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GEOELECTRICAL STUDY ON THE GROUNDWATER OCCURRENCE IN WADI EL NEWIYA AREA - EL SAFF - SOUTH CAIRO-EGYPT

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The area of study lies at Wadi El Wedy to the south east of ElSaff area (55 km south-east of Cairo). The main objective of that work is the study of groundwater occurrence and selecting the proper sites for the drilling water wells in case groundwater is proved to exist. The geoelectrical resistivity methods are used through conducting 14 vertical electrical soundings and one profile of two-dimensional electrical resistivity imaging (electrical tomography) of 720 m length.

The detected geoelectrical succession consists of five geoelectrical layers. These from top downwards are, the top layer is formed of wadi deposit, the second layer consists of sand and gravel, the third layer consists of clay, shale or sticky clay, the fourth layer is saturated sandy clay and the last geoelectrical layer consists mostly of the Eocene limestone of high resistivity. This detected geoelectricl succession is dipping towards the northwestern direction and affected by normal fault with the northwest throw. The thickness sticky clay unit increases in the northeast direction while the sandy clay bed increases towards the northwestern corner of the study area.

The water bearing formation is the fourth layer (sandy clay), with thickness increases towards the northwestern corner of the area. The groundwater potentiality of this aquifer is moderate. The groundwater table is recorded for about +40m.

It can be recommended that the new water well can be drilled at the northwestern corner of the area, but regarding the lithology of the revealed water-bearing formation and is limited thickness, the groundwater productivity will be moderate.

Keywords: geophysics, geoelectric, vertical electrical sounding, electrical resistivity imaging, (electrical tempography), Wadi El Nwaiya – ElSaff.

The area of study lies (Wadi El Nwaiya) in the eastern side of the Nile, about 10 km southeast El Saff (55 km southeast Cairo). It bounded by latitudes 29° 31'–

29° 33' N and longitudes 31° 20'–31° 23' E, with an area of about 7 km² (Fig.1). El Saff area is located in the arid to semi arid belt of northeast Africa. Warm winter, hot summer, low rainfall and high evaporation rates mark the climate. The relative humidity is moderate and active winds of intermediate speeds are recorded. The main annual rain fall ranges from 4.2 mm to 17.4 mm. Evaporation is generally high, it reaches 18.7 mm/day in May and minimum value of 2.3 mm/day recorded in December. The average daily temperature varying from about 37.1°C in August to about 5°C in January. The highest recorded value of relative humidity was 71.8 % in December.

The groundwater occurrence of this study area and selecting the proper sites for the drilling water wells in case that groundwater is proved to exist are the subject matter of the present work. The geoelectrical resistivity methods are used to achieve these purposes (vertical electrical soundings and two-dimensional electrical resistivity imaging or electrical tomography). This is beside, overview the previous general geomorphology and geology of the area from the studies of AbdlShafy *et al.* (1986), as well as, field observations and the stratigraphical data of some water wells drilled in the area and its vicinities.

GEOMORPHOLOGICAL, GEOLOGICAL AND HYDROGEOLGICAL SETTINGS

Geomorphlogical setting

El-Saff area constitutes the western land stretch of the Eocene plateau. It has moderate relief with topographic hights ranging in elevation (from east to west) between 350 and 30 m.a.s.l , while the study area ranges from 100 to 60 m. Pediments, plateaus, scarps, ridges and low lands are the main landforms. The low lands in the area are represented by drainage lines. The study area lies at one of these drainage lines (Wadi El-Nawaiya), shown in Fig.1. This wadi extends about 21.5 km in ENE-WSW direction and debauches in the Nile at El Wedy village. Generally, the drainage density is low (with a bifurcation ratio of 4.32) indicating more or less gentle stream erosion (AbdlShafy *et al.*, 1986).

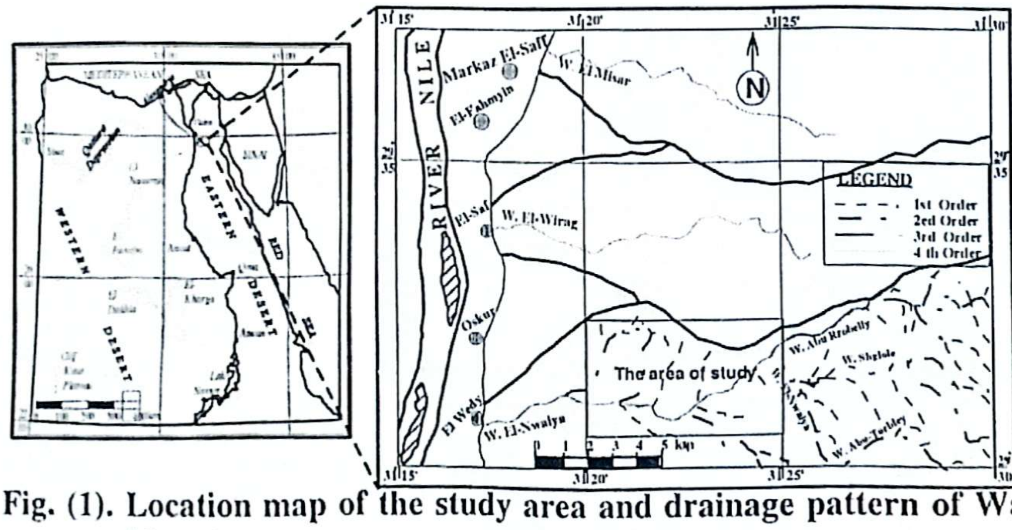


Fig. (1). Location map of the study area and drainage pattern of Wadi Nawaiya.

