GROUNDWATER MODELING OF THE BAZURGAN OIL FIELD AREA

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ABSTRACT

The hydraulic performance of the aquifer has been investigated through the use of a computer program package.

The hydrogeological information which are required for aquifer simulation have been collected from various sources, evaluated, then used as an input data for the computer package. Due to the scarcity of data, it has been a difficult task to delimit the location and type of the hydraulic boundaries along the northern and eastern sides of the area for modeling purpose. Accordingly, three cases are treated depending on the assumed nature of the boundaries. In the first all the boundaries are assumed at constant head. In the second, the northern and eastern boundaries are assumed to be of no flow type, whereas the Tigris river and Al- Musharah river both of which representing the western and southern boundaries are treated as constant head. The third case is similar to the first; however the effect of Al- Teeb River and the marshes in the south are also taken into consideration.

The steady- state natural head distribution prior to the effect of any external stresses have been obtained by the steady- state treatment, and by the unsteady- state treatment for a very long simulation period. Both results gave nearly similar head distribution which is comparable fairly well with measured head values. The steady- state head distribution is used as initial head values in the subsequent unsteady- state treatments.

The drawdown distribution for the effect of existing wells, and proposed plans for future groundwater exploitation have been determined. It is found that the aquifer is capable to yield good quantities of water.

الخلاصة

جرت دراسة الأدائية الهيدروليكية للمستودع المائي من خلال استخدام البرنامج الجاهز. جمعت و قيمت المعلومات الهيدروجيولوجية المطلوبة لنمذجة المستودع المائي من مصادر مختلفة. بعد ذلك استخدمت كبيانات إدخال للبرنامج الجاهز. نتيجة شحه البيانات كان من الصعب معرفة موقع ونوع الحدود الهيدروليكية على طول الحدود الشمالية والشرقية لمنطقة الدراسة لغرض تشغيل النموذج. افترضت ثلاث حالات اعتماد على طبيعة الحدود المفترضة. في الحالة الأولى افترضت كل الحدود كمنسوب ثابت. في الحالة الثانية، الحدود الشمالية والشرقية افترضت كحدود غير نفاذة، بينما نهر دجلة ونهر المشرح كلاهما يمثلان الحدود الغربية والجنوبية أخذت كمنسوب ثابت. أما الحالة الثالثة مشابهة للحالة الأولى؛ ولكن اخذ بنظر الاعتبار تأثير نهر الطيب والاهوار في الجنوب.

تم حساب الحالة المستقرة لتوزيع منسوب المياه الجوفية الطبيعي بدون أي تأثيرات خارجية من خلال معاملة الحالة المستقرة وكذلك بواسطة معاملة البرنامج للحالة غير المستقرة لفترة طويلة جدا. أعطت كلا الطريقتين توزيع منسوب مياه جوفية متشابه تقريبا والذي قورن مع منسوب المياه الجوفية المقاس. توزيع المنسوب للمياه الجوفية في الحالة المستقرة استخدم كقيم منسوب مياه ابتدائي لمعاملات الحالة غير المستقرة اللاحقة. تم حساب توزيع الانخفاض في منسوب المياه الجوفية كدالة للموقع والزمن بتأثير الآبار الموجودة والخطط المقدمة للاستغلال المستقبلي لتلك المياه حيث وجد أن المستودع المائي يمكنه توفير الكميات المقترحة من المياه

KEY WORDS
Ground water model, Bazurgan field, ground water exploitation

INTRODUCTION

Area of the Study

Bazurgan oil field area is about 60 km north of Amara city,south- east Iraq. It extends from the northwest to southeast .It is about 50 km in length and 10 km in width (Shawqi, 2000).
The study area is bounded from the west by Tigris river, & from the south by Musharah river and from the north and north east it extends beyond the Iraq-Iran borders. It lies between latitudes $31^0 48'$- $32^0 36'$ and longitudes $46^0 36'$- $47^0 48'$. **Figs. (1) and (2).**

Aim of the Study

The aim of the study is to investigate the possibility of using groundwater to cover the needs of the Bazurgan Oil field area. Such requirements are expected to cover human, rural, as well as industrial requirements.
In order to achieve the objective of the study the following topics have been investigated:
1- The hydrological and geological conditions, which are prevailed in the studied area.
2- The hydraulic properties of the aquifers.
3- A mathematical model is proposed to evaluate the aquifer response to various plans of its exploitation.

The mathematical model provides:
1- An idea about the hydraulic head changes (as a function of space and time) in response to well production. This will aid in suggesting an optimum plan for well location and scheme of efficient operations.
2- An idea about the aquifer behavior in the future and thus avoiding the exhaustion of the producing beds by posing the safe yields.

