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Amaricf_Basra office@yahoo.com
abdulalwan@yahoo.com
.marshbulletin@yahoo.com

Geoelectric monitoring of saline water intrusion in dibdibba aquifer at zubair-Safwan area/ southern Iraq

Emad H. Al-Khersan

Basrah University, College of Science, Geology department

Abstract

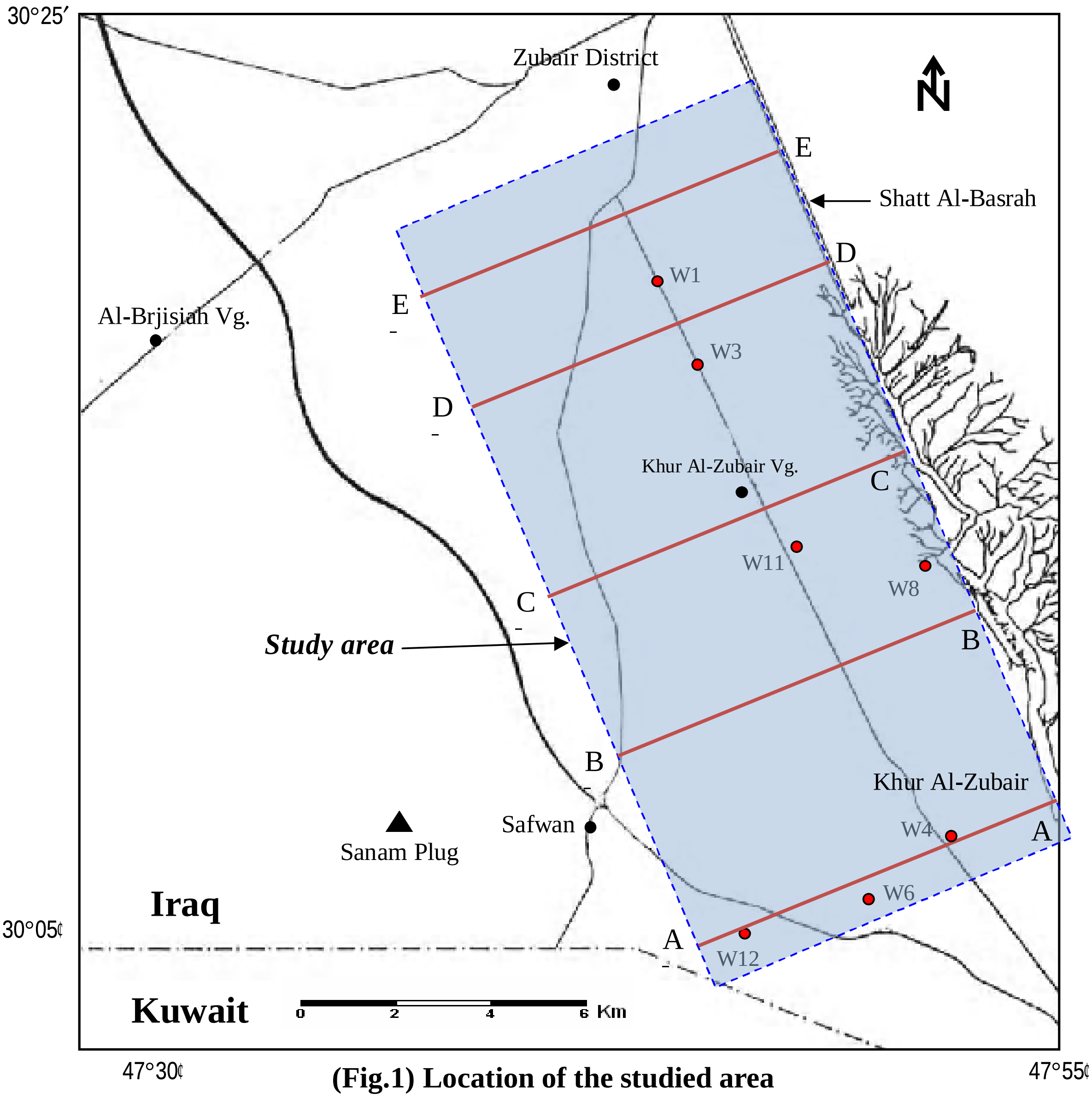
78 Vertical Electrical Sounding measuring points using Schlumberger array were carried out within Basrah Governorate at Zubair-Safwan area, southern Iraq, in order to determine the number of the underlying layers, depths and their thicknesses, boot to groundwater table and its influence by the saline water intrusion which coming from Khur Al-Zubair coastal or even deep layers towards Dibdibba Aquifer. Qualitative interpretation was applied using the type study of the electrical field curves for these VES's to get preliminary picture for lateral and vertical variations in underlying layers resistivities and lithology. Moreover, quantitative interpretation was carried out using IPI2win program. Five space sections and five geoelectrical sections were then drawn along five profiles for each one. The interpretation of these sections clarified that there are three underlying groundwater bearing beds. Thicknesses and resistivities of these beds were calculated depending on the assistance of the drilled observation wells. It is noticed that there is a decreasing in the apparent resistivity values with depth especially at the groundwater bearing intervals. This is because of the salinity increases occurred in groundwater at these intervals. Due to unprogrammed groundwater pumping, high concentration of salinity in the lower part of Dibdibba aquifer might be altering the upper part of it and changing it from fresh-brackish to saline. Large reduction in the apparent resistivity values is also observed at the eastern parts of the study area near Khur Al-Zubair boundaries which indicates high electrical conductivity values; however, this is led to the increasing of the saline water that probably comes from the sea. This fact is certainly approved by the interpretation of the extracted iso-resistivity contour map and an irregular front line separates between low (saline) and high (brackish to fresh) resistivities can be recognized along this map

1- Introduction

During the last decades, it was obviously clear that the groundwater considered as one of the major natural sources in many countries. Groundwater have more than one important reasons to be preferable than the surface water such as, it is well protected against the action of pollutant infiltration, less subjected to seasonal and diurnal variations and it has also commonly accumulated in desert areas. Geophysics plays an important role in hydrogeological investigations. Owing to its detailed acquainted information and less cost comparing to drilling data, electrical resistivity method is widely used for such approach. Water quality, hydraulic properties for aqueous reservoirs and saline water contamination can be determined using such technique.

Zubair–Safwan study area is located at southern part of Basrah governorate / South Iraq (Fig.1) where groundwater resources have been employed for irrigation purposes since 50 years ago. Increasing demand for groundwater caused to depletion in its resources, which led to decrease in both quality and quantity of it. The study area has more than one of the geomorphologic features such as the existing of sand dunes and Jabil Sanam (Al-Kubaisy, 1999). Tectonic setting of the meant area shows that it located within the southern part of the unstable shelf within Basrah Platform. On the basis of geophysical surveys, the basement rocks reach to the depth of 10 km (Jassim and Goff, 2006). Many investigators had been performed their researches dealing with this technique, such as Sang-Ho *et al.*, 2002 made their geochemical and geophysical monitoring of saline water intrusion in Korean Paddy Fields. Also, Oteri, 1982, achieved his geoelectric investigation of saline contamination of a chalk aquifer by mine draing water at Tilmanstone, England.

The present research aimed to identify the number of geological subsurface beds and their thicknesses, mapping water table in order to distinguish the salt wedge intrusion through the Dibddiba aquifer using Vertical Electrical Sounding (VES) technique by virtue of Schlumberger array.



