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Groundwater Management in Wadi El Natrun Pliocene aquifer, Egypt

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Abstract— Wadi El Natrun (WEN) Depression located in semi-arid area at El Behera governorate, western of Nile Delta, Egypt. The study area covers about 770 Km2. WEN Depression is very important for many aspects; agriculture, industrial, tourism and recreation investment because of high potential of groundwater, accessibility, and investment of facilities that provided by the government. During recent years, water resources of WEN have been encountered with problems due to overgrowth of exploitation establishments and agricultural processes. Thus, to evaluate the existing situation and managing a good usage of water resources, MODFLOW was used to simulate the groundwater behavior of Wadi El Natrun Pliocene Aquifer (WNPA). The calibration proses of the model parameters were applied under steady-state and transient-state conditions using the available data of 14 observation wells. Based on the MODFLOW model, four appropriate scenarios are proposed for a sustainable groundwater for prediction of the drawdown and head levels. The results of calibration appear that the hydraulic conductivity of the aquifer ranges between 10 and 45 m/day. Calibrated specific storage ranges from 0.0001 to 0.1. The results of the first scenario show that the predicted total IN budget of Pliocene aquifer will be (107250) m3/day, while the OUT budget will be (107220) m3/day after simulation period (50 years).

Index Terms— Groundwater Management, MODFLOW, Calibration, WNPA

1 Introduction

Generally, groundwater modeling is common in groundwater management. Modeling increases the value of observations and makes it easier to understand physical and geochemical responses. In the investigations of groundwater flow, the finite mathematics and computer technology has been used to make numerical modeling of these problems. These numerical solutions need a lot of data and a great deal of effort to get a simulation which is realistic enough. Analytical solutions of the same problems can be useful, because they don't need the same amount of data and details as the numerical solutions, but can still give an understanding of the physical conditions in the study area and how they affect the groundwater flow.

A simulation step of groundwater flow, takes several considerations that parameters and properties variability of aquifer is always possible through mathematical modeling; Kumar, (2013). Most models which are usually employed to simulate groundwater flow are based on the Partial Differential Equation (PDE) which can be solved numerically through Finite Difference (FD) or Finite Element (FE) techniques; Langevin CD and Guo W, (2006). These methods discretize the time and flow domains, and require finding the values of hydraulic head in every cell by making the time periods into smaller time steps. Modeling is the most effective method to make such estimations saluting complexities and any uncertainties. Therefore, the viability of the results of any step assessment effort based on modeling is directly related to the effectiveness of a using model in representing a groundwater system.

2 The Study Area

WEN lies at El Behera governorate, western of Nile Delta, Egypt as shown at Figure (1) between Longitudes 30° 00' and 30° 33' E and Latitude 30° 20' and 30° 30' N. It parallels to (Cairo-Alex. Desert Highway) Km 90 to Km 110. The study area covers about 770 Km2.

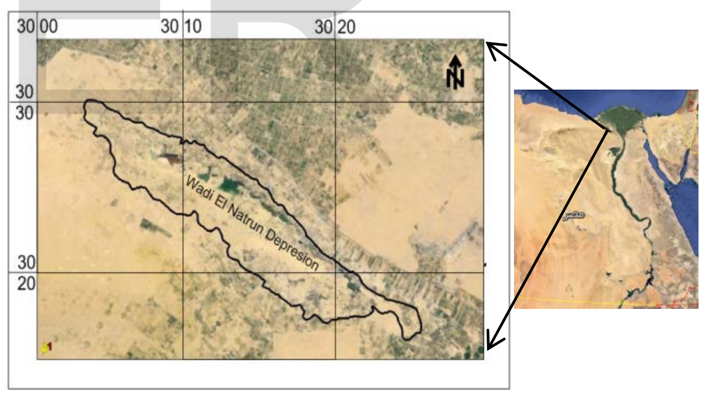

Fig. 1: Location of the study area

From the hydrological cross section which passed through Pliocene aquifer unit of WEN area in west-east direction, and, according to the vertical electrical sounding, WEN is mainly formed of alternating sand and clay and occasionally capped by thin layer of limestone. The Pliocene aquifer is considered as multi-layers aquifer under confined to semi-confined condition. Most of these water bearing layers belongs to the Upper and Middle Pliocene. In this study, the information of 111 pumping wells and 14 observation wells were collected as well as other parameters such as hydraulic conductivity. Table (1) shows the values of hydraulic conductivity, transmissivity, and storativity of Pliocene aquifer at WEN area from different authors. According to the analysis of Pliocene aquifer in the area of study we can notice that, the hydraulic conductivity (K) values ranged between 9.8

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and 38.9 m/day. The transmissivity (T) values ranged between 500 and 1660 m2/day in different zones of the Depression.

Table (1) Hydraulic parameters of the Pliocene aquifer

Author	Location of the test zone	Hydraulic parameters		
		K	T	S
Ahmed S. A. (1999)	North of WEN	-	1043.9	-
Ibrahim, S. 2005	North-east WEN	-	1240	-
Ahmed S. A. (1999)	Near El hamara	-	794	-
RIGW/IWACO, (1990)	WEN area	9.8	500-327	1.7*10-2
Mostafa, N E. (1993)	East WEN	47	943	7*10-3
Saad, K.F. (1964)	East WEN	38.9	695.5	1.35*10-3
Ahmed S. A. (1999)	South WEN	-	1660	-
El-Sheikh (2000)	Beni Salama	7.29	838	8.5*10-4
Kashouty, M and A Sabbagh. (2011)	East WEN	9.8	500	1.85*10-4
Saad, K F. (2012)	East of WEN	38.9	1350	7.5*10-3

2.1 GEOMORPHOLOGY AND GEOLOGY

The study area is occupied mainly by sedimentary rocks layers belonging to the Tertiary and Quaternary Eras. The sedimentary succession comprises several water-bearing formations which are particularly influenced by structural features and thus affect the groundwater flow. However, the surface deposits dominating the area are studied through the geological map which shown in Figure (2). In the study area, Tertiary and Quaternary succession were studied by many authors. Among them are, Said, R. (1962), Shata, A.A. and El-Fayoumy, I.F. (1970), Ahmed Y. A.A., (1970); Diab et al. (1980); Abdallah I.A., (2000); Sanad, S. (1973); Attia S. H. (1975), Omara, S.M. and Sanad, S. (1975).
The subsurface geology of the study area is studied from the well logs as from the WEN deep well. The Pliocene aquifer is local in extent, covers the entire WEN area, and is discontinuously covered by Quaternary deposits of the Pleistocene Aquifer. As a result, the Pliocene aquifer is considered to be partially confined. The Pliocene Aquifer's thickness ranges from 150 to 300 m thick, Pavlov, M. (1962).

