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RESEARCH ARTICLE

VERTICAL ELECTRICAL SOUNDINGS AND HYDROCHEMICAL STUDIES FOR GROUNDWATER INVESTIGATIONS, AT MATROUH AND NIGELLA BASINS, NORTHWESTERN COAST, EGYPT

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ABSTRACT

The fast growing development in Egypt has required big movements of investments and people from the Nile Valley towards the North Western Coast of Mediterranean Sea. A hydrochemical and geoelectrical investigation was conducted in the matrouh-negilla area in the northwestern coast of Egypt to investigate and find out the groundwater aquifer, its extension, depth and thickness. Also, chemical analysis was used to evaluate the chemical characteristics of groundwater and assessment of water quality. Twelve profile of vertical electric sounding were conducted to examine the variations of subsurface geology and associated groundwater chemistry. Results of VES interpretation classified the subsurface sequence of oolitic limestone aquifer into four geoelectric zones, top surface, oolitic limestone, intercalation with clay, fracture limestone, and limestone with saline water. The fracture limestone constitutes the upper aquifer and Limestone with saline water is considered as the lower aquifer. The groundwater reserves in the study area are mainly contained in oolitic limestone and Miocene aquifers. About 42 water samples representing both the Pleistocene Oolitic limestone and Middle Miocene fissured limestone aquifers and quaternary were collected and analyzed. The results of the chemical analysis showed wide ranges of TDS (156-25290 mg/l), and chloride concentration of (12-13050 mg/l).The quaternary aquifer hashigh salinity (average TDS)=17140-19830 mg/l),and the Miocene aquifer are slightly brackish to saline water (average TDS=956-2250 mg/l). The hydrochemical data indicate that the majority of the groundwater samples of the localities are related to recent meteoric origin. The variation in the chemistry of water is thought to be related to the weathering of minerals of the water-bearing sediments, mixing with marine water, and leaching of rainfall in area.

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INTRODUCTION

The study area is located in the far north-west extending from the kilometer 61 west Alexandria governorate until the Egyptian – Libyan border. It exhibits about110km along the Mediterranean Coast and extends south for about 50k, it is bounded by is bounded by longitudes 26.30 and 27. 30 E and by latitudes 31. 00 and 31. 30 N. (Fig.1). At present, the Northwestern coastal zone of Egypt, especially Matrouh-El Negilla area enjoys attention for future sustainable development, and this in turn depends principally on the occurrence and the continuity of the water resources. Therefore, studies on the groundwater in such region are considered to be important.

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The area is considered one of the areas that are suffering from the decreasing of fresh surface water and insufficient rainfall particularly in summer months. So, the groundwater is the only water resource in the investigated area for drinking and cultivation. The Egyptian government has put a strategy to solve the problems of water deficiency. So, searching for groundwater is of great importance to face the expecting high-demand on water. The study area (Fig.1) has a semi-arid Mediterranean climate, characterized by a brief, mild, rainy winter and long warm summer months. Most of the rainfall on the southern plateau is running on the surface, causing water runoff, where the annual runoff in the study area reaches about 150mm.The Groundwater is considered the most available source for water supply besides rain water which acts as the main source of recharge to aquifers. Geomorphologically, the area is characterized by; the coastal plain, Piedmont Plain and Structural Plateau (El-Shazly (1964 and 1972, and Raslan (1995), Shata (1957).

Mohamed Yousif *et al.* (2014), Saad Mehallel, (2009). The coastal plain runs almost parallel to the present Mediterranean coast while the piedmont Plain extends to the south of the coastal plain as a zone between the tableland and the coastal plain. It is occupied by thick calcareous soils of fine alluvial deposits and has relatively steeper rugged surface. Moreover, the southern structural Plateau surface of tableland is essentially occupied by calcareous rocks composed of alternating beds of Limestone and clays with occasional sandstones Fig (2). Geologic setting; the exposed rocks in the northwestern Mediterranean coastal zone are entirely of sedimentary origin ranging in age from Early Miocene to Holocene. The different exposed stratigraphic units in the area are starting by the younger Holocene deposits that are dominated by beach deposits, alluvial deposits, sand dunes, limestone crust, and loamy deposits. The Holocene deposits were followed by the Pleistocene deposits as ridges consisting of o'olitic limestone and cardium limestone. The Pliocene deposit is only exposed in the eastern side of the coastal plain. Downward, the Miocene deposits of Marmarica formation was exposed at Matrouh. However, the Miocene section at this area comprises four clay stone beds alternating with three limestone beds (Said (1960, 1990), Selim (1969), El shazly, (1964), Hammad,).

Hydrogeological Condition: Throughout the area under consideration, the main groundwater aquifer can be classified into the following.

- **Quaternary Alluvium Aquifer:** It occupies the main trunk at some drainage basins, it is composed of loose pebbles and gravels mixed with fine sand and silt. This type of deposits has limited distribution, and generally found in most wadi channels. This aquifer overlain the Pleistocene aquifer and mainly recharged from runoff.
- **The Pleistocene Aquifer (O'olitic limestone):** This aquifer is widely distributed in the coastal plain of the area and is found in the form of elongated ridges. This aquifer recharge from rainwater that percolate through the joints and streams where the rainwater falling on tableland moves directly northward.
- **The Pliocene Aquifer (Brown sandstone):** This aquifer is restricted in the eastern portion of area having a thickness of 17m underlain the contact between the porous brown sandstone and underlying impervious layer exists at 15m below sea level. This aquifer has fresh water at some areas forming local reservoirs bounded from north and south by large saline water reservoirs. (El Sazly, 1970)
- **Miocene Aquifer (Marly Limestone):** The aquifer is composed of fracture limestone of Miocene age separated by impervious clays with band of sandstone. The Miocene formation deposited under shallow marine conditions.