(Fig.1) Location of the studied area

Geologic Setting:

Dibddiba Formation is commonly observed as outcrop southern Iraq including the area understudy. It tends to be slightly inclined towards eastern north direction forming Dibddiba plain (Upper Miocene – Pliocene). Their deposits are changing gradually from marine to estuarine deposits (Clastic Terrigenous) (Buday, 1980). Type section of Dibddiba Formation in southern Iraq consists of alteration of sand and gravel beds with thin bedding of mud, limestone and chert. The maximum thickness is about 314 m and was observed in northern of

Zubair oil field (Bellen *et al.*, 1959). The existence of mud lenses within the formation deposits is to be indicated for quiet depositional environment into closed or semi closed basins of deltaic environment. Quaternary deposits are covering the old lithologic units and Dibddiba Formation as seen in Wadi Albatin (Al-Rawi *et al*., 1987).

Hydrology and Hydrogeology:

Dibddiba Formation at Zubair–Safwan region is subdivided into two parts, the unconfined aquifer with saturated brackish thickness interval ranging from 10-20 m and the lower confined (brackish–Saline) aquifer (Haddad and Hawa, 1979). The groundwater recharge is mainly happened due to the infiltration of water from the small valleys during the rainfall season. The water budget detailed study revealed that the upper sand part of Dibddiba Formation in Zubair-Safwan area is subjected to depletion during the last two decades as a result of the unplanned water pumping for the annual irrigation purposes (Ala'a and Al-Asadi, 2006). Khur Al-Zubair has salinity higher than its in the marine water. Whereas, it is influenced by tidal action and fluctuation of Shatt Al-Basrah cannel that connected to Al-Masab Al-Am canal. Sea water intrusion through the eastern part of the area along the costal line of Khur Al-Zubair is one of the possible reasons that led to the poverty in groundwater quality of the unconfined part. Overutilize of the groundwater and the relationship between the watershed and the aquifer cause to the movement of saline water towards the western part of the studied area, which in turn would affect negatively on such water resource. As a result of unplanned groundwater pumping, sea water would intrude into the above aquifers leading to lowering in their quality levels. Therefore, natural hydraulic gradient will be inversed towards land.

Methodology:

To achieve the current study, IRIS instrument-Syscal R2 with Converter 2000 W have been used. Precisely field work was done via Vertical Electrical Sounding using Schlumberger array covering an area of 240 Km^2 (with the assistance of specialized geophysical team) for nearly one year. Five profiles were distributed across the study area from Zubair district (North) to Um-Qasir county (South) (Fig.1). The length of the selected profiles B-B$^-$, C-C$^-$ and E-E$^-$ is about 7.5 Km with distribution of 16 VES points of each. While the length of A-A$^-$ and D-D$^-$ was 6.5 Km and 6 Km with distribution of 14 and 13 VES points respectively. The distance between profiles is differs from one to another according to work difficulty within the field. VES points for each profile were distributed equally with 500 m separated distance. The total amount of measuring VES points is 75. At each point there were 32 resistivity measurements. 80 m and 500 m are the maximum distances between total MN and AB electrodes respectively.

12 wells were drilled in the whole area (Fig. 1) using drilling Auger machine named "MR2000" belongs to the General Authority of Groundwater / Zubair Branch; however, water table levels were also measured during nine months (14/4–15/12/2009) as illustrated in Table-1. Wells W2, W5 and W7, W9, W10 were not included in this table because they were drilled near wells W1 and W6 respectively in order to determine water levels existing in the other underlying aquifers that might determined from electrical interpretation. A groundwater flow map for the upper aquifer had been plotted by the author for the last measuring day (14/12/2009) using processing MODFLOW for windows ver. 5.3 software (Fig.2), and it seems that the flow direction of groundwater is from northwest towards southeast parts of the considered area opposite to the marine water intrusion. Therefore, intrusion extremely depends upon pumping quantities.

Interpretation of Electrical Resistivity Data:

1-Qualitative Interpretation:

75 electrical field curves had been plotted depending on the apparent resistivity values for all mentioned measuring points. The qualitative interpretation of these curves shows that the soil has a wide range of resistivity values due to the fact of the agricultural operations as well as groundwater salinity. According to the nature of these curves, lateral and vertical variation in resistivities distribution of the surface layer of the meant area was established. Whereas, in some parts of the field curves there were high values of resistivity that may indicate the presence of dry sand, gravel and gypsum deposits. On the other hand, other VES points showed low resistivities of wet sand, silt and clays. Steep decreasing in the lower part of the resistivity curves related to depth could be explained to water table existence (Fig.3). On the basis of curves patterns, they were classified into 13 types (QQQ, QQ, HKQQ, KHK, QHK, HK, KQQ, KQQQ, KQ, HKQ, QH, QQQQ and Q) as illustrated in the table-2 below.

2-Apparent Resistivity Space Sections:

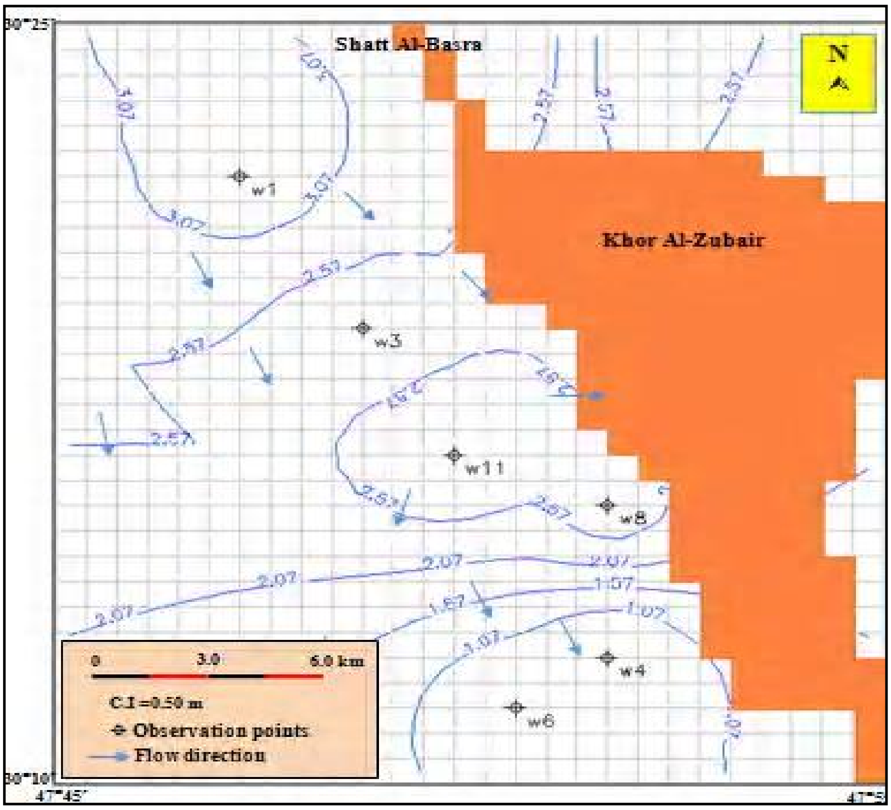
Five space sections of apparent resistivity were plotted using **IPI2Win** (Russian software). AB/2 spacing was ranged between 1.5–250 m. These sections showed gradual variation in apparent resistivity distribution according to the increment of current electrode layout. This is because of the diversity in moisture content and sedimentation with depth, especially at water table bearing. It also can be seen that resistivities were increased along the selected profiles from eastern part of Khur Al-Zubair and Shatt Al-Basrah canal towards west (Farms area), associated with appreciate concentrations of salinities. Vertical and horizontal variations in resistivities were observed at AB/2 spacing ranging between 1.5-10 m. It might be clue to the variation in moisture content and sediments underneath surface layers. The resistivity space sections of the studied area can be explained as following:

