Management of Groundwater Reservoir in Maghagh Aquifer System Using Modeling and Remote Sensing Technique (Upper Egypt)

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Abstract

According to the rapid extension of reclamation in Maghagha area, monitoring was essential to evaluate the reclamation impacts on the groundwater potentiality. Change detection map was produced, which was reflects the change in reclaimed lands. The main objective of this work is to study the reclamation impacts on the groundwater reservoir by using the modeling and Remote Sensing Techniques. The study led to producing two land use maps for the study area in years 1988 and 2006 and consequently a change detection map for the time period between 1988 and 2006.From land use maps of the study area for year 2006, it was observed a lot of changes in development areas especially on the border of the old land. The change in land reclaimed area was estimated with 44% in the period from year 1988 to 2006.There is a change in groundwater level during the period between 1988 –2006 due to; the effect extends to the adjacent areas, and the lack of recharge. The impacts of the present and future development have been evaluated by using the two-dimensional numerical groundwater flow Simulation Package (GWSTE). The package was used to construct and calibrate a numerical model that can be used to simulate the response of the aquifer in the study area under implementing different management alternatives in the form of changes in piezometric levels and salinity.

Keywords: Remote Sensing; Aquifer; Modelling; Upper Egypt

Introduction

Egypt is facing various types of problems related to shortages of water that can be alleviated through proper developments of groundwater resources.

Some regions are available for reclamation but await irrigation water supplies. Others, such as Maghagha Area in Southern Egypt on the desert fringes have been cultivated for several years are suffering from water logging especially at the edges of old cultivated land. According to the rapid extension of reclamation in Maghagha area, monitoring was essential to evaluate the impacts of the reclamation. Traditional methods, such as field investigation for producing land cover / land use maps are expensive and time consuming. Using Remote sensing techniques helps in producing land cover / land use maps in a short time, at low coast, and with high accuracy. Few studies concerning the biostratigraphy and lithostratigraphy of Western and Eastern banks of Maghagha area were carried out (Ghanem et al 1970). In an attempt to understand structural controls on the Nile valley, Blankenhorn (1921), Abdel Razik and Razvallaev (1972), and Yehia (1973) have studied the joint systems along the Valley of Kings and Valley of Queens. Hydrogeological mapping was carried out by the Research Institute for Groundwater of Egypt (RIGW, 1994). The Nile Valley is surrounded on both sides by plateaux topped by rocks ranging in age from Precambrian to Eocene. The Nile Valley itself is filled with Pliocene and Quaternary sediments. Holocene silt and clay occupy young alluvial plains whereas Pleistocene sand and gravels dominate old alluvial plains. The sediments range in age between lower Eocene to recent. The lower Eocene plateaux bound the old alluvial plain on both sides. The subsurface stratigraphic units range in age from Precambrian to Quaternary. The region is underlain by a Quaternary and a Plio-Pleistocene aquifer. Aquifers represented by the Qena formation consists of graded sand and gravel in the central portion of the Nile Valley. These aquifers are overlain by a silty clay layer of Pliocene age. The impact of land cover / land use on groundwater quantity and quality can be significant and land cover / land use maps give an early warning for planners to protect groundwater resources. The evaluation of groundwater potentiality should be executed dynamically according to the increase in land reclamation. The main objective of this work is to produce land cover / land use maps from Landsat TM images for the study area for 1984 and 2006in order to quantify the change in irrigated areas during this period. These change detection maps will be compared with maps showing the changes in iso-piezometric and of groundwater salinity during the same period. The purpose of this comparison is to evaluate the effect of changes of land cover / land use on the quantity and quality of groundwater. Piezometric and salinity maps and Landsat TM images that cover the Luxor region are used in this study. Supervised classification and NDVI techniques are used to extract land use maps from the Landsat TM images. The accuracy of the remote sensing analysis results were evaluated against insitu data from the Research Institute for Ground Water (RIGW) and (NARSS) inventory and field observation for different locations in the study area. The results indicate a change in piezometric level and salinity associated with an increase in cultivated land. The impacts of the present and future development in region have been evaluated by using the numerical groundwater flow Simulation Package (GWSTE). The package was used to construct and calibrate a numerical model that can be used to simulate the response of the aquifer in the study area under implementing different management alternatives in the form of changes in piezometric levels and salinity.

1. Study area.

1.1. Location of the study area

The study area has been chosen as it represents a typical case of landuse impact on groundwater. The Maghagha area is shown on figure 1. It is located between longitudes 30° 30` and 31° E, and the latitudes 28° 30` and 29° N. It covers an area of about 2,700 km^2. it is located in El-Maniya Governorate, Egypt.

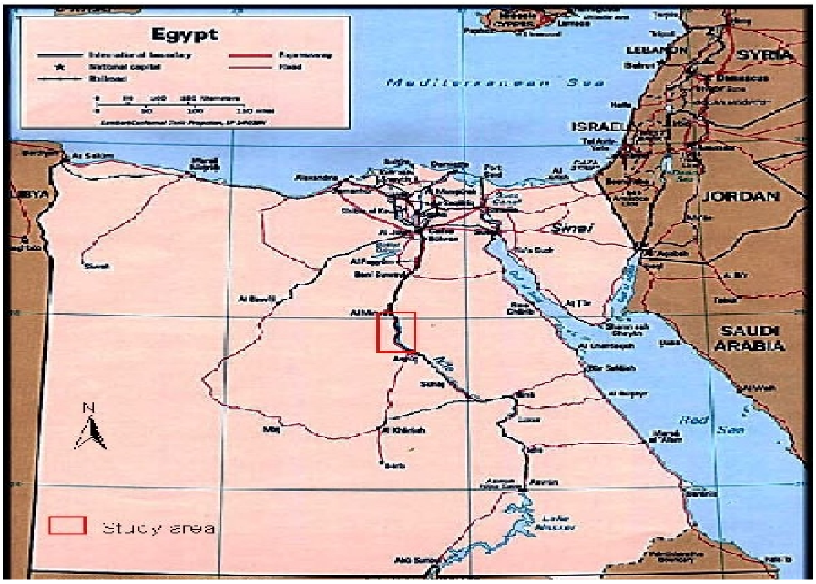

Fig.1: Location map of the studied area

1.2. Regional Geologic Setting of the Nile Valley

The Nile Valley in Egypt extends from the Egyptian–Sudanese border to North of Cairo with a total length of about 1000 km. It has a North–South trend along most of the river's course with some deviation in some parts such as the Maghagha area, where the River Nile makes a bend by flowing NE, then N, then SW before assuming its North flowing direction again.

1.2.1. Lithostratigraphy of the Area

The lithostratigraphic classification of the rocks exposed in the study area was established by Said (1960, 1981). The exposed rock units in the area are of sedimentary origin, ranging in age from middle Eocene to Quaternary Figure (2).The middle Eocene rocks are made up of limestone beds forming the plateaux on both sides of the Nile Valley. The Nile Valley plain is filled with Pliocene and Quaternary sediments. The Pliocene rocks consist of clay, sality sand while the Quaternary is composed of sand and gravel. Gravel of both the pliocene and Quaternary sediments is derived mainly from the Eocene limestone forming the plateaux. These sediments are generally poorly sorted. The

Quaternary sediments in the study area constitute the Qena formation which was deposited through the prenile system (Said, 1981). The neonil deposits are also of Quaternary age. According to Said (1962), the Quaternary sediments forming the aquifer in the study area can be subdivided into two units. The lower unit consists of graded sand and gravel with clay lenses.This unit forms the aquifer in the Nile valley. The upper unit consists of silt and clay forming the soil of the agricultural land. The aquifer thickness in the study area is about 85 m while thickness of the silty clay layer is about 8 m.