MATERIALS AND METHODS

In the present study, vertical electrical sounding (VES) survey is applied to investigate the vertical distribution of the resistivity in the examined layers. The geophysical survey described in this work is represented by DC (*VES*) surveys in the form of eighty-nine discrete vertical electrical soundings in the selected area. This VES' s were arranged in measuring profiles as shown in (Fig. (5). The well-known Schlumberger configuration with current electrode spacing (AB/2) starting from 1.5 m up to 700m,in successive steps was applied. Analysis of the measured resistivity was done using the IPI2win software program and twelve profiles were constructed. Output of this program was displayed in the form of apparent resistivity and thickness for each layer. Figure (6) shows an example of this output.

RESULTS AND DISCUSSION

Results of the interpretation of the vertical electrical soundings in the form of depth, thickness and true resistivity were used to construct four iso parametric maps to describe the lateral and vertical distribution of aquifer depth and thickness. (Koefoed, 1976) and, (Orellana and Mooney, 1966). The isopach map, Figure (7) represents that the thickness of the aquifer varies along the area and the mean value of the thickness ranges from 40 to 80 meters and the aquifer in the southeastern and the northern part of the study area has great thickness, while the depth to the aquifer varies along the area and increases at the northeastern part of the study area and decreases in the central part as shown in Figure (8) the mean depth to the aquifer reaches about 20-125 m while in the southeast part, the depth ranges from 15 to 75 m. The true resistivity map of third layer (fractured limestone) (Figure 9) indicated that this layer is characterized dominant resistivity values ranging from 10 to 40 Ohm, all over the area. Also, it reflects the litho logical nature and hydrological condition within the clay layer. However, the areas of relatively high electric resistivity values that reached 140 Ohm suggest relatively dry sediments were obtained at the southern part which occupies elevated surface toward the feeding drainage lines descending from the southern tableland. The true resistivity values of fourth, layer ranges from 0.4-80 Ohm m, dominant ranges all over the areas (Figure 10). In the northwest and central part of the area, the higher resistivity of this layer may be due to dryness and consolidation of the deposits at this site.

Geoelectric Cross-Sections

Twelve geelectrical cross-sections were constructed to reveal the lateral and vertical hydro-lithological variations in the study area Figures 11, 12 and 13 are examples oriented as SE-NW approximately parallel to the Mediterranean coast, and N-S. The three sections provide insight into the subsurface sequence in the study area. A total six vertical electrical soundings records in section A-A` (Fig.11) the geoelectrical layers along this section can be differentiated into four main units. The first layer was considered as the surface cover of resistivity ranges from 133 to 253 Ohm.m. and the thickness of this layer varies from 1 m to 7 m. It was interpreted as dry friable unit of wadi deposits. The second layer is composed of limestone with clay intercalation and has resistivity ranging from 149 to 488 Ohm.m. The thickness of this layer ranges from 3 to 20 m. The third geoelectric layer has low resistivity values vary from 28 Ohm.m to 81 Ohm. m, and its thickness ranges from 18 to 145 m this resistivity range represents fracture limestone unit, and considered the upper part of aquifer. The fourth layer comprises low resistivity and has resistivity ranging from 7.4 to 20 Ohm.m. This unit was interpreted as limestone with saline water and was considered as the lower part of aquifer. The lower part of this section has true resistivity ranging from 7.4 to 20 Ohm.m, which considered limestone saturated by saline water.

