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GEOELECTRICAL STUDY ON THE GROUNDWATER OCCURRENCE IN THE AREA SOUTHWEST OF SIDI BARRANI, NORTHWESTERN COAST, EGYPT

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دراسة جيوكهربية على تواجد المياه الجوفية بالمنطقة الواقعة جنوب غرب سيدي براني بالساحل الشمالي الغربي، مصر

الخلاصة: تعرضت منطقة الساحل الشمالي الغربي أثناء الحرب العالمية الثانية لزراعة الألغام بها مما أدى إلي إعاقة التنمية في هذه المنطقة وساعدت الدولة على إزالة بعض الألغام من بعض المناطق الصغيرة داخل المنطقة وذلك لاستغلالها للتنمية، وتعتبر منطقة الدراسة واحدة من هذه المناطق. ونظرا لأهمية المنطقة الواقعة جنوب غرب سيدى برانى بالساحل الشمالى الغربى لأجل التنمية الزراعية والرعوية المستقبلية فان وجود المياه الجوفية بها يشكل عنصرا مهماً ومساعدا لهذه التنمية بخلاف مياه الأمطار التي قلت كميتها فى السنوات الأخيرة ولذلك فقد تم استكشاف إمكانية تواجد الطبقة التحت السطحية الحاملة للمياه الجوفية والتي يمكن استغلالها كمصدر للتنمية فى هذه المنطقة.

وتم أجراء دراسة جيوكهربية على المنطقة المستهدفة باستخدام توزيع شلمبرجير لعمل الجسات الجيوكهربية العمودية وعددها ١٥ جسه و دراسة جيوكهربية مقطعية ثنائية الأبعاد باستخدام توزيع فينر خلال بروفيل طوله ٥١٠ أمتار. ومن المعلومات الجيولوجية والمعلومات المائية المحدودة من السوانى المتواجدة بالمنطقة تم وضع النموذج الأولى اللازم لعملية التفسير الكمي لبيانات الجسات الجيوكهربية. كما تم التوصل من خلال التفسير الكمي للجسات الجيوكهربية العمودية الى تتابع صخري تحت سطحي يتكون من خمس طبقات معظمها من الصخور الكربوناتية حيث أن الطبقة الثالثة هى الطبقة الحاملة للمياه وتتكون من صخور الحجر الجيري المتشقق وتم معرفة سمكها وانتشارها بالمنطقة.

وقد أسفرت نتائج القياسات الجيوكهربية المقطعية ثنائية الأبعاد خلال بروفيل يمر بسانية الشنيدرة التى تقع فى جنوب منطقة الدراسة والتي توجد المياه بها على عمق ٤١ متراً من سطح الأرض عن وجود أربعة نطاقات جيوكهربية ويمثل النطاق الثالث مقاومة كهربية نوعية منخفضة ترجع إلي وجود طبقة من الحجر الجيري المتشقق الحامل للمياه وعلى عمق يماثل و يكافئ العمق الذي وصلت إليه الجسات الجيوكهربية العمودية وأن هناك توافقاً بين نتائج القياسات الجيوكهربية العمودية والمقطعية ثنائية الأبعاد.

وقد أوضحت الدراسة أن التتابع الطبقي متأثر بثلاثة صدوع عادية لهم تأثير على تتابعات الطبقات التحتسطحية وعلى تواجد المياه الجوفية بالمنطقة. وعلى ضوء هذه النتائج يتضح أن تواجد المياه الجوفية بمنطقة الدراسة يتوقف على وجود تشققات بطبقة الحجر الجيري، علاوة على ذلك فأن سمك وعمق هذه الطبقة يختلفان من جسة لأخرى على طول القطاعات الجيوكهربية.ولكن القياسات الجيوكهربية المقطعية ثنائية الأبعاد حددت بدقة سمك وعمق وأنتشار الطبقة الحاملة للمياه وبناءاً على ذلك فان الوصول إلى قرار بتحديد مواقع لحفر الآبار يتطلب إجراء دراسات جيوكهربية تفصيلية متكاملة مثل هذه الدراسة لتحديد المواقع التي تتميز بأفضل الظروف لتواجدات المياه الجوفية بالمنطقة.

ABSTRACT: *The study area lies at the distance of about 35 km west of the city of Sidi Barrani and about 50 km to the east of the Sallum city and at about 9 kilometers south of the Mediterranean shoreline covering about 32 km.^{2}It occupies a portion of the semiarid climatic conditions area of Egypt. Geomorphologically, the study area lies on the piedmont plain having a general slope northward towards the Mediterranean Sea. Stratigraphically, deposits in the study area range in age from the Tertiary to Quaternary. The Miocene is the main aquifer in the area. It consists of different varieties from carbonate rocks, which play an important role in groundwater potentiality.* ***The water bearing formations would be recharged from local rainfall received generally by the area and its vicinities.***

The main purpose of the present investigation is finding out the shallow groundwater aquiferwhich exists in the area through the application of two geoelectrical techniques (vertical electrical sounding & two-dimensional (2D) geoelectrical imaging).

A grid pattern of 15 Vertical Electrical Sounding (V.E.S) stations has been used in the concerned area. The Schlumberger electrodes configuration was used, with current electrodes distance from 1000 to 1400m. Also, the two-dimensional (2D) geoelectrical imaging (tomography) with Wenner measurements has been carried out along a profile in West-East direction with a length of 510m at Sanyet Eshenderra with purpose of finding out the extension, depth and the thickness of the shallow aquifer. This technique can determine the fractures within the aquifer with high resolution.

