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Development of Hydro geological Conceptual Model (Him) To Manage Groundwater Resources in Wade El-Tumult Using Remote Sensing and GIs Technique

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Abstract : *The study area is approximately enclosed between latitudes 30^o 30$^/$& 30^o 40$^/$ N and longitudes 31^o 30$^/$& 32^o 00$^/$ E. Wadi El-Tumilat is an East-West elongated depression of 52 km length and 7 km width with total area of 364 km^{2}extending from El-Abbasa to Ismailia, Egypt. It is located at the eastern part of Nile River Delta. A hydrogeologic conceptual model (HCM) is a qualitative framework upon which data related to hydrogeologic settings can be considered. The basic components of a conceptual model are the sources of water to the study area and sinks of water from the study area, the physical boundaries of the region, the groundwater flow and solute-transport parameters, and the distribution of hydraulic properties within the study area. Consequently, a HCM allows for general conclusions regarding the effects of aspects of the current hydrologic conditions on current groundwater flow directions. In addition, a HCM is very useful for identifying knowledge or data gaps that must be filled before a groundwater numerical model can be constructed. Therefore, the HCM is prepared for the simulation of Quaternary aquifer system in Wadi El-Tumilat area. The potentiometric surface map of Quaternary aquifer system has been constructed to ascertain the groundwater flow directions and to show the equipotential lines (Figure 5). This map can be distinguished into three major parts. In the northern part of the map, the groundwater flow direction is observed to be towards the southern direction. At the middle part of the map, the groundwater flow direction is observed to be parallel to the main course of Ismailia canal. In the southern portion, the groundwater flow is generally towards the northern direction. This may be attributed to the recharge from the groundwater aquifer system to Ismailia canal. Consequently, Ismailia canal could be currently considered as gaining stream. From more than 10 years back, the Ismailia canal had been considered as losing stream depending upon previous studies. This may be attributed to the critical water crises in Egypt which the surface water levels are slightly declined. Due to the declining of surface water level, the groundwater levels become higher than the surface water levels reflecting gaining stream conditions. In general, the hydraulic gradient is low may be attributed to the slow movement of groundwater.*

The iso-salinity distribution map shows high values at the northern parts of Ismailia canal in comparison with the southern parts due to the high density of irrigation wells with heavily pumping rates at this portion. The iso-salinity map is generally well conformable with the potentiometric-surface map. This correlation exhibits where the salinity increases gradually the hydraulic gradient. Therefore, the high values of TDS measured in some locations may be attributed to the sedimentary evaporite rocks which available in the fluvio-marine deposits.

The computations of sources and sinks of water in the wadi El-Tumilat area are determined the total sources of water is equal to 10824857 ***m^3/d, the*** *total sinks of water is equal to 448382* ***m^3/d****, and the net groundwater inflow into the area cross the boundary is equal to 10376475* ***m^3/d****. These recharge/discharge estimations are comfortable with the interpretation of potentiometric surface map. The net groundwater inflow is discharged as groundwater base flow to the Ismailia canal and the available drains in the study area. The increase of groundwater recharge and the lower depth of groundwater levels at some locations exhibit as water logged area at Wadi el-Tumilat. There is no sea water intrusion from the Suez Canal may be attributed to the increase of groundwater inflow against the progress of intrusion in the study area. To develop the HCM, Wadi El-Tumilat is subdivided into two parts, i.e. the northern and southern parts of Wadi El-Tumilat due to the presence of Ismailia freshwater canal dividing the catchement area of wadi El-Tumilat into two hydrological parts. In the northern part of wadi el-tumilat, the aquifer boundaries and finite-difference grid are constructed (Fig.). The aquifer domain is subdivided into a finite-difference grid of 52 columns and 4 rows. The cell dimensions are 1000m * 700m. Ismailia fresh water canal is represented as specific-head (CHD) boundary with Dirichlet conditions. The northern aquifer boundary is treated as recharge boundary due to the directions of groundwater flow with Neumann conditions. The eastern and western aquifer boundaries are represented no-flow boundaries due to the directions of flow lines parallel to these boundaries. In the southern part of wadi el-tumilat, the aquifer boundaries and finite-difference grid are constructed (Fig.). The aquifer domain is subdivided into a finite-difference grid of 52 columns and 6 rows. The cell dimensions are 100m * 50m. Ismailia fresh water canal is represented as specific-head (CHD) boundary with Dirichlet conditions. The southern* *aquifer boundary is treated as recharge boundary due to the directions of groundwater flow with Neumann conditions. The eastern and western aquifer boundaries are represented no-flow boundaries due to the directions of flow lines parallel to these boundaries.*

Keywords: *hydrogeological conceptual model, groundwater resources, GIS.*

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I. Introduction

Watershed management implies prudent application of all the natural resources to ensure optimum and sustained productivity. Particularly, concern about widespread soil degradation and scarce, poorly managed groundwater resources in Quaternary aquifer system of wadi El-Tumilat area. The present study area has led to the implementation of watershed management activities. Consequently, development of hydrogeological conceptual model to manage groundwater resources assumes importance and holds the promise of making watershed management simpler and more effective. A groundwater conceptual model is a mostly qualitative approach and often pictorial description of the groundwater system, including a delineation of the hydrogeologic aquifers, the system boundaries, sources and sinks of groundwater, and a description of the soils and rocks and their hydraulic properties. Therefore, the hydrogeologic conceptual model (HCM) is built for understanding the system of groundwater flow and solute transport in the aquifer system, in addition, to can be used as input data for the groundwater numerical modeling technique.