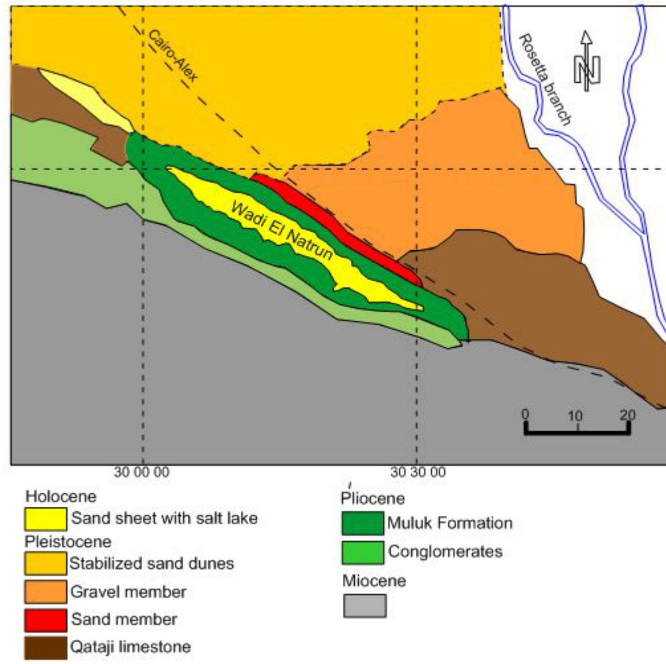

Fig. 2: Geological map of WEN and its vicinities (Modified after Abu Zeid, K., 1984)

2.2 HYDROGEOLOGY

Hydrogeologic setting in the WEN area is complex, and there is still significant uncertainty as to the precise flow regime and hydraulic connections between the aquifers. Nonetheless, multiple studies have observed both local and regional groundwater flow to be concentrated toward the base of the valley where it discharges to eleven saline lakes; Pavlov, M. (1962); Said M.M. (1968); El-Fayoumy, I.F., (1964); Atwa S. M. (1968); El-Shikh (2000).

Geoelectric cross section for Seventeen sections, which were constructed along specific trends with varying lengths in study area, are shown in figure (3). Twelve geoelectric cross sections (from A-A' to LL') are travers cross sections (from MM' to QQ') are longitudinal ones, oriented NW-SE on these cross section, the true resistivity, the depth to the base of each layer and the thickness are recorded with the interpreted lithology. These sections are very important to give acceptable idea about the subsurface geologic and hydrogeologic conditions of the study area.
Geoelectric cross section direction NE-SW, profile (A-A'), which the length of its profile is about 5 km and includes the VESes No. 10, 11 and 12, added to well No.1. The results of this profile shows that, Pliocene aquifer consist of five geoelectric layers with different thickness, figure (4).

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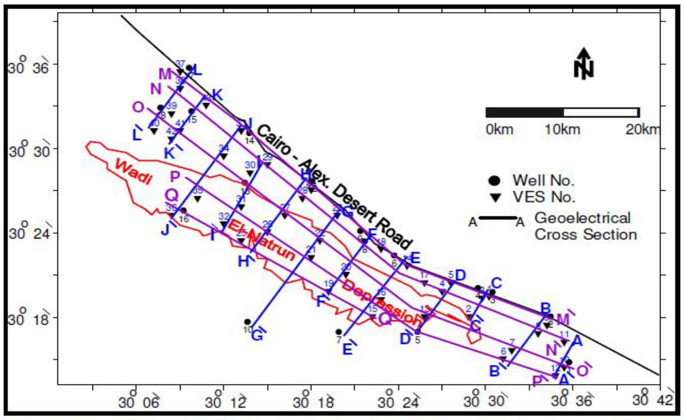

Fig. 3: Vertical electrical soundings (VESes)

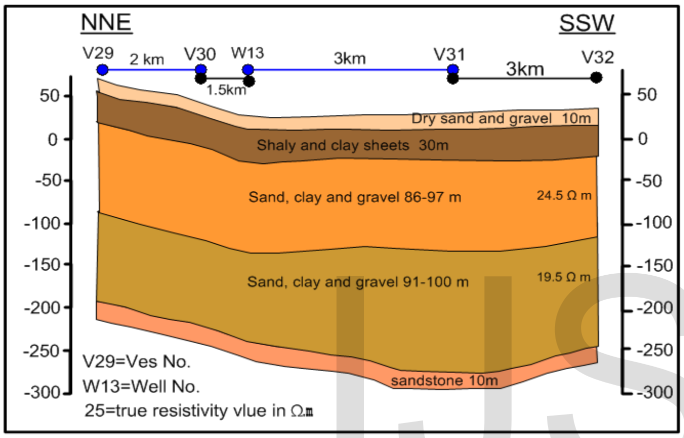

Fig. 4: Geoelectrical cross-section I-I', (after Ammar, A.I., 2002)

3 MATERIALS AND METHODOLOGY

Data of this paper are collected from different resources and several studies in WEN area, which include hydrologic data of 111 pumping wells and 14 observation wells; it also included discharge, distribution of pumping wells and groundwater depth of observation wells.

A general form of the governing equation which describes the three dimensional movement of groundwater flow of changeless density through the porous media is (McDonald and Harbaugh, 1988):

$$\frac{\partial}{\partial x}\left[Kx\frac{\partial h}{\partial x}\right]+\frac{\partial}{\partial y}\left[Ky\frac{\partial h}{\partial y}\right]+\frac{\partial}{\partial z}\left[Kz\frac{\partial h}{\partial z}\right]-w=Ss\frac{\partial h}{\partial t} \quad (1)$$

Where: Kx, Ky, Kz are values of hydraulic conductivity along the x, y and z coordinate axes (L/t); h: is the potentiometric head (L); w: is the volumetric discharge per unit volume and represents sources and/or sinks of water per unit time (t-1); Ss: is the specific storage of the porous material (L-1); and t: is time (t).

The first part of this problem was run to get a steady state solution that takes the form:

$$\frac{\partial}{\partial x}\left[Kx\frac{\partial h}{\partial x}\right]+\frac{\partial}{\partial y}\left[Ky\frac{\partial h}{\partial y}\right]+\frac{\partial}{\partial z}\left[Kz\frac{\partial h}{\partial z}\right]-w=0.0 \quad (2)$$

From the steady state solution, the hydraulic conductivity for model aquifers can be found. Then the equation is solved for transient case in order to solve for storage coefficient.

4 GROUNDWATER FLOW MODEL

To simulate groundwater flow, the model of the WNPA must constructed, which needs definition of; conceptual model, boundary conditions, model domain and aquifer properties.

4.1 CONCEPTUAL MODEL OF WEN

According to hydrogeologic properties in area of study WNPA Depression, internal descriptions represent (conceptual model) for system of water flow in aquifer constructed. The following details considered at construction of conceptual:

1. The aquifer of WEN consists of four layers appear as follows:

   - The first layer consists of dry sand, gravel and rock fragments, called the subsurface. The thickness of this layer is 10 m.
   - The second layer is formed from shaly, sand and presence of shale interbedded with sand and differential amounts of water. The thickness of this layer is about 30 m.
   - The third layer consists of clayey, sand and gravel and underground water included in this layer with a thickness of 200 m.
   - The fourth geoelectric layer is sandstone with a thickness of 10 m.

At the end, this section includes two water bearing layers, the third and the fourth geoelectric layers, which are saturated with water. These layers are considered the main aquifer of the study area, (Abdallah, 2000).

2. The groundwater flow generally from NE to SW direction toward WEN Depression. The loss due to the evapotranspiration and the recharge from irrigation will be neglected. The main discharge is represented by 111 pumping wells.

3. WNPA is under confining conditions.

4. The layer under aquifer is not considered.

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4.2 MODEL DOMAIN AND BOUNDARY CONDITIONS

The model domain was selected to cover 2016 km2 (56×36 km) include WEN depression area (770 km2). Model domain divided into 144 row and 224 columns of square cells. This division produces 32,256 cells at each layer as shown in figure (5).

