APPLICATION OF REMOTE SENSING AND GIS IN HYDROGEOLOGICAL AND HYDROLOGICAL STUDIES,QENA-SAFAGA-BIR QUEH, PART OF GOLDEN TRIANGLEPROJECT, CENTRAL EASTERN DESERT

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ABSTRACT

The central Eastern Desert (Golden project) planned to attract the dense population in Delta and construct new communities, besides mining and agriculture. Recently, remotely sensing (RS) and Geographic Information System (GIS) have been established the best hydrogeological sites. Satellite imageries (Landsat 8 ETM+), Digital Elevation Model (DEM), and geological map are used to prepare various thematic layers such as rainfall, geology, slope, lineament and drainage. These layers were then transformed into a raster single map (potential map) using ArcGIS 10.2.2, Envi 5.2, ERDAS 2014, and PCI Geomatica 2013 software. Red Sea drainage basins extracted are El Barud, Safaga, Gasus, Queh, and Abu Shiqayli, while the Nile basin is wadi Qena, which include five sub basins. Evaluation of surface rock-permeability in relation to morphometry (stream order, stream length, drainage density, channel maintenance, overland flow, basin shape, overland flow, frequency, and texture ratio) is established. This method involves the designation of various recharge related measures, based upon the relative ranking of surface-material permeability after comparison with the hydrogeological conditions. The scheme can also help to pin-point areas of study on a local scale, and thus facilitate developmental programs to augment groundwater recharge. The spectral behaviors were determined for the expose geological formation and established the geological map. An integrated approach has been adopted in this dissertation to delineate groundwater potential zones (GWPZ). The potential zones were categories as very high, high, moderate, low, very low. The GWPZ map reflects about 14 % (587 km^2) of the total area (4258 km^2) has highest recharge potential. It mainly confined to the highest rainfall that percolates into subsurface and was due northwest. About 6 % (268 km^2) of the area was the minimum recharge for groundwater, besides the lowest precipitation. It is concentrated in the southeastern part. The match among these GWPZ and hydrogeological conditions was established.

Keywords: Remote sensing, GIS, morphometric parameters, groundwater potential zones, Eastern Desert

1 INTRODUCTION

The Golden Triangle is the second largest development project run by the Egyptian government after the Suez Canal. The project aims to establish a new industrial city through assembling a global mining, commercial, agricultural, touristic, industrial, economic, and basic infrastructure zone.65% of the project will be composed of modern industrial hubs, whilst 35% will be residential, commercial, and touristic. The Golden Triangle project is located between the governorates of Qena and Red Sea, called the Golden Triangle, its head lies in Qena whereas the base is in Safaga and Quseir**(Fig. 1a)**.Groundwater is not enough to irrigate the land using the old techniques, meaning that modern irrigation systems need to be used.Land will not be used for water-consuming crops but mainly crops that can be processed and exported, such as medicinal herbs, which use very little water. The Millennium Dam (Ethiopia), Red-Dead Seas interconnection, anthropogenic sources, decline in groundwater levels, and lack in groundwater are impact on income per capita. So there is a need forefficient exploration and management of groundwaterresources.As a common method in groundwater exploitation, geologic maps are often used and combined with the available well logs and reports from existing wells; therefore, a field survey was carried out to determine the suitable site for boreholes. The traditional methods of groundwater exploration are not only tedious but also consume lot of time and money and require skilled manpower (Sander et al. 1996). Remote sensing and GIS tools can be used to detect areas with high potential for groundwater exploration (Wahyuni et al. 2008; Deepika et al. 2013). More developed procedures followed in-depth investigation such as test borings, fracture-trace analyses and geophysical surveys (Fetter 1994).Evaluation of the drainage characteristics of a basinis a reliable index of rock-permeability and also gives an indication of yield of the watershed basin (Wisler and Brater 1959). Spectral reflectance characteristics are used to differentiate the geological map.

