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EFFECT OF THE CONSTRUCTION OF NEW ASSUIT BARRAGE ON GROUNDWATER REGIME, (ASSUIT, EGYPT)

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ملخص :-
عزمت الحكومة المصرية استبدال القنطرة الحالية في أسيوط بقنطرة جديدة تضم محطة لتوليد الطاقة الكهرومائية وبعد دراسة البدائل المختلفة ، تم اتخاذ قرار لبناء قنطرة متعددة الأغراض لضمان إمدادات الري ، وتوليد الطاقة الكهرومائية ، وتحسين الظروف لكل من حركة المرور في الأنهار والطرق. لدراسة سلوك بناء القنطرة الجديدة على مناسيب المياه الجوفية ، تم استخدام برنامج Feflow لبناء نموذج لسريان المياه الجوفية لمحاكاة سلوك نظام السريان تحت ضغوط مختلفة. تمت معايرة النموذج للحالة الثابتة من خلال مطابقة خطوط الكنتور للبيانات المرصودة والناتجه من النموذج. واستخدمت بيانات المناسيب للفترة 2004-2008 لمعايرة النموذج عن طريق مطابقة البيانات المرصودة والناتجه من النموذج. بعد ذلك ، تم التحقق من صحة النموذج بإستخدام بيانات المناسيب عن تلك الفترة.
تم عمل سيناريو للتنبؤ باستجابة نظام طبقة المياه الجوفية في ظل ظروف مختلفة حيث تم دراسة تأثير إرتفاع مناسيب المياه على كميه الشحن للخزان، تم رفع منسوب المياه أمام , وخلف القنطرة الجديده ومناسيب مياه المصارف 0.5 متر مع ثبات كميات السحب لعام 2017.حيث تبين إرتفاع مناسيب المياه بمعدلات مختلفة وغير مؤثرة فى المنطقة الواقعة أمام القنطرة (أبوتيج 43 سم ,صدفة والغنيمية 46 سم , الفتح 31 سم , الساحل 44 سم) وقد تبين أنه لا يوجد أى اثار سلبية على مدينة أسيوط بسبب تنفيذ المشروع.

ABSTRACT:

The Government of Egypt intends to replace the existing barrage at Assuit with a new structure incorporating a hydropower plant. After studying various alternatives the decision had been taken to construct a multipurpose barrage to guarantee the supply of irrigation, to generate hydropower, and to improve conditions for both river and road traffic. To see the behavior of the construction of the new barrage on groundwater level, Feflow was used to build a groundwater flow model to simulate the behavior of the flow system under different stresses. The model was calibrated for steady state condition by matching observed and simulated initial head counter lines. The levels for the period 2004–2008 were used to calibrate the transient model by matching simulated drawdown with the observed one. Then, the transient model was validated by using levels for the period 2008–2017.

A scenario was developed to predict the response of the aquifer system under different conditions where the effect of rising water levels on the recharge of the aquifer was investigated. Rising the level of upstream, downstream of the new barrage and the drains levels 0.5m with constant abstraction of 2017. It was found that the water levels rise at different rates and are not effective in the area in upstream of the barrage (Abu Tig 43 cm, Sidfa & Ganaem 46 cm, El-Fath 31 cm, El-Sahel 44 cm) and there is no negative effects on the city of Assuit due to the implementation of the project.

1. INTRODUCTION

Assuit barrage was constructed in 1928 to divert River Nile water into the agricultural areas of the Nile Valley downstream of the barrage (Gasser, 1996). The design of the new barrage includes a headpond with constant water levels maintained at a level approximately 0.50 m higher than the highest water level in the headpond of the present barrage. The direct impact of Assuit barrage construction will be on water levels in the River Nile upstream of the barrage.

Allam and Dawoud (2004) said that the government of Egypt has decided to construct a new barrage with hydropower facilities, 3.5 km downstream of the existing old one. To evaluate the effect of increasing the head pond water level on the groundwater and drainage, Visual MODFLOW has been used to simulate the surface water/groundwater interaction in the area of proposed new barrage. Any increase in the head pond water level for new barrage will raise the groundwater levels upstream of the new proposed barrage and affect the drainage conditions. Due to the additional seepage, the distances between the lateral subsurface drains must be reduced in the areas where the drainage system is to be renovated. Also, the rehabilitation and improved maintenance of the open drains and the outlet structures is proposed to start immediately in order to restore and maintain the functionality of drainage system.

Dawoud et al. (2006) studied the impacts of rehabilitation of the Assuit barrage increasing the headpond level were assessed using a three-dimensional groundwater model. The model has been calibrated for steady state and transient conditions against historical data from observation wells. The mitigation measures for the groundwater rise in the urban areas have been tested using the calibrated mode. This rise in groundwater level will affect the urban areas. A low-cost pumping system is required to control the groundwater levels in the affected areas to abstract about 7.665 million m3/year.

Fekry and El-Fakharany (2014) said that Esna city was selected as the study area to assess the impact of the barrage effect on groundwater aquifer and to propose mitigation measures. The most powerful method for studying the problem is developing a groundwater model based on monitored groundwater levels and simulating the effect of the proposed measures. Results indicated that Nile River in reaches upstream the barrage feeds the aquifer. Then, a model is used to test the effect of the mitigation measures on the surrounding settlements. Results also indicated that using cut off drains with depth of 2.5 m is the most effective and safe solution, in terms of direct impact on the buildings without need for operation cost – only maintenance cost will be needed. Also, implementing a sewage network in the city as a long-term solution is recommended.

Asmael et al. (2015) provided steady-state three-dimensional (3D) groundwater model (FEFLOW which is an advanced finite element groundwater flow and transport modeling tool), was used to quantify groundwater budget components by using all available data of hydrological year 2009–2010. The results obtained may be considered as an essential tool for groundwater management options in the study area. The calibrated model demonstrates a good agreement between the observed and simulated hydraulic head. The result of the sensitivity analysis shows that the model is highly sensitive to hydraulic conductivity changes and sensitive to a lesser extent to water recharge amount.

Idris et al. (2017) used FEFLOW model to simulate groundwater flow and transport for a coastal island aquifer in Kg. Salang, Tioman Island, Malaysia. FEFLOW is designed to simulate 2D and 3D, variable density groundwater flow and multi-species transport. The impacts of pumping and recharge rates represented by three different groundwater scenarios, which were investigated by means of hydraulic heads, TDS concentrations and water balance components. Scenario A showed the standard saturated groundwater flow and the steady state fluid flow.

Sindhu and Vijayachandran (2018) used in this study, a finite element groundwater flow model of a costal aquifer system at Aakulam Trivandrum district is developed, calibrated and simulated using the software Finite Element subsurface Flow system (FEFLOW 6.2). This simulated model is then used to predict the groundwater levels for a future 5 year period during pre-monsoon and post monsoon season.

Usman et al. (2018) conducted this modeling study in the mixed cropping zone of the Punjab, Pakistan. Both remote sensing and secondary data were utilized to achieve objectives of this study. The study results show a drop in groundwater levels for almost all scenarios. The highest negative change was observed for the 4th scenario (i.e. 25% increase in groundwater pumping over a 10-year period), with a value of 3.73 m, by ignoring very wet summer and winter seasons.

