THE EFFECTS OF Al-JADREI LAKE ON THE GRUNDWATER FLOW PATTERN[+]

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Abstract

A hydrogeologic study for Al-Jadrei Area in Baghdad, Iraq is made. The area is bounded by the Tigris River from three sides. A numerical model is developed to simulate the water table levels in the area. The limited available data of unconfined aquifer properties of three existing wells are obtained and interpolated over all the area of Al-Jadrei. On running the model for a period of 4762 days, it is found that GWL is increased by 6.6m near the location of the lake; the rises in water table levels are reduced gradually toward the east direction to be (٠,١m) at Al-Hurria plaza and diminish at the eastern border of the modeled area.

المستخلص

اجريت الدراسة الهيدروجيولوجية الحالية في منطقة الجادرية الواقعة في مدينة بغداد- العرق والمحاطة بنهر دجلة من ثلاثة جهات. استخدم نموذج لرياضي لتمثيل مستويات المياه الجوفية في المنطقة. المعلومات القليلةالمتوفرة عن خواص الحشرج غير المحصور بالاعتماد على ثلاثة ابار متوفرة في المنطقة استحصلت وعممت على على منطقة الجادرية. بعد تشغيل الموديل الرياضي لمدة ٤٧٦٢ يوم وجد ان البحيرة قد سببت ارتفاعا في مستويات المياه الجوفية مقداره (٦,٦ متر) عند موقع البحيرة ويقل هذا الارتفاع تدريجيا باتجاه الشرق ليكون (٠,١ متر)عند ساحة الحرية ويتلاشى عند الحدود الشرقية لمنطقة الدراسة.

Abbreviations & Symbols

Symbol	Definition
GWL	***Groundwater Level***
S.W.L	***Static Water Level***
D.W.L	***Dynamic Water Level***
Ph	***Acidity***
Ec	***Electrical Conductivity***
Q	***Discharge***
TDS	***Total Dissolved Salt***
G.S	***Ground Surface***

[+]Received on ٥/٢/٢٠٠٧ Accepted on ٢٥/١٠/٢٠٠٧
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NC	***Number of Columns***
NR	***Number of Rows***

Introduction

[1], [2], [3], [4], [5] , and [6] are the firsts among others who worked in the numerical modeling aspect; some of them formulate programs to solve a set of linear equations which are resulted from the solution of the partial differential equation, whereas others simulate a groundwater scheme for a specified areas. Nowadays after the development of computer, several versions of software are available such as GMS and MODFLOW to simulate various cases of groundwater problems under various initial and boundary conditions. [7] formulated a model for groundwater for an aquifer in southern California. [8] did one in San Pedro River, [9] in Tikrit Samarra, [10] developed a model for Makutupora Groundwater Basin, [11] in Chad, Egypt, Libya and Sudan, [12] considered the basin southeast California, [13) modeled the groundwater in a part of the Himalayan Foreland Basin, [14] simulated Al-Adhaim groundwater system by a mathematical modeling. Many studies depend thoroughly on soft ware versions, whereas others used a programmable formulation. [15] modeled the groundwater scheme of Upper shunk Basin in Iowa. In this study a program in Fortran Language is used.

Definition of The Problem

In recent years (2002), Al-jadrei Lake was constructed for tourism purposes with an approximate area of 371847 m^2 (148.7 mishara). The designed water level of the lake is 33.5m a.s.l (measured by the author in Febrauary 2006), whereas the average water level of Tigris River is 26.8m a.s.l (measured by the author in February 2006). The natural ground surface elevation at the location of the lake is about 35m. a.s.l (measured by the author in February 2006). The excess in the hydraulic head at the lake with an earth bed causes a huge amount of seepage losses from the lake toward the unconfined stratum causing in turn a rise in water table levels in the vicinity of the lake and the surrounding areas. This rise in groundwater levels produces many harmful effects on the surrounding buildings around the lake.

Purposes of Study

The purposes of the current study are: 1- Evaluating the new groundwater levels overall Al Jadrei. 2- Estimation of the amount of seepage losses from the lake toward the underlying stratum. 3- Developing and adopting the possible solutions of the problem.

Geographic Location

The area is located between longitudes (44º 22″ 5′ – 44º 24″ 23′) and latitudes (33º 15″ 52′ – 33º 17″ 45′). The considered area comprises about 6.94 km^2; 3.57 km^2 for Al-Karrada and 3.37 km^2 for Al-Jadrei. The location map of Fig (1) shows that the considered area is surrounded by a natural boundary which is represented by the Tigris River which bounds the area from three sides with a length of 9.2 km, whereas the northern-east border of the study area is chosen at the street which joins Al-Muaillak Bridge, Al-Hurria plaza and Abu-Tabkan Bridge.

