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GROUND WATER IN WATER RESOURCES PLANNING

KOBLENZ, FEDERAL REPUBLIC OF GERMANY
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IN THREE VOLUMES
VOLUME I

PROCEEDINGS OF A SYMPOSIUM

convened by Unesco and organized in co-operation with the National Committee of the Federal Republic of Germany for the International Hydrological Programme and the Operational Hydrological Programme and technical and scientific counterpart organizations in the Federal Republic of Germany. The symposium is also organized in co-operation with the United Nations Department of Technical Co-operation for Development (UN/DTCD) and endorsed by the United Nations International Children's Emergency Fund (UNICEF), the Food and Agriculture Organization (FAO), the World Health Organization (WHO), the World Meteorological Organization (WMO), the International Association of Hydrological Sciences (IAHS), the International Association of Hydrogeologists (IAH), the International Commission on Irrigation and Drainage (ICID), and the International Water Resources Association (IWRA).

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FOREWORD

The National Committee of the Federal Republic of Germany for the International Hydrological Programme of UNESCO and for the Operational Hydrological Programme of WMO made an offer to UNESCO in 1979 to organize an International Symposium on „Ground Water in Water Resources Planning" and an International Workshop on „Ground Water in Rural Water Supply". In 1980 the General Conference of UNESCO accepted the offer and included the Symposium and Workshop in the general scope of the second phase of the International Hydrological Programme as IHP Projects A.2.11.1 and A.2.11.2.

Ground water is indispensable for water supply. However, ground-water resources are often subject to overdevelopment and to impairments in quality. The Symposium provides specialists in the fields of science, engineering, operations and management with the opportunity to discuss questions, problems and results of studies that arise from the restrictions, shortage and endangering of ground-water resources and that represent essential fundamentals of water resources planning.

By publishing three volumes, the organizers of the Symposium as well as the International Association of Hydrogeologists (IAH) and the International Association of Hydrological Sciences (IASH) wish to make the results of the Symposium accessible to all those scientists who could not participate in the Symposium.

The first two volumes comprise the papers submitted. The papers have been classified into the six subjects of the Symposium: importance of ground water in different regions, economical, social and institutional aspects, practicability of planning concepts; technical base for planning; multiple demand and conflicts; planning and management; hazards for and protection of the ground water. In a third volume the inaugural addresses of the Symposium and the reports of the general reporters are published.

For the organisation of the Symposium the German National Committee appointed a committee which has been working with the cooperation of: Armbruster, Offenburg; Dr. Böckh, Hanover; Buske, Berlin; Colenbrander, The Hague; Dr. Dirksen, Bonn; Dr. Eylers, Eschborn; Dr. Gladwell, Paris; Dr. Groba, Hanover; Dr. Hofius, Koblenz, Dr. Hölting, Wiesbaden; Dr. Lecher, Hanover; Dr. Lühr, Berlin; Dr. Massing, Düsseldorf; Dr. Merkel, Eschborn; Romijn, Amsterdam; Dr. Schwille, Koblenz (Chairman); Strähle, Stuttgart.

Redacted for privacy

(Dr. K. Hofius)
Secretary of the IHP/OHP National Committee
of the Federal Republic of Germany

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DESHMUKH, D.S., et al. (1973): Geology and groundwater resources of the alluvial areas of West Bengal: Bulletin Geological Survey of India, Series B, No. 34, p. 1-351