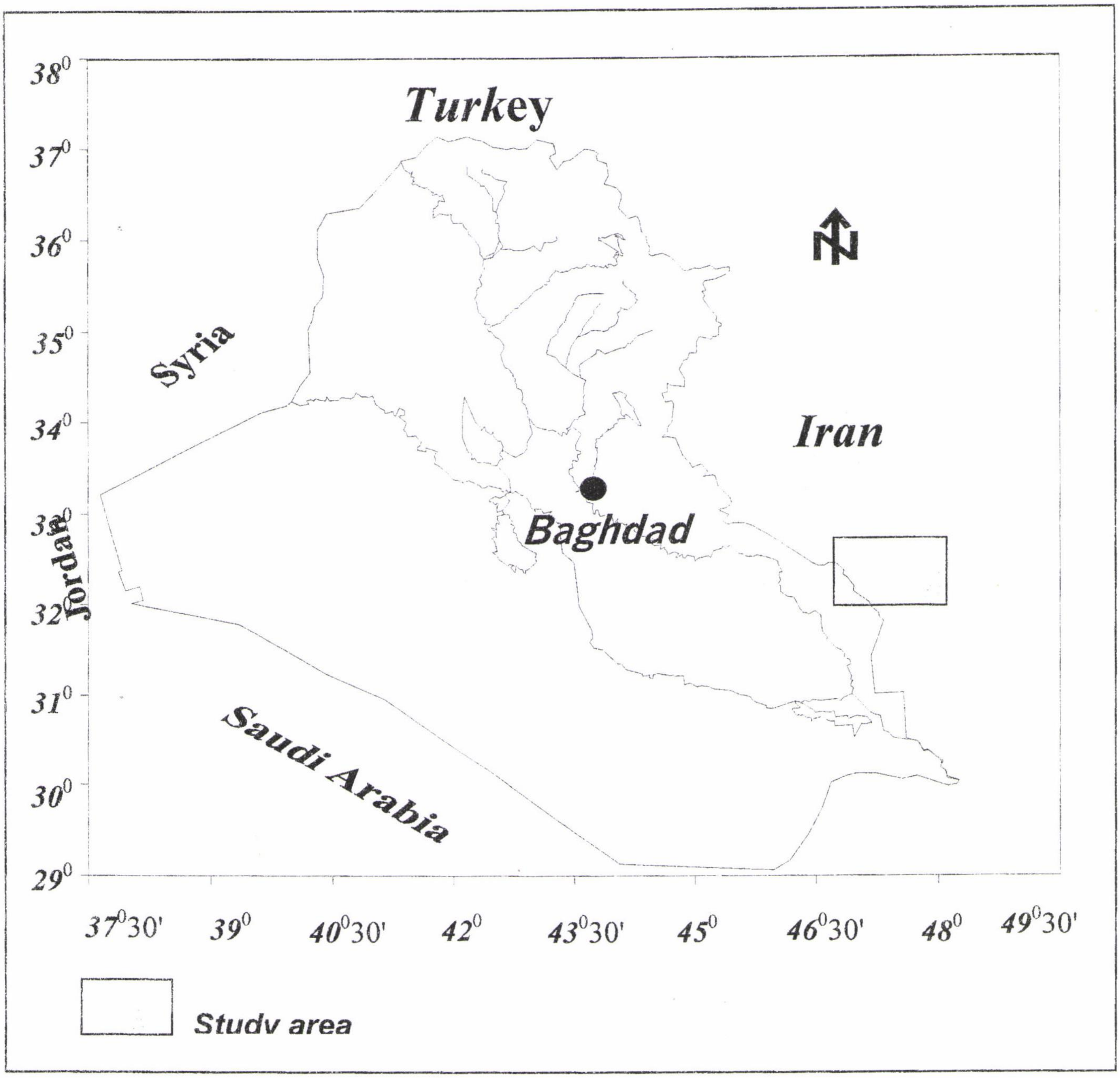

Fig. (1)- Location of the Study Area in Reference to Map of Iraq

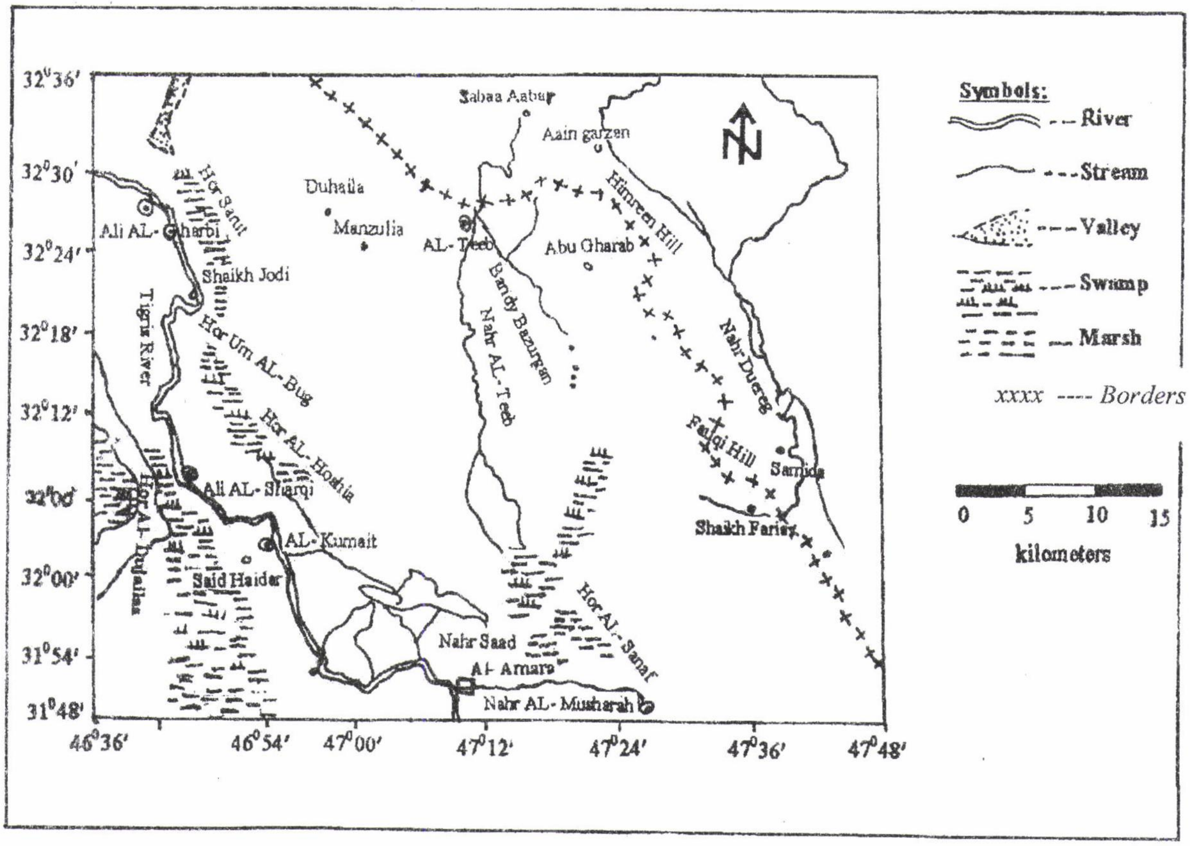

Fig.(2)- A Map for the Study Area

GEOLOGY OF THE AREA

Topography

The area is bounded from east and northeast by the Himreen hills, which extends from the northwest to southeast. The area is bounded by Tigris River along its western and south western borders and Al- Musharah River along its southern border. Al- Teeb river cross the area from north to south, where it branches to many distributaries that run towards south and southeast and end in local marshes.

A part from Himreen Hills, whose elevation varies between 100 to 250 m (a.s.l.), the area may be considered of low relief. Generally, the surface is sloping towards the west and south west where it reaches elevations of about 8 m (a.s.l.) along the Tigris River.

Structure

The study area is part of the Mesopotamian plain which lies on the near platform flank of the Mesopotamian Foredeep.

In the northeastern part of the area Himreen anticline lays, which is composed of a pattern of low folds built up by rocks of undifferentiated Mukdadiyah and Bai Hassan Formations (Lower and Upper Bakhtiari).

Several shallow anticlines may be identified with the south-western limbs generally has steepest dip. This system extends from Al-Teeb to Shaikh Faris.

HYDROLOGY

Climate
The important climatic factors are precipitation, humidity, temperature and wind; all of which directly affect evaporation and transpiration. The following discussion is based on data from Amara Station for the Period (1980-2000).

Temperature
Table (1) gives the values of the main meteorological elements in the nearby Amara Meteorological Station. It shows that the average maximum temperature occurs in summer during July (average maximum temperature 45^0C and minimum temperature 28^0C). The average minimum temperature in winter occurs during January (average maximum temperature is 17^0C and average minimum temperature is 6^0C).

