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GROUNDWATER POTENTIALS AND CHARACTERISTICS OF EL-MOGHRA AQUIFER IN THE VICINITY OF QATTARA DEPRESSION

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The study area lies between Wadi El Natrun (-23 m) in the east and Qattara Depression (-134 m) in the west of the Northern Western Desert of Egypt. It attains an area of about 150000 km^2 and is dominated by a major aquifer unit of clastic facies, namely El-Moghra Aquifer. Such aquifer, has a variable saturated thickness between 100 to 300 m, and is defined to be of Lower Miocene age and of continental to marine depositional environments. Many trials have been made to extract groundwater for irrigation purpose, especially in the eastern portion near Wadi El-Natrun where water salinity is less than 1000 ppm. While in the western portion near Qattara Depression, the water salinity is more than 10,000 ppm, and the groundwater of El-Moghra Aquifer is used widely for oil industry. Actually, the groundwater of more than 70% of the study area is still unexplored.

The main objectives of the present work are to focus on the configuration of El-Moghra Aquifer in the study area including its physical, chemical and hydraulic properties through the investigation of about 200 wells. The assessment of aquifer potentials as well as its lateral and vertical changes is one of the main targets of the present study. The aquifer in the area to the east of Longitude 29° 00' 00" is proved to be under unconfined condition and is evidently connected with the Nile Delta Aquifer, while that to the west of Longitude 29° 00' 00" is confined and subjected to upward leakage from younger and deeper aquifers. The pumping tests (9 experiments) carried out in the area indicate highly productive aquifer in Wadi El-Farigh (unconfined aquifer) with transmissivity ranging between 720 and 6500 m^2/day, and low productive aquifer west of El-Moghra Depression (confined aquifer) with transmissivity ranging between 61 and 600 m^2/day. Changes of water chemistry due to variation in the depositional environment and source of recharge have also been assessed and genetically classified. The water salinity–water level relationship has

revealed a very coherent picture about the fresh water–saline water interface, as well as delineation of promising areas within the study area for different purposes of development. The area to the east of water level 27 m below sea level has water salinity less than 2000 ppm covering an area of about 375000 hectare, within a distance of about 75 km, which is suitable for agriculture and domestic water uses. Additional area to the west of water level -27 m is about 488000 hectare having salinity between 2000 and 5000 ppm can be used for cultivation of salt tolerant crops. The water quality data have been also used for the differentiation between the continental and marine facies of the aquifer, as well as for the detection of the recharge sources and flow direction.

Keywords: groundwater, hydraulic parameters, water level, groundwater salinity, Egypt

The study area is considered as a part of the Western Desert of Egypt, and it encompasses Wadi El-Farigh (west of Wadi El-Natrun) and its extension westward to Qattara Depression and northward to the Mediterranean Sea. It lies between Longitudes 25° 30' 41" and 31° 00' 00" E and Latitudes 29° 00' 00" and 31° 42' 00" N covering an area of about 150000 km^{2} (Fig. 1).

The concerned area is characterized by arid to semi-arid climate, as indicated by the data obtained from three meteorological stations namely, Siwa, Wadi El-Natrun and El Dabaa during the period from 1988 to 1993. The mean annual rainfall is about 212 mm (at El-Dabaa station), decreasing eastward to about 31 mm (at Wadi El-Natrun station) and southwards to about 16 mm over Siwa Oasis.

1. Landforms

In the study area, the following landforms (Fig. 2) are recognized from east to west (Ball, 1933; El Shamy, 1968; Said, 1960 and 1962 and Hafiez, 2011).

- Wadi El Natrun Depression (-23 m).
- Wadi El-Farigh Anticline (+ 100 m).
- Geble El-Hadid Table-land (max. + 200 m).
- The Moghra Depression, it sinks below sea level by 38 m.
- El Heneishat Sand Dune Chains, this belt of elongates dune series extends without break from the southern portion of the study area till the northern periphery of the Fayum Depression, and has a distance of about 50 km in a NNW–SSE direction.

- Marmarica Table-land, it is built up mostly of Miocene carbonate rocks. It has an elevation up to +200 m.
- The coastal plain, lies between the Marmarica table-land and the Mediterranean recent shore and its elevation ranges between -3 and +35 m.
- The Qattara Depression is a closed inland basin bounded by steep escarpments along its northern and western sides, with an average escarpment elevation of 200 m above sea level.

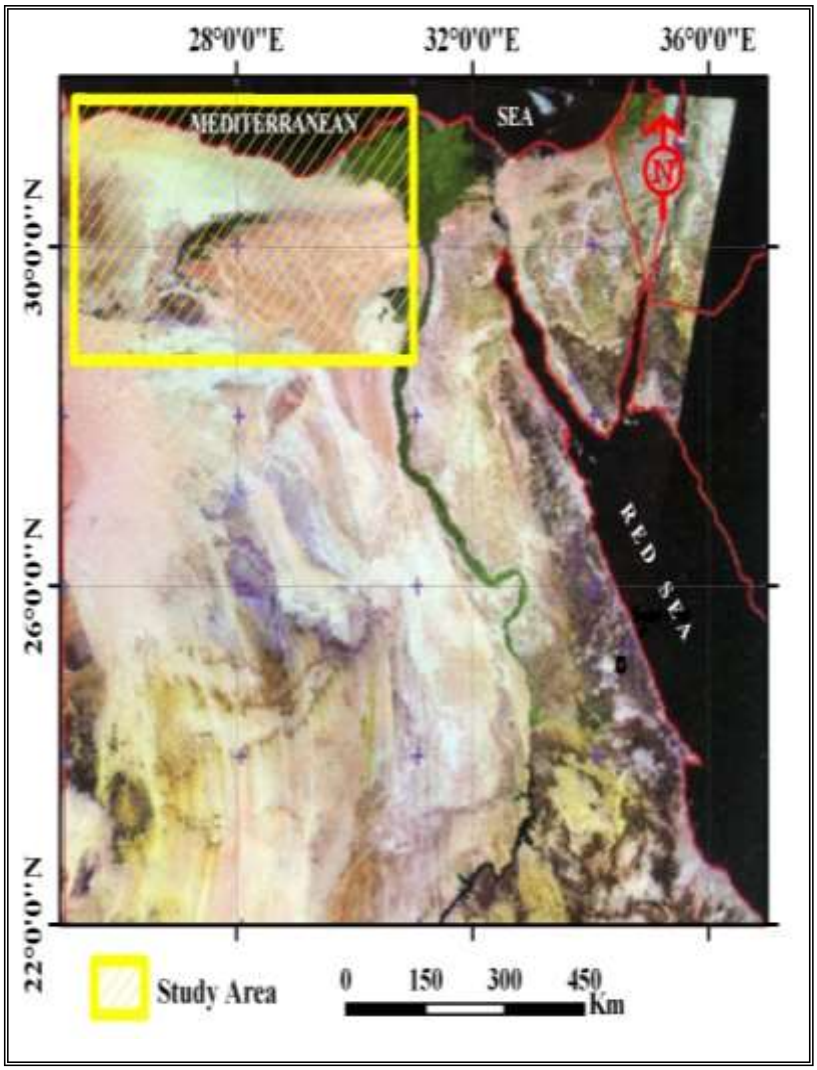


Fig. (1). Location of the study area.