2. STUDY AREA

The existing and new Assuit Barrages are located on the River Nile at river km 545, some 310 km north of Luxor within the Governorate of Assuit. The project's impacts on groundwater levels may vary especially in the Assuit city, but at a certain distance from the new barrage will become negligible. Consequently, the study region Figure (1) is defined as follows:-

- The northern (downstream) boundary is about 20 km downstream of the new barrage.
- The southern (upstream) boundary is located some 60 km upstream of the new barrage.
- The eastern and western boundaries (right and left banks) are given by the extent of agricultural land use in this part of the Nile Valley, and their transition to the desert region. The west bank ranges in which from about 9 to 17 km, while the east bank ranges in width from 0 to 11km.
- The study region is characterized by a large network of irrigation and drainage channels. The geological and hydrogeological situation, coupled with the influence of the River Nile and existing irrigation and drainage facilities, result in a relatively complex system of surface water and groundwater interaction.

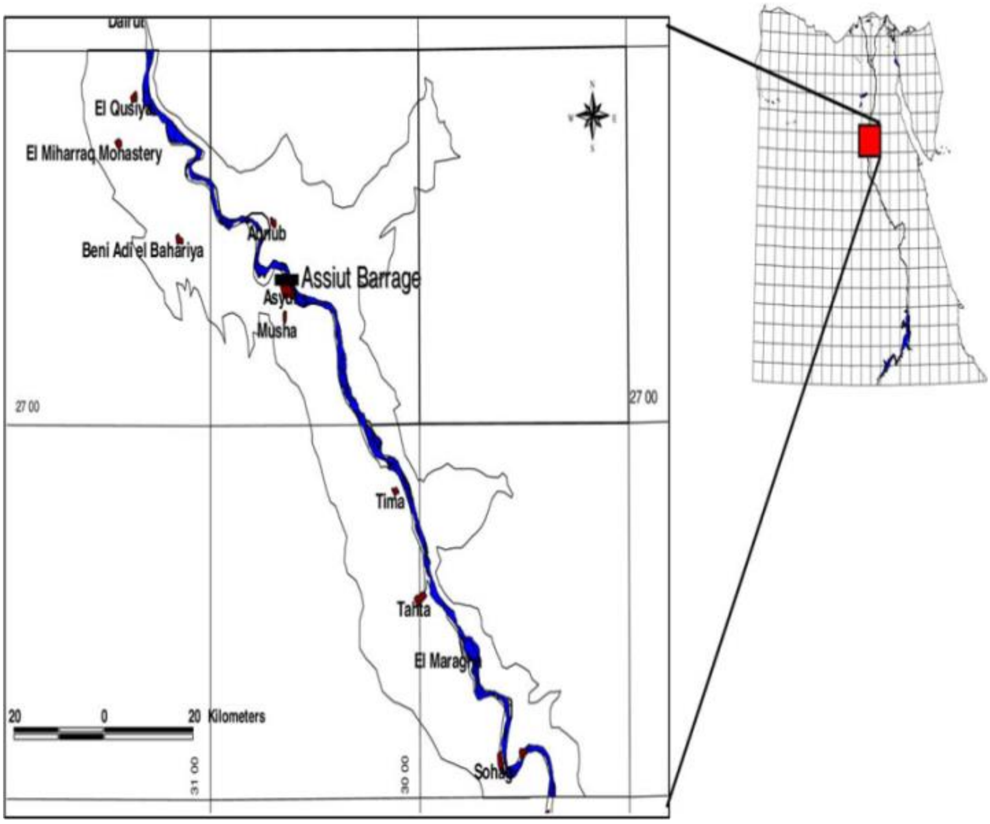

Figure 1. Study area location (After Dawoud et al., 2006)

2.1 Topography

For the model development, contour information representing the ground surface elevation within the study region is available from 3 sets of maps of different scale, age and quality:

- 1:25,000 scale mapping with 0.25 m contours (and numerous spot elevations) published by the Egyptian General Survey Authority (ESA) between the 1950s and 1990s, covering the entire study region.
- 1:5,000 scale mapping with 0.5 m contours and detailed spot elevations (accuracy = 0.01 m) prepared in 2008, published by the Nile Research Institute (NRI). These maps are confined to a limited zone approximately 1 to 2 km wide on either side of the River Nile.
- 1:2,500 scale mapping with detailed spot elevations (accuracy = 0.01 m) prepared in 2002, published by ESA. These maps cover the entire City of Assiut (west bank), the village of El-Nasreya in El -Fath district (east bank) and associated suburbs.

In total, 30,700 spot elevations (with x, y, z coordinates) were derived from the above listed sets of maps, and have been introduced into the model's database, representing the ground surface elevations of agricultural land over the entire study region, as well as a very detailed resolution of spot heights in Assiut City and its surrounding outskirts. The morphological structure (see Figure (2)) shows maximum ground surface elevations of about 57 m in the most southern part of the study region (Tima District), gradually decreasing to about 49 m at the northern model boundary (Abnob District). Elevated areas (> 60 m) appear along the outer fringes of the Nile valley, finally reaching up to 100 m asl on the right bank east of Assuit. Ground elevations along and adjacent to the river banks are generally higher than areas further from the river, due to sediment deposition caused by annual flooding of the River Nile prior to construction of High Aswan Dam.

For Assiut City, ground surface elevations are in general between 52 and 54 m, except for an elevated area in the south-western part of the city, where ground the surface steeply climbs up to about 60 m.

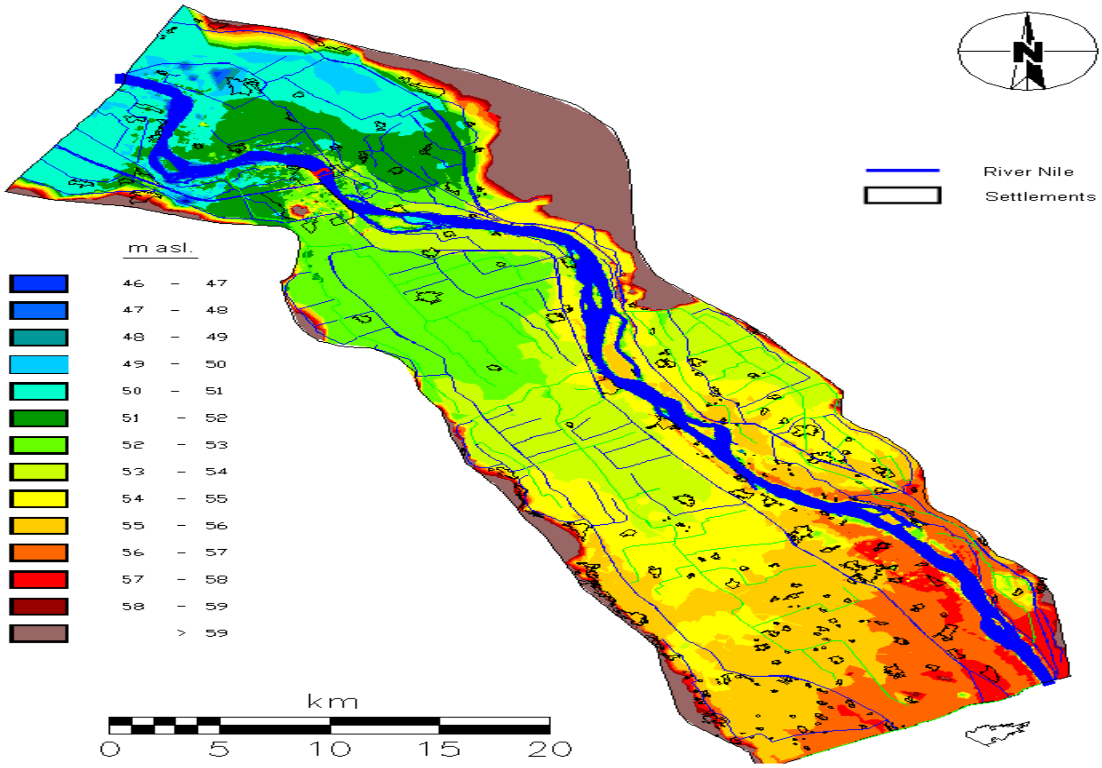

Figure 2. Topography of the study area

2.2 Geological Setting of the Modeled Area

The geology defined in the groundwater model must accurately reflect the observed geological structure of the region. Therefore, all available geological information obtained during the various campaigns of piezometer drilling and installation Figure (3). The available geological data comprised:

Geological profiles, locations, and screen depths of 89 new boreholes at various locations throughout the study area (ranging in depths from 7 to 25 m).

