Evaluation of Hydraulic Properties of the Euphrates Aquifer in Al-Qaim Area, West of Iraq

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Abstract

Three wells in Al-Qaim city (Western Desert of Iraq), which is located between latitude of (34° 16 52.5-34° 21 56) north and longitude of (41° 1 15 -41° 8 16.5) east, were selected to determine the hydraulic characteristics of the upper aquifer in the area by conducting pumping test operation on them. The Euphrates aquifer represents the shallow aquifer in the area where the flow direction is toward the north and northeast. The amount of hydraulic gradient was (0.036) were the groundwater flux (V) and pore velocity (U) values reached (0.35136) (8.784) m²/day respectively. Transmissivity(T), permeability(K), specific yield(Sy) and specific capacity(SC) are ranged between (656-777.9) m²/day, (7.40-11.45) m/day, (0.1-0.01) and (588.5-869.8) m²/day respectively. The obtained results show that there are no remarkable variations in the hydraulic values, which indicates the homogeneity of the aquifer in the studied area.

Keywords: Euphrates aquifer, unconfined aquifer, hydraulic properties, Al-Qaim.

1. Introduction

The study area is located in the western part of Iraq, in Al-Anbar Governorate; the area is located on the right side of the Euphrates River, where the river enters the Iraqi territory. The studied area located between latitude (34° 16 52.5-34° 21 56) north and longitude (41° 1 15 -41° 8 16.5) east (Fig. 1), covering a total area of about 103.9 km². Elevations of the studied area are ranged between (184-225) m.a.s.l. Tectonically and structurally, the area is located within Rutba-Jezira subzone which belongs to the Stable Shelf zone, and characterized by the absence of surface folds and low dipping beds of less than 1° toward northeast with a gradient of 10-20 m per km from Iraqi-Jordan-Saudi Arabia borders to the Euphrates river [1]. Geologically, two exposed formations: Fatha Formation (Middle Miocene) and Euphrates Formation (lower Miocene) cover the area in addition to the Quaternary sediments (Fig.2). The aim of this study is to determine the hydrogeological characteristics of the Euphrates aquifer in Al-Qaim area through pumping and recovery tests in three sites included wells (W-1, W-2 and W-19) and determine the velocity and direction of groundwater flow.
Hydrogeological Setting

Euphrates aquifer represents the upper groundwater aquifer in the study area [2][3]. Surface water infiltrates through fractures and caverns as a recharge source and flow toward
the Euphrates river as a discharge zone [4]. The Euphrates aquifer represents the uppermost principal unconfined aquifer [5], it is widely revealed on the right side of the Euphrates river (Fig. 3). Euphrates Formation is composed of limestone and dolostone contain impermeable marls and clay. Near to the surface, limestones beds are fractured, weathered and karstified, and have enhanced permeability [5]. Fig. 4 shows the hydrogeological section of the Euphrates aquifer.

Fig. 3: Explored Extension of Euphrates aquifer in the western desert [5]

Fig.4. Hydrogeological section of the Euphrates aquifer
2. Materials and methods

Groundwater levels were measured by Sounder instruments (Type 010, France) for 20 selected wells (Fig. 5) to determine the depth of groundwater in these wells (Table 1), in order to specify the groundwater movement, flux and flow velocity.

Pumping test was carried on three wells (W-1, W-2 and W-19) (Fig. 5) to determine the hydraulic parameters of the Euphrates aquifer. A Computer software (Schlumberger Aquifer Test 2011) was used to analyze the results of pumping and recovery tests to obtain these parameters. Neuman Solution is used for this purpose [6], as the following equation explain:

\[ S = \frac{Q}{4\pi T} W(u_b, \ u_a, \beta) \]  

Where:

- \( W(u_b, \ u_a, \beta) \) is the well function of water table
- \( S \) storativity
- \( S_y \) specific yield
- \( \beta \) \( (r^2 K_y)/(b^2 K_h) \)
- \( r \) radial distance from pumping well
- \( b \) initial saturated thickness of aquifer.
- \( S_y \) specific yield
- \( S \) \( (4Tu_b)/r^2 \) for early drawdown data
- \( S_y \) \( (4Tu_b t)/r^2 \) for later drawdown data
- \( K_v \) vertical hydraulic conductivity
- \( K_h \) horizontal hydraulic conductivity

![Fig.5 Location map of the selected wells](image)
Table 1- Geographic location and parameters of the selected wells

