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MANAGEMENT OF GROUNDWATER RESOURCES IN DHABAA SITE-WEST IRAQ.

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ABSTRACT

This research examined the hydrogeological conditions and the hydraulic characteristics of the water bearing horizons (according to pumping and recovery tests) within the hydrogeologic regime of Dhabaa site. Also this study shed light on the flow behavior regime due to artificial dewatering process, throughout huge exploitation and its impacts on the groundwater movement, groundwater flow velocities (hydraulic gradients) considering the regional structural and stratigraphical settings.

The traditional hydrochemical and hydraulic interpretation show same phenomenon of groundwater source and interconnection, where, the groundwater in Dhabaa site moves in different directions influenced by depletion process in a hydraulic gradient ranged between (0.00009-0.026) with groundwater flux of (0.000008-0.0023) m/day and groundwater pore velocity of (0.0008- 0.23) m/day. These variations are occurred as a normal result of pumping operations from the water wells.

Mullusiaquiferis characterized bycertain types ofaquiferswith mediumtransmissivityandpermeabilityundersemi-confined conditions, where the values of permeability, transmissivity and storage coefficients are ranged between (0.00785-0.286) m/day, between (1.063-6.057) m^2/day and between (2.64 x10^{-4}-2.73x10^{-2}) respectively. Accordingly, pumping system and distribution of wells is designed using a battery system of four wells to solve the impact of depletion in Dhabaa site.The suggested plan is ideal for processing must be applied according to the proposal of pumping from the first group including wells (W-1,3,6,7,10,12,15 and16) operated in one shift every six hours, alternating with the wells of the second group, which includes wells (W-4,5,8,9,11,13 and 17). While the wells (W-2 and 14) can be operated in case of stop pumping from any well or be under maintenance period.

إدارة الموارد المائية الجوفية في موقع الضبعة باستخدام المعاملات الهيدروليكية لخزان ملصي الجوفي

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الكلمات المفتاحية : المعاملات الهيدروليكية ،الخزان الجوفي،المياه الجوفية .

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المستخلص:

خلصت الدراسة إلى تحديد خطة لاستخراج المياه الجوفية من خزان ملصي الجوفي شرقي الرطبة (موقع الضبعة)، إذ تم تقييم الخصائص الهيدروليكية للطبقات الحاملة للمياه في تكوين ملصي الجيري من خلال اختبارات الضخ والرجوع في أربع مواقع لاستنباط وتحديد معامل النفاذية، الناقلية، معامل الخزن، كفاءة البئر، فاقد البئر و نصف قطر التأثير. استخدمت نتائج الضخ والرجوع في وضع خطة لإدارة الموارد المائية الجوفية وتصميم أفضل خطة إنتاج فعالة لمنظومة الآبار يمكن الاعتماد عليها في تجهيز سكان الرطبة بالمياه وحسب متطلبات الفرد الواحد للأغراض المنزلية والشرب و المقترحة عالميا .

سلطت الدراسة الضوء على سلوك نظام الجريان وانخفاض منسوب المياه الجوفية جراء الضخ المتزايد و العشوائي من منظومة الآبار البالغة (17) بئر إنتاجي ومدى تأثيرها على سرعة حركة المياه الجوفية واتجاهاتها ، و عرضها بموديلات هيدروجيولوجية (توزيع مكاني) ثلاثية وثنائية الأبعاد . أكدت الدراسة على ضرورة تطبيق خطة تنظيم الإنتاج وبكافة مقترحاتها لضمان عدم تدهور مياه الخزان الجوفي كما ونوعا . كما تم تحديد المواقع الرئيسية المفضلة ذات الإنتاجية المؤهلة للاستثمار مستقبلا وحسب الزيادة السكانية

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1.INTRODUCTION:

The hydraulic parameters that derived from pumping test are obtained permeability, transmissivity and storage coefficient, well loss, well efficiency and effective radius, where these parameters are used in planning and management. According to the fact of Mullusi aquifer is of major importance for the water supply of people in Rutba region in particular of increasing demand of water resources and sustainability assessment in the future, The main result that derived from this study is to develop a reliable strategic suggested plan in groundwater supply, depend on groundwater exploitation from the restricted area of Dhalaa site.

1.1. Location and Aims

The study area lies in the basin of Dhabaa valley within the plateau of Ubaid - Maudood - Zorhoran in the area bordered by longitudes (40°31'22"-40°28'56") and latitudes (33°01'27"-33°02'20"), which obtained water wells system of Dhabaa project. This area located to the east of Rutba city of about 16 km, includes (17) production wells spread over an area of (8) km^2 at elevations range between (585-600) meters above sea level. The slope of the land surface in the project site ranges between (0.04-17.6) m/km with an average of (5) m/km toward the NE, Fig. (1).The study area characterized by the phenomenon of the depressions evolution due to weathering, erosion and the formation of blind streams in the branches of Dhabaa Valley and Ubaid plateau. Depressions evolution forms karst morphology which represents a support manifestation hypothesis of water runoff in Dhabaa Valley within the scope of Dhabaa Fault extended towards the SW-NE, as confirmed by the geophysical study (Al-Dulaiymi etal,2010), in addition to the previous geological studies (Fouad, 2007; Al -Mubarak, 1996;Al-Bassam,etal. 2004).