Formulation of proper management plans requires reliable and up-to-date information about various factors such as topography, hydraulic-head, hydrostratigraphy, soil and their characteristics, hydraulic parameters, model boundaries and model grid, land use and land cover etc., that affect the behavior of a watershed. Further, it is necessary to convert the watershed ecosystem dynamics into predictive statements for the analysis of different spatial information. However, the hydrogeological conceptual models are simplified, conceptual representations of a part of the hydrological, hydrogeological and hydrogeochemical characteristics within given geological strata and the aquifer system. Development of reasonable hydrogeologic conceptual models is an integral step in any hydrologeological study. Generally, a hydrogeologic conceptual model is defined as an overall understanding and description of the characteristics and dynamics of the hydrogeologic system based on an interpretation of the available data. This research work presents valuable input data from a multi-level monitoring and sampling system at the study area to provide information on the all parameters of the hydrogeologic framework that serves as the basis for modeling groundwater flow systems and associated solute transport. From a hydrogeologic perspective, the hydrogeologic conceptual model incorporates many forms of information and relevant data including: geologic maps and geological cross sections, topographic maps using digital elevation model (DEM), potentiometric head data, surface water and groundwater quality data, hydraulic properties data, meteorological and hydrological records, information and data from previous studies and field work, well monitoring and water sampling, and available well construction, lithologic logs and pumping test data.

Satellite based remote sensing technology meets both the requirements of reliability and speed and is an ideal tool for generating spatial information needs. However, the use of remote sensing technology involves large amount of spatial data management and requires an efficient system to handle such data. The Geographical Information Systems (GIS) technology provides suitable alternatives for efficient management of large and complex databases. Thus, blending of remote sensing and GIS technologies has proved to be an efficient tool and have been successfully used by various investigators for water resources development and management projects as well as for watershed characterization and prioritization. Thus, it is generally accepted that sustainable land and water management must be approached with the watershed as the basic management unit.

II. Materials and methods

Groundwater management is mainly based on proper characterization of hydrogeological parameters. In the present study, the collection of previous studies relevant to this study has been done. The materials and methods will discuss in the following depending upon the different HCM parameters.

Location of the study area

The study area is approximately enclosed between latitudes $30^o\ 30^/$& $30^o\ 40^/$ N and longitudes $31^o\ 30^/$& $32^o\ 00^/$ E. Wadi El-Tumilat is an East-West elongated depression of 52 km length and 7 km width with total area of 364 km^2extending from El-Abbasa to Ismailia, Egypt. It is located at the eastern part of Nile River Delta as Shown in Fig. (1).

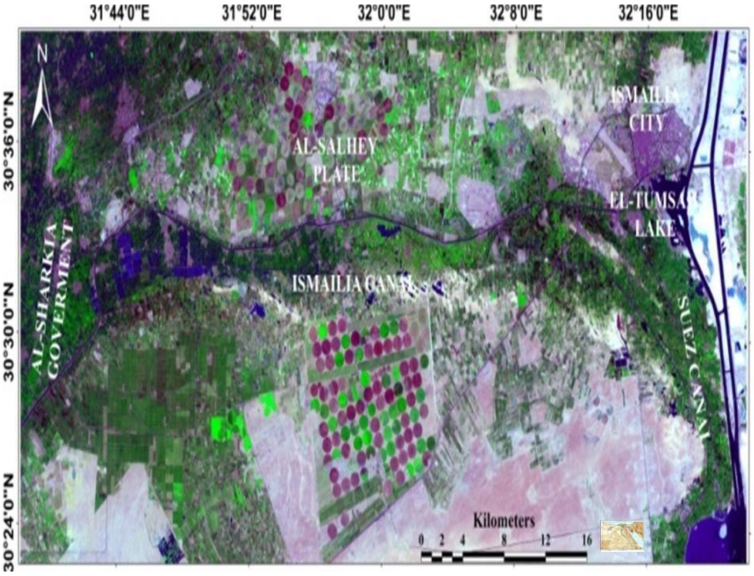


Fig. (1) locationmap of the study area.

Climate:

The meteorological data considers as important parameter for the preparation of the HCM. The study area is characterized by arid climatic conditions denominated by long hot, rainless summer and mild winter. The average monthly mean climatic parameters; rain fall; maximum and minimum temperature; evaporation and relative humidity are collected from five meteorological stations well distributed all over the study area. The considered stations are Ismailia, Port Said, El-Arish, Suez and Cairo stations.

The data collected are two periods (long, short), in the short term they were between 1 - 2017 to 12 - 2017. While the long-term collected during the period from 2009 to 2017. The average annual precipitation reaches about 30.6 mm. Most of this precipitation occurs with low intensities during the months from May to October. The frequency of the rainstorms varies between three and seven times a year with intensities varying between 0.2 and 11.8 mm/each storm event. The average annual minimum and maximum temperatures are – and - , respectively. The average annual evaporation is – mm. The average annual relative humidity is – mm.

Topography and geomorphology:

Geomorphologically, the study area could be classified as a low land area along its middle portions and a moderate undulated relief along its peripheries. The middle portions are characterized by low relief topography with several micro-depressions and terraces along the main course of Wadi El-Tumilat old valley and bounded by sand hills along its northern and southern boundaries.

The northern boundary is relatively high. It is represented by gravely plains and extended in a longitudinal form parallel to the main course of Wadi El-Tumilat depression. However, small hills of sand dunes and shale patches are located at many parts of this plain. Soils in the plain are characterized by fine texture and are particularly susceptible to water logging due to its low hydraulic conductivity.

Because of the topographic relief is one of the most significant factor that has direct relation with the logged sites, the first step of the present work was planned to prepare digital elevation models for the two main sectors of the study area as in Fig(2). These digital elevation models (DEM) are setup as grid pattern nodes representing the spatial distribution of ground elevation above the mean sea level. These maps help greatly in allocating the distributions of high and low areas which are the most susceptible locations for recharge and discharge sources.

