Egyptian Geophysical Society
EGS Journal, Vol. 9, No. 1, 135-143 (2011)

DELINEATING THE CONDITIONS OF GROUNDWATER OCCURRENCES IN THE AREA SOUTH BALOZA, ROMANA ROAD, NORTH WEST SINAI – EGYPT

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تحديد ظروف تواجد المياه الجوفية فى المنطقة جنوب طريق بالوظة– رمانة– شمال غرب سيناء – مصر

الخلاصة: تعد شبه جزيرة سيناء من المناطق الهامة و الواعدة لما تحتويه على مصادر كثيرة تدخل ضمن نتاج الدخل القومى مثل الطاقة و المياه فضلا عن السياحة لذلك فهى أرض ملائمة لكثير من الاستثمارات. و المنطقة الواقعة بين بالوظة ورمانة هى إحدى المناطق الخاضعة للتنمية و الاستثمار. و لكن تواجهها الكثير من المشاكل التى تعيق الاستمرار فى التنمية مثل قلة تواجد المياه و زيادة الملوحة نتيجة تداخل مياه البحر مع كثرة تواجدات الطين. لذلك أجريت تلك الدراسة كمساهمة للتعرف على ظروف تواجد المياه الجوفية و تحديد الحد الفاصل بين مناطق المياه شبه المالحة و شديدة الملوحة.

تتميز تلك المنطقة بوجودها فى منطقة منخفضة تسمح بتراكمات كثيرة من الرمال مع وجود سبخات حيث تتراوح الارتفاعات عن سطح البحر من ٢٠ – ٣٠م. و الرواسب السطحية تنتمى للعصر الرباعى و تتكون من الحصى و الطين و الرمال التى تأخذ أشكالاً متعددة من الكثبان. و الخزان المائى الجوفى الرئيسى فى منطقة الدراسة يتبع عصر البلستوسين و الذى يتكون من الرمل و الطين المتداخل معه. و تتراوح ملوحة المياه للآبار الموجودة بالمنطقة بين ٢٠٠٠ – ٣٥٠٠ جزء فى المليون.

تم إجراء ١٨ جسة كهربية رأسية موزعة على شكل شبكى لتغطية منطقة الدراسة. و خضعت تلك القياسات للتحليل الكيفى و الكمي. و أسفرت النتائج عن وجود ثلاث طبقات جيوكهربية. الأولى (A) و هى الطبقة السطحية التى تتكون من الحصى و الرمل و الطين و تتراوح قيم المقاومة بين ٤٨ – ٨٠٤ أوم.متر و السمك لا يزيد عن ٠,٥متر. الطبقة الثانية (B) و هى طبقة جافة وتتكون من الرمل و الطين المتداخل و الحصى و تتراوح قيم المقاومة بين ١٥ – ٦٥١,٨ اوم. متر و السمك بين ١,٤ – ٤ متر. أما الطبقة الأخيرة (C) و هى الطبقة الحاملة و تتكون من الرمل و الطين المتداخل معه مع زيادة نسبة الطين كلما اتجهنا إلى اسفل و تم تقسيمها الى ثلاث طبقات متعاقبة بناءا على قيم المقاومة النوعية. فالطبقة العلوية (C1) تتراوح قيم المقاومة بين ٤,٥ – ٣٣,١ اوم . متر والسمك بين ٢ – ٤ م ثم تليها الطبقة (C2) و تتراوح قيم المقاومة بين ١,٩٩ – ٤,١ اوم . متر و السمك بين ١٣ – ٢٢,٥ م أما الطبقة الأخيرة (C3) فقيمة المقاومة لا تزيد عن ٢ اوم . متر و هى تمثل تأثير تداخل مياه البحر عليها.

يتضح مما سبق أن الملوحة تزداد كلما اتجهنا إلى أسفل و هذا ما أظهرته قيم المقاومة النوعية. كما أن العمق لسطح الماء فى منطقة الدراسة يتراوح بين ١,٩ – ٥ م. لذلك نوصى بحفر آبار يدوية لا تزيد أعماقها عن ٨ م لكى لا يتم النفاذ إلى مياه شديدة الملوحة. و لمنع ارتفاع السطح الفاصل بين المياه شبه المالحة و شديدة الملوحة لابد من إجراء السحب الأمن و الذى يتراوح كلية بين ٢٨,٢٨ – ٤٢,٤٢ م^{3}/ اليوم.

