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Geoelectrical Exploration in South Qantara Shark Area for Supplementary Irrigation Purpose-Sinai-Egypt

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Abstract

This research paper is dealing with Geoelectrical Exploration as a Geophysical method used, Vertical Electrical Sounding (VES) and 2D profile imaging to find a solution of the problems affecting the research station in South of Qantara Skark. This research station is one of the desert research center stations used to develop the desert for agriculture. The area of study is suffering from the shortage of irrigation water whereas, it depends on the water flow of the tributary of Salam Canal which being not available all the time. The appropriate solutions of these problems have been delineated by the results of 1D and 2D geoelectrical measurements. It exhibits the subsurface sedimentary sequences and extension of subsurface layers in horizontal and vertical directions especially in the groundwater aquifer. Moreover, the most suitable locations of drilling water wells could be detected. The surface and subsurface layers of the quaternary deposits consists of sand, sandy clay and clay facies.

Nineteen Vertical Electrical Sounding (VES) are arranged as a grid to cover the study area and two 2D geoelectrical imaging profiles are acquired. The results are represented through different contour maps and cross sections that exhibit the horizontal distribution of successive layers which reflect the lithology and changes in all directions. The water bearing layers consisted of two zones. The upper one was less salty than the lower one. The thickness of the upper zone ranges from 5 to 7 meters, but the lower zone ranges between 15 and 30 meters. The last detected layer is clay that decreases in depth towards the Southwest of the study area, causing the phenomenon of water logging. The thickness of the upper zone of the water bearing layer is inadequate for irrigation. Recommended basins to be constructed and filled through nearby drilled wells to overcome this problem. The most suitable location to dig a channel for water drainage is in the Southwest, where there is a less depth to the clay layer and all the layers are dipping toward this side.

Keywords: Supplementary irrigation; Vertical electrical soundings (VES); Electrical resistivity tomography (ERT); Qantara shark

Introduction

Research stations of desert research center are considered as productive stations to solve most agriculture problems. One of these stations is South Qantara Shark that constructed in West Sinai. The present study area of this station has length reach 1600 m. and width 850 m nearly eight hundred Feddan in West of the Sinai region at East Qantara. It lies east Suez Canal between latitudes 30° 47' and 30° 49' N and longitudes 32° 27' and 31° 24' E and act as a model for neighboring areas (Figure 1). This station suffers from shortage water supply for agriculture in some seasons especially summer whereas it depends on one of tributary El Salam canal that not full of water all time. There is one drilled well for human activity just South of the study area. Because of not existence good drainage system, some patches of water logging appear in low land at Southwest of area. Geoelectrical resistivity techniques are used in the present study to deal with pervious mention conditions.

The geoelectrical resistivity survey technique is used to solve many problems related to groundwater assessment, investigation, exploration and salinity. Some uses of this method in groundwater are; determination of the thickness, boundary and depth of different layers of the aquifer [1], determination of boundary line between saline water and fresh water [2,3], exploration of ground water quality [4,5] and detecting the impact of geologic setting on the groundwater occurrence [6]. Khaled, et al. [7] studied the impact of salt water intrusion on the groundwater occurrence.

The target of this study is solving the problems suppressed developments by carrying out geoelectrical techniques. It comprises a grid of Vertical Electrical Sounding (VES) covering the study area. It can be used to detect form results the successive subsurface layers horizontally and vertically, also detect the water bearing layers with depth to water and its flow direction. For delineation, the detail lateral changes in lithological content, two dimensional imaging profiles are carried out to detect the different zones of water quality according to resistivity values. Finally, it can be detect the best side for drilled productive wells, do suitable safe discharge for drilled wells and suppose a suitable drainage system to reduce or prevent the extension of marshes.

Northwestern Sinai is located within the semi-arid belt of Egypt and is locally affected by the Mediterranean climate. This aridity is manifested by the occurrence of sand dunes and sand sheets, saltmarshes and ponds as well as lack of vegetation.

Geomorphologic setting

Northwestern Sinai comprises five distinctive geomorphologic units according to Al Hussein [8]. It includes coastal area, El-Bardawil Lagoon, aeolian sand, mobile sand dunes and salt marshes and sabkhas.

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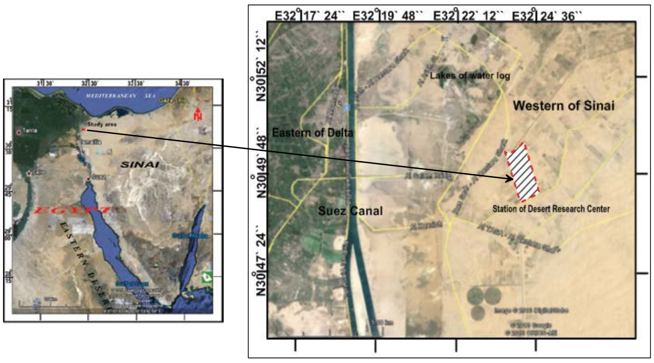

Figure 1: Location map of the study area.

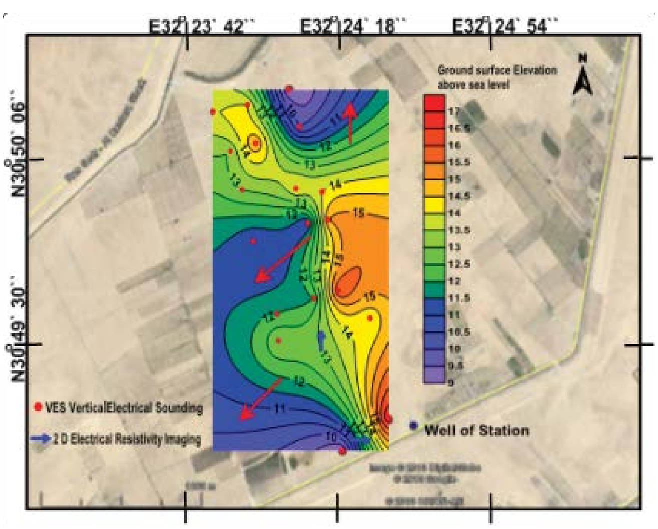

Figure 2: Topographic map of the study area.

The study area is entirely covered by quaternary sediments of littoral, alluvial and Aeolian origin which show a variation in their texture and composition ranging from unconsolidated sands to sand and clay. Ball and Said [9,10] studied the Northwestern part of Sinai that covered by aeolian sand and gravels with occasional clay interbeds of the Holocene and Pleistocene deposits. The sand dune deposits are deflected and diverted from Northwest to Southeast direction, most likely due to local winds. Sandy inland sabkhas are situated in low areas between hummocky surface and sand dunes. It formed as a result of high evaporation in low relief areas characterized by shallow groundwater and occasional rain fall water.

