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GEOELECTRICAL AND GEOCHEMICAL STUDIES FOR GROUNDWATER EVALUATION IN EL-GABEL EL-ASFAR AREA AND ITS VICINITIES, NILE DELTA, EGYPT

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The present work deals with the delineation of the water-bearing horizons through geoelectrical investigation as well as evaluation of groundwater quality through the hydrochemical analyses. This would provide the scientific basis required for launching the proposed drinking water plant.

The field work included carrying out 16-vertical electrical soundings and measuring two imaging profiles. Also, 50-groundwater samples, three reference surface water samples and three sewage water samples representing the common drains were collected.

The results showed that the subsurface succession consists of four geoelectrical zones (A, B, C and D). Zone A is dry, while zones B, C and part of zone D are water bearing. Generally, the resistivity values of these zones increase westward and decrease downward due to the increase of groundwater salinity as well as the presence of clay intercalations. By comparison between the geoelectrical and the hydrogeochemical studies in the study area, it is clear that the Quaternary aquifer (Zone B) is clearly distinguished into upper and lower parts with a groundwater salinity varying between 263 mg/l and 960 mg/l reflecting fresh water and is mainly characterized by HCO_3–Na water type, while that of Miocene groundwater (Zone C) ranges from 1056 mg/l to 2764 mg/l reflecting slightly brackish water and is characterized by Cl–Na water type. Generally, groundwater salinity increases from west to east. The Quaternary aquifer is chemically polluted as the detected constituents exceed the standard limits, representing a heavy hygienic threat, whereas the Miocene aquifer is mainly safe. Groundwater quality was evaluated for different uses and some recommendations were given.

Keywords: vertical electrical soundings, geoelectrical imaging, groundwater quality, groundwater pollution, El-Gabel El-Asfar

During the last two decades, great attention has been paid toward avoiding environmental pollution and preservation of the cultivated land. In the same time, the eastern part of Nile Delta has witnessed intensive developmental activities that led to ever-growing water demands. Due to lacking of detailed information about the subsurface setting of the area, many farm owners faced serious problems related to groundwater pollution.

The Local Unit in charge of the present area of study has proposed a drinking water plant based on the local groundwater resources to cope with the inhabitant's water demands. The present study deals with the evaluation of the groundwater resources of the area as they represent the only source of water.

The survey area is defined by lats. 30° 10' and 30° 15' N and longs. 31° 19' and 31° 26' E. It is bounded by El-Ismailia Canal due west, El-Salam-Belbeis Road due east, and the Circular Road due south, covering an area about 70 km^2 (Fig. 1).

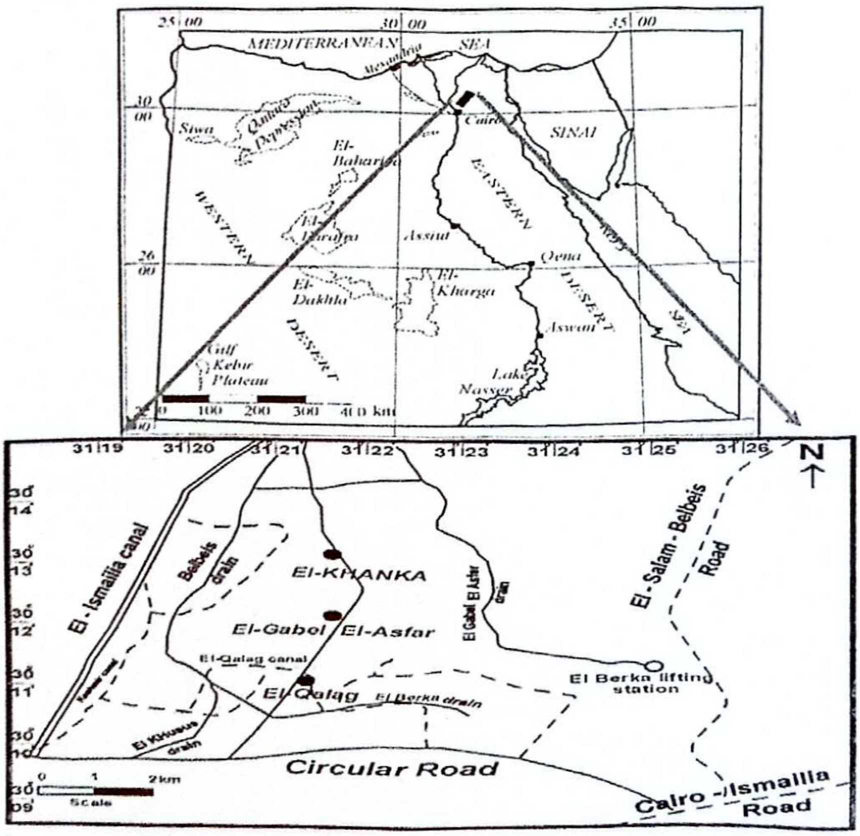

Fig. (1). Location map showing drains and canals in the study area.

The study involves delineating the water-bearing horizons through geoelectrical investigation and water quality evaluation through chemical analyses. This would provide the scientific basis necessary for launching the proposed drinking water plant.

In detail the geoelectrical and hydrogeochemical techniques were carried out to delineate:

1-The sedimentary succession with its vertical and lateral facies changes.

2-The water-bearing zones and their extension.

3-The geological structures and their impact on the groundwater occurrences.

4-The attitude of the basaltic sheet. 5- Recharge source.

6-Groundwater quality. 7- Pollution and its origin. 8- Water uses.

Physiographic Setting

The eastern part of the Nile Delta including the investigated area is characterized by a semiarid to arid climate with hot summer and mild rainy winter.

Geomorphologically, the area is characterized by slightly undulating land surface that generally slopes southwestward. The ground elevation ranges from +12m to +65m above sea level.

The surface geologic map shows that the eastern part of the Nile Delta is mainly covered by sediments and sedimentary rocks ranging in age from Tertiary to Quaternary (Fig.2). The schematically compiled stratigraphic section in the investigated area is shown (Fig. 3).

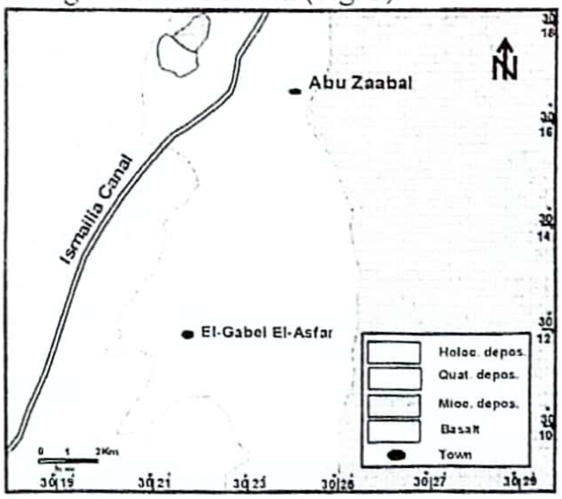

Fig. (2). Surface geologic map of the study area.

Oligocene deposits are represented by sand, gravel, sandstone, sandy clay, clay, as well as volcanic basalt which is exposed west of the Abu Zaabal area. The basalt thickness reaches about 37 m in Abu Zaabal area. The basaltic sheet unconformably overlain by the Miocene and/or Quaternary deposits (Said and Beheri, 1961). Miocene deposits are composed of coarse sand, gravel, clay and limestone interbeds with facies change laterally and vertically. Quaternary deposits are built up of clayey sand, sandy clay, sand, gravel, sand dunes, aeolian sand and sand accumulation (El-Fayoumy, 1968; Moussa, 1990).

Structurally, the investigated area and its vicinity is mainly affected by normal faults in two main trends the NE-SW Erythrean trend and the E-W Mediterranean trend (El-Fayoumy, 1968; El-Shazly *et al.*, 1975). Wells drilled by the Desert Research Center (DRC) and private companies in the area revealed that the Oligocene basaltic sheet is detected at depths ranging from 17 m in Abu Zaabal area to 84 m in El-Khanka area with a thickness of about 40 m. The detection of the basaltic sheet (as a marker bed) at different levels reflects the influence of the structures on the geologic succession and consequently, the groundwater occurrences

Age		Rock unit	Lithic description
Quaternary	Holocene		Quartz sand
	Pleistocene		Sand, gravel, Gravelly sand with clay intercalation
Tertiary	Miocene		Sand, gravels, clay and limestone intercalation
	Oligocene		Basaltic sheet
			Sand, sandstone, gravels & clay

Fig. (3). Compiled stratigraphic columnar section in the study area (After El-Fayoumy, 1968; Sadek, 1968; Barakat and Abou El Ala, 1970).

