[redacted]MOCRATIC REPUBLIC OF THE SUDAN

RURAL WATER CORPORATION

GROUND WATER RESOURCES

of

S U D A N

By

RAMSIS B. SALAMA

GROUND WATER RESOURCES OF SUDAN

BY RAMSIS B. SALAMA **

Abstract

The present minimum annual requirements of water for Human and Animal population in the Rural areas of Sudan was estimated to be 275 million cubic meters, the ground water Basins provide 23.2% of this amount.

Some 1381 million cubic meters are estimated to recharge the major Basins annually, only 143 million cubic meters of this recharged water is used. The Ground Water Resources (reserves) are estimated to be 41.8 milliard. It can be concluded that the ground water potenialities of the Basins are extremely high. Large quantities of ground water are available for future development in Irrigation and domestic supply.

** Rural Water Corporation.

Introduction:

Ground water is the most important mineral in Sudan. About 80% of the inhabitants of Sudan depend upon ground water for their living most of the year.

In the Northern part of the country rain rarely falls and the country is mainly desert, away from the river Nile, the wells are the only source of water.

Southwards a tropical continental type of climate prevails, except in the extreme south, where the climate is described as continental equatorial. Both these climatic zones have distinct dry season which increases in intensity and duration Northwards.

The river Nile and its tributaries are the main watering points, away from it, the water pools collected in natural depressions are used directly after the rainy season, when this dries out small unlined open wells (Mushush) are used for water supply. The constant hunt for new pasture land was always hindered by the availability of water. The system of open wells was developed along wadi beds in the alluvial deposits and in the depressions which collect surface water during the Summer. All the urban and semi-urban systems existing today which were pasture centres are found along wadi courses or natural depressions where water was available and easy to get. The settlers increased in number and need for water increased, new local techniques of open wells were used with lining of different materials, well depths increased as the water levels start falling down. Drilling of wells started in 1919 in El Obeid Town, with steem operating percussion rig. This was followed by several other wells drilled in different villages to sustain the water requirements.

Drilling techniques developed, rotary drilling was introduced in 1958, well locations and designs started to become a problem when new locations were needed away from the natural catchment areas. In 1966 the Rural Water Corporation was created, and the ground water Investigation Section was born. This new baby started to grow with knowledge and experience during the last ten years, and its first cry was the evaluation of the ground water resources of the country from the available data, this evaluation will help in the planning of future research programmes and the proper utilization of the resources.

The main water-bearing formations in Sudan include:

1. The Quaternary to Recent Superficial Deposits.
2. The Plio-Pliestocene Umm Ruvaba Formation.
3. The Tertiary Basalts.
4. The Cretaceous Nubian Sandstone Formation.
5. The Weathered Basement Complex Formation.

../..

Of these the most important aquifer is the Nubian Sandstone Formation. It occupies about 28.13% of the total surface area of Sudan. Fortunately most of this is situated North of 12° N where water is needed most.

These different formations constitute the major basins of Sudan, either in a simple form i.e. one geological formation, or in a Complex form, i.e. two or more geological formations.

The complex basins are two in the Nubian, Basalt Formations, and two in the Nubian, Umm Ruwaba Formations.

Geology of Sudan:

The geological formations which built the Sudan are:-

1. The Basement Complex (Precambrian).
2. The older granites (Lower Palaeozoic).
3. Nawa Series (Upper Palaeozoic).
4. The Nubian Sandstone Formation and the Yirol Beds of the South (Mesozoic).
5. a) Hudi Chert (Tertiry).
   b) Younger granites.
6. Umm Ruwaba Formation (Pilo-Pleistocene).
7. a) River gravels (Quarternary).
   b) Qoz sand, Clay Plains, red Sea-Terraces and reefs
   c) Nile valley alluvial.

Geological Summary:

The Basement Complex, which is the oldest rock type in Sudan, is used to include all these igneous, metamorphic and sedimentary rocks, that are overlain by horizontal and subhorizontal Paleozoic or mesozoic sedimentary or igneous rocks. These rocks were altered, folded and intruded by igneous rocks, elevated to form a land-surface, and denduded to form the sub-Nubian penoplain.

The later history of the region lacks any folding movement which produces mountain ranges, and the region was affected by the sea during the deposition of parts of the Nubian Formation.

The sea margin retreated steadily through the Eocene period. This sea margin retreat is visible in Egypt and Somal, where as in the Sudan it has been under subaerial erosion for a long time probably since the Cretrceous, As a result of this, extensive tracts were swept clear of the Nubian Formation, and there are few traces of the post-Cretaceous events.

There are important Tertiary deposits. The Mudic chert which is preserved partly because of the protection afforded by the later sheets of volcanic rocks and partly by its resistance to weathering. One of the lateritic ironstone sheets is regarded as mid-Tortiary (Anderew). It caps a peneplain in the Western part of equatoria Province. The third Tertiary deposit is the volcanic rocks which are of late tortiary and they owe their preservation to their bulk, toughness and younger age.