According to the available information, the local stratigraphical in the Assiut area can be characterized (from the ground surface down) as:

1. The Holocene unit (Neonile and young wadi deposits) representing the central portion of the Nile valley (young alluvial floodplain) and young wadi deposits located on the outer regions. The unit consists of silty clay intercalated with gravel and sand, and varies in thickness from 0 m to some 15 m. In addition to being the upper aquifer, the surface of this unit is the fertile agricultural land of the Nile valley.

2. The sands and gravel of the Late Pleistocene (pre-Nile deposits) which form the lower aquifer in the study region. The thickness of the unit varies from 40 m at the outer fringes to more than 250 m in the central portion of the valley. This aquifer is of high importance for drinking water supply by pumping, giving high yields.
3. The lower aquifer is underlain by several geological units which are interpreted as aquicludes (barriers) for the overlying aquifers, or which act as secondary aquifer systems. These are of little importance as sources of water supply because of the low yields and the relatively high salinity of the groundwater.

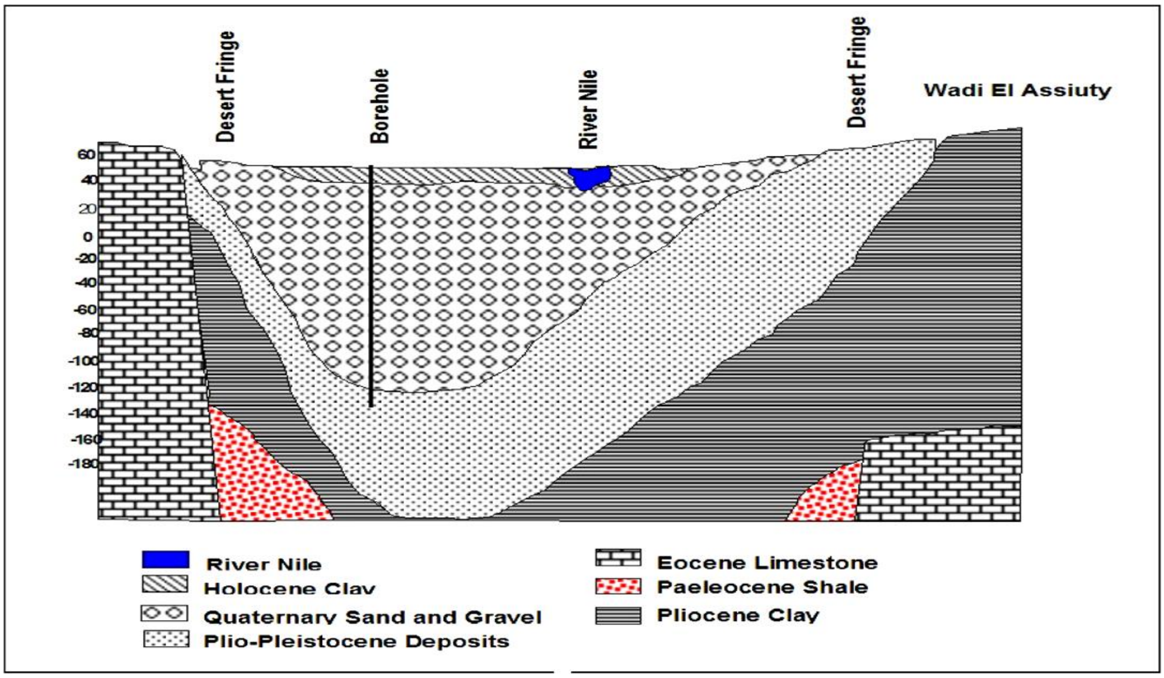

Figure 3. Hydrogeological cross section in the aquifer system (After Dawoud et al., 2006))

2.3 Hydrogeology (Hydraulic conductivity)

The definition of Hydraulic conductivities throughout the study area is important as it is one of the most critical parameters in determining groundwater flow in the aquifer systems. Prior to this study, Hydraulic conductivities were determined during earlier hydrogeological studies in the Nile valley by (Research Institute for Groundwater) RIGW. These were based on pumping tests and sieve analysis of material obtained at various depths during drilling. Hydraulic conductivities proposed in several studies by Attia et al. (1986), Attia (1989) and Research Institute for Groundwater (RIGW).

Based on the previous studied the overall Hydraulic conductivities for the aquifer system can be summarized as follows:

* For the upper Holocene layer, the horizontal Hydraulic conductivity (kh) are likely to be within the range of 1.2x10-5 to 2.3x10-5 m/s. The vertical Hydraulic conductivity (kv), is estimated to be within the range of 1.2x10-6 to 2.3x10-6 m/s.

* For the lower Pleistocene layer Horizontal and vertical Hydraulic conductivities are to be vary within a range of 8x10-4 to 1x10-3 m/s, representing a typical value for fine and medium sand.
* The resulting transmissivities range from 0.225 m²/s in the central portion of the valley to 0.036 m²/s at the outer fringes.

3. Hydrology (Hydrometric Data of River Nile)

Groundwater flows and levels are influenced both by the River Nile and the operation of irrigation and drainage facilities. River Nile water levels are subject to an annual fluctuation, with maximum water levels during the high flood season in summer (April to October), and minimum water levels during the winter season (November to March). Water levels at the existing Assiut barrage reflect a dynamic operation scheme, with an anticipated headpond level of 48.8 m asl during the winter season, and 50.0 m asl during the high flood season. However, the records show a temporary overshooting of some 0.3 m to 0.5 m above the anticipated maximum in summer (50.30 to 50.55 m asl), while winter headpond levels usually drop more than 1 m beneath the anticipated minimum (47.50 m to 48.00 m asl). The difference between headpond and downstream water levels is about 2.5 m in summer and 3 m in winter. The seasonal fluctuation of Nile water levels at the old barrage (U/S and D/S), the anticipated operation scheme (standard headpond curve), and river water levels at the upstream located river gauge at Abo Tig are given in Figure (4) (period 2004-2008).