Geoelectrical Studies

Field works

Vertical electrical soundings (VES)

A total of sixteen vertical electrical soundings (VES) were carried out along four profiles (AA', BB', CC' and DD') in the investigated area (Fig. 4). Some of the VES stations were measured close to water wells.

The Schlumberger electrode configuration was used in the VES measurements with a maximum current electrode separation 1500m using the Terrameter SAS 300 resistivity meter. The instrument directly measures the resistance with high accuracy. A land topographic survey was carried out in order to determine the accurate locations and ground elevations of the sounding stations.

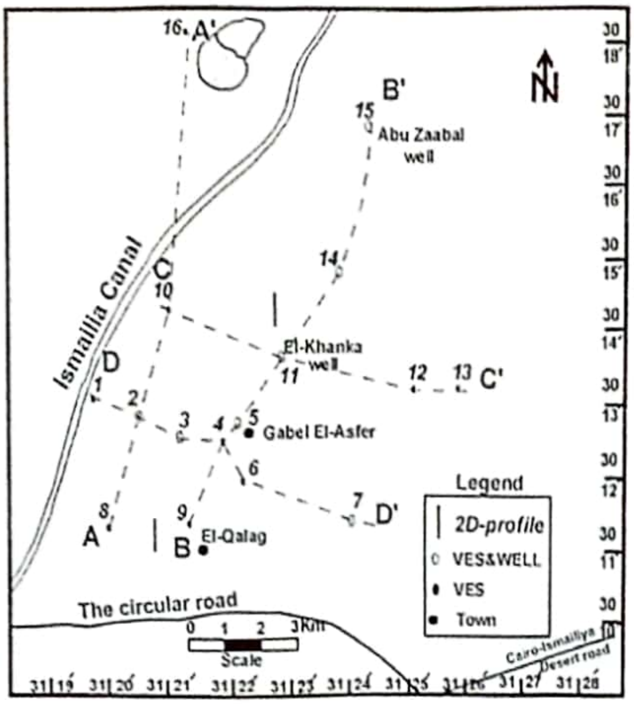

Fig. (4). Location map of VES, Wells, 2D and geoelectrical profiles.

Two-dimensional geoelectrical imaging (2D-Tomography).

Electrical Tomography or Two-Dimensional (2D) electrical resistivity imaging is a survey technique developed to investigate areas of complex geology, groundwater, fractured zones and engineering investigation. This method produces a continuous image for the distribution of the subsurface electrical properties (Griffiths and Barker, 1993).

In order to study the soil conditions and environmental pollution, high-resolution two-dimensional (2D) geoelectrical imaging (Tomography) measurements have been carried out along two profiles in the study area (Fig. 4). The first profile has been measured within an area that is irrigated by sewage water in El- Gabel El-Asfar area, while the other one has been measured within an area that is irrigated by fresh surface water in El-Qalag area. The two profiles have been measured in N-S directions with a length of 90 m.

The geoelectrical imaging measurements have been conducted by applying the Wenner array involves measuring a series of constant separation traverses (datum levels) with the electrode separation being increased with each successive traverse (Fig. 5). The measurements continued successively to reach the last datum, which is represented by only one point with the largest electrodes separation (equals one third of the total length of the profile). The measurement started at the first traverse with unit electrode separation "a= 3m" and increased at the successive traverses by one unit (2a, 3a, 4a, ... na, i.e. 6, 9, 12,......and 30 m., respectively).

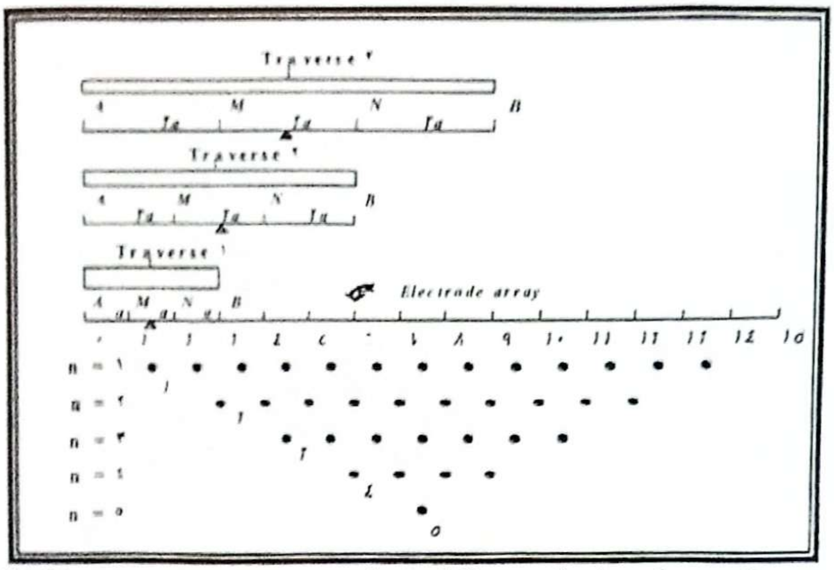

Fig. (5). The measurement sequence for building up the imaging section.

Interpretation of the Field Data

Interpretation of the VES measurements.

The field data of Vertical Electrical Sounding (VES) has been interpreted quantitatively using the computer programs of Zohdy and Bisdorf (1989) and Van Der Velpen (1988) to delineate the subsurface succession of the geoelectrical layers in the area.

Interpretation of the imaging measurements.

The computer program (RES2DINV) has been used for the interpretation of the imaging data developed by Loke (1996). The program automatically determines a two-dimensional (2-D) resistivity model for the subsurface using the data obtained from the imaging survey.

RESULTS AND DISCUSSION

A. Geoelectrical Succession

The comparison between the interpreted data of the Vertical Electrical Sounding and the lithology as well as well logs of some drilled wells revealed that the geoelectrical succession of the area under study consists of four geoelectrical zones, which have been referred to as A, B, C and D. The geoelectrical parameters (thicknesses and resistivities) are tabulated in table (1). Zones A and B are composed of sand, gravel and clay corresponding to Quaternary deposits. Zone A is dry, while zone B is saturated with water. Zone C (Miocene deposits) is mainly composed of sand, gravel, clay and limestone intercalation, while Zone D (Oligocene deposits) is divided into two main units. Unit D1 represents the basaltic sheet, overlying Unit D2 and is composed of sand, gravel, sandstone and clay. Zone C and unit D2 are water saturated.

TABLE (1). Interpreted geoelectrical data in the study area.

Section	Trend and length	VES'es No and wells included	Geoelectrical zones, unit, resistivity and thickness				
			Zone "A"	Zone "B"	Zone "C"	Zone "D"	
						Unit "D1"	Unit "D2"
A-A'	NE-SW 12 km	8,2,3,10&16 well 2	6-345Ω m 2.1-3.5m	10-51Ω m 6.2-98m	5.4-7.2 Ω m 10-36m	217-236 Ω m 34-38m	16.3-18.6 Ωm -------
B-B'	NE-SW 11 km	9,4,5,11,14 &15 Well 5,11,14&15	6-488Ω m 2.1-3.2m	9-47Ω m 5.6-99m	3.9-6.6 Ω m 10-37m	170-236Ω m 38-40m	11-17 Ω m -- ----
C-C'	NW-SE 8.3 km	10,11,12&13 Well 11	6-662Ω m 3.2-54.1m	10-25Ω m 5-45m	6.4-7.1 Ω m 30-53m	150--236Ω m 38-40m	11-18.6 Ω m -------
D-D'	NW-SE 7.6 km	1,2,3,4,6&7 Well 2,3&7	4.8-447Ω m 2.1-2.5m	4.6-55Ω m 68-100m	3.1-7 Ω m 32-44m	-------- --------	------- -------

The sequence of the geoelectrical zones as well as some other geoelectrical features are discussed as revealed along the S-N and W-E geoelectrical cross sections as following:

B. Geoelectrical Cross Sections

Four geoelectrical cross sections have been constructed from the interpreted data of the VES'es and lithologic data of wells (Fig. 4). These sections illustrate the geoelectrical sequence, lateral and vertical resistivity that reflect the lithology changes of the different zones and the subsurface structures along the profile directions. Cross-sections A-A' and B-B' traverse the area in S-N directions (Fig. 6), while cross-sections C-C' and D-D' are constructed in W-E directions (Fig. 7).

