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FACULTY OF ENGINEERING, CAIRO UNIVERSITY

PREDICTION AND ASSESSMENT OF SURFACE WATER QUALITY EFFECT ON GROUNDWATER IN EL-QALUYBIA, EGYPT

M. M. GALAL[1], A. SOLIMAN[2], G. KAMEL[3],
K. ZAHER[4] AND Z. EL-FAKHARANY[5]

ABSTRACT

Groundwater quality is an important issue that must be precisely considered for the efficient environmental management of groundwater resources. The aim of this study is to assess the impact of surface water quality on the nearby shallow groundwater quality of one of the main aquifers in Egypt, the Nile Delta aquifer, in El-Qaluybia Governorate, Egypt. Water samples were collected from canals, drains and irrigation wells distributed within the study area and were analyzed for bacteriological, nutrient and trace elements contamination. A numerical model was developed to simulate study area flow system using Visual MODFLOW software and also to predict the long term effect of surface pollutants on groundwater quality. Groundwater quality assessment indicated contamination from domestic, industrial and agricultural activities. Results indicated that both surface and groundwater are affected by pollution from human and animal sources due to the absence of sewerage treatment systems and the disposal of domestic wastewater in the surrounding agricultural drains. Results also revealed the role of clay cap thickness in hindering contaminants transport. The model results showed that, if current surface water pollution persists, groundwater will not be suitable for future irrigation purposes in the study area and pretreatment will be essential prior its use.

KEYWORDS: Surface water, Groundwater, Environmental management, Visual modflow, Contaminant transport.

1. INTRODUCTION

Groundwater is a strategic and very important source of fresh water in Egypt. One of the major groundwater aquifers in Egypt is lying under the Nile Delta region.

[1] Associate Professor, Environmental and Sanitary Engineering Division, Faculty of Engineering, Cairo University, Giza, Egypt, monamgalal@cu.edu.eg
[2] M. Sc. Candidate, Environmental and Sanitary Engineering Division, Faculty of Engineering, Cairo University, Giza, Egypt.
[3] Professor, Research Institute for Groundwater (RIGW), National Water Research Center (NWRC), Egypt.
[4] Professor, Environmental and Sanitary Engineering Division, Faculty of Engineering, Cairo University, Giza, Egypt.
[5] Associate Professor, Research Institute for Groundwater (RIGW), National Water Research Center (NWRC), Egypt.

The Nile Delta aquifer is a huge renewable groundwater reservoir that is mainly recharged from the River Nile seepage, canals and drains leakage in addition to deep percolation from excess irrigation water [1]. Groundwater has been considered a protected source of water as being safe and far from surface contamination by the upper soil grains which prevent contaminants from percolation with water [2].

Most of the rural population depend mainly on shallow groundwater as a source of water for irrigation and other domestic purposes. Meanwhile, most of these areas are not served by sewer systems to collect and treat domestic wastewater but rather depend on traditional onsite primary treatment systems like septic tanks. The effluents of these tanks can seep to the beneath water table while being disposed of into the nearby drains which serve irrigation areas and sometimes are disposed of into canals that supply these areas. About 12 billion m^3 of water is drained yearly and about 420000 ha are irrigated with such waters. The reuse of such water in irrigation without pretreatment deteriorates the soil and negatively affect the groundwater quality [3-5]. Eissa, et al. [6] stated that the main groundwater pollution problems are; sewage disposal in open drains; and using mineral fertilizer in agriculture. ElKashouty [7] confirmed that the groundwater in Nile Delta is influenced by microbiological contamination sources, which are causing many diseases for people and animals.

Recently, conservation of water resources has become at the top of national imperatives particularly the protection of groundwater quality in rural areas. Managing surface water quality is a first step towards protecting groundwater quality and hence, understanding and studying pollutants migration from the surface to groundwater is essential. Recently, many numerical models were developed to simulate groundwater flow migration and product future quantity and its behavior under different scenarios. These models include FEFLOW, GMS, SWAT, SUTRA, MT3D and Visual MODFLOW. Among these models, Visual MODFLOW software was applied in many studies related to groundwater modeling for different objectives including drought studies, climate change, landfills, constructed wetlands impacts, watershed analyses and others [8-11].

This study aims to assess the current surface and groundwater quality to identify the correlation between their water quality parameters in El-Qaluybia Governorate. Also, to predict the long term impacts of surface pollutants migration on the shallow groundwater quality by simulation of the aquifer system using Visual MODFLOW Pro.V.4.6 software.

2. MATERIALS AND METHODS

2.1 Study Area

This study is applied in El-Qaluybia Governorate which lies between latitudes $30^0 03'00''$ and $30^0 20'00''$ N and between longitudes 31°03'00" and 31°25'00" E as shown in Fig. 1. To assess current surface and groundwater quality and also to build a conceptual model for groundwater flow simulation; it was essential to investigate the land use, potential contamination sources, and hydrogeology in the study area.

