GROUND WATER IN WATER RESOURCES PLANNING

KOBLENZ, FEDERAL REPUBLIC OF GERMANY
28 AUGUST–3 SEPTEMBER 1983

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).

CONTROL OF GROUND-WATER LEVELS IN CAIRO, EGYPT, AFTER THE HIGH DAM

Tahani Youssef

ABSTRACT

An evaluation of the ground-water reservoir underlying the town of Cairo, Egypt, is conducted in this work. The results obtained include the ground-water flow rates, direction of flow and fluctuation of the ground-water table. These results may be helpful in investigating the reasons for the huge rise of the ground-water table below Cairo in the last few years. The study is conducted numerically using the method of finite elements on a two-dimensional mathematical model which represents the area. The different factors which influence this ground-water reservoir are mainly the amounts of discharge of the existing pumping stations, the amounts of seepage to or from the River Nile which crosses the town and the rates of waste water leakage from the existing old sewage and water systems. It is observed in nature and also on the model that a sudden rise of the water table in some parts of the area occurred after the construction of the High Dam. Recommendations for lowering the ground-water table are given. Suggested locations of new pumping stations and discharge rates which correspond to withdrawals are presented.

RESUME

Le rapport présente une évaluation de la nappe aquifère située au-dessous de la ville Caire/Egypte. Les résultats de l'étude comprennent les valeurs spécifiques de l'écoulement souterrain, la direction d'écoulement et les fluctuations dans le niveau d'eau souterraine. Ces résultats contribuent à la clarification des raisons de la montée énorme de la nappe souterraine sous Caire dans les années dernières. On a fait une étude numérique, en appliquant la méthode des éléments finis sur un modèle mathématique à deux dimensions qui représente le site étudié. Ce réservoir d'eau souterraine est influencé par les facteurs suivants: les débits des stations de pompages existantes, les infiltrations affluentes et effluents vers et de la rivière Nil qui coule à travers la ville, ainsi que le coulage de vieux systèmes de purification des eaux d'égout existants. On a observé en nature et sur le modèle qu'une élévation subite de la surface d'eau souterraine s'ensuivit après la construction du Grand Barrage. Le rapport donne des recommendations pour l'abaissement du niveau de la nappe souterraine. Les emplacements proposés pour de nouvelles stations de pompage et les taux de débits qui correspondent aux soutirages d'eau souterraine sont présentés.

INTRODUCTION

One of the major and important problems which has to be faced by any civil engineer, agricultural engineer or a geohydrologist in Egypt is the huge rise of ground-water levels in the River Nile valley starting from north of Sudan up to the Nile Delta after the construction of the High Aswan Dam. This phenomena is being studied by different specialists and research institutes inside and outside the country with the purpose of determining the effect of that rise on different engineering fields such as agriculture (i.e., crops, irrigation, drainage), building foundations, ground water, water quality, etc.

If we move 680 km northwards downstream for the High Aswan Dam to Cairo, a very complicated problem concerned with the ground-water reservoir below the Egyptian capital arises. In order to investigate this problem, a simulation of the ground-water reservoir is conducted using a two-dimensional mathematical model.

The boundaries of the chosen model are illustrated in Figure 1.

FORMULATION OF THE PROBLEM

Before presenting the technical problem let us give some statistical figures about some factors which may be directly or indirectly responsible for raising the ground-water level.

Table 1: Comparison between some factors in 1962 and 1979

Factor	1962	1979
I Inhabitants	6 Mill.	11 Mill.
II Number of water treatment plants	4	4
III Number of sewerage plants	3	3
IV Yearly average Nile water level in Roda station Cairo	H.W.L.(20.41) L.W.L.(14.78)	(16.80)

The above figures lead generally to one conclusion, being that a huge excess in the volume of the ground-water reservoir lying below the Egyptian capital has taken place in the last 20 years. The author wishes, by carrying out this research, to determine the amount of increase of the ground-water reservoir, reasons causing that increase and also to put forward some recommendations which may help in causing a withdrawal in the ground-water levels in Cairo.