The interpretation of the geoelectrical data led to the identification of the geoelectrical and geological successions comprising five geoelectrical layers (the first is surface layer, the second layer is dry and composed of limestone with clay intercalation, the third layer is a fractured limestone water bearing layer, the fourth layer is clay, while the last layer is dry limestone). Generally, the resistivity values and the thickness of the aquifer are increasing towards the east direction in the study area. This is attributed to increasing potentiality of water, good water quality and best production

of wells in that direction. The results of geoelectrical data revealed that groundwater exists in the study area depending mainly on the density of fissures and fractures within these rocks.
The area is influenced by faults which affected the subsurface successions forming a graben in the central part of the area. The above-mentioned results can help the decision-maker in the process of agricultural development in the area.

INTRODUCTION

The Northwestern Littoral Zone of Egypt overlooking the Mediterranean Sea is a part of the Western Desert that witnessed the end of the Second World War. Thousands of mine fields are buried under the drift sands of that desert, prohibiting any sort of development of that part of the country. Small limited areas have been demined and cleared, however, by the Egyptian armed forces and became ready to be agriculturally developed. Several trials have been made to provide the needed water through rainwater harvesting such as sisters but the amount of water so provided was insufficient. Additional water resources were then planned to be complementing the irrigation water of the area. As the nature and capacity of these local resources were not accurately known, geophysical exploration techniques are needed to clarify the groundwater setting within the demand area.

LOCATION OF THE STUDY AREA

The study area is in the form of a parallelogram lying at an average distance of about 35 km west of Sidi Barrani city and about 50 km to the east of the Sallum city and at about 9 kilometers south of the Mediterranean shoreline as shown in Figure (1). It lies between Latitudes 31º24'16" & 31º27'16"N and Longitudes 25º32' 00" & 25º 38' 33" E, with an area of about 32 km^2

GEOMORPHOLOGICAL AND GEOLOGICAL ASPECTS

The area of study lies within the northern part of the "Great Marmarican Homoclinal Plateau". It is characterized by semi-arid climatic conditions. Within the area the ground surface has an average elevation of about 40m. Different geomorphologic and geological studies were carried out along the northwestern Mediterranean coastal zone. Among these: Shata (1953, 1955 and 1971), Said (1962), Abdallah (1966 a and 1966 b), Sayed(1967), Selim(1969) and Taha (1973). The following are the geomorphologic and geological features that distinguish the study area:-

A- Geomorphologic Features

The is region in which the study area is located generally characterized by landforms that reflect the combined influences of several endo-genetic and exo-genetic factors, e.g. climatic conditions, lithologic features, geologic structures, paleo-geographic elements, etc. These landforms such as southern tableland, ridges, depressions, dunes, drainage lines control the distribution of surface runoff and consequently the groundwater accumulation and storage.

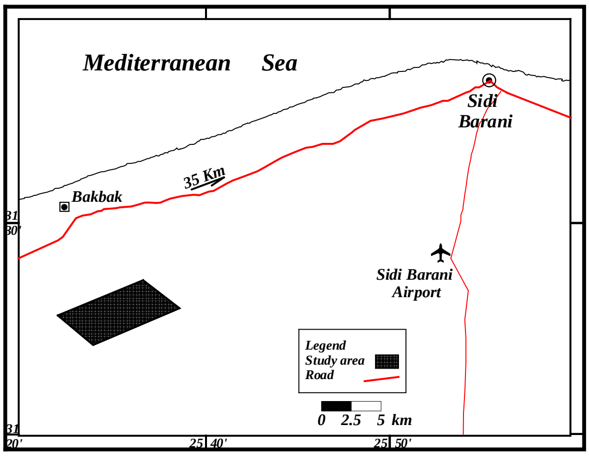


Fig (1):Geographic situation of the study area.

According to Selim (1969), the region exhibits three main geomorphologic units, from the south to north direction: the southern tableland, the piedmont plain and the coastal plain. The southern tableland is the most outstanding land feature in the northwestern littoral zone of Egypt. It extends southwards to the Qattara Depression. It is bounded on its northern side by an escarpment facing the coastal plain. Outlets of the drainage lines that pass to the coastal plain from high intake areas usually dissect the bounding slopes of the tableland. The piedmont plain in which the present study area is actually located. It extends to the north of the tableland and to the south of the coastal plain as a transitional zone between the tableland and the coastal plain. It is characterized by low land and hills. The coastal plain occupies a narrow strip of land stretching adjacent to the Mediterranean Sea. At the approaches of the headlands protruding seaward from the tableland, the coastal plain may be missing or becomes very narrow. Wherever the coastal plain is well developed, it displays features related to lithologic and structural conditions as well as fluctuation of sea level. Such features are mainly the alternation of low- lying elongate ridges separated by narrow depressions. Two of such ridges are present at Sidi Barrani which are the foreshore ridge and the inland ridge.

B- Rock Stratigraphy

The northwestern Mediterranean coastal zone is occupied by sediment and sedimentary rocks ranging in age from Tertiary to Quaternary (Selim, A.A., 1969) .In the study area the Miocene deposits are represented and underlie the Quaternary deposits.

Quaternary deposits are exposed in the study area. They are formed of thin cover of drift sands and loamy deposits covering mainly low-lying areas and the floors of narrow valleys dissecting the tableland as well as oolitic and cardium limestone followed by Miocene deposits which are represented by the Moghra and Marmarica Formations. The Moghra Formation is represented by a basal fluviatile to fluviomarine deposits. It is composed of argillaceous limestone intercalation with sand and shale, while upper limestone rocks of shallow marine origin having a wide areal extension representing the Marmarica Formation. It is formed of fractured white limestone and a lower grey calcarenite with some shale intercalation and represents the water bearing formation with salinity (>3000 ppm).