Geologic setting

In ElSaff area, the Quaternary sediments overlain unconformably the Tertiary ones where the Pleistocene deposits form many river terraces, reaching about 20 m above the flood plain (Abdel Daim, 1971). It distinguished into the older Sand-gravel Member and the young Clay-silt Member (Attia, 1954 and Said, 1975). Recent deposits dominate in the modern flood plain of the River Nile forming the base of the cultivated soil and fill the dry channels of the eastern wadis as well as the base of most Urban lands. They are distinguished into four types, the young nilotic, aeolian sand, gravelly alluvium and young wadi fill, AbdlShafy *et al.* (1986). Faulting is the dominant structural element in the area. Two normal gravity fault systems, the Mediterranean (E-W) and the Clysmic (NW-SE) are present (Fig.2). Minor associated folds have been recognized in the eastern portion and oriented NW-SE (Shukri, 1953).

Hydrogeological setting

The hydrogeological status depends generally on the climatic conditions and the lithology of the aquifer. The recharge from local precipitation during the Eocene period (expected 25-200 mm, annually) and during the alluvial period, could gain quantities of water. These waters, probably, percolated through deep fractures especially in the faulted and deep fractured zones. The quality of this water would be expected to be of high salinity due to the dissolution of salts from the Upper Eocene deposits. The most important aquifer in ElSaff area is the Quaternary deposits. Pleistocene graded sands and gravels are the main groundwater aquifer, which are fully saturated by water through the whole water bearing thickness (30-40 m). The groundwater is available at depth 35 m from the ground surface.

Hydrogeological setting

The hydrogeological status depends generally on climatic conditions and lithology of the aquifer. The recharge from local precipitation during the Eocene period (from 25-200 mm, annually), could gain quantities of water. Great quantities of water were gained also during the alluvial period. These waters, probably, percolated through deep fractures especially in the faulted and deep fractured zones. The quality of this water would be expected to be of high salinity due to the dissolution of salts from the Upper Eocene deposits.

The most important aquifer in ElSaff area is the Quaternary deposits. Pleistocene graded sands and gravels are the main groundwater aquifer, which are fully saturated by water through the whole water bearing thickness (30-40 m). The groundwater is available at depth 35 m from the ground surface. These sands and gravel underlain a semi-permeable layer composed of silt, clays, sands or fill deposits and overlie impermeable massive plastic clays. This maintains semi-confined to fairly free water condition upon the stratigraphic sequence of the water bearing or the confining layers. Generally, this aquifer is characterized by increase in grain size with depth and is interrupted by some silt and clay lenses, where the total depth of wells varies from 65 to 105 m (AbdlShafy *et al.*, 1986). The main trunks of the wadis in ElSaff area, are carve in the Middle Miocene limestone bedrock and the gravelly alluvium (wadi-fill) fills them. It is probable that the troughs of some valleys in these limetsones reach some horizons appreciably below the level of the Nile in ElSaff area. Among the shallow water wells drilled in ElSaff area, 3 water wells were investigated sedimentolgically by Abd-ElShafy *et al.*(1986) as representatives of Quaternary sediments (one of them lies in the study area, well No.4). Sediments of the studied wells are medium to coarse sand, sorting decreases downwards from moderately to poorly sorted, and the sorting decreases with the increase of grain size (Fig.3). These sediments could be ascribed to a river environment. The area under investigation is covered by soil cover of clay sand and gravel, underlain by sand and gravel of the Quaternary deposits. This formation represents the main aquifer of the flood plain of the Nile valley underlies by silt and clay Pliocene deposits.

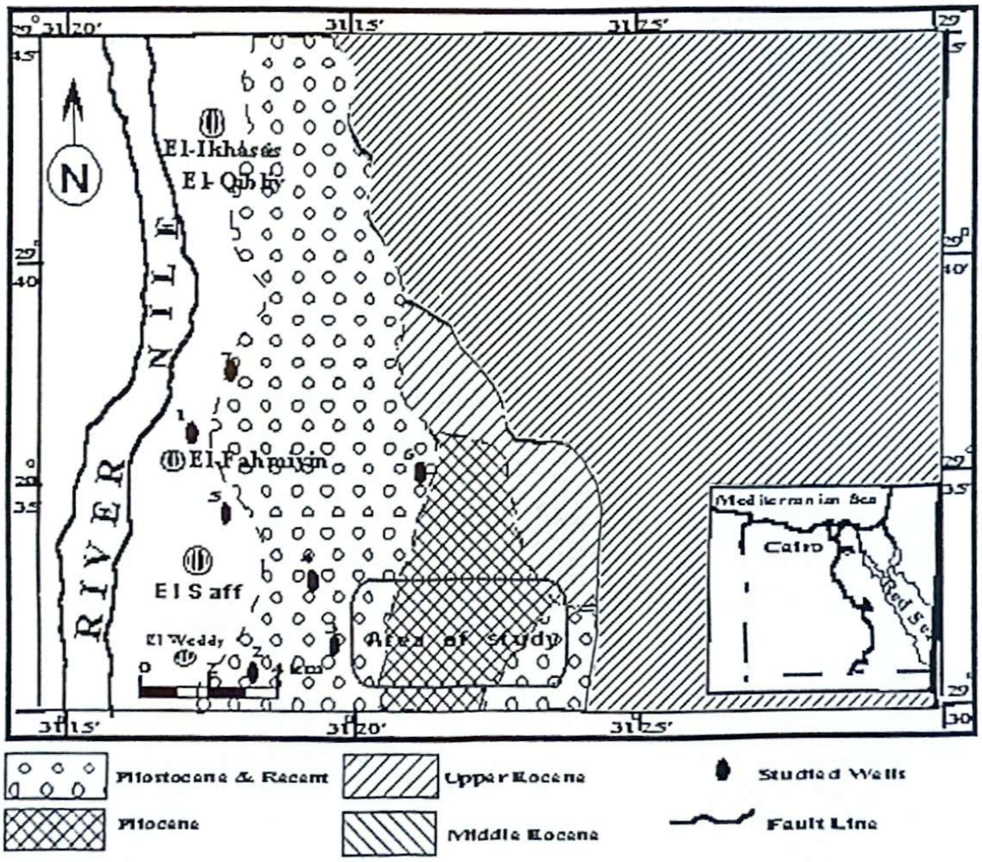


Fig. (2). Geological Map the study area and its vicinities (After Said R., 1962).