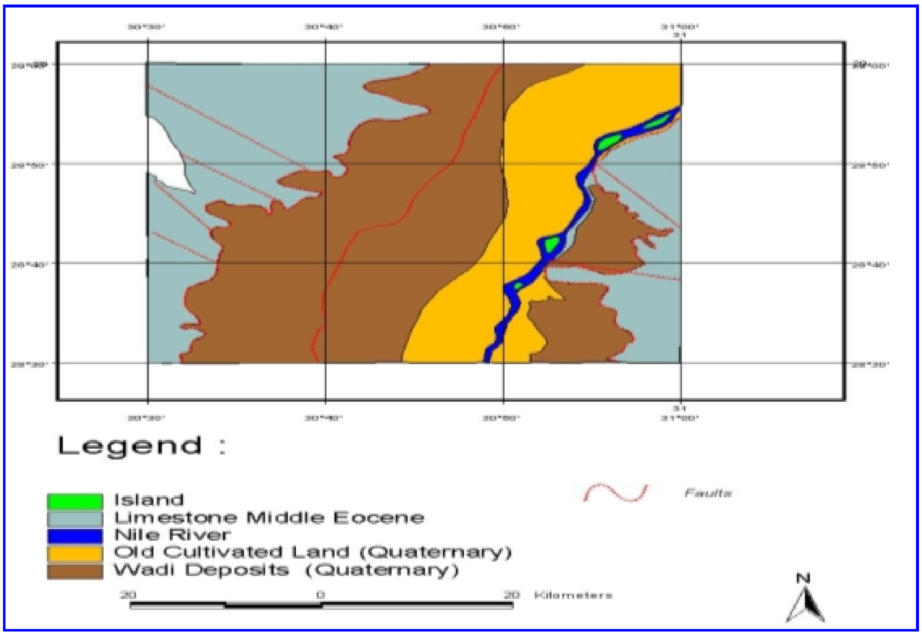

Fig. 2: Geological map of the study area (After Said 1981)

The neonile deposits include fanglomerate, silty clay layer, and recent wadi deposits. The fanglomerate overlies all rock units in the study area. It is composed of pebbles of chert and limestone embedded in a matrix of silt and sand. The silty clay layer forms the agricultural land in the reclaimed desert areas. The Wadi deposits are made up of cobbles and pebbles of chert and limestone covering the old units in the wadis and other topographic low areas in the study area.

Methodology

The remote sensing images of Landsat-TM and Spot4 acquired in 1988 and 2006 have been used for present study (Figure 3, 4). The digital data were processed for geometric and radiometric corrections using ERDAS Imagine processing software version 8.7.The TM and SPOT data were classified using unsupervised and supervised classification technique. The landuse maps of the years 1988 and 2006 were prepared and the original extent of the landuse in year 1988 is compared with the changes that have occurred in year 2006 to compute an overall change patterns in each category.

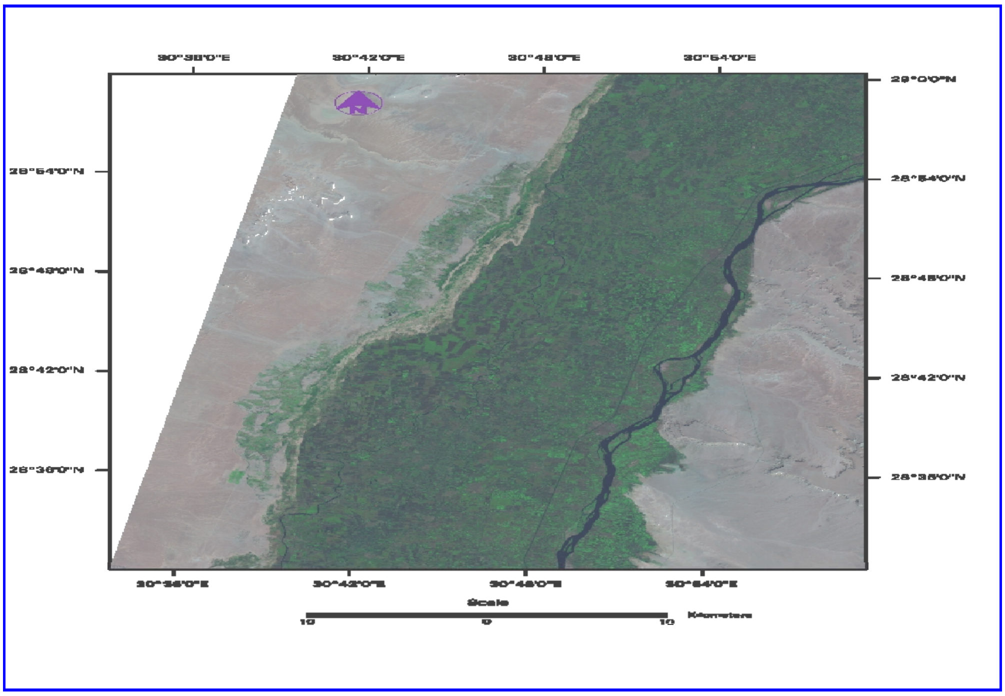

Fig 3: TM in year 1988

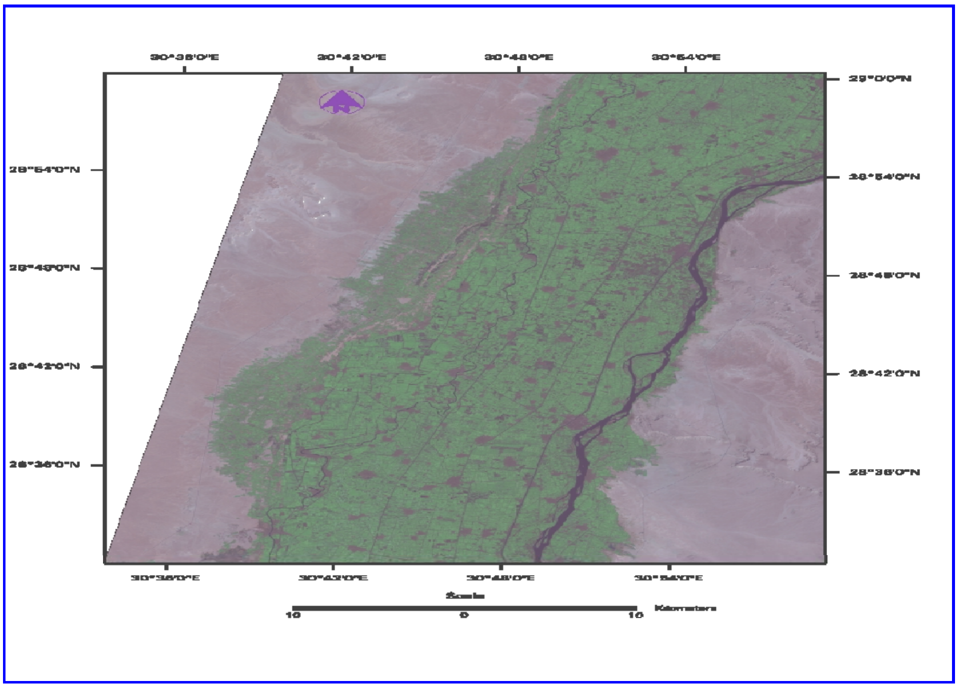

Fig 4: Spot 4 in year 2006

The various thematic layers generated using remote sensing data like Geology/ lithology, structure/ lineament; land use/land cover could be integrated with collateral data in a GIS framework. This could be further analysed in GIS domain using logical conditions to derive groundwater zones as well as artificial recharge sites. In order to assess the groundwater situation in an area, a systematic study of these factors is required in a GIS domain. GIS spatial database development various analogue maps, which were in different scales obtained from different organizations, were converted into digital format by using onscreen digitization method in Arc-View 3.2a software. Figure (5) shows the relation between remote sensing and GIS to produce groundwater maps.