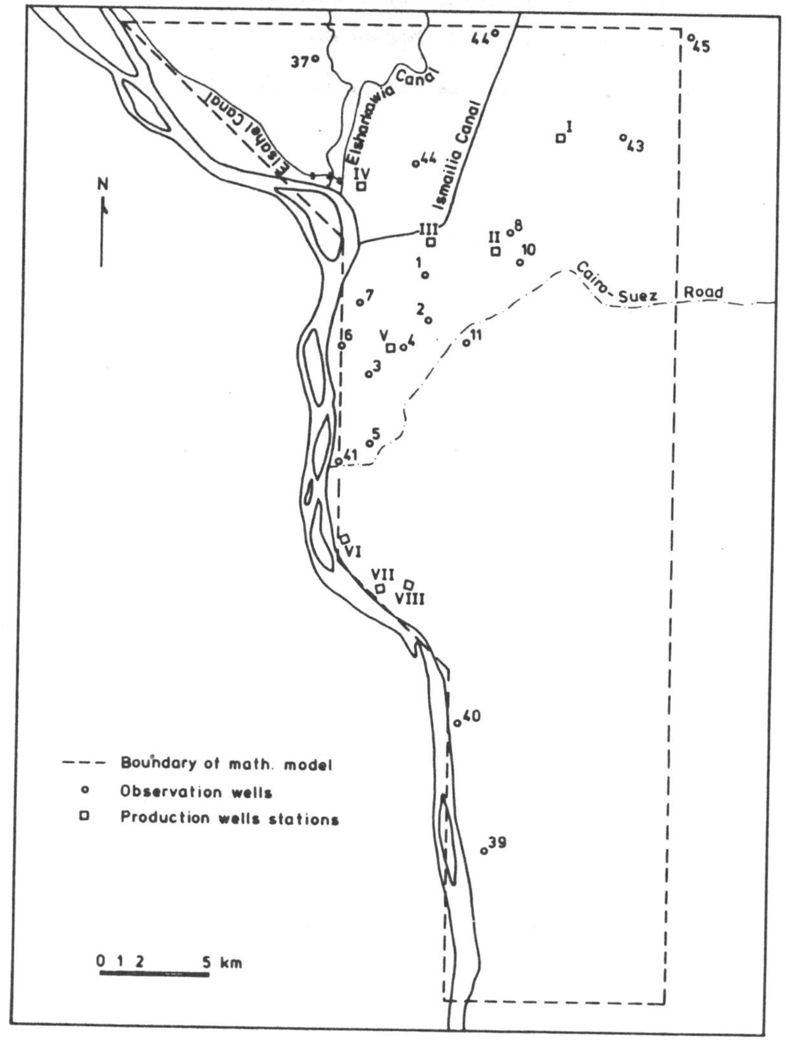

Figure 1. Boundaries of the Mathematical Model

GEOLOGICAL, HYDROLOGICAL AND METEOROLOGICAL CONDITIONS IN THE AREA

A technical report presented by the geology committee (1975) illustrates the complications in the underground structure below Cairo. The area is characterised by the existence of a big number of faults with different depths and in all possible directions (Fig. 2). However, the hydrologic section can be generally considered to be composed of a thin layer of clay not exceeding 10 m, underlain by a relatively thick water-bearing sandy aquifer of about 60 m thickness.

Thus, the assumption that the aquifer has a uniform thickness of 60 meters and is bounded from the top by a thin layer of clay (leaky aquifer) can be considered to be acceptable. In Figure 2 the location of production and observation wells in the area are also indicated. Water levels have been recorded daily since 1976. These wells are dug, controlled and maintained by the Ministry of Irrigation in Egypt. Data of a few pumping tests and analyses are also available. As the average yearly rate of rainfall in Cairo is slightly less than 20 mm, rain water infiltration to the ground-water body is too low to be considered.

