

National Research Institute of Astronomy and Geophysics NRIAG Journal of Astronomy and Geophysics

www.elsevier.com/locate/nrjag



Assessment of the Miocene aquifer in Wadi El Farigh area by using GIS techniques



M. Gad^{a,*}, M. El Hattab^a, Sh. Galal^b

^a Environmental Studies and Research Institute, Sadat City University, Egypt

^b Geol. Depart, Faculty of Science, Minufiya University, Egypt

Received 9 July 2016; revised 13 October 2016; accepted 10 November 2016
Available online 29 November 2016

KEYWORDS

Assessment;
Miocene aquifer;
Wadi El Farigh;
GIS

Abstract Land reclamation projects represent one of Egypt' strategic policies to meet the needs of over-increase in population. In this regard Wadi El-Farigh and surrounding areas are new promising reclaimed areas because it has reclaimable soils and adequate groundwater potentiality. Development of human activities especially agricultural and industrial activities has a negative impact on the groundwater quality. Geographic information systems (GISs) have become a useful and important tool in hydrology in the scientific study and assessment of water resources.

Landsat satellite images dated 2005 and 2013 were used in this study to access the changes in date land use/land cover that influenced the groundwater aquifer. ERDAS IMAGIN 9.2 image processing system was used for processing satellite images (geometric correction, classification, and change detection).

The integration of image processing and Geographic Information System (ArcGIS version 10) was employed to correlate the data and map the results.

© 2016 Production and hosting by Elsevier B.V. on behalf of National Research Institute of Astronomy and Geophysics. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

During the past decades land reclamation projects represent one of Egypt' Strategic policies to meet the over-increase in population. In this regard, study area is a new promising

reclaimed area because it has reclaimable soils and adequate groundwater potentiality. On the other hand, the geographic location of study area in addition to the favorable sedimentary sequence, the geologic structure and the physiographic setting is the factor that governs the occurrence of such groundwater resources. The present groundwater supplies in the study area and surrounding zones are generally limited to meet the expected increase in water demands; therefore, serious strategic plan for water management has to be established to fully utilize the groundwater resources at economic cost.

Nowadays, both remote sensing and GIS techniques represent most suitable and practical tools for monitoring changes, assessment of groundwater aquifers, water sustainability, monitoring land reclamation projects, and decision making.

* Corresponding author.

E-mail address: m_gad77@yahoo.com (M. Gad).

Peer review under responsibility of National Research Institute of Astronomy and Geophysics.



Production and hosting by Elsevier

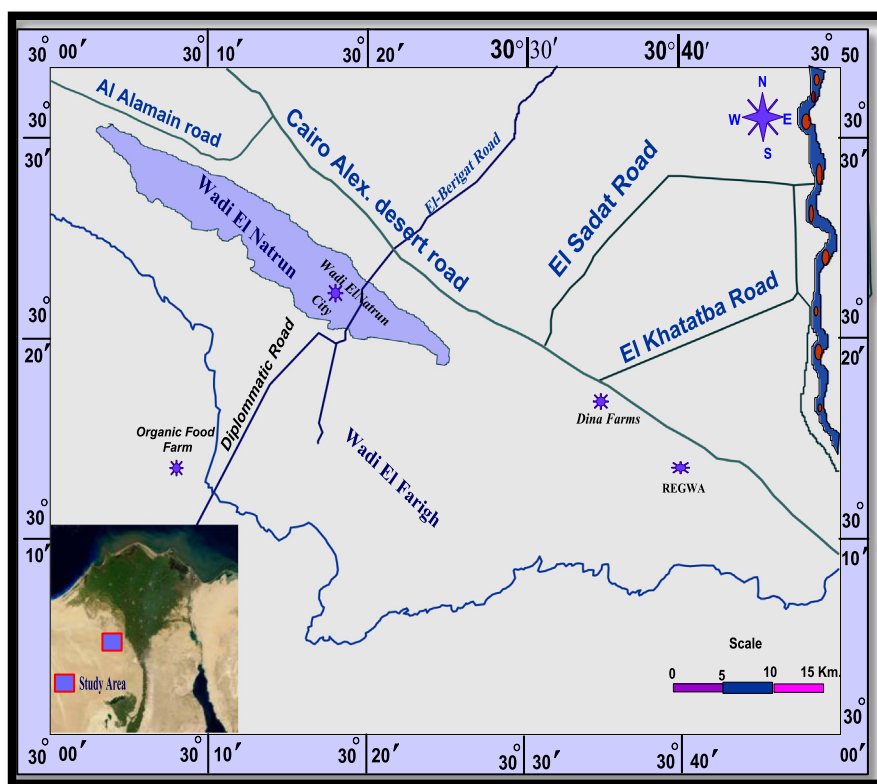


Figure 1 Location map of the Study area.

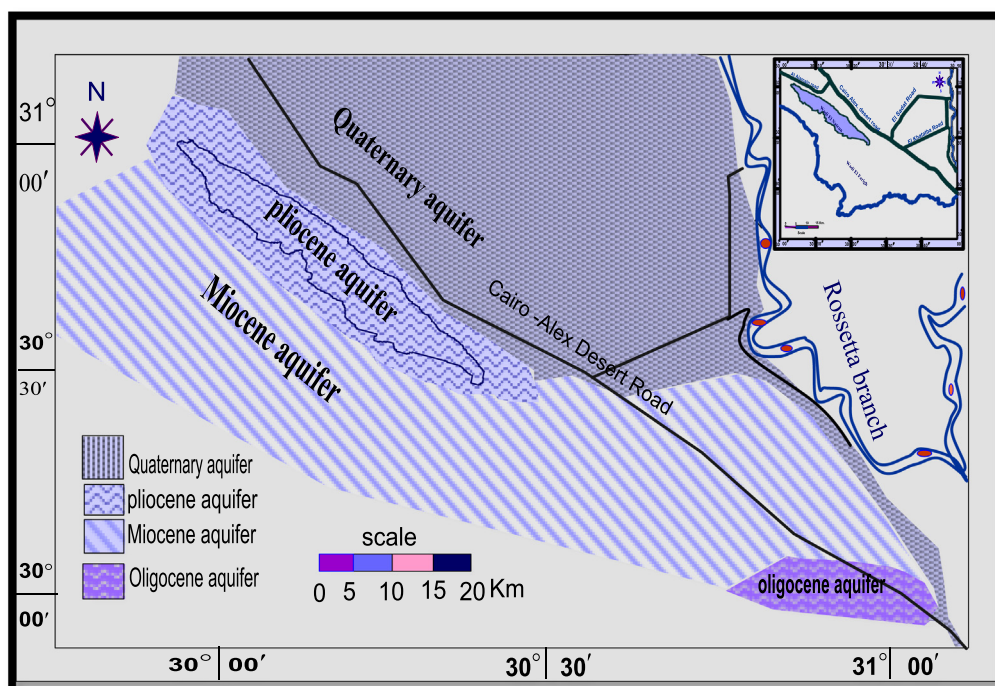


Figure 2 Distribution of the present Aquifer in the study area (After Gomaa 1995).

