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INTEGRATED GEOPHYSICAL AND HYDROGEOLOGICAL STUDIES ON THE QUATERNARY AQUIFER AT THE MIDDLE PART OF EL QAA PLAIN, SW SINAI, EGYPT

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دراسة متكاملة حول جيوفيزيائية وهيدروجيولوجية خزانات المياه من الحقبة الرباعية في الجزء الأوسط من سهل القاع بجنوب غرب سيناء

الخلاصة: يعتبر الجزء الأوسط من سهل القاع واحداً من المناطق الواعدة في شبه جزيرة سيناء من حيث إمكانية تنميتها اعتماداً على مصادر المياه المتوافرة به. وتهدف هذه الدراسة إلى التعرف على الخصائص الهيدرولوجية لخزانات المياه الجوفية من الحقبة الرباعية والتى تعتبر المصدر الرئيسى للمياه بالمنطقة قيد البحث.

ولهذا الغرض تم إجراء مسح جيوكهربى باستخدام ٣٩ جسة حيث تم التعرف على التتابع الصخرى لما تحت السطح كما أظهرت نتائج تفسير البيانات الجيوكهربية معلومات جيدة حول عمق وسمك وامتداد الصخور الخازنة للمياه، كما ساعدت بيانات الآبار في تحديد منسوب الماء (١-٢٢ متراً) وأن معدل التدفق للماء يتراوح ما بين ٠,٠٧ – ٠,٠٣ متر/يوم، كما بلغت الموصلية الهيدروليكية ما بين ١٠-٧١,٥ متر والانتقالية ما بين ١٠٠-١٤٠٠ متر مربع في اليوم، كما أوضح التحليل الكيميائى لعينات المياه المستخرجة من الآبار أن انخفاض ملوحة المياه مرتبط أساساً بالمناطق العالية الموصلية الهيدروليكية وكذا الانتقالية ومعدلات التصرف. وفي ضوء هذه النتائج أمكن التوصل إلى عدد من الاستنتاجات والتوصيات فيما يتعلق باختيار أفضل المواقع لحفر آبار جديدة للحصول على حياة جيدة الاستخدام وكذا التنبؤ بأعمال الخزانات الحاملة للمياه في الأجزاء المختلفة من المنطقة بالإضافة إلى أفضل معدلات الضخ والسحب من الآبار المنتجة في الوقت الحاضر.

ABSTRACT: *The middle part of El-Qaa Plain is one of the promising areas in Sinai Peninsula regarding its possible integrated development, based mainly on local groundwater resources. The main objective of the present work is to recognize the hydrologic characteristics of the Quaternary aquifer, which is the main groundwater resource in the area.*

A geoelectrical survey, conducted through 39 Vertical Electrical Soundings (VES), was found necessary first to reveal the rock succession in the area, including the aquifer. The interpretation of the VES data yielded good information about the depth, thickness and extension of the aquifer. The geoelectrical data, together with the available well information enabled in calculating the water level (1-22m), groundwater flow rate with direction (0.071 to 0.03 m/day), hydraulic conductivity (10-71.5m) and transmissivity (100- 1400 m^2/day). Chemical analysis of water samples indicated that low salinity is associated with areas of high hydraulic conductivity, transmissivity and flow rate. By discussing the results and conclusion it was possible to reach useful recommendations regarding the favorable sites of the future drilling of the water wells, total depth of wells to be drilled in the different parts of the area and optimum pumping rate of some of the already working water wells.

INTRODUCTION:

One of the areas that have been proved to be promising as to its soil and groundwater resources is the area of El-Qaa Plain, lying in southwest of Sinai, parallel to the Gulf of Suez. It is mainly covered by sedimentary deposits belonging to Quaternary surrounded by igneous and metamorphic Pre-Cambrian rocks, and is separated from the Gulf of Suez by Gebel Qabaliat. The middle part of El – Qaa Plain, which is the main part studied here, starts from El-Tur city in the South and extends northwards for about 20 km with an area of about 200 km^2. This part is bounded by latitudes 28° 15`, 28° 25` N and longitudes 33° 30`, 33° 43` E (Fig. 1).

Most of the geophysical work, previously carried out in the area, was of the purpose of exploring oil potentiality. This included mainly gravity, aeromagnetic and seismic exploration. However, these activities have contributed pretty-well to understanding the stratigraphic and structural setting of the area.

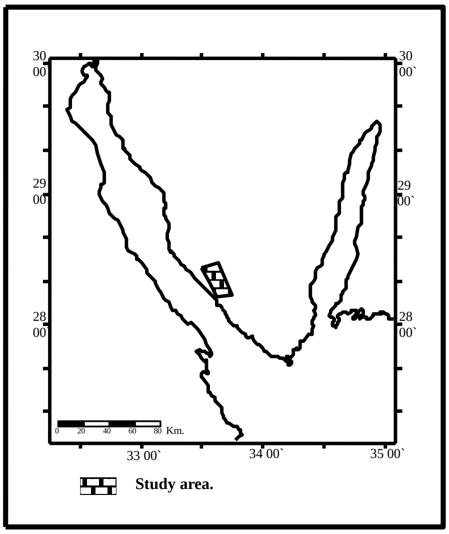


Figure (1): Location map of the studied area.

On the other hand, few geoelectrical studies have been carried out in the area on a rather reconnaissance level to study the groundwater resources in the whole Plain. Among the geophysical studies are that of, Geofizica(1963); Kamel and Fouad (1975); Webster and Riston (1982)

; Shendy (1984); Rizkalla (1985); Abdelrahman, et. al. (1987); Tealeb and Riad (1987); Meshref and El-Kattan (1989); Ibrahium and Ghoneimi (1992); and WRRI& JICA (1999). On the other hand, the groundwater of El-Qaa Plain has been studied by many investigators such as Dames and Moore (1985); RIGWA (1982 and 1986); El-Refai (1984 & 1992); and WRRI& JICA (1999). The Quaternary aquifer is composed of gravel, sand, silt and clay. Cobble and boulder-size rock debris of Pre-Cambrian rocks are dominant at the eastern part of El Qaa Plain, while the percentage of carbonates and evaporites of Pre-Quaternary sediments increases at the western side (El Refae, 1984). At the southwestern portion, the aquifer is composed of limestone, coral reef and clay alternations. The aquifer thickness varies between 300 and 650m and may reach 1000m at the central part of El-Qaa basin, while at the southwestern part it decreases to 30m.