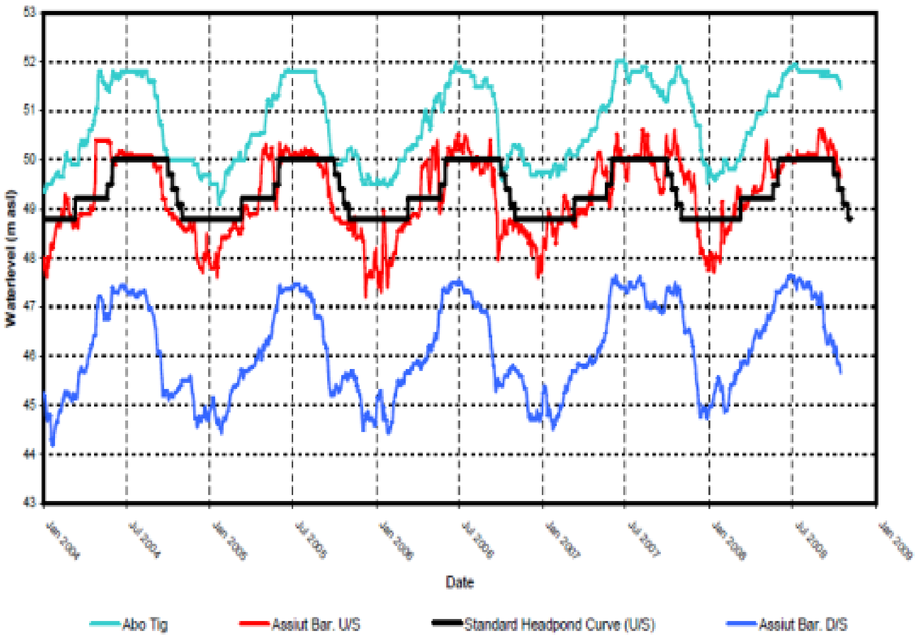

Figure (4): Nile river water levels U/S AND D/S of Assuit barrage and Abo Tig (2004-2008)

4. Groundwater Abstraction

Within the study region, groundwater abstraction occurs for both water supply and irrigation. Rural water supply depends mainly on groundwater production from the Pleistocene aquifer, while major towns (i.e. Assiut, Abu Tig, Sidfa, and Sahel Selem) are also partly supplied by Nile water. A comprehensive list of groundwater extraction rates, considering almost 100 towns and villages within the 9 districts of the model area. According to these data, the annual water production sums up to 110 Mio. m³ (300,000 m³/d), serving 1.8 Mio. inhabitants. Groundwater abstraction has to be taken into account for the purpose of irrigation.

The model output indicates an annual consumption of groundwater for the purpose of irrigation in a range of 60 to 80 Mio. m³ (165,000 to 220,000 m³/d), mainly extracted during the summer season. The abstraction of irrigation water leads to a temporary drawdown of groundwater levels in summer, which is in total contrast to the usual seasonal fluctuation. Two areas of extensive groundwater abstraction for irrigation on the Left Bank (Abu Tig-, Sidfa & Ganaem-, and Tima Districts), identified by the inverse seasonal fluctuation of groundwater levels. The total annual groundwater abstraction between 170 and 210 Mio. m³ (equal to 365,000 - 520,000 m³/d) has to be taken into account.

5. Irrigation and Drainage

Agricultural irrigation within the Project Area is mainly based on water supply from the River Nile through a complex system of irrigation canals.

A supplementary source for irrigation water is groundwater at certain locations. The Project area is served by two main canals, the Eastern and Western Naga Hammadi Canals, both supplied by gravity upstream of the Naga Hammadi Barrage. The Western Naga Hammadi Canal feeds the El Gergawia Canal, which serves the western edge of the valley. The Eastern Naga Hammadi Canal serves the entire East Bank, finally ending up a view kilometres upstream of Assiut, feeding the El Mianna Group. The Ibrahimia Canal starts directly upstream of the old Assiut Barrage, running through Assiut City and serving the west bank area further north as far as Giza Governorate. With an average discharge of approximately 450 m³/s during the high flood season, the Ibrahimia Canal is the most important canal in Upper Egypt. The main canals are controlled by a series of regulators, which also control the distribution of irrigation water to the secondary and tertiary canal system according to the given rotation scheme. the network of primary and secondary canals is shown in Figure (5). The drainage system in the Project Area is sub-divided into three drainage zones, associated with the El Zenar and Abu Tig main drains on the west bank, and the El Badary main drain on the east bank. In the northern part of the study area on the west bank north of Assiut, and on the east bank in Abnob and El Fath Districts, there are no drainage facilities at present. The main drains are coupled with secondary drainage (open field drains), and subsurface (tile) drains in certain areas where negative impacts on crops may arise from high groundwater levels. Drainage water is discharged into the River Nile by gravity. Figure (6) shows the alignment of the main drains and the network of the secondary drainage system within the Project Area. The depth of the field drains ranges from 1.25 to 1.5 m below ground surface, while the drain spacing is 40 m. The open drainage system has been in place for much longer than the tile drains. Their main purpose is to convey surplus irrigation water back to the River Nile. Their design has therefore been based on peak flows during the autumn and winter period.

