigable areas in the Sudan are :—

(a) Increasing the existing irrigated area in Kassala, Bara, El Ban Gadeed, Dar Hamid.
(b) In Jebel Marra 250 M M3 available for irrigating 34,000 hectares.
(c) Wadi El Khiway and Wadi El Kaab in the northern Province covering 84,000 hectares.
(d) Sag El Naam scheme of 63,000 hectares.
(e) Lower Atbara Karwat scheme of 42,000 hectares.
(f) Other areas not yet defined in northern Darfur, Wadi Hour, east of the Blue Nile, and Wadi El Mugaddam.

2.7.4. Utilization of Groundwater for Rural Water Supplies

The existing wells in the Sudan for water supplies are 3961 wells giving a net yield of 62.64 mm3 per year. The extra required number of groundwater wells is estimated as 4704 wells to provide an annual supply of 74.63 mm3 at the rate of 16,000 M3 per well annually.

2.8. Domestic Water Supplies

2.8.1. Rural Surface and Groundwater Supplies and Demands :-

The total demand is estimated as 275 mm3 per year of which 100 mm3 are intended for human use and 175 mm3 for animal consumption. The avilable supply as indicated above amounts to about 83.84 mm3 composed of 20 mm3 from hafirs and small embankments, 1.2 mm3 from hand dug wells and 62.64 mm3 from deep wells. The available supply constitutes about 30% of the total annual rural water requirements. There is need for extra 6360 surface water points, 6240 hand dug wells and 4706

deep wells which necessitates the provision of the required equipment and funds to the rural water corporation, the responsible institution entrusted to provide the rural water supply all over the country.

2.8.2. Urban Water Supplies and Demands

The Public Electricity and Water Corporation is responsible for the Urban water supplies to all the Provinces both from groundwater and surface water sources. It is presently serving about 2 million people (176,000 subscribers). consuming about 76.801 MM3 of water per year.

Most of the remaining population live in rural or semi urban regions and their water demand and supply situation has been reviewed above.

2.9. Agricultural Development from Rainfall

By 1970 the gross rainfed agricultural area totalled about 9.24 million hectares which constituted 3.66% of the total area of the Sudan, of which 4.8 million hectares was net cropped area.

It is envisaged that by 1985 the gross area shall amount to 14.8 million hectares with a cropped area of 6.66 million hectares. The mechanized area at present is about 1.35 million hectares.

3. Hydroelectric Power Development

The following table shows the actually installed capacity and the short and long term planned capacity from the River Nile and its main tributaries in the Sudan (In MW) :

SITE	Planned Capacity MW		Actually installed Capacity MW
	Short term	Long Term	
1. BLUE NILE			
(a) Roseiris Dam	120	—	90
(b) Sennar Dam	15	—	15
2. WHITE NILE			
(a) Jebel Aulia Dam	25	—	--
3. BEHR EL JEBEL			
The Rapids in the Nimuli — Juba reach, a drop of 162 m in 168 Km. length	100	400	—
4. THE MAIN NILE			
(a) Sabaloka gorge, 90 Km. from Khartoum ...	107	—	—
(b) The fifth Cataract at 435 Km. north of Khartoum	—	250	—
(c) The fourth catract, 750 Km. north of Khartoum	—	250	—
(d) The Dal and third cataracts, 1170 Km. north of Khartoum	—	200	—
e) RIVER ATBARA			
(a) K. El Girba Dam	—	—	13
(b) Upper Atbara Dam	20	- -	—
TOTAL	387	1100	118

Thus the total installed capacity from the above listed sites is 1605 MW and the anticipated total energy production when fully developed would be about 8,000 G.W.H., as compared to 400 G.W.H. from the existing 118 MW. The heads along the Nile vary from 6 m. to 36m depending on the seasonal flows and the reservoir operation cycles. During the low season when the discharges and heads drop, thermal back up is required for the optimum utilization of hydroelectric power potential.

4. Navigation

The regular navigational services at present comprise the following :—

(a) Along the Main Nile the reach from Kerima to Kerma, 280 kilometres long.

(b) Along the White Nile from Khartoum to Lake No., 860 kilometres long.

(c) Along Behr El Jebel from Lake No to Juba, 905 kilometres long.

(d) There are irregular seasonal services along the river Sobat from Mouth to Baro, 550 kilometres long and along Behr El Ghazal from Lake No to Wau, 600 kilometres long and from Suki to Roseiris, 200 kilometres long.

(e) The irrigation canalization network are not designed for navigation.

On the average a navigable network of 3,000 kilometres is considered workable. The annual capacity at present is 200,000 tons handled by 50 steamers and 200 barges whereas the required capacity is estimated as 400,000 tons.

The main hydrological difficulties encountering navigation are :—

(a) The existence of gorges, rapids and cataracts along the Main Nile and along Behr El Jebel South of Juba, a problem which can be solved in the long term by incorporating navigation locks with the proposed hydropower dams.

(b) The low flow (about 90 mm 3/day) during the dry season on the Main Nile.

(c) On Behr El Jebel south of Shambe navigation difficulties in the low season are due to insufficient depth, and sand banks.

(d) On the White Nile north of Malakal navigation difficulties are encountered as a result of fords, rocks, and shallows during the low season discharges.

(e) The water hyacinth is creating navigational difficulties along Behr El Jebel and the White Nile. River training works in the above critical reaches are under study.

Outlines of a Tentative Water Resources Master Plan for the next Decade

Based on the above, a tentative national Master Plan may be outlined as follows :—

1. Kenana Sugar scheme 35,000 hectares consuming 0.8 milliard M3 of water — execution period from 1976 to 1979 ; Financement secured.

2. Blue Nile Area Rahad 2 or Kenana, 170,000 hectares, consuming 1.3 milliard M3 — Execution period from 1977 to 1982 — Estimated cost 500,000,000 U.S. Dollars.

3. Roseiris Dam heightening for irrigation and power, execution period 1977 to 1982 — estimated cost is about 100,000,000 U.S. Dollars.

4. Jonglei Project for the increase of the Nile yield to provide an extra 2.4 milliards M3 — execution period from 1977 to 1982 — Jonglei Irrigation Scheme, 80,000 hectares, execution period from 1979 to 1985 — estimated cost 195,000,000 U.S. Dollars.