ABSTRACT: *Sinai Peninsula represents one of the main prospective areas for energy recourses including water, oil. natural gas, coal and some others. Groundwater is an important natural resource for investment such as south El Teina plain. It lies on low relief and is dominated by extensive sand accumulation alluvial deposits and sabkhas. The average ground elevation ranges from 20 to 31m. above the mean sea level. The Quaternary deposits are exposed in the study area and consist from sand dunes, graded sand, clayey sand, sandy clay and clay. The Pleistocene deposits represent the main aquifer in the eastern part of the study area. It formed of sand, gravely sand, clayey sand, sandy clay and sand with clay intercalations. A total of 18 of Vertical Electrical Sounding (VES) stations were carried out in the study area as a grid pattern. The quantitative interpretation of the field curves revealed that the geoelectrical succession is formed of a number of layers, which are grouped together in three main layers. The first layer is surface layer "A" and layer "B" is dry layer, while the lower layer "C" represents the water bearing formation which consists of sand with clay intercalation. The percentage of clay increases downwards. It is divided into three successive parts (C1, C2, C3). The first part "C1" represents resistivity values ranging from 4.5 33.1 Ohm.m. and a thickness from 2-4m, acting as brackish water zone. The second part "C2" represents resistivity values ranging from 1.99 – 4.1 Ohm.m and a thickness from 13 – 22.5m acting as saline water zone. The last one "C3" represents resistivity values not exceeding 2 Ohm.m., acting as more saline zone. Generally, the depth to water as recorded from the drilled wells and the* *interpreted from the geoelectrical study ranges between 1.9 m and 5m. Vertically, it is noticed that the salinity of water bearing formation increases downwards in the study area due to the effect of the sea water intrusion. It is recommended to exploit the brackish water layer which is considered as the strategic water supply to the area and has a suitable saturated thickness reaching to about 4m. Thus, wells should not penetrate the saline water to prevent a local rising of interface of brackish – saline water interface due to continuous discharge from water well. The safe yield is demonstrated, according to the hydrological condition in the study area. The wells can be dug by hand where the total depth should not exceed 10m. The total safe yield of every hand dug well varies from 28.28 to 42.42 m^3/day.*

INTRODUCTION

In the last decades, Egyptian government and investors pay more attention for development Sinai. One of the areas focused for investments is area between Baloza and Romana. It's located at the coastal area between latitudes 30° 57 and 31° 05N and longitude 32° 32 and 32° 41E with covers about 66Km^2 (Fig. 1).

Accordingly, a ten of farms were building up in the area. One of the problems faced these farms is decreasing in fresh water and increasing in saline water by sea water intrusion. Some shallow water wells were drilled and tapped the Pleistocene aquifer, the main resource of groundwater which consists mainly of sand, gravely sand, clayey sand, sandy clay with clay intercalation. These wells have indicated that there is restricted brackish water bearing zone its thickness is controlled by the underlying invaded saline water from the sea.

This paper an attempt to mapping sea water intrusion in this small area depending on the data from wells and vertical electrical sounding. The sounding stations were conducted in the area to complete view in the missed parts between wells. In addition recognizing the condition of the ground water occurrence in the study area.

Geomorphologicl, geological and hydrogeological setting:

Geomorphology, several geomorphologic studies were carried out by many authors such as Shatta (1955 and 1959), said (1962) and saad et al (1980). Also, geomorphologic studies carried out by DRC (1983& 1991) pointed out that that area divided into five distinct units as the follow:

1- Coastal area	2- El Tina plain
3- The Aeolian sand	4- The mobile sand duns
5- The salt marshes and sabkhas	

The investigated area is located to southeast of El Tina plain. It lies on low relief and dominated by extensive sand accumulation alluvial deposits and sabkhas. The average ground elevation ranges from 20 to 31m. above the mean sea level.

Geologically, the north Sinai is covered by sedimentary rocks related to the late tertiary and quaternary. Referring to the works of said (1962), El Ghazawi (1989) and lithostratigraphic correlation chart of Zaghloul and El Deftar (1990). The sedimentary successions attain about 3700m. which belongs to Jurassic, Cretaceous, Eocene, Oligocene, Miocene, Pliocene, Pleistocene and recent. The Quaternary deposits are exposed in the study area and consist from sand duns, graded sand, clayey sand, sandy clay and clay.