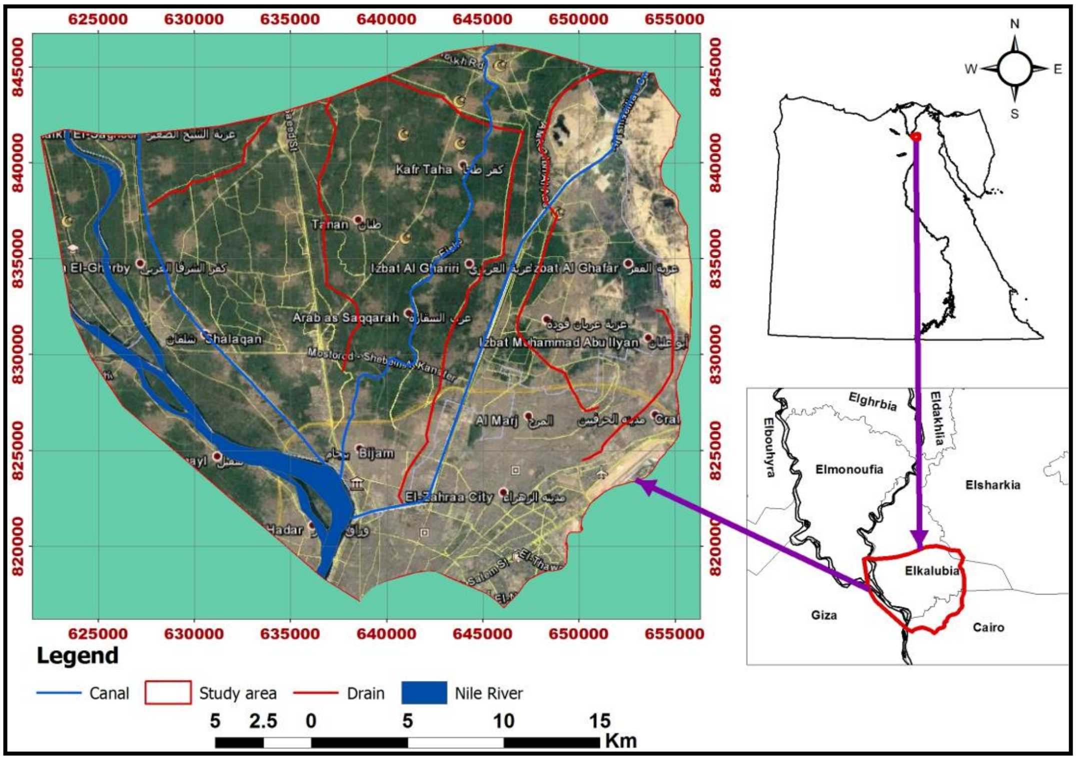

Fig. 1. El-Qaluybia Governorate location.

Investigating the land use of the study area as shown in Fig.2 showed that the center and western sides are occupied by agricultural areas depending mainly on groundwater for irrigation. The eastern side is predominantly heavily populated with a high density of industrial activities in El-Khanka [12]. The urban area extends in the southern part with some scattered settlements in the north. The urban area is served by sewerage systems while unplanned settlements and many scattered rural areas are either unserved or served with municipal septic tanks and local sewage collecting networks [13].

The surface water system in El-Qaluybia consists of a set of main canals as El-Sharqauiya, Ismailia and El-Basusiya canals, and also a set of drains as El-Qaluybia, Namul, Bilbeis, Shibin El-Qanatir and El-Sail drains as indicated in Fig. 2. In this area, the untreated domestic wastewater is directly discharged into canals, drains and sometimes is dumped on the land surface. The industrial wastes from El-Khanka area are disposed of in ElGabal ElAsfar drain in the eastern side. It is considered the main potential pollution source, which contaminates the aquifer beside Bilbeis and Shibin El-Qanatir drains. Namul drain which is located in the middle of the study area receives domestic wastewater effluents, excess agricultural drainage water rich in chemical fertilizers beside the leakage from bottomless local septic tanks distributed all over the study area. Water samples are collected from surface water and irrigation wells distributed in this study area as presented on Fig. 2.

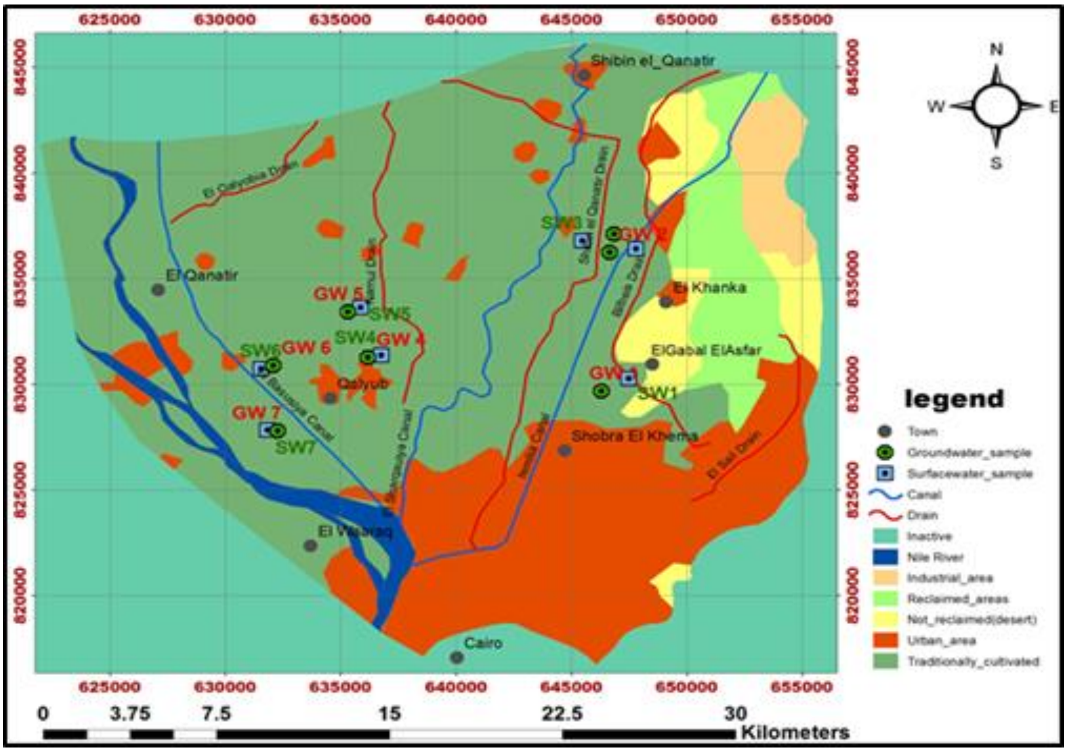

Fig. 2. Land use, surface water system, and samples location.

Topography of the study area is almost flat with surface elevation varying between 16 m to 20 m (asl) as shown in Fig. 3, based on data from two topographical maps produced by Egyptian General Survey Authority (EGSA,1998) of scale (1:50000); Cairo West sheet (NH36-13a) [14] and Cairo East sheet (NH36-13b) [15].

El-Qaluybia Governorate is underlain by Quaternary aquifer, which is one of the main groundwater aquifers in Nile Delta, Egypt. The upper layer of the aquifer is a clay cap aquitard layer with thickness varying between 5 to 20 m. It increases to more than 20m in the center of El-Qaluybia Governorate and vanishes towards the eastern area. The Quaternary is represented as a sandy gravel aquifer with an average thickness of 100 m [16, 17]. The aquifer system is mainly recharged by leakage from River Nile and main canals and also from the infiltration of excess water from irrigated fields. Groundwater piezometric head varies between 12 m in the northern area to 17 m in the southern area [18-20].

