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Estimation of Aquifer Parameters from Vertical Electrical Sounding Measurements South Gaza Strip, Palestine

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Abstract

In this study quantitative interpretation of some 14 Vertical Electrical Sounding (VES) points using the Schlumberger array and data from 10 boreholes were applied to study the aquifer geoelectrical/hydrogeological parameters in the southern governorates of Gaza Strip. The quantitative interpretation of (VES) results analyzed in order to find empirical relations between different aquifer parameters. The results represent the predicted hydraulic conductivity (K), transmissivity (Tr), TDS, earth resistivity, water resistivity, porosity and Dar-Zarrouk parameters (Longitudinal conductance and Transverse resistance). The results show the earth resistivity is strongly affected by the chemistry and salinity of the groundwater. The relation between longitudinal resistivity (ρL) and groundwater salinity (TDS) was achieved for groundwater aquifer. The geoelectric (Dar-Zarrouk) parameters determined and interpreted by using the integration of the results, which indicates that longitudinal conductance has a high values at the western part of the study area represents an increase in groundwater movement horizontally, that is a strong evidence of seawater intrusion. Porosity was estimated to be in the range of 38–52% with an average value of 46%. Transmissivity values for the study area were calculated. This result helps to delineate the contact between the saline and fresh groundwater aquifer in the study area.

Keywords:
Vertical electrical sounding (VES),
Seawater intrusion,
Dar-Zarrouk parameters,
Transmissivity,
Hydraulic conductivity,
Porosity.

1. Introduction:

Excessive groundwater exploitation may seriously affect the groundwater quality through the phenomenon of saline upcoming. Surface geophysical resistivity method may provide rapid and effective techniques for groundwater exploration an aquifer evaluation (Batte et al. 2010). It is an effective and useful tool routinely used under a variety of field conditions and geological settings in hydrogeology, geotechnical engineering and environmental geology for ascertaining the subsurface geologic framework of an area (McNeil. 1990; Davies et al. 1995; Vchery 2003). Application of the geoelectrical method has led researchers to develop surface resistivity techniques for making quantitative estimates of the water transmitting properties of aquifers (Griffith 1976; Louis et al. 2004).

The geoelectrical column and cross-sections deduced from the vertical electrical sounding (VES) can provide an effective tool to image the vertical and lateral variations of subsurface hydro-lithology with the minimum need of observation wells. Geoelectrical methods have been widely used for the estimation of aquifer hydraulic proprieties and investigate the relation between hydraulic and electric parameters (Kelly and Frohlich, 1985; Mazáč et al., 1985; Niwas and Singhal, 1981, 1985; Salem, 1999; Niwas and Lima, 2003; Singh et al., 2004; Sinha et al., 2009; Niwas and Celik, 2012; Utom et al. 2012; Al-Yasi et al., 2013; Alridha et al., 2013; Igboekwe and Amos, 2014; Abu Heen & Muhsen, 2016; Muhsen, 2016). Hydraulic properties including porosity and permeability (hydraulic conductivity (K), transmissivity (Tr) and storability are best obtained through pumping tests and down-hole well logging. The application of resistivity techniques in evaluating the relationship between aquifer electrical resistivity and hydraulic properties are applied in the present study through studying and analyzing of Dar-Zarouk (D-Z) parameters, which are: Longtudinal conductance (S) and Transverse resistance (T), deduced from surface vertical electrical sounding (VES) interpretation, to provide a useful and confident solution in differentiating between saline and fresh water aquifers.

2. Geological and Hydrogeological Setting of the Study Area:

The study area represents a region from the southern part of Gaza strip, the area bounded by coordinates longitudes 34° 2” and 34° 25” east, and latitudes 31° 16” and 31° 45” north (Figure 1), covering a surface area of 170.5 km2 representing 45% of the total area of the Gaza Strip, and has approximately 221,648 inhabitants (31.1 5% of the total population in the Gaza Strip, PCBS, 2015).

