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RESEARCH PAPER

Efficiency Analysis of Aquifer Parameters of Different Wells in Khabat Basin

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A B S T R A C T:
The study presented in this paper is the efficiency analysis of aquifer parameters in Khabat Basin through data collected from pumping test of the wells. The important indicator of the wells yield can be evaluated as the well efficient or not. Wells is considered as an efficient well if the efficiency is more than 70%. The pumping test is conducted to estimate the aquifer parameters (transmissivity and storativity) using (AQTESOLV4.5) software. Modified cooper Jacob (1946) for single pumping well is provides for estimation aquifer parameters. The results showed that the value of transmissivity is within the standard range for unconfined aquifer, while storativity is overestimated this was due to the total head losses in the pumping the well. Also, the objective of this study using aquifer response to pumping test to calculate the cone of depression than finding out the storativity of the aquifer.

KEY WORDS: transmissivity, storativity, well efficiency, AQTESOLV4.5
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1.INTRODUCTION:

many countries, Groundwater is the main source of drinking water and irrigation. In the last years, groundwater levels reduced due to many factors. The underground fresh water called aquifer are generally located no more than eight hundred meters beneath the earth's surface and are usually taped with wells at shallower depths. There are many methods are used to predict aquifer parameters. The pumping test is the traditional method to determine aquifer parameters. A pumping test is conducted on the production well in the case of a single well, and the drawdown is measured at the pumping well.

(AQTESOLV4.5) software used to analyze test data from pumping tests for all type of aquifers confined, unconfined, semi-confined, or leaky confined and fractured aquifers. This software can be easily account for different well conditions inclusive of horizontal wells, wellbore storage and single well analysis.

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Also, gives the result of aquifer parameters. A pumping test is a common way to estimate aquifer parameters and the efficiency of the well. The efficiency of the well can be found by dividing the theoretical drawdown on actual drawdown. also, the specific capacity of the well can be found by dividing is discharge on drawdown, where it is an indicator for measuring the productivity of the wells. The computed specific capacity when compared with the measured from the field also defines the approximate efficiency of the well. (Todd and Mays 2005) Reducing losses or increasing well efficiency is an important factor and the well needs a pump with lower energy. (Bierschenk 1963) Provided graphical solution of multiple steps-drawdown established by modified Cooper-Jacob (1946) to determine the total drawdown in several pumping well. (Rorabaugh 1953) suggested an empirical formula to predict the total drawdown in the pumping well. (Singh 2002) established an optimization method for simultaneous estimation of confined aquifer parameters and parameters of well losses using all drawdowns observed at the pumping well during a variable rate pumping test. The method yields more reliable estimates of the parameters as compared with conventional graphical methods. Recently, (Amah and Anam 2016) conducted A pumping tests on several production wells, to estimate hydraulic parameters and specific capacity for testing the most productive well. (Mace 1996) derived the empirical relation between specific capacity and transmissivity. The accuracy of the empirical equation is high its R^2 reaches about 0.9, this empirical equation does not require correction for well losses. (Mawlood 2019) conducted the pumping tests to the production well to compute the aquifer parameters. The results compared with using an observation well. A considerable difference is observed between them due to the available losses in production well. (Dana and Jwan 2016) performed the pumping test on single production well a cooper Jacob 1946 provided the aquifer parameters, the study noted that the storage coefficient is overestimated due to the absence of observation wells. However, obtaining drawdown from single pumping test is include aquifer losses and wells losses in the gravel pack and vicinity of the screens. (Jasim and Jalut 2020) used the pumping test to estimate the hydraulic parameters of the unconfined aquifer to analyze the data cooper Jacobs, Theis's recovery (AQTESOLV 4.5) is provided. It was observed from transmissivity value the specific capacity of the aquifer is high production with slightly heterogenous. In this study, pumping test is conducted on four production wells in Khabat district. The efficiency and specific capacity of wells are evaluated.

2. MATERIALS AND METHODS

2.1: Study Area

The study area is Khabat District consist of three sub-districts (Rizgary, Kawrgosk, and Darashakran), which is located at west of Erbil province at distance of about 37 km from the center of Erbil city. Khabat district located on Greater Zab River. The total area of this district is 687km^2. Khabat district is belong to northern (kapran) sub-basin. The area of this basin is about 915 km^2 which consist of Bakhtiary formation with a limited meter of alluvium deposit overlie the upper Bakhtiary formation at the lower part of the sub-basin. The four productive pumping wells for the present study are in the Khabat district shown in (figure 1) which is located at the west of the Erbil province in the Kurdistan Region-Iraq, the coordinate of wells is shown in table 1. Also, the lithology of wells shown in (figure 7).