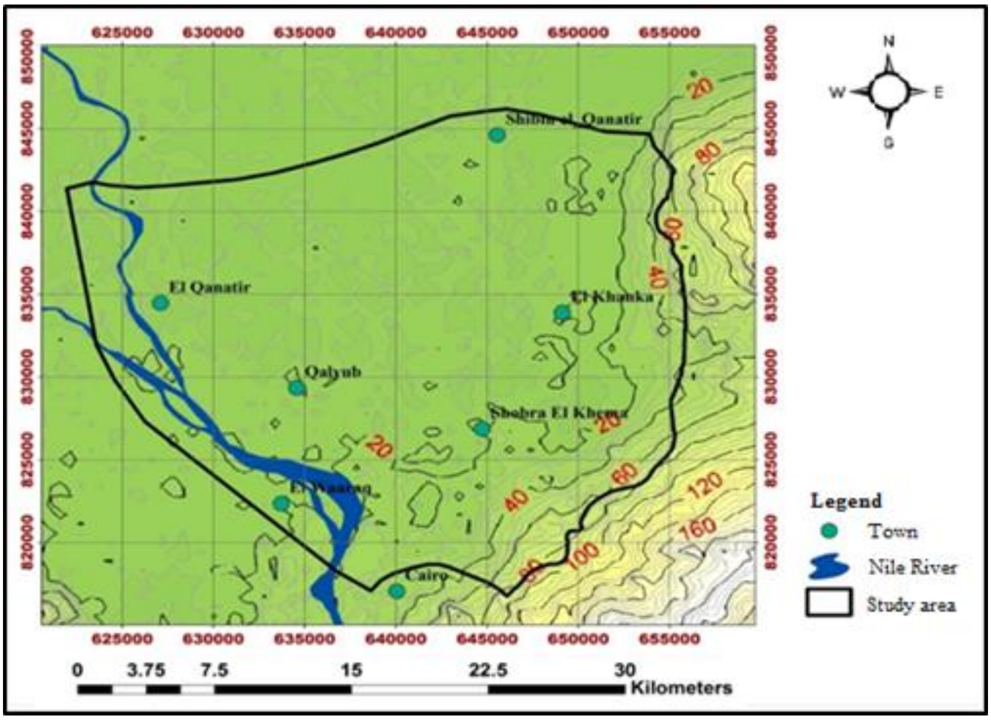

Fig. 3. Study area topographical map.

2.2 Water Quality Assessment

Seven surface water points (canals/drains) are selected and another seven nearby irrigation wells are chosen for groundwater sampling. Table 1 presents the location of these sampling points.

The irrigation wells selection took into consideration that all wells should have similar characteristics for appropriate results. The average distance between a surface water sampling point and the nearby irrigation well is about 400 m. The average depth of each well is 60 m, and the average clay cap thickness at the well sites is 13.5 m. Screens top levels are at a depth of 25 m each with screen length of 20 m.

All surface and groundwater samples were analyzed for different water quality parameters in the Central Laboratory for Environmental Quality Monitoring (CLEQM) at the National Water Research Center in Egypt. Water quality parameters were chosen to reflect nutrients contamination (Nitrate (NO_3) and Phosphate (PO_4)); industrial contamination by heavy metals (Iron (Fe), Manganese (Mn), Cadmium (Cd), and Zinc (Zn)); bacteriological contamination (biological oxygen demand (BOD), total coliform group (TC) that include fecal coliform (FC), fecal streptococcus (FS)), and Total dissolved solids (TDS). Fecal coliform (FC) is an indicator of fecal contamination that may be from human or animal sources. The suitability of groundwater use in drinking and irrigation is studied based on the guidelines approved by Egyptian ministry of health [21]; Egyptian code for reuse of wastewater in irrigation [22] and FAO [23]. Then based on the current water quality analysis results the correlation between surface water pollutants and groundwater quality was identified to study the relationship between surface water pollutants and groundwater quality.

Table 1. Characteristics of sampling points.

Surface Water Source (SW)		Nearby groundwater source (GW)			
	Canal / Drain		Latitude	Longitude	Clay Cap thickness, m
SW1	Bilibas El-Qebly drain	GW1	30° 10' 51.0″	31° 19' 03.0″	11.5
SW2	Bilibas drain	GW2	30° 14' 04.0″	31° 19' 56.0″	12
SW3	Ismailia canal	GW3	30° 14' 16.0″	31° 20' 1.80″	12
SW4	Local collector drain	GW4	30° 11' 05.0″	31° 13' 30.0″	14
SW5	Local collector drain	GW5	30° 12' 55.8″	31° 13' 4.10″	14.5
SW6	Local collector drain	GW6	30° 11' 10.1″	31° 10' 33.6″	13
SW7	Local collector drain	GW7	30° 09' 34.1″	31° 10' 52.6″	17.5

2.3 Development of Groundwater Model

A numerical model is developed to simulate the study area flow system using Visual MODFLOW software [24]. It is based on the finite difference technique for practical applications in three dimensional flow and solute contaminant transport [25]. MODFLOW software has been recently applied in many quantitative and qualitative studies due to its simplicity and, modular structure, and its ability to resolve many hydrogeological problems such as simulation and prediction of groundwater levels; groundwater management and seawater intrusion [26, 27].

The modeling of the groundwater flow is carried out to understand the flow system and to support the evaluation of the environmental risks associated with water supply from wells. It is also used to predict the potential future contamination of groundwater resulting from surface water pollution. The model dimensions are 36km in X-direction and 31km in Y-direction, grid element size was considered 100m x100m, the number of columns and rows are 360 and 310 respectively. The aquifer system is divided into two modeling layers in the vertical direction to represent the clay cap layer and the aquifer layer as shown in the cross sectional view for the model layers in Fig. 4.