Table (1) Monthly Average Meteorological Elements at Amara Station for the Period (1980-2000)

MONTH	EPAN(mm)	P(mm)	T.MIN(^{0}C)	T.MAX(^{0}C)	SUN SHINE(HR)	R.H(%)	WIND SPEED (m/sec)
OCT.	241.01	12.7	18.364	34.36	8.874	42.47	3.135
NOV.	118.15	21.45	12.67	25.594	7.08	59.47	3.247
DEC.	68.45	60.966	7.44	18.594	6.2	69.647	2.747
JAN.	63.54	35.7	6.323	16.69	6.326	71.88	2.68
FEB.	93.465	28.01	7.77	19.14	7.794	64.68	3.24
MAR.	155.545	41.726	11.94	23.5	7.05	59.235	3.64
APR.	242.247	14.665	17.5	31.02	8.71	52.53	3.776
MAY	379.345	3.375	23.38	37.97	9.82	36.117	4.14
JUN	547.29	0.05	26.4	43.06	11.985	26.44	6.35
JUL.	589.44	0	28.62	45.347	11.72	25.06	5.935
AUG.	525.295	0	27.535	44.623	11.645	26.76	5.417
SEP.	371.84	4.724	23.35	41.817	10.525	29.82	4.053
MEAN	282.968	18.584	17.608	31.81	8.977	47	4.03

Precipitation
Precipitation occurs during November to March, **Table (1)** indicate that the maximum quantity of precipitation occur in December (about 61 mm).

Winds
The maximum wind speed occurs in June (about 6.3 m/sec), while the minimum in January (about 2.7 m/sec) as given in **Table (1).**

Relative Humidity
The relative humidity reaches its maximum values in December and January (about 72%) while minimum values are observed during (May-October).

Evaporation
The maximum evaporation rate reached 589 mm during July, while the minimum rate is 63.5 mm in January as given in **Table (1).**

THE MATHEMATICAL MODEL

Description of the aquifer simulation

In the present work the MODFLOW of the GMS (1996) is used to simulate the area under study which has about 100 km in length and 87.5 km in width. The groundwater system which represents the flow domain is descritized by a grid. This process is carried out by superimposing a mesh over the area.

The grid system is referenced in terms of row, column, and layer-numbering scheme with block-centered nodes. A non-uniform mesh of (55) rows and (66) columns has been designed to simulate the aquifer as shown in **Fig. (3).** Areas of the nodal grids range from (1.25 km^2) to (6.25 km^2). In this design, considerations were given to the change in the hydraulic properties, well locations, hydraulic gradient, reliability of information, and the nature and distance from the boundaries.

The design of any model needs some simplification of the natural condition and certain assumptions, especially regarding the boundary conditions of the system. Among the problems that arose in simulating that area is that related to identification of the nature of the northern and eastern boundaries. In fact, part of the north eastern boundary coincide with the topographic divide; and accordingly if a water- table condition is assumed, that part of the boundary should be treated as no flow boundary. However, even if such treatment is made, it should be noted that such type of boundaries may not remain stationary; it may become a moving boundary. Due to the absence of detailed information about the exact location and type of the hydraulic boundaries inside and along the northern and eastern sides of the area, three cases are considered.

Case A: All the sides are assumed as constant head boundaries with infiltration from precipitation.

Case B: The northern and eastern sides are assumed as no flow boundary, while the Tigris River as constant head boundary. The recharge is assumed to occur through infiltration.

Case C: Same as case A in addition to enter Al-Teeb River and marshes as constant head with infiltration.

Since producing wells are relatively far from the river, average- level values should give results of practical accuracy.

whether no flow or constant head will have no appreciable effect on the drawdown values except probably after long periods of production.

Input data

Due to the presence of alluvium and Tertiary sediments which are fluvial in nature it is expected that a complex system of confined/ unconfined aquifers is present in the area. This is supported by the fact that some of the wells tap water from confined beds, while others produce from unconfined aquifers. The confined aquifers that are shallow are expected to be of local nature since they are present in an alluviam deposits and not part of a well- defined formation.

The transmissivity, elevations of the top of the aquifer, storage coefficient, point sources or sinks, and net withdrawal rate for each nodal point are required in the input data. Apart from the last parameter, the transmissivity and the elevations are determined for each nodal point through preparing a contour map for the areal distribution of each of them for each of the parameters. Thus, the value of the parameter may be determined for each nodal point.

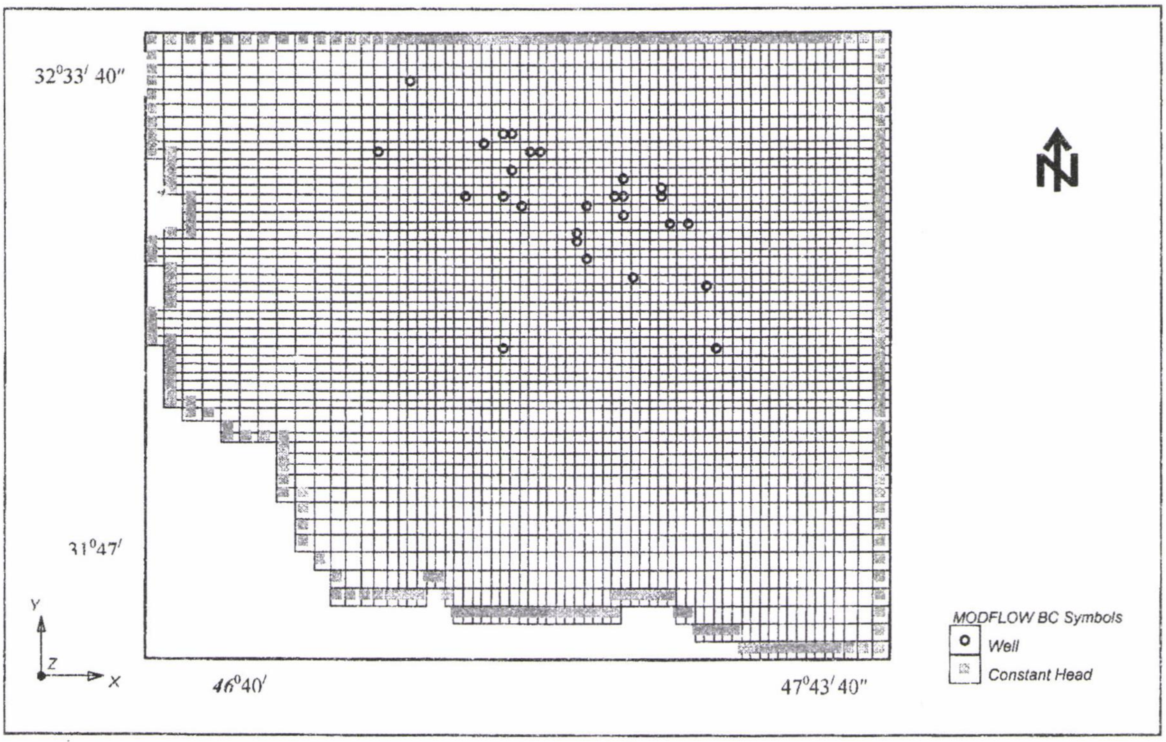

Fig. (3)- Grid Design for Study Area

It is to be mentioned, that since the northern and eastern boundaries are relatively far from the producing well sites, their nature, i.e.