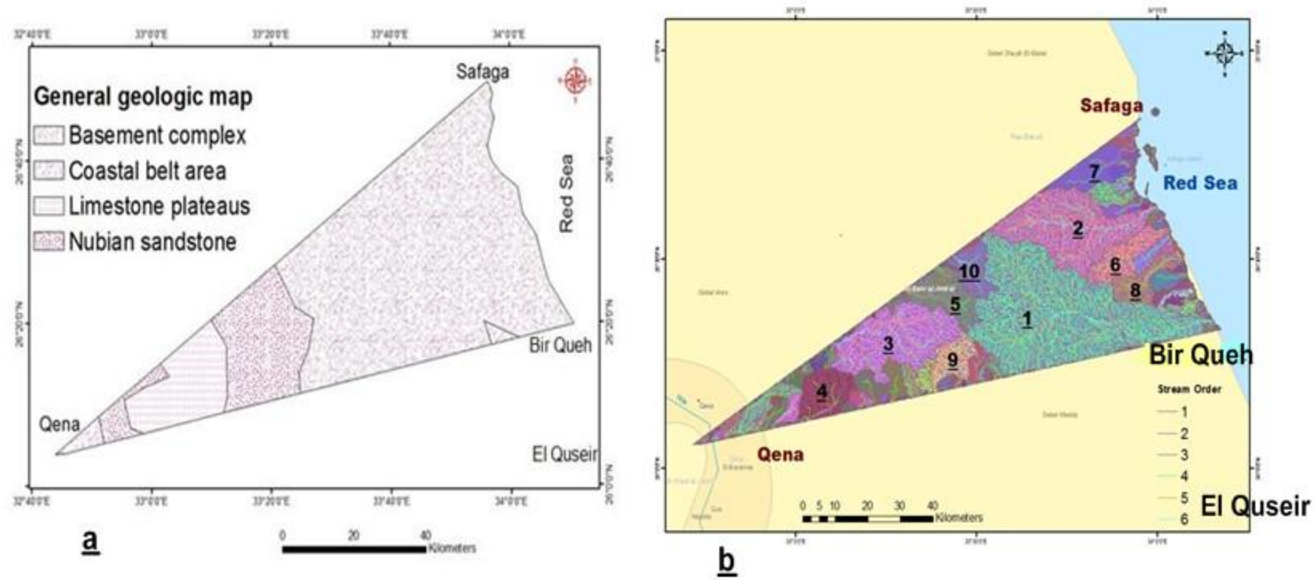

Figure 1. Hydrographic map (a),drainage network of Wadi El Barud (b), and lineaments detection (c). 1:w. Queh; 2: w. Safaga; 3, 4, 5,9, and 10: w. Qena; 6: w. Gasus; 7: w. Barud; 8: w. Abu Shaqayli

2 GEOLOGY AND HYDROGEOLOGY

Geologically, the study area is composed of both sedimentary and crystalline rocks **(Fig. 1b)**. The oldest exposed Pre-Cambrian overlain by the Nubian sequence and post-Nubian deposits. The crystalline rocks of the Pre-Cambrian basement complex form massive formations extending parallel to the Red Sea graben and consisting mainly of metamorphic rocks, as well as acidic and basic igneous rocks (Said 1962 & 1990 and El- Ramly 1972). TheNubian sandstone (Lower Cretaceous) consists of alternating beds of sandstones, shaleand clay. The Nubian sandstone overlies the basementcomplex and is itself overlain by the imperviousshaley strata of the Upper Cretaceous. The Post-Nubian deposits are represented by three main groups: the carbonate, the Neogeone and the Alluvial deposits.

Groundwater resources in the study area are very limited compared to Nile Valley, Nile Delta, Western Desert, and Sinai. This is due to the crystalline rocks (mostly igneous and metamorphic), covered the study area in most parts; in addition to the limited sources for recharge. The aquifers in the study area are represented by four main geologic units: the fractured crystalline Pre-Cambrian aquifer, the Nubian sandstone aquifer, the fractured limestone and sandstone aquifers, and the Quaternary aquifer (Abdel Moneim 2004):

3 METHODS AND TOOLS

Using of the digital elevation model (DEM)relying on the fact that the physical characteristics of a surface determine characteristics of the water flows across it. Factors controlling groundwater storage are rainfall; rock type ; rock fractures; slope and drainage characteristics. The integration of these factors in a systematic method will result in a map showing potential zones for groundwaterstorage, with a number of categories.The available ETM+ imagery was acquired by Landsat 8, provided in USGSdata format. The wavelengths, quick atmospheric, contrast stretching, radiometric are corrected.

Envi 5.1, Erdas 2014, Global Mapper 16, and ARCMAP 10. 2 are used. The principal component image (PCI) carry most information and suitable for lineaments extraction purpose (PCI Geomatica).

