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Geoelectrical contribution for delineation the groundwater potential and subsurface structures on Tushka Area, Egypt

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A B S T R A C T

Tushka area represents the South East Western Desert, Egypt. its contain many drilled wells which have many problems during use, so the present study aims at identify the aquifer conditions and its relation with surface water and subsurface structure in addition to determine the aquifer thickness by using the basement relief from previous work, then assess the current situation of the drilled water wells. Geoelectrical data were measured, processed and interpreted in one, two and three dimensions using special Equipments and software.

The interpretation results demonstrated that two types of groundwater aquifers (confined and unconfined) are present in the study area. The confined aquifer is located at the south of Khor Tushka and the unconfined aquifer is found in the north of Khor Tushka, where the last one is charged from Lake Nasser and Khor Tushka. The groundwater aquifers thicknesses are up to 440 m and the area is affected by normal faults of NW-SE and NE-SW trends. The study showed that there is no connection between the confined aquifer and the shallow overlaying aquifer. The confined aquifer is charged partially from the lake Nasser and Khor Tushka through specific areas under the capping layers of Nubian sandstone filled with hydrothermal solution and shale.

1. Introduction

The dream of geophysicists involved in electrical methods is to differentiate between buried geologic formations based on their geoelectrical parameters. The area under consideration is located to the southern portion of Egypt, it bounded from the south and east by Lake Nasser and it lies between latitudes 22°15′ & 22°57′N and longitudes 31°12′ & 31°54′E (Fig. 1). Geoelectrical methods are the most important tools in field of groundwater studies. It is applied to map the resistivity differences of the subsurface (Kirsch, 2009). Vertical electrical sounding, two and three dimensional modeling readings are used to identify the vertical and horizontal extensions of the sedimentary layers specially water bearing formation and the subsurface structure elements affects on it. Kotb (2013) and Abd El-Gawad et al. (2012) have used magnetic methods to calculate the total basement depth at the concerned area. Based on the integration between the geoelectrical results and basement depth, the total thickness of aquifer is calculated.

2. Geology of area

The surface geologic and stratigraphic column of the study area (Conoco, 1987, 1989; EGSMA, 1997) is shown in Figs. 2a and 2b were described. Quaternary deposits covers some parts which are differentiated into fluvial and alluvial deposits, lake and playa deposits, and aeolian deposits, the other parts is covered by Nubian sandstone formations like Abu Simbel Formation, Lake Nasser Formation, and Sabaya Formation. Abu Simbel Formation is the oldest unit exposed in the study area considered as the most important unit of the Nubian sandstone aquifer system and forms the escarpment of the Abu Simbel. It consists mainly of littoral, marine to continental clastic sequence that formed of sandstone

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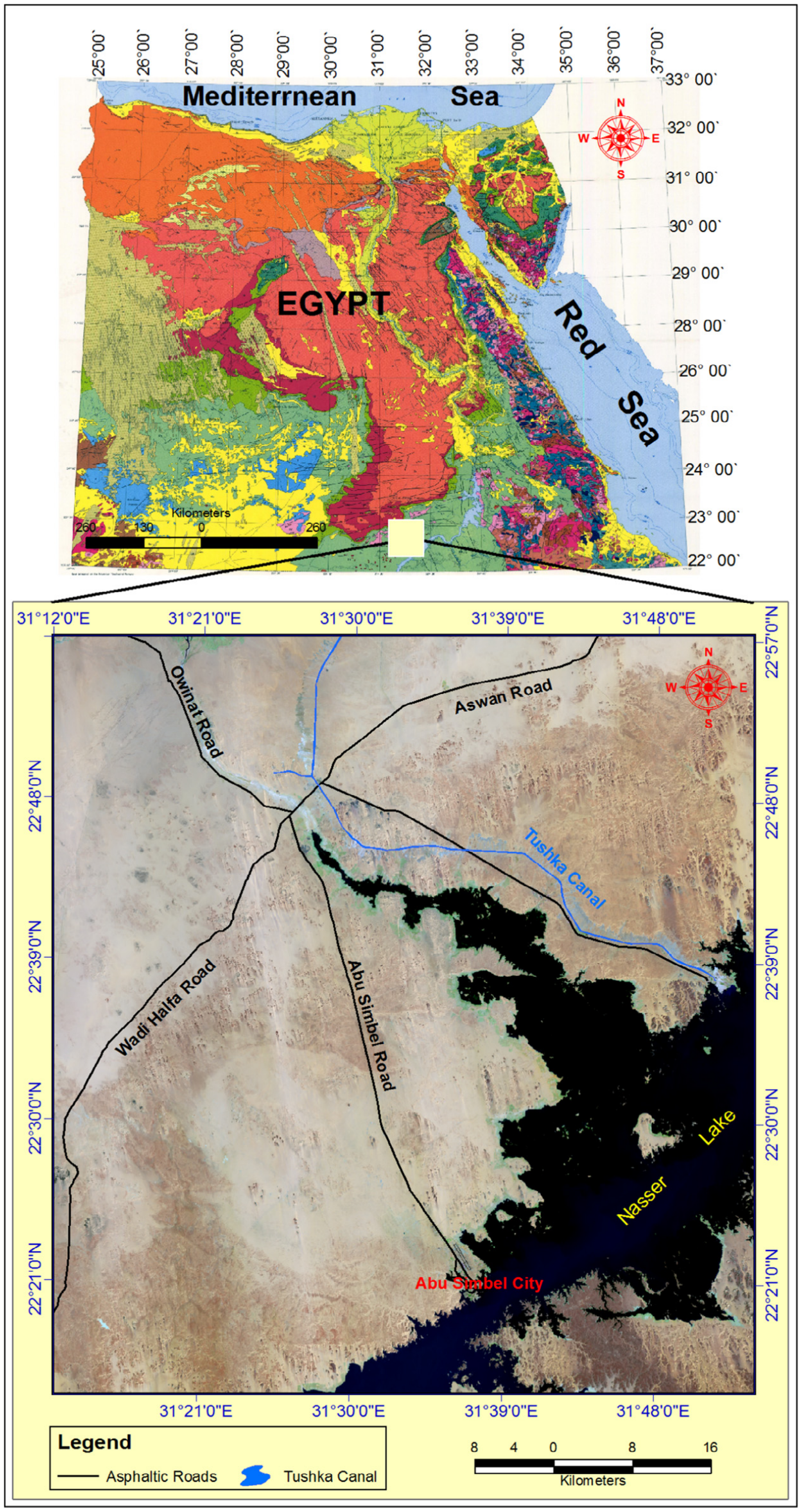


Fig. 1. Location map of the study area.

beds of different colors, well sorted permeable porous siliceous or ferruginous. The lower part of these continental clastics contains silicified trees and other plant fossils, Lake Nasser Formation describes as transgressive shallow marine sequences and consists mainly of silt and sandstone, intercalated with shale, mudstone and fluviatile sandstone, Sabaya Formation is made up from medium to coarse grained flood plain sandstone with inter-bedded channel deposits and soil horizon. Oligocene basalt is represented.

3. Methodology and interpretation technique

3.1. Vertical electrical sounding data (1D)

Fifty-two Vertical Electrical Soundings (VES) were executed (Fig. 3) in the study area using Schlumberger configuration with AB spacing ranging from 1400 m to 3000 m. The main goal is to detect the upper surface of Nubian sandstone aquifer in the study

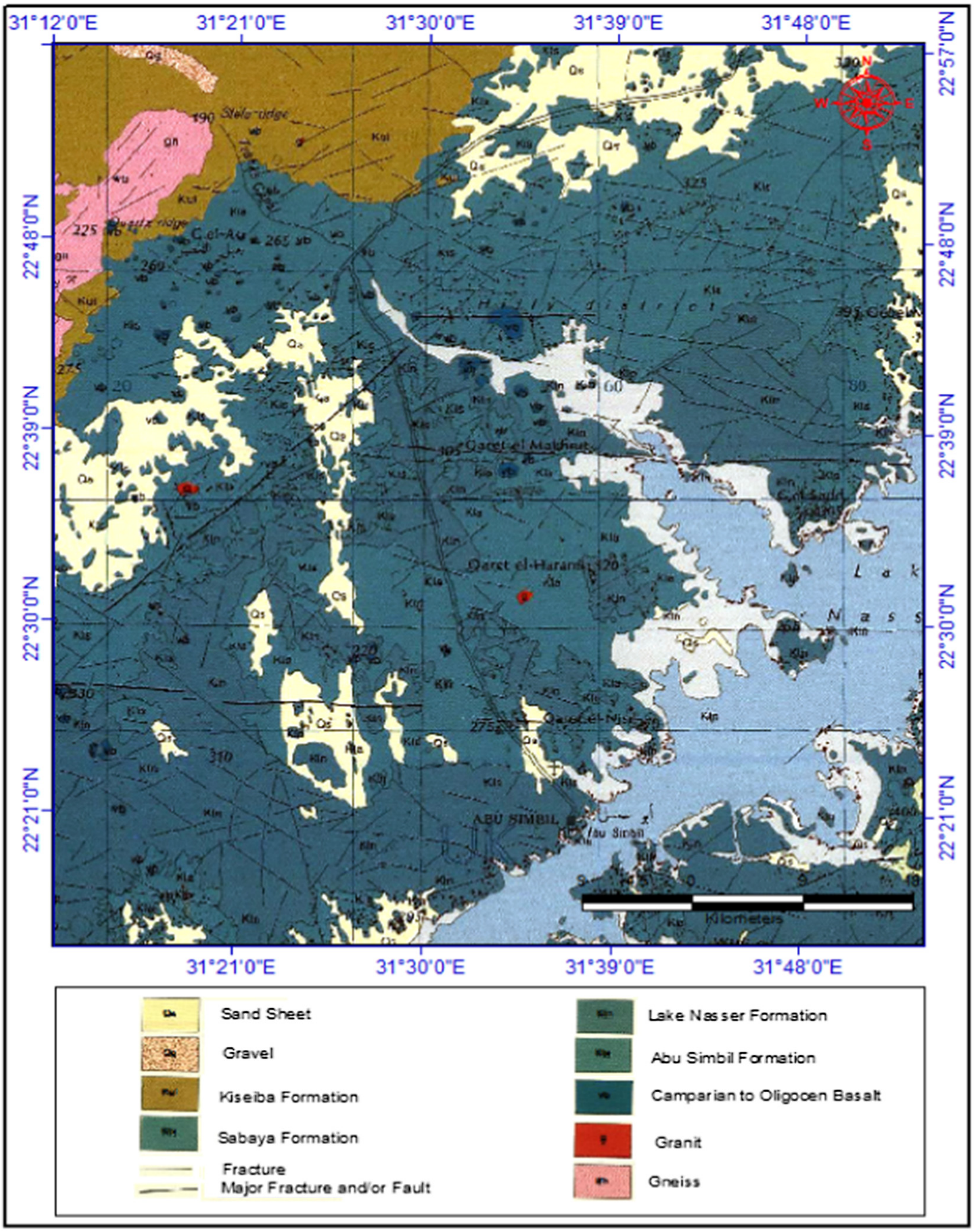


Fig. 2a. Geological map of the study area (after Conoco, 1987).

area. Three of these stations have been placed beside drilled holes with known lithologic logs to serve as parametric measurements. Such measurements are quite helpful in the interpretation process of the Vertical Electrical Sounding data.