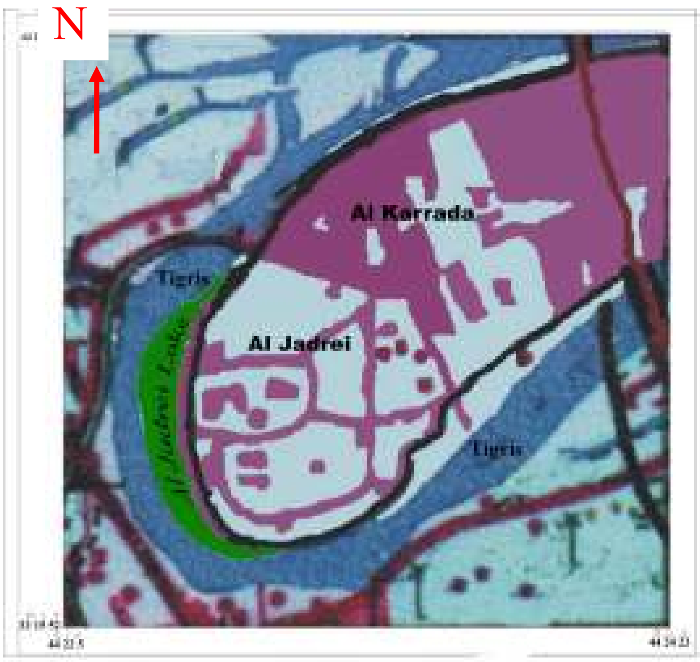

Fig.(1) Location Map of Al Jadrei and Al Karrada (Based on Google Earth Photos,2006)

Hydrologic & Hydro-chemical Data

Only three wells are found in the study area. Table. (1) includes the locations and the available hydrologic and hydro-chemical data of these wells.

Table. (1) Hydro-chemical Data, Based on [17]

NO	LATITUDE (1)	LONGITUDE (2)	ELEV. M (3)	DEPTH M (4)	S.W.L M (5)	D.W.L M (6)	Q ℓ/S (7)	PH (8)	EC (9)	TDS (PPM) (10)
1	33°17′ 3″	44°24′ 23″	31	19	4.5	6	7	7.2	2610	1708
2	33°17′ 3″	44°23′ 42″	30	19	6	9	5	-	-	-
3	33°16′ 4″	44°22′ 10″	35	19	7	9	5	7.2	2150	1402

Topographical Features

The topographic map of Iraq indicates that Al-Jadrei Area is located between the contour lines (30 and 35) with an average slope of 0.2 m\ km from the north toward the south. The average elevation of the study area ranges between 32-35m a.s.l. In general, the nature of the land is flat and is reduced in elevation toward the east. Fig. (2) shows topographic contour lines of the interesting area (based on surveying field measurements by the author with staff of surveyors at the College of Eng. Unv. of Baghdad, 2006, Surfer.7 software was used to draw this map). All leveling field works are referenced to a Local Ordinance Bench Mark at the University.