C- Geologic Structures

The study area is a part of the Marmarica Homocline, which occupies the area north of the Qattara Depression. Local structural undulations are present in the form of gentle upfold and downfold structures or broad monocline structures. Most of the folded structures are oriented NE-SW. Regionally, there is a number of major faults with their downthrow towards the north.

FIELD WORK

The field work comprised a geophysical survey and a land topographic survey. The geophysical field work involved the application of two geoelectrical methods of exploration to get an idea about the circumstances governing the occurrence of groundwater in the area. These methods are the Vertical Electrical Sounding method and the Electrical Imaging method .The land topographic survey was carried out to locate the sounding stations and determine their ground elevations. Each of these works is presented in the following:

1 – Vertical Electrical Sounding.

A grid pattern of 15 Vertical Electrical Sounding (V.E.S) stations has been carried out. The stations are reasonably distributed across the study area (Fig.2) in such as to yield subsurface information about the different parts of the area, accurate enough to cope with the targeted level of the present study. The current electrodes spacing used ranged between 1000 and 1400 meters in spite of the fact that the field conditions were very hard. One of the fifteen soundings has been carried out at the site of Sanyet Esheneidra well where the depth to water could be measured (41m). This station was used for the depth to water calibration for interpretation purposes.

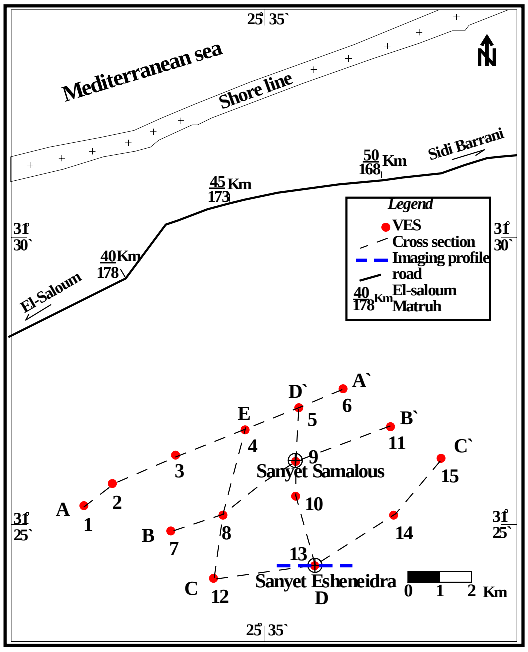


Fig. (2): Location map of the VES'es, wells and directions of geoelectrical cross sections in the study area.

In the geoelectrical field survey, Schlumberger electrodes configuration was used, with current electrode distance up to 1400m. The calculated apparent resistivity values (ρ_a) were plotted against half current electrodes spacing (AB/2) on bilogarithmic scale each cycle 6.25 cm as V.E.S curves (Fig 3-a, 3- b, 3-c). Topographic survey of V.E.S stations and wells were estimated from topographic map scale 1: 100000. Land topographic survey was carried out in the investigated area to locate the measuring points and to determine the ground elevation at each point as listed in the following table.

VES No.	Altitude (a.s.l)(m)	Longitude 00° 00` 00``	Latitude 00° 00` 00``
1	25	25° 31` 24``	31° 25` 19``
2	17	25° 31` 59.2``	31° 25` 38.4``
3	25	25° 33` 17.8``	31° 26` 11``
4	27	25° 34` 33.6``	31° 26` 34.3``
5	31	25° 35` 39.7``	31° 26` 59``
6	41	25° 36` 31``	31° 27` 17.4``
7	24	25° 33` 6``	31° 24 54``
8	28	25° 34` 19.56``	31° 25` 14``
9	33	25° 35` 40``	31° 35` 24``
10	38	25° 35` 41``	31° 25` 34``
11	46	25° 37` 30``	31° 26` 42``
12	36	25° 33`53.4``	31° 24` 6``
13	41	25° 35` 50``	31° 24` 7.1``
14	48	25° 37` 32.4``	31° 25` 12``
15	52	25° 38` 33``	31° 26` 2.5``

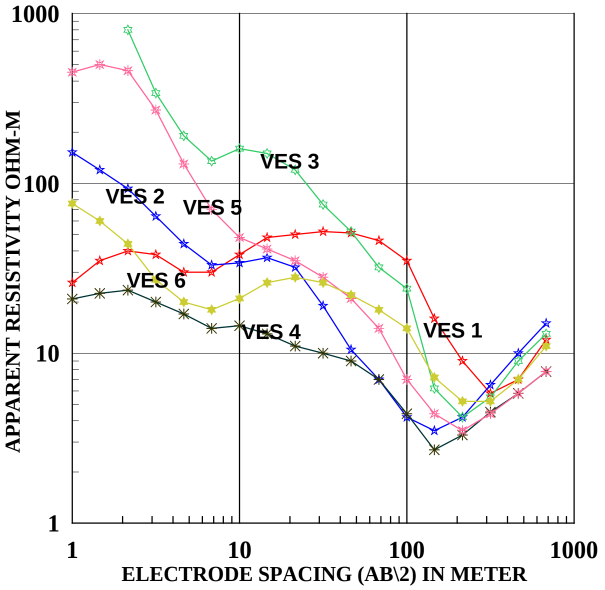


Figure (3 -a):Electrical sounding curves in the study area.