The data were acquired using the TERRAMETER SAS 300 C from ABEM instrument AB Sweden with ABEM BOOSTER SAS 2000 TERRAMETER SYSTEM. The geological data obtained from well No. 85 which was drilled by Desert Research Centre (2010) and well No. 2 which was drilled by RIGWA (1998) was used in the calibration of the geoelectrical models obtained from the apparent resistivity curves. (Fig. 4) shows the correlation between geoelectrical parameters of well No. 2 and the geology obtained from VES 51. Two methods were used for interpretation of VES data; one is manual (graphical) and the other is analytical methods.

The initials models have been constructed in view of the available geologic data from the existing wells in the area and from the result of graphical method and old programs of analytical methods such as (a) the program created by Zohdy and Bisdorf (1989), (b) Computer software Resist, ver.1 is written by Van Der Velpen (1988). These initials models used in IPI2win program (by Moscow State University V. 3.0.1 a 2003) to get the final result of quantitative interpretation of the geoelectrical sounding curves. The quantitative interpretation has been applied to determine the thicknesses and true resistivities of the stratigraphic units below each VES station.

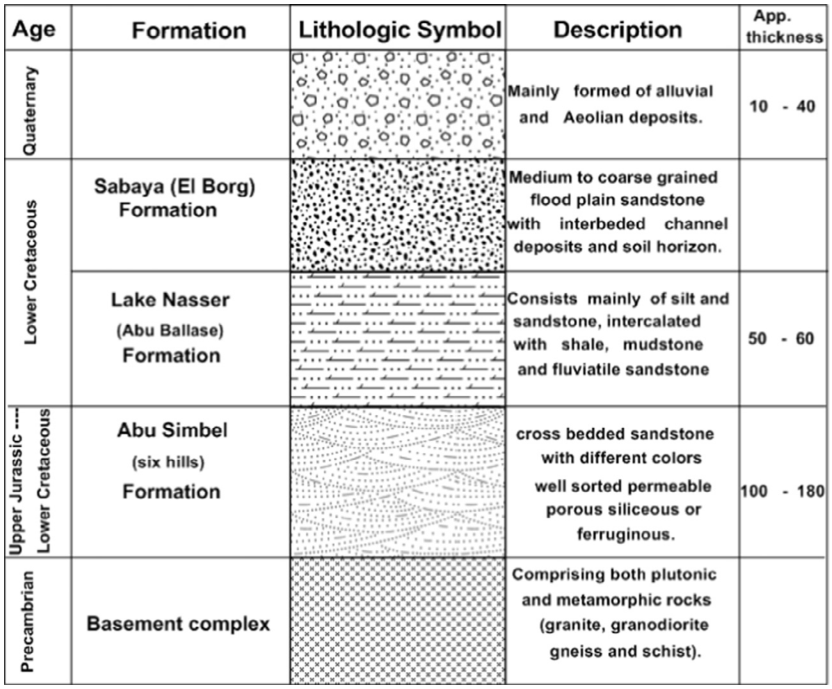


Fig. 2b. The composite stratigraphic succession of the study area.

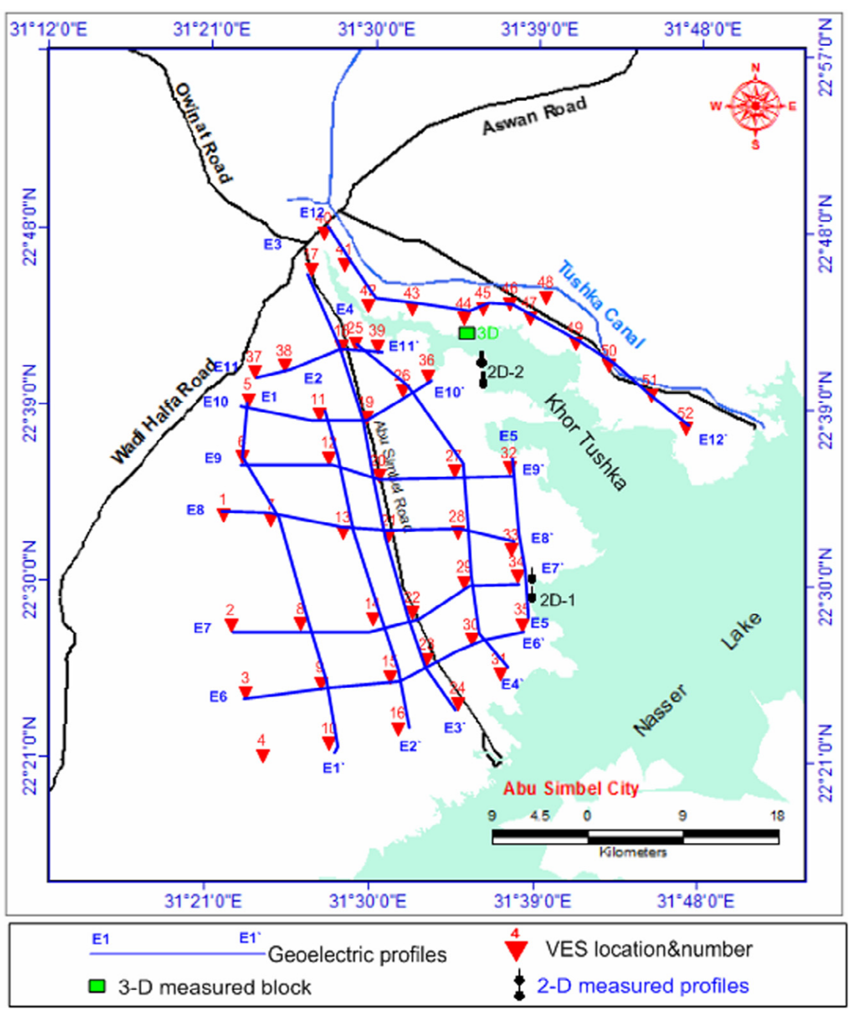
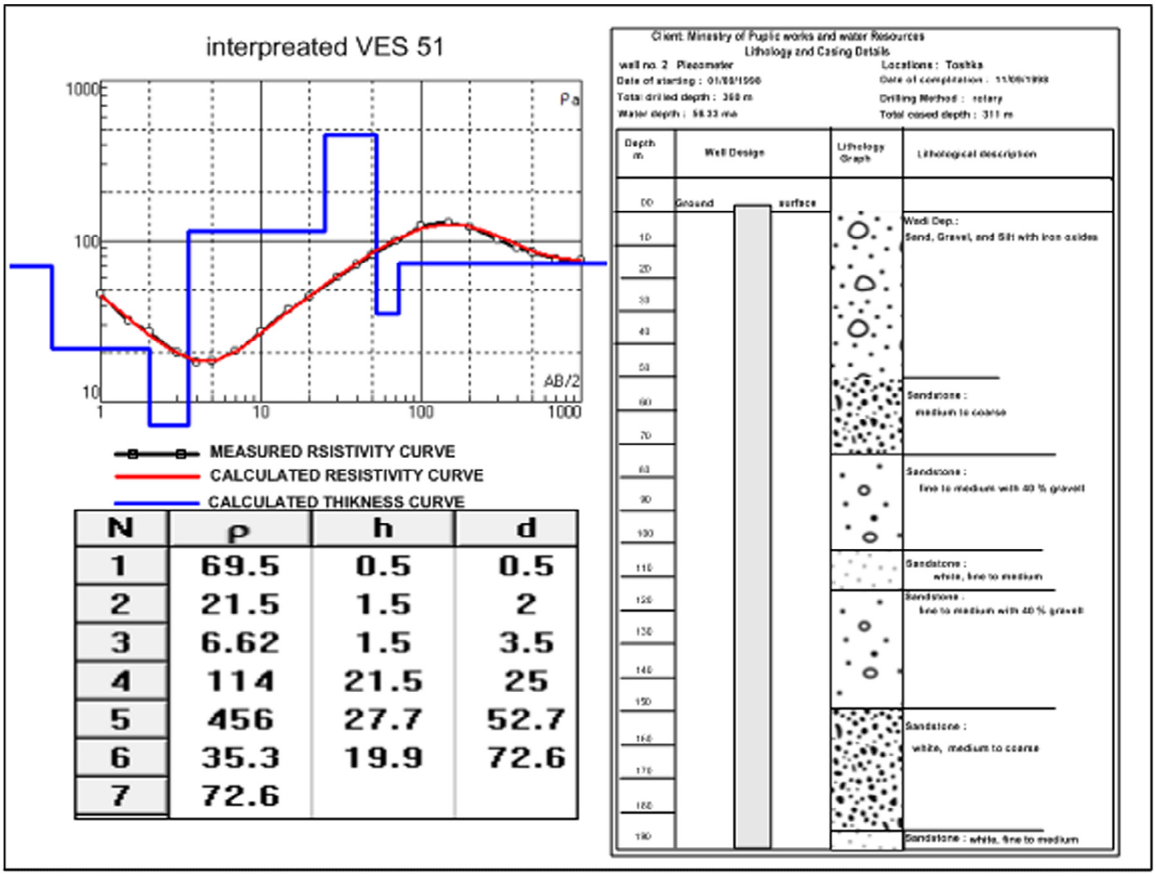


Fig. 3. Location map of geoelectrical measurements in the area.



N	ρ	h	d
1	69.5	0.5	0.5
2	21.5	1.5	2
3	6.62	1.5	3.5
4	114	21.5	25
5	456	27.7	52.7
6	35.3	19.9	72.6
7	72.6		

Fig. 4. Lithological data and the interpreted results of vertical electrical sounding station No. 51.