- **Section A-A⁻ : (Fig.4)**

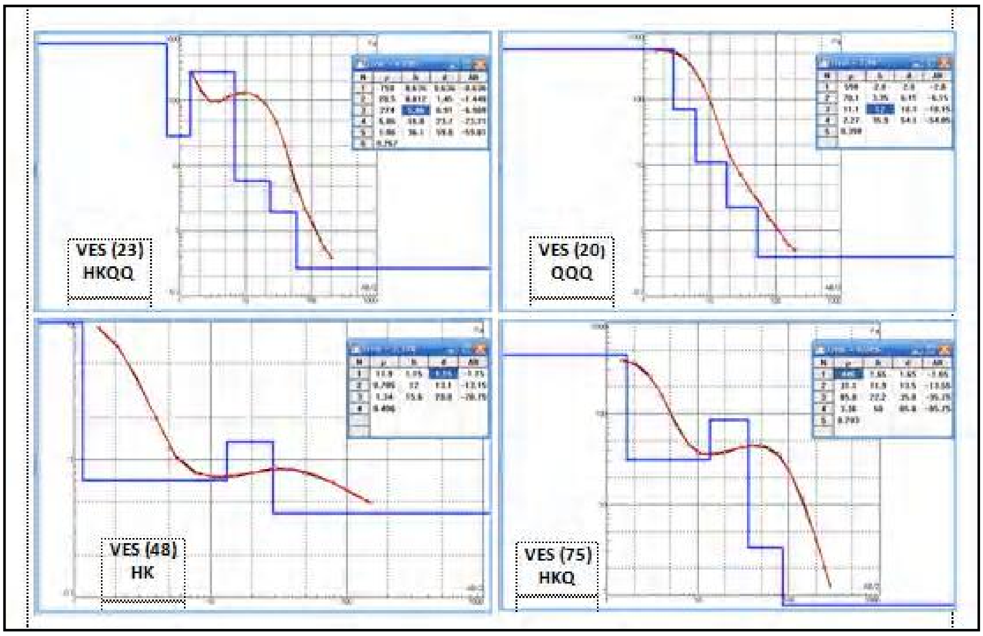
VES points 1, 2, 3 and 4 are points of low resistivities (less than 20 ohm.m) at 1.5-10 m of AB/2 spacing, where the high moisture content of the surface layers could be found as a result. While, the moisture content is owed to the approached groundwater level. For AB/2 spacing greater than 10 m, there will be significant decline in resistivity values. Otherwise, the rest of VES points revealed high resistivities at first of layout .The majority of these were in VES 6, 7, 8, 9, 10, 11 and 12. The biggest contour closure (more than 200 ohm.m) of extension about 350 m is resulted by dry sand and gravel deposits. In general, AB/2 spacing ranging between 20 – 250 m, have had low resistivities less than 20 ohm.m due to groundwater saturation.

(Table-1) Groundwater levels of the observation wells (upper aquifer) (measurements were executed by the field team)

Well No.	Depth (m)	Water table (m.) (a.s.l) measured in 2009									
		Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	14/12/2009
W1	30.60	3.22	3.18	3.15	3.13	3.09	3.06	3.02	2.98	2.94	3.28
W3	25	2.30	2.25	2.20	2.20	2.19	2.18	2.18	2.17	2.17	2.34
W4	30.60	0.54	0.60	0.60	0.60	0.52	0.52	0.45	0.45	0.40	0.54
W6	30.60	0.35	0.36	0.38	0.40	0.30	0.30	0.25	0.23	0.20	0.69
W8	30	3.20	3.00	2.92	2.75	2.66	2.60	2.59	2.55	2.50	3.60
W11	30	0.45	0.52	0.63	0.75	0.75	0.76	0.82	0.82	0.84	0.35
W12	30	-	-	-	-	-	-	-	-	-	0.45



(Fig.2) Groundwater levels map of the studied area showing flow direction



(Fig.3) Examples of electrical field curves

Table-2: Electrical resistivity values, thicknesses and curves types obtained from software interpretation

Profile Symbol	*VES Point*	*Electrical resistivity (r) in (Ohm.m) and thickness (h) in meter*											*Curve Type*
		Layer 1		*Layer 2*		*Layer 3*		*Layer 4*		*Layer 5*		*Layer 6*	
		r_1	h_1	r_2	h_2	r_3	h_3	r_4	h_4	r_5	h_5	r_6	
A-A-	1	0.6	0.7	2	2	0.5	11	1.5	44	0.6	-	-	*KHK*
	2	5.3	1.7	0.4	11	2	25	0.5	-	-	-	-	*HK*
	3	1.4	1	3	2	1.7	45	0.6	-	-		-	*KQ*
	4	11	1	1	1	4	10	1.6	34	0.6		-	*HKQ*
	5	117	3	18.7	6	3.8	12	1	22	0.4	-	-	*QQQ*
	6	492	2	54	5	6	22	10.5	45	0.1	-	-	*QHK*
	7	274	0.5	2848	0.7	62	4	8	12	2.6	30	0.7	*KQQQ*
	8	1166	1.7	75	4	6.7	21	1.8	52	0.8	-	-	*QQQ*
	9	1014	1	39	5.3	98	5	8.6	28	1.5	41	0.7	*HKQQ*
	10	682	1	231	8	15	22	3	62	0.6	-	-	*QQQ*
	11	533	1	15	2	86	10	9.7	25	2.7	48	0.8	*HKQQ*
	12	1316	0.8	13	1	60	10	17.4	25	1.3	42	0.5	*HKQQ*
	13	80	1	46	14	8.6	25	3	42	0.7	-	-	*QQQ*
	14	406	0.7	5.5	0.6	22.5	13.6	10.5	10.5	2.5	36	0.4	*HKQQ*

Continued table-2

Profile Symbol	*VES Point*	*Electrical resistivity (r) in (Ohm.m) and thickness (h) in meter*											*Curve Type*
		Layer 1		*Layer 2*		*Layer 3*		*Layer 4*		*Layer 5*		*Layer 6*	
		r_1	h_1	r_2	h_2	r_3	h_3	r_4	h_4	r_5	h_5	r_6	
B-B-	15	9	1.5	3	19	1.2	32	0.2	-	-	-	-	*QQ*
	16	7	1.7	3	12	1.2	29	0.4	-	-	-	-	*QQ*
	17	14	2.6	3.2	9.3	1	45	0.6	-	-	-	-	*QQ*
	18	16	2.8	2	19	1	42	0.3	-	-	-	-	*QQ*
	19	41	1.3	3.5	12	1.8	40	0.5	-	-	-	-	*QQ*
	20	590	2.8	70	3.4	9	12	2.3	36	0.4	-	-	*QQQ*
	21	307	1	39	2	210	4	7	20	1.4	44	0.4	*HKQQ*