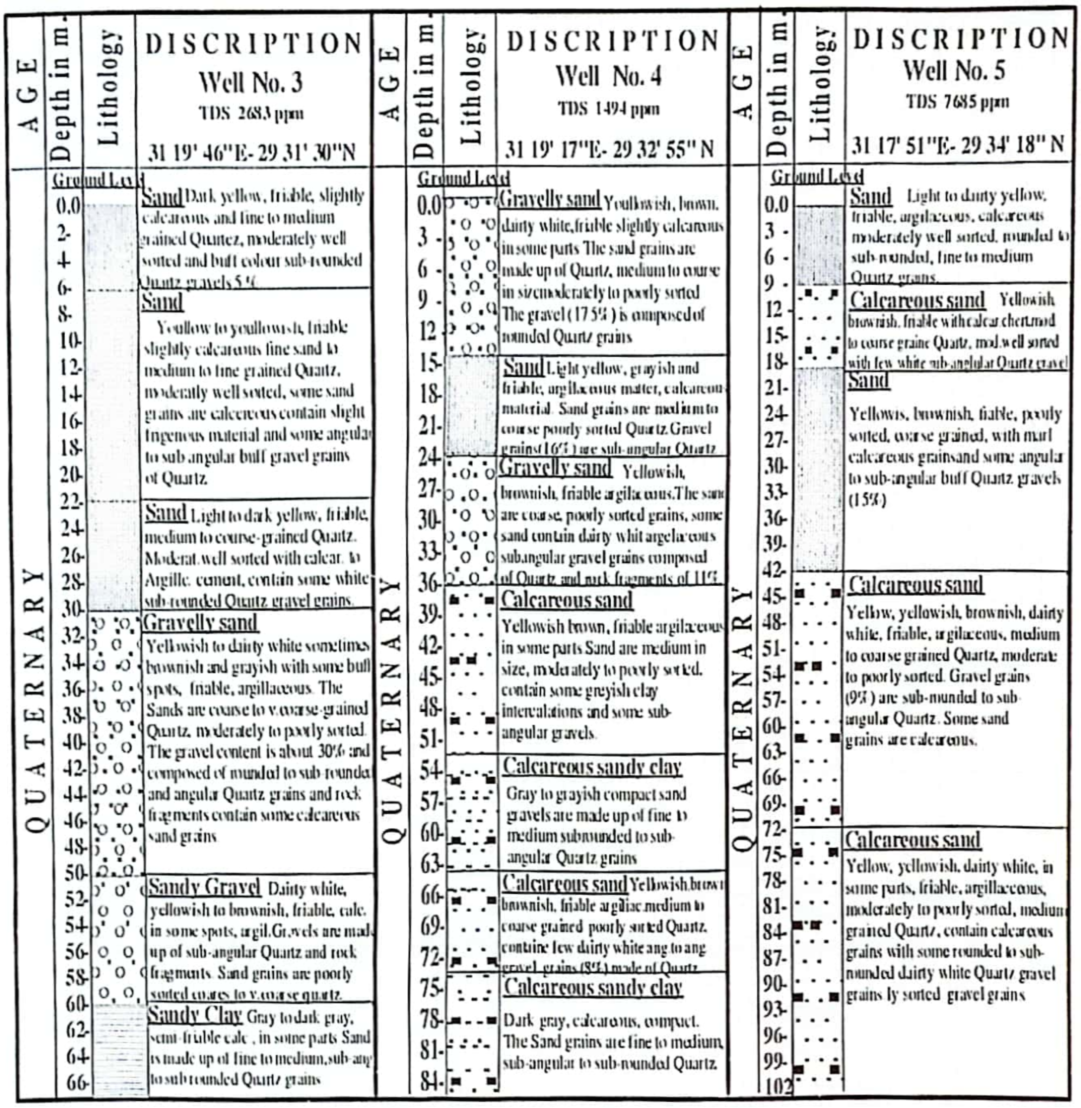


Fig. (3). Lithologic succession of the studied water wells Southeast ElSaff area.

FIELD DATA AQUSITION AND INTERPRETATION TECHNIQUES

1- The geoelectrical resistivity survey

A total of 14 Vertical Electrical Soundings (VES) were carried out in the study area. Most of the VES stations are distributed along East-West profiles as shown in figure (4). Two of the VES stations were conducted at the sites of two drilled wells. Such measurements were utilized in the quantitative interpretation of the field sounding curves. The Schlumberger 4-electrodes arrangement has been used during the geoelectrical measurements. The half-spacing distances of the current electrodes were successively increased from 1 to 1000 m at each of the sounding stations. Land topographic survey has been carried out by using the GPS instrument in order to locate the VES stations and determine their ground elevations (Table1). The measured values of the apparent resistivity in Ohm.m are plotted versus half electrode separation in meters in the form of resistivity sounding curves.

The geoelectrical resistivity curves were subjected to quantitative interpretation by using the computer program RESIX-PLUS (1996). The interpretation process lead to the detection of five geoelectrical layers by using the model according to all the geologic and subsurface information (from the groundwater wells). Some of the successive thin geoelectrical layers (mostly the uppermost ones) have been grouped together in one layer, while other layers are absent at some sounding stations.

TABLE (1). Location and ground elevation of the VES stations.