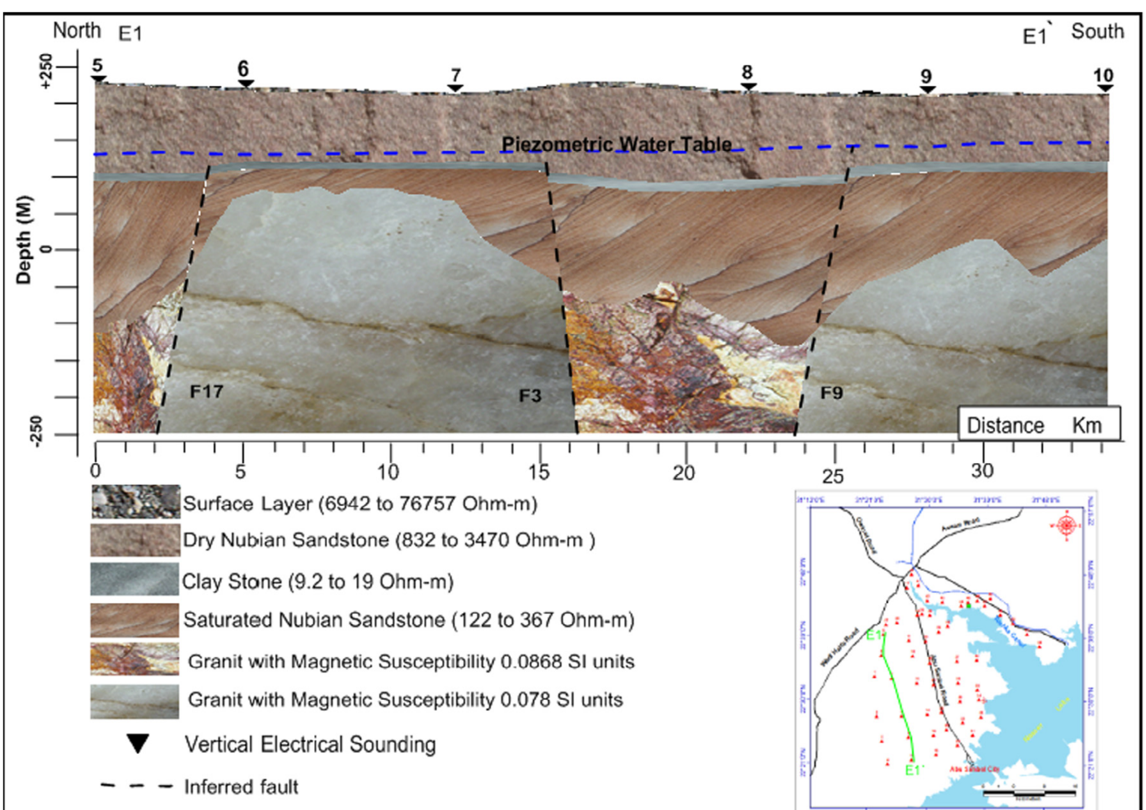


Fig. 5. Geoelectrical cross section E1-E1′.

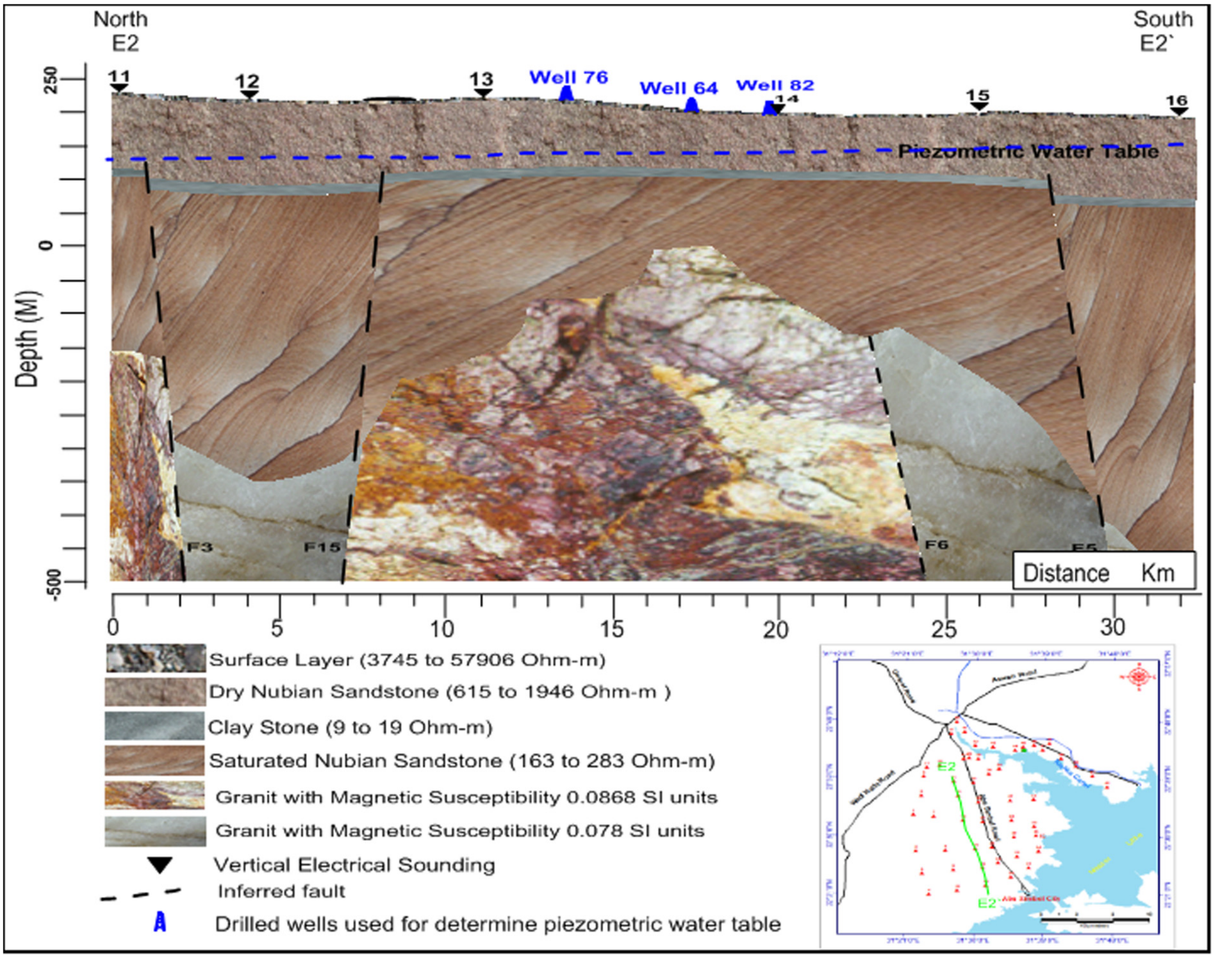


Fig. 6. Geoelectrical cross section E2-E2′.

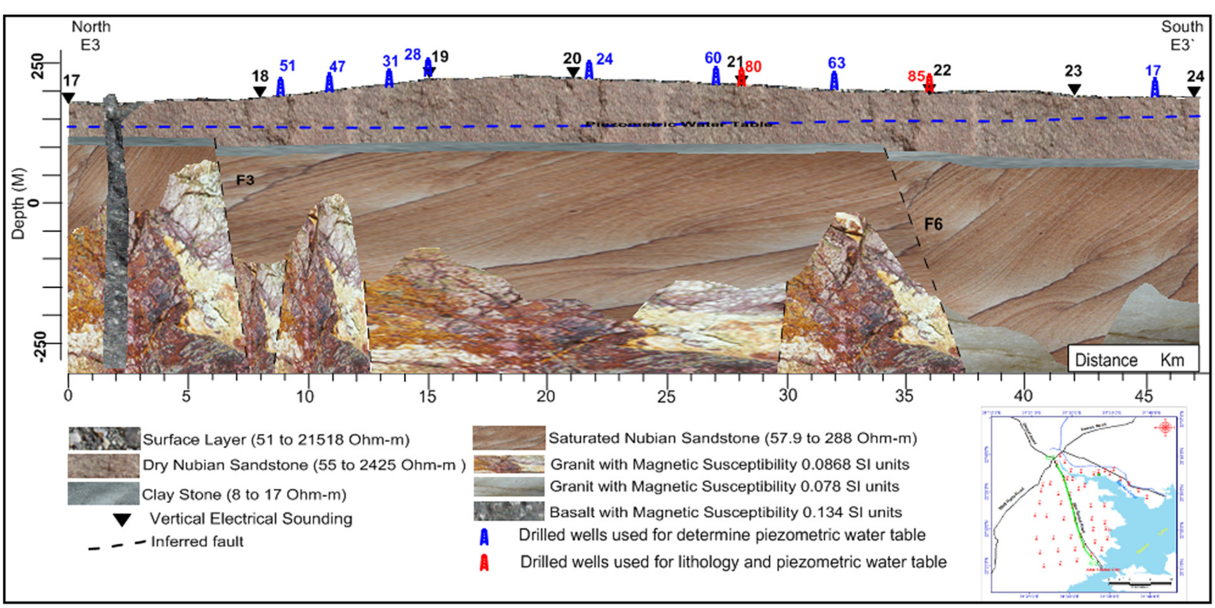


Fig. 7. Geoelectrical cross section E3-E3′.