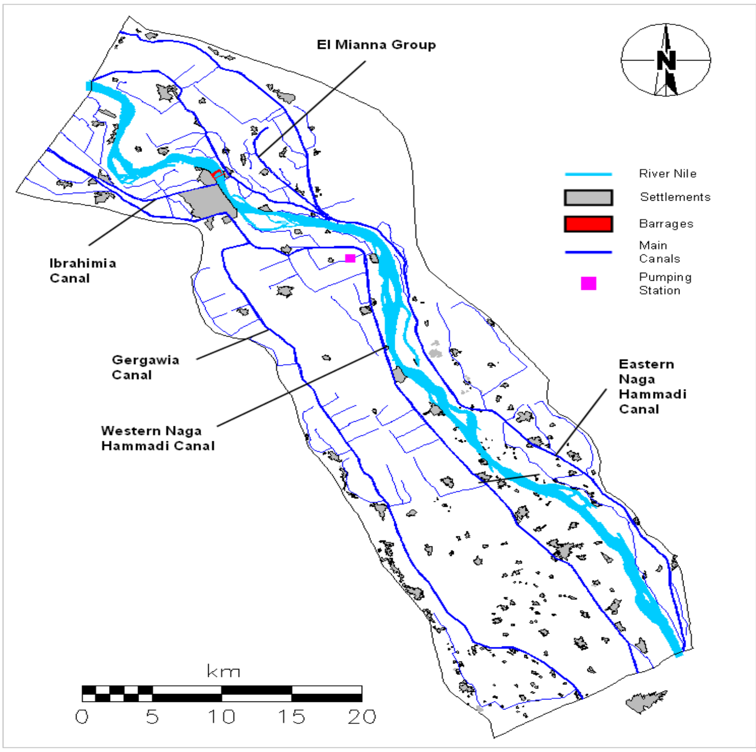

Figure (5): Network of irrigation canals

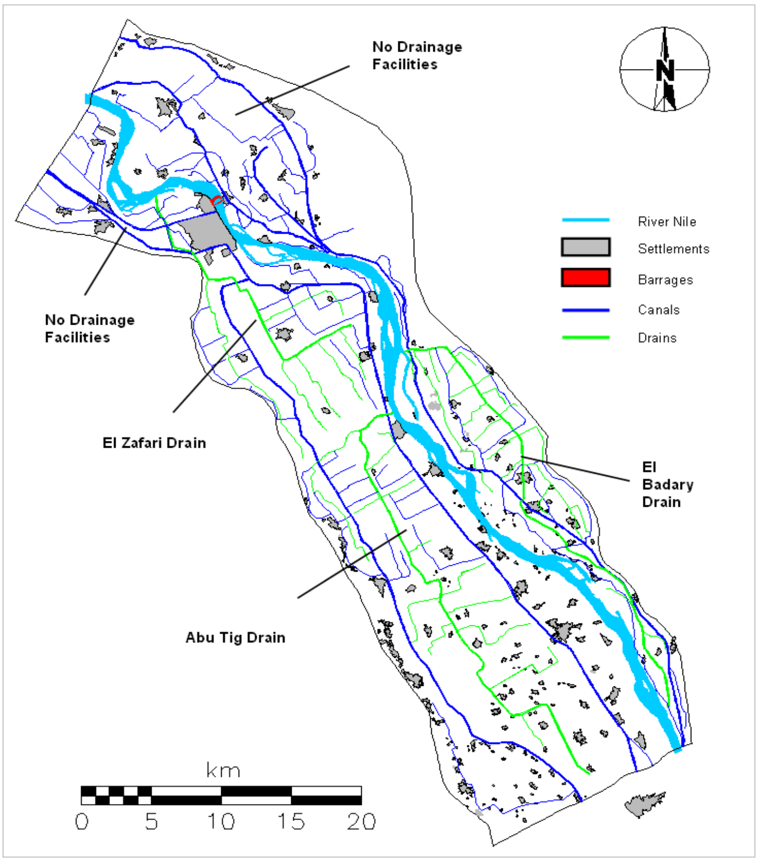

Figure (6): Network of open drains

6. Simulation of aquifer system

6.1 Conceptual model formulation

The main scope of the modeling study was to assess the extent and magnitude of groundwater level changes as a consequence of river level changes after the rehabilitation of the barrage. From this assessment the impact on the urban and rural environments can be assessed. So, the model should be capable of simulating flows in the aquifer system as well as the interaction between the groundwater aquifer systems and the surface environment. The model applied for the groundwater simulations is the software package FEFLOW (Version 6), developed and distributed by DHI/Wasy. FEFLOW provides a fully three dimensional simulation of groundwater flow under steady state and transient conditions, based on the finite element technique.It can be used to build models of groundwater flow in up to nine aquifers, separated by aquitards. The package consists of seven preprocessing, finite element and post-processing modules. In FEFLOW multiple pumping and injection wells can be implemented (Q would be positive for injection wells and negative for abstraction wells). The model is capable of simulating the interaction between surface water bodies and groundwater.

6.2 Model boundaries and extent

Two types of boundary conditions have been used. For certain areas a ‘no flow’ boundary was specified (Neumann conditions). In this case the derivatives of the head (flux) across the boundary are set to zero. This type of boundary has been used for the eastern and western boundaries. The western boundary is a fault where no flow enters the aquifer system and the eastern boundary is a hard Pliocene clay layer which is considered as an impermeable boundary. For other areas a fixed head boundary (Dirichelet Conditions) was used. In this case the derivatives of the peizometric head are constant and do not change with time. This head is specified by the model user across the specified boundary. This condition has been used for the northern and southern boundaries where the model boundaries cut the aquifer system along the Nile Valley. The river Nile branches form a naturally controlled head boundary to the aquifer system, and it is conceivable that the other main canals also act as a controlled head boundary. The model covers an area of 3526 km^2. The model grid comprises 16,627 nodes with 32,843 equilateral triangular elements ranging in size from 300 m in the main area of interest, 750 m in the remainder of the Nile Valley and the desert fringes outside the Nile valley, as shown in Figure (7).

6.3 Numerical simulation

The model comprises three layers representing the aquifer system. The top system represents the zone between the ground surface and just below the level of the artificial drainage systems (about 1.5 m). Within this layer recharge is specified, while outflow to tile drains (if present) is calculated from the drainage system properties, the characteristics of Layer 1 and the position of the groundwater table relative to the drain level. The difference between recharge and outflow to the tile drains represents the exchange between the Top System and Layer 1. This exchange can be positive (inflow to Layer 1) or negative (outflow from Layer 1), depending on the outflow from the tile drains. If no tile drains are present, the exchange is equal to the recharge to Layer 1. Depending on the choice of recharge option, capillary flux would be simulated in this layer.

Layer 1 represents the semi-confining layer (upper clay layer), which overlies the main aquifer. It is modeled as an aquifer in which vertical and horizontal flow is simulated. All surface water features such as the river, main irrigation canals and main open drains are included as 'rivers' in the model. The exchange between those 'rivers' and the aquifer systems occurs in Layer 1. The exchange between this layer and Layer 2 is through a leakage mechanism. Storage changes are only simulated if the model is run in transient mode.

Layer 2 represents the main aquifer in which horizontal flow is simulated. Groundwater abstraction occurs from this layer, while storage changes (confined or unconfined, depending on the groundwater level relative to the top of the layer) are simulated if the model is operated in transient mode. The exchange with Layer 1 is through a leakage mechanism. Where the upper clay layer is not present, a thin Layer 1 is specified with a hydraulic resistance of zero. This ensures that the aquifer system acts as a single-layer phreatic aquifer.

Figure 7: Finite element mesh (total model

7. MODEL CALIBRATION

The calibration process typically involves calibrating to steady-state and transient conditions. With steady-state simulations, there are no observed changes in hydraulic head with time for the field conditions being modeled. Transient simulations involve the change in hydraulic head with time (e.g. aquifer test, an aquifer stressed by a well-field (Khadri and Pande1, 2016).

7.1 Steady State Calibration in 2004

The steady state condition is a condition that existed in the aquifer before any development had occurred. Matching the initial heads observed for the aquifer with the hydraulic heads simulated by Feflow is called steady state calibration. It is done by sequential adjustment of the model Parameters. Hydraulic conductivities estimated from previous studies and from pumping tests were used as initial values for the steady state simulation. Observed and simulated heads were obtained. Simulated head values in 2004 using FEFLOW are shown in Figure 8. Figure 9 shows statistical plots of the observed and simulated hydraulic head obtained from the observation wells in the steady state model of 2004. Based on the results of model calibration, the overall Hydraulic conductivities for the aquifer system can be summarized as follows:

- For the upper Holocene layer The horizontal Hydraulic conductivity (kh) is likely to be 0.864 m/day. The vertical Hydraulic conductivity (kv), is estimated to be 0.086 m/d.
- For The Quaternary (sand &gravel) layer The horizontal Hydraulic conductivity (kh) are likely to be 0.9 m/day. The vertical Hydraulic conductivity (kv), is estimated to be 0.204 m/d.
- Plio-Pleistocene deposits layer. The horizontal Hydraulic conductivity (kh) is likely to be 60-77.7 m/day. The vertical Hydraulic conductivity (kv), is estimated to be 6-7 m/d.

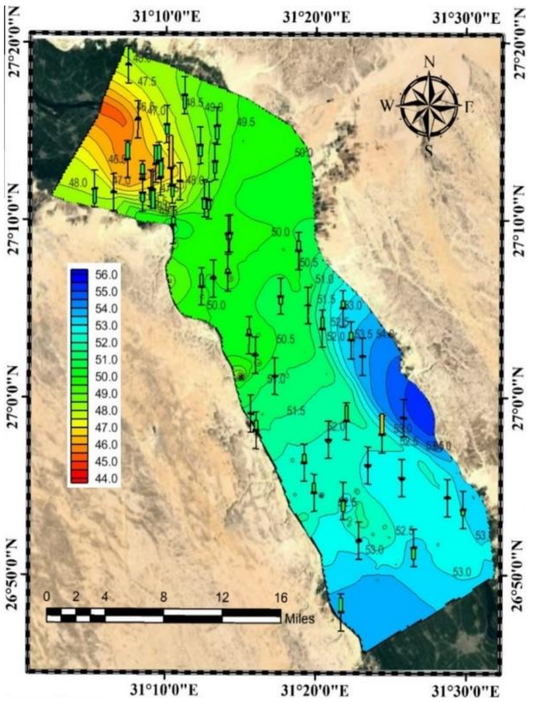

Figure 8: Simulated head values in 2004 using FEFLOW

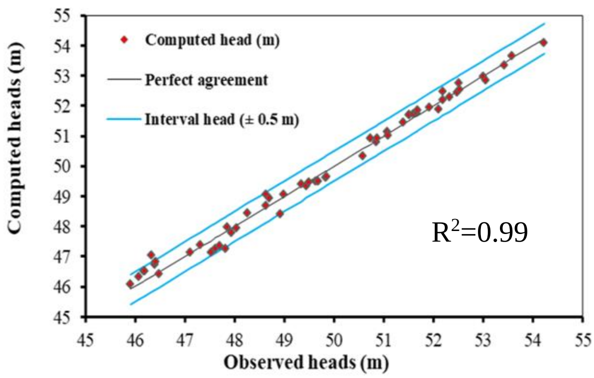

Figure9: Statistical plots of the observed and simulated hydraulic head obtained from the observation wells in the steady state model of 2004