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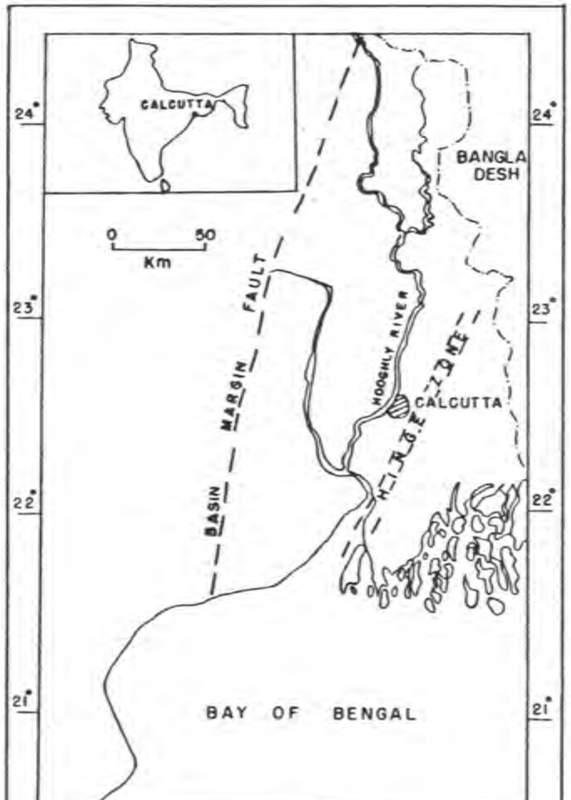

MAP SHOWING LOCATION OF CALCUTTA REGION IN THE WESTERN PART OF THE BENGAL BASIN

Figure 1

GROUNDWATER RESOURCES EVALUATION AND POSSIBILITIES OF THEIR DEVELOPMENT IN THE AREA OF THE THREE TOWNS (KHARTOUM PROVINCE, SUDAN)

Hans Bender, Manfred Hobler, Klaus Krampe

ABSTRACT

Hydrogeological and geophysical investigations were carried out in the area of Khartoum during 1976 to 1978. Aquifer parameters of the groundwater system in the Nubian sandstone aquifer were determined and its hydraulic principles clarified. A quantitative assessment of the groundwater flow was accomplished. Model simulations done for a part of the study area resulted in the determination of the extractable quantities in a well field and the expected drawdown. For three type areas well designs were elaborated and the cost of pumped water at the well head was calculated.

RESUME

Dans la région de Khartoum des explorations hydrogéologiques et géophysiques ont été effectuées pendant la période de 1976 à 1978. Les paramètres du système d'eau souterraine dans la nappe aquifère gréseuse de la Nubie ont été déterminés et leurs principes hydrauliques ont été éclaircis. On a réussi à estimer l'écoulement en sens quantitatif. Les simulations exécutées à l'aide des modèles pour une partie de la région étudiée ont eu pour résultat de pouvoir déterminer les quantités d'eau extractibles dans un champ de puits ainsi que les rabattements auxquels on peut s'attendre. Des plans de puits ont été élaborés pour trois types de région et les dépenses des pompages d'eau aux avant-puits ont été calculées.

PURPOSE, INVESTIGATIONS, RESULTS

The recent expansion of irrigated areas in the Democratic Republic of Sudan is linked with almost the total consumption of the Sudanese share of Nile water. In order to meet the fast growing water demand, optimal utilization of groundwater will become increasingly important.

From March 1976 until April 1978 the German Hydrogeological Team in cooperation with its Sudanese Counterpart, the Geological and Mineral Resources Department, carried out field investigations for the purpose of evaluating the groundwater resources of the central part of Khartoum province in the area of the confluence of Blue and White Nile (Three Towns area). The study comprised an inventory of groundwater occurrences, the prospection of groundwater, predictions on the effects of a more intensive groundwater exploitation, a quantitative estimation of exploitable groundwater resources and recommendations for their optimal utilization. This includes the observation and supervision of groundwater exploitation and the reaction of the aquifers. The hydrogeological studies included monitoring fluctuations of the groundwater table, geoelectrical investigations, borehole logging, drilling of test wells, pumping tests, and simulation model investigations.[1)]

The aquifer system is mainly developed in the Nubian Sandstone Formation and partly in the Gezira Formation. The practically impervious basement complex forms the horizontal boundary at the base of the system as well as the lateral boundary in the eastern part of the study area.

