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GEOLOGY OF GROUNDWATER RESOURCES IN THE RECLAIMED AREAS NORTH OF EL SAFF, EASTERN DESERT, EGYPT

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Geomorphologically, the El Saff area is classified into six geomorphic units, namely structural plateau, isolated hills, piedmont plain, alluvial fans, Nile flood plain and hydrographic basins. It is dissected by four main canals with different ground elevations. Three of them (El Hager, El Kashab and El Gabal) carry River Nile water with salinity ranging mainly from 220 ppm to 380 ppm (fresh water), while the other (El Saff Canal) carries treated industrial and wastewater released from the cities of Helwan and El Tabin, with salinity ranging from about 620 ppm to about 830 ppm (fresh water).

There are two main aquifer systems in the study area, belonging to Quaternary and Eocene units. The Quaternary aquifer system is located in the western part, while the Eocene aquifer system is restricted to the eastern part. They are hydraulically connected with each other through faults and intergranular flow. The Quaternary aquifer system can be differentiated into Nilotic and alluvial aquifers. The Nilotic Aquifer occupies a narrow strip adjacent to the River Nile. It is recharged mainly from the River Nile, irrigation systems and the alluvial aquifer, which produce a variation in groundwater salinity from 288 ppm (fresh water) near the River Nile to 2040 ppm (brackish water) in the eastern part. The alluvial aquifer occupies the alluvial fans of the main wadis and extends eastward to the piedmont plain. It varies in thickness from about 30 to 60 m. It recharged mainly from the El Saff and El Hager Canals, and the Eocene aquifer system. Groundwater salinity in the alluvial aquifer ranges from 1040 ppm to 2950 ppm (brackish water).

The Eocene aquifer system can be differentiated into Upper Eocene and Middle Eocene aquifers. The Upper Eocene aquifer is located at the high relief areas of the piedmont plain with groundwater salinity ranges from 2410 ppm to 5360 ppm (brackish water), where it recharged mainly from El Saff Canal. The Middle Eocene aquifer occupies most of the eastern part of the study area. It is recharged mainly from the eastern watershed area and the El Saff Canal especially in the northern part, as indicated by the variation of groundwater salinity between 2750 ppm (brackish water) and 13000 ppm (saline water).

Most of the surface water samples are suitable for drinking purposes except the El Saff canal water samples, while most of the groundwater samples are not suitable except the Nilotic aquifer adjacent to the River Nile. On the other hand, nearly all the surface and Nilotic aquifer water samples are suitable for irrigation of all crops, while most of the alluvial aquifer water is satisfactory for salt tolerant crops, but the Eocene waters are mainly not suitable for irrigation.

Keywords: Surface, groundwater, reclaimed, El Saff, Eastern Desert, Egypt.

Groundwater in Egypt is of vital importance for domestic, agricultural and industrial water supply. In the El Saff area, groundwater is the main water supply for different purposes of the main populated villages such as Al Aqwaz, Gamaza El Kobera, Gamaza El Soghra, Iksas and El Shorafa. The study area lies south of Cairo between latitudes 29° 33' 00'' to 29° 46' 00'' and longitudes 29° 30' 00'' to 30° 26' 00'' (Fig. 1). It is bounded by River Nile to the west and the Red Sea water divide to the east.

Topographically, the study area has ground elevations ranging from about +695 m in the eastern part to about +20 m above sea level near the River Nile. It has relatively steep slope in the eastern part and it changes westward to become of gentle slope. The variability of slopes is due to the effect of a fault system oriented mainly NW-SE.

From the climatic point of view, the study area has an arid climate and is characterized by very low rainfall, high temperature and high evaporation. Where, the mean maximum temperature ranges from 25 °C to 36 °C in summer season and the minimum ranges from 16 °C to 15 °C in winter season. The main rainfall ranges from 2 to 5 mm/year and the relative humidity is 50-60%.

Structurally, faulting is the dominant element in which the area is affected mainly by two fault systems trending E-W (Mediterranean) and NW-SE (Clysmic) as seem in figure (2). Minor associated folds have been recognized in the eastern portion and are oriented NW-SE.

The study area has attracted the attention of different workers for regional geomorphological and geological views (Attia, 1954; Said and Beheiri, 1961; Said, 1962, 1975 and 1990; and Gharieb, 1990); for groundwater prospecting (DRC, 1994; and Khaled and Al Abaseiry, 2003); for regional hydrogeologic setting (Abdel Shafy et al., 1986; RIGW /

IWACO, 1998; and Awad, 1999); and for groundwater pollution (Awad et al., 2002). These works did not take into consideration the impact of geomorphological, structural and geological aspects on the groundwater occurrence, distribution and quality in the El Saff area. Also, they did not detect the sources of recharge, the relationships between the groundwater aquifers and the surface water, and the use of the water resources for different purposes. Thereby, these points become the main objective of this work.

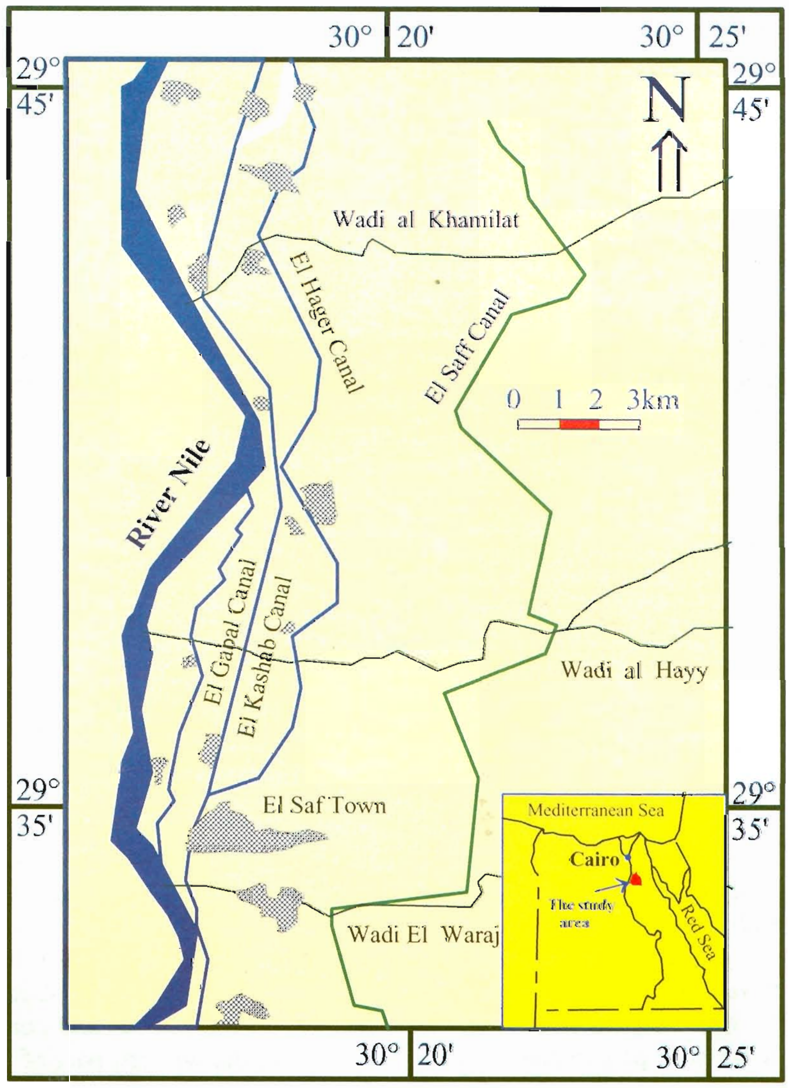

Fig. (1). Location map of the studied area.

MATERIALS AND METHODS

The present study was based on the following:

1- Geologic map (after Said, 1962).
2- Topographic maps (scale 1:50 000).
3- Satellite images.
4- Available composite logs of shallow and deep wells.
5- Detailed field observations and measurements.
6- Collection of water samples representing surface water and groundwater aquifers.
7- Chemical analyses of the collected water samples.
8- Literature.

RESULTS AND DISCUSSION

1- Geomorphology

Based on the geologic map (Fig. 2), topographic maps (scale 1:50 000), SPOT and TM satellite images (Fig. 3), field observations and literature, a geomorphologic map of the study area was made (Fig. 4). It is divided into six geomorphic units, including structural plateau, isolated hills, piedmont plain, alluvial fans, Nile flood plain and hydrographic basins. They are discussed as follows:

Structural Plateau occupies the western edge of the Red Sea drainage divide. This area is characterized by the presence of Gabal Al Jalalah al Bahariyya (+ 695 m), Gabal al Hayy (+521 m) and G. Maskharah (+458 m), from south to north. They are separated mainly by a NW-trending main fault system. The plateau is composed of middle Eocene rock. They are dissected by numerous tributaries.

