Egyptian Journal of Geology, v. 64, 2020, p. 35-50

EVALUATION OF GROUNDWATER RESOURCES OF THE FRACTURED EOCENE LIMESTONE AQUIFERS AT SOME WADIS, EAST EL MINIA GOVERNORATE, EASTERN DESERT, EGYPT

Abo Habibah, A.[1], Dahab, K.[1], Shabana, A.[2], Kamh, S.[3] and and Ibrahim, H.[1]

1 Geology Department, Faculty of Science, Menoufia University, Egypt
2 Geology Department, Desert Research Center, Cairo, Egypt
3 Geology Department, Faculty of Science, Tanta University, Egypt

ABSTRACT

El Minia governorate desert fringes represent one of the interested areas for the future land reclamation and establishing of new communities. The present work aims to evaluate the groundwater resources of the fractured Eocene limestone aquifers at some wadis, east El Minia governorate. The study area is characterized by large surface area, 6288 km^2 with good groundwater and soil potentialities. Accordingly, the evaluation of this groundwater resources is required. Hydrogeologically, two main aquifers are encountered in the study area, namely Maghagha marly limestone and Samalut chalky limestone aquifers.

Maghagha aquifer is composed of alternated layers of marly limestone and shale with penetrated thickness ranging from 3.49 m to 177.05 m and a depth to groundwater ranging from 8.5 m to 59.27 m from ground surface. This aquifer has groundwater salinity ranges from 603.5 mg/l to 978.5 mg/l, reflecting fresh water type. Samalut aquifer is made up of chalky, cavernous and fractured limestone with penetrated thickness ranging from 30 m to 205 m and a depth to groundwater ranging from 9 m to 86.77 m from the ground surface. The groundwater salinity of the concerned aquifer ranges from 349.7 mg/l to 2043.9 mg/l, reflects fresh to possibly brackish water types. Maghagha aquifer has low potentiality, while, Samalut aquifer represents the main productive water bearing rocks, reflecting moderate to high groundwater potentiality. The groundwater flows are mainly from northwest to southeast indicating that these aquifers are probably recharged from the Nile River. Water samples representing the investigated groundwater were collected, chemically analyzed and evaluated.

Keywords: Hydrogeology, Eocene limestone aquifers, El Minia governorate, Eastern Desert, Egypt.

INTRODUCTION

The study area encompasses an area of about 6288 km^2. It's bounded by longitudes 30º 44′ 35″ E and 32º 27′ 45″ E and latitudes 27º 55′ 40″ N and 28º 38′ 4″ N, relating to the eastern fringes of El Minia governorate (Fig. 1). The continued growing in agricultural activities in east El-Minia areas has consequently increased the water demands. Consequently, in order to meet these demands, groundwater exploration and evaluation are focused. The study area is characterized by arid to semi-arid, hot climate, dry, rainless in summer and mild with rare precipitation in winter. According to the Egyptian Meteorological Authority, El Minia station (1982-2017), the rainfall average value for the last 36 years ranged from 0 to 3.9 mm/year and the annual average air temperature is about 22.04°C, whereas the annual average relative humidity at day time is 35% and the mean winds velocity reaches average of about 16.7 Km/hour.

GEOMORPHOLOGICAL SETTING

Hydro-geomorphologically, the study area is classified into two main units (Fig. 2):

1- **The watershed areas (uplands):** It's represented mainly by El Maaza limestone plateau, it's dissected by several wadis drained to the west (Nile River). The surface level of this plateau ranges from (+40 m) at the western portion to (+1265) at the eastern portion of the study area. It's built of the Middle

Eocene carbonate rocks. The concerned area is represented also by some structural ridges like G. Al Murier (+413 m), G. Qurun Harhash (+415 m) and G. Al Ahmer (+215 m).

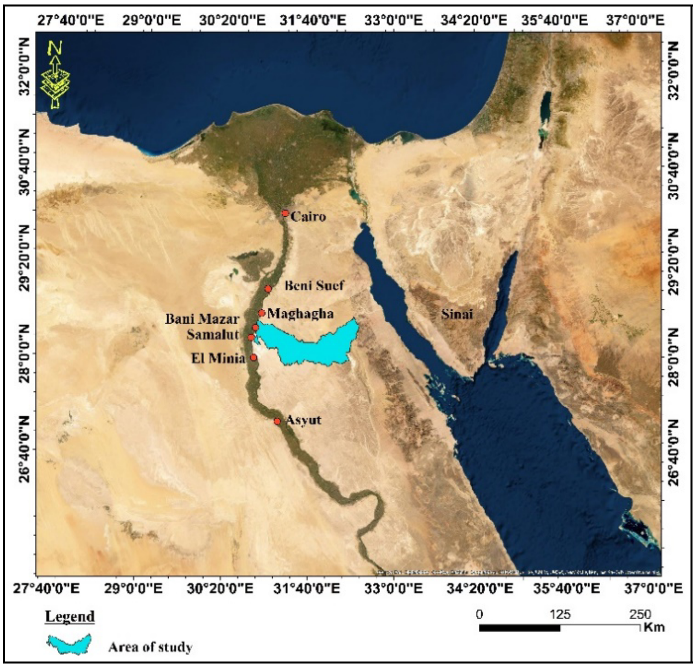
2- **The water collectors (lowlands):** it's distinguished into two main units:

a- The drainage network: it's represented by Wadi Al Muhasham (221 km^2), Wadi Al Tarfa (5977 km^2) and Wadi Al Sirrariah (89 km2), it drains rain water of El Maaza plateau westward to the Nile River.

b- The inland depressions are represented by three main depressions as follows:
- The eastern depression is nearly circular; it has a surface area of about 28.8 km^2.
- The central depression is nearly elongated; it has a surface area of about 34 km^2.
- The western depression is elongated with a surface area of about 43 km^2.

c- Recent Nile alluvial plain: It is a longitudinal strip of land occupied by the cultivated lands and urban villages. It runs parallel to the River Nile with a width varies from 2 km opposite delta of the studied wadis to less than 1 km at the rest of the plain. It has a ground elevation ranges between 33 m and 37 m above sea level.

Fig. 1: Location map of the study area.



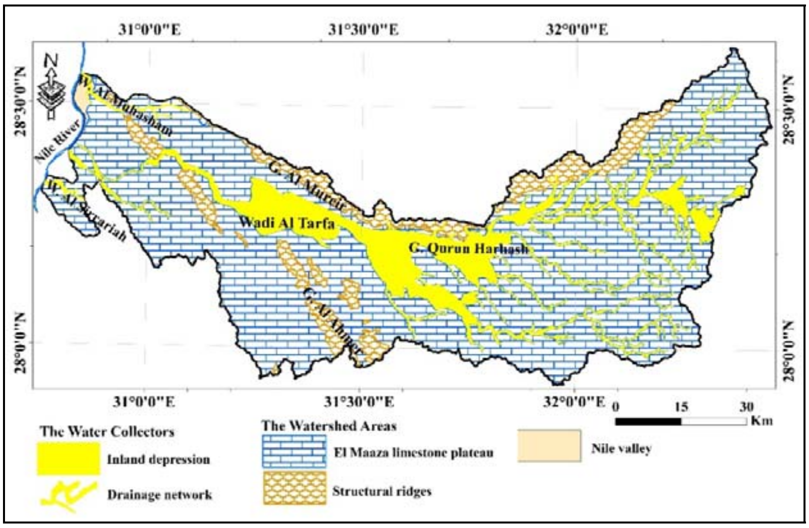


Fig. 2: Geomorphological map of the study area.