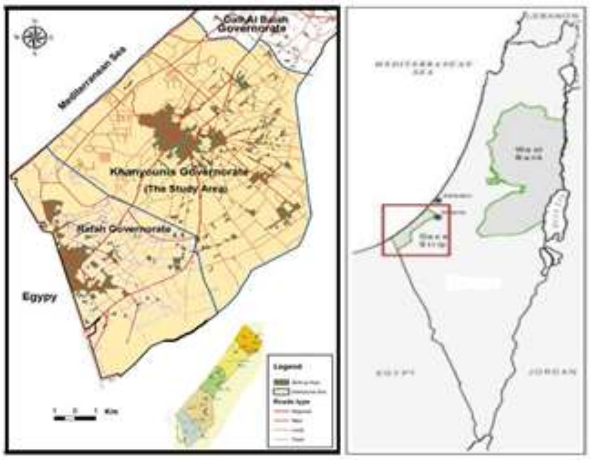

Figure 1 *Location map of the study area*

The average daily mean temperature in the Gaza Strip ranges between 31.10C in summer to 12.60C in winter. August is the hottest month. The relative humidity fluctuates between 60% and 85%. Average annual rainfall of Gaza strip ranged between 147.7 mm/year to 805 mm/year (PWA, 2015b, 2015c).

The coastal aquifer of the Gaza strip is a part of a regional groundwater system covering Palestine and Egypt areas. It extends alongside the Mediterranean Sea for 120 km from north Palestine to Gaza Strip and Sinai (Egypt) in the south, and its width varies between 7 to 20 km. The aquifer extends only 45 km long in the Gaza Strip. The regional area consists of a littoral zone, a strip of younger dunes situated on top of a system of older Pleistocene beach ridge, and to the east alluvial and loessial plains. The main aquifer is composed of calcareous sandstone with a thickness varying from about 120 m at the shoreline to few meters in the east (Abed and Alweshahy, 1999).

The geology of the Gaza Strip area consists of a series of Mesozoic to the Quaternary geological formations sloping gradually from east towards the west (Figure 2). It is a Pleistocene-age granular aquifer (Kurkar Group), formed by marine and eolian calcareous sandstone ("kurkar"), reddish silty sandstone ("hamra"), silts, unconsolidated sands and conglomerates with intercalation of clay of marine origin and loam. Some of them are lenses which are randomly distributed in the area, causing local perched water conditions; others begin at the coast, extending 2-5 km inland, and separate the aquifer into various subaquifers, indicated as A, B and C. Subaquifer A is phreatic, whereas B and C become confined toward the sea. The aquifer overlies marine clay of Miocene age, known as Saqiya Clay aquiclude, which is the bottom of the aquifer. The average thickness of the aquifer body is about 150 m, reaching its maximum of about 200 m near Gaza city and its minimum of about 20 m in the eastern part and in the south, near the city of Rafah.

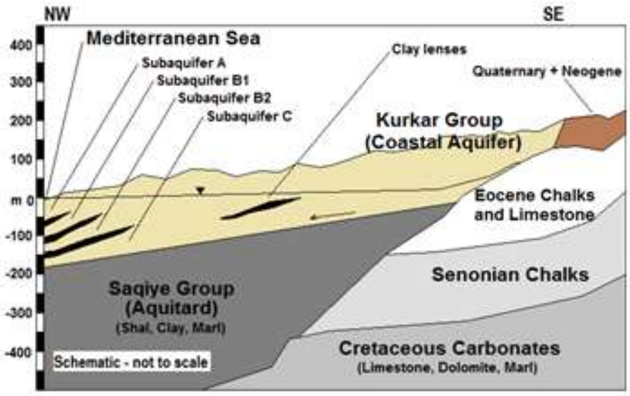

Figure 2 *Hydrogeological cross-section of the coastal aquifer (Qahaman, 2004)*

3. Materials and Methods:

The aim of this paper is to investigate the hydraulic properties of the groundwater aquifer based on the surface vertical electrical resistivity data (VES) conducted by Abu Heen & Muhsen (2016) to provide a useful and confident solution in differentiating between saline and fresh water aquifers and to estimate the relations between these parameters.