Results and Discussions

1. Groundwater System

Quaternary, Plio-Pleistocene, Lower Eocene and Nubian Sandstone aquifers are present in the study area. This work focuses on the Quaternary and Plio-Pleistocene aquifers only.

1.1. Quaternary Aquifer

The Quaternary aquifer occupies the central part of the study area extending in a North-South direction along the Nile Valley. Wells drilled by the Research Institute for Groundwater, private wells, and geo-electrical surveys have enabled to study the characteristics geometry of the aquifer. The aquifer thickness generally increases from 5 m at the outer edges of the Nile Valley to 95 m in the central part. The hydrogeological cross section in the study area shows that the alluvium is composed of graded sand and gravel with intercalations of clay lenses. The aquifer is considered as semi-confined in most of the area under investigation, particularly in the central part of the Nile Valley due to the presences of a silty clay cap. On the borders of the Nile valley, this layer vanishes, and the aquifer becomes phreatic. The iso-piezometric map shown in figure (5) displays the water levels along the fringes of the Quaternary aquifer in year 1984.

Methodology of producing Land Cover/ Land Use Maps and Change Maps land cover / land use map reflects the different activities for different regions. The terms, however, pertain to two different areas of land classification. While land use refers to how human beings use a particular piece of land, land cover simply refers to the actual biophysical materials found on that same area (Green et al., 1994; Cullingworth, 1997).

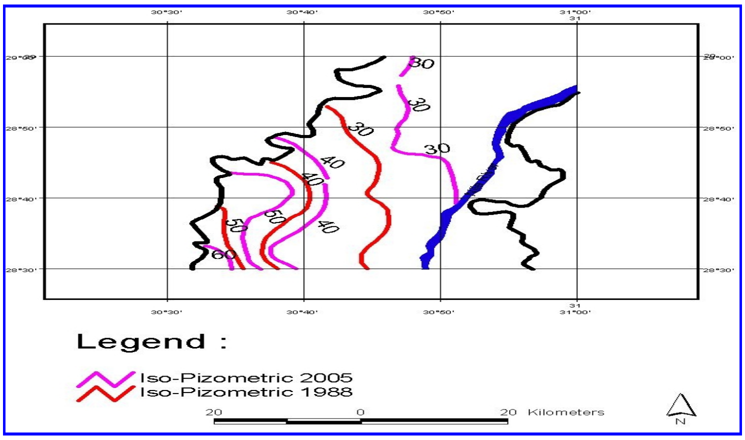

Fig.5: Iso-Pizometric contour map in year 1988 and 2006 for the study area

Recharge of groundwater flow occurs from the Plio-Pleistocene Wadi deposits to the Quaternary and the irrigation system and locally vertical flow from deeper aquifers along fault planes may occur. The main discharge component from the Quaternary aquifer is transversal flow to the river as seen from Figure (6). The daily groundwater pumpage from the Quaternary aquifer is determined from inventory carried out by (RIGW/IWACO, 1984) are estimated with 166 x 103 m3/day. The groundwaters pumpage supplements irrigation water deficits or for domestic uses. Figure (7) shows that the water level in year 2006 is lower than that of 1988.

1.2. The Plio-Pleistocene Aquifer

The Plio-Pleistocene aquifer is composed of sand, clay and gravel capped by a travertine bed. It extends along the foot slopes of the Eocene limestone on both sides of the Nile Valley and underneath the Quaternary aquifer in the central part of the valley. Its thickness changes from one place to another, averaging about 60 m. Groundwater extraction from the Plio-Pleistocene aquifer that estimated with 11 x 103 m3 /day is used for irrigation and domestic purposes and dominantly consumed on the Eastern fringes of Maghagha area.

2. Hydrogeochemistry

Groundwater percolating through various geological materials is continually dissolving or precipitating chemical ions. Chemical analyses include salinity content, chemical and electrochemical properties, and the concentration of major ions, and anions from these elements. The salt ratios are represented in the distribution of salinity contour map of year 1988 Figure (6). Testing carried out in the laboratory of the RIGW, for the determination of major ions and the Total Dissolved solids (TDS) found that the salinity of ground water increases toward the west and east, away from the young alluvial plain samples. Figure (7) illustrates the horizontal distribution of groundwater salinity that shows the increase of groundwater salinity in both sides of the Nile from year 1988 to 2006 Analysis of groundwater samples was taken from well sites. Figure (8) shows the change of salinity during the period from year 1988 to 2006 as a direct consequence of groundwater extraction being used for cultivation of newly reclaimed areas.

3. Remote Sensing Studies

Remote Sensing, with its advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas within short time, has become a very effective tool in assessing, monitoring and conserving groundwater resources. Satellite data provides quick and useful baseline information on the parameters controlling the occurrence and movement of groundwater such as geology/lithology, land use/ land cover and hydrological parameters. These parameters have to be integrated to assess groundwater. However, the conventional techniques have the limitation to study these parameters together because of the non-availability of data, integration tools and modelling techniques.