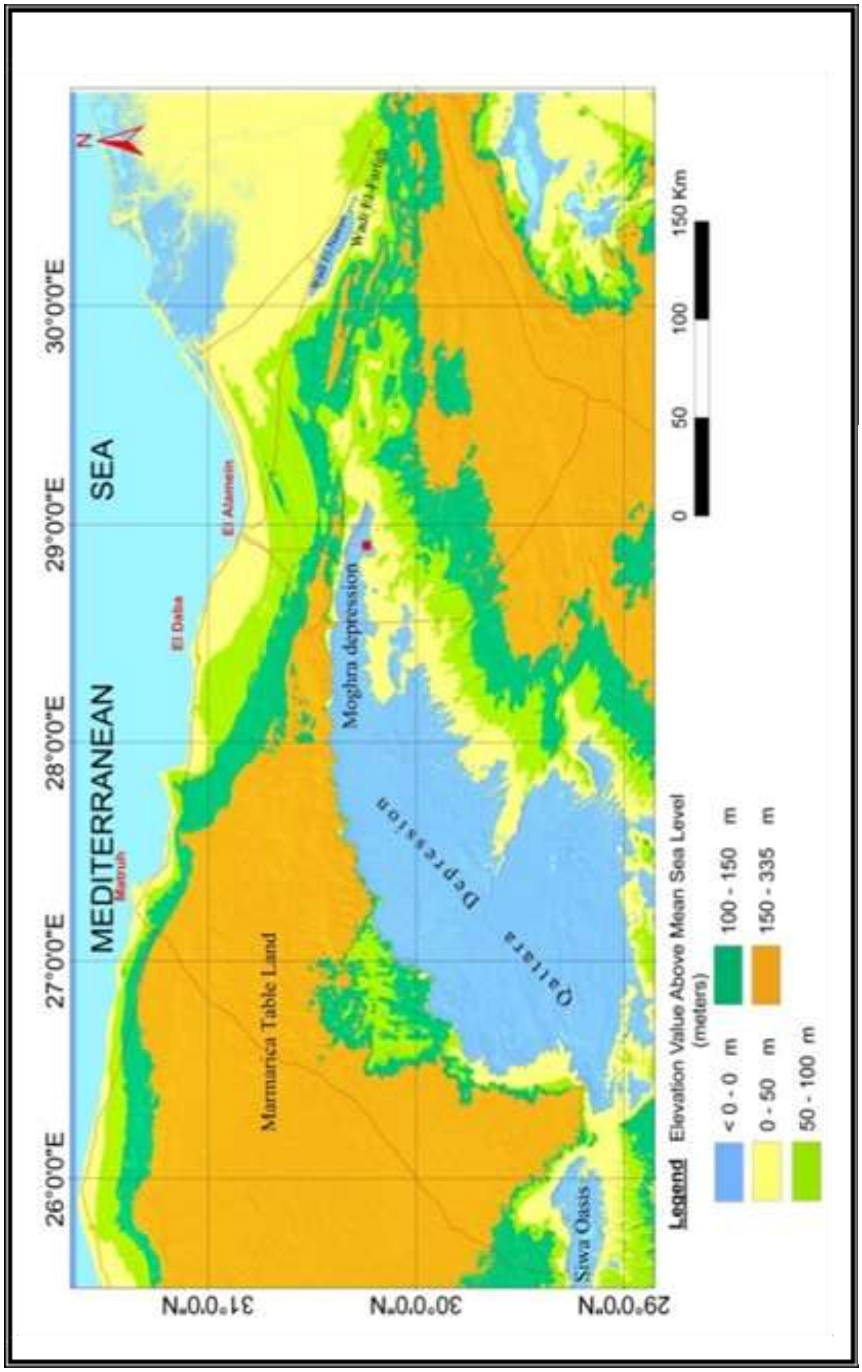


Fig. (2). Digital Elevation Model (DEM) showing the main landforms.

2. Geologic Setting

Recent drillings in the northern part of the Western Desert have shown that the geologic succession consists of a thick cover of Tertiary sediments belonging mainly to the Lower and Middle Miocene. The present work deals mainly with the Lower Miocene strata. Most of the study area surface is covered with gentle dipping Neogene strata of uniform lithology. There are a few patterns of major faults trending NE – SW and controlling the area.

The section of the Dabaa I well (31° 01' 19" N, 28° 29' 42" E) shows the following Miocene strata from bottom to top (Said, 1962):

2.1. Moghra formation: It is composed of continental to shallow marine clastic sequence of Early Miocene time, which grades laterally to the north and west into the marine Mamura Formation, while to the south into the genuine fluviatile redbeds of Gabal Khashab. It lies at the extreme eastern tip of the Qattara Depression where a 230 m section (base unexposed) of sandstone, siltstone and calcareous shale are described. The Lower Miocene overlies the Dabaa Formation and underlies the Marmarica Formation, with thickness distribution ranging from 500 to 0 m in the middle part and in the western and southern peripheries, respectively.

2.2. Mamura formation: It is composed of limestone and calcareous shale sequence, which is the marine equivalent of the Moghra, and of uniform lithology. It rests above the Dabaa Formation and is conformably overlain by the middle Miocene Marmarica Formation.

2.3. Marmarica formation: It is composed of limestone, dolomite and shale of Middle Miocene Age. The type locality is the scarp to the north of Siwa Oasis, where the surface section has 78 m thick (base unexposed) and is made up of limestone and marl. In all other areas, it overlies the Moghra Formation. The formation covers the Marmarica plateau of the north Western Desert and is overlained along the Mediterranean littoral, by a thin shallow marine unit of pink limestones (CONOCO, 1987 and Klitzsch et al., 1987) (Fig. 3).

Structurally, the Miocene terrain in the study area is built of a series of folds. The fold axes trend mainly in N 70° W to N 40° W direction. The study area is dissected by many normal faults belonging to three systems; NW–SE system, NE–SW system, and E–W system (Omara and Sanad, 1975 and Misak, 1979). Regionally, Meshrif (1990) has classified the Northern Western Desert of Egypt, on structural bases, into the following: Northern marine basin, North Abu El-Gharadig transitional basin, and South Abu El-Gharadig basin (Fig. 4).