In general, the proposal study area is delineated by Wadi El-Tumilat representing an old buried branch of the ancestral Nile River and most of this branch is occupied by Ismailia Fresh-water Canal. Physical and chemical weathering greatly modified the morphology of the land surfaces, especially the physical weathering due to the dominant arid conditions prevailing in the study area. Formation of desert pavement, sand dunes, and accumulation of sand drifts are common features of wind effects during the recent arid conditions in the area north of Ismailia Fresh-water Canal.

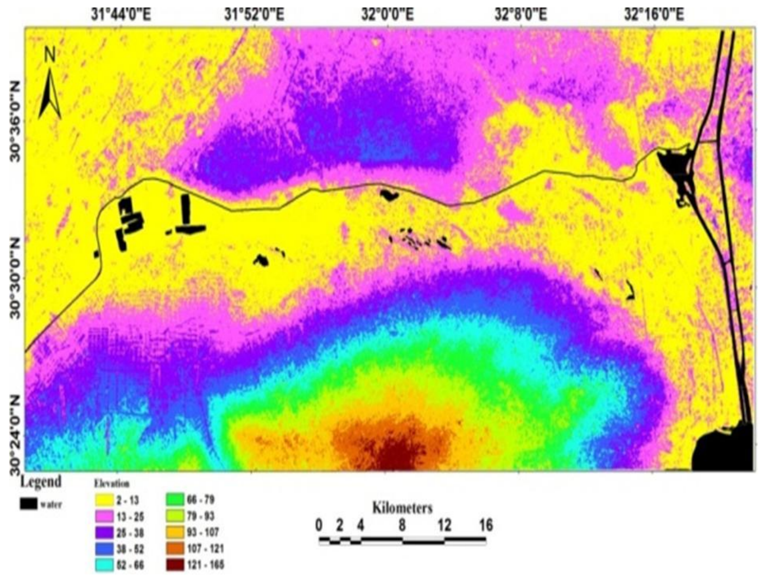
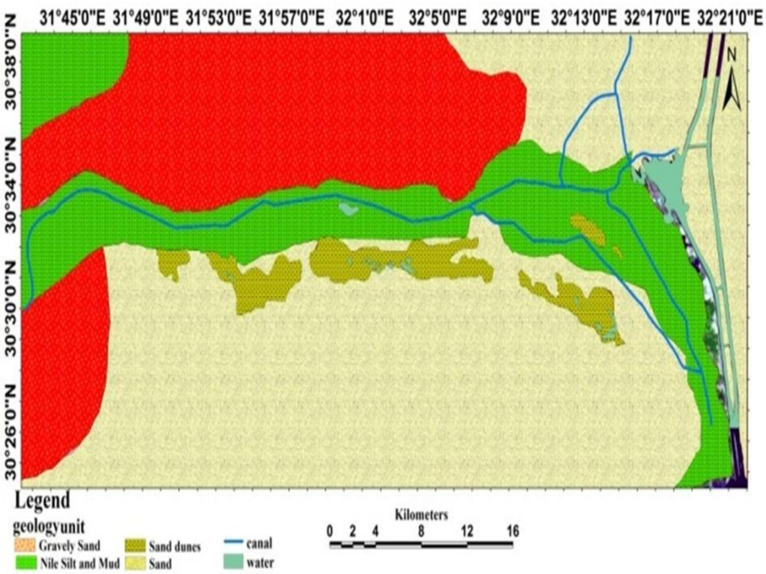


Fig (2) Topographic map of study area .

Geology

The subsurface stratigraphic section representing this wadi (Fig.3) shows that, its sediments are represented by two main stratigraphic units; the lower fluviomarine unit; and the upper flood plain unit. The lower unit extends in a lenticular form along the whole course of the Wadi with its maximum thickness at the east (about 20 m. thick) and minimum one (about 0.5 m) at the west. It overlies unconformably the gravely sand sediments of Um Gidam slopes and consists of evaporate loamy sand facies. The sediments are fine to medium grained, ill sorted, rounded to well rounded, calcareous, gypsiferous to salty and reddish to greenish grey in color (El-Shamy, 1992 and Geriesh, 1994). The grain size decreases gradually from west to east indicating a gradation process from the west. Evaporates are present as thin lenses and usually seen at the upper portions of the considered unit, especially in the eastern part of the wadi course.

The upper unit overlies unconformably the fluviomarine unit and consists of fluviatile fining upward sequences of gravely sand, sand and terminated with thick mud and silt lenses with total thickness varying between 2 and 5 m. Mud forms more than 50 % of these sequences, therefore this unit acts as semi-permeable layer and forms perched conditions along some parts of the wadi especially it eastern section. The mud is sticky, soft, showing thin uniform lamination and reddish to brownish grey color.



Fig(3). Geologic map of study area.

Hydrogeologic setting:

The monitoring program is designed to monitor the groundwater level fluctuations for one year at the periodical basis. A number of 45 groundwater monitoring wells were monitored for measuring the hydraulic-heads in the aquifer system. A groundwater level indicator (electrical sounder) was used to measure the depth to groundwater in the monitoring wells. The elevation of ground surface at the monitoring wells was also measured using the GPS. The distribution of the monitoring wells in the study area is shown in Figure 2. The available lithological logs of the monitoring wells in the study area are collected from the previous studies. These lithological data are used to prepare hydrogeologic cross sections and fence diagram throughout the study area using GMS software. The collection of previous hydrogeological information has been collected, reviewed and analyzed.

Geriesh, 1989, and El Shamy and Geriesh, 1989 and 1992 studied the groundwater of the study area. They concluded that, Surface water and groundwater are hydrologically connected systems .The quality and quantity of one is interdependent on the quality and quantity of the other. Understanding the groundwater flow system is very important for protection of surface water bodies (Toth, 1999). The hydrogeological setting of the study area is greatly affected by the Nile sedimentary processes (Said, 1981, Geriesh, 1994 and Afify, 2000). Groundwater around Ismailia Canal occurs in two main aquifer units; the upper semi-permeable unit and the lower highly permeable unit.