4 RESULTS AND DISCUSSION

4.1 Drainage Basins.

Red Sea Basin Group: wadi El Barud is dendritic and sub-dendritic **(Fig. 1b)**, where its tributaries are irregularly branching in many directions and at almost any angle considerably less than right angle (Thornbury, 1984). It is a result of the uniform resistance of the granite rocks (Badawy 2008). Wadi El Barud flows from west (mountainous area) to east (Red Sea) with general lineaments of WNW-ESE and NE-SW**.**Wadi Safaga is one of the largest drainage basins of the study area **(Fig. 1b)**that covers about 527 km².Wadi Safaga is structurally controlled and cuts through a great variety of basement and sedimentary rocks(bifurcation ratio 4.1). Gasus basin **(Fig. 1b)** has area 142 km^2 and of 5th order.Wadi Queh **(Fig. 1b)**is the largest drainage basin in the study area (1263 km² approx.). The trunk stream attains about 71.5 km in length and it is of the 6th order. The wadi drains and cuts through a very complex terrain that distinguishes the central Eastern Desert and involves several peaks. The trunk stream flows generally west-east and it is significantly structurally controlled where it adheres to Queh shear zone (Badawy 2008). As a result, tributaries of wadi Queh have distinctive directions that are NW-SE, NE-SW, and W-E. Wadi Abu Shiqayli **(Fig. 1b)**is about 110 km² and thetrunk channel is about 23.4 km in length that is of the 6thorder. The wadi drains primarilythe northern slopes of Jabal Abu Zarabit and the coastal tablelands.

Nile Basin Group: wadi Qena is one of the longest wadis in the Eastern Desert of Egypt**(Fig. 1b)**. It is a promising dry valley in the central Eastern Desert of Egypt. It collects sporadic rainfalls from many effluents, which join its main stream along a 270-km course from the east to the southeast. The wadi extends from north to south with an east–west average width of 40 km. It is located northwest of the Qena Governorate. Gheith and Sultan (2002) estimated the probable groundwater recharge rate for alluvial aquifers of the Eastern Desert (i.e., Wadi Qena) from the sporadic precipitation over the Red Sea hills (during the 1994 rainstorm events) as 49×106 m^3 which indicate the promising nature of the Quaternary alluvial aquifer in the area. The hydraulic interconnection between the Quaternary aquifer and the underlying Nubian aquifer system in Wadi Qena is favored through the structural region (Elewa and Abu El-Ella 2000, 2011). Elewa and Abu El-Ella (2011) concluded that the hydrogeological system in the wadi is made of four layers; the upper layers is unconfined Quaternary wadi deposits, the second and the third are conceded as aquiclude, and the bottom layer is the Nubian aquifers system.

4.2 Morphometric parameters

Total length of the ten basinsis 325.1 km, while basin perimeter vary from 36.5 km for wadi Qena (sub basin 10) to 85.7 km for wadi Queh. Gasus basin and wadi Qena (sub basin 5) are of 5th orders , while the rest basins are 6th orders. The total stream length *of* ten basins (ΣL) is about 7626 km. The largest drainage area (Da) was wadi Queh (1263 km^2), while the lowest area was wadi Qena (sub basin 10) (103 km^2). Elliptical basins is El Barud (elongation ratio of 0.43), while the rest are elongated to less (0.51-0.75).The infiltration rate was increased in El Barud basin rather than the rest basins. Average drainage density is 2.4km/km^2. The absolute values are greatly convergent ranging between 2.3 to 2.55 km/km^2. Therefore, the basins are poorly drained (<8 km/km^2). Stream frequencies of the drainage basins are greatly convergent (3.41-3.8 streams / km^2), excluding wadi Gasus of 4.7 streams per km^2. The last reflect the relatively intensive surface denudation. The constant of channel maintenance is about 0.41 km^2 that is required to support each linear kilometer of stream channels, it ranged from 0.4 to 0.43 (convergent values).Bifurcation ratio of the (2/3) order ranges from 3.9 to 4.6 with mean 4.3, which reflectlow to moderate infiltration rate.Length of overland flow ranges from 0.2 to 0.22 km (convergent values). Texture ratio ranges between 5.7 km for wadi Qena (sub basin 10) and 17.9 km for wadi Queh and the mean texture ratio of the whole basins is about 9.1 km. It is significantly correlated to drainage area *(A)*producing positive linear relationship (r = 0.94) and less correlated to drainage density (r = 0.03).

