Toxic Hazard Evaluation and Cleaning up of Groundwater Regime at the East of Euphrates River

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Abstract

A 3D groundwater model is developed, for the protection and remediation of any environmental contamination problem that may be occurred in the east of Euphrates River. The groundwater flow pattern is found from the northern-west toward sothern-east; therefore it is found there are no threats of any groundwater contamination coming from the East on the most densified populated area that located between the Euphrates and Al Hillah Rivers.

Experimental test results of the chemical analysis for groundwater dissoluble minerals in the area which is located between Euphrates and Al Hillah Rivers show that their values are fallen within the allowable limits of the World Health Organization (WHO) except that for total dissolved salt (TDS) and acidity and reversely they are exceeded for groundwater in the areas to the east of Al Hillah River.

In this mathematical modeling process, for any environmental pollution problem may be occurred between Euphrates and Al Hillah Rivers, it is found that an extraction a discharge of 3L/S of groundwater storage from the center of the polluted area is pumped by a temporary pipeline to be transferred across Al Hillah River and to get rid of by either disposing it directly in the Third River or injecting it in the groundwater to the east of Al Hillah River by a temporary injecting well. These are found the possible hydrogeologic alternative solutions to such environment problem for the protection of the most populated area within the region and consequently, there are no threads for drinking water.

Keywords: Contamination, Remediation, Pumping Well, Discharging Well

1.Introduction

Groundwater pollution by chemicals compositions occurs when hazardous substances come into contact and dissolve in the groundwater that may sink into soil body and rocks pore. Anyway changes in the ionic composition of water can exclude some species while promoting population growth of others For example, (Derry *et al.*, 2033) found that the rotifer *Brachionus plicatilis* and the harpactacoid copepod *Cletocamptus* sp. prevailed in lakes with Cl dominated water. In contrast, the calanoid copepods *Leptodiaptoums sicillis* and *Diaptomus nevadensis* were dominant in the SO_4^{-2}/CO_3^{-2}.

(Najah, 2011) develops 3d model that can mathematically simulate one, two, three dimensional non-steady advection-dispersion contaminant transport in a heterogeneous subsurface media. Time varying, point, line and/or area sources of permanent pollution but not a pulsing is considered. The work is based on a finite difference approach of a partial differential equation of advection dispersion phenomena. A modified alternating direction digital implicit method is used to solve the set of resulting finite difference equations.

(Aenab, 2012) evaluates water quality of Tigris River within Baghdad. He found that the concentrations of TH, TDS, PO4 and SO4 lie outside the allowable limits of WHO standards by using WQI analysis and C++ program.

(Vikas et al., 2012) study the hydrogeology of Karnal district which falls in the north-east part of the Haryana State. About 70% of the net irrigated area is covered through ground water, with rice- wheat being the major crop rotation. They found that the average water table depth in the district is about 20 m. A chemical analysis is performed for 67 locations during pre and post-monsoon seasons of the year 2011. Groundwater with sodium-calcium bicarbonate and magnesium bicarbonate is predominant during pre and post-monsoon seasons of the year 2011 respectively. They also studied the effect of different standard groundwater used for irrigation criteria to understand the chemical changes due to rain extraction recharge.

(Philip et al.,2013) presents the theory and practice of groundwater contamination, mitigation, and remediation of Ground Water Contamination and increased concern about source zone areas with non-aqueous phase liquids (NAPLs), residual oils, vapors in the unsaturated zone, gasoline spills which float on the water table, and chlorinated solvent spills which sink to the bottom of aquifers.

(Sal Assaf, 1976) study an environmental pollution problem that occurred in the north Shropshire catchment's area to control scheme adjacent to an industrial area through simulation by a mathematical model. Two arrangements of well distribution on the periphery of an industrial area were used in order to control the pollution beyond the area.

2.Research Significance

Recently, it is observed that Aquatic survivals (plants and animals) in some Iraqi rivers has been exposed to substantial variation in growth and growth deterioration rates and may be some time to communities extinction. Rivers and groundwater pollution (simultaneous reduction & increasing in many minerals inions and cations) in Iraq produces clearly many environmental phenomena's on human health and on aquatic survivals. Standing on causes and remediation become essential goals in the current study.

3.Objectives

The objectives of this study is aimed to evaluate :-

1- Evaluation of groundwater movement and its future environmental impact on human in Babylon City.
2- Evaluation of toxic hazard concentrations in subsurface water within the east of Euphrates river.
3- Adoption of the optimum scenarios to cleanup and remedy any possible pollution accident may be occurred to contaminate the groundwater in the most populated area that located between Euphrates and Al Hillah River.
4-

4.Current Work Strategy

The work in this research is divided in two methodologies; they are:-

1- Toxic hazard data collections, analyzing and evaluation.
2- Development of mathematical model to simulate and representing groundwater flow pattern at the east of Euphrates River.
3- Using of the current model for cleaning-up and remedy any possible pollution accident in the groundwater within the model area
.

