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STUDY OF THE IMPACT OF THE SURFACE WATER ON THE GROUNDWATER USING GEOELECTRICAL METHODS IN EL- SALHYIAH EL GEDIDAH, EGYPT

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دراسة تأثير المياه السطحية على المياه الجوفية باستحدام الطرق الجيوكهربية بمنطقة الصالحية الجديدة - مصر

الخلاصة: لدراسة تواجد العلاقة بين مصادر تغذية المياه الجوفية وظروف تواجدها بمنطقة الصالحية الجديدة التى تقع محصورة بين ترعة الأسماعيلية من الشمال وطريق القاهرة الأسماعيلية الصحرواى من الجنوب تم إجراء استكشاف جيوكهربباستخدام توزيع اشلمبرجير لعمل الجسات الجيوكهربية العمودية وعددها ١٠ جسات جيوكهربية (VES) وعدد ثلاث قطاعات من المقاومة الكهربية المقطعية ثنائية الأبعاد (2-D resistivity imaging) . وتم تجميع المعلومات الجيولوجية السطحية وتحت السطحية عن المنطقة. تم وضع النموذج الأولى اللازم لعملية التفسير الكمي للقياسات الحقلية للجسات الجيوكهربية. واسفر التفسير الكمي للجسات الجيوكهربية العمودية والقطاعات الجيوكهربية ثنائية الأبعاد ان التتابع الطبقى الرسوبى تحت السطحي يتكون من ثلاث طبقات جيوكهربية بخلاف الطبقة السطحية، وتم توضيح الأمتدات الأفقية والرأسية لهذه الطبقات الجيوكهربية وعلاقاتها بالمياه السطحية من خلال القطاعات الجيوكهربية والخرائط الكنتورية للمقاومة الكهربية وسمك كل طبقة.

وقد أظهرت الدراسة أن الطبقتين أ، ب الحاملتين للميه الجوفية تتعرضان للتغذية من مياه الترع والرى (الصرف الزراعى) وأن مياه الرى هى أكثر تأثيراً على الطبقة أ حيث يلاحظ زيادة ملوحة مياه هذه الطبقة، أما مياه الترعة (ترعة الاسماعيلية) فهى التى تؤثر على ملوحة الطبقة ب خاصة فى الجزء الشمالى منها، أما تأثير مياه الرى على هذه الطبقة فهو محدود، ومن ثم فإن المنطقة الشمالية للدراسة هى الأفضل من حيث الجودة وسمك الطبقة الحاملة للمياه لذا فإننا نوصى بحفر آبار إنتاجية بها.

ABSTRACT: *The main objectives of the investigation were to find out the impact of the surface water on the groundwater conditions and to detect any possible connection between the groundwater aquifers. A geoelectrical investigation has carried out in El-Salhyiah El-Gedidah, which lies between Ismailia Canal to the north and the Cairo-Ismailia desert road from the south. A grid pattern consists of 10 Vertical Electrical Sounding (V.E.S) stations have been carried out in the concerned area using Schlumberger electrodes configuration with current electrodes distance from 1000 to 1400m. Also, the two-dimensional (2D) geoelectrical imaging (Tomography) with Wenner measurements have been carried out along three profiles with a length of 460m with main purpose of finding out the extension, depth, thickness and lateral change of the water bearing layers.*

The interpretation of the geoelectrical data based on the information collected from existing wells in the area, indicated that the subsurface consists of four geoelectrical layers surface layer and layers (A, B and C) varying in depth, thickness and lithological composition. The upper layer "A" represents the water-bearing sandy clay and clay with a resistivity ranges 3.6 to 24 Ohm.m from south to north direction respectively. The lower layer "B" represents water saturated clayey sand and sand with a resistivity value ranges from (22-44 Ohm.m) from south to north direction respectively. The last layer "C" has low resistivity values ranges from 1.8 to 24 Ohm.m corresponds to clay.

Concerning the 2-D resistivity images, it is obvious that the apparent resistivity values show different trends and shapes, which indicate and reflect heterogeneous character, due to lateral and vertical facies change in the subsurface succession, which have a direct effect on both the quantity and quality of groundwater.

INTRODUCTION

Plagued areas of land reclamation in the desert lands suffer from the lack of water resources and face some problems such as salinization of groundwater and deficiency in productivity. In this sense, geophysical studies are required to determine the dimensions of aquifer and sources of groundwater and factors that affect the groundwater in the new reclamation areas.