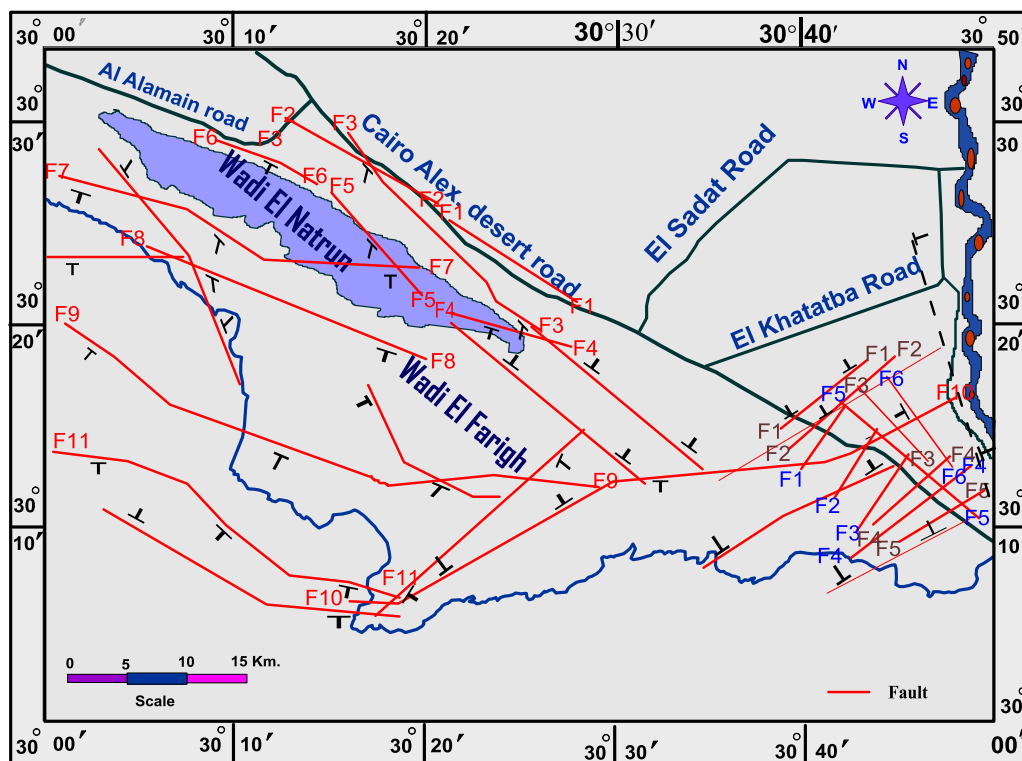


Figure 3 Structural map of the study area (After El Ghazawi, 1982).

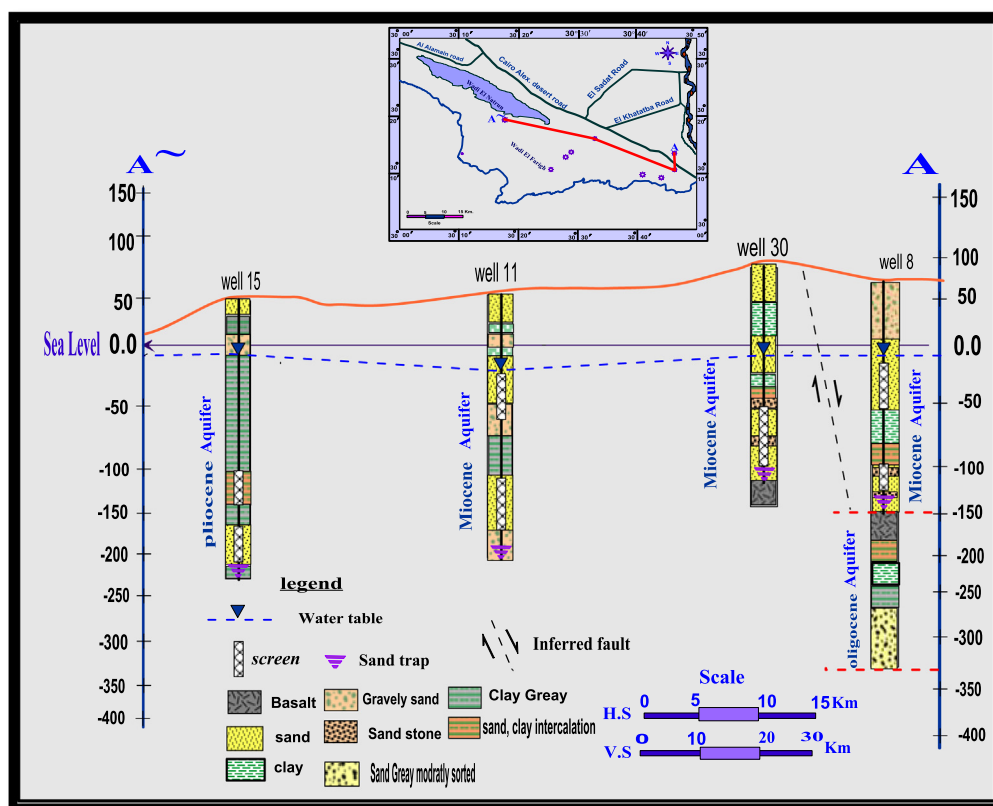


Figure 4 Hydrogeological cross section A-A'.