5.Development of a Numerical Model

The development of a mathematical model requires several preparations before any simulating and analyzing processes. The program is written by using a finite difference approach for aquifer simulation. It is issued to be flexible and modifiable for input and output data. The model in general is designed to solve the non-expectable problems that may be encountered in the model domain of the analyzing area.

5.1 Selection of Study Area

Recently, popularizing is dispersed in middle of Iraq about the observed rates increasing in toxic hazards in many contaminants in surface and groundwater regime. It is suggested to study, the area located east of the Euphrates River shown in Fig.(1)

5.2 Geography

The study area is located between longitudes of 44º 14′ and 45º 12′ and latitudes of 32º 14′ and 32º 46′ . Briefly the area is characterized with flat nature and covers about 4968km^2.It is bounded by Euphrates River from the *West* and the Third River from the *South*. The highest ground level is about 30m a.m.s.l. is located in *Al Musiab City* and 19m in *Al Shumaly City* Southern-East of the area. It is found that surface flow in the three rivers is from the North toward the South.

6. Modeling Technology

6.1 Discretization of Model Domain

Once, the modeling process starts with the discretization of the model domain into finite difference meshes over the area map under consideration. A suitable number of meshes should be chosen depending on the area extent and degree of accuracy. Uniform mesh spacing of 2km in both XY direction is used in this research as shown in Fig.(2).

6.2 Base Map implementation

The most important step in the modeling process is the performance of the base map which is defined as *a number of meshes bound the model domain or tracing the boundary of the modeled area, and it is assigned in the modeling process by their individual x & y coordinates. The Meshes trace the boundary of Fig.(2) represent the major part required to draw the base map. A technical method usually is used for the implementation of Fig.(2)*

7. Natural Groundwater Flow Regime

Fig.(3) presents the general groundwater flow system within the entire area. It shows that the flow in between *Euphrates* and *Al Hillah Rivers* from the North to the South. Whereas, to the East of *Al Hillah River* the nature of the flow pattern is changed toward the East to feed the *Third River*

8. Contaminants Transport Characterization

Once, it is found that groundwater pollutants at the area east of Euphrates River transmit from the North to the South as shown in Fig.(3), therefore any excessive pollution concentration in the north should be avoided because the areas in the middle and south are certainly affected, but east of Al Hillah River, the natural flow of groundwater is toward the East. Accordingly, any pollution in Al Hillah River will transfer toward the east causing an environmental contamination impact for the entire area between Al Hillah and the Third Rivers.

9. Natural Groundwater Dissoluble Elements

The study of any environmental impact of any pollution within groundwater media requires a chemical analysis of the dissoluble elements. Accordingly, a necessary analysis is carried out to indicate the real concentrations in mg/liter during the period between the years (2009-2012) of the available chemical dissoluble elements existing in the groundwater of the study area. Alkalinity, sulphate, and dissolved oxygen are indicated in Figs (4-6) respectively to show the natural distribution of such elements and other elements are abbreviated and presented in Table (1).

For good understanding on how the dissoluble elements transport in groundwater and their effects on human health, it is better to evaluate each as follows:-

1- Alkaline (ALK):- Fig. (4) Indicates that a minimum alkalinity of 150 is found along the Euphrates River whereas the maximum is encountered south of the Third River.
2- Sulphate (SO_4):- Fig.(5) shows that less concentration of SO_4 is located near Euphrates which is less than 500 and more than 2000 mg/Liter south the Third River.
3- Oxygen (DO_2):- The maximum dissolve oxygen of 9.5 is found North of Al Hillah and Euphrates Rivers and the minimum is located south of the Third River as shown in Fig.(6).
4- Calcium (Ca):- Table(1) presents that the Calcium concentration between 100 near Euphrates and 290 mg/Liter in the south of the Third River.
5- Chloride (CL):- Table(1) signifies that the value of chloride concentration is found to be 150 mg/Liter near the Euphrates River and 1000 mg/Liter at the South of the Third River.
6- Potassium (K):- Table(1) reveals that Potassium value is 5 near Euphrates and 11mg/Liter at the Third River.
7- Magnesium (mg):- Fig.(10) demonstrates that the Magnesium value is found between 50 and 200 mg/Liter at Euphrates and the Third River respectively.
8- Sodium (Na):- Table(1) illustrates that Sodium is found less than 200 around Euphrates and more than 500mg/Liter at the Third River.
9- Nitrate (No_3):- The Nitrate concentration is encountered to be less than 6 at the South of Euphrates whereas it is 8.8mg/Liter along the Third River as included in Table(1)
10- Acidity or Power of Hydrogen (PH):- Table(1) shows that the value of PH is within 7.8 and 8.1 which indicates that the groundwater media is alkaline in the study area.
11- Total Dissolved Salts (TDS):- The Laboratorial tests shows that TDS is found in the range of less than 1000 in region Al Hillah-Euphrates Rivers and up to 5500mg/Liter in the south corner of at the Third River, this is illustrated Table(1)
12- Phosphate (PO_4):- It is found that the phosphate is less than 0.25 mg/Liter at Euphrates and more than 1mg/Liter at the Third River as shown in Table(1)
13- Electrical Conductivity (EC):- The range of the electrical conductivity is between1000-7500 in the Euphrates and Third Rivers respectively as shown in Table(1)