2. SCOPE AND OBJECTIVES OF THE WORK

The main objective of the present work is to study and evaluate the Quaternary aquifer in the middle part of El-Qaa Plain in a more detailed way than that carried out before. This would be achieved through the following:

1-Recognizing the geology of the area in view of the previous geological work.

2-Carrying out a detailed geoelectrical resistivity survey covering the area of study to determine the aquifer geometry and characteristics.

3-Using the available data of some drilled wells such as electric logs, lithologic sections, and pumping test data in the area to determine the hydrologic parameters of the Quaternary aquifer and its relation to the concluded geoelectrical parameters.

4-Recommending the sites of relatively high developmental potential as to groundwater resources.

3 - GEOMORPHOLOGIC FEATURES

The geomorphology of El- Qaa Plain in general has been studied by several authors, among them are ؛Said (1962), El-Refai (1984), and Shendy (1984). A brief description of the main geomorphic units is given below.

a –The Eastern Mountainous Region

This unit is characterized by high relief, in which the highest elevation is 2624m, while the lowest elevation is 300m. It is composed of igneous and metamorphic rocks.

b- The Western Sedimentary Hills

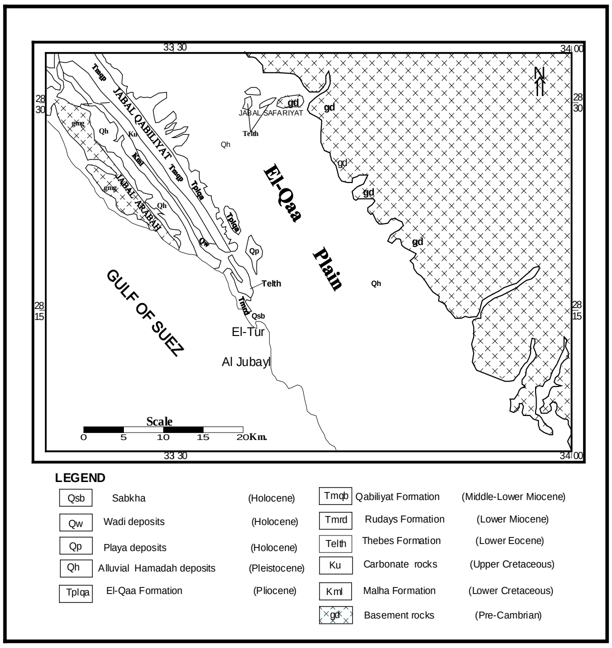
The western sedimentary hills comprising Gebel Qabaliat ridge are characterized by a thick sedimentary section. Due to the south, it is replaced by several hillocks, such as Gebel Abu Swiera and Gebel Hammam Saydna Mousa. The unit has an average elevation of 250m, with a moderate slope towards El-Qaa Plain. This unit is also characterized by a dense consequent net of drainage lines following the general slope towards the east. The main factor controlling the development and shaping of this unit is the primary structural tilting of the strata, which are eroded by wind and water.

c –The Central Plain

This unit seems to have been produced and developed mainly during the Quaternary periods and can be described as a pene Plain. It is not perfectly flat and is dissected by wadi courses, terraces, playa deposits, and alluvial fans in which sand dunes and sand sheets are observed.

4-Geologic setting

Many authors like Said (1962), Bunter (1982), El-Refai (1984), Webster and Riston (1992) and RIWR and JICA; (1999) have studied the stratigraphic succession of the study area. They indicated that the succession includes, generally, rocks ranging in age from Paleozoic to Quaternary as shown in figure (2). The sedimentary succession unconformably overlies the Pre-Cambrian basement rocks. The description of the different stratigraphic units from top to base can be summarized in the following table:



Figur (2): Geologic map of the studied area (after EGSMA, 1994).

Table (1): Stratigraphic units in the study area.

Age	Description	Thickness, m
Quaternary	Sand and gravel with some inter-bedded shale and anhydrite, in some places, they are covered with wadi deposits and sabkha.	300-650
Pliocene	Alternating beds of calcareous grits and sandstone	
Upper Miocene	Sandy argillaceous limestone	30
Lower Miocene	Conglomeritic sandstone and marl and evaporites	50
Middle Eocene	Will bedded Limestone	100
Lower Eocene	Chalky limestone with thin flint bands	110-212
Paleocene	Shale with intercalations of marl and chalky limestone	30-150
Upper Cretaceous	Limestone, marly limestone, sandstone and shale overlained by shale, limestone and chalky limestone	448-610
Lower Cretaceous	Sandstone of Nubia Facies (Nubia A)	777-783
Paleozoic	Sandstone of Nubia Facies (Nubia B & C)	330
Pre-Cambrian rocks	Igneous and metamorphic rocks	

5- GEOPHYSICAL SURVEY

a) Geoelectrical Measurements:

Thirty-nine Vertical Electrical Soundings were carried out in the study area where the sounding stations were arranged along 9 NE-SW profiles crossing the area of study (Fig. 3).

The Schlumberger electrode configuration was applied with current electrode spacing (AB) starting from 2 m up to 1000 or 2000 m depending on the field conditions. The electrical resistivity (ρ_a) is calculated from the following formula:

$$\rho_a = K\,(\Delta V/I)\text{----------------------(1)}$$

ρ_a : apparent resistivity in ohm.m.

ΔV: Potential difference in millivolt.

I : current intensity in milli. amper.

K : a geometrical factor (function of X and L) and has the value of:

$$K = \pi/4 * (L^2 - X^2)/X$$

L: is the distance between the current electrodes (A-B).

X: is the distance between the potential electrodes (M-N).

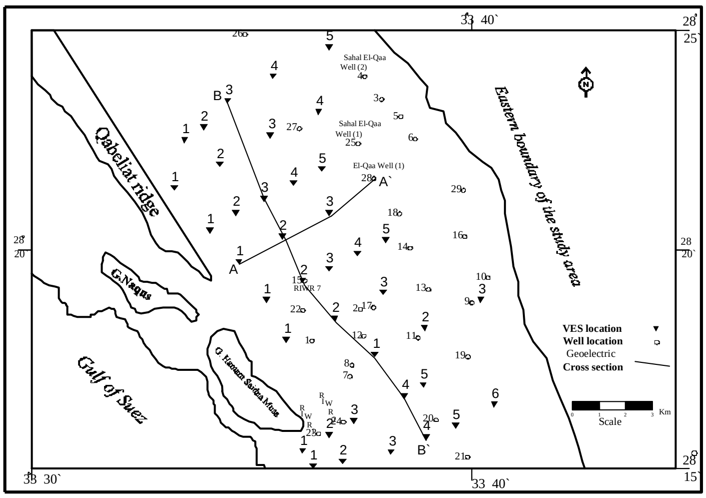


Fig.(3) Location map of VES stations and wells in the study area.