Profile Symbol	*VES Point*	*Electrical resistivity (r) in (Ohm.m) and thickness (h) in meter*											*Curve Type*
		Layer 1		*Layer 2*		*Layer 3*		*Layer 4*		*Layer 5*		*Layer 6*	
		r_1	h_1	r_2	h_2	r_3	h_3	r_4	h_4	r_5	h_5	r_6	
	22	240	0.6	39	1	193	8	7	12	1.6	49	0.3	*HKQQ*
	23	1803	0.5	21	0.6	257	6	5.4	16	2	40	0.3	*HKQQ*
	24	446	2	60	4	13.4	15	1.4	61	0.5	-	-	*QQQ*
	25	301	3	26	18	91	15	2.2	55	0.5	-	-	*QQQ*
	26	263	0.7	405	3	55	9	10	22	1.4	61	0.5	*KQQQ*
	27	1504	1.3	37	6.6	10.3	29	3	48	0.3	-		*QQQ*
	28	1418	1.8	41	9	27	25	8.3	39	0.3	-	-	*QQQ*
	29	1252	1	37	9	17	28	4	44	0.3	-	-	*QQQ*
	30	1500	2	100	18	26.3	10	5	48	2.5	-	-	*QQQ*
C-C-	31	0.6	2	0.2	2.4	1.5	8.4	0.3	-	-	-	-	*HK*
	32	0.8	2	0.6	12	0.3	22	0.9	-	-	-	-	*QH*
	33	0.8	2	0.7	9	0.4	30	0.9	-	-	-	-	*QH*
	34	3.8	0.7	6.5	1.4	0.9	25	0.5	19	0.2	-	-	*KQQ*
	35	13.6	0.8	3	8	0.8	110	0.01	-		-	-	*QQ*
	36	17.3	0.7	6.3	3	1	24	0.5	-	-	-	-	*QQ*
	37	19	1.2	3	2.3	1	27	0.6	-	-	-	-	*QQ*
	38	975	0.7	6	4	2	14	0.9	-	-	-	-	*QQ*
	39	13.3	1	2.2	5	1.6	25	0.8				-	*QQ*
	40	224	1.2	4.5	6	1	29	0.4				-	*QQ*
	41	495	2.3	37	11	15.3	16	2.4	26	1		-	*QQQ*

Profile Symbol	*VES Point*	*Electrical resistivity (r) in (Ohm.m) and thickness (h) in meter*											*Curve Type*
		Layer 1		*Layer 2*		*Layer 3*		*Layer 4*		*Layer 5*		*Layer 6*	
		r_1	h_1	r_2	h_2	r_3	h_3	r_4	h_4	r_5	h_5	r_6	
	42	1000	1	147	13	11	23	2.4	57	0.3		-	*QQQ*
	43	494	2.3	36	14	10	20	1.4	44	0.8		-	*QQQ*
	44	988	1.2	69	6.4	29	26	1.1	73	0.3		-	*QQQ*
	45	500	1	160	1.5	497	6.7	25	12.6	6.4	24	0.3	*HKQQ*
	46	63	2	90	7	22	10	5.5	29	0.5	-	-	*KQQ*

Continued table-2

Profile No.	*VES Point*	*Electrical resistivity (r) in (Ohm.m) and thickness (h) in meter*											*Curve Type*
		Layer 1		*Layer 2*		*Layer 3*		*Layer 4*		*Layer 5*		*Layer 6*	
		r_1	h_1	r_2	h_2	r_3	h_3	r_4	h_4	r_5	h_5	r_6	
D-D'	47	11	1.5	0.6	14	1.4	16	0.3	-	-	-	-	*HK*
	48	12	1	0.7	12	1.4	16	0.4	-	-	-	-	*HK*
	49	2.4	1.6	0.13	2.5	3	12	0.3	-	-	-	-	*HK*
	50	138	2	14	6	4	18	0.5	-	-	-	-	*QQ*
	51	20	0.6	7	4	2	13	1	64	0.2	-	-	*QQQ*
	52	12	3	6	12	0.9	-	-	-	-	-	-	*Q*
	53	10	6	3	10	1	50	0.4	-	-	-	-	*QQ*
	54	175	1.5	7.6	5.3	3	24	0.3	-	-	-	-	*QQ*
	55	43	0.4	223	1	4.7	9	2	26	0.5	-	-	*KQQ*
	56	446	1	68	3	5.5	9	2	25	0.4	-	-	*QQQ*
	57	148	1.2	41	2	9	10	2	27	0.5	-	-	*QQQ*
	58	28	1.7	102	9	9	20	2	38	0.2	-	-	*KQQ*
	59	154	0.7	26	1.6	16	16	4	10	2	38	0.6	*QQQQ*

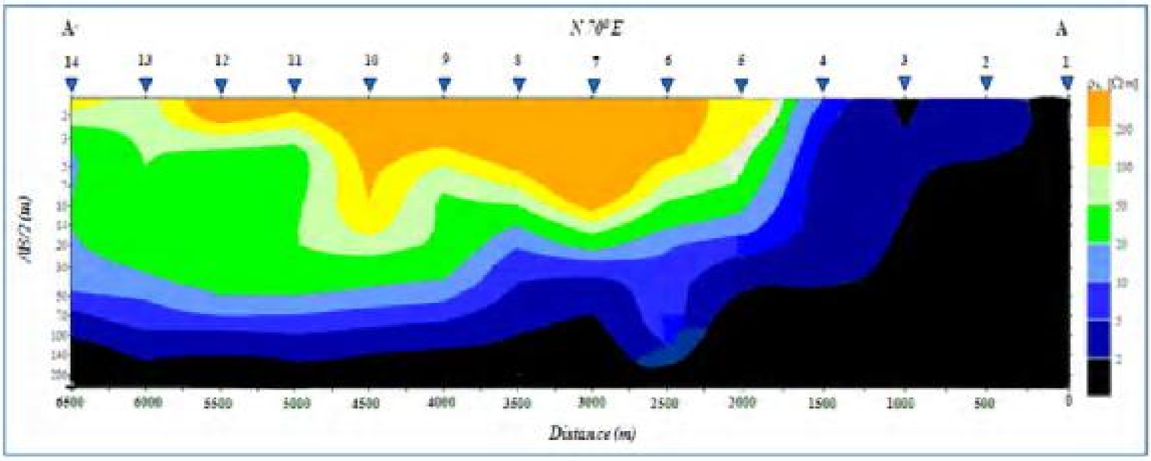
E-E⁻	60	2	0.5	9	3	4	15	0.5	-	-	-	-	*KQ*
	61	20	1	9	4	5	17	0.6	-	-	-	-	*QQ*
	62	95	0.5	16	5	6.4	14	0.7	59	0.3	-	-	*QQQ*
	63	349	1	15	3	7.4	14	1	44	0.3	-	-	*QQQ*
	64	396	0.6	81	4.4	7.3	11	1.4	47	0.3	-	-	*QQQ*
	65	523	1.4	131	4	12.5	16	1	57	0.2	-	-	*QQQ*
	66	203	1	17	1.7	82	5	4	25	1.8	38	0.3	*HKQQ*
	67	850	0.6	19	1	153	2.7	10	20	2.2	49	0.4	*HKQQ*
	68	321	0.8	29	0.6	125	7.6	29	16	6	45	0.3	*HKQQ*
	69	1186	2.4	85	15	34	25	2.5	77	0.2	-	-	*QQQ*
	70	1300	0.7	449	4	96	12	41	22	22	40	0.2	*QQQQ*
	71	338	3.5	88	8	40	25	20.5	39	1	-	-	*QQQ*
	72	1430	1.3	387	10	52	23	14	42	1	-	-	*QQQ*
	73	311	1.4	132	11	54	23	12	41	0.6	-	-	*QQQ*
	74	365	2	70	11	42	20	9.2	57	0.1	-	-	*QQQ*
	75	446	1.7	31	12	51	22	3.4	50	0.7	-	-	*HKQ*

Section B-B⁻ : (Fig.5)