The main observations and conclusions obtained from these cross sections (Figs. 6 and 7) can be summarized as follows:-

1- Generally, the geoelectrical succession in the study area consists of four geoelectrical zones (A, B, C and D).

2- The distribution of these zones differs from one location to another i.e. in the northern part of the study area, all the four zones A, B, C and D are recognized, while in the southern part, zone D is missing. The main factor governing such distribution are the subsurface structures represented by the normal faults F1 and F2.

3- Generally, the resistivity values of zones B and C increase westward towards El-Ismailia Canal and decrease downward due to the increase of water salinity and the presence of clay intercalation. On the other hand the thickness of these zones varies from one place to another due to the effect of the subsurface structure and dip of the basaltic sheet.

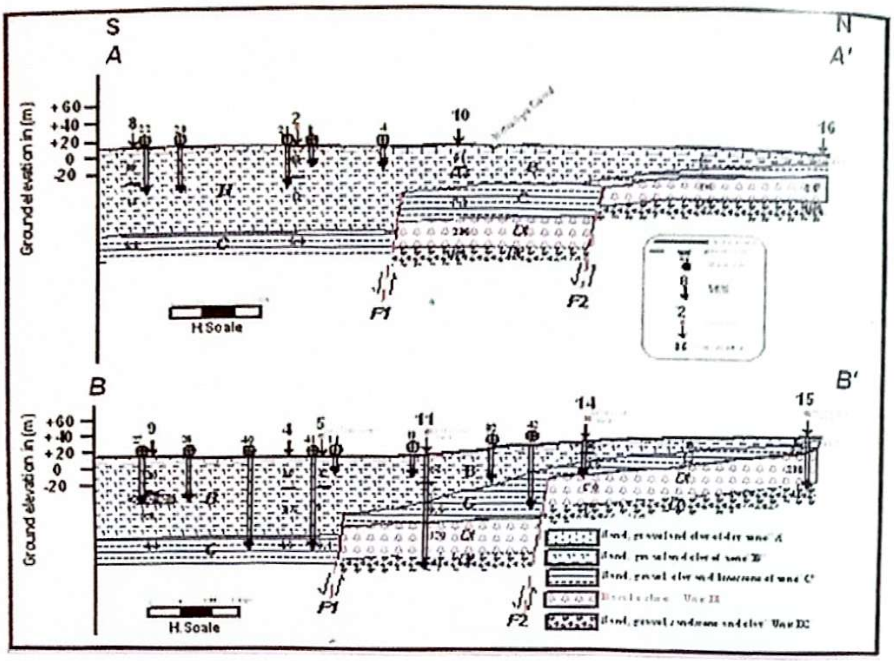

Fig.(6). Geoelectrical cross sections AA' and BB' in the study area.

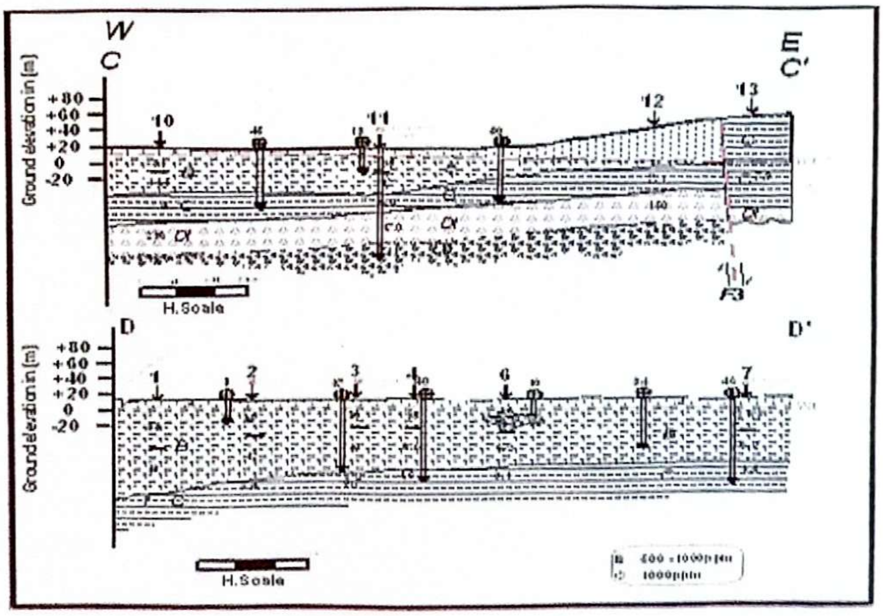

Fig.(7). Geoelectrical cross sections CC' and DD' in the study area.

4- The downward resistivity decrease is well displayed by the electric log of El-Khanka well (Fig. 8) beside VES station No. 11. From this log, high resistivity values and low natural gamma values are recorded at a depth interval from 5.5 m to 34.5 m reflecting low clay content as well as low groundwater salinity of the upper part of zone "B". On the other hand, low resistivity values and high natural gamma values are recorded over the depth interval from 34.5 m to 58m reflecting high clay content and relatively higher groundwater salinity, characterizing the lower part of zone "B". At the depth interval from 58 m to 84 m the zone "C" exhibits the lowest resistivity values and high natural gamma values due to high clay content reflecting much higher groundwater salinity.

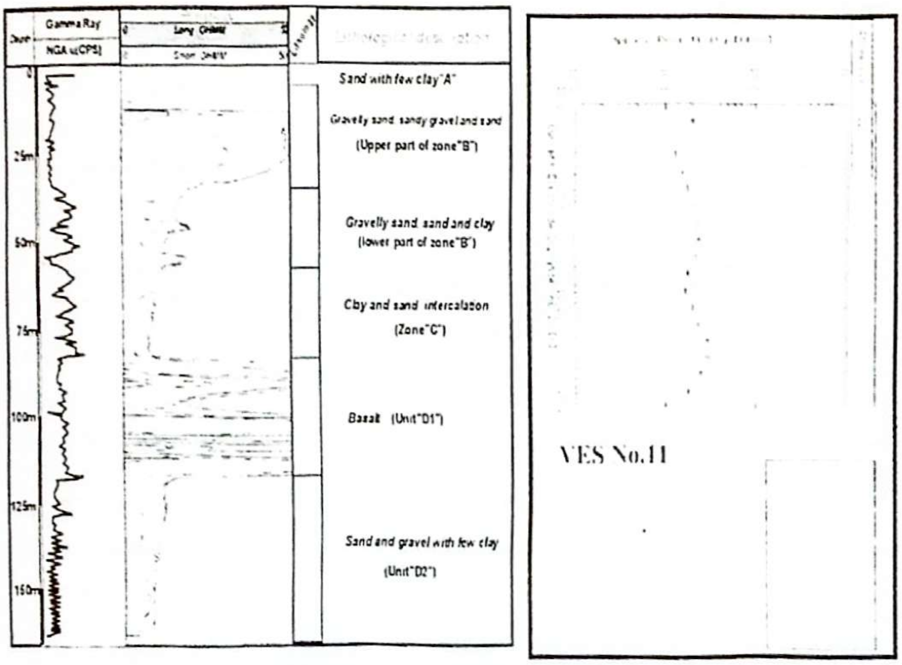

Fig. (8). Compsite log of El-Khanka well close to VES No. 11.

5- The depth to the basaltic sheet ranges from 17 m at Abu Zaabal area (VES stations No. 15 and 16) to 84 m at El-Khanka area (VES No.11, Fig. 6). The presence of the basaltic sheet (as a marker bed) at different levels reflects the effect of structure on both geologic succession and groundwater occurrences.