The study area is a flat to slightly undulated surface of aeolian sand with low ground elevation which ranges from 9 m to 17 m. a. s. l. (Figure 2). In low relief area at the Southwest direction, a Salt marshes and sabkhas are composed mainly from medium to coarse sands that are sometimes covered by salt crust.

Geologic setting

Northwestern Sinai is covered by quaternary deposits of littoral, alluvial and aeolian origin which show a variation in their texture and composition ranging from unconsolidated sands to sand and clay (Figure 3). The Pleistocene deposits include Sahl El-Tineh formation (a mixture of black and white sands with silt), Al-Qantara formation (sand and grits with minor clay interbeds, coquina deposits, conglomerates) and alluvial hamadah deposits [11]. According to this map, the Holocene deposits are classified into coastal sand dunes which extend parallel to the Mediterranean Sea coast, inland sand dunes and sheets that cover large areas of Northwestern Sinai (the main water bearing formation for groundwater), coastal and inland sabkhas, and interdunal playa deposits; consist of fine sand and silt associated with evaporates [12]. The sand dune deposits change direction from northwest to Southeast, most likely due to local winds. To the West, near the Suez Canal, Northeast trending linear dunes grade progressively into cresentic (transverse and barchans dunes) and complex cresentic dunes that are homogenous and continuous.

Hydrogeologic setting

According to different authors such as Said, Shata A, El Shamy and Khaled [7,9,13,14] the Northwest of Sinai area is covered by quaternary deposits which are composed of sand, gravel, clay and sand dunes. Either clay or sand is saturated with saline water underlies the aquifer. The groundwater resource in the study area and its vicinity is represented by the unconfined aquifer of the quaternary deposits. There is a drilled well in the study area with total depth 21 m, depth to water 11 m and its salinity reached 2528 ppm.

Geoelectrical Studies

Geoelectrical field work in the area of study is represented by Vertical Electrical Soundings (VES) and Electrical Resistivity Tomography (ERT) profiles.

Methodology

The process of vertical electric sounding takes sequential measurements of the resistance by increasing the virtual distance between the poles of the current deployment, while the center of array and the trend remains constant. The ratio between the depth of

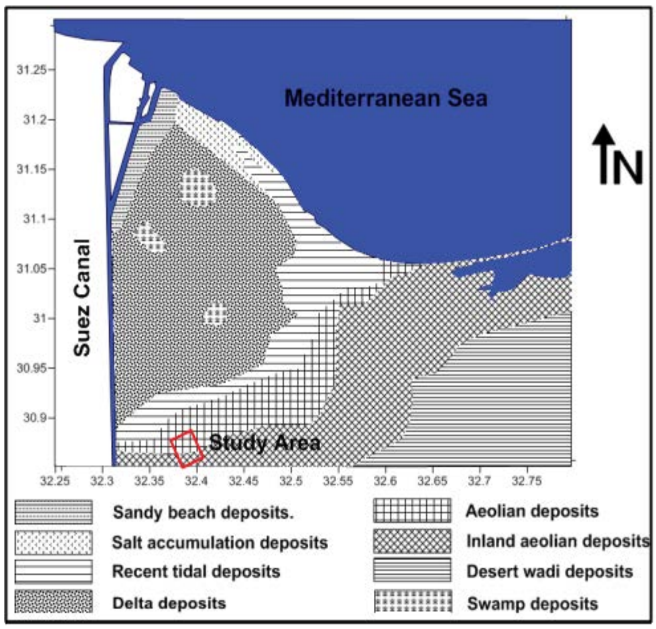

Figure 3: Geological map of the study area (After GSE 1992 and AL Hussein, 2012).

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current penetration and the distance between the electrodes is called penetration factor. The depth of current penetration is of about (1/4 to 1/3) the distance between the poles of power. Rock resistance values are ranging from one to a few tens (ohm-m) in the mud and marl, and (10-1000) ohm-m in sand and sandstones.

Electrical Resistivity Tomography (ERT) is a useful tool to determine variations with depth in soil resistivity. The resistivity changes along the vertical and horizontal directions can be more accurate using the 2D model. The survey technique involves measuring a series of constant separation traverses.

Vertical electrical soundings (VES): The study area is covered by 19 Vertical Electrical Soundings (VES) (Figure 4). The Schlumberger configuration is applied in the present investigation. The current electrode separation (AB) start from 1 m and extended in successive manner to reach maximum distance 600 m. This electrode separation is found to be sufficient to reach reasonable depth range that fulfills the aim of the study. One of these soundings is conducted beside a drilled well in order to parameterize and verify the geoelectrical interpretation.

The RESIST computer program [15] is applied for the quantitative interpretation of the geoelectrical sounding curves. It is an interactive, graphically oriented, forward and inverse modeling program for interpreting the resistivity curves in terms of a layered earth model. An arbitrary initial model has been constructed in view of the overall shape of the sounding curves and refers to data of drilled well.

Electrical resistivity tomography (ERT): Two imaging profiles are conducted (Figure 4) to verify the results of Vertical Electrical Sounding (VES) especially the boundary between geoelectrical layers. One of these imaging profiles measures from West to East and other from South to North. The resistivity changes along the vertical and horizontal directions can be more accurate using the 2D model. The survey technique involves measuring a series of constant separation traverses. In the present study the Wenner electrode array is applied where the measurements start at the first traverse with a unit electrode separation "a" equals 5 m and increases at each traverse by one unit i.e. 10, 15, 20,. ., n. to reach 105 m.

For the interpretation of the imaging data, the computer program RES2DINV, ver 3.4 written by Loke [16] is used. It is a Windows based computer program that automatically determines a two-dimensional (2-D) subsurface resistivity model for data obtained from electrical imaging surveys [17].

The direct current resistivity meter "Tetrameter" model SAS 1000 C is used for measuring the resistance "R" with high accuracy. The accurate locations (coordinates) of the sites of the geoelectrical measurements and their elevations relative to sea level are determined using the

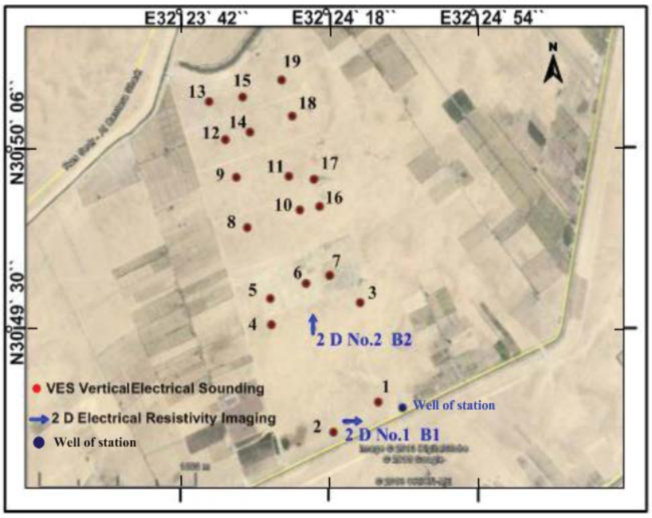

Figure 4: Location map of the Vertical Electrical Sounding (VES) and 2-D electrical resistivity imaging in the study area.

geographic positioning system (GPS) GPS apparatus (Trimble type) contact with nine satellites and topographic map scale 1:50,000. The obtained locations and ground elevations are listed in Table 1.