Table (2): Summary of the interpretation of the resistivity sounding curves

Profile No.	*VES No.*	*G. Elev. (m)*	*Geoelectrical layers*										
			Layer A			*Layer B*			*Layer C*			*Layer D*	
			ρt	**T**	**D**	**ρt**	**T**	**D**	**ρa**	**T**	**D**	**ρt**	**D**
I	1	68	1000	1.4	0	47.7	46.2	1.4	10	55	47.6	7.2	102.6
	2	48	3410	1.4	0	49	31.1	1.4	10.2	58	32.5	5.7	90.5
	3	58	15122	3.1	0	240	36	3.1	20	86	39.5	6	125
	4	65	11794	7.1	0	320	42.5	7.1	32	65.7	49.6	23	115.3
	5	84	4329	12.3	0	235	52.8	12.3	36		65.1		
II	1	70	2336	2.9	0	76	51.1	2.9	17	57	54	4.5	111
	2	45	2307	2	0	145	31	2	26	63	33	5	96
	3	55	3276	7.9	0	270	27.6	7.9	83	76.8	33.5	23	112.3
	4	67	2474	10.5	0	200	31	10.5	82	85	41	23	126
III	1	68	1515	2.7	0	52	45	2.7	12	50	47.7	8	97.7
	2	42	9570	1.4	0	106	26	1.4	20	40.3	27.4	3.2	67.7
	3	43	4313	7.9	0	175	12.1	7.9	37	65	20	14	85
	4	45	753	7.5	0	167	30	7.5	89	71	37.5	20.5	108
	5	48	1141	2.9	0	190	25	2.9	60	57	28	6.4	85
IV	1	60	8078	1	0	81	39	1	20	56.5	40	5	97
	2	42	4201	1	0	265	21.4	1	16	60	22.4	6	82.4
	3	38	850	0.3	0	150	19	0.3	53	60	19.3	7	79.3
V	1	39	4070	1	0	104	16	1	14	68	17	4.7	85
	2	40	1441	1.4	0	113	20.1	1.4	59	50.4	21.5	9.5	72
	3	41	1026	1.1	0	176	19	1.1	59	59.5	20.1	7.2	80.1
	4	34	940	0.6	0	160	14.2	0.6	55	70	14.8	10	84.8
	5	40	2070	2.2	0	100	17.2	2.2	51	57	19.4	4.5	76.4
VI	1	38	645	1	0	132	17.4	1	14	70	18.4	3.7	88.4
	2	45	751	0.8	0	210	24	0.8	22	65.3	24.8	5.3	90
	3	35	320	0.9	0	154	15.7	0.9	31	30.2	16.6	10.9	46.6
VII	1	37	870	3.4	0	292	16.1	3.4	29	54	19.5	4.3	70.1
	2	40	2804	4.7	0	293	22.3	4.7	43	47	27	5.8	74
	3	57	3488	10.2	0	329	32	10.2	43	47	42.5	7.6	89.5
VIII	1	4	20	1.2	0	4.9	2	1.2	2.6	49	3.2	1	52.1
	2	10	80	0.5	0	74	2.7	0.5	4.1	50.8	3.2	1.8	55
	3	31	50	6	0	36	15	6	7.8	65	21	3	91
	4	41	180	9.4	0	34	12	9.4	14	64.5	21.5	3.8	86
	5	46	210	12	0	81	15	12	12.5	53	27	4	80
IX	1	10	150	2.1	0	16.7	2.8	2.1	9.7	30	4.9	2.5	34.9
	2	16	160	4	0	14	6	4	8.7	39	10	2.7	49
	3	27	50	3.6	0	12	10	3.6	9	48	13.6	3.7	61.6
	4	39	70	5.2	0	13.6	13	5.2	17	55	18.5	3.8	73
	5	50	300	2.8	0	95	27	2.8	27	43	30	9	73
	6	65	900	3.7	0	81	40	3.7	15	36	44	9.5	79

ρt: Resistivity in Ohm.m T : Thickness in m. D : Depth to top in m

b- Quantitative interpretation of sounding curves:

The quantitative interpretation of the sounding curves was made, using the computer programs; Velpen (1988) and Zohdy (1989). The geoelectrical parameters (depth, thickness and resistivity) obtained from the interpretation of all the sounding curves were correlated with the available geological and hydrogeological data obtained from wells drilled in the area. The results of the quantitative interpretation are summarized in table (2), which indicates the number of layers (A,B,C and D), true resistivity(ρ_t), thickness (T) and depth to top of the different layers (D) for each of the 39 interpreted VES curves.

It was necessary to correlate the interpretation results with the available drilled well data of the area to find out the following:

1-The lithologic units corresponding to the interpreted geoelectrical layers in terms of their depth of occurrence.

2-The resistivity range of each of the major lithologic units.

3-The resistivity range characterizing in particular the water –bearing formation, so that it would be possible to trace the aquifer in the whole area and to judge to some extent the change in water quality laterally and vertically.

In this respect the lithologic logs of wells Sahal El-Qaa Well-2, Sahal El-Qaa well-1, El-Qaa well-1, El-Qaa well-20, RIWR-7 and RIWR1 are correlated with the interpreted geoelectrical succession reached at the sites of these wells. Figure (4) was selected to represent a model for the correlation between the lithologic section and the interpreted resistivity sounding curve. The results of the correlation process are summarized in table (3).

Table (3) Summary of the correlation between lithologic logs and interpreted resistivity sounding curves.