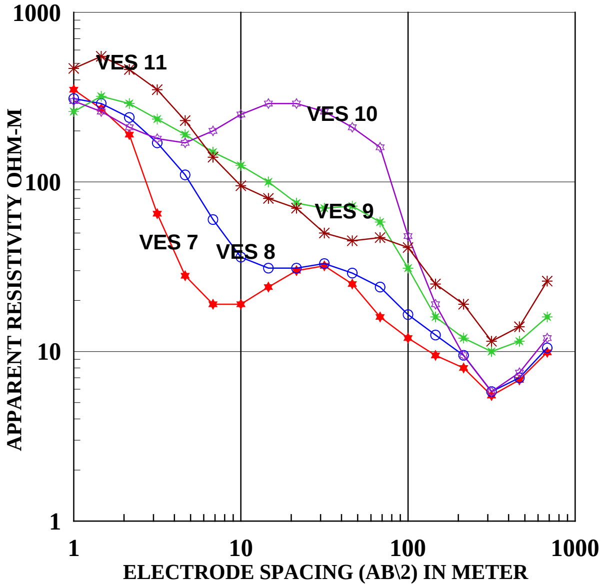


Figure (3 -b):Electrical sounding curves in the study area.

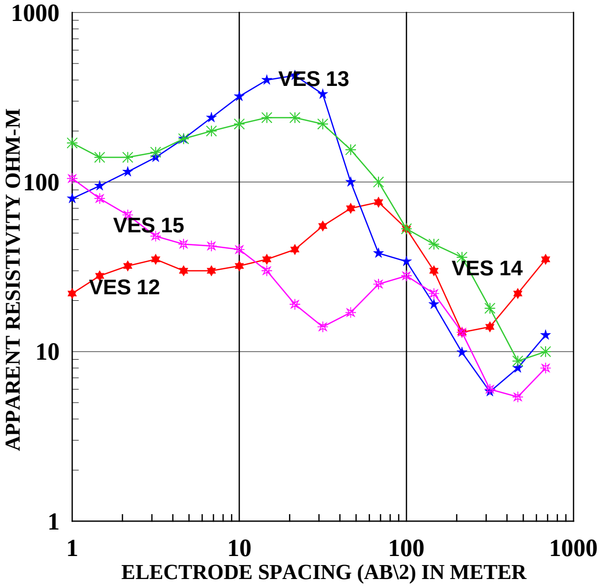


Figure (3 -c):Electrical sounding curves in the study area.

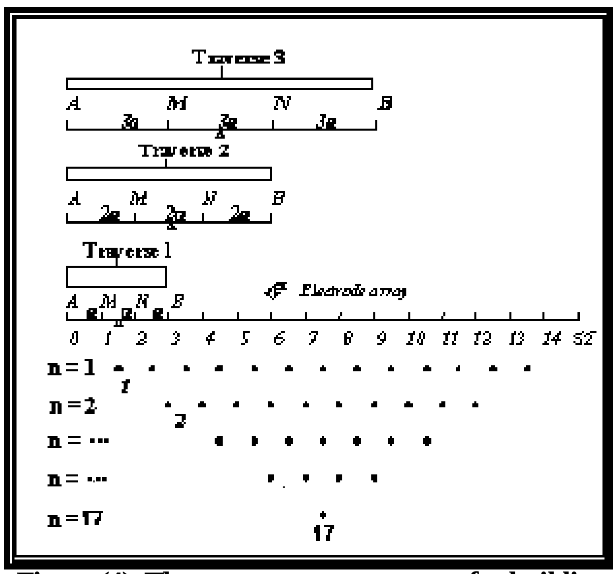


Figure (4): The measurement sequence for building up the electrical imaging section.

2- Two-Dimensional (2D) Geoelectrical Imaging (Tomography).

To study the conditions under which groundwater occurs in the area, high-resolution two-dimensional (2D) geoelectrical imaging (tomography) measurements have been carried out along a profile at Sanyet Esheneidra. The profile has been measured in West- East direction with a length of 510m. These measurements have been conducted at that locality as a case study with the main objective of studying the conditions under which groundwater occurs. This technique can determine the fractures within the aquifer.

The geoelectrical imaging technique with Wenner array involves measuring a series of constant separation traverses (datum levels) with the electrode separation being increased with each successive traverse (Fig. 4). The measurements continued successively to reach the last datum, which is represented by only one point with the largest electrodes separation (equals one third of the total length of the profile). The Wenner electrode configuration was applied in the present survey with unit electrode spacing (*a)* started with 10m and increased in the following traverses to 2a, 3a,…., i.e. 20, 30, 40,……and 170 m.

The measurements were conducted by using the direct current resistivity meter model (SAS 300). The instrument measures directly the resistance with high accuracy.

DATA INTERPRETATION AND DISCUSSION

1– Interpretation of the VES Curves

In the present study, the field curves were quantitatively interpreted using the computer program "RESIST" written by Van Der Velpen (1988). It is an interactive, graphically oriented, forward and inverse modeling program for interpreting the resistivity sounding data in terms of a layered earth model. The Sounding No. 13 has been carried out at the site of Sanyet Esheneidra well where the depth to water could be measured (41m). This station was used as modeling for the quantitative interpretation (Fig. 5).

The results of the quantitative interpretation of the sounding curves (resistivities and thicknesses) were transformed into geoelectrical cross-sections AA`, BB`, CC`, CE and DD` (Figs. 6, 7, 8, 9, 10) indicating the number of the geoelectrical layers as well as the true depth, thickness and electrical resistivity.

