The American Journal of Interdisciplinary Innovations Research
(ISSN – 2642-7478)
VOLUME 04 ISSUE 05 Pages: 23-41
SJIF IMPACT FACTOR (2020: 5. 498) (2021: 5. 676) (2022: 6. 233)
OCLC – 1091588944 METADATA IF – 7.895
Publisher: The USA Journals

Journal Website: https://theamericanjournals.com/index.php/tajiir

Research Article

DRAINAGE PATTERN PHENOMENA IN SANDY AREAS IN ARID ZONES FOR IDENTIFICATION HIGH POTENTIAL AND EXCELLENT GROUNDWATER

Submission Date: May 03, 2022, **Accepted Date:** May 13, 2022,
Published Date: May 24, 2022 |
Crossref doi: https://doi.org/10.37547/tajiir/Volume04Issue05-03

Ahmed Fawzy Yousef
Geology Department, Desert Research Center, Egypt

ABSTRACT

The drainage pattern phenomenon in the sandy area is rare in the world and has very high yields with excellent quality groundwater. It was recorded and tested in the Qattara Delta to the west of the River Nile. The study is based on data sets of remote sensing, groundwater wells, chemical analyses, pumping tests, stable isotope, and field measurements. The drainage is trillic to dendritic, structurally controlled by NW, NE, and E-W fault systems, and has reduced flooding ability and a good chance for groundwater recharge. There are two main aquifers, Samalut karst and Nubian clastic. Samault is confined to semi-confined, and has huge thickness reaching 395 m and groundwater flow from SSE to NNW. The structural elements and multiple sources of recharge much effect on the distribution of the salinity of groundwater which is less than 1000 in the south and increases northward to 2727 ppm owing to the decline the rate of recharge from the River Nile, and dominant upward leakage from deep Nubian. The maximum drawdown exceeded 6 meters, transmissivity ranges from 6,200 to 45,900 m2/day, the storativity values vary from 8.2x10-6 to 8.6x10-4, and the overall static water level will decline ~15 meters over the first 10 years and then an additional 3 meters through a total of 50 years of continuous pumping. Samalut is less depleted in the south owing to the imparting of the River Nile changed to moderately deplete in the center and depleted in the north part that means that upward leakage from paleo-water of deep Nubian aquifer. A Nubian confined aquifer is tapped by one flowing well with salinity 1614 ppm, and the transmissivity is 720 m2/day. We can conclude that the productivity and hydrogeochemical properties of the aquifer of drainage pattern in the sandy area are highly potential and low salinity. This concept can be replicable in similar terrain elsewhere.
Exploration of groundwater with good quality and quantity, the governorate must identify drainage patterns in this area for selection the site of drainage lines to drilling highly potential wells.

The American Journal of Interdisciplinary Innovations Research
(ISSN – 2642-7478)
VOLUME 04 ISSUE 05 Pages: 23-41
SJIF IMPACT FACTOR (2020: 5. 498) (2021: 5. 676) (2022: 6. 233)
OCLC – 1091588944 METADATA IF – 7.895
Publisher: The USA Journals

KEYWORDS

Drainage pattern phenomena, sandy area, groundwater, Samalut, Nubian aquifer.

INTRODUCTION

Water resources in arid and semi-arid areas of the world play an important role in the development, especially with the growing of population and the consequent agricultural and city expansion stressed. With the scarcity of fresh surface water, groundwater is exploited to meet the demand exerted by various sectors. Prospecting of groundwater with good quality is very important of rapid development, reduction food shortage, new jobs, and communities decrease migration and economy point of view. Desert sand in arid zones is almost entirely without surface drainage, an indication that there is no surface run-off and suggesting that all precipitation infiltrates due to the high permeability of the surface. The occurrence of drainage patterns in sandy areas is a new phenomenon that may reflect deep drainage and structure. It is associated with spring sapping and land-surface subsidence (Owen and Dahlin, 2010). The location of the drainage system becomes of fundamental interest in the development and understanding of the water resources in the desert sand. Water boreholes drilled into this drainage pattern in Zimbabwe have very high yields with excellent quality (MacDonald 1970). Therefore, this phenomenon is potentially a very significant and improved knowledge, understanding of the groundwater occurrence, and design of groundwater exploration strategies within these sediments. This phenomenon was recorded in the Qattara Delta to the west of the River Nile (Fig. 1) and south Great Sand Sea in Egypt. The figure shows the high development of main channel and their tributaries in the sandy area. The objectives of the present study were to: (1) delineating this phenomenon and mode of formation; (2) geomorphological, geological and structural features; (3) identification of groundwater occurrences and potentialities for future development; and (4) delineation the environmental isotope and hydro-geochemical characteristics of aquifers.

Figure 1. Satellite images of main channel and tributaries in the sandy area.

The American Journal of Interdisciplinary Innovations Research
(ISSN – 2642-7478)
VOLUME 04 ISSUE 05 Pages: 23-41
SJIF IMPACT FACTOR (2020: 5. 498) (2021: 5. 676) (2022: 6. 233)
OCLC – 1091588944 METADATA IF – 7.895
Publisher: The USA Journals

Description of the area

Egypt is the ideal case of the arid zone of the world owing to rare rainfall, fixed share surface water from the River Nile, and the expensive groundwater abstraction. The area to the west of the River Nile and in the southern part of the arid Qattara Delta of Egypt (Fig. 2) was selected for a detailed study of this phenomenon. It's located west of the town of Minia between longitudes 29° 30′ and 30° 38′ E and latitudes 27° 36′ and 28° 33′N covering an area of 7358 km2. The area now is under extensive land reclamation depending on groundwater, where it's the only way of water resources. The area is hot in summer and has warm winters. The average minimum temperatures range from 5°C during January to 18°C during July, while the maximum temperatures vary from 20 in January to 44 °C in June. Rainfall in the region is rare, with an average of 19 mm/year which occurs as sudden events (Egyptian Meteorological Authority 2006) that clear the contribution of rainfall to the groundwater recharge is expected to be small and the remnants of wadis are due to the old rainy seasons in Pleistocene Period. The area contains one main hydrographic basin that started from the River Nile. The surface water system is restricted to the eastern part and is represented by the River Nile and El Ibrahimia Canal which run from the south to the north and gets its water at the upstream side of Assiut Barrages to the south.

In general, structural features have influenced the morphology and topography and the main courses of dry wadis. The study area can be divided into eastern, central, and western sectors based on topography (Fig. 3). The eastern is moderately high with some small isolated hills that reach an elevation of up to + 160 m above sea level (asl) and decrease westward.

The central part consists of low-lying land that has elevations of + 116 to + 124 m asl with some isolated multilevel hills. The western sector has a moderately high and rugged topography that varies from +140 to +150 m asl with some isolated hills. Figure (3b) shows the main channel and surrounding tributaries that reflect high undulating near them and a relatively gentle slope far from.

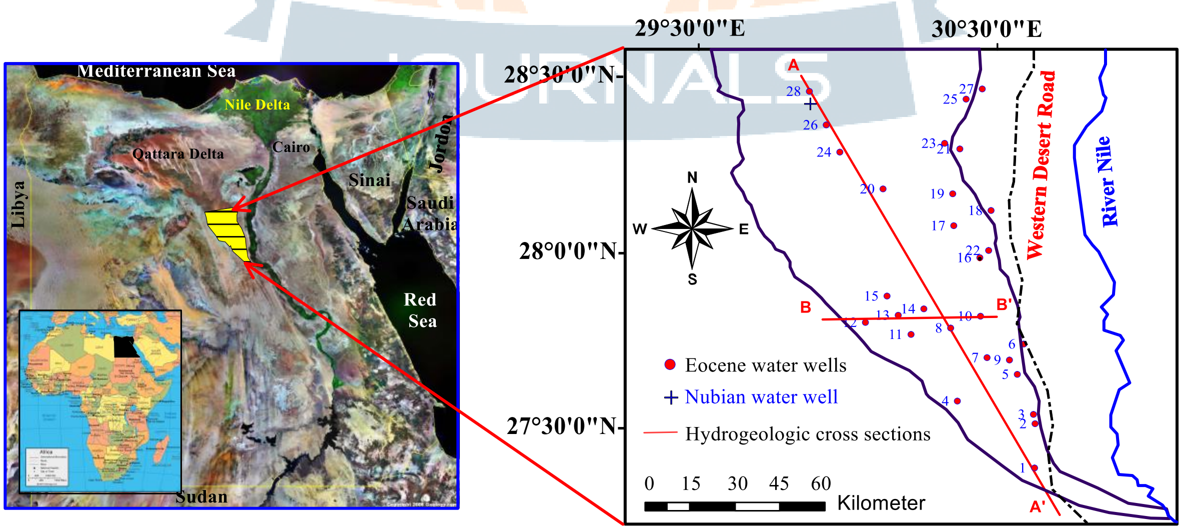

Figure 2. Location map of the study area.