The study area is under the effects of desert climate of dry arid zone for the duration of the second half of the twentieth century (Hussien, 2010). The mean annual of temperature, relative humidity, wind speed, rainfall, evapo - transpiration in the search area for the period (1941-2008) reached, 20.1° C, 45.5%, 3.1 m/sec, 107.9 mm/year and 2579 mm/year, respectively (Al-Dulaiymi, etal, 2010).

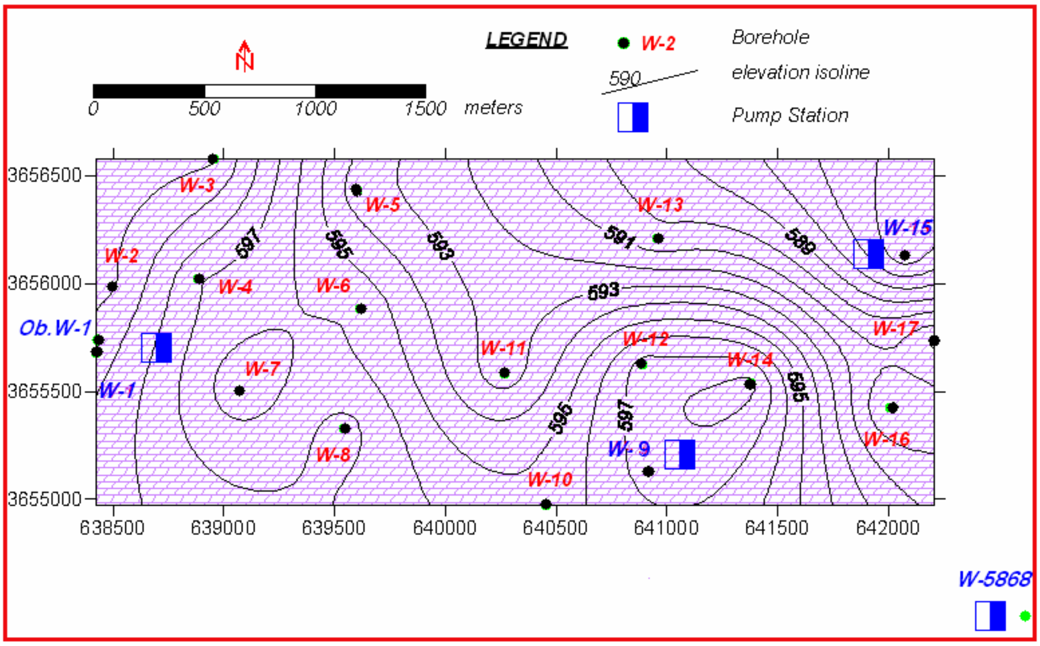

Fig-1: Topographic map and location of wells within Dhabaa site

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The research aims to identify the hydrogeologic characteristics of Mullusi aquifer (quantitative evaluation) through the identification of hydraulic coefficients of aquifers using the pumping test in four sites, and determine the direction of groundwater movement, groundwater flux and groundwater flow velocity through observation and measurement of groundwater levels in (17) wells, as well as field measurements of temperature, pH and electrical conductivity of groundwater in (14) wells for the purpose of matching between the hydraulic and hydrochemical phenomena. Also develop a suitable production plan from pumping wells of Mullusi aquifer,
sufficient for Rutba city resident's need of drinking water and domestic use, including the number and depths of wells and the distances between them without deterioration in water quality.

1.2. Hydrogeology:

From a geological perspective and depending on the study (Sessikian and Mohammed, 2007), the study area on multiple levels of topography includes Quaternary sediments, Maudod and Naher Umer Formations (L. Cretaceous-Albian),Ubaid Formation of calcareous clay dolomite (Lower Jurassic). ZorhoranFormation of marly limestone and dolomite (U. Triassic), Mullusi Formation of limestone and dolomite (U. Triassic) and Ga'ara Formation (Carboniferous) are exposed in the vicinity of the northern side, while Rutba sandstones Formation (Cenomanian–Upper Cretaceous), Msad limestone Fn. (Cenomanian-Turonian) are exposed in the southern part of the region. The spatial distribution of geologic Formations in three dimensions attributed to (620) meters above sea level can be observed in (Fig.-2), which was prepared from the geological sections of the drilled wells in the region using a computer program (rock ware-rw14).

