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MATHEMATICAL MODEL FOR SIMULATION THE RELATIONSHIP BETWEEN GROUNDWATER AND NORTH AL-JEZIRA IRRIGATION PROJECT, NW IRAQ

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ABSTRACT

Rabia plain is located in the northwestern part of Iraq. It covers an area about 3000 Km^2 forming part of the hydrological basin of Wadi Al-Mur which drains from the west to the east and discharges its water to Tigris river near the village of Aski-Mosul. The area is a semi-flat land having an altitude ranges between 325 and 400 m a.s.l. Groundwater in Rabia basin is found in the prevailing sedimentary geological formations in northwest Iraq among which an Injana Formation (upper Miocene) which consists of alternation of clay and sandstone beds covered by recent alluvial deposits. The Northern Al-Jezira is an agricultural project that occupies part of Rabia plain; Tigris River is the main source of surface water which is transported by pumping station, main conveyer canals. The project consists of two stages implemented during two different times; the first one was established in 1992, while the other one was established in 1995. The gathered field data for this study had assisted in applying a mathematical model that aims to evaluate the effects of different irrigation practices on the aquifer. The model has shown that the operation of the project for the next 20 years will lead to increase the aquifer hydraulic head from few centimeters to more than 4.5 m in the modeled area. This increase in hydraulic head is equal to an annual recharge of aquifer storage of about 130 million m^3. The results are encouraged a recommendation, aiming to invest the extra recharge gained by the aquifer via digging more wells in the upper layer especially in the second stage area. The extra pumped water could be used to cultivate additional land.

Keywords: Mathematical model, Groundwater, North Jezira, Irrigation project

INTRODUCTION

Rabia basin is located in the Northwest part of Nineveh Governorate with longitudes 42° 00' – 43° 00' E, and latitudes 36° 30' – 37° 00' N. It covers about 3000 Km^2. Tigris River is at the north and north east boundary, the Iraqi/ Syrian boundary represents the western and north western boundary. While Sinjar, Ashkft, Sasan and Alkasir anticlines are the southern boundary. Figure 1 shows the location of the studied area.