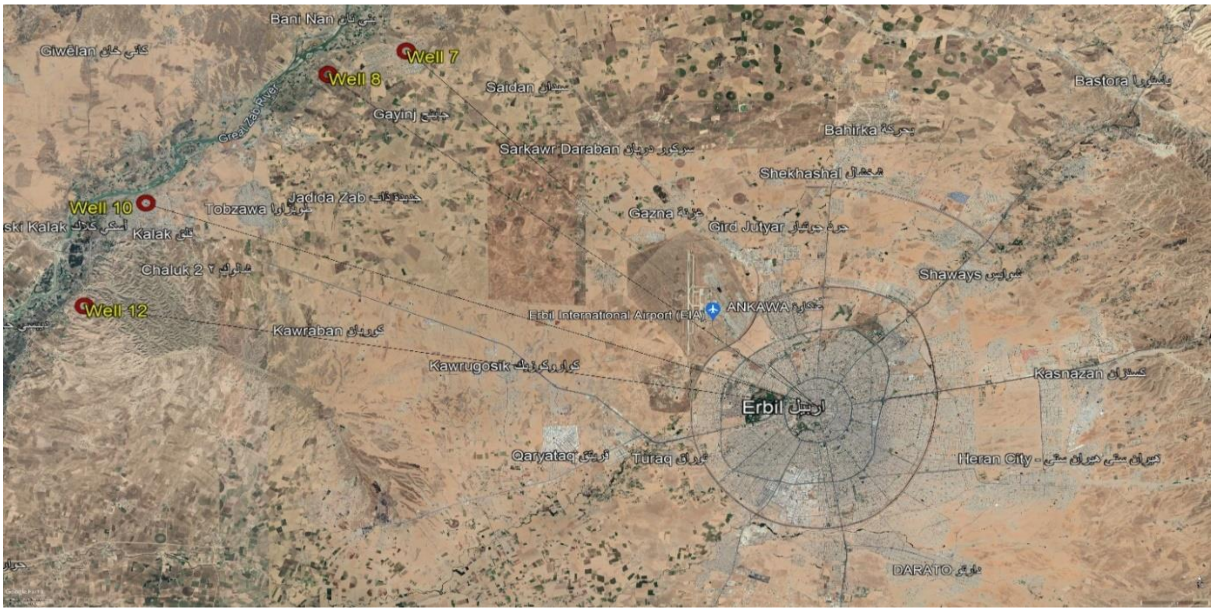

Figure 1: study area

Table 1 well Coordinates and Elevation in Khabat

Well description	E (longitude) 38 S	N(latitude)	Elevation
7	393052	4023653	314
8	389581	4022518	293
10	378675	4016120	294
12	382478	4010952	297