7.2 Transient State Calibration (2004-2008)

Successful transient calibration depends mainly on the good estimation of hydraulic conductivities and boundary conditions obtained from the steady state calibration. Generally, specific yield for unconfined aquifers and storage coefficient (specific storage) for confined aquifers are the main parameters that are changed during the transient calibration (Abdulla and Al-Assad, 2006).

The purpose of the transient calibration is to achieve a reasonable correlation between the natural and simulated groundwater regime under consideration of the temporal variations of internal and external boundary conditions. Based on the available data, the transient calibration covers a calculation period from April 1, 2004 to June 1, 2008 (3 years), (Transient state) indicate that:-

- For the upper Holocene layer,the calibrated specific yield value is 0.06.
- For the Quaternary (sand &gravel) layer, the calibrated specific storage value is 0.001.
- For Plio-Pleistocene deposits layer. The calibrated specific storage value is 0.0004.

Figure 10 shows Simulated head values in 2008 using FEFLOW. Figure 11 shows Statistical plots of the observed and simulated hydraulic head for the predictive transient model 2004-2008.

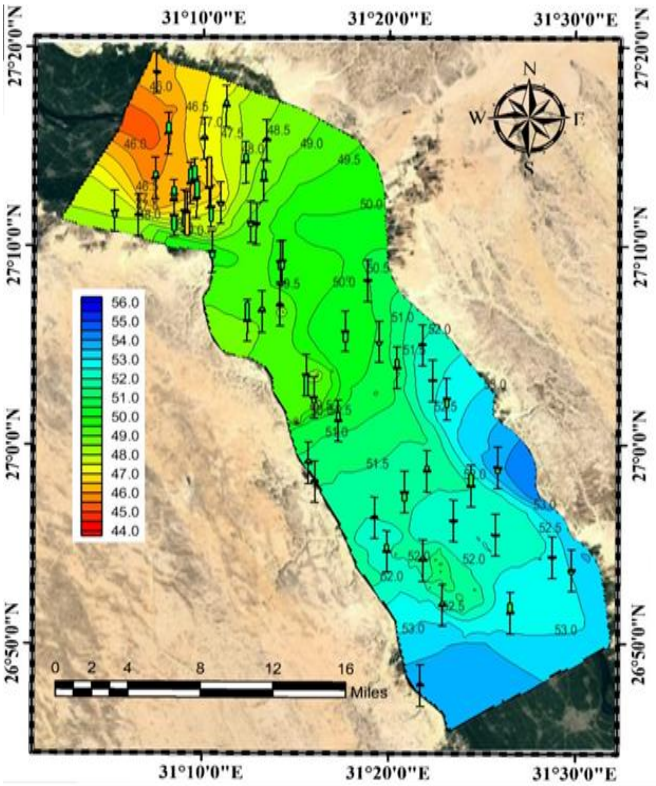

Figure10: Simulated head values in 2008 using FEFLOW

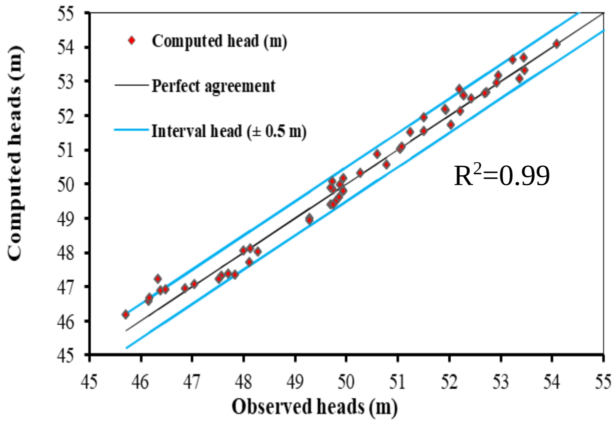

Figure11: Statistical plots of the observed and simulated hydraulic head for the predictive transient model 2004-2008.

7.3 MODEL VERIFICATION (2008-2017)

Model validation is in reality an extension of the calibration process. Its purpose is to assure that the calibrated model properly assesses all the variables and conditions which can affect model results. While there are several approaches to validate a model, perhaps the most effective procedure is to use only a portion of the available record of observed values for calibration. Once the final parameter values are developed through calibration, simulation is performed for the remaining period of observed values and goodness-of-fit between recorded and simulated values is reassessed. This type of split-sample calibration/validation procedure is commonly used, and recommended, for many groundwater flow modeling studies. Model credibility is based on the ability of a single set of parameters to represent the entire range of observed data. The data of groundwater levels 2017 before the operation of the new barrage from the monitoring wells used to perform the model verification. The calibrated results of ME, MAE and RSME are 0.08 m, 0.30 m and 0.62 m respectively and correlation coefficient (R) was 0.90. Figure 12 shows Simulated head values in 2017 using FEFLOW. Figure 13 shows Statistical plots of the observed and simulated hydraulic head for the predictive transient model 2008-2017.The result shows good quality for the simulation.