Layer	Depth (m)	Thickness (m)	Resistivity range (Ohm.m)	Corresponding lithology
A	0 - 0	0.3 - 12	20-15122	Sand, gravel with igneous boulders
B	0.3 -12	2 - 53	12-329	Sand and gravel
C	3.2 - 65	30 - 86	3-89	Sand and gravel with clay intercalation **(Water bearing)**
D	35 -126	-	1-23	Sand, clay and/or silt **(Water bearing)**

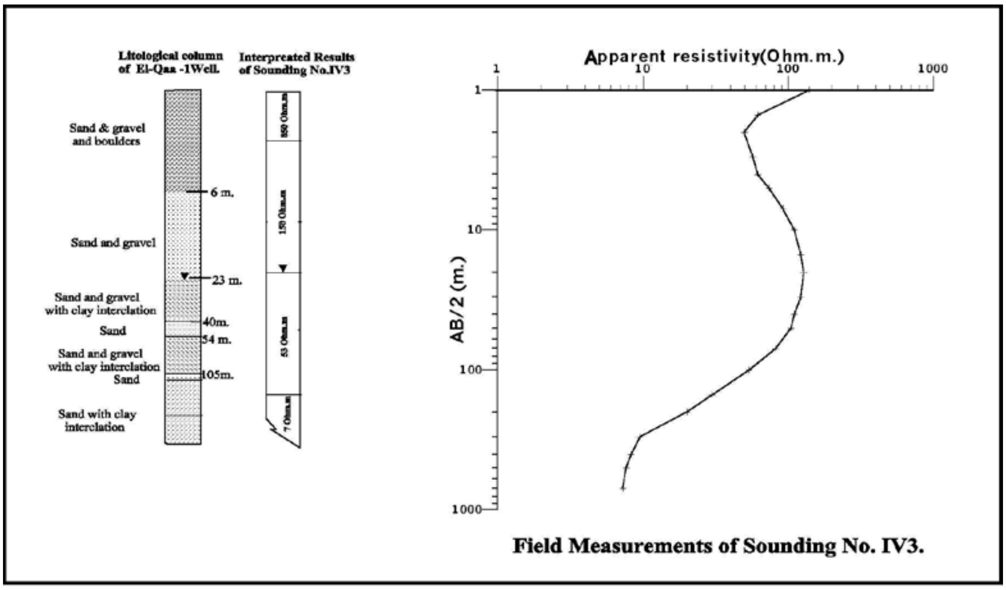


Fig. (4): Correlation between interpreted results of sounding No. IV3 and lithology of El- Qaa – well.

The study of the interpretation results (tables 2&3) reveals the following:

1-The main geoelectric succession is divided into an upper layer C and a lower one D. The lower layer differs from the upper one in that the salinity of water is possibly higher and/or the clay content is larger.

2- The water-bearing formation extends across the whole studied area with its top at a depth of 3.2-65m from the ground surface.

3-The aquifer extends downwards beyond the investigated depth and consequently the bottom of the aquifer is not reached. This means that the aquifer thickness is more than what is concluded from the present work, although the water quality deteriorates downwards.

4-There is no sharp lithologic change along the investigated depth. Consequently, the discrimination between the successive geoelectric layers is governed mainly by other factors such as nature of the surface cover, the water content, and quality of water.

c- Representation of the results:

The results of interpretation from geoelectric data represent the subsurface setup of the area, much better, when they are displayed in the form of contour maps and cross --sections as shown in figures (5-7).The study of these figures reveals the following:

1-A surface layer A varying in thickness from few meters to 12m, characterized by a wide range of resistivity (20-15122 Ohm.m.). This layer consists of sand, gravel and boulders drived to the Plain from the surrounded highlands (Fig. 7).

2-A dry layer B consists of sand and gravel but with a relatively narrower range of resistivity (12-329 Ohm.m). The thickness of this layer varies from 2 to 52m (Fig. 7).

3-A water-bearing layer C occupies a wide portion of the investigated area with a resistivity range of 3-89 Ohm.m. (Fig. 5). The resistivity of the layer C gradually decreases away from the middle of the study area which reflects good water quality at the middle portion and can be defined by the resistivity level of 40 Ohm m and confirmed with the salinity map (Fig. 8). The layer C consists of sands and gravel with some clay intercalation and has a thickness ranging between 50 and 86m (Fig. 6 & 7).

4-A water-bearing layer D that represents actually the downward extension of the overlying layer as it is more or less similar in its lithologic composition. However, the water quality of this layer is lower as it is characterized by both low and narrow range of electrical resistivity (1-23 Ohm.m). The thickness of this last layer was not determined because of the principle of the D. C. electrical exploration itself and regarding the great thickness of the Quaternary aquifer.

5- Figure (9) illustrates the total depth of recommended new wells to be drilled in the area. This map was constructed making use of the interpreted depth to top of the aquifer plus the thickness of the upper layer of the aquifer at each of the sounding stations. The map indicates that in the northern part of the area, the total depth of new wells to be drilled should be within 100 to 120m, while for the middle and southern parts, the total depth should in the range of 50 to 80m below the earth's surface.

6- HYDROGEOLOGIC SETUP

a- Depth to water and water level:

Depth to water and water level maps were constructed from the field measurment. The inspection of these maps indicates the following:

The depth to water contour map (Fig. 10) indicates that high water depth (>60m) is recorded at the East and the lower one (<1m) is detected at the southwest. The water level contour map (Fig. 11) shows that high water level (22m) is recorded at east of the study area and the lower one (<1m) is detected at southwest. The recharge area is located at the eastern parts, whereas the discharge area is recorded at the southwestern portions. The direction of groundwater flow is from east to west and southwest. This means that the aquifer is mainly recharged from the sudden floods, which fall on the eastern mountains. The rate of flow of groundwater varies between 0.071 m^3/day at the eastern part of the aquifer and 0.03m^3/day at the southwestern portion.

b- Aquifer hydraulic parameters

The aquifer parameters involve transmissivity, hydraulic conductivity and storage coefficient. The study of the hydraulic parameters of any aquifer define the characteristics of that aquifer and helps in recognizing its potentiality. This is considered to be of an important aspect added to the geometry of the Quaternary aquifer in the study area, defined from the analysis and interpretation of the geophysical data.

The authors applied Jacob's time drawdown method (1947) and Theis recovery method (1935) to recalculate the aquifer hydraulic parameters from the pumping test data of wells Nos. 3, 4, 5, 6, and 25. Also, the results of some wells, which were previously calculated by El-Refia (1992) and RIWR (1994) are recalculated and reevaluated by the modern interpretation programs as (GWW and AQTESOLV) softwares. It has to be mentioned that the storage coefficient (S) could not be determined because the pumping test data were taken directly from the production wells where no piezometers were found.