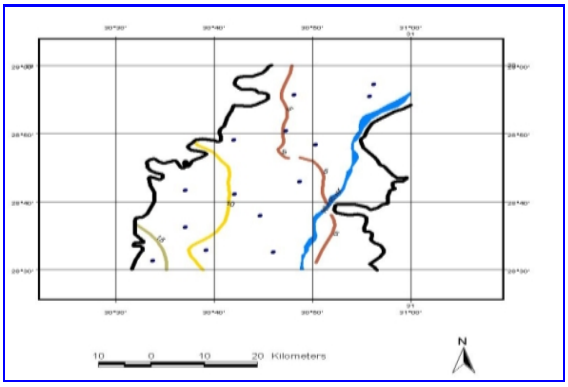

Fig. 6: Change of Iso-Pizometric contour map from year 1988 to 2006

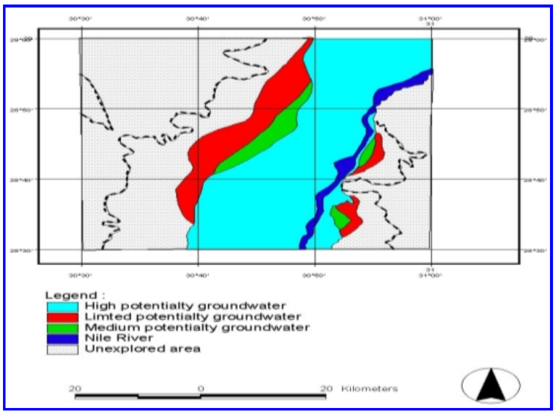

Fig. 7: Potentiality map of groundwater in 2006 for the study area

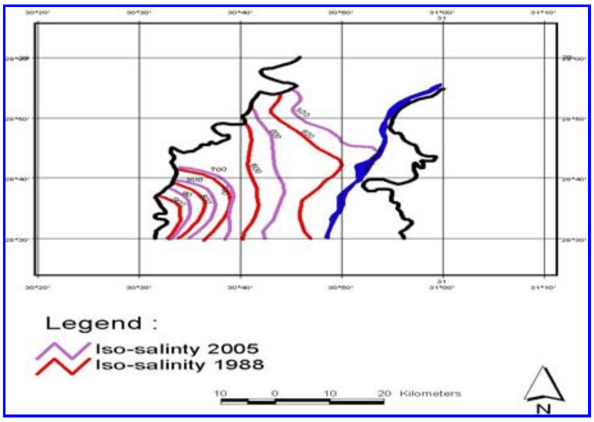

Fig. 8: Change of Iso-Salinity map (ppm) during the period from 1988 to 2006

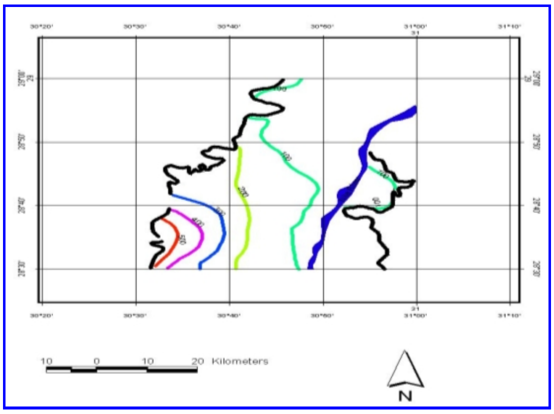

Fig. 9: Iso- Salinity map (ppm) in year 1988 and 2006.

Change detection application was done using a post classification comparison method to produce a change detection map for the period from 1988 to2006. ERDAS Imagine software was used in this study to analyze the Landsat TM and SPOT images and produce a classified image for the study area.

3.1 Images Classification

In order to produce a more accurate classification of the MAGAHA area, the classification of the two images was completed in two stages. First, an unsupervised classification was preformed on both the 1988 and 2006 Landsat TM and SPOT images in which there were eight classes. The default classes were then modified by merging or deleting some of them as needed. For instance, the water class was created from a user identified area. These new classes were then used for a supervised classification. This combined classification technique produced an image with less error compared to either of the two classification choices alone. (Figure (10), (11) illustrate the final classified images for the study area at the two dates. The result of the process is the creation of 5 separate classes: cultivated area, water, urban, wadis, limestone and wadi gravel. The classification technique still incurred a great deal of error. Most of this error occurred due to an inability to differentiate between urban structures and gravel.

3.2. Post classification change detection

In this paper change detection application using post classification comparison along with field investigations were used to detect the changes in cultivated area in MAGAHA during the period from 1988 to 2006. Post classification comparison was applied through ERDAS Imagine (1997) according to the following steps:

1-A classified image was prepared for the years 1988 and 2006 Figure (12), (13).
2-The landuse map of year 1988 was then subtracted from that of year 2005 to produce a change detection map for the study area Figure (14).

The study area is one of the most dynamic and highly changing areas in Egypt for the last two decades. The area has been affected by many natural and human activities. Results obtained from current and previous land cover studies basically summarize the main factors responsible for these changes, which are increase in the total cultivated land, active urbanization processes, decreasing desert and water bodies as illustrated in Figure (15).