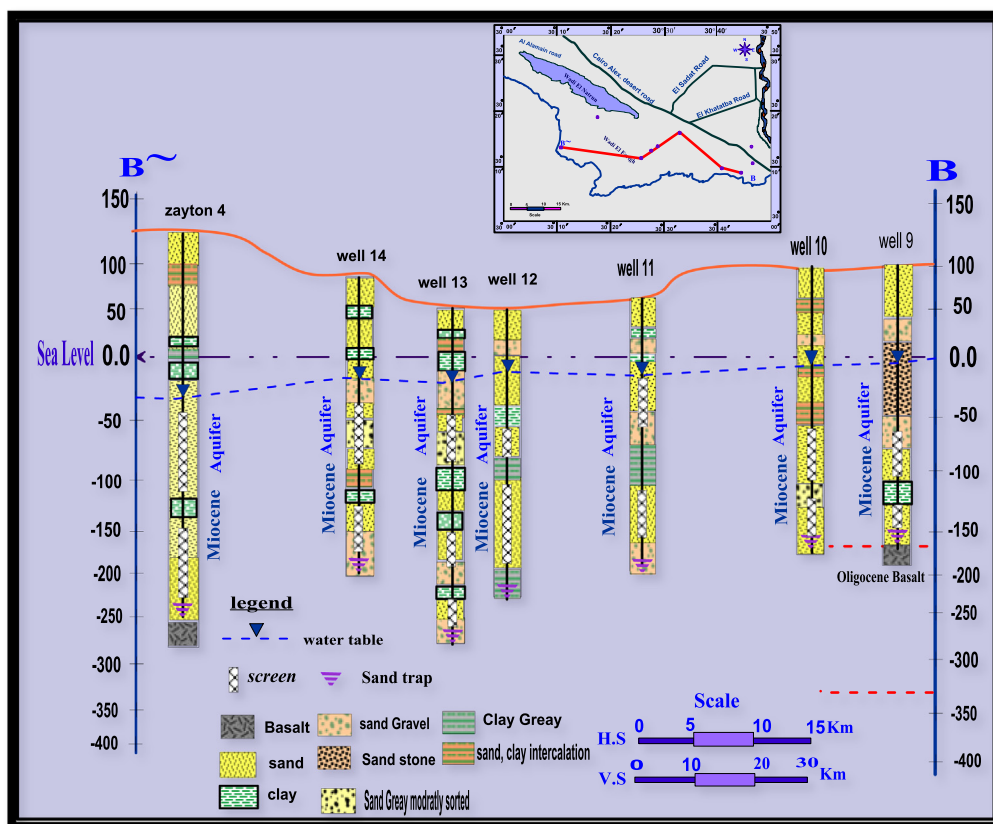


Figure 5 Hydrogeological cross section B-B'.

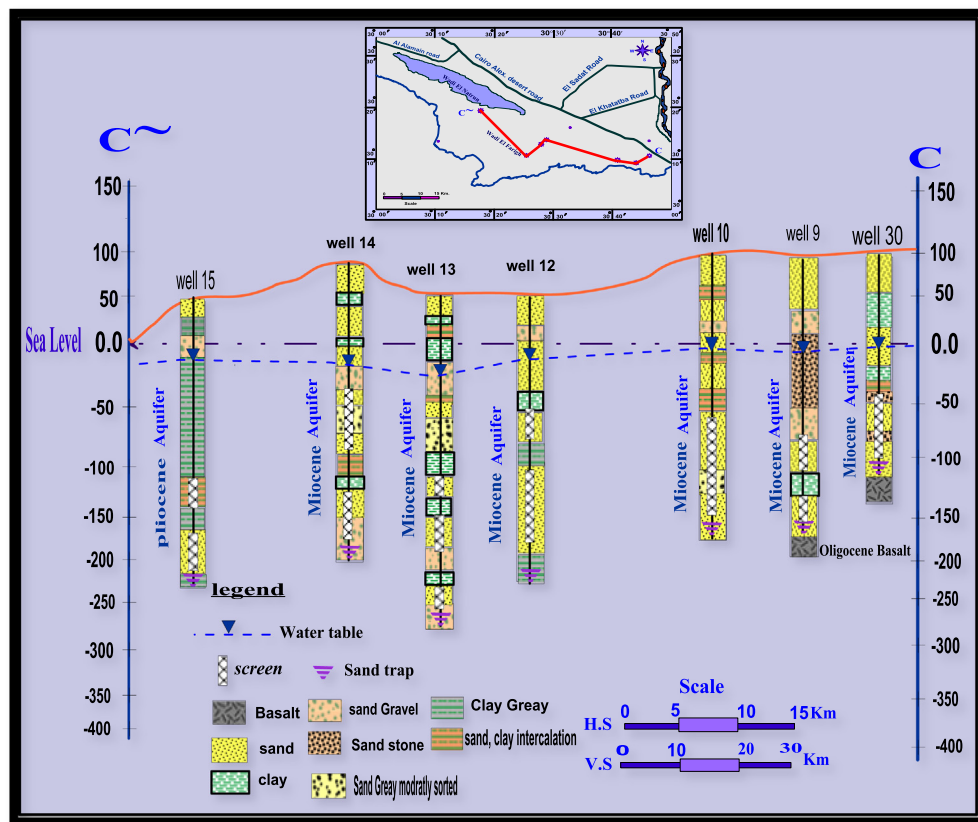


Figure 6 Hydrogeological cross section C-C'.

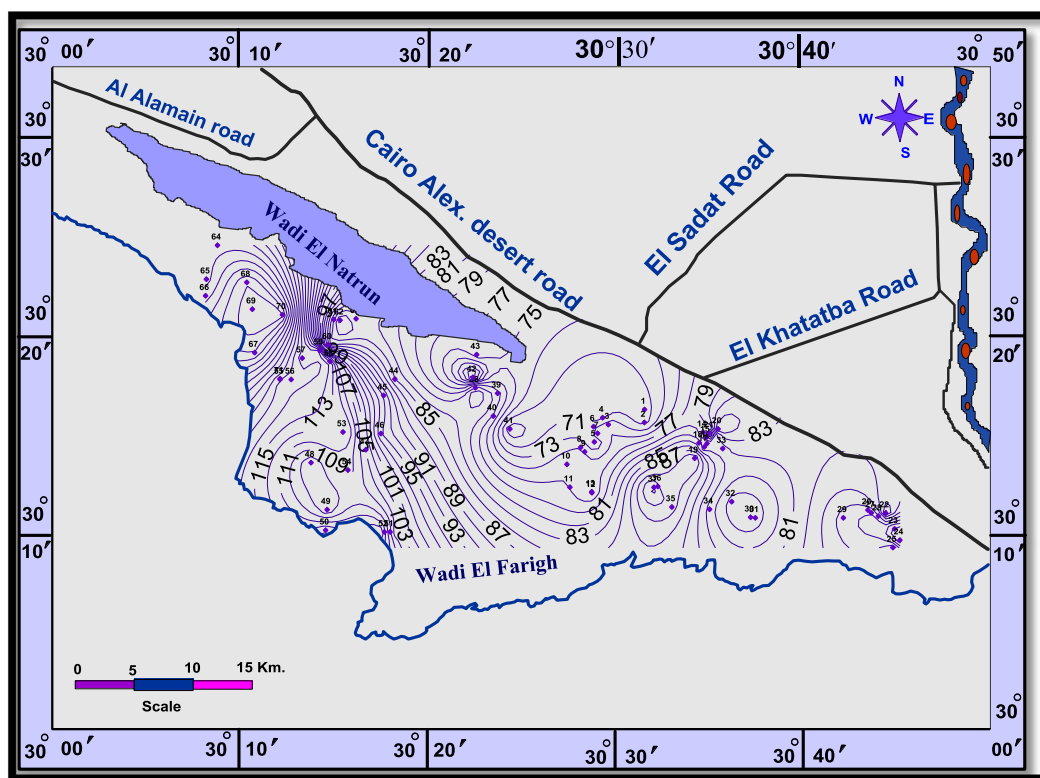


Figure 7 Depth to water contour map of the Miocene Aquifer.