A total of 14 vertical electrical sounding were conducted at Khan Younis and Rafah Governorate (South Gaza Strip) with a NW-SE direction as shown in Figure 3 using a Schlumberger array. The VES soundings were conducted with Iris Syscal R1 Plus Switch-24 resistivity instrument, in order to determine the number of the underlying layers, depths, thicknesses and their conductivity, with a maximum current electrode half-spacing (AB/2) of 200 m and (MN/2) varying from 0.25 to 16 m.

Figure 3 *VES location map*

The results were compared with lithology boreholes which are located near VES points to adjust the interpreted models. Data obtained from chemical analyses of groundwater also used to calibrate the changes in salinity of the proposed geo-electrical model of the study area (Table 1).

Table 1 *Results of hydrogeoelectrical analysis of groundwater in the study are*

ell No.	Well name N	Well name E	EC µS /cm	TDS mg/l	CL mg/l	Na mg/l
1	31^0 18' 58.72"	34^0 13' 28.82"	5200	3302	1469.5	544
2	31^0 19' 05.93"	34^0 13' 36.70"	7300	4635	2109.3	732
3	31^0 18' 34.46"	34^0 13' 33.03"	7900	5016	2149.3	906
4	31^0 21' 02.37"	34^0 15' 22.52"	6080	3360	1597	
5	31^0 21' 23.71"	34^0 15' 44.22"	8700	5829	2024.4	-
6	31^0 21' 25.62"	34^0 16' 48.72"	950	603.2	189.9	99.2
7	31^0 21' 33.29"	34^0 16' 31.66"	1000	670	154.4	-
8	31^0 22' 12.95"	34^0 17' 02.54"	4530	2430	788	460
9	31^0 22' 28.93"	34^0 16' 56.93"	9370	4766	2900	-
10	31^0 22' 53.47"	34^0 17' 56.95"	3440	1973	625	-

4. Results and Discussion:

4.1. VES interpretation:

The results of a resistivity sounding survey can be interpreted both qualitatively and quantitatively. Qualitative interpretation of resistivity sounding data, involves the study of the types of sounding curves obtained, such curves are K, H, A and Q or a combination of two or three curves type e.g. KH, KHA, etc. (Keller and Frischknecht, 1966). The results reveal that 50% of the total soundings are interpreted of 3 layer modes, while the other 50% are of 4 layers mode l. All soundings in the study area are descending types, which mean decreases the layer resistivities as depths increased. Table 2 summarized the quantitative interpretation of all soundings of the study area as deduced from geoelectrical, geology, cross sections and other available geophysical data (Abu Heen & Muhsen, 2016; Muhsen, 2016).

Table 2 *VES interpretation of the study area*

VES	RMS %	Electrical resistivity (ρ) in (Ohm.m) and thickness (h) in meter								Curve type
		Layer 1		Layer 2		Layer 3		Layer 4		
		ρ1	h1	ρ2	h2	ρ3	h3	ρ4	H4	
S1	2.1	479	4.75	134	4.2	12.3	30	4.3	-	QQ
S2	1.33	141	8.39	41.4	13	11.1	-			Q
S3	2.07	919	2.2	99.2	4.94	7.53	22.1	0.93	-	QQ
S4	1.95	491	2.71	474	18.5	5.41	-			Q
S5	2.67	332	11.6	3.94	34.6	0.94	-			Q
S6	2.13	866	17.9	46.7	44	9.9	-			Q
S7	2.20	272	9.84	6.45	33.5	0.55	-			Q
S8	2.37	484	3.35	107	8.19	10.9	38.3	4.09	-	QQ
S9	2.92	141	10.4	7.3	23.5	0.46	-			Q
S10	2.22	465	10.9	46.2	24.9	2.46	-			Q
S11	1.16	336	10.5	41	10.1	3.4	29.3	0.78	-	QQ
S12	1.95	561	3.38	62.6	11.6	15.8	27.4	5.34	-	QQ
S13	3.06	84.7	1.6	359	2.58	4.64	23	0.69		KQ
S14	1.06	860	10.1	434	17.5	62	27.9	4.49	-	QQ

4.2. Hydrogeophysical parameter of the study area:

4.2.1. Relationship between geoelectrical parameters and ground water chemistry:

Many researchers (Ebraheem et al., 1997; Al-Amoush, 2006; Sherif et al., 2006; Alridha et al., 2013) reported that it is possible to determine the correlation between the observed earth resistivity, electrical conductivity and the amount of total dissolved solids in the groundwater.

