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Hydrogeophysical investigation at El-Hammam area, North Western Desert, Egypt

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ABSTRACT

El Hammam area is situated in the North-Western Coast and it is one of the most challenging regions for sustainable development. Transient Electro-Magnetic (TEM) survey has been applied for distinguishing the groundwater aquifers at the study area. Eighteen (TEM) stations were measured and interpreted to evaluate the subsurface aquifers. The final models were used for the construction of a number of cross-sections showing the vertical and lateral distribution of the geoelectrical parameters. The results of the quantitative interpretation indicate that the subsurface sequence consists of four geoelectrical units where the aquifers are represented by the second, third, and fourth layers. The hydrochemical analyses for collected samples included the determination of total dissolved solids (TDS), hydrogen ion (pH), electric conductivity (EC) and indicate that the salinity of the groundwater in El Hammam area increases with depth..

Keywords: TEM; Chemical analysis; Groundwater aquifer; El Hammam; Egypt.

1. Introduction

El Hammam area occupies a portion of the North-Western coastal zone of Egypt and represents one of the potential localities for future developments and agricultural expansion beyond the Delta and Nile Valley.

El- Hammam area is located approximately 80 km from the city of Alexandria and 35 km to the south of the coastal road as shown in Fig. 1. It extends between latitudes 30° 42`- 30° 52`N and longitudes 29° 05`- 29° 29`E.

Several authors used geophysical methods, which are applied to Stratigraphy, Structures, Groundwater exploration, Mineral's exploration, Subsurface Mapping and Sustainable development (e.g., Sultan and Santos, 2008, Mohamed et al, 2012, Mohamaden et al, 2016, Abdel Zahar et al, 2018, Al Deep et al, 2021, Abdel Zahar et al, 2021 and El-Sayed et al, 2021).

Electromagnetic (EM) method is well-known in exploration geophysics and commonly applied in near-surface applications (Massoud et al 2009; Khalil et al 2013; A. Younis et al 2016). EM techniques have particularly succeeded in groundwater exploration and the mapping of groundwater contamination and saltwater/freshwater interfaces (Massoud et al 2010; Khalil et al 2013; Metwaly et al 2014; A. Younis et al 2016).

This study aims to characterize the groundwater aquifers in El Hammam area, describing their spatial distribution and delineating the most suitable sites for drilling new water wells by TEM data. As well as the interpretation of hydrochemical data to determine the concentration of some important parameters like TDS, pH, EC of groundwater.

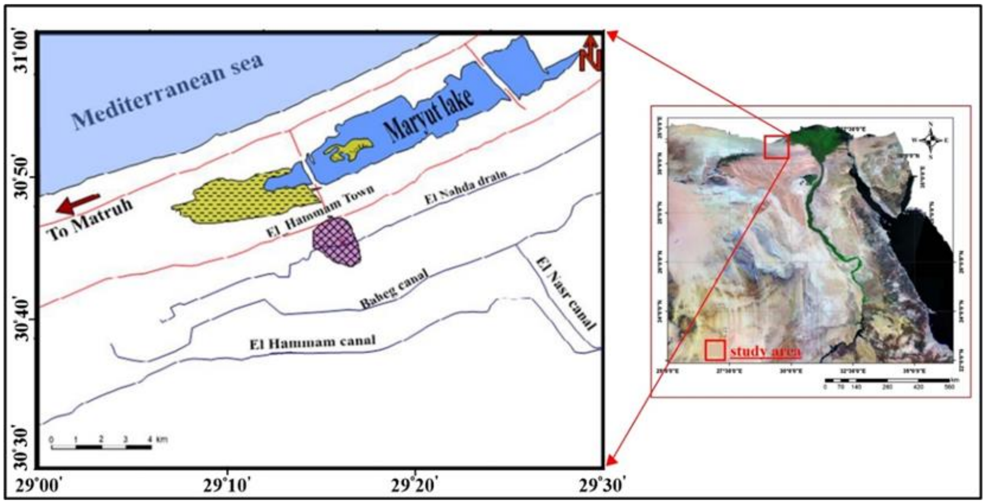

Figure 1: Location map of the study area.