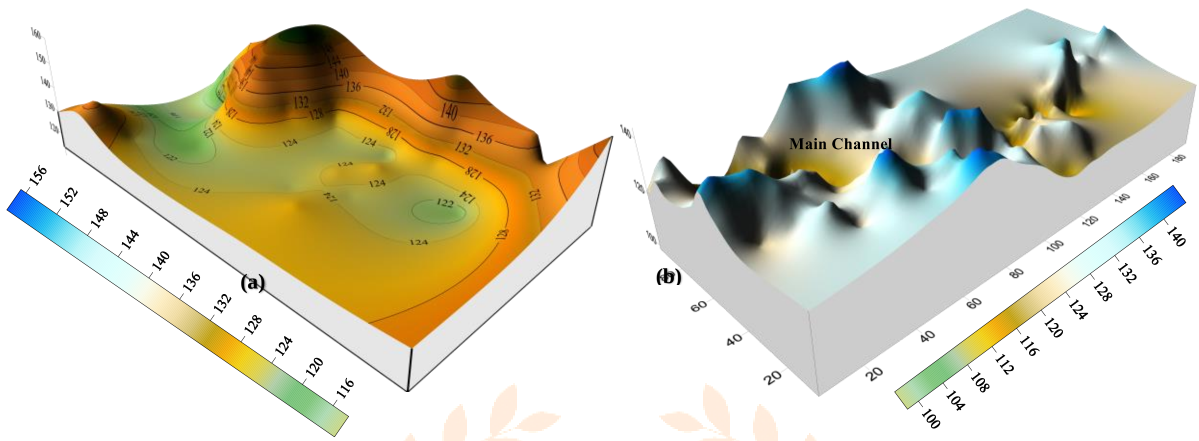

Figure 3. 3D of the ground elevation of the study area (a) and 3D in the selected area around the main channel (b).

MATERIAL AND METHODS

The study is based on:

- Surface data includes remote sensing, topographic (1:100,000 and 1:50,000) and geological maps (1:500,000 and 1:250,000) after CONOCO (1986) and EGSMA (2005).
- Surface and subsurface data were integrated into a geographic information system (GIS) for studying the surface and subsurface lithology and structures.
- Groundwater wells from different sources and the interpreted shallow geophysical data.
- Fieldwork was carried out by collecting the hydrogeological data (e.g. well location, depth to water, and some well logs). 29 groundwater samples are collected from the drilled wells which are distributed along the study area. Samples are collected after a pumping period of at least 1/2 h in a polyethylene bottle and preserved using the standard methods of the American Public Health Association (APHA 2012). Electric conductivity (EC), PH, CO_3^{--} and HCO_3^- are measured in the field.
- The concentrations of major ions in the collected water samples are analyzed in the Laboratory of Desert Research Center, Cairo (DRC), using Ion chromatography (ICS-1100, Dionex, Sunnyvale, CA, USA).
- Nine (9) constant rate pumping tests were conducted in the central-western part. The duration of the pumping tests ranged between 24 to 72 hours. The pumping test data were plotted and analyzed following the Cooper and Jacob (1946) straight-line approximation method for aquifer properties of transmissivity (T) and storativity (S). Three (3) pumping tests by DRC (2016) and 5 by Ismail et al. (2017) were selected to coverage other parts. Based on hydrological data, a drawdown projection was performed to estimate cumulative drawdown within a planning period of up to 60 years.
- The analytical data of the collected water samples has been interpreted by plotting different graphical representations such as Sulin (1948), Piper (1944), and Stuyfzand (1986), to define the classification of groundwater.
- For stable isotope analysis, 13 samples were collected. The surface water was represented by the River Nile (Awad et al., 1997) and Ibrahimia Canal (Korany et al., 2013). The groundwater isotopes

The American Journal of Interdisciplinary Innovations Research (ISSN – 2642-7478)
VOLUME 04 ISSUE 05 Pages: 23-41
SJIF IMPACT FACTOR (2020: 5. 498) (2021: 5. 676) (2022: 6. 233)
OCLC – 1091588944 METADATA IF – 7.895
Publisher: The USA Journals

were represented by 11 samples, (2) from Korany et al. (2013), (2) from El Sabri and Salem (2013), and (7) from Ibrahim and Lyons (2017). The global meteoric water line (MWL) of Craig (1961) and the paleometeoric line of Sonntag et al. (1978) were considered as a reference line. The point representing the isotope composition of Nubian Sandstone of the Western Desert and Gulf of Suez are of Sturchio et al. (2004), while the Eastern Desert and Wadi Qena are of Hamza et al. (1999). The present local precipitation of Egypt given by Nada et al. (1995) contains (δO^{18} = -2.6, δ D= +11.9) for comparison.

- ArcMap and Surfer 13 are used to prepare the maps used in our work. The technique of inverse distance weighted (IDW) is used to generate the spatial interpolation maps for different parameters.

DISCUSSION

Geomorphology

Landforms

The main landform features of the study area are the plateau complex, flood plains, and sand dune belt (Fig. 4a). Plateau complex is structurally controlled by step faults and divided into tableland and isolated hills that cut by some wadis. Tableland surrounded the study area and composed mostly of Eocene limestone with ground elevation reach +211 m. There are a lot of isolated hills in the tableland that is characterized by more hard rocks and high topography. But, the famous hills Gabal Nashfa and Abu Rouh are located in the gravely plain. There are two types of flood plains, silty and gravely. Silty plain occupies the cultivated area around the River Nile and is composed of silt and clay. The surface is nearly flat with elevation from +50 m to +60 m that cut by irrigation and drainage systems parallel to the Nile River. Gravelly plain occupies a huge area of the study area with elevation ranges from +110 m to +145 m, and is composed of sand with gravel. There are some old and young terraces are composed of sand, limestone fragments, and gravels with elevation reach 60 m above the plain. The sand dune belt of Western Desert extended from south Qattara Depression in the north to the study area cut roads and some cultivated lands. They are longitudinal and composed of medium to fine sand. There are some sand sheets in gravely plain.

The American Journal of Interdisciplinary Innovations Research
(ISSN – 2642-7478)
VOLUME 04 ISSUE 05 Pages: 23-41
SJIF IMPACT FACTOR (2020: 5. 498) (2021: 5. 676) (2022: 6. 233)
OCLC – 1091588944 METADATA IF – 7.895
Publisher: The USA Journals

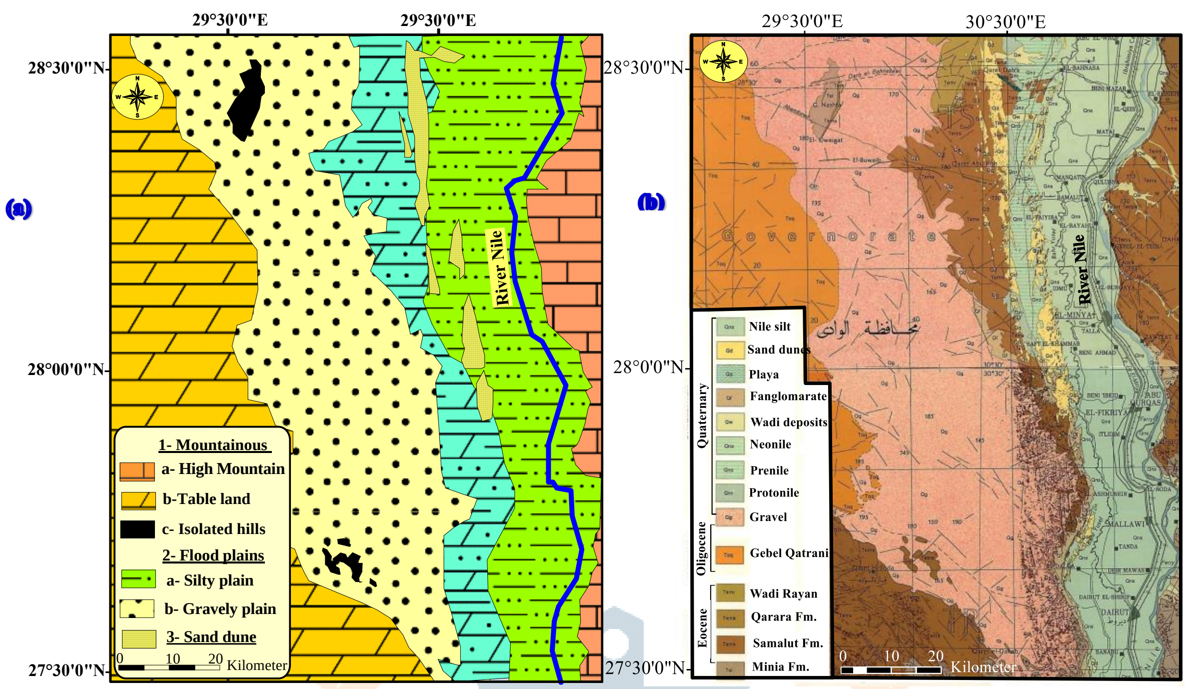

Figure 4. Landforms (a) and geologic map (after CONOCO, 1986) of the study area (b).

