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Prediction of aquifer reaction to different hydrological and management scenarios using visual MODFLOW model-Case study of Qazvin plain

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Abstract

Regarding to increased use of groundwater resources, it seems necessary to have more accurate knowledge of characteristics of aquifers in order to improved usage and accurate management of these resources. In this study, we simulated groundwater flow of Qazvin aquifer using Visual MODFLOW model, collecting data and statistics, as well as using different studies. The simulation model has operated and it has calibrated through changing the input parameters in logical range and comparing the results to level of the groundwater in observation wells. calibrated model has been administered in one year and then it got to validate. We planned different scenarios which is possible to occur in future. Then we predicted the reaction of aquifer to these environmental stresses by implementing the model and they have considered by hydrographic frame of average groundwater level for each scenario separately and the results compared to each other. At end, the results of annual water table balance of aquifer are studied and explained.

Keywords

Prediction, hydrological scenarios, groundwater balance, Visual MODFLOW Model.

1. Introduction

The estimation of Yunesco in 1987 showed that the freshwater comprised only 2. 5% of total waters in the world, this amount is distributed in glaciers and poles in 68. 581% and groundwater in 30.061%. So, it seems necessary to have more accurate knowledge of characteristics of aquifers in order to improved usage and accurate management of these resources. In this study Qazvin aquifer was simulated by visual MODFLOW model and the reaction of the aquifer according to three different hydrological and management scenarios in 10 future years was analized.These scenarios are 1. The impact of about 40% decrease in rainfall in 10 future years .2.The coincidental impact of discharging 20% more water from agricultural wells and decrease of about 40% in rainfall.3.The impact of improvement irrigation practices efficiency by using new methods of irrigation such as pressurized and micro irrigations. The impact of these three scenarios was compaired to normal conditions through the groundwater unit hydro-

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graph. Shigin Wang et.al (2008) using MODFLOW and geographic information system to simulate groundwater flow in North China plain. He used MODFLOW and GIS for simulation and compaired calculated data with observations and results showed that there were a good correlation between them. Ghanavati (2009) simulated groundwater flow in Qom aquifer, His study area was 431 km^2,he also evaluated the impact of some hydrological changes in future on the aquifer.Zalnejad (2000) simulated water resources of Ashnavie plain.His study area was about 475 km^2 .He run his model for 1996-1997 for one day time steps and one month stress periods and he also calculated the result of groundwater balance in the plain.

2. Methods and Materials:

This study is done in part of Qazvin province with area of 3161 km2. This region placed in distance of 150 km of west north of Tehran. Maximum height is 2833 m and minimum height 1141 m and the average height is 1250 m from the sea level. This region, on the base of hydrological division of Latrine basin, is placed in Hoz-e-Soltan lake, and in fact it is sub-basin of Shur River. (Toosab2010) The climate of this region, based on Du Martin Climate Classification, is semi-dry and on based of Ambrege Climate Classification, is dry and cold semi-dry. Qazvin aquifer is an unconfined aquifer which is surrounded by heights, (except a small area in east of plain where it is near a marsh). Geological studies show that there is a discharge from the boundary of Salt marsh area to Shur river as base water.The only exit of plain is placed in east of it ,near a march,as result it dosent have any hydraulically exchange head and aqueous head with adjacent aquifer.The alluvial deposits in the adjacent regions of heights are middle-sized in upper parts (clay, sand, and gravels) and are large-sized in under parts (gravels, sand, silt and clay). The diameter of alluvium is maximum in center of the plain, and when we move toward east, it comes up because of coming up bed rock of Marni Miosen. (Toosab2010) To solve the partial differential equations of groundwater flows, the studied region is divided into cells and it is assumed that the hydraulical and hydrogeological characteristics of aquifer are constant in each cell.(Istok 1989) Bed rock layers and the watertable level are introduced to model in GRD format. Then, the hydrodynamics coefficients of aquifer are introduced to the model. These coefficients are including hydraulic conductivity, storativity, transmisivity of the aquifer (K,T,S). The amount of each parameter with applied input was introduce for Visual MODFLOW.(Toosab2010)

2.1. Introducing The Recharge And Discharge Factors Of Aquifer In Model

1- Introducing The Discharge Factors Of Aquifer

A) The discharge of groundwater from the wells: the total number of wells in plain with available data is 406, in which 278 of these wells have more accurate statistics. These wells are used for drink, agriculture and industry. The discharge volume of these wells is 1359. 8 million m3 for agriculture and is 122. 8 million m3 for drink and industry in 2005. (Toosab2010)