According to the resistivity values, along with the available information about the geology of the study area, each of the geoelectric layers was identified as to its lithologic composition and consequently checked for the occurrence of groundwater. The interpretation results indicate that the geoelectrical succession consists of five geelectrical layers. A detailed description of each layer from top to botom is given as follows:

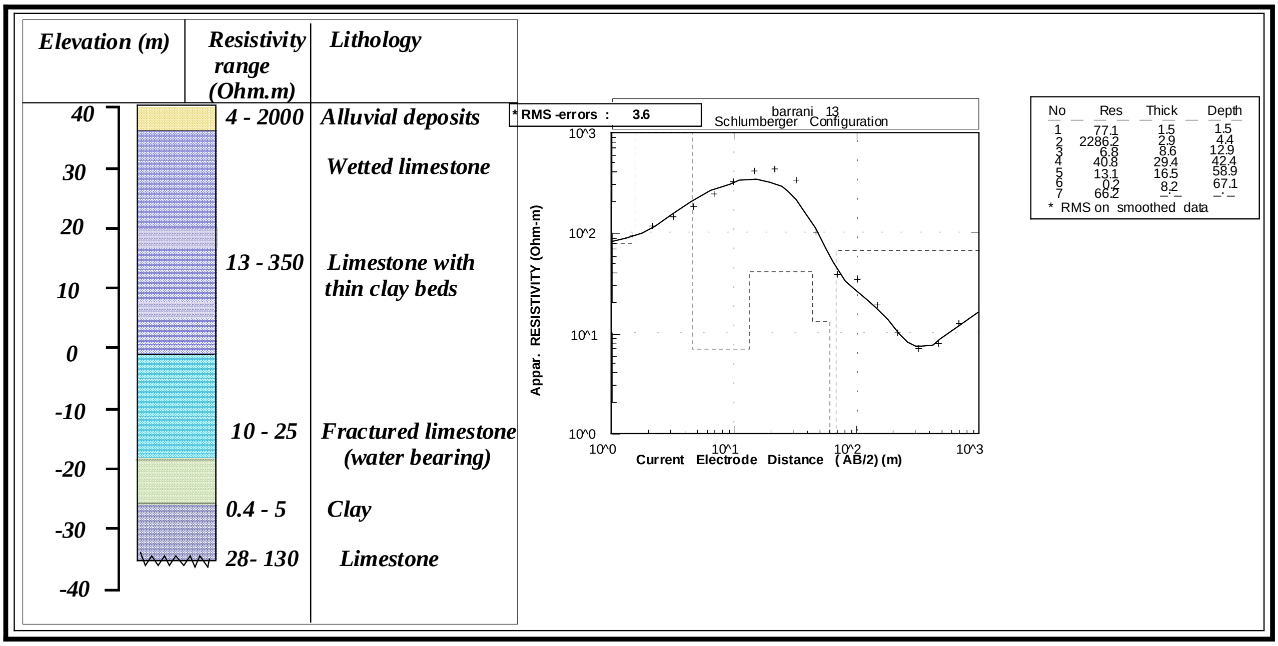


Fig. (5): Range of resistivities and corresponding lithological data in the study area and the interpreted results of VES No.13 at Sanyet Esheneidra (hand dug well).

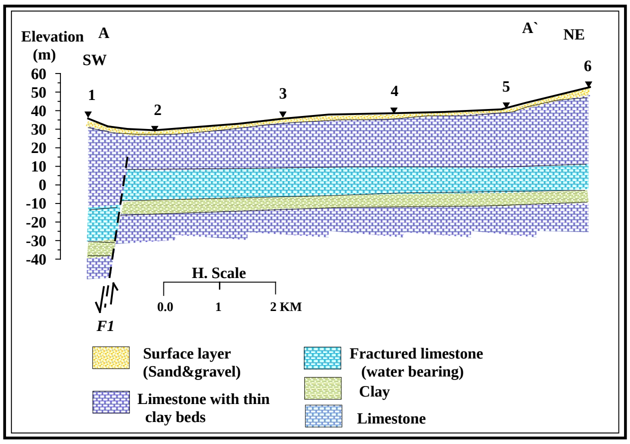


Fig. (6): Geoelectrical cross section A-A`.

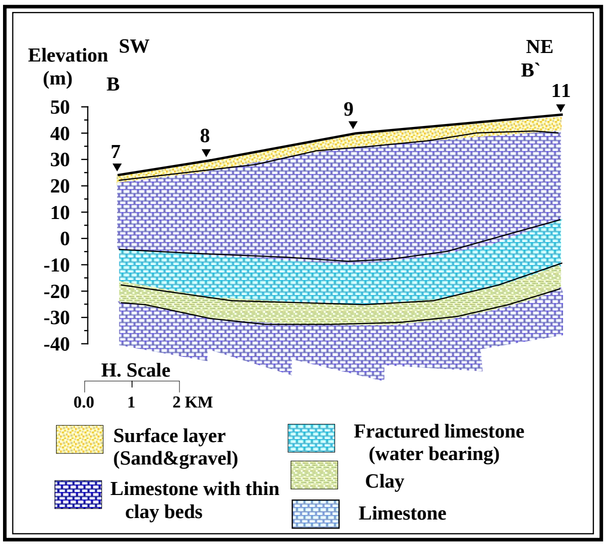


Fig. (7): Geoelectrical cross section B-B`.

1. A surface layer coverd with alluvial deposits, of gravel, sand and limestone fragments. It has a thickness < 6 meters with a wide range of electrical resistivity, being 4 to 2000 Ohm.m depending on the lithologic composition.