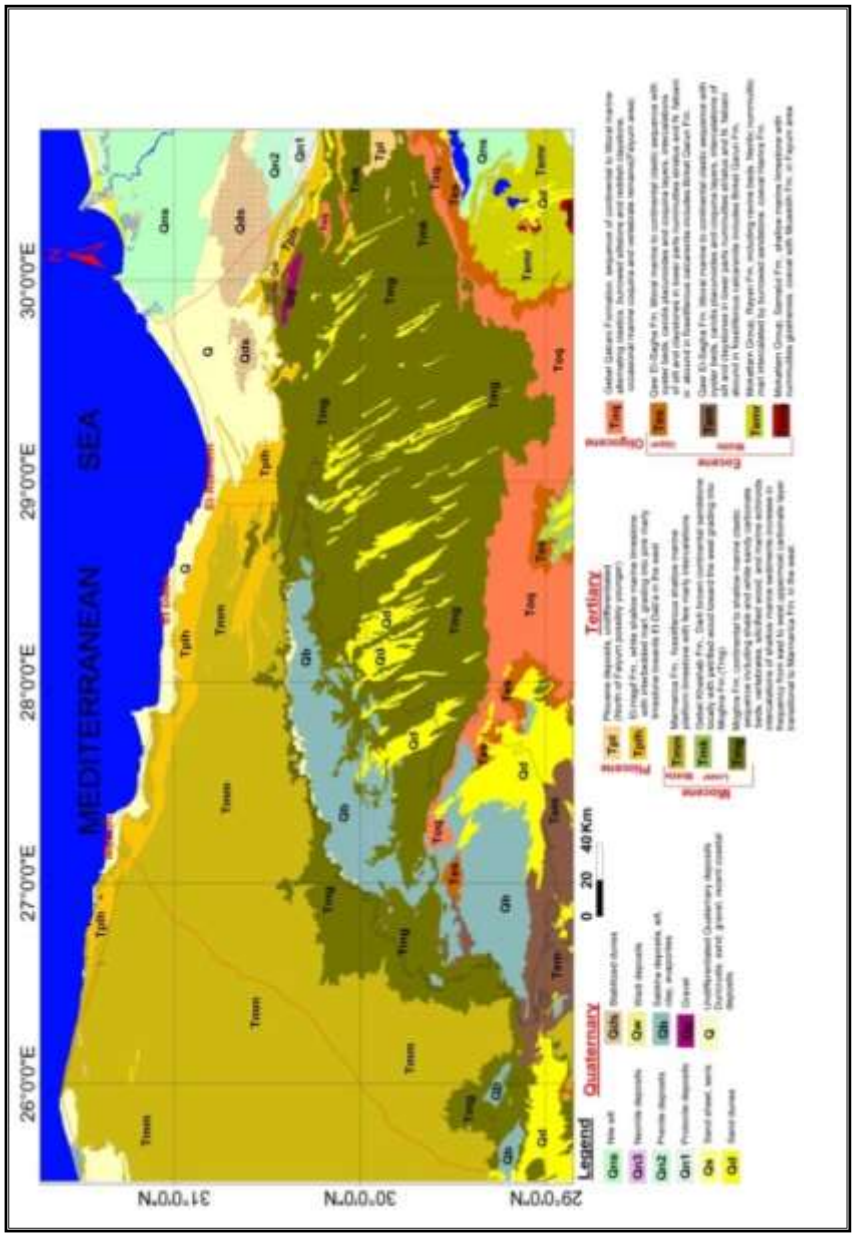


Fig. (3). Regional geologic map of the study area (CONOCO, 1987).

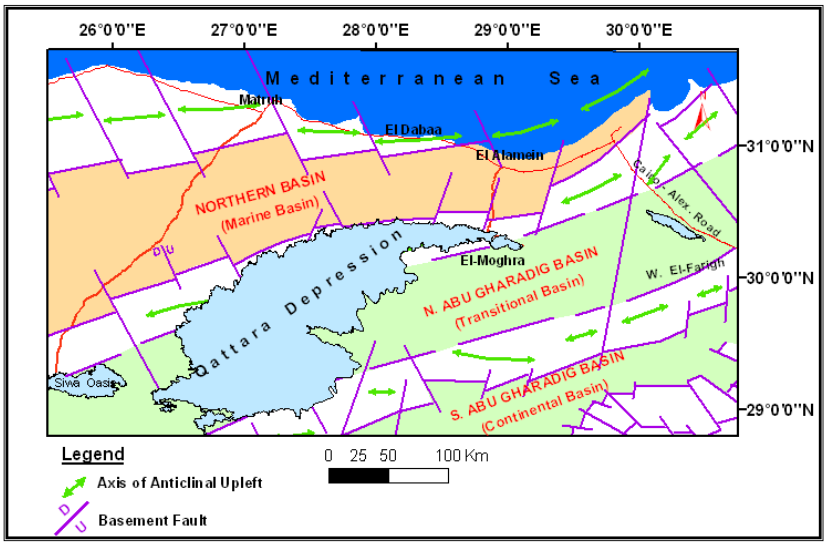


Fig. (4). Regional structural map of the Northern Western Desert of Egypt during Paleozoic times (Meshrif, 1990).

RESULTS AND DISCUSSION

1. Aquifer Conditions

In the present work, a number of 200 wells are tapping El-Moghra Aquifer in the area ranging in depth from 120 to 470 m have been investigated for flow directions, water quality, aquifer dimensions and hydraulic parameters (Fig. 5). Such investigations have been carried out through a number of field trips during the period 2008-2010, including data collection, nine pumping experiments and 45 water samples collection and analysis for major ion content. The fruitful cooperation with the oil companies working in the area, as well as the water drilling companies for providing different facilities was very helpful for the completion of the present work in the field.

The following four hydrogeological cross sections are constructed to define the aquifer extensions as well as the water flow directions; A-A' and B-B' in a West-East direction, C-C' in Northwest-Southeast direction and D-D' in Northeast-Southwest direction (Figs. 6 & 9, inclusive). The following features are clarified:

1. The subsurface strata consist mainly from top to bottom of Middle Miocene (Marmarica Formation) and Lower Miocene (Moghra Formation).
2. The thickness of the unsaturated zone of El- Moghra sandstone ranges between 12 m at well no. 150 at Qattara Depression and 173 m at well

no. 75 and it is attributed mainly to the topography, the depth to water and faults.

3. Generally, the Moghra Aquifer is partially penetrated by most of the wells. However, the thickness of this aquifer increases westward and northward. At the eastern part of the study area, the uplifting of the Oligocene basaltic sheet is the main reason for the relatively smaller thickness of the Moghra Aquifer (sections B-B' and C-C', Fig. 7 & 8), (its thickness ranges between 47 m at well no. 20 at the east, section B-B', Fig. 8) and 443 m at well no. 130, section A-A', Fig. 6).
4. The Moghra Aquifer occurs under unconfined condition at the east, while it occurs under confined condition at the west where it is overlained by the Marmarica limestone on its top (sections A-A', B-B', and D-D', Fig. 6, 7 & 9).
5. Regionally, the groundwater flow has the directions from east to west and from west to east, i.e. towards Qattara Depression (section B-B', Fig. 7), where it ranges between -7.013 m at well no. 5 and -111.1 m at well no. 153. Along the cross section A-A' (Fig. 6), the flow is from east (-24.37 m at well no. 107) and west (4.11 m at well no.184) to the middle part (-48 m at well no. 130). This means that Qattara Depression (-134 m) acts as a natural drain (major discharge area) for El- Moghra Aquifer water as shown in the potentiometric surface map (Fig. 10). There is an abrupt sinking of the water table (section D-D', at well no. 172, Fig. 9).
6. The geological structures play an important role on the distribution of El-Moghra Aquifer thickness, where most of the normal faults have their thrown westward and northward and consequently increase the thickness of the aquifer in the same direction. The normal faults make some horsts (section C-C', Fig. 8) and some grabbens (section A-A', Fig. 6).
7. The Marmarica limestone, which acts as an overlying rock (water bearing rock) on the Moghra Aquifer to the west of Qattara Depression, affects considerably the hydrogeological conditions of groundwater from unconfined to confine and the recharge process. The Marmarica Limestone Formation represents a good aquifer in the area to the north of Qattara Depression. It has a hydrogeological potentialitiy, which controls the recharge of the Moghra Aquifer and control the flow regime of such aquifer (Korany, 1975 and Hilmy et al., 1977).