The interpretation of the geoelectrical resistivity data depends on determining and following up the geoelectrical parameters i.e. resistivities and thicknesses of a series of layers. The interpretation includes also correlation of similar layers where a layer or some layers may be absent because of lithology variations. The results are a geological model that can be reflected in terms of lithological variation and stratigraphy.

Results and Interpretation

The interpretation of Vertical Electrical Sounding (VES) data comprises qualitative and quantitative processes. The qualitative interpretation 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. The quantitative interpretation, on the other hand, involves the determination of the number of the geoelectrical layers as well as the true depth, thickness and resistivity of each layer.

The computer program automatically determines a two-dimensional (2-D) resistivity model for the subsurface using the

VES No	Latitude (N.)	Longitude (E.)	Elev. (m.)	VES No.	Latitude (N.)	Longitude (E.)	Elev (m.)
1	30° 49' 15.3"	32° 24' 30.1"	17	11	30° 50' 0.1'	32° 24' 8.3"	14
2	30° 49' 9.3"	32° 24' 19.2"	9	12	30° 50' 7.4'	32° 23' 52.8"	13
3	30° 49' 35"	32° 24' 25.7"	14	13	30° 50' 15'	32° 23' 48.8"	14
4	30° 49' 30.6"	32° 24' 4.1"	13	14	30° 50' 8.9'	32° 23' 58.8"	15
5	30° 49' 35.8"	32° 24 3.8"	12	15	30° 50' 15.9'	32° 23' 57"	14
6	30° 49' 40.4"	32° 24' 18.3"	12	16	30° 50' 54.1'	32° 24' 15.8"	15
7	30° 49' 38.8"	32° 24' 12.5"	16	17	30° 50' 59.5'	32° 24' 14.1"	14
8	30° 49' 49.9"	32° 24' 58.2"	11	18	30° 50' 15.3'	32° 24' 9.1"	10
9	30° 49' 59.9"	32° 24' 55.5"	13	19	30° 50' 19.3'	32° 24' 6.5"	9
10	30° 49' 53.4"	32° 24' 11"	11				

Table 1: Coordinates of the measured sounding stations.

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data obtained from the imaging survey. The results of interpreting geoelectrical field data indicate the following:

Interpretation of the vertical electrical sounding (VES) Data

The delineation of the subsurface sequence of the geoelectrical layers according to the qualitative and quantitative interpretation is as follow:

Qualitative interpretation: A preliminary qualitative interpretation of the sounding curves using partial curve matching [18] provides the initial estimates of the resistivities and thickness (layer parameters) of the various geoelectrical layers. The qualitative interpretation of the field curves (Figure 5) indicate generally QQ types of the vertical electrical sounding curves exhibiting homogeneity in resistivity values. It shows decrease in resistivity values with depth due to increases clay content with depth and high resistivity values reflect sand deposits. Generally, it can be detected from curves homogeneity in thickness but there is a variation at last cycle curves of VESes No 17 and 19 at North West direction

Quantitative interpretation: The quantitative interpretation involves the determination of the number of the geoelectrical layers as well as the true depth, thickness and resistivity of each layer. The geologic setting and relevant information are visualized and described in view of a number of generated geoelectrical cross sections crossing the concerned sites in different directions and contour maps. Figure 6 shows the interpretation of the modeled resistivity sounding VES No. 1 beside drilled well.

The results of the geoelectrical interpretation (Table 2) are correlated with available lithological information obtained from well that found in the study area. Three geoelectrical layers can be detected and their parameters (resistivity and thickness) are listed in Table 3.

The detailed interpretation results of the geoelectrical resistivity sounding measurements in the study area are discussed as follows:

The subsurface geoelectrical succession

The geoelectrical succession is formed of a number of layers being grouped together in three main layers In order to make the above mentioned description more illustrative the geoelectrical parameters of the interpreted layers. The first layer is surface layer "A". The second is

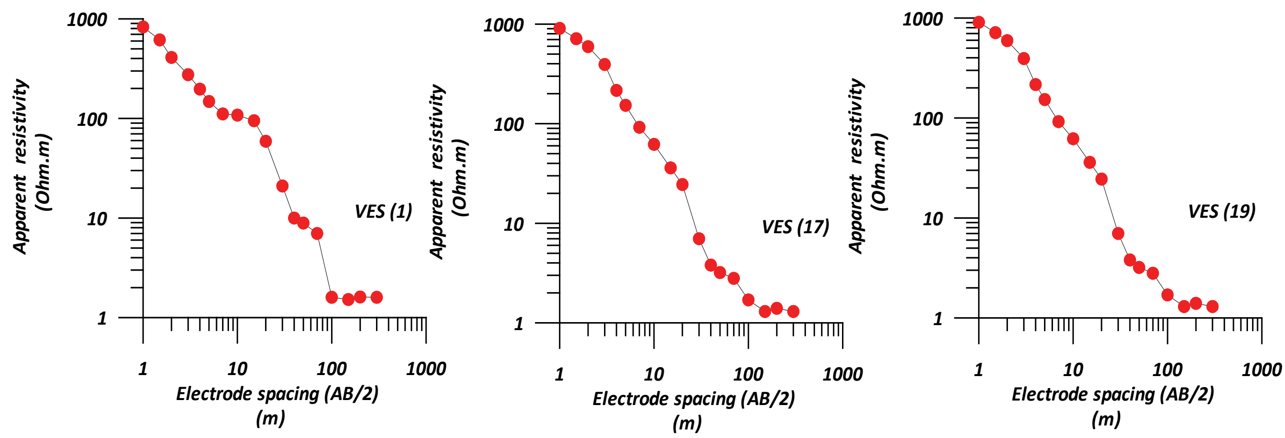

Figure 5: Examples of the resistivity sound curves.