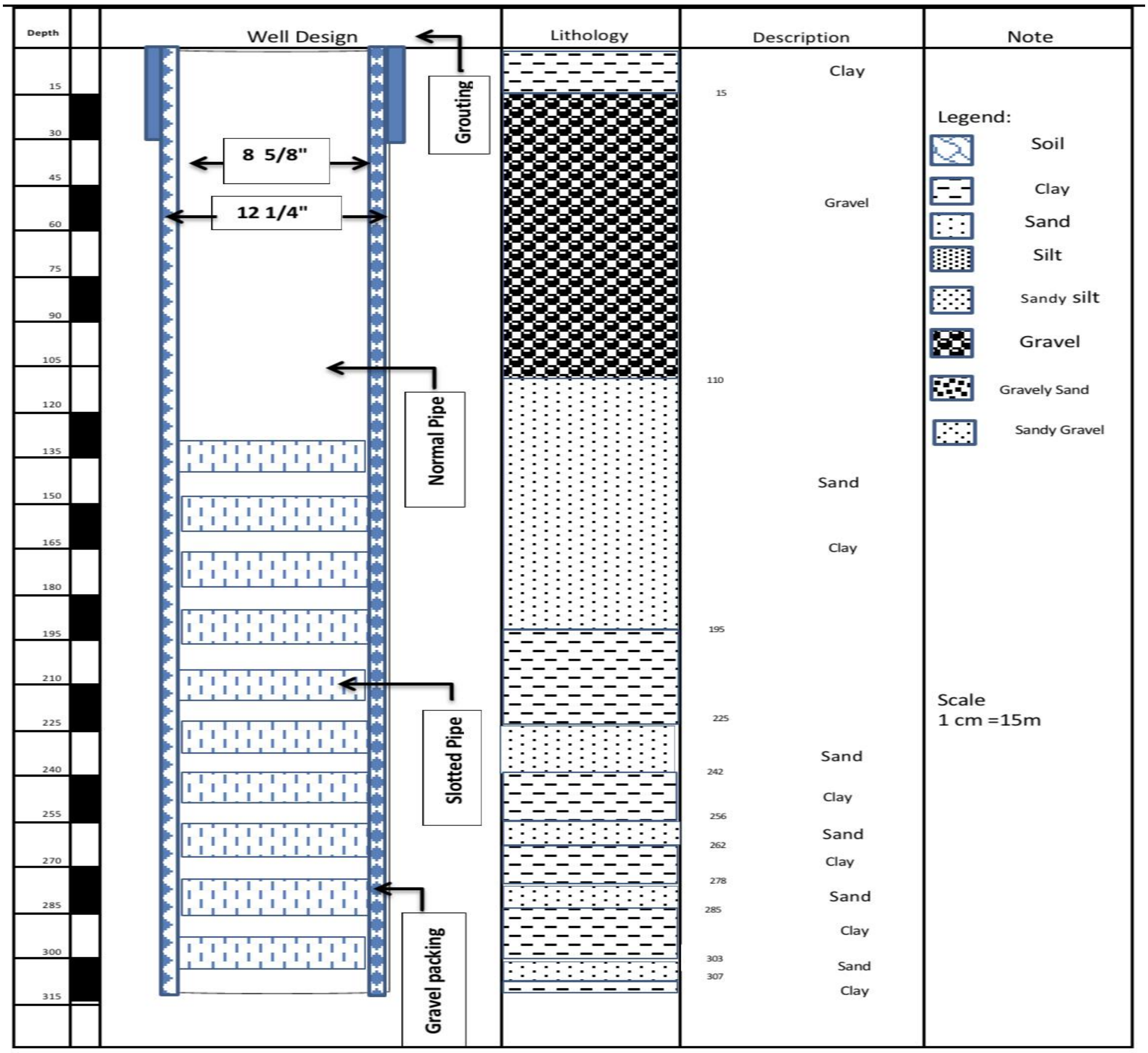

Figure 7: lithology of the well 7

2.2: Methodology of the study

The pumping tests are conducted to estimate the aquifer parameters then calculate the well efficiency. The pumping test was done by using some equipment such as a submersible pump, a container, and a stopwatch for measuring the discharge, three qualified persons, and a sounder for recording the water level in the well at any elapsed time.

Cooper-Jacob’s simplified method (1946) was used to estimate well efficiency. The transmissivity and storativity can be expressed as:

$$W\ (u) = \left[-0.5772 - \ln(u) + u - \frac{u^2}{2.2!} + \frac{u^3}{3.3!} + \cdots\right] \qquad 1$$

Where:
W(u): Thesis well function
Euler number = -0.5772

$$u = \frac{r^2 S}{4Tt} \quad 2$$

Where:
r: is the radial distance pumping well to point of measuring drawdown (L).
S: is the storativity of the aquifer (dimensionless).
T: is the Transmissivity of the aquifer (L^2/T).
t: is the time of observed drawdown (T).
To estimate the Transmissivity value using Jacob’s equation:

$$T = \frac{2.3Q}{4\pi\Delta s} \quad 3$$

Where:
Q: is the pumping flow rate (L^3/T).
T: is the Transmissivity of the aquifer (L^2/T).
Δs: is the difference in drawdown per one log cycle of time (L)
The above equation is used to conduct the value of transmissivity, plot Δs as a function of logt on semi-logarithmic axes and draw a straight line through the data.

$$S = \frac{2.25\, Tt_o}{r^2} \quad 4$$

Where:
S: storativity of the aquifer (dimensionless)
T: Transmissivity of the aquifer (L^2/T).
t_o : theoretical time of zero drawdown at steady state (T).

2.2.1 Cooper-Jacob Straight Line Method

however, (Jacob,1946) derived a method based on (Theis's,1935) equation for large values of time(t) and small value of u and for time versus drawdown after considering Jacob's assumptions (C. W. Fetter., 1952). it can be used:

$$s = \frac{2.3Q}{4\pi T}\log_{10}\frac{2.25Tt_o}{r^2 S} \quad 5$$

The relation between drawdown and discharge from the pumping well can be expressed by the straight-line method as:

$$\frac{s_w}{Q} = B + CQ \quad 6$$

By plotting (sw/Q) versus discharge and fitting a straight-line through points, the coefficient of aquifer losses (B) which is the intercept when Q = 0, and well losses coefficient (C) which is the slope of the line can be estimated (Figure 7). The efficiency of the well is the ratio between aquifer losses to the total losses:

$$E\% = \left(\frac{Aquifer\ losses}{Aquifer\ losses + well\ losses}\right) * 100 \quad 7$$

$$E\% = \left(\frac{a_1 Q}{a_1 Q + a_1 Q^2}\right) * 100 \quad 8$$

$$E\% = \left(\frac{BQ}{BQ + CQ^2}\right) * 100 \quad 9$$

Where:
B: is a linear aquifer loss coefficient (L^{-2} T^{-2}).
C:is non-linear well loss coefficient (L^{-2} T^{-1}).
Q: is the pumping rate (L^3 T^{-1}).