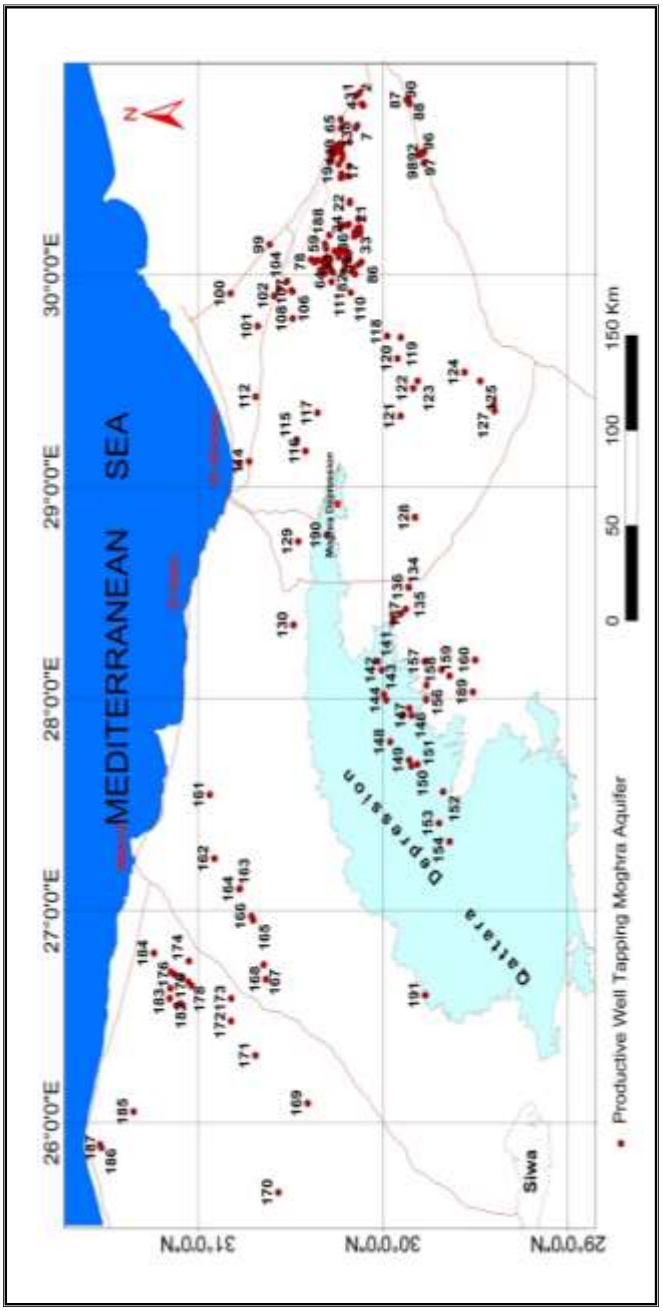


Fig. (5). Location of wells tapping El-Moghra Aquifer.

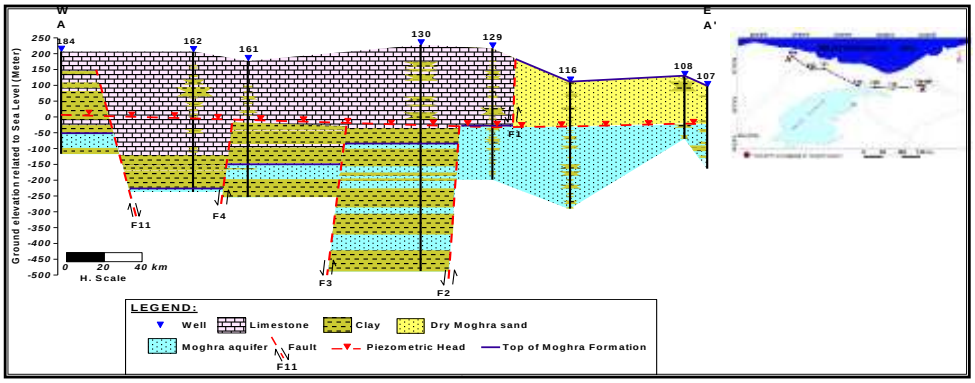


Fig. (6). Hydrogeological cross section A-A'.

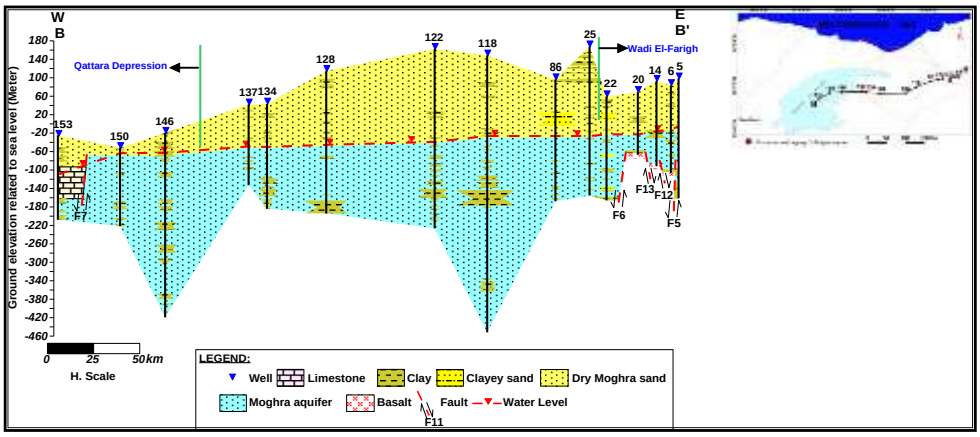


Fig. (7). Hydrogeological cross section B-B'.

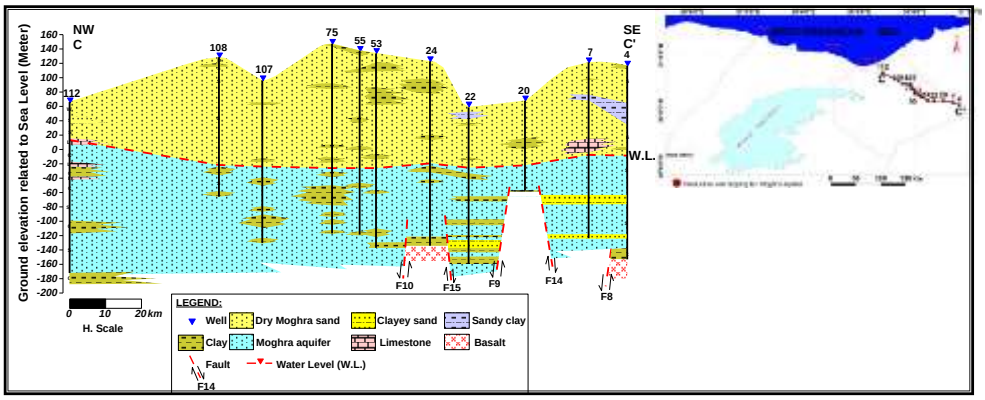


Fig. (8). Hydrogeological cross section C-C'.

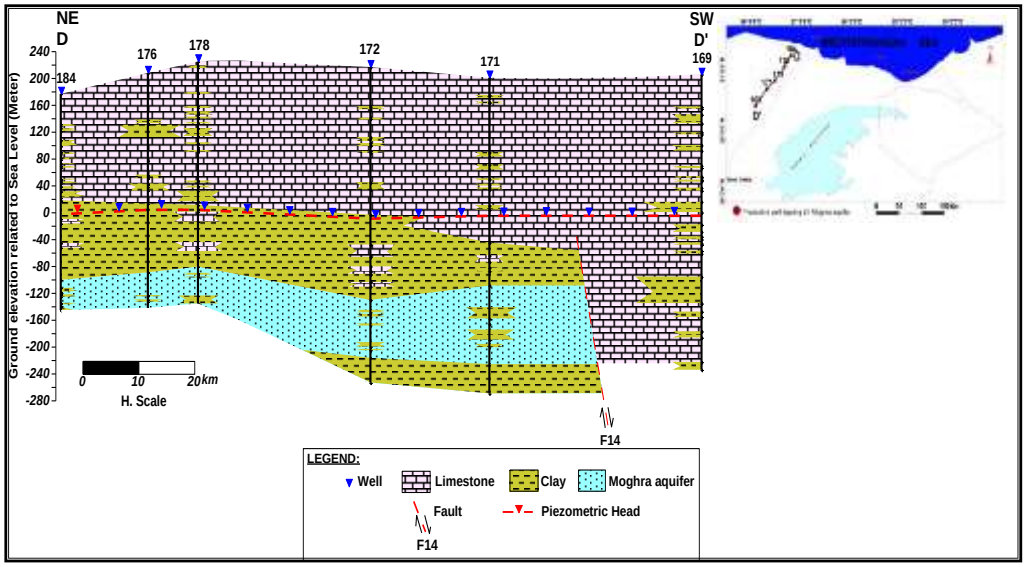


Fig. (9). Hydrogeological cross section D-D'.