The earth resistivities and TDS values for the studied area were plotted and presented in Figure 4 and the best fitted line was obtained by the following empirical relationship:

$$\rho e = 15277 * (TDS)-0.93$$

With R2 =0.798

Where TDS is the total dissolved solids in mg/l of the groundwater samples, and ρe is the earth resistivity in Ω.m. This equation used to predict total dissolved solid (TDS) in every geoelectrical column within the study area.

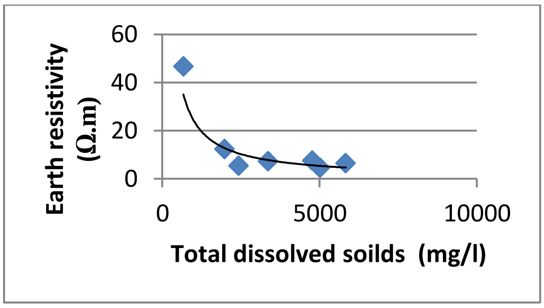

Figure 4 *Regression between total dissolves solids (TDS) and water resistivity*

A Similar empirical relationship is achieved by AL-Amoush (2006) were the relation between TDS and ρe as follows:

$$\rho e = 3150.3 * (TDS)-0.7427$$

Comparison of the above empirical relationship between the earth resistivity and the total dissolves solids have been achieved in the study area as proposed by Metacalf & Eddy (2009). Accordingly it is possible to classify the aquifer of water- bearing formations into five different geoelectrical units according to the resistivities and TDS values as shown in Table 3.

Table 3 *Comparison between resistivity, salinity and lithology in present Study and Metacalf & Eddy studies (2009)*

USGS TDS (mg/l)	Present Study Lithology/ Groundwater	Present Study Resistivity Range(Ωm)	Metacalf & Eddy (2009) Lithology/ Groundwater	Metacalf & Eddy (2009) Resistivity Range(Ωm)
> 35000	Brine saturated formation	< 0.87	Brine saturated formation	< 0.8
10000 – 35000	Seawater intrusion (Very saline)	0.87 - 2.8	Seawater saturated kurkar or clay	0.8 - 2
3000 – 10000	brackish water (Moderately saline)	2.81-16	Clay – rich zone or brackish water	2 - 15
1000 – 3000	Slightly saline	16 - 24	Sands filled with fresh to brackish water	15 - 75
< 1000	Fresh water zone	> 24	Dry or fresh water filled sands	> 75

4.2.2. Relationship between earth resistivity and water resistivity:

To obtain a relationship between water resistivity and earth resistivity, some of six water wells have been selected and located near VES locations. The earth resistivities (ρe) and water resistivities (ρw) values were plotted and presented in Figure 5. The calculated empirical relation between the two parameters showed in the equation:

$$\rho e = 2.6478\ \rho w + 3.1495$$

with R2 = 0.798

This relationship between earth resistivity ρe and water resistivity ρw reveals that the earth resistivity is strongly affected by the chemistry and salinity of the groundwater.