Drainage system

The presence of drainage pattern phenomenon in sandy Sahara must shed light on their properties in the study area, where it's a prerequisite to any hydrological study. The morphometric analysis provides a quantitative description of the watershed geometry, structural controls, geological, and geomorphic history of watersheds (Strahler 1964 and Clarke 1966) as well as the amount of water flowing and the periodicity of the flow. Different morphometric parameters of the drainage basin in the study area (Figs. 5a and b) were measured and statistically analyzed (Tables 1 and 2), based on topographic maps (at a scale of 1:50,000), satellite images, and information from literature such as Horton (1945), Schumm (1954), and Strahler (1952) for an evaluation of the surface hydrology. Watershed lies near the Nile drainage system draining and is trillic to dendritic owing their sediment nature (Fig. 5b), and structure (Fig. 6) that characterized by the following:

- Their shape or pattern develops in response to the local topography and subsurface geology.
- It's of six orders and has 5 sub-basins.

The American Journal of Interdisciplinary Innovations Research (ISSN – 2642-7478)
VOLUME 04 ISSUE 05 Pages: 23-41
SJIF IMPACT FACTOR (2020: 5. 498) (2021: 5. 676) (2022: 6. 233)
OCLC – 1091588944 METADATA IF – 7.895
Crossref doi Google Scholar METADATA INDEXING WorldCat MENDELEY
Publisher: The USA Journals

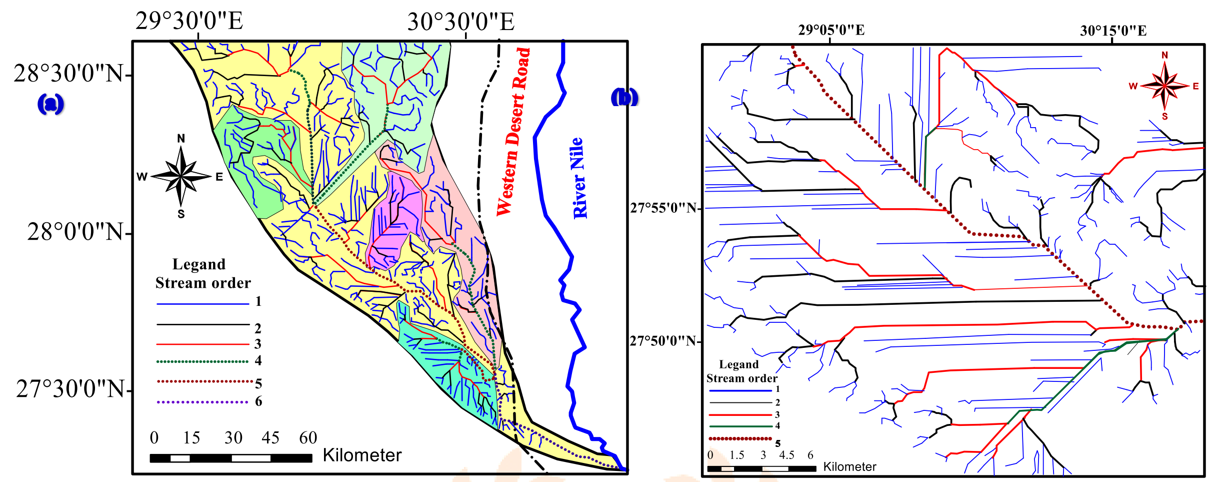

Figure 5. Drainage pattern in the sandy area (a) and drainage in the central-western part.

Table 1. Morphometric parameters of the hydrographic basin.

First-order		Second-order			Third-order			Fourth-order			Fifth order			Sixth order		
N.	**L.**	**N.**	**L**	**Rb**	**N.**	**L.**	**Rb**	**N.**	**L.**	**Rb**	**N.**	**L.**	**Rb**	**N.**	**L.**	**Rb**
233	1143	51	414	4.57	19	362	2.68	5	180	3.80	2.00	127	2.5	1.00	61	2.00

N= Number L= Lenght

Table 2. Statistical analyses of morphometric parameters of the hydrographic basin.

Basin order	Tributary total number (N)	Tributary total length (km)	Area (km^2)	Density (km/km^2) (D)	Frequency (n/km^2) (F)	Bifurcation ratio (Rb)	F/Rb	D/Rb
6th	311	2287	7358	0.31	0.042	3.11	0.0135	0.10

- The majority of the drainage lines are initiated along NW to NE with some E-W especially in the central-western part (Fig. 5b). They have the potential of groundwater discharge rather than the surrounding.
- The morphometric parameters of the basin indicate that they have reduced flooding ability and a good chance for groundwater recharge.
- Dry wadis or paleo drainage systems are filled with friable alluvial deposits and aeolian sands and the percolated water will then flow within these deposits downstream where it recharges aquifers that were developed during previous pluvial periods.
- These phenomena are positively affecting the development activities in the similar desert of the world.

The American Journal of Interdisciplinary Innovations Research
(ISSN – 2642-7478)
VOLUME 04 ISSUE 05 Pages: 23-41
SJIF IMPACT FACTOR (2020: 5. 498) (2021: 5. 676) (2022: 6. 233)
OCLC – 1091588944 METADATA IF – 7.895
Publisher: The USA Journals

Geology

The outcrops of the investigated area extend from the Lower Eocene to the Quaternary (Fig. 4b). Eocene sediments are distinguished into Minia, Samalut and Wadi Rayan Formations from base to top. Lower Eocene Minia was represented in Gebel Nashfa to the north and is formed of snow-white limestone with some claystone and marl interbeds. Middle Eocene Samalut Formation is recorded to the northern and eastern portions overlie the Minia Formation and underlie the Qatrani Formation. Samalut consists of marl in the lower, highly fractured limestone in the middle, and cavernous fractured chalky limestone in the upper. Wadi Rayan Formation is restricted in the northern part and is composed of limestone with shale and marl intercalation. The Oligocene Qatrani Formation unconformably overlies the Middle Eocene rocks in the western part and is composed of sandstone with clay intercalation. The Quaternary sediments are divided into Nile silt, sand dunes, Neonile, Prenile, Protonile, gravel, and fanglomerate. Nile silt is well distributed around the River Nile, while gravels are restricted in the central part.

Structure

According to geologic maps, satellite images, field investigation, and literature; the structure maps of the study area were extracted (Fig. 6a and b). They show the following:

- The study area lies within the stable shelf of Egypt (Said 1962).
- The Nile valley is bounded by wrench faults that more or less parallel either to the Gulf of Suez (NW) or the Gulf of Aqaba (NE) directions (Youssef, 1968).
- The main fault system is NW followed by NE and N-S in decreasing order. E-W fault system was recorded especially in the central-western part (Fig. 6b) that may old shear zone?
- Structural lineaments are concentrated in the proximities of the southwest, southeast, and northeast of the study area. The exposures of Eocene rocks are highly fractured by cracks and joints that are mostly connected.
- Abdel Baky, (2013) referred to the presence of water-bearing buried channels run NW-SE, NE-SW, and E-W trends through structural grabens especially in the western part of the investigated area.

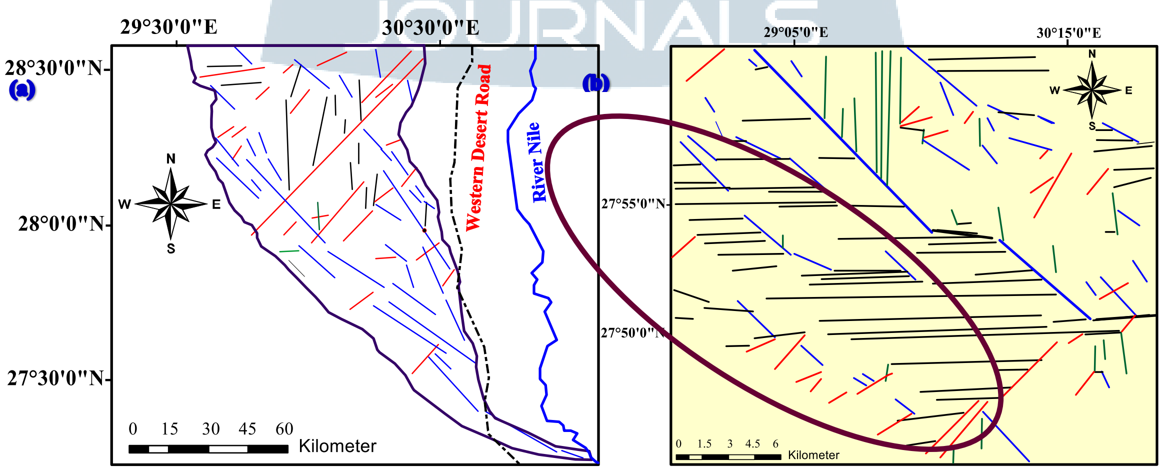

Figure 6. Structural map of the study area (a) and of the central-western part (b).