VES No.	Longitude	Latitude	Altitude (m)	VES No.	Longitude	Latitude	Altitude (m)
1	31°20`.896	29° 31`.336	64	8	31°21`.797	29° 31`.331	83
2	31° 20`.974	29° 31`.339	64	9	31° 21`.824	29° 31`.168	80
3	31° 21`.170	29° 31`.176	65	10	31° 22`.333	29° 31`.136	97
4	31° 21`.363	29° 30`.975	68	11	31° 22`.297	29° 31`.282	97
5	31° 21`.359	29° 31`.172	71	12	31° 22`.769	29° 31`.168	88
6	31° 21`.392	29° 31`.316	73	13	31° 20`.225	29° 1`.963	91
7	31° 21`.355	29° 31`.543	80	14	31° 20`.452	29° 31`.729	61.5

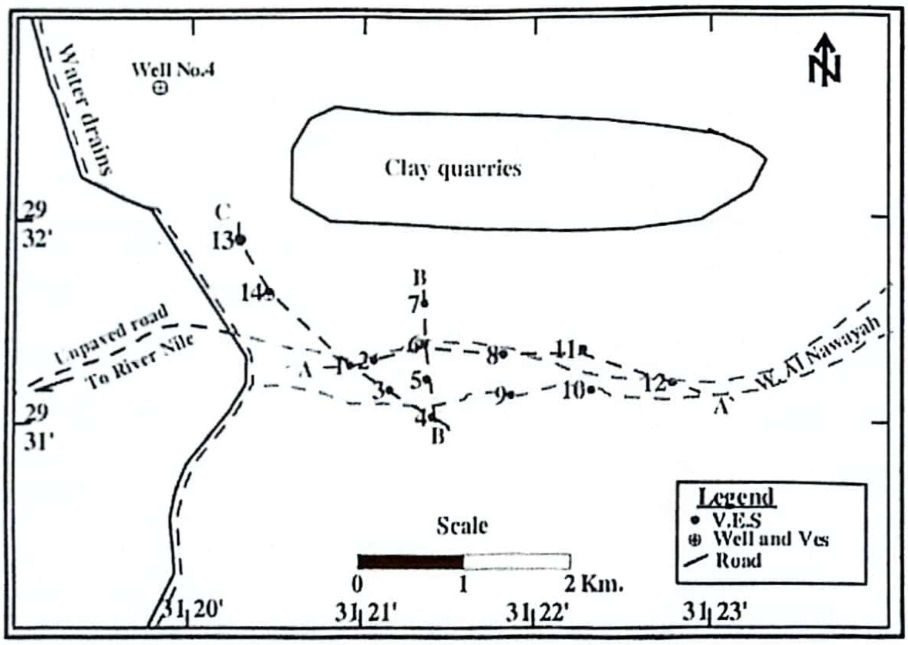


Fig. (4). Location map of the VES stations, wells, geoelectric cross sections and electrical tomography profile.

2- The electrical tomography

The two-dimensional electrical resistivity imaging or electrical tomography is a survey technique developed for the investigation of areas of complex geology particularly for groundwater and engineering investigations. The method produces continuous image for the distribution of the electrical properties in the subsurface (Griffiths and Barker, 1993). The tomographic surveys normally employ arrays of electrodes on the ground surface for data collection. This survey technique involves measuring a series of constant separation traverses with the electrode separation being increased with each successive traverse (Fig.5). In the Wenner electrode array the measurements start, at the first traverse with unit electrode separation "*a*" and increased at each traverse by one unit i.e. *2a, 3a, 4a* ....,*na*; where n is multiplier.

.For the interpretation of the imaging data, use was made of the computer program RES2DINV, ver3.4 written by Loke (1998). It is a Windows-based computer program that automatically determines a two-dimensional (2-D) subsurface resistivity model for data obtained from electrical imaging surveys (Griffiths and Barker 1993). The program enables removing bad datum points before inverting the data so that they do not influence the resulting model.

DISCUSSION

The geoelectrical parameters (resistivities and thicknesses) as concluded from the interpreted field data are used to construct three geoelectrical cross sections (A-A', B-B' and C-B') shown in figures (6, 7 and 8). These geoelectrical cross sections show the vertical and horizontal extensions of the detected geoelecteical layers. From these geoelectrical cross sections, five main layers are distinguished. Generally, these layers can be described from top to bottom, as follows:

- The upper most geoelectrical layer consists of a group of thin layers having different resistivities and thicknesses; these layers show a wide range of resistivity (0.2-1400 Ohm.m). This wide range is attributed to the type of deposits consisting the Quaternary alluvial deposits formed of gravel, sand and clay interbeds. These layers extend with an average thickness of about 12m. This layer represents the dry surface layer of the study area.
- The second geoelectrical layer is characterized by relatively high resistivity values (54-185 Ohm.m) with an average thickness of about 10 m. These values represent coarse-grained materials composed of clay, gravel and sand.
- The third geoelectrical layer is characterized by relatively low resistivity values. These values represent fine-grained materials such as clay, shale (which correlated to be sticky clay). This layer is characterized by a

narrow range of low resistivities (0.4–5.2 Ohm.m) and its thickness ranges from 11.4m at VES 4 to 28.1 at VES 4 with median of about 25 m. It is not detected at VES stations 3, 4 and 5.

- The fourth geoelectrical layer shows a relatively higher resistivity than the previous one (13.0–17.5 Ohm.m). It is mostly composed of sandy clay and it thickness ranges from 28.1m to 11.4m with an average of about 20 m. Although this layer is water-saturated, it is of moderate productivity due to its moderate permeability.
- The fifth geoelectrical layer is characterized by a relatively high resistivity in the range of 80 Ohm.m at VES station No. 10 to 197.4 Ohm.m at VES station No.3 with median value reach 109 Ohm.m. This layer is mostly composed of limestone bedrock, correlated to be of Eocene Age. The base of this layer has not been reached in any of the measured soundings as it represents the last layer in the geoelectrical succession. According to structural contour map of the upper surface of the limestone (Fig. 9), it can be noticed that the depth to the Eocene limestone bedrock in the area of study ranges from 25.5 m at VES station No.1 to 73m at VES station No.6. It detected to be shallow in the southwestern side of the area. The maximum thickness of the sediments over that bedrock is detected at stations 1, 2, 3 6, 7, 8, 13 and 14 (at the northern corner).