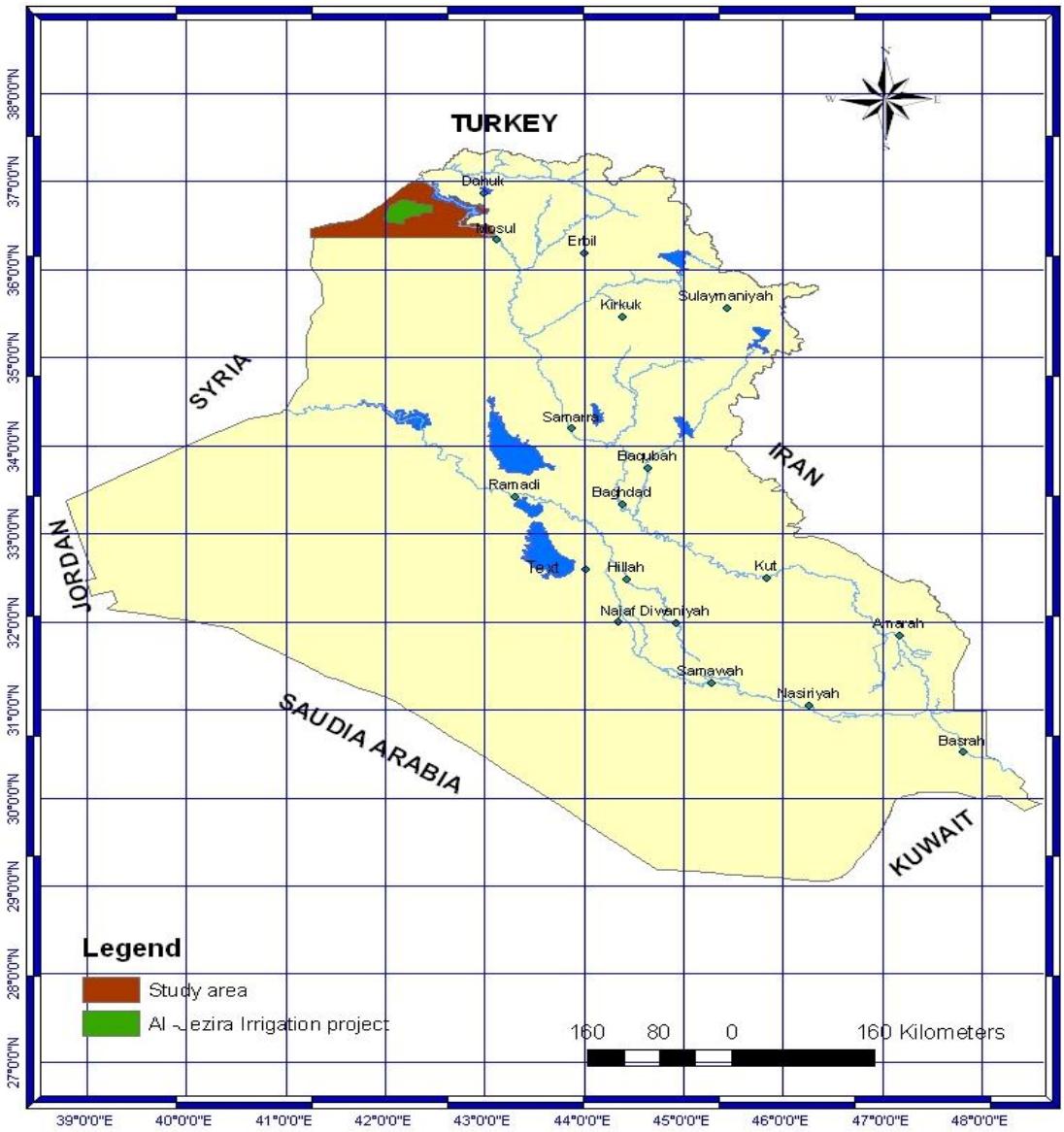


Fig. 1: Location map of the study area

Before 1992 the groundwater in the area under study faced a draw down in its water table due to heavy pumping, which led to design and established an irrigation project to supply the agricultural areas with surface water instead of groundwater.

Topographically, the basin is almost semi flat surrounded by the mentioned anticlines, the highest elevation of the area is 400 m a.s.l. While the lowest is 325 m a.s.l., the most valleys gathered and drained their water in the main valley which is locally named Al-Murr Valley, Figure 2 shows the topographic map of the study area.

The outcrops in the study area are composed of the Euphrates, Fatha and Injana formations which belong to Miocene even with deposits of Quaternary (Holocene and Pleistocene). (Sissakian and Hagopian, 1995) as in Figure 3.

Injana Formation is the most important unconfined aquifer (F.C.S.D.I.P, 1989) since most of the wells were drilled to penetrate it which consists of inter bedded layers of sand, silt and mud, with some proportion of secondary gypsum. 66 wells were drilled in the study area, with depth ranged between (20 – 272) m, and discharge ranged between (25 – 1407) m^3/day, the electrical conductivity (EC) ranged between (670 – 8100 µmohs/cm). Groundwater movement in Rabia plain has a cumulative flow pattern that follows the general topography of the area. This system is discharged in Wadi Al-Murr, which is the major valley in the area and drains its water to the Tigris River near the Aski-Mosul.