B) Evaporation from the surface of groundwater: Because we consider 5 m for critical depth of water table for beginning the evaporation, on the base of water table map in 2005, the evaporation rate from surface of groundwater is assumed zero. (Toosab2010)

2- Introducing the recharge resources of aquifer

A) Recharge the aquifer from the rivers seeping: about 35% of rivers flow rate in month is indicated as speed (mm in year) as a infiltration from plain to aquifer. (toosab2010)

B) Feeding the aquifer from returned water of wells: the coefficient of returned water for agriculture is 33% and for drink and industry wells is 60%. (Feng Bo2010)

C) Feeding the aquifer from rainfall: the rainfall rate in 2005-2006: 288.62 mm, the annual volume from rainfall: 912 million m3, the share of feeding the aquifer: 127.7 million m3.

D) Feeding from artificial recharge pond: the predicted ponds in this plain: 27 plain, the ponds which are constructed: 9, and their capacity: 3.1 m3/s. (Toosab2010)

2.2. Preparation of PIEZOMETRIC HEAD MAPS of ground water flow from observation data:

In this study the watertable fluctuation of 53 piezometer of the plain is used. At first, in order to determine the fluctuating of groundwater level in stress period and the srorage of groundwater, the groundwater unit hydrograph is drawn. For drawing the groundwater unit hydrograph, data of 10 years are used. Then, water table maps and the depth of ground water, with their changes during 10 years, are prepared using field data from the depth of water in piezometers for comparing with calculated results of simulated model and real physically conditions. After specifying the input parameters in models, the model was run for 2 short period in 2005-2006. The results of first run of model compared with field data. These two periods include August and September 2006 and January, February and March 2006. In the first two months the infiltration of surface flows is considered zero and the hydraulic conductivity and boundary condition are calibrated. In later 3 months period the infiltration flows is calibrated and during the unsteady condition, the drain rate and infiltration of surface flows in aquifer is calibrated. For validation of this model are considered in 2006-2007 because of more accurate statistics data from field data, and the results are compared with field data. Then three scenarios are evaluated in order to predict the hydraulic behavior of aquifer in future. (Ghanavati2009)

3. Results and Discussion

3.1. Comparing the calculated and observed results at the end of unsteady condition in the first run of model

After the first run of model, we analyzed the calculated and observed water table in unsteady condition (End of September 2006) and the regression of calculated and observed watertable are shown in" fig 1". The coefficient of determination R^2 for first run of model is 0. 95. The errors include normalized RMS, RMS, SEE are 0. 394, 0. 87 and 0. 134 respectively.

For calibrating of model the unsteady period is divided into 4 stress periods.First period is from October to December 2005,The second period is from January to March 2006.The third period is from April to June 2006,and the last period is from July to September2006, and the calculated results of watertable elevations are evaluated at the end of each stress period. The results from the model at the end of each period after calibration had suitable regression with field data and the coefficient of determination R^2 in the end of fourth period is 0. 99 which is logically accepted "fig 2" .

3.2. The results of analyzing the sensitivity of calibrated model

The mathematical model of aquifer of Qazvin plain has high sensitivity to hydraulic conductivity parameter and well discharge. While the ratio of infiltration of surface flows has less sensitivity. The results of analyses on sensitivity by program are shown in "figures 3 to 5. "

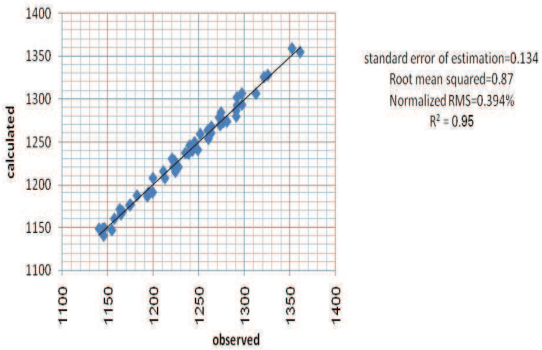

Fig.1: The regression of calculated and observed watertable elevation result of first run(units are in meters)