Isolated hills are located west of the structural plateau. This unit is characterized by the presence of Gabal al Tur al Asfar (+215 m), Gabal Ash Shihaiyybh (+202 m), Gabal Shihaiyybat Abu Knufs (+194 m) and Gabal Hisan Maijli (+168 m). These peaks are also separated by the main NW fault system. They are composed mainly of limestone belonging to Upper Eocene in the southern part and Middle Eocene in the northern part. They are dissected by many tributaries that debouch their water through three main wadis, namely; al Warij, al Hayy and al Khamilat from south to north.

The piedmont plain is present west of the isolated hills. It has variable elevations, ranging from about +137 m in the eastern part to about +56 m in the western part. Grain size varies from boulders, gravels and coarse sand in the eastern part to coarse to medium sand in the western part of Pleistocene age. The alluvial sediments are derived mainly from the eastern high mountains during rainy seasons. The plain is dissected mainly by al Warij, al Hayy and al Khamilat wadis.

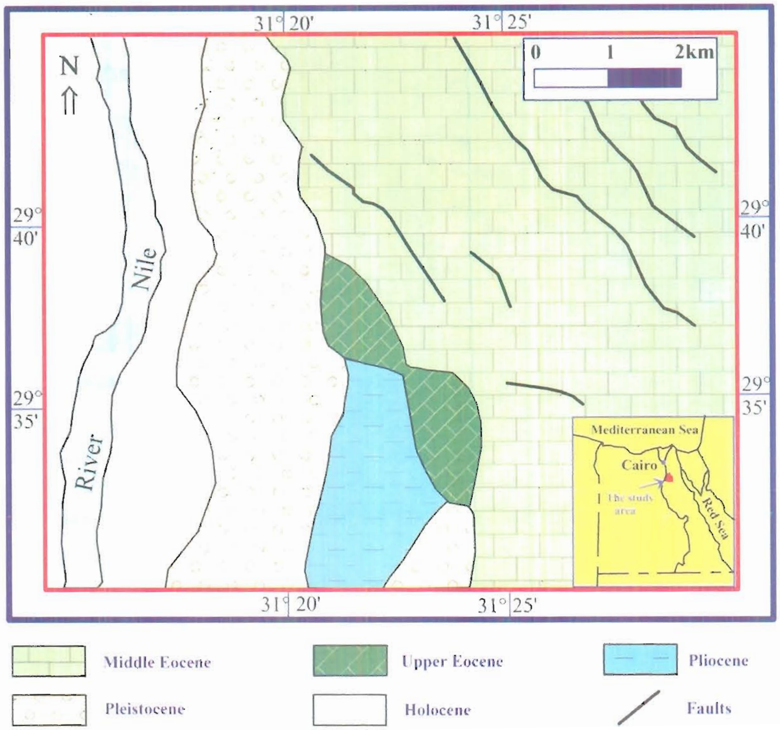

Fig. (2). Geological map of El Saff area, Eastern Desert, Egypt (after Said, 1962).

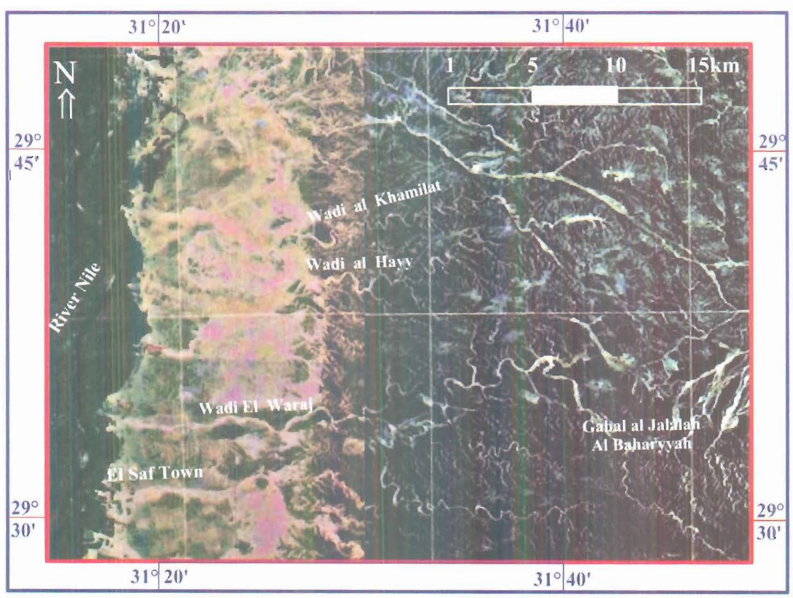

Fig. (3). SPOT satellite image of El Saff area, Eastern Desert, Egypt.

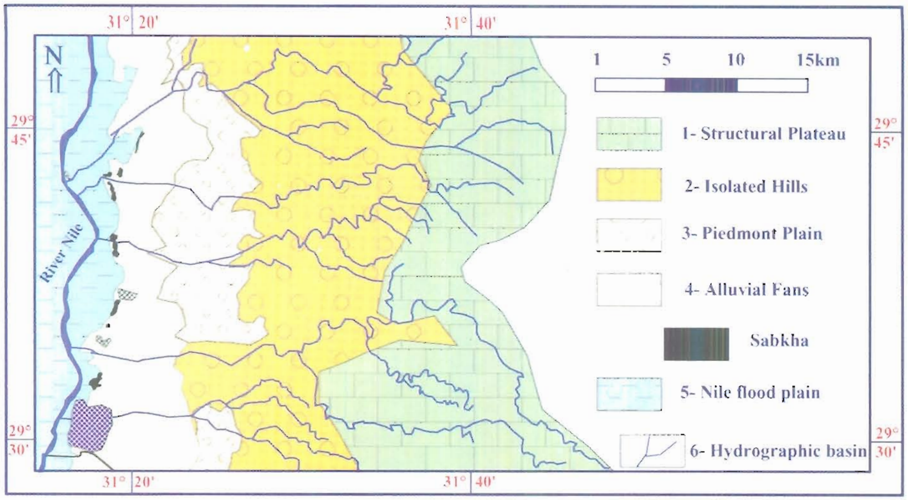

Fig. (4). Geomorphological map of El Saff Area, Eastern Desert, Egypt.

Alluvial fans are located at the mouths of the al Warij, al Hayy and al Khamilat wadis, where the coalesce to form a bajada. They are characterized by ground elevations varying from +24 m to +45 m and are bounded to the west by the El Hager Canal. They are composed mainly of medium to fine sand. Deposition of these fans occurred mainly during rainy seasons in the Pleistocene Epoch. There are a series of sabkhas in the study area that are located in low lying positions between the alluvial fans and Nile flood plan. They are composed mainly of fine sand, silt and clay covered by a thin salt crust. They are formed due to the intersection of water table with depressional areas.

The Nile flood plain is located adjacent to the River Nile. It is characterized by ground elevation ranges from +23 to +21 m with smoothly undulating topography. It is composed mainly of gravel and sand of Pleistocene age, overlain by Holocene silt and clay deposited by River Nile floods.

There are three main hydrographic basins, including the al Warij, al Hayy and al Khamilat wadis, occurring from south to north. They are elongated in shape and are strongly controlled by the structural framework of the area. They allow rain water from heavy storms to pass towards the Nile.

2- Geologic Setting

According to the geologic map (Fig. 2), the main outcropping geologic units in the study area belong to the middle Eocene, upper Eocene, Pliocene and Quaternary. The middle Eocene rocks occupy the eastern part and are composed mainly of limestone with thin lenses of shale, while the upper Eocene rocks are located only in the southern part and are composed mainly of limestone with sand and shale layers. Pliocene rocks are located also in the southern part of the area and are composed mainly of shale with lenses of sand. On the other hand, Quaternary sediments occupy most of the western part of the study area, which can be differentiated into Pleistocene and Holocene units. The Pleistocene sediments lie to the east and are composed mainly of gravel, coarse sand and medium sand, whereas, the Holocene sediments are located around the River Nile and are composed mainly of silt and clay.

5- Surface Water

The studied area is dissected by four main canals (Fig.1) with different ground elevations (Table 1), which are used to irrigate the cultivated lands at different levels. Water flows by gravity from the relatively high lands to the relatively low lands. Three canals (El Hager, El Kashab and El Gabal) carry River Nile water. They are used to irrigate the old lands adjacent to the River Nile. The water salinity of these canals increases at low flow from about 220 ppm to about 280 ppm (Table 1) except at the end of El Hager Canal that reaches about 1520 ppm where the canal in this area acts as a drain for groundwater.