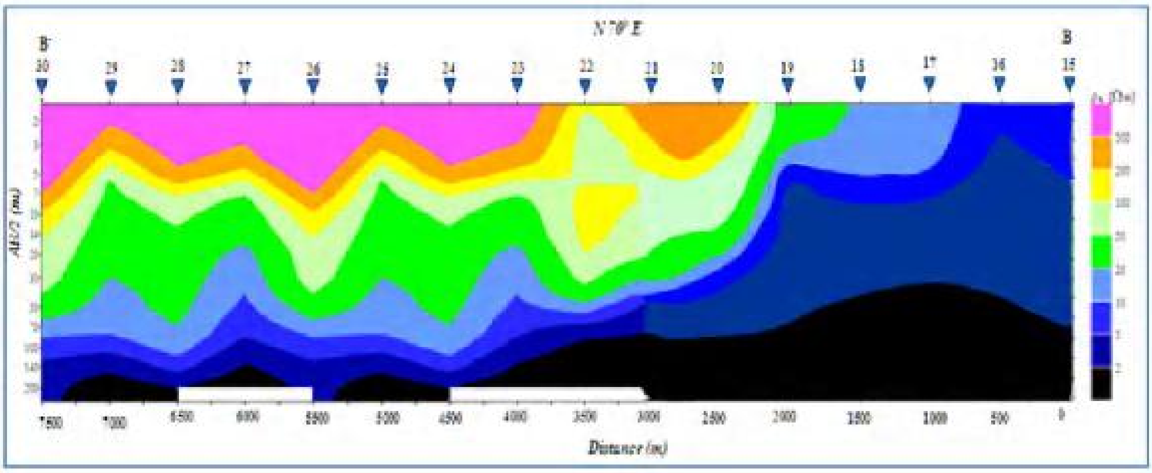
VES measuring points 15,16,17 and 18 showed low resistivities less than 20 ohm.m at the beginning of electrode layout as the same reason as in section A-A⁻ , then it will be followed by distinct decreasing in resistivities depending upon extension of AB/2 spacing. Whereas, the remained points have high resistivities at layout starting, especially at VES 23, 24, 25, 26,27,28,29 and 30. A 375 m contour closure of 500 ohm.m noticeably distinguished in this section and another contour closure of 100 m and 200 ohm.m of VES 20 and 21 is also founded which represented by dry sand with proportional gravel and gypsum deposits. Gravel lens belongs to 10 m contour closure of 100 ohm.m in VES 21 and 22 were also observed in this section. Saline groundwater could be investigated in low resistivity zones (less than 2 ohm.m) in which the AB/2 spacing is 200 m.

- **Section C-C⁻ : (Fig.6)**

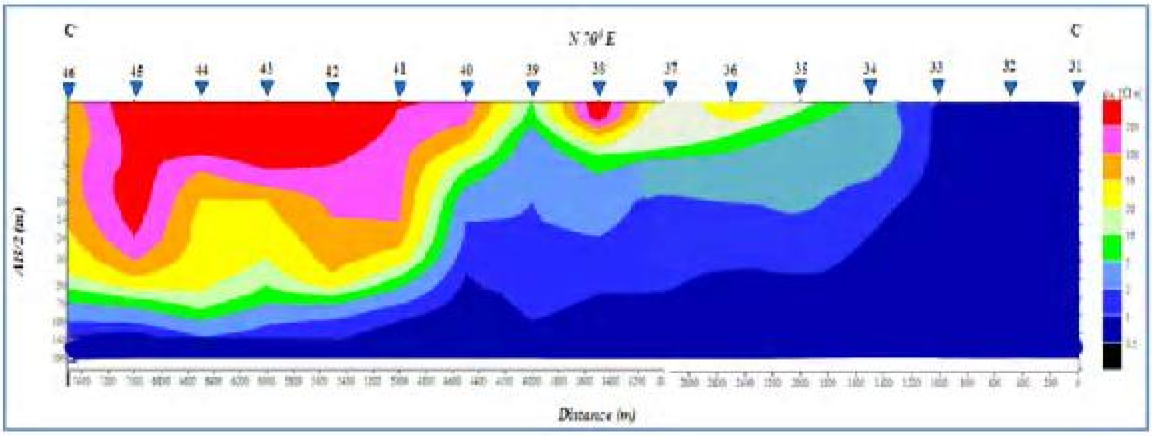
At the beginning of spreading, VES points 31, 32, 33 and 34 showed low resistivities (less than 10 ohm.m) due to the effect of groundwater level on the surface layers. As distance of layout spacing increased, there will be pronounced lowering in resistivity values. On the other hand, the other remained points showed high resistivities at the first layout spacing as seen in points 41, 42,43,44,45 and 46. Contour closure at 2250m of resistivity greater than 200 ohm.m has been noticed in the above VES's and it is also appears in VES 38 owing to the presence of dry surface layer. An appreciate decreasing in resistivities at VES 39 can be explained to the effect of unplanned groundwater dewatering. Towards bottom, resistivities will decrease as the layout spacing increased till it becomes 5 ohm.m at 70 m AB/2 of saline saturated zone.



(Fig. 4) Space section of the profile (A-A⁻)



(Fig. 5) Space section of the profile (B-B⁻)



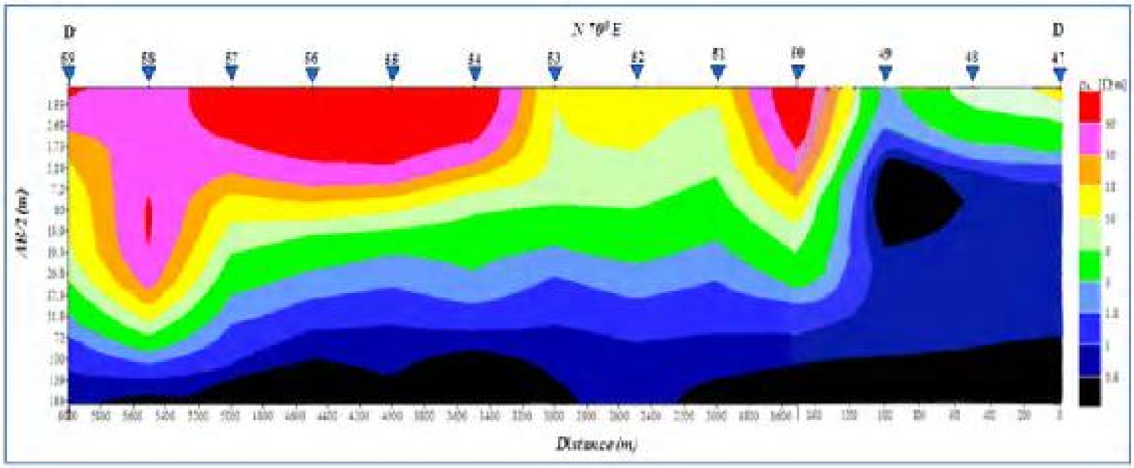
(Fig. 6) Space section of the profile (C-C⁻)