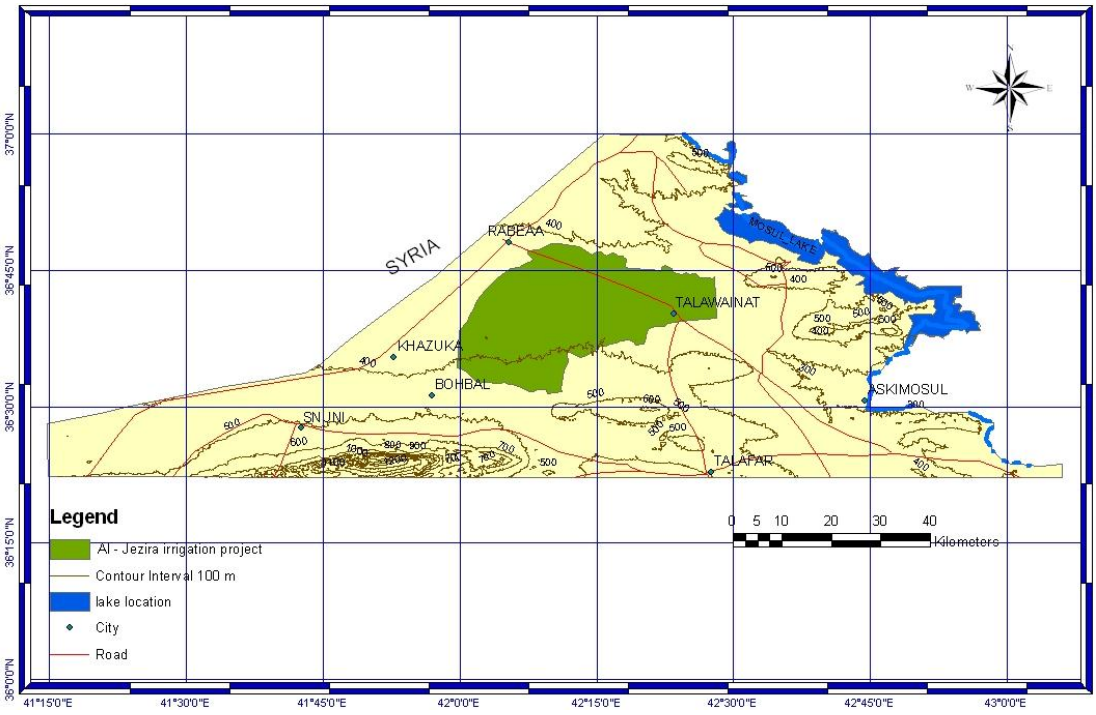


Fig. 2: Topographic map of the study area

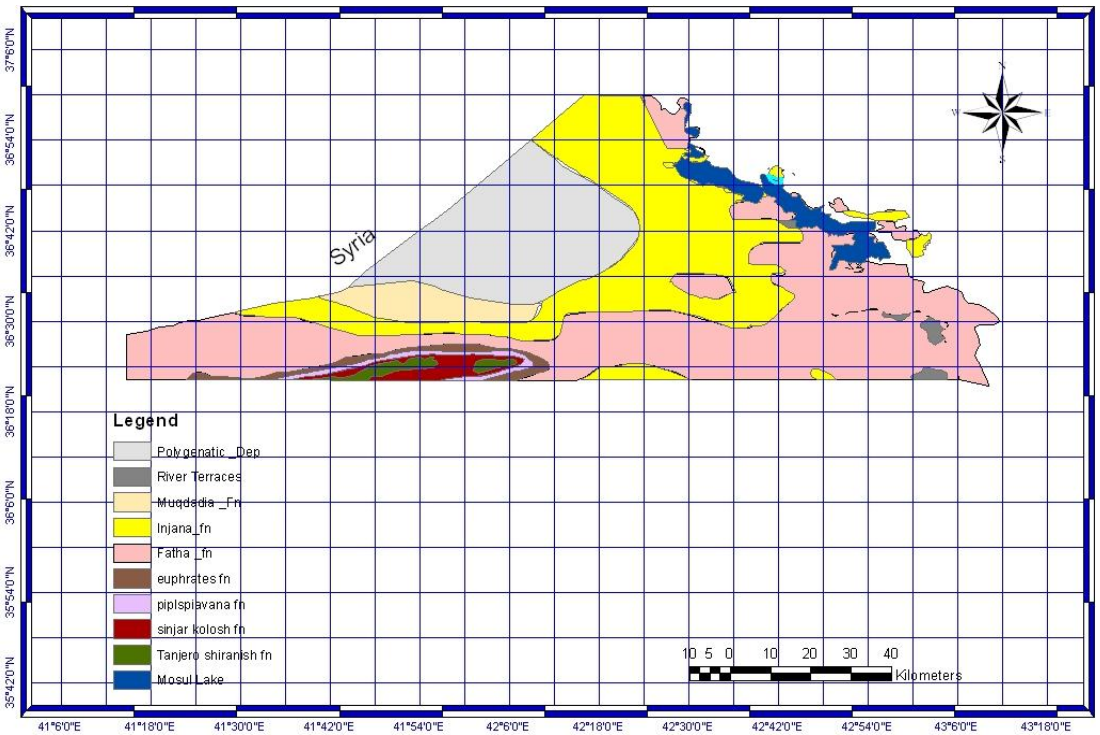


Fig. 3: Geological and structural map of the study area (State Company of Geological Survey and Mining, 1995)

PURPOSE OF STUDY

The purpose of this study was to evaluate the effect of the Al-Jezira irrigation project on the groundwater behavior and the possible investment of groundwater due to extra recharge by infiltration to the groundwater especially after the operation of the second stage of Al-Jezira irrigation project. Beside the possibility of extra pumped water to cultivate additional land.

METHOD OF STUDY

The Hydrogeological data bank was used as the principal data for the model. These data are precisely documented until 1988 in the National Center for Water Resources Management/ (MoWR). Processing MODFLOW for Windows {(PMWIN) V 7.0.2} was applied in this study to simulate the behavior of groundwater through different simulations.

Further data for the wells which were drilled in the area after 1992 were added to calibrate the model. Results of monitoring data for four wells which are located in the modeled area were used to verify the model (Domenico and Schwartz, 1999).

NORTHERN AL-JEZIRA IRRIGATION PROJECT

Northern Al-Jezira irrigation project was established on the right side of the Tigris River and extended about 80 Km in the northwest of the Mosul city. The project area covered 240000 Donum (1Donum = 2500 m^2), which is equivalent to 600 Km^2. The area of the project represents low elevation in the center and Al-Murr valley, leading to become a natural drain. The source of the water is Tigris River and Mosul Dam lake, the water is supplied to the project by the main pump station. The irrigated area are divided into two stages the first one irrigated by the main cannel covered 100000 Donum while the second one irrigated by the parallel canal branched from the main canal and covered 140000 Dunom, (Evaluation of Performance of Northern Al-Jezira Irrigation Project/ 1999) (Fig. 4).