5. Construction of Upper Atbara and Setit Dam to store 1.6 milliard M3 of water, execution period 1977 to 1986 estimated cost is700,000,000 U.S. Dollars.

6. The first Phase of Machar Project for the increase of the Nile yield to provide 4 milliards M3 execution period from 1982 to 1988 estimated cost 300,000,000 U.S. Dollars.

7. With respect to irrigation from groundwater, the realistic prospective plan shall be laid down subsequent to the investigations currently underway.

8. With respect to rainfed agriculture, the plan is to undergo the development at an average rates of 160,000 hectares annually.

9. With respect to water supply in urban and rural areas, the plan aims at developing the total annual requirement of 274 MM3 of water for human and animal use by constructing hafirs and wells, noting that the present available supply is about 77 MM3 per year.

The estimated expenditure for the rural water development per year is 10 Million Dollars.

10. With respect to hydroclectric Power, the installed power in Roseiris Dam is to be increased from 90 MW to 250 MW and the construction of Sabaloka power project on the Main Nile, due before 1985 to provide an installed capacity of 100 MW as well as Bedden Rapids Dam in Behr El Jebel of a possible capacity of 75 MW. The estimated cost of the three projects is 50,100, and 100, million Dollars respectively.

5. Technology Potential and Limitations :-

5.1. Labour Intensive Methods

The general practice in the Sudan has been the application of labour intensive methods in securing water supplies for irrigation, water supply and other water resources aspects such as flood, control hydropower and river training.

(i) The system of data collection and surveys are mainly manual. There is no application of capital intensive technological systems in the fields of hydrology, hydrometeorology and meteorology such as automatic remote control equipment and transmission systems. The observations rely on the diligence of the human observers and transmission of data between the stations and the central control panels through the traditional telegraph and radio telephone devices. However, the use of a radar network in five regional stations in the country for rainfall measurements, the establishment by the Met. Dept., of APT ground station, RTT link with Cairo, SSB national network, and the steps taken recently to initiate the use of sattelite technology for the survey of water and other natural resources in the country through limited technical asisstance are the only domains where the technological conception started to activate.

(ii) With respect to irirgation, the distribution network is composed primarily of open canals fed via head regulators incorporated with the dam structures under free flow or by pumps directly from rivers. The operation of the canalization systems, caliberated sluices, regulators, weirs, pumping stations are controlled manually, mechanically or electrically).

In many places in the World today advanced technology is applied in the field of water resources such as the use of sprinkler irrigation and automated irrigation systems which are accounted for by the shortage of labour, rise in labour costs and the need to save water while maintaining efficiency. The use of electronic computers or the automatic remote control and transmission systems have not been attempted for the management of irrigation systems in the Sudan. Considerable labour is employed on permanent and temporary terms for the maintenance, silt clearance and weed clearance of canals which constitute one of the labour intensive aspects.

The rainfed agricultural schemes whether developed by the traditional or mechanized means are labour intensive.

(iii) With respect to water supply systems for domestic, and industrial uses in urban and rural areas, the operation and control of the water works, pipe networks and pumping equipment is undertaken manually through mechanical and electrical systems therby involving employment of considerable labour force.

(iv) Flood control depends mainly on manual and mechanical methods. Flood warning is achieved through the traditional manual observations relayed by the convential radio telephone transmission systems. No automation nor remote control has yet been attempted.

(v) Measures for the erosion and sediment control along the Nile and Gash rivers are limited due to lack of funds, and intensive studies involving hydraulic models are being undertaken.

Accordingly a hydraulic research station is currently under establishment with the U.N.D.P. Assistance to arrive at advanced technological solutions for the erosion control and for the increased efficiency of irrigation systems as well.

5.2. Environmental Impact of Labour Intensive Methods :-

Many of the population engaged in the traditional sector, the pastoralists and the rainland farmer, who are living in the regions where water resources projects are undertaken, tend to gradually desert their traditional way of living and join the labour force constructing, operating or maintaining those projects. This helped to minimize the tendency of imigration from rural to urban districts.

The engagement of labour in flood and erosion control works has assisted considerably in the conservation of the highly fertile riverain lands and consequently the prevention of desert creep.

5.3. As for making use of advanced technologies for increasing the efficiency in the use and reuse of water by adopting canal lining, sprinkler irrigation and such similar techniques, it is generally admitted that sprinkler irrigation systems induce less labour force and achieve the economic use of water, but in the Sudan the topography of the irrigated schemes is generally gently sloping flat terrain, with no

undulations, suitable for free flow open canal distribution systems. The irrigation schemes plots are generally large in size. Plans are underway to introduce sprinkler irrigation in small scale holdings in the contemplated horticultural crops in few areas in the west and south where the groundwater and surface water supplies are limited during the dry season.

With respect to canal lining, this technique has not been experienced in this country due to the fact that the existing and potential irrigation lands are confined to the clay plains and to the alluvial riverain deposits adjoining the river banks, the soils of which are characterized by low permeability. Moreover, it should be noted that the Sudan's share of the Nile Waters has not yet been fully exploited. However, there is no conception for transforming the conventional irrigation system to sprinkler or automated systems. On the other hand the agronomical research authorities are undergoing extensive research for determining the optimum and hence the most economical use of water for crop irrigation.

5.4. With regard to water recycling and waste water reclamation, no action of considerable magnitude has been initiated in these respects in the Sudan.

5.5. In cases where conditions of water scarcity exist, some water saving approaches have been undertaken e.g. :—

(a) Construction of dams to store water during the abatement of the flood for use during the dry season. Such flood waters would not have been substantially made use of otherwise.

(b) In small artificial ponds (hafirs) for storage of water, plastic membranes and butyle rubber were used to minimize seepage losses.

(c) Groundwater development in semi desert and Savannah regions is receiving considerable attention. In some areas clearance of trees which consume the ground water resources and cause lowering of the water table through evapotranspiration during the dry season is being considered as a measure to save water for use by man and animals and for agricultural development.

(d) Agro-meteorological research work for the determination of the optimum water crop factors.

5.6. Some efforts have been made to develop and apply local technologies. These comprise the use of local materials for the construction of water structures such as masonry regulators and bridges. Brushwood revetments for flood protection and erosion control have been going on for the last four decades in many regions.