4.3 Multispectral Supervised Classification.

Multispectral supervised classification is the process of sorting pixels into a finite number of individual classes or categories of data based on their data file value (Lecia Geosystems, 2003). About 58 supervised training or areas of interests (AOIs) are selected and controlled to represent 18 categories (rock types) in order to assemble a set of statistics that describe the spectral response pattern of each rock unit. The classified geological map **(Fig. 2a-b)** represents a well base map within the present study that is helpful for further analysis. The map contains 18 classes, which represent the main rock units in the study area.

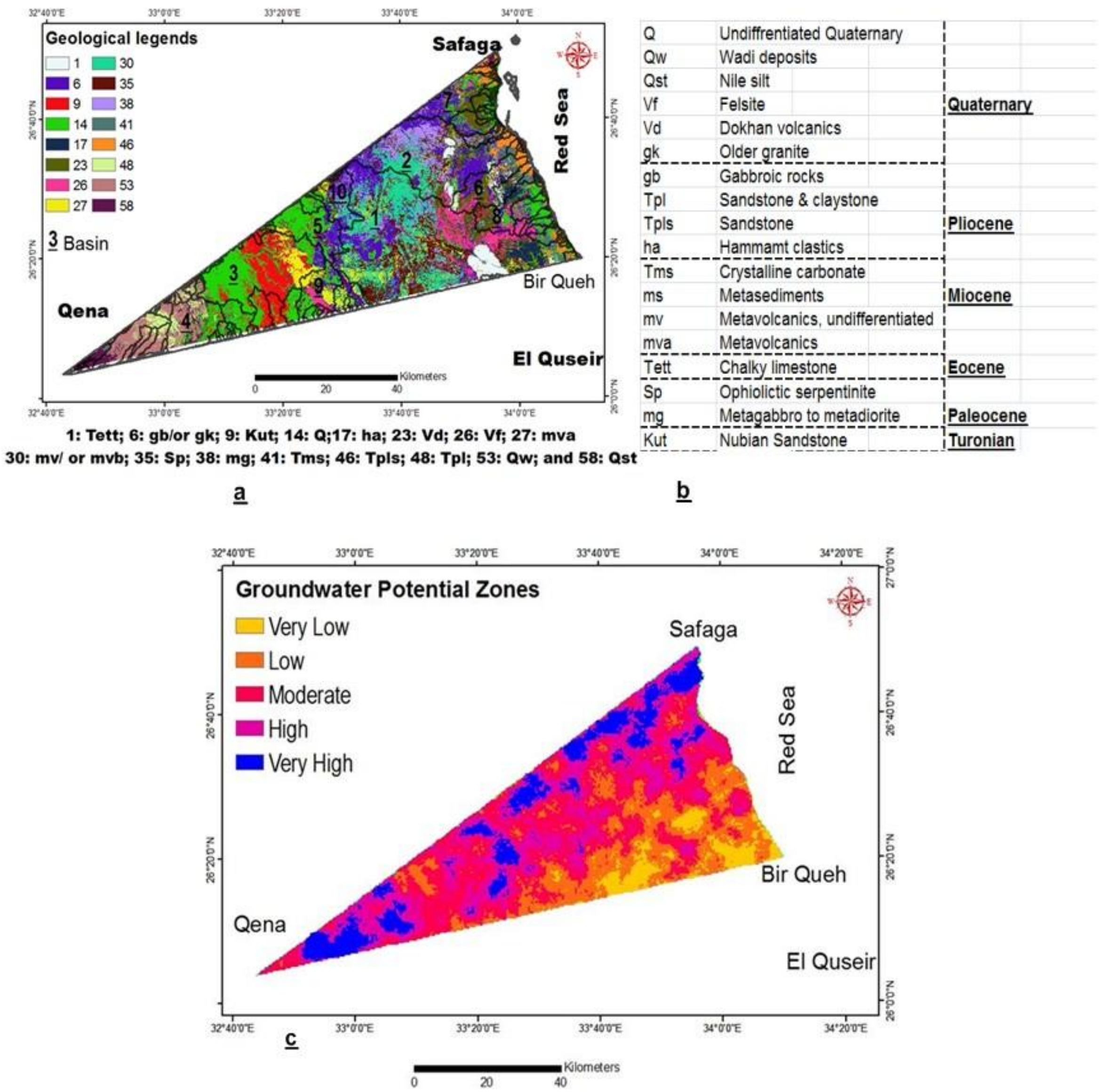

Figure 2. Drainage density/reclassify (a), GIS components (b), and GWP zones (c)