The upper unit is of Nioltic origin and consists of fine to medium sands with silt and clay caps of sticky characters especially to the east. The eastern part of this unit is formed under lagoon to fluviomarine conditions and is characterized by salty nature due to the high percentage of evaporation (Zoetbrood, 1984). The deposits of the western part of the study area have better hydraulic properties and could be hydrologically connected with the lower aquifer. The thickness of this unit ranges between 5 to 30 meters from west to east successively.

The deeper unit represents the main aquifer in the region. It consists of gravelly sand deposits of pure fluviatile origin and attains thickness more than 200 meters. It is composed of pure sand and gravel of high hydraulic properties and low salt contents. This aquifer is unconfined to semi-confined in the west and became confined to the east. Groundwater flow is almost from west to east and outward of Ismailia canal course. The canal acts as an influent stream in most parts. There are lots of swamps in the low lands due to seepage from Ismailia Canal. The water losses from the canal may reach as maximum as 374 million m^3/year (Geriesh, 1994 and Afify, 2000).

The deeper groundwater aquifer is characterized by good hydraulic properties; average Transmisivity is about 3000 m²/d; average hydraulic conductivity is 50 m/d and average specific yield is 0.23.(Geriesh, 1994 and Afify, 2000) stated that, the rate of seepage from Ismailia Canal is about 1m/d, but they referred that, most of the seepage water runs to El Timsah Lake through the adjacent El Mahsama Drain, giving little chance for this water to recharge the main aquifer.

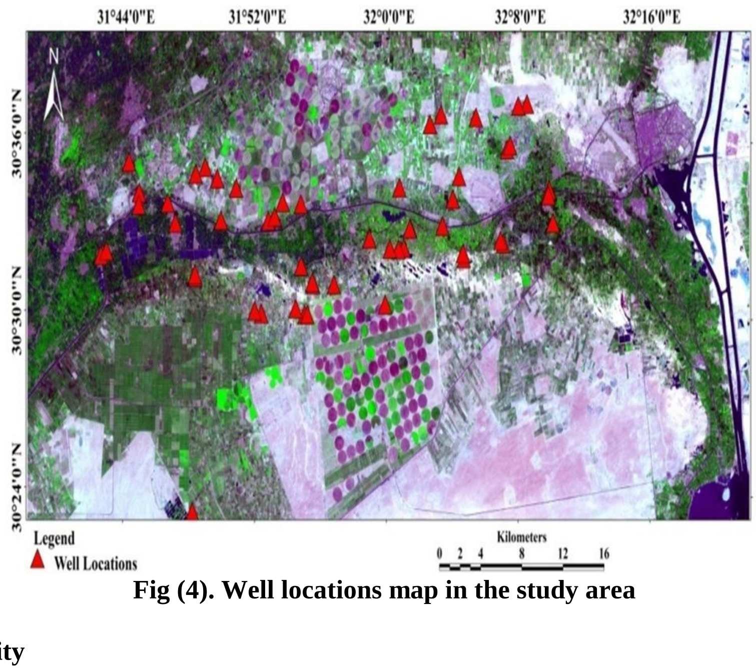


Fig (4). Well locations map in the study area

Groundwater quality

Groundwater samples were periodically collected from drilled wells during 2017. On spot measurements were made for groundwater levels, temperature, pH values and Electric conductivity (EC). As initial step, all the samples were immediately preserved in the ice tanks after their collections, and then sent to the laboratory to chemically analyze major ions and total dissolved solids. Special care has been taken to ensure that all solvents used in standard solutions and dilutions are free of the target compounds and one of the highest purity. All analytical procedures were carried out according to the Standard Methods for the examination of water and wastewater by AWWA. The analyzed chemical data for Quaternary aquifer system are shown in Figure4 and the location map of groundwater samples is shown in Figure (5).

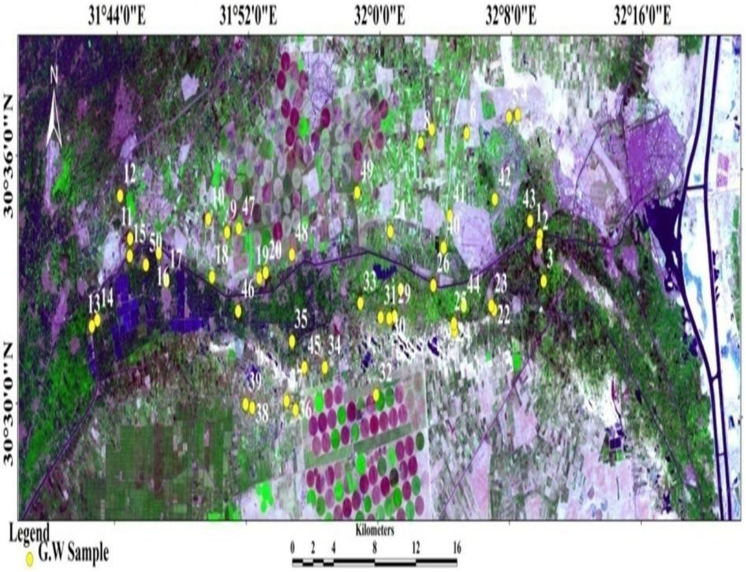


Fig (5). Sample locations map in study area

Remote sensing and GIS Technique

Remote sensing techniques were used with geographic information systems in this study. Through this technique, the study area was classified into four main categories that cover the area. These are (vegetation cover - sandy cover - urban areas - wetland areas). See figure (9)

Land use and land cover maps were created, which helped to identify the distribution of vegetation cover and sand cover as well as the urban cover and wetlands, which in turn give clear evidence of being recharge areas for the reservoir. This is the amount of irrigation pumped annually for agricultural projects, and can be considered as urban and agricultural as part of the elements of nutrition. As for Ismailia, it represents an important part of the direct recharge of the reservoir as one of the classification elements.