Steady- State Simulation

Steady or equilibrium flow occurs when there is equilibrium between the discharge (total output) and the recharge (total inputs) of a basin. However, in practice, it is said that a steady state is reached if the changes in hydraulic heads with time become negligible, or the hydraulic gradient has become constant (Kruseman, G. P. & De Ridder, N. A., 1970).

A comparison between the contour maps of the observed (natural conditions) and the computed head values for the steady state conditions shows some anomalies between both, **Figs.(4) and (5),** specially towards the north eastern parts. However, it may still be considered acceptable for the following reasons:-

1- All the data are subjected to very high degrees of inaccuracies, from those concerning location and head values at the boundaries to the results of pumping test analysis and the absence of reliable values of storage coefficients.

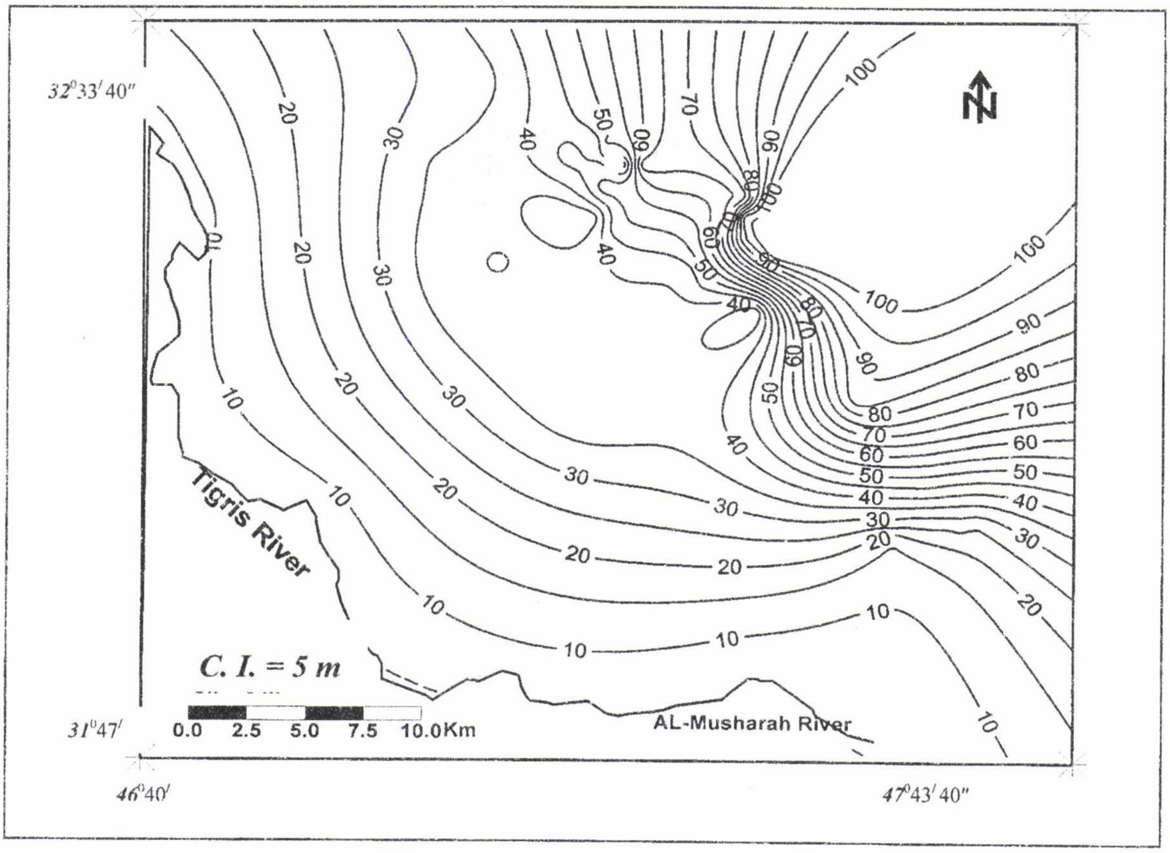

Fig.(4)- Measured Groundwater Contour Map.