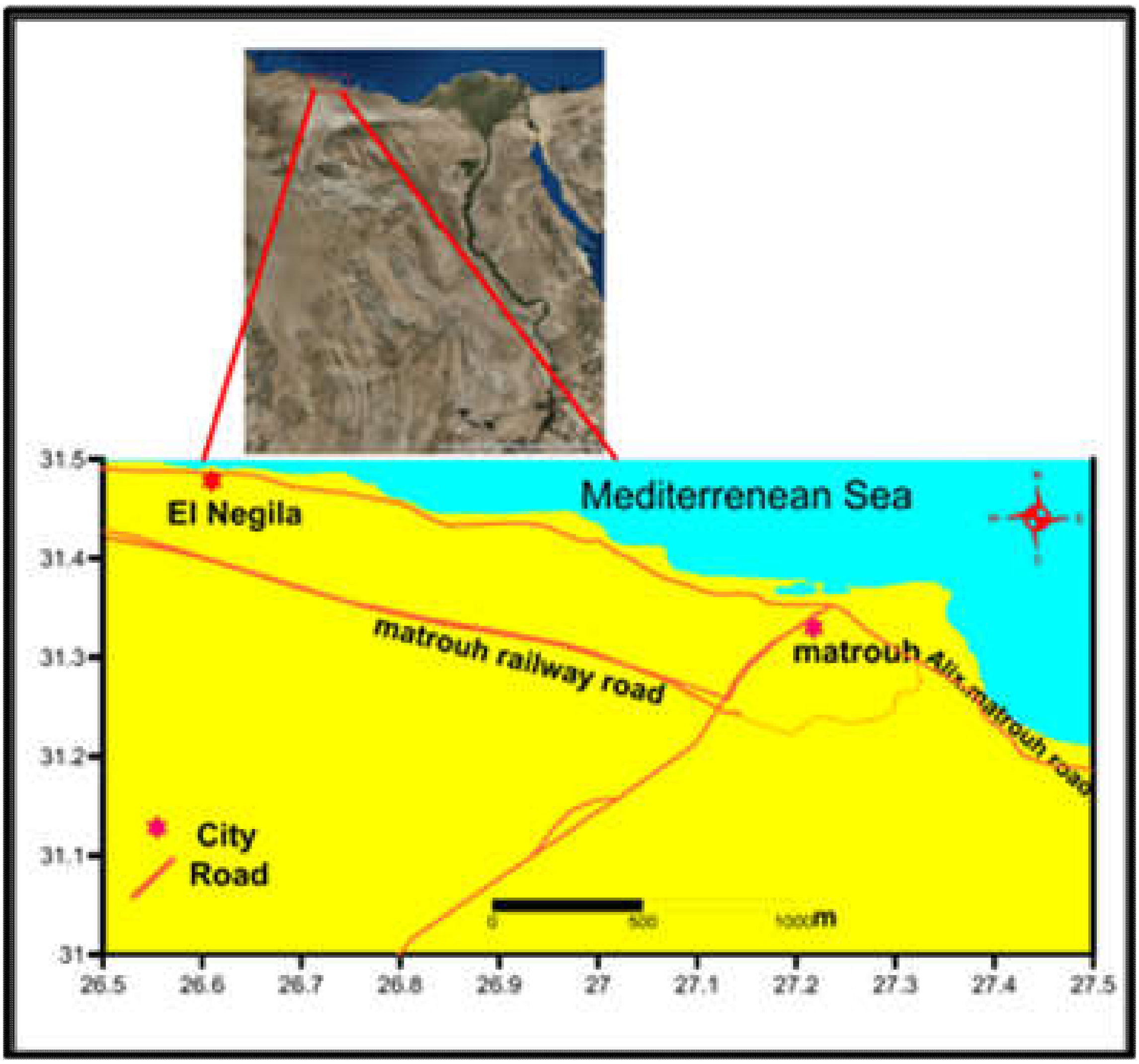

Figure 1. General Location Map for the Study Area

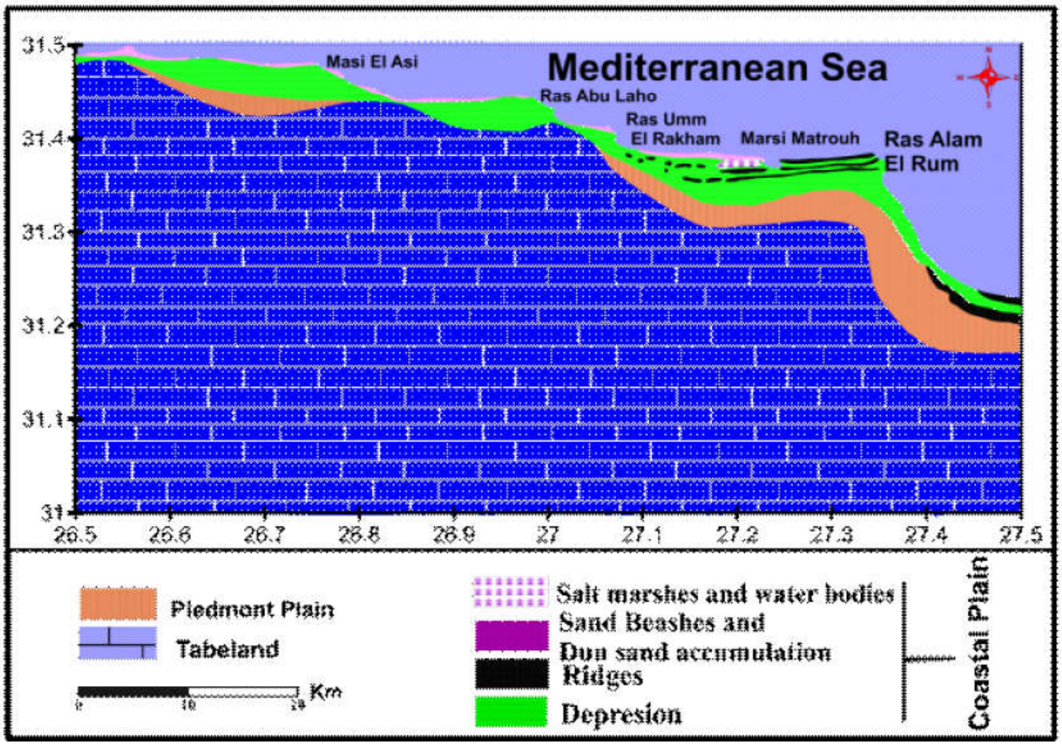

Figure 2. Geomorphological Map of Study Area