../..

The movements which have affected the Sudan since the deposition of the Nubian Formation consisted of gentle warping with uplift of the Eastern part of the region, accompanied by faulting in the East.

This resulted in the rising of the Red Sea hills and the abyssinyan plateaue and the formation of the Red Sea. The plateaue has tended to continue its rise slightly, this is shown by marine sediments now above water on the present coastal plain. Its height was further increased by extensive volcanicity producing a thick mantle of lava, capping volcanoes of jebel Marra type.

This elevation of the Eastern margin of Sudan was produced by a warping movement, resulting in the formation of the Nile valley. Depressions have formed in plain, now filled by unconslidated sediments.

The tertiary and quaternary history is represented by non-marine deposits and by peneplains, and by volcanic accumulations.

Ground Water Basins:

The ground water basins are either in a simple form or in a complex form, according to their geological formations. There are six basins in the Nubian Sandstone Formation, two in the Nubian/Umm Ruwaba Formation, eight in the alluvial deposits, two in the Umm Ruwaba Formations and two in the Nubian/Basalt Formations.

1. The Nubian Basins:

11 Sahara Nile Basin.

The Nile Basin covers the Northern part of Northern Kordofan Province and extends from North of Khartoum to the Egyptian Border. It covers an area of 273,980 square Km. It's separate from Sahara Nubian Basin by a Basement ridge extending in a North Eastern direction. This ridge outcrops in the surface in few localities, i.e. J. Reheib and J. Magria, its extension Northward was recorded from Aeromagentic survey in the area.

The geological formations in this area the Nubian Sandstone formation and the Basement Complex. The Basement Complex consist of schists and slates with interbedded marbles. The area is covered by the "qoz" deposits which forms extensive sheets and fixed dunes. This qoz deposits occur on both banks of the Nile North of Khartoum but are less common on the east. This is related to the distribution of the Nubian Sandstone Formation which is much more restricted on the right bank.

../..

The water levels range from 10 meters near the Nile and falls rapidly moving away from the source of recharge, it reches a maximum depth of 25 meters in the central part of the basin. The ground water is flowing in Selima casis which is a natural depression. The flowing water is also due to the damming of water by the Basement Complex subsurface ridge.

The ground water movement is from the South to the North, with a velocity ranging from 0.44 to 1.46 meter per year.

In Wadi El Qa'ab West of Dongola, the water levels are near to the surface, this is partly due to the ground water movement from the east to the west, and the effect of the recharging water from the Nile together with the damming of water ...ich is caused by the Basement Complex outcropping near Kerima, and to the decrease in velocity caused by the entrace of the water from this area to the regional trend of ground water movement.

The saturated thikness of the aquifer ranges from 100-500 meters. Mudstone layers of more than 200 meters -- thick are usually found between 50-500 meters. This mudstone layers appear to be consistent in the area adjacent to the Nile 7 meters South of Ed Damer and extending in a southern direction down to latitude $16^{\circ}45^{\circ}$. The water is usually under water table condition near the Nile, and becomes semi-confined where the mudstone layer persists.

The ground water fluctuations together with the environmental isotopes indicates that the main source of recharge is from the River Nile, together with the under flow from the Blue Nile Basin.

The water quality of this basin has a total dissolved solids ranging between 200-400 p.p.m., the salinity increases parallel to the direction of ground water movement away from the recharge zones.

The amount of water recharged annually is estimated to be 136 million cubic meters . The out flow from this basin is in the Northern border of the Sudan, this is estimated to be some 7.3 million cubic meters.

Three premising areas are recommended for further detailed studies, the water levels are near, the transmissibilities are high and good cultivable land is available. These areas are:

a) Wadi El Mugadam
b) Wadi El Qa'ab
c) Wadi El Khuewi and Wadi El Seleim.

../..

2. Sahara Nubian Basin:

The Sahara Nubian Basin covers the Northern part of Northern Darfur Province. It extends northward from the Tagabo-Meidob groundwater devide up to the Egyptian border, covering an area of 324,656 square kilometers.

The geological formation constituting this region are the Nubian Sandstone formation which covers most of the area, the Basement Complex, with the tertiary volcanics of Meidob and Tagabohills. These consist of Trachytes and basalt. Dykes and dissected flow occur in the Meidob hills, and fresh lavas occur in and around the Malha crater. In Jebel Uweinat, which forms a ring complex around borders of Libya - Egypt and Sudan, conglomerates, sandstones, and slates are present and are greater than 400 meter thick on the south-west flank of the Kufra Basin (Whiteman). All these sediments were intruded by granite and syenetic rocks.

