# Characterizing Groundwater West of Nile Delta Using Electric Resistivity

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**Abstract**: Six vertical electrical sounding points (VES) were measured northern western desert. The analysis of the given well log data was used to estimate the groundwater level in the study area. The study area covers about 100 feddans, located at 80 km northwest Giza city. The Digital Elevation Model (DEM) of the investigated area was extracted from the Shuttle Radar Topography Mission (SRTM) satellite image. Thieves were interpreted with assessment of Digital Elevation Model (DEM) to determine the subsurface layers and the true resistivity, lithology and thickness variations of such layers. The obtained result is the subdivision of the shallow section into three units of sediments arranged as: top surface layer "A" of dry sand and gravels with mud overlaps; the second layer "B" of sand and mud layer. This layer composed of saturated sand which was considered as the water-bearing zone of the investigated interval, its thickness ranges between 80m and more than basement rocks. The depth to the basement surface has an average value of 104.7 m at the eastern side and 114.1m at the western side of the study area.

**Keywords**: Vertical Electrical Sounding (VES), Geo-electrical survey, groundwater, west Nile Delta.

## Introduction

Many geophysical studies have been undertaken toward understanding the subsurface geological structure and groundwater potentiality of this area. At El Sadat City, **Usama Massoud *et al*.,2014**, found the shallow Pleistocene aquifer consists of sand and gravel saturated with fresh water and exhibits large thickness exceeding 200 m. In El-Nubariya–Wadi El-Natrun area **Ismael *et al*.(2016)**, depending on the obtain data of the geoelectric prospecting indicate that the brackish groundwater can be found at the northern and northeastern parts of the study area at shallow depths whereas relatively fresh water can be detected at the southern and southeastern parts around Wadi El Natrun city.The obtained hydrochemical data of, **Mohamed M. and Mohamed G. (2015)** at Eastern side of Nile Delta, showed that Miocene groundwater samples are not suitable for drinking and agricultural purposes but can be used only in industrial projects.

Integrated remote sensing and GIS are widely used in groundwater mapping. Locating potential groundwater targets is becoming more convenient, cost effective than invasive methods and efficient with the advent of a number of satellite imagery. The nature of remote sensing-based groundwater exploration is to delineate all possible features connected with localization of groundwater. Data, driven out of remote sensing, support decisions related to sustainable development and groundwater management (**Salwa Farouk Elbeih. 2015**). In West Ismailia area ,**Mohamed and Ahmed(2013)**, developed a GIS-based model to assess groundwater contamination in west Ismailia based on its hydrochemical characteristics. The results of them study revealed that the groundwater is highly vulnerable to contamination result from the inappropriate application of agrichemicals and domestic and industrial activities.

West Delta area is considered part of the dry belt, which covers Egypt and consists of four geomorphological units (**Said, 1990**) as young alluvial plains, old alluvial plains, structural plains, table lands and drifting sand. The study area considered as part of the old alluvial plain covered with 1) Oligocene sediments which consist of gravel, sand and mud with thickness up to 390 meters, and basalt which resides on different depths and its thickness between 25 and 35 meters. 2) Miocene sediments are composed of sand, gravel and clay overlaps, Moghra formation represent that composition with thickens up to 250 meters. 3) Pleistocene sediments consist of gravel and sand with mud interference and the thickness of these deposits -in West Delta- is 500 meters. 4) Holocene sediments in the West Delta area which consist of sand dunes and Nile sediments. In terms of composition, the study area, consider as part of the West Delta area affected by faults take trends northeast-southwest and northwest-southeast.