Ground elevation was extracted from DEM. The maximum elevation was 181 m while the minimum elevation was -37 m.

Depending on the groundwater flow pattern of WEN aquifer and the faults in the boundary of Pliocene aquifer and the field measurement of water head at wells of WEN Depression, the northeastern and the southwestern boundary conditions are chosen to be general head because that, the elevation of groundwater is not fixed (changed with time). These general head shown in figure (5), and can be described as follows:

1- The first boundary condition (NW-SE 1) lies between the Pliocene-Pleistocene aquifer on the boundary aquifer of WEN Depression parallel to Cairo-Alex Desert Road.

2- The second boundary condition (NW-SE 2) lies between the Pliocene-Miocene aquifer on the boundary WEN.

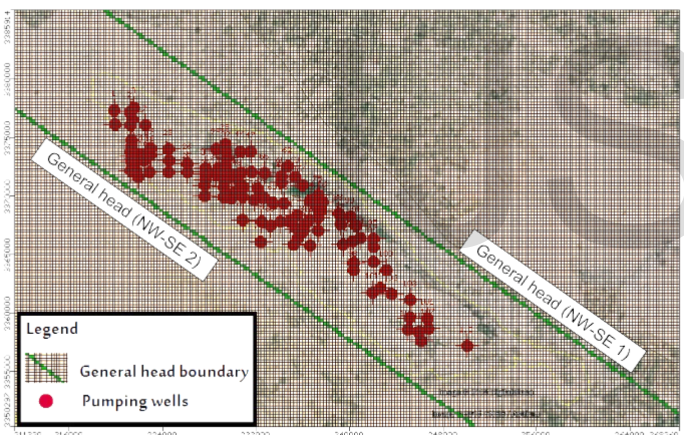

Fig. 5: The finite-difference grid of the model domain with 32256 cells and boundary conditions.

4.3 AQUIFER PROPERTIES

The material properties of the WNPA included the transmissivity, the storage coefficient and the hydraulic conductivity. The transmissivity ranges from 500 to 1660 m2/day and the storage coefficient from 1.85x10-4 to 1.7x10-2. Vertical heterogeneity was assumed adequate to allow treatment as complex layered aquifer. The vertical hydraulic conductivity, estimated from the aquifer thickness and aquifer transmissivity values, was varied from 9.8 to 38.9 m/day. Furthermore, the availability of a relatively complete database of 111 pumping wells and 14 observation wells in the WNPA helped in constructing the present model.

4.4 CALIBRATION OF STEADY-STATE CONDITIONS

The hydraulic conductivities are the main parameter used in the calibrating of the model. Whenever, any difference happened, error of input data will present, so it must be changed for several times until getting satisfied results. This means that the model succeeded, for calculating the distribution of hydraulic head at every cell at aquifer. As results and by using calculated heads, contour map of water level can be constructed.

Relation between the calculated and observed heads is checked from the calculated-observed head curve.

The variance appears as 48.30 %, figure (6). After finishing calibration, variance between the observed and simulated heads was minimized to 3.41 %, as the calculated - observed curve, figure (7).

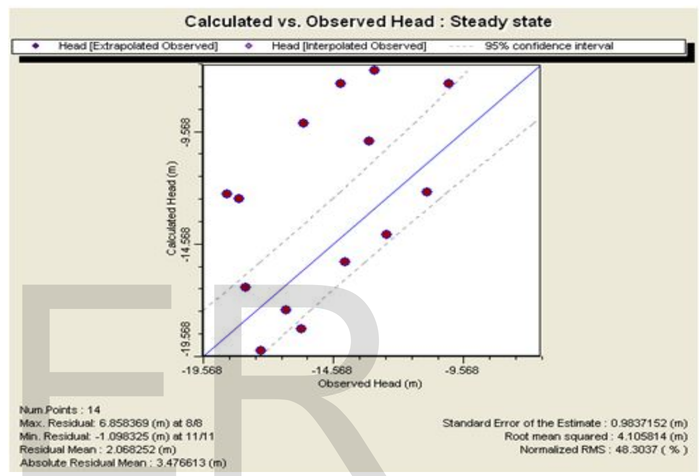

Fig. 6: The calculated and observed heads of the WNPA (steady state, year 2015) before calibration

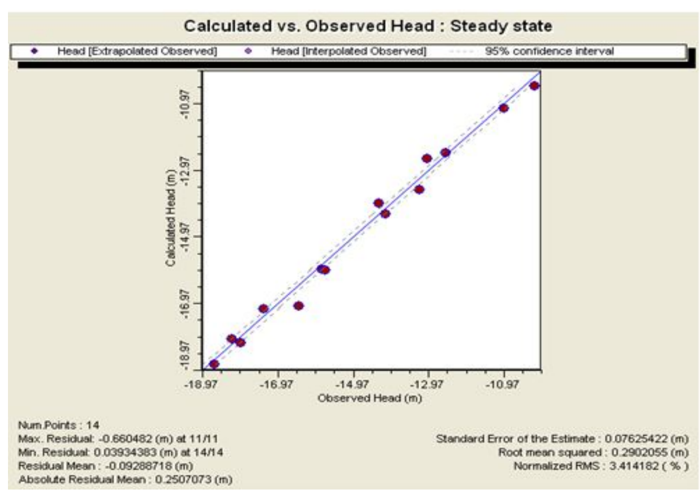

Fig 7: The calculated and observed heads of the WNPA (steady-state, year 2015) after calibration

4.5 CALIBRATION OF TRANSILET-STATE CONDITIONS

Successful transient calibration depends mainly on the good estimation of hydraulic conductivities obtained from the steady state condition. Generally, specific storage for confined aquifer is the main parameter that is changed during the transient calibration. Figure (8) shows the calculated-observed head before calibration.

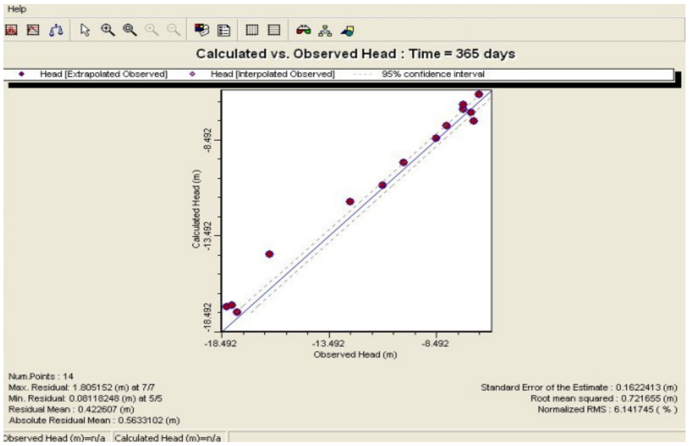

Fig. 8: The calculated- observed heads of the WNPA (unsteady state, year 2015) before calibration

In the process of transient state calibration, specific storage values were modified on a trial and errors basis, until reach a good match between the observed and the calculated heads of year 2015 figure (9). The range of the result of specific storage after the final calibration of the transient state was found to be varying from 0.0001 to 0.1. In general it can be seen that, there is good agreement between the observed and simulated head.