10. World Standards for Drinking Water

The laboratorial test results show that many chemical elements deviate from the World Health Organization standard whereas many don't. Anyway, it is observed in Table (1) that the acidity and total dissolve solids are exceeded the allowable limits overall the study area, Whereas Chloride, Sulphate, Potassium, and Sodium exceed the allowable limits in the Third River.

11. Environmental Consideration

The trend of natural groundwater flow as shown in Fig.(3) is from the north toward south in the area between Euphrates and Al Hillah Rivers and from the west toward the east elsewhere. Fortunately, the high population intensity is found in the areas in between and around Euphrates and Al Hillah Rivers, therefore any expected groundwater contamination to east of Al Hillah river don`t cause any harmful effect to the population since groundwater flow in opposite direction.

Comment

The model study informs that any pollution within the area has two sources:-

1- Outer source which may be caused by the pollution of the upstream of Euphrates and Al Hillah Rivers. The remediation of this situation is curried out at the upstream of the two rivers.
2- Inner temporary sources which may be treated by somehow suitable methodology.

12. Conceptualization of Modeling Process

It is a good application to develop a basic method to control any accidental pollution disaster which may be either point or area source. To predict effect of such pollution on groundwater system and how to defeat these accidents, a mathematical model based on a finite difference approach is developed. To do this, the following preparations may should be achieved:-

12.1Aquifer Hydraulic Conductivity

A pumping test analysis is performed at wells site to estimate the hydraulic conductivity of unconfined aquifer. A pumping test results of the hydraulic conductivities of the pumping test analysis for 15 wells scattered over the modeled are interpolated overall the study area and represented graphically by the contour map of Fig. (7) which indicates that a maximum hydraulic conductivity of (17m/day) is occurred in between Euphrates and Al Hillah Rivers.

12.2 Specific Yield

It is concluded that the ideal specific yield is 0.2; such value was recommended by (Najah, 2011) to be used for aquifers of similar formations

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12.2 Hydraulic Boundaries

Euphrates, Al Hilla, and the Third Rivers are the most important hydraulic boundaries within the modeled area with maximum water level of (29m a.m.s.l)occurred at the head of Euphrates River and (16.5m a.m.s.l.) occurred downstream of the Third River.

12.3 Initial Water Table level

It is suggested in the modeling process that (30 M.a.s.l) is an initial water table level to be used during the calibration process.

12.4 Calibration of the Model

The main and important process is the calibration of the model. This is required to match the natural groundwater levels overall the modeled area with the computed by the mathematical model after it has been run for a long period until a steady state condition is obtained, in this study a steady state condition is obtained after (1244.6 years with 125 iterations) . The permissible error is about ±10% as outlined by (Al-Assaf, 1976). The aquifer properties are adjusted through the best fit between the natural and computed water levels during the model run as presented in Fig.(8).

13. Environmental Application

In this research, it is assumed that a certain temporary pollution (chemical, biological, or nucleic) accident is occurred within the populated area which located between the Euphrates and Al Hillah Rivers. Accordingly, the probable environment possible solutions may be summarized in the following scenarios:-

13.1 Scenario (1) If a point or an area pollution source with limited size is occurred, it is suggested to setup a impermeable reactive barrier wall extended to the bedrock to capture the polluted organics and inorganics in the groundwater plume and continue a monitoring program to ensure cleaning up remedy throughout the plume area to meet the final media standards.

13.2 Scenario (2) In this scenario, after the polluted area is buffered, the pollutant may be transmitted far away.

13.3 Scenario (3) Since most chemical elements are exceeded in and around the Third River, A) it is suggested to extract a specified discharge from the center of the polluted area with an amount depending on size and dangerousness of the contaminant and then is pumped across Al Hillah River by a temporary pipelines to be disposed in the Third River or B) in an injecting well at the east of Al Hillah River to protect the populated area located between the Euphrates and Al Hillah River.