The chemical quality of this area ranges from 500 - 800 p.p.m. around the region of Malha crater, sodium carbonate and bicarbonat (Natron) rich waters occur at Malha; natron also occurs in the lak at Nakheila Oasis and at Natron well. The natron in this area was suggested to be of juvenile origin, since it occurs within an area of feeble volcanicity and these deposits may be simply evaporates

The water levels range from 10 - 50 meters. The water is flowing in two localities:-

a) El Natron Oasis
b) Nukheila Oasis.

During the rainy season, pools were formed in the upper part of Wadi Hawar, lake Tunder being the largest of these.

The ground water movement is from the south to the north with a velocity ranging from 0.4 - 2.1 meters per year.

The saturated thickness of the aquifer ranges from 100-1000 meters, two defined channels within the basin are detected from the Aeromagnetic surveys, the deepst one is in the Eastern part and having a North Eastern direction, the second one in the Eastern side parallel to the first. The water is recharged mainly from rain that falls occasionally and seeps through crack and joints, and accumulate in fans and wadi deposits (e.g. wadi Hawar) and E. in Dua of jebel Uweinat. Between the Nile and Wadi Hawar few oases were found (e.g. Nukheila and Natron). These oases are due structural origin, being formed by erosion of the core of an antic-line pitching south-east ward.

../..

The water found in the Meidob and Tagabo hills as derived partly from rainfall, partly from the zone of saturation, and partly from deep-seated volcanic sources. One the Malha crater springs occur at the contact of the Nubian Sandstone formation and the Basement Complex.

The amount of water recharged annually is estimated to be 20.6 million cubic meters per year, and the abstraction rates are 1.2 million cubic meters per year, and the amount of water under permanent storage is 9740 million cubic metres.

Wadi Hawar region which forms the southern margin of the Sahara area is a promissing area for furture development and further detailed studies.

3. Central Darfur Basin:

This Basin covers the central part of Darfur Province and the western part of Northern Kordofan Province. It extends southward from the Tagabo - Meidob ground water devide, and is connected to the Baggara Basin in the South, its surface area is 52,924 square kilometers.

The geological units which forms the basin are the Nubian Sandstone Formation and the Basement Complex. The Basement Complex is formed mainly of schists, acid gneisses, acid & basic volcanics & younger granites. The Nubian Sandstone consists of Sandstone with extensive beds of mudstones.

The Basement rocks are high at some localities and forms subsurface ridges, within the basin, these ridges although saturated with water, but their yield is very low. The water quality has a total dissolved solids ranging from 100-400 p.p.m.

In the Northern part of the basin the water quality is very good, at some localities it does not exceed 80 p.p.m. which is very low and indicates that the aquifer material at this part is siliceous and that this area is a zone of recharge.

The total dissolved solids increases parallel to the direction of ground water movement and reaches some 400 to 500 p.p.m. In jebel Hilla area in the southern part of the basin salinity reaches up to 18000 p.p.m., this salinity is of local origin and is due to evaporate beds within the Nubian Sandstone.

The depth to water ranges from 25 - 100 meter and the ground water movement is from the north to the south east with a velocity of 0.3 to 6.0 meters per year.

The saturated thickness ranges from 100 - 350 meters, the amount of recharge is 47.6 million cubic meters, this basin is connected to the Baggara basin in its southern part and the amount of outflow is estimated to be 12.8 million cubic meters, the amount of water under permanent storage is 794 million cubic meters and the abstraction rates are 5.63 million cubic meters.

../..

Umm Bayada and Saniya Hayei, are two promissing areas for further detailed studies and future development.

4. Nuhud Basin:

This basin is an isolated outlier, of Nubian Sandstone, covering an area of 6798 square kilometers in the central part of Northern Kordofan Province.

Geologically it's formed of Nubian Sandstone Formation, it is in the form of a syncline, occupying a saddle between the Nuhud uplift in south west and the Wadi El Malik - Sodri uplift, in the North.

The chemical quality of the water is low in total dissolved solids, being about 500 p.p.m.

The saturated thickness of the aquifer ranges from 150-250 meters, thick mudstone layers are present in the Northern part of the basin, at some localities they form the total thickness of the sedimentary column i.e. 250 meters.

The Heidob well field west of Nuhud town is the most exploited part of the aquifer, the abstracted water is used for the twon water supply, further detailed studies are required to know the long time safe yield.

The annual recharge is estimated as 15.4 million cubic meters, this amount of recharge is estimated from flow out and isotope analysis.

The depth to water levels ranges from 75 - 120 meters, the direction of ground water flow is from the west to the east with a velocity of 1.0 to 2.75 meters/Year.

5. Sag El Na'am Basin:

This Basin covers a trough which extends along Wadi El Ku, 40 kilometers south from El Fasher, capital of Northern Darfur Province, and covers an area of 2,678 square kilometers. It's connected to central Darfur Basin through a narrow straight.

The chemical quality is good as has low values of total dissolved solids ranging from 80 - 500 p.p.m., the Sodium absorption ratio (S.A.R.) is ranging from 1.08 to 3.5.