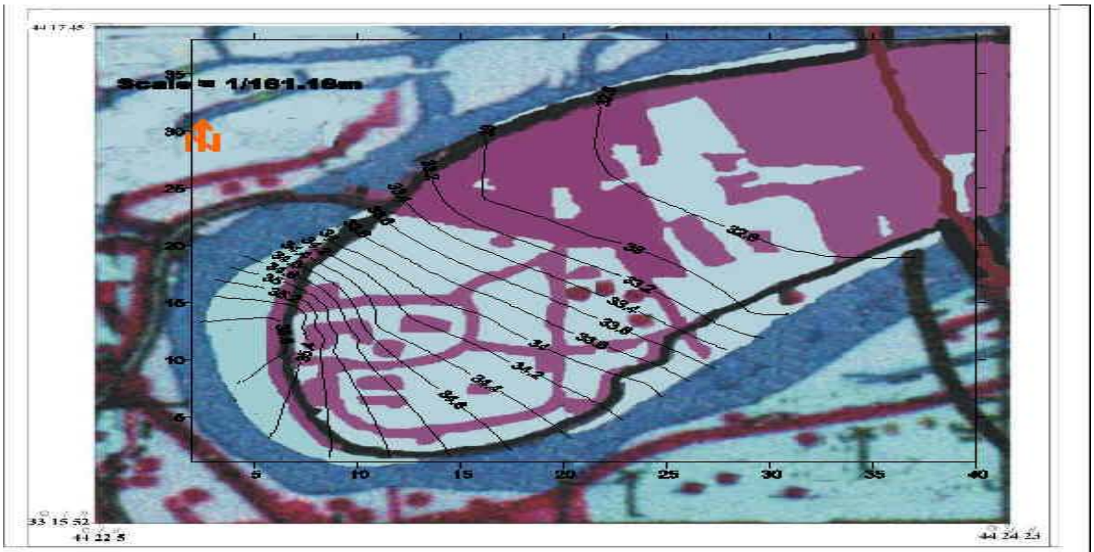

Fig. (2) Topographic Map of Al-Jadrei, m.a.s.l

Geology of the Area

Tectonically the study area is located in the stable subzone of Tigris Arm [18]. Tigris River Valley is characterized by synclines and subsurface structures in the area [18]. Al-Jadrei is located within the area of crack movement in the Al-Rafidian Valley which in turn is found between Zakros Monuntain in the eastern–west of Iraq and the western desert; this movement reduces the thickness of the sedimentary rocks and creates topographic relieves which recently disappear as a result of erosion and sedimentation processes. Pliocene and Holocene Deposit cover the layers of Mukdadia and Injana Formations. Alluvial deposits can be represented by the sediments, siltysand fans and small islands of Tigris River. The structure of these sandy and clayey sediments is usually mixed with gypsum [18]. The shore sediments which are located on both sides of Tigris River (for about 10-15km) are the most modern deposits in the Tigris River Valley [19]. Fig. (3) presents a part of most important geological details of Al-Jadrei Area.

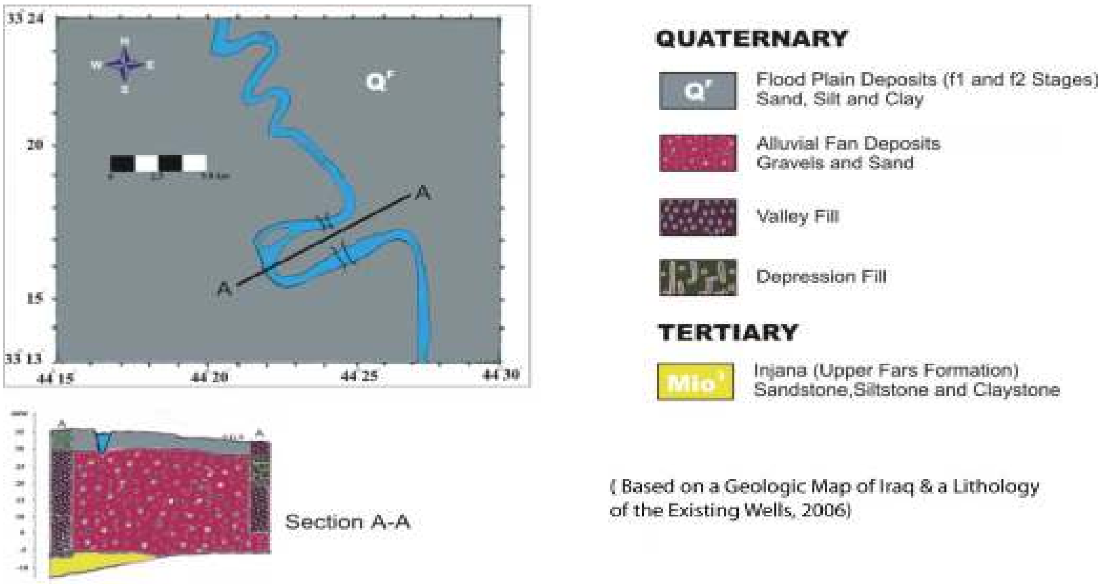

Fig. (3): Geologic Map of Al-Jadrei

<u>Lithology of Subsurface Deposits</u>

A large number of wells have been drilled in Baghdad with depths ranging between (19and125m), but only three wells are found at Al Jadrei and Al Karrada. They are used to study the hydrogeology of the interesting area.. The subsurface investigation reveals that there are consecutive layers of clay and sand or clay with gravel found alternatively. Fig. (4) shows the lithology of well No.3 that is listed previously in Table. (1). At first glance of the well profile, one concludes that a confined aquifer exists, but really the clay layer is thin with limited extent and donot represent a confining layer moreover, and it is not found in the stratification of other existing wells.