In terms of GIS technology, it is considered an important tool for the preparation of maps after processing, which in turn was used to produce sample distribution maps in addition to water level maps and salinity distribution maps.

III. Results and discussion

Groundwater modeling is commonly based on a hydrogeologic conceptual mode. A hydrogeologic conceptual model of groundwater-flow and solute transport is a qualitative framework upon which data related to hydrogeologic settings can be considered. The basic components of a conceptual model are the sources of water to the study area and sinks of water from the study area, the physical boundaries of the region, the groundwater flow and solute-transport parameters, and the distribution of hydraulic properties within the study area. Consequently, a HCM allows for general conclusions regarding the effects of aspects of the current hydrologic conditions on current groundwater flow directions. In addition, a HCM is very useful for identifying knowledge or data gaps that must be filled before a groundwater numerical model can be constructed.

Groundwater flow in the Quaternary aquifer system:

The potentiometric surface map of Quaternary aquifer system has been constructed to ascertain the groundwater flow directions and to show the equipotential lines (Figure 6). This map can be distinguished into three major parts. In the northern part of the map, the groundwater flow direction is observed to be towards the southern direction. At the middle part of the map, the groundwater flow direction is observed to be parallel to the main course of Ismailia canal. In the southern portion, the groundwater flow is generally towards the northern direction. This may be attributed to the recharge from the groundwater aquifer system to Ismailia canal. Consequently, Ismailia canal could be currently considered as gaining stream. From more than 10 years back, the Ismailia canal had been considered as losing stream depending upon previous studies. This may be attributed to the critical water crises in Egypt which the surface water levels are slightly declined. Due to the declining of surface water level, the groundwater levels become higher than the surface water levels reflecting gaining stream conditions. In general, the hydraulic gradient is low may be attributed to the slow movement of groundwater.

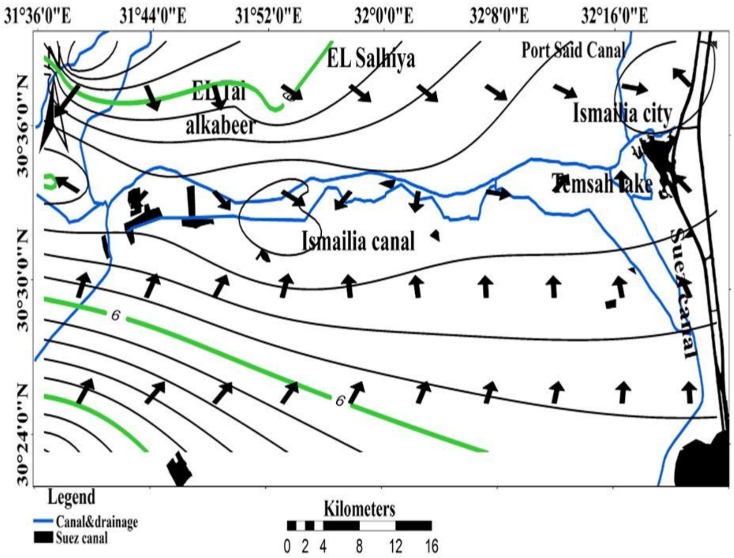


Fig (6). Potentimetric-surface map showing equipotential lines and Groundwater flow directions of the Quaternary aquifer system in the study area

Integrated groundwater quality data:

The iso-salinity distribution map of the Quaternary aquifer system in the study area has been constructed to assess the groundwater quality. The groundwater quality data is important to build a HCM which can be used to prepare the solute-transport model. TDS values are observed to abruptly increase in general far from the main course of Ismailia canal. This may be attributed to the dilution effect as a result of the mixing between surface water in Ismailia canal with TDS value equals to 500 mg/L and the groundwater with TDS values varying from 1000 to 7000 mg/L. In general, the iso-salinity distribution map shows high values at the northern parts of Ismailia canal in comparison with the southern parts due to the high density of irrigation wells with heavily pumping rates at this portion. The iso-salinity map is generally well conformable with the potentiometric-surface map. This correlation exhibits where the salinity increases gradually the hydraulic gradient. Therefore, the high values of TDS measured in some locations may be attributed to the sedimentary evaporate rocks which available in the fluvio-marine deposits.

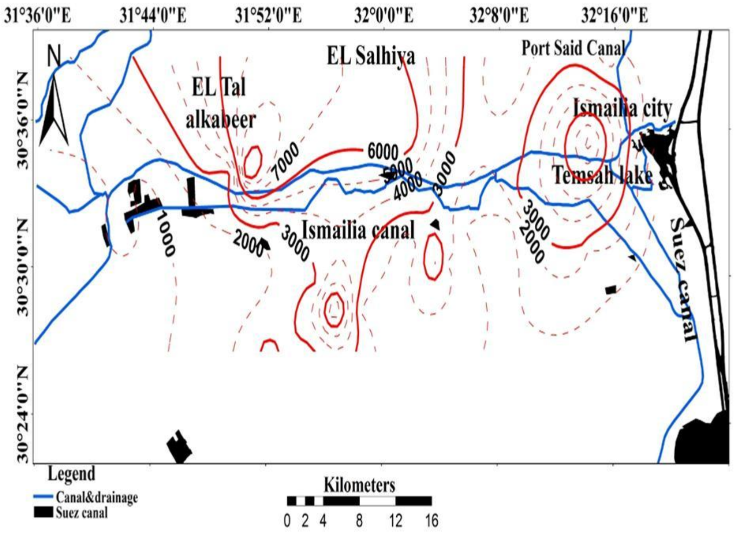


Fig (7) Iso-salinity distribution map in study area Integrated remote sensing and GIS results

A- band combination

band combination include combining multiple images into a single composite image. ENVI furnish interactive capabilities for placing non-georeferenced images within a mosaic, and automated placement of georeferenced images within a georeferenced output.