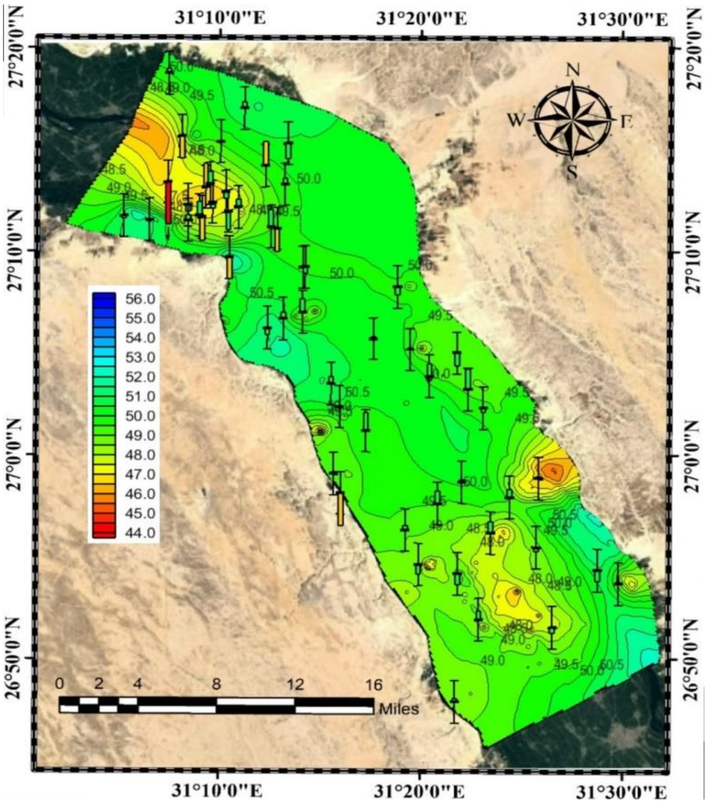

Figure12: Simulated head values in 2017 using FEFLOW

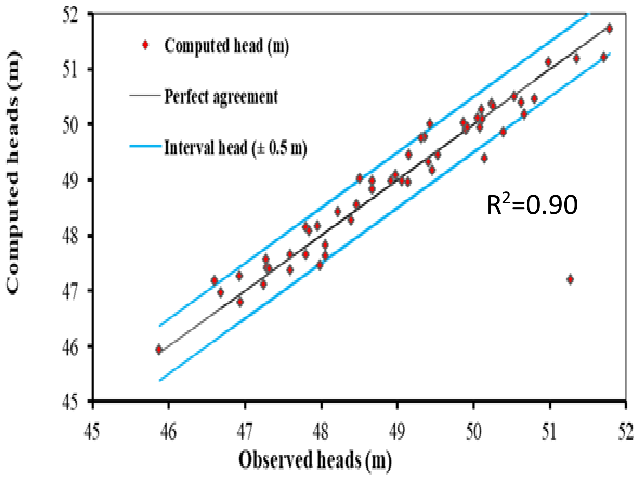

Figure13: Statistical plots of the observed and simulated hydraulic head for the predictive verification model 2008-2017.

8. MODEL PREDICTION

After obtaining the calibrated parameters, the model was run to predict the groundwater behavior through one scenario to determine future conditions, and to support the planning of mitigation measures for any adverse impacts caused by the construction and operation of the new barrage. This scenario is explained below:

8.1 Scenario 1: Rising the level of upstream, and the drains levels 0.5m with constant abstraction of 2017

In this scenario after the operations of the new barrage the upstream, downstream and drains levels will rise 0.5 m with constant abstraction of 2017. Figure 14 shows simulated head values after rising upstream, downstream and drains levels 0.5m using FEFLOW. Irrigation districts in the study region are given in Figure 15.

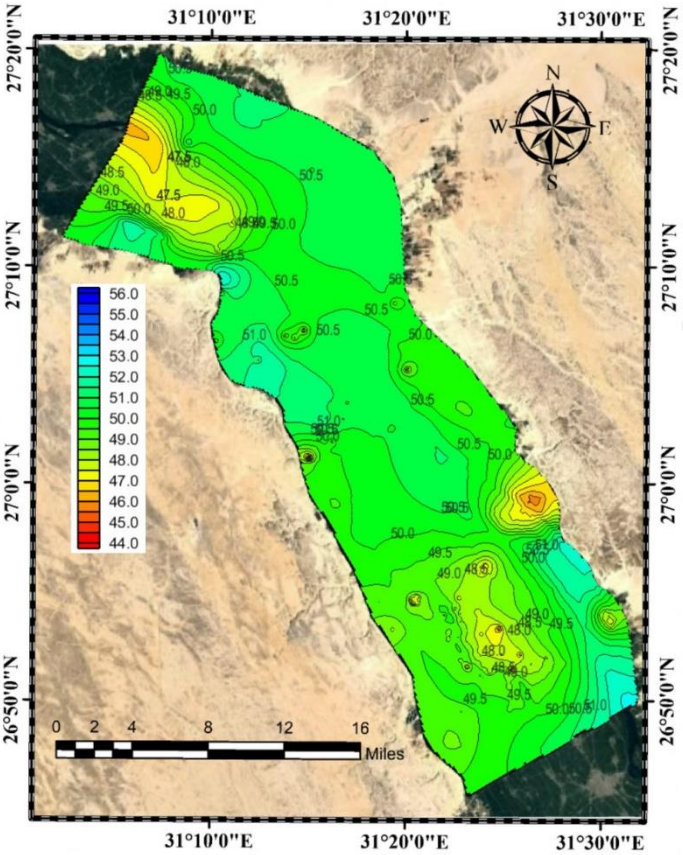

Figure14: Simulated head values after rising upstream, and drains levels 0.5m using FEFLOW

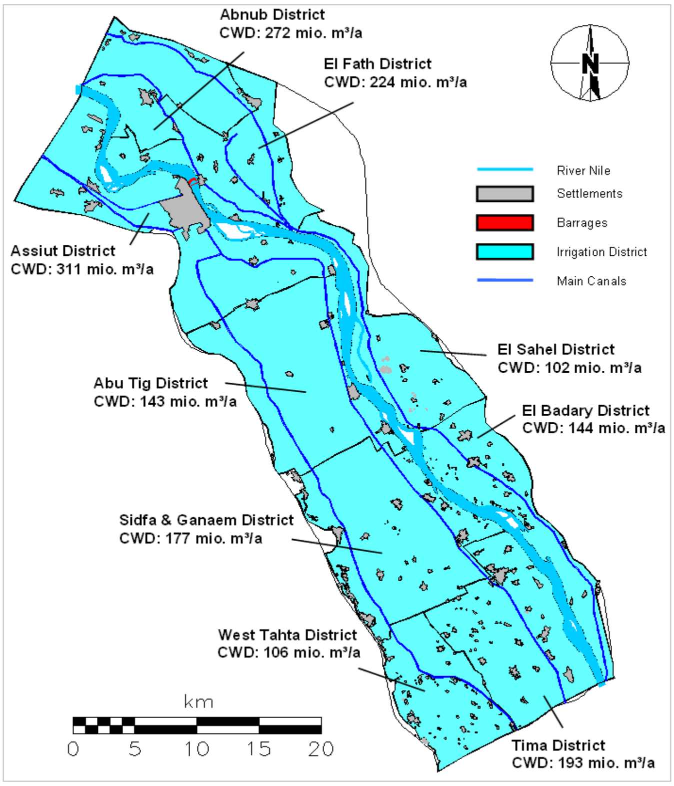

Figure 15: Irrigation districts in the study region

- ***Abu Tig district***

A shallow groundwater table is observed throughout this area. The model predictions indicate an average rise in the groundwater table of only 0.43 m from the head values of 2017. Figure 16 shows Predicted groundwater levels at Abu Tig District.

- ***Sidfa & Ganaem district***

A shallow groundwater table is observed throughout this area. The model predictions indicate an average rise in the groundwater table of only 0.46 m from the head values of 2017. Figure 17 shows Predicted groundwater levels at Sidfa & Ganaem District.

- ***El-Fath District***

A shallow groundwater table is observed throughout this area. The model predictions indicate an average rise in the groundwater table of only 0.31 m from the head values of 2017. Figure 18 shows Predicted groundwater levels at El-Fath.

- ***El-Sahel District***

A shallow groundwater table is observed throughout this area. The model predictions indicate an average rise in the groundwater table of only 0.44 m from the head values of 2017. Figure 19 shows Predicted groundwater levels at El-Sahel District.

- The resulting depths of groundwater are greater than 3 m. it will not affect the base of the root zone.