GEOLOGIC SETTING

The studied area represents a portion of the Eastern Desert and its geological settings play an important role in controlling the geomorphic and hydrogeological settings. The geologic setting of the study area can be discussed herein by its stratigraphic succession and structural lineaments analysis:

Stratigraphic succession

The surface of the study area is covered mainly by Middle Eocene rocks. Cretaceous rocks cover small areas at the upstream portions of the basin (Said, 1962). The Quaternary deposits occupy low land areas (Conoco, 1987). The exposed rock units in the study area are discussed based on the previous work of Said (1962), Bishay (1966), EL Boukhary and Abdelmalik (1983), Said (1983) and Shileby (2000) and the field geologic investigations from base to top as follows (Fig. 3):

1. **Carboniferous (Somr El-Qaa Fm.)**; occupies the northeastern portion of Wadi Al Tarfa area. It consists of fluviatile sandstone with near shore intercalations (Scolithus).
2. **Cretaceous rocks**; occupy the upstream portions of Wadi Al Tarfa basin. They are represented by the following units from base to top:
   a. **Lower Cretaceous;** are only represented by Wadi Qena Fm. It occupies the northeastern portion of Wadi Al Tarfa area. It consists mainly of fluviatile white and yellow massive sandstone
   b. **Upper Cretaceous**; are represented by the following units:
      - **Cenomanian (Galala Fm.)**; composed of marine fossiliferous limestone, partly sandy intercalated by shale in the lower part.
      - **Turonian (Umm Omeiyid Fm.)**; represented by brown to yellowish brown cross-bedded fluviatile to aeolian sandstone partially marine in the middle and upper parts.
      - **Santonian (Hawashiya Fm.)**; composed of marine to lagoonal carbonate and shale, locally interbedded by sandstone beds.
      - **(Sudr Fm.)**; composed of marine chalk with shale intercalations at top, with locally flint concretions.
3. **Eocene rocks;** cover large surface areas of the studied basins specially at the downstream portions. They are represented by the following from base to top:
   a. **Lower Eocene (Thebes Group)**; occupies the eastern portion of Wadi Al Tarfa area. Thebes Group includes the following formations from base to top:
   - **Serai Formation**: Composed of fine-grained thinly-bedded micritic limestones, chalky and cherty with rare shales, grading upward into massive bioturbated.
   - **Abu Rimth Formation**; composed of well-bedded open marine to shelf limestones and marls with intercalated thin turbidite.

   b. **Middle Eocene;** cover most of the surface area of the studied basins. They can be distinguished from base to top into the following formations:
   - **Samalut Formation;** occupies the southwestern portions of Wadi Al Tarfa and all of Wadi Al Sirariah. It consists mainly of snow white to greyish white chalky limestone rich with Nummulite gizahensis. It represents the main water bearing rocks in El Minia governorate.
   - **Maghagha Formation;** occupies the low lands to the south of Al Mureir scarp and also forms the relatively high hills overlying Samalut Formation. It is composed of marly limestone with chalky limestone interbeds with few clay intercalations. The rocks of the concerned formation are highly fossiliferous with Pelecypods and Gastropods species.
   - **Qarara Formation;** occupies most of G. Al Mureir scarp. It overlies conformably Maghagha Formation. It is composed mainly of yellow marly limestone and greenish grey to yellowish grey clay intercalations with some Pelecypods species.
4. **Quaternary deposits;** cover large surface areas of the studied basins. They are represented by the following deposits:
   a. Recent wadi deposits; composed mainly of silt, sand and gravel representing the weathering product of the country rocks. They occupy the drainage channels of the studied basins and their main tributaries floor.
   b. Nile silt; represents the eastern Nile valley and composed mainly of silt and clay.

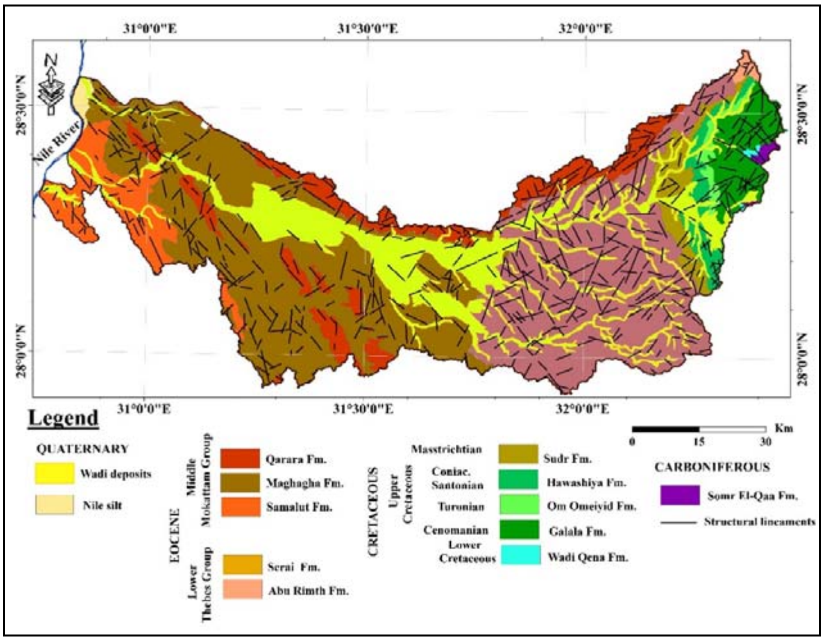


Fig. 3: Geologic map of the study area (modified after Conoco, 1987).

Structural setting

The study area is controlled by two main trends of structural lineaments. The first one is northwest-southeast which represent the regional trend of the Red Sea and the Gulf of Suez. This trend is clearly distinguished in the western and northern portions crossing the Middle Eocene carbonate rocks. The second one is the northeast-southwest trend which represents Wadi Araba structure (Syrian Arc system). This trend is clearly distinguished in the surface areas covered by the Upper Cretaceous carbonate rocks. It's clear that the rock units manifest the two main trends, Wadi Araba structure (Syrian Arc system) and Red Sea and the Gulf of Suez trend, this is coinciding with that suggested by Youssef (1968).

It is obvious that the structural lineaments of the study area have moderate to high density over Eocene rocks at the middle and downstream portions of the studied hydrographic basins (Fig. 4). Also, they are aligned and enhanced at G. Al Mureir scarp. Importantly, the topography and the drainage system are mostly controlled by this structural lineament system and the intersection points with these structural lineaments are considered as the pathways which feed the shallow groundwater aquifers in the study area.

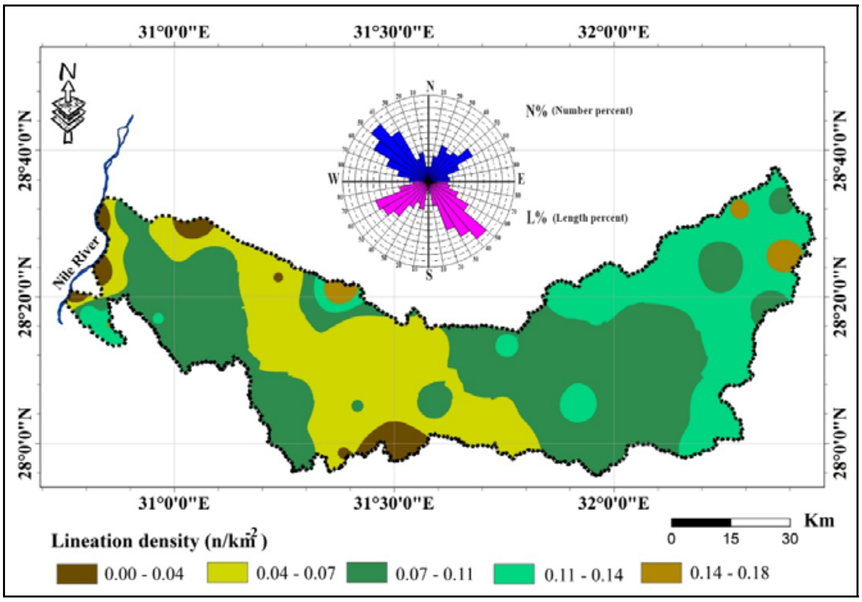


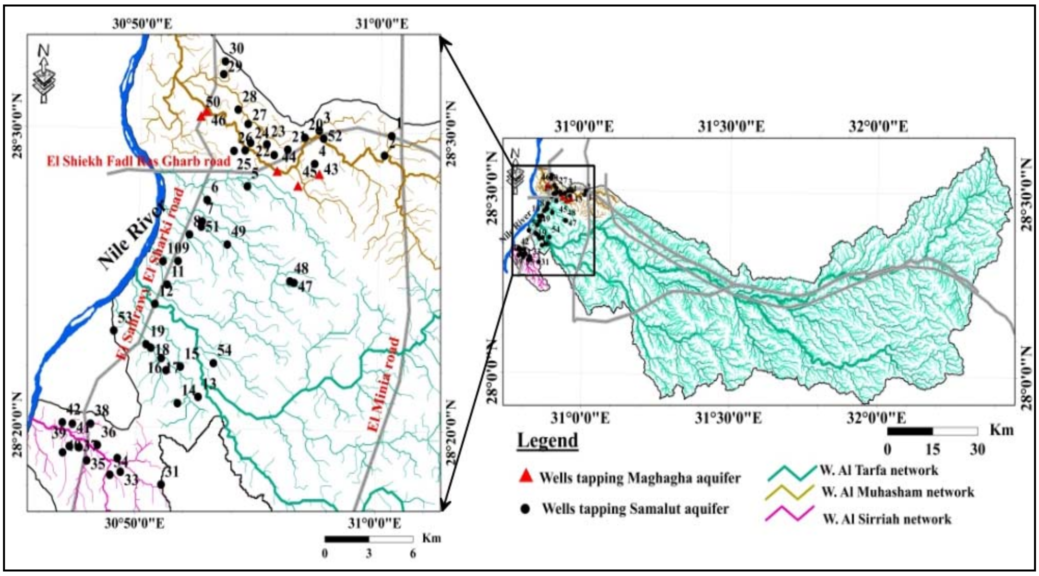
Fig. 4: The structural lineaments density map of the study area.