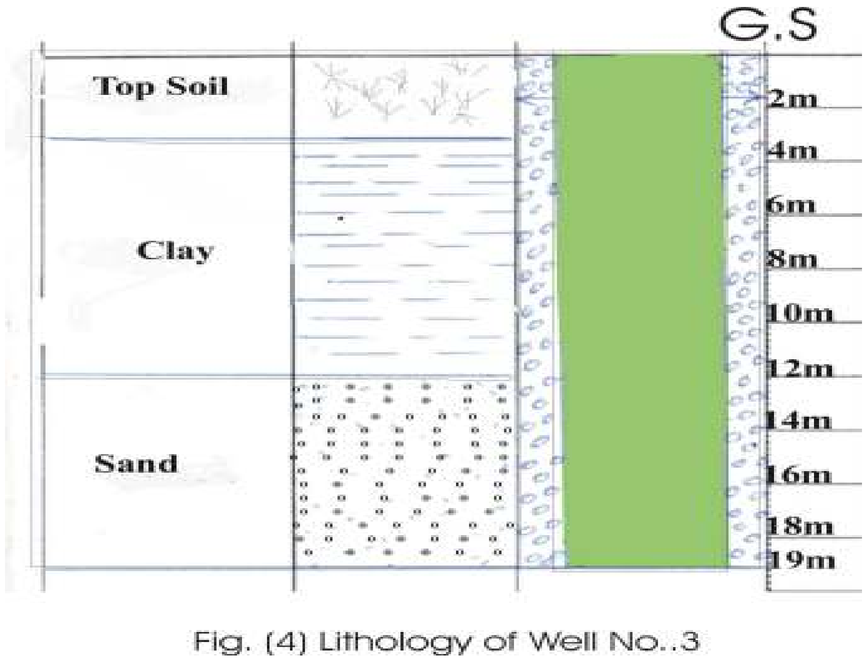

Fig. (4) Lithology of Well No..3

Hydraulic Properties of the Aquifer

As may be seen from the geology of the considered area, the confined aquifer is not found. After a high number of the model run, it is concluded that the ideal specific yield is 0.2; such value was recommended by [16] to be used for aquifers of similar formations. A pumping test analysis is performed at wells site to estimate the hydraulic conductivity of unconfined aquifer. A summary of pumping test results is shown in Table (1) columns No. (5), and (6)). The estimated hydraulic conductivities of the pumping test analysis for the three wells of Table. (1) are interpolated overall the study area and represented graphically by the contour map of Fig. (5) which indicates that a minimum hydraulic conductivity occurs at the eastern border of the interest area of (about 5.8m/day),and increases gradually toward the lake to be at its maximum values (about 8.4m/day). The values of the hydraulic conductivity are expected, since the field investigations of soil and laboratory test results of selected specimens from Al Jadrei proved that the texture of the soil becomes looser near the lake. This map is matched overall of the model domain and the values of hydraulic conductivity are entered for each mesh.

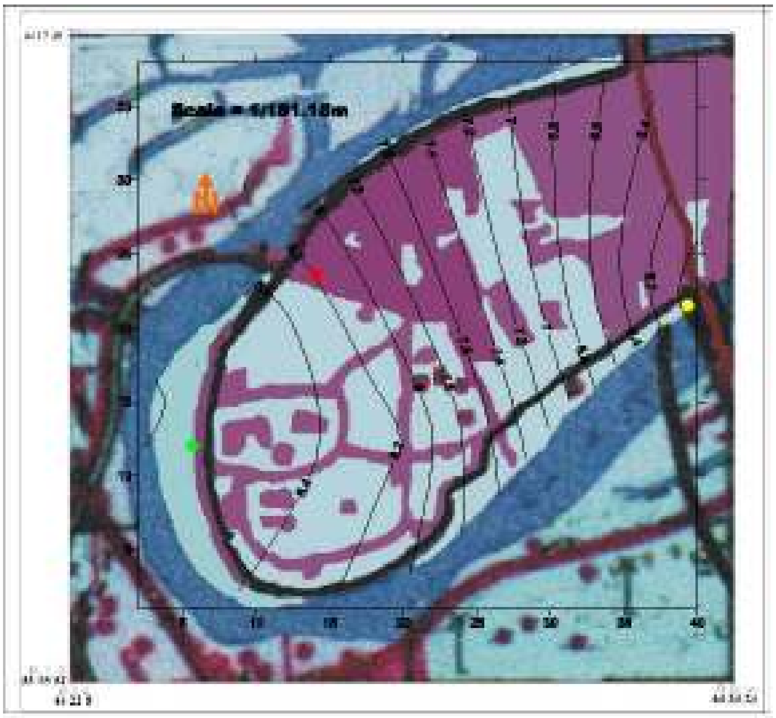

Fig.(5) Hydraulic Conductivity Contour Map of Al Jadrei, m/day

W No2

W No.3

W No.1

Hydrochemistry of Al-Jadrei

A hydro-chemical analysis is also considered in this study. The results of a laboratory test of a selected samples for the wells of Table.(1) are listed in Table. (2) and presented graphically by the contour map of Fig.(6). The current results seem unpopular because the minimum total soluble salts are expected to be close to the lake. This may be attributed to the geologic formation of the area.