The hydrogeological section within the study area represented by well (W-9), (Fig. 3), indicates that the Mullusi layers composed of limestone and dolomite represents the saturation zone, while clayey dolomitic limestone of Zorhoran Formation, yellow calcareous dolomite of Ubaid Formation, sandstones layer of NaherUmer, clayey sandy dolomite of Maudod,in addition to Quaternary

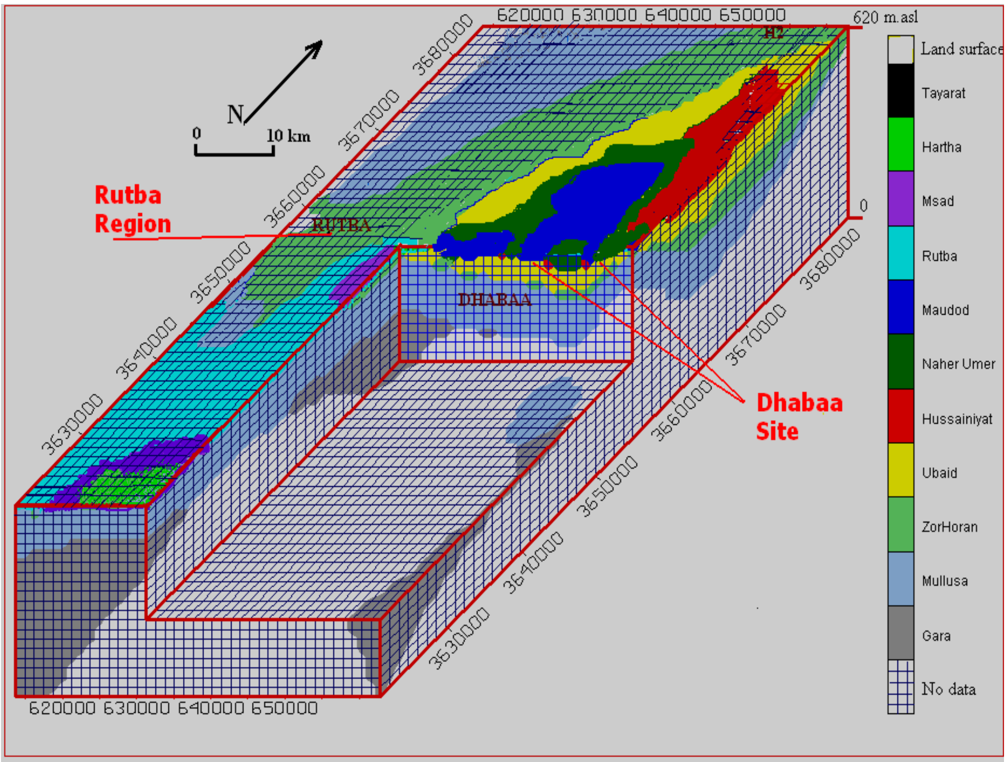


Fig-2: 3D Geologic model between (0-620) m.asl.

sediments represents the unsaturated zone. Regionally, Mullusi aquifer sediments are exposed in Rutba uplift region, particularly in the southern part of Ga'ara depression (N and NW of the study area),
which represents the recharge zone of this aquifer. Also the aquifer recharged from Wadi Horan and its tributaries, which represents the groundwater divide, where the water penetrates throughout geological layers above Mullusi aquifer (Hussien, 2010).
On this basis, the rock layers of Mullusi Formation are a perched aquifer when isolated by impermeable layers from Ga'ara aquifer and of semi-confined storage in areas that leak into the regional aquifer. Groundwater storage conditions in the layers of Mullusi Formation depends on the amount of distance and proximity to the water divide, the amount of rechargewater controlled by the thickness of unsaturated zone and space exposure, in addition to the aquifer characteristics (porosity and permeability). Finally, (Fig-4) shows the extensions of Mullusi aquifer in three dimensions.