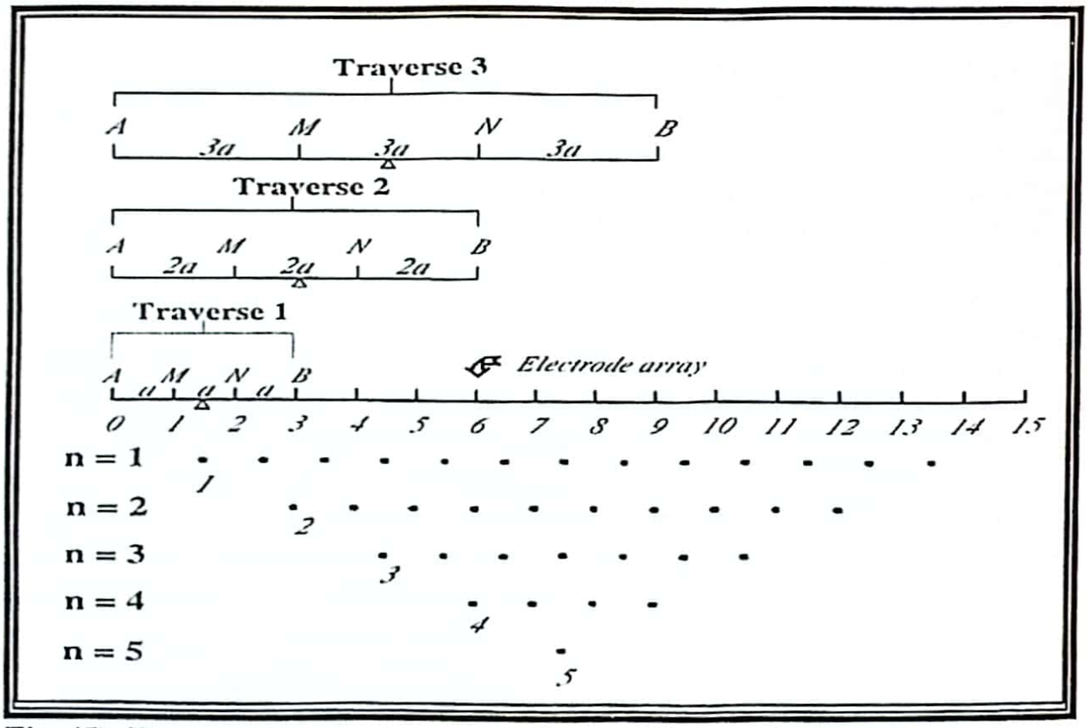


Fig. (5). The measurement sequence for building up the imaging section.

Generally from these geoelectric cross sections, the detected geoelectrical succession is affected by a normal fault with the down through towards the northwest.

Also the geoeletric layers are dipping towards the northwest direction. The thickness sticky clay unit increases in the northwest direction and the sandy clay bed increases also towards that direction. Due to the faulting, the depth to the top of limestone bedrock is shallow in the southern direction; its maximum depth is detected in the northwest direction. The pizometric level of water table is recorded of 40m in the well at the vicinity of VES No.14.

C- Interpretation of the electrical tomography

An imaging profile of 720 m length was measured directly crossing Wadi El Nowaiya in N-S direction in-concordance the geoelectric profile B-B`. The Wenner electrode array was used for acquiring this imaging resistivity data. The measurements were started, at the first traverse, with unit electrode separation "a" equals 20 m and increased at each traverse by one unit i.e. 20, 40, 60, ...,240 m.