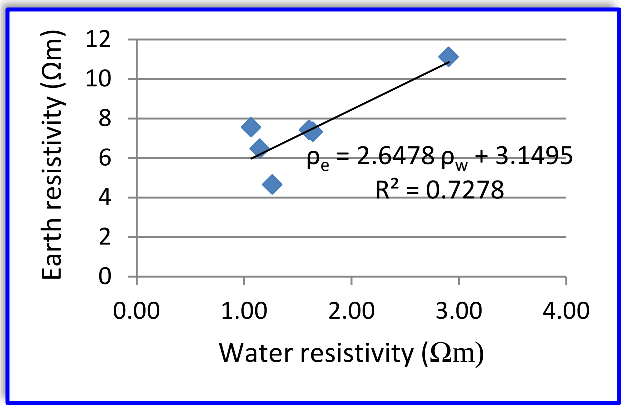

Figure 5 *Regression between Earth resistivity (ρe) and water resistivity (ρw)*

4.3. Estimation of Aquifer characteristics (Dar-Zarrouk parameters) from VES results:

Dar Zarrouk Parameters (D-Z) defined by the longitudinal conductance in mS (layer thickness over resistivity) and transverse resistance in Ω·m2 (layer thickness times resistivity) are two of the most important parameters in electrical prospecting (Maillet, 1947; Huntley, 1986). Since Dar Zarrouk parameters are also bulk parameters, taking the relationship between hydraulic conductivity and resistivity a stage further leads to a relation between transmissivity values estimated from pumping tests and Dar Zarrouk parameters from surface resistivity measurement .

The D-Z parameters were used to differentiate aquifers of fresh groundwater from those of saline ones. This technique reduced the ambiguity related to interpretation which mainly produced by principles of equivalence and suppression and cause intermixing in recognizing depth limits for the electrical zones fresh and saline water bearing formation and clay bands and sand layers during interpretation (George et al., 2011).

Maillet (1947) termed the Dar Zarrouk (D-Z) parameters, where T is the resistance normal to the face and S is the conductance parallel to the face for a unit cross section area, which plays an important role in resistivity soundings (Honriet, 1976).

For a section consists of N layers with thickness h1, h2, hn and resistivity ρ1, ρ2, ... ρn for a block of unit square area and thickness

$$H = \sum_{i=1}^{N} h_i$$

Other geoelectric parameters can be derived from its resistivity and thickness (Zohdy et al., 1974). For i = 1, 2, ..., n-layer, these parameters are:

1. The total longitudinal conductance unit :

$$S_L = \sum_{i=1}^{n} \left(\frac{h_i}{\rho_i}\right) = \frac{h_1}{\rho_1} + \frac{h_2}{\rho_2} + \frac{h_3}{\rho_3} + \cdots \frac{h_n}{\rho_n}$$

2. Transverse unit Resistance:

$$T = \sum_{i=1}^{n} h_i.\rho_i = h_1.\rho_1 + h_2.\rho_2 + h_3.\rho_3 + \cdots h_n.\rho_n$$

3. The average longitudinal resistivity:

$$\rho L = H / S \quad \sum hi / \sum(hi / \rho i)$$

where H = ∑hi (hi is the thickness for each layer (i))

4. Transverse Resistivity:

$$\rho T = T / h \quad \sum (hi \cdot \rho i) / \sum hi$$

5. The anisotropy: $A = \sqrt{\rho_T / \rho_L}$

The Dar-Zarrouk (D-Z) parameters (SL, T, ρL and ρT) have been calculated for each of the geoelectrical columns and presented in Table 4. These data values obtained from 14 resistivity soundings interpretation.
The total longitudinal unit conductance (SL) values ranging between 0.04 – 16.5 mS, that shows an increase to the western part of the study area, which reflects the validity of the electrical current in parallel to the layers, as this represents an increase in groundwater movement horizontally. According to Oteri (1981), the increase in S_L may correspond to an average increase in the clay content and consequently and a decrease in the transmissivity.
The total transverse unit resistance (T) values ranging between 1168–18845 Ωm² shows minimum at the western part of the area. The average longitudinal resistivity and Transverse resistivity show decrease to the eastern direction. It can be observed that longitudinal resistivity (ρ_L) is, in general, less than Transverse Resistivity (ρ_t), which indicates that the current flow along the bedding planes is greater than that normal to the bedding planes (Khalil, 2006).
Most eastern parts of the study area (located 1000 m east of coast line) yielded the longitudinal conductance (SL) values ranging between (0.04-2.4 mS), a Transverse resistance (T) range between (2900-8545 Ω.m2), Longitudinal Resistivity (ρL) range between (14.2-543 Ωm), and Transverse resistivity (ρt) range between (9–413 Ωm). According to AL-Yasi et al. (2013), this referred to a relatively fresh groundwater aquifers.
The western parts of the study area have brackish to saline groundwater aquifer and have higher S_L values that ranging between (2.4-16.4 mS), resistance (T) between 2.9 to 15 Ωm, transverse resistivity (ρ_t) range of (1.3-9 Ωm). The relation between longitudinal resistivity (ρL) and groundwater salinity (TDS) depicted in (Figure 6).

