Hydraulic Characteristics of Dammam Aquifer in Sayed Al-Shuhadaa Agricultural city, Karbala- Iraq

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ABSTRACT

This study's objective is to investigate the hydraulic properties of the Dammam aquifer utilizing three acceptable pumping wells for experimental pumping. The location under study is an agricultural project known as Sayed Al-Shuhadaa agricultural city, which is located in the Al-Ukhaidir section of the Ain Al-Tamar district, to the southwest of Razzaza Lake and west of the Holy Karbala province. Theis and Hantush methods had been applicated to analyze pumping test data. The ranges for transmissivity, hydraulic conductivity and storage coefficient are (111.3 - 1705.1) m2/day, (22.23 - 32.11) m/day, and (0.00075-0.0011) respectively. The agricultural city of Sayed Al-Shuhadaa was formerly a desolate desert, but it was transformed into an agriculturally productive region after (5000) donams of wheat were cultivated this season. The most important characteristic of this region is the use of pivotal irrigation systems of global origin, and the water source used in the farm is from the ground sea (groundwaterwater), as this source provides greater assurance of the sustainability of the farm's production, and aims to determine the hydraulic characteristics of the aquifer in the event that suitable wells are available for pumping tests. Calculating water excess and shortfall by performing the water balance. Assessing the appropriateness of groundwater for agricultural and irrigation purposes by analyzing its hydrochemical properties and quality. An attempt to implement a plan for agricultural groundwater management.

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1. Introduction

Groundwater resources play an important role in sustaining water needs . Groundwater is widely adopted for crop irrigation, food production, industry, and domestic use in urban and rural communities [1]. Groundwater also provides a valuable base flow, supplying water to rivers, lakes, and wetlands, thus serving as an essential resource for maintaining various ecosystems that depend on it [2] [3] [4] [5] . where as Groundwater is one of the more reliable and extensively used natural resources, it constitute about twenty percent of the world's fresh water supply, which is of the entire world's water. This makes it an important resource which can act as a natural storage that can be utilized during water scarcity periods [6]. At present where the water scarcity became a more serious issue, especially in arid and semi-arid climates areas Iraq like, In comparison to other dry and semi-arid countries in the Middle East, Iraq may be regarded fortunate in terms of water resources; they eventually pass those countries' territory before joining and emptying into the Arab Gulf. Additionally, there are certain untapped groundwater resources in Iraq that have potential. However, due to Iraq's increased water demand, an unresolved dispute between riparian nations over the division of the two rivers' supplies, and the continued use of traditional resource management techniques, Iraq will run out of reliable water resources in the not too distant in future.

2. Location of the study area

The study area locates southwest of the governorate center in Karbala (Figure 1), between latitudes (32^o 17' 00" – 32^o 22' 00" N') and longitudes (43^o 29' 00" – 43^o 40' 00" E), with a general altitude ranging from 35 m to 158 m above sea level, and so it is regarded as having smooth and low topographic features (Figure 2).

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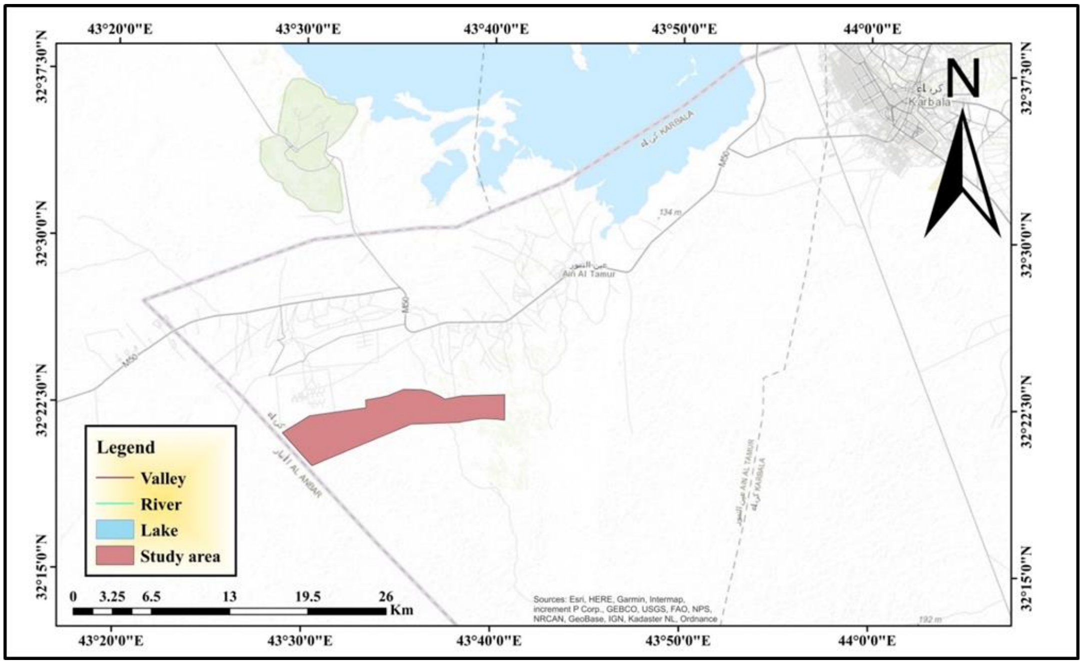