III. POLICY OPTION FOR ACTION

6. Water Laws and Regulations in Existence in Sudan

These include the current legislations, regulations and general principales pertinent to the various aspects of water resources.

6.1. Constitutional

The Constitution of the Democratic Republic of the Sudan has provided for the conservation, and efficient exploitation of the available water resources.

6.2. River Control Regulations :-

There are adequate Regulation Rules for all the river control works in the Sudan comprising the reservoirs of Sennar, Roseiris, Jebel Aulia, Khashm El Girba and the stretch of the High Dam reservoir within the Sudan. These Rules have been set out in accordance with the provisions for the control of the flows of the Nile which include the working arrments for the operation of river works embodying the hydrological aspects relating to the natural flows, time lags, transmission and other losses, reservoir characteristics, as well as the principles of the filling, emptying, hydraulic control and the aportionment of usage for irrigation, hydropower, water supply taking into account the down stream rights and the minimum acceptable flows.

6.3. Reservoirs Compensation Ordinances

When a new reservoir is constructed, the normal practice is the enactment and enforcement of an ordinance for compensation. As an example of this, there is the Jebel Aulia compensating ordinance of 1937 which makes provision for the award of compensation in respect of damages to property caused

by the raising of the level of the White Nile consequent upon the construction of the dam. The ordinance defines the compensation to be determined the appointment of the Commissioner and assessors and the date at which the final dam conditions are reached. Similar ordinances have been enacted in case of all the other reservoirs in the Sudan.

6.4. Irrigation Regulations :-

There are ordinances and regulations governing irrigation schemes.

For example the Gezira scheme ordinance and regulations contain rules for the control, regulation, distribution and other technical directions to ensure the safe and efficient operation of the canal system. It defines the relationship between the water control irrigation authorities and the agricultural authorities. According to these regulations the supply of water, its control and distribution is mainly a weekly indent by the block agricultural inspector on the sub-divisional irrigation Engineer expressed in m3/day based on water factors at the various control points. Each sub divisional engineer indents on the upstream sub-divisional engineer above him and finally the last one indents upon the head works Engineer (Dam Engineer).

The Regulations also define the measures related to wide spread and local flooding, drainage of rainwater and escapage of surplus canal water as well as the operation of the regulators and other structures.

6.5. Nile Pumps Control Board Ordinance :-

This ordinance issued in 1939 aims at controlling the pumping of water and water renting licences from the River Nile for irrigation, including the extent of land to be cultivated, the canalization, the methods of cultivations etc.

The Ordinance stipulates the establishment and the powers of the Nile Pumps Board, the main duties of which include the equitable distribution of the available waters amongst riverain owners and allotting from time to time specified proportions of water to any particular province or district and making regulations consistent with the requirements of public health. According to such regulations the Board would issue water renting licences, prescribe penalties, fix conditions of land tenure, lay down rules for making canals and drains, and regulates the crop rotation on the land irrigated by pumps. In accordance with the above Ordinance of 1939, new regulations were issued by the Nile Pump Control Board in 1951. Later in 1960 Regulations for the land tenancies were issued for the purpose of the distribution of tenancies and pertinent issues.

6.6. Taxation Ordinances :-

Such ordinances are issued from time to time with respect to the land watered from rivers, ground water or rainfall. Examples of such ordinances are :—

(a) In the case of lands watered by sagia, matara wheel or shadouf, a rate is fixed by the Government.

(b) The rainlands watered periodically by rain or river ; all crops grown on rainlands shall also be liable to a tax.

The organs responsible for water supply for irrigation, domestic use, industrial use, or generation of power issue legislations from time to time fixing water rates to be paid by the public or Government Units.

6.7. Ordinances Pertinent to other uses of Water Channels :-

6.7.1. The Fresh Water Fisheries Ordinance :-

This Ordinance issued in 1954 regulates and controls fishing in fresh water fisheries, and it applies to all fresh water rivers and lakes in the Sudan.

6.7.2. There is another similar ordinance regulating marine fisheries in the Sudan.

6.7.3. River Transport in the Nile and inland Waters Ordinance :-

This Ordinance enacted in 1907 comprises river navigation regulations, boat regulations and harbour and shipping regulations within the territorial waters or on the shores of the Sudan.

6.8. Water Pollution Control Ordinance :-

This Ordinance lies in section three of the Environment Health Ordinance issued by the Sudan Ministry of Health in 1975. The main clauses of this Ordinance aim at preventing the addition of any solids, fluids, industrial wastes, chemicals, sewage, refuse, and remains of animals on the water supply sources or inside rivers, canals, hafirs, wells, natural ponds or into the sea to avoid causing harm to the health of man and animals. The Ordinance

stipulates the control and supervision measures to be undertaken by the Provincial Health Authorities on the Water supply sources and water works and the collection of water samples there from as well as inspection of rural and urban water supply networks.

The Ordinance also includes the conditions of the storage and supply of water which ban the supply of water to the public before analysing it by the appropriate technical authorities to ensure its freedom from pollution. The Ordinance provides, as well, protective measures against the spread of epidemic diseases, the collection of water samples for bacteriological analysis, treating the water supply source and conducting medical examination for employees on water supply systems until the absence of pollution is confirmed.

Finally, the Ordinance regulates the disposal of sewage and industrial wastes in water courses and specifies the proportion of biochemical oxygen and suspended material in p.p.m. by weight of water conveyed by canals which are used for conveying treated sewages and irrigation water.

6.9. The Water Hyacinth Ordinance :-

This was enacted in 1960 and is cited as the Ordinance for the combatment of water hyacinth and the control of its spread in Sudanese rivers and waterways. According to this Ordinance the areas infested with hyacinth should be published in the Gazette. Observation and control points should be established in the infested reaches. Any vessels passing a control point should be cleared from the hyacinth — Owners of pump schemes should instal mesh screens in inlet channels and should notify the concerned authorities of the appearance of any water hyacinth in their schemes. The Ordinance bans the transference of water hyacinth from place to place and it permits the concerned authorities to enter into any land with the object of controlling the spread of the water hyacinth. Regulations should be issued from time to time to help in the implementation of the context of this Ordinance. Any person who breaches the Ordinance shall be liable to penalty.