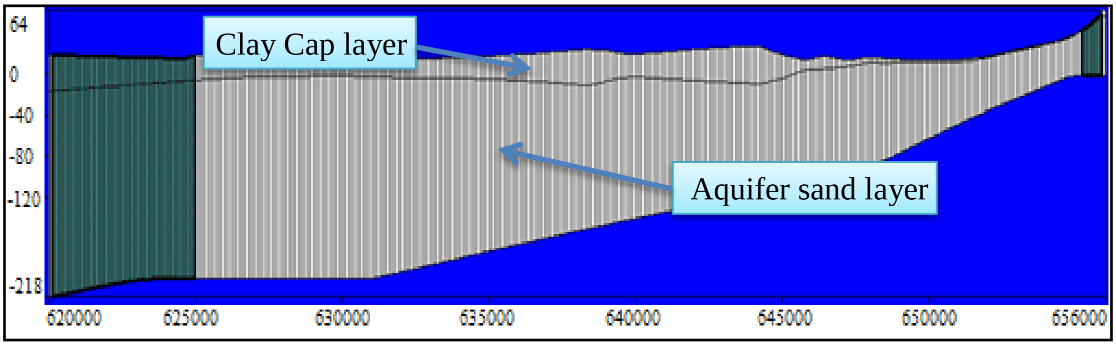

Fig. 4. Cross section in the model layers.

The model boundary conditions are defined based on the understanding of natural hydrogeological conditions of the study area [16-18, 20] and Nile Delta hydrogeological map [19] as shown in Fig. 5 as follows:

1- The northern boundary of the model is represented as a constant head boundary 12 m above the mean sea level. The southern boundary of the model is represented as a constant head boundary 17 m above the mean sea level and this hydraulic head is assigned to the second sand aquifer layer.

2- The western boundary of the model is referred to as a *No Flow* boundary where the direction of flow is perpendicular to piezometric headlines. The eastern boundary of the model is also represented as a *No Flow* boundary as no aquifer is found in the northern area and because the flow lines are perpendicular to piezometric headlines in the southern area.

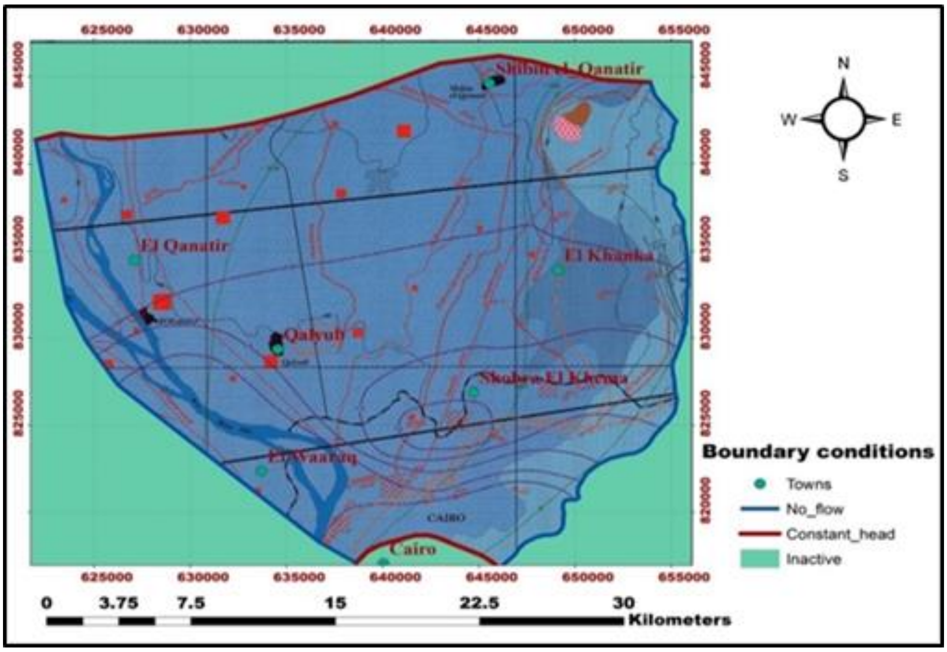

Fig. 5. Boundary conditions drawn on hydrogeological map.

The initial input hydraulic parameters to the model area as horizontal (K_h) and vertical (K_v) hydraulic conductivities are summarized in Table 2. The net recharge range is between 25 to 350 mm/year [18, 27]. These values are used as input data for model layers.

Table 2 Model layers hydraulic parameters.

Hydraulic Units	Layer	K_h, m/day	K_v, m/day
Clay cap	1	0.15-0.4	0.015-0.04
Graded Sand and Gravel (L*)	1	35-40	3.5-4.0
Graded Sand and Gravel (L*)	2	60	6
Graded Sand and Gravel (H**)	2	70-95	7-10

*L: low productivity aquifer **H: high productivity aquifer

The calibration approach of the model is based on the simulation of the real situation of flow system in the aquifer while achieving minimum error between the model results and the real situation. The difference between the maximum and minimum head values in the study area is 5 m, and the permissible limit of error is set to be less than 10% (i.e. 0.5 m).

A calibration step is performed to identify the main parameters that control the aquifer flow system by several trials and error. Calibration is applied using ten observing wells covering the study area. Calibrated case shows that the parameters are with minimum acceptable errors R.M.S.= 0.246 with correlation coefficient 0.983 as shown in Fig. 6, and minimum difference between calculated and observed head is 0.025 m and the maximum difference is 0.462 m.

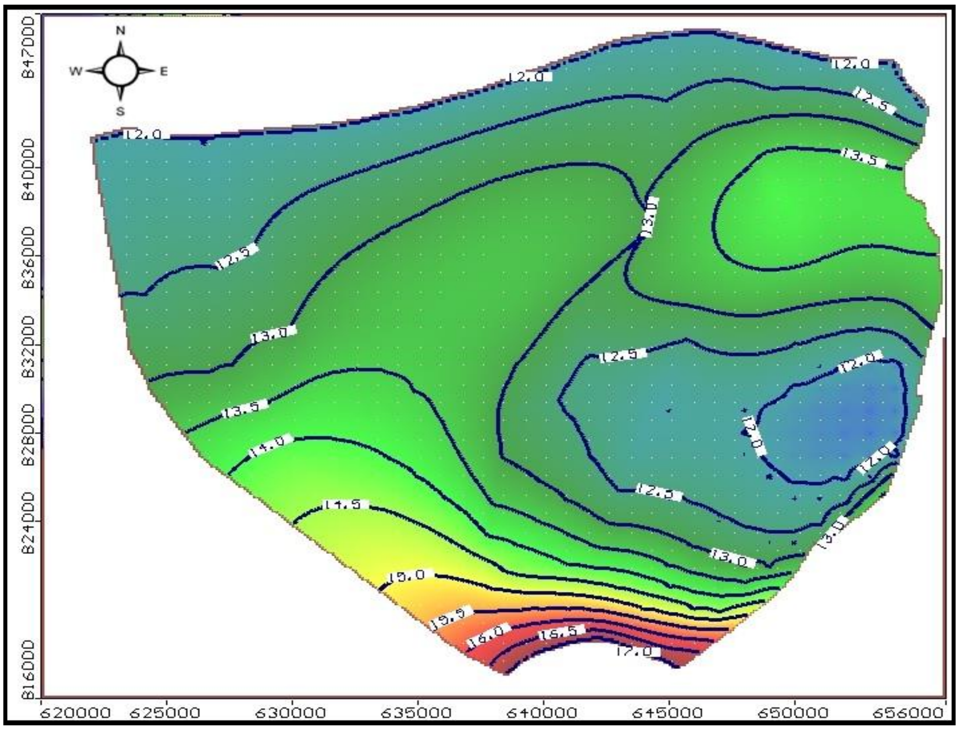

Fig. 6. Calculated calibrated piezometric heads.