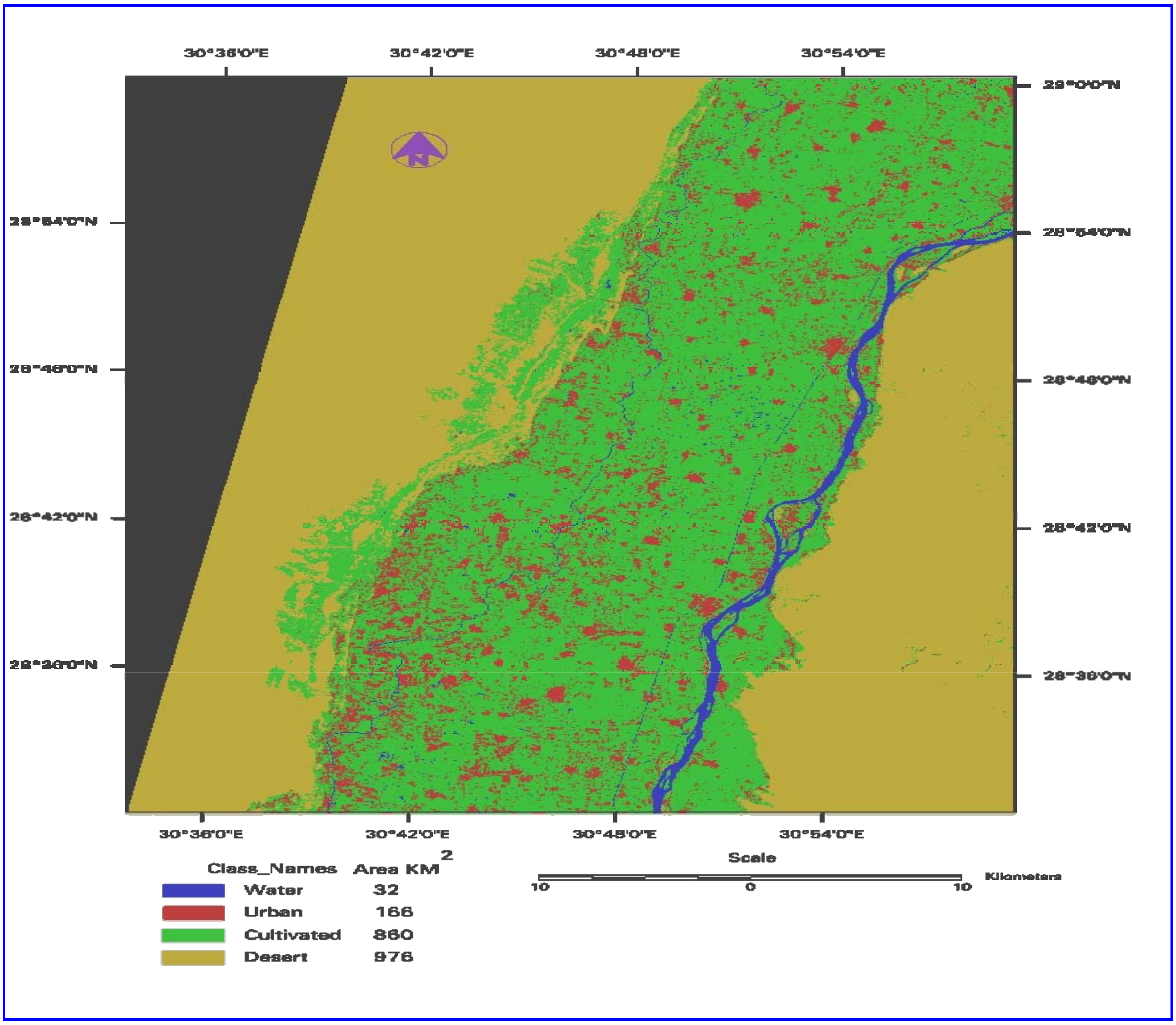

Fig. 12: Land use map of year 1988

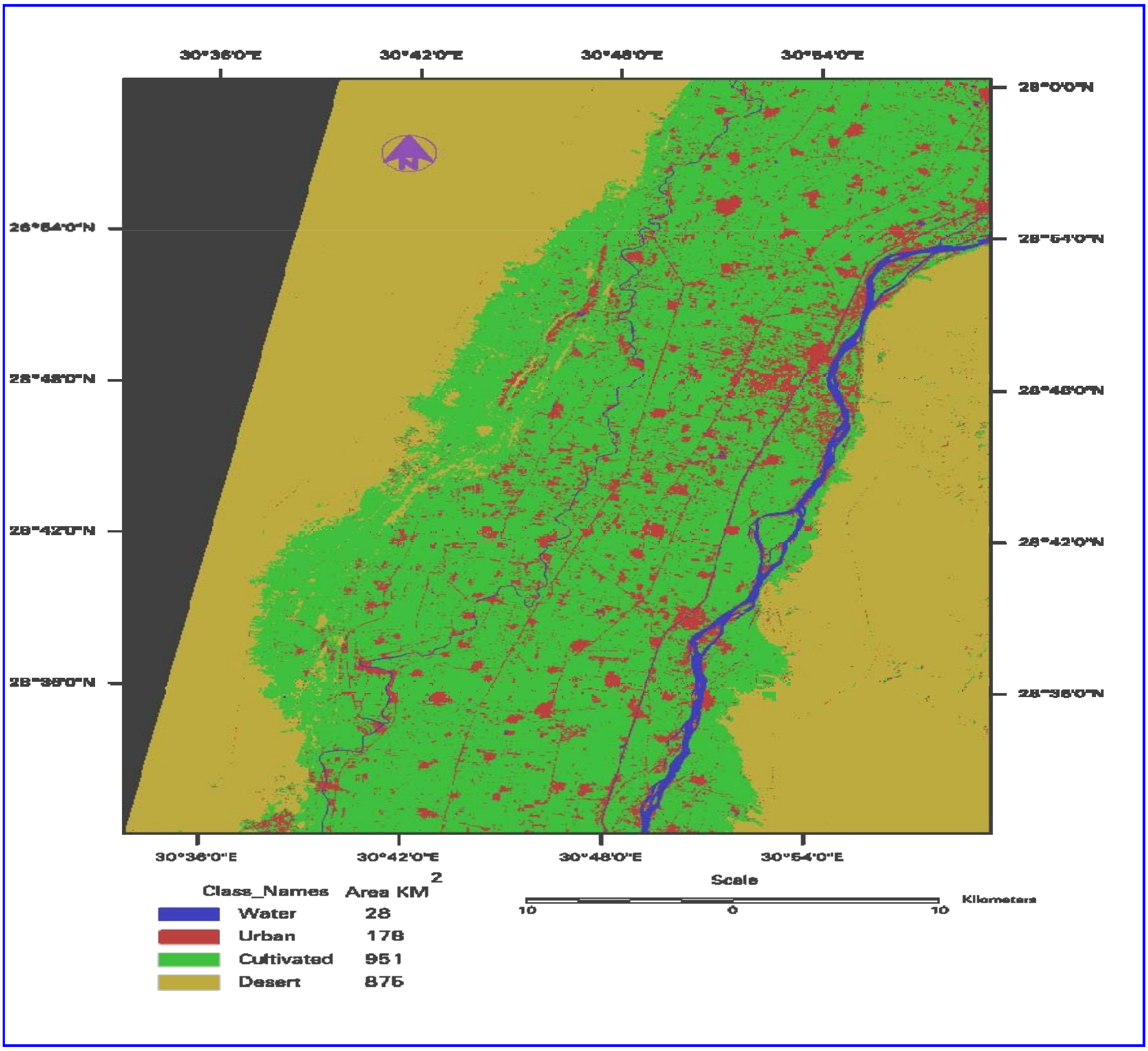

Fig. 13 land use map of year 2006

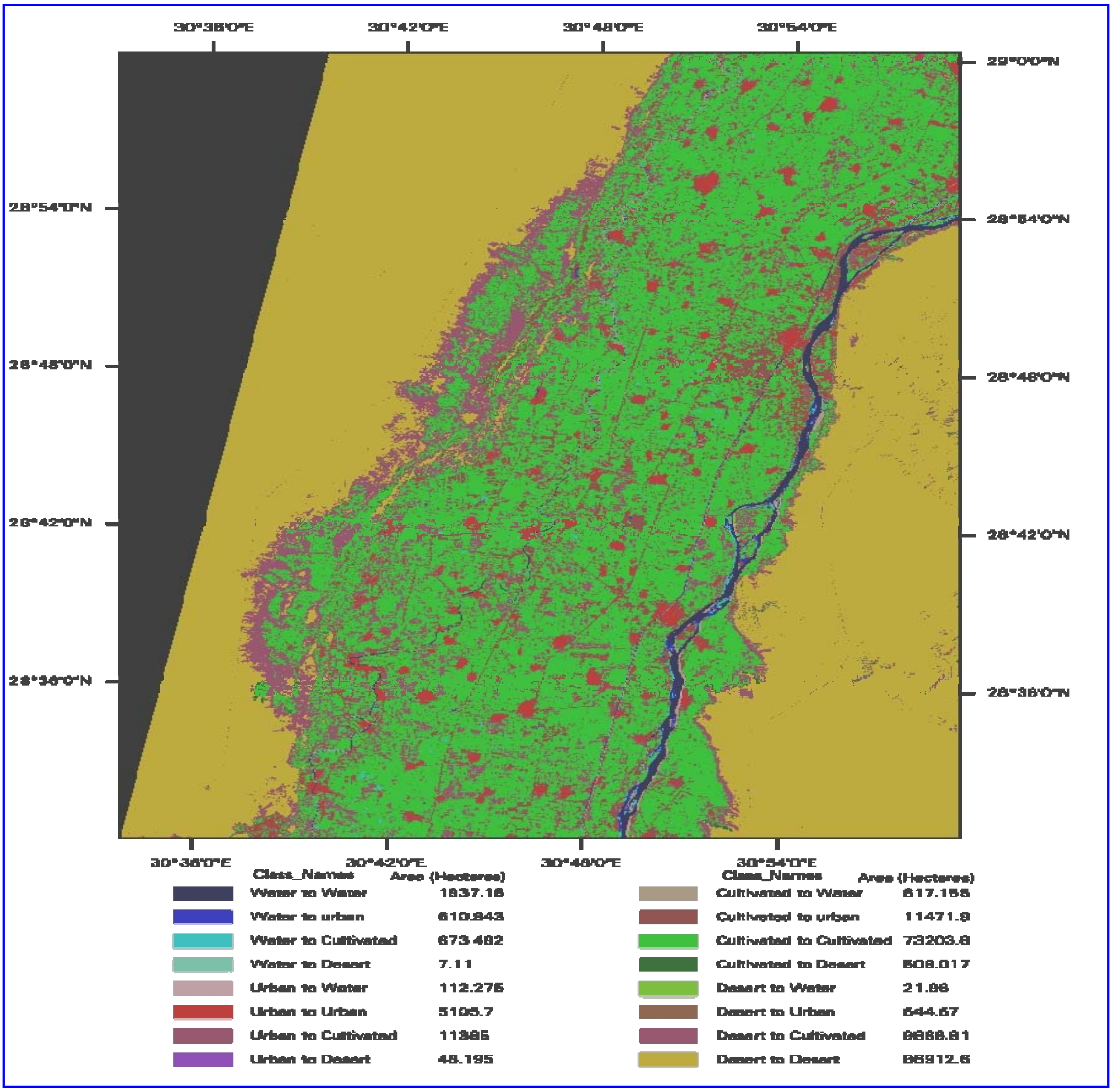

Fig. 14 Change detection from the year 1998 to 2006

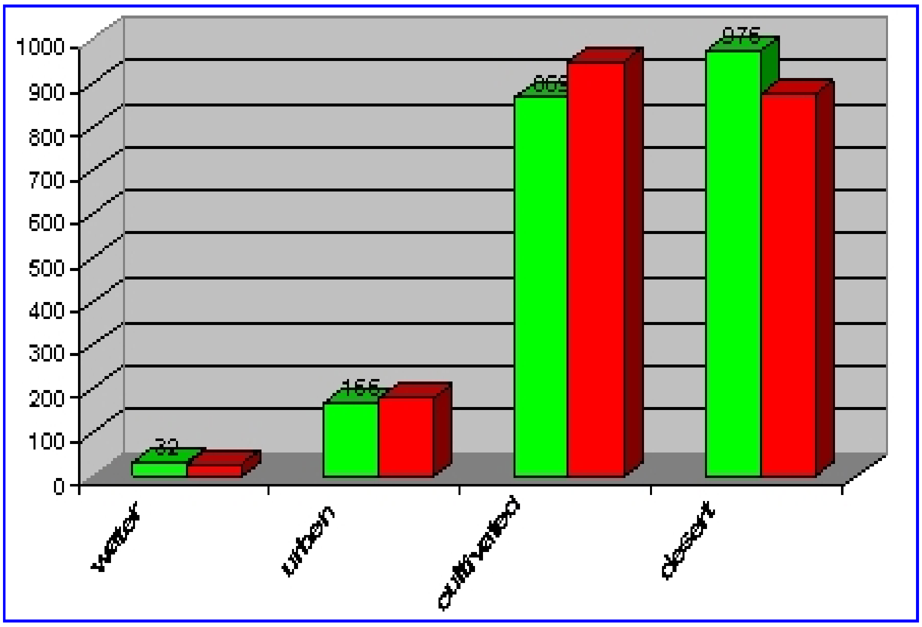

Fig. 15: Detected Changes for land use &land cover areas in Hectares map from year 1988 to 2006

4. Numerical Modeling by GWSTE

The two-dimensional numerical groundwater flow model (GWSTE) was calibrated and applied to simulate the flow of groundwater and solute transport in the selected study area. The input data which were collected by the team work during the site visits were used in addition to the data and results of the previous studies, (RIGW), in constructing and calibrating the GWSTE Magahgha model.
Two-dimensional model will be applied and calibrated to simulate the flow of groundwater and solute transport. The input data which were collected by the Research Institute for Groundwater (RIGW) and the previous studies will be used for this calibration purposes. The piezometric head map of year 2006 that prepared by RIGW for Maghagha area is used for the steady state condition.

4.1. Groundwater Flow and Solute Transport Model of Moghagha Area:

4.2. Aquifer Properties

From the previous studies the aquifer in the study area is classified as a leaky pleistocene aquifer system, overlain by a semi-pervious Holocene aquitard (clay cap) and underlain by an impervious Miocene aquiclude. RIGW, (1986) gave recommended values for the hydraulic conductivity in the modeled area ranging between 80 and m/day with storativity coefficient ranging between 0.00099 and 0.0049 The vertical hydraulic conductivity of the aquitard obtained by Auger-hole method and pumping tests varies from0.033 up to 4.01 mm/day

4.3. Model Construction

Figure (16) shows a two-dimensional finite element mesh which is used for the aquifer simulation. The mesh consists of 357 nodes and 704 triangular elements. From the description of the aquifer in the last section, the aquifer is considered as a leaky confined aquifer due to its semi-pervious clay cap. In this area, there are available data for only eleven observation wells which are used for comparison with computed values. Figure (17) Shows the observation wells and effective water ways which have been simulated by nodes.

4.4. Model calibration

The results obtained by the model will not be valid without illustrating that the model accurately represents the real system, and faithfully produces the past behavior of the water head as known from historical records. Practically, calibration process is frequently achieved through a trial-and-error adjustment of the model's input data until the model's solution match the field values. In fact, the heads computed from the first run of the model did not match the field values.

In general, the model calibration is to design a steady state model to solve for the head distribution to be used as the initial conditions in a later transient simulation. It is noticed that the increasing of the hydraulic conductivity at the downstream the grid point gives increasing in the inflow to the grid point and vis versa.