In the present study, since the step drawdown test does not available, so the aquifer and well losses cannot be estimated. In this case, the alternative method was used.

The efficiency of the well is the ratio between theoretical to the actual drawdown:

$$E\% = \frac{Theoretical\ drawdown}{actual\ drawdown} * 100 \quad 10$$

For transient (non-equilibrium condition), the theoretical drawdown can be replaced by Jacobs (1946) equation as below:

$$E\% = \frac{s = \frac{Q}{4\pi T}\left[-0.5772 - Ln(\frac{r^2 S}{4Tt_s})\right]}{actual\ drawdown} * 100 \quad 11$$

Where:
E: is an efficiency of the well (%).
s: is the drawdown at any time (L).
Q: is the pumping flow rate (L^3/T).
T: is the Transmissivity of the aquifer (L^2/T)
Euler number = -0.5772.
r: is the radial distance of pumping well to point of measuring drawdown (T).
S: is the storativity of the aquifer (dimensionless)
t_s: is the time of observed drawdown (T)

$$t_c = \left(\frac{0.017\ (d_c^2 - d_p^2)}{\frac{Q}{s}}\right) * 100 \quad 12$$

$$E\% = \frac{4 * T_1}{T_2} \quad 13$$

$$E\% = \frac{4 * \frac{2.3Q}{4\pi \Delta s_1}}{\frac{2.3Q}{4\pi\ \Delta s_2}} * 100 \quad 14$$

$$E\% = \frac{4\Delta s_2}{\Delta s_1} \quad 15$$

t_c: time after casing storage can be considered negligible (T)
d_c: Inside well casing diameter (L)
d_p: outside pump column pipe diameter (L)
Q/s :is the specific capacity oh the well (L^2/T)
Δs_1: slope provided by drawdown and influenced by casing storge (L)
Δs_2: slope provided by drawdown and influenced by aquifer drawdown (L).

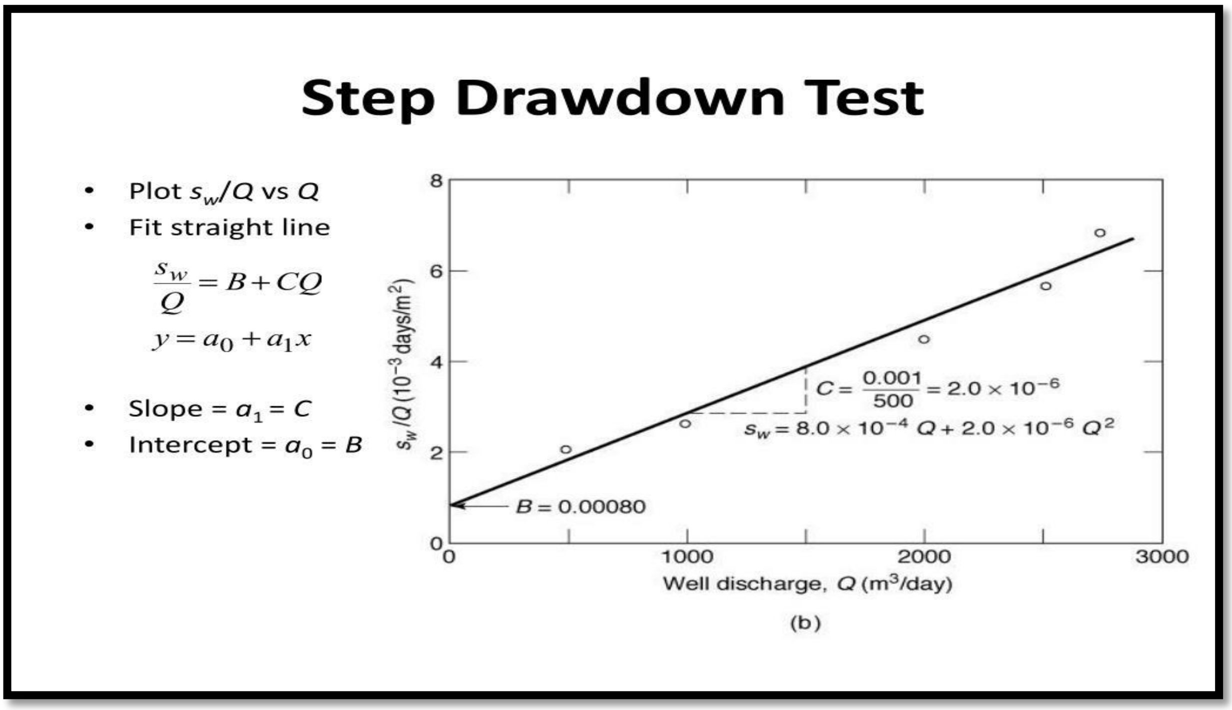

Figure 6: specific drawdown vs well discharge (DRISCOLL 1986)