TABLE (1). Chemical analyses of the surface water in El Saff area in ppm.

Sample no.	Canal	Location	Ground elevation (m) above sea level	EC (mmohs/cm)	TDS (ppm)	PH	K^+	Na^+	Mg^{++}	Ca^{++}	CL^-	SO_4^{--}	HCO_3^-
1	River Nile	At the start	25.00	0.37	220.00	7.80	6.00	41.00	6.00	25.00	2.40	2.00	217.70
2		At the end	19.00	0.63	377.00	7.50	7.00	85.00	11.00	30.00	45.00	65.00	217.70
3	El Gabal		23.00	0.37	220.00	7.60	5.00	43.00	6.00	24.00	3.00	1.50	217.70
4	El Kashab	At the start	24.00	0.37	221.00	7.40	5.50	50.00	5.00	19.00	3.10	0.90	217.70
5		At the middle	23.00	0.40	241.00	7.50	5.90	60.00	4.00	18.00	10.00	3.50	221.00
6		At the end	22.00	0.47	281.00	7.70	7.80	75.00	3.00	17.00	28.00	8.00	217.70
7	El Hager	At the start	25.00	0.38	227.00	7.40	7.40	45.00	6.00	22.00	3.00	3.00	217.70
8		At the end	22.00	2.54	1523.00	7.50	53.00	385.00	30.00	90.00	470.00	130.00	550.00
9	El Saff	At the start	86.00	1.03	616.00	7.50	11.10	135.00	24.00	40.00	205.00	30.00	217.70
10		At the middle	82.00	1.38	828.00	7.80	16.00	172.00	28.00	55.00	280.00	60.00	217.70
11		At the end	80.00	1.38	829.00	7.60	16.20	184.00	30.00	58.00	290.00	90.00	217.70

Ec= Electric conductivity TDS= Total dissolved salt K^+= Potassium
Na^+= Sodium Ca^+= Calcium Cl^- = Chloride
SO_4^{--} = Sulphate HCO_3^- = Bicarbonate

On the other hand, the El Saff lined canal has a ground elevation ranging from +86 m at the start to +80 m at the end (Table 1). The main source of the canal is the release of the treated industrial and wastewater from the cities of Helwan and El Tabin. It is used to irrigate the newly reclaimed lands in the eastern fringes of the El Saff area that are characterized by ground elevation ranging from about +80 m to about +30m.

It has a water salinity of 616 ppm at the start of the canal, increasing along its course to 829 ppm, probably due to the effect of groundwater seepage from the Eocene Aquifers through fissures in the canal lining.

The same phenomenon is recorded in the salinity of River Nile, which increases from about 220 ppm at El Saff to about 380 ppm at the downstream end of the area. The increase of salinity, which reaches 580 ppm, may be due to groundwater discharge into the river

3- Groundwater

Based on composite logs and well logging of the available shallow and deep water wells (Fig. 5), hydrogeologic cross sections (Figs. 6 and 7) and chemical analyses of the selected water points according Rainwater and Thatcher (1960) methods (Tables 2, 3 and 4) as well as literature, there are two main aquifer systems in the studied area belonging to Quaternary and Eocene (Fig. 8). They are discussed as follows:

a- Quaternary Aquifer System

The Quaternary aquifer system is located in the western part of the study area (Fig. 8) and can be differentiated into two aquifers according to the source of sediment, namely Nilotic (Prenile and Protonile) and alluvial. The Nilotic aquifer occupies a narrow strip adjacent to the River Nile. It consists of Pleistocene sands and gravels with thickness ranging from a few meters in the eastern part to about 150 m adjacent to the River Nile. The aquifer has two units separated from each other by a clay layer. Water quality is represented by 11 water samples (Fig. 5 and Table 2). The top of the aquifer is hydraulically connected with the River Nile, irrigation systems and the alluvial Aquifer. This is indicated by the variation of groundwater salinity that ranges from 288 ppm (fresh water) near the River Nile to 2040 ppm (brackish water) in the eastern part. On the other hand, the deep layer is hydraulically connected with surrounding deep aquifers having water salinity ranges from 1578 to 1580 ppm (brackish water).

The Alluvial aquifer occupies the alluvial fans of the main wadis and extends eastward to the piedmont plain. It is composed mainly of boulders, gravels and coarse sand in the eastern part and changes westward to become mainly coarse and medium sand that is derived mainly from the eastern marine rocks. It has a thickness ranging from about 30 to 60 m. It is represented by 12 water samples (Table 3). It is recharged mainly from El Saff and El Hager Canals and Eocene aquifer system (relatively high groundwater salinity). This is indicated by the variation of groundwater salinity that ranges mainly from 1040 ppm to 2950 ppm (brackish water).

b- Eocene Aquifer System

The Eocene aquifer system can be divided into Upper Eocene and Middle Eocene aquifers. They are hydraulically connected. The upper Eocene aquifer is located at the high relief areas of the piedmont plain. It is composed mainly of limestone with sand and shale layers. It is represented by four water samples (Table 4). It is recharged mainly from the El Saff Canal and the eastern middle Eocene aquifer. These appear from the variation of groundwater salinity that ranges from 2410 ppm to 5360 ppm (brackish water).

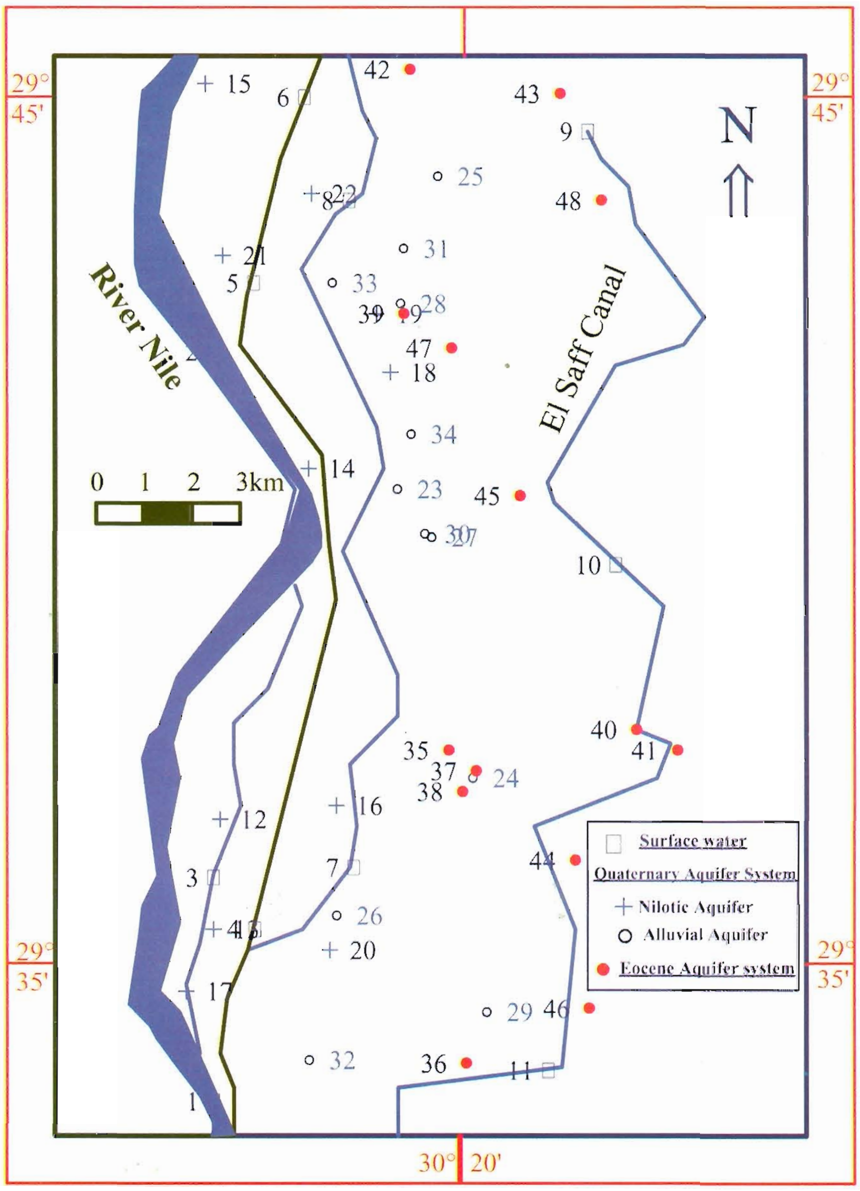

Fig. (5). Location map of the selected water samples of El Saff area, Eastern Desert.