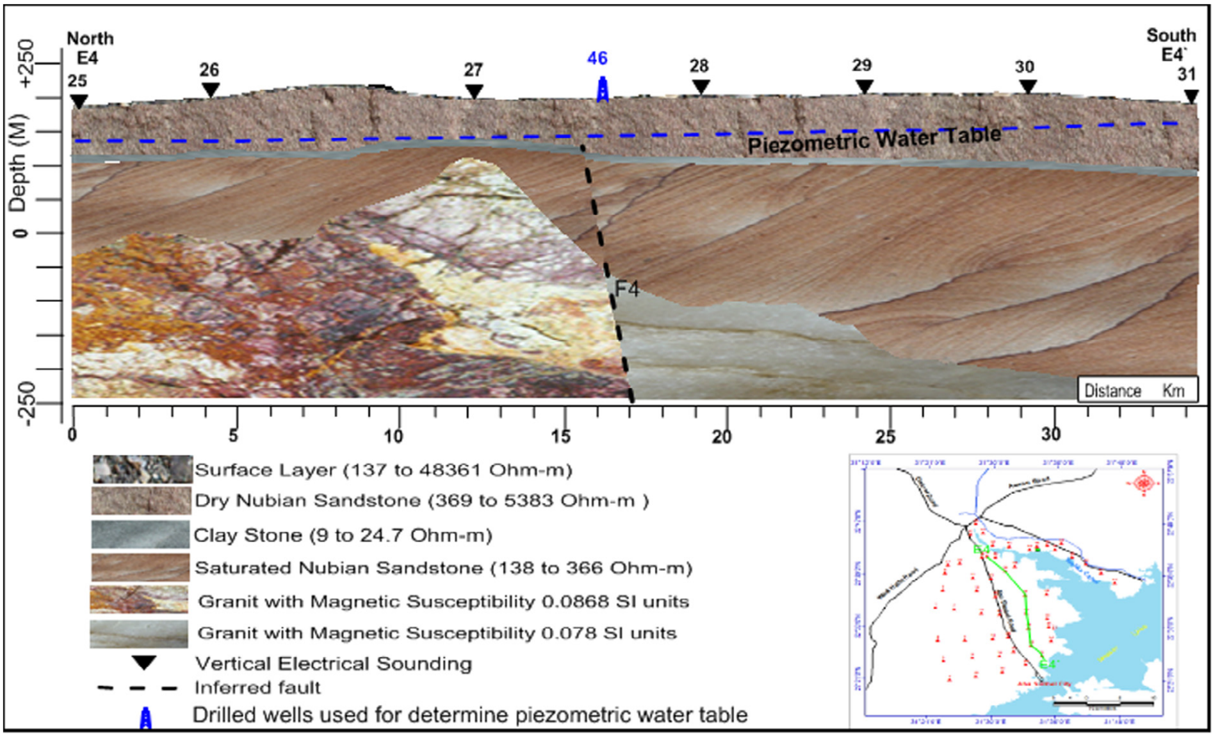


Fig. 8. Geoelectrical cross section E4-E4′.

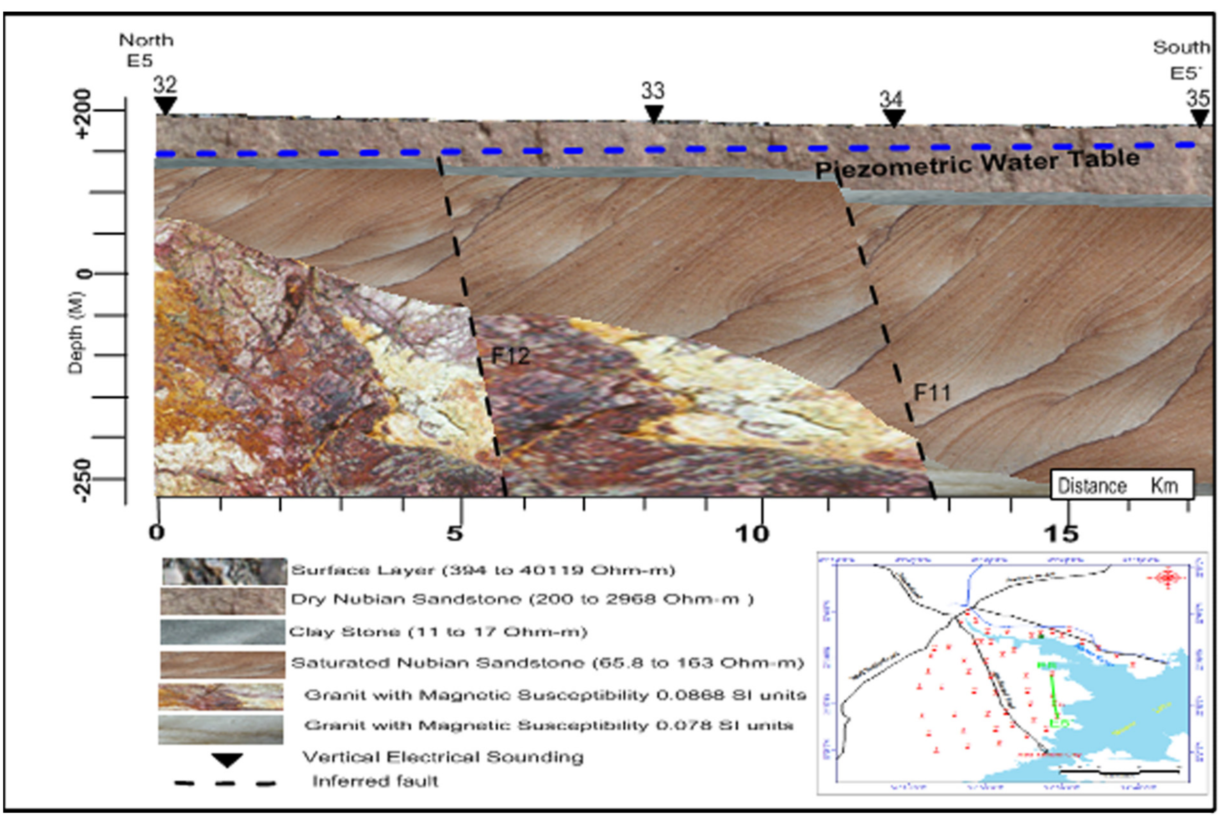


Fig. 9. Geoelectrical cross section E5-E5′.

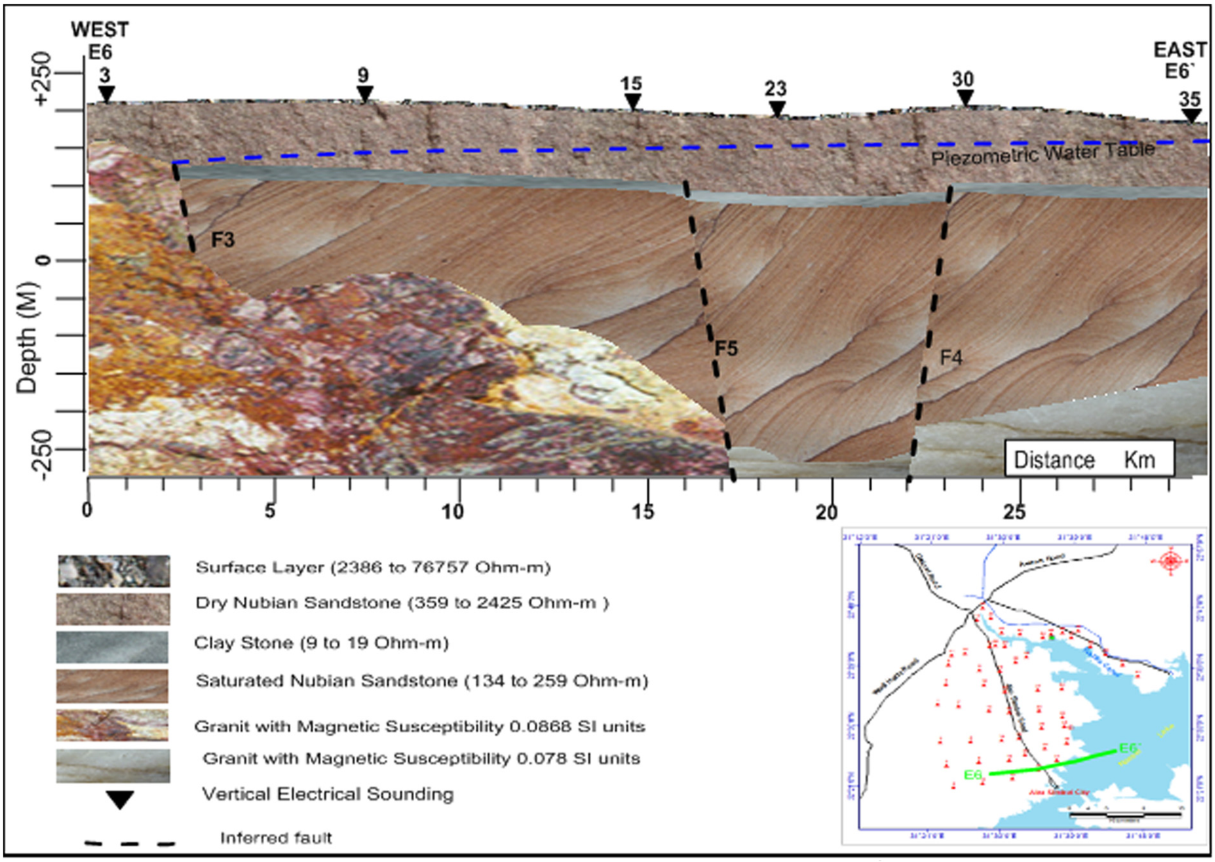


Fig. 10. Geoelectrical cross section E6-E6′.