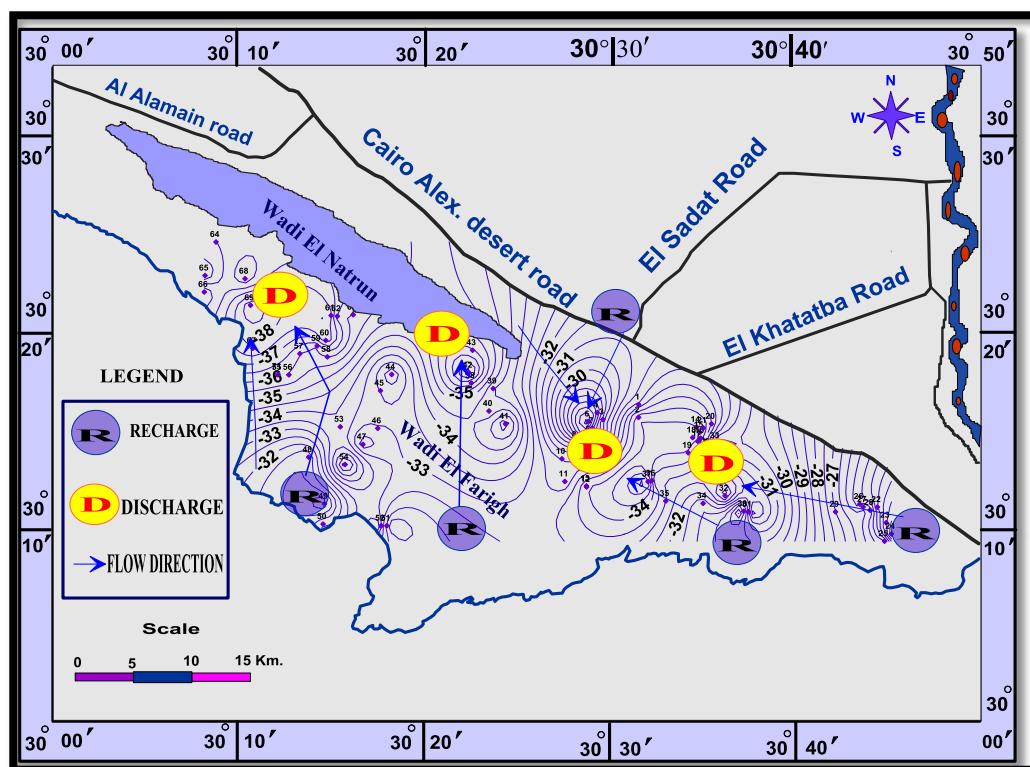


Figure 8 Flow net map of the Miocene Aquifer.

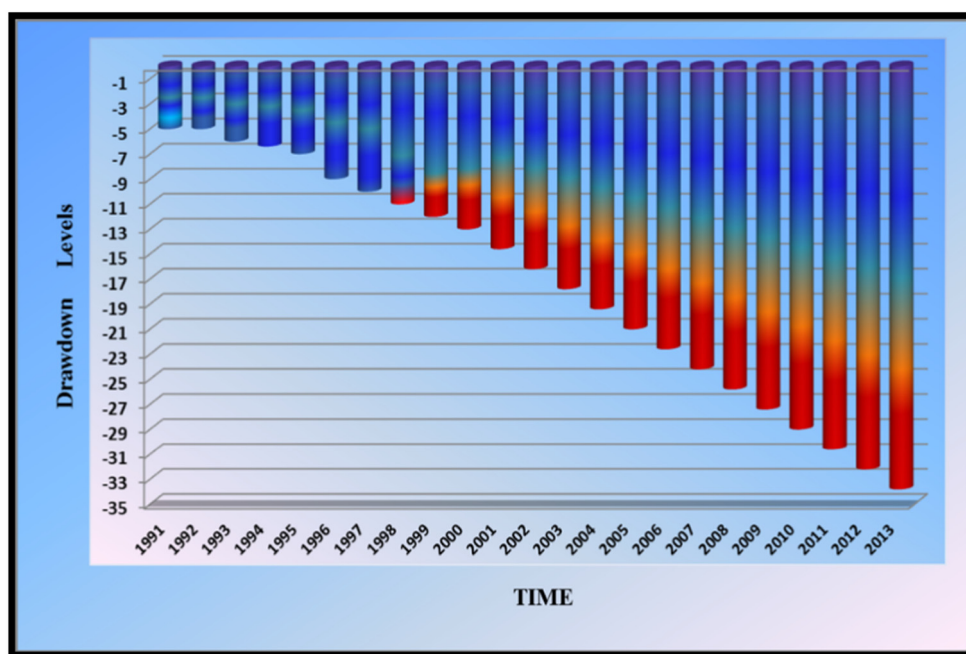


Figure 9 Hydrograph shows lowering in groundwater heads in the study area from 1991 to 2013.

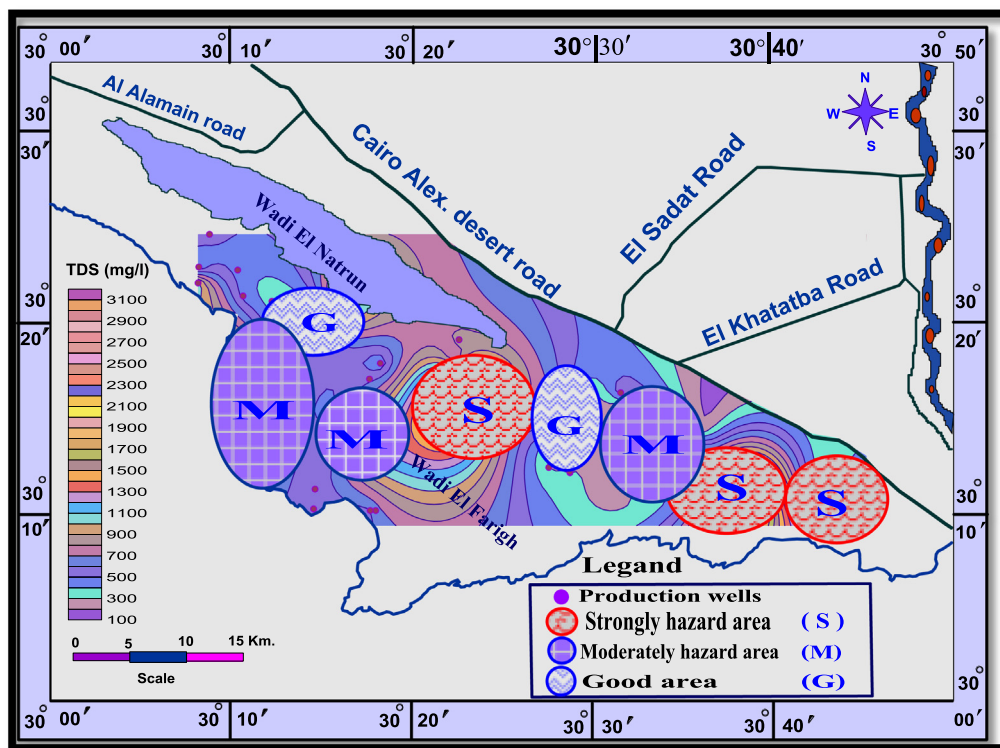


Figure 10 Classifications of hazard Areas in the Miocene Aquifers.