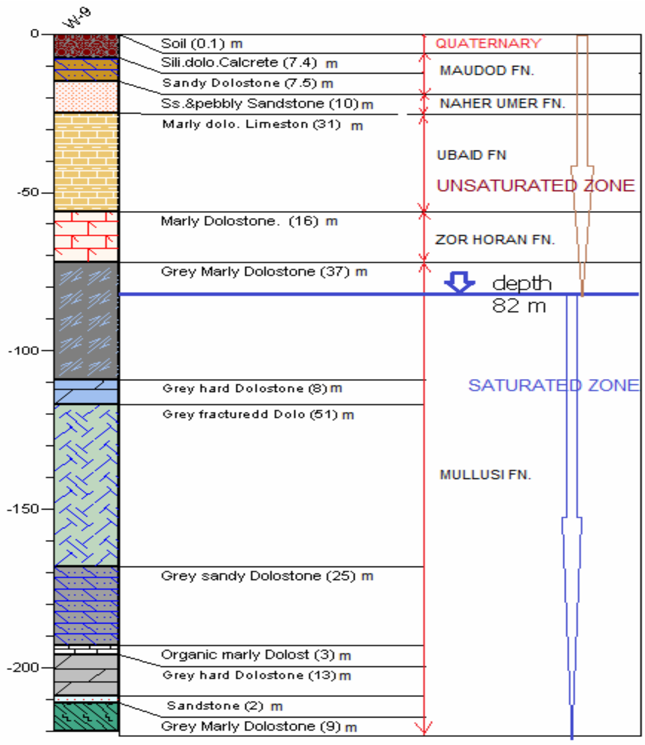


Fig -3:Hydrogeologic section of well (W-9

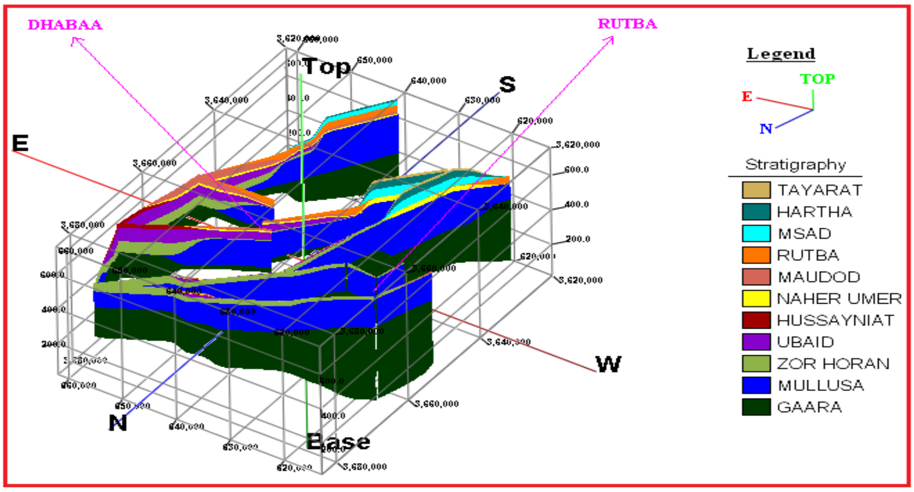


Fig -4: 3D Regional hydrogeological model.

2. METHODS AND MATERIALS

2.1. Field Works

Hydraulic properties were evaluated for Mullusi aquifer at Dhabaa site through pumping and recovery tests in three sites included wells (W-15, W-9, and W-1) and interpretation of a previous experimental data pump in the fourth site (W-5868), (Table-1), (Fig-1).

For the purpose of the pumping test completion, the Company of Water Wells drilled the observation well (W-1 Ob.) ,which is away from the production well (W-1) by a distance of (33) meters and totaling depth of (210) meters and both are used for all measurements of pumping and recovery tests. Also, the well (W -9), was drilled as a production well at depth (220) meters, conducted by the measurements of step test in multi-pumping discharges. The measurements of recovery test are achieved at well (W-15), which was previously drilled in the project.Pumpingtestwas carried outatobservationwell(Ob.W-1)away from the productionwell(W-1) at distance of(33) meters in steadydischarge capacity of(Q=777 m^3/day) for pumping period of(390 minutes), during whichthe drawdown was stoppedandthe static water levelsettled ata depth of(88.60 meters)fromthe land surface, which representsthe hydrodynamic level atdischargeabove. Then the pumping was shut down and directly followed by aprocess of recovery test lastedfor a period of (900 minutes) andreachingthe static water levelagain at depth of(84.0 meters).

Pumping test was carried out in production well (W-9) at a discharge rate of (Q=627 m^3/day) for a period of pumping reached (270 minutes) during which the groundwater level is settled at a depth of (178 meters) from land surface, which represents the hydrodynamic level of groundwater at a discharge rate of 627 m^3/day, while the static water level before pumping recorded at a depth of (84.5 meters). Also, step test process was performed in a production well (W-9) at variable water discharge ranged between (Q=100.6-627 m^3/day) for a period of pumping reached (240 minutes).

Recovery test process was carried out refer to the production well (W-15). The static water level recorded at depth (95.8)m and after a period of pumping reached (181 minutes) the groundwater level settled at a depth (190.2 meters) from land surface, which represents the hydrodynamic level of groundwater at the rate discharge of (Q=375 m^3/day).

Pumpingtest process was carried out refer to the production well (W-5868). The static water level recorded at depth (99.3) meters and after a period of pumping reached (2685 minutes) the groundwater level settled at a depth of (110.7 meters) from land surface, which represents the hydrodynamic level of groundwater at the rate discharge of (Q=50.112 m^3/day). Also, the field work obtainedgroundwater

Table-1: Wells information in Dhabaa site.