As the number of sewerage plants and the whole sewerage system and pipelines in Cairo are all supposed to be unchanged since their construction started 100 years ago, and with a quick look at the increase in the number of inhabitants in the last twenty years (Table 1), it is obvious that the efficiency of the sewerage network must have decreased considerably. This results (among other effects) in an increase in the amount of leakage from the sewerage networks through the soil reaching the ground-water body.

Unfortunately, the exact percentage of this leakage is not known. A technical report of the AMBRIC (June 1980) gives an average value for leakage from sewerage conduits as well as infiltration from gardens and irrigated lands. This value is taken to be 10 % of the sewerage system discharge.

CONSTRUCTION OF MATHEMATICAL MODEL

The area of study extends to the political boundaries of the Cairo Governorate (Figure 2). It is bounded to the west by the River Nile, to the north and to the south, by the borders between the Cairo Governorate and the "Qualiubia" and "Beni Suif" Governorates respectively. To the east it is bounded by the eastern desert beginning with the chain of Mockattam Hills.

A two-dimensional mathematical model is constructed to cover the area of study described above. The area represented by the model is about

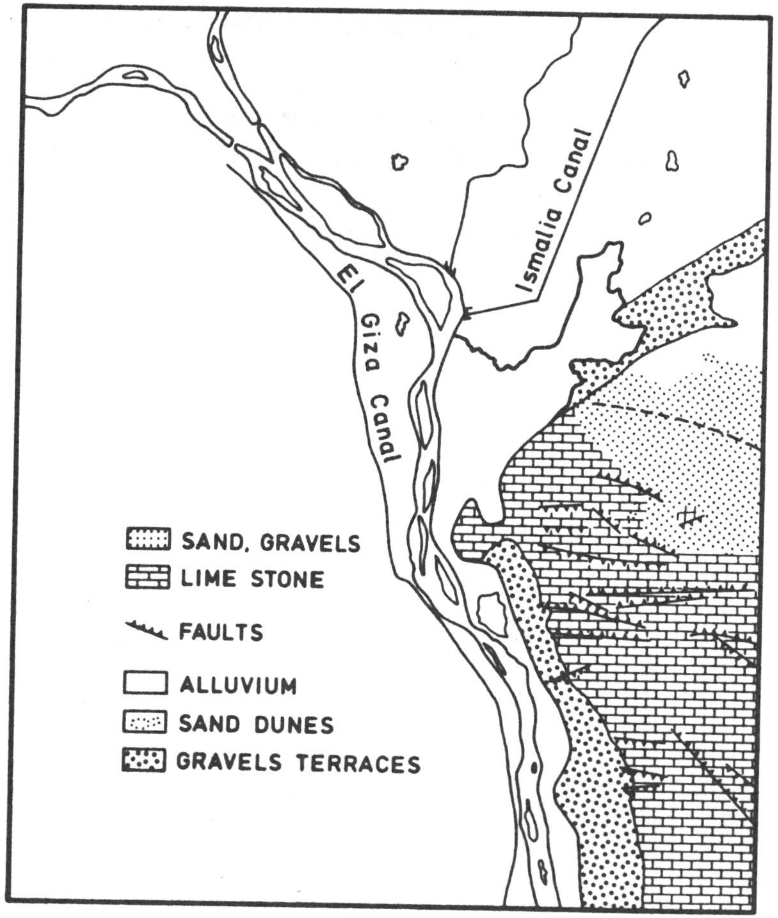

Figure 2. Geological Map for Greater Cairo Region

634 square kilometers. The simulation is conducted by applying the method of finite elements where the area is divided into 102 triangular elements having 66 nodal points.

FIELD DATA ANALYSES

The hydrographs shown in Figure 3 represent the water levels of the River Nile at El-Roda observation station in Cairo. They represent the water levels in years 1963 and 1979. From comparison of the two hydrographs, it can be concluded that the levels in 1979 are generally higher than those in 1962, except during flood months which begin in August until the end of October.