13.3.1 Implementation of Scenario (3)

The achievement of this scenario requires deciding the value of the optimum extraction discharge of the pumping well that located in the center of the polluted area. This should be done by running the model for a long period to reach a steady state condition. This process can be adjusted during the model operation subjected to the following constraints:-

1. The extraction water should be maximized until the area of the cone of depression covers the polluted area to guarantee the groundwater flow toward the center of the con of depression (center of polluted area).
2. The extraction water should be minimized to avoid groundwater exploitation (depletion) and reducing of extraction discharge.

Accordingly, an area of (4km^2) located to the east of Al Hillah River of mesh coordinates (6,20) is chosen to be the center of the pollution disaster and the pumping well location, then the model is run several times to adjust the optimum extracted water.

14. Results & Discussion

The resulting groundwater levels and drawdowns in the mesh (6,20) is shown in Fig.(9).

It is concluded that there are many acceptable steady pumping situation; for all cases of operation included in Fig.(9) which are obtained under the following conditions:-

1- $A\ steady\ state\ condition\ is\ obtained\ after\ 654166.32\ days$ (1972yrs).

2- No. of Iteration is 127. Table (2) shows a shortcut to the output data of the computer results.

Solution Key

in this situation the optimum solution Q(6,20) is found within the range (3 to 6 liters/second), because Q(5,14) = 3 L/S produces a cone of depression covers the polluted area of 4km^2, whereas Q(6,20)= 6 L/S causes a drawdown of 30% of the unconfined aquifer depth (The allowable limits) with a cone of depression area exceeding 4km^2. Accordingly, the optimum solution Q(6,20) = 3 L/S is chosen which is causing 2.35m drawdown and the resulting area of the cone of depression as shown in the groundwater category under a steady state conditions is presented in Fig.(10).

Comment: it is obviously as shown in Fig.(10), the cone of depression takes a fusiform shape (with dimensions of 4km west-east and 16km north-south); this because groundwater flow direction.

15. Polluted Groundwater transportation

According to scenario No.(3) and in order to get rid of the infected groundwater with the hazardous pollutants, it is suggested to either pump it by a pipeline across Al Hillah River to be disposed in the Third River as shown in Fig.(10) scenario (3A), or to be discharged by using injection well in the area to the east of Al Hillah River as shown in Fig.(11) Scenario (3B).

16. Conclusions

The following may be concluded:-

1- The groundwater flow pattern is from the Northern- West toward Sothern-East, therefore no threats of any contamination may be expected from the East on the populated area which is located between Euphrates and Al Hillah Rivers.
2- All groundwater chemical pollution minerals found in the populated area between Euphrates and Al Hillah River are within the allowable limits except that for Total Dissolved Salt (TDS) and Acidity.
3- For any type of pollution disaster between Euphrates and Al Hillah Rivers, an extraction discharge of 3L/S from the center of the polluted area is extracted and pumped by a pipeline across Al Hillah River is an optimum hydrogeologic solution to this environment problem to protect the most populated area within the region as shown in Fig.(10).

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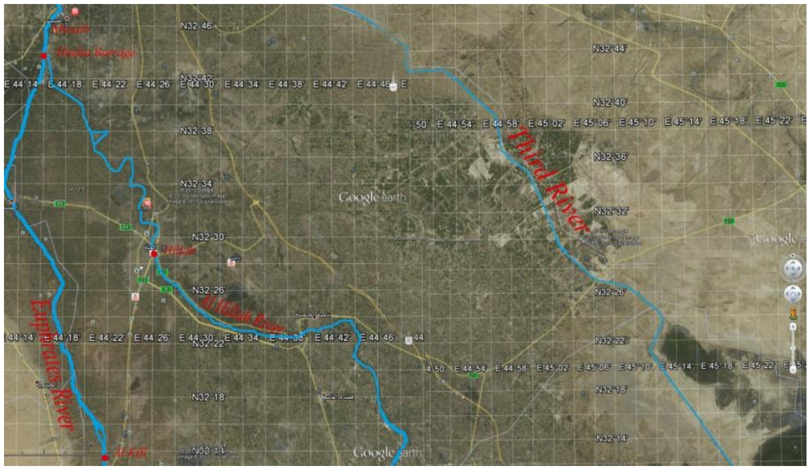

Fig.(1) Modeled Area Exposed to the Contaminants Toxic Hazards showed the Location of Hillah City, Google Earth