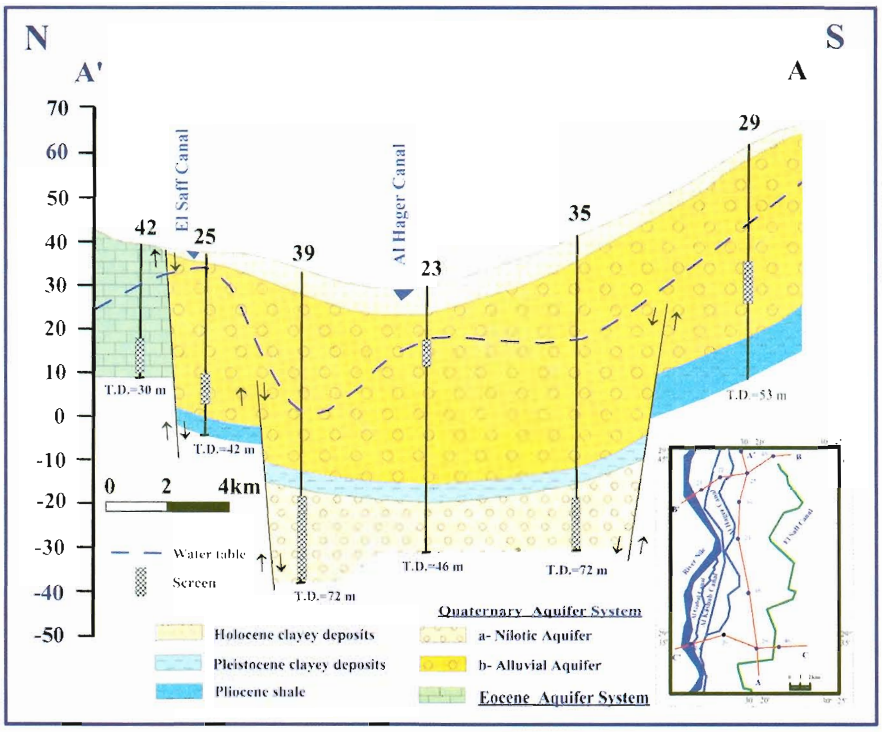

Fig. (6). N - S hydrogeological cross sections in El Saff area, Eastern Desert.

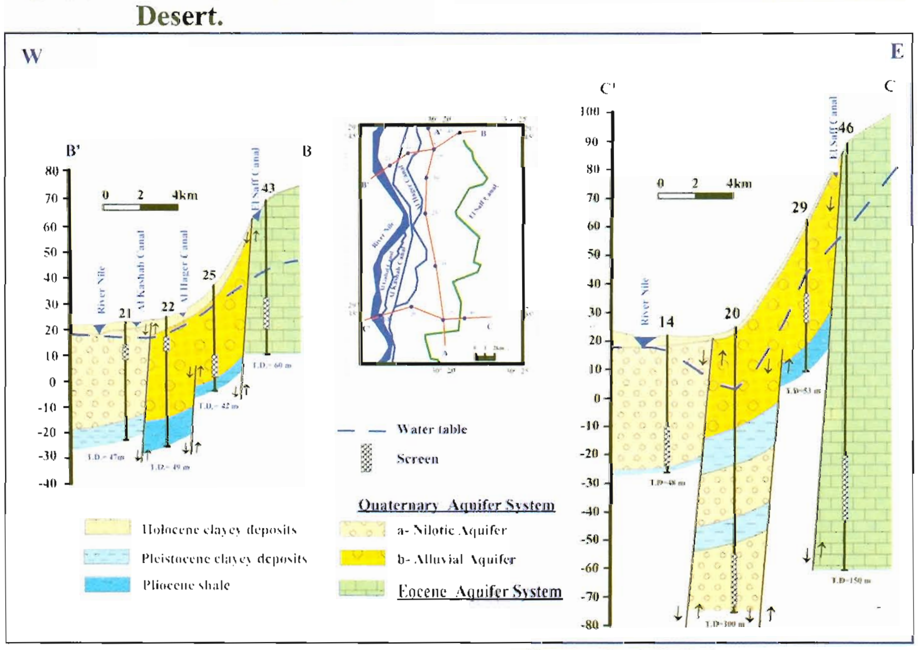

Fig. (7). E - W hydrogeological cross sections in El Saff area, Eastern Desert.

TABLE (2). Chemical analyses of the Nilotic groundwater aquifer in El Saff area.

Sample No.	Ground elevation (m) above sea level	Total depth	Depth to water (m) above sea level	EC (mmohs/cm)	TDS (ppm)	PH	K^+ (ppm)	Na^+ (ppm)	Mg^{++} (ppm)	Ca^{++} (ppm)	Cl^- (ppm)	SO_4^{--} (ppm)	HCO_3^- (ppm)
12	24	10	7	0.48	288	7.6	3.90	65	11	19	32	40	185
13	24	10	7	0.49	292	7.8	4.30	70	10	18	35	45	180
14	22	25	12	0.66	395	7.5	4.70	89	16	20	61	50	210
15	22	40	5	0.98	582	7.8	5.46	110	24	55	150	50	260
16	23	12	6	1.21	733	7.4	9.98	114	40	70	140	180	262
17	22	48	4	1.51	908	7.5	5.80	240	30	40	270	80	349
18	28	12	6	2.64	1578	7.7	14.00	410	36	100	600	200	300
19	36	66	10	2.10	1580	7.5	7.40	338	36	60	360	330	218
20	25	100	21	2.10	1580	7.5	5.00	360	24	60	340	330	262
21	22	16	8	1.95	1830	7.7	4.70	250	55	75	410	120	305
22	24	15	8	3.41	2040	7.5	39.00	398	110	132	900	200	262

Ec= Electric conductivity   TDS= Total dissolved salt K^+= Potassium
Na^+= Sodium Ca^+= Calcium Cl^- = Chloride
SO_4^{--} = Sulphate HCO_3^- = Bicarbonate

TABLE (3). Chemical analyses of the alluvial groundwater aquifer in El Saff area.

Sample No.	Ground elevation (m) above sea level	*Total depth*	Depth to water (m) above sea level	EC (mmohs/cm)	TDS (ppm)	PH	K^+ (ppm)	Na^+ (ppm)	Mg^{++} (ppm)	Ca^{++} (ppm)	Cl^- (ppm)	SO_4^{--} (ppm)	HCO_3^- (ppm)
23	30	13	11.5	1.68	1040	7.50	3.0	250	35	50	180	300	300
24	39	36	8	2	1200	7.80	5.6	270	36	100	350	300	218
25	37	16	4	2.57	1539	7.50	14.8	280	60	155	603	220	217
26	24	27	19	2.64	1578	7.70	10.1	390	28	120	400	410	330
27	38	50	22	4.22	2530	7.50	10.5	650	96	100	980	450	260
28	36	36	10	4.24	2540	7.60	7.0	850	24	60	1100	305	290
29	63	36	28	4.24	2540	7.60	8.6	780	30	110	890	520	370
30	36	25	16	4.3	2570	7.40	7.0	800	36	100	1040	550	131
31	42	41	12	4.51	2710	7.80	6.2	600	90	200	1150	300	280
32	28	65	6	4.59	2750	7.40	3.9	810	36	125	970	530	349
33	23	20	6	4.93	2950	7.80	15.6	750	71	200	1150	500	360
34	24	42	16	16.44	9870	7.70	8.6	2300	360	670	4800	1200	174

Ec= Electric conductivity   TDS= Total dissolved salt K^+= Potassium
Na^+= Sodium Ca^+= Calcium Cl^- = Chloride
SO_4^{--} = Sulphate HCO_3^- = Bicarbonate

TABLE (4). Chemical analyses of the Eocene Aquifer System in El Saff area.