The depth to water level ranges from 50 - 100 meters, the water is under free water table condition on the fringes of the basin, whereas in the central part of the basin where the mudstone layer is usually 50 ft. thick the water level is under semi-artesian pressure.

../..

The ground water movement is from the north to the south and south east with a velocity ranging from 1.0 meter/year on the southern part of the basin to 25 meter/year in the central and eastern parts.

The saturated thickness ranges from 500 - 2000 meter a mudstone layer 50 ft. thick is persistent in the central part of the basin, this layer increase in thickness in the southern part when it becomes more than 1000 ft.

The exploitation of the basin for irrigation purposes is bein developing, due to the deep water levels the economics of the irrigation is rather doubtfull, but is estimated for many reasons as profitable.

6. River Atbara Basin:

It extends North to Abu Haraf water devide up to the Atbara River covering an area of 23,896 Kilometers, and is bounded by the river Nile from the west and the Basement from the east.

The geological formations are mainly the Nubian Sandstone formation with the terrace deposits on the river banks. The gravels of the lower Atbara valley contain much Hudi chert Formations. Upstream the terraces contain agates which may be derived from the Gedaref volcanic rocks.

The water level ranges from few meters near the Nile and the River Atabara, the water level drops away from sources or recharge and reaches down to 100 meters.

The saturated thickness from 100 meters in the northern and western part of the basin, it reaches 500 meters in the central part where thick mudstone layer is found between 50 to 250 meters.

After the construction of Khashm El Girba dam in the upper part of River Atbara, the flow in the lower part becomes seasonal only during the floods, this greately affected the life of the citizen, the development of ground water resource becomes a necessity.

It is expected that some 100,000 feddans will be irrigated frp, the ground water resources.

7. Umm Ruwaba Basins:

1. Sudd Basin:

This is the largest basin in the Sudan. It covers an area of 365,268 square kilometers extending from south of Bahr El Arab in a south east direction down to Juba, and North east up to Renk. Two major basins are connected to this aquifer and their outflow recharges, the basins:

a) The Baggara Basin from the western part of Sudan, and;

b) The Eastern Kordofan Basin from the central part of Sudan.

../..

The main geological units which forms this Basin is the Umm Ruwaba, which consists of fine sediments. These sediments are of clean washed sands with laminated clays. The sands are mainly without pebbles and are well graded. Iron-stained horizons have been recorded. This formation is polygentic and the sediment probably have swept by the Nile and its tributaries, and by the wadis and khors draining the Nuba Mountains and the adjacent areas. These deposits are laid down in a series of land deltas.

The ground water in the Sudd Basin is forming a closed Basin, water is flowing into this Basin from the Baggara Basin north of Bahr El Arab and from Umm Ruwaba Basin north of [illegible] areas, in addition to the ground water of the Sudd Basin flowing to its central part.

The Ground Water levels in the central part of the Basin intersect the surface contours of lower elevations, indicating the possibility of the discharge from the aquifer to the streams and lakes in the Sudd area.

The ground water flowing into the central part of the Basin is some 200 million cubic meters, the major part of this water is believed to be discharged to the surface.

The water levels are near to the surface, they range from 10-25 meters, the ground water movement is towards the central part of the basin, the velocities range from 0.1 to 1.8 meters per year, which compared to the velocities of the other basins is very slow.

The chemical quality of the water is variable, it ranges from 200 - 500 p.p.m. in the peripheral zones of the basin, the salinity increased gradually with distance and depth, in the central part of basin where the water current is sluggish the salinity jumps to 5000 p.p.m.

The annual recharge is some 341 million cubic meters, the amount of water under permanent storage is 11,000 million cubic meters, and the abstraction rates are 1.8 million cubic meters, the saturated thickness is between 100 - 3000 meters.

2. Eastern Kordofan Basin:

The Eastern Kordofan Basin covers the central part of Northern Kordofan Province from North of El Obeid extending in a south east direction down the White Nile. The Basin is covering a NW-SE trough of a maximum thickness of 2 kilometers. The surface area of the basin is 68,392 square kilometers.

The geological formation is mainly Umm Ruwaba which is covered by the qoz sand. The Umm Ruwaba is a series of fluviatile and lacustrino deposits, with numerous facies chaneges. In places the formation thins down cover the Basement Complex.

The chemical quality is hard with total dissolved solids between 500 - 600 p.p.m. in Bara region and it's high in the other parts of the Basin ranging from 1000 - 5000 p.p.m.

../...

The water levels range from 50 - 75 meters in the northern partsof the trough. Some of the water is under artesian pressure (Umm Balagei well). The velocity of the water is slow, between 0.1 to 0.3 meters per year due to the small values of permeability and sluggish gradient. This is the cause of the high total dissolved solids in the eastern part of the Basin.

The saturated thickness ranges between 100 - 500 meters.

The annual recharge is some 15.0 million cubic meters, the basin storage is about 1.710 million cubic meters while the abstraction rates is about 4.5 million cubic meters, which is high.