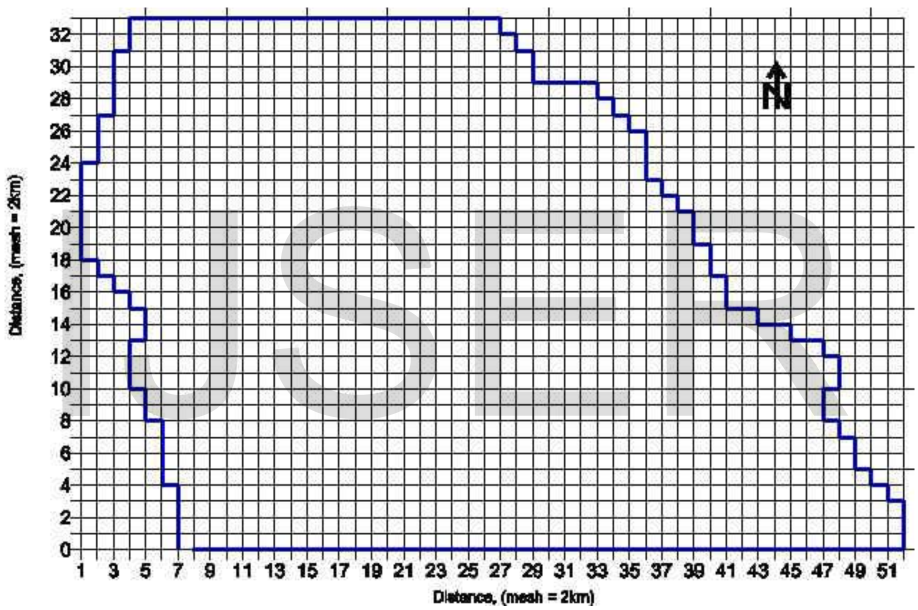

Fig.(2) Mesh Design Map showing the Boundaries of Model Domain

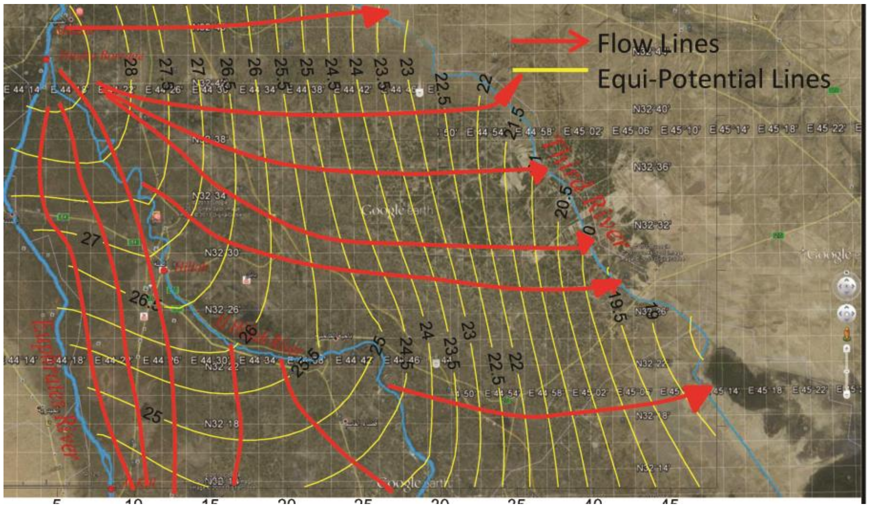

Fig.(3) Contour Map of Natural Groundwater Flow Regime

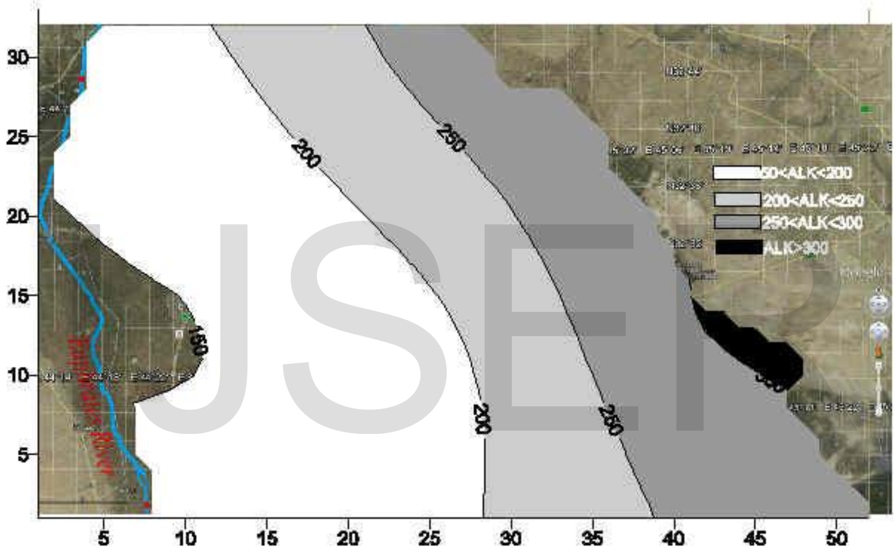

Fig.(4) GW Alkalinity (ALK)