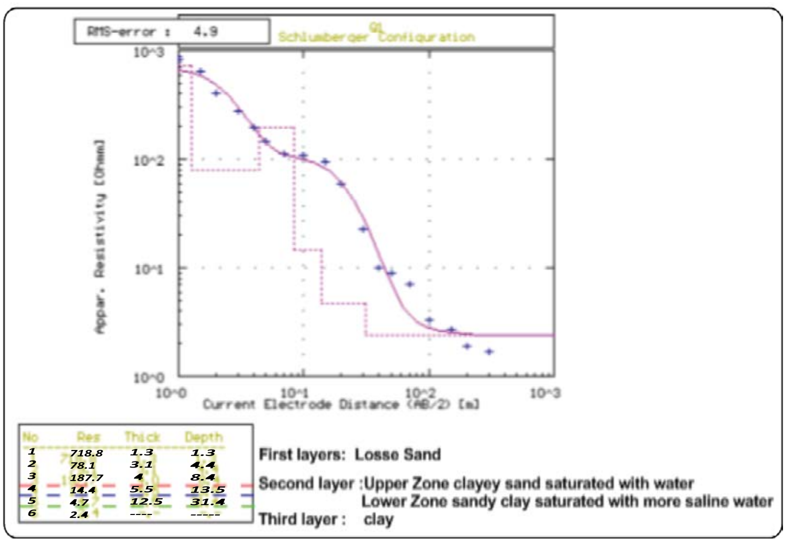

Figure 6: The geoelectrical results and lithologic data at VES No. 1, that closed to the drilled well.

VES No	Geoelectrical layer (A) (Dry loose sand)						Geoelectrical later (B) (Clayey sand saturated with water)				Geoelectrical layer (C) (clay)	
							Upper zone (B1)		Lower zone (B2)			
	ρ1	h1	ρ2	h2	ρ3	h3	ρ4	h4	ρ5	h5	ρ6	h6
1	718.8	1.3	79.1	3.1	197.7	4	14.4	5.5	4.7	17.5	2.4	-
2	600.2	1	57.5	1.7	168	0.7	13	5.5	4.1	16.3	0.7	-
3	736.7	0.4	252.8	2.3	137.8	5.9	37.7	6.2	4.1	16.6	1.2	-
4	156.6	3.2	11.2	1.5	92.8	3.4	17.6	5.5	8.6	18.8	1.4	-
5	595.9	0.6	217.2	2.1	118.5	2.4	18.2	5.2	7.6	19.6	1.6	-
6	656	0.9	367.5	1.1	213.1	5.4	23.9	5.6	6	14.1	1.3	-
7	1200.3	0.4	431.9	1.7	108.7	6.2	20.6	7.2	9.3	16.4	1.6	-
8	1999.6	0.4	146.9	1.6	80.5	3	19	5.3	6.8	18.6	1.4	-
9	1864.5	0.5	317.1	0.9	89.6	4.8	17.3	5	3.8	18.8	1.3	-
10	876.5	0.5	382.6	1.5	133.3	3	32	4.8	5.1	14.3	1.7	-
11	2607.7	0.4	215.9	1.4	84.3	5.5	13.7	5.8	7.9	22	2.3	-
12	1169.9	0.4	223.6	1.2	141.2	3.4	31.8	4.8	8.4	18.6	2.1	-
13	803.5	0.6	91.4	1.1	118.8	6.4	37	5.4	9.8	29	1.8	-
14	817.6	0.7	116.6	1	162.1	5.9	37.5	5.5	7.6	18.1	2	-
15	1407.8	0.3	408	1.9	159.2	6.2	33.7	5.3	6.2	16.5	1.4	-
16	1300.9	0.6	449.3	1	133	6	31	5.2	8.2	21	1.5	-
17	2015.6	0.4	246	0.4	90.4	7.5	30	4.9	7.7	27	0.8	-
18	3648.3	0.3	188.1	1.4	87.7	4.8	28.7	5.1	7.7	22	0.9	-
19	1022.2	0.7	670.6	0.7	103.1	4	34.5	4.7	6.7	16.5	1.3	-

Table 2: Resistivities and corresponding thicknesses at vertical electrical sounding stations.

Layer No.		Resistivity (Ohm.m)	Thickness	Corresponding lithology
Geoelectrical layer (A)		>50	1-5	Dry loose sand
Geoelectrical layer (B)	Upper zone (B1)	10-50	5	Clay Sand saturated with water
	Lower zone (B2)	5-10	15-30	sandy clay saturated with more saline water
Geoelectrical layer (C)		<5	---	Clay

Table 3: Resistivities and the thicknesses range and the corresponding lithologic composition of the detected geoelectrical layers.

layer "B" dividing according to resistivity values in two zones (B1 and B2). The last one is layer "C". A description of each of these layers is given as follow:

Layer "A": The surface layer (A) consists of three thin dry layer grouped in one layer to reach optimum correlation between the geoelectrical layers and the predominant geologic units. The resistivity of such a layer is plausibly expressed in terms of the average transverse resistivity (ρt) (Equation 1) [19]. This parameter can be calculated from the resistivities and thicknesses of the group of thin layers as follows

$$pt=\sum(\rho i.hi)/\sum hi....i=1 \text{ to } n \quad (1)$$

Where; ρi is the resistivity of the ith layer, hi is its thickness and n is the number of layers. This layer formed from sand and clay content as the data of drilled well and the exhibited lithological surface with resistivity larger than 50 Ohm.m. and their thickness not exceed 12 m.

Layer "B": The second layer (B) consists of two zones (B1 and B2) according to resistivity values and formed of saturated sand. The upper zone (B1) exhibits resistivity less than 50 Ohm.m and thickness reached 5m. But the lower zone (B2) represented resistivity ranges from 5 to 10 Ohm.m and thickness varies 15 - 30m. The changes in resistivity values reflect the groundwater quality so the lower zone (B2) more saline than the upper one (B1). The resistivity values decrease downward with depth then reach to the last layer. It can be called this water bearing layer (B) as a perched aquifer due to the presence of lower impermeable clay layer.

Layer "C": The last detected layer (C) consists of clay with resistivity value less than 5 Ohm.m. It acts as a barrier that prevents groundwater more passage.

The geoelectrical cross sections

These sections illustrate the geoelectrical sequence, lateral and vertical variation for different layers along the profile direction. Two geoelectrical cross sections are constructed, section South - North direction (Figure 7) while, the other section has the direction of West - East (Figure 8). The detailed description of the geoelectrical layers from top to bottom can be described as follows:

1. Generally, the geoelectrical cross sections (A-A') and (B-B') (Figures 7 and 8) consist of three geoelectrical layers "A", "B", and "C". The surface layer (A) is formed of sand deposits, the second layer (B) is divided into zone (B1 and B2) acting as water bearing. It is formed of sand and the last layer (C) consists of clay.
2. These layers exhibited a regular thickness although changed in the relief of last clay layer at VESes No. 17 and 19 in the Northwest direction of the study area due to lateral in lithological changes.
3. It is noticed that the resistivity values of geoelectrical layers decrease downward in the study area due to increasing clay intercalation.
4. The first geoelectrical layers decrease in their thicknesses Southward direction.