6.10. The Continental Sea Shelf governing the use of the territorial Sea waters was enacted in 1970. It defines the base line and the extent of the coast as well as the rights of sovereigniter and the legal status of the superjacent waters.

6.11. International Agreements Governing Water Policy :-

These are mentioned later under the item of of multi-national cooperation.

7. Institutions Dealing with Water Planning and Management Aspects :-

7.1. The Ministry of Irrigation and Hydro-Electric Power :-

This organ was established since 1920 and the functions it undertakes today comprise the control, regulation and development of the water resources in the Sudan.

The organization set up is composed of two main directorates and a public corporation designated with the following tasks :-

(i) Hydrological investigations and formulation of projects for the conservation and optimum utilization of the Sudan's share of the Nile Waters and other riverain sources together with the Projects for the increase of the Nile Yield.

(ii) Water resources research through the hydraulic research station.

(iii) Investigation, Planning, design, construction, operation, and maintenance of storage, irrigation, hydropower, flood control and river training projects.

(iv) Maintenance and operation of dams and other control works.

This organization setup ensures full coordination among the various departments of this Ministry

7.2. The Permanent Joint Technical Commission for Nile Waters :-

This Commission has been set up since 1959 between Egypt and the Sudan to undertake jointly the gauging of the Nile, to formulate plans for the increase of the Nile Yield, to draw up the working arrangements for any works to be constructed on the Nile and to consider and reach a unified view regarding the Nile control claims of the other riparian countries.

7.3. The Rural Water Development Corporation :-

This organ was initially created since 1944 as a land use and rural water department. Today this corporation undertakes the following tasks through its well coordinated organization set up :—

(i) Provision of water supply to human and livestock in rural areas.

(ii) Help in the better maintenance, development and utilization of natural resources.

(iii) Meet water requirements for rural development schemes and assist in the development of nomads.

The activities implemented by the groundwater and surface water departments and regional offices include hydrological and hydrogeological investigations, drilling excavation and construction of rural water supply works such as bores, hafirs and embankments.

7.4. Geological Survey Department :-

At present this Department is mainly concerned, among other functions, with hydrogeological investigations particularly in mining areas.

7.5. The Public Electricity and Water Corporation :-

The main functions of this Corporation can be outlined as follows :—

(i) Investigation, planning, design, construction, operation and maintenance of water supply systems, water works, and water supply networks mainly for urban and industrial uses.

(ii) The planning and generation, and distribution of electricity from the hydroelectric power or thermal stations.

The corporation is vested with the powers of fixing the rates and tarriffs for the water supply and electricity services.

7.6. The Meteorological Department :-

This Department ; operating as an organ of the Ministry of Defence, undertakes the installation, operation, and maintenance of the various grades of the meteorological, hydrometeorological, rainfall and agrometeorological stations in the Sudan as well as weather forecast systems.

In addition, the Department undertakes the processing, analysis, interpretation and dissimination of meteorological data.

This Department is providing basic services to the water resources planning and management institutions in the Counctry.

7.7. The Hydro Biological Research Unit :-

This unit was established within the University of Khartoum since 1953 to undertake, among other functions, the hydro–biological research in the River Nile and its tributaries and the impact of storage reservoirs on the hydro-biological characteristics of rivers.

7.8. The Agricultural Research Corporation :-

The Agro-meteorological section conducts studies in respect of the optimum use of water for irrigation to determine the crop factors, the duration and number of waterings, the soil moisture investigation on the various types of soils and under the various climatic conditions prevalent in the country.

The research conducted in this field is of prime importance to the economic use of water.

7.9. There are other institutions whose work influences and is considered pertinent to the water planning and management such as the River Transport corporation and the fisheries research section.

The main evaluation of the above water resources organization can be summarized in one main aspect, that is the lack of a legal integral organization to coordinate the activities of the various water planning and management institutions in the Sudan.

8. Man Power and Educational Programmes :-

8.1. The water Resources Educational Institutions in the Sudan :-

8.1.1. *The Faculty of Engineering,* University of Khartoum, there is the total number of 143 Graduates per year at present of which 37 are electrical, 42 Civil 47 Mechanical 17 Chemical. The syllabus includes fluid mechanics, hydrology irrigation, hydropower as main subjects pertinent to water resources.

8.1.2. *The Department of Geology,* with total number of 40 Graduates per year. The syllabus includes groundwater and hydrogeology as one of the main subjects.

8.1.3. *The Faculty of Agriculture,* with a total number of 190 Graduates per year. The syllabus includes agronomy, irrigation and agricultural engineering.

8.1.4. The Khartoum Polytechnic

This used to graduate technicians and assistant Engineers, about 60 per year ; but since 1972 it has been converted to a technical institute to teach Engineering technicians, and the number of graduates is 135 per year.

8.1.5. The Meteorological School

This is teaching met. observers, who later undergo a class four meteorologist course. It is planned that the courses will be extended to cover class 3 and 2 personnel.

8.1.6. The Rural Water Corporation Institute :-

This institute is intended to graduate drilling technicians, topographic surveyors to meet the technician level requirements of the Corporation.

8.1.7. Post Graduate Courses and Training

There are limited facilities for post graduate research and studies in the water resources branches at the University of Khartoum. Some graduates are sent abroad to attain post graduate diploma, M.S.C. ph.d and the membership of recognized institutions and pursue in the job training programmes.

8.2. Manpower

The number of manpower employed in the various water resources institutions can be outlined as follows :—

(i) *The Ministry of Irrigation and Hydroelectric power*

It comprises 150 Professional engineers, 250 Graduates from the Khartoum polytechnic, 132 technicians and 13,800 labourers. These numbers have to be increased during the forthcoming ten year plan by 100% Professional engineers.

(ii) *The Rural Water Department Corporation*

There are 14 professional engineers, 32 graduates from the polytechnics, 30 hydrogeologists and 275 technicians.

(iii) *The Geological Survey Department*

There are ten hydrogeologists and five technicians; this number has to be doubled in the forthcoming six year development plan.

(iv) *The Meteorology Department*

There are 30 class I meteorologists, 28 class 2 meteorologists, 23 technicians and 360 officers and observers. According to the projection in the forthcoming six year plan the numbers are to be increased by to 40 class I, plus 60 class 2 plus 40 technicians and 500 met. officers and observers.