Borehole No.	Latitude	Longitude	Elevation (m.asl)	Aquifer Thickness(m)	Well Radius (inch)	Discharge (m^3/day)
W-5868	33°01'06"	40°32'02"	590	130	5 inch	50.112
W-1	33°01'51"	40°28'56"	599.5	130	4 inch	777
W-9	33°01'32"	40°30'32"	599	140	4 inch	627
W-15	33°02'06"	40°31'29"	588	150	5 inch	375

observation in (14) production wells for qualitative evaluation and groundwater levels in (17) water wells. Static and dynamic water levels were measured in the wells using electrical sounder for levels application depending on the procedures of (USEPA, 1989; Thornhill, 1989; Plazak, 1994;Nielsen, D and Nielsen, G 2005; Driscoll, 1986; Barcelona et al.1985), which related to the monitored variables in this study. Groundwater samples were collected using the procedures of (Shelton, 1994; USEPA, 2000; Hem, 1990). All equipment used for sample collection, storage, and analysis of chemical components were cleaned using de-ionized water. Such cleaning and storage procedures ensure that there are no detectable contaminants in the sampling equipment (Shafer etal.1997). The samples were collected from discharge pipes of submersible pumps, preserved in polypropylene bottles after filteration process through 0.45 mm paper filters. Groundwater pH, temperature and electrical conductivity were determined at the sites of sample collection. The pH was measured using a field pH meter that was standardized immediately before each reading. Conductivity in micro-Siemens per centimeter was measured using conductivity meter. The instrument was calibrated before use in the field. The values of electrical conductivity are reported as conductivity of the water samples at 25̊ C.

2.2. Data Processing

A computer program (Aquifer Test 4.2) is used for the purpose of interpreting the results of pumping and recovery tests to extract the hydraulic parameters of Mullusi aquifer.The following methods are used in the analysis of pumping and recovery tests to find the hydraulic coefficients of Mullusi aquifer depending on the references of (Kruseman and Ridder, 1994), (Fitts, 2002) and (Walton, 1970).

1- Theis method in wells (W-1 and W-5868).
2-Theis with Jacob correction methodin wells (W-1 and W-5868).
3-Hantush with Storage method in wells (W-1 and W-5868).
4-Cooper and Jacob methodin wells (W-1, W-9 and W-5868).
5-Monech Fracture Flow method in wells (W-1and W-9).
6- Warren Root (double porosity) method in wells (W-1, W-9 and W-586).
7- Agarwal -Theis Recovery method in wells (W-1and W-15).
8-Boulton method in well (W-5868).
9- Theis with variable dischargemethod in well (W-9).
10- Step test method in well (W-9).
11- Hantushmethod in well (W-5868).

The interpretation of hydrochemical phenomena and groundwater flow were determined, based on spatial analysis maps of various physico-chemical variables and static water levels. Rockware-14 program is used in completion of 3D hydrogeologic model and section. The study of groundwater flow was examined, using data base achieved by activity of measuring the static water levels as seasonal regime observation (4th records performed in each borehole) during water year (2009), approved after water point inventory using GPS apparatus (Garmin summit e-Trex).

3. RESULTS

3.1. Hydraulic Properties and Pumping Test

3.1.1. Hydraulic Properties and Pumping Test(Obs.W-1)

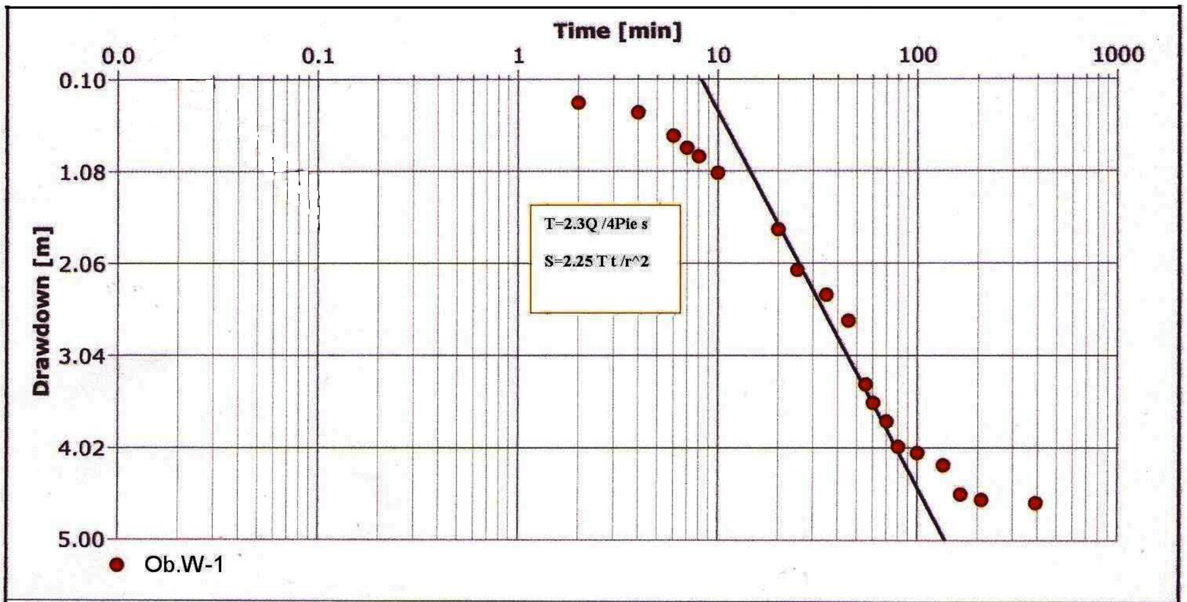
A computer program (Aquifer Test 4.2) is used for the purpose of interpreting the results of pumping and recovery tests to extract the hydraulic parameters of Mullusi aquifer in the region of well (W-1). Summary analysis and processing of data which referred to the abovementioned methods in well (Ob.W-1) are shown in Table (2). The hydraulic parameters of the Mullusi aquifer at the site of the well (W-1) includes, transmissivity, permeability and storage coefficients derived from (Table-2). Hydraulic characteristics of Mullusi aquifer in Dhabaa Site (W-1).