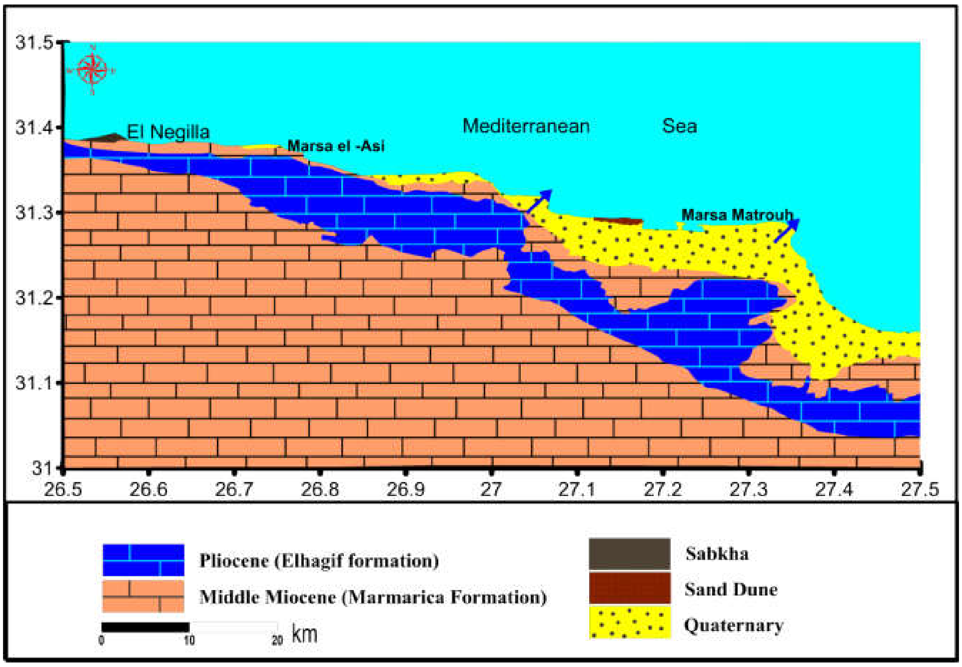

Figure 3. Geological Map of Study Area

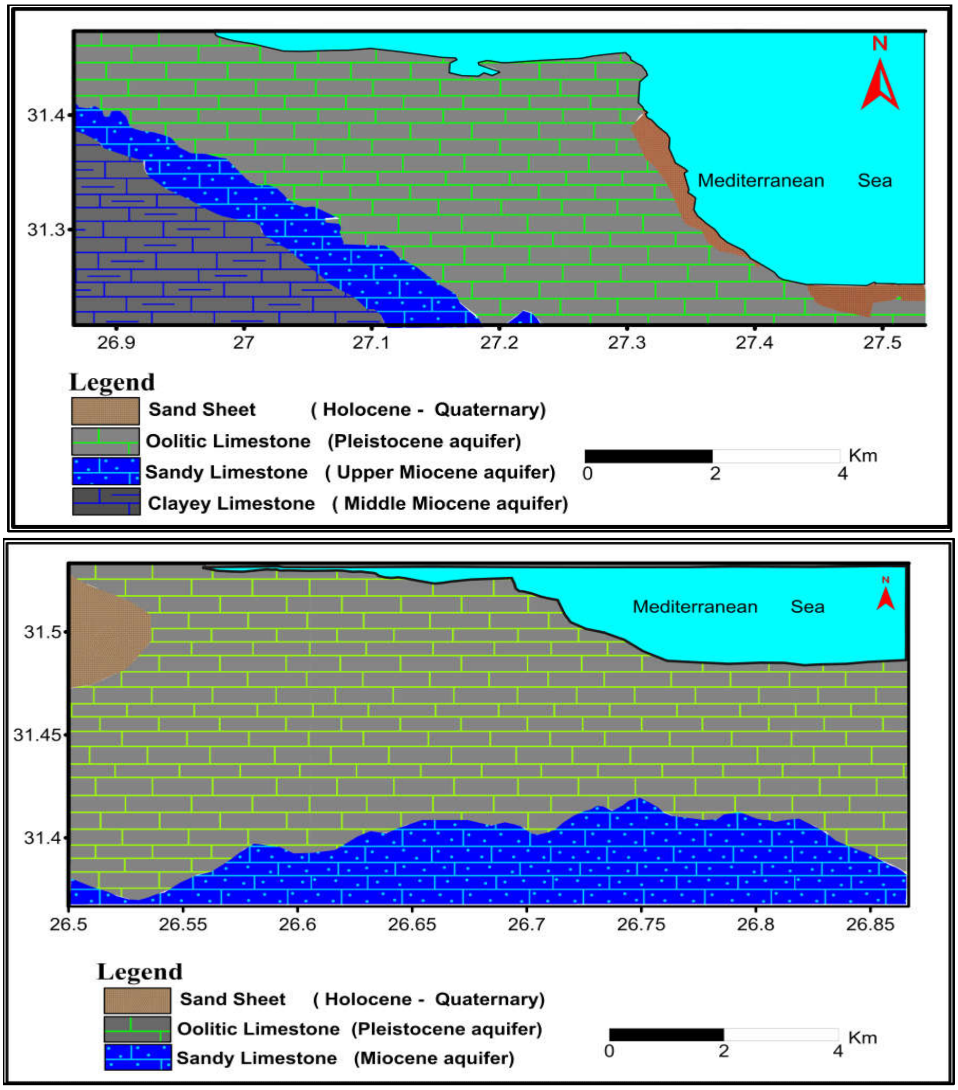

Figure 4. Hydrogeological Map of Matruh and El-Negilla Basin