Hydrogeologically, the water bearing formation in the study area belongs to Pleistocene aquifer. Groundwater in north Sinai is tapped from wide variety of rocks type. These rock types are distinguished according to El Ghazawi (1989) and Remote sensing report (1994).

Geoelectrical field works

Geoelectrical survey described in the work is representing by DC resistivty sounding. A total of 18 of Vertical Electrical Sounding (VES) stations were carried out in the study area as a grid pattern between Baloza and Romana area. Five of these sounding stations were measured near hand dug wells to estimating the geophysical parameter available for verifying the geoelectrical interpretation. The distribution of the sounding stations and the trend of geoelectrical profiles are shown in (Fig. 1).

The Schlumberger 4- electrodes arrays were used in carrying out the field measurements with a current electrode separation (AB) ranging from 200 to 400m. The "Terrameter SAS 300" resistivity meter was used for measuring the apparent resistance with high accuracy at different electrode spacing stating from 2m. The topographic survey was carried out with the purpose of determine the location (latitudes and longitudes) of the sounding stations on topographic map by using the GPS apparatus and concluding the ground elevations.

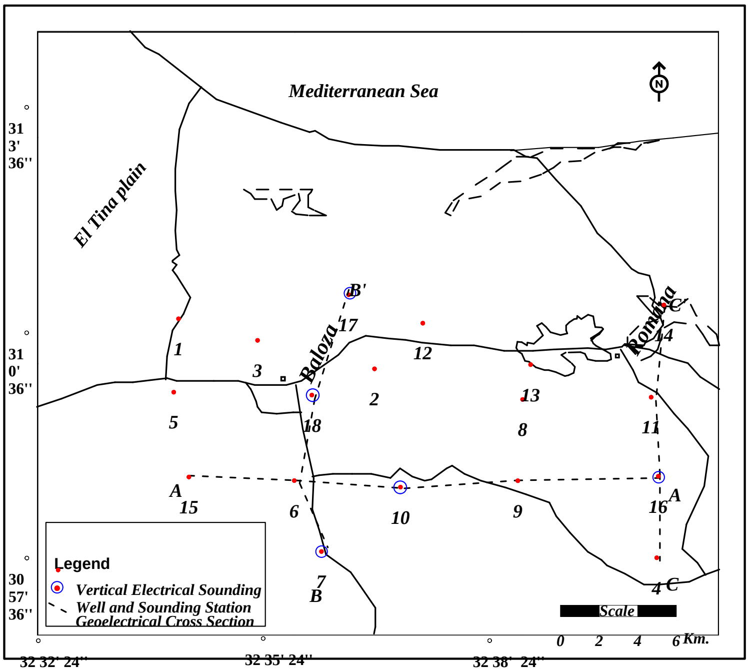

Fig. (1): Location map of sounding stations and geoelectrical cross sections

INTERPRETATION AND DISCUSSION

The field data of the Vertical Electrical Sounding curves have been interpreted qualitatively and quantitatively to delineate the subsurface sequence of the geoelectrical layers in the area as follow:

1. *Qualitative interpretation:*

It includes comparison of the relative changes in the apparent resistivity and thickness of the different layers. It gives information about the number of layers, their continuity throughout the area or in a certain direction and reflects the degree of homogeneity or heterogeneity of the individual layer. Qualitative interpretation of the field curves (Fig.2) indicates the following:

- The general types of the vertical electrical sounding curves can be grouped in one sector. This sector has certain type curves which are characteristic by KQQ and HKQQ types curves of four or five geoelectrical layers.
- The resistivity values on the first cycles of the resistivity curves (AB < 10) represented the surface and near surface variations. However, they reflect heterogeneity characterizing of the first layers. In going downwards on the field curves (The second cycles (AB > 10)), the filed curves show nearly the same type which reflects homogeneity. All field curves terminate with Q-type .
- From a visual inspection of these types curves, it is noticed that the resistivity values decrease with depth due to increase in clay intercalation and salt water intrusion.

2. *Quantitative interpretation:*

The apparent resistivity sounding curves were quantitatively interpreted to determine the true resistivities and thicknesses of the different geoelectrical layers. The interpretation of the resistivity field curves was carried out by making use of the computer programs developed by Van der Velpen (RESIST, 1988) and Zohdy (ATO, 1989). The interpreted data of each curve represent the geoelectrical layers with their corresponding thicknesses and resistivities. The available information about the regional and local geologic setting of the area were taken into consideration in assigning the lithology to the resulting resistivities. The number of boundaries of layers were adjusted according to the data of the well to increase fitness the obtained modeled and field data. Figure (3) shows the interpretation of the modeled resistivity sounding VES No. 17 beside hand dug well.