The calibrated model describes the performance of the water balance, the flow system and the source of groundwater supply, this is presented in Table 3. The inflow is represented as the Nile River leakage and the recharge from water streams (canals and drains). The outflow from the model is presented as the abstraction from the aquifer through production wells, outflow through model boundary and the river suction from the aquifer in some parts when water table in the river is below the groundwater level in the aquifer. The permissible error is set to not exceed 1% of the total inflow. Calibrated water balance difference between inflow and outflow is 5888.09 m^3/d representing an error of 1 %.

Table 3. Calibrated water balance components, m^3/day.

Water Balance	Inflow (+)	Outflow (-)	Inflow - Outflow
Recharge	513265.8	0	513265.80
Production Wells	0	249200	-249200
River leakage	21532.35	225779	-204246.65
Constant head	43083.14	97014.2	-53931.06
Total	577881.3	571993.2	5888.09

In the current study, the MODPATH engine is used to simulate particle tracking and contaminate migration direction within the flow field. MODPATH is a molecular post processing tracking program designed to work with the U.S. Geological Survey's finite difference flow groundwater model widely known as MODFLOW [24]. In general, numerical schemes can be divided in two categories, i.e., Eulerian and Lagrangian methods. The first method depends on finite element and finite difference methods for solving solute transport equations while the other depends on simulating the motion of solute particles in the flow field [28, 29]. MT3DMS engine is used to simulate three dimensional transient solute contaminant transport and predict its future concentrations in the groundwater aquifer system at different times using concentrations of selected surface water parameters. MT3DMS depends on the application of mixed Eulerian-Lagrangian methods for solving the solute transport equation [29] as shown in Eq. (1). The Lagrangian method is used for solving the advection term whereas the Eulerian method is used for solving the dispersion and chemical reaction terms.

$$\frac{\partial \mathrm{C}}{\partial \mathrm{t}} = \frac{\partial}{\partial \mathrm{xi}}\left(\mathrm{Dij}\frac{\partial \mathrm{C}}{\partial \mathrm{xj}}\right) - \frac{\partial}{\partial \mathrm{xi}}(\mathrm{viC}) + \frac{\mathrm{qs}}{\theta}\mathrm{Cs} + \sum_{\mathrm{k}=1}^{\mathrm{N}} \mathrm{R_K}\frac{\partial C}{\partial t} = \frac{\partial}{\partial xi}\left(Dij\frac{\partial C}{\partial xj}\right) - \frac{\partial}{\partial xi}(viC) + \frac{qs}{\theta}Cs + \sum_{k=1}^{N} Rk \quad (1)$$

Where: C is the concentration of pollutants in groundwater sample (ML^{-3}), t is time (T), X is the distance along coordinate axis in horizontal direction (L), D_{ij} is the hydrodynamic coefficient of dispersion (L^2T^{-1}), v_i is the seepage or linear pore water velocity (LT^{-1}), q_s is the volumetric flux of water per unit volume of aquifer, C_s is source/sink concentration (ML^{-3}), θ is the medium's porosity, dimensionless and $\sum_{k=1}^{N} Rk$ is a chemical reaction term ($ML^{-3}T^{-1}$).

3. RESULTS AND DISCUSSION

3.1 Current Water Quality Assessment

Results indicate a direct relation between contaminants concentration in both surface and groundwater as shown in Fig. 7. As the concentration of any parameter in surface water increases, its concentration in the nearby groundwater sample increases.