2.2.2 Application of Diffusion equation:

(Mawlood and Ismail 2021) investigated aquifer diffusivity of the area is about (0.3 m^2/min) based on geological formation of northern (kapran) sub-basin. And deducting storativity based on the radius of influence

then finding Storativity based on the radius of influence by diffusivity equation.

by aquifer diffusivity.

$$\eta \frac{1}{l^2} = \frac{1}{T} \quad 16$$

$$l^2 = 4\eta\, T \quad 17$$

$$L = 2\sqrt{\eta T} \quad 18$$

$$\eta = \frac{T}{S} \quad 19$$

$$\eta = \frac{Kb}{Ssb} \quad 20$$

$$\eta = \frac{k}{Ss} \quad 21$$

L: radial distance from pumping well to monitoring drawdown (L) (replacing L= r (L)

t: is time (T).

η: is aquifer diffusivity(L^2/T)

3. RESULT AND DISCUSSION:

The pumping test is applied on the four production wells in Khabat distinct. The aquifer parameters are and well efficiency is estimated using modified Cooper Jacob 1946 method with the help of (AQTESOLV4.5 software and excel sheet). All aquifer data for all wells are shown in table 2. The pumping test results is conducted on the production well is shown in (table 3 to table 6) which is the relation between time and drawdown. The results of transmissivity and storativity, by applying AQTESOLV4.5 software (figure 2 to figure 5) and excel sheet, in addition, results of specific capacity and well efficiency are shown in Table 7. It was illustrated that value of the transmissivity within the standard range, while the value of the storativity is overestimated by modified Cooper- Jacob (1946) subsequently, the alternative method is provided for estimation of storativity which is used the aquifer diffusivity. The alternative method results ranges between (1.55E-5 to 2.99E-4). The storativity values using alternative method is within the standard range for the unconfined aquifer. Due to the losses in the production well which is divided into two parts which are linear losses and nonlinear losses is difficult to determine the efficiency of the well. For this reason another alternative method is provided for evaluation production well efficiency. (Schafer 1978) has proposed that early (drawdown versus time) data cannot be sufficient for Thesis and Jacob graphical analysis. The first slope shows the water lost because of casing storage, while the second slope shows how the aquifer supplied water to the well. The results of the efficiency using alternative method is observed that the production wells (well 7 and well 8) are considered as an efficient well since the value is more than (70%), while production wells (well 10 and well 12) is considered as non-efficient wells with a value of less than (65%).

Table 2 wells detail

Well details	**well -7**	**well -8**	**well -10**	**well -12**
well depth	310	320	320	320
well location	kawrgosk	kawrgosk	Khabat	Khabat
static water level (m)	106	26	40	43
dynamic water level (m)	136	77.4	98	81
well, yield (gpm)	155	277	225	267
drawdown (m)	36	51.6	58	38
saturated aquifer thickness (m)	204	294	280	277
groundwater table (m)	209	267	254	254
test date	18-4-2022	9-7-2022	23-9-2021	16-11-2021
well test length (m)	180	180	150	200
well test diameter (m)	0.0762	0.0762	0.0762	0.0762
pump type	sp46-18	Sp 46-22	Sp 46-20	sp 46-22
well casing radius (m)	0.1016	0.1016	0.1016	0.1016
effective well radius (m)	0.156	0.156	0.156	0.156

Table 3: Pumping test data well-7

Time (min)	**s (m)**	**s corr (m)**	**Time (min)**	**s (m)**	**s corr (m)**
0.0	0.00	0.0	10.0	32.20	29.66
0.5	7.00	6.88	15.0	33.40	30.67
1.0	13.00	12.59	20.0	34.80	31.83
1.5	17.00	16.29	25.0	35.30	32.25
2.0	19.80	18.84	30.0	35.60	32.49
3.0	23.00	21.70	40.0	35.80	32.66
4.0	25.50	23.91	50.0	35.90	32.74
5.0	26.70	24.95	60.0	36.00	32.82
6.0	28.20	26.25	80.0	36.00	32.82
7.0	29.50	27.37	100.0	36.00	32.82
8.0	30.70	28.39	120.0	36.00	32.82
9.0	31.40	28.98	140.0	36.00	32.82

Table 4: Pumping test data well-8

Time (min)	s (m)	s corr (m)	Time (min)	s (m)	s corr (m)
0	0	0	10	43.2	36.81
0.5	18	16.89	15	43.9	37.30
1	27.5	24.91	20	45.1	38.13
1.5	31	27.71	25	45.8	38.62
2	35	30.80	30	46.5	39.10
3	38.7	33.57	40	47.53	39.79
4	40.2	34.67	50	48.54	40.47
5	41	35.24	60	49.35	41.01
6	41.4	35.53	80	50.8	41.96
7	41.8	35.82	100	51.2	42.22
8	41.95	35.92	120	51.4	42.35
9	42.4	36.24	140	51.4	42.35