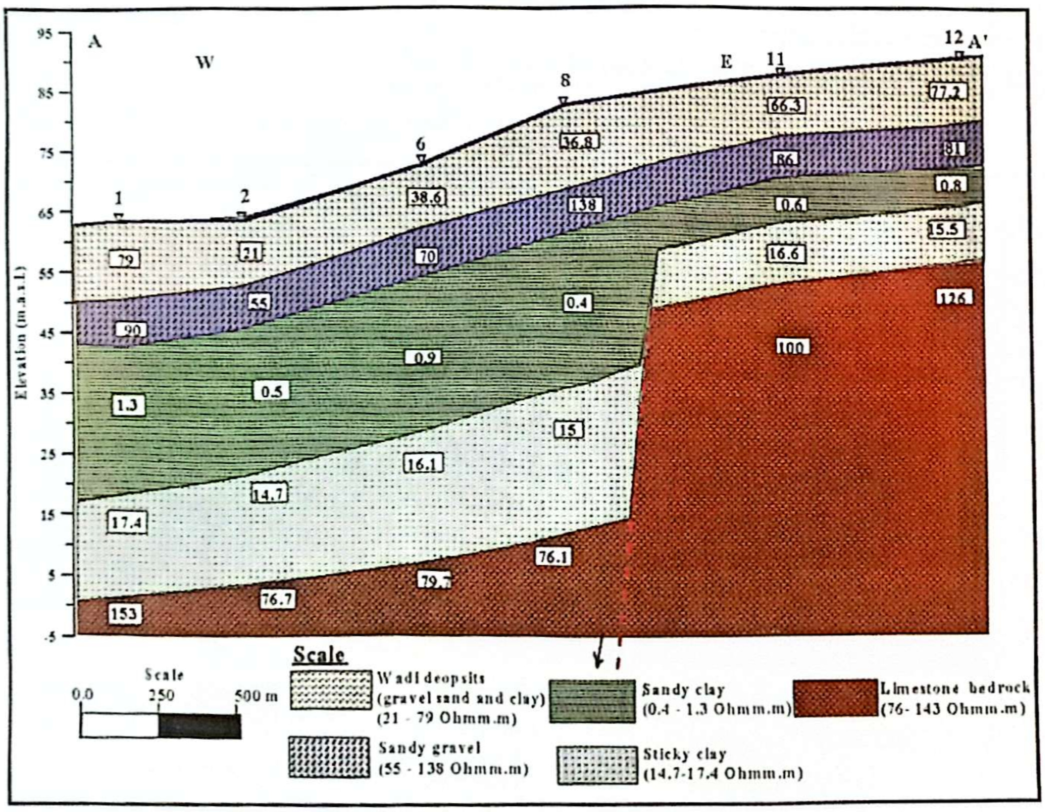


Fig. (6). Geoelectrical cross section (A A)

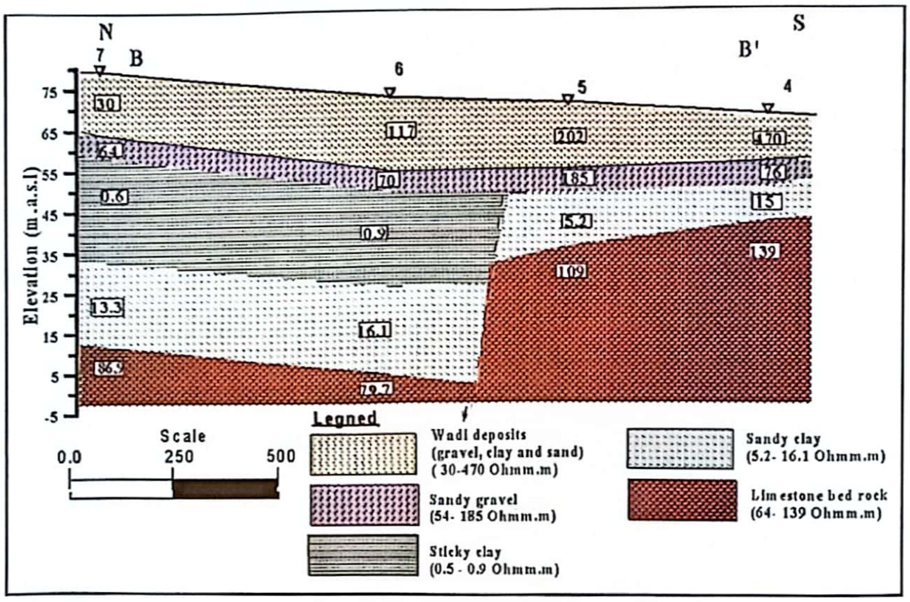


Fig. (7). Geoelectrical cross section (B B)

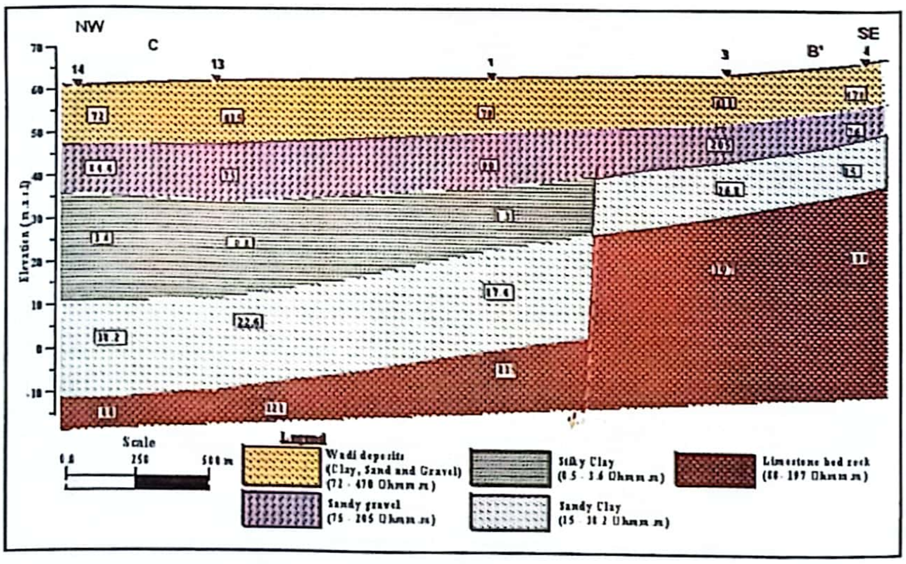
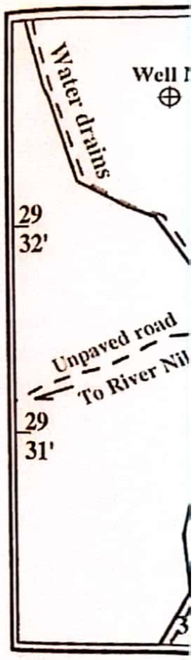


Fig. (8). Geoelectrical cross section (C C)