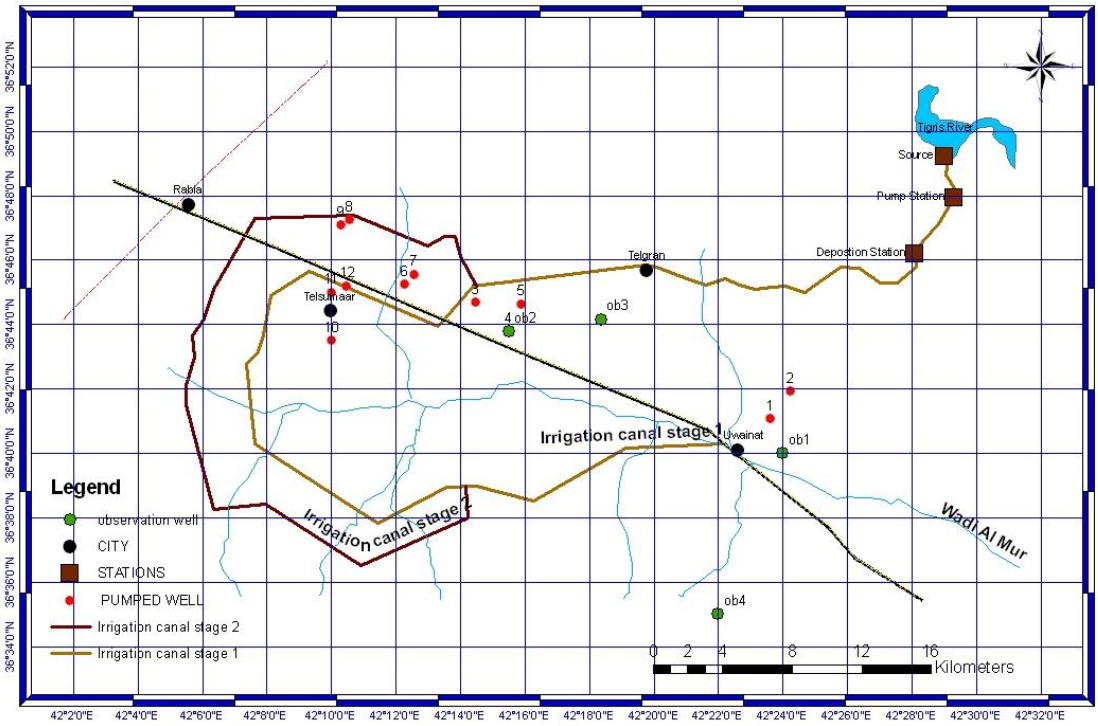


Fig. 4: Main irrigation canals and irrigated areas of the Northern Irrigation Project (E.P.N.J.I.P., 1999)

Mathematical model

Grondwater models provide additional insight into the complex system behavior and (when appropriately designed) can assist in developing conceptual understanding (Sinclair Knight Merz, 2012).

Mathematical model was applied in the Northern Al-Jezira Irrigation project in order to identify the effects of the irrigation project on the groundwater behavior. A (Processing mod flow proVersion 7.0.13) three dimensional model developed from (Chaing, W.H. and Kinzelbach. W. 2003) for steady state simulation, transient state simulation and prediction simulation was applied, This model composed of 7700 cells, (110 columns and 70 rows), the length of each cell equals to 400 m.

To simulate the steady state available data of the hydraulic head of the wells were used for the period from 1970 to 1992 (the year of the beginning of project operation). Figure 5 shows the calculated hydraulic head behavior of the groundwater for steady state simulation (Domenico and Schwartz, 1999).

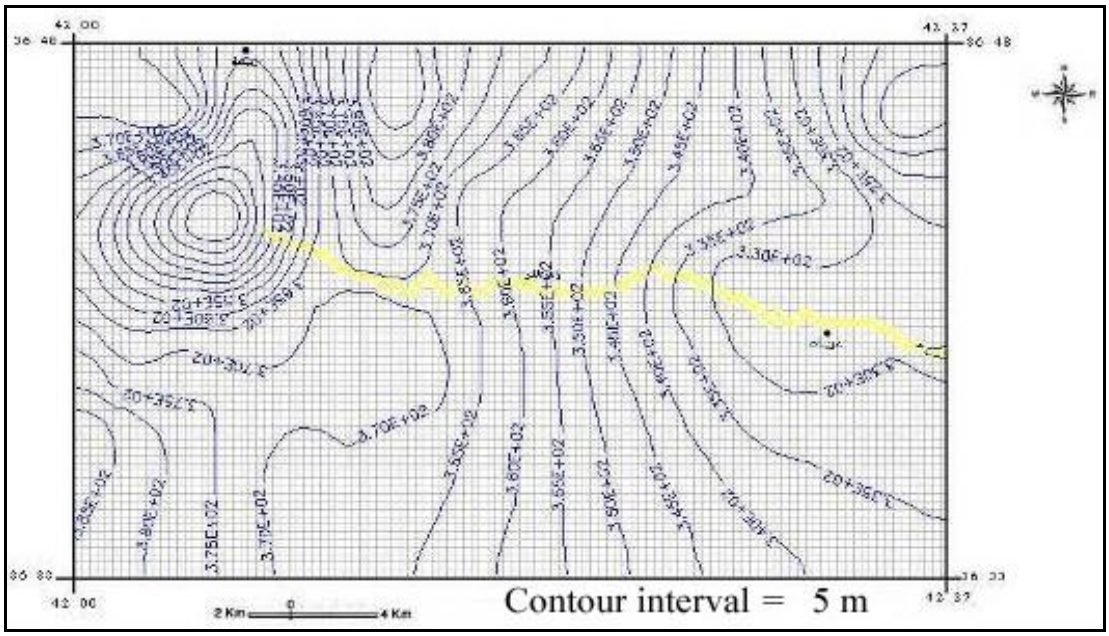


Fig. 5: Calculated hydraulic heads of Steady State Simulation

For transient simulation, the rainfall that equal to 1.447×10^{-7} m/day and the loss of irrigation canals equal to 0.002 m/day were loaded to the model.