Table (2) Chemical Analysis, [17]

WELL NO.	ANIONS (MG/ℓ)					CATIONS (MG/ℓ)				*TDS (PPM)*
	NO_3^-	SO_4^{-2}	HCO_3^-	CO_3^-	CL^-	K^+	Na^+	Mg^{+2}	Ca^{+2}	
1	2.5	327	75	-	434	4.2	514	92	224	*1708*
2	-	-	-	-	-	-	-	-	-	-
3	*2.5*	*361*	*94*	*0.0*	*234*	*3.1*	*478*	*126*	*80*	*1402*

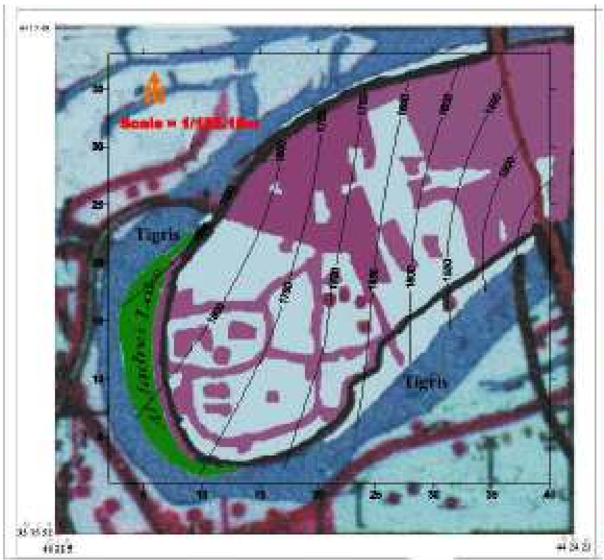

Fig.(6) TDS Distribution of Al Jadrei Area, (ppm)

Electrical Conductivity

Laboratory test results indicate that the electrical conductivity of the tested groundwater specimens is relatively high as shown in Fig. (6a); it shows that the value of the Ec is increased near the lake. The Ec values are found to be within 2150-2700

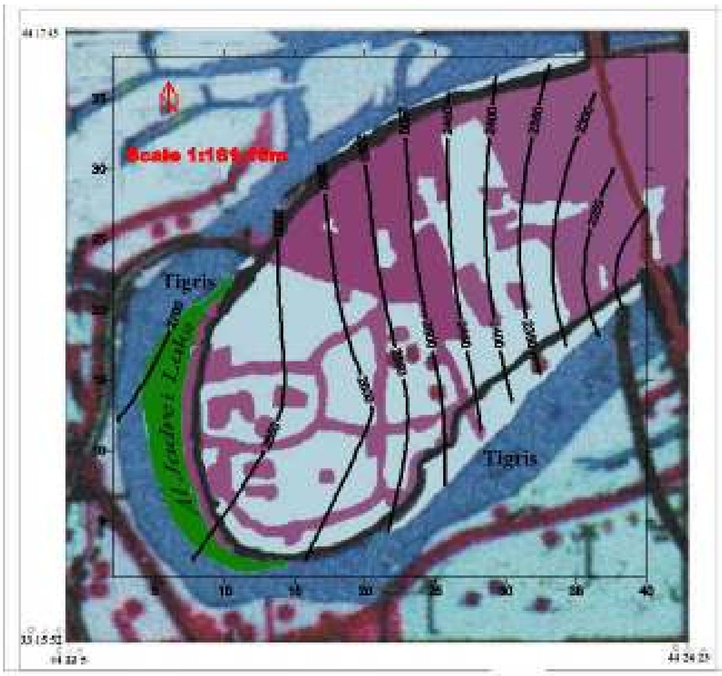

Fig.(6a) Ec Distribution Contour Map of Al Jadrei Subsurface Water

Simulation Technique

A modified program of [3] in Fortran Language is used for the simulation of groundwater in Al-jadrei under the unconfined condition. A mathematical model is prepared for the quantitative study of Al-Jadrei. A program listing by [3] is modified and used to simulate the groundwater system. The program solves the set of finite difference equations which are regarded as numerical solution of the partial differential equation governing a non-leaky and non-steady groundwater flow in heterogeneous aquifer. It is chosen because of its flexibility for modification. The model is also used to evaluate the potential discharge for both the unconfined aquifer. The derivation of finite difference equation is based on the mass conservation principle and Darcy's Law. A detailed derivation of the finite differences equations and convergence test for errors study are found in [3]. The necessary data files such as; hydraulic conductivity, bed levels, recharge and discharge, initial water levels, boundaries, and constant hydraulic head boundaries are prepared before running the model. The value of each parameter is specified for each mesh in the model domain by interpolation.