2. Geological Setting

The geology in the Northwestern Desert including El Hammam area is entirely of sedimentary origin ranging in age from Pliocene to Holocene with a maximum thickness of about 200 m (Atwa 1979) as in Fig. 2. The Pliocene Rocks are located in the southern part and are represented by El Hagif Formation belonging to Pliocene. It is composed mainly of white shallow marine limestone with interbedded marl, grading into pink marly limestone towards El Daba, in the West. The Quaternary deposits occupy most of the Northern part and are represented by alluvial deposits, Pleistocene (oolitic calcareous ridges), and Holocene sediments (sabkha and beach). The Quaternary alluvial sediments are deposited mainly in El Hammam depression and composed mainly of loamy deposits composed of quartz sand, silt, and clay with abundant carbonate grains in the North while pebbles and gravels are abundant to the south. They are overlain by an evaporite series of alternating gypsum and clays, from which gypsum is quarried at both the El Gharbaniat and El Hammam localities (Yousef and Salem 2007). The detrital oolitic limestone sediments that belong to the Pleistocene are exposed as ridges. They are built mainly of whitish layers of oosparite with a detrital texture that developed along successive paleo-shore lines of the Mediterranean Sea (Hilmy et al 1978). The sabkha deposits are recorded between the Pleistocene Northern ridges and are composed mainly of evaporites (gypsum with halite). The beach deposits are located parallel to the present shoreline and are built mainly of calcareous white loose medium sands with shells.

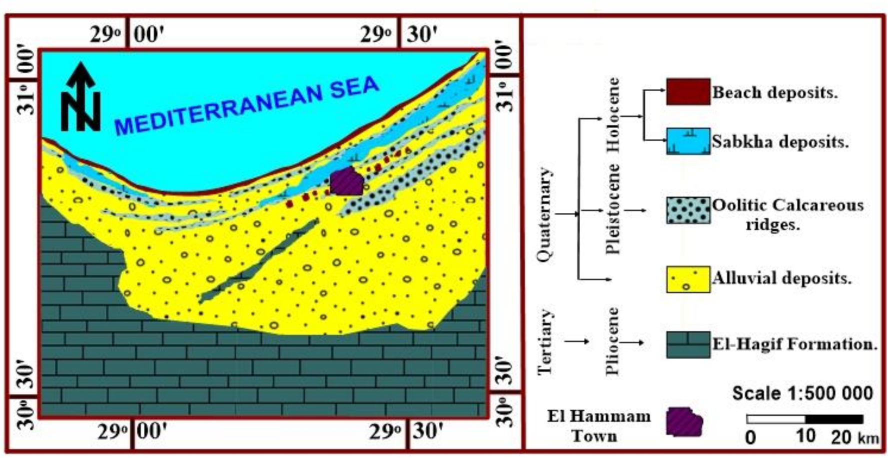

Figure 2: Geological map of the study area after (Conoco 1987) and (Yousef & Salem 2007).

3. Methodology

3.1.1 Geophysical measurement and interpretation

The Geophysical measurement carried out in this study included eighteen TEM soundings stations. The location of the measuring sites is shown in Fig. 3.

3.1.2 Transient Electromagnetic

The TEM measurements were carried out using the AIE-2 instrument with a coincident configuration. 50 x 50 m^2 transmitter/receiver loops were used. The data was inverted assuming layered models and using the ZONDTEM1D version 5.2 (2016). Figure 4 shows examples of the apparent resistivity curve (borehole Rx.2 logging data, which correlate with TEM No.16) and the result of its inversion. In general, the TEM soundings were inverted assuming four layers models. A better resolution of the low-resistivity layers is expected, relative to high-resistivity ones and reveals that the depth of the groundwater is 8 m from the ground level.

The TEM data results are used to create the geological cross sections as shown in Fig. 5.