Sample No.	Aquifer	Ground elevation (m) above sea level)	Total depth	Depth to water (m) above sea level	EC (mmohs/cm)	*TDS* (ppm)	PH	K^+ (ppm)	Na^+ (ppm)	Mg^{++} (ppm)	Ca^{++} (ppm)	CL^- (ppm)	SO_4^{--} (ppm)	HCO_3^- (ppm)
35	Upper Eocene	42	72	24	4.02	2410	7.50	5.40	640	36	180	840	500	349
36		64	36	24	5.47	3280	7.50	3.10	1130	12	60	1220	630	340
37		39	45	11	6.2	3710	7.60	10.14	800	72	420	1600	600	218
38		44	45	13	8.99	5360	7.40	5.85	1400	120	360	2400	750	262
39	Middle Eocene	43	72	18	4.59	2750	7.40	5.50	470	114	310	1200	320	300
40		74	10	73	5.31	3400	7.96	49.00	400	160	420	400	1800	205
41		78	11	75	6.4	4100	7.88	98.00	450	109	660	950	1500	195
42		39	30	18	6.89	4120	7.50	6.90	980	96	340	1763	600	305
43		70	60	27	7.37	4400	7.80	11.70	1320	108	140	1900	750	262
44		77	12	76	1.31	6600	7.9	11.00	1725	268	520	1650	3450	250
45		76	12	75	15.78	10100	7.4	47.00	1800	435	800	2350	400	287
46		90	150	60	20.3	12180	7.50	9.90	3400	312	560	5100	1700	1300
47		51	42	10	21.1	12670	7.60	23.00	3000	540	600	6000	1600	131
48		80	15	75	20.32	13000	7.3	10.00	3500	268	550	2100	6650	240

Ec= Electric conductivity TDS= Total dissolved salt K^+= Potassium
Na^+= Sodium Ca^+= Calcium Cl^- = Chloride
SO_4^{--} = Sulphate HCO_3^- = Bicarbonate

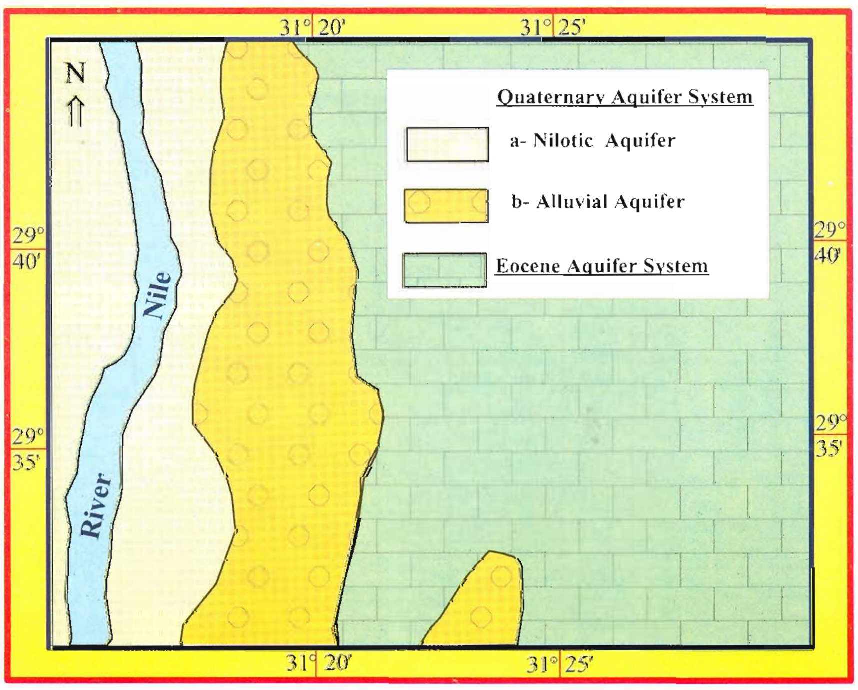

Fig. (8). Groundwater Aquifers in El Saff area.

On the other hand, the middle Eocene aquifer occupies most of the eastern part of the study area. It is composed mainly of limestone with sand

and shale layers. It is represented by ten water samples (Table 4). It is recharged mainly from the eastern watershed area and the El Saff Canal especially in the northern part. This is indicated by the variation of groundwater salinity that ranges from 2750 ppm (brackish water) to 13000 ppm (saline water).

From above discussion it can be concluded that all the groundwater aquifers are hydraulically connected with each other through faults and pores. However, the variation of groundwater salinity is due to the variation of the salinity of aquifer sediments and the main source of recharge. These relationships are illustrated by water table and groundwater salinity maps of the study area presented below.

The ground elevation of the water sampling points have a relatively gentle westward slope ranging from more than +100 m in the eastern part to about +21 m in the western part of the area(Fig. 9). The water level map of the study area (Fig. 10) is strongly controlled by the ground elevation (Fig. 9) and highly affected by the water recharge from the irrigation canals (El Saff, El Hager, El Kashab and El Gabal), River Nile and the eastern watershed area. The water level ranges from about +76 m in the eastern part (near the El Saff Canal) to about +4 m near the River Nile in the western part.

The ground water salinity is highly affected by the salinity of the source of recharge (Fig. 11). This is reflected in the restriction of the high groundwater salinity (7000 ppm to about 13000 ppm) in the east, which is recharged mainly from the eastern watershed area. On the other hand, the recharge from the El Saff fresh water canal decreases the groundwater salinity to about 2000 ppm. Westward, the irrigation canals (El Hager, El Khashab and El Gabal) and the River Nile decrease the ground water salinity to about 300 ppm.

4- Hydrogeochemistry

a- Major cations and anions

From the chemical analyses of the collected surface and groundwater water samples (Tables 1, 2, 3 and 4) and the hydrochemical ion contents in the study area, the source of groundwater recharge and the type of sediments in the groundwater aquifers can be interpreted, as mentioned before. The following relationships are illustrated in figs. (11-16):

i- The distribution of calcium, sodium and chloride ions (Figs. 12, 13 and 14) shows high concentrations of these parameters in the east, decreasing toward the west.

ii- The relative similarity of HCO_3 in the study water samples due to the River Nile is the main source of recharge and the groundwater aquifers is hydraulically connected. That might explain similar values obtained for HCO_3 at table (1).

iii- The dominant sequence of ion content in both surface water and the Nilotic aquifer is Na + > Ca ++>Mg ++ - Cl -> HCO_3 -> SO_4 --, while the dominant sequence within the other aquifers is Na +>Ca++ > Mg++ - Cl -> SO_4 --> HCO_3 –.

iv- The main salts present within the Eocene aquifer system are NaCl and $MgSO_4$, which change westward to NaCl and $CaSO_4$ due the effect of the recharge from the eastern watershed area. In the alluvial aquifer, the dominant salts are mainly NaCl and Na_2SO_4, due to the effect of the recharge from El Saff fresh water canal. The recharge from the irrigation canals (El Hager, El Khashab and El Gabal) and the River Nile produces salt contents of NaCl and $Ca(HCO_3)_2$.

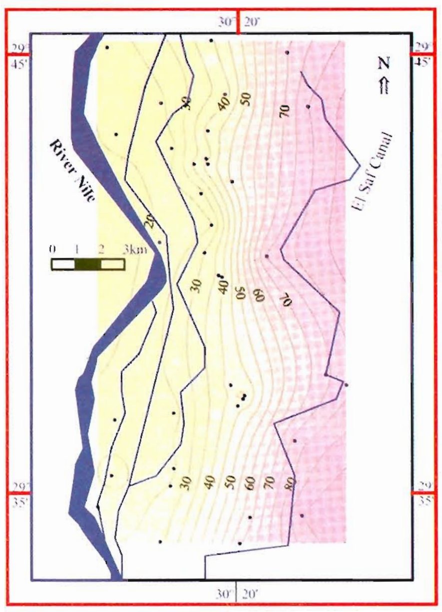

Fig. (9). Ground elevation map of El Saff area.

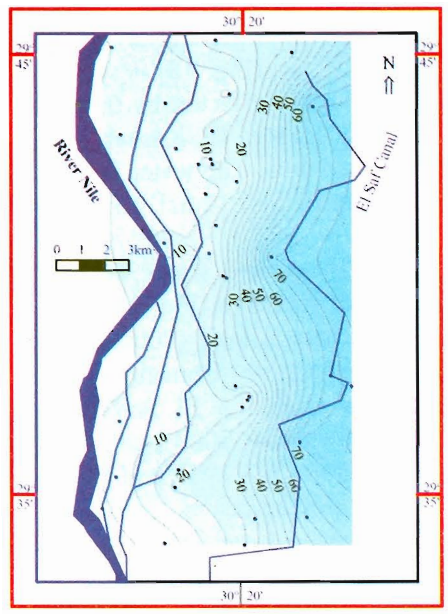

Fig. (10). water level map of El Saff area

b- Diagenesis of Groundwater

Plots of the hydrogeological and hydrochemical analyses on the diagram of Piper (1944) and the diagram of Sulin's (1948) (Figs. 15 and 16) indicate that the water quality of the surface water and the various aquifers are controlled by infiltration (meteoric type). However, the chemical composition of the aquifer systems reflects the role of aquifer sediments only.