Grid System Design

The first step in modeling job is to discretize the system by superimposing a mesh of finite difference grid over the map of the area. The size of mesh or in other words the number of rows and columns that is to be adapted depends on the required accuracy. The total dimensions of the grids are defined by NC (the number of columns), and NR (the number of rows) of the model. The number of columns (NC = 40) and the number of rows (NR = 38) are the selected number of columns and rows respectively. Such mesh design gives a scale equals 1: 181.18m. Fig. (7) shows meshes descretization of the modeled domain.

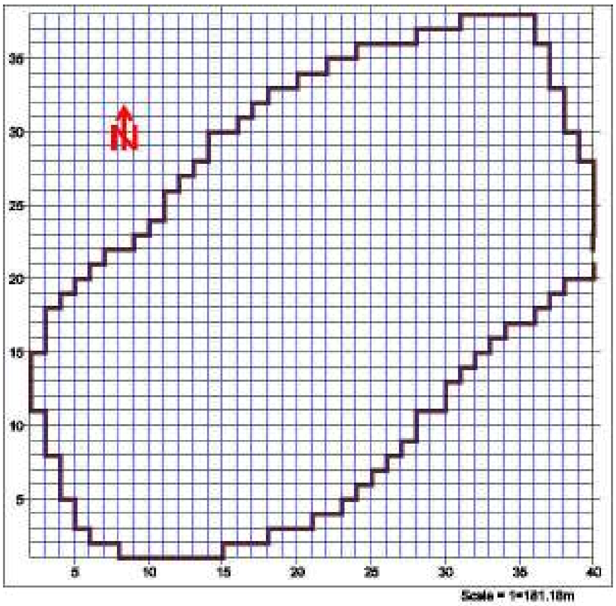

Fig. (7) Mesh Design of Al-Jadria Area

Verification and Adjustment of the Model

Once the input-output information is specified, the program is run by a computer for a time long enough to perform a state of dynamic equilibrium in which the inflow-outflow relations become steady. This step is made in order to simulate the natural conditions in the field [6]. If the computed hydraulic heads show large differences from the measured (field) groundwater levels, then inflow-outflow parameters or aquifer coefficients should be reconsidered and checked until best match is achieved. An exact match between the computed and field data is rarely possible, because of the lack of detailed and accurate input data. In general, the more accurate input data the better match is obtained.

Thus, the ideal approach of simulation of an area is to run the program without any artificial stresses for assumed uniform hydraulic heads until a steady state condition is reached. Then the model prediction is used as an input initial head to compute the change in hydraulic heads as a result of any other artificial stresses. The current model is adjusted to give a good match between the model results and the static water table level (S.W.L) of the existing wells of Table (1).

Input Data Files

A file for each of the hydrogeologic parameters is prepared that contains the value of that parameter at each nodal point within the model domain. These parameters include hydraulic conductivity and specific yield for water table aquifer; pumping rate with infiltration; bottom level of impervious beds, wherever they occur; hydraulic heads, or elevations of the surface water body wherever it occurs, dimensions of the meshes net; initial hydraulic heads, or initial water table level.

Simulated Groundwater Levels before Lake Construction

The model was run for 4762 days to estimate the water table levels in a steady state condition without the effect of Al-Jadrei Lake. In this case only the water levels at the hydraulic boundary and the natural static water levels (S.W.L) of the existing wells of Table (1) are entered in the data file of initial water levels. The resulting water levels of the natural groundwater flow regime are shown in the contour map of Fig.