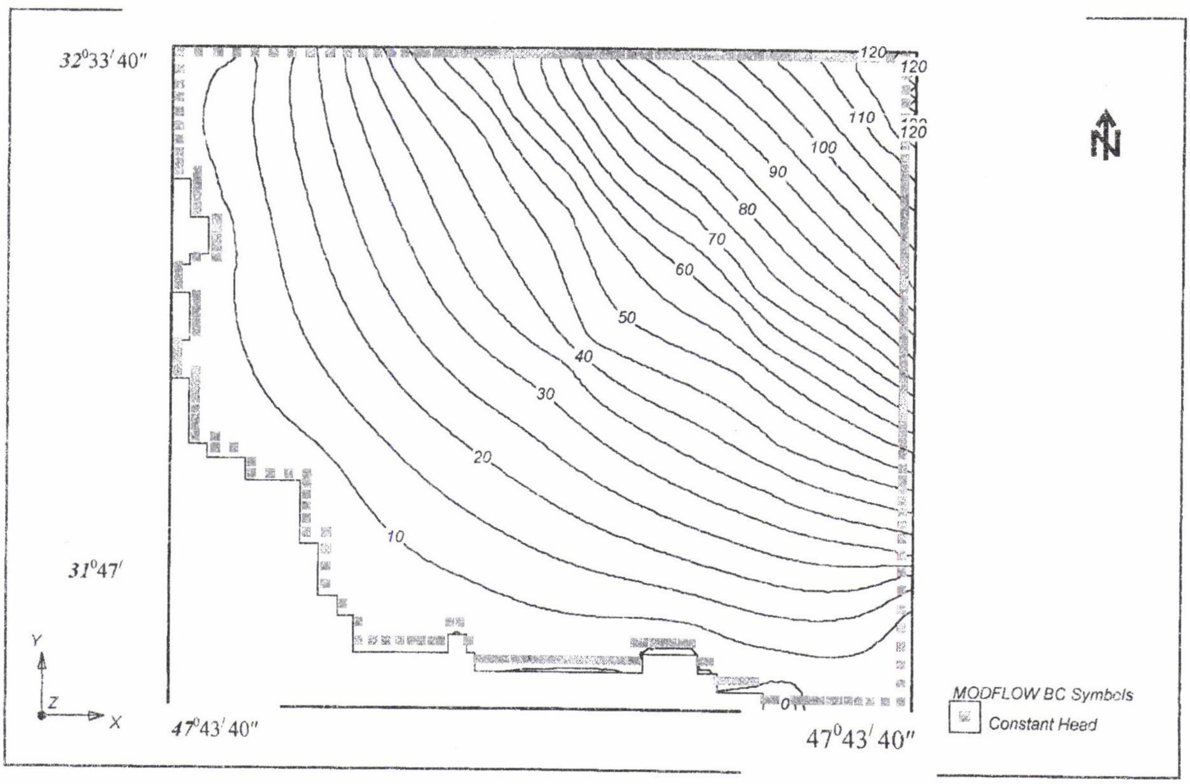

Fig.(5)- Groundwater Contour Map for Steady State Simulation.

2- The measured head values are not actually representing natural groundwater levels which are not affected by production from other wells (i. e. the wells are drilled at different times, accordingly the measured head value in a new well is affected by the production from old wells which were drilled before it).
3- No data is available for the northeastern part of the study area because this part is located in Iran.
4- The inaccuracy in the initial heads has a very small effect on the computed drawdown values.

Unsteady- State Simulation

Unsteady- state or non- equilibrium flow occurs from the moment pumping started. In practice, well- flow is considered to be in unsteady state condition as long as the head changes with time.
Unsteady state simulation is the second important step and the main aim of simulation in the present work. Prediction of the aquifer behavior for various plans of its exploitation is the objective. The head values which are computed for the steady- state condition have been used as initial input head values for simulating the unsteady- state behavior.
Sensitivity analyses are made by running the model with different values of certain parameter in order to evaluate the effect and role of that parameter on the head changes. Because the data of the storage coefficient is not available, assumed values of the storage coefficient is considered on the basis of analysis of well testing in the same formation (Bakhtiari Formation) in other areas (the values of storage coefficient which are assumed for the formation in the study are 0.05 & 0.01 respectively). The results of the sensitivity analysis have shown that the model is very sensitive to the change of the storage coefficient (Lazim, S.A., 2002).

Effect of Existing Wells

An attempt is made to predict aquifer response to the effect of production from the existing wells. A low value of storage coefficient of 0.01 is assumed for all nodal points. A period of 1 year of continuous production is considered first.
The drawdown contour map for the first case, (case A in which all the boundaries are assumed at constant head) with a recharge effect (infiltration of 1.515E-3 mm/day) are shown in **Fig. (6).** The maximum drawdown is found to be 10.8 m.
The drawdown contour map for the second case B (in which the northern and eastern boundaries are assumed to act as no flow barrier) is shown in **Fig. (7).**The maximum drawdown is found to be 10.7 m.
For case C (in which all the boundaries are assumed at constant head; and the effect of Al-Teeb river and the mashes are introduced), the drawdown contour map is shown in **Fig. (8).**The maximum drawdown is found to be 10.7 m.
The effect of existing wells for a 10 years period of continuous production is also computed (Lazim, S.A., 2002).

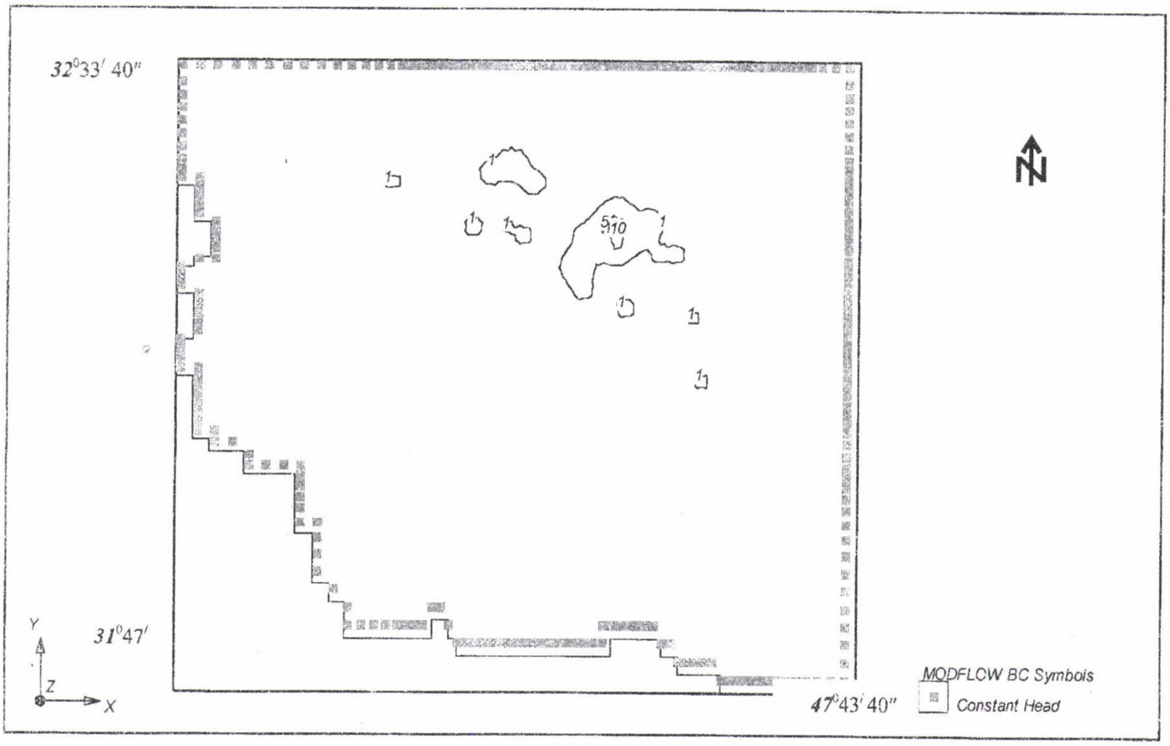

Fig. (6)- Case A: Drawdown Contour Map of the Study Area after One Year from the Operation, with Recharge, S=0.01, Max. Value = 10.8 m