On the other hand, Figure 4 illustrates the same hydrograph of the river at the same location, and those of some observation wells in Cairo in the year 1979. From the hydrographs, it can be concluded that a steady difference of about 1.10 meters exists between the river hydrograph and that of observation well No. 41 which is about 350 m away from the river bank. Noting that the distances from wells 41 and 5 to the river bank are 350 m and 1750 m respectively, we can say that the Nile acts as a big drain for the ground water near to its banks, and as we move eastwards, ground-water levels get higher. It can be also observed that the ground-water gradient towards the River Nile is not constant but varys from about 170 cm/km to 285 cm/km. This means by a quick estimation that the velocity of ground-water flow towards the Nile exceeds 1.7 meters/second. The value of the velocity component of ground water, moving in the westerly direction does not remain constant but increases with the distance.

This simple conclusion presents a very critical problem concerning the foundations of the buildings lying near to the Nile banks in Cairo. The effect of uncontrolled sewerage in Cairo appears very clear when we compare the hydrograph No. 45 which represents the ground water in the north-east of Cairo with that of the Nile. In that location, in spite of the fact that the area is not heavily populated, the rise of the ground-water table may be caused by leakage from the existing old sewerage pipes and canals to the underground.

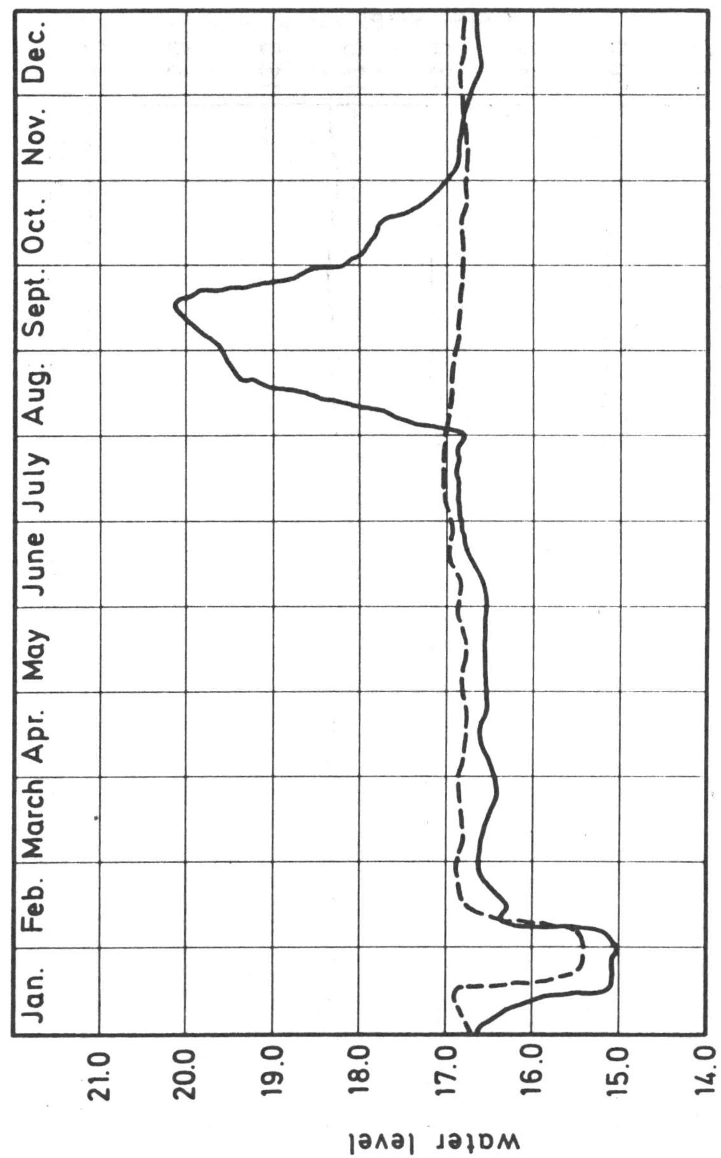

Figure 3. River Hydrographs (El Roda Station) —— 1963 --- 1979

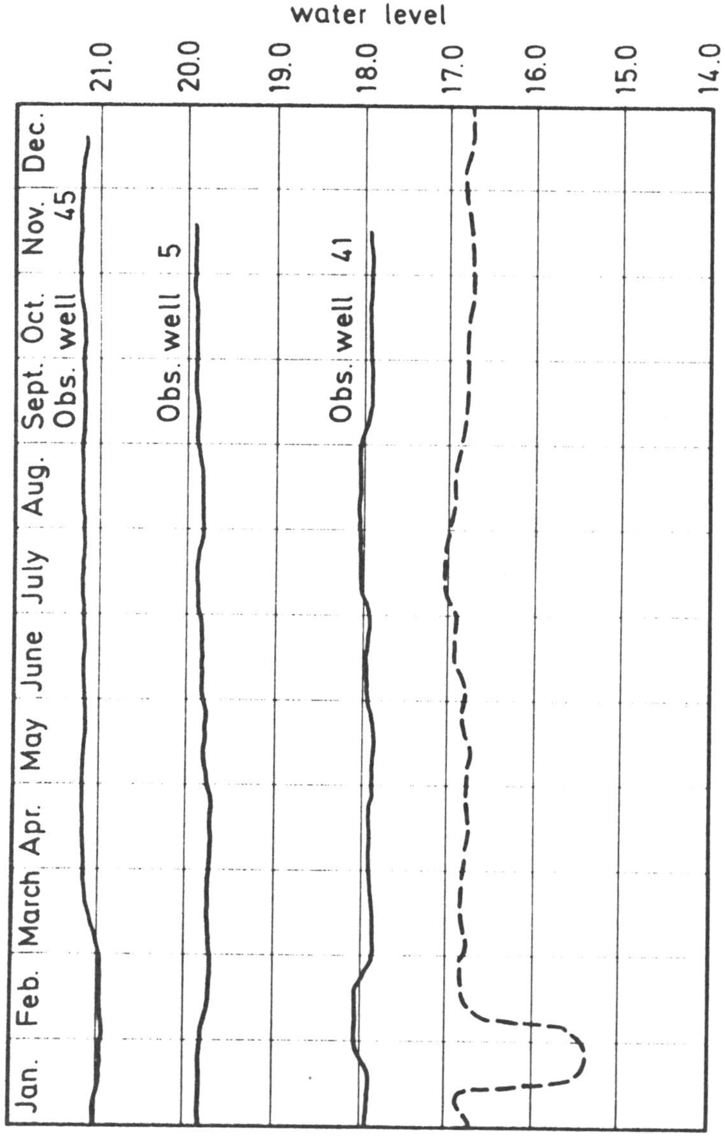

Figure 4. Hydrographs of River (El Roda St.) & Oberserv. Wells 5, 41, 45 in 1979

RESULTS OF MATHEMATICAL MODEL

The results of application of the previously prescribed mathematical model are shown in Figures 5 and 6. In Figure 5 the existing water table map of year 1979 which resulted from the model is presented. The effect of the amounts of water discharged from the 8 pumping stations lying on the eastern side of the River Nile in Cairo is taken into con-