Figure 1: Location map of the Study area

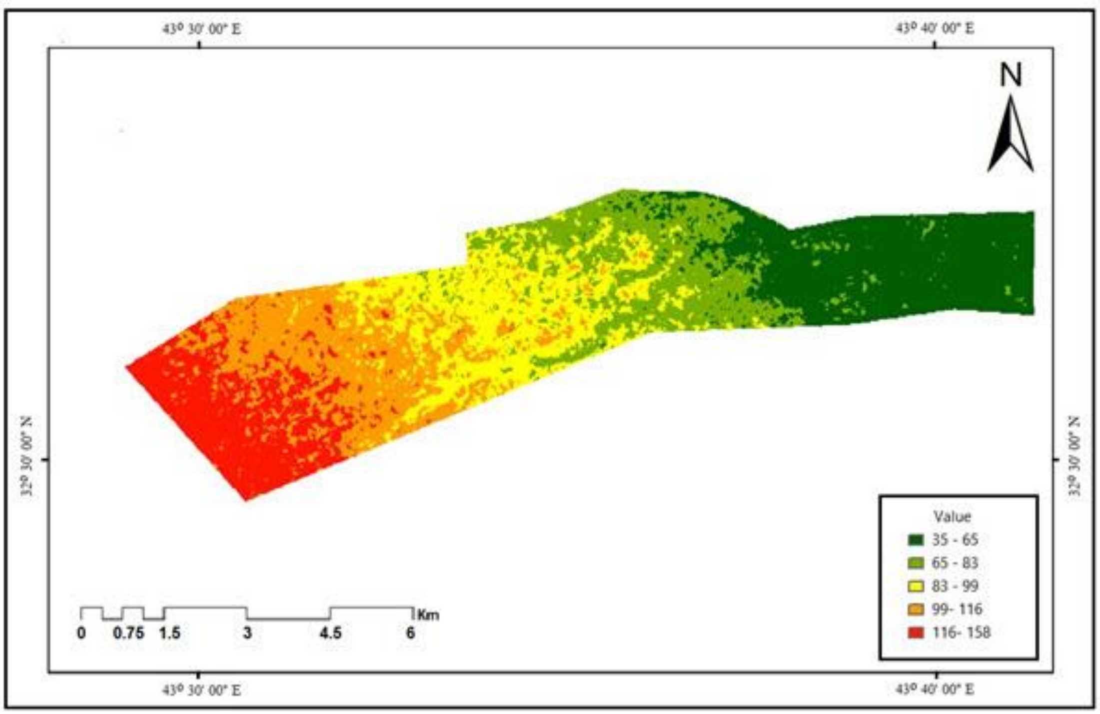

Figure 2: Topographic map of the study area

3. Geology of the study area:

Quaternary deposits, which consist of gravel, sand, and mud, represent the lithology of the study area. These deposits are utilized in producing washed sand, sifting sand, crushed gravel. The

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Quaternary deposits are underline by the Euphrates formation (Early Miocene) which is made up of chalky limestones, recrystallized limestones, and marl lenses, which in turn are underlain by the Dammam formation (Eocene) (Figure 3).