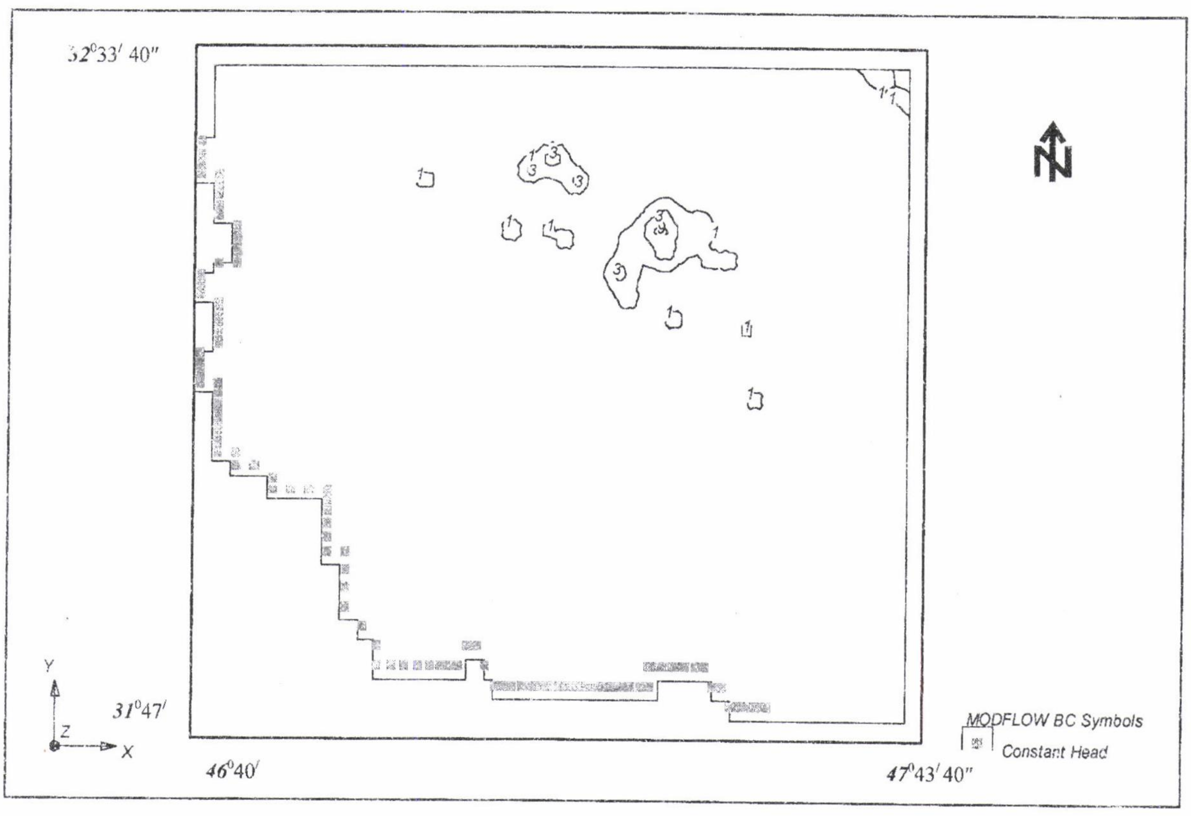

Fig. (7)- Case B: Drawdown Contour Map of the Study Area after One Year from the Operation, with Recharge, S=0.01, Max. Value= 10.7 m

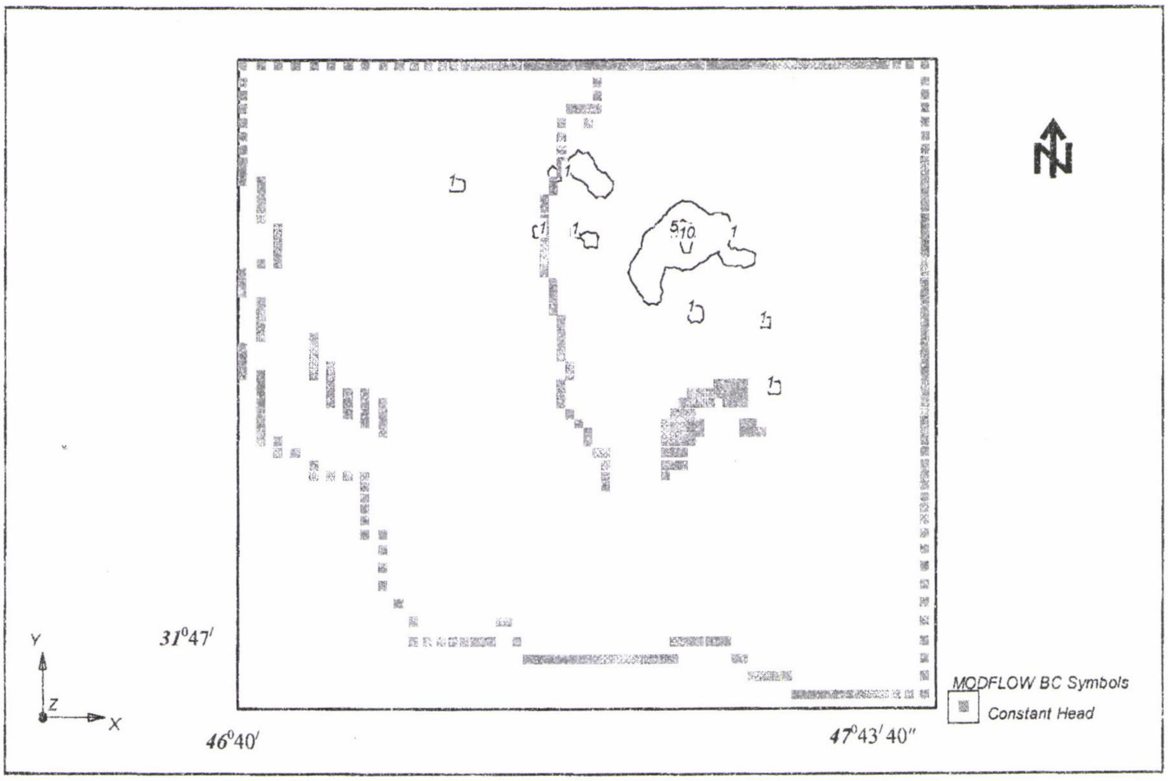

Fig. (8)- Case C: Drawdown Contour Map of the Study Area after One Year from the Operation, with Recharge, S=0.01, Max. Value= 10.7 m

Effect of Suggested and Existing Wells

To fulfill the possible future needs for groundwater, a battery of 18 new wells is assumed to be installed in Bazurgan oil field area. It is suggested that each of these wells is producing at a constant rate of 20 l/sec (Lazim, S. A., 2002)

The drawdown contour after 1 year of continuous pumping of the existing and suggested wells for case A (all boundaries at constant head) is shown in **Fig. (9).** The maximum drawdown is found to be 35.8m near the center of the battery of the new wells.

For case B, where two of the outer boundaries are assumed to act as no flow barriers, the drawdown contour map is shown in **Fig. (10).** It is found that the maximum drawdown is 35.6m.