The quantitative interpretation of the field curves revealed that the geoelectrical succession is formed of a number of layers, which are grouped together in three main layers. The first layers is surface layer “A” and layer “B” is dry layer, while the lower layer “C” represents the water bearing formation and consists of Three Units (C1, C2, C3). The ranges of the resistivites and thickness of these geological layers are shown in table (1).

The common features characterizing the lithologies and hydrological settings in the investigated area described in view of geological cross section and constructed maps. The detailed description of the geoelectrical zones from top to bottom can be shown as follows:

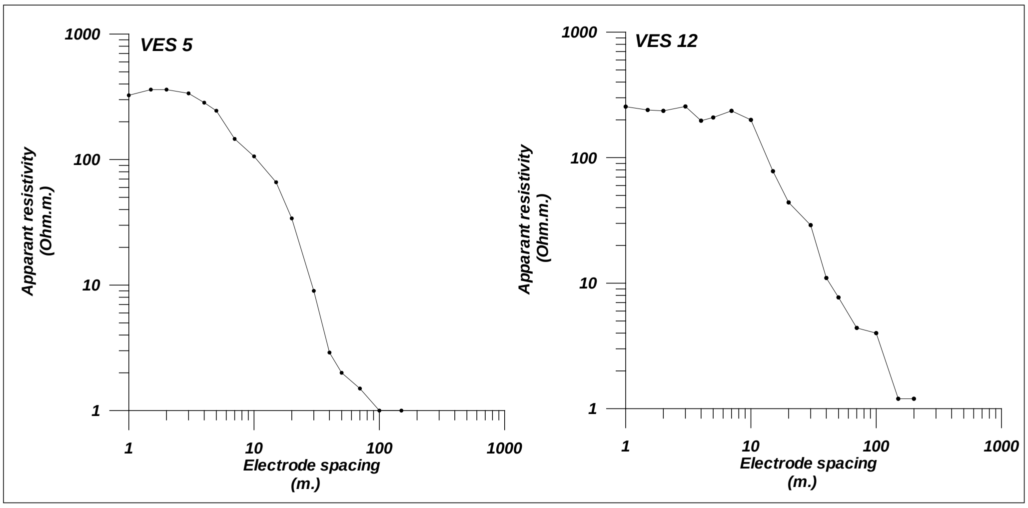

Fig. (2): Examples of the resistivity sounding curves.

Fig. (3): Interpretation model of VES No. (17)

Table (1): Resistivity, thickness ranges and the corresponding lithologic composition of the detected geoelectrical layers.

Layer No.	Resistivity (Ohm-m)	Thickness (m)	Corresponding lithology	
A)(	48 - 804	> 0.6	Sand ,gravels and clay (Surface layer)	
(B)	15 - 615.9	1.5 - 4	Sand and gravels (dry layer)	
(C1)	4.5 – 33.1	2 - 4	Sand, clayey sand (Brackish water)	(Saturated layer)
(C2)	1.99 – 4.1	13 – 22.5	Sand and sandy clay (Saline water)	
(C3)	0.6 – 1.9	--------	Clay (More saline water)	

A. Geoelectrical cross sections:

Three geoelectrical cross-sections AA’ (W-E), BB’ (S-N) and CC’(S-N) crossing the area were constructed to illustrate the subsurface conditions within the study area (Figs. 4, 5 & 6). These sections illustrate the geoelectrical sequence, lateral and vertical variation of the different layers in the profile direction and facilitate comparisons among these sections. Such geoelectrical cross sections would complete the hydro-geophysical picture and determine the thickness and extension of the water bearing formation. The main observations and conclusions from these sections are:

1. Generally, the geoelectrical cross sections consist of a complete geoelectrical successions of three geoelectrical layers "A", "B", and ”C” . The resistivity values of these layers decrease downwards due to increasing percentage of clay and presence of the effect of the sea water intrusion.
2. The thickness of layer "B" decrease towards the north direction of the area, while layer "C" of the water bearing formations increase toward the South and East.
3. The depth to water as recorded from the drilled wells and the interpreted from the geoelectrical study ranges between 1.9m and 5m.