The Nile rivers are almost the only source of groundwater recharge; the groundwater table dips away from the rivers on both sides. West of the Nile the groundwater flow shows a westbound direction. East of the Nile rivers however, the groundwater initially moves eastwards, than turns into a vertical downward direction forming several depressions in the groundwater table. At depth the groundwater flow finally changes to a horizontal westbound direction and passes beneath the Nile river at greater depth. As a result, west of the Niles the regional groundwater flow is composed of both the portion which originated on the western side and the other one which originally moved eastwards. The hydraulic regime of the system can figuratively be described as the "Nile role" (Fig. 1).

The base level of the total westward-bound groundwater flow is

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1) The authors are grateful to Mr. G. SCHMIDT and Dr. K. TRIPPLER of BGR, Hannover, for carrying out the simulation model investigations.

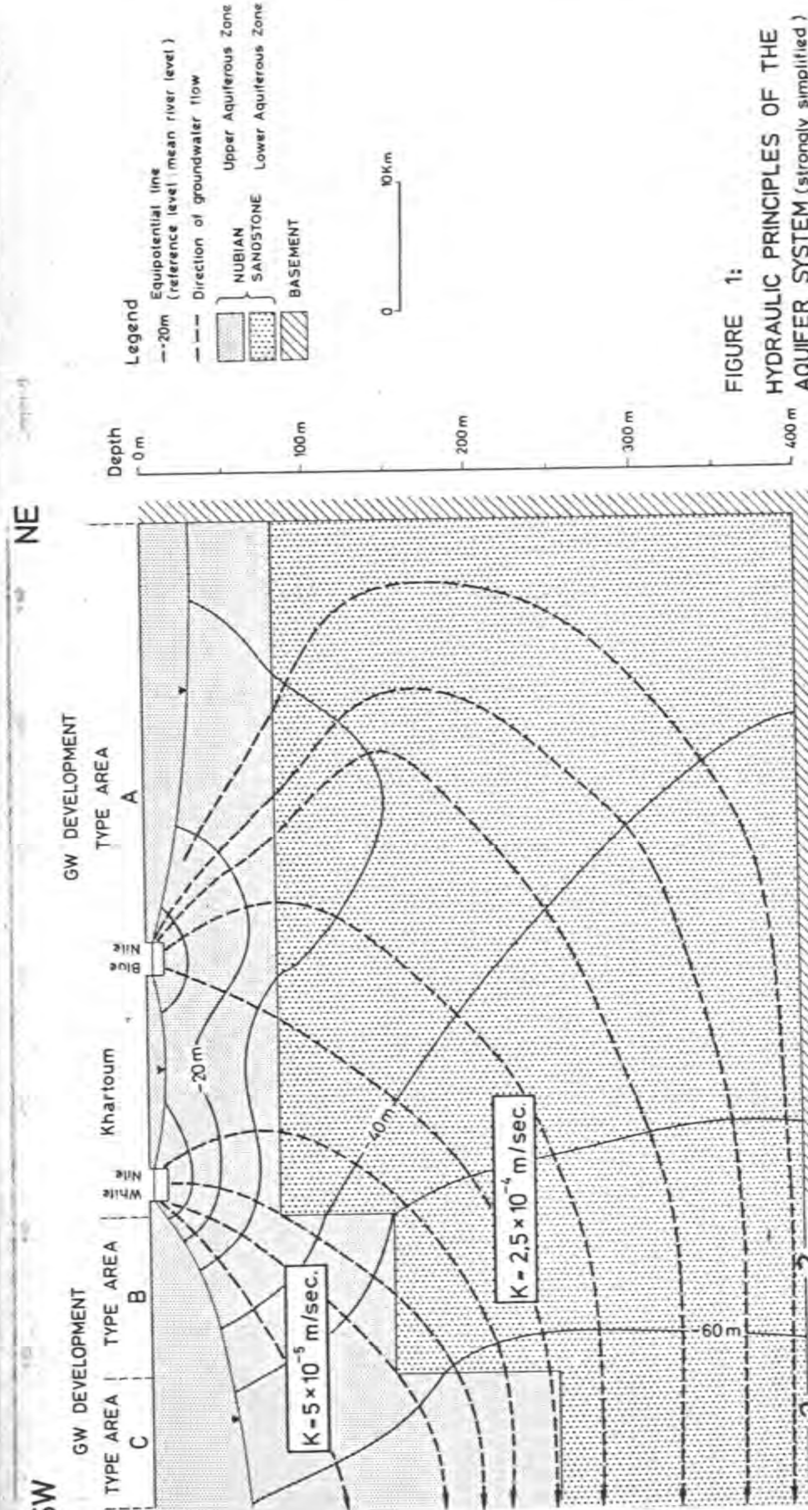

FIGURE 1: HYDRAULIC PRINCIPLES OF THE AQUIFER SYSTEM (strongly simplified)

not known. Presumably it is directed towards the Nile upstream of Dongola where the river could be of influent nature.

In general there is a relation between permeability and groundwater salinity: drainage zones are marked by low mineralized groundwater. Such zones penetrate far inland from the river to the depressions in the groundwater surface. These depressions can be explained as areas of higher vertical permeability. Here the groundwater is drained to the lower part of the system where relatively high permeabilities occur.

The groundwater salinity of the uppermost part of the saturated zone ranges from fresh to saline. However, numerous boreholes prove the existence of fresh groundwater at greater depths (see Fig. 2).

The aquifer system can be subdivided into an Upper and a Lower Aquiferous Zone. The thickness of the upper zone ranges between zero and more than 300 m. The thickness of the lower one can exceed 400 m. It is of great importance for the groundwater management that the permeability of the lower zone is larger by a factor of about 10 compared with the upper one:

$$k_{upper} = 5 \times 10^{-5} \text{ m/sec}, \quad k_{lower} = 2.5 \times 10^{-4} \text{ m/sec}$$

Due to the great thickness and relatively high permeability the Lower Aquiferous Zone may be considered quite appropriate for large-scale exploitation of water, such as irrigation and town water supply.

Since the depth to the Lower Aquiferous Zone varies throughout the study area (e. g. often more than 400 m below surface in the southern part between Blue and White Nile) three type areas for