- **Section D-D⁻ : (Fig.7)**

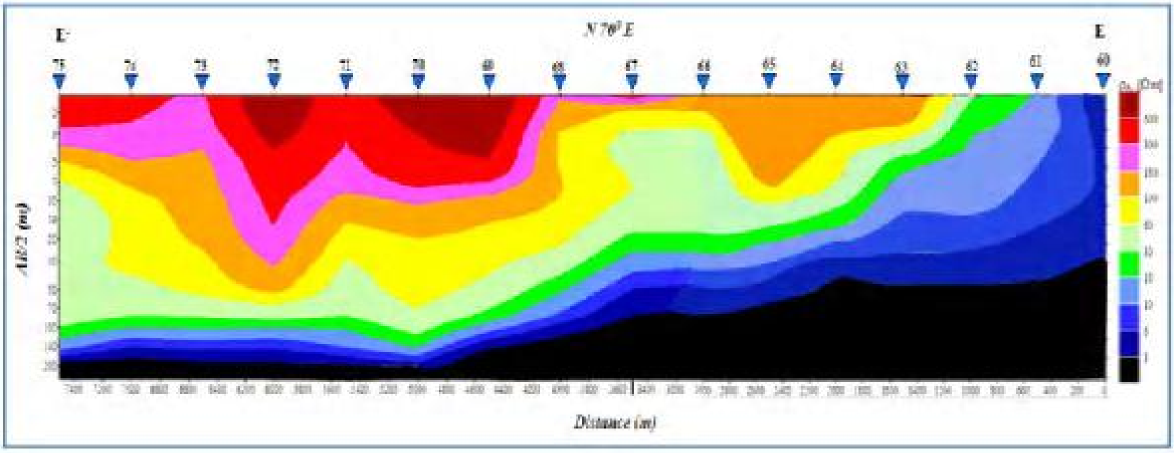
VES measuring points 47, 48, 49, 51, 52 and 53 revealed low resistivities (less than 15 ohm.m) at the beginning of spreading. From VES 49 we can clue the effect of moisture on the surface layers owing to be near to the groundwater level. It also has significant amount of clay deposits. Noticeably, the resistivity contour lines are declining with increment of spreading spacing among the electrodes. On the other hand the rest of VES's showed moderate resistivities at the commence layout. A 6o Ohm.m closure of 1750 m of extension has been noticed in both VES 50 and 59. It also can be seen at VES 58 of 8 m in extension which followed by decreasing in resistivity (less than 3 Ohm.m) as the spreading spacing increases simultaneously the thing that would lead us to the thought of being approached to salt water saturation zone.

- **Section E-E⁻ : (Fig.8)**

This section shows resistivities lower than 18 Ohm.m at the beginning of spreading, especially at the VES points 60 and 61. These values indicate the influence of the moisture content regarding to its near to groundwater table and the existence of some clay deposits. On the other hand, VES 63, 64, 65 and 66 recorded higher values than 100 Ohm.m. While the other points 69, 70 and 72 had values greater than 180 Ohm.m. The way that makes it different from the other profiles. In general, the perceptive decreasing in resistivities can be observed along the studied profiles and for this profile we can see that the resistivity was lowered to reach 6 Ohm.m, which indicates for the water table bearing.



(Fig. 7) Space section of the profile (D-D⁻)



(Fig. 8) Space section of the profile (E-E⁻)

2- Quantitative Interpretation

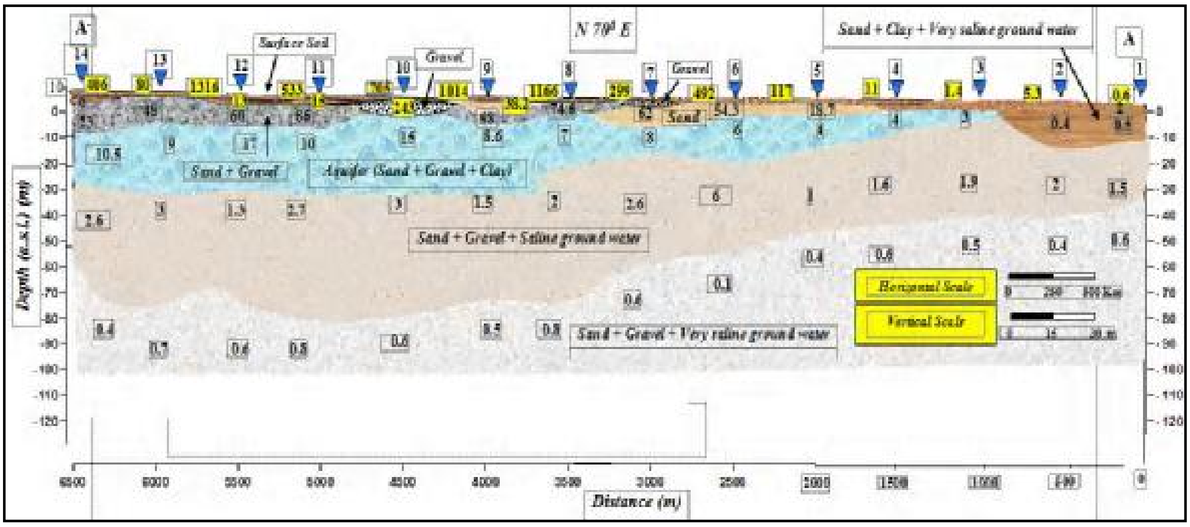
Five geoelectrical sections were drawn along the selected profiles in which manual quantitative interpretation was firstly done using auxiliary point of partial curve matching method (Ebert technique) depending on Orellana and Mooney, 1966 and Compagnie General de Geophysique, 1963 theoretical master curves. Then, IPI2WIN program was used to fulfill the quantitative interpretation for the same sections in the direction N 70^0 E . Number of the subsurface layers, depths, thicknesses and water table levels were determined for each VES point along the investigated profiles. The interpretation revealed highly resistivity values with significant variations especially at the beginning of spreading spacing where AB/2 is small. This can owed to the heterogeneity in sediments of surface layers. Geoelectrical sections denote to the existence of surface layer that characterized by its moisture content and dry sediments such as sand, gravel with few amount of gypsum which spreading laterally. Decreasing of the apparent resistivity values with depth were noticed especially in groundwater bearing intervals due to the effect of high concentration of salinity as shown in the middle of these sections. Due to unprogrammed groundwater pumping, high concentration of salinity in the lower part of the Dibdibba aquifer might be altering the upper part of its and changing it from fresh or brackish to saline. The interpretation of the studied area sections clarified that there are three underlying groundwater bearing beds. Thicknesses and resistivities of the first two beds for the five sections are as follows:

- The first bed thicknesses are ranging between 10-25 m, 10-28 m, 8-26 m, 10-27m and 11-25 m and the resistivity values were ranged between 3-7, 3.5-27, 1-25, 2-8 and 3-51 ohm.m respectively.

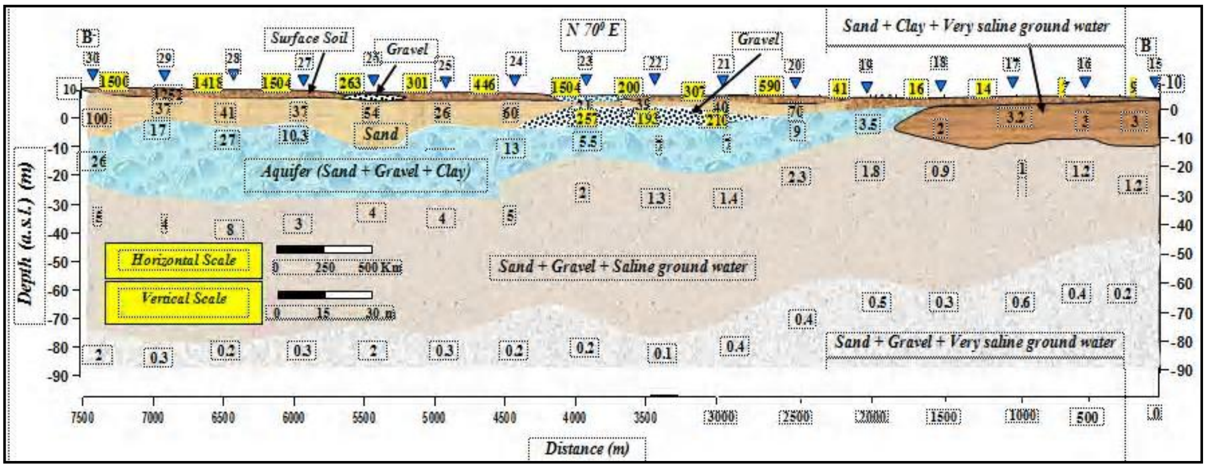
- The second bed thicknesses are ranging between 30-62 m, 36-60 m, 24-73 m, 36-38m and 37-77 m and the resistivity values for these sections were ranged between 1-3, 0.9-8, 1.4-6, 1.5-2 and 1-14 ohm.m respectively. While for the third bed we have acquainted their resistivity values: 0.5 (average value), 0.2-2, 0.2-2, 0.4 (average value) and 0.2-1 ohm.m respectively. Lithology, resistivities and thicknesses of the extracted three beds were drawn with the assistance of drilled observation wells in the area as shown in the geoelectrical sections below (Figs. 9, 10, 11, 12 and 13).