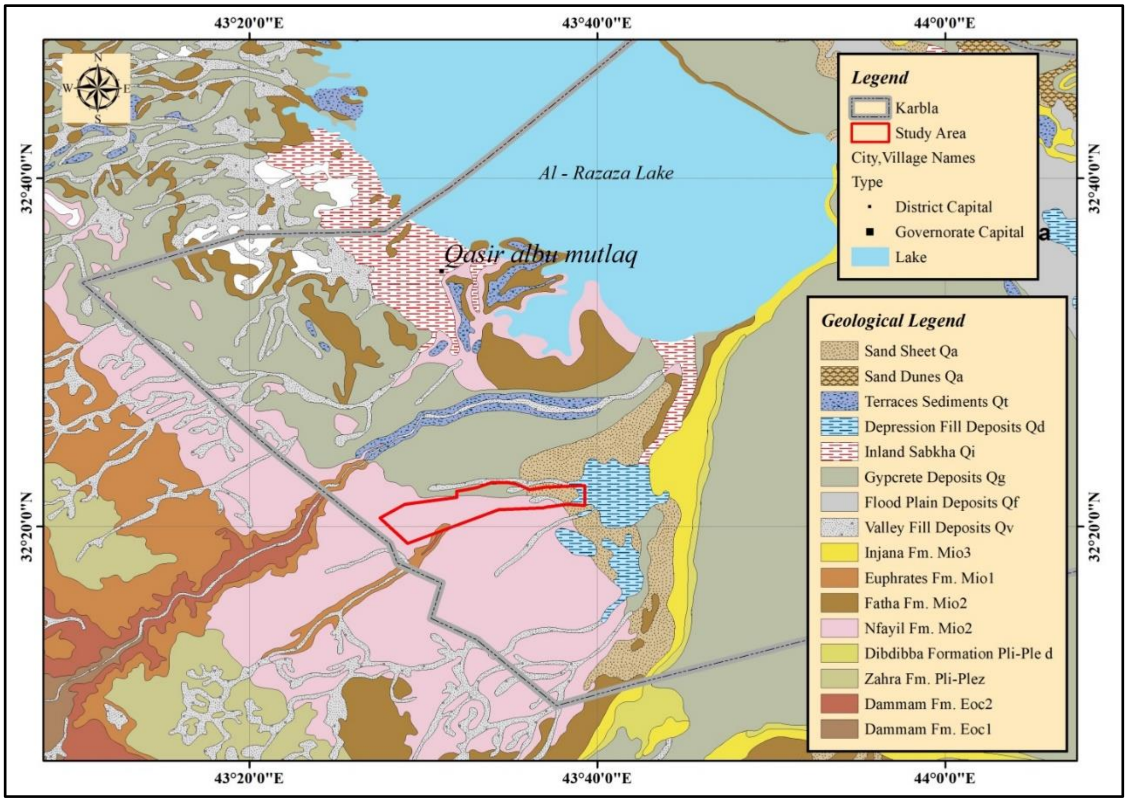

Figure 3: Geologic map of study area (Groundwater Authority, 2021).

The Formation of Dammam represents the main aquifer in the study area and is made up of Heterogeneous [7] in which is underlain by Umm Er Radhuma formation (Upper Paleocene) which consists of dolomite and dolomitic limestone with beds of gypsum [7].

4. Groundwater aquifer in the study area:

The Dammam Aquifer is one of the Iraq's most important aquifers, located in the west and southwest parts of the country [8], It is composed of variable carbonate rocks mainly limestone, dolomatic limestone and dolomite, with marl and evaporates. It is characterized by the presence of cavities and karstified canals in addition to fractures, fissures and joints, which cause the formation to have highest transmissivity and permeability, in most area [8]. Dammam aquifer in the study area is considered as a confined aquifer as a result of the presence of the overlying Euphrates formation, which has a significant impact on preventing rain and surface runoffs from

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infiltrating underground in the examined area, [9]. The two formations (Dammam and Umm Er Radhuma) form a multi-aquifer system of confined type in the study area, where they recharged from their unconfined parts in their outcrops to the west and southwest of the study area towards the Euphrates depression [9].

5. Movement of Groundwater

Ground water flows from the west and southwest to the east and northeast in the Western Desert [10]. Figure 4 shows the water level reaches (10-46) meters above sea level . The vertical migration of groundwater in the research area shows the loss of water from the Um Erdhuma Aquifer, which lies beneath the Dammam aquifer. Where a hydraulic continuation arises from the west to Razzaza and Bahr Al-Najaf basin, the hydraulic interaction between Dammam and Um Erdhuma aquifers may be alternating.