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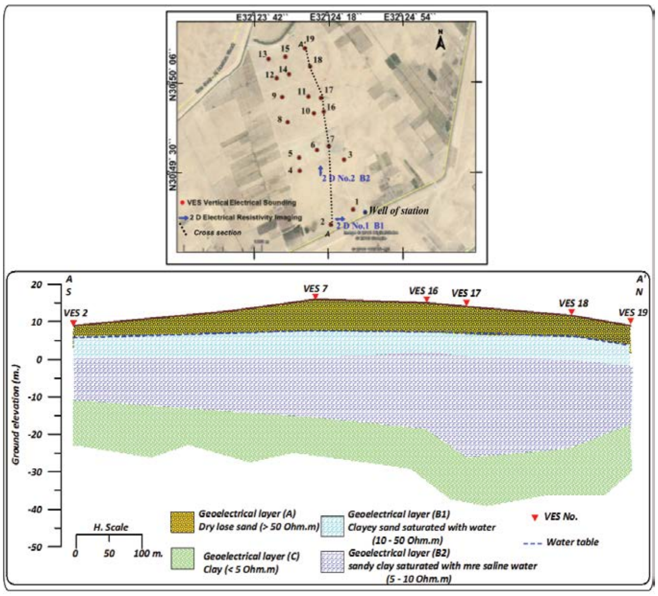

Figure 7: Geoelectrical cross section AA'.

5. The thickness of saturated water bearing layer (B) is generally increases toward the Southeast direction.

6. The groundwater is shallower toward the South due to low ground elevation but it becomes deeper at VESes No. 6, 16 and 17 in center of the study area.

Interpretation of the electrical resistivity tomography (ERT) data:

Examination of the imaging profiles at the selected two sites (B1 and B2) in the study area (Figures 9 and 10) indicates deposits of high resistivity corresponds to the dry coarse grain sand dominate in the upper parts. These images shows obvious downward resistivity decrease that represents saturated sand deposits. It can be detected two geoelectrical layers. The upper layer acts as surface layer of the study area with high resistivity values (larger than 70 Ohm.m) reflecting homogeneity content of dry sand. The lower layer is saturated with water and divided into two zones according to resistivity differentiation. The first zone exhibited resistivity values ranges from 10 to 50 Ohm.m and relatively high than the second zone which exhibits resistivity values less than 10 Ohm.m. This means that the lower zone is more saline than the upper one.

The depth to water reaches 8 m from the ground surface. The thickness of the upper zone is 5 m and composed of sand and clayey sand. The thickness of the lower zone is not detected and composed of sandy clay and clay. These results are compatible with the interpretation of Vertical Electrical Sounding (VES).

Groundwater Occurrences

According to the limited hydrogeological information in the study area, the applied geoelectrical methods are integrated to collect the common features that may suggest groundwater occurrence. The quaternary aquifer dominates the area of study consisting of sand gravel (unconfined aquifer). There is one drilled well in area of study with total depth 21 m. and depth to water reach 11 m. Its salinity has record 2528 ppm. As mention above, the study area belong research station for agriculture and depends on the tributary of El Salam Canal during irrigation. The problem in this area that the water for irrigation not sufficient. So, the results of geoelectrical data deal with this problem to suggest a suitable solution.

The interpretation of geoelectrical data of both Vertical Electrical

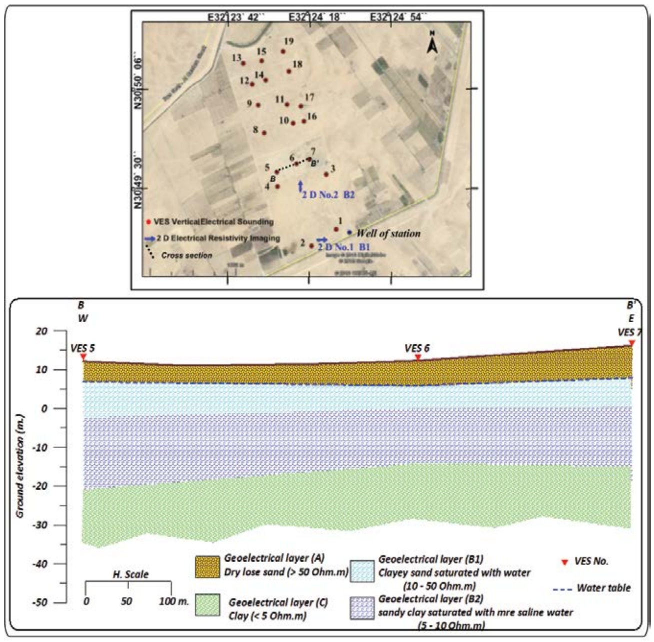

Figure 8: The geoelectrical cross section BB.

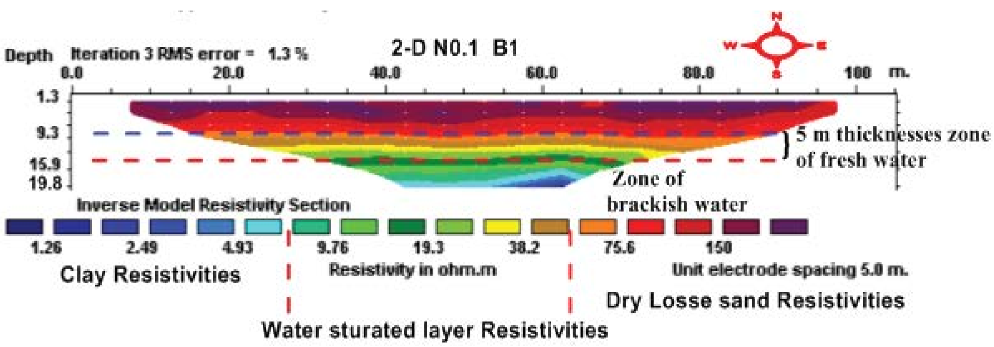

Figure 9: True resistivity 2-D imaging profile at the first site B1.