It can be drawn that the groundwater aquifer is subdivided into three beds. The first one that contains brackish water is consist of sand deposits, gravel and clay. The second bed of saline water is consisting of sand and gravel. While the third bed has similar lithology to the above one, but with very saline water. The decreasing in resistivity versus depth increasing can be seen towards Khur Al-Zubair and Shatt Al-Basrah canals. So, this is explaining the high concentration of salinity of groundwater in these areas as a result of both vertical salt water intrusion into the bed beneath Dibdibba Formation and lateral intrusion by the marine water intrusion of Khur Al-Zubair.

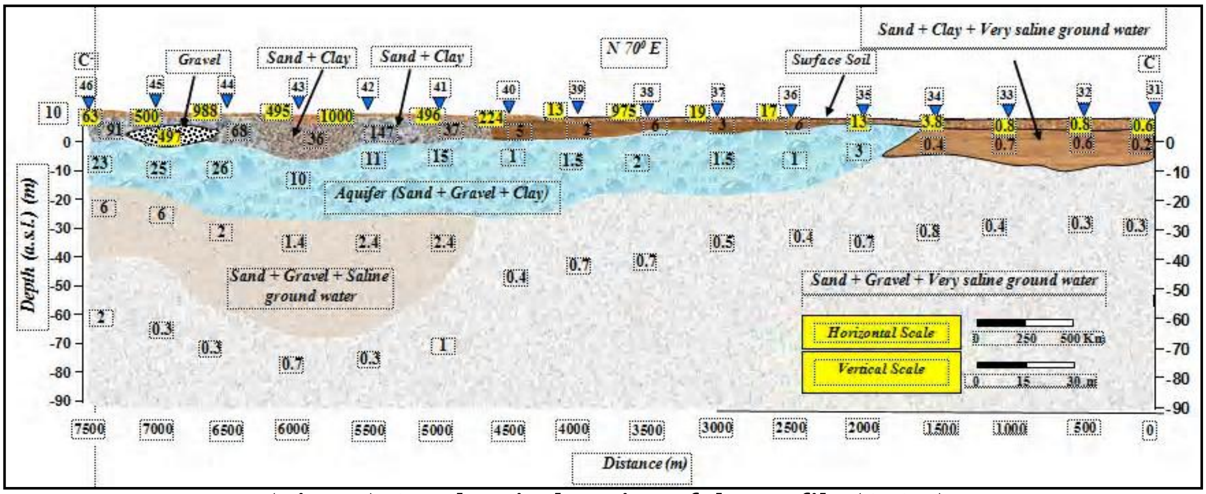
In order to get better understanding about the distribution of groundwater resistivities of the upper part of Dibddiba aquifer, a resistivity contour map has been plotted (Fig.12), whereas these resistivities have values of AB/2 spacing complied with real depth that salt water intrusion have been reached and an irregular front line of marine water intrusion coming from Khur Al-Zubair coast can be distinguished along this map (the line which separates between light highly resistivities and dark low resistivities) . On the basis of salt water intrusion at each AB/2 spacing for VES points, we could estimate the preferred location in which we can make the best selection for drilling decisions to yield fresh groundwater for irrigation purposes



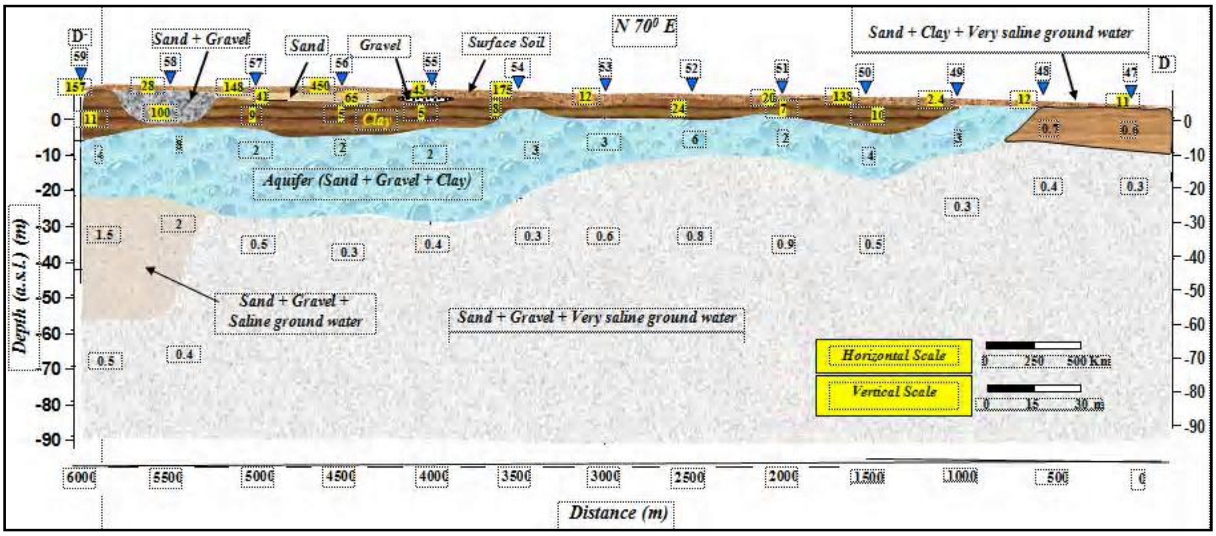
(Fig. 9) Geoelectrical section of the profile (A-A⁻)



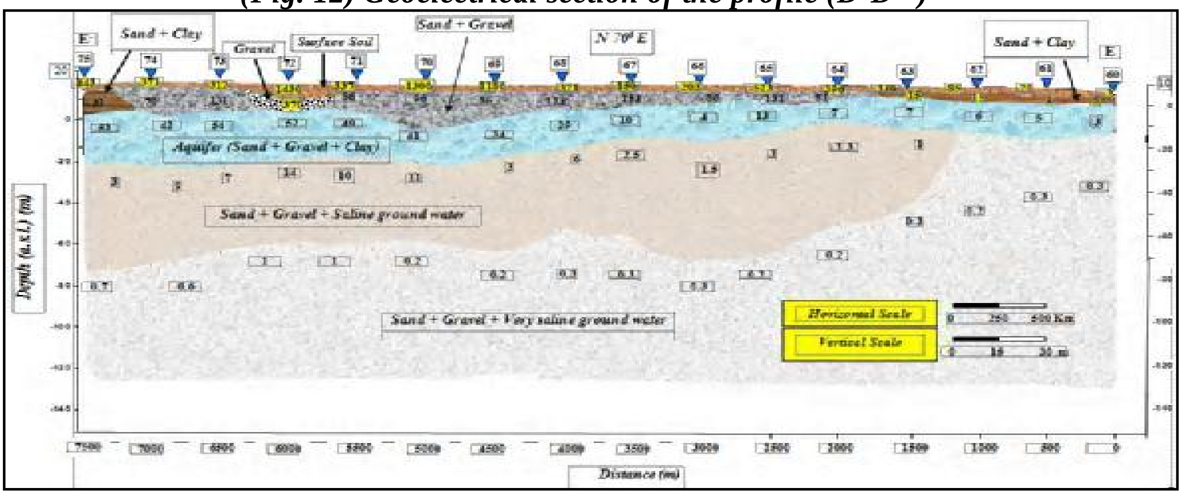
(Fig. 10) Geoelectrical section of the profile (B-B⁻)