The American Journal of Interdisciplinary Innovations Research
(ISSN – 2642-7478)
VOLUME 04 ISSUE 05 Pages: 23-41
SJIF IMPACT FACTOR (2020: 5. 498) (2021: 5. 676) (2022: 6. 233)
OCLC – 1091588944 METADATA IF – 7.895
Publisher: The USA Journals

Hydrogeology

Based on geologic, DEM, and structural maps, the available data set of drilled wells (Table 3 and Fig. 2), geophysical studies, hydrogeological cross sections (Figs. 2 and 7), chemical analysis of the collected water samples (Table 3), and literature; the groundwater aquifers of the study area are classified into Eocene Samalut Aquifer (SA) and Nubian Sandstone Aquifer System (NSAS) from top to bottom as follows:

Samalut Aquifer (SA)

SA or fractured limestone aquifer covers a large portion around River Nile and is composed of cavernous dolomitic limestone with shale and evaporite layers with variable thicknesses from few meters to more than 400 m. The aquifer is partially covered by Miocene sandy sediments and/or Quaternary sand sheet, and underlain by Minia marly limestone formation i.e. unconfined to a semi-confine aquifer. The depth to water map of the aquifer (Fig. 8a) shows its shallow in the southern part (42 m) increase northwest and more increase northeastward to ~123 m. There is a good relationship between the depth to water and topography (Fig. 3) except the southern part related to the recharge from the River Nile and Ibrahimia Canal. The saturated thickness is relatively thin (less than 100 m) in the southern and eastern parts and increases NNW to 395 m related to the structural elements (Fig. 8b). The static water level map (Fig. 9a) shows the groundwater flow from SSE to NNW and the main source of recharge from the River Nile and Ibrahimia Canal (narrow distance between contour line) in the southern part and the maximum level +94 m that decrease NNW. There are other partial sources related to NW and E-W fault systems that make connections between the aquifer and the deep-seated Nubian aquifer (upward leakage). Where, they much control the water level line. The multiple sources of recharge and structural elements much effect on the distribution of the salinity of groundwater (Fig. 9b), which is less than 1000 ppm in the southern part and increase northward to 2727 in well no. 28 owing to the leaching process of cracks carbonate rocks and shale, and decline the rate of recharge from the River Nile, and dominant from deep Nubian Aquifer through faults (upward leakage).

Table (3): Hydrogeological properties and isotope of the groundwater aquifers.

No.	X N°	Y E°	Elevation (m)	The total depth of drilling (m)	Total screen (m)	Depth to water (m)	water level (as sea level)	Q (m3/h)	Saturated thickness	Salinity (mg/L)	Deuterium)(δD	Oxygen 18)δO^{18}(	Transmas-ivity m2/day	Storativity
Eocene (Samalut) aquifer														
1	27.432935°	30.647658°	149	70		55.0	94.0			428	-20.00**	-3.00**		
2	27.548419°	30.651447°	129	135		42.0	87.0			353	8.00**	0.40**		
3	27.600000°	30.560000°	140							449				
4	27.599752°	30.412930°	121							534	-3.48***	-2.01***		
5	27.688862°	30.603375°	138	130		94.5	43.5		35	578	-20.17*	-3.54*		
6	27.794417°	30.609056°	151	205	94	113.6	37.4	120	91	684			1440 x	
7	27.749843°	30.542669°	126	180	62	88.5	37.5	195	92	382			1800 x	
8	27.763871°	30.496941°	126	182	65	87.1	38.9	200	95	650	-5.71***	-2.38***	1140 x	
9	27.787361°	30.581861°	135	211	81	102.1	32.9	135	109	784	-21.6*	-3.23*	1720 x	
10	27.826867°	30.441702°	122	382	75	1. 86		200	296	909	-15.1***	-3.23***	6895 x	
11	27.865240°	30.088970°	123	385	305	87.3	35.7		233	789				
12	27.809890°	30.160130°	127	463	312	0 .89			263	852				

The American Journal of Interdisciplinary Innovations Research (ISSN – 2642-7478)
VOLUME 04 ISSUE 05 Pages: 23-41
SJIF IMPACT FACTOR (2020: 5. 498) (2021: 5. 676) (2022: 6. 233)
OCLC – 1091588944 METADATA IF – 7.895
Crossref Google Scholar METADATA INDEXING WorldCat MENDELEY
Publisher: The USA Journals

13	27.828517°	30.241543°	124	390	241	85.7	38.3		241	808				
14	27.966670°	30.196670°	125	379	224	86.2	38.8		220	754				
15	27.908500°	30.139030°	123	453	214	88.4	34.6		205	832				
16	28.032879°	30.457202°	124							962				
17	28.100000°	30.340000°	130							1015	-4.62***	-40.80***		
18	30.459000°	28.168000°	157	250		122.8	34.2		127	1087			600 XX	
19	28.176017°	30.435033°	147							1102	-12.80***	-2.38***		
20	30.112000°	28.231000°	120			87.3	32.7			1985			1650 XX	
21	30.359000°	28.352000°	138	170		104.9	33.1		65	2184				
22	28.360918°	30.377510°	126							2383	22.90***	2.70***		
23	30.322554°	28.372801°	114	250		81	33		139	2007				
24	28.339000°	29.963000°	124	300		91.3	32.7		208.7	2238			1650 XX	
25	28.466487°	30.461404°	116							2427	–8.32***	–63.60***		
26	28.440000°	29.911000°	138	500	250	105.3	32.7		395	2427				
27	30.427837°	28.537825°	116	300	85	82.8	33.2		217	2561			1650 XX	
28	28.537000°	29.848000°	130	212	60	99.6	30.4		80	2727				
Nubian (Pre-Upper Cenomanian) aquifer														
29	28.430000°	29.911000°	137	1490						1614			720 XX	0.0015 XX

* El Sabri and Salem (2013) ** Korany et al. (2013) *** Ibrahim and Lyons (2017) x Ismail et al. (2017) xx Mousa (2018)

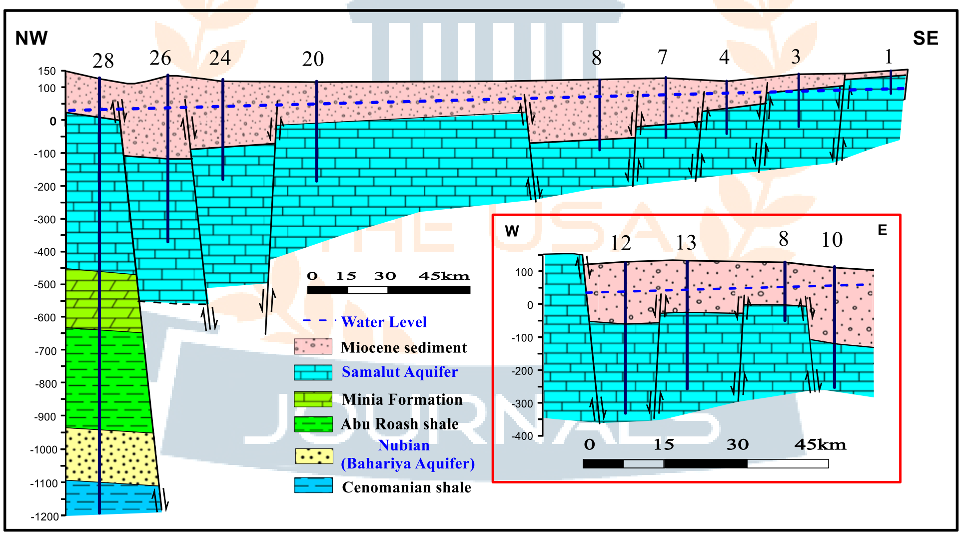

Figure 7. Hydrogeologic cross-sections.