(v) *The Central Electricity and Water Supply*

In the water supply directorate, there are 30 professional engineers, 31 graduates from the Khartoum polytechnic, and 83 technicians.

MULTINATIONAL AND INTERNATIONAL COOPERATION :-

9.1. International Agreements :-

9.1.1. In 1920 the Egyptian Government issued a programme for the Nile Control and appointed an International Commission which endorsed the proposals to construct Gezira scheme, Jebel Aulia reservoir and Naga Hamadi Barrage. The commission estimated the ultimate water requirements for Egypt as 58 milliards, but could not fix a quota for the Sudan. Consequently the Egyptian Government postponed all irrigation projects awaiting agreement on the political future of the Sudan.

9.1.2. In 1925 a new International Commission was formed and the 1925 Nile Water Agreement was based on the recommendations of that Commission. The Agreement restricted the construction of any works on the Nile, its tributaries and the Lakes from which it flows without the previous agreement of Egypt. The Agreement specified that the natural flow of the river should be reserved for the benefit of Egypt from January to mid-July subject to certain pump irrigation — rights in the Sudan covering 25,500 hectares, while the Sudan water requirements during the low flow period were to be provided entirely from Sennar dam storage.

9.1.3. The 1904 Agreement between the United Kingdom and Ethiopia stipulated that Ethiopia undertakes not to construct any works on the Blue Nile or its tributaries which may obstruct the flow without the prior consent of the Sudan Government

9.1.4. In 1932 an Agreement was concluded between Sudan and Egypt, under which Jebel Aulia Reservoir was constructed to give additional water supplies to Egypt.

9.1.5. In 1935 and 1946 an Agreement with Ethiopia to construct an over-year storage dam at Lake Tana was proposed, but not yet finalized.

9.1.6. In 1946 Egypt proposed the future conservation of the Nile involving over-year storage in Lake Tana, Lake Victoria and Lake Albert, the Jonglei canal, and the 4th cataract reservoir. Modifications were suggested by the Sudan, but no further action was taken at the time.

9.1.7. In 1949 an Agreement was reached between Egypt and Britain on the construction of Owen Falls Dam at the outlet of Lake Victoria which was completed in 1954.

9.1.8. In 1952 Egypt and the Sudan agreed to raise Sennar dam by one metre and Jebel Aulia dam by ten centimetres.

9.1.9. In 1959 the Nile Water Agreement was concluded between the two countries, whereby the net benefit from Aswan High Dam would be divided at the ratio of 14.5 milliard M3 for Sudan and 7.5 milliard M3 for Egypt and as a result the Sudan share has become 18.5 milliard M3 and that of Egypt 55.5 milliard M3 leaving 10 milliard M3 for evaporation from Aswan High Dam reservoir. The Agreement stipulated the formation of a Permanent Joint Technical Commission to undertake the gauging of the Nile, to draw plans for the increase of the Nile yield, to draw up the working arrangements for any works to be con, structed on theNile and to consider and reach a unified view regarding the other riparian countries' claims and any such accepted claims shall be deducted from the shares of the two countries.

9.1.10. Following a series of discussion, Egypt, Sudan, Uganda, Kenya, Tanzania and UNSF agreed in 1967 to conduct the hydrometeorological survey of the Catchments of Lakes Victoria, Kyoga and Albert. Burundi and Rawanda joined this project in 1972 and Ethiopia joined the Technical Committee of this project as an observer. The first phase of the project was accomplished in 1975 and thereafter the second phase has started with the object of formulating a mathematical model representing the Upper Nile system to assist in the conservation, control and development of the Nile Water resources taking into consideration the optimum benefit of the riparian countries.

9.1.11. Contacts have been initiated with Ethiopia and the UNDP to formulate agreements aiming at conducting joint hydrological studies on the upper catchment areas of River Gash and Baraka.

9.1.12. The UNDP has proposed ajoint project between Ethiopia and the Sudan to conduct hydrometeorological studies in the Blue Nile Catchment area within Ethiopia to study the flood forecast of the Blue Nile

9.1.13. The UNDP has proposed a joint project to study the environmental impact of the Aswan High Dam reservoir together with the limnological, hydrogeological, hydrological and meteorological aspects.

.9.2. Technical Assistance :-

Examples of the Main Projects implemented under the UNDP Technical Assistance are as follows :—

9.2.1. Jebel Marra land and water resources survey, UNDP contribution of 1,362,450 U.S. dollars and Sudan Government's contribution 1,920,000 dollars over 5 years.

9.2.2. Kordofan Project.

9.2.3. The Savanh project, phase 1 and 2

The UNDP contribution amounts to the equivalent of 512,000 Sudanese pounds, and the Government contribution is about 549,000 pounds.

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9.2.4. Assistance is offered to the met. Dept. by the W.M.O. in the form of equipment to the value of 200,000 Sudanese pounds and 40 different fellowships.

9.2.5. Technical Assistance in other cases is granted by Governments and institutions in the form of equipment, experts and fellowships e.g.

(i) Part of the feasibility and pre-investment studies of Upper Atbara Stit dam Project, by the French Government.

(ii) ILACO, Netherlands for the Pangko and Jonglei water resources pilot projects.

(iii) Canada, for the remote sensing using sattelites for the National Resources Surveys.

9.3. Financing

With regard to financing of water resources projects in the Sudan, the following are examples of loans given by IBRD and other Governmental financial institutions to some major projects :—

9.3.1. The IBRD and IDA made eight loans and credits totalling more than 150 million U.S. dollars including 53 millions to the Agricultural sector.

(i) The Roseires Dam Project was completed in 1966 with financial assistance from IBRD/IDA (284 — SU (IBRI) of U.S. dollars 19.5 million and/S.U. (IDA) U.S. dollars 13 million in 1961.

(ii) IBRD/IDA have provided Loan 258 — U.S. of 15.5 million dollars in 1960 to finance the Managil Extension.

(iii) Credit 556—S.U. of 5 million dollars in 1968 and credit 11.25 million dollars in 1972 to finance mechanized rainfed farming.

(iv) Rahad Irrigation Project loan 284 U.S., amounting to 40 million dollars by IDA, 10 millions by Kuwait Fund and 11 millions by U.S. AID — These were increased due to recent escalation trends.

(v) Roseires hydroelectric power project loan 522 S.U. amounting to 19 million dollars for the Roseires Dam hydroelectric.