The hydraulic conductivity of the aquifer ranges between <10 and 71.5 m/day (Fig. 12) and the transmissivity values range between 100 and 1900 m^2/day (Fig. 13). This points out to an aquifer of moderate to high potentiality. High values of hydraulic conductivity (K) and transmissivity (T) are recorded at the eastern portions, whereas the lower ones are detected at the western and southwestern parts. It is worthy to mention that the lithology of the aquifer, flow rate and transmissivity affects salinity distribution in groundwater.

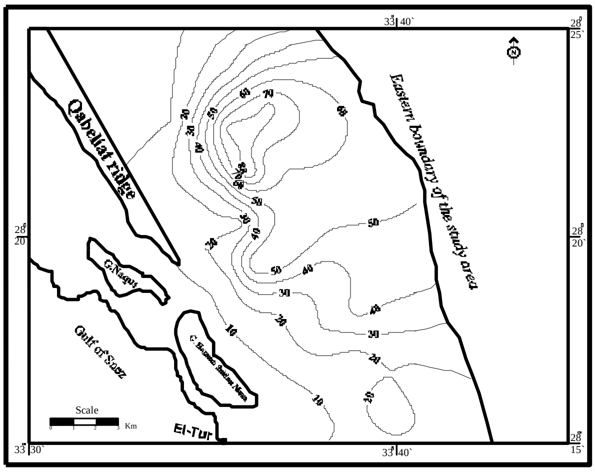


Fig.(5): Iso-resistivity contour map of the geoelectrical layer C.

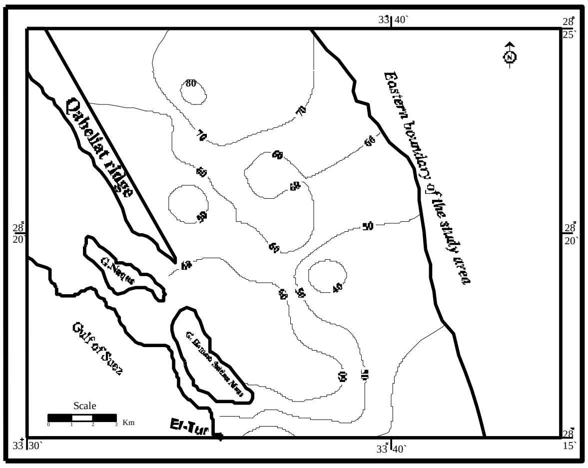


Fig.(6): Iso-pach contour map of the geoelectrical layer C.

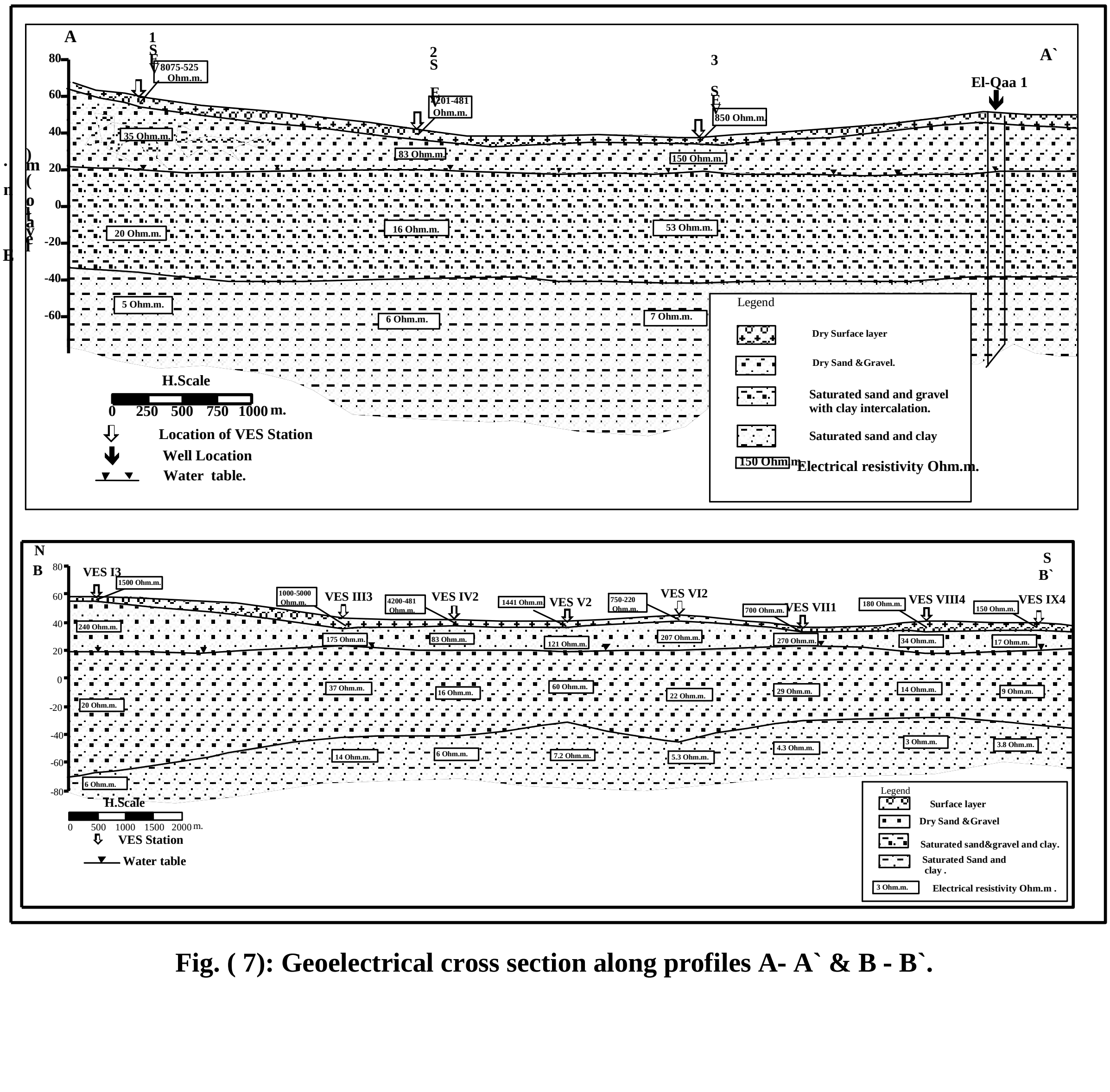


Fig. (7): Geoelectrical cross section along profiles A- A` & B - B`.