After completion of calibration, it is found that the modeled area gave good results when the average value of the aquifer Transmissivity is taken as 0.408 n^/sec(average hydraulic conductivity of 100 m/day and average thickness of 450 m). Furthermore, the leakage factor of the vertical hydraulic conductivity of the aquitard has been modified to get good results. The average value of the calibrated leakage factor is about 1 X 103 day-1 (average vertical hydraulic conductivity of 2.5 mm/day and an average aquitard thickness of 10 m). The modeled area has been classified into three types of soils.

4.4.1. Unsteady state calibration

From the steady state calibration, the model transmissivity and the leakage factor were determined. For unsteady state condition the model will be run to simulate the transient conditions at the period from 1999 to 2005. The initial conditions were obtained from the steady state calibration. The calibration process follows the trial and error procedure with adjusting and modifying the storativity for each run until the calculated heads can be matched the observed heads at the pumping wells. It is found that the average value of calibrated storativity is 6xl0-4. The groundwater contours are illustrated in figure (17)

4.5. Solute transport

Groundwater quality in this region is affected by sea water intrusion phenomenon. In addition, the increasing of the groundwater table causes increasing of salinity concentration in the groundwater. Furthermore, uncontrolled abstraction of the groundwater helps the rapid spread pollutants in the aquifer.

It is necessary to investigate a manner that provides protecting ground water against pollution. In this section, the two-dimensional finite element model will be used and calibrated to simulate the solute transport through the porous media and then to be used in predicting future aquifer response to external activities.

Due to the scarcity of chemical data, the model will be used to simulate the steady state condition only.

4.6. Model construction

The solute transport model was set to simulate the study area. Using the same finite element mesh of the groundwater flow model and the available chemical data were used here. The velocity distribution of the steady state simulation of 21.07.1989.   The boundary conditions are presented as follows:-

1- The southern boundary condition is taken as first-type boundary condition with a concentration values of the observation wells (800 mg/1), (900 mg/l) and the values at the other points have been estimated by interpolation.
2-The eastern boundary condition is taken the first-type boundary condition, the value of the concentrationhave been estimated by the hydrological map at some points (425 mg/1) and (600 mg/1) .
3-The western boundary condition is assumed as second-type boundary condition with zero concentration gradient.

4.7. Model calibration

The solute transport submodel linked to the flow model of the West Delta in order to calibrate the aquifer parameters which affect the solute transport in this region. The main objective of the calibration process, here, is to evaluate the model value of the regional dispersivity. As mentioned before, the model was used to simulate the steady state condition and the calibration process was continued by comparing the field observations with numerical solution until a satisfactory convergence is obtained.. The observed concentration values for pumping wells numbering have been used in the comparison with the model results.