Hydrogeological setting

The groundwater of the investigated area is recorded in two main water bearing rocks; Maghagha marly limestone aquifer and Samalut chalky limestone aquifer. The previous work of El Sayed (1987), Tantawai (1992), Sultan et. al. (2000), El Miligy (2004), Osman (2006), El Sayed (2007), Shabana (2014), Ahmed et. al. (2019) and El Ammawy et. al. (2020) are taken into consideration.

The hydrogeological study depends on the data of selected fifty-one drilled wells representing the two aquifers (5 wells representing Maghagha marly limestone aquifer and 46 wells representing Samalut chalky limestone aquifer) (Fig. 5 and Table 1).

Fig. 5: Wells location map of the y area.



Aquifer characteristics

The aquifer characteristics are discussed as follows:

Maghagha marly limestone aquifer

It represents the shallow aquifer in the area of study and detected in the area south of Gebel Al Murier scarp. It is detected mainly in Wadi Al Muhasham. The water bearing rocks are composed mainly of alternated layers of marly limestone and shale, reflecting low hydraulic potentiality of the aquifer. The main recharging source of Maghagha aquifer is probably the Nile River beside the infiltration of the local precipitation and surface runoff. This aquifer is taped by five wells (Nos. 43, 44, 45, 46 & 50) (Table 1 and Fig. 5). The groundwater of this aquifer occurs under free water table conditions (unconfined). The depth to water ranges from 8.51 m (well No. 46) to 59.27 m (well No. 43) and the total drilled depths of the wells range from 12 m (well No. 46) to 216 m (well No. 44). The saturated thickness of this aquifer ranges from 3.49 m (well No. 46) to 177.05 m (well No. 44).

The groundwater salinity of the collected samples representing this aquifer ranges from 603.5 mg/l (well No. 50) to 978.5 mg/l (well No. 45). Its effective porosity attains 13% (Abdel Tawab, 1994). This value is relatively lower than the underlain Samalut limestone aquifer.

Samalut Chalky limestone aquifer

Samalut limestone rocks represent the main productive aquifer in the Eastern and Western Desert fringes of El Minia governorate. The rocks forming this aquifer are exposed on surface at the downstream portions of the study area. It is composed of hard chalky fractured limestone. It represents the main source of water for the new reclaimed areas due to its high potentialities and good qualities. The main recharging source of Samalut aquifer is probably the Nile River beside the infiltration of the local precipitation and surface runoff.

Table 1: Hydrogeological data of the studied aquifers.

Well No.	Aquifer	Basin	Location		Depth to Water (m)	Elevation (m)	Water level (m)	Total depth (m)	Saturated thickness (m)	Salinity (mg/l)
			Latitude (N)	Longitude (E)						
43	Maghagha Limestone	W. AL Muhasham	30.9579	28.476222	59.27	88.083	28.8	142	82.73	927.2
44			30.9286	28.477583	38.95	66.28	27.33	216	177.05	862.5
45			30.9432	28.469556	45.47	74.666	29.196	180	134.53	978.5
46			30.8788	28.510194	8.51	37.938	29.428	12	3.49	687.5
50			30.8751	28.507472	15	43.53	28.53	110	95	603.5
1	Samalut limestone		31.0079	28.49825	ND	115.9	ND	ND	ND	828.4
2			31.0031	28.487194	81	111.84	30.84	113	32	825.2
3			30.9574	28.5005	59.72	90.7	30.984	160	100.28	899.2
4			30.9546	28.481861	60	89.57	29.57	142	82	637.7
20			30.9474	28.496444	ND	82.72	ND	190	ND	905.9
21			30.9357	28.489556	51	75.89	24.89	213	162	874.3
22			30.9263	28.486423	41.9	63.72	21.82	206	164.1	814.6
23			30.9211	28.492306	ND	55.86	ND	ND	ND	1028.2
24			30.9098	28.492972	22	53.96	31.96	215	193	720.9
25			30.9061	28.48875	13.7	52.33	38.63	ND	ND	603.1
26			30.8983	28.488333	ND	68.86	ND	ND	ND	1474.5
27			30.9079	28.503472	15	46.11	31.1	220	205	959
28			30.9008	28.511389	9	45.28	36.28	210	201	1010.3
29			30.8904	28.531006	23.36	40.01	16.65	210	186.64	986.5
30			30.8914	28.538167	12	55.68	43.68	150	138	745.5
5		W. AL Tarfa	30.908	28.468667	30.2	58.47	28.27	105	74.8	603.2
6			30.8802	28.460667	16.8	45.87	29.07	ND	ND	475.6
7			30.8771	28.448667	18	49.45	31.452	110	92	482.5
8			30.8683	28.441278	18.3	46.97	28.67	ND	ND	461.6
9			30.8607	28.426333	25.75	54.07	28.32	105	79.25	454.9
10			30.8502	28.426056	10.55	41.85	31.3	120	109.45	482.6
11			30.8533	28.413111	15.41	43.92	28.51	120	104.59	654.6
12			30.845	28.402167	10	40.65	30.65	100	90	1361.2
13			30.876	28.350722	38.3	67	28.7	137	98.7	418.5
14			30.8618	28.346972	42.25	72.29	30.04	140	97.75	363.4
15			30.8634	28.367444	32.75	56.44	23.69	ND	ND	536.8
16			30.8534	28.365222	31.15	59.72	28.57	ND	ND	455.2
17			30.85	28.371944	21.8	48.87	27.07	ND	ND	642.7
18			30.8428	28.377583	ND	45	ND	ND	ND	530.5
19			30.8394	28.379472	ND	43.29	ND	ND	ND	684.1
47			30.9414	28.415333	78.92	108.09	29.17	143	64.08	2043.9
48			30.9386	28.416139	ND	108.09	ND	ND	ND	1278.1
49			30.8947	28.436028	ND	62.62	ND	ND	ND	762.4
51			30.8764	28.445722	22	51.3	29.3	105	83	657.2
31		W. AL Sirrariah	30.8513	28.301472	86.77	120.47	33.70	ND	ND	719.6
32			30.8206	28.31575	73.47	95.06	21.59	130	56.53	399.5
33			30.8229	28.308117	70	94.85	24.848	100	30	422.2
34			30.8156	28.306361	ND	87.79	ND	ND	ND	448
35			30.7994	28.314083	ND	86.24	ND	ND	ND	1264.1
36			30.8066	28.322861	ND	82.25	ND	ND	ND	349.7
37			30.794	28.321361	48.83	76.34	27.51	ND	ND	1523.2
38			30.8016	28.334611	50.38	81.41	31.03	ND	ND	932.7
39			30.7873	28.321889	44.31	73.46	29.15	80	35.69	422.8
40			30.7826	28.318333	50	75.89	25.89	93	43	782.4
41			30.7891	28.334389	35	62.59	27.59	90	55	559.3
42			30.7821	28.335028	27.81	56.46	28.65	100	72.19	2027.9
Nile River water level was 30.20 m in 16 March 2013 (Shabana, 2014)										

*ND (not detected)

Samalut Chalky limestone aquifer

Samalut limestone rocks represent the main productive aquifer in the Eastern and Western Desert fringes of El Minia governorate. The rocks forming this aquifer are exposed on surface at the downstream portions of the study area. It is composed of hard chalky fractured limestone. It represents the main source of water for the new reclaimed areas due to its high potentialities and good qualities. The main recharging source of Samalut aquifer is probably the Nile River beside the infiltration of the local precipitation and surface runoff.