The main recharge is from the White Nile, and also from the surface flow during the rainy season.

3. Nubian/Umm Ruwaba Basin:

1. Baggara Basin :

This basin covers nearly the whole areas of Southern Dar fur Province and the western part of Southern Kordofan Province. The basin is occupying a big trough extending in a NW - SE direction, with step faults characterizing the shape of the basin, where the deepst part is in the centre of the basin. The area is about 141,316 square kilometers.

The Nubian and the Umm Ruwaba Formations which appear at the surface are underlain by Basement Complex; in some places they are overlain by superficial deposits such as cracking clays, laterites and qoz sand.

The chemical quality is varying as the Basin consists of Nubian and Umm Ruwaba Formations. In the east and west, where the aquifer is mainly Nubian sandstone the total dissolved solids is low ranging between 100 - 400 p.p.m., while in the centre it reaches up to 800 ppm where the main water body is the Umm Ruwaba Formation.

The water levels range from 50 - 75 meters, the deepst water levels are in the central part of the aquifer, the saturated thickness is verying from 100 - 2000 meters.

Ground water is moving from the North, east and west towards central part of the aquifer, from there the ground water moves in a south eastern direction towards the Sudd Basin, the velocities ranges from 0.13 to 1.75 meters per year. The better velocity rates are these of the Nubian Formation.

The annual recharge is some 155 million cubic meters, the basin storage is 7110 million cubic meters while the abstraction rates is about 11.9 million cubic meters, the recharge is being mainly from Northern, Eastern and Western wadis and Bahr El Arab, also recharge takes place by infiltration through the superficial deposits and wadi fill deposits.

../..

2. Blue Nile Basin:

The Blue Nile Basin covers the area between River Rahad and the Blue Nile in the Blue Nile Province and extends in a N" direction along the Blue Nile up to Khartoum and is bordered from the North East by Abu Haraf water devide and from the west by the White Nile, extending over an area of 75,808 square kilometers.

The geological units which form the Blue Nile Basin are the Basement Complex which is acid gneisses and schists with acid and basic volcanic rocks. These are overlain by the Nubian Sandstone formation and the Umm Ruwaba Formation, along the White Nile the beds are more clayey and silty, where as along the Blue Nile sandy deposits are more prominent.

The chemical quality is varying. The total dissolved solids is low along the Blue Nile ranging from 300 to 500 p.p.m. and high along the White Nile ranging between 1000 -- 5000 p.p.m. This is due to the variations of the formations, which accordingly result in variations of permeability recharge, potenialities and contact time between the ground water and the formation.

The water levels range from few meters near the rivers down to a maximum of 50 meters away from the stream. The direction of ground water flow is paralleled to the direction of the surface runoff, i.e. the recharge from the rivers. The saturated thickness is ranging from 100 - 500 meters.

The average velocity is from 1 -- 2.52 meters per year which is rather slow compared to the high permeability rates, but is mainly due to the sluggish gradient.

The basin storage is about 2270 million cubic meters, the annual recharge is about 70.9 million cubic meters, per year.

The areas along the Blue Nile are most promissing for future development.

5. Nubian/Basalt Basin:

1. Gedaref Basin:

The Basin covers the central part of Kassala Province extending over an area of 28,016 square kilometers.

The geology of the basin is formed mainly of Nubian Sandstone formation and Basalts. These basalts are multiple sheets and irrigular intrusions, of "Jurrassic" age, being extended over the Nubian Sandstone formation. The Nubian Sandstone Formation in the Gedaref region is proved to be older than the Nubian Sandstone in the rest of Sulan, i.e. they are classified as "Gedaref Formation", constituted sands, sandy mudstone and mudstones, which sometimes contain conglomerates. In many

../..

places the sandstones are silicified to such an extend that they are almost quartzites e.g. Jebel Manta area.

The base of the Gedaref Formation is varying due to variation of pro- Gedaref topography or to post Gedaref earth movement, represented by the large scale warping and faulting.

The water chemistry is good with low values of total dissolved solids ranging from 500 - 400 p.p.m. in the Gedaref Formation, where as in the basalt the salinity ranges from 1000 to 3000 p.p.m.

The water levels range from 50 75 meters, the water is moving in a North west direction with a velocity of 0.3 to 3 meters. The water is found to be under artesian pressure, locality (Idd El Teen).

The Basin storage is about 700 million cubic meters, the annual recharge is 41.7 million cubic meters per year, while abstraction rates is 1.2 million cubic meters per year.

The saturated thickness of the aquifer ranges from 200-500 meters. The recharge is mainly from the water seeping into the mudstone Formation from River Setit, (branch from River Atbara). The basin is receiving some under flow from adjacent basin in the borders, this amount is estimated to be 12 million cubic meters per year.