different methods of analysis ranged between (22.3-53.0) m^2/day, (0.177-0.421) m/day and ($0.574x10^{-6}$- $0.397x10^{-3}$), in an average of (36.057) m^2/day, (0.286) m/day and (2.64 $x10^{-4}$), respectively. It is noted that the results obtained from the method of Cooper-Jacob is one of the closest results to the general rates of hydraulic parameters, followed by the results of Monech method (fractures flow) and Warren Root method (double porosity) while the results of other methods are away from general rates. Accordingly, the results of Cooper-Jacob (Fig-5), Monech or Warren Root (Fig-6) methods can be accredited in determining the type and conditions of storage, which emphasizes the type of aquifer is of confined - semi-confined conditions of double storage in the rock pores with small margin of fractures storage.

Warren Root method emphasized that there is slow process of transition through the fractures and the water moves through the pores of water horizons. Also Monech method confirmed that (38.68%) of transmissivity coefficient related to storage in the fractures and (61.32%) is due to storage of the pores, reflected by value of (SF=Kb/Kb'=0.631).Depending on Laboutka classification, 1974), Mullusi aquifer in this location is classified as aquifer of medium transmissivity and permeability.

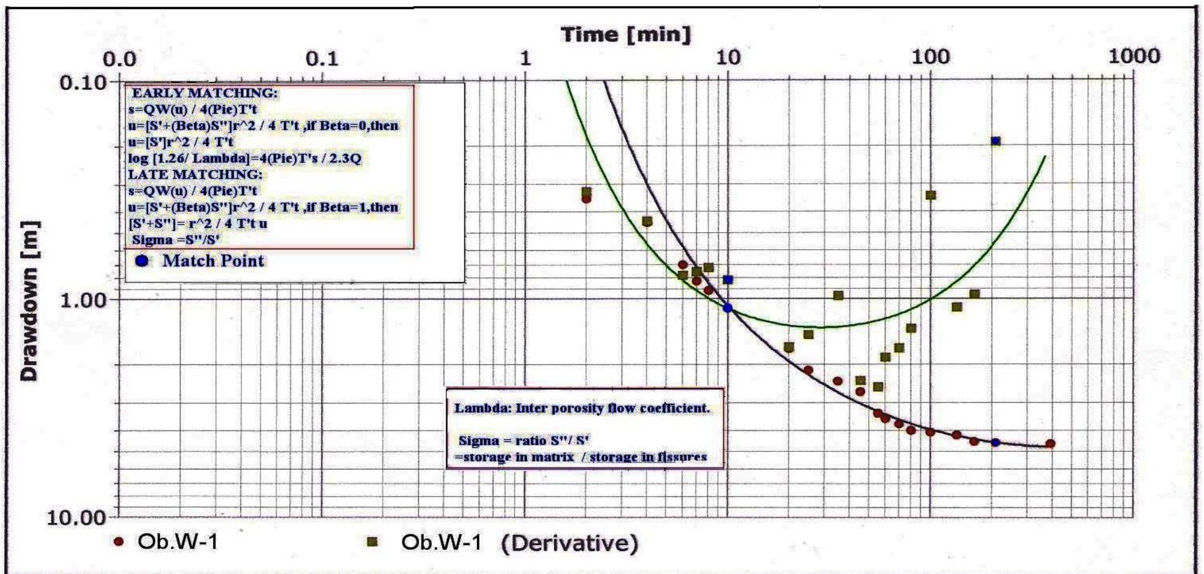
Table-2: Hydraulic characteristics of Mullusi aquifer in Dhabaa Site (W-1).