The proposed study area is located on the southern eastern edge of the Nile Delta, which represents the extension of the delta along the Cairo-Ismailia Desert Road new Salhyiah area. This area suffers from a lack of groundwater and increased salinity. Accordingly, this was conducted to investigate and subsurface the aquifer and to identify sources of feeding for horizontal and vertical extension of the recharge. A geoelectrical survey of the area using Vertical Electrical Soundings (VES), and Two-dimensional electrical resistivity imaging (2-D) were carried out to achieve the objective in intgration with the previous geomorphological, geological and hydrological studies. The study area is located between latitudes 30° 25'and 30° 35' N and longitudes 31° 53' and 32° 03' E south of Ismailia canal (Fig.1)

GEOLOGICAL BACKGROUND

According to the previous geological works, the stratigraphy of the investigated area was differentiated by many authors such as Shukri and Ayouty (1956), Shata (1956), Said and Beheri (1961), El Fayoumy (1968), Shata and El Fayoumy (1970), El Shazly et al.(1975), Hefny (1980), and Moussa (1990).

The area east of the Nile Delta is occupied by Quaternary and Tertiary deposits. They have a thickness of 400-900m (Hefny, 1980). El Salhyiah area is covered by Quaternary deposits consisting of young aeolian sediments at the top and old deltaic deposits at the base. Tertiary deposits are exposed south of the study area and are represented by Pliocene, Miocene, Oligocene and Eocene sedimentary rocks that are formed of sand and gravel. In the subsurface, the Oligocene deposits are unconformably underlain by the Upper Eocene sandy limestone that contains occasional sandstone and shale beds (Said, 1962) Downwards the Upper Eocene deposits are followed by the Middle Eocene hard limestone and the Cretaceous rocks.

According to Sallouma (1983), Gad (1995) and Dahab, et al. (2007), the main aquifer in the area is formed of Quaternary deposits (sand, sandstone, clay and shale). The clay and shale separate the aquifer into an upper unit and a lower one such that the upper unit is considered to be a free aquifer while the lower one is regarded to be of confined to semi-confined condition. Recharge is provided by the surface irrigation system.

FIELD SURVEY

Two geoelectrical measurements are applied; the first is Vertical Electrical Sounding (VES), the second is Two-dimensional electrical resistivity imaging (2-D), Figure (1).

a- Vertical Electrical Soundings (VES):

The area was covered by a total of 10 Vertical Electrical Soundings (VES) (Fig. 1). The Schlumberger 4-electrode configuration was applied, where the maximum current electrode separation (AB/2) used was 700 meters. The D.C. resistivity meter (Terrameter SAS 300) was used for the field measurements. The Ground Positioning Systems (GPS) and the conventional land topographic survey were applied to determine the accurate location and the ground elevations of the VES stations and the observation wells. The measured apparent resistivity was plotted versus the apparent depth (AB/2) using a bilogarithmic scale the form of VES curves as shown in Fig. (2).

b- Geoelectrical imaging (2-D) :

The geoelectrical imaging (tomography) survey has been applied along three profiles 2-D N0.1, 2-D N0.2 and 2-D N0.3 at locations of VES. 9, VES.6 and VES.10 respectively, with a profile 460-m in length. The main objective of conducting such a technique is to image the horizontal and vertical variations of the subsurface lithology and the groundwater recharge limits along a continuous section with relatively high resolution. The Wenner electrode array with unit electrode separation of 5m was applied in measuring the profile.