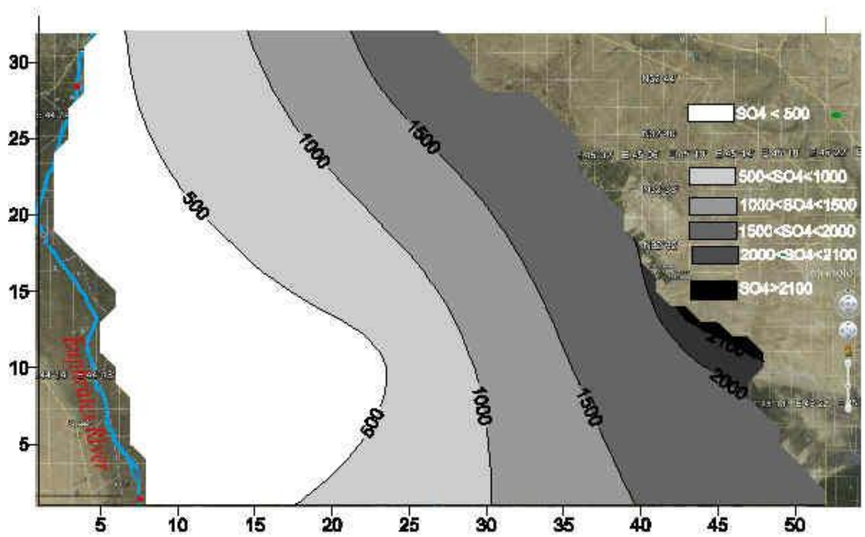

Fig.(5) GW Sulphate (SO_4)

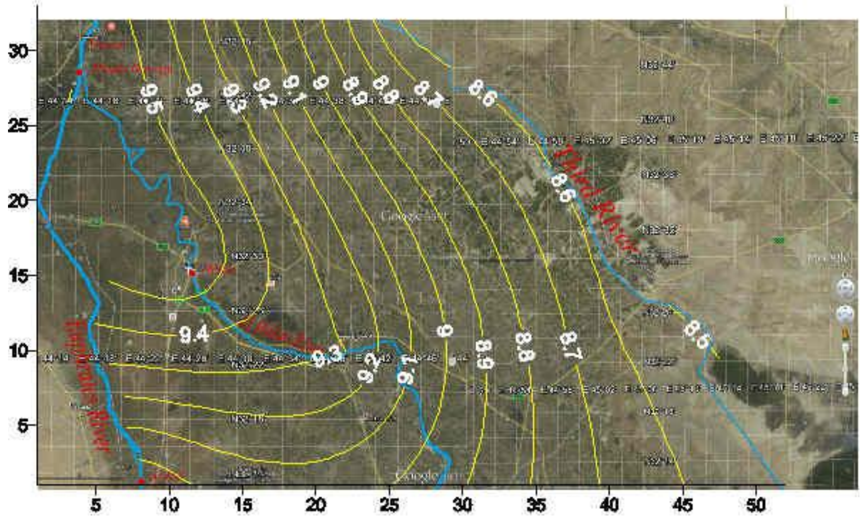

Fig.(6) GW Dissolve Oxygen (DO_2)