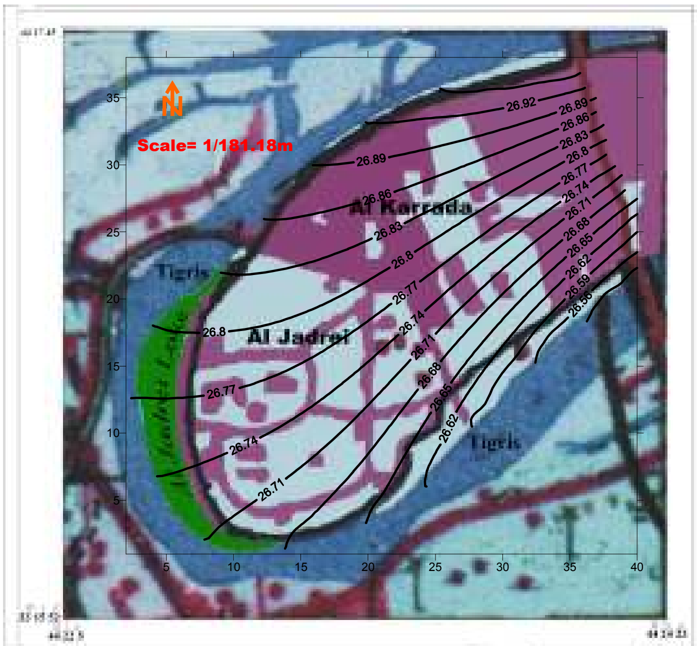

Fig.(8) Simulated W.T.L for the Unconfined Aquifer of Al Jadrei before Lake Construction

Simulated Water Table Levels After the Lake Construction

After the construction of Al-Jadria Lake, the groundwater flow regime is changed completely since the lake induces a large amount of seepage to the unconfined aquifer, therefore a new hydraulic boundary of the lake is considered in the input data file of initial water table. The model is run again and simulated groundwater levels are represented graphically by the contour map of Fig. (9).

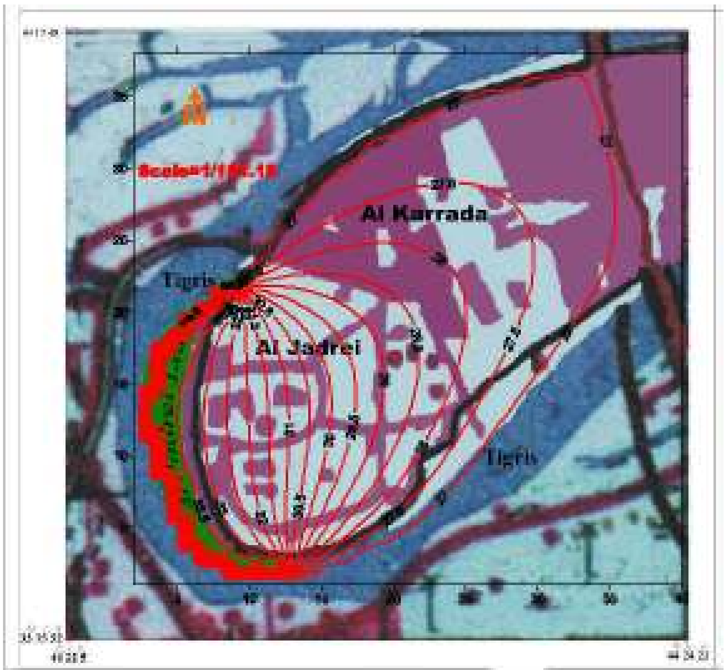

Fig.(9) Simulated Groundwater Levels after Al Jadrei Lake Construction, m.a.s.l

Evaluation of the Lake Effects

The inspecting of the simulated groundwater levels of Al-Jadrei before and after the lake construction of Figs. (8 and 9) one concludes that groundwater flow pattern is changed completely in reverse direction after the lake construction; moreover levels are increased by 6.6m around the location of the lake. This rise in the GWL is reduced gradually as departing toward the east from the site of the lake i.e. groundwater rise after the lake construction at the building of Baghdad University is 5m, whereas at the entrance gate of the University is 1.6m. In summery the rise reduces gradually toward AL-Hurria Plaza to be 0.1m as shown in Fig. (10).The amount of groundwater rise around the lake 6.6m and 5m under the building of Baghdad University is too large. This rise has a deleterious effect on the building of the university; moreover the underground storages were filled with water.