The period from 1992 to 1995, 0.001 m/day was simulated and loaded to the model for the areas which irrigated by sprinkler manner and 0.0024 m/day for the areas that irrigated by furrows represented the additional losses value from the canals after operation the second stage of the project. The discharges of the drilled wells were loaded to the model as well.

Then the model was run to simulate the behavior of the groundwater flow until 2010. The comparison between the measured water level of 12 wells in two times with that of calculated values revealed a good result as shown in Table 1.

While the Figure 6 shows the calculated heads for the transient simulation during 2010.

Table 1: Comparison of groundwater levels of wells that have been measured for two seasons 12/ 2009 and 4/ 2010 with the calculated using the mathematical model

Well No.	Cell		12/ 2009		4/ 2010	
	Row	Column	Observed Head	Calculated Head	Observed Head	Calculated Head
1	38	92	–	330.64	330.75	330.67
2	35	92	–	329.71	329.75	329.74
3	26	55	360.96	360.94	361.00	360.96
4	36	57	359.30	360.05	359.50	360.05
5	21	61	357.60	357.58	357.60	357.60
6	26	43	374.80	374.94	374.85	374.94
7	26	47	369.15	369.14	369.20	369.16
8	9	43	391.95	392.29	392.15	392.29
9	10	42	392.40	392.42	392.40	392.42
10	31	45	365.30	365.40	365.35	365.38
11	26	35	374.25	374.41	374.37	374.44
12	20	40	382.60	382.59	382.60	382.63

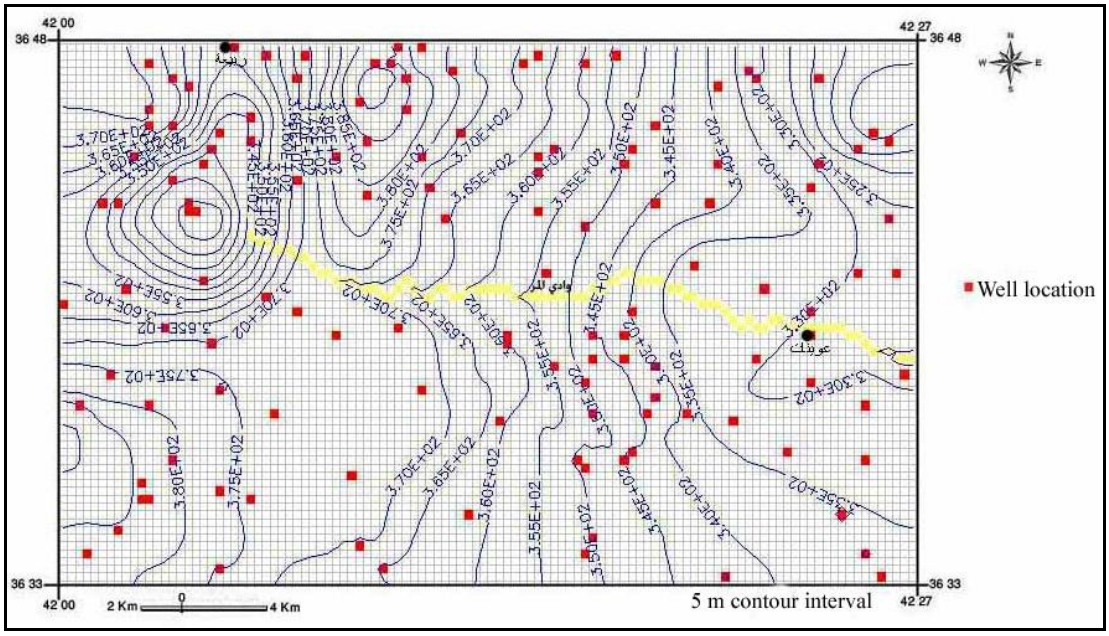


Fig. 6: Calculated hydraulic heads of Transient Simulation during 2010

Monitoring data for four wells were used to verify the model after running the model during the period of monitoring; these wells were monitored during the 2010. the below table shows the results of the measured and calculated values.