9.3.2. Interest free Loan from the United Kinddom amounting to 1,100,000 sterling pounds for the purchase of four new pumping stations for the Northern Province irrigation scheme, and another loan of 459,000 sterling pounds plus 360,000 sterling pounds towards the cost of new sluice gates for Snnar Dam. Another loan was given by the United Kingdom for intensive planning survey for Southern Darfur land use, amounting to the equivalent of 379,000 Sudanese Pounds.

There are many other similar loans and credits for the water resources development projects.

There is more need for technical assistance from the UNDP with respect to water resources, prefeasibility investigations, feasibility and pre-investment studies, and in particular the groundwater and small rural streams. International lending agencies and wealthy countries are obliged to finance the contemplated water resources projects especially those relating to irrigation from surface and groundwater storage dams, hydroelectric power, projects, water supply reservoirs and waterworks, drilling of wells and boreholes.

10 Environmental Aspects of Water Resources Development in Sudan

10.1. Prospects of Land Use

Following is a general outline of the present land use and the anticipated use by 1985, according to FAO, which gives an indication on the anticipated impact on the country-wide environmental aspects.

10.1.1. Present land use

The total inland water area = 12.976 million hectares.

The total land area in the Sudan = 250.476 million hectares.

The total area considered unsuitable for agricultural development comprises 127.927 million hectares composed of 12.975 million hectares of inland water and 114.952 million hectares of swamps and desert.

The present area suitable for agricultural development comprises 89,179 million hectares of forests, 22.848 million hectares of pastures and 10.8 million hectares of rainfed and irrigated lands.

10.1.2. The Prospective Land Use By 1985 :-

A general envisaged plan is as follows :—

The forests are expected to decrease from 89.179 to 85.1 million hectares.

The pastures are expected to decrease from 22.848 to 20.798 million hectares.

The rainfed and irrigated area to increase from 10.8 to 16.7 million hectares.

it is planned to reserve 53.6 million hectares as central and regional forests for the next 25 years to meet the requirements of timber products and to conserve and maintain the soils and pastures from erosion and desert creep.

The area to be reserved for wildlife is estimated as 2.32 million hectares.

10.2. Impact of Water - Resources Projects on the Characteristics of Rivers

Very little studies were conducted prior to 1953 on the physio-chemical and hydrobiological characteristics of the Nile Waters. Recently substantial surveys in this field have been undertaken by the Hydrobiological Research Unit of the University of Khartoum. The results of the surveys are outlined hereunder :—

10.2.1. The Influence of the Swamps of the White Nile and Tributary Contribution on the Nile Waters

These swamps extend from kilo 950 to kilo 1720 South of Khartoum. The results of a number of surveys on the influence of the swamps showed a marked decrease in dissolved oxygen, PH, and sulphates accompanied by increase in ammonia nitrogen

The changes due to the tributaries contribution indicated that Bahr El Ghazal showed a significant longitudinal succession with its characteristics different from those at Lake No. On the other, hand Bahr El Jebel, when passing through the Zeraf, becomes enriched with nutrient salts which results in the dense plankton population of the Zeraf.

10.2.2. *Determination of the Periodic Changes,* in the water characteristics of the rivers and the study of the longitudinal succession in the water characteristics :—

In 1957 a detailed study of the lonitudinal changes in the physical and chemical characteristics of the Nile between Lake Victoria and Khartoum was conducted.

In 1956, 1964, 1965 and 1969 surveys were conducted on the Blue Nile from Khartoum to Roseires to study the longitudinal distribution of Phyto and Zooplan kton, with the result that the Plankton population on which was brought to full development in Sennar Dam reservoir persisted down to Khartoum, 300 kilometres downstream.

In 1969 a study was made on the influence of the algae of the Blue Nile as a result of Rosires Dam on the design of the water supply treatment in Khartoum, with the result that no significant increase in the algal crop reaching Khartoum has occurred.

10.2.3. The Impact of the Water Hyacinth

The Eichhornia crassips is widely spread in Bahr El Jebel El Zeraf, Sobat, the White Nile but absent in Bahr El Ghazal. In 1959 a study was made on the effect of the Eichhornia crassips on the Nile fisheris. In 1969 studies were conducted on the ecology of the floating weeds in the White Nile to determine the principal factors affecting their movements in the Nile. Surveys have indicated that the invasion of the water hyacinth did not change the water chemistry of the White Nile.

The marked decrease of the nitrate nitrogen at Jebel Aulia reservoir is partly attributed to its uptake by the water hyacinth.

The other major effects of the water hyacinth include increased evaportranspiration, obstruction to navigation, blockage of inlet channels in pump schemes.

10.2.4. The Impact of Storage Reservoirs on the Riverain Water Characteristics

10.2.4.1. Jebel Aulia Dam (Built in 1937)

The effect of the seasonal storage was studied in 1951 through to 1956 and also in 1972 indicating an increase in oxygen content and PH value and a decrease in transparency, alkalinity, nitrate, phosphates, silicon and iron.

10.2.4.2. Sennar Dam (Built 1925) :-

Studies on the Zooplankton of the Blue Nile

concluded in 1970, indicated that the build up of the Zooplankton in Sennar Reservoir was greater than in Roseires Reservoir.

10.2.5.2. Roseires Dam (Built 1966)

The water impoundment in this resevoir resulted in the bloom of certain species of phyto and Zooplankton. Fish increased in number. Transparency and productivity showed a remarkable increase. This phenomenon affected the Blue Nile reach down to Khartoum. This together with the ponding effect of the White Nile created conditions favourable for mosquitoes and chironomids. Fish in the reservoir suffered depletion in 1967 to 1969 due to low oxygen tension, lack of food and lack of fish ladder. The effect of the reservoir on the climate, forestry and game parks shall be studied.

10.3. The Impact of Irrigation Projects on the Environment

It is no doubt that large scale irrigation projects have their environmental and ecological impacts. If we take the Rahad Project, some 126,000 hectares, it will profoundly affect the ecology of the region by increasing the incidence of bilharzia and malaria, and consequently a programme of control and treatment has been formulated. The project will interrupt the traditional migration of cattle and game. Other changes in the flora and fauna may occur.