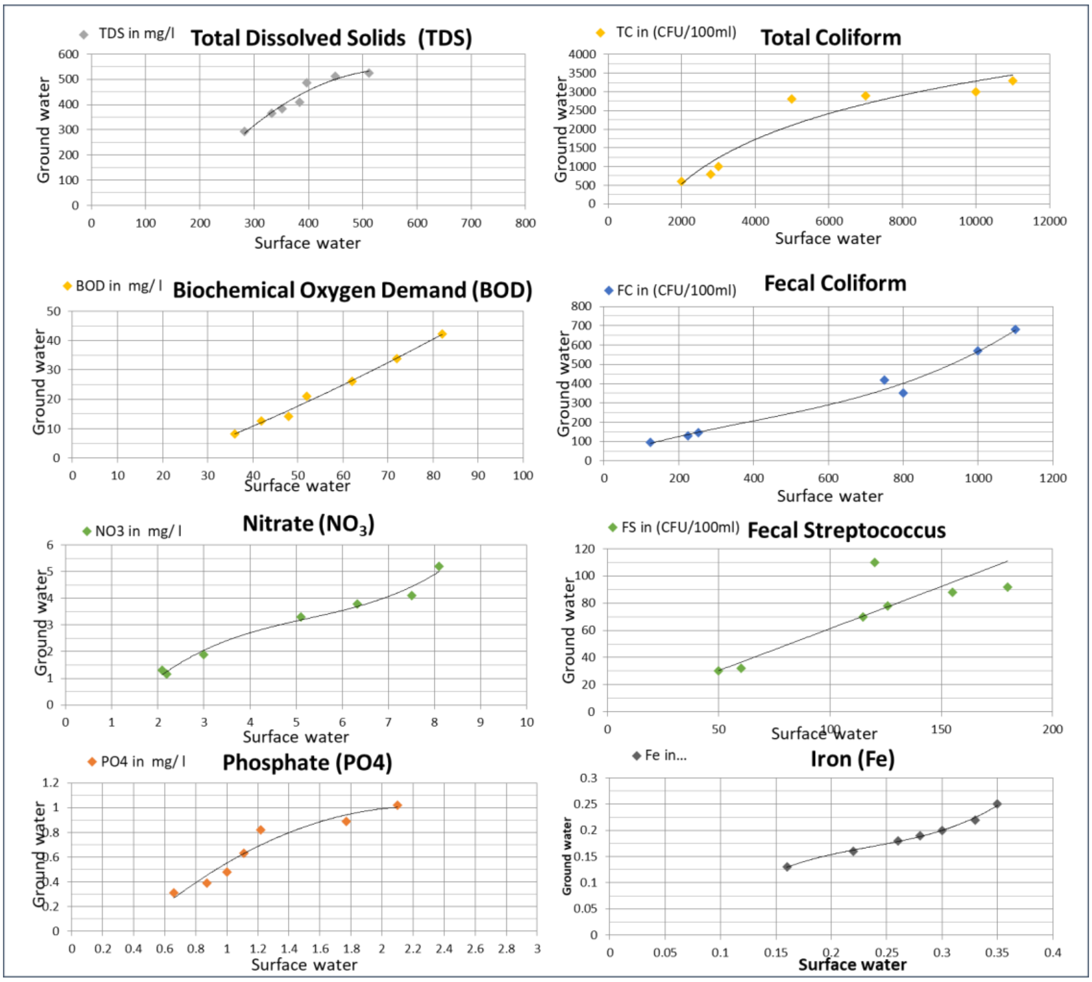

Fig. 7. Correlation between surface and groundwater results.

For TDS, BOD and PO_4 the correlation can be presented by second order polynomial functions with coefficients of determination of R^2=0.9458, 0.9904 and 0.935 respectively. Nitrates and FC are presented by third order polynomial functions with coefficients of determination of R^2=0.9835 and 0.9833, respectively. TC is presented by a logarithmic function with coefficients of determination of R^2=0.9067 while FS is presented by a power function with coefficients of determination of R^2=0.8637. For trace elements the correlation can be presented by third order polynomial functions with coefficients of determination of R^2=0.9955, 0.9776, 0.9978 and 0.9659 for Fe, Mn, Cd and Zn respectively.

Surface and groundwater samples are analyzed and the results are shown in Table 4 for chemical parameters and Table 5 for bacteriological parameters. The results indicated that:

- Surface water samples SW1 and SW2, taken from Bilibas El-Qebly and Bilibas drains, receiving industrial wastes showed the presence of relatively high content of trace elements (Fe, Mn, Cd, and Zn) which emphasizes the industrial contamination according to [30] especially for values exceeding the natural water concentration range (0-10 μg/l). This is evident in both surface and groundwater samples near El-Khanka industrial zone, which affected the groundwater quality in the nearby irrigation wells (GW1 and GW2).
- Groundwater samples taken from GW3 showed the least concentrations of bacteriological, nutrient and trace elements parameters as it is affected by the nearby good water quality of Ismailia Canal (SW3).
- Surface water samples taken from the local collectors drains (SW4 and SW5) showed the highest bacteriological (BOD and Total Coliform) and nutrients (NO_3 and PO_4) concentrations. This complies with the fact that these collectors are receiving untreated domestic wastewater as well as excess agricultural drainage water rich in chemical fertilizers. As a result, the nearby groundwater samples (GW4 and GW5) also showed the highest bacteriological and nutrient contamination.
- Surface water samples taken from the local collectors drains (SW6 and SW7) receiving only excess irrigation water showed only elevated concentration values of

NO3. This also affected the water quality in the nearby irrigation wells (GW6 and GW7).

- TDS values are higher in groundwater samples. This is expected as seepage water dissolves soil minerals during its migration from the surface water source to the nearby aquifer.

Table 4. Concentrations of organic, nutrients and trace elements, mg/l.

ID	BOD	NO_3	PO_4	Fe	Mn	Cd	Zn	TDS
SW1	62	6.32	1.22	0.35	0.35	0.017	0.112	384
GW1	26.2	3.8	0.82	0.25	0.21	0.012	0.096	410
SW2	52	2.1	1	0.33	0.37	0.015	0.101	450
GW2	21	1.3	0.48	0.22	0.26	0.011	0.082	512
SW3	36	2.2	0.87	0.16	0.14	0.006	0.062	282
GW3	8.2	1.16	0.39	0.13	0.10	0.004	0.053	294
SW4	72	8.1	1.77	0.3	0.28	0.015	0.09	397
GW4	33.8	5.2	0.89	0.2	0.20	0.011	0.070	486
SW5	82	7.5	2.1	0.28	0.39	0.015	0.08	512
GW5	42.2	4.1	1.02	0.19	0.27	0.010	0.062	525
SW6	48	5.1	0.66	0.26	0.31	0.011	0.066	333
GW6	14.11	3.3	0.31	0.18	0.21	0.009	0.045	365
SW7	42	3	1.11	0.22	0.16	0.008	0.072	352
GW7	12.6	1.9	0.63	0.16	0.10	0.006	0.058	384
Drinking limit*	--	45	--	0.3	0.4	0.003	3	1000
Irrigation limit**	classA:15 classB:30 classC:80	10 ***	30 2 ***	5	0.2	0.01	5	2000

* Decree of Egyptian Ministry of Health (EMH-458, 2007) *** FAO (2013)
** Egyptian Code for reuse of wastewater in irrigation (ECP-501, 2015) -- No available limit

- The number of Total Fecal Coliform (TC) bacteria concentration values are high in groundwater and surface water, which indicates domestic and agricultural pollution sources.
- The bacteriological results indicate that both surface and groundwater are affected by pollution from human and animal sources.

- Fecal coliform/Fecal Streptococcus ratio (FC/FS) is suggested to indicate the possible source of pollution [31]; FC/FS ratio exceeding 4 indicates human wastes sources whereas a FC/FS ratio from 0.1-4 indicates possible animal wastes source. Groundwater samples (GW4, GW5, and GW7) have FC/FS ratios that exceed 4 indicating that these wells are affected by untreated domestic wastewater. For the rest of groundwater samples, the FC/FS ratios are between 0.4-2 indicating the pollution from animal wastes sources [32].

Table 5. Bacteriological results of surface and groundwater samples (CFU/100ml).