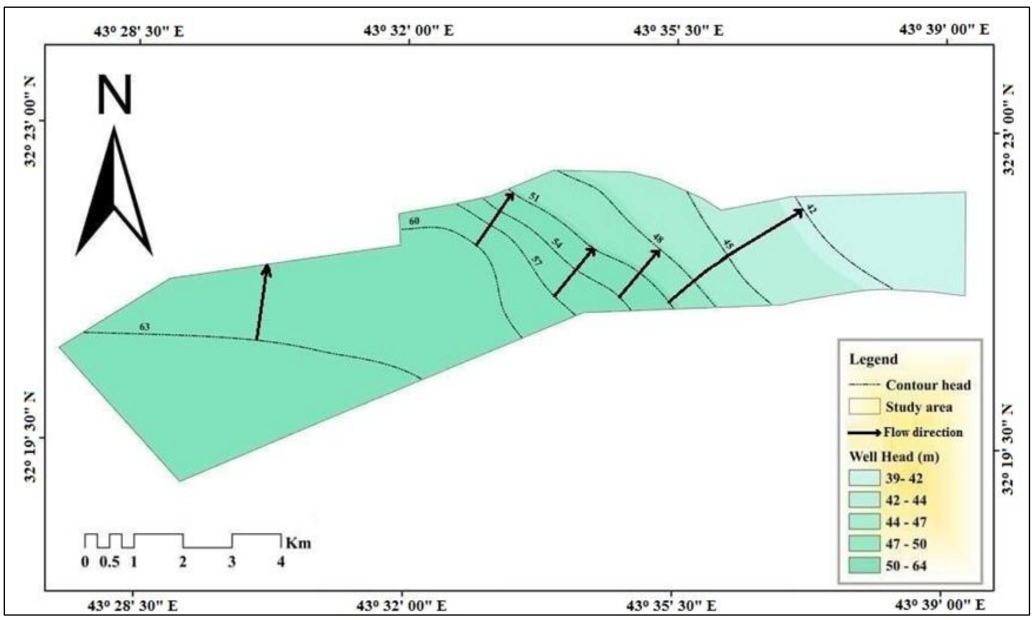

Figure 4: The groundwater flow map of the study area

6. Materials and Methods

6.1. Pumping Test

Adequate and reliable estimates of aquifer parameters are of utmost importance for proper management of vital groundwater resources. The pumping (aquifer) test is the standard technique for estimating various hydraulic properties of aquifer systems, viz., transmissivity (T), hydraulic

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conductivity (K), storage coefficient (S), and leakance (L) [11] . as The hydraulic properties of the aquifer have been divided according to the degree of importance into two types, significant and less significant. The significant properties that can be estimated from the result of pumping test ,The hydraulic conductivity value change from one place to another according to the way of formed geological formation deposit [12]. Aquifer parameters are an essential tool for managing groundwater potentials. These parameters are mostly estimated by the pumping tests [13]. The geological and hydrological conditions at the test location must be known. Pumping test data can be properly interpreted with the support of subsurface lithology and aquifer geometry, [14]. Provide a good description of several strategies with examples; although the methods described above were designed for homogenous granular formations, they can also be used for heterogeneous granular forms. The usage of a double porosity model in heterogeneous aquifers is important since the method is illustrated by a practical application utilizing data from a pumping test conducted in a constrained limestone karst aquifer. The model fits Dammam aquifer wells in the study area rather well. It was able to compute these parameters even for single wells using the computer software programs AQTESOLV Professional version 4.50 (2011)Several analytical solutions are applicable in solving the problem of unsteady-state flow; well-known theoretical solutions are introduced in this section, and the method that will be addressed in this study is the method; Theis and Hantush solution [15] (Figure 5). Theis (1935)/Hantush (1961) solution is a pumping test analysis method that is adopted in the study area.