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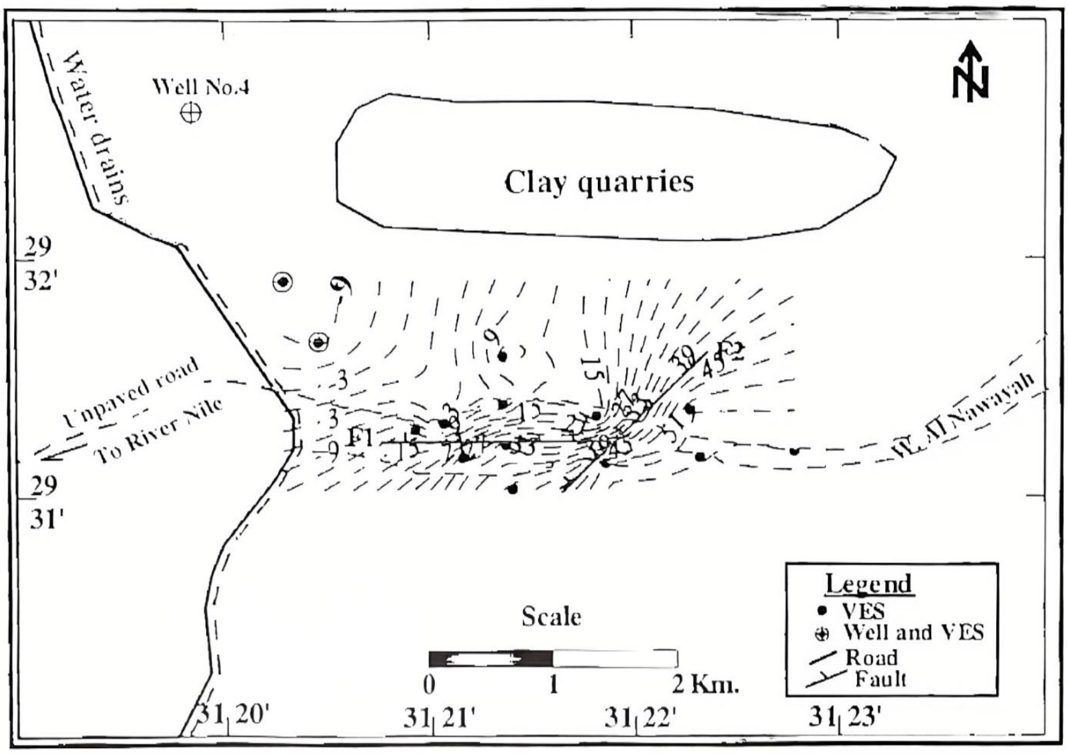

Fig. (9). Structural contour map for the upper surface of limestone.

The upper image of fig. (10) is a plot of the measured apparent resistivity pseudo-section down to datum level n=12. Examination of this section indicates the domination of different low resistivity zones at two datum horizons. Downwards the formation dominates by wadi fill, gravel and sand, sticky clay, sandy clay and limestone deposits (downward to depth of about 77 m).

The lower image is the true resistivity plot obtained after 3 iterations of the inversion program. Examination of this section indicates the domination of high resistivity zones (>200 Ohm.m) extending along the upper parts of the profile. The high resistivities correspond to alluvial deposits consisting of clay, sand and limestone fragments derived from the eastern escarpment rocks. Beneath the second unit (the gravelly sand layer) the image shows some low resistivity (to a value > 10 Ohm.m) zones that extend and attributes to clay deposits. The image shows zones of moderate resistivity (13-18 Ohm-m) downwards at the lower part of the profile most probably attributed to the occurrence of water bearing saturated sandy clay.

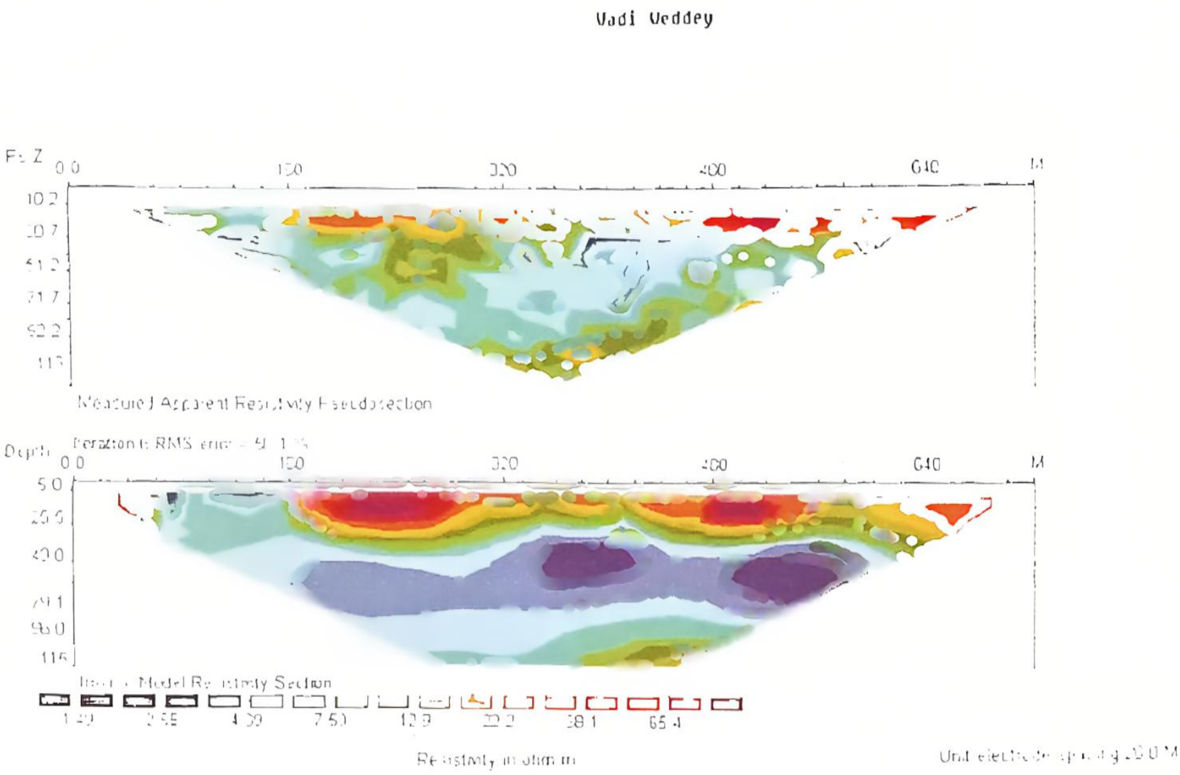

Fig. (10). The apparent resistivity and true resistivity 2-D images

Accordingly, it can be concluded that the whole geological succession at that location of measurements consists of wadi deposits underlain by gravelly sand, sandy clay, sticky clay, sandy clay sandstone deposits followed downwards by the Eocene limestone bedrock which may be detected only at the southern end of the profile. This is produced continuous resistivity image confirmed the results of the previous geoelectricl cross-sections.