Vertically, it is noticed that the salinity of water bearing formation "C" increases downwards in the study area. It can be differentiated into three zones according to resistivity values. The first one "C1" represents resistivity values ranging from 4.5 33.1 Ohm.m. and thickness ranges from 2-4m.acting as brackish water zone. the second unit "C2" represents resistivity values ranging from 1.99 – 4.1 Ohm.m and thickness rang from 13 – 22.5m acting as saline water zone. the last one "C3" represents resistivity values not exceed 2 Ohm.m. acting as more saline due to the effect of the sea water intrusion and clay content.

B. Constructed maps:

To avoid unnecessary repetition, The constructed maps facilitate comparisons among layer in all direction. It gives a complete hydro-geophysical picture especially the water bearing formation. The main observation from top to bottom as follows:

Surface layer “A”, This layer represents the Surface cover, which is composed of gravel, sand, gravelly sand with clay intercalations and attain a wide range of resistivity varying from 48 to 804 Ohm-m. The wide range of resistivity is due to different composition. The thickness of this layer not exceeding from 0.6 m..

- ***Dry layer “B”***, This layer has resistivity values varying from 15 to 615.9 Ohm-m, while its thickness ranges from 1.5 to 4 m. This layer is composed of sand and gravels.

Layer "C", This layer represents the water bearing formation in the study area. According to the resistivity, it can be differentiated into three parts (C1, C2 &C3). The upper part "C1" consists of sand and clayey sand saturated with brackish water. The resistivity values vary from 4.5 to 33.1 Ohm.m. Figure (6) represents the distribution of the resistivity values in this part. It shows increasing in resistivity values in the northern and eastern directions but at VES No. 17 the high resistivity values due to more sand deposits. The thickness of this unit ranges from 2 to 4m. Figure (7) exhibits increasing in thickness values in the north western and eastern directions. The second part "C2" underlies the part "C1" and consists mainly of sand and sandy clay. It has a resistivity value varying from 1.99 to 4.1 Ohm-m. saturated with saline water. The isoresistivity contour map for this part (Fig. 8) represent decreasing values in northeastern direction due to the effect of sea water intrusion and the presence of the clay content. The thickness of this part ranges from 13 to 22.5m and decreases toward the north and eastern directions as shown in isopach contour map (Fig. 9). The last part "C3" consists mainly of clay. It has a resistivity value varying from 0.6 to 1.9 Ohm-m. saturated with more saline water according to hydrologic information from well in the study area.

HYDROLOLOGICAL SETTING

The water bearing formation in the study area belongs to Pleistocene aquifer. It's composed of sand, gravelly sand, clayey sand, sandy clay with clay intercalation. The depth to water ranges from 1.9 to 5m. as recorded from the drilled wells and the interpretation of the Vertical Electrical Sounding. Figure (10) exhibits the depth to water increase in south eastern and north western directions but decrease in north eastern direction. The slope of the water table is from south to north i.e. towards the sea as shown in Figure (11). It rang from12.5 m. to 26 m. The total dissolved solids (TDS) from available water wells indicate high salinity values ranging from 2000 to 3500ppm.

1. Computation of the depth to brackish water – saline water interface:

The salinization of fresh water in coastal aquifer is a big problem facing the extraction of water, which is required for different purpose. The brackish water being less in density and tends to float on salt water and the natural equilibrium is developed. The depth to interface between brackish water and salt water is determined from the interpreted sounding curves. Figure (12) shows decreasing in value of the level to the brackish water – salt water interface towards the north western direction. It represents the maximum value (22.5m.) record at VES No. 4 in the east southern part and the minimum value (10.5m.) record at VES No. 5 in the western part.