Method	T (m^2/day)	K (m/day)	S	Remark
Theis	**51.6**	**0.41**	**$0.3x10^{-3}$**	
Theis with Jacob correction	**53.0**	**0.421**	**$0.32x10^{-3}$**	
Hantush with Storage	**22.3**	**0.177**	**$0.172\ x10^{-3}$**	**Hydraulic Resist. (C)=b'/K'=27.8 $x10^5$** **Storage Coeffi. of Aquitard= 0.0012** **L =Leakage factor =$(T*C)^{½}$**
Cooper and Jacob	**35.5**	**0.282**	**$0.396x10^{-3}$**	
Monech Fracture Flow	**32.8**	**0.261**	**$0.574x10^{-6}$**	**Sigma $\sigma=S_m/S_{f}=$ 6.72 $x10^2$** **Gamma (Inter porosity flow Coeffi.)** **$\Gamma = r/b \times K_f/K_m = 0.0191$** **SF= Kb/K'b' =0.631** **SF= Fracture Skin**
Warren Root double porosity	**32.8**	**0.260**	**$0.397x10^{-3}$**	**Sigma $\sigma = S_m/S_f$ =1 $x10^5$** **Lambda $\lambda=\alpha r^2 K_f/K_m = 0.11$** **Kf= fracture Permeability.** **Km=Matrix Permeability.** **Sm= Matrix Storage.** **Sf = fracture Storage. .**
Agarwal-Theis Recovery.	**24.4**	**0.193**	**/**	
Average	**36.057**	**0.286**	**$2.64x10^{-4}$**	



Calculation after Cooper & Jacob					
Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Storage coefficient	Radial Distance to PW [m]	
Ob.W-1	3.55×10^{1}	2.82×10^{-1}	3.96×10^{-4}	33.0	

Fig-5:. Pumping test interpretation according to Cooper & Jacob method (W-1).



Calculation after Double Porosity (Warren Root)						
Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Specific storage	Sigma	Lambda	Radial Distance to PW [m]
Ob.W-1	3.28×10^{1}	2.60×10^{-1}	3.97×10^{-4}	1.00×10^{5}	1.10×10^{-1}	33.0

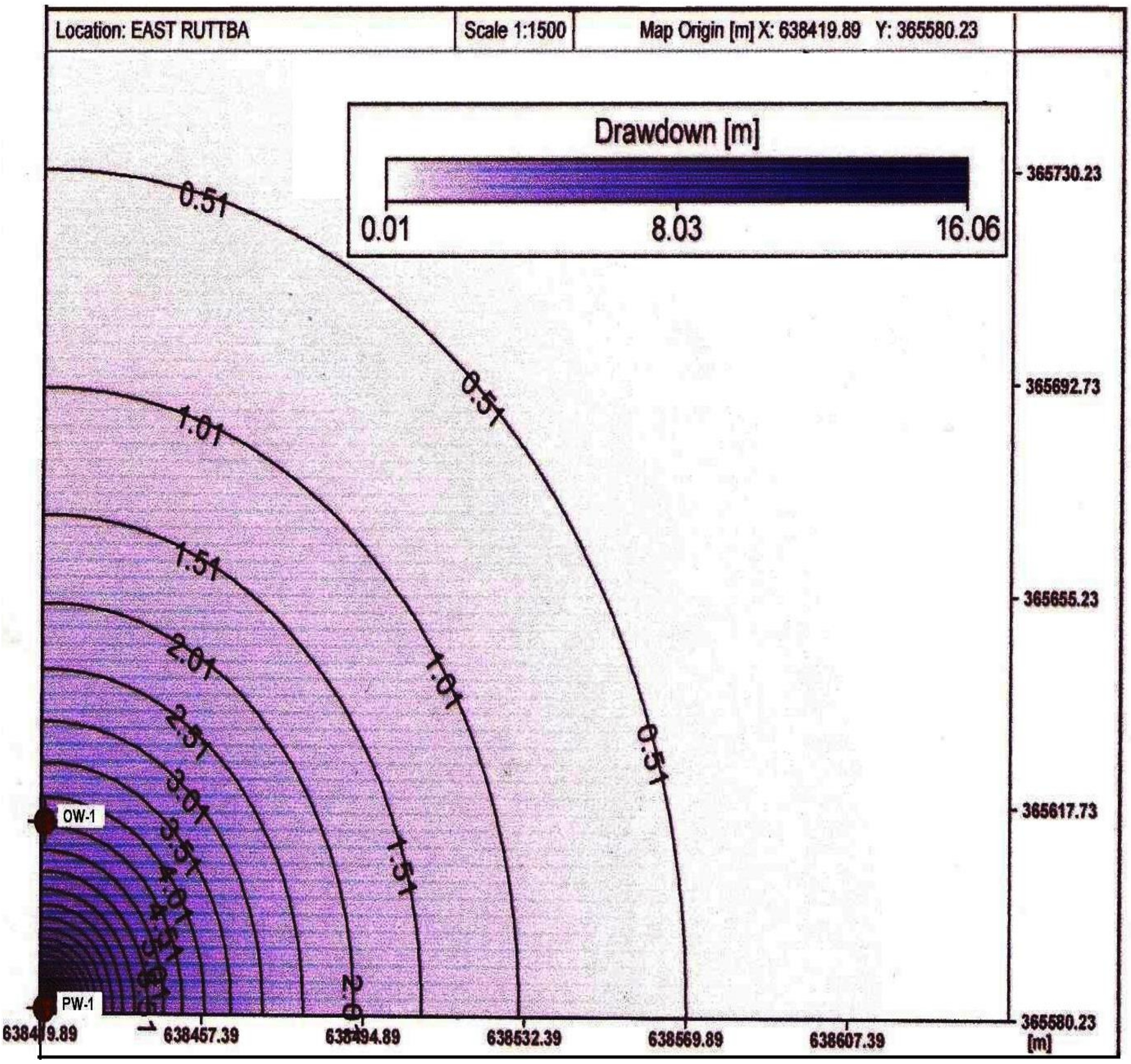
Fig- 6:. Pumping test results according to Warren Root method (W-1)