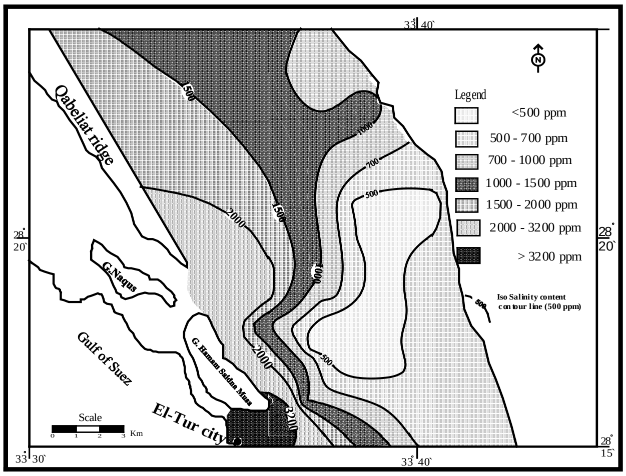


Fig. (8): Salinity content distribution map of the Quaternary aquifer.

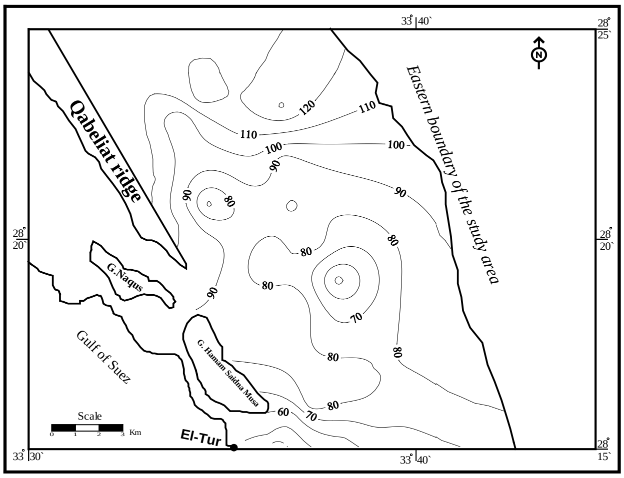


Fig. (9): Recommended depths of Wells to be drilled in the area.

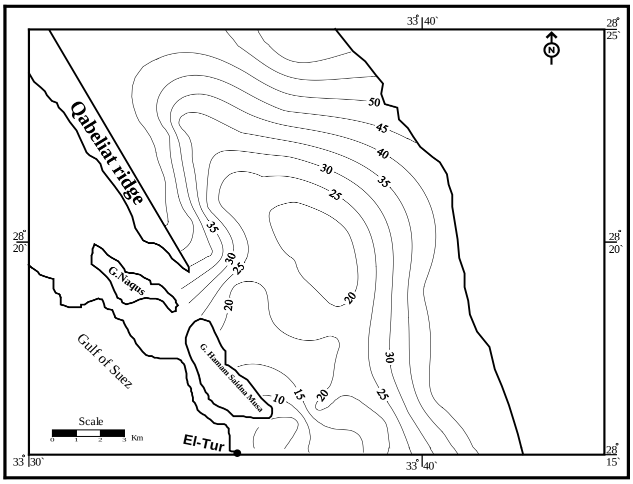


Fig.(10) Depth to water contour map.

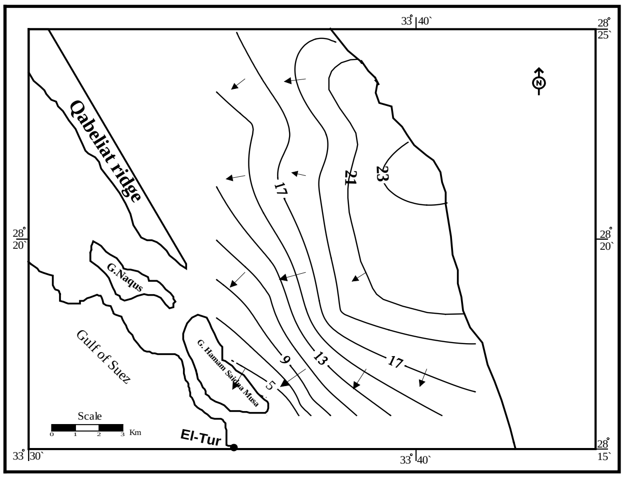


Fig.(11): Water table map of the Quaternary aquifer in the study area.

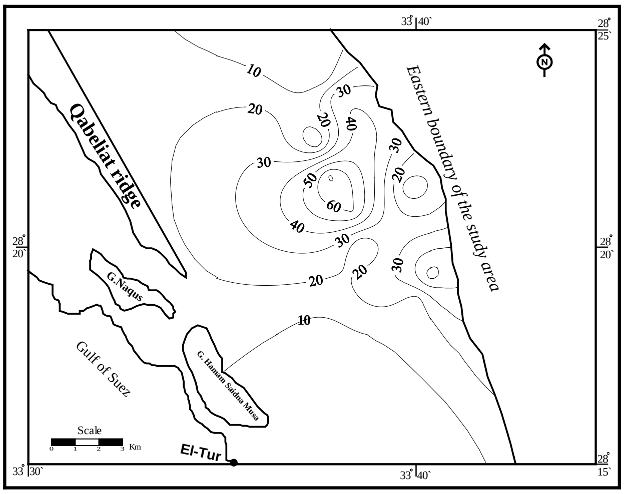


Fig.(12) Hydraulic Conductivity distrabution contour map.

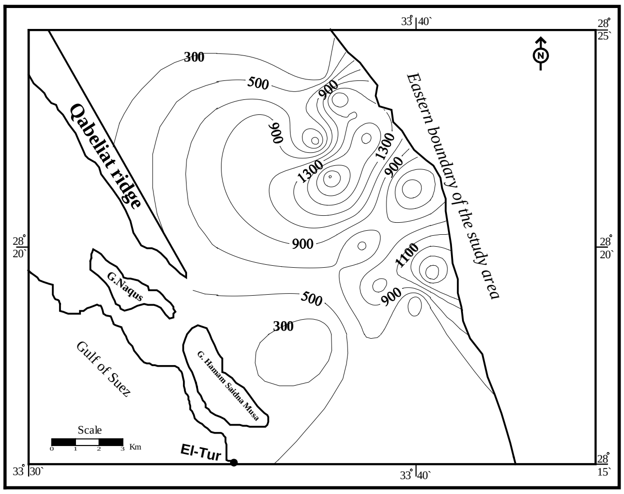


Fig.(13) Transmissivity distrabution contour map.