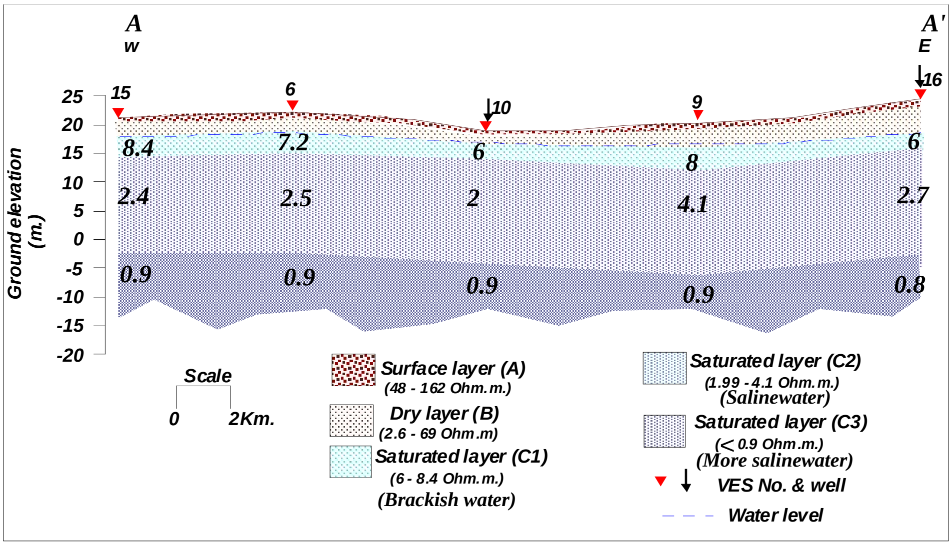

Fig. (3): Geoelectrical cross sections AA'.

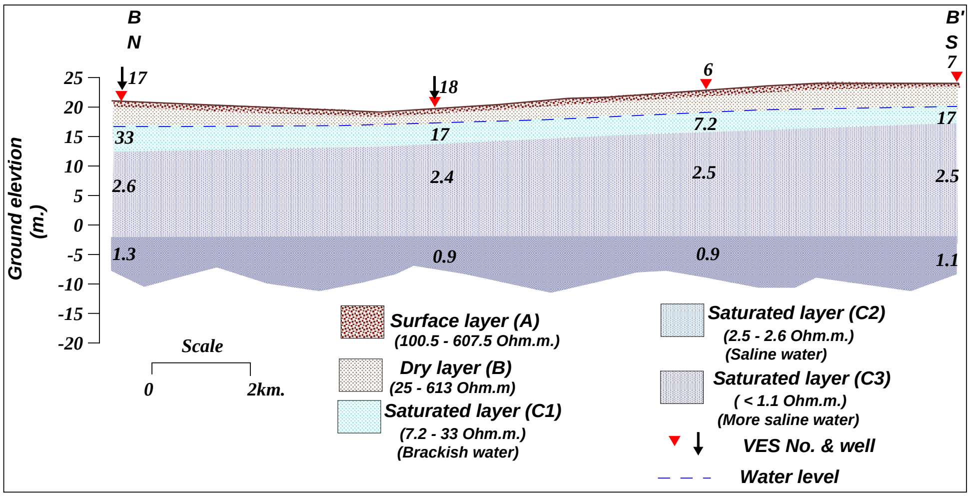

Fig. (4): Geoelectrical cross sections BB'.

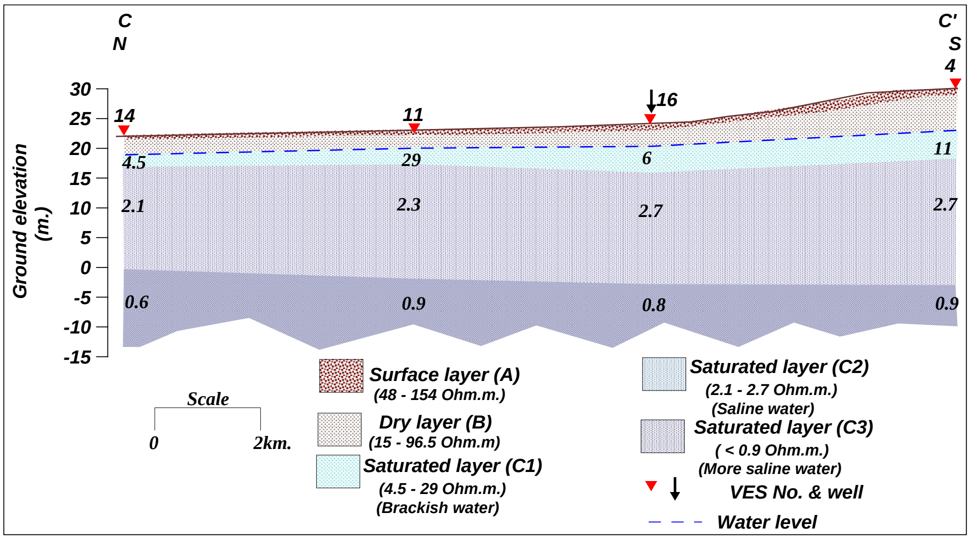

Fig. (5): Geoelectrical cross sections CC'.