2. Materials

LANDSAT Enhanced Thematic Mapper (ETM+) images acquired on 2005 and 2013, and digital topographic maps digitized from hardcopy topographic maps with scale of 1:50,000

were used mainly for geometric correction of the satellite images, and for some ground truth information. Finally, ground information was collected during field trips conducted in March 2013 for the purpose of supervised classification and classification accuracy assessment.

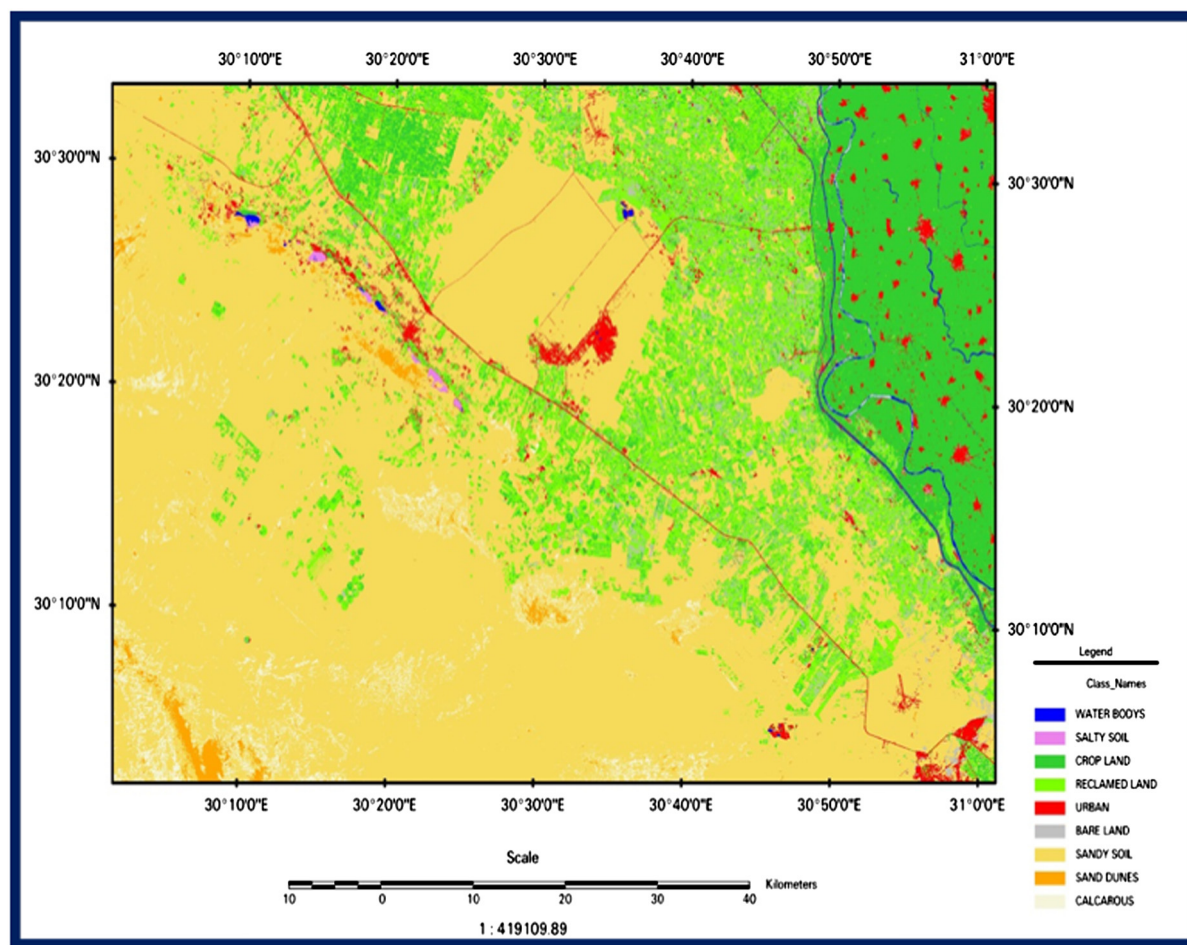


Figure 11 Land cover classification map of southwest of Nile and Delta of Egypt, using Landsat ETM+ (2005).

3. The study area

Wadi El-Farigh area is located in Western Desert, south of Wadi El-Natron depression, southwest of the Nile Delta and west of the Cairo-Alexandria desert road. It extends in a WNW-ESE direction for about 90 km with an average width of about 10 km. The studied area lies between Longitudes 30°30' and 30°55'E and Latitudes 29°50' and 30°30'N (Fig. 1).

4. Hydrogeological settings

Miocene aquifer has a large geographical distribution in Wadi El Farigh and its extension (Fig. 2). The Miocene sediments are represented by the Moghra Formation, and are mainly composed of sand, sandstone and clay interbeds with vertebrate remains and silicified wood (Said, 1962). Miocene aquifer has been deposited on the basaltic sheet at different levels, in the form of horst like and graben like structures (Fig. 3).

Three hydrogeological cross sections were constructed to describe the lithological facies, hydro structural setting and hydrogeological properties of the aquifer (Figs 4–6).

The hydraulic parameters (effective porosity, hydraulic conductivity and transmissivity) of the Miocene aquifer were estimated using pumping test data analysis (REGWA, 1993).

The effective porosity (specific yield) of the Miocene water bearing formation ranges from 0.12 to 0.06. It increases from the western and eastern portions to the middle. On the other hand the hydraulic conductivity values obtained from pumping tests ranged from 5.76 m/day to 116.6 m/day.

The hydraulic conductivity nearly increases from the western and eastern portions of the Miocene area to the middle portion. The hydraulic conductivity and effective porosity of the Miocene aquifer change laterally and vertically reflecting the heterogeneity which affect on the recharge and potentiality of the Miocene aquifer.