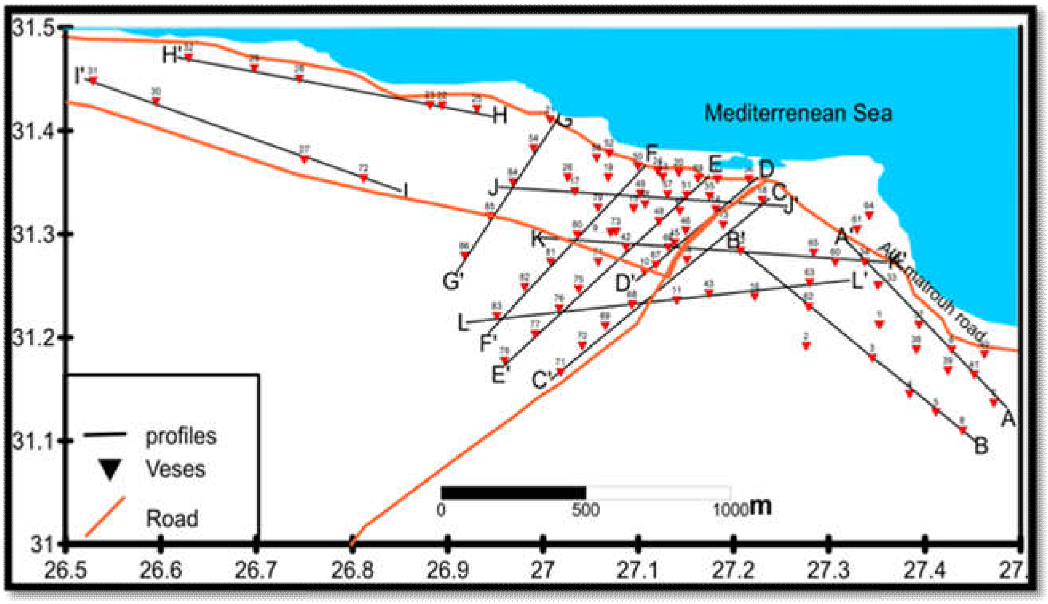

Figure 5. Geoelectrical Profiles at the Studied Area

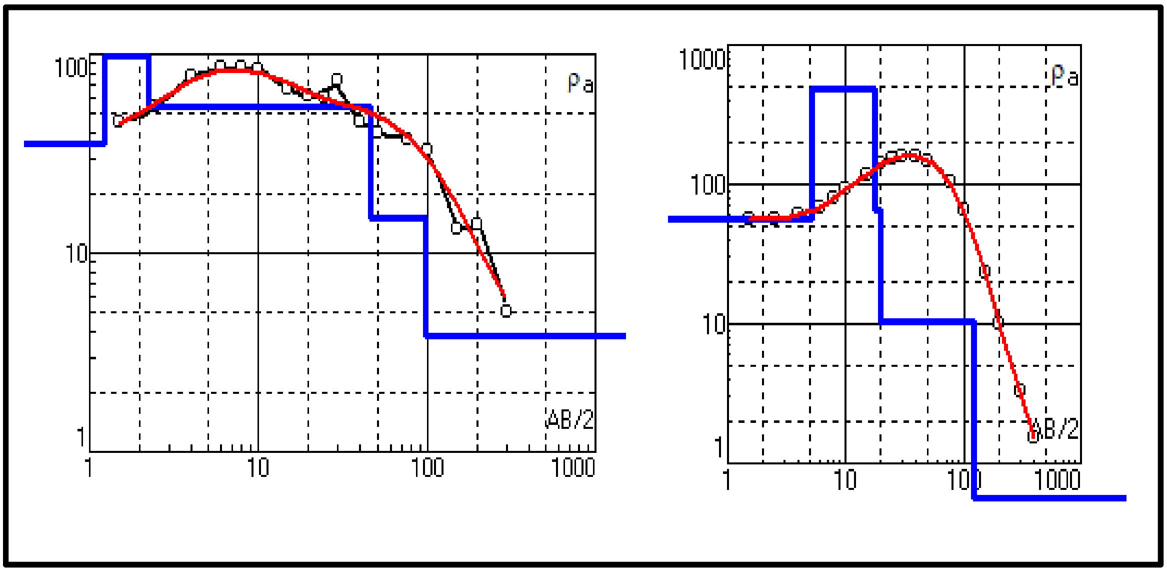

Figure 6. Interpreted Field Curves Data for VES, s(4 and 6)