6- From the cross-sections A-A' and B-B', it is clear that, the basaltic sheet is regionally slopping southward (Fig. 6). The dissection of the basaltic sheet by different normal faults has resulted in a hydraulic connection between Quaternary, Miocene (B and C) and the underlying Oligocene aquifers (D2) in the study area.

7- Generally, the depth to water as recorded from the drilled wells and geoelectrical study in the study area ranges from 2.1 m to 54.1 m.

8- Water-bearing layers in the western and southern parts of the study area have a high potential. This is due to presence of sand, gravels, clayey sand and sandy clay with large thickness, while it is of limited potential in the other parts due to small thickness of the water-bearing zones and the presence of clay.

C. Imaging Profiles

According to the available geologic information and measured depth to water in the study area, the two imaging sections (Figs.9a and 9b) show different resistivity zones with variable thicknesses. The objectives of such imaging profiles are to follow up the investigated area which is affected by irrigation water (sewage water or fresh water), in addition to the detection of percolation paths to the main aquifer. The main observations and conclusions are:

1. The depth to water in the two profiles ranges from 2.8m in El-Qalag area to 6.5m in El-Gabel El-Asfar area, this is confirmed from the drilled wells and geoelectrical study in the study area.

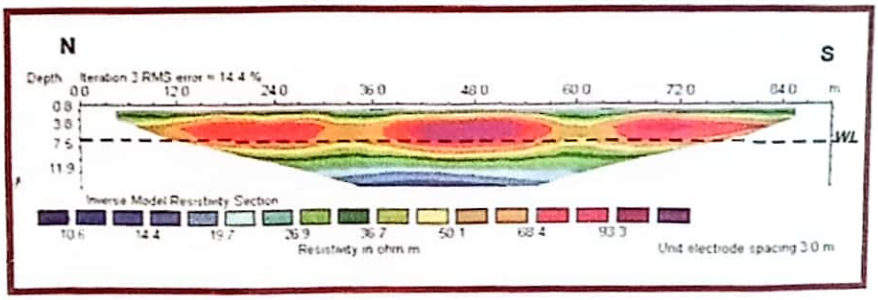

Fig. (9a). Two-D resistivity imaging profile in El-Gabel El-Asfar area.

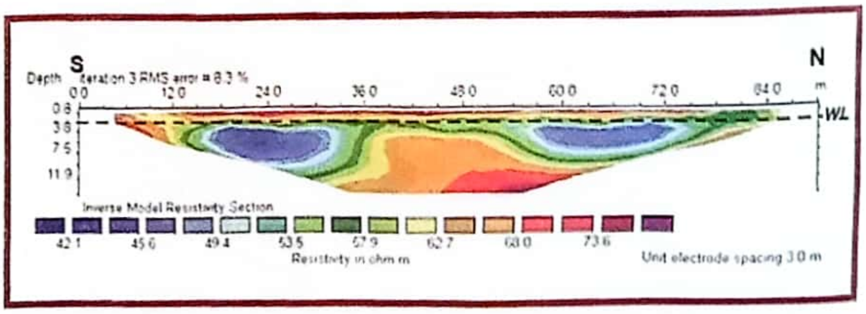

Fig. (9b). Two-D resistivity imaging profile in El-Qalag area.

2. The unsaturated zone is affected by irrigation water, where in El-Gabel El-Asfar the surface cover is affected by sewage water. The surface cover shows a thin layer acting as a semi-perched aquifer and has low resistivity < 20 Ohm.m due to the presence of the dissolved solids within the sewage water (Fig.9a), while in El-Qalag area, the resistivity becomes higher, where the surface cover is irrigated by fresh water from El-Ismailia Canal (Fig.9b).
3. Lenses of sand and gravel are recorded in the dry zone, reflecting a high resistivity in El- Gabel El-Asfar area. Between these lenses, there are low resistivity zones at profile coordinates 30-36m and 57-63m that act as paths to the main aquifer. The decrease in resistivity within these zones is due to its partial saturation with sewage water coming from the surface cover and percolates to the main aquifer, causing groundwater pollution.

4. The connection between sewage water and main aquifer is strongly confirmed through the hydrochemical analyses of groundwater samples (Tables 2 and 4).

D. Groundwater Quality

In discussing the hydrogeochemistry of the area under consideration. Quaternary and Miocene aquifers are considered to be of prime importance. Quaternary deposits are mostly of fluvial origin and cover most of the area. Miocene deposits are of marine origin and mostly present in the eastern and northern parts. Generally. the thickness of the investigated water-bearing zones shows a gradual increase toward southwest. The surface is intensively dissected by a number of surface water courses comprising irrigation canals and drains (Fig. 1). It is more or less fully saturated with interstitial water. The degree of water saturation is highly affected by the excess irrigation water.

Fifty groundwater samples were collected in March. 2003 from the investigated area (Fig. 10). By comparison between the geoelectrical and the hydrogeochemical studies as well as the available field information in the study area. it is clear that Zone B is corresponding to the Quaternary aquifer. whereas Zone C is corresponding to the Miocene aquifer (Figs. 6 and 7).

According to the hydrochemical analyses data of the collected groundwater samples. taking into consideration the chemical analyses of El Ismailia canal water at Seriyaqous village. drains water. rain water and sea water (Table 2). the following could be deduced.

Groundwater salinity

Regionally. groundwater salinity decreases from east to west. Westward decrease of salinity is mainly attributed to the perennial recharge from El-Ismailia Canal fresh water as well as the infiltration of the return flow after irrigation. On the other hand. eastward increase of groundwater salinity is mainly attributed to the presence of the Miocene marine deposits. Concentrations of major ions are variable in their horizontal distributions and generally increase from the recharge area in the west to the discharge one in the east. Quaternary aquifer (Zone B) is clearly distinguished into upper and lower parts due to salinity variation as well as their depths. The upper part of Zone B has a depth ranging from 2.1 m to 6.2m. it is tapped by water points number 1 to 16. Its groundwater salinity reflects fresh type. where it ranges from 263 mg/l (well No. 1) to 488 mg/l (well No. 16). (Table 2) and is highly affected by seepage from El-Ismailia fresh water Canal as well as the infiltration of return irrigation water. Iso-salinity contour map indicates a slight increase due east (Fig. 11a). The lower part of Zone B has a depth ranging from 22 m to 42 m. it is tapped through water wells number 17 to 35. Its groundwater salinity increases eastwards (Fig. 11b) and varies from 523 mg/l (well No. 17) to 960 mg/l (well No. 35). (Table 2). On the other hand. Miocene aquifer (Zone C) has a depth varying from 33 m to 102 m, it is tapped by water points number 36 to 50, its groundwater salinity exceeds 1000 mg/l (Table 2), reflecting fairly brackish water type as water-bearing sediments are of marine origin. It also increases eastward (Fig. 11c). This is strongly confirmed from normal electrical logging and geoelectrical study, where the resistivity values of these zones decrease downward (Figs. 6, 7 and 8).

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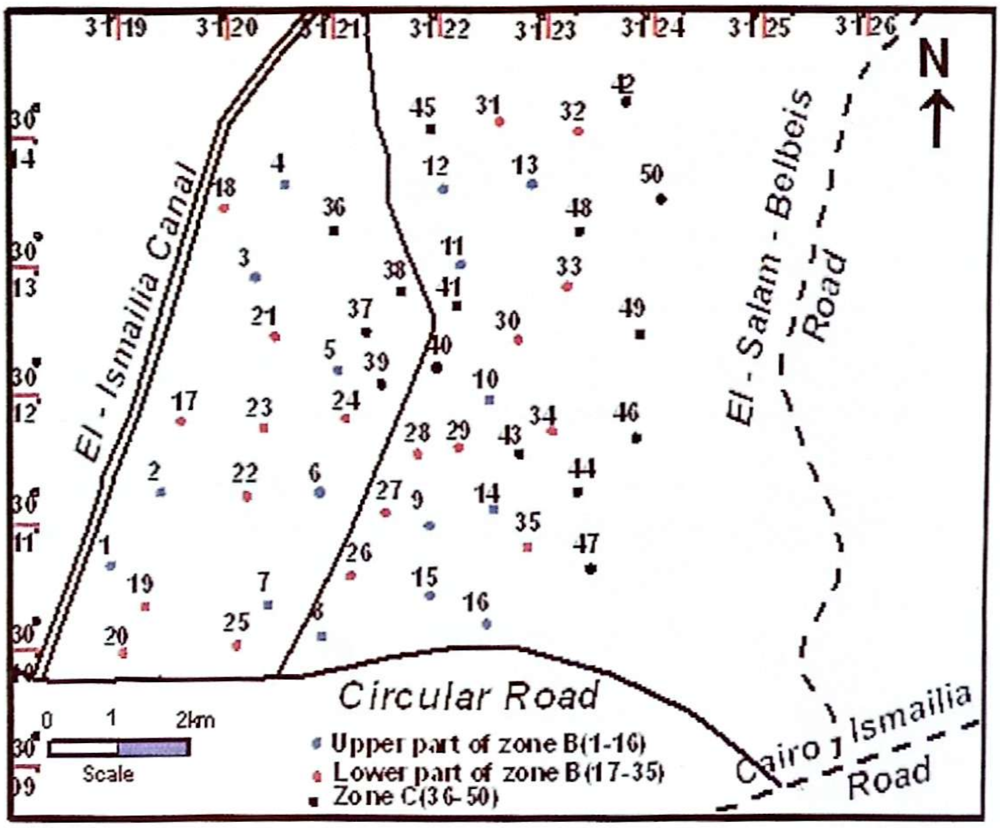