Nubia Sandstone Aquifer (NSAS)

NSAS is the more spread aquifer in Egypt and is divided into different water bearings with huge thicknesses. NSAS is tapped partially by one productive well only with depth 1490 m and ground elevation +137 m to represent the topmost Bahariya water-bearing (Table 2). Bahariya belongs to the Lower Cenomanian age (Said, 1962) and overlies unconformably the Alam El-Bueib Formation and underlies the Abu Roash claystone Formation (Said, 1962) i.e. confined aquifer. It is composed of fine to medium sandstone with thick shale layers especially at the lower part that deposited in fluviatile and deltaic environments (Hilmy et al., 1983). NSAS is flowing with a head reach 0.5 m above ground surface and groundwater salinity of 1614 ppm.

The American Journal of Interdisciplinary Innovations Research
(ISSN – 2642-7478)
VOLUME 04 ISSUE 05 Pages: 23-41
SJIF IMPACT FACTOR (2020: 5. 498) (2021: 5. 676) (2022: 6. 233)
OCLC – 1091588944 METADATA IF – 7.895
Publisher: The USA Journals

The higher salinity may attribute to the impact leaching processes of the shale layer.

Hydrology

Groundwater hydrology

Eight (8) pumping tests were selected, 5 by Ismail et al. (2017) in the eastern part and three (3) by Mousa (2018) in the northern part (Table 1) of SA. They reflect the effect of structural elements and sources of recharge. Where the transmissivity decreases northward from 6895 to 600 m2/day (Fig. 10a). Also, the average hydraulic conductivity decrease from ~22 m/ day (Ismail et al., 2017) to 1.8 m/day (Mousa 2018). Owing to the dense fault systems and drainage pattern as a new phenomenon, nine (9) pumping tests were done by author to delineate their hydrologic properties (Table 4). The pumping rates of it range from 235 to 795 m3/hour and the maximum drawdown in the pumping well exceeded 6 meters in only 2 tests. The drawdown in the associated observation wells, which are approximately 100 meters away from the pumping wells, ranged from 0.1 to 1.5 meters. Based on the analysis of the pumping tests, the calculated transmissivity was generally high, although highly variable between wells, ranging from 6,200 to 45,900 m2/day. The calculated storativity values range from 8.2x10-6 to 8.6x10-4. They mean that SA is highly productive and the recharge of the pumping area may be from secondary porosity (fractures) that supported by the relatively high temperatures reach 40°C. Based upon the assumptions, it is estimated that the overall static water level will decline ~15 meters over the first 10 years and then an additional 3 meters through a total of 50 years of continuous pumping.

The average effective porosity of the topmost of NSAS (Baharyia) is 20.82 % (Mousa, 2018). The transmissivity is 720 m2/day that is highly productive according to Georhge (1979) classification. The storativity of the confined Nubia sandstone aquifer attains 1.5 X10-4.

Table (3): Hydrogeochemical and hypothetical salts of the collected water samples.

No.	Chemical analyses												Hypothetical Salts							
	EC (Mohs)	TDS (ppm)	pH	Cations (mg/l)				Anions (mg/l)				KCL	NaCl	$MgCL_2$	Na_2SO_4	$MgSO_4$	$CaSO_4$	$NaHCO_3$	$Mg(HCO_3)_2$	$Ca(HCO_3)_2$
				K^+	Na^+	Mg^{++}	Ca^{++}	CL^-	SO_4^{--}	HCO_3^-	CO_3^{--}									
Surface water																				
Nile	0.58	298	7.1	11	68	6	40	78	26	89	45	4.92	33.64		9.51			8.43	8.61	34.89
Ibrh	0.64	329	7.4	12	74	7	45	99	28	85	43	4.84	41.25		9.41				9.06	35.43
Eocene (Samalut) aquifer																				
1	0.76	428	7.8	16	81	8	60	117	56	180	-	5.41	39.05		7.35	8.39			0.28	39.53
2	0.65	353	7.7	10	69	9	48	89	28	200	-	4.01	35.19		9.12	0.00		2.60	11.57	37.52
3	0.81	449	7.8	5	91	10	62	144	46	182	-	1.60	49.11		0.30	10.27	1.41		0.00	37.30
4	0.94	534	8.3	9	115	12	63	192	64	158	-	2.46	53.38	0.50		10.03	1.25		0.00	32.38
5	1.04	578	7.4	8	119	18	70	194	60	218	-	1.98	49.94	1.19		12.15			0.95	33.79
6	1.23	684	7.4	5	132	22	91	262	71	202	-	1.05	46.94	12.65		2.15	10.01		0.00	27.21
7	0.69	382	7.4	6	79	8	52	104	38	190	-	2.25	40.61		9.56	2.02			7.59	37.98
8	1.09	650	7.6	7	126	12	82	187	56	260	-	1.67	47.58		3.41	7.50			1.69	38.16
9	1.403	784	7.7	11	155	17	112	248	74	334	-	2.01	47.82		0.25	9.97	0.77			39.06
10	1.63	909	7.9	12	178	21	130	300	89	354	-	1.89	47.56	3.02		7.60	3.91			36.03
11	1.455	789	7.6	6	158	16	124	225	60	400	-	1.06	43.75		3.50	5.34			3.71	42.64
12	1.55	852	7.7	8	168	18	130	240	68	440	-	1.32	42.60		4.55	4.65			4.90	41.96

The American Journal of Interdisciplinary Innovations Research
(ISSN – 2642-7478)
VOLUME 04 ISSUE 05 Pages: 23-41
SJIF IMPACT FACTOR (2020: 5. 498) (2021: 5. 676) (2022: 6. 233)
OCLC – 1091588944 METADATA IF – 7.895
Publisher: The USA Journals

13	1.47	808	7.7	7	160	17	123	225	66	420	-	1.22	42.19		5.18	4.24			5.28	41.88
14	1.38	754	7.8	5	151	16	115	215	62	380	-	0.93	43.67		4.04	5.47			4.09	41.79
15	1.50	832	7.8	9	162	18	125	236	77	410	-	1.54	42.77		4.17	6.52			3.35	41.65
16	17.2	962	7.9	13	187	22	138	317	93	384	-	2.05	49.96	3.43		7.69	4.34			36.68
17	1.82	1015	7.9	16	201	23	142	314	108	422	-	2.26	46.84		1.33	10.43	0.73			38.41
18	1.93	1087	8.1	17	217	24	148	344	132	410	-	2.27	48.31		0.72	10.26	3.38			35.08
19	1.98	1102	8.2	15	219	25	155	336	148	420	-	1.95	46.75		1.55	10.43	3.89			35.43
20	3.52	1985	8.2	19	378	48	285	640	270	690	-	1.39	46.80	3.38		7.86	8.22			32.35
21	3.93	2184	8.1	20	430	49	320	710	195	920	-	1.31	47.65	2.02		8.25	2.10			38.44
22	4.24	2383	7.9	22	469	48	350	780	264	900	-	1.33	48.09	2.61		6.70	6.33			34.94
23	3.60	2007	7.8	23	395	45	290	640	184	860	-	1.64	47.76	0.74		9.55	1.10			39.20
24	4.20	2238	7.9	21	510	56	277	940	239	590	-	1.31	53.86	9.21		1.98	10.13			23.52
25	4.27	2427	8.3	23	530	62	280	965	265	604	-	1.38	53.93	8.50		3.44	9.52			23.24
26	4.32	2427	8.2	23	540	61	273	980	250	600	-	1.38	54.94	8.41		3.33	8.88			23.06
27	4.5	2561	8.1	22	620	62	247	1040	265	610	-	1.25	59.94	4.17		7.17	5.15			22.31
28	4.78	2727	8.2	18	665	65	260	1090	319	620	-	0.97	60.59	2.79		8.42	5.51			21.30
	Nubian (Pre-Upper Cenomanian) aquifer																			
29	2.8	1614	8.2	30	510	15	75	740	84	320	-	2.75	72.12		6.29	0.00		1.00	4.42	13.43

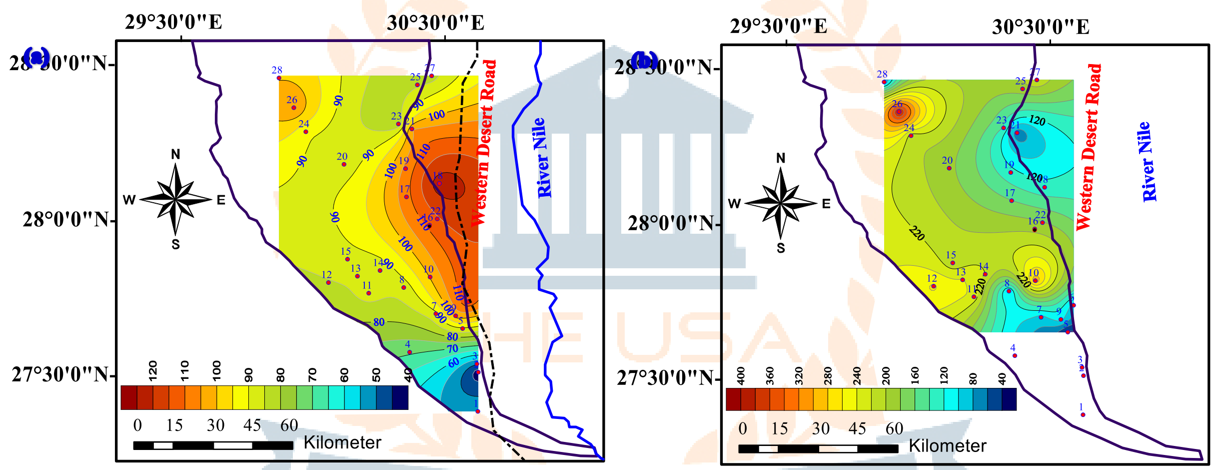

Figure 8. Depth to water map (a) and saturated thickness map (b) of SA.