Table 5: Pumping test data well-10

Time (min)	s (m)	s corr (m)	Time (min)	s (m)	s corr (m)
0	0	0	10	51.5	42.03
0.5	7.8	7.58	15	55.5	44.50
1	15.2	14.37	20	56.6	45.16
1.5	21.5	19.85	25	57.2	45.51
2	25.1	22.85	30	57.6	45.75
3	33.2	29.26	40	57.85	45.90
4	36.5	31.74	50	57.9	45.93
5	38.1	32.92	60	58	45.99
6	41.5	35.35	80	58	45.99
7	43.9	37.02	100	58	45.99
8	46.2	38.58	120	58	45.99
9	49.1	40.49	140	58	45.99

Table 6: Pumping test data well-12

Time (min)	s (m)	s corr (m)	Time (min)	s (m)	s corr (m)
0.0	0.0	0.0	10.0	37.0	34.53
0.5	11.0	10.78	15.0	37.4	34.88
1.0	18.0	17.42	20.0	37.7	35.13
1.5	22.0	21.13	25.0	37.9	35.26
2.0	25.0	23.87	30.0	37.8	35.22
3.0	28.0	26.58	40.0	38.0	35.39
4.0	31.0	29.27	50.0	38.0	35.39
5.0	34.0	31.91	60.0	38.0	35.39
6.0	35.5	33.23	80.0	38.0	35.39
7.0	36.1	33.75	100.0	38.0	35.39
8.0	36.5	34.10	120.0	38.0	35.39
9.0	36.8	34.36	140.0	38.0	35.39

Table 7 : pumping test results

Well no	Q m^3/min	T m^2/day	S	Sc m^2/day	efficiency %
7	0.6975	10.54	4.30E-5	27.90	73.2
8	1.2500	13.07	1.55E-5	34.94	83.3
10	1.0125	8.67	6.00 E-5	25.14	61.0
12	1.2020	15.23	2.99E-4	42.42	50.0

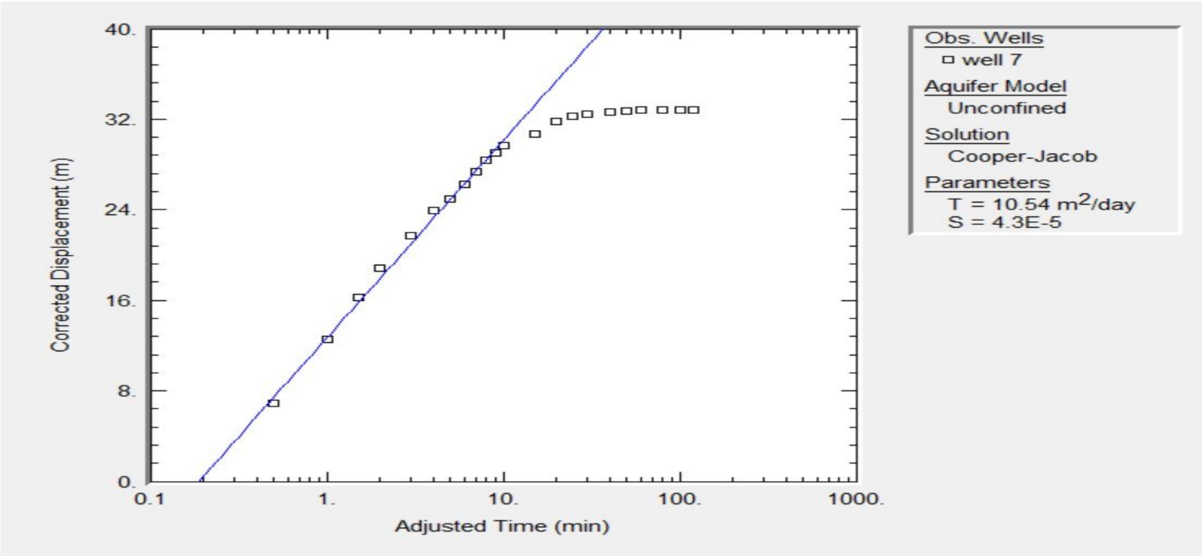

Figure 2: Modified Cooper-Jacob (1946) well 7 using (AQTESOLV4.5)