2. The second geoelectrical layer represents the dry layer. It is generally formed of limestone with thin beds of clay intercalation. This layer exhibits a wide electrical resistivity range from 13 to 350 Ohm.m, and with an average thickness ranging from 18.2 to 35.5m. The lower resistivity values are mainly attributed to the increase of the argillaceous material and thin clay beds within this layer.

3. The third geoelectrical layer represents water-bearing formation in the area. It is composed of fractured limestone with an average resistivity values ranging from 10 to 25 Ohm.m and with an average thickness varying from 13.3 to 19.5m. According to the data of Sanyet Esheneidra well, it has been found that this geoelectrical layer is tapping to the water-bearing layer. The lower resistivity values may be attributed to the increase the fracture system within the layer and increase of the water salinity.

4. The fourth geoelectrical layer attains low resistivity values that range from 0.4 to 5 Ohm.m. According to geologic evidence, this resistivity range represents clay or shale. This layer extends allover the area with thickness ranging from 5 to 8.2m.

5. The last geoelectrical layer is represented by limestone having an average resistivity range from 28 to 130 Ohm.m. The base of this layer has not been reached as it represents the last detected layer throughout the investigated area.

6. Generally, the resistivity values and thickness of water bearing layer increase towards the east direction. This is attributed to the increasing potentiality of water, good water quality and best production of wells in that direction.

7. The area is influenced by three faults (F1, F2 and F3), where uplifting of the water bearing layers in some locality and downthrowing it in other locality forming a graben in the central part of the area (Figs 6, 9 &10).

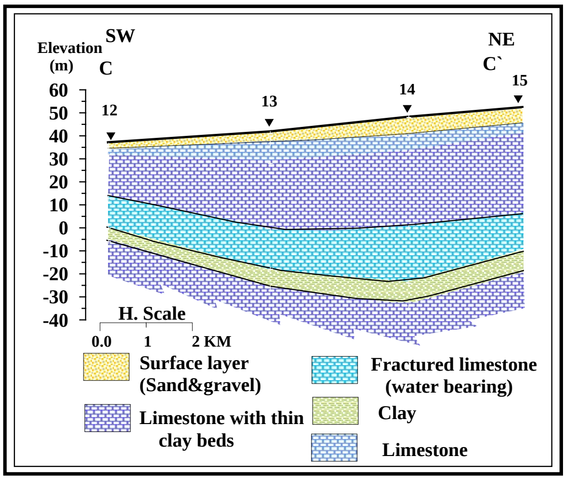


Fig. (8): Geoelectrical cross section C-C`.

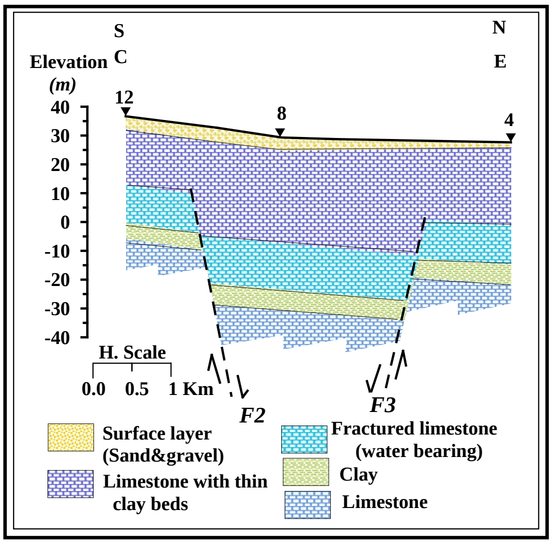


Fig. (9): Geoelectrical cross section C-E.

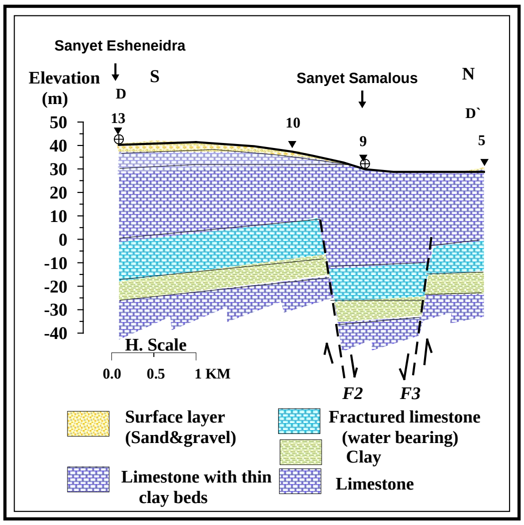


Fig. (10): Geoelectrical cross section D-D`.

The upper surface of the last geoelectrical layer is selected to draw a structural contour map (Fig. 11). The structural contour map shows the locations, extension and relative displacement of the inferred faults (F1, F2 and F3) in the investigated area. From this map and according to the correlation between the equivalent layers along the cross sections, three normal faults F1, F2 and F3 affected the area. This map is characterized by high gradient in the NW- SE and NE-SW directions. The fault F1 strikes NW- SE direction, and throws towards SW direction. The fault F2 strikes NE-SW direction, and throws towards NW direction, whereas the fault F3 strikes NE-SW direction, it is throwing towards south direction.

2- Interpretation of the Imaging Measurements

The computer program (RES2DINV) developed by Loke (1996) automatically determines a two-dimensional (2-D) resistivity model for the subsurface using the data obtained from imaging survey.

The program interprets the true resistivity structure using the 2D smoothness constrained inversion. A finite difference model of the resistivity distribution is generated and adjusted to fit the data iteratively. The smoothness constraint prevents unstable and extreme solutions.