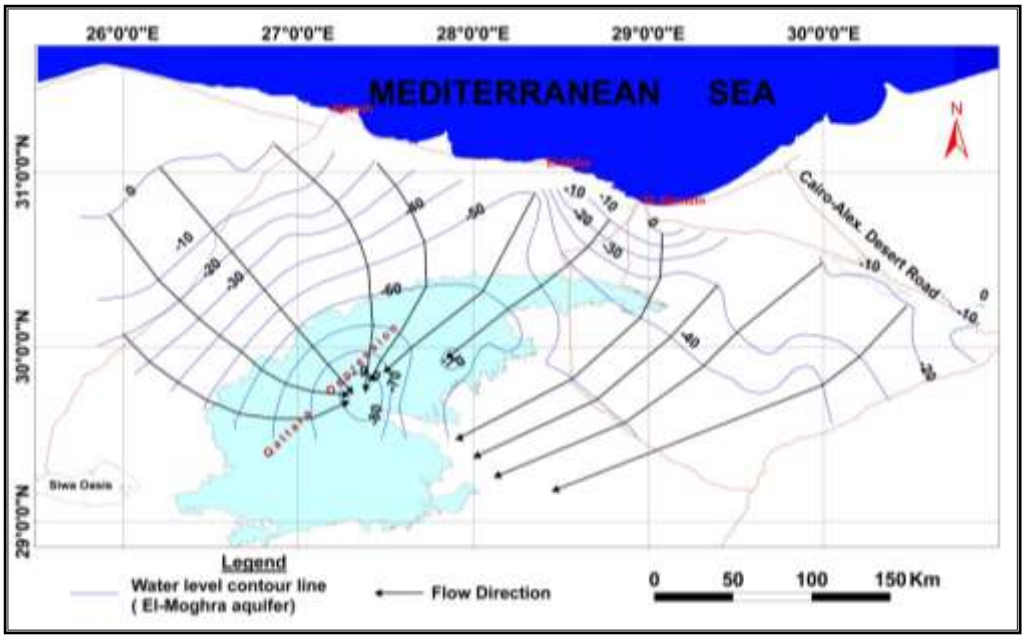


Fig. (10). Potentiometric surface map for El- Moghra Aquifer (2010).

2. Hydraulic Parameters of El-Moghra Aquifer

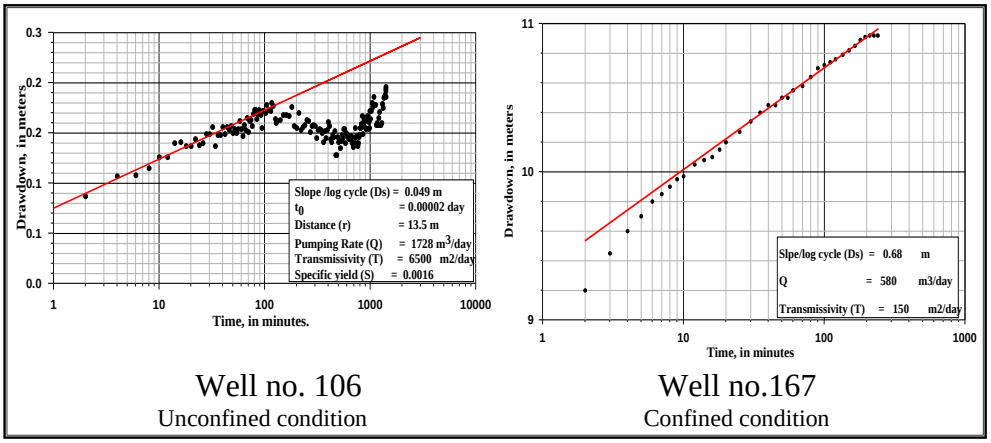
One of the main objectives of groundwater resource evaluation is the prediction of hydraulic head drawdown in aquifer under proposed pumping schemes. For the determination of the hydraulic parameters of El-Moghra Aquifer, a number of long duration pumping tests were carried out for nine wells in the study area representing the two conditions of El-Moghra Aquifer (unconfined to the east and confined to the west), using Jacobs and Hunter (1950) equations. The results obtained from these tests (Table 1 and Fig. 11) reflect the following:

- El-Moghra Aquifer shows wide variety of transmissivity, from 61 to 6500 m^2/day).
- The high values of transmissivity of El-Moghra Aquifer are recorded in the wells no. 4, 6, 80, 106 and 108 where the aquifer is unconfined with saturated thickness more than 100 m, while the low values of the transmissivity are in the wells no. 167, 172, 173 and 186 where the aquifer is confined. The low values of transmissivity can be attributed to the low saturated thickness (less than 50 m) and the presence of thick clay layers intercalated in the aquifer (sections A-A' and D-D', Figs. 6 and 9).
- The specific yield calculated in three wells tapping El-Moghra unconfined aquifer and the values range from 0.0005 to 0.0016.
- The specific capacity values (Q/s) range between 1.3 and 37.6 m^3/h/m. The decrease in Q/s values is, mainly, due to the increase in the drawdown (s) for constant discharge rate (Q) and this resulted from the low of transmissivity.

Table (1). Calculated hydraulic parameters of El-Moghra Aquifer in some selected wells.

Well no.	Aquifer type	Q (m^3/h)	Drawdown S (m)	Specific capacity (m^3/h/m)	T (m^2/day)	Specific yield	Well productivity classification
4	Unconfined	52	1.38	37.6	3560		Highly productive
6	Unconfined	113	5.20	21.7	720		Highly productive
80	Unconfined	103			2800	0.0005	Highly productive
106	Unconfined	72			6500	0.0016	Highly productive
108	Unconfined	25			1500	0.0013	Highly productive
167	Confined	24	12.00	2.0	150		Moderately productive
172	Confined	28	7.00	4.0	250		Moderately productive
173	Confined	33	4.29	7.7	600		Moderately productive
186	Confined	44	33.85	1.3	61		Low productive

According to well productivity classification (Sen, 1995), the tested wells of El-Moghra Aquifer can be classified into highly productive (Q/s more than 18 m^3/h/m), Moderate productive (Q/s from 18-1.8 m^3/h/m) and low productive (Q/s from 1.8-0.18 m^3/h/m).



Well no. 106
Unconfined condition

Well no.167
Confined condition

Fig. (11). Selected pumping test data analysis.

3. Hydrochemical Characteristics

To study the variation in groundwater quality of El-Moghra Aquifer, a number of wells (45 wells) was chosen representing the different conditions of El-Moghra water and the evolution of water quality within the flow direction was also assessed. The chemical analysis of selected 45 water samples has revealed the following (Table 2):

1. The water salinity TDS in the regional Moghra Aquifer ranges between 289 and 31000 ppm. The geographical distribution of TDS indicates fresh water in the vicinity of Wadi El-Natrun and highly saline water in the vicinity of Qattara Depression (Fig. 12).
2. The majority of the aquifer in the study area attains water salinities between 5000 and 10,000 ppm.
3. Such wide range in water salinity is evidently attributed to the changes of depositional environment of El-Moghra Formation from continental to marine. The hydrochemical indices Na^+/Cl^- and SO_4^{--}/C^- (based on equivalent values) are used in this work to differentiate between water affected by each of both environments.
4. Genetically, from the water analysis data, the values of Na^+/Cl^- less than 0.85 indicate marine environment, while that more than this value indicate continental one. On the other hand, SO_4^{--}/Cl^- ratio less than 0.1 indicate marine condition, while values more than this figure indicate continental condition (Hem, 1985). From table (2), all samples collected to the east of Long 30° 00' 00" are of continental facies while those lying to the west of Long 29° 00' 00" are related to marine environment where the Marmarica Formation is exposed on the surface.