Evaluation of groundwater resources

The groundwater of Samalut aquifer in the study area exists under unconfined conditions in the southern portions of the study area to semi confined conditions due north. The effective porosity of Samalut chalky limestone aquifer reaches 34% (Abdel Tawab, 1994). The saturated thickness of this aquifer ranges from 30 m (well No. 33) to 205 m (well No. 27), while the depth to water ranges from 9 m (well No. 28) to 86.77 m (well No. 31) and the total depth of the wells tapping this aquifer ranges from 80 m (well No. 39) to 220 m (well No. 27). The groundwater salinity ranges from 349.66 mg/l (well No. 36) to 2043.9 mg/l (well No. 47).

Samalut aquifer is investigated through forty-six wells. They are distributed in three main hydrographic basins (15 wells at Wadi Al Muhasham, 19 wells at Wadi Al Tarfa, 12 wells at Wadi Al Sirariah). They are discussed as follow:

At Wadi Al Muhasham, the groundwater is available from fifteen water points. The depth to water ranges between 9 m from the ground surface (well No. 28) and 81m (well No. 2). The groundwater salinity ranges between 603 mg/l (well No. 25) and 1474 mg/l (well No. 26).

At Wadi Al Tarfa, the groundwater is available from nineteen water points. The depth to water ranges between 10 m from the ground surface (well No. 12) and 78.9 m (well No.47). The groundwater salinity ranges between 363 mg/l (well No. 14) and 2043 mg/l (well No. 47).

At Wadi Al Sirariah, the groundwater is available from twelve water points. The depth to water ranges between 27.8 m from the ground surface (well No. 42) and 86.8 m (well No.31). The groundwater salinity ranges between 349 mg/l (well No. 36) and 2027 mg/l (well No. 42).

Groundwater flow

The groundwater flow direction is defined from the west and northwest to southeast (Figs. 6, 7and 8). The water table map of Maghagha marly limestone aquifer (Fig. 9) and Samalut chalky limestone aquifer (Fig.10), indicates that the groundwater flow is mainly from west and southwest to east and northeast, i.e. Nile River is probably the main source of recharge beside the infiltration of the local precipitation and surface runoff. It is clear that the water level decreases at the southeastern part due to excessive pumping for irrigation activities in this area.

Hydrologic parameter

For evaluating the hydraulic parameters of Samalut fractured limestone aquifer, six pumping tests were operated for six wells distributed over the area of the concerned aquifer (Table 2). Cooper-Jacob method (1946) was applied for the analysis of the obtained data, as follows (Fig. 11).

Transmissivity of the water bearing rocks is estimated according to the following equation:

$$T = 2.30\, Q/4\pi\Delta s \quad (m^2/day)$$

Where Q: is the rate of the discharge in m^3/day and Δs: is the residual drawdown difference per log cycle of time.

The calculated Transmissivity values ranges from 53.81 m^2/day (well No. 3) to 1571.62 m^2/day (well No. 20). Due to the small time of recovery test in wells Nos (5, 6 & 20), the value of transmissivity from recovery tests couldn't be calculated. According to Gheorghe classification (1979), Samalut aquifer potentiality ranges from moderate to high potentiality (Table 3). This variation in transmissivity is attributed mainly to the lineaments density and penetrated thickness which ranges from 3.49 m to 205 m.

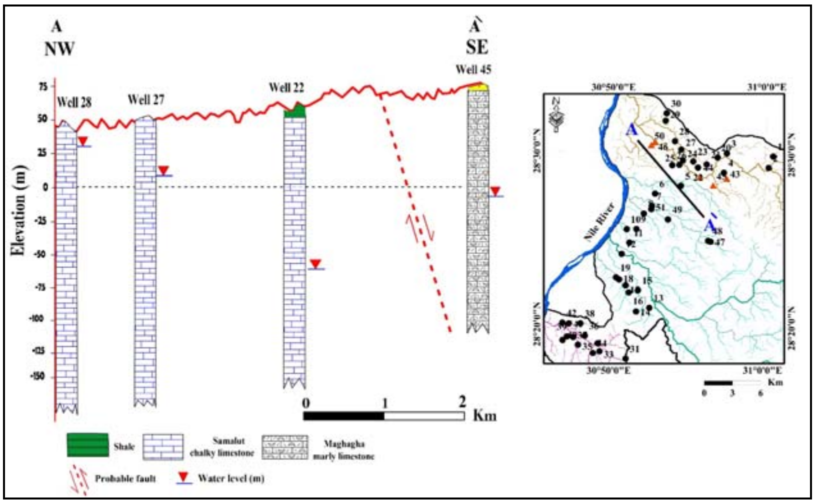


Fig. 6: Hydrogeologic cross section (NW-SE) along W. Al Muhasham

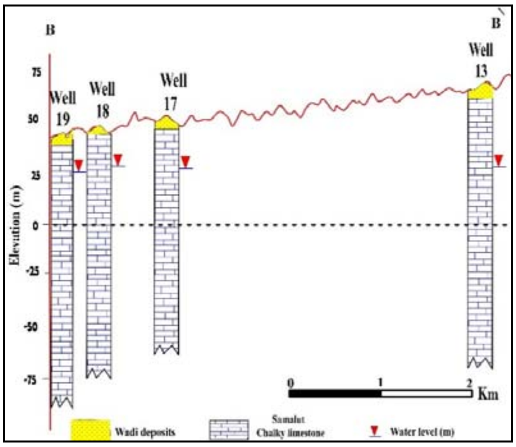


Fig. 7: Hydrogeologic cross section (W-E) along W. Al Tarfa.

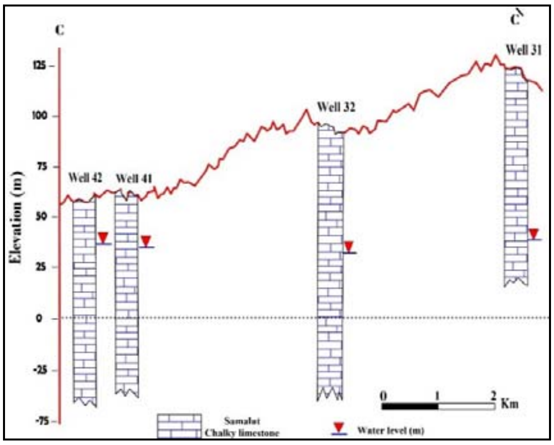


Fig. 8: Hydrogeologic cross section (W-E) along W. Al Sirrariah.

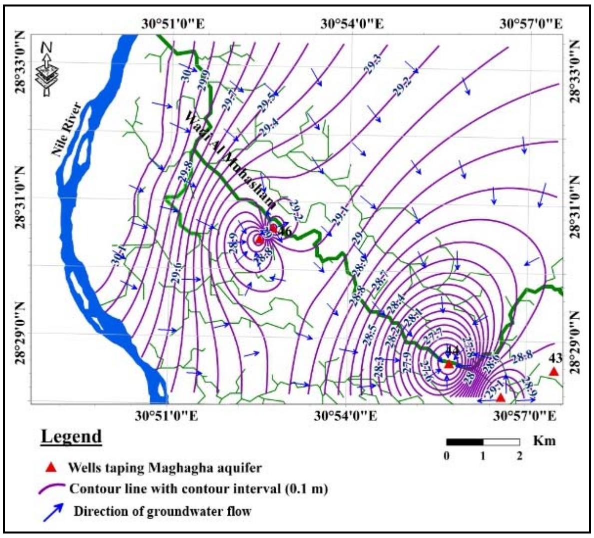


Fig. 9: Water table map of Maghagha aquifer.

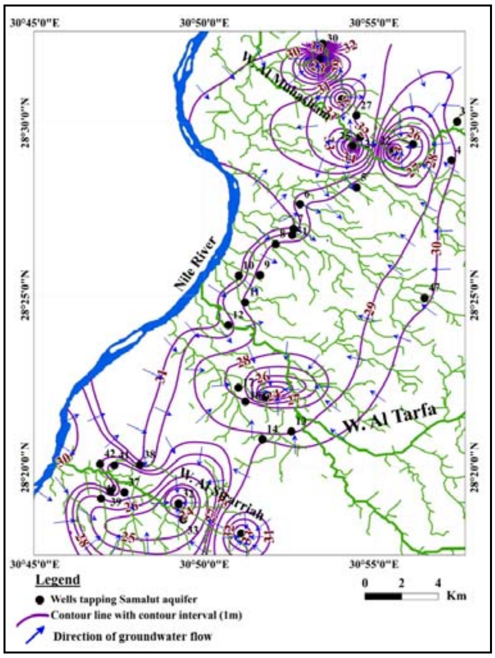


Fig. 10: Water table map of Samalut aquifer in the study area.