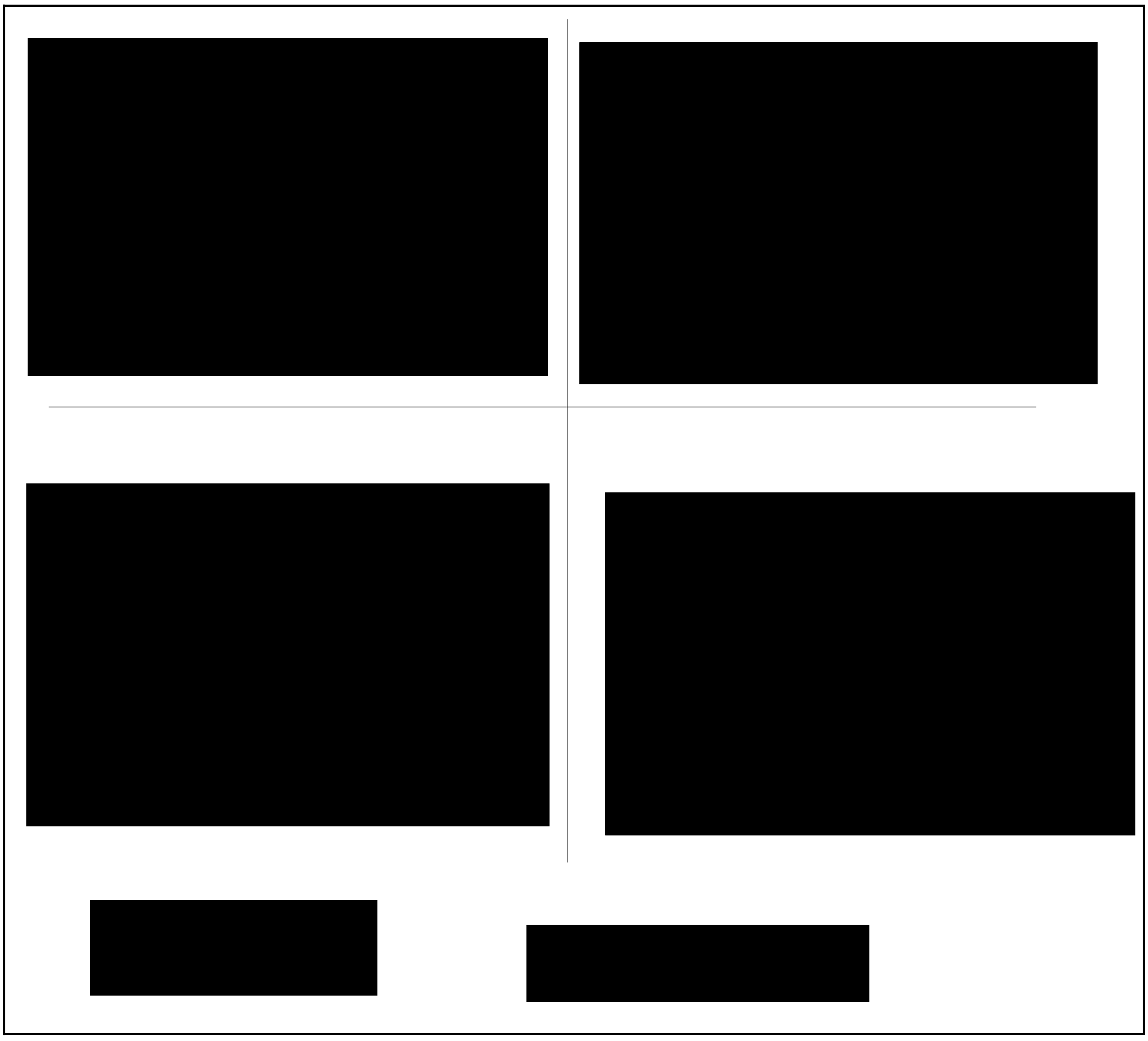


Fig.(14) Relation between Pumping rate an well hydraulic parameters.

c- Well Hydraulic Parameters of Selected Wells

Well parameters include specific capacity and well efficiency. More than 29 production wells have been drilled in the study area. Some wells were abandoned during the last few years due to inadequate discharge. As a matter of fact, the yield of any well depends on the aquifer characteristics, well parameters and the pump efficiency. A decline in the well yield is due to change in one or more of these elements (Hamill and Bell, 1986). As the aquifer is proved to be of moderate to high potential, then the well design may be responsible for the inadequate water discharge. For this reason, the well parameters of some wells, for which the data of step-drawdown tests are available, have been measured and evaluated. The parameters include specific capacity, well loss and well efficiency. specific capacity of a well is the yield per unit of drawdown and is determined by dividing the pumping rate at any time during the test by the drawdown of the same time. Well efficiency is an important consideration in well design and in well construction and development. Well efficiency (E) is defined as the ratio of drawdown in the aquifer (s_a) at the radius of the pumping well to the drawdown inside the well (s_t).

The total drawdown in a well (s_t) is often represented by an equation (Jacob, 1947) of the form:

$$s_t = s_a + s_w$$

$$E = (s_a/s_t) \times 100$$

where s_w is the well loss and E is well efficiency

The authors used the GWW relatively recent software to analyze the step-drawdown test data that are available through RIWR (1994) and RIGWA (1982&1986) for wells 9, 25, 27 and 28. The results of these analyses are represented graphically in (Fig. 14).

From this Figure, the general observations are summarized as follows:

1-Well and aquifer losses increase with increasing pumping rate.

2-Well specific capacity and well efficiency decrease with increasing pumping rate.

3-Most of wells are operated at relatively high pumping rates. These pumping rates are accompanied by relatively low specific capacities, low efficiencies, high well loss and high aquifer loss. So, the present pumping rates must be corrected to obtain the highest well efficiency and well specific capacity with less well and aquifer losses. In the future, the suitable well design must be used with the appropriate pumping rate to have wells with less well loss and long operating life.