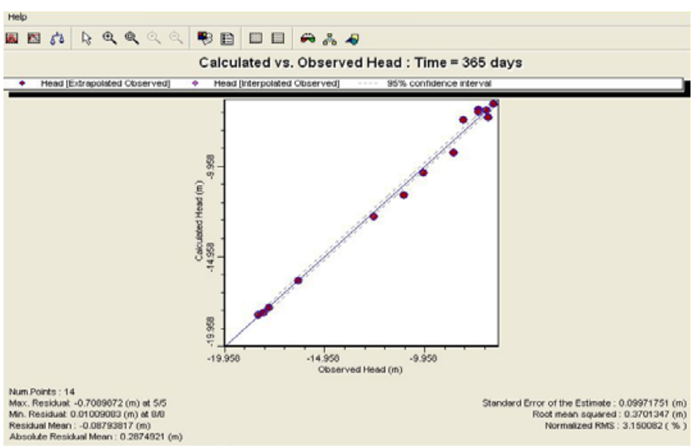

Fig. 9: The calculated- observed heads of the WNPA (unsteady state, year 2015) after calibration

Based on the calibrated model, the estimated hydraulic conductivity values are ranging from (10) to (45) m/day, figure 10. These values are generally agreed with the calculated one from the field data.

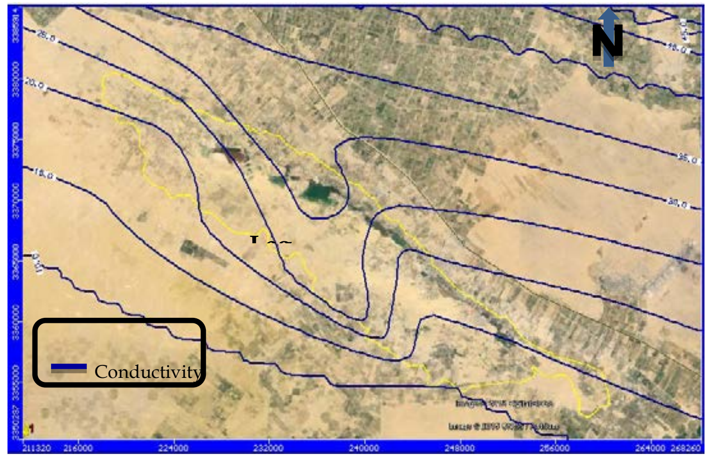

Fig. 10: The calibrated hydraulic conductivity (m/day) of the WNPA model domain

4.6 MODEL VERIFICATION

The data of groundwater levels of 14 distributed monitoring wells in WNPA figure (8) were used to perform the model verification. The simulation errors were quantified using Mean Error (ME), Mean Absolute Error (MAE) and Root Mean Squared Error (RMSE). The comparison criteria are presented as:

$$ME = \frac{1}{n}\sum_{i=1}^{n}(h_{obs} - h_{sim})_i \quad (3)$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|(h_{obs} - h_{sim})_i\right| \quad (4)$$

$$RMSE = [\frac{1}{n}\sum_{i=1}^{n}(h_{obs} - h_{sim})_i^{0.5}] \quad (5)$$

Where hobs and hsim are the observed and simulated ground water heads respectively and n is number of wells. The calibrated results of ME, MAE and RSME are -0.879, 0.287 and 0.96 m, respectively.

5 DISCUSSIONS AND ANALYSIS OF RESULTS

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Based on the steady and transient state conditions of calibrated model, the estimated hydraulic conductivity values in the modeled area are ranged from 10 to 45 m/day, and specific storage ranges from 0.0001 to 0.1, respectively. These values were relativity differed from the corresponding values of the field, due to uncertainty. Next the unsteady state model will be used to predict the future heads under different testing scenarios of pumping stresses.

6 TESTING SCENARIOS

Four scenarios were considered to predict the head and evaluate Pliocene aquifer of WEN. At the initial time which includes transient calibration at year 2015, the drawdown is zero, so the both of observed and calculated head are equals. The developed model was run after 10, 15, 25, 50 years, at years (2025, 2030, 2040, and 2065) for all scenarios.

6.1 FIRSR SCENARIO (CURRENT SITUATION)

This scenario investigates the current of 111 pumping wells penetrating the Pliocene aquifer of WEN with total discharge 56428 m3/day. The applied model was run for years 2025, 2030, 2040, and 2065. Figures 11, 12, 13, and 14, show the contour head. Table 2 below shows the extra Max drawdown at observation well number 8.

The main reason of Max drawdown at observation well No. 8 belongs to the high pumping rate from the area nearby this comparing with other observation wells.

Table (2) the Max extra drawdown for first scenario at observation well No. 8.

Year	2025	2030	2040	2065
Max extra drawdown	0.76	0.91	1.73	3.29

From the previous data obtained from MODFLOW model for first scenario, the max extra drawdowns from year 2015 to year 2065 are about 0.76 m to 3.29 m respectively. Drawdown in head at the 14 observation wells for 1st proposed scenario with total discharge 56428, m3/day figure (15).

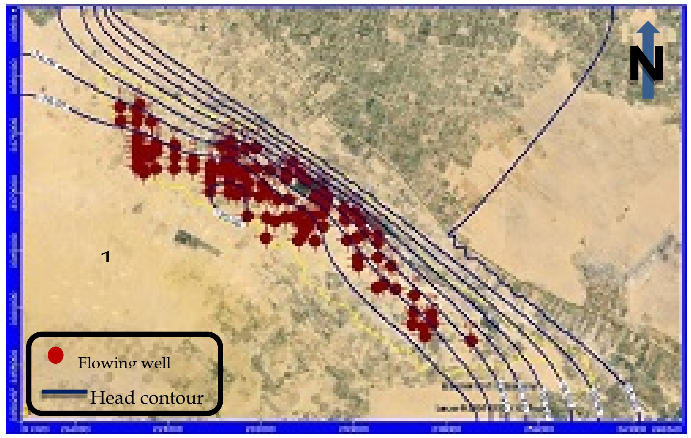

Fig. 11: Predicted head-distribution map of WNPA for current pumping rate for 1st scenario at 2025 with total discharge (56428) m^3/day.

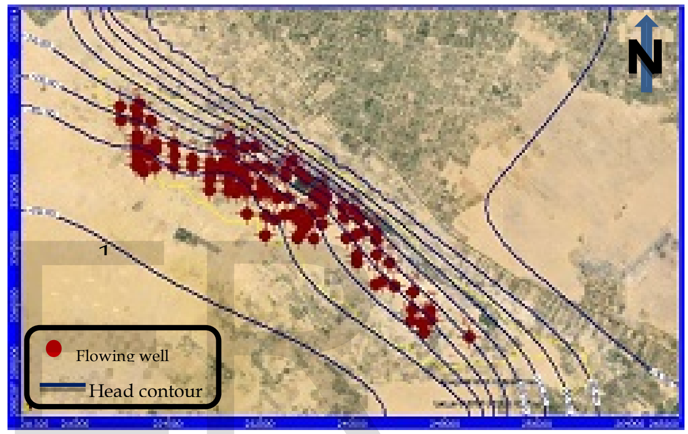

Fig. 12: Predicted head-distribution map of WNPA aquifer for current pumping rate for 1st scenario at 2030 with total discharge (56428) m^3/day.