2. Shagara Basin:

Shagara Basin is the smallest basin covering an area of 824 square kilometers, west of El Fasher town capital of Northern Darfur Province, and is bounded from the west by Jebel Marra, and is north west of Sag El Naam Basin.

This basin is formed geologically of Nubian Sandstone Formation and basaltic flow in the centre of the Basin.

Water levels are near to the surface, about 25 meters, the saturated thickness of the aquifer ranges between 200-300 meters.

The recharge is from surface flow during the rainy season. The basin is 4.5 million cubic meters, the annual recharge is about 1.1. million cubic meters while the abstraction rates is 0.7 million cubic meters.

4. The Alluvial Basins:

The major alluvial basins are seasonal streams (khors), the runoff in those streams does not exceed three months per year, the runoff during this period is substanial, and the aquifers are completely recharged after the rainy season.

../..

The alluvial deposits are characterised by high transmissivity values and storitivity figures, the shallow depths enabled the natives to develop their own technology of abstracting water for irrigation purposes.

These basins are the oldest known cultivation centres from ground water resources.

Many of these basins are promising future development centres if the infra-structures are developed.

SUMMARY & CONCLUSIONS :

Ground Water Resources will be a governing factor in the development of many areas in Sudan, these resources will be used in multipurposes projects, Industrial, irrigation and livestock. The appraisal of Ground Water resources is expensive and time consuming procedure if exact quantitive estimates are required.

This work is a trial to define these resources, they are based on the available data which in many cases are very scanty. The Author hopes that this trial will shed some light on the importance of these resources, to continue the ground water research projects within defined basins. The estimates of resources in this project were always kept on the low side, so that when the definete figures are reached they will always be higher than the estimated ones.

Some 1381 million cubic meters are estimated to recharge the major basins annually, only 143 million cubic meters of this recharged water is abstracted for different purposes.

Several projects are now developing for the use of Ground Water in irrigation, some 500,000 feddans are planned to be irrigated from Ground Water within the six year plan starting in 1977.

The continuation of the numerous research work is essential for proper utilization of these resources.

REFERENCES :

Abdel Salam Y. (1966)	The Ground Water Geology of the Gesira, M.Sc. Thesis, University of Khartoum.
Davies, S.N. & DEWIEST, R.J.M, (1966)	Hydrogeology, John Willey and Sons, New York.
Hem, J.D. (1956)	Study and Interpretation of the Chemical Charchteristics of Natural Water, U.S.G.S.W.S. 1473.
Hunting Geology & Geophysics Ltd., (1970)	Water Supply & Development in Darfur Province, Report No. 4.
Iskander, Y. (1969)	An appraisal of Ground Water Resources of Zalingei Area, Darfur Province, Sudan M.Sc. Arisona.
Karkanis, B.G. (1965)	Hydrochemistry of North West Sudan, M.Sc. Arizona.
Kheiralla, M.K. (1967)	The Ground Water Geology of the Nile Valley M.Sc. University of Khartoum.
(1973)	Application of Current Techniques in Ground Water Investigation R.W.C. Report No. 85.
Piper, A.M. et al (1939)	Geology & Ground Water Hydrology of Nokelume Area U.S.G.S.W.S. No. 780.
Saeed, E.M. (1969)	Ground Water Appraisal of the Gash River Basin, G.S.B. No. 17.
Salama, R.B. (1971)	Hydrogeology of Wadi Nyala, M. Sc. London.
-	Water Provision in the Problem Areas using water Harvesting Techniques, R.W.C. Report No. 21.
- et al	Geology & Hydrogeology of Southern Province, R.W.C. Report No. 2.
Tahir, M. H. (1975)	Hydrogeological Investigation of Khor Arbaat Basin G. & M.R. Bulletin No.28.
Walton, W.C. (1970)	Ground Water Resources Evaluation, McGraw-Hill Book Company, New York.
Whiteman, A.J. (1971)	The Geology of the Sudan, Oxfor.

Ground Water Potentialities of the Basins

Ground Water Basin	Underflow Milion m^3	Recharge million m^3	Basin Storage million m^3	Abstraction million m^3 Year	Percentage of Abstraction to Recharge
I Nubian Basin					
1. Sahara Nile Basin	7,3	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	5.6	11.82
4. Nuhud Basin	1.5	15.4	136	2.5	16.49
5. Sag El Na'am Basin	1.3	14.8	134	1.5	9.89
6. River Atbara Basin	3.7	23.0		0.5	1.90
II Umm Ruwaba Basin					
1. Sudd Basin	50.8	341.0	11000	1.9	0.54
2. Eastern Kordofan B	2.3	15.8	1710	4.5	28.31
III Nubian/Umm Ruwaba B					
1. Baggara Basin	22.7	154.6	7110	11.9	7.71
2. Blue Nile Basin	10.	70.9	2270	21.6	30.00
IV Nubian/Basalt Basin					
1. Gedaref Basin	6.1	41.7	700	4.2	10.14
2. Gedaref Basin	1.0	1.1	4.5	0.7	64.22
V. Alluvial Basins					
1. Nyala 2.Azum 3.Kutum 4. Ubra 5.Abu Gebeiha 6. Arbaat 7. Khor Barka	45.0	500		80.0	16.00