ID	Total Coliform (TC)	Fecal Coliform (FC)	Fecal Streptococcus (FS)	(FC/FS)
SW1	5000	800	155	5.16
GW1	2800	350	88	3.98
SW2	7000	750	180	4.17
GW2	2900	42	92	0.46
SW3	2000	124	50	2.48
GW3	600	96	30.2	3.18
SW4	10000	2000	120	16.67
GW4	3000	570	110	5.18
SW5	11000	1100	126	8.73
GW5	3300	680	78	8.72
SW6	3000	252	115	2.19
GW6	1000	145	70	2.07
SW7	2800	224	60	3.73
GW7	800	130	32	4.06

3.2 Suitability of Groundwater for Drinking and Irrigation Purposes

Results of water quality analysis of surface and groundwater samples presented in Table 4 indicate the presence relatively low content of TDS and nutrients concentration (NO_3 and PO_4) compared to the permissible limits for drinking and irrigation. Fe concentrations are within the natural concentrations in groundwater samples that are suitable for irrigation. However, Mn concentrations in most samples exceed the permissible limits for water use in irrigation (0.2 mg/l) as suggested by [22, 23]. Also, in most samples, the permissible limits of Cd for use in irrigation (0.01 mg/l) is also exceeded according to [22, 23]**.**

For total coliform, the water is not suitable for drinking purposes without pretreatment as measured parameters are exceeding their permissible limits (0 CFU/100 ml) according to Egyptian and WHO standards. Regarding the bacteriological quality of the groundwater and according to the Egyptian regulations for treated wastewater reuse in irrigation [22]; groundwater quality in different samples can be classified as the following:

- Class A (BOD less than 15 mg/l) for samples (GW3, GW6, and GW7): suitable for fruit Crops (eaten without peeling) and green landscapes in educational and recreational facilities.
- Class B (BOD less than 30 mg/l) for samples (GW1 and GW2): suitable for irrigation of any kind of crops which do not come in direct contact with water (fruits as lemon, olives, palms), crops that are normally eaten after cooking (as potatoes, eggplants, etc.), crops the peels of which are not eaten (melons, watermelons, citrus, bananas, nuts, groundnuts) or medical plants. Farmers should be warned of adverse health effects resulting from direct contact with water of this class.
- Class C (BOD more than 30 mg/l) for samples (GW4 and GW5): only suitable for certain types of crops including fiber crops (Linen, Cotton, etc.), flowers, berries for silk production, roads planting and others.

3.3 Prediction of Groundwater Quality

As presented earlier, the MODFLOW 2000 engine is used to simulate steady state groundwater flow. The model is calibrated and water balance in the study area is performed. Then the MODPATH engine is used to simulate particle tracking and contaminate migration direction on the flow field obtained from MODFLOW 2000. The obtained results of particle tracking using the MODPATH model show the contaminate migration by percolation with the flow from the ground surface to the aquifer. Figure 8 shows a section view for the path lines migration from the surface to the aquifer system for some wells.

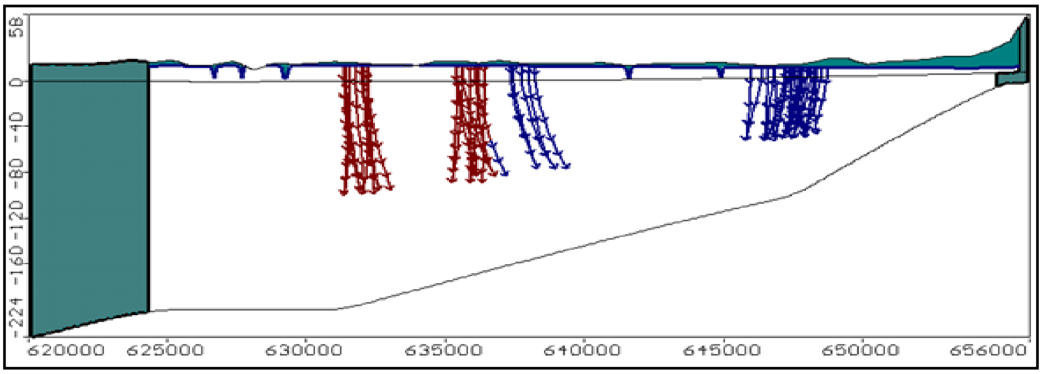

Fig. 8. Cross section for path lines migration through aquifer layer.

To predict the future impact of continued surface pollutant on groundwater quality, the MT3DMS solute contaminant transport model is used. The predicted concentrations of the selected water quality parameters after 50 years are summarized in Table 6. These concentrations are the result of the pollutants migrating from surface water sources only i.e. not taking into account the direct infiltration of pollutants from upper soil layers or current pollutants concentrations in the wells.

Table 6. Predicted groundwater quality parameters concentrations.

Parameter	GW1	GW2	GW3	GW4	GW5	GW6	GW7	%Increase
NO_3	7.8	2.8	2.56	11.2	10	7.3	4.2	105-143
PO_4	1.57	1.26	0.94	2.19	2.62	0.82	1.48	91-164
Fe	0.42	0.445	0.23	0.5	0.46	0.355	0.41	68-156
Mn	0.42	0.54	0.2	0.41	0.57	0.46	0.22	100-120
Cd	0.02	0.019	0.012	0.0155	0.025	0.0167	0.018	40-200
Zn	0.166	0.151	0.093	0.145	0.11	0.115	0.118	72-155
TDS	660	812	444	811	925	640	659	51-76

The prediction of groundwater parameters concentrations was performed taking into account that these values only represent the effect of surface water pollutants ignoring other potential sources of onsite contamination. The results indicated that the groundwater quality is worst in wells near drains receiving different types of inadequately treated effluents from domestic and industrial sources as well as excess irrigation effluents (GW4 and GW5). These wells exceed the permissible limits for water use in irrigation for nitrates, Mn and Cd concentrations. Also, the percentage increase in nutrients ranged from 105 to 143% for nitrates and from 91 to 164% for phosphate. GW7 showed the highest percentage increase for trace elements in spite of having the least initial values. This can be attributed to the high hydraulic conductivity of soil at GW7 location compared to other wells. Whereas TDS showed the least percentage increase ranging from 51 to 76%. It can also be noticed that the presence of surface water canals has positive effects on reducing groundwater deterioration and this is clear from GW3 results. Finally, at the well site, the concentration of pollutants is higher in the upper layers of the soil and decrease in the lower layers. Figures 9 and 10 present the predicted concentrations of TDS and NO_3, respectively.