Table 2: Comparison of observed hydraulic heads with calculated hydraulic heads

Months	Observation Well No. 1		Observation Well No.		Observation Well No.		Observation Well No.	
	Obs. head	Cal. head	Obs. head	Cal. head	Obs. head	Cal. head	Obs. head	Cal. head
Oct	377.75	377.82	378.12	379.23	329.20	329.02	343.33	343.96
Nov	377.78	377.82	378.15	378.22	329.00	329.02	343.37	343.96
Dec	377.70	377.82	378.20	378.22	328.95	329.02	343.66	343.96
Jan	377.65	377.80	378.00	378.27	328.90	329.00	343.11	343.96
Feb	377.50	377.80	377.97	378.26	328.85	329.01	343.74	343.96
Mar	377.50	377.80	377.95	378.26	328.80	329.01	343.58	343.96
Apr	377.60	377.80	377.90	378.25	328.88	329.01	343.63	343.96
May	377.65	377.80	377.98	378.25	329.00	329.01	343.43	343.96
Jun	377.70	377.81	378.00	378.24	329.05	329.01	343.37	343.96
Jul	377.78	377.81	378.02	378.24	329.14	329.01	343.36	343.96
Aug	377.80	377.81	378.05	378.23	329.18	329.02	343.60	343.96
Sep	377.80	377.81	378.08	378.23	329.15	329.02	343.52	343.96

Prediction Simulation

To predict the behavior of groundwater in the studied area, the annual discharge of 50 wells are added to the model starting from 2010 until 2025, it has shown that the additional water from the losses and infiltrations will equal to (130) million cubic meters/ year.

The prediction the of the hydraulic head behavior for different next years are shown as below (Figs. 7 and 8).

From these figures the difference behavior of the hydraulic head of groundwater for the two periods has been observed as well as the differences in hydraulic head for different cells Table 3, shows clearly.