TABLE (2). The hydrochemical analyses data of groundwater samples in mg/l (2003).

Well No	Zone	pH	TDS	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl
1	UPPER PART OF ZONE B	6.90	263	30.20	20.39	50	6	11.62	173.12	35	55.50
2		7.15	283	37.25	19.05	52	6	15.48	188.86	24	60.50
3		7.00	309	24.70	12.50	50	6	11.61	133.77	20	55.20
4		7.03	324	49.01	17.86	61	11	15.48	224.26	24	77.70
5		7.00	340	30.40	19.20	62	13	15.48	223.10	25	74.23
6		7.12	345	30.10	20.38	60	10	23.24	220.33	18	44.40
7		7.11	348	33.24	21.33	65	12	23.48	224.12	25	46.12
8		7.10	374	43.63	14.27	84	8	Nil	299.02	40	55.50
9		7.50	409	26.70	24.50	68	5	11.61	143.16	60	88.80
10		7.04	420	19.61	25.01	75	9	7.74	251.81	14	66.60
11		7.10	422	29.41	27.39	70	8	11.61	173.12	76	77.70
12		6.98	424	30.20	22.43	68	8	7.74	188.86	16	99.90
13		6.97	444	56.50	25.48	74	11	Nil	432.80	16	44.40
14		7.00	460	25.49	15.48	110	25	11.61	230.10	42	98.50
15		7.13	473	40.10	19.37	80	13	Nil	295.09	40	55.50
16		7.00	488	36.20	31.70	57	8	11.61	243.94	38	69.38
17	LOWER PART OF ZONE B	7.21	523	35.29	23.82	82	15	19.35	165.25	42	122.10
18		7.04	524	50.50	25.10	110	6	11.61	275.42	60	122.10
19		7.41	529	58.73	35.68	82	5	19.36	295.09	52	94.35
20		7.31	547	60.10	27.12	80	9	Nil	385.58	50	56.20
21		7.12	552	39.21	20.15	80	9	11.61	141.64	70	111.00
22		7.00	559	58.73	15.29	115	10	23.32	326.56	28	83.25
23		7.06	600	73.83	24.47	110	23	Nil	385.58	65	124.88
24		7.24	601	68.62	32.16	150	17	15.48	302.86	190	122.10
25		6.99	616	80.10	38.74	100	9	Nil	452.47	72	94.35
26		6.97	633	48.50	28.20	80	9	7.74	149.51	80	140.00
27		7.00	694	63.10	32.78	110	25	11.62	314.74	100	124.88
28		7.31	679	25.49	29.77	95	8	19.36	291.15	36	72.16
29		7.05	701	75.10	30.58	120	20	Nil	409.19	100	122.10
30		7.07	720	102.40	38.74	110	10	Nil	433.80	160	111.00
31		7.04	748	49.01	29.77	125	9	Nil	204.50	180	120.60
32		7.12	752	19.60	28.58	145	9	19.35	275.42	120	77.60
33		7.25	774	49.01	41.50	80	6	Nil	149.51	120	155.40
34		7.00	964	66.20	35.73	190	11	Nil	141.64	220	284.18
35		7.10	960	99.90	34.54	230	22	15.48	346.24	230	249.75
36	ZONE C	7.13	1056	137.25	35.73	210	43	77.40	377.71	230	233.10
37		7.10	1094	25.491	28.58	250	9	46.44	235.09	40	125.10
38		7.00	1152	139.21	39.30	215	37	30.96	354.11	240	290.15
39		6.98	1209	45.09	58.36	260	18	11.61	212.46	260	340.10
40		7.00	1235	121.56	47.67	240	17	69.66	402.32	180	277.50
41		7.15	1324	49.01	59.55	260	15	11.61	220.33	300	301.80
42		7.14	1420	121.56	53.60	270	31	11.61	291.15	350	348.50
43		7.13	1446	43.13	41.49	330	24	19.35	236.07	290	314.54
44		7.81	1523	60.41	32.62	400	4	7.74	448.53	310	321.90
45		7.00	1625	85.70	62.50	350	18	11.62	271.48	320	475.70
46		7.16	1964	134.24	66.26	420	9	15.48	460.34	500	390.50
47		7.18	2137	117.60	89.33	390	16	11.62	192.79	670	480.20
48		7.00	2160	83.90	61.16	550	17	85.14	613.78	180	582
49		7.11	2316	98.20	79.80	490	15	7.74	161.31	320	830.24
50		7.15	2764	78.43	89.33	520	31	11.62	251.81	320	810.20
Ismailia canal water		6.78	293	28.30	17.19	56	4	Nil	217.40	30	50.72
Rain water		7.00	155	0.50	0.74	0.91	0.05	Nil	1.03	0.29	0.87
Sea water		6.96	38120	21.91	110.45	521.76	9.72	0.60	2.25	47.89	608.73
El Gabel El Asfar drain		6.80	653	54.32	24.51	155	19	Nil	410	40	155.93
El Berka drain		8.6	1455	66.67	57.18	365	10	11.88	229.5	500	330
Belbeis drain		8.6	2436	100.39	85.76	630	16	15.84	391.90	900	492.90