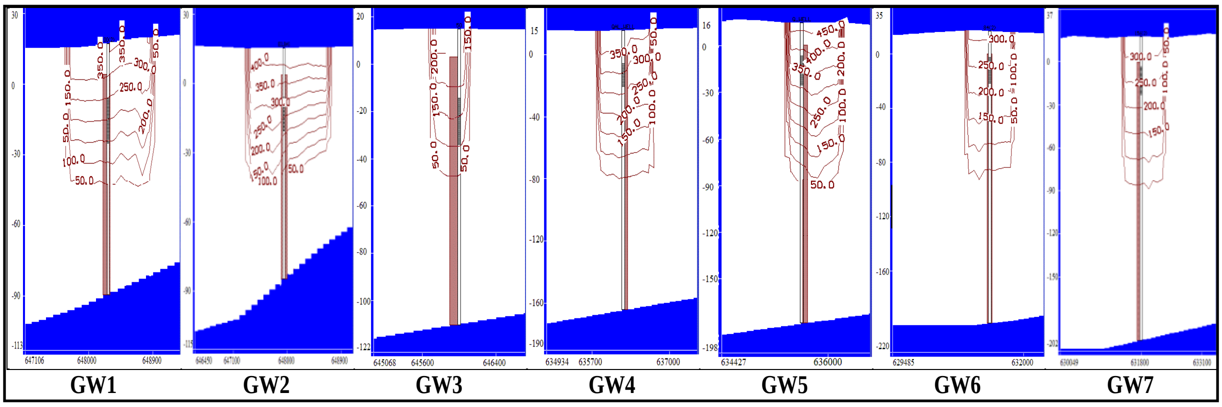

Fig. 9. Predicted TDS concentrations in wells after 50 years.

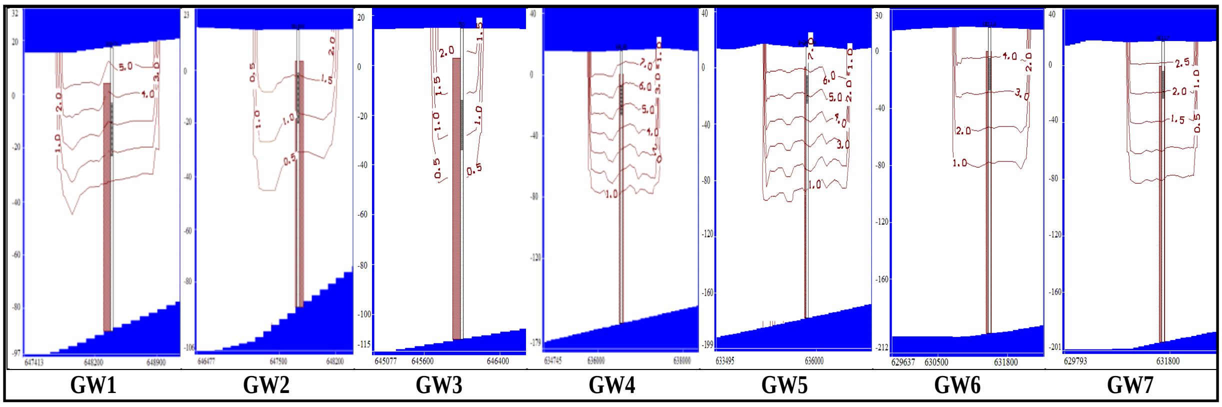

Fig. 10. Predicted NO_3 concentrations in wells after 50 years.

4. CONCLUSIONS

From the discussed results, the influence of surface water quality on groundwater quality is emphasized. Results showed the strong correlation between surface water pollutants and nearby groundwater quality indicating their potential seepage from surface water to the groundwater. The clay cap thickness plays an important role in hindering the contaminants transport. This is evident from comparing contaminants levels in GW1 (with least clay cap thickness) to GW7 (with the largest clay cap thickness). Also, the presence of surface water canals with accepted water quality helps in reducing the impact of polluted drains on groundwater. To the contrary, drains receiving inadequately treated domestic, agricultural and industrial effluents can adversely affect the quality of nearby aquifers. Results indicated the unsuitability of groundwater in the study area for drinking purposes due to fecal contamination. Also, groundwater samples indicated variable BOD concentrations suitable for certain restricted irrigation application use. The results of this study also emphasizes that monitoring surface water quality is a priority in implementing sustainable strategies for the protection and conservation of groundwater. Numerical modelling forms the basis to improve study area environmental management by better understanding of water flow transport and pollutants migration.

DECLARATION OF CONFLICT OF INTERESTS

The authors have declared no conflict of interests.

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التنبؤ بتأثير وتقييم جودة المياه السطحية على المياه الجوفية بالقليوبية، مصر

تعتبر جودة المياه الجوفية من القضايا الهامة التي يجب أخذها في الاعتبار للوصول للإدارة البيئية الفعالة لمورد المياه الجوفية. ولهذا فإن الهدف من هذه الدراسة هو تقييم تأثير جودة المياه السطحية على جودة المياه الجوفية بالآبار الضحلة في محافظة القليوبية. هذا وقد تم تجميع عينات المياه من القنوات والمصارف وآبار الري الموزعة في منطقة الدراسة وتحليلها بكتريولوجيا والمغذيات والعناصر الثقيلة. تم إعداد نموذج رياضي لمحاكاة نظام سريان المياه الجوفية في منطقة الدراسة باستخدام برنامج Visual MODFLOW وأيضًا للتنبؤ بالتأثير طويل المدى للملوثات السطحية على جودة المياه الجوفية. وقد اتضح من تقييم جودة المياه الجوفية والسطحية وجود ملوثات نتيجة الأنشطة المنزلية والصناعية والزراعية وذلك نتيجة لعدم وجود أنظمة معالجة للصرف الصحي والتخلص من المياه العادمة المنزلية والصناعية في المصارف الزراعية المحيطة. وأوضحت النتائج أهمية طبقة الطين العلوية وتأثيرها على الحد من انتقال الملوثات. كما أظهرت النتائج أنه في حالة استمرار تلوث المياه السطحية بالمعدل الحالي، فلن تكون المياه الجوفية مناسبة لأغراض الري المستقبلية في منطقة الدراسة وستكون المعالجة المسبقة ضرورية قبل استخدامها.