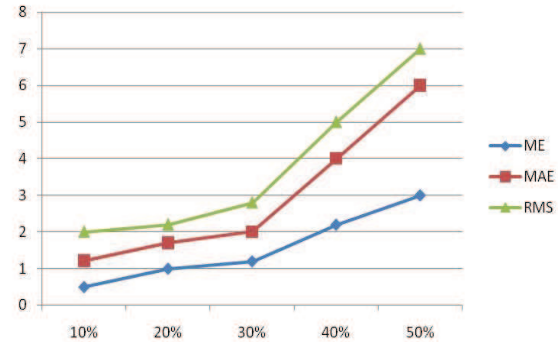

Fig.4: Sensitivity to discharge rate of aquifer from the wells

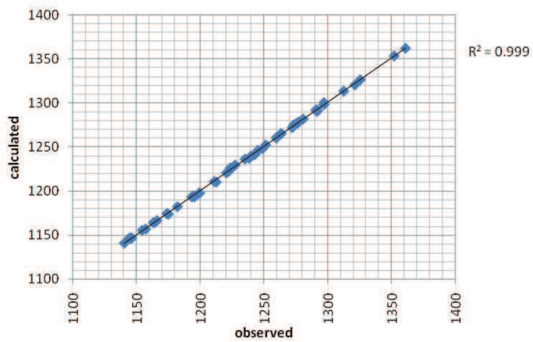

Fig.2: The regression of calculated and observed watertable elevation result, after calibrating(units are in meters)

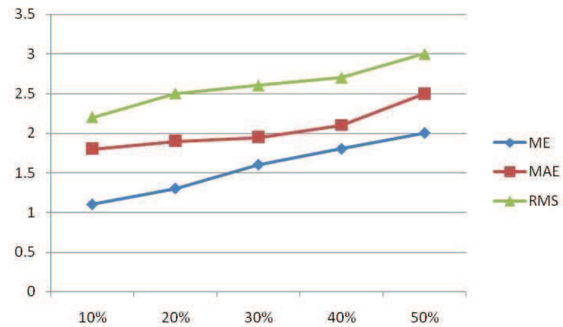

Fig.5: Sensitivity to infiltration of surface flow

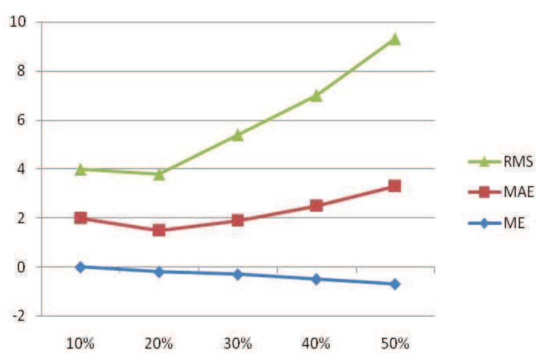

Fig.3: Sensitivity to hydraulic conductivity

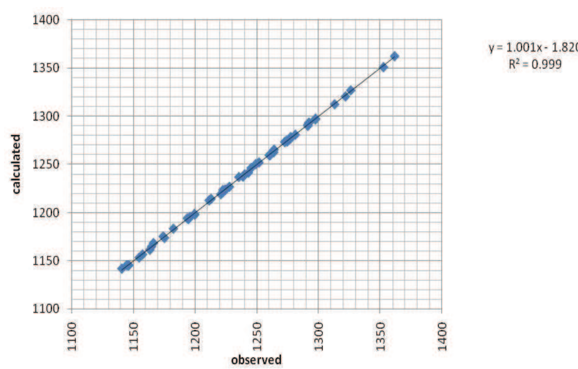

Fig.6: The result of calculated and observed watertable elevation at the end of validation(ynits in meters)

3.3. The results of validation model

The regression of calculated and observed results of model at the end of validation period (October 2007) are shown in "fig 6" The R^2 is 0. 99 and it confirmed the validation of model .

3.4. The results of annual balance of groundwater in Qazvin plain

According to hydrological conditions Qazvin plain is divided into four different zones."fig7"The balance of groundwater in 4 hydrogeological zones of plain is considered in Zonebudget menu. The results are shown in "table 1". The total rate of discharge is 149 million m^3 on the base of balance results in 2006-2007 more than the total drainage. Regarding the surface of 3161 km^2 of plain Only 3 cm decrease of water table is observed.

3.5. The results of different scenarios:

The first scenario showed a decrease of 40% of rainfall in future years, which is resulted to decrease of 2 m of water level. The second scenario is included the increase of 20% of draining water from agricultural wells and decrease of 40% of rainfall, which showed a decrease of 2. 5 -3 m of water during the next 10 years. In the 3rd scenario, the water table increased to 1-1. 5 m during next 10 years, with increasing the efficiency of irrigation using new irrigation methods. These results are shown in figures 8-10 .