The geoelectric measurements can be used to search for water-bearing formation, stratigraphic correlation in oil fields, prospecting for conductive bodies, finding the depths of high or low conductive-anomalous layers, finding the depth and approximate shape of resistivity-anomalous ore bodies and identifying the depth of low-velocity sand and gravels (**Dobrin 1960; McGinnis and Kempton 1961;Bhattachryya and Patra 1968**). Application of electrical resistivity methods includes prospecting for resistive materials, structural investigations, delineating saline and fresh water bearing zones, geothermal exploration (**Telford *et al*. 1990**). The present investigation was carried out using geoelectrical data and digital elevation model (DEM) of the northwestern Giza area to identify the subsurface rock sequence, water bearing layers affecting the study area. Over the last decades digital elevation model (DEM) has been increasingly derived directly from Shuttle Radar Topography Mission (SRTM) images (**Ambili and Narayana, 2014; Magesh and Chandrasekar, 2014** and

**Ghosh *et al*., 2015**). DEMs have been used in several studies where terrain and drainage network play noticeable roles (Wang *et al*. 2010). In this study the DEM was used to characterize the surface elevation, slope and slope direction of the study area. This data could be used to describe the relation between soil sequences and the direction of water movement.

## Materials and methods

**Study area*:*** The study area is located northwestern Giza city, between longitudes 30º3422 E and 30º3452 N and latitudes 30º140.7 and 30º1421 N. The area is almost flat and the elevation between 83 and 85 m (Figure 1).

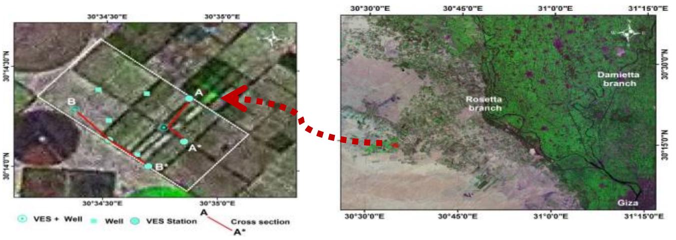


**Figure (1)** Location of the study area and investigated sites.

**Digital elevation model (DEM):**SRTM is one of the most significant space surveys of the earth ever undertaken, using precisely positioned radar to map its surface at intervals of 1-arc seconds (30 m). It can be used with controlled imagery sources to provide better visualization of the terrain. The Digital Elevation Model (DEM) of the study area was extracted from the SRTM image using Arc-GIS 9.2 software. DEM is 3D electronic model of the land's surface (**Brough, 1986**) provide better functionalities than the topographic maps. Land surface information, i.e. Surface elevation, slope% and slope direction could be derived from a DEM (**Lee *et al*., 1988**).

**Geoelectrical survey*:***It comprises 6 vertical electrical sounding (VES) using the Schlumberger electrode configuration. Data were collected at 2-3 km, station interval as easy access location. The principle of this method is to insert an electric current, of known intensity, through the ground with the help of two electrodes (power electrodes – AB) and measuring the electric potential difference with another two electrodes (measuring electrodes – MN). The investigation depth is proportional to the distance between the power electrodes. The field measurement technique is adjusted to the different topographic conditions and the interpretation of the data can be done with specialized software, with a primary interpretation immediately after the measurements. The results of VES measurements can be interpreted qualitatively as well as quantitatively. At each VES location, the distance between the potential electrodes was increased only a few times (from 0.5 to 50 m) while the current electrode separation increased from 2 up to 2,000 m where the depth of current penetration increases with increasing electrode separation which will reflect the resistivity effect at larger depths. Resistance curves were then drawing at every profiling represent the distance AB/2 and resistance value for each distance AB/2 on logarithmic paper. Analysis of Geo-electrical resistivity measurements, when accompanied by DEM information and data, can permit determination of groundwater occurrence and structural features that control the water-bearing strata in any area.

Application of the Geo-electric resistivity methods includes prospecting for resistance materials, structural investigations, delineating saline and fresh water-bearing zones, geothermal exploration (**Telford *et al*. 1990**). *RESIST & RESIX* modern computer programs have been used to interpret the field data and due to of the lack of information on the rocky relay from any wells near the study area, the DEM and hydrogeological data were used in the development of the optimal model for the electrical soundings. The coordinate of the studied VES sites were defined using GPS and topographic map of the area scale of 1: 25000.