Table (2). Chemical analyses of selected water samples from El-Moghra Aquifer.

		Cations								Anions									
Well	**TDS**	**Ca^{++}**		**Mg^{++}**		**Na^{+}**		**K^{+}**		**$HCO3^{-}$**		**$CO3^{--}$**		**$SO4^{--}$**		**Cl^{-}**		**rNa+K/rCl**	**rSO_4/rCl**
no.	**ppm**	**ppm**	**epm**	**ppm**	**epm**	**ppm**	**epm**	**ppm**	**epm**	**ppm**	**epm**	**ppm**	**epm**	**ppm**	**epm**	**ppm**	**epm**	**epm**	**epm**
16	991.7	83.4	4.16	36.5	3.01	205.0	8.91	7.0	0.18	146.1	2.39	14.4	0.48	180.0	3.75	319.3	9.00	1.00	0.42
17	289.0	17.5	0.87	18.9	1.55	40.0	1.74	4.0	0.10	153.4	2.51	14.4	0.48	10.0	0.21	30.9	0.87	2.10	0.24
18	333.7	17.8	0.89	7.2	0.59	62.0	2.69	7.0	0.18	173.9	2.85	4.5	0.15	28.0	0.58	33.3	0.94	3.10	0.62
27	730.0	60.0	3.00	30.0	2.50	130.5	5.67	1.8	0.05	183.0	3.00	12.0	0.40	145.0	3.02	168.6	4.75	1.20	0.64
34	773.0	50.0	2.50	30.0	2.50	163.1	7.09	1.8	0.05	189.1	3.10	12.0	0.40	155.0	3.23	172.5	4.86	1.47	0.66
37	752.0	35.0	1.75	28.0	2.30	176.4	7.67	2.3	0.06	183.0	3.00	0.0	0.00	115.0	2.40	212.8	6.00	1.28	0.40
38	794.0	30.0	1.50	36.0	3.00	187.5	8.15	2.3	0.06	201.5	3.30	12.0	0.40	115.0	2.40	210.1	5.92	1.38	0.40
39	941.0	40.0	2.00	48.0	4.00	200.1	8.70	2.8	0.07	183.0	3.00	0.0	0.00	210.0	4.37	257.1	7.25	1.21	0.60
44	1066.0	60.0	3.00	60.0	5.00	208.5	9.07	3.4	0.09	207.4	3.40	0.0	0.00	270.0	5.63	257.1	7.25	1.26	0.78
48	754.0	60.0	3.00	24.0	2.00	160.0	6.95	2.3	0.06	172.0	2.82	12.0	0.40	120.0	2.50	203.9	5.75	1.22	0.43
49	696.0	40.0	2.00	22.0	1.80	165.0	7.17	2.3	0.06	158.6	2.60	12.0	0.40	110.0	2.29	186.5	5.26	1.37	0.44
51	681.0	30.0	1.50	20.0	1.67	167.9	7.30	2.3	0.06	158.6	2.60	12.0	0.40	110.0	2.29	181.2	5.10	1.44	0.45
58	784.0	80.0	4.00	0.0	0.00	172.7	7.51	3.4	0.09	158.6	2.60	12.0	0.40	145.0	3.02	212.8	6.00	1.26	0.50
77	1998.6	180.0	9.00	60.0	5.00	430.7	18.70	36.9	0.95	48.8	0.80	60.0	2.00	450.0	9.38	732.2	20.63	0.95	0.45
79	1591.9	160.0	8.00	60.0	5.00	314.0	13.65	32.8	0.84	73.2	1.20	72.0	2.40	170.0	3.54	710.0	20.00	0.72	0.18
81	1152.0	100.0	5.00	48.0	4.00	208.5	9.07	3.4	0.09	189.1	3.10	0.0	0.00	320.0	6.67	283.7	8.00	1.14	0.83
84	1109.5	60.0	3.00	60.0	5.00	225.6	9.81	3.9	0.10	207.4	3.40	0.0	0.00	260.0	5.42	292.5	8.25	1.20	0.66
93	7008.0	630.0	31.50	378.0	31.50	1305.0	56.74	14.1	0.36	61.0	1.00	0.0	0.00	1400.0	29.17	3220.0	90.80	0.63	0.32
94	8240.0	950.0	47.50	270.0	22.50	1627.5	70.76	18.0	0.46	91.5	1.50	0.0	0.00	1800.0	37.50	3483.9	98.25	0.72	0.38
111	1585.1	160.0	8.00	48.0	4.00	322.0	14.00	32.8	0.84	42.7	0.70	54.0	1.80	260.0	5.42	665.6	18.75	0.79	0.29
133	11540.0	365.0	18.25	270.0	22.50	3651.0	158.74	37.6	0.96	48.8	0.80	12.0	0.40	700.0	14.57	6455.7	184.45	0.86	0.08
144	21839.6	600.0	30.00	744.0	62.00	6633.2	288.40	420.4	10.80	54.9	0.90	54.0	1.80	420.0	8.75	12913.1	363.75	0.86	0.02
155	12827.4	820.0	41.00	348.0	29.00	3513.8	152.80	214.0	5.50	42.7	0.70	42.0	1.40	525.0	10.94	7321.9	206.30	0.76	0.05
159	16434.3	1000.0	50.00	408.0	34.00	4545.4	197.60	183.0	4.70	24.4	0.40	36.0	1.20	2250.0	46.88	7987.5	225.00	0.89	0.21
164	6450.8	200.0	10.00	300.0	25.00	1688.6	73.42	194.8	5.00	30.5	0.50	42.0	1.40	800.0	16.67	3195.0	90.00	0.87	0.19
165	20939.0	571.1	28.50	243.2	20.00	6590.0	286.50	149.5	3.83	73.2	1.20	0.0	0.00	2900.0	60.41	10412.5	297.50	0.97	0.20
166	30522.5	1000.0	50.00	600.0	50.00	8970.0	390.00	634.4	16.20	18.3	0.30	6.0	0.20	4650.0	96.88	14643.8	412.50	0.98	0.24
167	5815.2	200.0	10.00	84.0	7.00	1707.4	74.24	179.2	4.60	12.2	0.20	12.0	0.40	980.0	20.42	2640.3	74.38	1.06	0.28
168	8200.0	480.0	24.00	192.0	16.00	2086.6	90.72	199.9	5.15	36.6	0.60	36.0	1.20	1575.0	32.80	3594.4	101.25	0.95	0.32
172	13934.9	700.0	35.00	420.0	35.00	3494.6	151.94	317.2	8.10	18.3	0.30	6.0	0.20	2145.0	44.69	6833.8	192.50	0.83	0.23
173	9637.7	560.0	28.00	240.0	20.00	2610.3	113.49	296.6	7.60	30.5	0.50	30.0	1.00	390.0	8.13	5480.3	154.40	0.78	0.05
177	13521.0	220.4	11.00	267.5	22.00	4579.5	199.12	41.5	1.06	73.2	1.20	0.0	0.00	1950.0	40.63	6389.0	180.20	1.11	0.23
181	14943.0	420.0	21.00	252.0	21.00	4543.9	197.60	337.9	8.70	12.2	0.20	12.0	0.40	2465.0	51.35	6900.0	194.59	1.06	0.26
183	16589.0	460.0	23.00	396.0	33.00	4910.0	213.50	368.8	9.50	12.2	0.20	12.0	0.40	2520.0	52.50	7910.0	223.00	1.00	0.24
186	6959.0	180.0	9.00	180.0	15.00	2073.7	90.16	158.6	4.05	48.8	0.80	48.0	1.60	720.0	15.00	3550.0	100.00	0.94	0.15
189	31000.0	480.9	24.00	449.9	37.00	10321.6	448.78	224.5	5.74	73.2	1.20	0.0	0.00	1600.0	33.31	17850.0	510.00	0.89	0.07
192	301.0	15.2	0.76	6.9	0.57	60.0	2.61	3.0	0.08	162.0	2.66	4.7	0.16	14.0	0.29	35.0	0.99	2.72	0.30
193	330.0	19.0	0.95	11.5	0.95	60.0	2.61	3.0	0.08	162.0	2.66	0.0	0.00	15.0	0.31	60.0	1.69	1.59	0.18
194	387.0	19.0	0.95	11.5	0.95	85.0	3.70	4.0	0.10	171.6	2.81	9.4	0.31	12.0	0.25	75.0	2.12	1.80	0.12
195	489.0	15.2	0.76	13.8	1.14	125.0	5.44	3.0	0.08	171.6	2.81	14.1	0.47	36.0	0.75	110.0	3.10	1.78	0.24
196	396.0	15.2	0.76	13.8	1.14	88.0	3.83	3.0	0.08	185.9	3.05	14.1	0.47	16.0	0.33	60.0	1.69	2.31	0.20
197	371.0	26.6	1.33	11.5	0.95	72.0	3.13	4.0	0.10	143.0	2.34	14.1	0.47	50.0	1.04	50.0	1.41	2.29	0.74
198	302.9	19.7	0.98	19.2	1.58	40.0	1.74	7.0	0.18	143.0	2.34	14.1	0.47	30.0	0.63	30.0	0.85	2.26	0.74
199	319.6	23.6	1.18	14.4	1.18	45.0	1.96	5.0	0.13	157.3	2.58	9.4	0.31	40.0	0.83	25.0	0.71	2.96	1.18
200	344.1	23.6	1.18	11.9	0.98	54.0	2.35	4.0	0.10	181.	2.97	9.4	0.31	25.0	0.52	35.0	0.99	2.48	0.53