-/ANIS

Characteristics Of The Basins

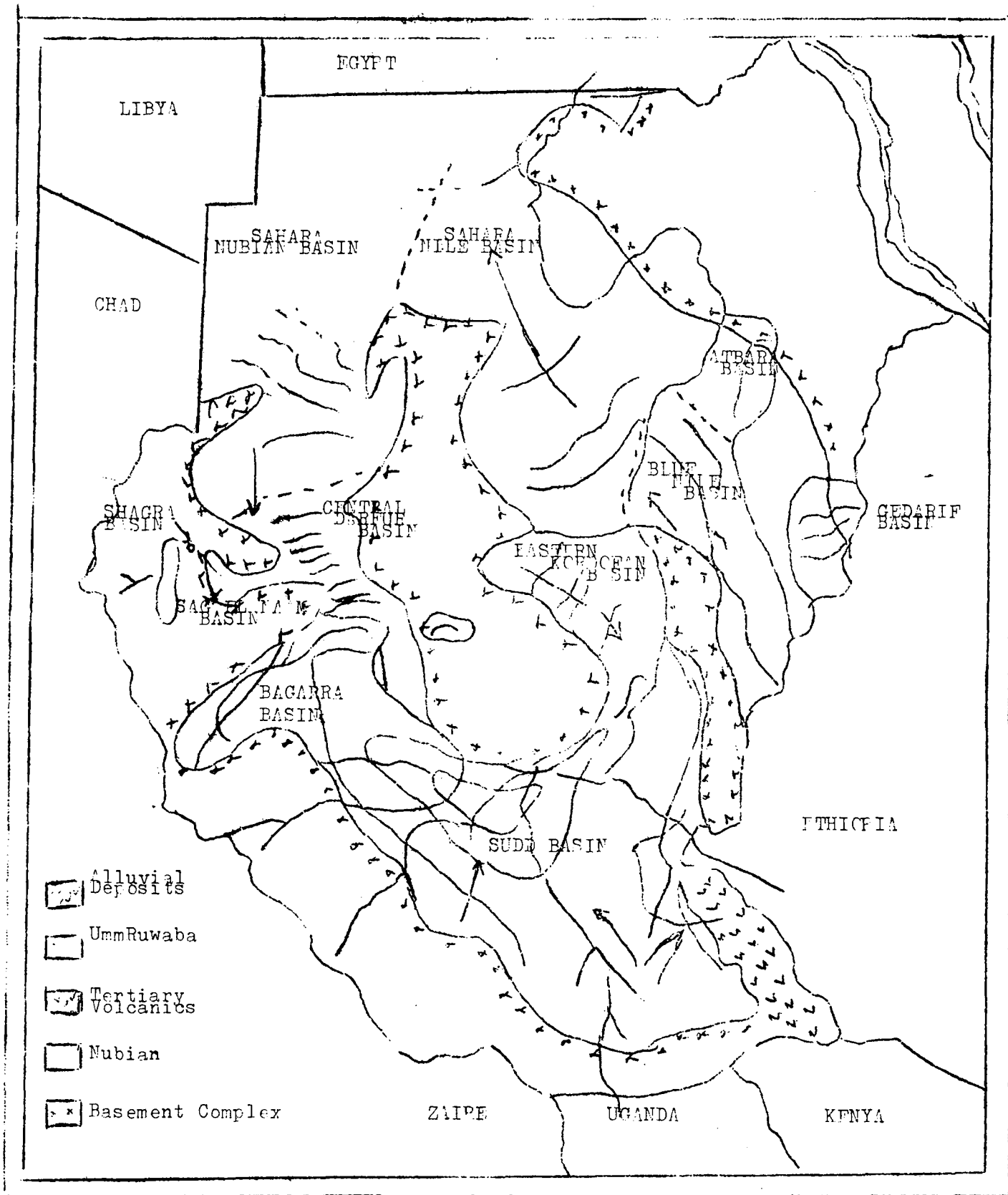
Ground Water Basins	Depth to Water : meters	Saturated Thickness : meters	Area of The Basin square kilometers
I Nubian Basins			
1. Sahara Nile Basin	10-25	100-500	273,980
2. Sahara Nubian Basin	10-50	100-1000	324,356
3. Central Darfur Basin	25-100	100-350	52,9[illegible]4
4. Nuhud Basin	100-120	150-250	6,798
5. Na'am Basin	50-100	500-2000	2,678
6. River Atbara Basin	10-100	100-500	23,896
II Um Ruwaba Basins			
1. Sudd Basin	10-25	100-3000	365,268
2. Eastern Kordofan	50-775	100-500	68,392
III Nubian/Umm Ruwaba B.			
1. Baggara Basin	30-75	100-2000	141,376
2. Blue Nile Basin	10-50	100-500	75,808
IV Nubian/Basalt Basins			
1. Gedaref Basin	5[illegible]75	200-500	28,016
2. Shegara Basin	25	200-350	,,824
V Alluvial Basins:			
1. Nyala 2. Azum 3. Kutum 4. Ibra 5. Abu Gebeiha 6. Arbaat 7. Khor Barka 8. El Gash	3-10	10-50	