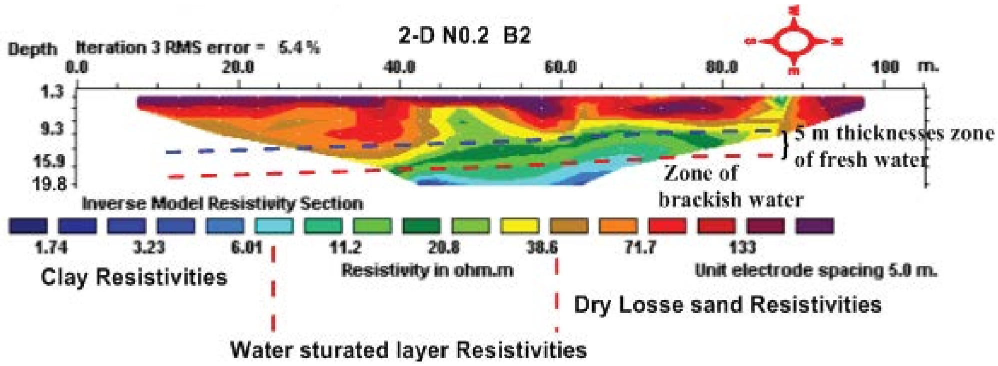

Figure 10: True resistivity 2-D imaging profile at the first site B2.

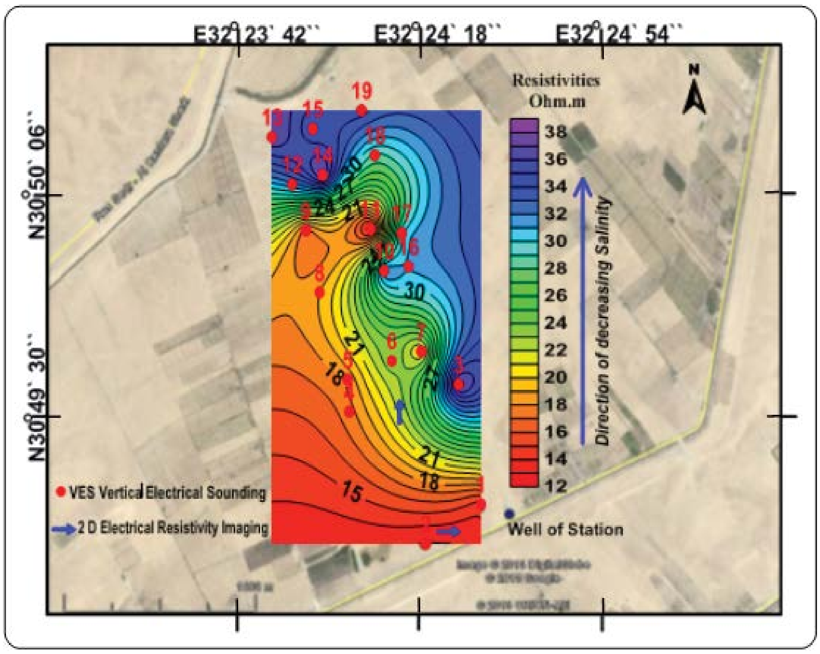

Figure 11: Isoresistivity contour map of upper saturated zone (B1).

Sounding and 2D imaging reveals that the second layer (B) acts as a water bearing layer. It is divided in two zones (B1 and B2) according to resistivity values reflecting the degree of groundwater quality whereas, the lower one more saline than the upper. The isoresistivity contour maps (Figures 11 and 12) of the two saturated zones (B1 and B2) are constructed for more details. They exhibited high resistivity values in the Northeastern and South Western directions. This means that the priority sites of the drilled wells can be chosen in these trends. Generally, the upper saturated zone is better groundwater quality than the lower saturated zone whereas, the resistivity values of the upper zone is higher than the lower

The thickness of saturated layer (B) is an important geoelectrical parameter judging suitable sites for drilled well. The isopach contour maps (Figures 13 and 14) are constructed. They represented increase in thickness values in South-eastern and South-western direction and generally, the lower saturated zone (B1) has larger thickness than the upper saturated zone (B2).

The level of the water bearing layer related to sea level from VES results is used to construct contour map (Figure 15). It shows groundwater flow direction. The level contour map clarifies the groundwater flow in two directions. The first flow direction is toward South Western trend of the study area. This is caused accumulation of ground water in this site that appears as a pond in the area according to raise of clay layer. The second flow direction is towards North Eastern trend whereas; the depth to clay layer has large record in this location. It is obvious that, the clay layer is played an important role in the ground water condition so; the contour map (Figure 16) of the depth of clay layer will be constructed. This map shows generally increase depth of clay layer towards North Eastern direction. According to this information, the best suitable place for a drainage system is constructing in South Western direction whereas, the dipping layer and less depth of clay.

The geoelectrical results represent the best priority sites of the productive drilled wells for supplementary irrigation in the study area in North Eastern and South Eastern direction. These wells must be drilled with total depth not exceed 30 m. The suitable technique for

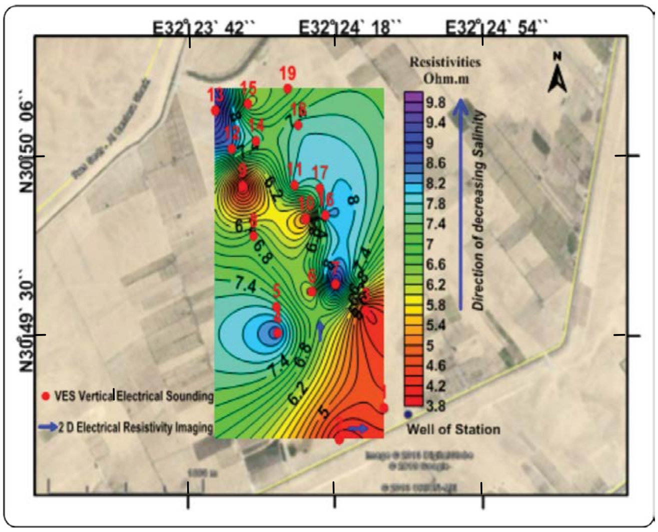

Figure 12: Isoresistivity contour map of lower saturated zone (B2).