## Results and discussion

Figure 2 (a,b&c) represent the main surface characteristics of the investigated area extracted from the SRTM image using Arc-GIS 9.2 software. The data indicate that the surface elevation ranges between 67 and 86 meters above sea level, the most of the area is characterized by an elevation of 78 to 81 meters above sea level. Surface slope is in general low where the most of the area is attributed by less than 1% to less than 2% surface slope. Most of the area has a north, northeast and northeast slope direction.

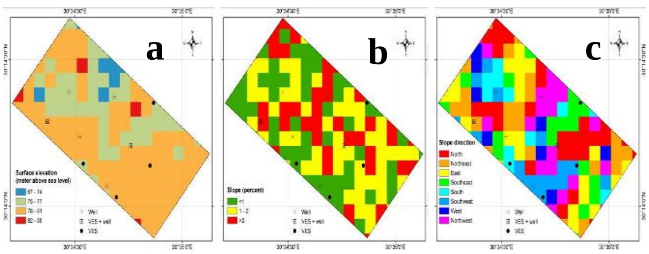


**Figure (2):** Surface elevation, slope and slope direction of the investigated area

The electric resistivity methods developed in the early 1900s are widely used since 1970s, due to the availability of computers to process and analyze the raw data. These techniques are used extensively in the search for suitable groundwater and to monitor types of groundwater pollution. These methods are also used to locate subsurface cavities, faults and fissures, permafrost and mineshafts (**Al-Tarazi *et al.* 2006**). The quantitative interpretation of

the acquired resistivity sounding data was carried out to represent the horizontal and vertical variations of resistivity data. Iterative and indirect procedure is used to invert the acquired resistivity data. **El-Bihery (1990)** indicates the basic theory of this technique assumed that, the subsurface model consists of a finite number of layers separated by horizontal interfaces. Each layer is electrically homogeneous, isotropic and has a finite

thickness, except for the deepest layer which extends to an infinite depth. **Koefoed (1979)** showed that, the resistivity transform function can be obtained when it contains all the subsurface model parameters. RESIX-P computer program developed by **Interpex Limited (1996)** is used in this study. For each step in the iteration process the mean error between the observed and the calculated data in addition to selected values for the model parameters (resistivity and thickness) are obtained as output results. These results can be illustrated as a resistivity cross sections and/or contour maps. To demonstrate the distribution of the calculated resistivity parameters (true resistivity and thickness) in the horizontal and vertical directions across the study area, three geoelectric cross sections are constructed covering the area under investigation. Resistance curves was drawing at each profile represent the distance AB/2 and resistance value for each distance AB/2 on logarithmic paper (Fig. 3).

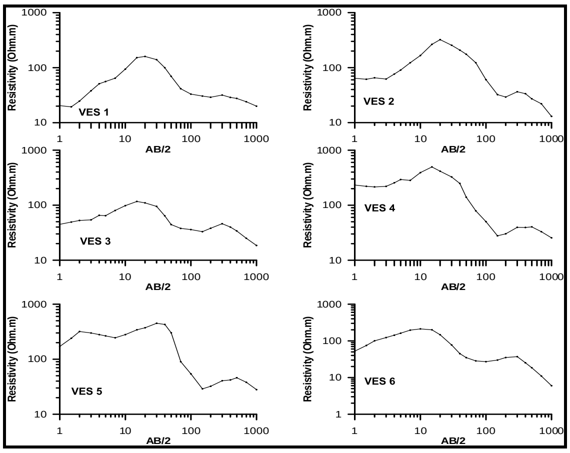


**Figure (3):** Resistance curves at each profile.

Analysis of geo-electrical data from top to bottom shows that the successive layer consists of four geo-electrical units (A, $B_1$, $B_2$ & C). To illustrate the horizontal and vertical proliferation of these geo-electrical units two geo-electrical cross sections have been done A-A` & B-B` in the direction of north- south (Figures 4 and 5).