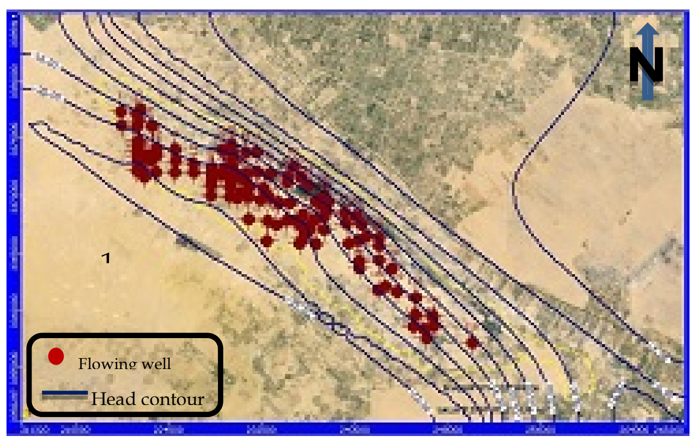

Fig. 13: Predicted head-distribution map of WNPA for current pumping rate for 1st scenario at 2040 with total discharge (56428) m^3/day.

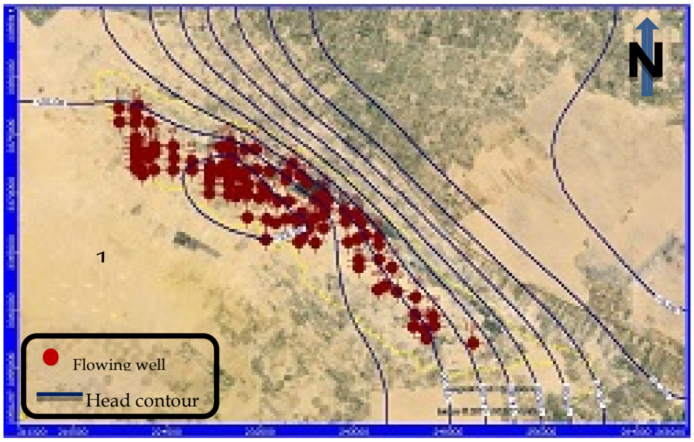

Fig. 14: Predicted head-distribution map of WNPA for current pumping rate for 1st scenario at 2060 with total discharge (56428) m³/day.

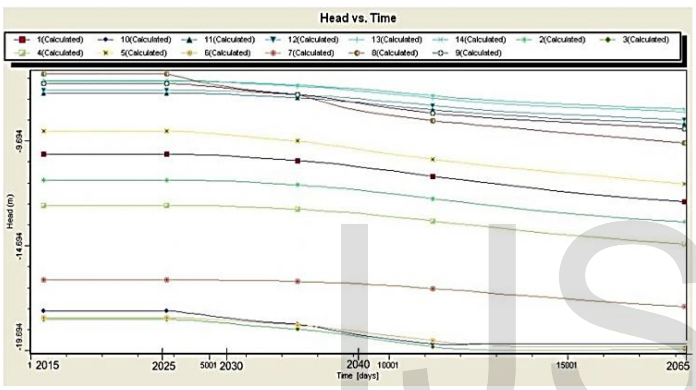

Fig. 15: Extra drawdown in head at the 14 observation wells for 1st proposed scenario with total discharge 56428, m3/day.

6.2 SECOND SCENARIO

This scenario investigates the current of 111 pumping wells penetrating the Pliocene aquifer of WEN with total discharge 64954 m3/day.

The model was applied for years 2025, 2030, 2040, and 2065. Figures 16, 17, 18, and 19, show the contour head. Table 3 below shows the Max extra drawdown observation well number 8.

Table (3) the Max extra drawdown for second scenario at observation well No. 8.

Year	2025	2030	2040	2065
Max extra drawdown	1.09	1.24	1.98	3.65

From the previous data obtained from MODFLOW model for second scenario, the max extra drawdown from year 2015 to year 2065 with value of about 1.04 m to 3.65 m, respectively. Drawdown in head at the 14 observation wells applying 2nd proposed scenario with total discharge 64954 m3/day, figure (20).

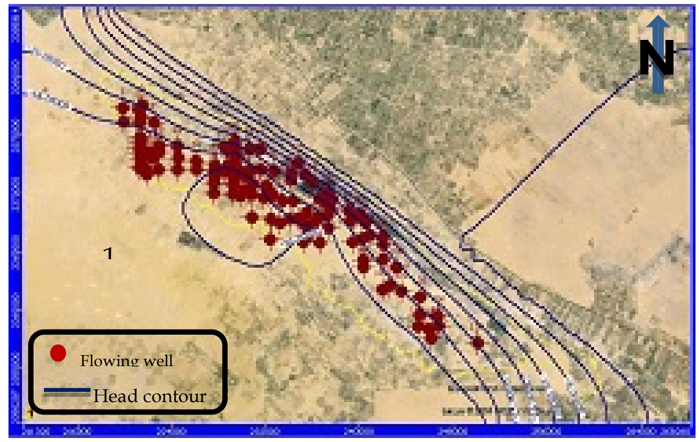

Fig. 16: Predicted head-distribution map of WNPA for pumping rate for 2nd scenario at 2025 with total discharge about (64954) m³/day.

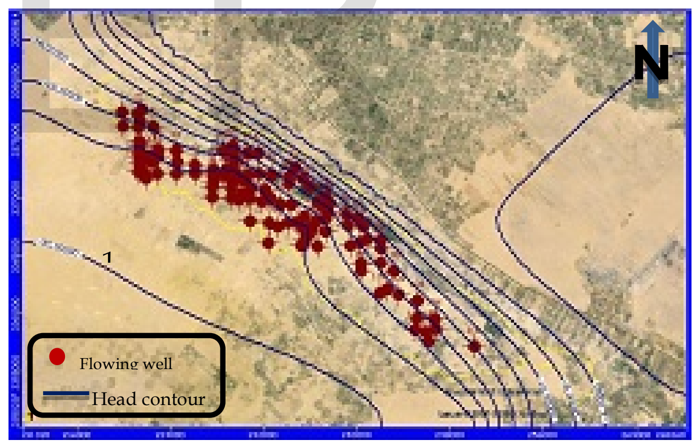

Fig. 17: Predicted head-distribution map of WNPA for pumping rate for 2nd scenario at 2030 with total discharge about (64954) m³/day.

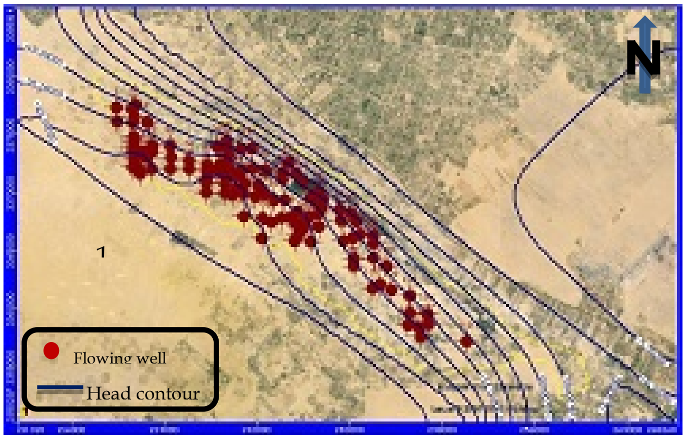

Fig. 18: Predicted head-distribution map of WNPA for pumping rate for 2nd scenario at 2040 with total discharge about (64954) m3/day.