10.4. The Impact of Swamp Reclamation Projects

If we take the proposed Jonglei canal project, the main envisaged impact would be :—

(i) The swamp area shall be decreased by 15% during the flood season and by 20% during low river, resulting in more dry season pastures.

(ii) The proposed canal shall constitute a new source of navigation, road transport, fisheries and population settlement throughout the flood and dry season.

(iii) The project shall result in integrated development in the area including a modern irrigation and drainage scheme of 80,000 hectares comprising essential services.

(iv) The ecological conditions shall in general be improved.

10.5. The Impact of Rural Water Projects on the Environment

The plans for the rural water development projects using surface and groundwater aim at the prevention of the exhaustion of natural pastures and the prevention of deterioration of soils and desertification. They encourage settlement of nomadic pastoralist. To achieve this, the area to be served by each water point has been fixed accordingly such that one water point serves 200 kilometres in semidesert areas, 100 Km^2 in the light savanah and 50 kilometres in dense savanah.

10.6. Erosion Control Along the Main Nile

Along the Main Nile the river course is characerized by formation of curves, considerable meandering, branching, bank erosion island formation and the gradual diminishing of the alluvial agricultural land strip accompanied by the encroachment of the desert. Scouring and erosion due to diagonal currents and waves is taking a heavy toll of the soil and plantation year by year and endangering the safety of pump schemes.

Temporary protection works, longitudinal slopes revetments and groynes have been tried on a limited scale to check erosion and other measures are underway to combat this phenomenon, and steps will be enhanced subsequent to the completion of the national hydraulic research station.

10.7. Water Pollution Control :-

This has been mentioned under water laws and regulations in ample detail.

IV ACTION PROPOSALS

II. Actions that Might be Taken by Government

11.1. Expediting the finalization of the studies necessary for the formulation and implementation of the swamp reclamation projected encompassing the Basins of Bahr El Jebel, Bahr El Zeraf, Bahr El Ghazal Sobat and Machar with the object of minimizing the water lost in these regions and consequently providing extra water yield for further resources development.

11.2. Formulating and implementing an accelerated plan for the rural water development during the forthcoming decade especialy with the view to providing water supplies for human, animal and small scale irrigation consumption which will help environmentally in the settlement of nomads and the conservation of land and pastures.

11.3. Intensification of the studies aiming at the determination of the optimum crop water factors to achieve saving and economic use of water resources.

11.4. Inview of the fact that there are several departments assigned with water resources activities, it is necessary to form an inter-departmental national coordinating council to coordinate all aspects relating to water resources investigations and development.

11.5. As the main catchment areas of the Blue Nile Basin, the Sobat Basin, the Gash and Baraka Basins lie within Ethiopia, and as its is necessary to conduct technical studies pertinent to the runoff forecast and formulation of joint water resources projects, it is of vital importance that multinational cooperation be established between Ethiopia Sudan and Egypt along the lines of the project of Lake Victoria, Kyoga and Albert currently undertaken by the Riparian countries and UNDP assistance.

11.6. The establishment of a scientific institute to be established within the common river basins to promote scientific studies, to formulate basin wide plans for the integrated basin development and to undertake the promotion of manpower training and institutional framework within the basin and to undertake as well the responsibility of transferring technology to the Basin so as to reduce progressively the dependence on foreign consultancy enterprises.

12. Action by the Organization of the U.N. System :-

12.1. Technical Assistance, especially in the form of equipment and fellowships from UNDP from rich countries to expand and operate the hydrometeorological, hydrological and hydrogeological national network. The Assistance should give a particular emphasis on the establishment of groundworks for the application of modern technological systems.

13. Actions By International Bodies as Whole

13.1. Provision of financement in the light of the feasibility and preinvestment appraisals of the water resources projects embodied in the National Master Plan outlined earlier in this Report.

3.2. 1 Groundwater exploration, asessment, and rational use of storage capacity of aquifer systems is of vital importance to go alongside with the suface water inventory and development, and as such the assistance of the United Nations Organizations and advanced countries should be given special emphasis to this vital component of water resources.

13.3. In view of the great water losses caused by water hyacinth in the White Nile and its tributaries and its nuisance effects in waterways since 1958, the U.N. organizations and advanced countries are expected to provide further assistance for the combatment and ultimate eradication of this plant.

ANNEX (1)

Table 1 — Representative Climatic Normals 1941—1970

Station	Latitude		Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug	Sep.	Oct.	Nov.	Dec.	Year
Karima (Northern Sudan)	18°33′N	Rainfall (mm)	0	0	0	0	0	0	13	23	4	1	0	0	41
		Evaporation* (mm/day)	5.3	6.6	8.2	8.8	9.3	9.1	8.6	8.3	8.1	7.4	6.1	5.1	7.6
		Air temperature (°C)	20	22	26	30	33	35	34	34	34	32	26	22	29
		Sunshine duration (%)	91	93	88	88	85	80	83	79	81	89	94	95	87
		Solar radiation (cal/cm²/day)	Not Available												
Wad Medani Central Sudan)	14°23′N	Rainfall (mm)	0	0	0	1	15	29	116	133	48	19	1	0	362
		Evaporation* (mm/day)	5.6	7.3	7.8	8.3	8.8	8.9	7.8	6.9	7.0	6.5	6.3	5.9	7.3
		Air temperature (°C)	24	25	28	31	33	32	29	28	29	30	27	24	28
		Sunshine duration (%)	92	93	87	86	80	72	60	61	76	85	92	94	82
		Solar radiation (cal/cm²/day)	487	540	574	595	578	554	517	523	550	521	493	473	537
Malakal (South Central Sudan)	9°33′N	Rainfall (mm)	0	0	7	21	102	109	149	167	144	82	6	0	787
		Evaporation* (mm/day)	6.7	7.8	7.4	7.5	6.7	5.9	5.4	5.5	5.7	5.8	6.0	6.7	6.4
		Air temperature (°C)	27	28	31	31	30	28	26	26	27	28	27	27	28
		Sunshine duration (%)	83	82	73	70	60	45	39	45	50	60	79	89	65
		Solar radiation (cal/cm²/day)	481	527	530	534	496	447	440	469	480	484	499	496	490
Juba (Southern Sudan)	4°52′N	Rainfall (mm)	4	8	51	95	156	112	136	150	114	115	38	9	988
		Evaporation* (mm/day)	4.8	5.2	5.9	5.2	5.7	5.4	4.6	5.0	5.5	5.2	5.2	5.2	5.2
		Air temperature (°C)	28	29	30	29	28	27	26	26	26	27	28	28	27
		Sunshine duration (%)	78	69	58	54	63	60	48	56	64	62	66	79	64
		Solar radiation (cal/cm²/day)	443	449	446	433	480	456	413	460	503	474	455	444	455

* Evaporation is Penman Open Surface Evaporation

Source ; Climatological Normals (1941—1970). Sudan Meteorological Department.