After completion of calibration, the average value of the model longitudinal dispersivity, and the lateral dispersivity, were determined to be 200 km and 10 km respectively. the computed total dissolved contours in 2006

4.8. Model Construction

Figure (16) shows the two-dimensional finite element grid which was used for simulating the problem. The grid consists of 484 nodes and 882 triangular elements. The aquifer is considered as a leaky confined aquifer due to its semi-pervious clay cap. In the study area, there are available data for only eleven observation wells which are used for calibration purpose comparing with the computed values. The model boundary conditions are presented as follows:

1- The Southern boundary is defined as first type boundary condition. The prescribed head at this boundary is obtained from the piezometric map.
2- The Eastern boundary is represented by the River Nile and considered as a third Cauchy type boundary condition.
3- The other boundaries were considered as flow lines boundaries.

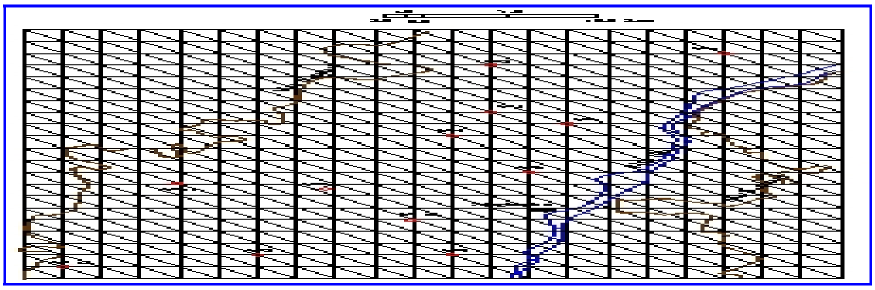
Figure (16): Finite element grid of (GWSTE) numerical model

4.9. Model calibration

The results obtained by the model are not valid without illustrating that the model accurately represents the real system, and faithfully produces the past behavior of the water head as known from historical records. Applying GWSTE, calibration process is achieved through a trial-and-error adjustment of the model's input data until the model's solution match the field values in the allocated guide points. In fact, the heads computed from the first run of the model usually do not match the field values. A prescribed maximum number of iterations should be carried out until a prescribed criterion of computation error is satisfied; then, the constructed model is considered calibrated and can be used for simulation of another hydrological situations. Furthermore, the calibrated model is a design steady state model used to solve for flow conditions that can be used as initial conditions in transient flow simulations.

After completion of calibration, it was found that the modeled area gave good results when the average value of the aquifer Transmissivity is taken 0.408 m2/sec, (average hydraulic conductivity of 100 m/day, and average thickness of 450 m). Furthermore, the leakage factor of the vertical hydraulic conductivity of the aquitard was modified to get good results. The average value of the calibrated leakage factor is about 103 day-1, (average vertical hydraulic conductivity of 2.5 mm/day, and an average aquitard thickness of 10 m). Due to calibration process, the modeled study area was classified by three types of model parameters.

4.10. Transient calibration

From the steady state calibration, the model transmissivity and the leakage factor were determined. For transient conditions, the model was run to simulate the flow situation in the period between the years 1999 and 2006. The initial conditions were obtained from the steady state calibration and the transient calibration process follows the trial and error procedure with adjusting the storativity for each run until the calculated heads approached the observed satisfying the prescribed criteria. It was found that the average value of calibrated storativity is 6xl0-4. The simulated piezometric map is illustrated in Figure (17).

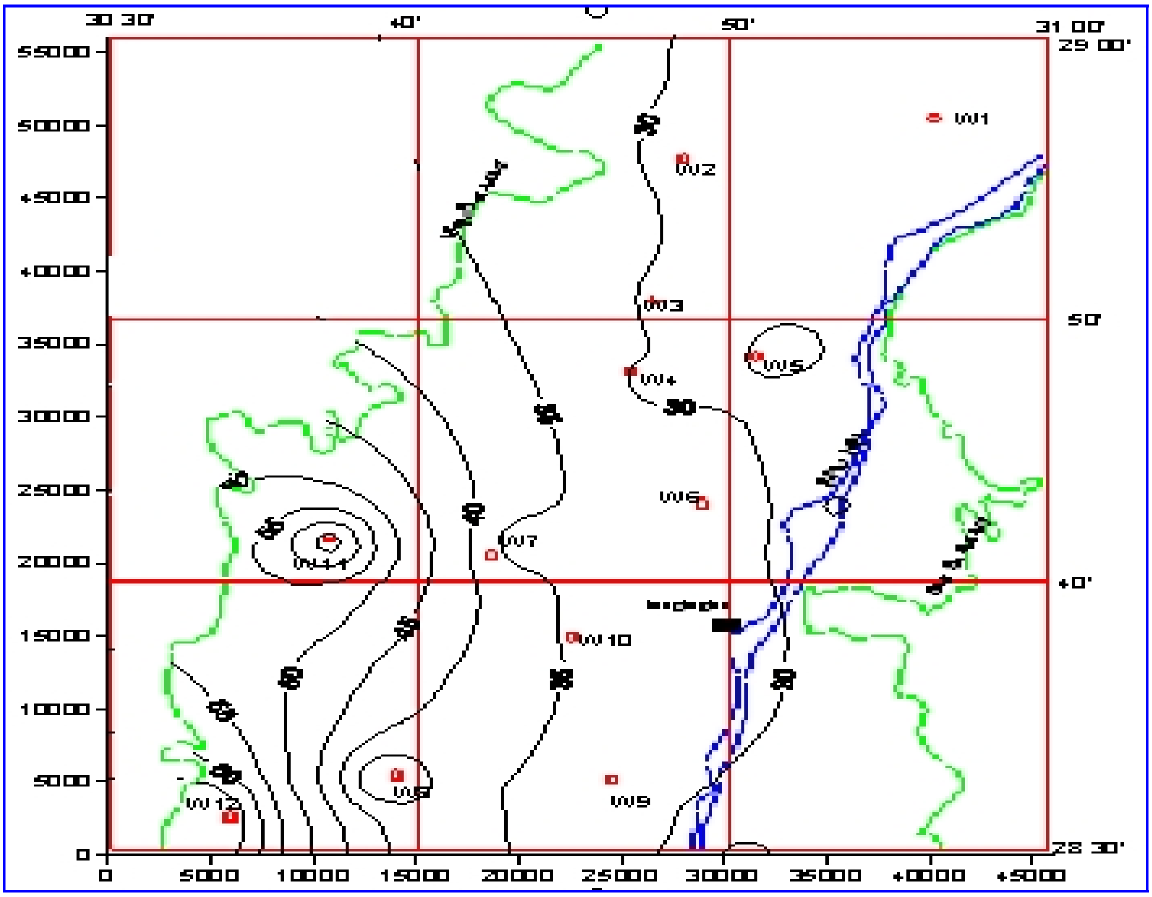

Figure 17: Simulated piezometric map for the year 2006, (GWSTE)

4.11. Solute Transport Model

In this area the GWSTE solute transport module was used to calibrate and simulate the salinity distribution in the aquifer. Thereafter, the calibrated salinity model could be used in predicting future aquifer response to groundwater exploitation activities.

4.12. Model construction

Using the same finite element grid of the groundwater flow model and the available salinity data, the solute transport model of the study area was constructed applying the velocity distribution of the date 21.07.1989 flow simulation.The boundary conditions are presented as follows:

1- The Southern boundary condition is taken as first-type boundary condition with concentration values at the observation wells of 800 mg/1, 900 mg/l and the values at the other points have been estimated by interpolation.
2- The Eastern boundary condition is taken also as first-type boundary condition. The concentration value was estimated using the hydrogeological map at some points with values of 425 mg/1 and 600 mg/1.
3- The Western boundary condition is assumed as second-type boundary condition with zero concentration gradient.