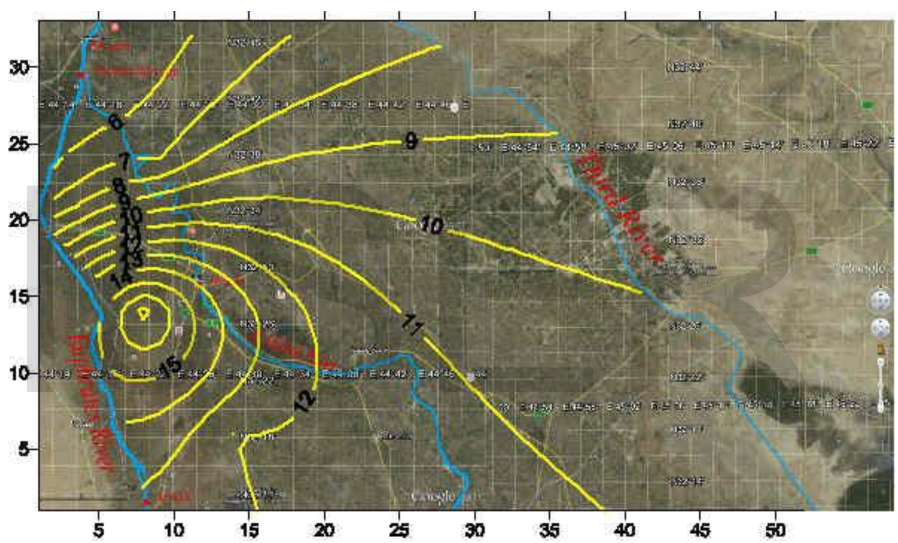

Fig.(7) Hydraulic conductivity of the Unconfined Aquifer

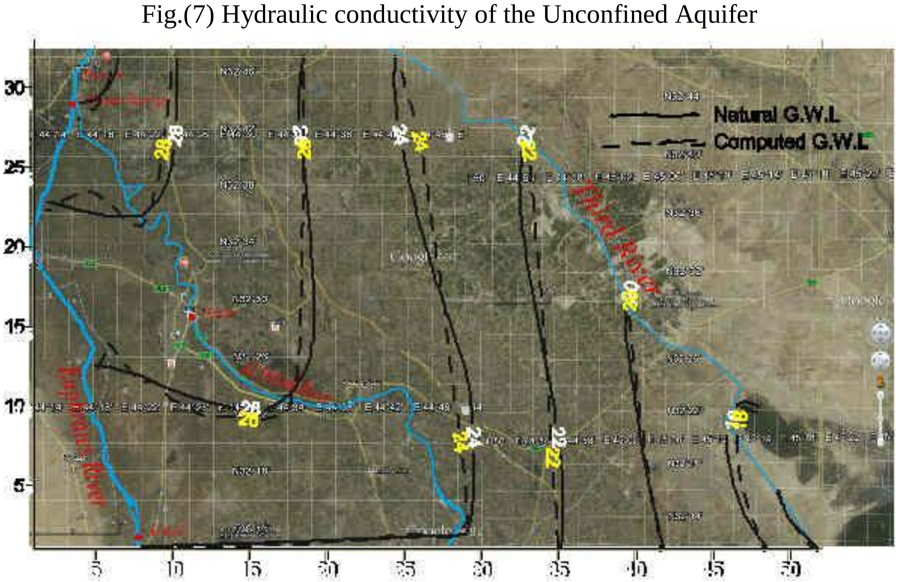

Fig.(8) Comparison between the natural and Computed Groundwater Levels, in (M.a.s.l)

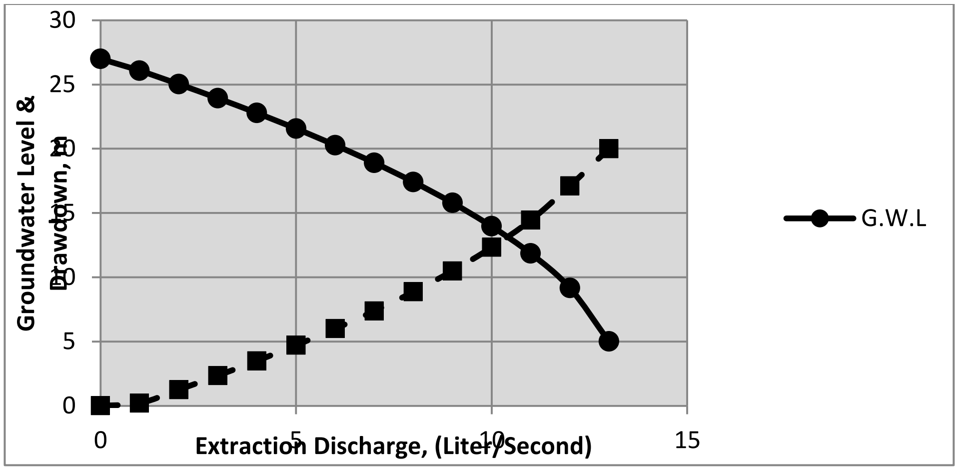

Fig.(9) The G.W.L & Drawdown Versus the Extraction Discharge in the Mesh (6,20)