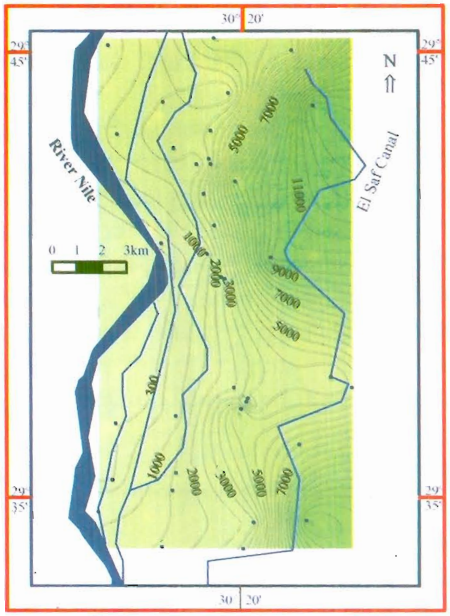

Fig. (11). Iso-salinity map of El Saff area.

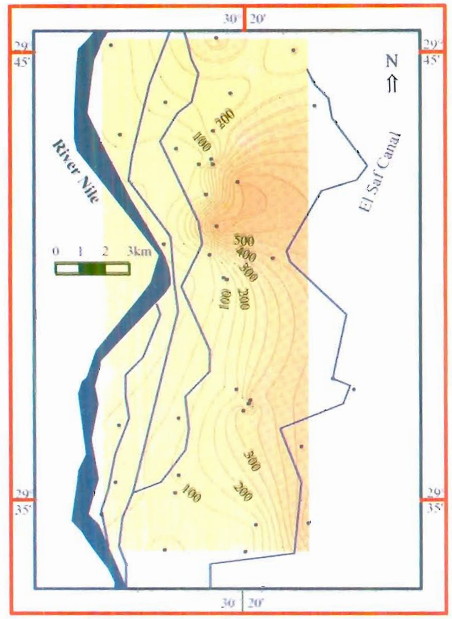

Fig. (12). Calcium distribution map of El Saff area.

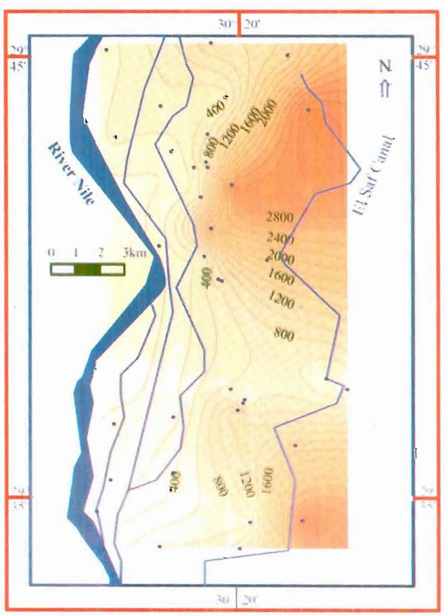

Fig. (13). Sodium distribution map of El Saff area.

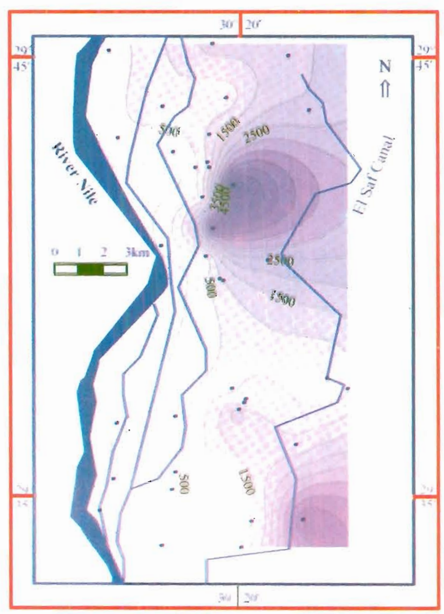

Fig. (14). Chloride distribution map of El Saff area.

5- Water Resources Evaluation

With regard to the suitability of water quality for drinking, domestic and irrigation purposes, the following conclusions can be made:

a- Evaluation of water quality for drinking and domestic purposes

According to the international standards (Table 5) proposed by the World Health Organization "WHO" (1971), all the surface water samples are suitable for drinking purposes except Sample no. 8 of the El Hager Canal and the El Saff water samples that contain relatively high salinity and a high percentage of microbiological content. On the other hand, although the groundwater within the Nilotic aquifer adjacent to the River Nile is suitable for drinking purposes, groundwater from the other aquifers is not suitable due to its high salinity and the presence of some microbiological content.

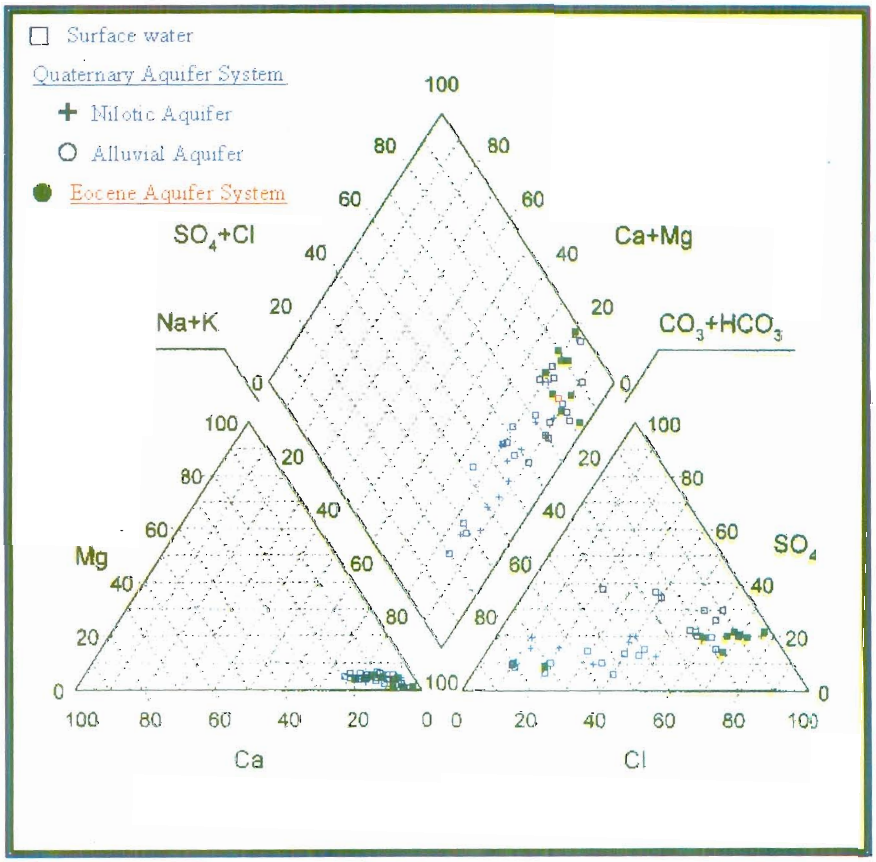

Fig. (15). Piper Diagram of the studied water samples.

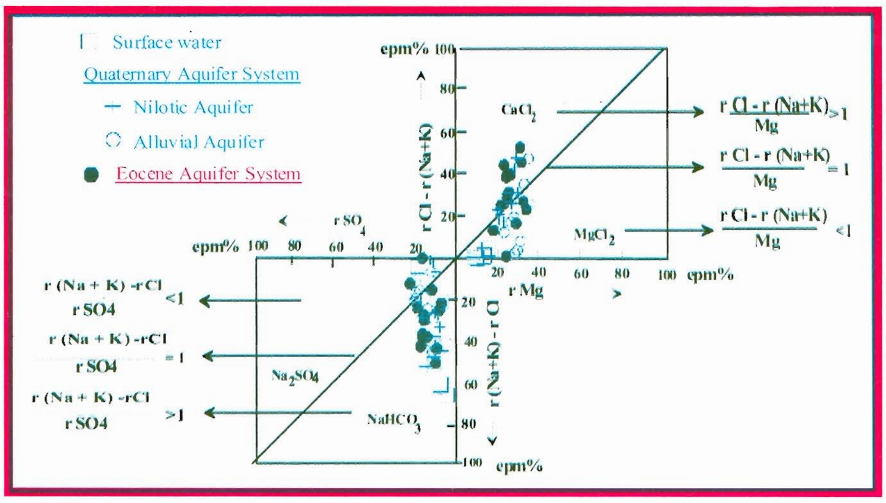

Fig. (16). Sulin Diagram of the studied water samples.

TABLE (5). International Standards for drinking by the World Health Organization (1971).