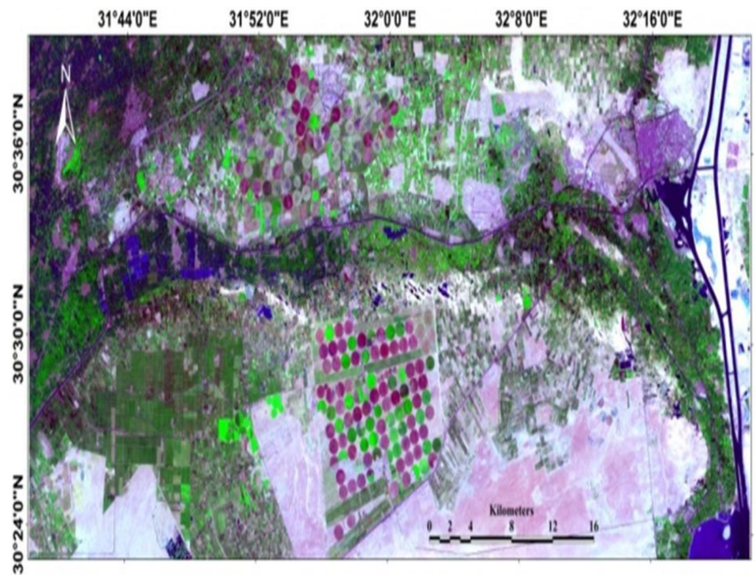


Fig (8):Band combination, RGB for OLI and TIRS Bands in year 2017.

B- classification

Unsupervised classification

Unsupervised classification was performed to classify the land covers at the study sites. 60 ground control points were checked. The number of classes was specified by hierarchical clustering.

Supervised classification

Supervised classification using the maximum probability approach has been performed. Image accuracy was estimated, it was 88%. A number of 4 classes were observed at the study sites (Fig.9) including, Nile deposits and cultivated areas with green color, surface water and witelands areas with red colour, salt crust and urban areas with blue color, sand cover with yellow color.

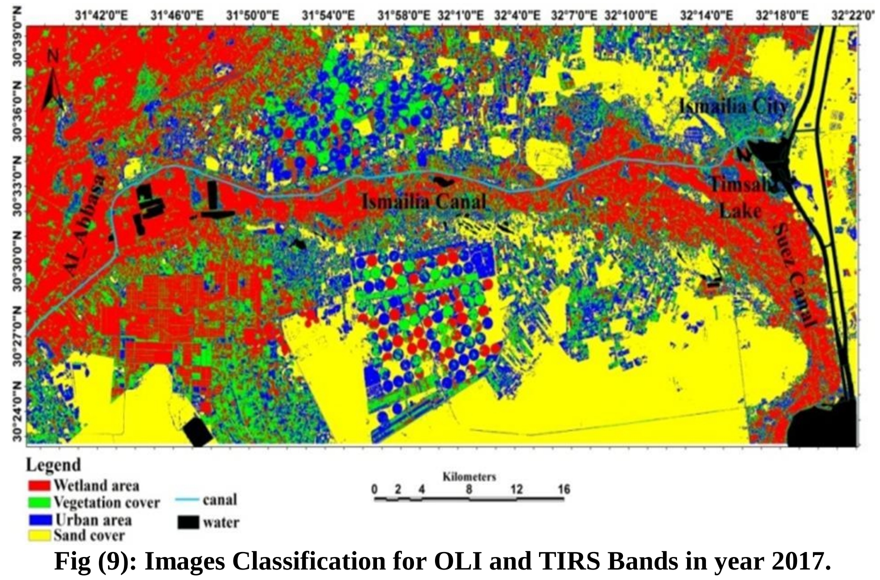


Fig (9): Images Classification for OLI and TIRS Bands in year 2017.

Hydraulic properties

The hydraulic properties of an aquifer must be defined to construct the HCM. The values of hydraulic parametersare gathered from the previous studies, lithological logs, pumping test data, laboratory measurements of hydraulic conductivity. The previous works considering the hydraulic properties of the Quaternary aquifer were collected from the published studies such as Gerish 1989, Geaish1994 ,Faruk 2003, Gerish 2007, Bassma 2011, Gad 2015, Ryes and Arnos 2013, Mogren and Shehata 2012.Then, the values of hydraulic parameters are reviewed, summarized and analyzed. The statistical mean of hydraulic parameters values are computed to apply these values in the HCM. Therefore, the table of hydraulic parameters statistical mean values is shown in Table 1.

Table 1. The mean values of hydraulic parameters in the Quaternary aquifer system in the study area.

Aquifer properties	Mean values
Hydraulic conductivity	47.65 m/d
Transmissivity	3300m^2 / d
Storativity	0.22
Groundwater Velocity	$11*10^{-3}$ m / d

Sources and Sinks of water:

The primary parameter controlling the rate and pattern of groundwater flow are quantity of water enters the aquifer system and the water withdrawal from it. Generally, sustainable water withdrawal within the aquifer system cannot exceed the amount of water that is provided to this aquifer system. The sources of water are considered as the net recharge sources to the Quaternary aquifer system including the precipitation, irrigation water, and seepage from Ismailia canal. The quantitative calculations of water sources are computed precisely, and their values are shown in Table 2. On the other hand, the sinks of water are considered as the net discharge from the aquifer system including the quantity of extraction water by the pumping wells drilled in the study area and the base flow into stream the area. To determine the sources and sinks of water, the groundwater balance equation is applied, which is stated in general terms as follows:

Input – Output = Storage increase (Eq. 1)

The water level fluctuation method is based on the application of groundwater balance equation. In the above equation, the terms input and output are generally used, referring to all components of groundwater balance, which are either input to the aquifer or output from the aquifer. Then, the water level fluctuation method is applied toestimate the groundwater recharge:

$S = RG – DG – B + Is + I$ (Eq. 2)

Where,
S = Groundwater increase,
RG = Gross recharge due to rainfall and irrigation,
DG = Gross groundwater draft,
Is = recharge from streams into groundwater system,
I = Net groundwater inflow into the area across the boundary (inflow-outflow)

Table (2) Computations of sources and sinks of water assessment in the study area.