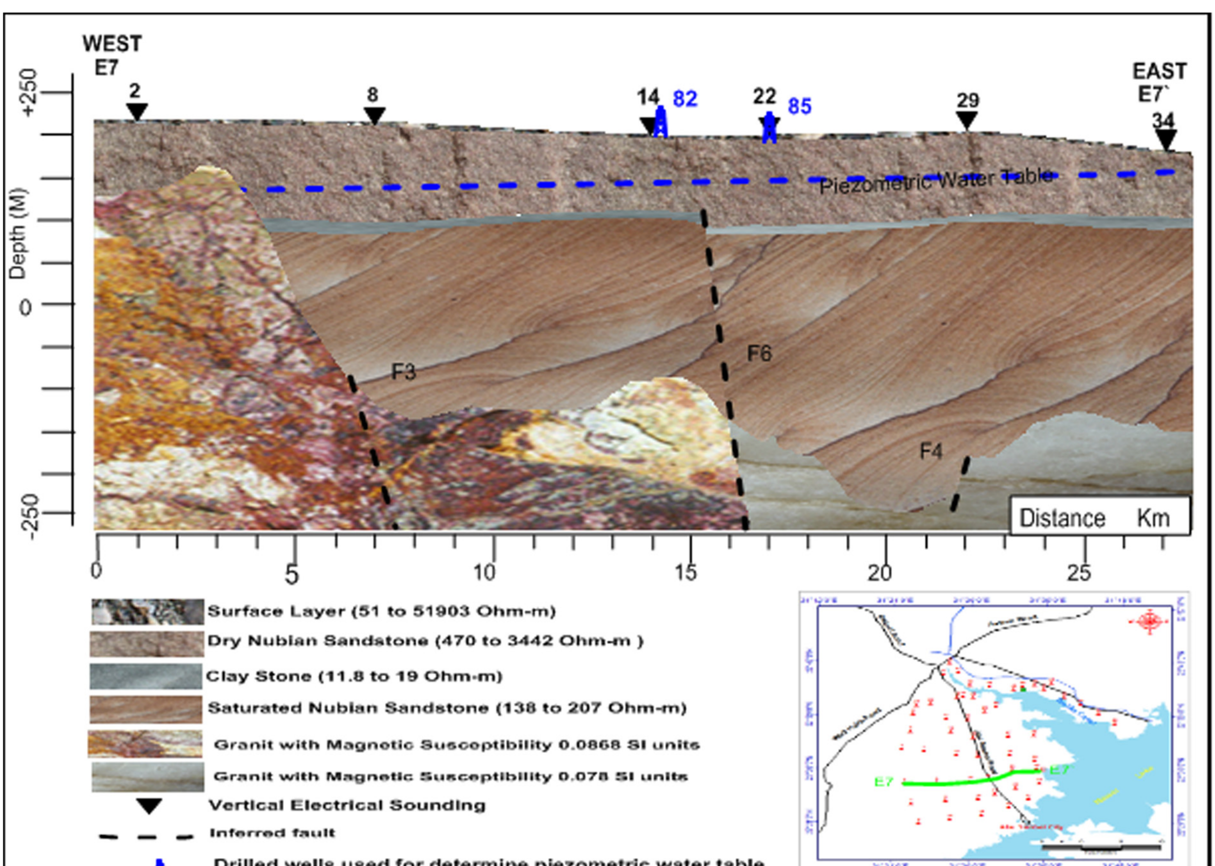


Fig. 11. Geoelectrical cross section E7-E7′.

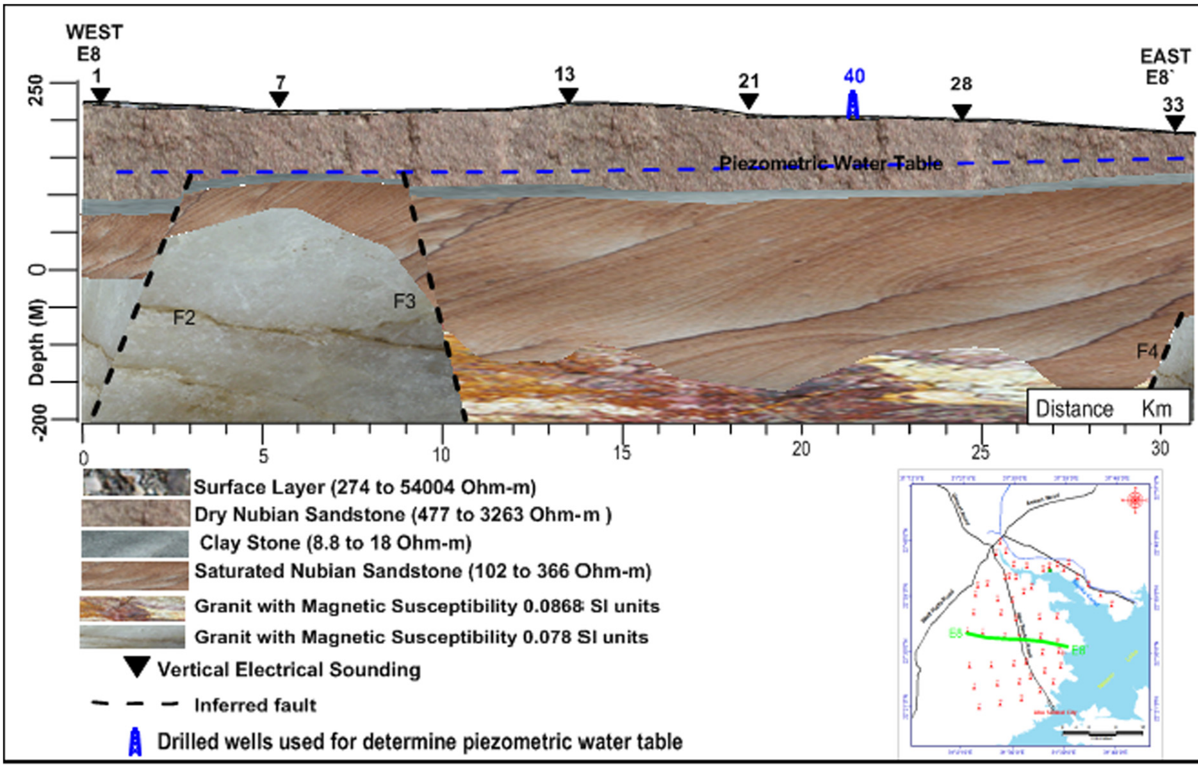


Fig. 12. Geoelectrical cross section E8-E8′.

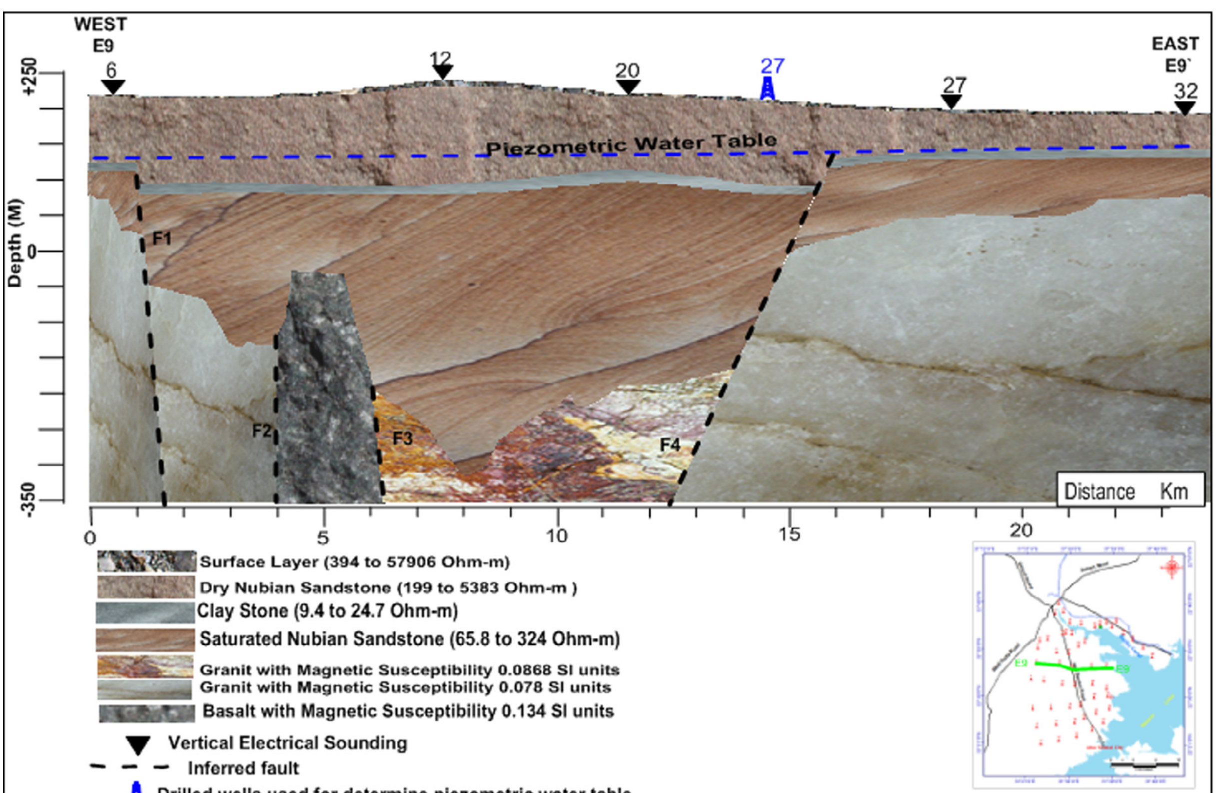


Fig. 13. Geoelectrical cross section E9-E9′.

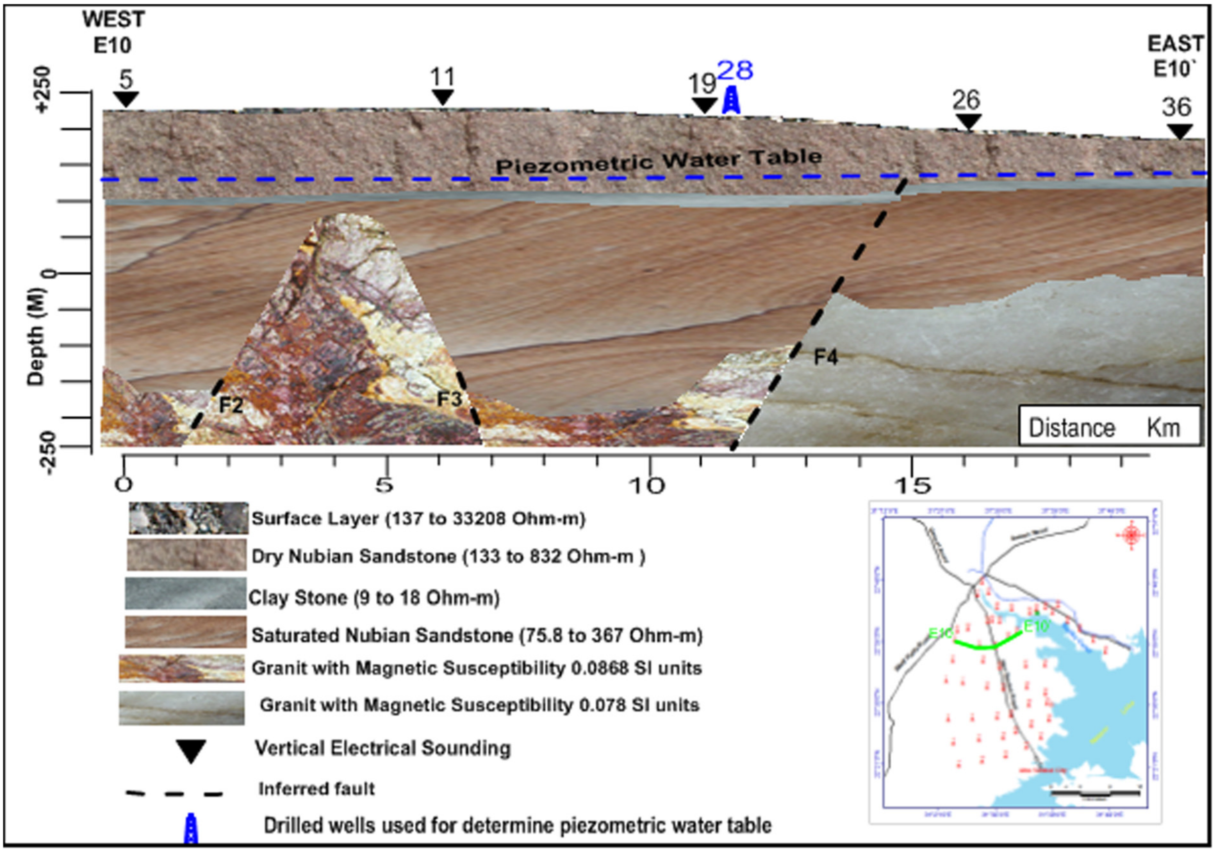


Fig. 14. Geoelectrical cross section E10-E10′.