4.1. Groundwater flow

The depth to water in Miocene aquifer varies from 69 m at the area close to El Rayah El Naseri to 160 m at high topographic areas toward in the west (Fig. 7). The groundwater level in the Miocene aquifer varies between +6 m at its border with the Nile delta Quaternary aquifer and about –33.8 at the west.

The groundwater in the Miocene aquifer flows westward through Wadi El Farigh. This movement is mainly controlled by an old buried Nile channels which divert groundwater flow toward Wadi El Natrun depression (El Abd (2005). There are other groundwater direction from the northeast (from Quaternary to Lower Miocene) and from southeast (Fig. 8).

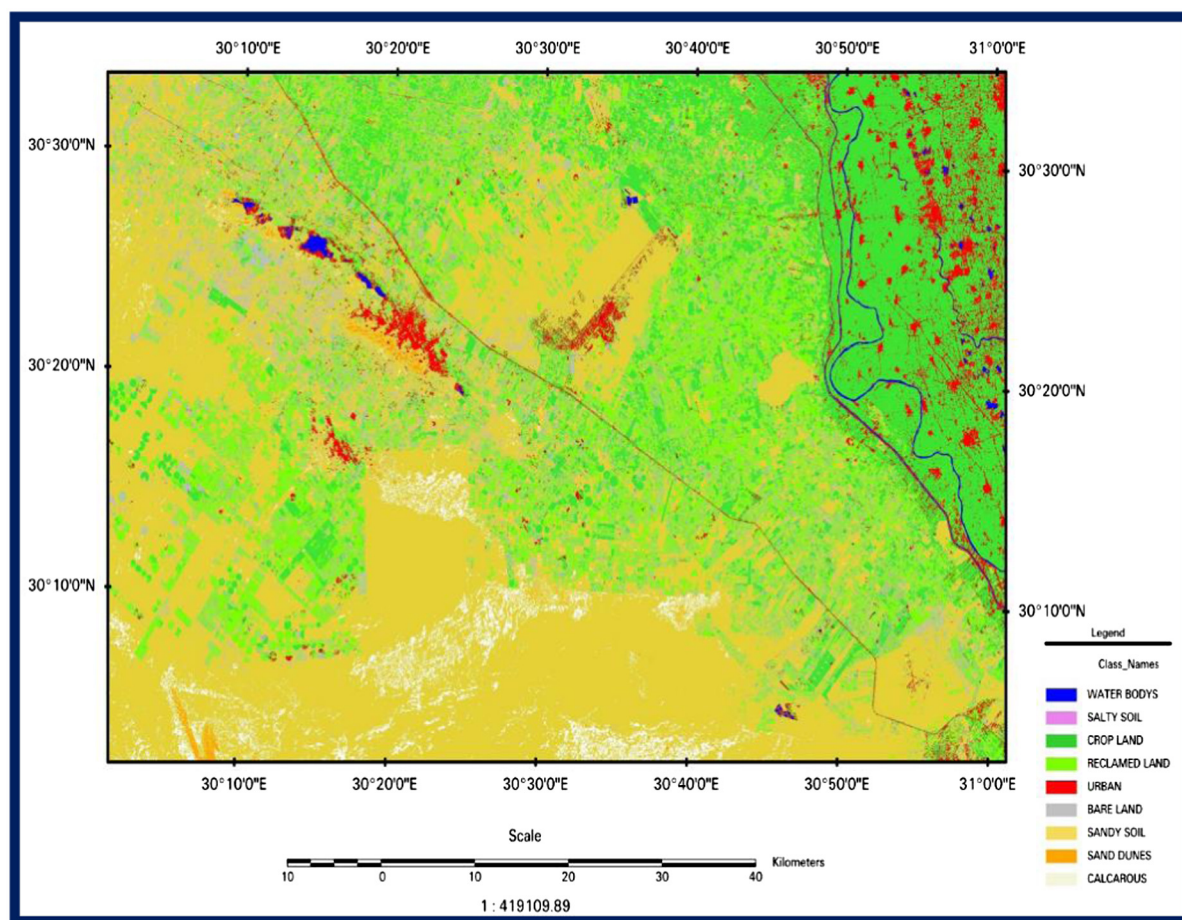


Figure 12 Land cover classification map of southwest of Nile and Delta of Egypt, using Landsat ETM+ (2013).

The total amount of groundwater recharge from the Nile Delta aquifer is estimated to be in the range of $50\text{--}100 \times 10^6 \text{ m}^3/\text{year}$ (RIGW/IWACO, 1990b). The amount of recharge was estimated using groundwater model as $84 \times 10^6 \text{ m}^3/\text{year}$ (Diab et al. 2002).

The environmental isotopes indicate that the main recharging source for the Miocene aquifer is the old Nile water before the construction of the High Dam with few contribution of recent Nile water in the area beside El Rayah El Naseri (Dahab et al., 2004). The estimated age using C14 is 16,737 YBP confirming the dominance of ancient recharge component (Dahab et al., 2004).

The discharge of this aquifer is mainly through the extraction from wells and is relatively discharged into the Pliocene aquifer at the southern part of Wadi El Natrun (Gomaa, 1995).

High extraction rate ($20\text{--}30 \times 10^6 \text{ m}^3/\text{year}/\text{Km}^2$) was found along Cairo-Alexandria desert road (El Fakharany, 1998). The extractions of large volumes of groundwater allow the formation cones of the depression of piezometric levels. Since the extraction rate is still increasing the lowering of water level and will continue in the future (RIGW/IWACO, 1990b), a remarkable change in groundwater levels is recorded as shown in Fig. 9.

4.2. Groundwater salinity

The Miocene aquifer in the Wadi El-Farigh and its vicinity area is underlain by a disconnected thin layer of basalt that

separates the aquifer from Oligocene deposits. The Oligocene deposits are made up of sandy mudstone and shale, sandstone and limestone, with occasional gravelly sandstone intercalations (Sadek et al. 2005). These Oligocene deposits are characterized by relatively high water salinity because of the dissolving salts of the Oligocene fluviomarine deposits during the circulation of the water (Abdel Baky 1983). Due to the disconnection in the basalt layer, the hydraulic contact between the Miocene aquifer and the Oligocene layer may lead, with every increase in the groundwater extraction from the Miocene aquifer, to the increase of salinity in the Miocene aquifer. According to salinity, Miocene aquifer can be classified into several hazard areas (Fig. 10), as follows:

1. **Strongly hazard areas** include the highly affected by structure. These areas are as follows: the area where the Miocene and Oligocene aquifers come in contact with other, the areas have been affected by the horst like structure, and the areas have been affected by the graben like structure (Fig. 3). These areas suffer from high salinities ($1000\text{--}5100 \text{ mg/l}$), high percentages of shale ($10\text{--}57$), low saturated thickness ($38\text{--}56.5 \text{ m}$ at horst areas, $60.5\text{--}118 \text{ m}$ at graben areas and 510 m at southwest Wadi El Natrun), low effective porosity ($7.5\text{--}9\%$) and high degree of drawdown (1 m/year to 1.60 cm/year). Overpumping due to farther developments will cause more problems that would completely destroy the aquifer at these localities.