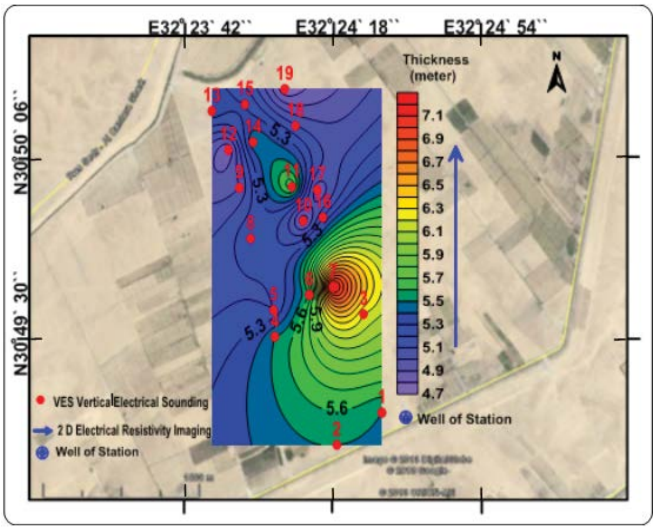

Figure 13: Isopach contour map of upper saturated zone (B1).

drilling is hand dug but possible rotary drill is to detect depth. It must be observing the mission of drilled wells to construct a suitable casing. Also, pumping test is important for safe yield and serves good quality of groundwater recharge.

According to the small thickness value of the upper saturated zone (B1) which is approximately 5 m. of good quality groundwater, suggestion is considered to construct three cement treasurers with distance 3 × 20 × 20 m. These treasurers permit collecting water approximately 1200 m³. This collecting water can be used during shortage of water in tributary of El Salam Canal. The distribution of these treasurers may be one constructed in South Western direction of the study area and using the existing water in the ponds for recharge. The other two treasurers are constructing in the center and the end of the study area as showing in Figure 17.

Geoelectrical measurements indicate two saturated zones (B1 and B2) with different salinities. The upper saturated zone (B1) is in good quality groundwater and low salinity degree than the lower saturated zone (B2). So it must be noticed that the safe yield for preventing a mixing of the groundwater of both saturated zones (B1 and B2) during discharge from wells and consequence harmful effect on cultivation. When an aquifer contains an underlying layer of saline water such as the study area and is pumped by a well penetrating only the brackish water of the upper part of the aquifer, a local rise of the interface between the saline and brackish water below the well occurs. This phenomenon is known as up-coning, by pumping. This generally necessitates that the well has to be shut down because of the influence of the saline water. Up-coning is a compiler phenomenon and only in recent years has significant headway been made in research to enable criteria to be formulated for the design and operation of wells for skimming brackish water from the saline water.

There is an analytical solution for safe yield of drilled wells. Calculation of safe yield needs to know the type of the well, total

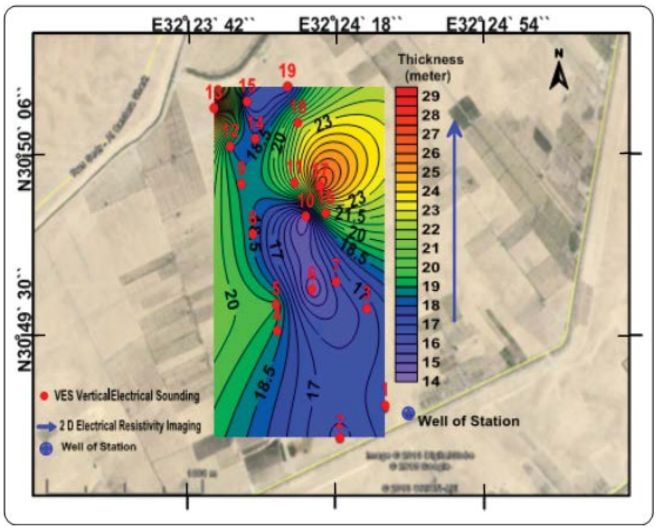

Figure 14: Isopach contour map of lower saturated zone (B2).

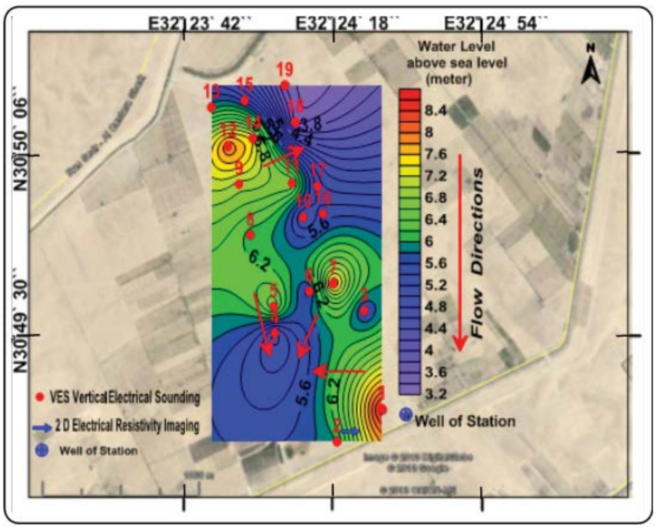

Figure 15: Water table contour map.

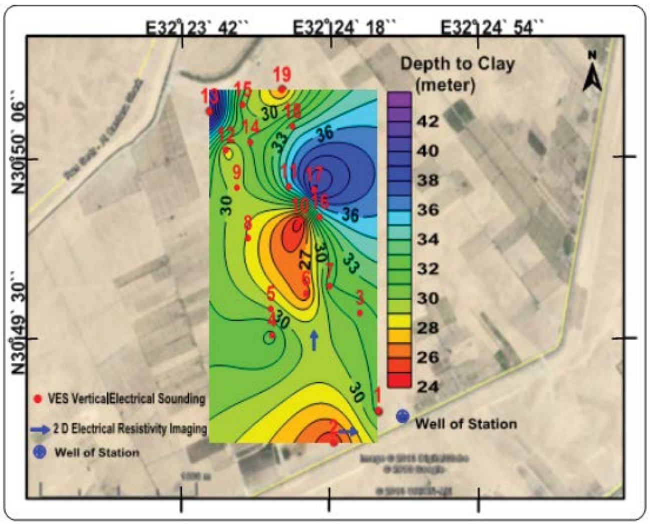

Figure 16: Depth to clay layer contour map.