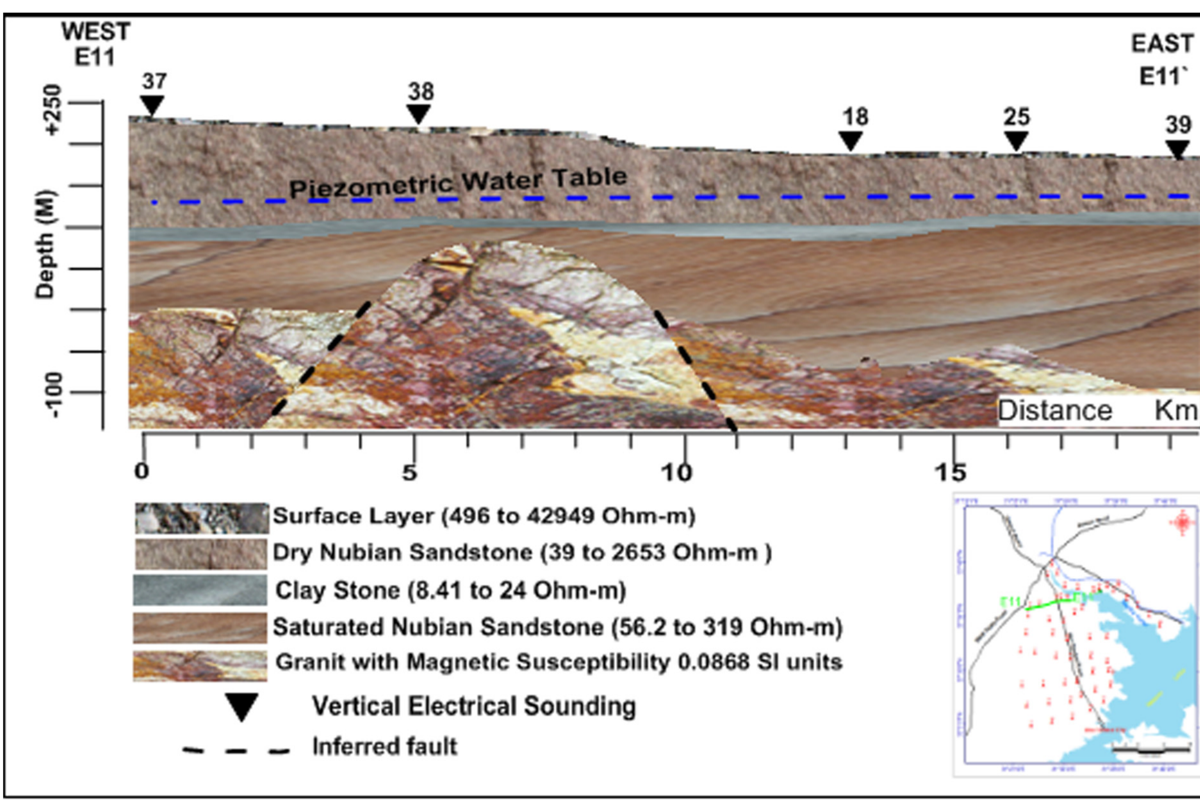


Fig. 15. Geoelectrical cross section E11-E11′.

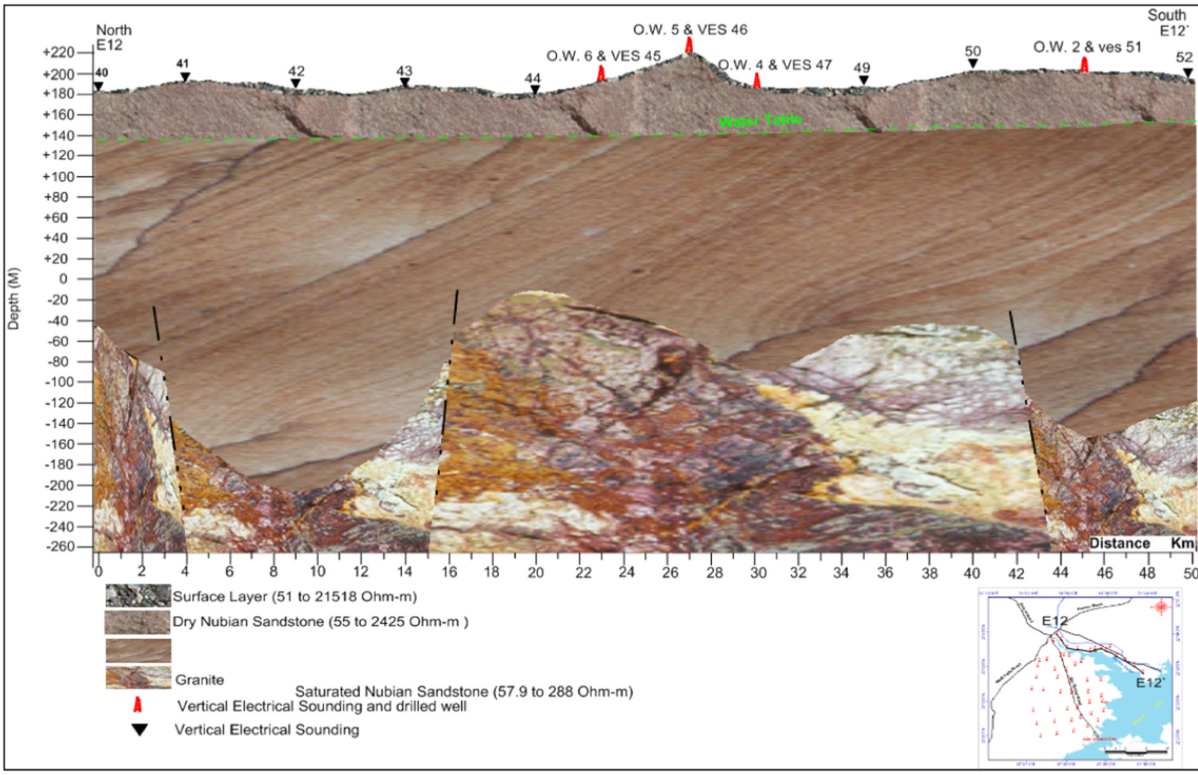


Fig. 16. Geoelectrical cross section E12-E12′.

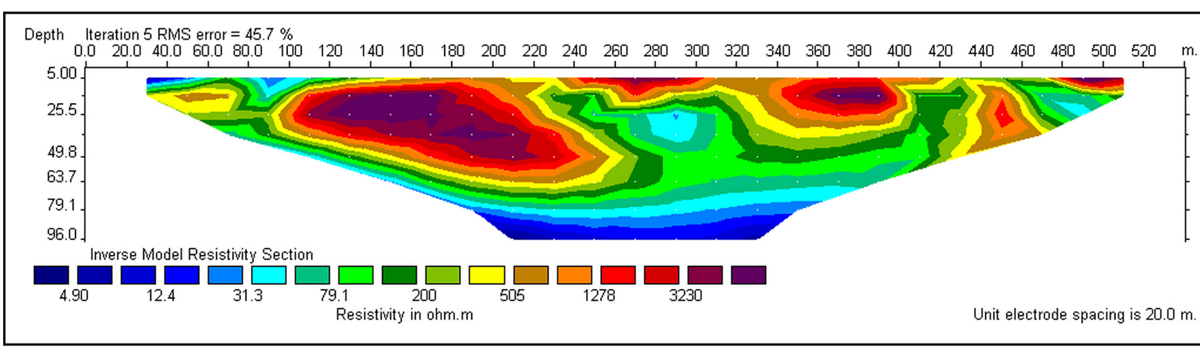


Fig. 17. The inversion model (true resistivity) along the first sit of 2-D imaging.

3.2. Electrical imaging (2D)

The electrical imaging as contentious vertical electrical sounding along one profile (Loke and Dahlin, 2002), Wenner array were used to carry out two geoelectrical imaging profile to identify the relationship between groundwater and surface water in Khor Tushka (Fig. 3). The first profiles have length 600 m and a unit electrode separation "a" is 20 m, and it is increased successively at each traverse by one unit to reach 40 m (i.e. 20, 40, 60 ... 200 m). The second profiles have length 540 m and unit electrode separation "a" of 20 m, which increases successively at each traverse by one unit to reach 180 m (i.e. 20, 40, 60 ... 180 m). The pseudo section contouring method is normally used to plot the data from 2-D imaging survey to gives a very approximate picture of the true subsurface resistivity distribution, then the section was made by regarding the pseudo section as a series of closely vertical electrical soundings, Extracted one after the other. Each sounding is interpreted in terms of a multi-layer model and merged together to form a section. Accordingly, the multi-layer model is adjusted to fit the data as closely as possible.

3.3. Electrical tomography (3D)

One site of 3-D resistivity imaging measurements was carried out with 81 electrodes as the Pole-Pole array (Fig. 3). The electrodes are arranged in a 9 by 9 square grid with a unit spacing of 7 m between adjacent electrodes. The two remote electrodes were placed at more than 600 m from the grid to reduce their effects on the measured apparent resistivity values. To reduce the survey time, the cross diagonal survey technique was applied.

4. Results and discussions

The results of VES (1D) interpretations have been used to construct eleven cross sections to represent southwest portion of Khor

Tushka (Figs. 5–15) and one represent the northeast portion (Fig. 16) using golden software (Surfer 10.7.9). To construct these sections the authors use the information drained from Abd El-Gawad et al. (2012), who measured the depth to basement and the basement relief, in addition to El Tahlawi et al. (2008), which indicated that, the sandstone aquifer is bounded below by impervious basement rocks. This valuable information was integrated with VES which carried out during this study.