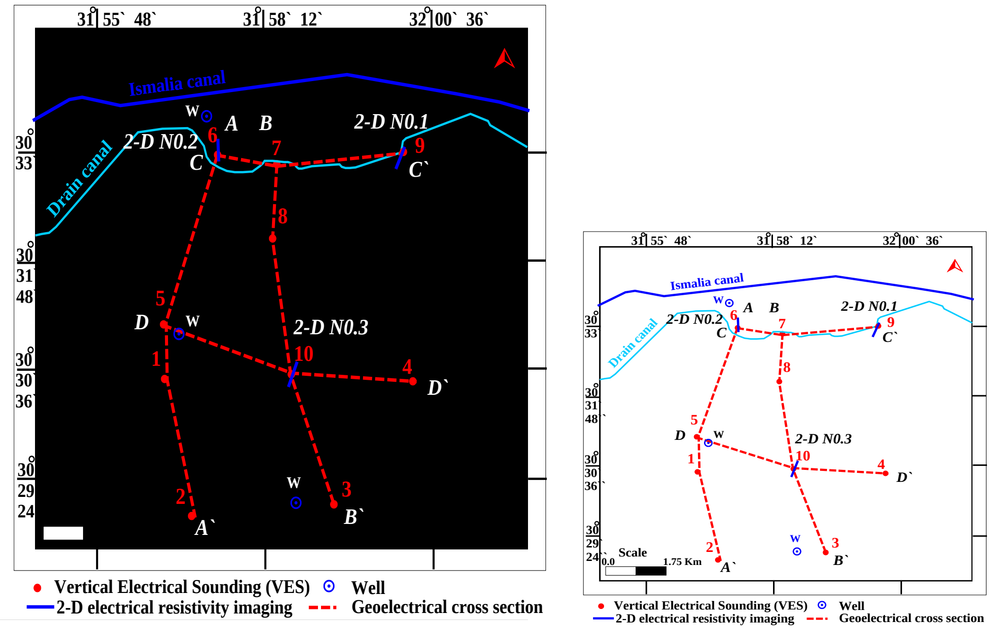


Fig. (1): Location map of the VES stations, Well, 2-D geoelectrical resistivity imaging and the geoelectrical cross sections in El-Salhyiah El-Gedidah