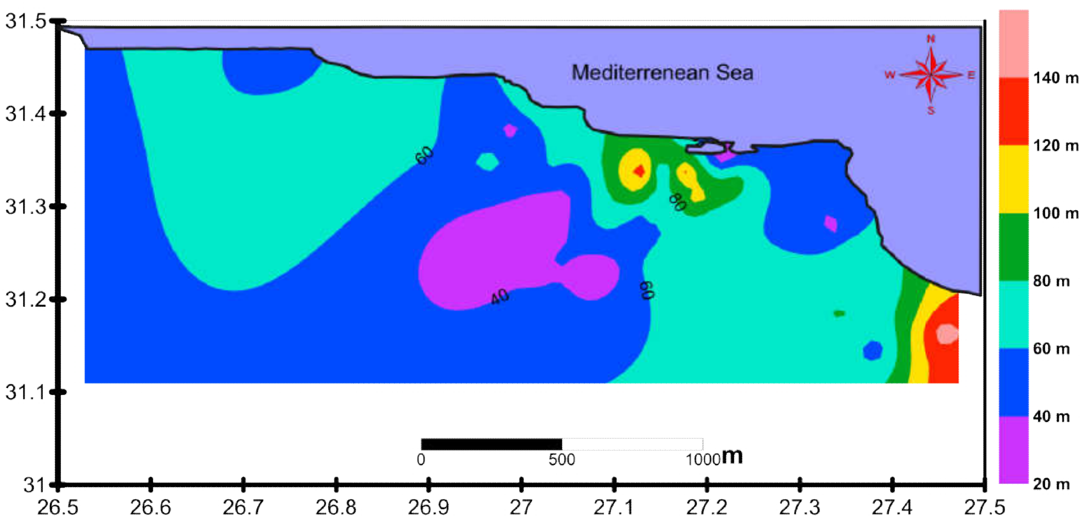

Figure 7. Isopach Contour Map of the Upper Part of the Aquifer

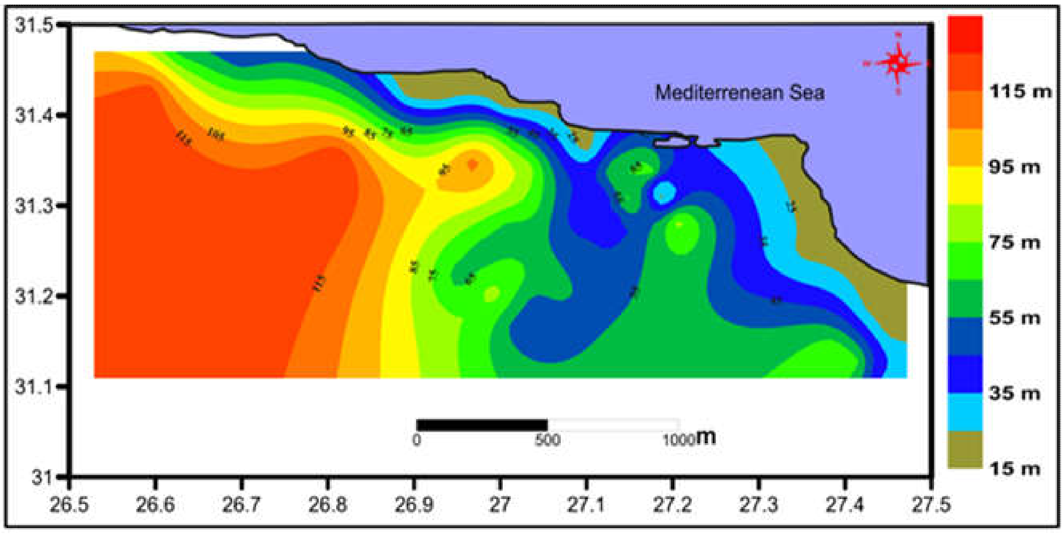

Figure 8. Contour Map of the Depth to the Upper Part of the Aquifer

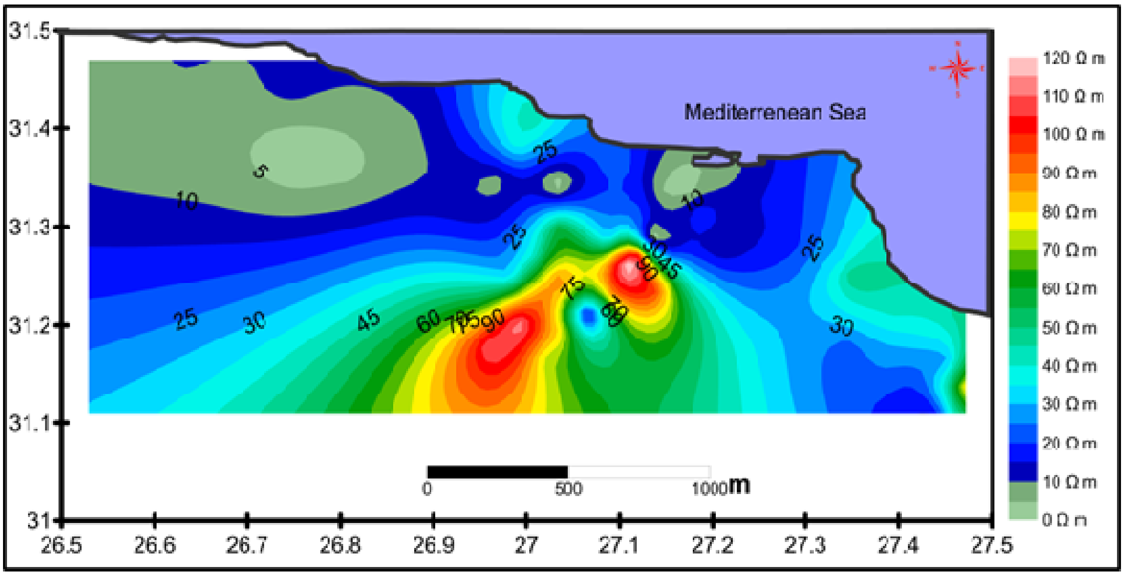

Figure 9. True Resistivity Contour Map of Fracture Limestone Layer