The contour map for the drawdown values for case C is shown in **Fig. (11).** It may be noticed that, the effect of Al-Teeb River and the marshes in the south reduced the maximum drawdown to 30.6m.

The effect of existing and suggested wells for a 10 years period of continuous production is also computed.

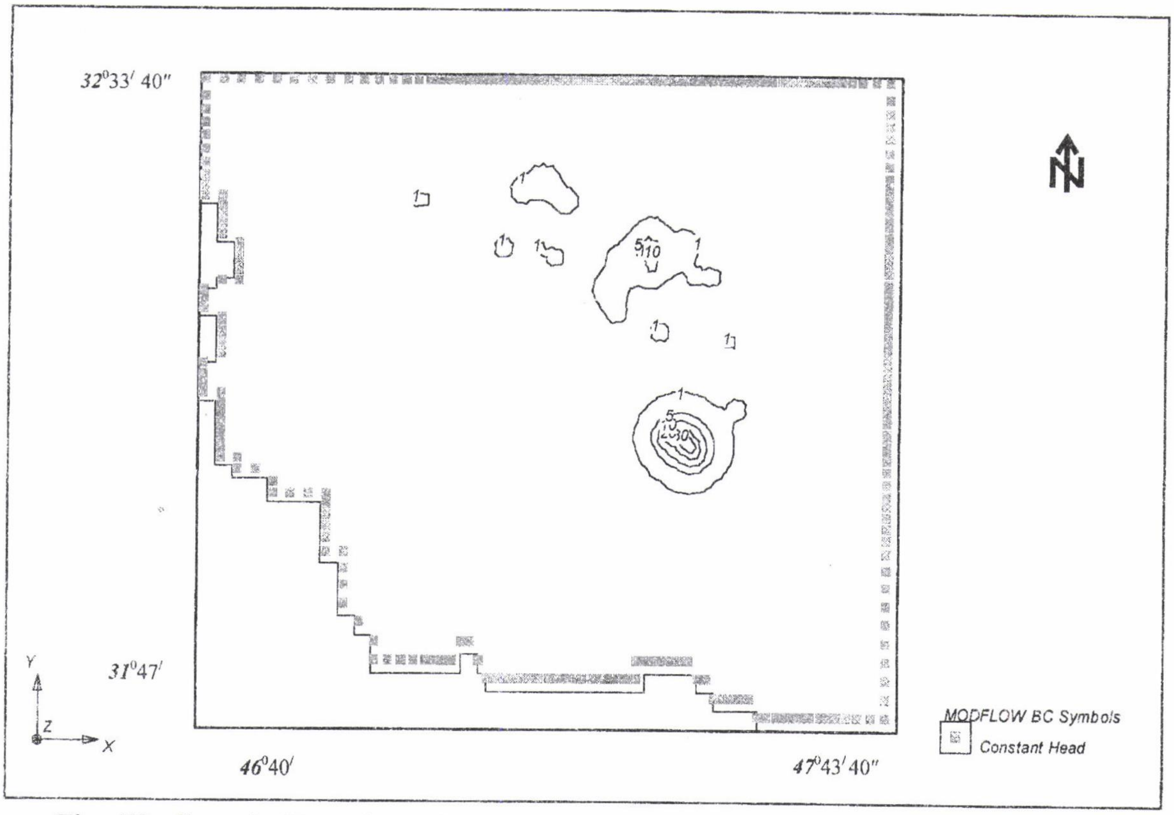

Fig. (9)- Case A: Drawdown Contour Map of the Study Area after One Year from the Operation with Suggested Wells, with Recharge, S=0.01, Max. Value = 35.8 m

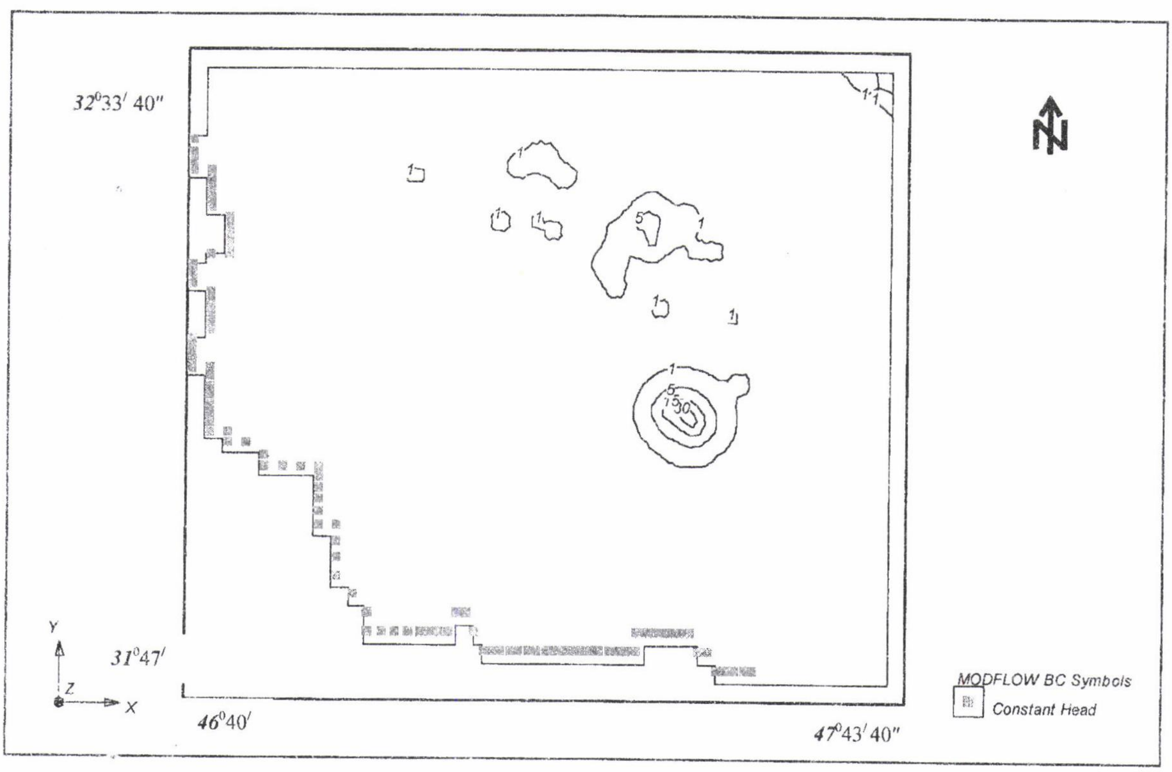

Fig. (10)- Case B: Drawdown Contour Map of the Study Area after One Year from the Operation with Suggested Wells, with Recharge, S=0.01, Max. Value=35.6 m