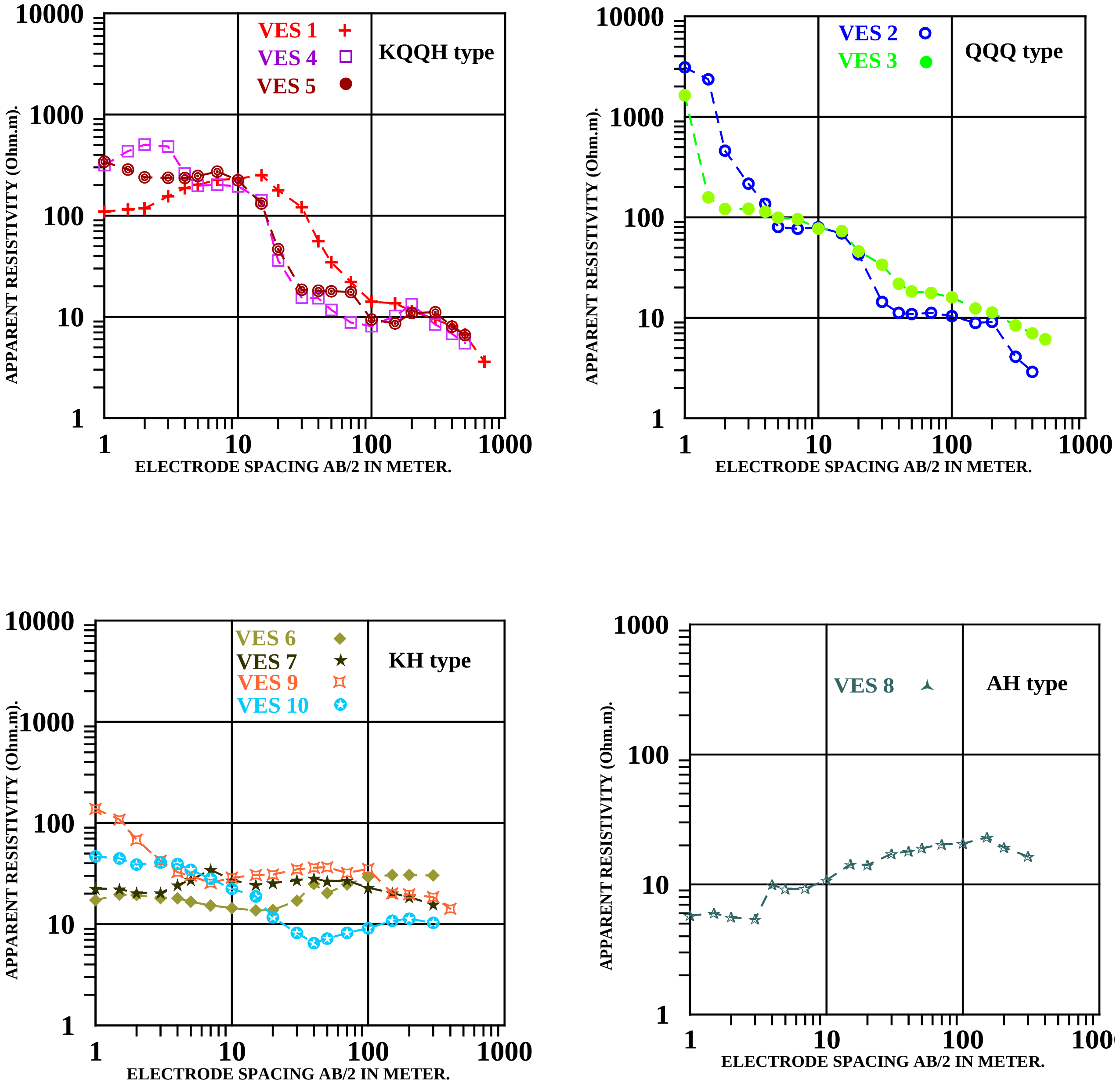


**Fig. (2) The field curves of the Vertical Electrical Soundings (VES)
in Salhyiah El Gedidah.**

INTERPRETATION AND RESULTS

1- Groundwater Exploration:

a- Interpretation of the Vertical Electrical Sounding Data:

Figure (2) shows the resistivity sounding curves with different varieties: KQQH, QQQ, HK and AH types which have been carried out in the investigated site. From this figure, it is obvious that the apparent resistivity values at the surface and near the surface show different trends and shapes, which indicate and reflect a heterogeneous character. In going downwards on the resistivity sounding curves, a low resistivity layer can be observed at AB/2 value of 300m.

The detailed quantitative interpretation of the field measurements was carried out by using a computer program "RESIST" written by Velpen (1989). It is an iterative and inverse modeling program for interpreting the resistivity curves in terms of a layered earth model. The data of the drilled wells at locations of VES stations 3, 5 and 6 were used in modeling the geoelectrical succession.

The quantitative interpretation of the geoelectrical resistivity sounding data is discussed in terms of the geoelectrical parameters of the resulting geoelectrical zones i.e., resistivity and thickness. The resistivities are related to the lithology according to the available geologic information of the area and the existing wells. The parameters of the geoelectrical zones such as thicknesses and resistivities are given in (Table1).

From top downwards, these layers can be described as follows;

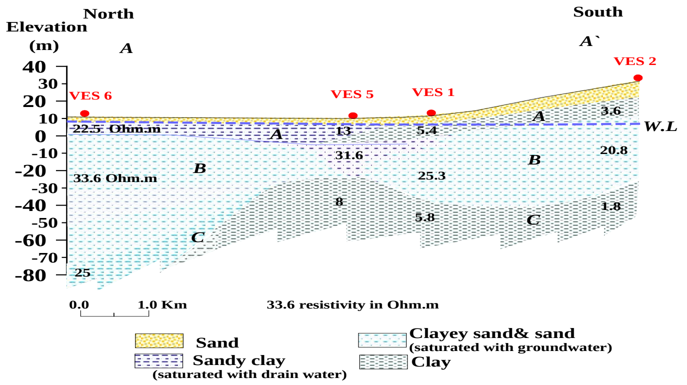
1- **Surface layer:** This layer consists of a group of thin layers that attain a resistivity ranging between 5.4 to 350 Ohm.m. The wide resistivity range reflects variable lithology corresponding to sand, gravel and clay intercalations. The thickness of this layer varies from 2.5 to 9.6m.
2- **Geoelectrical layer "A"** This layer exhibits low resistivity values ranging between 3.6 Ohm-m and 24 Ohm.m. This resistivity range represents clay and sandy clay layer. The thickness of this layer varies from 6.2 to 34m.
3- **Geoelectrical layer "B"** This layer exhibits resistivity values ranging between 22.1 Ohm.m and 44.2 Ohm.m. This resistivity range represents clayey sand and sand layer. The thickness of this layer varies from 21.8m to 43m.
4- **Geoelectrical layer "C"** This layer exhibits low resistivity values which range from 1.8 to 16.4 Ohm.m corresponding to clay with a lower resistivity values and water bearing sandy clay with a higher resistivity value within this layer. The base of this layer has not been reached.