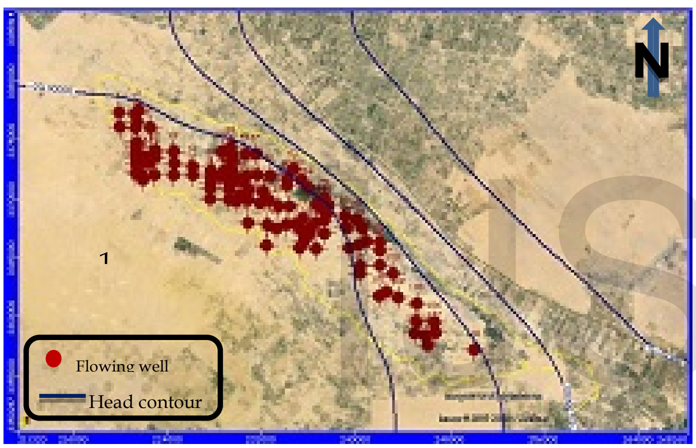

Fig. 19: Predicted head-distribution map of WNPA for pumping rate for 2nd scenario at 2065 with total discharge about (64954) m3/day.

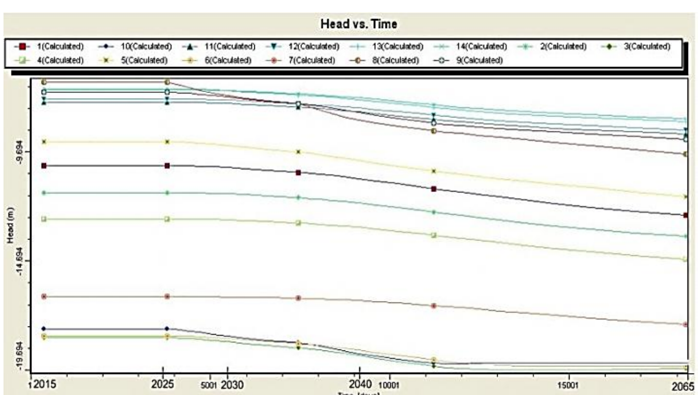

Fig. 20: Extra drawdown in head at the 14 observation wells applying 2nd proposed scenario with total discharge (64954) m3/day.

6.3 THIRD SCENARIO

This scenario investigates the current of 111 pumping wells penetrating the Pliocene aquifer of WEN with total discharge (70602) m3/day.

The applied model was run for years 2025, 2030, 2040, and 2065. The figures 21, 22, 23, and 24 show the contour heads. Table 4 shows the Max extra drawdown at observation well number 8.

Table (4) the Max extra drawdown for third scenario at observation well No. 8.

Year	2025	2030	2040	2065
Max extra-drawdown	1.45	1.63	2.14	3.9

From the previous data obtained from the MODFLOW model for third scenario, the max extra drawdown from year 2015 to year 2065 with value of about 1.4 m to 3.9 m, respectively. Drawdown in head at the 14 observation wells applying 3rd proposed with total discharge (70602), m3/day, figure (25).

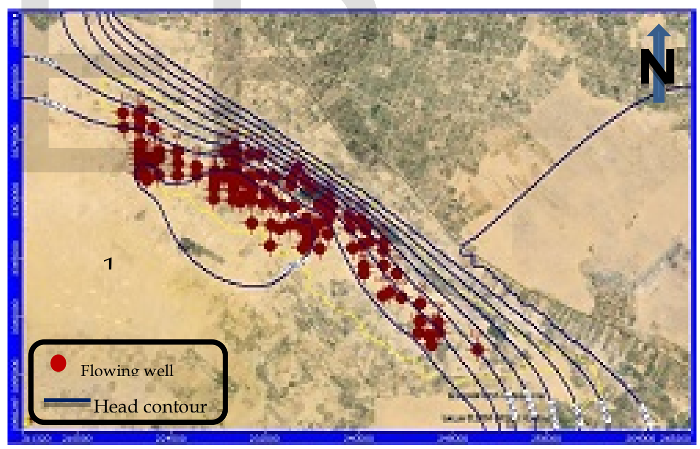

Fig. 21: Predicted head-distribution map of WNPA for pumping rate for 3rd scenario at 2025 with total discharge about (70602) m3/day.

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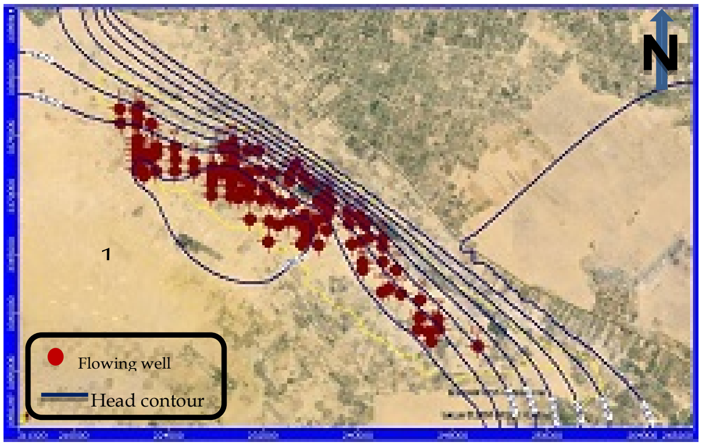

Fig. 22: Predicted head-distribution map of WNPA for pumping rate for 3rd scenario at 2030 with total discharge about (70602) m³/day.

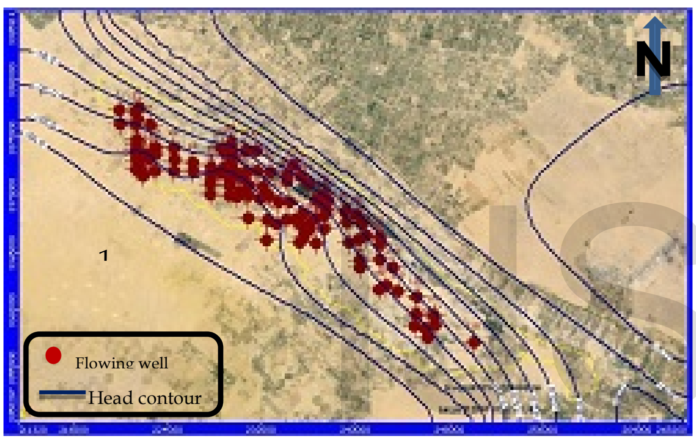

Fig. 23: Predicted head-distribution map of WNPA for pumping rate for 3rd scenario at 2040 with total discharge about (70602) m³/day.