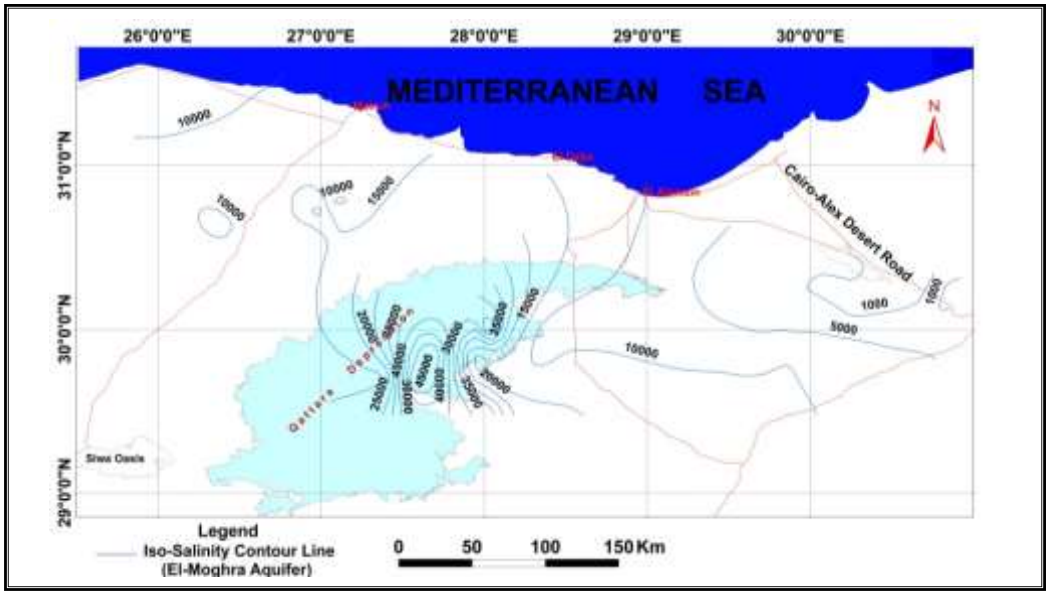


Fig. (12). Iso-Salinity contour map for El-Moghra groundwater.

5. The Piper (1944) genetic diagram (Fig. 13) shows that El-Moghra Aquifer at Wadi El-Farigh is recharged from the Nile aquifer in the east, while that lies near El-Moghra Oasis and near Qattara Depression is probably recharged through upward leakage under artesian condition from deeper marine strata as indicated from the field measurements as well as from the well correlations and hydrogeological cross sections.

CONCLUSION

Five main issues have been raised up in conclusion of the present study, as follows:

1. The first issue deals with the relationship between water levels and salinity, where the following are concluded (Fig. 14):
   - i- The potentiometric level varies from about -7 m at well no. 5 to -111 m at well no.153 through a distance of about 340 km in E-W direction.
   - ii- In the same direction, the water salinity increases from about 1000 to 125000 ppm from east to Qattara Depression.
   - iii- A transional zone appears after about 75 km in E-W direction where the water salinity starts rising up from 1000 ppm where the water level is 27 m below sea level.

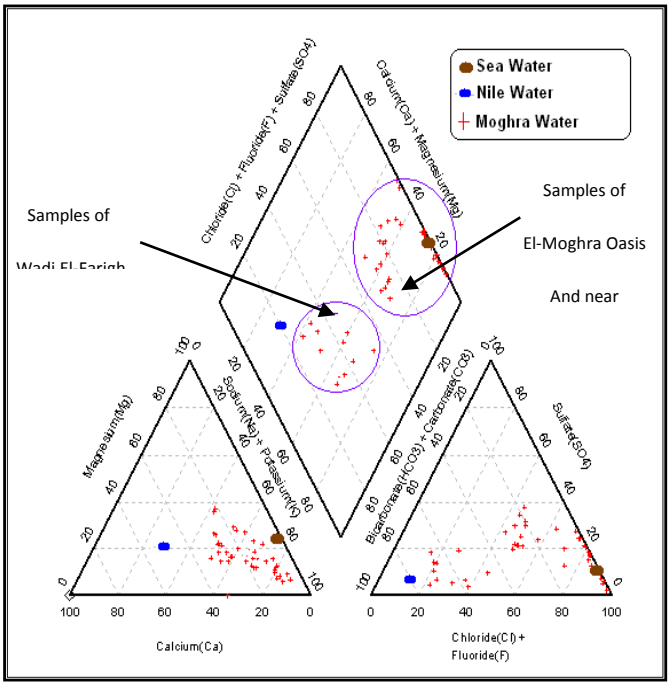


Fig. (13). Piper Trilinear diagram for hydrochemical classification of El-Moghra Aquifer.

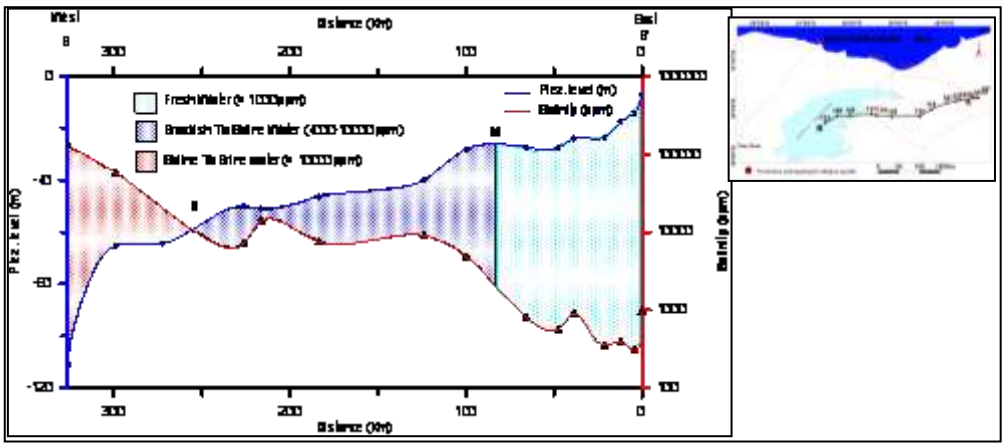


Fig. (14). Profile B-B' showing the relationship between water level and water salinity in El-Moghra Aquifer.