Table 2: Transmissivity values of selected wells representing Samalut limestone aquifer.

Well no.	Transmissivity (m^2/day)
3	87.84
5	1340.64
6	15821.28
12	137.376
13	292.99
20	32577.12

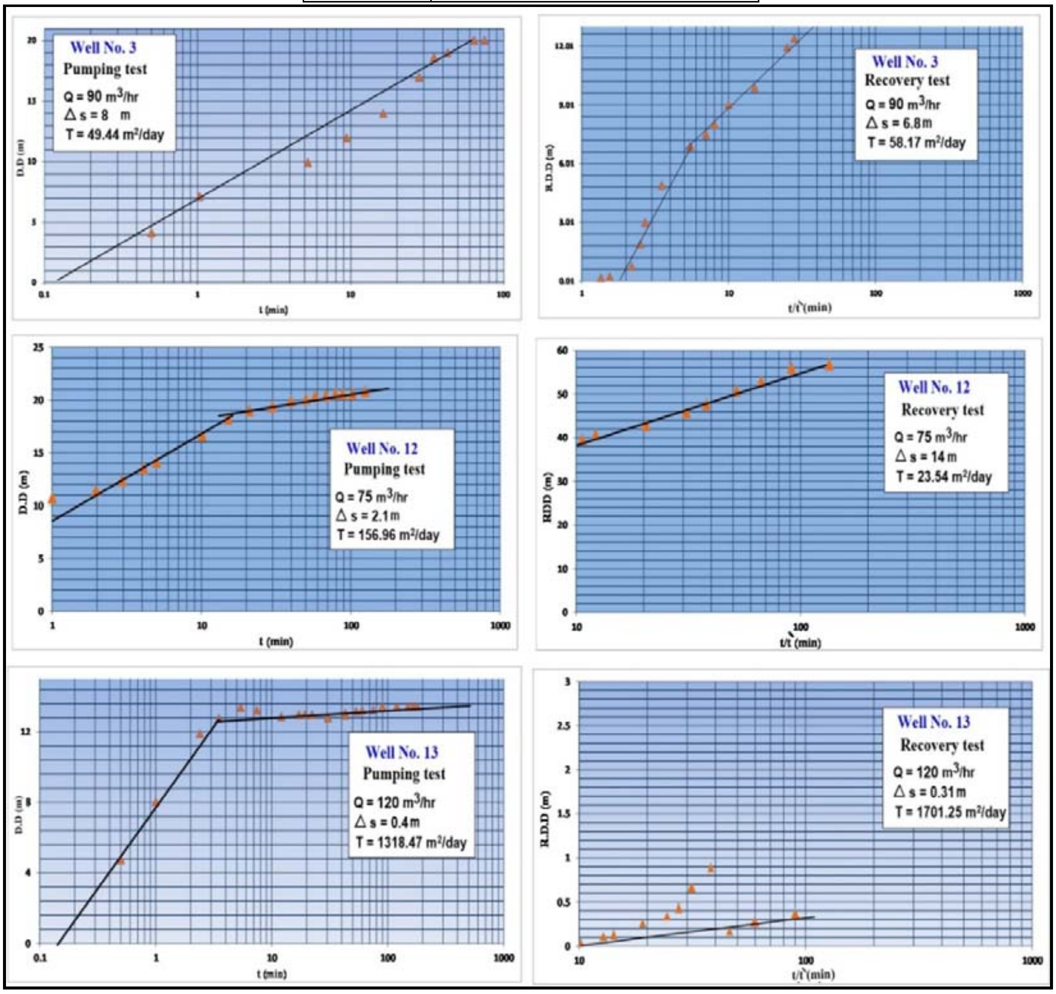


Fig. 11: Pumping test analysis using Warren Root's straight-line method (1963).

Table 3: Aquifer potentiality according to the transmissivity values (Gheorhge, 1979).

Aquifer potentiality.	Transmissivity.
Negligible	Less than 0.5 m2 / day
Very low	0.5 – 5 m2 / day
Low	5.0 – 50 m2 / day
Moderate	50 – 500 m2 / day
High	Over 500 m2 / day

HYDROCHEMICAL CHARACTERISTICS

Fifty-one groundwater samples representing Maghagha (five samples) and Samalut (forty-six samples) aquifers were collected from the selected wells (March, 2017) and chemically analyzed (Table 4). The geochemical characteristics of the groundwater of these two aquifers are discussed through the composition and classification of groundwater as follows:

Table 4: Chemical analysis data of the collected water samples in the study area.

Sample No.	Locality	Aquifer	Salinity (mg/l)	Ca^{++} (mg/)	Mg^{++} (mg/)	Na^{+} (mg/l)	K^{+} (mg/)	CO_3^{--} (mg/)	HCO_3^{-} (mg/l)	SO_4^{--} (mg/l)	Cl^{-} (mg/l)
43	W. AL Muhasham	Maghagha	927.2	29.00	109.5	145.3	11.2	12	353.8	134.6	308.7
44			862.5	29.00	105.0	138.7	11.7	18	400.9	105.1	254.6
45			978.5	31.9	112.6	147.8	13.1	24	373.2	134.9	327.6
46			687.5	35.8	66.1	126.7	5.8	18	398.7	66.4	169.4
50			603.5	36.0	92.6	61.4	4.8	48	382.6	54.1	115.1
1		Samalut	828.4	58.2	43.4	181.3	5.4	21.8	310.9	108.9	254.1
2			825.2	57.3	46.2	181.9	6.9	0.00	344.2	104.8	256.2
3			899.2	73.9	56.9	175.1	4.5	10.9	421.9	101.9	264.9
4			637.7	47.5	36.2	138.2	4.3	10.9	371.9	60.8	153.8
20			905.9	104.4	65.6	315.3	10.2	27.3	360.8	146.6	552.8
21			874.3	60.1	46.1	185.9	10.7	32.8	310.9	108	275.3
22			814.6	69.1	45.1	173.8	8.1	16.4	318.6	91.7	251
23			1028.2	54.2	45	260.1	9.7	32.8	266.4	132.7	360.5
24			720.9	47.8	34.8	164.6	7.9	16.4	344.2	80.4	197
25			603.1	44.2	39.3	121	9.5	21.8	344.2	56.7	138.5
26			1474.5	72.8	59.6	410.7	8.4	21.8	333.1	128.8	606
27			959	83	50.4	202.1	8	10.9	449.6	103.2	276.6
28			1010.3	50.9	56.8	230	6.4	16.4	333.1	127	356.3
29			986.5	82.8	52.1	201.9	10.9	32.8	444.1	106.7	277.3
30			745.5	69.5	38.4	144.7	8.1	38.2	399.7	60.2	186.5
5	W. AL Tarfa		603.2	39.8	41	137	4.8	21.8	338.6	35.6	153.9
6			475.6	37.3	30.8	91.6	6.8	21.8	333.1	28.5	92.3
7			482.5	38.3	30.9	96.3	6.8	32.8	333.1	25.6	85.2
8			461.6	52.2	28.6	73.2	6.2	21.8	366.3	25	71.4
9			454.9	35	28.9	102.1	4.6	10.9	322	26.1	86.3
10			482.6	50.2	28.9	74.7	9.9	0	299.8	77.9	91.2
11			654.6	55.1	39.5	130.1	6.3	21.8	299.8	110.4	141.6
12			1361.2	115.8	81.9	268	11.6	16.4	161	317.8	469.2
13			418.5	33	28.4	81.1	5.8	16.4	344.2	18.2	63.5
14			363.4	40.7	27.3	69.3	6.6	10.9	320.8	8.8	39.3
15			536.8	43.5	32.1	126.8	6.3	21.8	344.2	24.4	109.8
16			455.2	44.1	31.5	79.8	7.9	16.4	355.3	27.6	70.3
17			642.7	43.7	39.9	142.6	6.5	21.8	322	38	189.1
18			530.5	57.4	23.9	96.3	6.7	16.4	322.9	87.3	81.2
19			684.1	71	34.8	117.2	9.4	10.9	349.7	129.2	136.8
47			2043.9	43.9	162.9	446.9	22.4	6	390.4	404.4	762.2
48			1278.1	60.1	142.2	211.6	9.9	18	390.4	232.4	408.7
49			762.4	35.9	105.5	114.4	5.5	36	372.1	67.4	211.6
51			657.2	35.1	64.8	120.6	6.3	30	405.3	64.8	132.9
31	W. AL Sirrariah		719.6	37.9	93.2	103.1	5.5	12	353.8	63.3	227.7
32			399.5	26.3	65.1	34.7	5.5	22	412.2	10.6	29.2
33			422.2	26.7	68.3	38.4	5.1	24.00	408.7	14.8	40.5
34			448.00	28.8	69.4	43.5	5.5	36	375.8	12.4	64.6
35			1264.1	63.3	144.8	210.7	9.7	18	427	138.8	465.3
36			349.7	26.01	53	37.2	6.4	18	366	14.9	11.1
37			1523.2	65.2	160.5	275.1	10.2	6	329.4	196.7	644.8
38			932.7	28.04	104.3	139.4	9.7	6	311.1	345.7	144
39			422.8	27.3	73.1	36.1	5.8	18	427	15.1	33.9
40			782.4	35.5	101.2	114.2	5.7	2.4	385.5	170.4	160.2
41			559.3	32.9	81.1	64.3	4.19	12	390.4	96	73.6
42			2027.9	39.9	161.2	432.7	16.4	18	419.2	553.1	597
Nile water			196.8	32.6	10.5	22.2	4.7	0	177	22.6	15.7