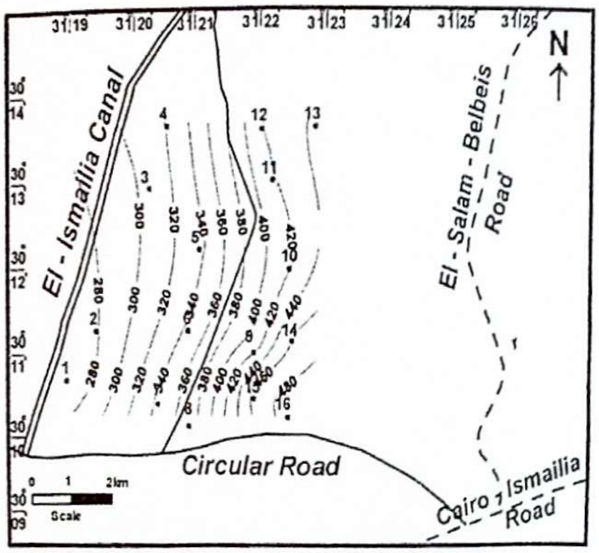

Fig. (11a). Iso-salinity contour map of the upper part of zone B

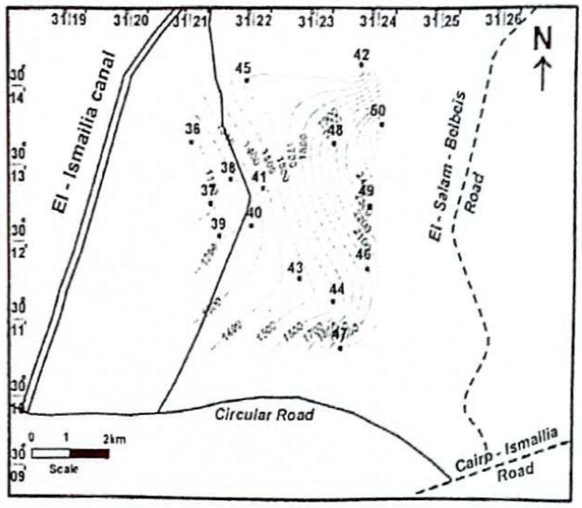

Fig. (11b). Iso-salinity contour map of the lower part of zone B

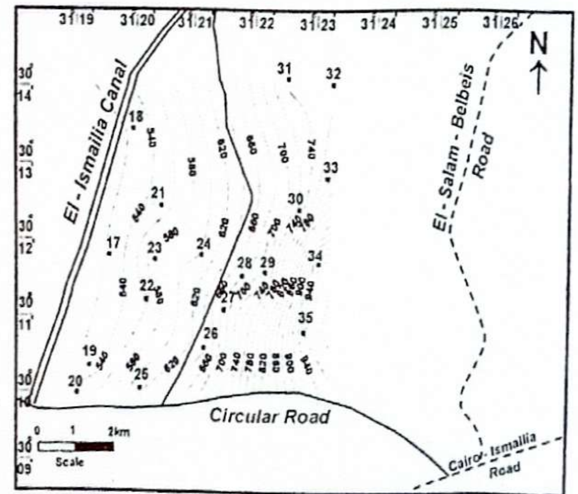

Fig. (11c). Iso-salinity contour map of zone C

Water types

In the Quaternary aquifer (Zone B), ion dominance in the groundwater of the upper part of Zone B reveals the availability of Bicarbonate-Sodium type (Table 3 and Fig. 12a), reflecting fresh water category (initial stage of groundwater evolution), while ion dominance in the lower part of Zone B indicates two water types: Bicarbonate-Sodium and Chloride-Sodium (Table 3 and Fig. 12b), reflecting an intermediate stage of groundwater evolution. On the other hand, the majority of Miocene groundwater samples (Zone C) indicates Chloride-Sodium water type (Table 3 and Fig. 12c), revealing a mature stage of groundwater metasomatism due to the availability of marine sediments (particularly due east).

Groundwater hardness

According to Hem (1989), groundwater in the investigated area is hard to very hard due to high concentration of divalent ions, particularly Ca and Mg. Groundwater hardness of the upper part of Zone B ranges from 113 mg/l to 246 mg/l as $CaCO_3$, in the lower part of Zone B, water hardness varies from 166 mg/l to 415 mg/l as $CaCO_3$, while in zone C, it ranges from 181 to 661 mg/l as $CaCO_3$ (Table 3).

TABLE (3).Total hardness and chemical water types of the investigated water zones (2003).

WELL	Zone	TOTAL HARDNESS	WATER TYPE	WELL	Zone	TOTAL HARDNESS	WATER TYPE	WELL	Zone	TOTAL HARDNESS	WATER TYPE
1	UPPER PART OF ZONE B	159.65	HCO3-Na	17	LOWER PART OF ZONE B	186.18	Cl-Na	36	ZONE C	489.98	HCO3-Na
2		171.67	HCO3-Na	18		229.22	HCO3-Na	37		181.18	HCO3-Na
3		113.11	HCO3-Na	19		293.29	HCO3-Na	38		509.50	Cl-Na
4		196.19	HCO3-Na	20		261.79	HCO3-Na	39		352.85	Cl-Na
5		154.65	HCO3-Na	21		181.18	Cl-Na	40		499.99	HCO3-Na
6		159.15	HCO3-Na	22		209.70	HCO3-Na	41		367.86	Cl-Na
7		170.17	HCO3-Na	23		284.78	HCO3-Na	42		524.52	Cl-Na
8		167.66	HCO3-Na	24		303.30	HCO3-Na	43		278.27	Cl-Na
9		167.16	HCO3-Na	25		359.85	HCO3-Na	44		284.78	Cl-Na
10		152.15	HCO3-Na	26		232.23	Cl-Na	45		496.49	Cl-Na
11		186.18	HCO3-Na	27		292.79	HCO3-Na	46		608.10	Cl-Na
12		167.66	HCO3-Na	28		186.18	HCO3-Na	47		661.66	SO4-Cl
13		246.24	HCO3-Na	29		313.31	HCO3-Na	48		460.96	Cl-Na
14		127.12	HCO3-Na	30		415.41	HCO3-Na	49		573.57	Cl-Na
15		179.67	HCO3-Na	31		245.24	SO4-Cl	50		563.56	Cl-Na
16		221.22	HCO3-Na	32		166.66	HCO3-Na				
				33		293.29	Cl-Na				
				34		307.30	Cl-Na				
				35		391.89	Cl-Na				

Groundwater origin

The investigated water samples were plotted on the semilogarithmic paper suggested by Schoeller (1962). Groundwater samples of each zone reflect a general resemblance and similarity among each other (Figs. 13a inclusive 13d). In zone B, the ionic pattern is Ca > Mg < Na and K > Cl > SO_4 < HCO_3, exhibiting fresh water characters (the same direction of El Imailia Canal). On the other hand, in zone C, Mg and SO_4 exceed Ca and HCO_3, respectively (Ca< Mg < Na and K > Cl > SO_4 > HCO_3) reflecting the impact of marine sediments (limestone deposits) on groundwater quality.