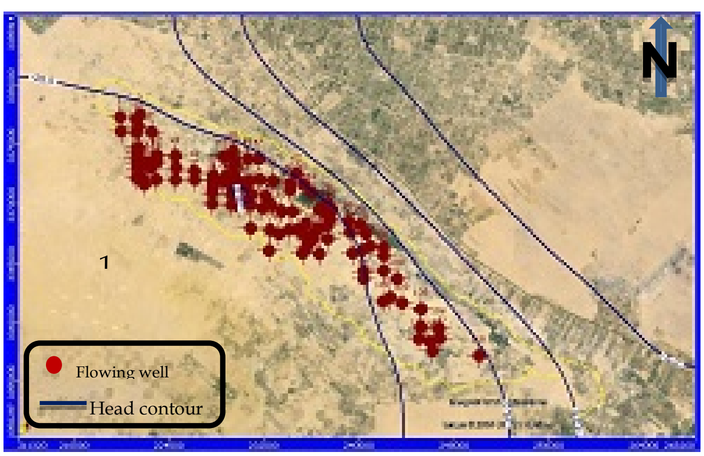

Fig. 24: Predicted head-distribution map of WNPA for pumping rate for 3rd scenario at 2065 with total discharge about (70602) m³/day.

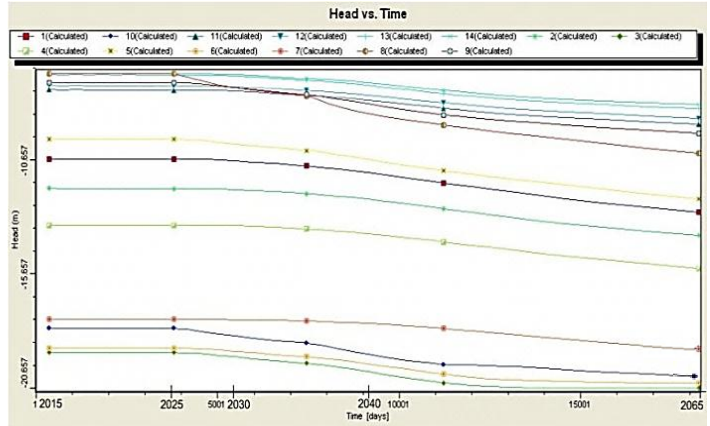

Fig. 25: Drawdown in head at the 14 observation wells applying 3rd proposed with total discharge (70602), m³/day.

6.4 FORTH SCENARIO

This scenario investigates the current of 111 pumping wells penetrating the Pliocene aquifer of WEN with total discharge (84723) m3/day.

The applied model was run for years 2025, 2030, 2040, and 2065. The figures 26, 27, 28, and 29 show the contour head. Table 5 below shows the Max extra drawdown at observation well number 8.

Table (5) the Max extra drawdown for fourth scenario at observation well No. 8.

Year	2025	2030	2040	2065
Max etra-drawdown	2.67	2.79	2.93	4.55

For the previous data obtained from the MODFLOW model for forth scenario, the range of Max extradrawdown from year 2015 to year 2065 with value of about 2.77 m to 4.55 m, respectively. Drawdown in head at the 14 observation wells applying 4th proposed scenario with total discharge (84723) m3/day, figure (30).

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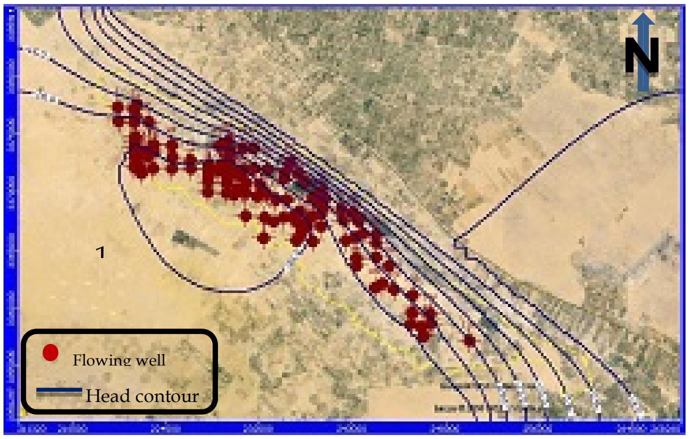

Fig. 26: Predicted head-distribution map of WNPA for pumping rate for 4th scenario at 2025 with total discharge about (84723) m³/day.

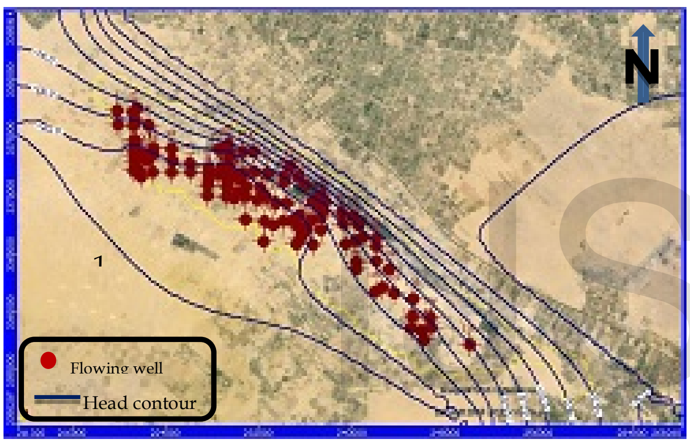

Fig. 27: Predicted head-distribution map of WNPA for pumping rate for 4th scenario at 2030 with total discharge about (84723) m³/day.

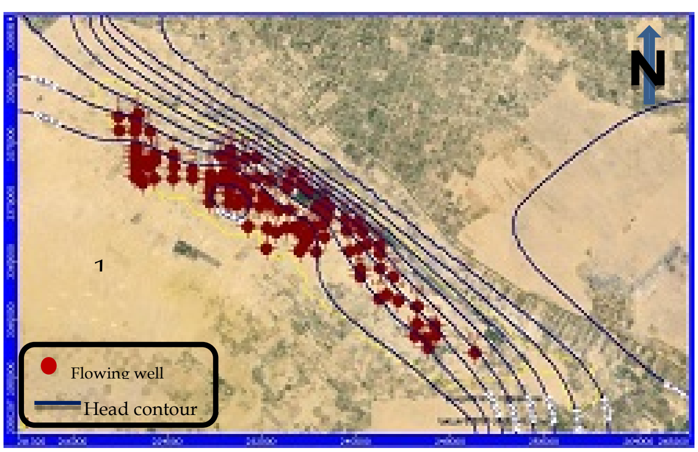

Fig. 28: Predicted head-distribution map of WNPA for pumping rate for 4th scenario at 2040 with total discharge about (84723) m³/day.

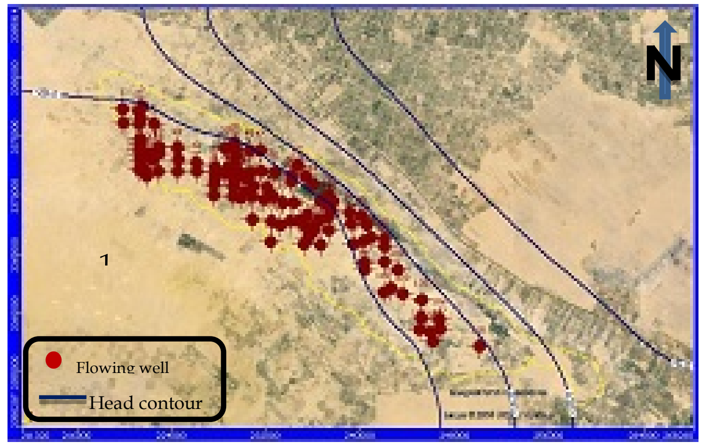

Fig. 29: Predicted head-distribution map of WNPA for pumping rate for 4th scenario at 2065 with total discharge about (84723) m³/day.