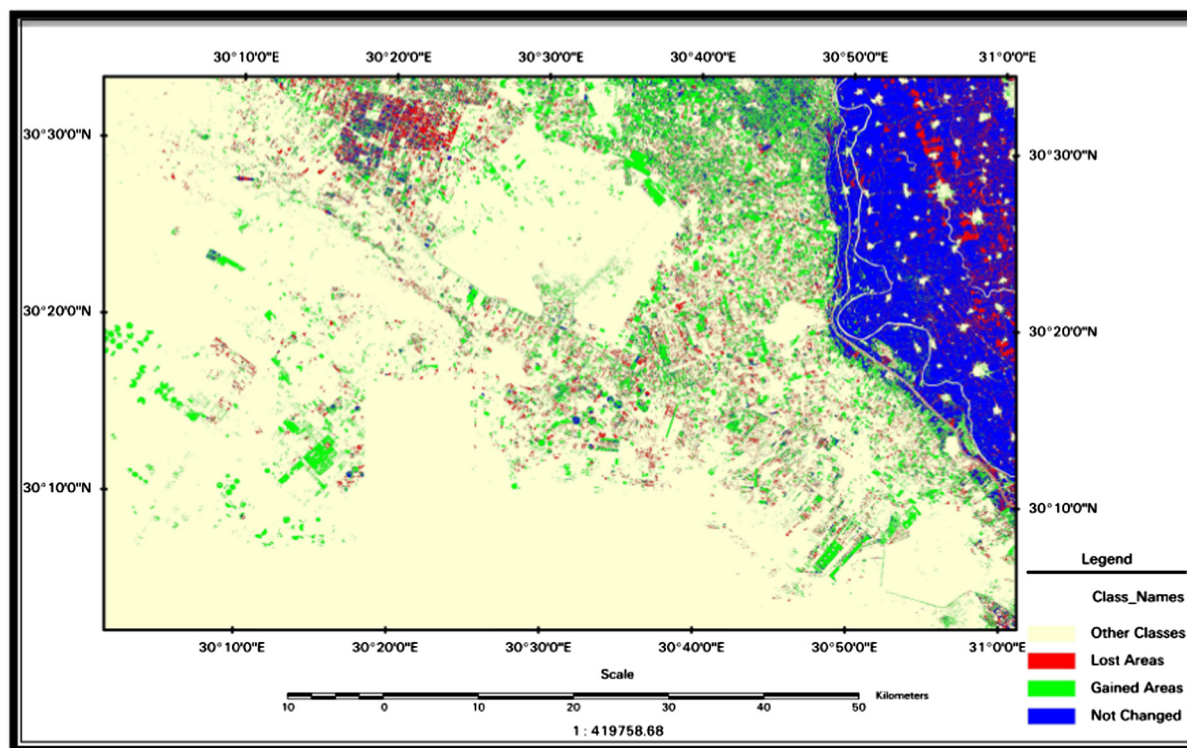


Figure 13 Change detection of “Crop Land” class.

2. **Moderately hazard areas**, characterized by low salinities, low percentages of shale (38–0), high saturated thickness in graben area, low saturated thickness in horst areas (70–328 m), variable hydraulic conductivity (74.5–12.5), variable effective porosity (11.3–5.7%) and high degree of drawdown range from 90 cm/year to 1.20 cm/year. So any farther developments in this area would completely destroy the aquifer. The amount of groundwater stored in the Miocene aquifer at these localities is about $9.04 \times 10^9 \text{ m}^3$, while the amount of its annual withdrawal which equals the drawdown is about $27.5 \times 10^6 \text{ m}^3$.
3. **Slightly hazard areas** are characterized by low salinities, variable percentages of shale (5–48), high saturated thickness (116–179 m), variable hydraulic conductivity (23.6–17.6), variable effective porosity (9–7.6%) and high degree of drawdown (60–80 cm/year) of the groundwater level. Groundwater tapped at depths ranged from 110 m to 60 m according to ground elevation and drilling should be to depths from 250 to 300 m. So any farther developments in this area would completely destroy the aquifer. The amount of groundwater stored in the Miocene aquifer at these localities is about $0.87 \times 10^9 \text{ m}^3$, while the amount of its annual withdrawal which equals the drawdown is about $3.2 \times 10^6 \text{ m}^3$.

5. Assessment of Miocene aquifer by using GIS techniques

The images were supervised classified using the Maximum Likelihood classifier. A comparison of classified unit areas was insinuated to detect changes in land use/land cover related to sustainability parameters.

Change detection analysis is performed on a pixel-by-pixel basis; therefore, any misregistration greater than one pixel will provide an anomalous result of that pixel. Images of both dates were geometrically corrected using 32 ground control points with root mean-square error (RMSE) not exceeding 0.5 pixel.

5.1. Image classification

Supervised classification was done using about 32 ground points (collected during field survey), and digital topographic maps of the study area. All signatures were compared, only nine land cover classes were found to be separable, and they are water body, saline soil or (salt marches), cropland, reclaimed land, urban, bare land, sandy soil, sand dunes, and calcareous land. Figs. 11 and 12 show the result of the classification.

Post-classification change detection technique was applied for both supervised images. Post classification is the most obvious method of change detection, which requires the comparison of independently produced classified images. Post-classification comparison proved the most effective technique, because data from two dates are separately classified, thereby minimizing the problem of normalizing for atmospheric and sensor differences between two dates. Cross-tabulation analysis was carried out to analyze the spatial distribution of different land cover classes and land cover changes.