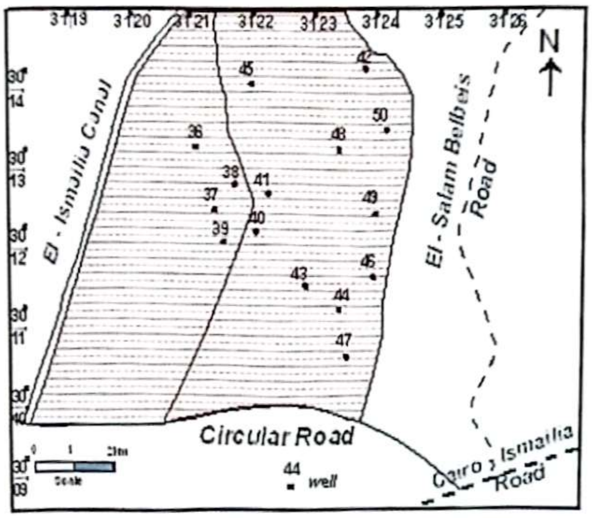

Fig (12a). Bicarbonate-Sodium water type, upper part of zone B

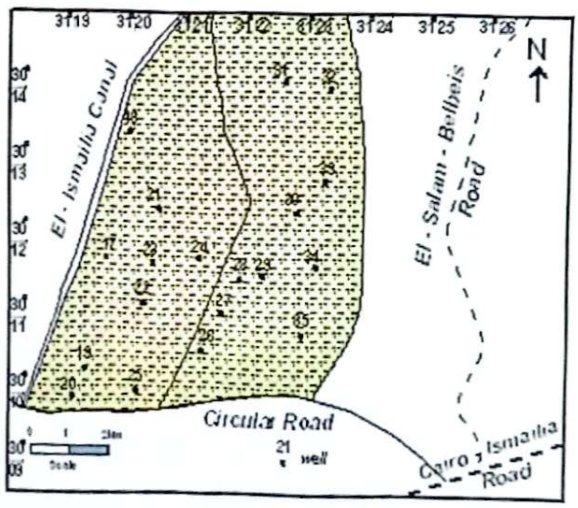

Fig (12b). Bicarbonate and Sulphate-Sodium water types, lower part of zone B

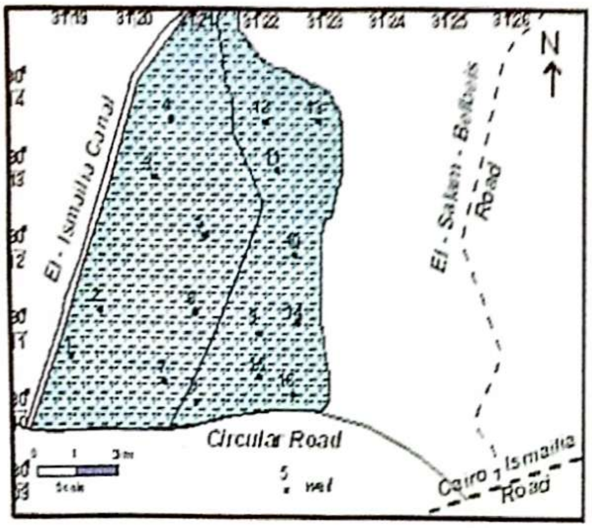

Fig. (12c). Chloride-Sodium water type of zone C

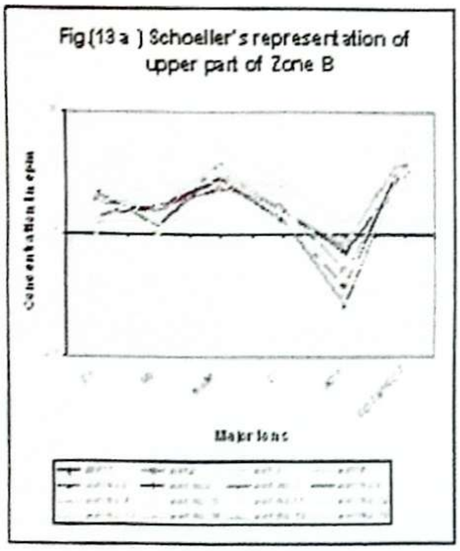

Fig (13 a) Schoeller's representation of upper part of Zone B

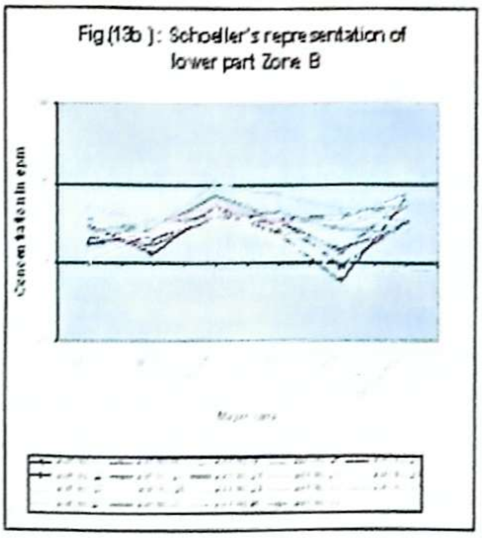

Fig (13b): Schoeller's representation of lower part Zone B

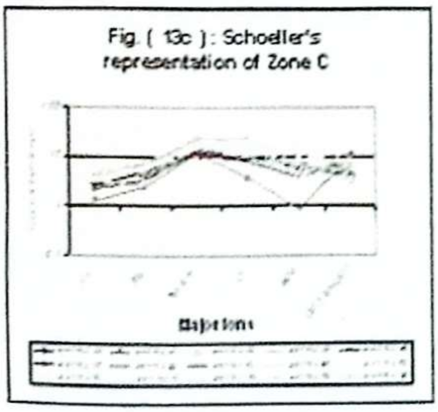

Fig. (13c): Schoeller's representation of Zone C

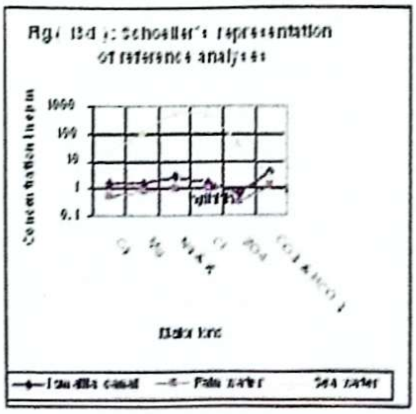

Fig (13d): Schoeller's representation of reference analyses

Groundwater pollution

The study of groundwater pollution in the investigated area was carried out through the detection of the effective components as iron, manganese, lead, cadmium, copper, nitrates and boron. Comparing the average concentration of the detected samples (Table 4), with their standard limits in drinking water (Table 5), it is clear that, the groundwater of the Quaternary aquifer (Zone B) is polluted as the detected components exceed the standard limits (except copper allover the area), whereas, the Miocene aquifer (Zone C) is free or safe (polluted only with nitrates).

Evaluation of groundwater quality

In general, water for drinking and domestic uses should be colorless, clear and free from excessive dissolved solids as well as harmful organisms (i.e high standards of physical, chemical and biological purity). Generally, for water of good quality (potable), the total dissolved solids should not exceed 500 mg/l. Comparing the hydrochemical analyses data of the two different zones (Tables 2, 3 and 4) with the WHO standard limits (Table 5), it is clear that, the upper part of Zone B is the best from salinity point of view (salinity < 500 mg/l), but polluted with iron, manganese, lead, cadmium and nitrates, representing a heavy hygienic threat for groundwater quality.

Also, such part is subjected to sewage water and infection with microorganisms (as the area is dominated by drains). On the other hand, the lower part of zone B is not good as the salinity ranges from 500 up to 1000 mg/l and mainly polluted. Zone C (Miocene aquifer) is the worst due to its relatively high water salinity (> 1000 mg/l) although safe or free from chemical pollutants except nitrates (Table 4).

Generally, total dissolved solids should not exceed 2000 mg/l in irrigation water, but it has been found that, this is flexible if the soil has a good drainage system. Concerning the suitability of groundwater quality for irrigation in the study area, it is clear that, the Quaternary groundwater is suitable for all kind of crops. Also, the quality of groundwater is suitable for all classes of livestock, poultry as well as most industries (fruit and vegetable, paper, textile and boiler feed water).

TABLE (4). Ranges and averages concentrations of minor and trace components (2003).

EL GABEL EL ASFAR AREA						
	ZONE B				ZONE C	
	Upper part		Lower part			
Component	Range	Average	Range	Average	Range	Average
Fe	0.82-3.63	2.22	0.82-1.60	1.21	0.001-0.002	0.0015
Mn	1.470-1.545	1.50	1.487-1.528	1.50	0.007-0.00	0.008
Pb	0.078-0.103	0.09	0.001-0.005	0.003	N.D	N.D
Cd	0.294-0.488	0.39	0.289-0.490	0.389	N.D	N.D
Cu	0.010-0.040	0.025	0.001-0.030	0.015	N.D	N.D
NO_3	5.60-31.40	18.50	54.79-134.90	94.84	95-134	114.5
B	0.09-0.78	0.43	0.69-1.36	1.02	2.17-4.18	3.17
EL KHANKA AREA						
Fe	0.82-2.85	1.83	1.22-2.03	1.62	0.001-0.003	0.002
Mn	1.470-1.480	1.475	1.501-1.544	1.52	0.005-0.008	0.006
Pb	0.051-0.134	0.092	0.032-0.087	0.059	N.D	N.D
Cd	0.292-0.299	0.295	0.288-0.291	0.289	N.D	N.D
Cu	N.D	N.D	N.D	N.D	N.D	N.D
NO_3	9.80-22	15.90	20.20-25.60	22.90	2-11.50	6.75
B	0.49-0.66	0.55	0.35-1.03	0.69	N.D	N.D
EL QALAG AREA						
Fe	0.40-4.43	2.41	1.30-1.90	1.60	0.003-0.004	0.003
Mn	1.477-1.542	1.50	1.401-1.502	1.45	0.004-0.006	0.005
Pb	0.004-0.118	0.061	0.030-0.075	0.052	N.D	N.D
Cd	0.291-0.489	0.390	0.287-0.295	0.291	N.D	N.D
Cu	0.02-0.04	0.030	0.020-0.040	0.030	N.D	N.D
NO_3	3-36.80	19.90	21.40-30.12	25.76	3-7.17	5.08
B	0.12-1.25	0.68	0.87-1.25	1.06	N.D	N.D

SEWAGE DRAINS			
Components	ElGabel El Asfar Drain	El Berka Drain	Belbeis Drain
Fe	0.21	1.22	3.25
Mn	0.34	1.48	0.35
Pb	0.039	0.011	0.034
Cd	0.33	0.12	0.24
Cu	N.D	N.D	N.D
NO_3	57.50	46.20	51.40
B	0.68	0.90	0.78

N.D mean less than 0.0001 ppm

TABLE (5). International standards for drinking water.