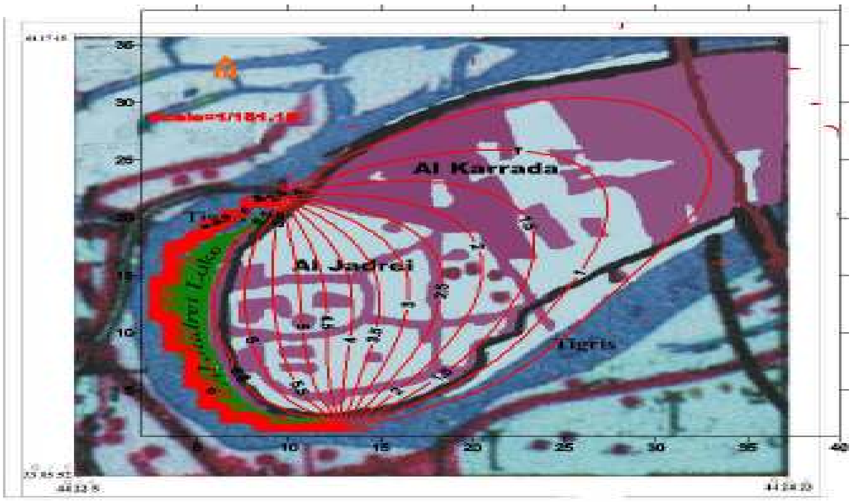

Fig.(10) Groundwater Table Rise Due to the induced recharge of the lake, m

Reasonable Solutions

The purpose of this study is to search for the possible solution to reduce or even cancel the rise in groundwater levels in the vicinity of the University. The first mission in this situation is to evaluate the amount of induced seepage which is easily found to be 100ℓ/s using the basic principle of Darcy's law. The second mission is the adoption of the possible solution. Many constructional solutions may be suggested, such as lining with asphaltic materials or by using a sheet piles or concrete barriers between the lake and the interesting area. But the current hydrogeologic solution is preferred for its economic adjective and less undesirable effects. It is suggested to construct a number of a production pumping wells a round the eastern boundary of the lake as shown in Fig.(11) to absorb the incoming seepage charges from the lake toward the subsurface stratum of Al-Jadrei. On running the current model, it is found that 19 wells with a production capacity of 6 ℓ/s (may be 4 wells with 25ℓ/s or 2 wells with 50 ℓ/s) can cancel this rise in GWL (The practical production capacity of the production well is (7-50 ℓ/s, [17]), the number of the wells depends on the designer priorities). The abstraction of water may be used to irrigate the gardens of the university or to be pumped back to the lake or to Tigris River. The groundwater scheme due to this scenario is shown in Fig. (11). The Figure shows the location of 19 pumping wells around the induced seepage border of the lake.

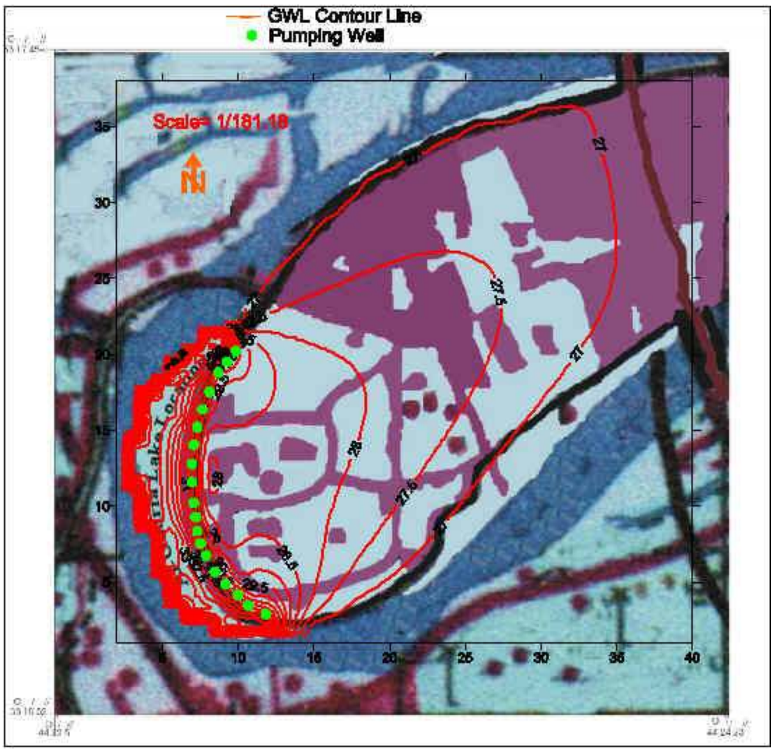

Fig.(11) Simulated WTL Due to the Pumping Scenario, m.a.s.l

Conclusions

The new water level 33.5m.a.s.l causes a 6.6m rise in the natural GWL around the vicinity of the lake, 1.6m at the gate of Baghdad University and 0.1m at Al-Hurria Plaza. The effect of the lake seepage can be canceled by using four wells with 25 ℓ/s production capacity to be constructed around the eastern boundary of the lake.

Recommendations and suggestions

The foregoing results reveal that the rise in groundwater levels with about 6.6m around the location of Baghdad University is too high.

1- The removing of this artificial lake is recommended for the following reasons:
   a) The rise in GWL has terrible effects on the buildings of the university; since it causes an uplift pressure and that in turn may cause cracks to the buildings, this indeed what is happening.
   b) The rise in GWL will increase soil salinity at the area.
   c) This lake was originally constructed for tourism purposes which are not necessary because the whole area of Al-Jadrei is characterized by its beauty and touristic nature.

2) It is suggested that the lake site might be occupied by buildings for the staff of the university and for the students as well.

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