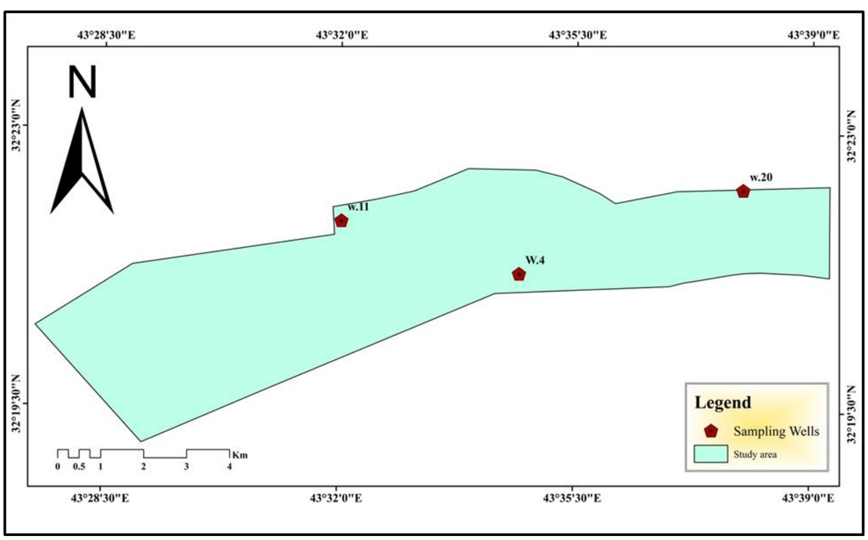

Figure 5: Pumping test well location

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6.2 Theis (1935)/Hantush (1961) method:

Theis, 1935 proposed a straight-line solution for calculating transmissivity and storativity from residual drawdown data gathered during the recovery phase of a pumping test, based on the idea of superposition in time. Because the method assumes a line source for the pumped well, wellbore storage is ignored. [14]. (Figure 6) Theis (1935) proposed the following equation for analyzing data:

Where

Q is pumping rate [L^3/T]

s' is residual drawdown [L]

S is storativity during pumping [dimensionless]

S' is storativity during recovery [dimensionless]

t is time since pumping began [T]

t' is time since pumping stopped [T]

T is transmissivity [L^2/T]

By plotting s' as a function of log (t/t') on semi-logarithmic axes, one can determine values of T and S/S' by drawing a straight line through the data. Without the influence of boundary effects, the value of S/S' determined from the intercept of the straight line with the log (t/t') axis should be close to unity. A value of S/S' > 1.0 indicates the influence of recharge during the test. Conversely, a value of S/S' < 1.0 suggests the presence of a barrier or no-flow boundary

For variable-rate pumping, we may use the principle of superposition in time to compute residual drawdown after N constant-rate steps as follows [16]

$$S^t = \frac{2.303Q_N}{4\tau T}\log\left(\frac{2.25T}{r^2\,S}B_t\right)$$

$$B_t = \prod_{n-1}^{N}\left(\frac{t-t_n}{t^t}\right)^{\Delta Q_n I Q_n}$$

$$\Delta Q_{n=} Q_n - Q_{n-1}$$

Where

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Q_N is the pumping rate in the last constant-rate step prior to recovery [L^3/T]

t_n is the time since pumping began when the nth constant-rate step starts [T]

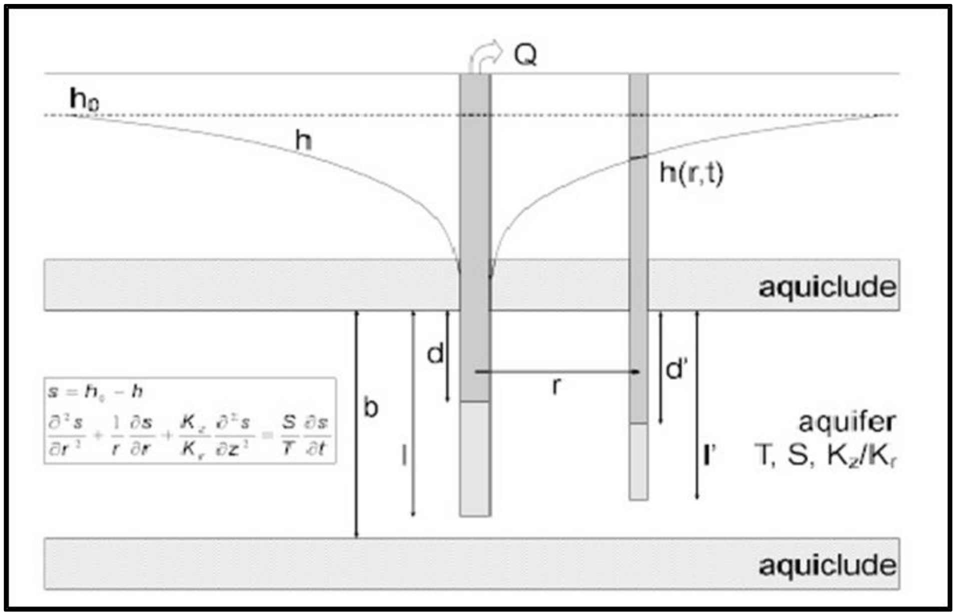

Figure 6: Solution for a Pumping Test in a Confined Aquifer by (Theis 1935 and Hantush1961) (AQTESOLV.2011).