4.4 Groundwater potential and validation.

Recharge potential zone map was prepared and divided into five descriptive levels **(Fig. 2c)**. The descriptive levels are very high, high, moderate, low, and very low. The maximum recharge for groundwater was due northwestern part, while the poor recharge was in the southeastern **(Fig. 2c)**.Validation approach was achieved by comparing the TDS of groundwater in dug wells with respect to the zones determined in this study. The basis of this validation implies the existence of successful wells (i.e., with high water quality) in zones described as high or very high potentiality in the resulting map. The TDS of groundwater (Cretaceous and three wells) are declined in the highest potential zones, indicate much recharge **(Fig.3a)**. The TDS of basement is the highest (13209 ppm) coincide with the moderate potential zones **(Fig.3b)**, while the lowest TDS (1232 ppm) was included in the high potential zones **(Fig.3b)**. The TDS of 5163 and 10130 ppm were located in high to very high potential **(Fig. 3b)**, it is mismatch with reultant GWP zones.The TDS of the basement aquifer is 801 ppm (Hussien et al 2016), which is match with low potential **(Fig. 3b)**. It fails to satisfies with the resultant potential map.

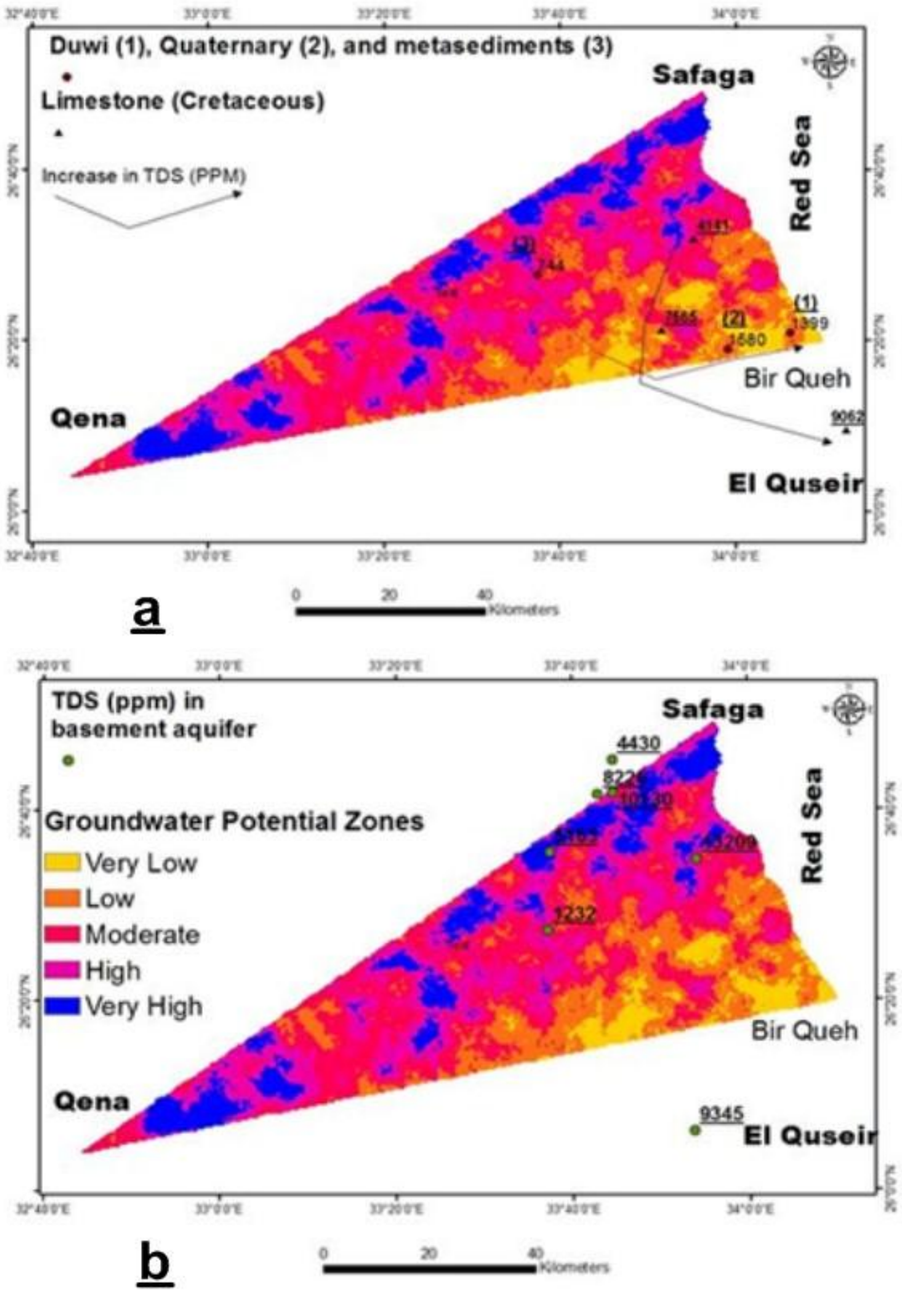

Figure 3. Validation of the groundater potentiality areas

5 CONCLUSION

Wadi Queh is the largest drainge basin followed by Safaga. An attempt was made to prepare groundwater recharge potential zones. Various thematic maps such as fractures, geology, slope, lineament and drainage maps were prepared and integrated for preparing groundwater prospects map. The various thematic maps were assigned with different weightage of numerical value with respect to groundwater potentiality. The results demonstrate that the groundwater recharge potential zone of this area include; very high, high, moderate, and low. Excellent groundwater recharge potential zone is concentratedin the northwestern part, while the lowest was in the southeastern.

REFERENCES

Abdel Moneim, M. (2004) Overview of the geomorphological and hydrogeological characteristics of the Eastern Desert of Egypt. *Hydrogeology Journal (2005) 13:416–425.*