Value/Description	Parameter	S. No.
	General	1
Egypt	Country	1.1
Ismailia	State	1.2
El-Qassasine	District	1.3
Around Ismailia Canal	Area	1.4
2017	Year of assessment	1.5
Alluvial	Predominant type of terrain	1.6
3640000	Geographical area in square meters	1.7
Block	Type of groundwater estimation unit	1.8
October to February	Rainfall season	1.9
March to September	Non-Rainfall season	1.1
	Sources/Sinks parameters	2
1024657 m^3/d	Seepage from Ismailia canal	2.1
3160000 m^3/d	Recharge from surface water and groundwater irrigation	2.2
36890000 m^3/d	Rainfall recharge	2.3
0.18	Rainfall infiltration factor as a fraction	2.4
6640200 m^3/d	Gross Rainfall recharge	2.5
7942 m^3/d	Gross Groundwater Draft (DG)	2.6
9.2 m	Hydraulic-head in rainfall season	2.7
8.1 m	Hydraulic-head in non-rainfall season	2.8
1.1 m	Groundwater level fluctuation in the study area	2.9
0.11	Specific-yield as a fraction	2.1
440440 m^3/d	Change in groundwater storage (S = h * Sy * A)	2.11

1024657 + 3160000 + 6640200 = 10824857 m^3/d	Total Sources of water (Recharge)	2.12
7942 + 440440 = 448382 m^3/d	Total Sinks of water (Discharge)	2.13
10376475 m^3/d	Net groundwater inflow into the area across the boundary (inflow-outflow)	2.14

The aforementioned computations of sources and sinks of water in the wadi El-Tumilat area are determined the total sources of water is equal to 10824857 **m^3/d, the** total sinks of water is equal to 448382 **m^3/d**, and the net groundwater inflow into the area cross the boundary is equal to 10376475 **m^3/d**. These recharge/discharge estimations are comfortable with the interpretation of potentiometric surface map. The net groundwater inflow is discharged as groundwater base flow to the Ismailia canal and the available drains in the study area. The increase of groundwater recharge and the lower depth of groundwater levels at some locations exhibit as water logged area at Wadi el-Tumilat. There is no sea water intrusion from the Suez Canal may be attributed to the increase of groundwater inflow against the progress of intrusion in the study area.

Boundaries and Grid of HCM

Groundwater modeling system (GMS) version (10.1) is used to construct the aquifer boundaries and the finite-difference grid of the hydrogeological conceptual model (HCM) in the study area.The conceptual model approach in the GMS involves using the GIS tools in the map module to develop a hydrogeologic conceptual model of the site being modeled. The location of sources/sinks, aquifer boundaries, layer parameters, and all other hydraulic properties for the simulation can be defined at the hydrogeologic conceptual model. The HCM is used as input data for preparation the numerical groundwater flow and solute-transport models. The aquifer boundaries and the finite-difference grid should be primarily constructed to define the simulation technique.

To develop the HCM, Wadi El-Tumilat is subdivided into two parts, i.e. the northern and southern parts of Wadi El-Tumilat due to the presence of Ismailia freshwater canal dividing the catchment area of wadi El-Tumilat into two hydrological parts. In the northern part of wadi el-tumilat, the aquifer boundaries and finite-difference grid are constructed (Fig.10). The aquifer domain is subdivided into a finite-difference grid of 52 columns and 4 rows. The celldimensions are 100m * 50m. Ismailia fresh water canal is represented as specific-head (CHD) boundary with Dirichlet conditions. The northern aquifer boundary is treated as recharge boundary due to the directions of groundwater flow with Neumann conditions. The eastern and western aquifer boundaries are represented no-flow boundaries due to the directions of flow lines parallel to these boundaries. In the southern part of wadi el-tumilat, the aquifer boundaries and finite-difference grid are constructed (Fig.11). The aquifer domain is subdivided into a finite-difference grid of 52 columns and 6 rows. The cell dimensions are 1000m * 700m. Ismailia fresh water canal is represented as specific-head (CHD) boundary with Dirichlet conditions. The southern aquifer boundary is treated as recharge boundary due to the directions of groundwater flow with Neumann conditions. The eastern and western aquifer boundaries are represented no-flow boundaries due to the directions of flow lines parallel to these boundaries.

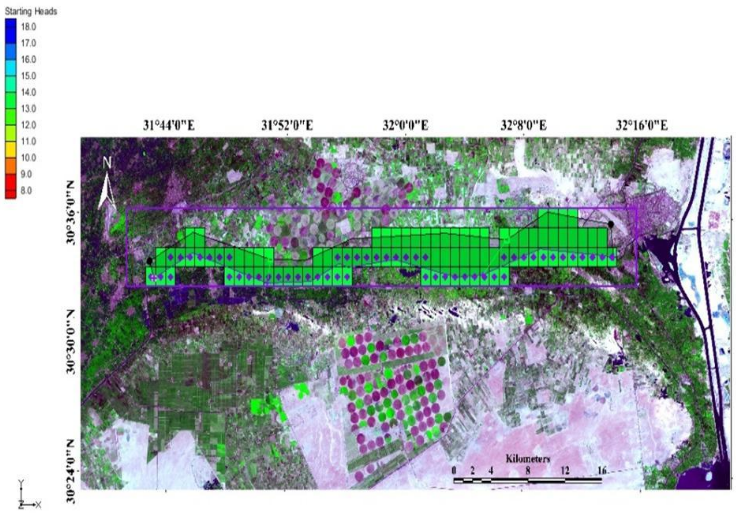


Figure (10) The aquifer boundaries and the finite difference grid of the HCM in the northern part of wadi El-Tumilat.