The models in southwest Khor Tushka sections indicated that the subsurface lithological column is represented by five geoelec-

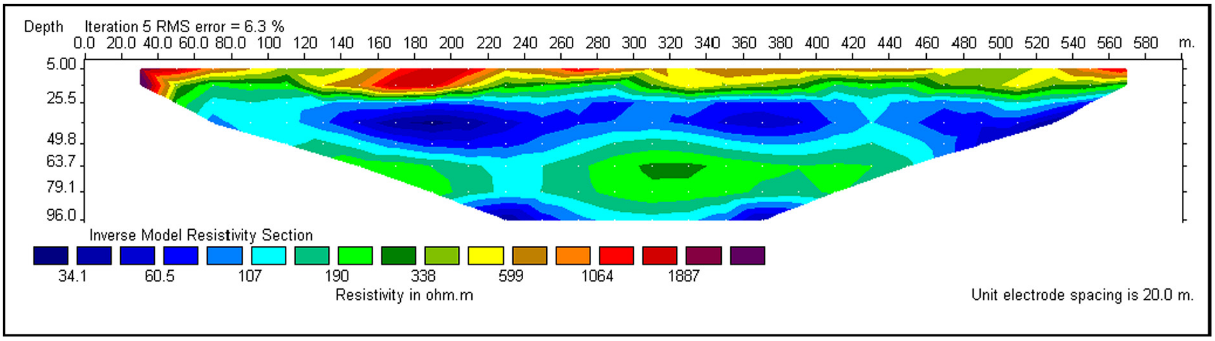


Fig. 18. The inversion model (true resistivity) along the second sit of 2-D imaging.

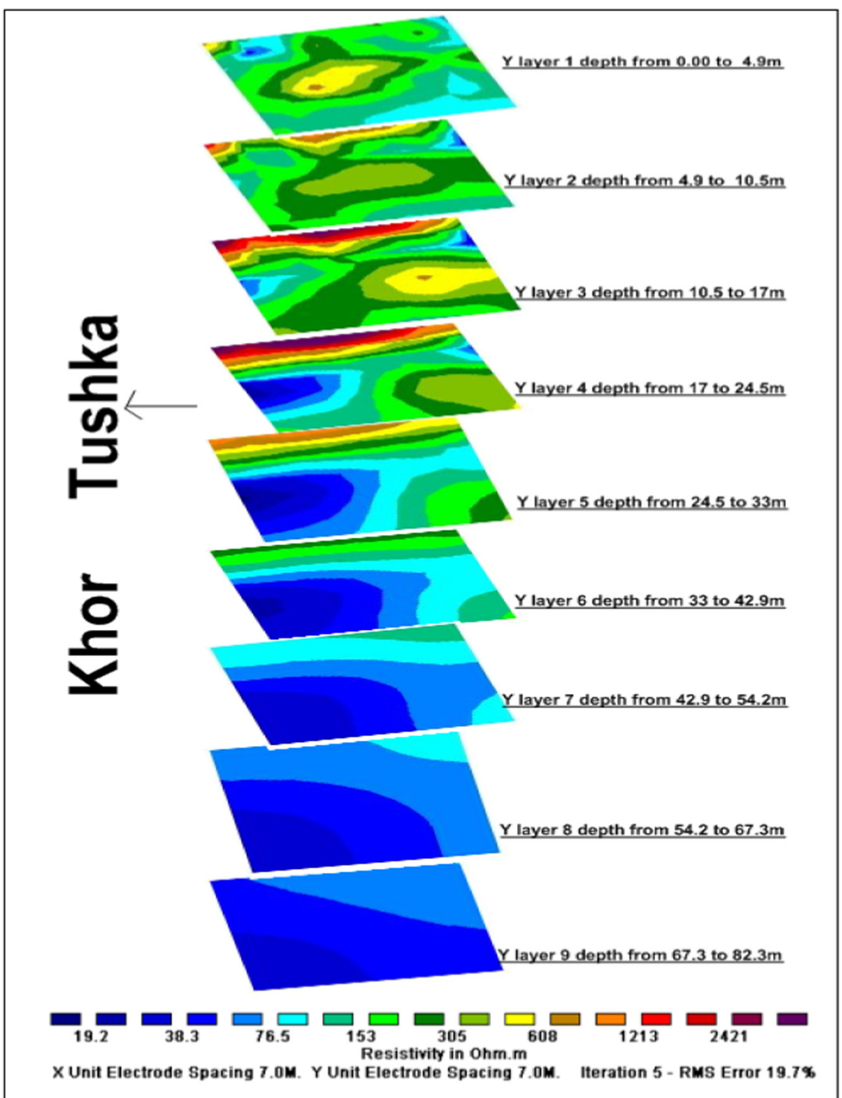


Fig. 19. Horizontal slice of 3-D obtained model from the inversion of pole-pole Survey.

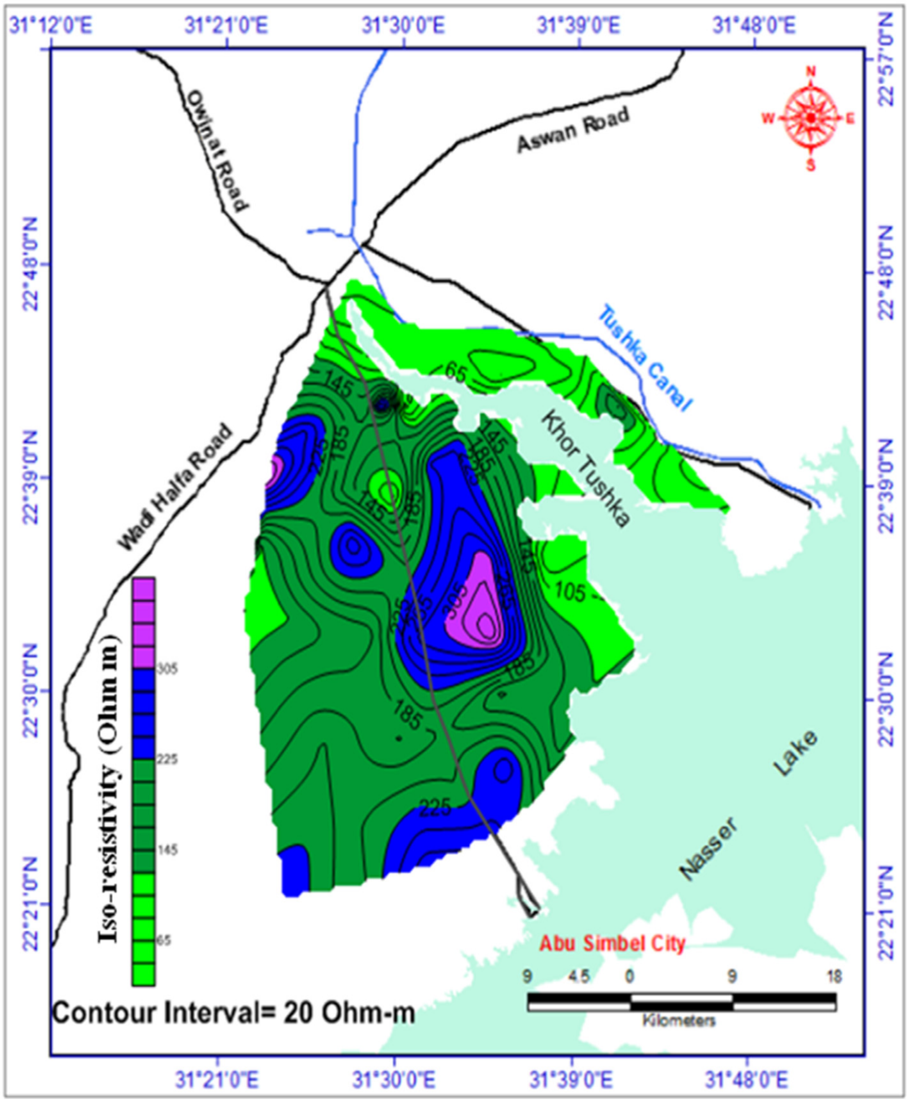


Fig. 20. Iso-resistivity contour map of the water bearing sandstone in the area.

trical layers A, B, C, D, and E are corresponding to surface layer (Heterogeneous in compositions, textures and solidifications), dry zone of Nubian sandstone, Shale comprises the cape rock of the main aquifer, saturated Nubian sandstone which comprises the main aquifer and basement complex respectively. on the other hand, the northeast Khor Tushka model contains three geoelectrical layers A, B, and C are corresponding to surface layer, dry zone of Nubian sandstone, and saturated Nubian sand stone which comprises the main aquifer. The integration between wells data and resistivity of water bearing layers indicate that, the aquifers are filled by fresh water and they have powerful thickness for development.

The relation between the surface water in Khor Tushka and aquifers is produced from the result of 2D tomography, where showed that, the sandstone is highly resistance and compact over the main aquifer at the first site (Fig. 17) while it consists a shallow local aquifer at the second one (Fig. 18). But the main aquifer at northeastern portion is rechargeable from surface water according to the interpretation result of 3D measurements (Fig. 19).

Finally we can summaries the results of geoelectrical measurements integration which have yielded valuable information, as follows:

1. Two types of groundwater aquifers (confined and unconfined) are present in the study area.
2. The confined aquifer is located at southwest of Khor Tushka.
3. The resistivity of water bearing layers in southwest portion has range between 60 and 370 Ω-m (Fig. 20) and it increases at the middle and decreases to east and west due to increasing shale mount.
4. Depth to water bearing layers has range between 65 m and 155 m (Fig. 21).
5. Water bearing layers have a thickness up to 440 m (Fig. 22) increase at the middle and decrease to east and west due to basement rising.
6. The structural framework represented by 12 normal faults with NW-SE and NE-SW directions (Fig. 23).
7. There is no connection between the confined aquifer and the shallow overlaying aquifer.