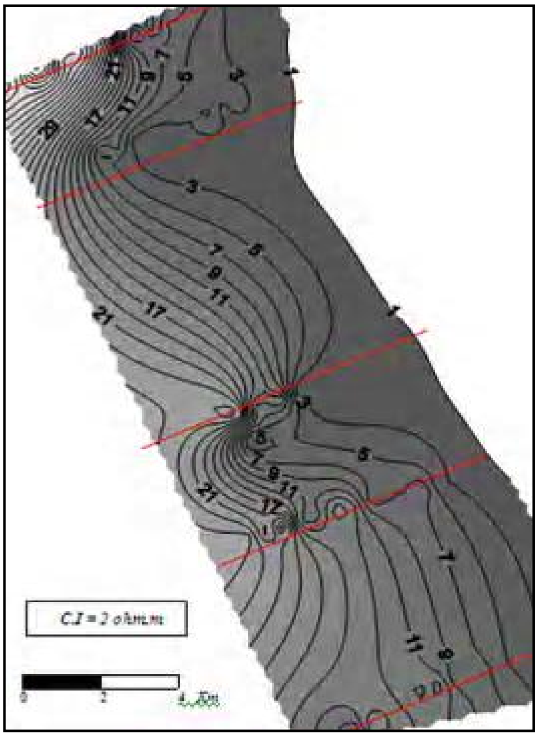
(Fig. 11) Geoelectrical section of the profile (C-C⁻)



(Fig. 12) Geoelectrical section of the profile (D-D⁻)



(Fig. 13) Geoelectrical section of the profile (E-E⁻)



(Fig. 12) Iso-resistivity map for the area understudy

Hydrogeochemical Analysis

In order to get better information about salt water intrusion, there is a real need to investigate the hydrogeochemical analysis for such samples to improve the exact intrusion might salt water have. Type and the source of the groundwater were studied depending upon the chemical analysis (that made by the groundwater authority- Zubair Branch) for several samples extracted from five observed wells drilled in the area understudy (Table-3). It shows that the type of the water existed in the wells away from Khur Al-Zubair area is brackish, while the saline water is presented at the nearest wells. Source of the groundwater at wells located near Khur Al-Zubair coastal is mainly related to chloride group with marine origin. Moreover, rises of the saline water from lower part of Dibdibba aquifer towards the upper one may mix both saline and brackish water together due to the extensive pumping operations in western area and make it more saline. Chemical type of this water is mainly referred to continental origin. Therefore, groundwater chemical results were extremely support our performed electrical interpretations.

(Table-3) Hydrogeochemical analysis for the selected groundwater samples

Well No.	TDS	Groundwater chemical analysis (ppm)					Type of water
		Mg^{+2}	Na^{+}	Cl^{-}	Mg/Cl ratio	Na/Cl ratio	
W1	6501	261.5	11.8	1554.5	0.00759087	0.1682213	NaCl
W3	7600	327.7	391	1649.5	0.23704153	0.1986663	NaCl
W4	3595	679.8	13.79	148	0.02028538	0.2177111	NaCl
W6	7436	1899	402	325.6	0.21169036	0.1714587	MgCl
W11	8310	2349.3	601	232.2	0.25582088	0.098838	MgCl

Conclusions

According to the nature of electrical field curves, qualitative interpretation was applied and 13 types (QQQ, QQ, HKQQ, KHK, QHK, HK, KQQ, KQQQ, KQ, HKQ, QH, QQQQ and Q) were classified. Moreover, five space sections, five geoelectrical sections and iso-apparent resistivity map were drawn along the selected profiles was used to complete the quantitative interpretation . The interpretation of the above results gives large variations occurred in the apparent resistivity values especially at the beginning spreading distances when AB/2 is small. It represents the existence of surface layer that characterized by its moisture content and the presence of dry sediments such as sand, gravel and few sediments of gypsum which spreading laterally. Also, decreasing of the apparent resistivity values with depth is noticed especially at the groundwater bearing intervals. This is because of the salinity increases occurred in groundwater at these intervals especially at the mid-way of all considered profiles. The rises of the saline water belong to the lower part of the Dibdibba aquifer towards the brackish to fresh water existed in the upper one due to the unprogramming pumping processes may cause mixture between them and make the resultant water more saline. Large reduction in the true resistivity values is also observed at the eastern parts of the study area near Khur Al-Zubair boundaries which indicates highly electrical conductivity values; however, this is led to the increasing of the saline water that probably comes from the sea.This fact is certainly approved by the interpretation of the iso-resistivity contour map that plotted for the upper unconfined aquifer. A irregular front line may drawn along this map that separates between brackish and saline water the matter which make us to conclude the proper locations for irrigation drilling.

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الخلاصة

تضمن العمل الحقلي القيام بمسح كهربائي عمودي باستخدام ترتيب شلمبرجر في (78) نقطة جس كهربائي والواقعة ضمن محافظة البصرة / منطقة الزبير- سفوان / جنوب العراق وذلك بهدف تحديد عدد الطبقات تحت السطحية وأعماقها وسماكاتها فضلا عن تحديد مناسيب المياه الجوفية ودراسة مدى تأثرها بالمياه المالحة المتأتية سواءا من البحر أو من طبقات أعمق.

فسرت منحنيات المقاومة النوعية الحقلية لجميع نقاط الجس الكهربائي نوعيا للحصول على صورة أولية للتغاير الجانبي والعمودي للمقاومة النوعية للطبقات تحت السطحية فضلا عن صخاريتها، بعد ذلك تم تفسيرها كميا بأستخدام برنامج (IPI2win) حيث رسمت من خلاله خمس مقاطع بينية وخمس مقاطع جيوكهربائية على طول خمس مسارات كل على حده. يوضح تفسير هذه المقاطع تواجد ثلاث طبقات صخرية حاوية على المياه الجوفية أذ تم حساب سماكاتها وأعماقها ومقاوماتها النوعية بالأعتماد على الآبار المحفورة في المنطقة. لوحظ من خلال تفسير المقاطع المرسومة النقصان الحاصل في قيم المقاومة النوعية مع العمق خاصة عند الفترات العمقية المحتملة لتواجد المياه الجوفية والذي يشير إلى حصول زيادة في ملوحة هذه المياه عند هذا العمق . أن أختلاط المياه المالحة للجزء السفلي من مكمن الدبدبة المائي مع المياه الجوفية المويلحة للجزء العلوي منه نتيجة عمليات السحب غير المبرمجة ربما يؤدي الى تغيير المياه المويلحة الى مالحة. لوحظ حصول أنخفاضا كبيرا في قيم المقاومة النوعية شرق منطقة الدراسة بالقرب من حدود خور الزبير لتدل بذلك على زيادة قيم التوصيلية الكهربائية وبالتالي زيادة ملوحة المياه المتأتية من أحتمالية اقتحام المياه البحرية المالحة المتأتية من البحر والتي تم ملاحظتها بصورة واضحة من خارطة تساوي المقاومة النوعية المرسومة حيث تم ملاحظة خط غير منتظم يمثل جبهة تقدم المياه البحرية المالحة باتجاه الغرب على طول الخارطة المرسومة.