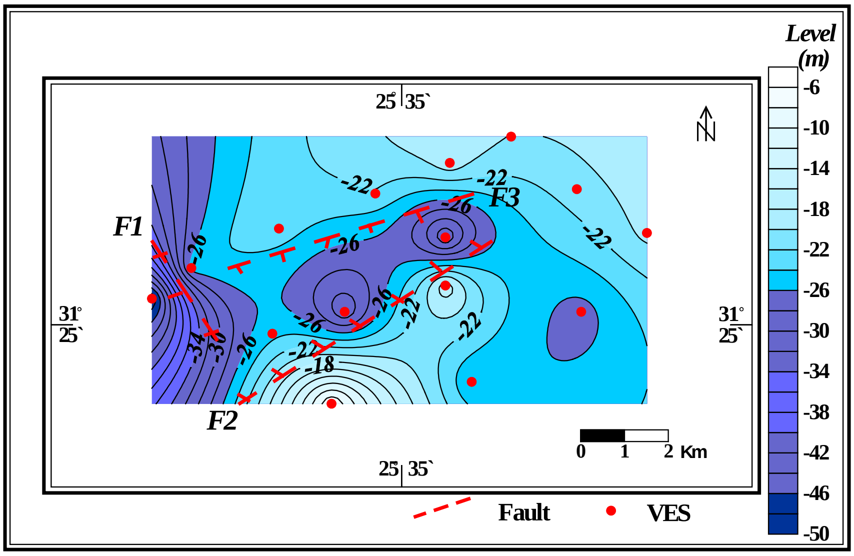
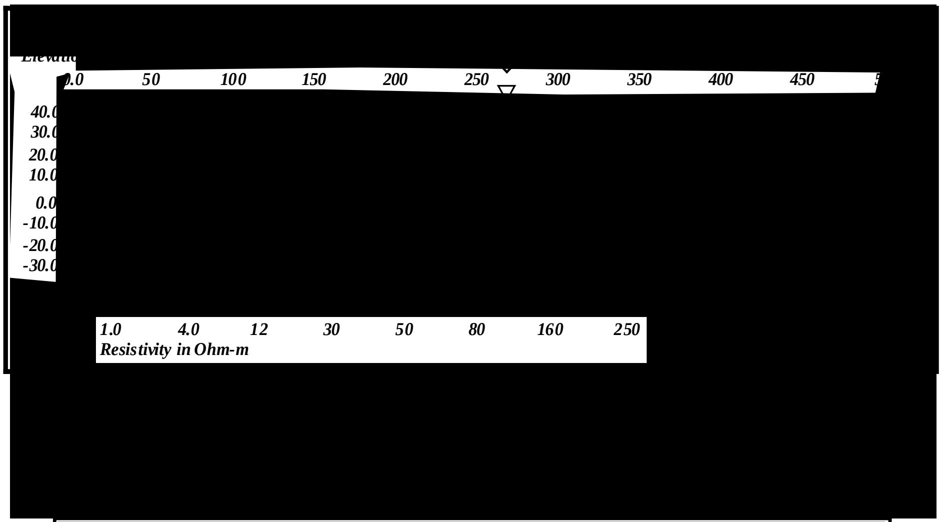


Fig. (11): Structural contour map of the upper surface of the last geoelectrical layer.



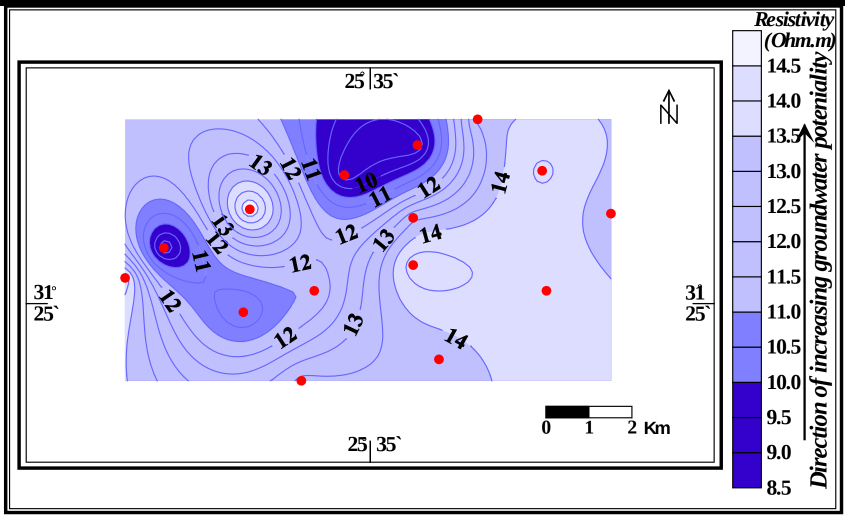


Fig. (13): Isoresistivity contour map of the third geoelectrical layer (water bearing) in the geoelectrical succession.

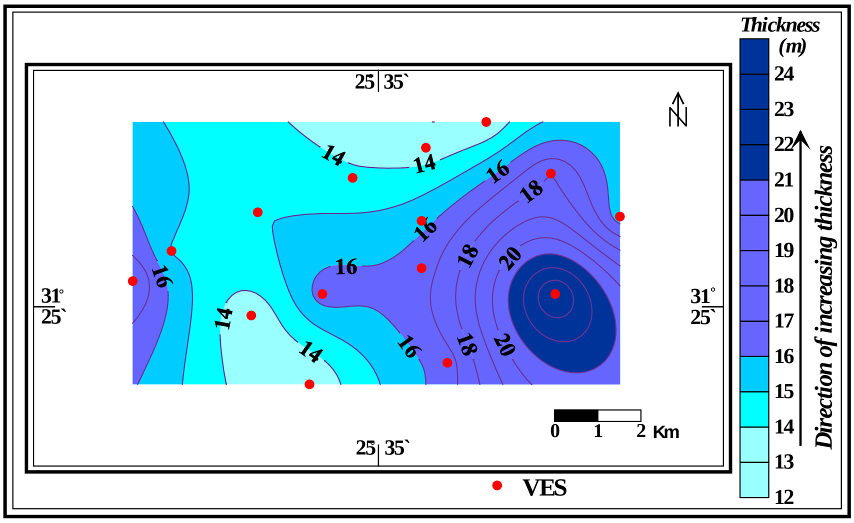


Fig. (14): Isopach contour map of the third geoelectrical layer (Water bearing) in the geoelectrical succession.