CONCLUSIONS

1-Through the qualitative and quantitative interpretations of the sounding curves, it was revealed that the aquifer extends in the whole area at a depth of 3-65m below the ground surface. The aquifer was found to consist of two parts. The upper part consists of sand and gravel saturated with fresh water with a thickness of 30-86 m. This part is characterized by a resistivity range of 2-82 Ohm.m. The lower part consists of sand and gravel with clay intercalation having a resistivity of 1-23 Ohm.m, which refers to water of less quality than that of the upper part. The lower part is much thicker than the upper one and extends downwards beyond the maximum depth of investigation reached during the geoelectrical survey. It was possible to locate the best sites for the drilling of water wells, along with the total depth and specification of each of these wells.

2- High water level (22m) is recorded east of the study area and the lower one(<1m) is detected at the southwest. The direction of groundwater flow is from East to west and southwest. The rate of flow of groundwater varies between 0.071 m/day in the eastern part and 0.03m/day in the southwestern part. High values of hydraulic conductivity (71.5 m/day) and transmissivity (1900 m^2/day) are recorded at the eastern portions, whereas lower ones (<10 m^2/day and 100 m^2/day, respectively) are detected at the western and southwestern parts. High values of hydraulic conductivity, transmissivity and flow rate are at the eastern parts and are accompanied by low salinity, whereas low values at the southwestern part are associated with high salinity.

3- Most wells, operated at relatively high pumping rates, are accompanied with relatively low specific capacity and efficiency, high aquifer and well losses.

RECOMMENDATIONS

1-For future drilling of groundwater in the area, the middle and eastern parts of the study area are recommended as they are characterized by the following:

A- Appropriate depth to top of the aquifer (20-30m.)

B- Good water quality as the total water salinity is less than in the other parts of the study area.

C- Relatively higher values of transmissivity and hydraulic conductivity of the aquifer

D- Relatively greater thickness of the upper part of the aquifer where the water quality is better.

2-The total depth of any of the water wells to be drilled in the area in future should be in the range of 75-125 m according to the topography of the area and thickness of the upper part of the aquifer where fresh water is present.

3-The present pumping rates of wells Nos.9, 25, 27 and 28 should be reduced to allow for higher well specific capacity, well efficiency, lower well and lower aquifer losses.

REFERENCES

Abdel Rahman, E. M ،.Refai, E. M., and Adawy,H.F.,1987: Gravity interpretation of El-Qaa Plain area, Gulf of Suez. JL. Egyptian Society of Engineers,Vol.26, No .3

Dames and Moore; 1985: Sinai Development Study, phase 1, Final Report, Water Supplies and Coast, Vol. V.; Report submitted to the Advisory Committee for Reconstruction Ministry of Development. Cairo, 147 P.

EL-Refai, A. A; 1984: Geomorphological and Hydrogelogical Studies on El-Qaa Plain ,Gulf of Suez ,Sinai, Egypt. M. Sc. Thesis, Fac. Sci., Cairo Univ., 298p.

EL-Refai A. A; 1992, Water Resources of Southern Sinai, Egypt. (Geomorphological and Hydrogeological studies). Ph.D. Thesis, Fac. Sci. Cairo. Univ., 357pp.

Geofizika , 1963: Final report, southwestern Sinai, reconnaissance investigations, hydrogeology, geophysics and soil studies, Zagreb,Yugoslavia, Cairo branch, 184p.

Hamill, L .and Bell, F.G., 1986" :(Groundwater resource development" British Library, ISBN 0-408-01409-1, pp. 1-32.

Ibrahim, S. and Ghoneimi, A. A., 1992:A contribution of the potential field data to establish the subsurface configuration of the southwestern Sinai, Egypt. Proc. 3rd Conf. Geol. Sinai Develop., Suez Canal Univ., Ismailia.

Jacob, C.E., (1947): Drawdown test to determine effective radius of artesian well, Trans. Am. Soc. Civ. Engrs, 112, 1047-1070.

Kamel, H. and Fouad, A., 1975: Project of establishing the gravity map of Egypt, Bouger map, scale 1,500,000. G. P. C. Co., Egypt.

Meshref, W. M., and El-Kattan, M. I., 1989 : Tectonic pattern of El-Qaa Plain,Sinai Develop., Ismailia, pp. 33-42.

Rizkalla, R. I.,1985 : Preliminary statistical gravimetric- tectonic trend analysis in Sinai Peninsula and its surroundings, Egypt.,10th International Congress for Statistics. Computer Science, Social and Democaratic Research.

RIGWA, 1982: Geological logs and hydrological data for wells in El-Qaa Plain. General Company for Research and Groundwater , Cairo, Egypt.(phase 1)

RIGWA, 1986: Geological logs and hydrological data for wells in El-Qaa Plain. General Company for Research and Groundwater , Cairo, Egypt.(phase 2)

RIWR; 1994: Internal Reports of the Research Institute of Water Resources, El-Kanater El-Khayeria, Egypt.

Said, R., 1962 :The Geology of Egypt. Elsevier Publishing Company. Amsterdam, New York .377 P.

Shendy,E.H.;1984 :Geological and Geophysical investigation for groundwater in El-Qaa Plain ,Southwestern Sinai. M.Sc.Thesis, Fac.of Sci.,Suez Canal University, Ismalia, Egypt.

Tealeb, A. and Riad, S., 1987: Regional tectonic of Sinai Peninsula interpreted from gravity and deep data. E. G. S. Proc. Of 5th ann. M., pp.18-49.

Theis, C. V., 1935:The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage. Trans. Am. Geoph. Union , Vol. 16.

Velpen, B. P. A., 1988 : "Resist" a computer program for the interpretation of resistivity sounding curves. An ITC. M. Sc. research project, Delft, The Netherlands.

Webster, D. I., and Riston, N., 1992: Post- Eocene Stratigraphy of the Suez rift in South-west Sinai ,Egypt .E.G.P.C., Sixth Exploration Seminar ,Cairo ,March, 1992.Vol.1,PP. 276-288.

WRRI & JICA, 199: South Sinai Groundwater resources study in the Arab Republic of Egypt, Main Report.

Zohdy, A. A. R., 1989: A new method for automatic interpretation of Schlumberger and Wenner sounding curves; Geophysics, Vol.54, P.245-25.