The American Journal of Interdisciplinary Innovations Research (ISSN – 2642-7478)
VOLUME 04 ISSUE 05 Pages: 23-41
SJIF IMPACT FACTOR (2020: 5. 498) (2021: 5. 676) (2022: 6. 233)
OCLC – 1091588944 METADATA IF – 7.895
Publisher: The USA Journals

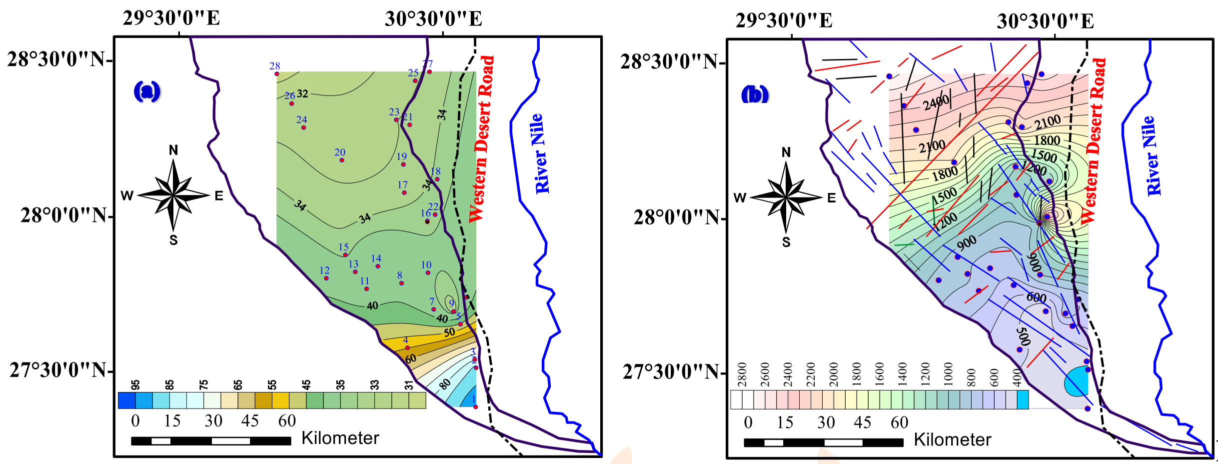

Figure 9. Water level map (a) and salinity map (b) of SA.

Table (4): Hydrological properties of SA in the central-western part of the study area.

	Well No.	X N°	Y E°	Elevation (m)	Total depth (m)	Total screen (m)	Depth to water (m)	Water level	Saturated thickness	Q (m3/h)	Drawdown (m)	Transmasi-vity m2/day	Storativity	Temp
1	1NE	27.893014°	30.263771°	136	371	175	88.2	47.8	200	600	4.67	42,800	8.6E-04	33.0
2	2NW	27.888553°	30.266315°	141	347	92	87.1	53.9	160	600	3.07	45,900	6.6E-04	33.2
3	4NW	27.888564°	30.266332°	141	379	230			200	235	0.88	27,700	1.1E-04	37.0
4	5NW	27.888561°	30.266448°	141	357.5	125	85.7	55.3	125	709	12.74	12,900	9.3E-05	34.0
5	6NW	27.888542°	30.266469°	141	355.5	204	87.3	53.7	220	281	1.86	10,800	2.1E-04	33.0
6	7NE	27.888542°	30.266468°	141	394	241	89.0	52	241	795	5.52	48,100	8.2E-06	35.4
7	9NE	27.888542°	30.266468°	141	453.5	305			246	695	4.02	9,200	1.5E-04	40.0
8	10NE	27.888541°	30.266468°	141	386.5	233			233	772	3.85	39,500		27.0
9	11NE	27.888541°	30.266468°	141	384.5	219	81.95	59.05	219	643	19.82	6,200	4.5E-05	34.0

Isotopes of hydrology

Hydrogen and oxygen isotope ratios are ideal tracers of the origin and evolution of groundwater because they compose the water molecules and being sensitive to physical processes such as atmospheric circulation, groundwater mixing, and evaporation (Clark and Fritz, 1997; Dansgaard, 1964). It is used to estimate the contribution of different groundwater to the water budget or recharge mechanisms. The global meteoric water line (MWL) of Craig (1961) and the paleometeoric line of Sonntag et al. (1978) were considered as a reference line. The point representing the isotope composition of Nubian Sandstone of the Western Desert and Gulf of Suez are of Sturchio et al. (2004), while the Eastern Desert and Wadi Qena are of Hamza et al. (1999). The present local precipitation of Egypt given by Nada et al. (1995) contains (δ O^{18}= -2.6, δ D= +11.9) for comparison.

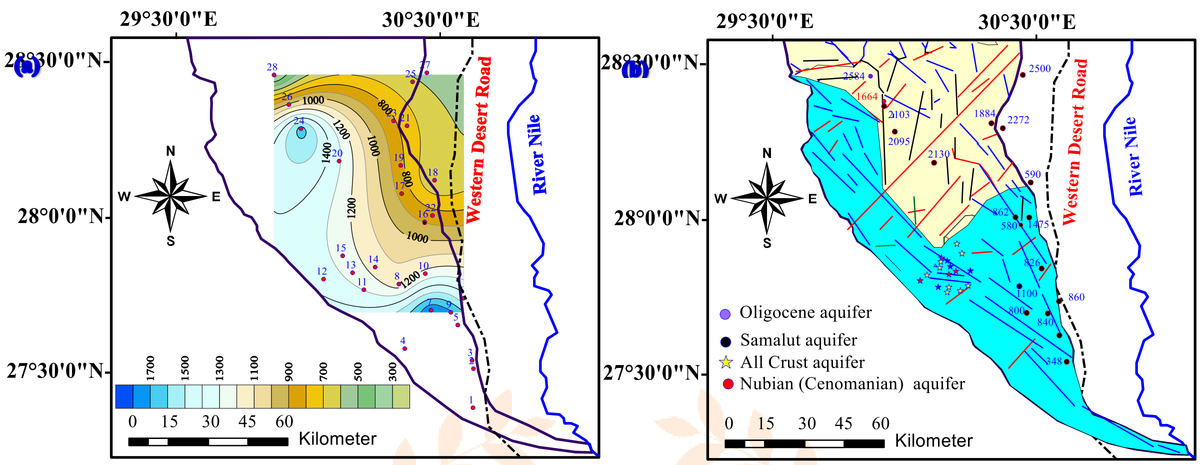

Figure 10. Transmissivity map (a) and promising area of good groundwater quantity and quality map (b) of SA.

Thirteen (13) water samples were collected (Table 3 and Fig. 11). Two samples from the nearby surface water River Nile and Ibrahemia Canal, and eleven (11) from SA. They show the following:

- The isotopic composition of the River Nile are δ D 23.61 and δ ^{18}O 3.01, and Ibrahimia Canal is δ D 17.00 and δ ^{18}O 1.90.
- The isotopic compositions of SA vary from area to another according to the sources of recharge. The relative direct recharge from the River Nile and Ibrahemia Canal decreases the paleo- water into δ D 8.00 and δ ^{18}O 0.40 in well No. 2. With the decrease in their impact, the groundwater becomes less depleted (δ D -2.01 and δ ^{18}O -3.48) as in well No. 4. While NE and NW fault systems create connections between the River Nile and advancement Quaternary Aquifer with SA in the central-eastern part to transform it into recent water (δ D 22.90 and δ ^{18}O 2.70) as in well No. 22. Other parts of the study area are highly depleted and the δ D reach -20.17 in well No. 5 and δ ^{18}O reach -63.60 in well No. 25, which means that the occurrence of upward leakage from paleo-water of deep NSAS.
- The distribution of δ D and δ ^{18}O maps (Fig. 12a and b) show the impact of structural elements especially NW, NE, and E-W, respectively.
- The isotopic compositions of the study area are of wide distribution between the Egyptian Western Desert paleo-waters and the Eastern Desert, possibly reflecting a geographic trend in the isotopic composition of paleo-precipitation stored (Fig. 11). The less depleted water reflects variable degrees of mixing between fossil water and meteoric water of the River Nile and their canals. More isotope analyses are required through specialists in the field of isotope hydrology.