Substance or characteristic	Undesirable effect	Highest desirable level	Maximum permissible level
TDS	Gastrointestinal	500 mg/l	1500 mg/l
PH	Corrosion	7.5 to 8.5	6.5 to 9.2
Total hardness	Excess scale formation	100 mg/l Ca CO3	500 mg CaCO3
Calcium	Excess scale formation	75 mg/l	200 mg/l
Magnesium	Hardness tests, gastrointestinal irritation in the presence of sulphate	Less than 30 mg/l if there is 250 mg/l sulphate. If there is less sulphate, (Mg) up to 15 0 mg/l may be allowed	150 mg/l
Sulphate	Gastrointestinal irritation where magnesium or sodium are present	200 mg/l	400 mg/l
Iron	Discoloration deposits and growth of iron, bacteria turbidity	0.1 mg/l	1. 0 mg/l

b- Evaluation of water quality for livestock and poultry

According to standards of National Academy of Science and National Academy of Engineering (1972), the following classes are deduced (Table 6):

i-All the surface waters are excellent for livestock and poultry except sample no. 8 of the El Hager Canal and the El Saff Canal samples that are very satisfactory.

ii- Most of the Nilotic and alluvial aquifer water are very satisfactory for all classes of livestock and poultry, whereas the Eocene Aquifer System water samples are satisfactory for livestock but may cause temporary diarrhea.

TABLE (6). Guide to the use of saline water for livestock and poultry (National Academy of Science and National Academy of Engineering, 1972).

TDS (mg/l)	Character
Less than 1000 mg/l	Relatively low level of salinity. Excellent for all classes of livestock and poultry.
1000 to 2999 mg/l	Very satisfactory for all classes of livestock and poultry. May cause temporary and mild diarrhea in livestock not accustomed to them or watery dropping in poultry.
3000 to 4999 mg/l	Satisfactory for livestock, but may cause temporary diarrhea or be refused at first by animals not accustomed to them. Poor water for poultry, often causing water face, increased mortality and decreased growth, especially in turkeys.
5000 to 6999 mg/l	Can be used with reasonable safety for dairy and beef cattle for pregnant or locating cows, swine and horses. Avoid use for pregnant or locating animals. Not acceptable for poultry.
7000 to 10000 mg/l	Unfit for poultry, for swine. Considerable risk in using for pregnant or locating cow, horses or sheep or for young of these species. In general. Use should be avoided although older ruminants, horses, poultry and swine may subsist on them under certain conditions.
Over 10000 mg/l	Risk with these highly saline water are so great that they can not be recommended for use under any conditions

c- Evaluation of water quality for irrigation

The classification of U. S. Salinity Laboratory (1954) is used in the present study to evaluate the water samples analyzed for irrigation purposes. This classification depends on the relationship between the sodium adsorption ratio (S.A.R.) and the electrical conductivity (EC) of the water samples. The plotted water samples on the diagram (Fig.17) give raise the following result:

i- Water of medium salinity and low S.A.R. (C_2S_1) that can be used for the irrigation of most crops includes most of the surface water samples and Nilotic water samples nos. 12, 13 and 14.

ii- Water of high salinity and low S.A.R. (C_3S_1) that can be used for the irrigation of most plants and is suitable for all soil texture includes the El Saff water samples (nos. 9, 10 and 11), and the Nilotic groundwater sample nos. 15 and 16.

iii- Water of high salinity and medium S.A.R. (C_3S_2) that can be used for the irrigation of relatively sensitive plants includes Nilotic groundwater sample nos. 17, 19 & 21 and alluvial groundwater sample nos. 24 & 23.

iv- Water of very high salinity and medium S.A.R. (C4S2) that are satisfactory for salt tolerant crops and soils of good permeability with special leaching includes Nilotic groundwater sample no. 22 and alluvial groundwater sample no. 25 as well as Middle Eocene sample no. 39.

v- Water of very high salinity and high S.A.R. (C4S3) that is suitable for irrigation under ordinary conditions includes water sample no. 18 of Nilotic aquifer and 26, 27, 31 and 33 of the alluvial aquifer and sample no. 35 of the Eocene Aquifer.

vi- Water of very high salinity and very high S.A.R. (C4S3) that is not suitable for irrigation under ordinary conditions includes water sample nos. 28, 29 and 30 of the alluvial aquifer.

vii-The remaining water samples that have high electric conductivity (more than 5000 micro mohs) should not be applied for irrigation purposes.

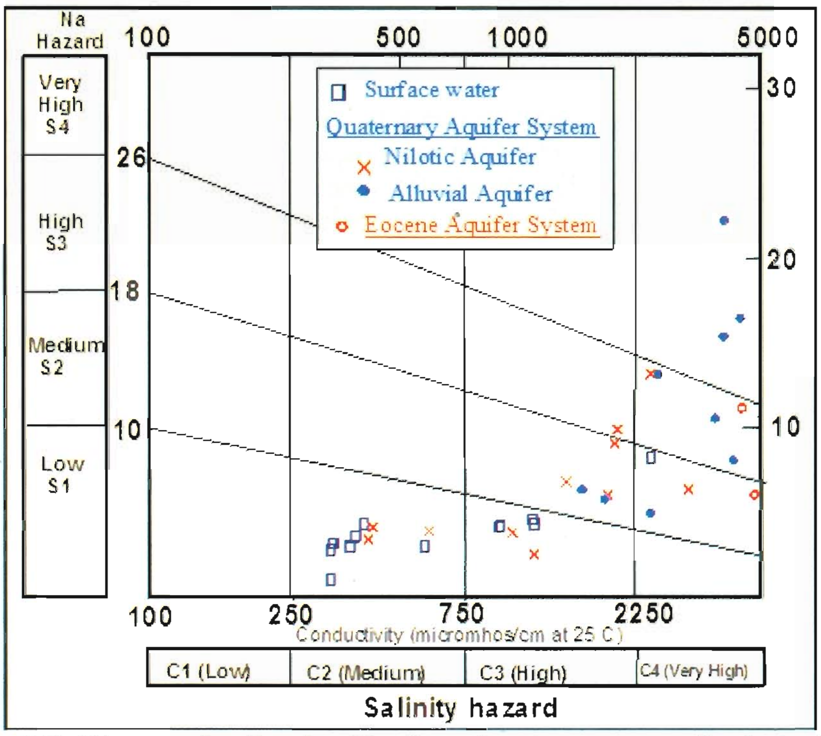

Fig. (17). Diagram for the classification of water resources for irrigation purposes (According to U.S. Salinity Laboratory Staff, 1954).

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The present work is concerned with the impact of geomorphological and geological factors on groundwater occurrence, distribution, and water quality in the El Saff area. It is also concerned with detection of the sources of groundwater recharge; the relationship between groundwater aquifers & the surface water; and the use of water resources for different purposes. It is based on analysis of geologic maps, topographic maps, satellite images, available composite logs of shallow & deep wells, detailed field observations and measurements, collection of water samples representing surface water and groundwater aquifers, chemical analyses of the collected water samples and the literature.

Geomorphologically, the study area is classified into seven geomorphic units: including high mountains, isolated hills, piedmont plains, alluvial fans, Nile flood plain, sabkhas and hydrographic basins. It is dissected by four main canals at different ground elevation. Three of them (El Hager, El Kashab and El Gabal) carry River Nile water with salinity ranging mainly from 220 ppm to 380 ppm, while the other (El Saff Canal) carries drainage water of treated industrial and wastewater released from Helwan and El Tabin Towns having salinity ranging from about 620 ppm to about 830 ppm.

The two main aquifer systems in the study area belong to the Quaternary and Eocene. The Quaternary aquifer system is located in the western part, while the Eocene aquifer system is restricted to the eastern part. The Quaternary aquifer System can be differentiated into Nilotic and alluvial aquifers. The Nilotic aquifer occupies a narrow strip adjacent to the River Nile and is recharged mainly from the River Nile, irrigation systems and the alluvial aquifer which produce a variation in groundwater salinity ranging from 288 ppm near the River Nile to 2040 ppm in the eastern part. The alluvial aquifer is located in the alluvial fans of the main wadis and extends eastward to the piedmont plain. It is recharged mainly from the El Saff and El Hager Canals, as well as the Eocene Aquifer (relatively high salinity). It has groundwater salinity ranges from 1040 ppm to 2950 ppm.

The Eocene Aquifer System is differentiated into Upper Eocene and Middle Eocene aquifers. The Upper Eocene Aquifer is located at the high relief areas of the piedmont plain with salinity ranging from 2410 ppm to 5360 ppm. The Middle Eocene aquifer occupies most of the eastern part of the studied area and with groundwater salinity varying from 2750 ppm to 13000 ppm. It is recharged mainly from the eastern watershed area and the El Saff Canal, especially in the northern part.

There is a direct relationship between the surface water (El Saff Canal, El Hager Canal and El Kashab Canal, as well as the River Nile) and the groundwater aquifers. The River Nile and the El Kashab Canal are the main source of recharge of Nilotic Aquifer. El Saff canal is the main source of recharge in the alluvial aquifer and the El Saff canal is the main source of recharge in the Eocene Aquifer especially in the northern part. On the other hand, all the groundwater aquifers are hydraulically connected with each others through faults and pervious sediments. The variation of groundwater salinity is due to the variation of the salinity of aquifer sediments and the main source of recharge.