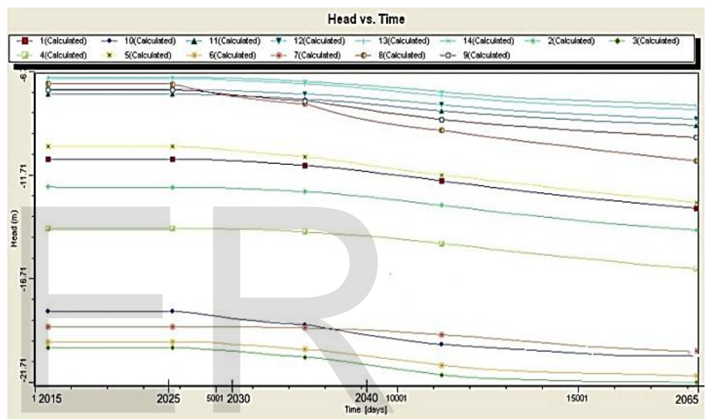

Fig. 30: Extra drawdown in head at the 14 observation wells applying 4th proposed scenario with total discharge (84723) m³/day.

For all scenarios, the max extra drawdown at observation well No. 8 for the years 2025, 2030, 2040 and 2065 shown in figure (31).

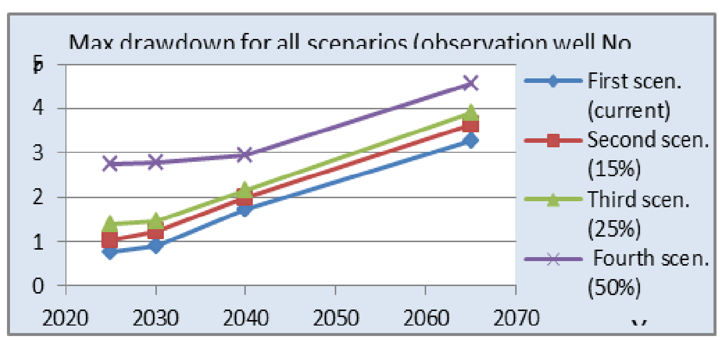

Fig. 31: max extra drawdown at observation well No. 8, for the years 2025, 2030, 2040 and 2065 for all scenarios

The distribution of drawdown at WEN and the location of observation wells are shown in figure (32). Generally, the drawdown increasing in SW of WEN, in the middle, there is high abstraction area with red color by comparing with other. This red area includes the observation well No. 8.

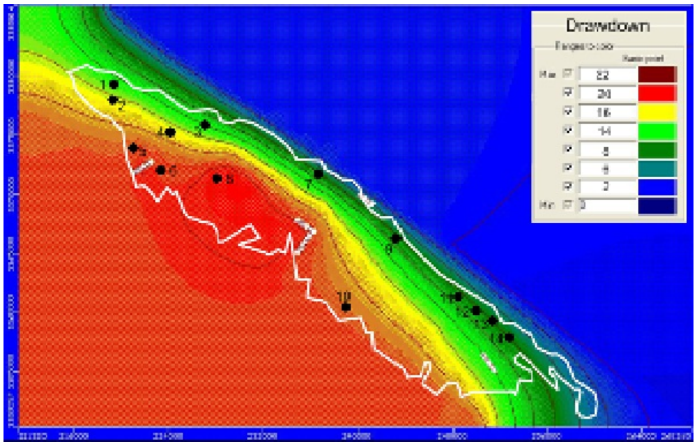

Fig. 32: the contour lines of the drawdown in the study area (first scenario) after 50 years and the location of observation wells at WEN

7 WADI EL NATRUN PLIOCENE AQUIFE BUDGET

The budget of aquifer means, the amount of water which move into or out that aquifer. The budget of aquifer can be divided into total IN budget and total OUT budget, the different between them limited the value of groundwater head. If the total OUT budget is more than the total IN budget, the head of groundwater decrease. The tested scenarios showed different values of budget according to the total discharge for each scenario. The aim of estimating budget mainly is to evaluate the current pumping system then, predicting the maximum amount of water that can be obstructed from aquifer.

For the first scenario, the values of total IN & OUT budget of the MODFLOW model after 50 years are 107250 m^3/day & 107220 m^3/day, respectively, which mean that the IN budget values more that OUT budget, figure (33).

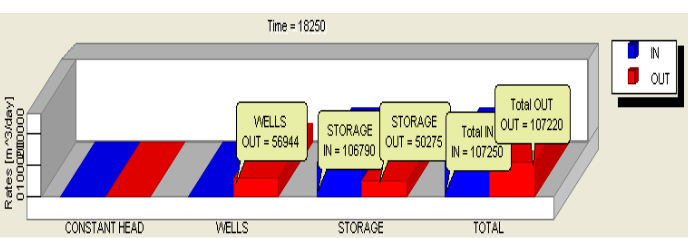

Fig. 33: Total IN & OUT budget of the MODFLOW model after 50 years, first scenario with total discharge 56428 m^3/day.

For the second scenario, after 50 years, the total IN budget value was about, 111760, m3/day while the total OUT budget value was 112730 m^3/day, figure (34).

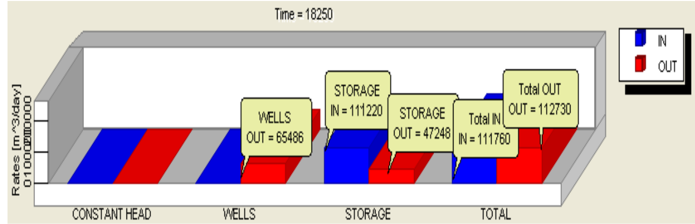

Fig. 34: Total IN & OUT budget of the MODFLOW model after 50 years, second scenario with total discharge 64954 m3/day

8 CONCLUSIONS

MODFLOW was used to obtain the distribution of the hydraulic head, simulate the behavior of flow at Wadi El Natrun depression and predict the values of drawdown and water head for different periods for different scenarios. From this study the obtained result and their discussion; the conclusions are summarized as follow:

The results of calibrated MODFLOW model indicated that the hydraulic conductivity of the Pliocene aquifer ranged from 10 m/day to 45 m/day and the specific storage ranged from 0.0001 to 0.1.

The maximum drawdown was at observation well No. 8, while the minimum drawdown was in wells 11 & 14. The main reason of Max drawdown at observation well No. 8 belongs to the high pumping rate from the area nearby comparing with other observation wells as contrast for wells 11 & 14 which lay at low pumping rate areas.

For the first scenario, the values of total IN & OUT budget of the MODFLOW model after 50 years are 107250 & 107220 m^3/day, respectively, which mean that the pumping at allowable range which not increasing the total OUT budget.

For the second scenario after 50 years, the total IN budget value about, 111760 m^3/day while the total OUT budget value was 112730 m^3/day.

The budget of WEN Pliocene aquifer shows that the total IN budget is more than the total OUT in the first scenario after 50 years, while the total IN budget is less than total OUT in the second scenario after the same period.

It is clear that, for the next 50 year, increasing pumping rate must not exceed 10% of the current pumping. We can increase the pumping rate by 15% percent (second scenario) for 42 years (total budget IN = total budget OUT = 109460) m^3/day.

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