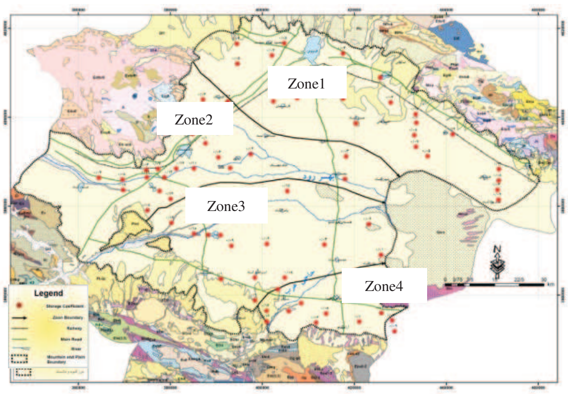

Fig.7: Four hydrological zone of the plain

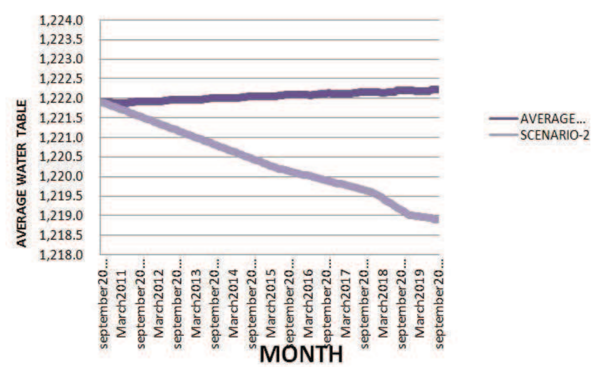

Fig.9: Result of the second scenario(units in meter)

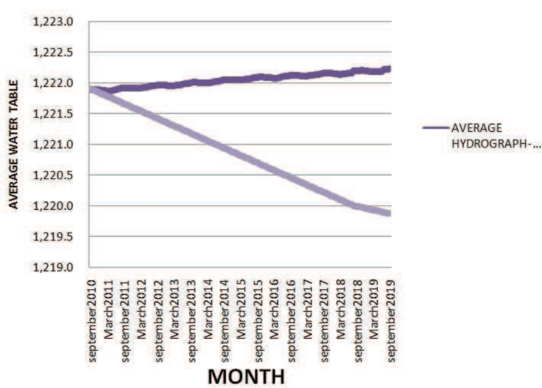

Fig.8: Result of the first scenario(units in meter)

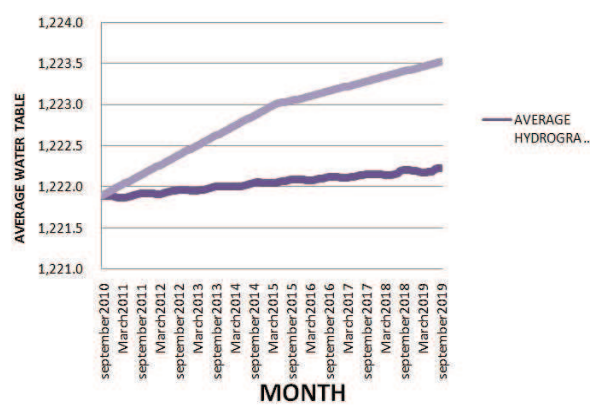

Fig.10: Result of the third scenarios

Table 1. Annual balance of groundwater in Qazvin plain

Storage differences(mm^3)	Total rate of drainage(mm^3)	Total rate of recharge (mm^3)	Area(km^2)	zone
-02/32	99/522	98/490	27/1036	1
-83/36	18/383	35/346	33/849	2
-92/68	35/437	43/368	31/952	3
-24/11	39/70	16/59	78/228	4
-149	91/1413	91/1264	3161	Sum-annual

4. Conclusion

Comparing the calculated water level by simulated model to observed water level in plain, we can conclude that this model can make an exact evaluation to real condition regarding the natural condition. So, we assure that the results of balance of ground water are correct.

Another goal of this mathematical model is to consider the accuracy of the information and data. After making the model, some failures in data appeare. The piezometric wells didn't have appropriate range and transmittance and have statistical failures. So, the alignment maps and depth of water didn't have enough accuracy and the depth of bed rocks in some places of geoelectric sundage does not match with well tapping. Climate and hydrology data in Qazvin plain are not correct. For example, measuring the drainage rate in rivers especially northern rivers have many failures in statistical period. We hope that after implementing the data and eliminating the failures, the mathematical model of aquifer of plain is prepared.

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