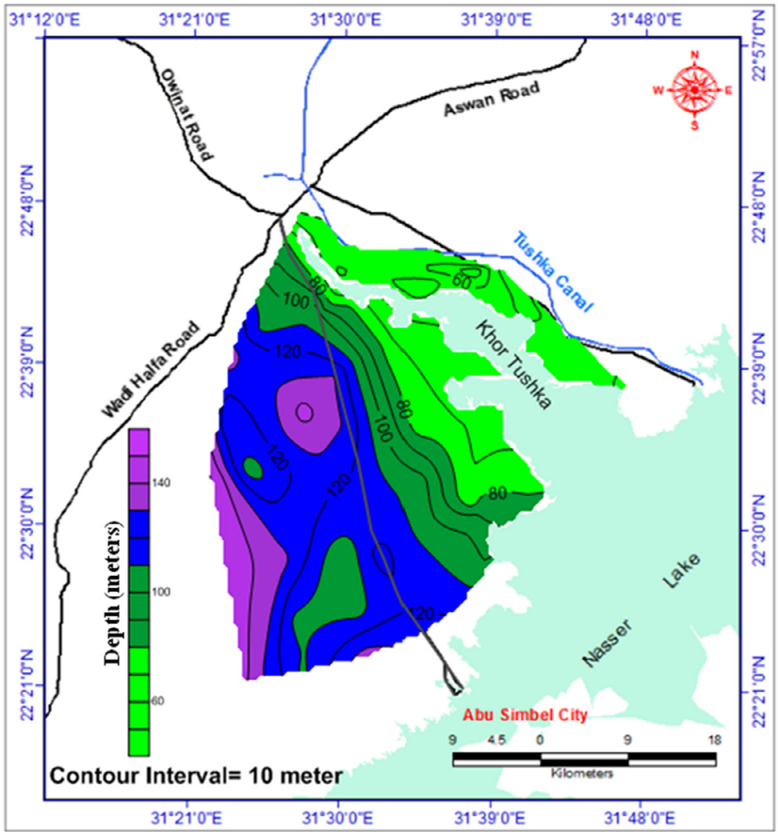


Fig. 21. Depth to water bearing sandstone in the area.

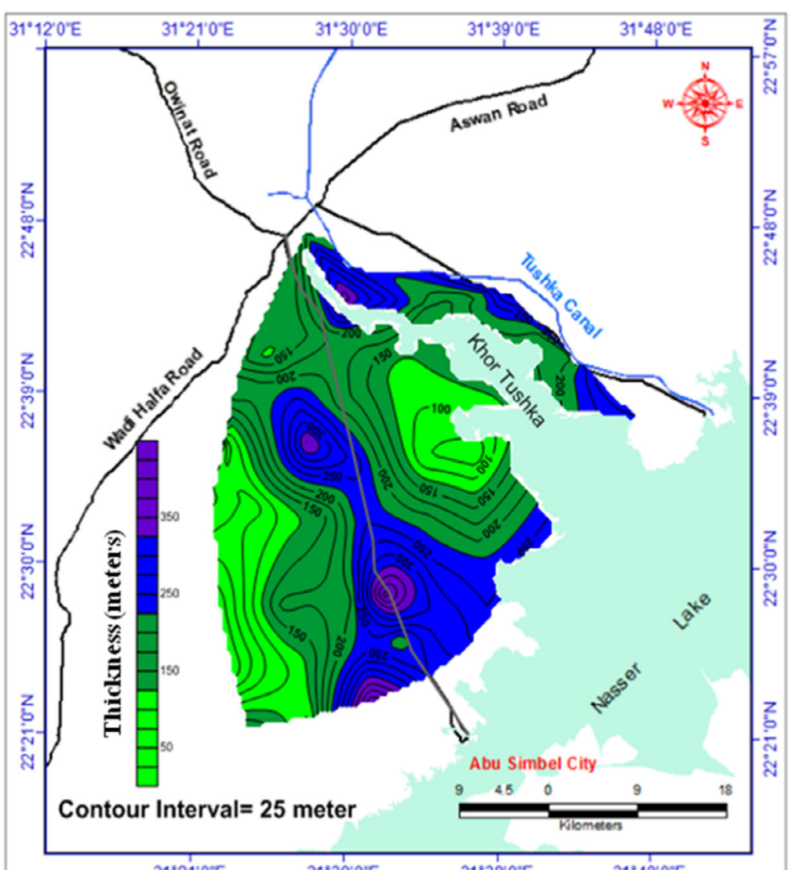


Fig. 22. Isopach contour map of the water bearing sandstone in the area.

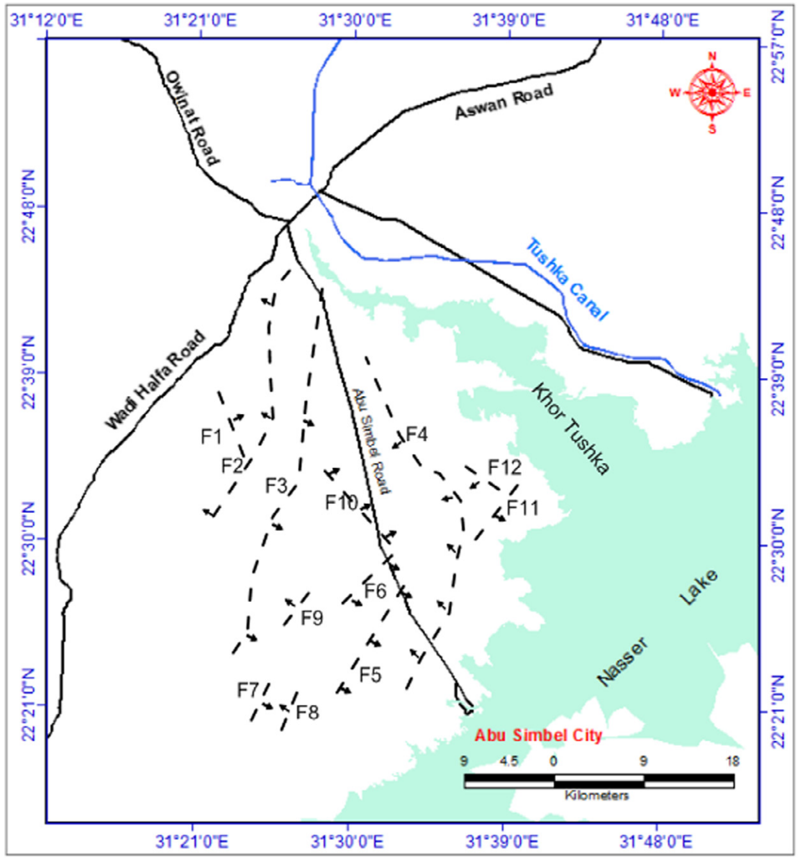


Fig. 23. Inferred faults from the geoelectrical data interpretation.

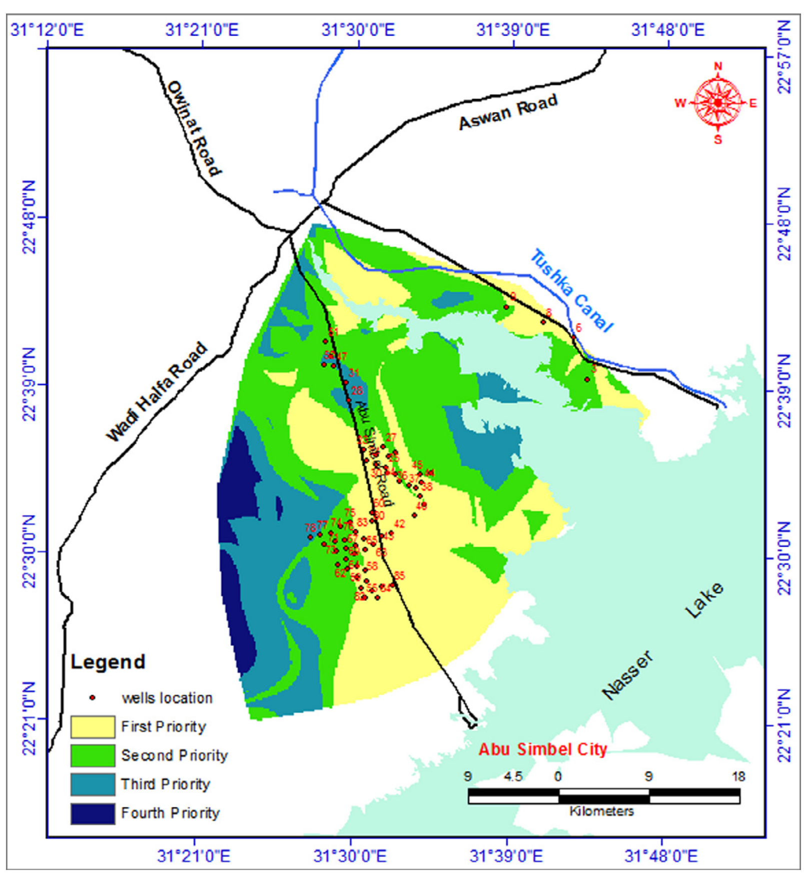


Fig. 24. Priority map according to result of geoelectrical measurements.

8. The unconfined aquifer is found in the northeast of Khor Tushka and charged from Lake Nasser and Khor Tushka.
9. The confined aquifer is charged partially from the lake Nasser and Khor Tushka through specific areas under the capping layers of Nubian sandstone affected by hydrothermal solutions and shale.

5. Priority map

ArcGIS software was used for preparing the different layers of the aquifer parameters (Depth to water bearing formation, Resistivity and thicknesses of water bearing formation) that gained from the geophysical study in addition to salinity map of the study area and used for spatial analysis and modeling our suitability map by applying Equal wait for the used layer. The resulted suitability map gives us four priority classes (Fig. 24), high thickness, small depth, low salinity and respectively high resistivity represent class one -the best- and opposite of these parameters represent class four. This map contributes to identifying the situation of all water wells in the study area. The drilling water wells 6, 8, 23, 24, 25, 27, 29, 30, 33, 35, 40, 42, 43, 44, 54, 55, 56, 58, 60, 63, 65, 67, 80, 81, 84 and 85 are in suitable places for drilling water wells respectively due to its locations in the first priority areas which are represented by greatest thickness, highest resistivity, smallest depth, and lowest salinity. While the drilling water wells 3, 9, 46, 51, 59, 61, 64, 69, 70, 71, 72, 73, 74, 75, 76 and 77 are in second suitable places for drilling water wells. The drilling water wells 22, 28, 31, 47, 51 and 78 are drilled in poor places it is represented by small thickness, low resistivity, great depth, and high salinity.

So, we recommended that Drilling water wells in the future must be done in areas that represent the maximum thickness of the water-bearing layers (first priority area). And must be deepened to take advantage of the water bearing formation which is the shale amount is decrease with depth increases.

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