The American Journal of Interdisciplinary Innovations Research
(ISSN – 2642-7478)
VOLUME 04 ISSUE 05 Pages: 23-41
SJIF IMPACT FACTOR (2020: 5. 498) (2021: 5. 676) (2022: 6. 233)
OCLC – 1091588944 METADATA IF – 7.895
Crossref doi Google Scholar METADATA INDEXING WorldCat MENDELEY
Publisher: The USA Journals

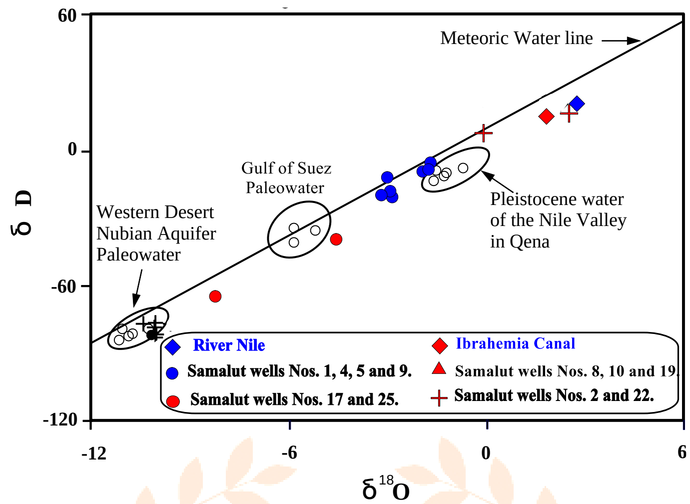

Figure 11. δD versus $\delta^{18}O$ for selected surface and groundwater samples of SA West El Minia plotted with reference points for Nubian sandstone paleowater and rainwater.

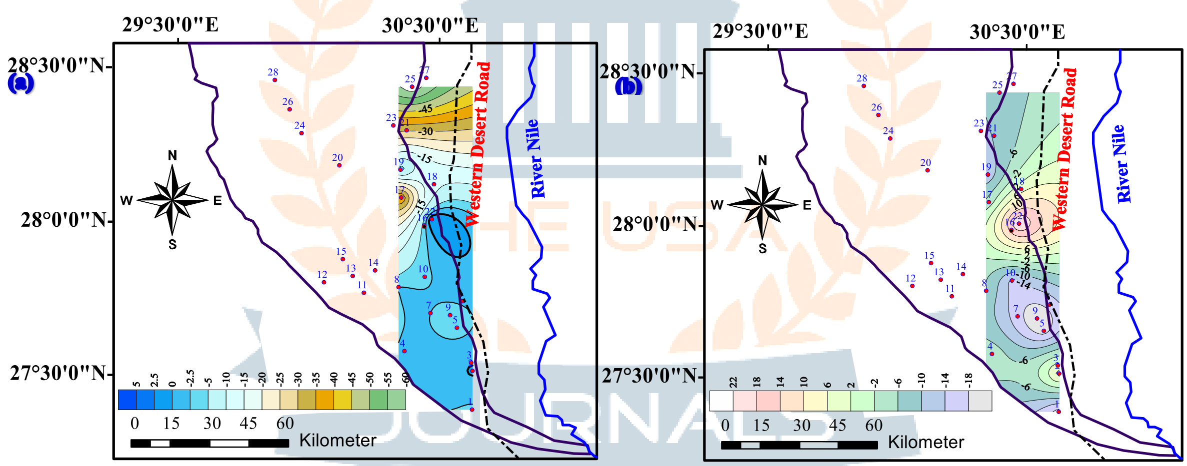

Figure 12. Oxygen 18 (a) and deuterium (b) in SA.

Hydrogeochemistry

The hydrogeochemical characteristics of water samples in the study area reflect the high impact of the lithology of aquifers sediment, the density of fracture systems, and sources of recharge as follows:

- The salinities of the surface water are 298 ppm of the River Nile and 329 of the Ibrahemia Canal. The groundwater salinity of SA increases with their flow from 353 ppm (well No. 2) in the southern part to 2727 (well No. 28) in the northern part may owing to leaching processes. The groundwater salinity of NSAS is 1614 ppm.
- The main hypothetical salt combinations of surface water and groundwater are NaCl and Ca $(HCO_3)_2$. The appearance of magnesium salts ($MgSO_4$, $CaSO_4$, and $MgCl_2$) in the eastern part might be owing to the dissolution of naturally occurring gypsum in the aquifer.

The American Journal of Interdisciplinary Innovations Research
(ISSN – 2642-7478)
VOLUME 04 ISSUE 05 Pages: 23-41
SJIF IMPACT FACTOR (2020: 5. 498) (2021: 5. 676) (2022: 6. 233)
OCLC – 1091588944 METADATA IF – 7.895
Publisher: The USA Journals

- According to Stuyfzand (1986), the main component of water samples is the mix that changed northward to NaCl. But, the eastern part is MgCl.
- According to Piper (1944), water types changed from NaHCO3 to Na2SO3 and NaCl with groundwater flow owing to the impact of the aquifer matrix.
- According to Sulin (1948), the groundwater changed from deep meteoric water in the southern part related to the main sources of recharge is the River Nile and Ibrahemia Canal northward to shallow marine owing to leaching process with groundwater flow.
- According to Ovitchinikov graph (1963), the center of western part water samples is affected by upward leakage from Nubian Aquifer as springs through faults that affected by leaching of carbonate and mixed with meteoric water. This phenomenon is supported by the higher temperature of groundwater (33-40 °C) than others (Table 4).

SUMMARY AND CONCLUSION

The occurrence of drainage pattern phenomenon in the sandy area is rare in the world and has potentially a very significant of groundwater exploration strategies within these sediments. It was recorded and tested in the Qattara Delta to the west of the River Nile for identification of groundwater aquifer characteristics, potentiality, and hydrogeochemical properties. The study is based on data sets of remote sensing, groundwater wells, chemical analyses, pumping tests, stable isotope, fieldwork observation and measurements, and literature.

The drainage pattern phenomenon is trillic to dendritic and is of six orders that are structurally controlled by NW to NE with some E-W systems, especially in the western part. The morphometric parameters indicate that the area has reduced flooding ability and a good chance for groundwater recharge. The groundwater aquifers are SA and NSAS. The saturated thickness of confined to semi-confined SA is less than 100 m in the southern part and increases NNW ward to 395 m. The groundwater flow is from SSE to NNW and the main source of recharge is from the River Nile and Ibrahimia Canal to the south and the maximum level +94 m decrease NNE. There is also recharge from the deep-seated Nubian aquifer (upward leakage) through NW, NE, and E-W fault systems. The multiple sources of recharge and structural elements much effect on the distribution of the salinity of groundwater which is less than 1000 ppm in the south and increases northward to 2727 in owing to the leaching process and decline in the rate of recharge from the River Nile. NSAS confined aquifer is tapped by one productive well to represent the topmost Bahariya water-bearing. It is flowing with a head reach 0.5 m above surface and groundwater salinity of 1614 ppm.

The hydrologic properties of SA reflect the effect of structural elements and sources of recharge. Where, the transmissivity and hydraulic conductivity decrease northward. Detail pumping tests in dense E-W and NW fault systems in the central-western part with rate from 235 to 795 m3/hour reveal that (1) the maximum drawdown exceeded 6 meters, (2) the transmissivity ranging from 6,200 to 45,900 m2/day, (3) the storativity values range from 8.2x10-6 to 8.6x10-4, (4) the recharge mostly from the deep-seated aquifer through fault systems that supported by the relatively high temperatures than surrounding, and (5) the overall static water level will decline ~15 meters over the first 10 years and then an additional 3 meters through a total of 50 years of continuous pumping.

The American Journal of Interdisciplinary Innovations Research
(ISSN – 2642-7478)
VOLUME 04 ISSUE 05 Pages: 23-41
SJIF IMPACT FACTOR (2020: 5. 498) (2021: 5. 676) (2022: 6. 233)
OCLC – 1091588944 METADATA IF – 7.895
Crossref Google Scholar METADATA INDEXING WorldCat MENDELEY Publisher: The USA Journals

The isotopic compositions of the study area are of wide distribution between the Egyptian Western Desert paleo-waters and the Eastern Desert and are highly affected by the structural elements and sources of recharge. Where SA is less depleted in the south owing to the impact of the River Nile, changed to moderately depleted in the center and depleted in the north part related to the upward leakage from paleo-water of deep NSAS.