ANNEX (2)

AGRICULTURAL COMMODITY PRODUCTION TARGETS

1985 (in 1000 metric tons)

Commodity	1972—1973	1985	% increase (rounded)
Crops :			
Rice	5	60	1100
Wheat	150	860	500
Sorghum	1300	3030	130
Millet	365	560	50
Maize	12	90	650
Pulses	35	75	100
Groundnuts	450	1355	200
Sesame	345	520	50
Cotton Seed	370	800	100
Other Oil Seeds*	57	209	250
Root Crops	2550	2980	20
Fruits & Vegetables	925	1830	100
Sugar Cane	1100	8100	650
Cotton Lint	270	447	70
Gum Arabic	40	100	150
Tea	Nil	22	—
Coffee	Nil	27	—
Tobacco	1	3	—
Animal Products :			
Meats (Red)**	375	808	120
Poultry	12	34	180
Eggs	17	47	180
Fish	22	57	160
Skins and Hides	24	38	60
Milk	2000	4100	110

* Sunflower, castor and melon seeds.

** Excluding game animals.

ANNEX (3)

COST OF IRRIGATION DEVELOPMENT IN SUDAN
RAHAD IRRIGATION PROJECT

1. The Project in the development of irrigated agriculture on a net area of about 300,000 Feddans (1 Feddan = 1.038 acre) on the east bank of the Rahad River using water pumped from the Blue Nile, The Project involved the construction of all irrigation supply, distribution system, drainage works, installation of all agricultural processing equipment, storage facilities and settlement of 13,700 tenanent families (70,000 people) with all the necessary facilities and infrastructure.

2. *GENERAL DATA :*

(i) Cropped Area :

Cotton	140,000	Feddans
Groundnuts	93,000	
Gardens	20,000	
Fallow	47,000	
	300,000	Feddans

(ii) Cropping Intensity : 84%

(iii) Irrigation water requirement : 1200 million M3 per year

(iv) Capacity of irrigation Pumps : 105 M3/Sec.

(v) Crop production : 120,000 tons seed cotton
84,000 tons Groundnuts
15,000 tons Fruits & Vegetables

3. *COST ESTIMATES* (Million U.S. Dollars)

Irrigation Works	126	35%
Agricultural equipment & facilities	62	17
Buildings	62	17
Services & utilities	70	19
Settlement	20	5
Administration, overheads & Consultants	25	7
	365	100%

(ii) Project Cost per hectares ... ... 3040 Dollars

(iii) Irrigation cost per hectare ... ... 1050 Dollars

4. *Tenants Income* (10 ha Tenancy)

1972 *Estimates*

Gross revenue	3180	Dollars
Production cost	2030	"
Gross farm income	1150	"
Project charges	450	"
Net farm income	700	"

ANNEX (4)

The Six Years Economic and Social Development Plan

(1977/78 — 1982/83)

A. Agricultural Production Targets

Area : in Thousand Feddans
Yield : in Kgs. Per Feddan
Output : in Thousand MT.

Product	1974/75 (Actual) Area	Yield	Output	Base Year 1976/77 (Provisional) Area	Yield	Output	Target 1982/83 Area	Yield	Output	% Annual Increase in Output
1. Cotton :				760	635	483	790	707	559	2.5
Long Staple	856	617	529	210	500	105	350	849	297	18.99
Medium Staple	222	459	102	155	122	19	350	200	70	24.3
Short Staple	141	116	16							
	1219	531	647	1125	540	607	1490	621	926	7.3
2. Sorghum (Dura)	5577	306	1702	6000	316	1900	9100	411	3740	12.0
3. Wheat	591	461	269	622	500	311	890	750	668	12.6
4. Millet (Dukhn)	2576	156	402	2500	160	400	2800	185	518	4.4
5. Rice (Paddy)	15	492	7	24	500	12	100	570	57	29.7
6. Maize	197	231	46	210	250	53	315	380	120	14.6
7. Cassava	80	1144	92	110	1500	165	180	2000	360	13.9
8. Sesame	2173	107	233	2200	100	242	2700	140	378	7.7
9. Groundnut	1792	519	930	1840	456	839	2900	541	1568	11.0
10. Coffee	1	500	0.5	3	500	1.5	15	670	10	37.2
11. Tobacco	1	200	0.2	1	200	0.2	8	200	1.6	41.4
12. Sugar Cane	40	3225	1290	40	3023	1200	288	3021	8700	39.1
13. Horsebeans	38	673	39	36	800	29	55	850	47	8.4

B. Production Targets for Forest Products

Product	Unit	1974/75 (Actual)	Base 1976/77	Target 1982/83 (Estimated)	% Annual Increase
Sawn Timber	Thousand M3	19.6	16.5	38.2	15.0
Round Wood	do	1207.5	1241.2	1422.0	2.3
Bamboo	do	3.9	4.0	7.4	10.8
Poles	do	6.3	6.6	9.1	5.5
Firewood	do	16.802	18.639	22.953	3.5
Charcoal	Thous. Tons	592	657	805	3.5
Gum Arabic	do	43.0	49.2	62.0	4.0

C. Targets For Animal Products

Quantities in Thousand MT.

Product	Base Year 1976/77 (Estimates)	1982/83 Targets	% Increase Over Base	Annual Rate of Increase %
Beef	171.2	246.2	43.7	6.2
Mutton & Goat Meat	145.9	239.7	64.3	8.6
Camel Meat	24.0	33.9	67.4	6.7
Poultry Meat	13.7	21.3	55.5	7.6
Fish	26.7	44.2	65.5	8.8
Total Meat	380.5	585.1	53.8	7.4
Milk	1129	1523.7	55.0	5.2
Eggs	23.7	50.5	113.1	13.3