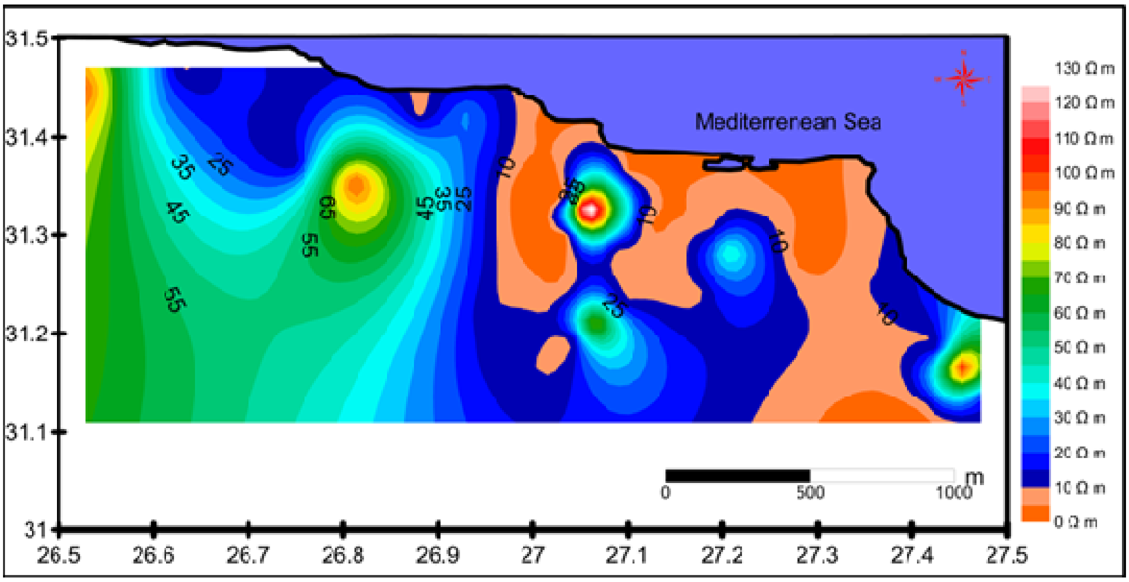

Figure 10. True Resistivity Contour Map of Fourth Layer

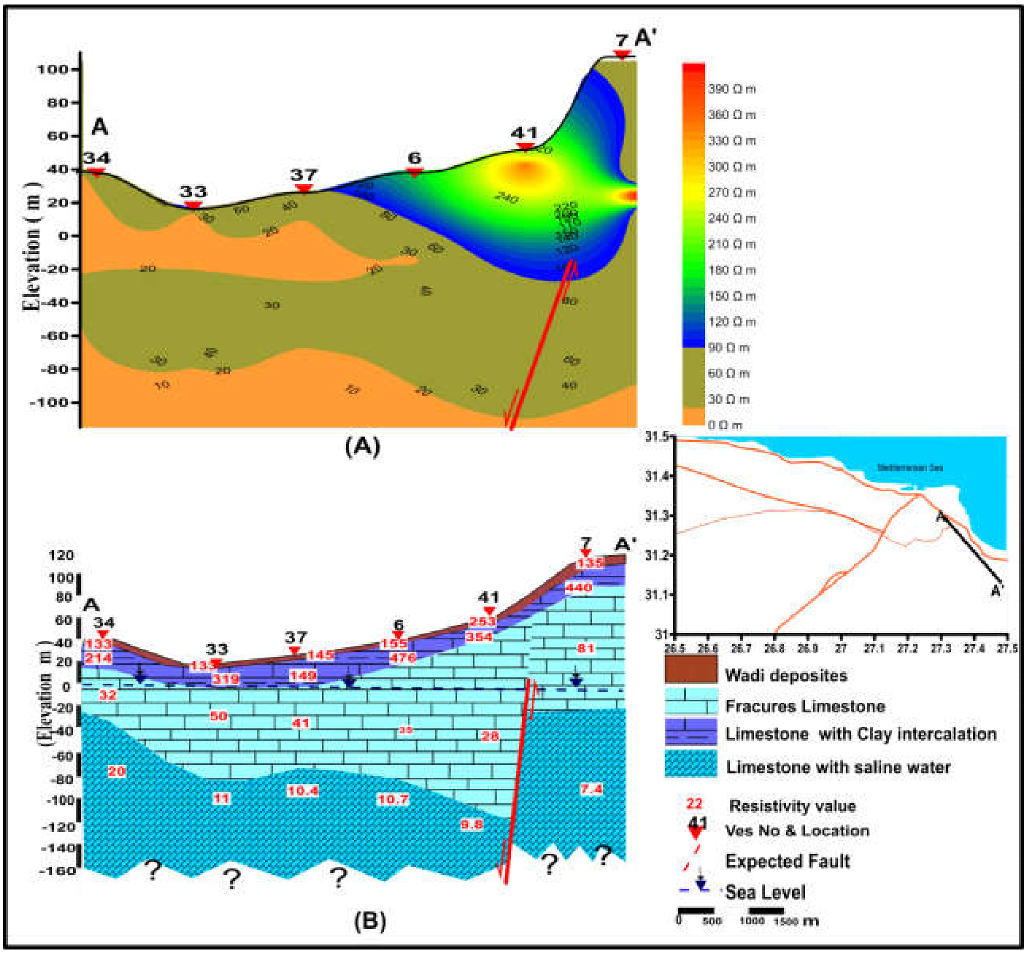

Figure 11. Geoelectric Cross-Section A-A

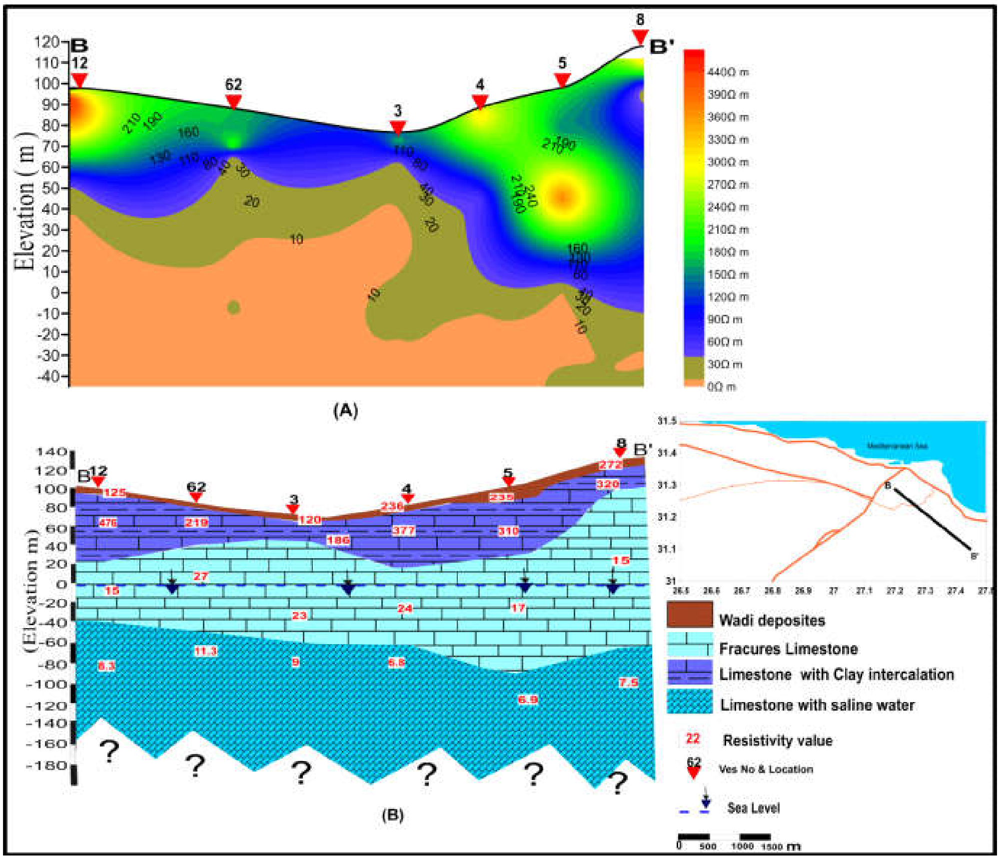

Figure 12. Geoelectrical Cross Section BB'