| Well no. | Latitude       | Longitude      | Total depth (m) | Elevation (m a. s.l) | Static water level (m) | The head (m.a.s.l) |
|----------|----------------|----------------|-----------------|----------------------|------------------------|-------------------|
| W-1      | 34°18'17.226" | 41°4'18.459"  | 100             | 225                  | 50.68                  | 174.32            |
| W-2      | 34°20'25.289" | 41°5'17.993"  | 108             | 199                  | 33.5                   | 165.5             |
| W-3      | 34°20'20.577" | 41°6'8.104"   | 80              | 201                  | 37.5                   | 163.5             |
| W-4      | 34°19'16.76"  | 41°6'8.961"   | 110             | 205                  | 33                     | 172               |
| W-5      | 34°18'31.788" | 41°05'8.142"  | 110             | 203                  | 33                     | 170               |
| W-6      | 34°18'38.213" | 41°5'47.546"  | 90              | 203                  | 33                     | 166               |
| W-7      | 34°18'48.92"  | 41°4'54.436"  | 90              | 203                  | 30                     | 173               |
| W-8      | 34°19'19.33"  | 41°05'36.838" | 95              | 196                  | 28.7                   | 167.3             |
| W-9      | 34°20'38.566" | 41°3'56.615"  | 101             | 187                  | 29.5                   | 157.5             |
| W-10     | 34°20'12.868" | 41°3'48.049"  | 88              | 197                  | 30                     | 167               |
| W-11     | 34°19'51.453" | 41°4'36.019"  | 85              | 184                  | 25.7                   | 158.3             |
| W-12     | 34°19'13.334" | 41°4'39.874"  | 60              | 201                  | 29                     | 172               |
| W-13     | 34°19'25.754" | 41°4'9.036"   | 51              | 206                  | 31                     | 175               |
| W-14     | 34°19'34.749" | 41°5'8.57"    | 88              | 192                  | 27.6                   | 164.4             |
| W-15     | 34°20'0.875"  | 41°2'31.811"  | 80              | 190                  | 22.4                   | 167.6             |
| W-16     | 34°20'32.141" | 41°2'35.238"  | 50              | 193                  | 16.5                   | 176.5             |
| W-17     | 34°19'48.883" | 41°3'4.362"   | 50              | 204                  | 25.4                   | 178.6             |
| W-18     | 34°18'35.215" | 41°2'46.802"  | 60              | 208                  | 30                     | 178               |
| W-19     | 34°18'51.49"  | 41°3'39.055"  | 120             | 207                  | 30                     | 177               |
| W-20     | 34°18'52.347" | 41°3'16.355"  | 125             | 209                  | 30.8                   | 178.2             |

3. Results and Discussions

- **Groundwater levels and flow direction and velocity**

  The groundwater level is ranged between (178.6-157.5) m. a.s.l, (Table.1), whereas, the regional groundwater movement is toward north and northeast (Fig.6).
The calculation of hydraulic gradient amount was done according to the following equation [7]:

\[ I = \frac{dh}{dl} \]  

(2)

Where:

\( I \): hydraulic gradient (without units)
\( dh \): Head loss between two water points (m).
\( dl \): Horizontal distance between the same two water points (m).

The groundwater moves under the hydraulic gradient effectiveness in the studied area is (0.036). The parameters of this equation are used to calculate both of groundwater pore velocity (\( U \)) and flux (\( V \)) [8] as shown in the following equations:

Groundwater flux \( V = KI \)  

(3)

Where:

\( K \): Permeability (m/day). \( I \): Hydraulic gradient (without units).

Groundwater pore velocity \( U = \frac{V}{S} \)  

(4)

Where:

\( V \): groundwater flux (m/day). \( S \): Specific yield (without units).

The amount of the groundwater flux (\( V \)) and pore velocity (\( U \)) according to the equations (3 and 4) are equal (0.35136 m/day) and (8.784 m/day) respectively.
Hydraulic properties and pumping test

The obtained results of hydraulic properties includes transmissivity ($T$), hydraulic conductivity ($K$) and specific yield ($S_y$) were obtained from the analysis of the drawdown-recovery relation curve for the three pumped wells, W1 (Fig.7), W2 (Fig. 8) and W9 (Fig. 9), the results are as follows: transmissivity values of Euphrates aquifer were ranged from 656 to 777.9 m$^3$/day, the hydraulic conductivity was ranged from 7.4 to 11.45 m/day, and the specific yield values are ranged from 0.01 to 0.1 and this value range indicates that the aquifer is unconfined aquifer.

There are no significant variations in the values of hydraulic parameters within the Euphrates aquifer (Table 2).

Table 2- Results of the hydraulic properties from pumping test analysis.

| Well No. | Ob. W-1      | Ob. W-2      | Ob.W-19     |
|----------|--------------|--------------|-------------|
| Latitude | 34°18'17.226"| 34°20'25.289"| 34°18'51.49"|
| Longitude| 41°4'18.459" | 41°5'17.993" | 41°3'39.055"|
| Well depth (m) | 120          | 108          | 100         |
| S.W.L (m) | 50.68        | 33.5         | 30          |
| b (m)     | 49.32        | 74.5         | 90          |
| Q (m$^3$/day) | 2505        | 2160         | 2703        |
| T (m$^3$/day) | 656         | 777.9        | 666.7       |
| K (m/day) | 11.45        | 10.44        | 7.40        |
| S        | 0.09795      | 0.00652      | 0.002076    |
| $S_y$    | 0.1          | 0.01         | 0.01        |
| SC (m$^3$/day) | 869.8      | 588.5        | 705.6       |

Fig. 7: Drawdown-recovery curve of Euphrates aquifer for W-1 (Neuman, 1974 solution).
Fig. 8: Drawdown-recovery curve of Euphrates aquifer for W-2 (Neuman, 1974 solution).

Fig. 9: Drawdown-recovery curve of Euphrates aquifer for W-19 (Neuman, 1974 solution).

4. Conclusions

The main conclusions of the present study can be summarized as follows:

1- The direction of the groundwater flow from the recharge zone in the southern part of the studied area to the zone of discharge along the right side of the Euphrates river, is toward the north and northeast.

2- Groundwater flux and pore velocity values are reached (0.3513 and 8.784) m/day respectively.

3- By using Neuman method, pumping and recovery test results were analyzed for three selected wells in the studied area. There is no remarkable difference in the hydraulic parameters calculated for the three wells, therefore, it could be said that the aquifer is homogeneous.
4- The specific yield values proved that the aquifer is unconfined.

5. References

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