GROUND WATER RESOURCES OF THE BASINS

Ground Water Basins	Present State of Development	Management state	Future potentialies	Areas for future Development & Detailed studies
I Nubian Basins				
1. Sahara Nile	Undeveloped	Required	Excellent	1. Wadi El Khuwei El Qaab 2. Wadi El Muggdam
2. Sahara Nubian	Undeveloped	Required	Excellent	1. Wadi Hawar.
3. Central Darfur Basin	Developed	Required	Good	1. Umm Byada 2. Saniya Haiyei
4. Nubin Basin	Developed	V. Essential	Good	1. Haidob Field
5. Sag El Na'am Basin	Developing	V. Essential	Excellent	1. The whole Basin
6. River Atbara Basin	Undeveloped	Required	Excellent	1. Lower River Atbara
II Umm Ruwaba Basins				
1. Sudd Basin	Undeveloped	Required	Excellent	Regional study to establish northern areas.
2. Eastern Kordofan B.	Developed	Required	Fair	
III Nubian/Umm Ruwaba B.				
1. Baggara Basin	Developing	Essential	Good	Town localities from town supply.
2. Blue Nile Basin	Developing	V. Essential	Excellent	Along the Blue Nile
IV Nubian/Basalt Basins				
1. Gedaref Basin	Developed	Required	Poor	-
2. Shagera Basin	Well Developed	V. Essential	Fair	-
V. Alluvial Basins				
1. Wadi Nyala	Developing	V. Essential	Good	1. Down stream to Nyala
2. Wadi Asum	Undeveloped	Essential	Good	1. Dankuch 2. Umm Bala
3. River Gash	Well Developed	Essential	Good	Zalengi
4. Wadi Kutum	Developed	Essential	Good	At Kutum area
5. Khor Barka	Undeveloped	V. Essential	Good	Tokar Delta
6. Abu Gebeiha	Abu Gebeiha	Essential	Good	
7. Arbaat	Well Developed	Required	Good	
8. Ibra	Undeveloped		Fair	

Ground Water Basins	T m^2/day	K m/day	I m/km	V m/year	S
I Nubian Basin					
1. Sahara Nile Basin	100-1000	3-10	4.0×10^{-4}	0.44-1.46	10^{-4} -10^{-5}
2. Sahara Nubian Basin	500-1000	1-5	1.13×10^{-3}	0.41-2.06	10^{-2}- 10^{-4}
3. Central Darfur Basin	300-700	0.5-10	1.75×10^{-3}	0.32-6.4	10^{-4}
4. Nuhud Basin	300-1000	5-15	5.0×10^{-4}	1.0 -2.74	10^{-2}- 10^{-4}
5. Sag El Na'am Basin	500-1000	1-20	3.5×10^{-3}	1.33-25.5	10^{-2} -10^{-4}
6. River Atbara Basin	100-1000	3-10	1.0×10^{-3}	1.1 -3.65	10^{-2} -10^{-4}
II Umm Ruwaba Basins					
			1.0×10^{-3}	0.18-1.8	
1. Sudd Basin	100-500	0.5-5	5.0×10^{-4}	0.09-0.27	10^{-2} -10^{-5}
			3.0×10^{-4}	0.05-0.15	
2. Eastern Kordofan B.	100-500	0.5-5	5.3×10^{-4}	0.1 -0.27	10^{-4} -10^{-5}
III Nubian/Umm Ruwaba B.			3.6×10^{-4}	0.13-1.97	
1. Baggara Basin	250-750	1-15	1.2×10^{-3}	0.45-6.75	10^{-2} -10^{-4}
			75×10^{-3}	0.27-4.10	
2. Blue Nile Basin	500-2000	10-30	2.3×10^{-4}	0.84-2.52	10^{-2} -10^{-4}
IV Nubian/Basalt Basins					
1. Gedaref Basin	100-250	0.5-5	1.7×10^{-3}	0.31-3.1	10^{-4} -10^{-5}
2. Shagera Basin	100-250	0.5-5	9.0×10^{-4}	0.16-1.6	10^{-4}
V Alluvial Basins					
1. Nyala 2. Azum 3. Kutum 4. Ibra 5. Abu Gebaiha 6. Arbaat 7. Khor Barka	300-3000	3-20			10^{-2}

GROUND WATER BASINS IN SUDAN
MAJOR BASINS



GROUND WATER BASINS IN SUDAN
ALLUVIAL BASINS