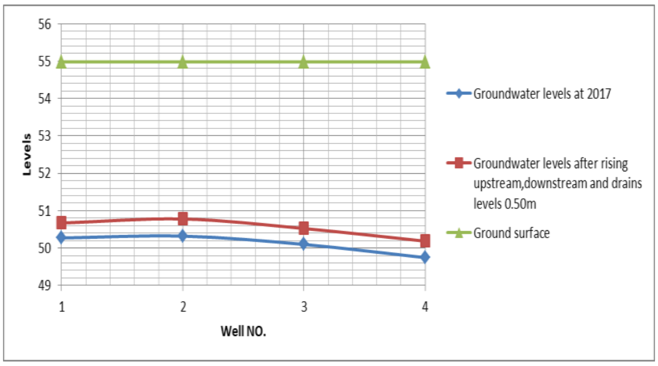

Figure 16: Predicted groundwater levels at Abu Tig

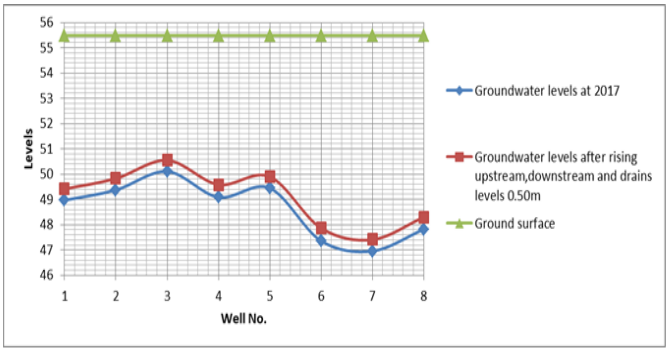

Figure 17: Predicted groundwater levels at Sidfa & Ganaem district

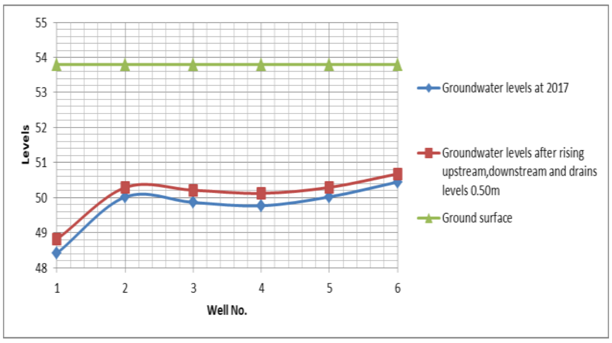

Figure 18: Predicted groundwater levels at El-Fath District

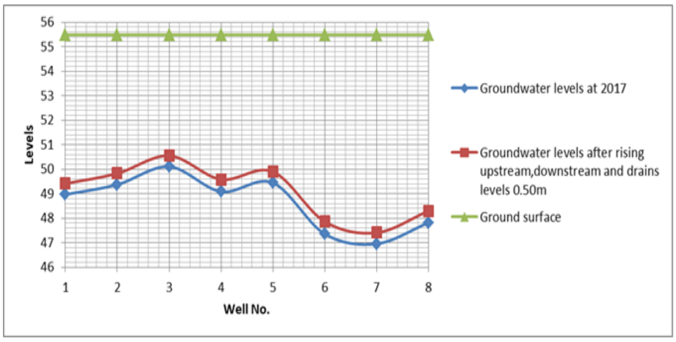

Figure 19: Predicted groundwater levels at El-Sahel District

9. CONCLUSIONS

Based on the present study the following conclusions can be drawn:
Processing FEFLOW version 6.0 is used in this study to simulate the groundwater flow for the aquifer system for both steady and transient conditions. Results of the calibrated flow model (steady state) indicate that:-

- For the upper Holocene layer, the horizontal Hydraulic conductivity (kh) is likely to be 0.864 m/day. The vertical Hydraulic conductivity (kv), is estimated to be 0.086 m/d.
- For the Quaternary (sand &gravel) layer the horizontal Hydraulic conductivity (kh) are likely to be 0.9 m/day. The vertical Hydraulic conductivity (kv), is estimated to be 0.204 m/d.
- Plio-Pleistocene deposits layer. The horizontal Hydraulic conductivity (kh) is likely to be 60-77.7 m/day. The vertical Hydraulic conductivity (kv), is estimated to be 6-7 m/d.

(Transient state) indicate that:-

- For the upper Holocene layer, the calibrated specific yield value is 0.06.
- For the Quaternary (sand &gravel) layer, the calibrated specific storage value is 0.001.
- For Plio-Pleistocene deposits layer. The calibrated specific storage value is 0.0004.

A scenario was developed to predict the response of the aquifer system under different conditions where the effect of rising water levels on the recharge of the aquifer was investigated. Rising the level of upstream, downstream of the new barrage and the drains levels 0.5m with constant abstraction of 2017. It was found that the water levels rise at different rates and are not effective in the area in upstream of the barrage (Abu Tig 43 cm, Sidfa & Ganaem 46 cm, El-Fath 31 cm, El-Sahel 44 cm) the resulting depths of groundwater are greater than 3 m, it will not affect the base of the root zone. There are no negative effects on the city of Assuit due to the implementation of the project.

10. REFERENCES

1. **Abdulla F. and Al-Assad T. (2006),** "Modeling of groundwater flow for Mujib aquifer, Jordan", Journal of Earth System Science, Vol. 115 No. 3, pp. 289–297.
2. **Allam and Dawoud (2004),** "Effect of New Nag Hammadi Barrage on Groundwater and Drainage Conditions and Suggestion of Mitigation Measures",
3. Journal of Water Resources Management Vol. 18, pp. 321–337.
4. **Asmael N. M., Dupuy A., Huneau F., Hamid S., and Coustumer P. L. (2015),** "Groundwater modeling as an alternative approach to limited data in the northeastern part of Mt. Hermon (Syria), to develop a preliminary water budget", Journal of Water, Vol. 7, pp. 3978-3996.
5. **Dawoud M. A., El-Arabi N. E., Khater A. R. and Wonderen J. V. (2006),** "Impact of rehabilitation of Assiut barrage, Nile River, on groundwater rise in urban areas", Journal of African Earth Sciences, Vol. 45, pp. 395–407.
6. **Dawoud M. A. and Ewea H. A. R. (2011),** "Sustainable Development via Optimal Integration of Surface and Groundwater in Arid Environment: Nile River Quaternary Aquifer Case Study." Resources, Conservation and Recycling.
7. **Fekry A. and El-Fakharany Z. (2014),** "Assessment of New Esna Barrage Impacts on Groundwater and Proposed Measures," Journal of National Water Research Center, El-Kanater, El-Khairiya, Egypt, Vol. 28, pp. 65–73.
8. **Gasser, M.M. (1996),** "Impact of high Aswan Dam on Egypt. Issues and Directions in Hydraulics". pp. 377–417.
9. **Idris A. N., Aris A. Z. and Narany T.S. (2017),** "Simulation of Saltwater Intrusion in Coastal Aquifer of Kg. Salang, Tioman Island, Pahang,Malaysia," MATEC Web of Conferences 103, 04024.
10. **Khadri S. F. R. and Pande C. (2016),** "Ground water flow modeling for calibrating steady state using MODFLOW software: a case study of Mahesh river basin, India", journal Modeling Earth Systems and Environment , Vol. 39, No. 2, pp. 1-17.
11. **Sindhu G. and Vijayachandran L. (2018),** "Effect of Pumping on Groundwater Levels: A Case Study," Journal of The Institution of Engineers (India),Vol. 99, No. 2, pp. 369–377.
12. **Usman M., Lied R., Arshad M. and Conrad C. (2018),** "3-D Numerical Modelling of Groundwater Flow for Scenario-Based Analysis and Management," Journal of Water SA, Vol. 44, No.2, pp. 146-15