The vertical and horizontal extensions of the detected geoelectrical layers are illustrated as geoelectrical cross sections (A-A') and (B-B`), figure (3) from north to south and (C-C`) and (D-D`) from west to east direction figure (4). The details of some common findings from the geoelectrical cross sections are discussed as follows:

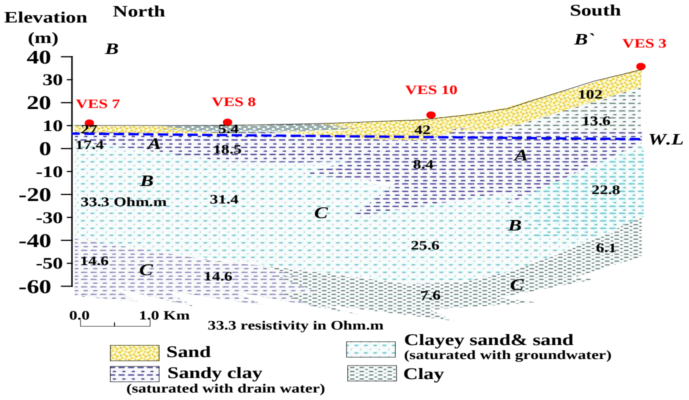
- The surface and the layer "A" geoelectrical layers (sand, sandy clay and clay deposits) show, along the north-south directed cross sections, relative thickening towards the central and southern parts of the area.
- The layer"B" is recorded at a lower depth along the north-south cross sections due to existence of feeding resources.
- Most of the detected layers extend throughout the investigated site with variable thickness.
- The geoelectrical resistivity values of the water bearing layer "B" decrease southwards. The resistivity variation is an indication of decreasing groundwater potentiality in the same direction.

Table (1) : Concluded geoelectrical layers in Salhyiah El Gedidah.

VES No.	Surface layer Dry Sand		layer "A" Sandy clay & Clay (Drain water saturated)		layer "B" Clayey Sand & Sand (groundwater saturated)		Last layer "C" Clay	
	ρ Ohm.m	h (meter)	ρ Ohm.m	h (meter)	ρ Ohm.m	h (meter)	ρ Ohm.m	h (meter)
1	>100	7.0	5.3	9.8	26.3	36	5.8	-------
2	>100	9.6	3.6	15.4	28.4	33	1.8	-------
3	65	9.5	13.6	24	22.8	30	6.1	-------
4	350	7.1	8.1	14.8	22.1	25	6.9	-------
5	300	5.6	12.7	11.4	31.5	19.8	8.0	-------
6	15	3.1	22.5	8.9	33.6	43	16.4	-------
7	45	3.2	17.3	7.1	33.2	37	14.5	-------
8	5.4	2.5	16.0	14	31.4	42	14.5	-------
9	100	3.0	24	6.2	44.2	40	14.6	-------
10	35	9.3	8.4	34	25.6	28.7	7.6	-------

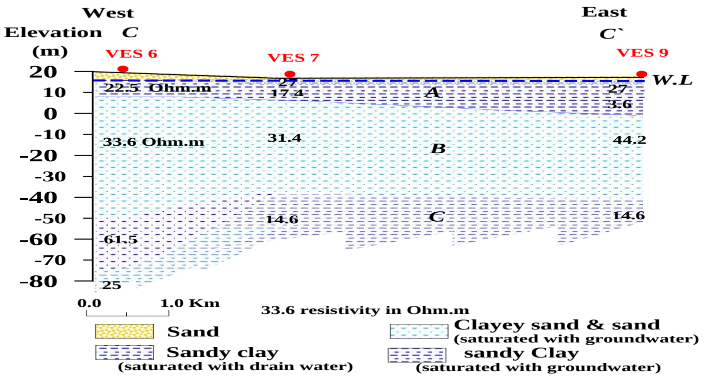


Geoelectrical cross section A-A`

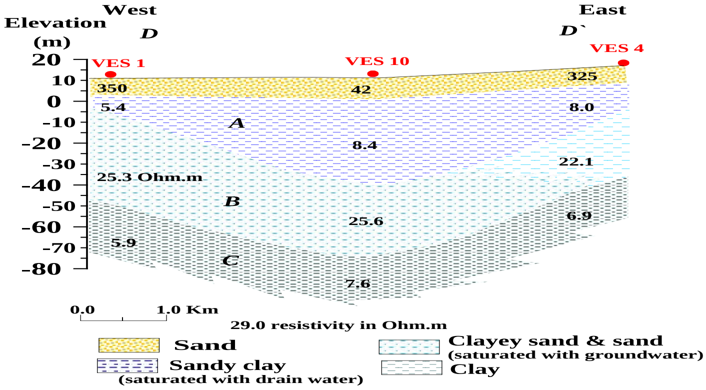


Geoelectrical cross section B-B`

Figure (3): Geoelectrical cross sections (A-A`) and (B-B`)