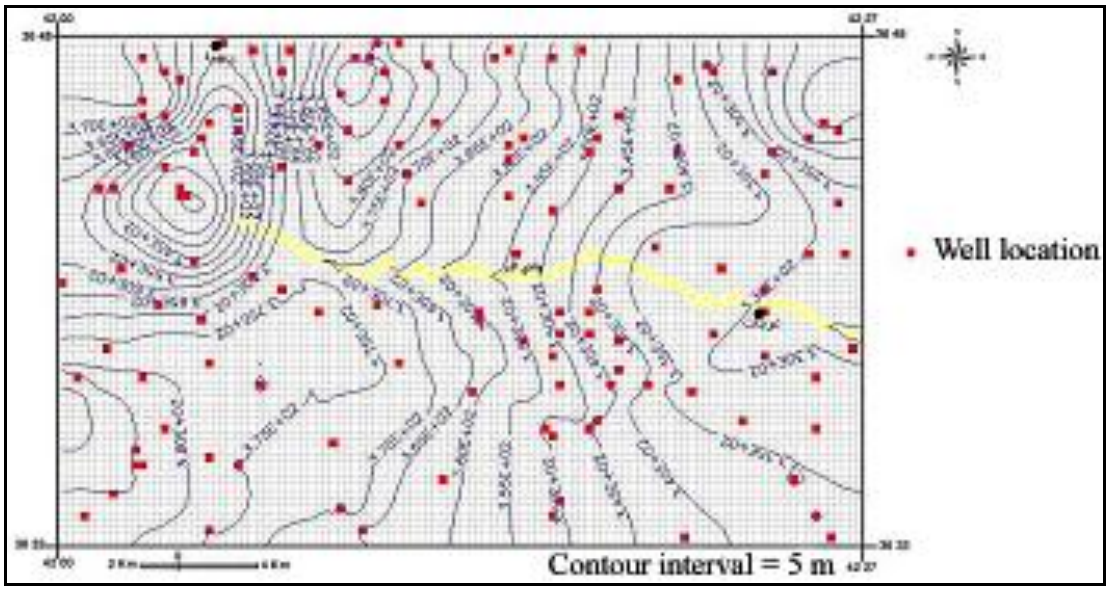


Fig. 7: Predictive simulation of hydraulic head in 2015

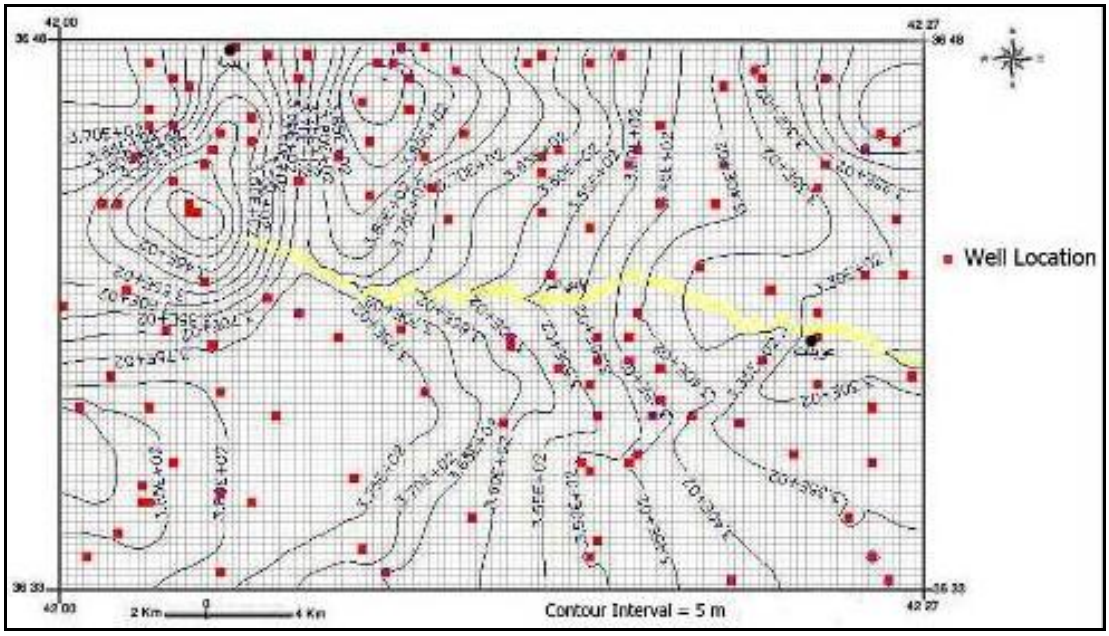


Fig. 8: Predictive simulation of hydraulic head in 2025

Table 3: Calculated hydraulic heads through predicted simulation for selected cells up to 2025

Location	Cell		Hydraulic head				
	Row	Column	2005	2010	2015	2020	2025
Stage 1	20	60	359.10	359.72	360.36	361.01	361.68
	40	60	358.44	359.14	359.82	360.48	361.12
	30	80	333.12	333.79	334.45	335.10	335.74
	40	70	345.02	345.57	346.06	346.54	347.02
Stage 2	10	40	392.78	393.53	394.30	395.08	395.89
	10	60	367.37	368.57	369.75	370.91	372.04
	40	40	373.20	374.44	375.66	376.86	378.04
	50	50	369.07	370.26	371.42	372.55	373.64

CONCLUSIONS

The given results shows the importance of Injana aquifer in the area, where most of the wells were penetrated this aquifer and affected seriously by North Al-Jazera project. The renewable water obtained from the model is found to be 130 million cubic meter/ year; this quantity can be utilized during summer season instead of surface water to compensate the reduction in surface water.

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