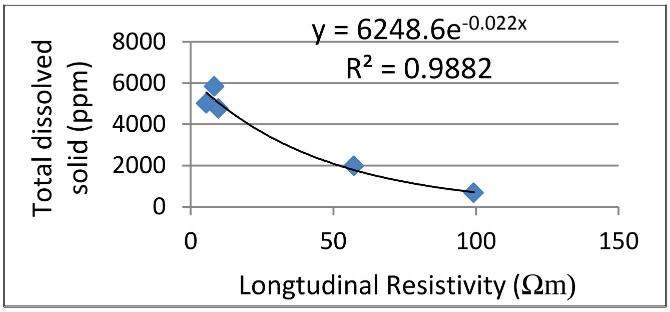

Figure 6 *Regression between total dissolves solids (TDS) and longitudinal resistivity (ρw)*

It was found that the highest correlation coefficient (R) value (R=0.98) belongs to the relation between (ρL) and (TDS), that (ρL) represent the affected variable by the (TDS) content for the currently studied aquifer. The (ρL–TDS) inversely proportional relation yielded the equation:

$$TDS = 6248.6e^{-0.022\,\rho_L}$$

4.4. Estimation of Aquifer Hydraulic Characteristics from Surface Electrical Resistivity Data:

The aquifer resistivity obtained from the surface resistivity methods can be used to estimate the hydraulic conductivity of the aquifer such as:
transmissivity (Tr), specific capacity (Sp), discharge (Q), porosity (φ), permeability (k), saturation zone thickness (H) and electrical conductivity (E.C.).

Table 4 *Summary of aquifer parameters of the study area*

VES No.	ρ1	ρ2	ρ3	ρ4	h1	h2	h3	First Layer		Second Layer		Third Layer		S_L total (mS)	T total Ωm^2	H (m)	Tr Transmissivity	ρ_t Transverse resistivity Ωm	ρ_L Longitudinal Resistivity Ωm
								S_L Longitudinal conductance (mS)	T Transverse resistance (Ωm^2)	S_L Longitudinal conductance (mS)	T Transverse resistance (Ωm^2)	S_L Longitudinal conductance (mS)	T Transverse resistance ($\Omega m2$)						
S1	479	134	12.3	4.3	4.75	4.2	30	0.01	2275.25	0.03	562.8	2.44	369	2.48	3207	39	600	82.34	15.704
S 2	141	41.4	11.1	-	8.39	13	-	0.06	1182.99	0.31	538.2	-	-	0.37	1721	21.4	260	80.47	57.267
S3	919	99.2	7.53	0.9	2.2	4.94	22	0.002	2021.8	0.05	490.05	2.93	166.41	2.99	2678	29.2	442	91.596	9.7887
S4	491	474	5.41	-	2.71	18.5	-	0.01	1330.61	0.04	8769	-	-	0.04	10099	21.2	370	476.17	476.11
S5	332	3.94	0.97	-	11.6	41.8	-	0.03	3851.2	10.61	164.692	-	-	10.6	4016	53.4	836	75.204	5.017
S 6	866	74.2	8.94	-	17.5	45.7	-	0.0202	15155	0.62	3390.9	-	-	0.64	18545	63.2	914	293.45	99.354
S7	272	6.45	0.55	-	9.84	33.5	-	0.04	2676.48	5.19	216.1	-	-	5.23	2893	43.3	670	66.741	8.287
S 8	484	107	10.9	4.1	3.35	8.19	38	0.01	1621.4	0.077	876.33	3.51	417.47	3.60	2915	49.8	766	58.4912	13.86
S 9	141	2.33	0.39	-	10.4	38.2	-	0.07	1466.4	16.395	89.01	-	-	16.5	1555	48.6	764	32.004	2.95
S10	465	46.2	2.46	-	10.9	24.9	-	0.02	5068.5	0.539	1150.4	-	-	0.56	6219	35.8	498	173.71	63.66
S11	336	41	3.4	0.8	10.5	10.1	29	0.03	3528	0.246	414.1	8.62	99.62	8.90	4042	49.9	586	80.996	5.61
S12	561	62.6	15.8	5.3	3.38	11.6	27	0.01	1896.18	0.185	726.2	1.73	432.92	1.93	3055	42.4	548	72.09	22.01
S13	84.7	359	4.64	0.7	1.6	2.58	23	0.02	135.52	0.007	926.2	4.96	106.72	4.98	1168	27.2	460	42.99	5.45
S14	860	434	62	4.5	10.1	17.5	28	0.01	8686	0.040	7595	0.45	1729.8	0.50	1802	55.5	558	324.519	110.54