Geochemical Composition

The geochemical composition of the recorded groundwater is discussed through the total salinity which reflects the chemical composition as follows:

Total salinity

According to Chebotarev (1955) classification (Table 5), the groundwater salinity of Maghagha and Samalut limestone aquifers are discussed as follows:

1- **Maghagha aquifer:** The groundwater salinity ranges from 603.5 mg/l to 978.5 mg/l. It is clear that, the quality of groundwater ranges from fresh to fairly fresh water; reflecting meteoric water origin.
2- **Samalut aquifer:** The groundwater salinity of the concerned aquifer varies from area to another, at Wadi Al Muhasham it ranges from 603.1 mg/l to 1474.5 mg/l. It is clear that, the majority of samples are fairly fresh. At Wadi Al Tarfa the groundwater salinity ranges from 363.4 mg/l to 2043.9 mg/l. It is clear that the groundwater ranges from good fresh to fairly fresh water, except samples no. 47 which belongs to possibly brackish water. At Wadi Al Sirrariah the groundwater salinity ranges from 349.7 mg/l to 2027.9 mg/l. Therefore, the quality of groundwater ranges from good fresh to possibly fresh water. Relatively high salinities of some samples reflect dissolution of Maghagha marl and shale.

Table 5: Water types based on total salinity (TDS in mg/l), Chebotarev (1955).

Water type	Class	Total dissolved solids (mg/l)
Fresh	Good	<500
	Fresh	500-700
	fairly	700-1500
Brackish	possibly	1500-2500
	Slightly	2500-3200
	Brackish	3200-4000
	definitely	4000-5000
Saline	Slightly	5000-6500
	Saline	6500-7000
	Very saline	7000-10000
	Extremely saline	>10000

Geochemical Classification

The classification of groundwater provides abasis for grouping samples with similar characteristics. Two diagrams are used in this study for geochemical classification of groundwater as follows:

The classification of groundwater provides abasis for grouping samples with similar characteristics. Two diagrams are used in this study for geochemical classification of groundwater as follows:

Scholler diagram

According to Schoeller's semi logarithmic graph (1962), the ion dominance sequences of the studied Maghagha and Samalut groundwater samples were discussed as follows (Table 6 and Figs. 12 & 13):

Maghagha aquifer: The majority (60%) of groundwater samples in this aquifer have (Mg^{2+}>Na^{+}+K^{+}>Ca^{2+})/(Cl^{-}>HCO_3^{-}+CO_3^{2-}>SO_4^{2-}) ion sequence (Fig. 12). Therefore, the dominant anion in most of Maghagha groundwater samples is (Cl^{-}) due to leaching and dissolution of shale and marl of Maghagha and Qarara Formations and the dominant cation is (Mg^{+}) that may be attributed to the hydrolysis and dissolution of the dolomitic limestone.

Samalut aquifer: The ion dominance sequences ordering of groundwater in Samalut aquifer will be discussed in each of the studied basins as follows:

At Wadi Al Muhasham, the majority of Samalut groundwater samples (66.67%) have (Na^{+}+K^{+}>Mg^{2+}>Ca^{2+})/(Cl^{-}>HCO_3^{-}+CO_3^{2-}>SO_4^{2-}) ion sequence (Fig. 13 a). While, at Wadi Al Tarfa, 57.9% have (Na^{+}+K^{+}>Mg^{2+}>Ca^{2+})/(HCO_3^{-}+CO_3^{2-}>Cl^{-}>SO_4^{2-}) ion sequence (Fig. 13 b). And at Wadi Al Sirariah, 58.33% have (Mg^{2+}> Na^{+}+K^{+}>Ca^{2+})/(HCO_3^{-}+CO_3^{2-}>Cl^{-}>SO_4^{2-}) ion sequence (Fig. 13c).

As a result of the aforementioned discussion, the dominant anions in Samalut aquifer at both of wadi Al Tarfa and wadi Al Sirariah are (HCO_3^{-}+CO_3^{2-}), reflects the leaching and dissolution of carbonate minerals and probably the recent recharge from the Nile River, but at wadi Al Muhasham (Cl^{-}) is the dominant anion due to leaching processes of chloride bearing minerals as in this wadi Samalut aquifer is covered by Qarrara and Maghagha Formations which are composed mainly of shale and marl rich in chloride minerals. While, the dominant cations are (Na^{+}+K^{+}) in both of wadi Al Muhasham and wadi Al Tarfa due to the hydrolysis and dissolution of Na-K bearing minerals (shale and marl of Maghagha and

Qarara Formation, while in wadi Al Sirariah (Mg^{+}) is the dominant due to the dolomitization of Samalut chalky limestone.

Table 6: Ion dominance of the studied groundwater samples according to Schoeller (1962).

Ion sequence	**Wadi Al Muhasham**	**Wadi Al Tarfa**	**Wadi Al Sirrariah**	**Chemical water type**
$Na^{+}+K^{+}>Mg^{2+}>Ca^{2+}$ $Cl^{-}> HCO_3^{-}+CO_3^{2-}>SO_4^{2-}$	1, 2, 3, 21, 22, 23, 26, 27 & 28	12		Na – Cl
$Na^{+}+K^{+}>Mg^{2+}>Ca^{2+}$ $HCO_3^{-}+CO_3^{2-}>Cl^{-}>SO_4^{2-}$	4, 20, 24, 25, 29 & 46	5, 6, 7, 9, 11, 13, 14, 15, 16 & 17		Na – HCO_3
$Na^{+}+K^{+}>Ca^{2+}>Mg^{2+}$ $HCO_3^{-}+CO_3^{2-}>Cl^{-}> SO_4^{2-}$	30	8, 10, 18 & 19		Na – HCO_3
$Mg^{2+}>Na^{+}+K^{+}>Ca^{2+}$ $Cl^{-}> HCO_3^{-}+CO_3^{2-}> SO_4^{2-}$	43, 44 & 45	48	31,35 & 37	Mg – Cl
$Na^{+}+K^{+}>Mg^{2+}>Ca^{2+}$ $Cl^{-}> SO_4^{2-}>HCO_3^{-}+CO_3^{2-}$			42	Na – Cl
$Mg^{2+}>Na^{+}+K^{+}>Ca^{2+}$ $HCO_3^{-}+CO_3^{2-}>Cl^{-}> SO_4^{2-}$	50	49 & 51	32, 33, 34, 36, 39, 40 & 41	Mg – HCO_3
$Mg^{2+}>Na^{+}+K^{+}>Ca^{2+}$ $SO_4^{2-}>HCO_3^{-}+CO_3^{2-}>Cl^{-}$			38	Mg – SO_4
$Na^{+}+K^{+}>Mg^{2+}>Ca^{2+}$ $SO_4^{2-}>HCO_3^{-}+CO_3^{2-}>Cl^{-}$		47		Na – SO_4