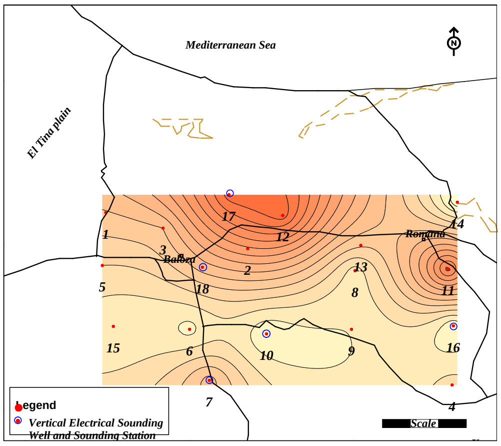

Fig. (6): Isoresistivity contour map of the brackish water bearing layer "C1".

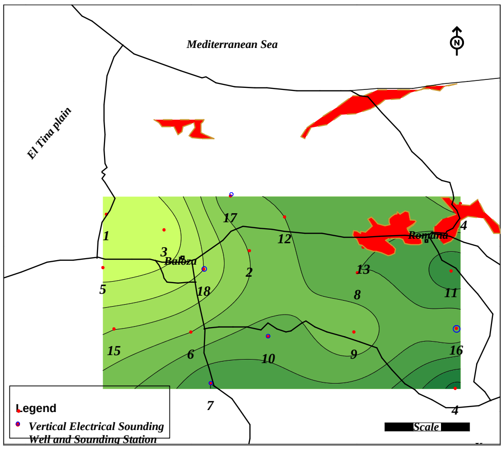

Fig. (9): Isopach contour map of the salinewater bearing layer "C2".

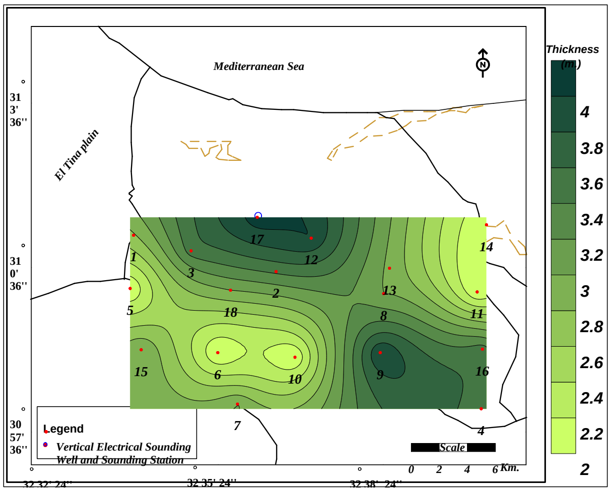

Fig. (7): Isopach contour map of the brackish water bearing layer "C1".

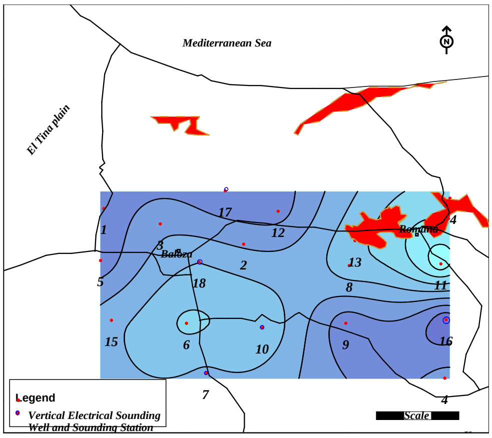

Fig. (10): Contour map of the depth to water.

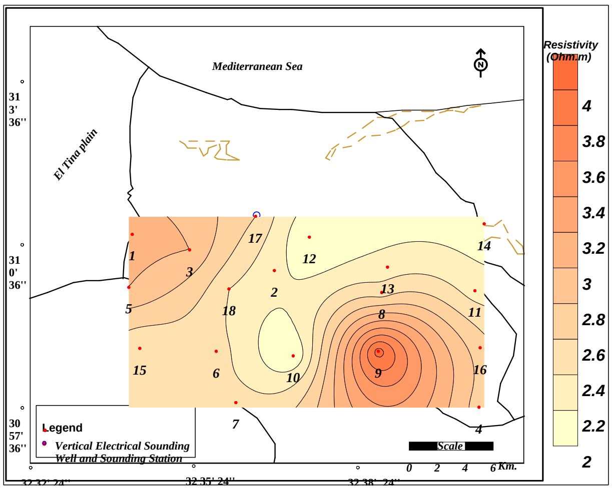

Fig. (8): Isoresistivity contour map of the saline water bearing layer "C2".