4.4.1. Porosity estimation of the aquifer:

Archie's (1942) proposed an empirical power law relating the bulk resistivity, water resistivity and porosity:

$$\rho e / \rho w = a * \varphi^{-m}$$

Where ρe = bulk (earth) electrical resistivity; ρw solution (water) resistivity; φ = porosity; the constant (m) is the usually referred as the cementation degree while the constant (a) is referred as the coefficient of saturation. The numerical values for (a) generally fall between 0.6 and 1.0 while those for (m) fall between 1.4 and 2.20.

The higher the degree of cementation, the higher the pore geometry coefficient and the ratio (ρe /ρw) is called formation factor (F).

Electrical conductivity measurements of groundwater samples were converted into water resistivities (EC = 104/ρw, where the units of EC and ρw are in µS/cm and Ωm, respectively).

The average formation factor in the study area was calculated to be 4.92, the pore geometry coefficient (a) and cementation factor (m) used in this estimation are 1 and 2 respectively. Applying the modified Archie's law, the porosity was calculated to ranges from 0.38 to 0.52 with an average of 0.46 as shown in Table 5.

Table 5 *Estimation porosity and formation factor of the aquifer*

VES no.	Well no.	EC µS /cm	ρ_w Ωm	TDS mg/l	ρ_e Ωm	F	φ
S2	10	3440	2.91	1973	11.1	3.82	0.51
S3	9	9370	1.07	4766	7.53	7.06	0.38
S4	8	3530	202	2430	5.4	2.45	0.64
S7	5	8700	1.15	5829	6.45	5.61	0.42
S9	4	6080	1.64	3360	7.3	4.44	0.47
S13	3	7900	1.27	5016	4.64	3.67	0.52

4.4.2. Estimation of Transmissivity values of the study area:

Groundwater flow through an aquifer is not governed only by hydraulic conductivity (K) alone, but also by the bulk parameter transmissivity according to the following equation (Huntley, 1986; Batayneh, 2009):

$$Tr = K \cdot h$$

Where (Tr) is transmissivity and expressed in m^2/s, (h) is the thickness of the aquifer and (K) hydraulic conductivity (permeability).

Calculated transmissivity (Tr) values for the groundwater reservoir of the study area using the previous equation are presented in Table 4. The data of hydraulic conductivity (K) that equal 20 m/s are available from PWA report (2005) and saturated zone thicknesses (H) are from present geoelectrical soundings interpretation.