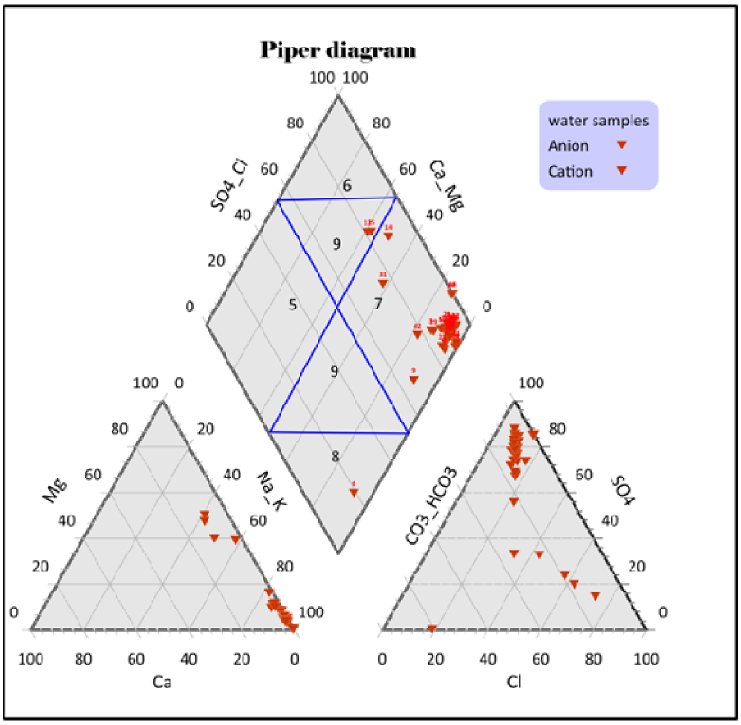

Figure 14. Application of Piper Diagram

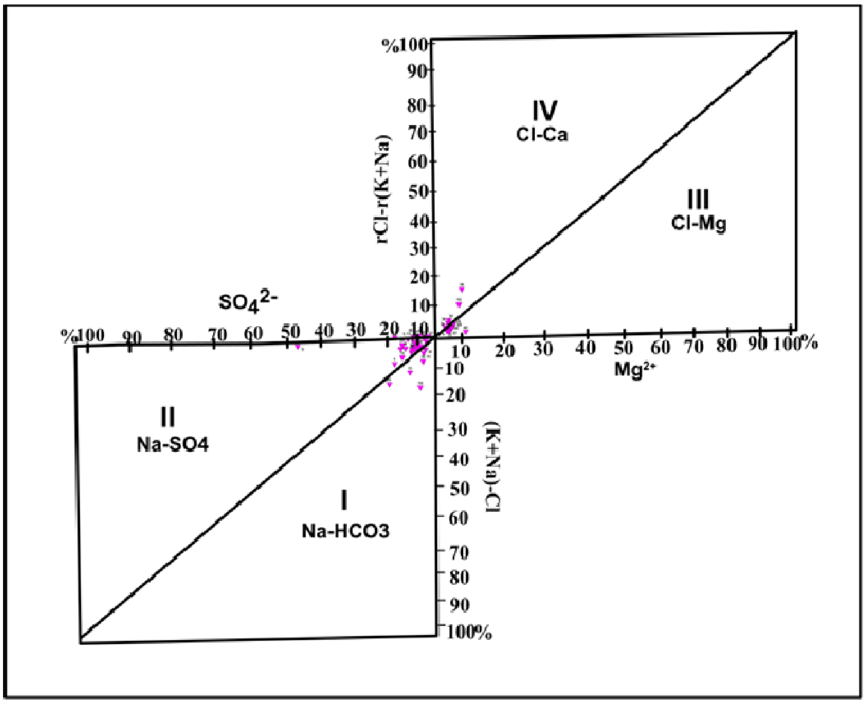

Figure 15. Sulin's Diagram for Representation of Chemical Analysis of the Groundwater Samples

Profile B-B` (Fig.12), includes the same four geoelectrical layers represented in the previous section with some slight difference in their resistivites and thicknesses. The groundwater along this section is also expected to be found in third and fourth layers which composed of water bearing fractured limestone. The depth to water varies from 120 m at the east to 44 m at the west. Profile C-C `is crossing the study area from the South-west to North East (Fig 13.). It passes through seven vertical electrical soundings and indicates the main four geoelectric units in addition to another unit appeared as a lens beneath VES's 68, 69 and 70. The thickness of the second layer decreases, toward northeast and increases toward, southwest due to, structural effect. The third unit attains thickness of about 25 m in the middle and maximum of 100 m in the northeast. This layer represents fracture limestone and saturated with brackish water. The downward fourth layer has resistivity ranging from 6.3 Ohm.m to 11 Ohm.m and represents limestone saturated by saline water.

Groundwater potentiality

To evaluate groundwater potentiality based on the constituents of both cations and anions, this approach can help in the identification of the mixing, leaching and other chemical processes during water circulation as following: Results of chemical analysis of the groundwater samples from the studied area. The salinity of groundwater ranges between 0.25 ms/cm and 42 ms/cm. Also, the salinity of aquifer increases northward in the same direction of groundwater movement, while the maximum conductivity was increased from west to east along the study area. Also, the TDS ranges from 148 mg/l to 30240 mg/l. The Magnesium content changes from 1.5 mg/l to 145 mg/l, and the Magnesium ion increases in southwest and southeast in the study area due to the seepage of saline water from the surface water to the aquifer, or may be due to the presence of marine deposits such as Limestone and Dolomite. The Calcium ion ranges between 23- 894 mg/L and this decreasing in most area may be due to the seepage of rainfall, while, increasing in content to the southwest and southeast is due to the effect dissolution of aquifer sediments. The Sodium content in the groundwater varies from 12 mg/l to 7891 mg/. In some sites of area, the sodium content reaches less than 500, while the highest sodium concentration was attributed to the dissolution of Sodium in soil and subsoil layer during the rainfall periods and to the seepage of drainage water to the groundwater. The Chloride content in the study area ranges between 12 mg/l and 13050 mg/l where the maximum value is taking trend from west to southeast direction. While, the lower values in the area was attributed to percolation of fresh water from local precipitation.

The phosphate varies from 0.2 to 22mg/L where the concentration is increased in the northeast and decreasing in the middle of the area due to the presence of clay interbred that adsorb phosphate on their surface. The Sulfate content ranges from 14.2 mg/L to 2600 mg/L, the distribution of sulphate in the area has a trend elongates from west to east. The tri-linear diagram has proved to study of the chemical character of natural waters. It shows that the distribution of samples according diamond shaped field as indicated in Figure (14). About 85% of the groundwater samples are located in subarea 7, and the other samples are located in subarea 9. This means that the groundwater samples are located in the field of Na-K and Cl-SO4 water type, indicating secondary salinity properties which can be attributed mainly to dissolution of salts in the water-bearing deposits. From Sulin diagram (Figure.15). It was noticed that the majority of groundwater samples were related to Cl-Mg genetic chemical water type which refer that this water is of recent meteoric origin. On the other hand, few groundwater samples belonging to Na-HCO3 genetic chemical types indicate old meteoric origin. And a few of groundwater samples related to MgCl, Ca Cl genetic water type of marine origin.

Conclusion

Two aquifers can be identified in the study area, oolitic limestone aquifer and clastic sediments aquifer. The water is used mainly to meet the demands of the agricultural sector in the area. The o'olitic limestone aquifer consists of fracture limestone (upper layer) and middle Miocene aquifer lower layer of aquifer consists of limestone with saline water. The thickness of this aquifer ranges from less 20 to 100m, the thickness of aquifer increase towards the north Groundwater occurs in this aquifer under semi-confined conditions. In the study area, the groundwater chemical composition has some changes from south to north passing through different rock types. The main changes in groundwater chemistry were affected by its movement from South to North. On the other hand, the probable changes in water chemistry from West to east, i.e., parallel to the coast due to changes in aquifer types are also considered. Data from this integrated hydrochemical and geoelectrical studies indicated that water quality from the water wells and geophysical surveys varies from slightly brackish to saline water. Based on the resistivity values and geoelectric cross-sections.

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