4.13. Model calibration

The constructed solute transport model linked with the calibrated flow model of Maghagha was run to calibrate the aquifer model parameters which affect the solute transport in this region. The main objective of the calibration process, here, is to evaluate the model value of the regional dispersivity. The model was used to simulate the steady state condition. The calibration process was continued by comparing the field observations (collected data during site visits) with numerical solution until a satisfactory convergence was obtained. The observed concentration values for pumping wells were used in the comparison with the model results.

After completion of the calibration process, the average values of model the longitudinal and lateral dispersivities, were determined as 200 km and 10 km, respectively. Figure (18) shows the simulated salinity distribution for the year 2006.

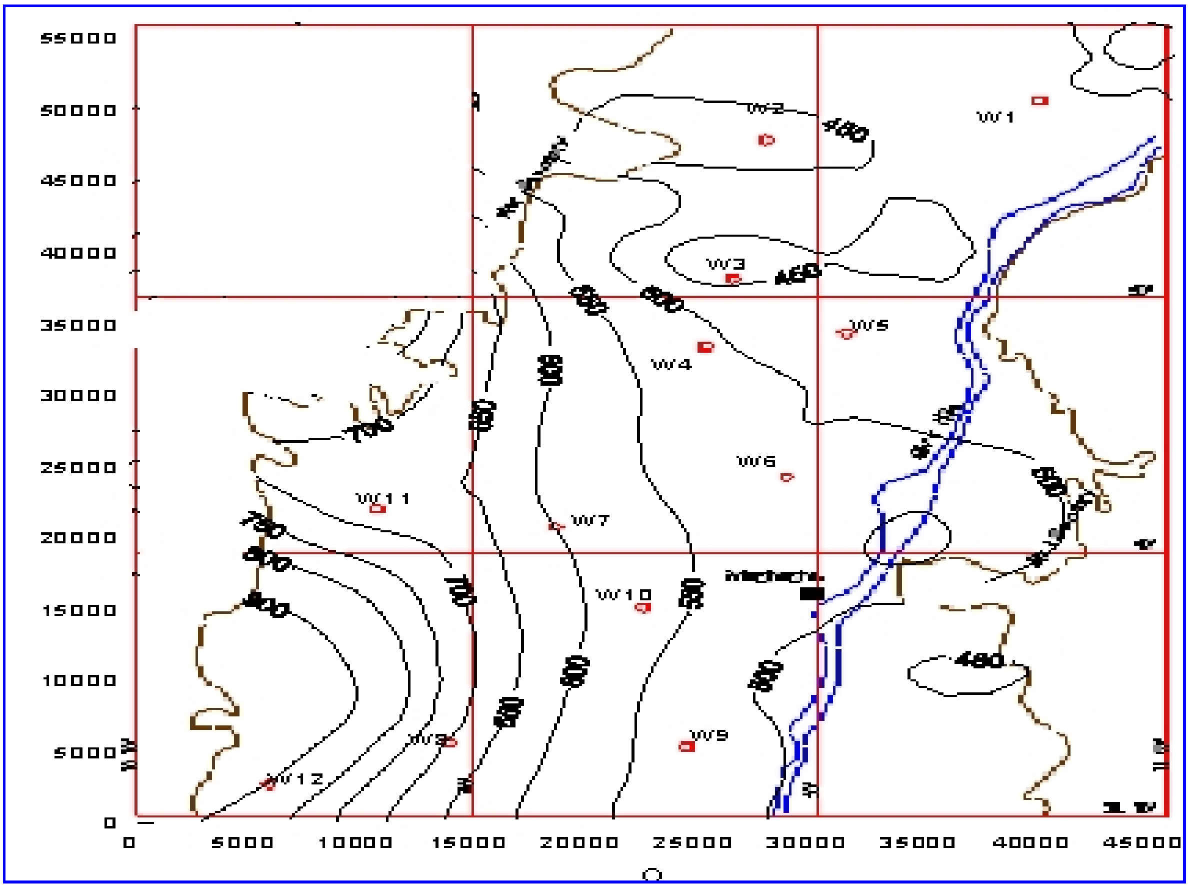

Figure 18: Simulated salinity distribution for the year 2006

5. Prediction of Pizometric head and Salinity distribution maps in year 20017

The calibrated model was used to predict the anticipated Pizometric head and Salinity distribution in year 2017.Figures (19), (20) present the Pizometric head and Salinity distribution in year 2017 in Mahgagha area respectively. A significant lower of groundwater level and increase in salinity concentration could be detected from Figures (19), (20)

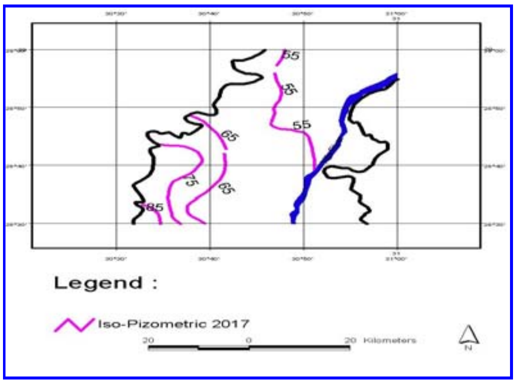

Fig. 20 Iso-Pizometrric map in 2017 for the study area

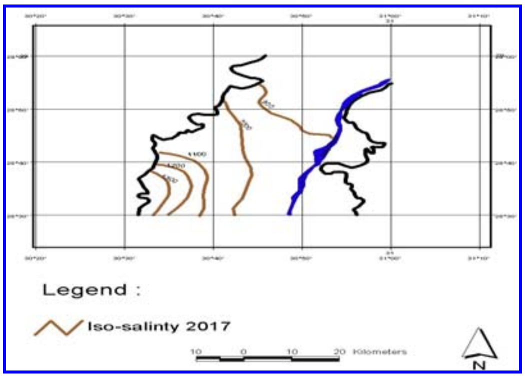

Fig 19 Iso-salinity map in 2017.

Conclusions

Two land use maps for the study area for two different years1988 and 2006 were produced with high accuracy and short time and presented. According to the confusion between urban class and road class and for more accuracy, road class was represented as vector layer. Change detection map was produced, which was reflects the change in reclaimed lands. From land use maps of the study area for year 2006, it was observed a lot of changes in development areas especially on the border of the old land. The change in land reclaimed area was estimated with 44%? in the period from year 1988 to 2006. The numerical groundwater flow simulation package GWSTE was used to predict the expected drawdown and water balance in the future as a result of groundwater development in the area. The study led to the conclusion that the most critical areas which have been affected by remarkable lowering in the groundwater level are in new cultivate land. There is a change in groundwater level during the period between 1988 –2006 where, the effect extends to the adjacent areas, and the lack of recharge into the aquifer. It is observed that there is slight increase in salinity in some locations.

Recommendations

There is still much to be done in the studied following recommendations for future works are suggested:

1- Applying different kind of change detection technique (post classification comparison, image deference and image ratio) on the new development areas to compare between the results.

2- Continuous monitoring for western Magahga development areas by using different kind of satellite images to protect groundwater resources from depletion and deterioration.
3- It is recommended also to apply well license system in order to avoid groundwater deterioration at wastern Maghagha and also follow the regional plan of aquifer development.
4- It is recommended to apply the calibrated numerical models of the aquifer to study response to deferent future management scenarios.
5- It is recommended to study the scenarios of applying conjunctive use of surface and ground water recourses in order to prevent the increase of water salinity.

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