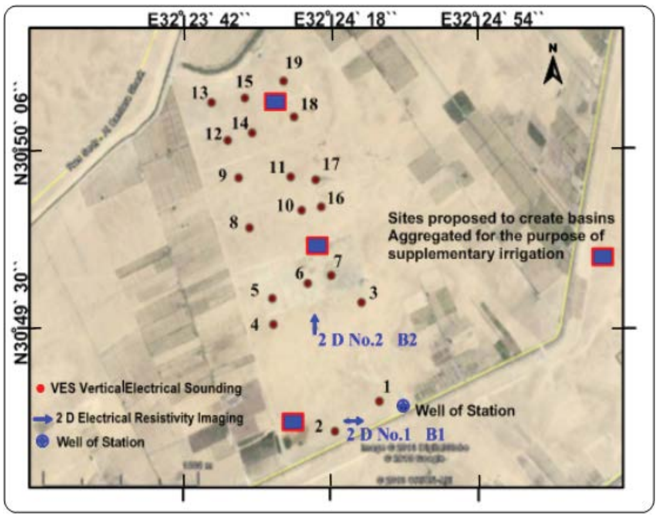

Figure 17: Location of sites proposed to create basins aggregated for the purpose of supplementary irrigation.

depth and well design. Well design and safe yield can be calculated by Ghyben-Herzberg relation [20] and discussed as follows:

Hand dug well

This type of wells is recommended at an area lying near to shore. These wells have 3 m in diameter (2r) and thickness of water (Z) reaches to 5 m (Figure 18a). The safe yield (Q) (Equation 2) of these wells can be calculated by the following equation:

$$Q=\pi r^2 Zm^3 \qquad (2)$$

Where: r is the half diameter of the well. And Z is the thickness of water

Then, $Q = 3.14 \times (1.5)2 \times 5 = 35.33m^3$

The discharge of hand dug well would be two times per day in the morning and in the evening. The total safe yield of every hand dug well is (Q) 35.33 m^3/day.

Drilled well

This type of wells (Figure 18b) is recommended and can be dug where thickness of the brackish water exceeds 25 m and depth to interface more than 35 m. Due to the upconing of the brackish-saline water interface during pumping, the safe yield (Q) (Equation 2) for every well can be calculated according the following:

$$Z=Q/[2\pi d2k(\Delta\rho/\rho b)] \qquad (3)$$

Where $\Delta\rho = \rho s - \rho b$; ρs (1.025), ρb (1.0) is the specific weight of saline and brackish water.

K=Hydraulic conductivity. Z=the critical rise.

d=the distance between the end of the well and interface between saline and brackish water.

If the upcoming exceeds a certain critical rise (z), it accelerates upwards in the well (Figure 18b). Critical rise (z) has been estimated to approximate S=0.3 to 0.5 Thus, adopting an upper limit of Z / d =0.5.

Conclusions and Recommendation

The Sinai peninsula has enormous development evidence especially in agricultural activities to face growing settlements and communities. This development process increased the demand for water. The continuous research services and scientific guidance becomes important for development. Many research stations are constructed by desert research center covering desert land in Egypt. One of these stations is South Qattara Shark that constructed in West Sinai for solving problems related to agriculture and also considered as productive station. The present study concentrates on the area of this station having length reach to 1600 m. and width 850 m., nearly eight hundred Feddan in West of the Sinai region at East of Qattara. The surface and subsurface layers belonging to quaternary deposits consists of sand, sandy clay and clay facies of Pleistocene. This station suffers from shortage water supply for agriculture in some seasons especially summer whereas it depends on a tributary of El Salam Canal that not fully of water all the time. There is one drilled well for human activity just South the study area with total depth 21 m and depth to water reach 11 m. Its salinity has record 2528 ppm. Some patches of water logging appear in low land at South west of area because of not existence good drainage system. Geoelectrical resistivity techniques were used in the present study to deal with pervious mention conditions. The appropriate solutions to these problems have been delineated by the results of 1D and 2D geoelectrical measurements. It exhibits the

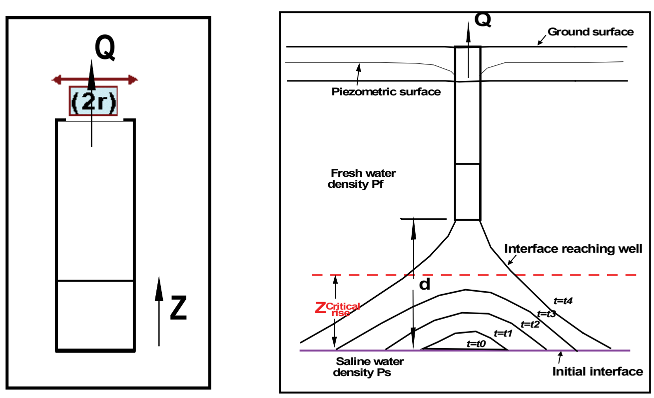

Figure 18: a: Hand dug well. b: Drilled well.

subsurface sedimentary sequences and extension of subsurface layers in horizontal and vertical directions. As well as the choice of the most suitable places to drill production wells with good possibilities and quality.

Nineteen Vertical Electrical Sounding (VES) arranged in a grid to cover the study area and two 2D geoelectrical imaging profiles are carried out. The results of geoelectrical successions are formed of a number of layers being grouped together in three main layers. The first layer is surface layer "A" and the second is layer "B" which divided according to resistivity values in two zones (B1 and B2) that acts as water bearing layer, while the last one is layer "C". The results are represented through different contour maps and cross sections that exhibit the horizontal distribution of successive layers which reflect the lithology and extent of change in all directions. The results declare that the thickness of the water bearing layers consists of two zones. The upper one was less salty than the lower zone. The thickness of the upper zone ranged from 5 to 7 meters but the lower zone ranged from 15 to 30 meters. The last detected layer is clay that decreases in depth towards the Southwest of the study area causing the phenomenon of water logging.

As the results of geoelectrical measurements, the two saturated zones (B1 and B2) exhibited different salinities. The upper saturated zone (B1) is in good quality groundwater and low salinity if compared with the lower saturated zone (B2) according to resistivities values. It is recommended that the safe yield prevent to mixing of the groundwater of both saturated zones (B1 and B2) during discharge from wells and consequence harmful effect on cultivation. This phenomenon is known as up-coning, by over pumping. Generally, necessitates that the well has to be shut down because of the influence of the saline water by a local rise of the interface between the saline and brackish water.

The best priority of the sites of productive wells for supplementary irrigation in the study area is at North eastern and South Eastern directions. These wells must be drilled with total depth not exceed 30 m. The suitable technique for drilling is hand dug but possible rotary drill to detect depth. It must be observing the mission of drilled wells to construct a suitable casing. Also, pumping test is important for safe yield and serves good quality of groundwater recharge. The discharge from hand dug well would be two times per day in the morning and in the evening. The total safe yield of every hand dug well is (Q) 35.33 m^3/day when these wells have 3 m in diameter and thickness of water reaches to 5 m.

It can be recommended that a construction of three cement treasurer with distance 3 × 20 × 20 m according to the small thickness of the upper saturated zone (B1) approximately 5 m of good quality groundwater. These treasurers permit collecting water approximately 1200 m^3. The collecting of water can be used during shortage of water in branch of El Salam Canal. The distribution of these treasurers may be one which is constructing in South-western direction of the study area and using the existing water in the ponds for recharge. The other two treasurers are constructed in the center and the end of the study area at North trend.

The best suitable place for a drainage system is constructing in South-western direction whereas, the dipping layer and less depth of clay.

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