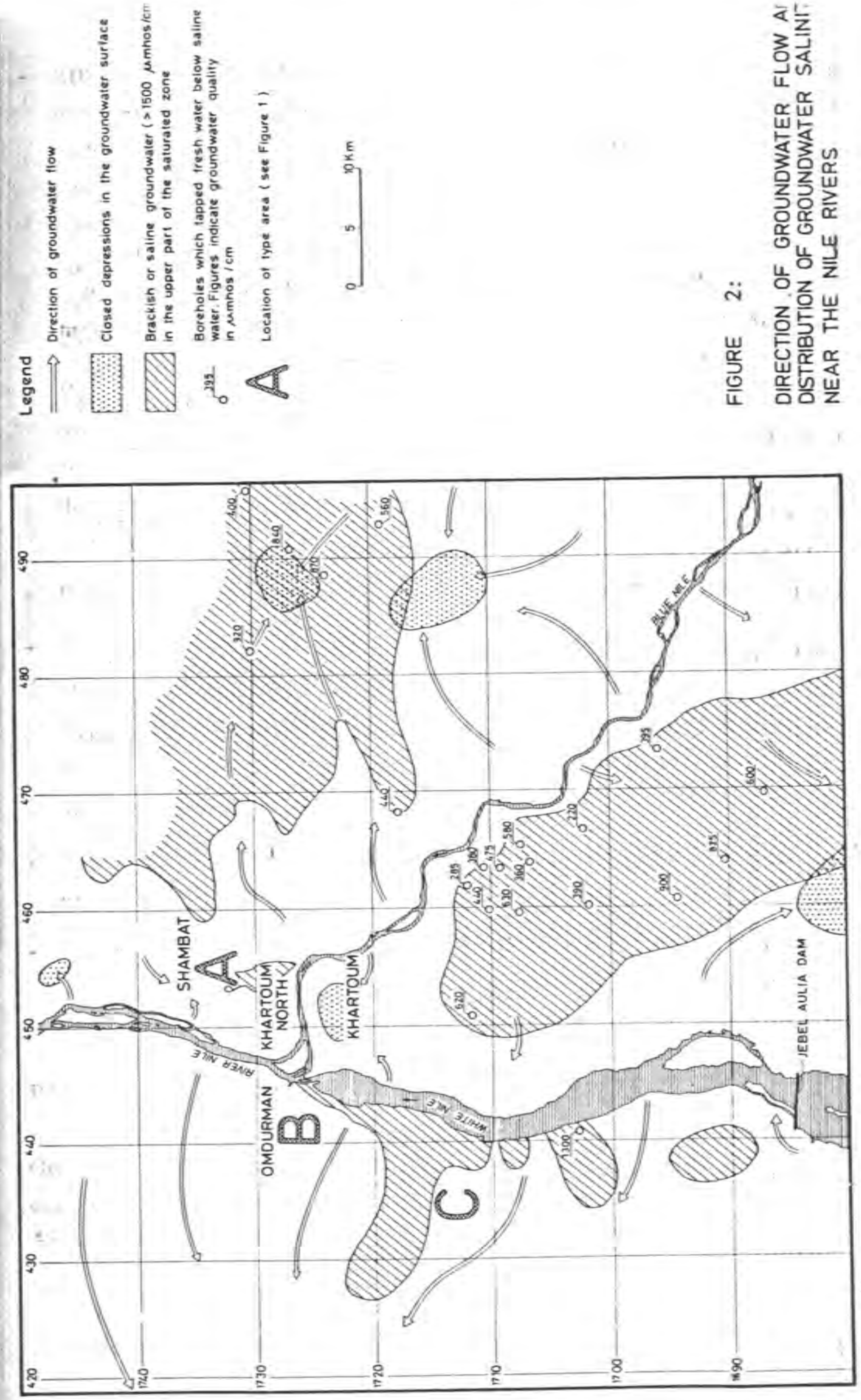

FIGURE 2: DIRECTION OF GROUNDWATER FLOW A
DISTRIBUTION OF GROUNDWATER SALINI
NEAR THE NILE RIVERS

groundwater development have been distinguished (see Fig. 2 and 3). For these type areas, A, B, and C, recommendations were elaborated on the optimal well design, well costs and the cost of groundwater under different irrigation concepts.

For a quantitative assessment of the groundwater flow simulation model investigations were carried out. As a model area the region north of Khartoum North was chosen. Here groundwater development is extensively advanced. However, the model studies show that a multiple increase of groundwater extraction is possible. The actual pumping which causes a maximal drawdown of about 10 to 12 m amounts to approximately $19 \times 10^6 m^3$/year. If the additional water demand is met by tapping the Lower Aquiferous Zone, an increase of the groundwater exploitation to about $100 \times 10^6 m^3$/year would cause a maximal drawdown of less than 20 m.

Applying the results of the model simulations and general considerations on the hydraulics of the system the total amount of groundwater which underflows the study area is estimated to be approximately $300 \times 10^6 m^3$/year.

GENERAL WATER STRATEGY ASPECTS

Water requirement will exceed the presently available resources of the Sudan in the near future (SALIH, 1978). However, in the Nubian Sandstone Formation especially in its Lower Aquiferous Zone there is a very important, almost untapped reservoir of groundwater available in the area of the "Three Towns". Besides the possibility of reducing the Nile water extraction the utilization of groundwater offers the following advantages:

TYPE AREA C

- Water can be tapped by drilling wells at the point where it is needed. This makes the installation of expensive distribution systems to isolated consumers unnecessary. Isolated areas of arable land become economically usable; e. g. in the area of the Three Towns there are many patches of suitable farm land lying idle because obstacles like occupied housing and farming areas, roads or big distances from the river do not allow the transmission of river water to the land.