Most of the surface water samples are suitable for drinking purposes except El Saff canal water samples, while most of the groundwater samples are not suitable except the Nilotic Aquifer adjacent to the River Nile. On the other hand, all the surface waters are excellent for livestock and poultry except that of El Saff Canal samples that are very satisfactory, while most of the groundwater samples are very satisfactory for all classes of livestock and poultry except the Eocene Aquifer System water samples which are satisfactory for livestock but may cause temporary diarrhea. Nearly all the surface and Nilotic Aquifer water samples are suitable for irrigating all crops, while most of the alluvial aquifer waters are satisfactory for salt tolerant crops but, the Eocene water is mainly not suitable for irrigation.

Therefore, the following recommendations may be stated:

i- Detailed shallow and deep groundwater exploration in the eastern part to detect the extension, thickness and potentiality of the Eocene Aquifer System.

ii- Detailed deep groundwater exploration in the area of alluvial aquifer to detect the Pliocene aquifer and its potential yield.

iii- Drilling several observation wells to monitor the groundwater aquifers from chemical and biological point of view.

iv- The smell of the groundwater samples seemed to have some microbiological pollution from the El Saff Canal and septic tanks of the scattered villages, thereby the groundwater must not be used for drinking purposes.

v- The El Saff Canal should be perfectly lined to prevent seepage of water to the groundwater aquifers.

vi- El Saff Canal water should be treated or mixed with Nile water before using for different purposes.

vii- New water resources planning should be conducted based on he results of the recommend works.

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REFERENCES

Abdel Shafy, E.; B. Mabrouk; and M. Shehata (1986). Geological studies on Quaternary sediments in El Saff area with some regional hydrogeological emphasis. Bull. Fac. Sci., Zagazig Univ., Egypt, No. 30, p. 52-76.

Attia, M. I. (1954). Deposits in the Nile valley and the Delta. Mines and Quarries Dep. Geol. Surv. Egypt, Cairo, 356 pp.

Awad, S. R. (1999). Environmental studies on groundwater pollution in some localities in Egypt. Ph.D. Thesis, Faculty of Science, Cairo University, Egypt.

Awad, S. R.; N. E. El-Arabi; J. B. Khalil and A. E. Eweida (2002). Hydrogeology, hydrochemistry and pollution of groundwater in El Saff area, Egypt. Third Proceeding of the International Conference of Groundwater Level Control Inside Urbanized Areas, Faculty of Engin., Mansoura Univ., Egypt. p. 266-277.

DRC (Desert Research Center) (1994). Geoelectrical prospecting on the groundwater in the area East of Ghamaza (South Helwan, Egypt), an Internal Report. Desert Research Center, Egypt.

Gharieb S. E. M. (1990). Geological and geomorphological studies on the limestone, East of Nile, Beni Suef and Minia Governorates. M. Sc. Thesis, Faculty of Science, Cairo University, Egypt.

Khaled, M. A. and A. Al Abaseiry (2003). Geoelectrical study on the groundwater occurrence in Wadi El Newiya area – El Saff – South Cairo – Egypt, *Egyptian J. Desert Research*, Vol. 89, p. 111-122.

National Academy of Sciences and National Academy of Engineering (1972). Water Quality Criteria. Report Prepared by Committee of Water Quality Criteria at Request of US. Environmental Protection Agency, 594 p, Washington, D.C., U.S.A.

Piper, A. M. (1944). A graphic procedure in the geochemical interpretation of water analyses. Trans. Am. Geophy. Union, Vol. 25- 6, p. 914 – 923, Washington, D. C., U.S.A.

Rainwater, F. H. and L. I. Thatcher (1960). In "Methods for collection and analysis of water samples". U. S. Geol., Water Supply, 1454, 301 pp.

RIGW/IWACO (1998). Environmental Management of Groundwater Resources (EMGR): Identification, priority setting and selection of area for monitoring groundwater quality. Technical Report TN/70.00067/WQM/97/20, Res. Instit. For Groundwater (RIGW), Egypt.

Said, R. (1962). "*The geology of Egypt*". Elesvier, Amsterdam, 377 PP.

Said, R. (1975): Subsurface geology of Cairo area. Memoires deL. Inst. d'Egypt, Tome soixante, le Cairo, 70 p.

Said, R. (1990). "*The Geology of Egypt*". A. A. Balkema, pub. Comp. Rotterdam,734p.

Said R. and S. Beheiri (1961). Quantitative geomorphology of the area to the east of Cairo. Bull. Soc. Geogr. D'Egypt, Tome. 34, p. 125-150.
Sulin's, V. A. (1948). Condition of Formation, Principles of Classification and Constituents of Natural Waters. Particularly Water Petroleum Accumulation. Leningrad Acad. Sci., Moscow, U.S.S.R (In Russian).
U.S. Salinity Laboratory (1954). Diagnosis and Improvement of Saline and Alkaline Soil. S.S. Dept. of Agriculture, Hand Book, No. 60, 160 pp.
World Health Organization "WHO" (1971). International standards for drinking water. Geneva, World Health Organization, 70 pp.

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جيولوجية مصادر المياه في مناطق الاستصلاح شمال الصف، الصحراء الشرقية، مصر

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تم تقسيم منطقة الصف إلى ستة وحدات جيومورفولوجية هي الهضبة التركيبية، التلال المعزولة، السهل البيدمونتى، المراوح النهرية، السهل النيلي الفيضى و أحواض الصرف. تخترق المنطقة أربعة ترع رئيسية ذات مناسيب مختلفة بالنسبة لسطح الأرض. ثلاثة منهم (الجبل، الخشاب و الحاجر) تتغذى من نهر النيل وملوحة مياهها تتراوح بين ٢٢٠ و ٣٨٠ جزء في المليون (مياه عذبة). بينما الترعة الأخرى (الصف) تتغذى من مياه الصرف الصحي والصناعي لمدن حلوان والتبين وملوحة مياهها تتراوح بين حوالي ٦٢٠ و حوالي ٨٣٠ جزء في المليون (مياه عذبة).

تم تحديد نظامين رئيسين للخزانات الجوفية بمنطقة الدراسة وهما نظام الخزان الرباعي الذي يتواجد في الجزء الغربي ونظام الخزان الايوسينى الذي يتواجد في الجزء الشرقي. الخزانات متصلة هيدرولوكيا من خلال الفوالق والشقوق ومسام الصخور. يتكون نظام الخزان الرباعي من الخزان النيلي والخزان الفيضى. الخزان النيلي يشغل الشريط الملاصق لنهر النيل و يتغذى من النهر وترع الري والخزان الفيضى. مما أدى إلى تغير ملوحته مياهه من ٢٨٨ جزء في المليون (مياه عذبة) بجوار النيل إلى ٢٠٤٠ جزء في المليون (مياه مالحة قليلا) إلى الشرق. أما الخزان الفيضى فانه يشغل المراوح النهرية ويمتد في السهل البيدمونتى. يتغذى الخزان في الغالب من ترع الصف والحاجر ونظام الخزان الايوسينى مما أدى أيضا إلى تغير ملوحته من ١٠٤٠ إلى ٢٩٥٠ جزء في المليون (مياه مالحة قليلا).

نظام الخزان الايوسينى يتكون من خزان الأيوسين العلوي وخزان الأيوسين الأوسط. يتواجد خزان الأيوسين العلوي في الأماكن المرتفعة من السهل البيدمونتى وملوحة مياه تتراوح بين ٢٤١٠ و ٥٣٦٠ جزء في المليون (مياه مالحة قليلا) حيث يتغذى أساسا من ترعة الصف. بينما يشغل خزان الأيوسين الأوسط معظم الجزء الشرقي لمنطقة الدراسة و يتغذى غالبا من أحواض الصرف الشرقية إضافة إلى ترعة الصف في الجزء الشمالي. وهذا يتضح من التغير في ملوحة مياهه من ٢٧٥٠ جزء في المليون (مياه مالحة قليلا) و ١٣٠٠٠ جزء في المليون (مياه مالحة).

معظم المياه السطحية صالحة للشرب ماعدا مياه ترعة الصف، بينما معظم المياه الجوفية غير صالحة للشرب ماعدا مياه الخزان النيلي الملاصقة لنهر النيل. من ناحية أخرى معظم المياه السطحية ومياه الخزان النيلي صالحة لرى كافة المحاصيل بينما مياه الخزان الفيضى صالح لرى المحاصيل التي تتحمل الملوحة. أما معظم مياه نظام الخزان الأيوسينى غير صالحة للري.