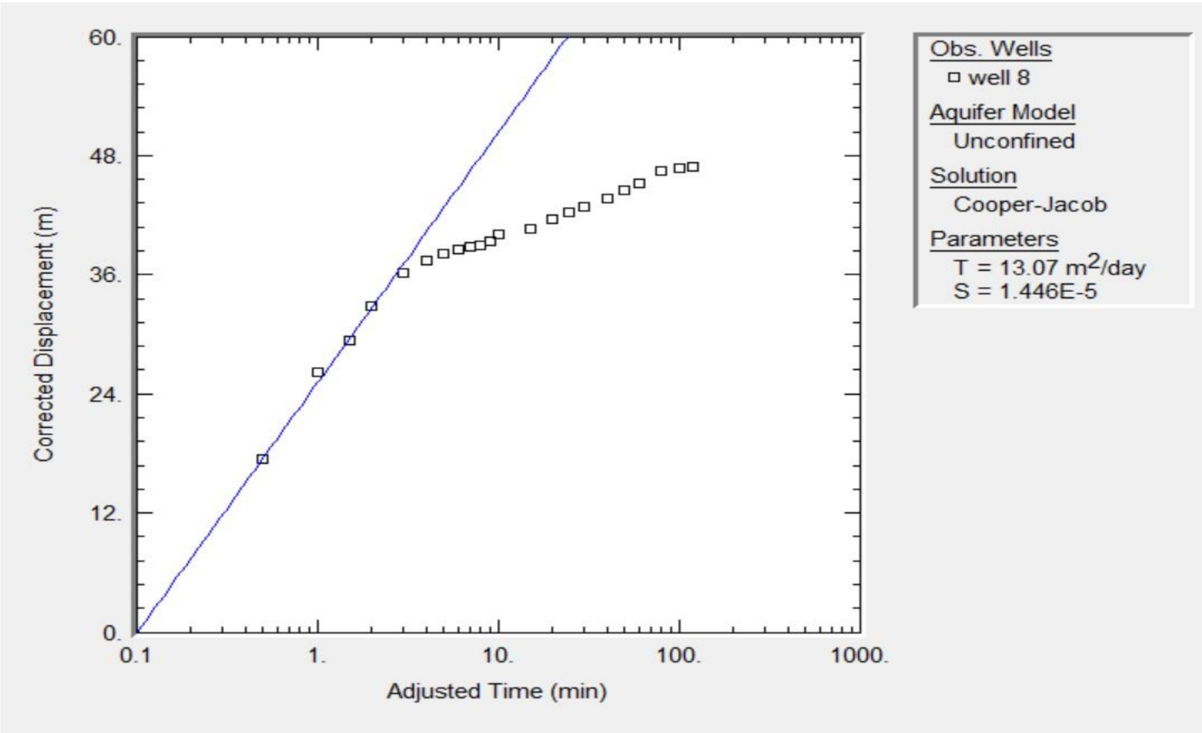

Figure 3: Modified Cooper-Jacob (1946) well 8 using (AQTESOLV4.5)