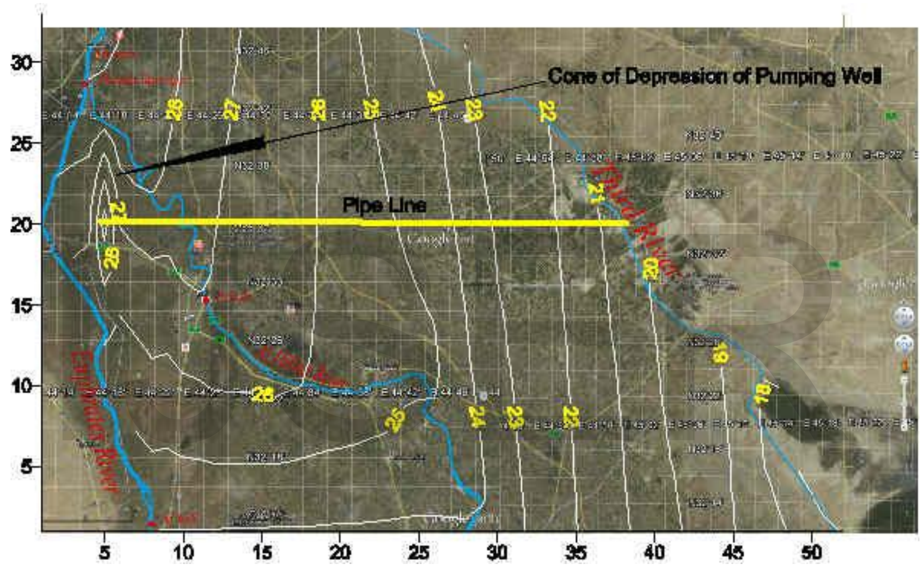

Fig.(10) Groundwater Category of Scenario (3A)

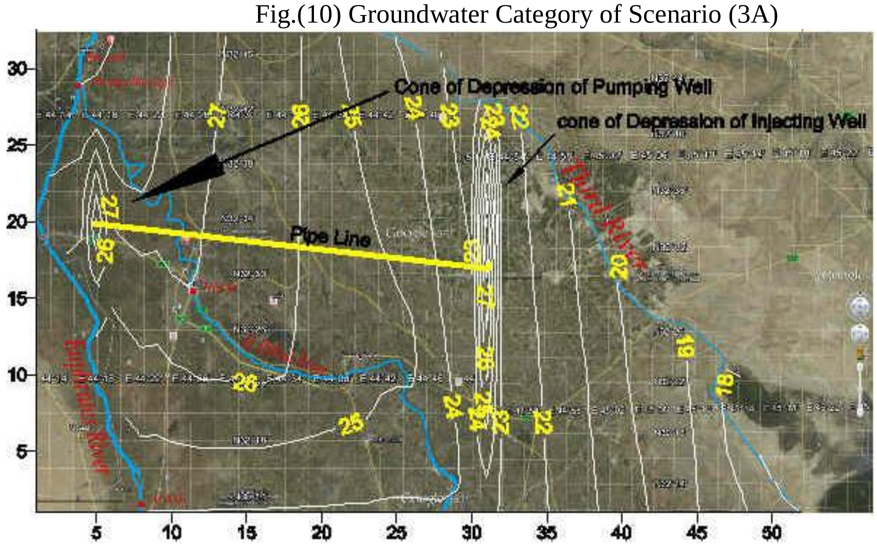

Fig.(11) Groundwater Category of Scenario (3B)

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Table (1) WHO Standards for Drinking Water and Extreme Values of Groundwater Rejime, mg/liter

No.	Element	Symbol	WHO, 2012	Extreme Values around the Existing Rivers		
				Euphrates	Al Hillah	Third
1	Alkaline	ALK	-	160	152	310
2	Sulphate	SO_4	250-1000	359	375	2147
3	Calcium	Ca	100-300	161	100	296
4	Chloride	CL	< 200	175	170	1005
5	Dissolve Oxygen	DO_4	-	8.9 Minimum	9.3 Minimum	8.5 Minimum
6	Potassium	K	-	5.7	5.5	11.3
7	Magnesium	mg	< 500	60	55	243
8	Sodium	Na	< 200	136	126	603
9	Nitrate	NO_3	< 15	5.5	7.7	9
10	Acidity	PH	7	8.04	8.1	7.95
11	Total Dissolve Solids	TDS	< 600	890	800	5686
12	Phosphate	PO_4	< 0.4	0.26	0.26	1.25
13	Electrical Conductivity	EC	-	1360	1262	7960

Table (2) Resulting Drawdown & Elapsed Time

Elapsed Time, days	No. of Iterations	Initial Groundwater Level, m.a.s.l	Final Groundwater Level, m.a.s.l
.000011500	1	27.040000	27.040000
.000025300	2	27.040000	27.040000
⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮
0.05	37	27.040000	27.03998
0.06	38	27.040000	27.03998
⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮
1.09	54	27.040000	27.03965
1.30	55	27.040000	27.03958
⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮
4762.05	100	27.040000	26.36950
5714.46	101	27.040000	26.29821
⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮
24571.15	109	27.040000	25.44688
29485.38	110	27.040000	25.29544
⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮
545138.58	126	27.040000	24.57001
654166.32	127	27.040000	24.56785
784999.62	128	27.040000	24.56710