CONCLUSIONS AND RECOMMENDATIONS

The geoelectrical survey of the study area is accomplished through carrying a total of 14 Vertical Electrical Soundings (VES) besides a geoelectric tomogrphy profile (two-dimensional resistivity profile). Two of these VES stations were conducted beside the sites of two drilled wells, which utilized in the quantitative interpretation of the field sounding curves. The Schlumberger 4-electrodes arrangement has been used during the geoelectrical measurements. An imaging profile of 720 m length was measured directly crossing Wadi El-Nowaiya in the N-S direction. The Wenner electrode array was used for acquiring this imaging resistivity data.

The measurements were started, at the first traverse, with unit electrode separation "a" equals 20 m and increased at each traverse by one unit i.e. 20, 40, 60, ...,240 m.

In view of the reached results, from both the three-constructed geoelectricl cross sections and the imaging profile, it can be concluded that the geoelectrical succession of the explored area consists of five geoelectrical layers from top downwards. The top layer is formed wadi deposit of clay, sand, gravel and rock fragments. It shows a wide range of electrical resistivity. The second layer consists of sand and gravel with relatively high resistivity. The third layer consists of sticky clay, with remarkably low resistivity. That fourth layer consists of sandy clay layer saturated with water but of moderate water productivity due to its moderate permeability. The last geoelectrical layer consists mostly of the Eocene limestone, which could be revealed through its relatively high resistivity.

From the present study, the detected geoelectrical succession is affected by a normal fault with the down throw towards the northwest. Also the geoeletric layer is dipping towards the western direction. The thickness of the sticky clay unit increases in the northwest direction and the sandy clay bed increases towards the northwestern corner of the study area. Due to the faulting, the depth to the top of limestone bedrock is shallow in the southern part, its maximum depth is detected in the northern direction. The water bearing formation is the fourth layer (sandy clay), with thickness increases towards the northwestern corner of the area. The groundwater table is recorded to be 40m in the well at the vicinity of VES No.14. The groundwater potentiality of the area of study is moderate.

It can be recommended that new water well can be drilled at the northwestern corner of the studied area, but regarding the lithology of the revealed water-bearing formation and is limited thickness, the groundwater productivity will be moderate.

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دراسة جيوكهربية على ظروف تواجد المياه الجوفية بمنطقة وادي الودي-الصف جنوب القاهرة – مصر.

محمد عبداللاه خالد وعبدالله الأباصيرى عبدالرحمن
قسم الاستكشاف الجيوفيزيائى- مركز بحوث الصحراء- المطرية – القاهرة – مصر.

تقع منطقة الدراسة بوادى النوية جنوب شرق مدينة الصف (٥٥ كم جنوب القاهرة). ومن خلال دراسة الوضع الجيولوجى والجيومورفولوجى. وقد تمت دراسة جيوكهربية على ظروف تواجد المياه الجوفية بالمنطقة. تم خلالها عمل عدد ١٤ جسه كهربية رأسية وبروفيل تخريط جيوكهربى طوله ٧٢٠ متر.

في ضوء تفسير وتحليل نتائج القياس الحقلية وجد أن التتابع الطبقي الرأسي لصخور المنطقة يتكون من عدد خمسة طبقات من أعلى الى أسفل كما يلي:

أ_ طبقة السطحية ذات مدى واسع من المقاومة النوعية الكهربية وسمك حوالى ١٥ متر وتتكون من رواسب الوادى التابع للعصر الحديث والتى تتكون من الطين و الحصى والرمل.

ب_ طبقة جافة تتميز بمقاومة عالية نسبيا وتتكون من الرمل والحصى بمتوسط سمك يصل حوالي ١٠ متر.

ج_ طبقة منخفضة المقاومة الكهربية وتتكون من الصلصال المتماسك وتنخفض مقاومته النوعية الى ما دون ٥ أوم/ متر ويتكون غالبا من الصلصال أو الطفل بسمك ٢٥ متر.

د- الطبقة الرابعة وتتكون من الطين الرملى ترتفع مقاومته النوعية الى ١٣-١٧,٥ أوم/متر وسمكه ٢٠ متر تقريبا وهو الذي يحتوى على المياه الجوفية. تتميز بنفاذية متوسطة تجعل منه خزانا جوفيا متوسط الإنتاجية .

هـ- الطبقة الخامسة والأخيرة في التتابع الصخري الذي تمت دراسته تتكون غالبا من الحجر الجيرى ذو المقاومة النوعية المرتفعة نسبيا.

ومن نتائج تلك الدراسة أمكن تحديد موضع فالق عادى رميته السفلى لجهة الشمال الغربى. وقد أمكن تعيين العمق لسطح طبقة الحجر الجيرى الذى يقل جهة الجنوب ويزيد حهة الشمال الغربى. أيضا من التخريط الكهربى تم تحديد طبقة الطين الصلصال المتماسك والتى يزيد سمكها فى اتجاه الشمال الغربى.

على هذا يمكن التوصية بحفر بئر أو آبار للمياه يعتمد في إنتاجيته على نوعية الطبقة الرابعة الحاملة للمياه فى المنطقة الشمالية الغربية فقط من منطقة الدراسة .