TYPE AREA B

- Minimum costs of water treatment, because the removal of silt, filtration, and chemical treatment for disinfection are normally not necessary. The quality of groundwater remains the same throughout the year in contrast to the high silt content of Nile water during flood season
- Extraction is practically not affected by water level fluctuations

TYPE AREA A

- Development proceeds successively according to need and financial capabilities. Investment costs can be distributed between various enterprises
- Decentralized water exploitation makes the consumer independent of a widespread collapse of the supply system
- Groundwater is the only reliable source of water in the semi-arid areas distant from the Nile
- Animal quarantine stations located at a safe distance from the Three Towns can be supplied with water.

RECOMMENDATIONS FOR GROUNDWATER DEVELOPMENT

Groundwater for domestic water supply and watering of live-stock can be found almost everywhere in the study area. The Upper Aquiferous Zone in most areas yields sufficient water for the purpose of rural water supply. Even in areas where brackish groundwater occurs at a shallow depth, suitable groundwater can be found at a greater depth.

For large-scale production, such as irrigation and town water supply, tapping of the Lower Aquiferous Zone is necessary. The most favorable areas for this purpose are situated east of the blue Nile, on both sides of the main Nile, and west of Omdurman.

In some regions the groundwater is not suitable for irrigation. Most of them coincide with areas where the groundwater table is deep (more than 10 km east of Khartoum, e. g. area of Esh Sheikh el Amin), or the Lower Aquiferous Zone is situated at great depth (southwestern part of the study area around the White Nile).

In general, the special agricultural and economical situation of the Khartoum area suits the economical use of groundwater for irrigation: Irrigable land is often available in small plots only, the distances to a market with a high demand for cash crops are short, the export of high priced agricultural goods to neighbouring countries is favoured by the short distance to the airport. Agro-economical calculations for model farms showed that vegetable growing results in reasonable farm income for owner and farmer.

Recommendations for the development and utilization of groundwater in the type areas, A, B, and C are given in the following:

A comparison of the results of water cost calculations shows that in the type areas A and B the deeper wells yield the more profitable water production (see Fig. 3). The area of Shambat (type area A) was chosen for time depending well field models (Theis solution) in order to determine the optimal well field design of an irrigation area.