Geoelectrical cross section C-C`



Geoelectrical cross section D-D`

Figure (4): Geoelectrical cross sections (C-C`) and (D-D`)

b- Interpretation of the imaging profiles :

For the interpretation of the imaging data, use was made of the computer program RES2DINV, ver. 3.48a written by Loke (1998). Three imaging profiles were conducted at three sites. The first is close to VES N0.9, in a NE-SW direction, the second lies at VES stations N0. 6 it strikes in an N-S direction and the third profile lies at VES N0. 10. It trends in a NE-SW direction. The variability of the resistivity and the irregular shapes of the layers suggest heterogeneous character for the upper part of the images, surface and near surface layers that consist of sandy clay and clay with different degrees of clay content, corresponding to the geoelectrical layer "A" which has been delineated through electrical sounding. The middle part of the images shows, more or less, irregular surface below which the resistivity increases steadily to values of more than 15 Ohm-m. This layer represents groundwater bearing clayey sand and sand corresponding to the geoelectrical layer "B" which has been delineated through electrical sounding. The lower part of the images shows a lower resistivity layer less than 10 Ohm.m, corresponding to the geoelectrical layer "C" which consists of clay. Moreover, the resistivity decrease has been extended to the lower layers. The image is the true resistivity plot obtained after iterations through the inversion program. The results indicate the domination of three resistivity layers. The image illustrates the distributions of the true resistivities along each profile figure (5). The interpreted results can be illustrated as follows:

1. The resulting electrical image outlines a high resistivity layer (more than 150 Ohm.m) that extends to a depth of about 25m. This layer is interrupted by layers of low resistivity (2-10 Ohm-m). At the north eastern side of the profiles an anomalous low resistivity layer (less than 10 Ohm.m) can be observed on the surface the increase in resistivity is mainly attributed to increase of water content in the pores of the soil due to the infiltration of water after irrigation. This feature is repeated along the profiles. Actually, these anomalies have been initiated from the downward infiltrating water of irrigation and effect of recharging from the drainage canal at the northern side of the site. The layer represents a sandy clay layer and clay corresponding to the layer "A" which has been delineated through electrical sounding.
2. The second layer "B" represents water saturated clayey sand and sand with a resistivity value ranging from more than 15 Ohm.m and thickness from 20 to 45m. This layer as indicated on the profiles is detected at a depth of about 25m at the central part of the profiles. It represents a clayey sand layer. Along these profiles there are two contradicted resistivity ranges (high and low) detected at almost the same depth. The highest resistivity is mainly attributed to increase of water content in the layer while the lowest resistivity attributed to increase of clay content.