Post-classification change detection technique (El-Hattab, 2014) was carried out, through cross-tabulation GIS module, for the classification results of 2005 and 2013 images in order to produce change image (Figs. 13 and 14) and statistical data about the spatial distribution of different land cover changes

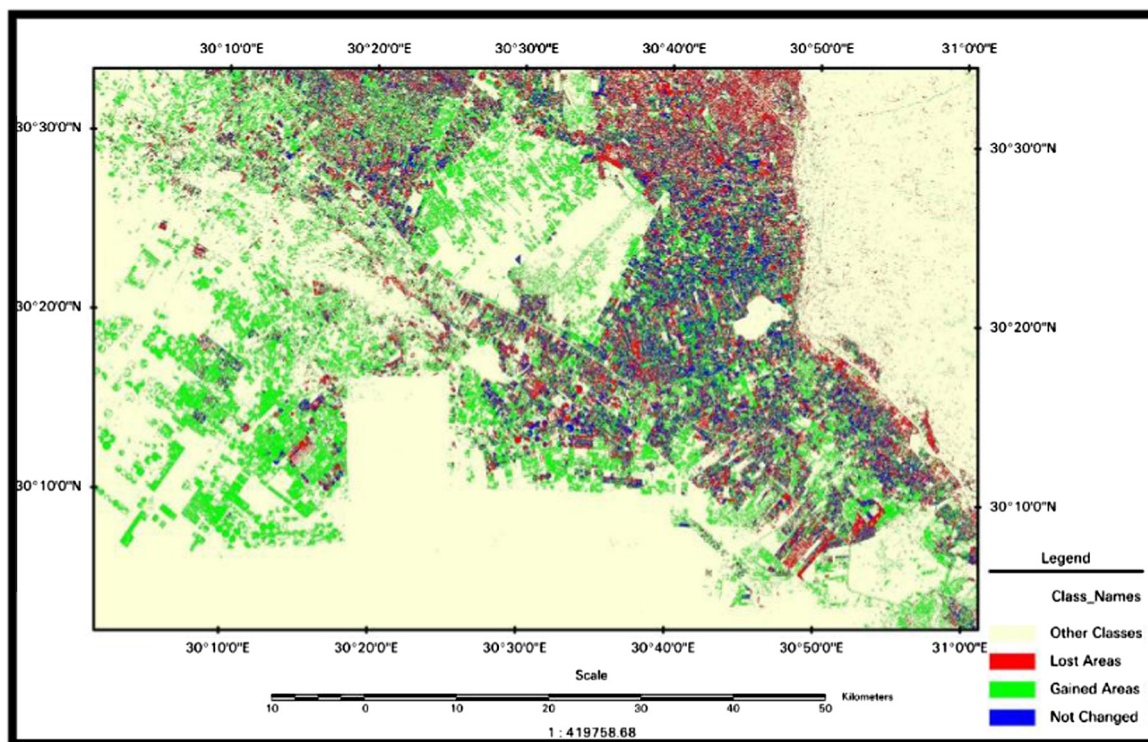


Figure 14 Change detection of “Reclaimed Land” class.

and non-change areas (as a result of change detection technique).

In order to increase the accuracy of land cover mapping of the two images, ancillary data and the result of visual interpretation were integrated with the classification results using GIS. The visual interpretation gave a general idea about the forms of land cover changes over the period.

By discussing the change detection results, it could be concluded that a notable increase is remarked in vegetation area, as well as the urban area which increases similarly. Expanding vegetation and urban areas occurred on the account of bare land and sandy soil, which significantly decreased. Wadi El Farigh and Wadi El Natrun are newly reclaimed promising areas for agricultural purposes. Settlements mostly exist along the main roads. These areas are not served by a fair irrigation and drainage network, which makes difficult more sustainable development. Land areas of exposed soil surface are influenced by human impacts and/or natural causes. It contains sparse vegetation with very low plant cover value because of over-grazing, woodcutting, etc., in the study area where there are a lot of bare lands as a result of farms destroyed which are produced from the deterioration of water and soil quality.

6. Conclusion

The obtained results indicated that the water consumption rate during the comparison period (2005–2013) in the study area was increased by about 26%. Increase of human activities in the study area resulted in more exhaustion of groundwater from the Miocene aquifer which is accelerated also by the poverty of groundwater aquifer recharge. Accordingly, the groundwater declination increase and the Up-coning effect

occur and lead to the groundwater salinity increase and so the deterioration in water quality and soil salinity occurs.

Acknowledgment

I would like to express my deepest thanks and highest appreciation to Prof. Dr. K. A. Dahab, Professor of Hydrogeology, Geology Department, Faculty of Science, Minufiya University. My sincere thanks are also due to all the staff members of the Environmental Studies and Research Institute (ESRI), Minufiya University.

References

- Abdel Baki, A.M.A., 1983. Hydrogeological and Hydro Geochemical Studies in the Area West of Rosetta Branch and South El Nasr Canal Ph. D. Thesis. Ain Shams Univ., p. 156.
- Dahab, K.A., Kipfer, R., El Gamal, H., Aeschbach-Heritig, W., 2004. Assessment of Groundwater Recharge Resources using Hydrochemistry and Environmental Tracers in New Reclaimed Areas Southwest of the Nile Delta, Egypt. In: Intern. Conf. on geochemistry. Alex. Univ., Egypt, pp. 353–370.
- Diab, M.Sh., Gad, M.I., El-Sheikh, A., 2002. Study the Effect of New Reclamation Projects on the Groundwater System in the Area Northwest Wadi El Natroun and South El Nasr by Using Mathematical Modeling. Diab. Faculty of Engineering, Mansoura University, El Mansoura, Egypt.
- El Abd, A.E., 2005. The Geological Impact on the Water Bearing Formations on the Area Southwest Nile Delta, Egypt Ph.D. Thesis. Fac. Sci. Minufiya Univ; Cairo, Egypt.
- El Fakharany, 1998. The impact of excessive pumping on groundwater at El Marwah area, Cairo – Alexandria Desert Road, Egypt. Sci. J. Fac. Sci, Menufiya Univ. XII, 1–19.

- El Ghazawi, M.M., 1982. Geological studies of the Quaternary – Neogene aquifers in the area northwest Nile Delta M.Sc. Thesis. Fac. Sci, El Azhar Univ, Cairo, Egypt, p. 170.
- El-Hattab, M.M., 2014. Change detection and restoration alternatives for the Egyptian Lake Maryut, Egypt. J. Rem. Sens. Space Sci. <http://dx.doi.org/10.1016/j.ejrs.2014.12.001>.
- Gomaa, M.A., 1995. Comparative Hydrogeological and Hydrochemical Study on Some Aquifers, West of Nile Delta, Egypt Ph. D. Thesis. Fac. Sci; Ain Shams Univ, Cairo, Egypt, p. 236.
- REGWA, 1993. The groundwater in a study area southern of Wadi El Farigh. The general company for research and groundwater, Interior report, Cairo, p. 74.
- RIGW/IWACO, 1990b. Hydrogeological inventory and groundwater development plan, Western Nile Delta region. Main report, vol. 4, Technical Note 77.01300-90-02.RIGW, 64 p.
- Sadek, A., Pigott, J., Barakat, M., Abu, El.-Atta A., Sadek, S., 2005. Hydrocarbon evaluation of Natrun basin, West Nile Delta, Egypt. GRMENA, Cairo 1, 3–31.
- Said, R., 1962. The Geology of Egypt. Elsevier Pub. Co., Amsterdam-New York, p. 377p.