According to the available geologic information about the study area and the measured depth to water in Sanyet Esheneidra (41m), the obtained resistivity ranges have been assigned to rock types.

The imaging section (Fig.12) shows four main resistivity zones with a variable thickness. These zones can be described, from top to bottom, as follows:

1. The first zone represents the surface cover and shows a high resistivity > 200 Ohm.m corresponding to gravel and sand with limestone fragments. The thickness of this zone < 6m.

2. The second zone is represented by intermediate resistivity (20 – 200 Ohm.m) that can be assigned to dry limestone with clay intercalation. The thickness of this zone varies from one point to another along the profile; it is about 35m at the central part of the profile. The downward decrease in resistivity within this zone indicates the occurrence of groundwater at a level similar to that measured at Saneyt Esheneidra well.

3. The third zone attains a resistivity lower than 20 Ohm.m that, most probably, corresponds to water bearing fractured limestone with undulated upper surface and its thickness is nearly < 20m.

4. The lowermost detected zone attains a resistivity <5.0 Ohm.m that corresponds to a clay layer.

In view of the above-mentioned discussion, it is obvious that groundwater occurrence is controlled by existence of fractured zones in the limestone layer. Moreover, the level and thickness of this water-bearing layer show remarkable variations along the distance of the profile.

GROUNDWATER OCCURRENCE

The geoelectrical survey revealed that the groundwater exists in the investigated area. The geoelectrical layer No.3 represents it through the geoelectrical sections. This layer is characterized at the most soundings by resistivity values ranging between 10 to 25 Ohm.m. The lower resistivity values that have been recorded within this layer are considered to represent groundwater occurrence. The isoresistivity contour map, Fig. (13), shows that the third layer has resistivity values increase gradually toward the east direction of the investigated area. This can be attributed to good water quality in the same direction, while the low resistivity values may be attributed to increase of water salinity. The isopach contour map of the water-bearing layer No.3, Fig. (14), indicates that the thickness of the water-bearing layer increases in the east direction of the area. The hydrogeologic information throughout the investigated site infers that a water-bearing layer is recharged directly through the percolation of the local precipitation and surface runoff along the prevailing structures.

SUMMARY AND CONCLUSIONS

In view of the above-mentioned discussion, it is obvious that groundwater occurrence is controlled by existence of fractured zones within the limestone layer.

Generally, the resistivity values and the thickness of the aquifer are increasing towards the east direction in the study area. This could be attributed to increasing potentiality of water, good water quality and best production of wells in that direction. The eastern portion of the concerned area was found the best site for locating production wells. This study is an example which can be applied on a large scale. Accordingly, reaching a decision for locating production wells needs carrying out further integrated geoelectrical studies to detect the sites of the best potential, concerning thickness and depth, for groundwater occurrence in the study area.

The above-mentioned results can help the decision-maker in the process of agricultural development in the area.

REFERENCES

Abdallah, A.M. (1966 a): Geology of some gypsum deposits in the northwestern desert of Egypt. Geol. Surv. Egypt. Paper No 41, 1- 11 p

———— **(1966. B):** Stratigraphy and structure of a portion in the northwestern desert of Egypt. Geol. Surv. Egypt, Paper No. 45, 1- 19 p.

Ghazarian, Gh. P. (1957): Final report on the electrical resistivity survey carried out at Wadi El Kharruba, Mersa Matruh, Egypt. Publ. Inst Desert No. 10, Le Caire.

Loke, M.H. (1998): " RES2DINV". V. 3.4, rapid 2 – D resistivity inversion using the lest-squares method., ABEM instrument AB, Bromma, Sweden.

Said, R. (1962): Geology of Egypt, Elsevier Pub. Co., Amsterdam, New York.

Sayed, M.A.A (1967): Geophysical study on the groundwater resources of Ras El-Hekma area, northwestern littoral zone of Egypt. M. Sc. Thesis, Faculty of Science, Cairo University, 129P.

Selim, A. A. (1969): "Geology of El Salum area western Mediterranean coastal zone**,** U. A. R." Ph. D. Thesis**,** Faculty of Science, Alexandria University p. 5-19.

Shata, A. A. (1953): New light on the structural development of the Western Desert of Egypt. Bull. Inst. Desert, Tome III, No. 1, Cairo, Egypt PP. 101-106.

———— **(1955):** An introductory note on the geology of the northern portion of the Western Desert of Egypt. Bull. Inst. Desert, Tome V, No. 2, Cairo, Egypt. PP 96-106.

———— **(1971):** The geomorphology, pedology and hydrogeology of the Mediterranean Coastal desert of the A. R. E. Symposium of the Geology of Libya. PP. 431-445.

Taha, H. A. (1973): Geology of the water supplies of Matruh-Barrani area, northwestern Mediterranean coastal zone, Egypt. Ph.D. Thesis, Faculty of Science, Alexandria University P. 5-19.

Van Der 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.