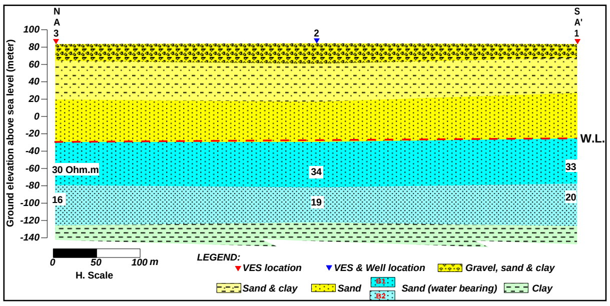


**Figure (4):** Geoelectric cross section A-A`

**Geo-electric cross section A-A`:**This section was constructed from the VES 1, 2 and 3 data in Table (1) shows the surface characteristics of geo-electric cross section AA`, as well as DEM data to determine electrical borings heights to the sea level.

**Table (1):** Heights and coordinates of the cross section A-A`

| Site | Elevation (m) | Slope (%) | Slope direction |
|---|---|---|---|
| 1 | 81 | 1.0 | southwest |
| 2 | 79 | 1.4 | north |
| 3 | 80 | 0.8 | southeast |

**Geoelectric cross section B-B`:**This section extends in the northeast–southwest and present in the central part of the study area. It passes through the VES 4, 5 and 6 and DEM data in Table (2) shows the surface attributes of Geo-electric cross section BB`.

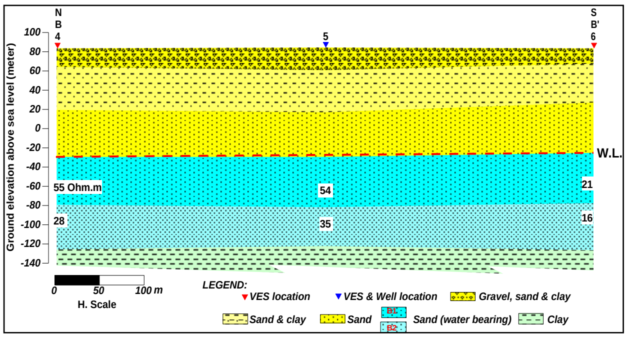


**Figure (5):** Geoelectric cross section B-B`

**Table (2):** Heights and coordinates of the cross section B-B`

| site | Elevation (m) | Slope (%) | Slope direction |
|---|---|---|---|
| 4 | 80 | 1.3 | northeast |
| 5 | 77 | 0.8 | south |
| 6 | 81 | 0.6 | southwest |

Table (3) shows the resistance averages and thickness of these geo-electrical units. The geo-electrical units description from top to bottom is as follows:

The first geo-electrical units "A": a set of dry layers, which consists of sand and gravel and overlaps of clay and resistance ranging between 8-1297 ohm/m, the low resistors reflecting mud overlaps, while high indicating the presence of gravel and sand. The thickness of this unit ranges between 104.7 m (site 5) and 114.1 m (site 2). This unit is directly above the unit bearing groundwater in the region and its thickness represents the depth to the groundwater surface.

**Table (3):** Thickness and resistance of geo-electrical layers

| Geo-electrical units | **Thickness(m)** | | **Ohm/m( Resistance)** | |
|---|---|---|---|---|
| | Greater thickness | Less thickness | Higher resistance | Less resistance |
| **(A)** | site 2 (114.1) | site 5 (104.7) | site 2 (1297) | site1 (8) |
| **(B1)** | site 6 (53.5) | site 3 (49.3) | site 4 (55) | site 6 (21) |
| **(B2)** | site 6 (53.2) | site 2 (40.7) | site 5 ( 35) | site 6 (16) |
| **(C)** | ------ | ------ | (0.7-2) | |

The second geo-electrical units "B": This unit represents the aquifer groundwater in the study area and represent lower Miocene reservoir (Ocher) which consists of deposits of sand and mud overlaps. Based on the values of electrical resistance of this unit has been divided into two parts ($B_1$, $B_2$). The upper part ($B_1$) resistance ranging between 21-ohm/m (site 6) and 55 ohm/m (site 4), while its thickness ranges between 49.3 meters (site 3) and 53.5 meters (site 6). The lower part ($B_2$) drops its resistance from the upper part, where between 16 ohm/m (site 3) and 35 ohm-meters (site 5), while its thickness ranges between 40.7 meters (site 2) and 53.2 meters (site 6).