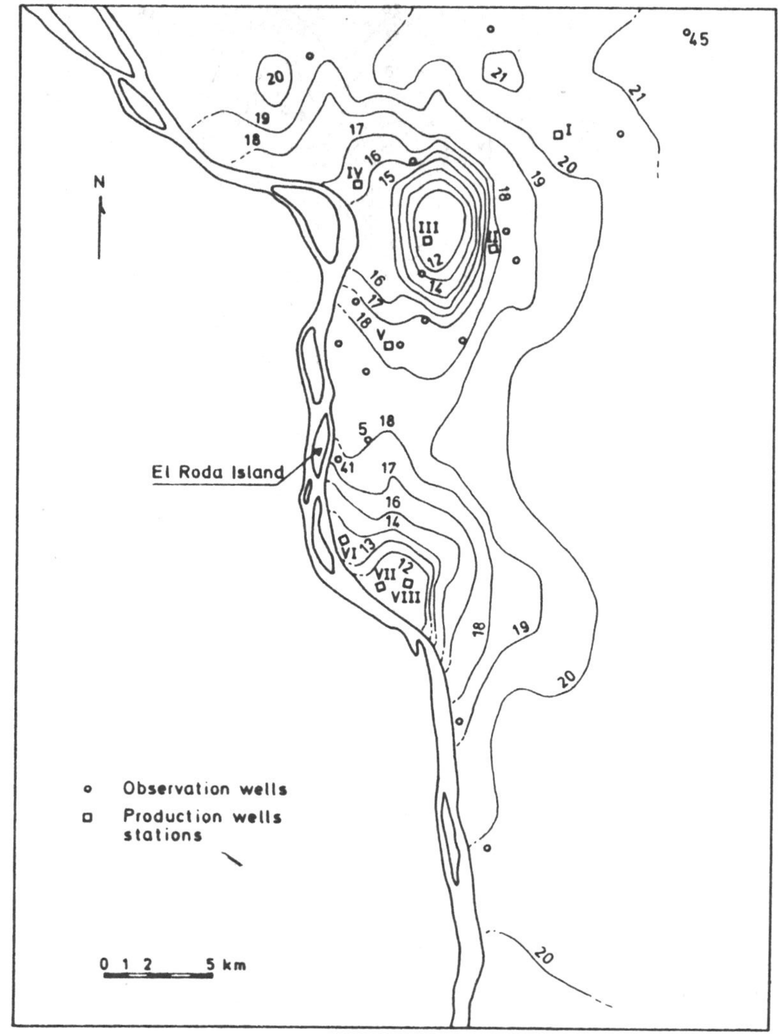

Figure 5. Water Table Map - 1979

sideration in the calculations. The amounts of water discharged from the different stations are shown in Table 2.

As a suggested solution for lowering the ground-water table, 4 pumping stations were suggested, each having a steady pumping rate of 40,000 m³/day. The resulting water table map and the locations of the pumping stations are shown in Figure 6. Comparison between the two maps indicate