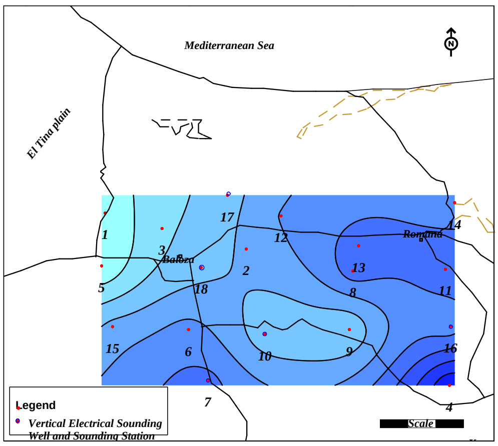

Fig. (11): Contour map of the water level.

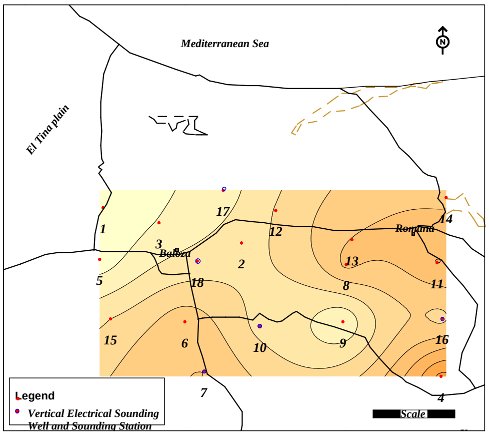

Fig. (12): Counter map of the level to brackish water – salt water interface.

2. *Safe yield:*

To prevent a local rising of interface of brackish – saline water interface due to continuous discharge from water well. The safe yield and well design is demonstrated. According to the hydrological condition in the study area. The wells can be digging by hand where thickness of the brackish water is not exceeding than 8m. The design of this wells has 3m in diameter (2r) and thickness of water (Z) ranges from 2 to 3m (Fig. 13).

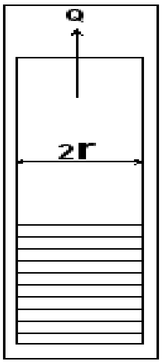

Fig. (13): Design of Hand dug well.

The safe yield (Q) of the wells can be calculated by Ghyben – Herzberg equation:

$Q = \pi r^2 Z \quad m^3$

Where:

r is the half diameter of the well

Z is the thickness of water from 2 to 3m.

Then

$Q = 3.14 * (1.5)^2 * 2 = 14.14\ m^3$ when Z = 2m.

$Q = 3.14 * (1.5)^2 * 3 = 21.21\ m^3$ when Z = 3m.

The discharge (Q) from hand dug well will be two times per day. The total safe yield of every hand dug well varies from 28.28 to 42.42 m^3/day.

CONCLUSIONS AND RECOMMENDATIONS

According to the above mentioned discussion of the results reached from the interpretation of the resistivity sounding measurements, it can be concluded that:

1. The geoelectrical succession in the area consists of three main geoelectrical zones (surface Layer ”A”, Layer “B” and Layer “C”).
2. The surface layer ”A” and layer “B” are dry and consist of sand, gravel and clay, while the water bearing formation (Layer C) comprises three parts (C1, C2 &C3) and consists of sand, sandy clay, clayey sand, sand with clay interactions.
3. The depth to water in the study area and its vicinities ranges from 1.9 to 5m as recorded from the drilled wells and the interpreted Vertical Electrical Sounding curves. The expected water table ranges between 12.5 to 26m.
4. The values of salinity in the study area and its vicinities range from 2000 ppm to 3500 ppm as recorded from the drilled wells.
5. Vertically, the salinity of the water-bearing formation (Layer C) increases downward. This is due to the sea water intrusion and presence of clay intercalation.
6. The wells can be digging by hand to reach a total depth 8 m, as the groundwater becomes more saline downward.
7. Also, it is recommended to drill trenches with depths ranging from 2-3m. instead of hand dug wells to collect water with suitable amount and appreciable quality.

The total safe yield of every hand dug well varies from 28.28 to 42.42 m^3/day, to prevent a local rise of interface of brackish – saline water interface due to continuous discharge from water well.

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