The third geo-electrical unit "C": This unit consists of overlaps of mud and sand. Its resistance ranging between 0.7 - 2 ohm/m and the surface of the bottom of this class is not reach, but from the geological information, this class represents the base of the fresh aquifer and after it directly layer of basalt separates the upper fresh reservoir (ocher) from the saline lower reservoir (Oligocene), which affects the salinity of the upper aquifer through the hydraulic contact and geological structures through cracks in basalt layer.

General inspection of this section indicates four geoelectric units of different resistivity values and thicknesses.

The first unit reflects the top of a surface gravely layer. The second unit is a thin (less than 10 m) layer of shaley material with lower resistivity values. The third unit indicates the presence of high resistivity materials range from 37 to 283 X m and its thickness is about 90 m, reflecting the presence of dry sand layer with some clay intercalations beneath VES no. 3&2.

Moreover, the fourth unit of this section indicates the presence of low resistivity layer (range 1.5–25 X m) reflecting the presence of saturated sandy layer.

The first layer composed of thin very high resistivity material, reflecting the presence of dry surface cover of coarse sands and gravels. The second unit is of lower resistivity ranging from 47 to 79 X m and its thickness ranges from 15 to 67 m indicating a silty sand layer when calibrated with borehole data. The third unit has resistivity material ranging from 60 to 407 X m and its thickness ranges from 60 to 85 m, reflecting a dry zone of sandy and gravely sediments. The fourth unit is of low resistivity ranging from 2.5 to 29 X m, and undefined thickness along most of the profile, reflecting the saturated zone of sandy materials. The fifth unit is of very high resistivity material located only beneath VES 18 and reflects the presence of basement rock. This section was dissected by two normal faults.

**Conclusion and Recommendations**

The geoelectrical relay of the study region consists of three geoelectrical units (A, B, C). Surface unit "A" consisting of dry sand and gravel with mud overlaps. The second is "B" represents the aquifer groundwater in the study region and represented by the lower Miocene reservoir (Ocher). It consists of sand and mud interference. The third is "C" consists of clay and represents the base of the aquifer. The depth to the surface of the groundwater aquifer ranges from 104.7 - 114.1 meters from the earth surface. Resistant of the unit-bearing groundwater decreases with depth, ranging between 21-55 ohm/meter in the upper part (B1), while ranging between 16-35 ohm/meter at the bottom (B2), which reflects the high salinity of the groundwater with depth and impact so to increase the salinity of wells with overdraft as well as with time. The high electrical resistance specially at sites no.4 and no.5 of reflects a decrease in the salinity of the groundwater at the borings electrical 4 and 5.

Under these circumstances, the site No. 5 is the most suitable locations for drilling productive well with water salinity almost within the limits of the salinity of wells neighbors (site 4) where the salinity of about 400 ppm, while the site No.2 comes second and the salinity of water has a relatively high salinity of the water from the well No. 1 of the farm (800 ppm). Drilling depth in the range of 200 meters and access to the end of the aquifer has to penetrate the clay layer and reach the basalt layer.

Thus the electrical monitoring is very important to determine sedimentary sequences and various border between them accurately to identify and locate the mud layers of reservoir accurately develop appropriate design of the well and determine the salinity of the water with depth and determine the appropriate depth of the wells productive. Due to the high salinity in wells, it is necessary to test pumping to determine the hydraulic transactions and determine the rate of productivity of the well and safe withdrawal rate of the well.

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