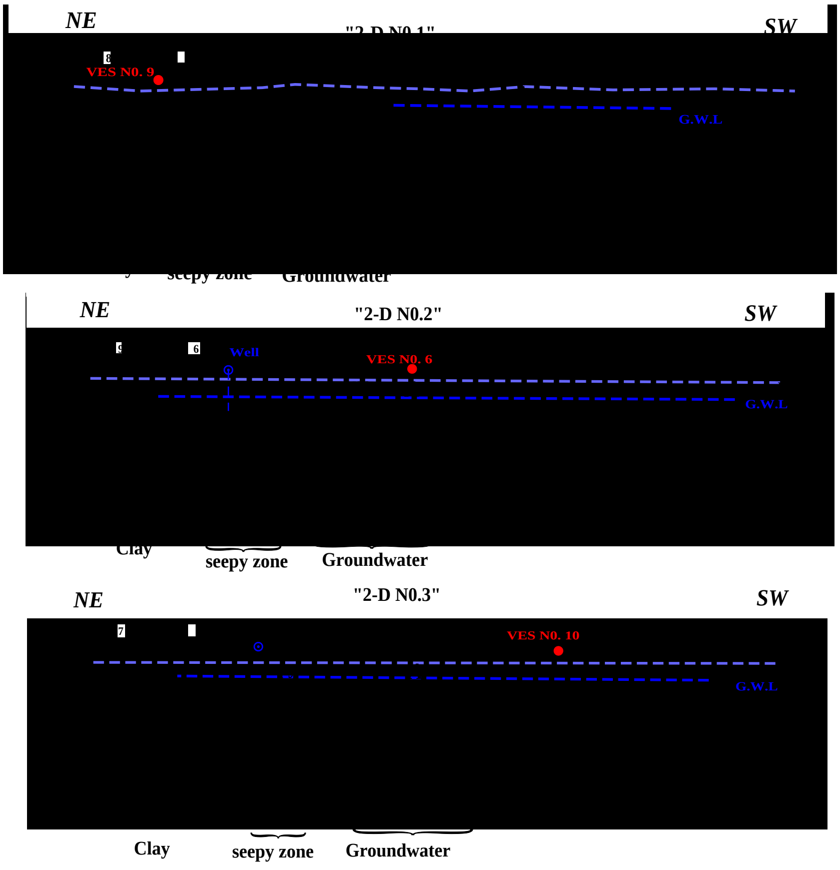


Fig. (5): True resistivity 2-D imaging profiles

3. The last layer represents a clay layer corresponding to layer “C” which has been delineated through electrical sounding with a resistivity from 14.5 - 25 Ohm.m. The lower part of the images shows, more or less, a regular surface below which the resistivity decreases steadily to values of less than 10 Ohm.m.

2- Groundwater Conditions:

From the geoelectrical cross sections (Figures. 3, 4) and the geoelectrical imaging profiles (Figure. 5), it is obvious that groundwater occurrence in the investigated area could successfully recognize two main water-bearing layers; the upper one represents the first shallow layer ‘A”, found to attain a resistivity range from 10 to 20 Ohm.m. This resistivity range represents sandy clay layer. A resistivity range around this value can be considered to represent downward infiltrating water of heavy irrigation and the lateral recharging from the drain canal, located to the north side of the area. The thickness of this layer ranges from 6 to 34 m and increases south ward.

The lower layer “B” is thick with much relatively higher resistivity values than the upper zone (more than 20 Ohm.m). The resistivity distribution within this layer reflects anomalous flow layers where the effect of recharging water has extended laterally indicating that this layer is characterized by different degrees of hydraulic conductivity. The thickness of this layer varies from 20 to 45m.

The groundwater potentiality of these layers in the area has been evaluated in view of the distribution of the electrical resistivity exhibited by the concerned layers. This has been achieved through isoresistivity maps for the water bearing layers in the investigated area. The groundwater potentiality within these layers have been determined by making use of the isoresistivity and isopach contour maps, from the isoresistivity maps. It is evident that the low resistivity values, that may represent water occurrences, are localized at the southern part of the investigated area.

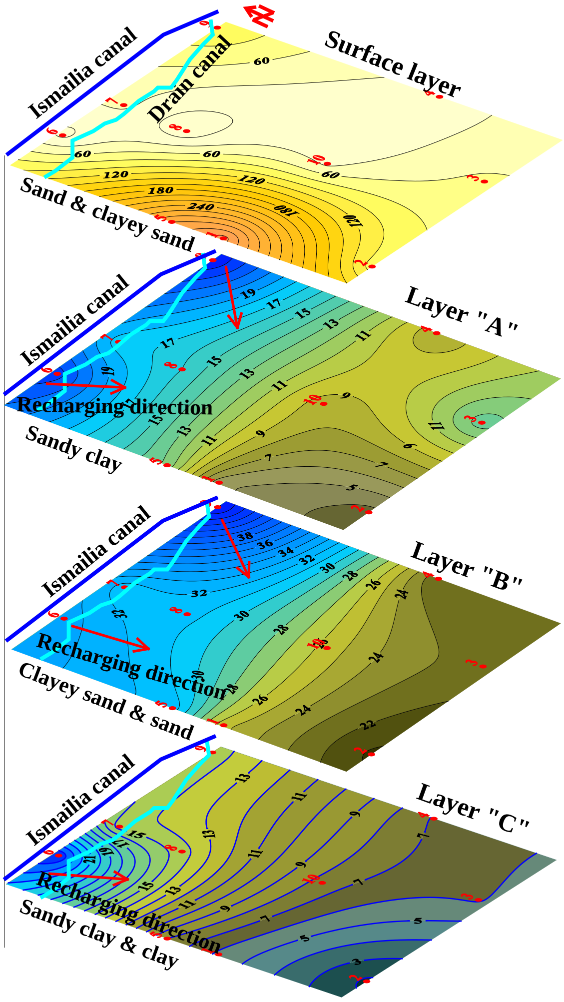
The groundwater potentiality within the concerned layers increases by increasing the resistivity values due to increasing the density of the water saturation. On the other hand, the groundwater potentiality decreases by decreasing the resistivity values due to the increase in clay content within the layer and hence lower permeability. Based on the same concept, high resistivity values are considered to represent layers of high water saturation within layer that has higher permeability.