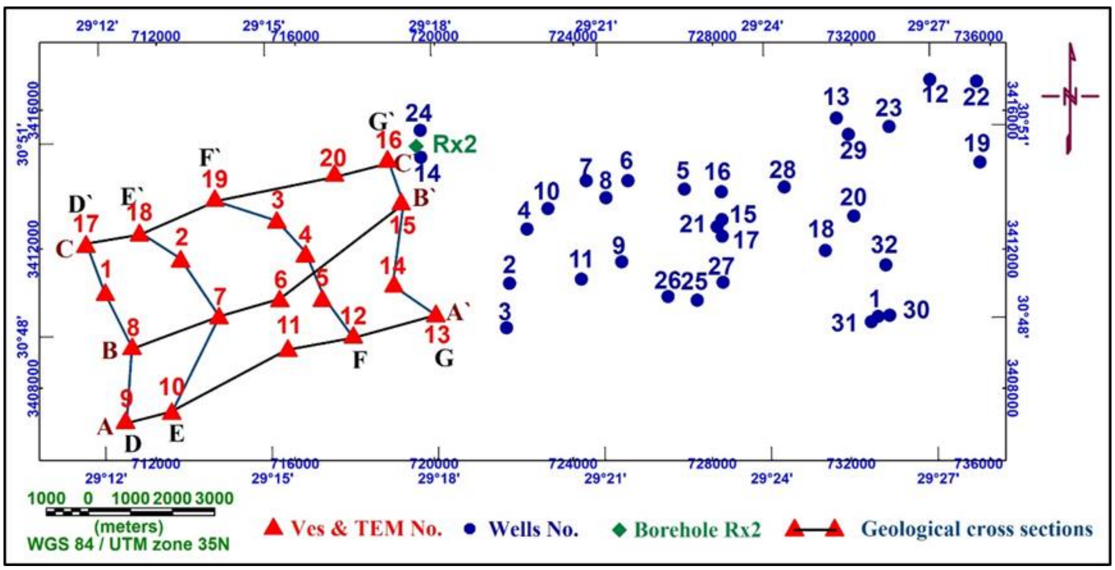

Figure 3: Location map of TEM soundings, groundwater samples and direction of the constructed profiles.

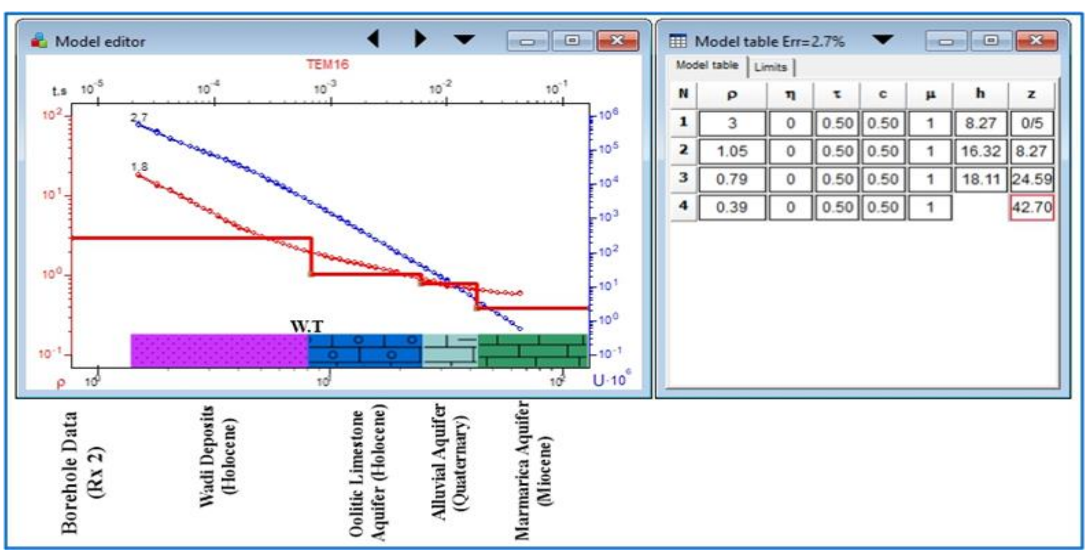

Figure 4: Interpretation of TEM 16 compared with borehole (Rx 2) data.

The results of the interpretation allowed characterizing four geoloelectric units. The first unit consists of Wadi deposits of high resistivity (4.3 to 687.7 Ω.m) and thickness (5.8 to 15m). While the second one consists of Oolitic limestone of low to moderate resistivity (1.1 to 28.6 Ω.m) (Brackish to Saline water) and thickness (7.3 to 20.2m); this unit represents the main aquifer of the study area. The third unit consists of clay and limestone of low resistivity (0.53 to 0.96 Ω.m) (Brackish water) and thickness (18.2 to 65m); this unit represents the second aquifer (Alluvial aquifer) of the study area. The last unit represents Marmarica aquifer of very low resistivity (0.1 to 0.67 Ω.m) and consists of clay and limestone; this unit represents the third aquifer (Saline water) of the study area.