The hydrogeochemical characteristics of the aquifers also reflect the high impact of the lithology of aquifers sediment, the density of fracture systems, and sources of recharge as follows: (1) the groundwater salinity of SA increase with their flow from 353 ppm in the south to 2727 in the north, but the salinity of NSAS is 1614 ppm, (2) the hypothetical salt is NaCl and Ca $(HCO_3)_2$, (3) water types changed from $NaHCO_3$ to Na_2SO_3 and NaCl with groundwater flow, (4) the central of western part water samples are affected by upward leakage from Nubian Aquifer as springs through faults.

The main conclusions are:

- The more productive area with low salinity was recorded in the southern and western part of the study area (Fig. 10 b) related to high recharge from the River Nile and upward leakage from deep Nubian aquifer through NW and E-W fault system.
- This concept can be replicable in similar terrain elsewhere.

REFERENCES

1. Abdel Baky, N. F. (2013): Exploring groundwater possibility in the area west of El Fayoum-Asuit road using remote sensing, geophysical and GIS techniques. Ph.D. Thesis. Zak. Univ.
2. American Public Health Association (APHA) (2012): Standard methods for the examination of water and wastewater (22nd ed., 1496). Washington, DC: APHA, American Water Works Association.
3. Awad, M., El Arabi, E. N., Hamza, M. S. (1997): Use of solute chemistry and isotope to identify sources of groundwater recharge in the Nile aquifer system, Upper Egypt. Ground Water, 35(2):223–228.
4. Clark, I. D. and Fritz, P. (1997): Environmental Isotopes in Hydrogeology. Lewis Publishers, NY, p. 328.
5. Clarke, J. (1966): Morphometry from maps, essays in geomorphology. Elsevier Publication Press, New York
6. Craig, H. (1961): Isotopic Variations in Meteoric Waters. Science, 133, 1702-1703.
7. Conoco (1987).: Geologic map (scale 1:500.000), Beni Suef chart.
8. Cooper, H. H. and Jacob, C. E. (1946): A generalized graphical method for evaluating formation constants and summarizing well history: Am. Geophys. Union. Trans., 27: 526-534.
9. Dansgaard, W. (1964): Stable isotope in precipitation. Tellus, 16, 436 – 468.
10. DRC (2016): Water and land resources maps in west Minia, Egypt. Internal progress report, 260p.
11. Egyptian Geological Survey and Mineral Authority (EGSMA), (2005): Geologic Maps of Minia. Scale 1:250,000 Sheet 2. Geol. Surv. Egypt, Cairo, Egypt.
12. El Sabri, M. A. and Salem, W. M. (2013): Sustainable development of groundwater resources in the area west of the old cultivated lands between Dayrout and Mallaw, Egypt. Assiut Univ. J. of Geology, 42 (1), 17-40.
13. Gedamy, Y., Abdulhady, Y. and Zaghlool, E. (2019): Hydrochemistry of the Eocene aquifer at the desert fringes of west El-Minya Governorate,

The American Journal of Interdisciplinary Innovations Research
(ISSN – 2642-7478)
VOLUME 04 ISSUE 05 Pages: 23-41
SJIF IMPACT FACTOR (2020: 5. 498) (2021: 5. 676) (2022: 6. 233)
OCLC – 1091588944 METADATA IF – 7.895
Publisher: The USA Journals

Egypt. Current Science International, 08 (4), 734-763

14. Gheorghe, A. (1979): Processing and synthesis of hydrogeological data, Abacus Press, p. 390.
15. Hamza, M. S., Aly, A. I. M., Awad, M. A., Nada, A. A., Abdel Samie, S. G., Sadek, M. A., Salem, W. M., Attia, F. A., Hassan, T. M., El Arabi, N. E., Froehlich, K. and Geyh, M. A. (1999): Estimation of recharge from Nile Aquifer to the desert fringes at Qena area, Egypt. Isotope Techniques in Water Resources Development and Management Symposium 1999, International Atomic Energy Agency, Vienna, IAEA-CSP-2/C, session 4: 34 - 46.
16. Horton, R. E. (1945): Erosional development of streams and their drainage basins: Hydrophysical approach to quantitative morphology. Geol. Soc. Am. Bull., 56, 275–370
17. Korany, E. A., Tempel, R. N., Gomaa, M. A., and Mohamed, R. G. (2013): Detecting the roles of physicochemical processes on groundwater evolution, Assuit area, Egypt – Application of hydrogeochemical and isotope approaches. Egyptian Journal of Geology, 57, 63-83.
18. Ibrahim, R. and Lyons, W. B. (2017): Assessment of the hydrogeochemical processes affecting groundwater quality in the Eocene limestone aquifer at the desert fringes of El Minia governorate, Egypt. Aquat Geochem, 23, 33–52.
19. Hilmy, M. E, Abu Zeid, M. M and Saad, N. (1983): Contribution to the sedimentology of the Bahariya Formation of Gebel El-Dist, Bahariya Oasis, Western Desert, Egypt. Qatar Univ., Sci., 3, 217-231.
20. Ismail, E., El-Sayed, E., Sakr, S. and Youssef, E. (2017): Characteristic of groundwater potentialities in West Nile Valley South, Minia Governorate, Egypt Article in Arabian Journal of Geosciences, 10, 52.
21. MacDonald, D. (1970): The development of railway borehole water supplies on the Bulawayo Dett section since 1950. Rhod. Sci. News, 4(12), 398–405.
22. Mousa, A. A. (2018): Geology of Groundwater Resources in The Western Desert fringes of El Minia Governorate, Egypt. M Sc. Thesis, Al-Azhar University.
23. Nada, A. A., Hussein, M. F., Awad, M. A. and Salem, W. M. (1995): Environmental isotopes and geochemistry of groundwater in the Red Sea governorate of Egypt. Isotope & Radiation Research Bulletin issued by the Middle Eastern Regional Radioisotope Center for the Arab Countries, Cairo, Egypt.
24. Owen, R. and Dahlin, T. (2010): Inherited drainage - paleochannels and preferential groundwater flow. Hydrogeology Journal, 18, 893–903.
25. Ovitchinikov, A. M. (1963): Mineral water, Gosgeolitchizdat, R. 375, Moscow, (in Russian).
26. Piper, A. M. (1944): A graphic procedure in the geochemical interpretation of water analyses. Trans. Am. Geophy. Union, 25, Washington, D.C., 6, 914-923.
27. Said, R. (1962): The Geology of Egypt. El Sevier, 377 p.
28. Schumm, S. (1954): The relation of drainage basin relief to sediment loss. In: International Union Geodesy Geophysics, 10th General Assembly (Rome). Int. Assoc. Sci., Hydrol. Publ. 36, no 1, 216–219
29. Sonntag, C., Klitzsch, E., Lohnert, E. P., El Shazley, E. M., Munnich, K. O., Junghans, C. H., Thorweihe, U., Weistrofer, K., and Swailem, F. M. (1978): Paleoclimatic information from deuterium and oxygen-18 in carbon-14-dated north Saharian groundwaters, Isotope Hydrology 1978: Proceedings of an International Symposium on Isotope Hydrology: Vienna, International Atomic Energy Agency, 569-580.

30. Sulin, N. A. (1948): Oil water in the systems of natural groundwater, Gostoplezdat, Moscow, USSSR (In Russian)
31. Strahler, A. N. (1952): Hypsometric (area attitude) analysis of erosional topography. Geol. Soc. Am. Bull, 63, 1117–1142.
32. Strahler, A. N. (1964): Quantitative geomorphology of drainage basins and channel networks. In: Ven CT (ed.) Handbook of applied hydrology. McGraw Hill, New York, 4–76
33. Sturchio, N. C., Du, X., Purtschert, R., Lehmann, B. E., Sultan, M., Patterson, L. J., Lu, Z. T., Muller, P., Bigler, T., Bailey, K., O'Connor, T. P., Young, L., Lorenzo, R., Becker, R., El Alfy, Z., El Kaliouby, B., Dawood, Y., and Abdallah, A. M. A. (2004): One million-year-old groundwater in the Sahara revealed by krypton-81 and chlorine-36: Geophysical Research Letters, 31.
34. Stuyfzand, P. J. (1986): A New Hydrochemical Classification of Water Types. Principles and Application to the Coastal Dunes Aquifer System of the Netherlands, Proc. 9th. Salt Water Intrusion Meeting (SWIM), Delft, Netherlands, 641-655.
35. Youssef, M. I. (1968). Structural pattern of Egypt and its interpretation. AAPG. Bull., 52, 601-614.