Badawy, M. (2008) Applications Of Remote Sensing And Geographic Information Systems In Geomorphological Stud-Ies:: Safaga -- El Quseir Area,, Red Sea Coast,, Egypt As An Example. *M. Sci. Thesis, Universitat Mainz, 302p.*

Deepika, B., Kumar, A. & Jayappa, K.S. (2013) Integration of hydrological factors and demarcation of groundwater prospect zones: insights from remote sensing and GIS techniques. *Environ. Earth Sci., v.70(3), pp.1319-1338.*

Elewa, H.H., Fathy, R.G., Zaghloul, E.A (2000) Groundwater potential of the southern part of Wadi Qena basin, Eastern Desert, Egypt. *J Remote Sens Sp Sci 3:135–152*.

Elewa, H.H., Abu ElElla, E.M. (2011) Numerical modeling for the Nubian aquifer development in Wadi Qena, Eastern Desert, Egypt. Egypt *J Geol 55:105–125*.

El Ramly, I.M. (1972) Final report on geomorphology, hydrology planning for groundwater resources and reclamation in lake Nasser region and its environs. *Cen And Des Inst, Cairo 603 pp*.

Fetter, C. (1994) Applied hydrogeology, 3rd edn. *Prentice Hall, Englewood Cliffs, NJ, 680 pp*.

Geomin (1971) Preliminary report on hydrogeological investigations performed in Hamrawein area. *Mining Geology of States Bucharest, Romania. 50p*.

Gheith, H., Sultan, M. (2002) Construction of a hydrologic model for estimating wadi runoff and groundwater recharge in the Eastern Desert, Egypt. *J hydrology 263:36–55.*

Hussien, M., Alan, E., Tarek A., Ezat K., Abotalib Z. , Samah M. (2016) An integrated approach for identification of potential aquifer zones in structurally controlled terrain: Wadi Qena basin, Egypt. *Catena 149 (2017) 73–85.*

Lecia Geosystems & GIS Mapping Division (2003) Erdas field guide. *7th ed. Erdas LLC.,* Atlanta, Georgia, USA, 698 p.

Said, R. (1962) The Geology of Egypt. *Elesvier Publication, Amsterdam.*

Sander, P., Chesley, M., Minor, T. (1996) Groundwater assessment using remote sensing and GIS in a rural groundwater project in Ghana: lessons learned. *Hydrogeol J 4(3):78–93*.

Thornbury, W. D. (1984) Principles of geomorphology. Wiley Eastern Limited, *New Delhi, 2ed edition, 594p.*

Wahyuni, S., Oishi, S. & Sunada, K. (2008) The estimation of the groundwater storage and its distribution in Uzbekistan. *Annual Jour. Hydraulic Engg., v.52, pp.31–36.*

Wisler CO, Brater BF (1959) Hydrology. *Wiley, New York, 408 pp*