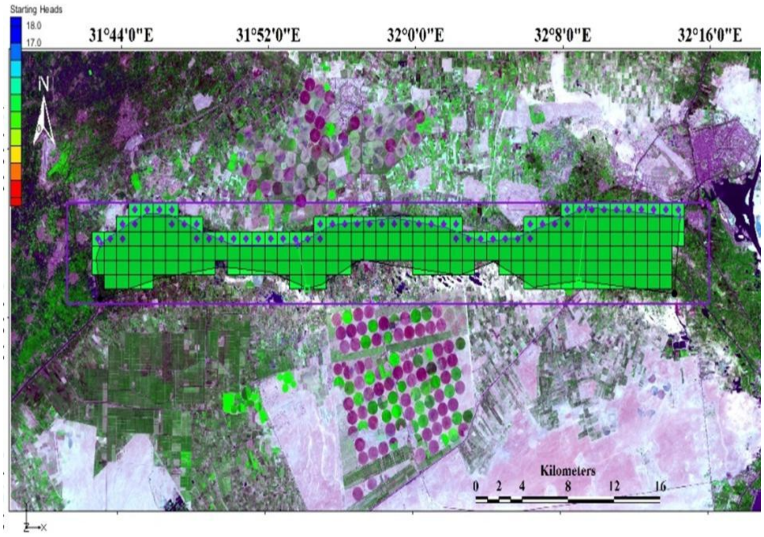


Figure (11) The aquifer boundaries and the finite difference grid of the HCM in the southern part of wadi El-Tumilat

IV. Conclusions

A hydrogeologic conceptual model (HCM) is a qualitative framework upon which data related to hydrogeologic settings can be considered. The basic components of a conceptual model are the sources of water to the study area and sinks of water from the study area, the physical boundaries of the region, the groundwater flow and solute-transport parameters, and the distribution of hydraulic properties within the study area. Consequently, a HCM allows for general conclusions regarding the effects of aspects of the current hydrologic conditions on current groundwater flow directions. In addition, a HCM is very useful for identifying knowledge or data gaps that must be filled before a groundwater numerical model can be constructed. Therefore, the HCM is prepared for the simulation of Quaternary aquifer system in Wadi El-Tumilat area. The important conclusions have been summarized in the following sections:

1. The potentiometric surface map of Quaternary aquifer system has been constructed to ascertain the groundwater flow directions and to show the equipotential lines (Figure 6). This map can be distinguished into three major parts. In the northern part of the map, the groundwater flow direction is observed to be towards the southern direction. At the middle part of the map, the groundwater flow direction is observed to be parallel to the main course of Ismailia canal. In the southern portion, the groundwater flow is generally towards the northern direction. This may be attributed to the recharge from the groundwater aquifer system to Ismailia canal. Consequently, Ismailia canal could be currently considered as gaining stream. From more than 10 years back, the Ismailia canal had been considered as losing stream depending upon previous studies. This may be attributed to the critical water crises in Egypt which the surface water levels are slightly declined. Due to the declining of surface water level, the groundwater levels become higher than the surface water levels reflecting gaining stream conditions. In general, the hydraulic gradient is low may be attributed to the slow movement of groundwater.

2. theiso-salinity distribution map shows high values at the northern parts of Ismailia canal in comparison with the southern parts due to the high density of irrigation wells with heavily pumping rates at this portion. The iso-salinity map is generally well conformable with the potentiometric-surface map. This correlation exhibits where the salinity increases gradually the hydraulic gradient. Therefore, the high values of TDS measured in some locations may be attributed to the sedimentary evaporate rocks which available in the fluvio-marine deposits.

3. The aforementioned computations of sources and sinks of water in the wadi El-Tumilat area are determined the total sources of water is equal to 10824857 **m^3/d, the** total sinks of water is equal to 448382 **m^3/d**, and the net groundwater inflow into the area cross the boundary is equal to 10376475 **m^3/d**. These recharge/discharge estimations are comfortable with the interpretation of potentiometric surface map. The net groundwater inflow is discharged as groundwater base flow to the Ismailia canal and the available drains in the study area. The increase of groundwater recharge and the lower depth of groundwater levels at some locations exhibit as water logged area at Wadi el-Tumilat. There is no sea water intrusion from the Suez Canal may be attributed to the increase of groundwater inflow against the progress of intrusion in the study area.

4. To develop the HCM, Wadi El-Tumilat is subdivided into two parts, i.e. the northern and southern parts of Wadi El-Tumilat due to the presence of Ismailia freshwater canal dividing the catchment area of wadi El-Tumilat into two hydrological parts. In the northern part of wadi el-tumilat, the aquifer boundaries and finite-difference grid are constructed (Fig.10). The aquifer domain is subdivided into a finite-difference grid of 52 columns and 4 rows. The cell dimensions are 1000m * 700m. Ismailia fresh water canal is represented as specific-head (CHD) boundary with Dirichlet conditions. The northern aquifer boundary is treated as recharge boundary due to the directions of groundwater flow with Neumann conditions. The eastern and western aquifer boundaries are represented no-flow boundaries due to the directions of flow lines parallel to these boundaries. In the southern part of wadi el-tumilat, the aquifer boundaries and finite-difference grid are constructed (Fig.11). The aquifer domain is subdivided into a finite-difference grid of 52 columns and 6 rows. The cell dimensions are 100m * 100m. Ismailia fresh water canal is represented as specific-head (CHD) boundary with Dirichlet conditions. The southern aquifer boundary is treated as recharge boundary due to the directions of groundwater flow with Neumann conditions. The eastern and western aquifer boundaries are represented no-flow boundaries due to the directions of flow lines parallel to these boundaries.

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