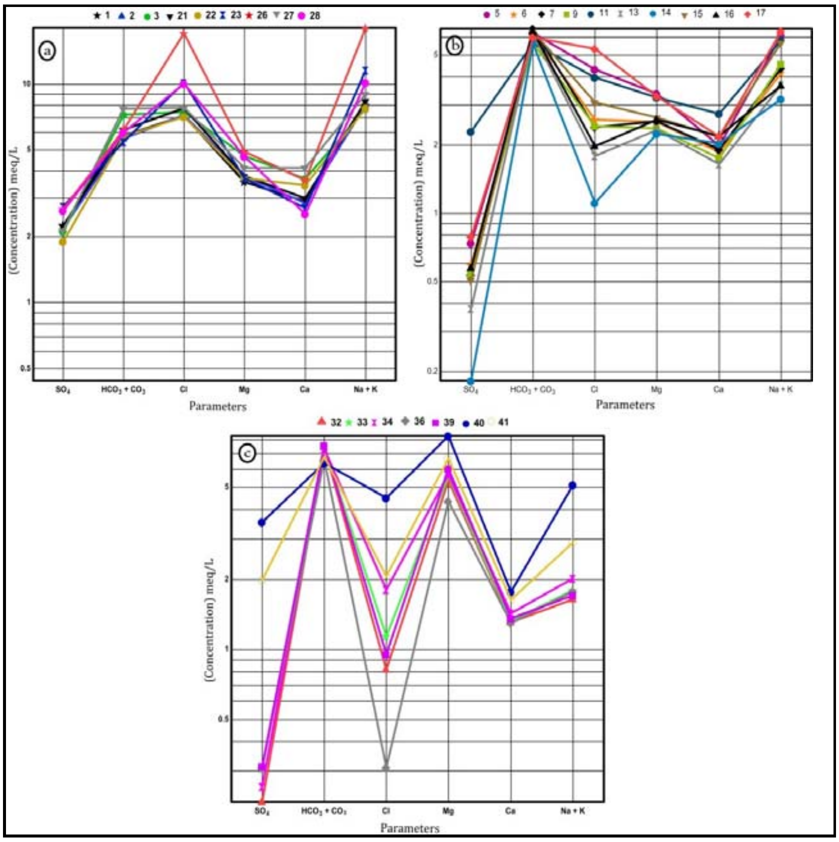


Fig. 12: Geochemical classification of groundwater using Scholler diagram at (a)Wadi Al Muhasham, (b) Wadi Al Tarfa and (c) Wadi Al Sirrariah

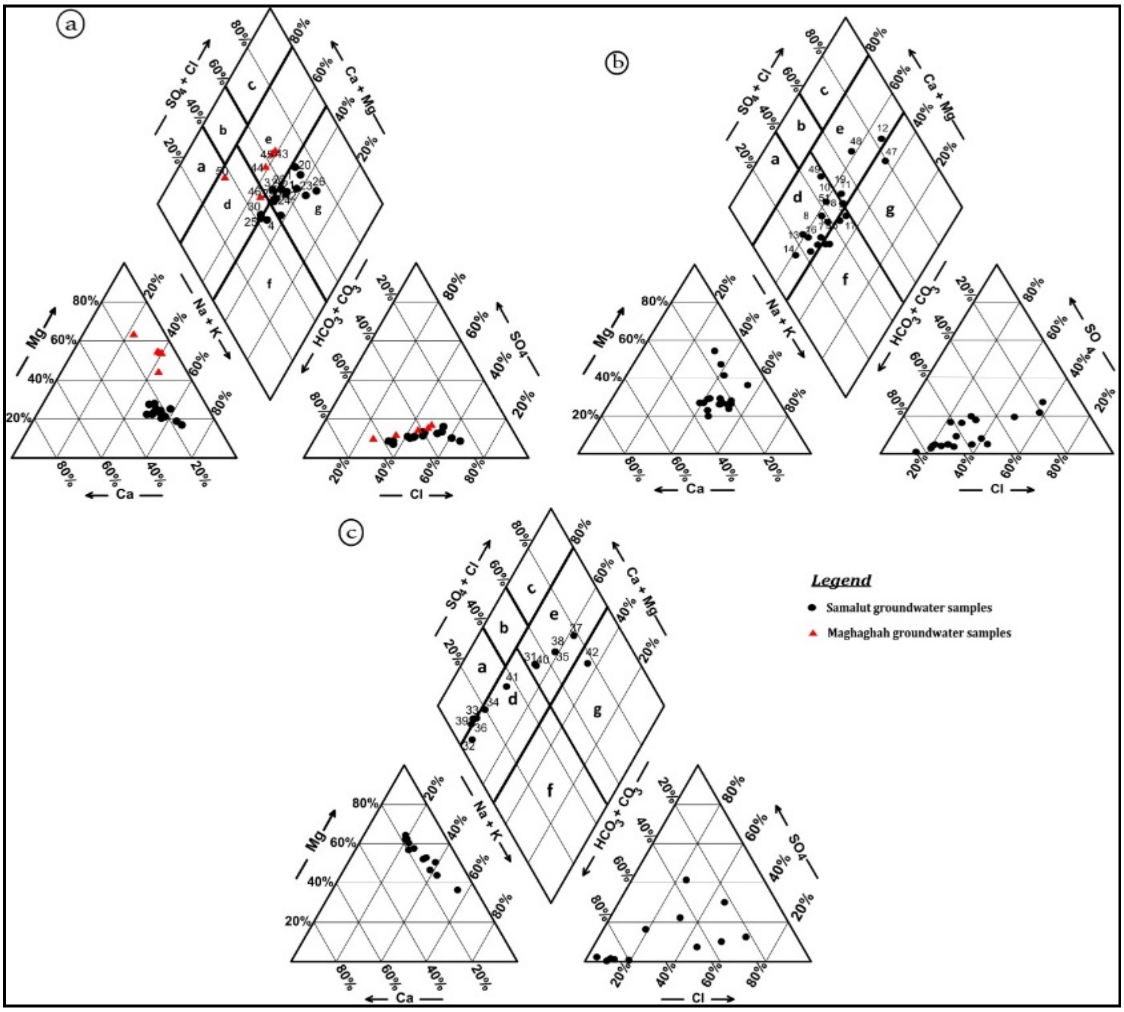


Fig. 13: Geochemical classification of groundwater using Piper trilinear diagram at (a)Wadi Al Muhasham, (b) Wadi Al Tarfa and (c) Wadi Al Sirrariah.

Piper diagram

According to Piper trilinear diagram (1953), the groundwater samples of Samalut and Maghagha aquifers are classified as follows:

Maghagha aquifer: Most of Maghagha groundwater samples are plotted in sub-area (e) indicating earth alkaline water with prevailing sulphate and chloride (Fig.14 a). The increase in sulphate and chloride is attributed to the leaching and dissolution of shale and marl of Maghagha and Qarara Formations rich in gypsum and chloride bearing minerals.

Samalut aquifer: At Wadi Al Muhasham, the majority of Samalut groundwater samples are plotted in sub-area (g) indicating alkaline water with prevailing sulphate and chloride (Fig. 14 a). While most of Samalut groundwater samples in Wadi Al Tarfa and Wadi Al Sirrariah are plotted in sub-area (d) indicating earth alkaline water with prevailing bicarbonate (Fig. 14 b & c). The increase in (HCO_3^-+CO_3^{2-}) anions in Wadi Al Tarfa and Wadi Al Sirariah is probably attributed to the recent recharge from the Nile River and the interaction between groundwater and the carbonate rocks. While the increase in (Cl^- and SO_4^{2-}) anions in Wadi Al Muhasham is due to the hydrolysis and dissolution of shale and marl of Maghagha and Qarara Formations rich in gypsum and chloride bearing minerals. Furthermore, it was noticed that erroneously farmers used to spread and mix shale with the soil prior to cultivation.

CONCLUSION AND RECOMMENDATIONS

The investigated area occupies an area of the Eastern Desert of Egypt. It represents one of the most important areas for the land reclamation projects. It is covered mainly by Middle Eocene carbonate rocks. Two main aquifers are encountered in the study area, namely Maghagha marly limestone and Samalut chalky limestone aquifers. The groundwater of Maghagha marly limestone aquifer is recorded at depths range from 8.51 m to 59.27 m and the total drilled depths of wells tapping this aquifer range from 12 m to 216 m. The groundwater salinity representing this aquifer ranges from 603.5 mg/l to 978.5 mg/l, reflecting fresh water type. While, the groundwater of Samalut chalky limestone aquifer is recorded at depths range from 9 m to 86.77 m and the total depth of the wells tapping this aquifer range from 80 m to 220 m. The groundwater salinity of the concerned aquifer ranges from 349.7 mg/l to 2043.9 mg/l, reflects fresh to possibly brackish water types.