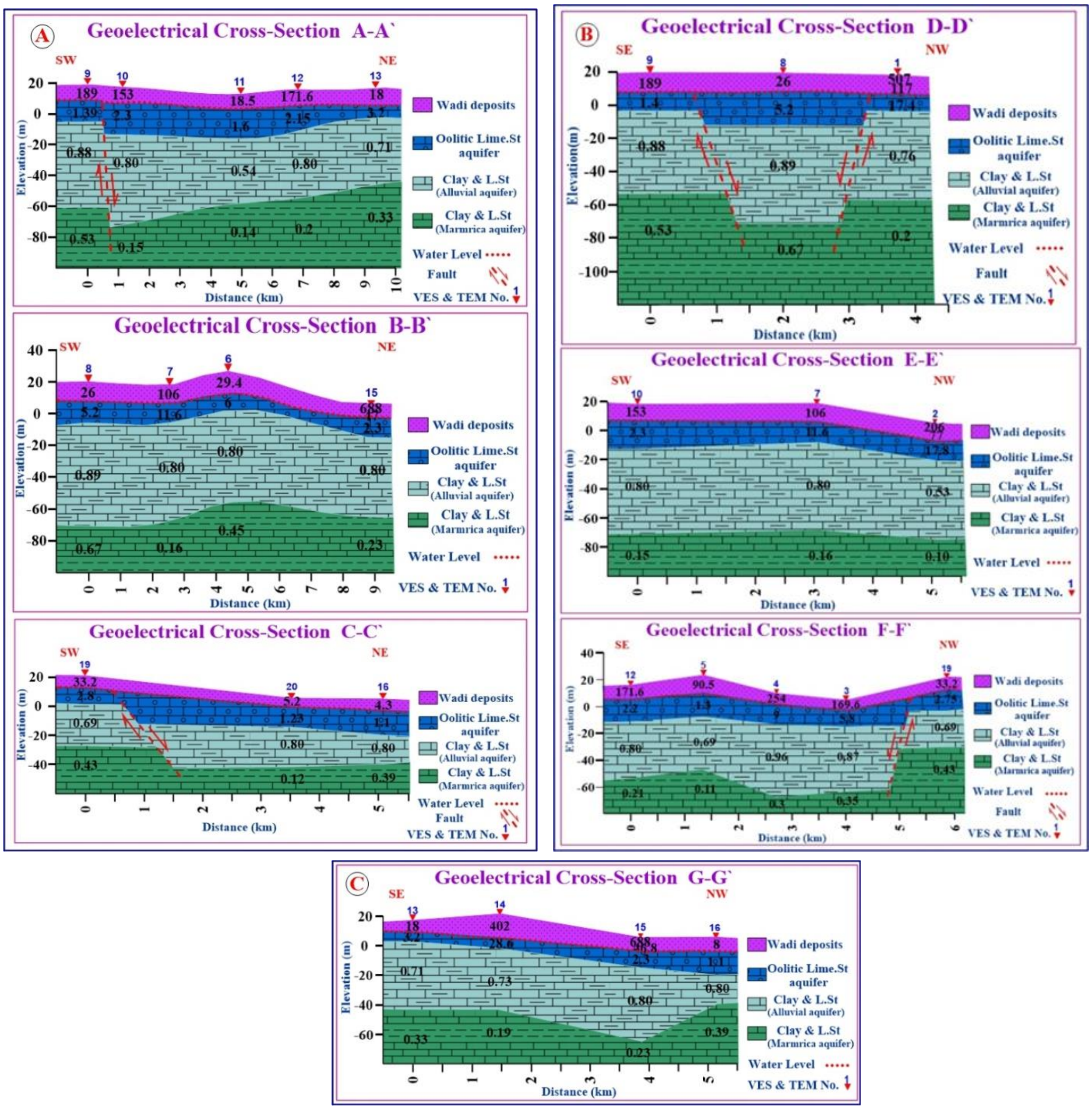

Figure 5: Geoelectrical cross sections from TEM data.