2. The second issue deals with the relationship between water quality on one side and the depositional environment and source of recharge on the other side. The calculated hydrogeochemical indices and the applied genetic classification (Piper method) strongly indicate that the area in the vicinity of Wadi El-Natrun in the east is characterized by continental facies and a close contact with the Nile Delta aquifer, while to the west of Wadi El-Farigh the marine facies and characters dominate.
3. The third issue deals with the groundwater flow direction, where the potentiometric water level map has obviously indicated that the recharge area is in the Nile Delta up to Wadi El-Farigh anticline, while the Qattara Depression is the discharging area for the whole aquifer unit.
4. The fourth issue deals with the visual interpretation of the landsat image acquired on 2009, which detects the extensions of the agricultural development in the study area compared with the present status of agricultural investments as shown in Fig. (15), where the total cultivated area depending on El-Moghra fresh water aquifer is about 67768 hectare.
5. The fifth issue deals with the extractable water volume of El-Moghra Aquifer in the eastern area where the aquifer is unconfined to semi-confined and where the water salinity is less than 5000 ppm; (already invested area for agricultural development). The water well investigations indicate an approximate volume of 984×10^6 m^3.

RECOMMENDATIONS

From the present study, one can recommend the following:

1. All agricultural investments of El-Moghra Aquifer should be to the east of Longitude 30° 00' 00" E where:
   - The water level is above -27 m.
   - The water salinity is less than 2000 ppm.
   - The transmissivity of the aquifer is relatively high ranging between 720 and 6500 m^2/day.
2. Laterally, the promising area for the agricultural investments of El-Moghra Aquifer should not exceed Latitude 30° 00' 00" N at south and 30° 45' 00" N at north.
3. This means that the promising area based on the above criteria is about 375000 hectare. An additional area of about 488000 hectare having water salinity between 2000 and 5000 ppm can be used for cultivation of salt tolerant crops, while those having water salinities more than 5000 ppm could be used for industrial purposes; e.g. oil industry, mineral washing and specific salts extraction.

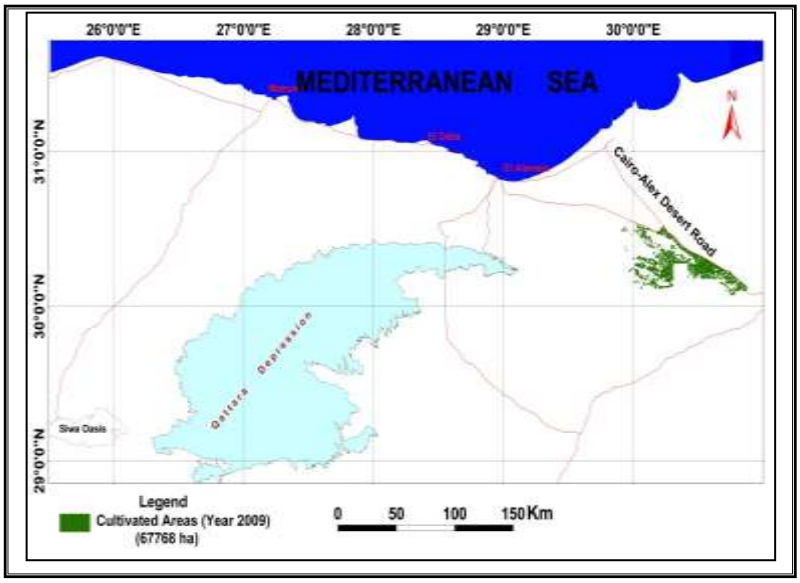


Fig. (15). Distribution of the agricultural investments in the study area interpreted from landsat image (2009).

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إمكانيات وخصائص المياه الجوفية لخزان المغرة فى المناطق المتاخمة لمنخفض القطارة

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تقع منطقة الدراسة بين وادي النطرون شرقًا ومنخفض القطارة غربًا وتغطى مساحة حوالى ١٥٠٠٠٠ كم٢ حيث يتواجد خزان المغرة (الميوسين السفلي) ذو البيئة الترسيبية القارية إلى البحرية. وقد تمت بهذه المنطقة محاولات عديدة لإستخراج المياه الجوفية بغرض الري في الجزء الشرقي بالقرب من وادي النطرون، حيث ملوحة المياه أقل من ١٠٠٠ جزء في المليون، بينما في الجزء الغربي المتاخم لمنخفض القطارة تستخدم المياه الجوفية في صناعة البترول، حيث تزيد ملوحة مياه خزان المغرة عن ١٠٠٠٠ جزء في المليون. ويهدف البحث إلى دراسة الخصائص الطبيعية والكيميائية والهيدروليكية لخزان المغرة بالإضافة إلى تقييم إمكاناته وتغيراته الأفقية والرأسية بمنطقة الدراسة من خلال دراسة البيانات المتاحة لحوالي ٢٠٠ بئر إنتاجى. وقد أظهرت الدراسة تواجد مياه خزان المغرة تحت ظروف حرة في المنطقة الواقعة شرق خط طول ٠٠ ٠٠ ٢٩° شرقًا وتتصل هيدروليكيًا بخزان دلتا النيل، بينما تتواجد تحت ظروف حبيسة غرب خط الطول ٣٠ شرقًا وتتأثر بالتصرف الرأسى للمياه المالحة العميقة. وقد أظهرت نتائج تحليل تجارب الضخ التي تم إجراؤها بالمنطقة أن خزان المغرة يتميز بإنتاجية عالية في الجزء الشرقى (خزان حر) حيث تتراوح قيم معامل الناقلية بين ٧٢٠ م٢/يوم إلى ٦٥٠٠ م٢/يوم، بينما الإنتاجية ضعيفة غربًا (خزان حبيس) حيث تتراوح قيم معامل الناقلية بين ٦١ م٢/يوم إلى ٦٠٠ م٢/يوم. كما تم تقييم الخزان كيميائيًا حيث يعزى التغير الهائل في ملوحة المياه من الشرق إلى الغرب إلى إختلاف البيئة الترسيبية لطبقة المغرة (الميوسين الأسفل) من ظروف قارية شرقًا إلى ظروف بحرية غربًا. وأيضًا أمكن تحديد مصادر تغذية خزان المغرة. وبدراسة العلاقة بين ملوحة المياه ومستواها منسوبًا إلى سطح البحر وجد أن هناك علاقة ملموسة بين السطح الفاصل بين المياه العذبة والمالحة والمناطق الواعدة للتنمية، حيث أمكن إستخلاص أنه في المنطقة شرق منسوب المياه ٢٧ متر تحت سطح البحر فإن ملوحة المياه أقل من ٢٠٠٠ جزء فى المليون وتقدر بمساحة حوالي ٣٧٥٠٠٠ هكتار ملائمة لأغراض الزراعة والإستخدامات المنزلية. بينما توجد غرب منسوب المياه ٢٧ متر تحت سطح البحر مساحة قدرت بحوالى ٤٨٨٠٠٠ هكتار تتراوح ملوحتها بين ٢٠٠٠ و٥٠٠٠ جزء في المليون يمكن ملائمتها للمحاصيل التي تتحمل الملوحة العالية.