Substance or property	Acceptable drinking water (ppm)	Permissible drinking water (ppm)
Color*	5	50
Turbidity*	5	25
PH*	7 – 8.5	6.5 – 9.2
TDS*	500	1500
Cl*	200	600
SO_4*	200	400
Mg*	50	150
Ca*	75	200
Fe*	0.3	1.00
Mn*	0.1	0.5
Pb*	-	0.05
Cu*	1.0	1.50
T.H*	250	500
Cd*	-	0.01
NO_3**	-	10
B**	-	0.75

*WHO (1984)

**National Academy of Science and National Academy of Engineering (1972)

RECOMMENDATIONS

In view of the current study, aiming to the best utilization of water resources as well as avoiding water pollution, the following is recommended:

1- Prohibition of direct or indirect disposal of any wastes that cause pollution to water resources.
2- All private shallow water wells must be abandoned, as the investigated area is mainly dissected by improper sanitary drainage network.
3- If it is necessary to construct groundwater wells, a proper sanitary protection should be provided against surface contamination and a well should be located at a safe distance from all possible source of pollution (Table 6).
4- It is recommended to design an advanced sanitary drainage network that can be quickly installed.
5- Periodical chemical and microbiological analyses must be carried out to avoid any contamination.
6- It is recommended to construct a new drinking water plant in the study area with a high standard pipe line originating from El-Ismailia Canal to the study area.

TABLE (6). Recommended minimum distance between a groundwater well and source of contamination (Raghunath, 1987).

Contamination source	Recommended distance (m)	Contamination source	Recommended distance (m)
Building sewer	15	Seepage pit	30
Septic tank	15	Cess poll	40
Disposal field	30		

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دراسات جيو كهربية وجيوكميائية لتقييم المياه الجوفية بمنطقة الجبل الأصفر ومجاوراتها – دلتا النيل – مصر

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نظرا للنقص الحاد في إمداد منطقة الجبل الأصفر ومجاوراتها بمياه الشرب اللازمة اتجهت الأنظار لإنشاء محطة مياه شرب تستمد مياهها من الخزان المائي الجوفي مما أوجب القيام بدراسة خزانات المياه الجوفية . لتحقيق ذلك تم إجراء ستة عشر جسه جيوكهربية لمعرفة سمك وامتداد الطبقات الحاملة للمياه وكذلك التراكيب التحت سطحية المصاحبة لها وعمل بروفلين ثنائي الأبعاد لمعرفة مدى تأثر الطبقة السطحية بمياه الري (سواء كانت مياه صرف أو مياه عذبة) حيث تبين انخفاض قيم المقاومات للطبقة السطحية فى منطقة الجبل الأصفر التى تروى بمياه صرف وارتفاعها فى منطقة القلج حيث تروى بمياه عذبة من ترعة الإسماعيلية .إضافة إلى ذلك تم جمع خمسين عينة مياه جوفية وعينات مرجعية للوقوف على مدى تأثر نوعية المياه الجوفية بالمصارف المنتشرة بالمنطقة ومعرفة مصدري التغذية والتلوث.

أوضح تفسير البيانات الجيوكهربية أن التتابع الجيوكهربى يتكون من أربع نطاقات أ،ب،ج، د. النطاقات ب،ج ، والجزء السفلي من د حاملة للمياه. وقد لوحظت الزيادة المطردة في المقاومة الكهربية للنطاقات الحاملة للمياه تجاه ترعة الإسماعيلية مؤكدة أنها مصدر التغذية ، كذلك الانخفاض فى قيم المقاومات إلى أسفل لزيادة ملوحة المياه ورواسب الطين المصاحبة لرواسب الميوسين البحرية. سمك الطبقات يتباين من مكان لأخر نتيجة التراكيب تحت السطحية ويظهر جليا مصاحبا لطبقة البازلت حيث ارتفاعها في مكان ما وانخفاضها فى أخر.

أبرزت الفحوصات الكيميائية لعينات المياه الجوفية الممثلة للنطاقين ب،ج أن النطاق ب يتميز إلى جزئين علوي وسفلي (تم الفصل بينهما على أساس أعماقها وتباينهما في الملوحة).الجزء العلوي من نطاق ب ملوحة مياهه أقل من ٥٠٠ ملجم/لتر، نوعية المياه هي صوديوم-بيكربونات، ملوثا كيميائيا بالعناصر الثقيلة وميكروبيولوجيا لاتصاله المباشر بمياه الصرف. أما الجزء السفلي من نطاق ب ملوحة مياهه تتراوح مابين ٥٠٠ حتى أقل من ١٠٠٠ ملجم/لتر، نوعية المياه هي صوديوم-بيكربونات (كلوريد)، ملوثا كيميائيا. ويتميز النطاق ج بملوحة أكبر من ١٠٠٠ ملجم /لتر، نوعية المياه هي صوديوم-كلوريد ، غير أنه امن من الملوثات إلى حد ما. المياه الجوفية عسرة إلى عسرة جدا. كثرة المصارف بالمنطقة مثل مصرف الجبل الأصفر والبركة و البلبيسى أدى إلى تدهور نوعية المياه الجوفية وتلوثها حيث انه لا توجد طبقة تحجز رشح المصارف راسيا وأفقيا وهذا يمثل تهديدا عظيما لصحة المواطنين والذين يقدر عددهم بنصف مليون نسمة. وحفاظا على الصحة العامة وتدعيما للاقتصاد القومي فأنه يوصى بالاتي:

١-حظر حفر أبار مياه جوفية بالمنطقة على الإطلاق نتيجة تلوثها كيميائيا بالعناصر الثقيلة.
٢-يوصى بإنشاء محطة مياه شرب ذات تقنيات معالجة حديثة تستمد مياهها من ترعة الإسماعيلية مع إجراء التحليلات الكيميائية والميكروبيولوجية دوريا لمتابعة التغير فى نوعية المياه من عدمه.
٣- إذا كان هناك ضرورة لحفر الأبار يلزم المعالجة للمياه الجوفية للتخلص من زيادة تركيزات المكونات السامة والكائنات الدقيقة الضارة.

إضافة إلى ما سبق فان نوعية المياه الجوفية بخزان الزمن الرباعي تصلح للإنتاج الداجنى وللحيوانات المختلفة وري جميع الزراعات بالمنطقة وصناعات الأغذية المحفوظة والورق والنسيج والتبريد.

ولقد تم الأخذ بنتائج البحث لدى الجهة التنفيذية للمجالس المحلية بالمنطقة بمد خط مواسير بقطر مناسب من ترعة الإسماعيلية لتغذية محطة مياه الشرب بمياه ذات عذوبة تفوق نظيرتها فى الخزان المائي الجوفي بالمنطقة مع الأخذ فى الاعتبار مراقبة نوعيتها من أن لأخر من خلال إجراء الفحوصات الكيميائية والميكروبيولوجية الدورية للمياه.

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STUDIES ON NABKHA FORMATION A
NORTH SINAI PENINSULA

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The most obvious dune in lightly vegetated a
nabkha or coppice dune. This study was
for monitoring nabkha in two sites of Sina
location at the middle part of Sinai that ext
Wadi EL-Technologia to EL-Gevgafa which
arid zone climate. The second location i
northern part extended from EL-Sheikh Zov
which represent the arid Mediterranean
nabkhas were studied formed by three pl
Anabasis articulate, Suaeda fruticose ar
scoparia at Wadi EL-Technologia - EL-
eighty nabkhas were studied composed
species i.e *Ammophila arenaria, Callig*
Zygopyllum album and Tamarix mannif
Zowied to Rafah area. Length, width
estimated for natural plants and nabkh
and crown cover for both of nabkha
calculated. The data obtained were
statistical analysis to define the relat
three axes of plants crown volume
volume.

Keywords: *Anabasis articulate, Suaeda fruticose,*
Ammophila arenaria, Calligonum
album, Tamarix mannifera, crown
Nabkha, North Sinai.

In arid and semi arid areas, the most obvious dune
is the nabkha or coppice dune or when larger (rab
such as shrub and under shrub are effective natu
carrying sands reaches a bush or preliminary pl
rise up to 30 time of its original height. In other
near the surface, in which wind velocity is lo
means that wind shear velocity changes drasti
around the plants (Cooke and Warren, 1973).