The recharge of Samalut chalky limestone aquifer is probably from the Nile water due to:

1. The water table map indicates that the groundwater flow from west and northwest.
2. The relatively low groundwater salinity.
3. The relatively high transmissivity reaches (1571.62) m^2/day, that reflect good ability for transmitting water.

In order to have a sustainable development of groundwater resources in this area, further investigations are needed as follows:

1. Establishment of a well distributed meteorological network to obtain accurate climatic records.
2. Geophysical exploration for groundwater at the inland depressions. These depressions have large surface areas with good soil cover.
3. Drilling a grid of piezometers in order to record continuously the levels and monitoring the fluctuations.
4. Drilling a deep well to the east of Assuit-Cairo desert road (Maghagha marly limestone aquifer area) to penetrate the complete thickness of Qarrara and Maghagha Formations and penetrate the chalky limestone of Samalut Formation.
5. Criminalization of both flood irrigation methods and the use of shale in cultivations that lead to increase of salinity.

REFERENCES

Abdel Tawab, S., (1994): A geotechnical evaluation of Minia-Maghagha area, Upper Egypt: JKAU: Earth Sci., 7, 143-157.

Ahmed, A., El Ammawy. Hewaidy, A., Moussa, B., Abdel Hafz, N. and El Abd, E., (2019): Mapping of lineaments for groundwater assessment in the Desert Fringes East El-Minia, Eastern Desert, Egypt, Environ Monit. Assess (2019) 191:556.

Bishay, Y., (1966): Studies on the large foraminifera of the Eocene, the Nile Valley between Assiout and Cairo. Ph. D. Thesis, Fac. Sci., Alex Univ., Egypt, 244 p.

Chebotarev, I., (1955): Metamorphism of Natural Waters in the Crust of Weathering Geochimica et Cosmochimica Acta, 8, 137-170.

Conoco Coral Egypt, (1987): Geological map of Egypt (scale 1:500000). General Petroleum Company, Cairo.

Egyptian Meteorological Authority, (1982-2017): Annual meteorological reports. EMA, Cairo.

El Ammawy, M., Hewaidy, A., Moussa, B., Abdel Hafz, N., El Abd, E. and Abu Risha, U., (2020): Hydrogeologic investigations to determine the sources of groundwater recharge of Samalut carbonate aquifer in some wadis, East El Minia, Egypt, NRIAG Journal of Astronomy and Geophysics, 2020, 9(1), 206–219.

El Boukhary, M. A and abdelmalik, W., (1983): Revision of the strataigraphy of the Eocene deposits in Egypt. N. Jb., Geol. palaont. Mh, Stuttgart, 6: 321-337.

El Miligy, E. M. M., (2004): Groundwater resources evaluation studies of Assuit governorate. Ph. D. Thesis, Fac. Sci., Assuit Univ. 307.

El Sayed, E. A. E., (1987): The groundwater resources in El-Minia district, Egypt., M. Sc. Thesis, Fac. Sci. El-Minia Univ., 115.

El-Sayed, M. H., (2007): Hydrogeochemistry of the Tertiary-Quaternary aquifers in the newly reclaimed areas in El-Minia governorate, Egypt, Bul. Ain Shams Univ., 45, 22 p.

Gheorghe, A., (1979): Processing and synthesis of hydrogeological data, Abacus press, p. 390.

Gringarten, A. C. and H.J. Ramey Jr., (1974): Unsteady state pressure distributions created by a well with a single horizontal fracture, partial penetration or restricted entry. Soc. Petrol. Engrs. J., 41 3-426.

Kazemi, H., Seth, M. S. and Thomas, G. W., (1969): The interpretation of interference tests in naturally fractured reservoirs with uniform fracture distribution. Soc. Petrol. Engrs. J., pp. 463-472.

Osman, E. A., (2006): Hydrogeological study of East Minia area, El-Minia District, Egypt. M.Sc. Thesis, Fac. of Sci., Minia Univ., Egypt. 166p.

Piper, A. M., (1953: A graphic procedure in the chemical interpretation of water analysis. USGS Groundwater Note, 12.

Said, R., (1962): The geology of Egypt. Elsevier Publ., Co., 377 p.

Said, R., (1981): Geological evaluation of the Nile; Springer-Verlag, NY, Berlin, 151p.

Schoeller, H., (1962): Geochmie des eaux Souteraines Rev. De l'Institue Français du Petrole,(10), 230-244.

Shabana, R. A., (2014): Geology of water resources of Wadi El Tarfa, Eastern Desert, Egypt: Egypt. J. Geol., 58, 23-42.

Shileby, A. I., (2000): Contribution to the stratigraphy of Wadi El Tarfa area, Ann. Geol. Surv. Egypt, XXIII, 33-43.

Sultan, M., Sturchio, N.C., Gheith, H., Abdel Hady, Y. and El Anbeawy, M., (2000): Chemical and isotopic constraints on the origin of Wadi El Tarfa groundwater, Eastern Desert, Egypt: Ground Water, 38(5), 743-751.

Tantawai, M. A., (1992): Isotopic and hydrochemical application to the surface and groundwater assessments in El Minia district, Egypt, Ph. D. Thesis, Fac. of Sci., Al Minia Univ., Egypt.

Warren, J. E. and P. J., Root (1963): The behavior of naturally fractured reservoirs. Soc. Petrol. Engrs. J., 3, 245-255.

Youssef, M. I., (1968): Structural pattern of Egypt and its interpretation. Bull. Amer. Petrol. Geol., 52(4), 601-614.

تقييم موارد المياه الجوفية بخزانات الحجر الجيري الإيوسيني المتشقق ، ببعض الأودية ، شرق محافظة المنيا ، الصحراء الشرقية ، مصر.

الزهراء أبوحبيبة[١] ، كمال دهب[١] ، أشرف شبانه[٢] ، سمير قمح[٣] ، حكمت إبراهيم[١]

١- قسم الجيولوجيا، كلية العلوم، جامعة المنوفية
٢- قسم الجيولوجيا، مركز بحوث الصحراء، القاهرة
٣- قسم الجيولوجيا، كلية العلوم، جامعة طنطا

الخلاصة

تقع منطقة الدراسة بالظهير الصحراوي الشرقي لمحافظة المنيا وهى تتكون من ثلاثة أودية رئيسية وهي من الشمال "وادي المهشم ، وادي الطرفة ، وادي السرارية " وتصب هذه الاودية مياهها بنهر النيل . و تركز هذه الدراسة علي الوضع الجيولوجي لمنطقة الدراسة و تأثيرها علي مصادر المياه الجوفية و تهدف هذه الدراسة الي تنمية مصادر المياه الجوفية بمنطقة شرق المنيا .

و تبلغ مساحة منطقة الدراسة حوالي ٦٢٨٨ كم مربع وهى مغطاه أساسا بصخور الحجر الجيري التابع للعصر الإيوسيني الأوسط. و تتواجد المياه الجوفية بوحدتين صخريتين أساسيتين وهما صخور الحجر الجيري التابع لمكون مغاغة و صخور الحجر الجيري التابع لمكون سمالوط و التي تتبع عصر الإيوسين الأوسط .

يتراوح العمق الي الماء في خزان صخور الحجر الجيري التابع لمكون مغاغة من ٨.٥ متر إلى ٥٩.٢٧ متر من سطح الأرض بينما يتراوح العمق الكلي للآبار من ١٢ متر الي ٢١٦ متر . و تتراوح الملوحة الكلية للمياه الجوفية بين ٦٠٣,٥ ملغم / لتر و ٩٧٨,٥ ملغم / لتر. أما بالنسبة لخزان صخور الحجر الجيري الطباشيري التابع لمكون سمالوط فيتراوح العمق الي الماء من ٩ متر الي ٨٦,٧٧ متر من سطح الأرض بينما يتراوح العمق الكلي للآبار من ٨٠ متر الي ٢٢٠ متر. و تتراوح الملوحة الكلية للمياه الجوفية بين ٣٤٩,٦٦ ملغم / لتر الي ٢٠٤٣,٩ ملغم / لتر .