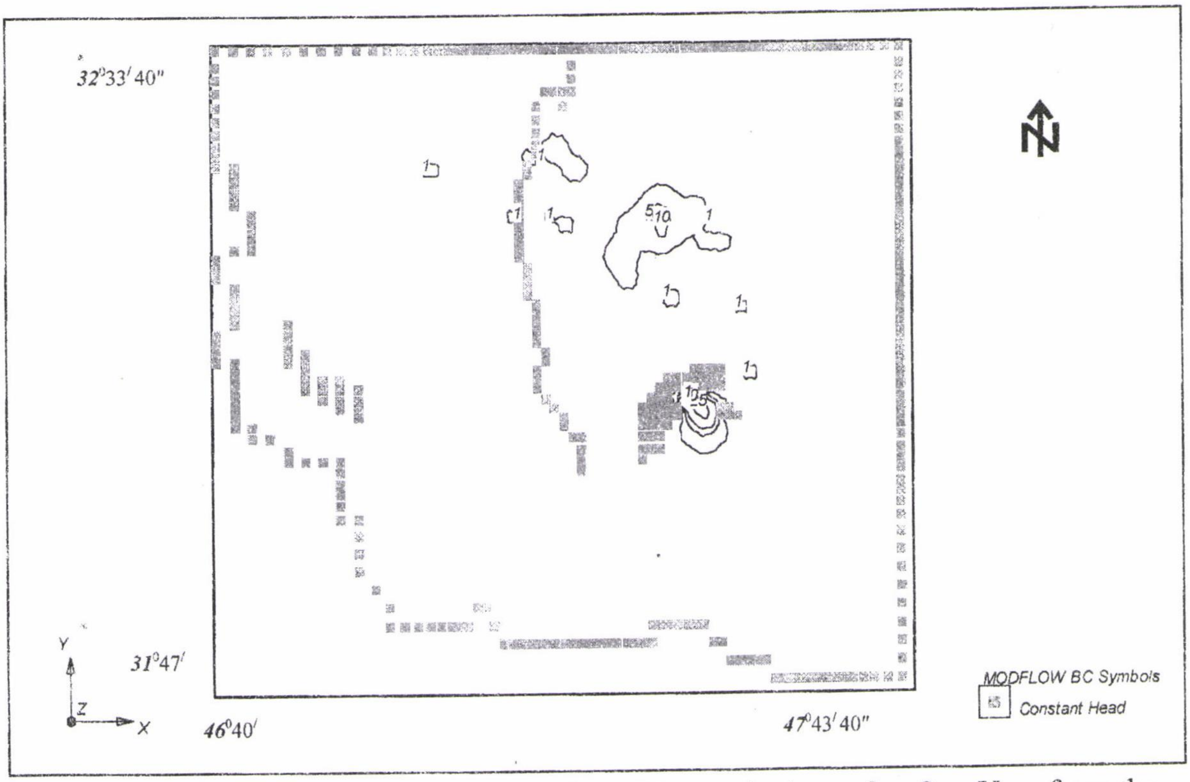

Fig. (11)- Case C: Drawdown Contour Map of the Study Area after One Year from the Operation with Suggested Wells, with Recharge, S=0.01, Max. Value=30.6m

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

A hydrogeological study of Bazurgan region has been made.The main aquifer in the basin belongs to the Bakhtiari Formation (Bai- Hassan and Mukdadiyah formations). It is mainly consists of sands and gravels.

One of the main purposes of aquifer simulation is to predict aquifer response to various plans of its exploitation and operation. A computer program (package) called MODFLOW is used for this purpose. The hydrogeological information about the area has been collected from the literature. The other required input data to the MODFLOW are either computed from available data, or obtained from previous studies, or assumed. In the present work, three cases are considered depending on the assumed nature of the boundaries.

The steady- state (natural) head distribution prior to pumping has been obtained by two methods. In the first, the steady- state choice of the program was selected. In the second method, the program was run for unsteady- state conditions, but without any sources or sinks (no injection or production (wells) for a very long period until the head values become constant (or nearly so) with time. Both methods gave nearly similar results in all the cases which are considered.

The computed steady- state distribution has been used as initial head distribution for the subsequent transient runs. Aquifer responses to two plans of groundwater exploitation have been investigated by the model.

In the unsteady- state condition, the two values of storage coefficients are assumed depending on the values of storage coefficient in the same formation else where. The worse condition is assumed to evaluate the aquifer response (i.e. the storage coefficient or the specific yield is considered equals to 0.01)

In the first plane, (31) existing wells are tested for a continuous production (24 hr/d). An average production rate (7 ℓ/sec.) is supposed to be required from each well; i.e. a total production rate of (217 ℓ/sec.). The maximum drawdown of one year in the area is found to be as follow:
Case A: 10.8 m
Case B: 10.7 m
Case C: 10.7 m
In the second case, the groundwater development plan is assumed to be completed, with (18) producing wells (i.e. a total production rate of (360 ℓ/sec.)) .The worse condition is considered in which, all the wells are supposed to be operating. The output results indicate that the maximum drawdown for a period of one year is expected to reach:
Case A: 35.8 m
Case B: 35.6 m
Case C: 30.6 m

Conclusion

The area is simulated by a mathematical model that can be used for prediction of aquifer response for various plans of exploitation.

The efficiency of the model results depends on the accuracy of the input data. Accordingly, the model may be largely improved when more and accurate data become available.

Recommendations

The degree of accuracy of the output results of any mathematical model, regardless of its sophistication and efficiency, depends on the accuracy and density of the input data. The preceding work is based on scares, shallow and probably inaccurate data which are collected from observations taken at different times and in many cases very old. The most important data related to transmissivity and storage coefficient are missing or very doubtful. Thus, the accuracy of the previous analyses should be considered with the above comments in mind. However, in all the cases, it is better to have an idea and expectations for future planning than starting from null. Accordingly, the following recommendations could have not been suggested without the preceding work.

1- Installation of a meteorological station to evaluate some of the hydrological parameters, preferably near its center.
2- Determination of the amount of infiltration within and outside the area to both the confined and unconfined aquifers.
3- Drilling of few deep wells to delineate the areal and vertical extensions of the unconfined and confined aquifers and the elevation of the piezometric surface.
4- Long-term pumping tests are very necessary for some of the old and new drilled wells, and observation wells are required for the tested wells.
5- A periodical water-level observation plan should be made in order to observe the regional fluctuations of water levels. This will assist in the determination of the seasonal variation of water levels.
6- It may be worthwhile attempting an optimization and economic evaluation to investigate an alternative plans for bringing fresh water from Tigris river (or other nearer source) for the required purpose.

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