Table 6 *Permeability characteristics of litho-units*

Soil type	Depth (m)	Permeability (m/s)
Clay sand	29.5	0.06
Clay	40	0.06
Kurkar	45	20
Sandstone	50	20

Source: *(PWA, 2005)*

5. Conclusions:

The use of VES method provide an inexpensive technique for characterizing the geological setting, as well the hydrogeological conditions (geometry of the aquifer systems) of the basin, and the study and analysis of Dar-Zarrouk (D-Z) parameters provide a useful and confident solution in delineating the saline and fresh water aquifers and aquifer hydraulic parameters. Empirical relationships have been obtained between total dissolved solid (TDS) and earth resistivity that used to identify four zones of water-bearing formation for the study area: fresh water zone (> 24 Ω.m); slightly saline water zone (16-24 Ω.m); brackish water zone (2.81-16 Ω.m); saline water zone (0.87 - 2.8 Ω.m) and (< 0.87 Ω.m) for brine water zone. The relationship between earth resistivity ρe and water resistivity ρw reveals that the earth resistivity is strongly affected by the chemistry and salinity of the groundwater.

Longitudinal unit conductance has a high values that shows an increase to the western part of the study area which reflects the validity of the electrical current in parallel to the layers, as this represents an increase in groundwater movement horizontally, This is a strong evidence of seawater intrusion.

The aquifer of western parts of the study area have brackish to saline groundwater and have higher SL values that ranging between (2.4-16.4 mS), transverse resistance (T) range between (0-2800 Ωm2), ρL range of (2.9 -15 Ωm), and ρt range of (1.3-9 Ωm), whilst most eastern parts of the study area (located 1000 m east of coastline) have a relatively fresh groundwater aquifers area. An inversely relationship between longitudinal resistivity (ρL) and (TDS) is observed for the study area and the transmissivity (Tr) values for the groundwater reservoir is also calculated. The combination of the interpretation of the field data VES sounding results, borehole data, TDS analyses and the geoelectric (Dar-Zarrouk) parameters indicates a high potentiality and a brackish to saline groundwater aquifers in the western part of the study area along coastal line, whereas it is fresh to slightly saline to about 1000 m east of the coast line.

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تعيين خصائص الخزان الجوفي باستخدام طريقة السبر الكهربائي العمودي (VES) للمحافظات الجنوبية لقطاع غزة – فلسطين

في هذه الدراسة تم استخدام (14) نقطة مسح كهربائية عمودية بتشكيل طريقة شلمبرجير إضافة إلى استخدام المعلومات من (10) أبار محفورة في المنطقة وذلك بهدف دراسة وتعيين الخصائص الجيوكهربائية/ الهيدروجيولوجية لمنطقة الدراسة (وهى المحافظات الجنوبية لقطاع غزة). ولقد تم تفسير المعلومات الكهربائية تفسيرا كميا بهدف إيجاد علاقات تجريبية لعناصر الخزان الجوفي المختلفة. وأظهرت النتائج قيم التوصيلية الهيدروليكية (K), المرورية (Tr), مجموع الأملاح المذابة (TDS), مقاومة الصخور, مقاومة المياه, المسامية, ومعاملات دارالزاروق (التوصيلية الطولية والمقاومة المستعرضة). وبينت النتائج ارتباطا قويا بين ملوحة التربة وكمية الأملاح المذابة في المياه الجوفية وكذلك المقاومة الكهربائية الطولية لها. ولقد استخدم في الدراسة الحالية كل المعلومات المتاحة لأجل الحصول على معاملات دار الزاروق والتي أظهرت ارتفاع قيم التوصيلية الطولية في المناطق الغربية من منطقة الدراسة والناتجة عن الحركة الأفقية للمياه وهذا دليل قوى لغمر الخزان لجوفي بمياه البحر المالحة. وتم حساب قيمة المسامية بين 38-52% وبقيمة متوسطة 46%، كما تم حساب قيم المرورية لمنطقة الدراسة. ولقد ساعدت نتائج الدراسة في رسم وتحديد العلاقة بين المياه المالحة والمياه العذبة في الخزان الجوفي لمنطقة الدراسة.

كلمات مفتاحية:
السبر الكهربائى العمودي,
تداخل مياه البحر,
معاملات دار الزاروق,
المرورية,
التوصيلية الكهربائية,
المسامية,
قطاع غزة,
فلسطين.