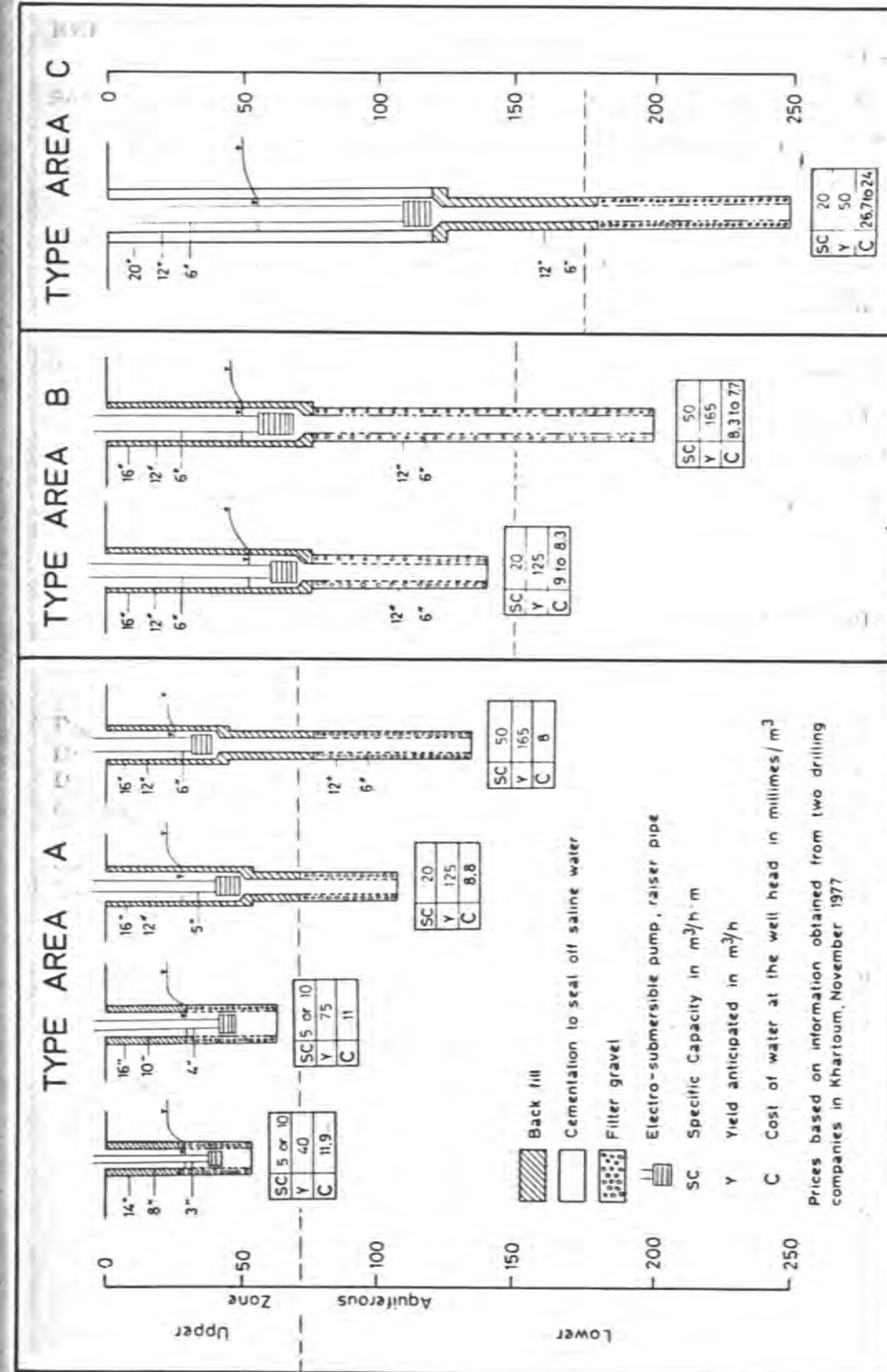

Figure 3: Well design and cost of water at the well head

For the irrigation of an area of 1000 feddan (420 ha) approximately 12×10^6 m^3 of water are necessary yearly. If an aquifer thickness of 300 m, and a permeability value of $k = 2.5 \times 10^{-4}$ m/sec ($T = 6480\ m^2/d$) are assumed, as can be expected for the Lower Aquiferous Zone, 9 wells located 600 m apart would be sufficient to produce this amount of groundwater. According to the model calculations, drawdown would still be less than 10 m after 50 years of pumping.

From the technical point of view, irrigation units of medium size with few deep boreholes are preferable to small units with many shallow boreholes. If groundwater is drawn from the Lower Aquiferous Zone, a much smaller drawdown can be expected and the total number of drilling meters for production of the same amount of water would be considerably reduced. In case the farm size does not allow the investment in an individual deep borehole, joint establishment and use of one well for a group of farmers is recommended.

In type area C, west of the White Nile, the hydrogeological conditions (brackish to saline water in shallow depth; top of Lower Aquiferous Zone more than 150 m below surface) are not favourable for irrigation. In addition, soil conditions are generally poor. However, the high cost of groundwater (Fig. 3) does not exclude its use for the water supply of towns and villages. Besides, the Sudanese administration has selected that section for new residential and industrial areas.

Finally it is recommended that large-scale exploitation of groundwater should always be implemented in stages. The results of initial development stages should then be used for the updating of model calculations.

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