Figures 6 to 8 illustrate the time-drawdown curve by using AQTESOLV software output for each of the tested wells. The depth of the examined wells ranged between 120-140m with a discharge rate of 10 and 15 l/s causing a minimal in certain wells, the drawdown is less than one meter; the results of the pumping tests show a wide range of values for both transmissivity and resistance, ranging from (111.3 to 1705.1) m2/day and (22.23 to 32.11) m/day, respectively (Table 4). The Dammam aquifer is a carbonate-karstified aquifer with secondary porosity, which explains this wide range in values. Table 1, 2, 3 show Data Observation through pumping test.

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Table 1 : Data Observation through pumping test for well No.4

Time (min)	Displacement (m)	Time (min)	Residual Displacement (m)
1	0.08	151	0.16
2	0.09	152	0.15
3	0.09	153	0.14
4	0.1	154	0.14
5	0.105	155	0.13
6	0.11	156	0.125
7	0.11	157	0.12
8	0.115	158	0.12
9	0.12	159	0.115
10	0.13	160	0.115
15	0.14	165	0.11
20	0.15	170	0.105
25	0.16	175	0.1
30	0.1625	180	0.095
45	0.165	195	0.0875
60	0.1675	210	0.085
90	0.17	240	0.08
150	0.175	300	0.07
		360	0

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Table2 : Data Observation of Observation well through pumping test for well No.11

Time (min)	Displacement (m)	Time (min)	Displacement (m)	Time (min)	Displacement (m)
1	0.7	20	0.1	105	0.12
2	0.7	25	0.1	120	0.125
3	0.08	30	0.105	180	0.125
4	0.08	35	0.11	240	0.125
5	0.085	40	0.11	300	0.125
6	0.09	45	0.11	360	0.125
7	0.09	50	0.11	420	0.13
8	0.09	55	0.11	480	0.135
9	0.09	60	0.115	540	0.135
10	0.09	75	0.12	600	0.14
15	0.095	90	0.12	660	0.14

Table 3: Data Observation of pumping well through pumping test for well No.20

Time (min)	Displacement (m)	Time (min)	Displacement (m)	Time (min)	Displacement (m)
1	0.03	9	0.28	90	0.74
2	0.06	10	0.33	105	0.77
3	0.09	15	0.37	120	0.79
4	0.13	20	0.48	180	0.84
5	0.16	30	0.55	240	0.89
6	0.2	45	0.61	300	0.92
7	0.22	60	0.68	360	0.92
8	0.26	75	0.71	420	0.92

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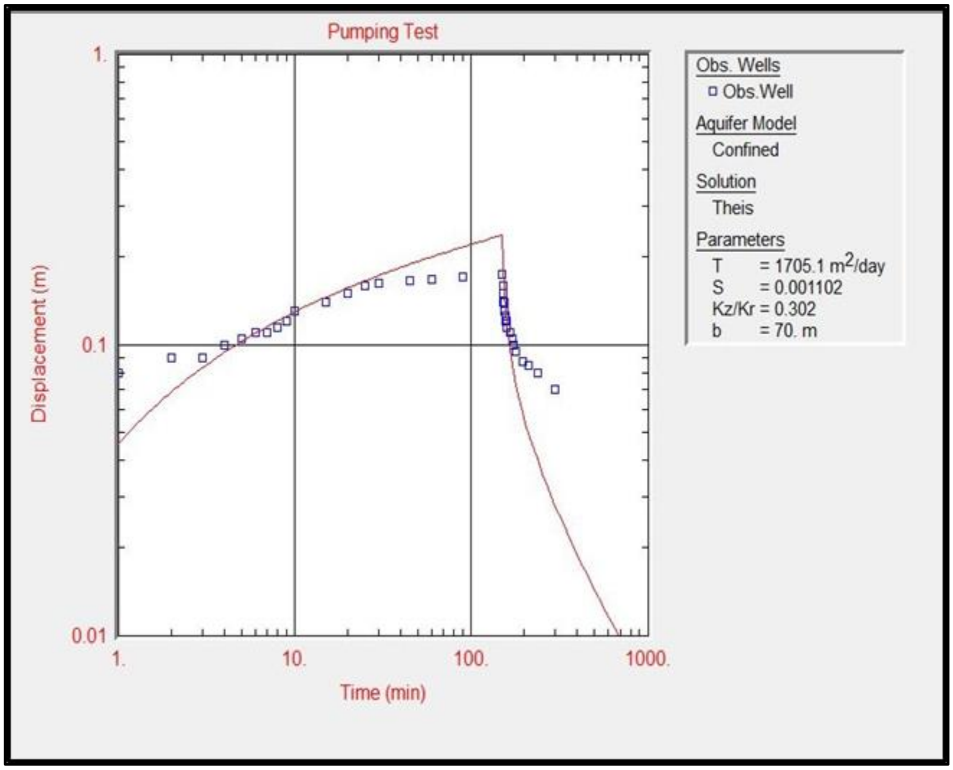