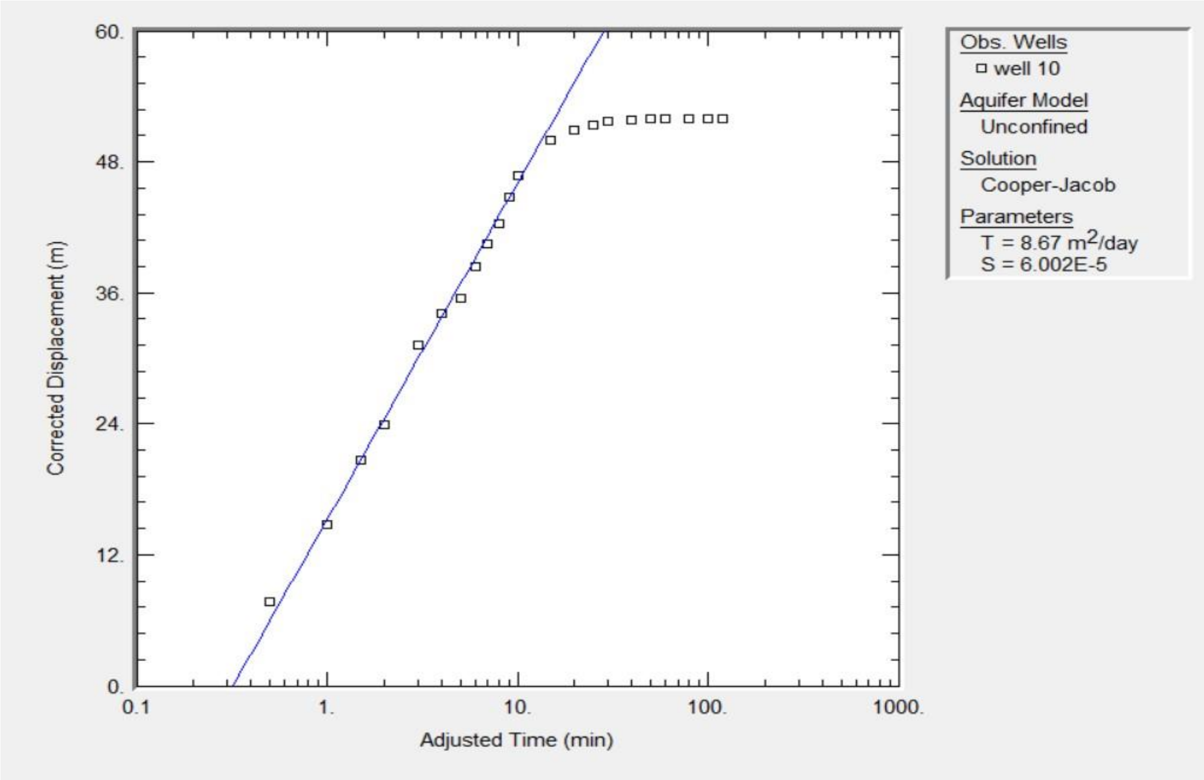

Figure 4: Modified Cooper-Jacob (1946) well 10 using (AQTESOLV4.5)

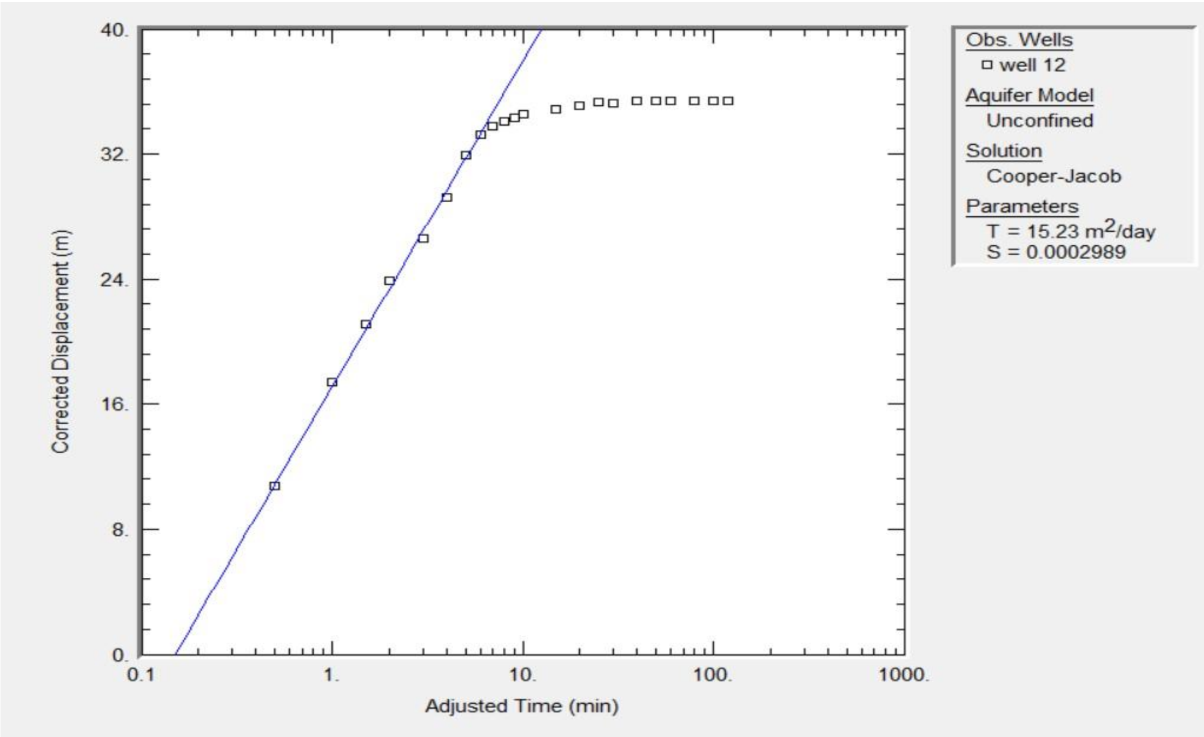

Figure 5: Modified Cooper-Jacob (1946) well 12 using (AQTESOLV4.5)

4. CONCLUSION

Pumping test is conducted on four production wells in Khabat district, The aquifer parameters is estimated using Jacob 1946 method and AQTESOLV, furthermore, the efficiency of wells is calculated using alternative method.

1-The value of Transmissivity is considered as acceptable value while storativity is over estimated, this was due to the head losses in the

production wells which is divided in two to parts linear and nonlinear losses.
2-Jacob method cannot be used for estimation well efficiency since the pumping test is conducted on the production well without data collected on observation wells.
3-Schafer method is reasonable estimator the value of the well efficiency.
4-Two production wells are considered as efficient well and other as non-efficient well.

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