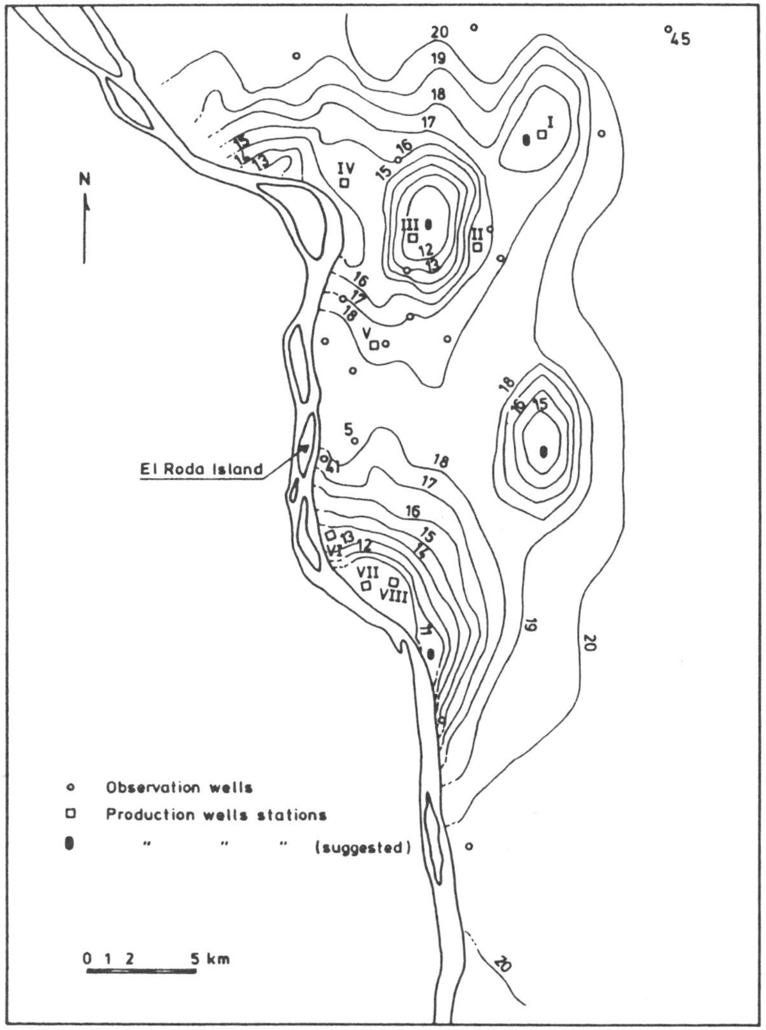

Figure 6. Water Table Map 1979

that the pumping of water in the new locations causes local effects only. Each pumping station has a radius of influence of about 3 km with a water drop of almost 2 meters. Thus, in order to reduce the water level in the whole area by about one meter we have to increase the number of pumping stations so that they are about 8 km apart and so that their discharge is reduced to one fourth of that used in the calculations.

Table 2: Average daily discharge from existing pumping stations, year 1979

Pump station	1	2	3	4	5	6	7	8
Discharge m³/day	4210	15210	69970	51610	33920	11435	79080	45185

CONCLUSIONS

From the presented field data as well as the water table map resulting from the mathematical model, one may conclude that Cairo, this old capital which is over 2000 years old, is swimming on a huge ground-water reservoir. The trend of its dimensions is to increase with time unless effective precautions or solutions take place. The solution suggested in this paper to lower the ground-water table by adding some pumping stations to those existing today has proved to be unsuccessful in lowering the water table. Not only are these local withdrawals of no benefit in solving the problem, but on the contrary they may cause big damage to the buildings lying within their radius of influence. The other suggestion of scattering small pumping stations in order to get a uniform sinking of the water table is only a theoretical idea of the author and if taken into consideration, it has to be studied from economical as well as technical points of view.

REFERENCES

MULL, R. (1977): Anwendung von Grundwassermodellen. Wasser und Boden, 3, Hamburg, pp. 65-68

NORRIE, D.H. and G. De Vries (1978): An introduction to finite element analysis. Academic Press, New York, San Francisco, London

PINDER, George F. and William G. GRAY (1977): Finite element simulation in surface and subsurface hydrology. Academic Press, New York, San Francisco, London

SAID, R. (1975): Surface geology of Cairo area. Techn. Report

ZIENKWICZ, O.C. (1971): The finite element in engineering science. McGraw-Hill, London

AUTHOR'S ADDRESS

Dr. Ing. Tahani Youssef
Staff Member in Irrigation and Hydraulics Division
Department of Civil Engineering
Mansoura University
Mansoura
Egypt

STUDYING THE CONTRIBUTION OF GROUNDWATER TO THE TOTAL WATER RESOURCES AND THE WATER BALANCE OF MAJOR REGIONS

I. S. Zektser

ABSTRACT

The contribution of natural groundwater resources to the production of water intake yields is discussed. The main methods for the regional estimation of groundwater discharge and natural resources are briefly presented. The groundwater contribution to the total water resources and water balance of the USSR is shown on the basis of estimates. Methodological principles of making these estimates are analysed.

RESUME

On examine le rôle des ressources naturelles en eau souterraine dans la formation des débits des puits. On a caractérisé brièvement les méthodes généraux d'évaluation régionale d'écoulement souterrain et des ressources naturelles en eau souterraine. Sur le base des calculs on a montré le rôle des eaux souterraines dans les ressources totales et dans le bilan en eau du territoire de l'URSS, on a examiné les méthodes des telles opérations.

Groundwater is an important source of water. Fresh groundwater is most valuable. As compared to surface water, groundwater has a number of essential advantages. It is, as a rule, purer and its composition better, it is better protected from pollution, less subjected to seasonal and long-term variations, and more regularly distributed. Groundwater intakes may be brought into operation gradually as water demands grow, while construction of hydraulic structures for surface-water development commonly requires immediate allocation of large funds.