According to the resistivity distribution (Fig. 6), layer “A’ reflects degree of recharging water from drain canal that lies to the north of the investigated area and the infiltration water due to irrigation within the concerned layer increasing towards the northeastern part of the area which is directly recharged from irrigation water or the water of drain canal that lies to the north of the area. This layer shows a potentiality which decreases gradually towards the south is due mainly to the increase in clay content towards the same direction which acts as a barrier against the water flow in this direction. Whereas, the resistivity distribution (Fig. 7), in layer “B” shows resistivity values of this layer decrease southward and the potentiality decrease towards the same direction that can be attributed to the increase of clay content acting as a barrier against the lateral flow of the groundwater in this direction. The higher resistivity values at the northern portion of the area attributed to this layer is directly recharged from water of Ismailia canal at the northern side of the area or by infiltration from the upper layer through the zones of higher permeability. On the resistivity distribution (Fig. 8), in layer “C” it is obvious that the groundwater occurrences at the northwestern part attributed to the relative higher resistivity values (13 -20 Ohm.m) at this location that may be recharged from the upper layer “B”.

Fig. (6) Isoresistivity and iaopach contour maps of the geoelectrical layer“A”

Fig. (7): Isoresistivity and isopach contour maps of the geoelectrical layer “B” .

Fig. (8): Isoresistivity contour map of the geoelectrical layer “C”.



Isoresistivity contour maps for geoelectrical layers in Ohm.m

Fig. (9): Isoresistivity contour maps of the geoelectrical layers show the direction of the impact of the surface water canals on the groundwater potentiality in the study area.

Figure (9) shows the horizontal and vertical resistivity variations of the different layers and the impact of recharging resources on the water bearing layers in the investigated the area.

SUMMARY AND CONCLUSIONS

A geoelectrical study has been carried out with the purpose of detecting groundwater existence and delineating the relation between feeding resources and groundwater. Geoelectrical resistivity sounding and two-dimensional electrical imaging measurements were conducted to fulfill the objective of the study.

The results of the geoelectrical resistivity sounding and geoelectrical imaging revealed that the subsurface succession in the area consists of three main layers without surface layer. The surface layer has a wide resistivity range which reflects a variable lithology composition corresponding to sand, gravel and clay intercalations. The underlying layer “A” consists of water bearing sandy clay that has low resistivity values ranging between 3.6 and 24 Ohm-m. This layer is affected by two feeding water resources differentiated into infiltration of heavy flood irrigation and drain water from the drain canal which lies to the north of the investigated area. This layer is underlain by a second water bearing layer “B” which exhibits resistivity values ranging between 22.1 and 44.2 Ohm-m. This resistivity range represents clayey sand and sand layer. The thickness of this layer varies from 19.8m to 43m. This layer is recharging by fresh water from Ismailia canal and the downwards infiltrated water from the upper layer.

According to this study the following findings can be concluded:

1- Water table exists at depth of 2.5m from the ground surface increasing southwards the area.
2- The infiltration of irrigation water below 2.5m is affected by heavy flood irrigation and drain water from the drain canal.
3- The thickness of the shallower saturated layer “A “decreasing southwards is due to increasing clay content in the same direction.
4- The groundwater potentiality of the lower layer “B” decreasing southwards due to decreasing permeability that attributed to increasing of clay content which acts as a barrier wall against the lateral groundwater flow in this direction.
5- The existence of sandy clay (the first detected zone “A”) is not quite enough to prevent any possible infiltration to the groundwater bearing layer “B” which lying beneath.
6- In view of the above-mentioned discussion, it is obvious that groundwater occurrence is feeding from three resources; the first is infiltration from water irrigation, the second is drain water from the drain canal, the third resources is fresh water from Ismailia canal and it controlled by existence of clay content within the water bearing layers.

Generally, the resistivity values and the thickness of the water bearing layers are increasing toward the north direction in the study area and increasing the groundwater potentiality of water, and water quality. The best site for production wells is that at the northern and the northeastern parts of the study area.

This study is an example which can be applied on large scale. Accordingly, reaching a decision for locating production wells needs carrying out further integrated geoelectrical studies to detect the sites with the best conditions, concerning thickness and depth of groundwater occurrence. The above-mentioned results can help the decision-maker in the process of agricultural development in the area

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