3.2 Hydrochemical data

Interpretation of the hydrochemical parameters in groundwater can help in understanding the hydrogeological conditions and can also aid in decisions relating to the water quality intended for different uses (Hiscock 2005); the groundwater was measured at 32 samples collected from El Hammam area as shown in Fig. 3. The geochemical properties of aquifers are summarized as follows:

3.2.1 Quaternary Aquifer

3.2.1.1 Pleistocene Aquifer (Oolitic limestone)

This aquifer is characterized by the following:

i- The pH value ranges from 7.23 to 8.99.

ii- The TDS varies from 687 ppm (Freshwater) to 5094 ppm (brackish water).

iii- The obtained values of EC in the groundwater samples range from 1.1 (μmhos/cm) for well no. 18 to 173 (μmhos/cm) for well no. 22.

3.2.1.2 Alluvial Aquifer

This aquifer is characterized by the following:

i- The pH value ranges from 7.15 to 8.55.

ii- The TDS varies from 800 ppm (Freshwater) to 9344 ppm (Saline water).

iii- The obtained values of EC in the groundwater samples range from 1.25 (μmhos/cm) for well no. 1 to 14.6 (μmhos/cm) for well no. 6.

3.2.2 Miocene Aquifer (Marmarica Aquifer)

This aquifer is characterized by the following:

i- The pH value ranges from 7.78 to 8.04.

ii- The TDS varies from 5670 ppm (brackish water) to 30976 ppm (saline water).

iii- The obtained values of EC in the groundwater samples range from 8.86 (μmhos/cm) for well no. 30 to 48.4 (μmhos/cm) for well no. 32.

4. Discussion

The results obtained from TEM data refer to the subsurface medium consisting of four geologic layers, where the aquifers are represented by the second, third, and fourth layers. Thirty-two groundwater samples were used to indicate the hydrochemistry of groundwater aquifers. The groundwater samples indicate that the salinity increases with depth. Also, the decrease of resistivity values for TEM data with depth are similar to the increase in water salinity; this decrease of resistivity values by depth is compatible with the increase of the salinity according to hydrochemistry of groundwater samples.

The results obtained from TEM data are identical with the results of the groundwater samples and borehole Rx 2 where the groundwater depth from TEM data no. 16 is 8 m while the water depth at well no. 14 is 6.5 m and borehole Rx 2 (drilled near TEM no. 16) is 7.5 m.

5. Conclusions

The TEM is operant tool for groundwater studies. There is a powerful approach to overcome the problems of model equivalence, layer suppression, and to produce a well-constrained and robust multi-layer model for the subsurface medium. The results obtained from TEM data indicate that the subsurface section consists of four geologic layers. There are three aquifers in the study area; the Oolitic limestone, Alluvial, and Marmarica aquifers; the Oolitic limestone aquifer represents the main aquifer in the study area. The Oolitic limestone aquifer exhibits these parameters: the upper surface depth ranging from 10 to 39 m, the thickness of this aquifer varying from 7 to 20 m, the resistivity is ranging from 1.2 to 28.6 Ω.m, the salinity varies from 687 to 5094 ppm (Brackish to Saline water), EC varies from 1.1 to 173 (μmhos/cm) and the groundwater is slightly alkaline with pH value ranged from 7.23 to 8.99.

The Alluvial aquifer exhibits these parameters: the upper surface depth ranging 20 to 49 m, the thickness of this aquifer varying from 18 to 65 m, the resistivity is ranging from 0.53 to 0.96 Ω.m, the salinity varies from 800 to 9344 ppm (Brackish to Saline water), EC varies from 1.25 to 14.6 (μmhos/cm) and the groundwater is slightly alkaline with pH value ranged from 7.15 to 8.55. The Marmarica aquifer exhibits these parameters: the upper surface depth ranges from 47 to 111 m, the resistivity is ranging from 0.1 to 0.67 Ω.m, the salinity varies from 5670 to 30976 ppm (saline water), EC varies from 8.86 to 48.4 (μmhos/cm) and the groundwater is slightly alkaline with a pH value ranging from 7.78 to 8.04.

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