Figure 7: Time-Drawdown curve of well No. 4

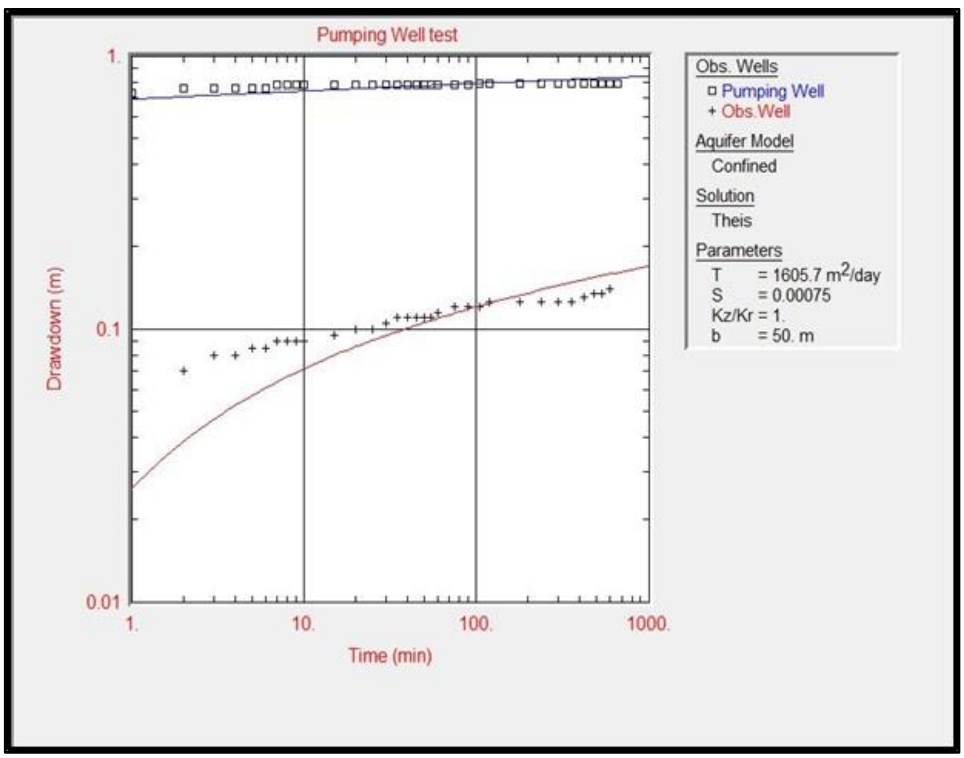

Figure 8: Time-Drawdown curve of well No.11

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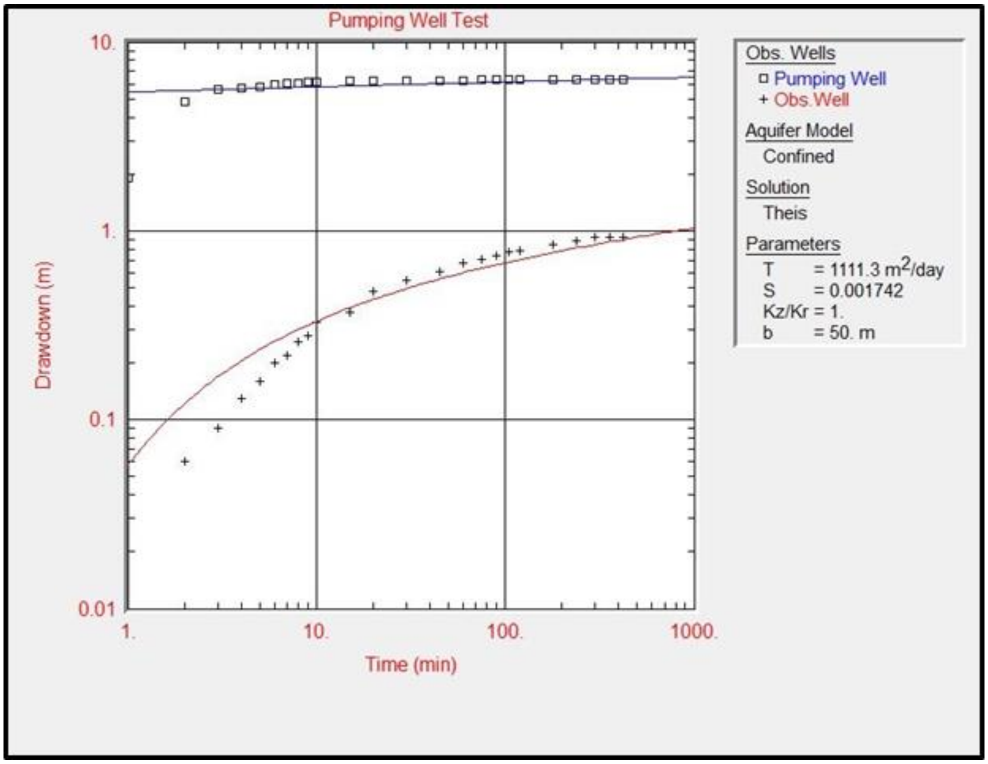

Figure 9: Time-Drawdown curve of well No.20

Table 4. Hydraulic parameters of Dammam aquifer in the selected wells

Well No.	Longitude	Latitude	Discharge	Saturated thickness	Transmissivity	Hydraulic conductivity	Storage coefficient
			Q (l/s)	b(m)	T(m^2/day)	K(m/day)	
4	43º 34´ 40.1"	32º 21̀ 13.0"	10	70	1705.1	24.36	0.00110
11	43º 32´ 01.4"	32º 21′ 51.6"	5	50	1605.7	32.11	0.00075
20	43º 37´ 30.2"	32 22̀ 19.5"	25	50	1111.3	22.23	0.00174

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7. Conclusions

The results of the pumping test were analyzed in order to determine the values of transmissivity, hydraulic conductivity and storage coefficient for the three selected wells in the study area. Transmissivity values ranged from (111.3 to 1705.1) m^2/day and hydraulic conductivity values ranged from (22.23 to 32.11) m/day, whereas the storage coefficient is ranged between (0.00075-0.0011). Since the Dammam aquifer is a carbonate highly karstified aquifer, its hydraulic characteristics varies both laterally and vertically, whereas in well No. 4, the results were based on the pumping well. As for wells 11 and 20, observation wells were relied upon because the results were clearer and more accurate than the pumping well.

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الخواص الهيدروليكية لخزان الدمام في مدينة سيد الشهداء الزراعية، كربلاء - العراق

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المستخلص

تهدف هذه الدراسة إلى تقييم الخواص الهيدروليكية لخزان الدمام باستخدام ثلاثة آبار ضخ مختارة مناسبة للضخ التجريبي. منطقة الدراسة هي مشروع زراعي يسمى مدينة سيد الشهداء الزراعية ، وتقع ضمن منطقة الأخيضر في ناحية عين التمر ، جنوب غرب بحيرة الرزازة ، وغرب محافظة كربلاء المقدسة. تم تطبيق طريقة عمل Theis and Hantush لتحليل بيانات اختبار الضخ. نطاقات النفاذية والتوصيل الهيدروليكي ومعامل التخزين هي (111.3 - 1705.1) م ^{2} / يوم ، (22.23 - 32.11) م / يوم ، و (0.00075-0.0011) على التوالي. كانت مدينة سيد الشهداء الزراعية في السابق صحراء قاحلة ، ثم تحولت إلى أرض زراعية منتجة بعد أن شهدت هذا الموسم زراعة (5000) دونم من محصول القمح. أن أهم ما يميز هذه المنطقة هو استخدام أنظمة الري المحورية ذات المنشأ العالمي ، ومصدر المياه المستخدم في المزرعة هو من البحر الجوفي (المياه الجوفية) ، حيث يعتبر هذا المصدر أكثر ضمانا لاستدامة إنتاج المزرعة ، ويهدف البحث إلى تحديد الخصائص الهيدروليكية للخزان الجوفي في حالة توفر آبار مناسبة لاختبار الضخ. عمل الميزان المائي لحساب فائض المياه او نقصها. دراسة الخصائص الهيدروكيميائية وتقييم جودة المياه الجوفية لتحديد مدى ملاءمتها للاستخدامات الزراعية والري، محاولة تقديم خطة إدارة للمياه الجوفية للأغراض الزراعية.

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