The distribution map of cone of depression during the period of pumping test Fig (7), showed that the amount of drawdown caused by the process of pumping from the well in a discharge rate of (777 m^3/day) is (31.73 m), while the limits of its impact on a distance of (33 m) is (4.80) meters. Also, the amount of the radius of influence has reached (400) meters, and this means that the effective diameter for such pumping is (800) meters.

The effective diameter represents the critical distance for the distribution network of pumped wells in Dhabaa site, which should not be less than 800 meters in any case, to avoid the phenomenon of excessive depletion of groundwater and the possible deterioration in groundwater quality.

3.1.2. Hydraulic Properties and Pumping Test (W-9).

A computer program (Aquifer Test 4.2) is used for the purpose of interpreting the results of step test, pumping and recovery tests to extract the hydraulic parameters of Mullusi aquifer at this location. Results of hydraulic parameters for Mullusi aquifer at the site of the well (PW-9), includes transmissivity, permeability and storage coefficients derived from different methods of analysis (Table 3), ranged between (1.61-2.57) m^2/day, (0.018-0.072) m/day and (1.79×10^{-1}-3.13×10^{-1}), at averages of



(Fig-7). Cone of depression around Well (W-1).

(2.0175) m^2/day, (0.0351) It is noted that the results obtained from pumping test methods (Table 3) are comparable with the average values of hydraulic coefficient and reliable to the results of the Thies variable discharge (Fig-8) and Monech methods in determining the type and conditions of storage.

The results of these methods revealed a high probability of the presence of groundwater in unconfined- semi-confined conditions of storage in the pores of rocks and fractures together. Warren Root method emphasized that there is a slow transition process of groundwater through the fractures and the predominant of water

moves through the pores of the rocks. Also Monech method, (Fig-9), indicated that (50%) of the value of coefficient of transmissivity related to fractures storage and (50%) is due to pores storage, which reflected by the value of [SF (fracture storage) =Kb/Kb'=1). Finally, and depending on Laboutka classification(Laboutka, 1974) classifies

Mullusi aquifer in this location considered within the aquifers of low transmissivity and permeability at a discharge of (100.6, 181, 261.5, 342, 422, 503 and 627) m^3/day is (14, 27, 39, 60, 73, 92 and 93.5) meters, respectively. The result of step test pumping Fig (10) indicates that the amount of drawdown caused by pumping in the productive well. Also, the value of

Well Loss is of about (20) meters and Well Efficiency of about (79%). On the base of this information, type and appropriate pump can be installed within the above-mentioned limits of discharge and drawdown.

3.1.3. Hydraulic Properties and Recovery Test at the Well (W-15)

A computer program (Aquifer Test 4.2) is used for the purpose of interpreting the result of recovery test to extract the hydraulic parameters of Mullusi aquifer at this location.

Table-3: Hydraulic parameters of Mullusiaquifer at Dhabaa site (W-9).

Method	T (m^2/day)	K (m/day)	S	Remark
Theis variable discharge	2.18	0.0233	$2.56x10^{-1}$	
Cooper and Jacob	2.57	0.0274	$1.79x10^{-1}$	
Monech Fracture Flow	1.71	0.018	$2.85x10^{-1}$	Sigma $\sigma = S_m/S_f$ = 8.65 $x10^3$ Gamma (Inter porosity flow Coef.) $\Gamma = r/b \times K_f / K_m$ =0.1 SF= Kb/K'b'=1.0 SF= Fracture Skin
Warren Root double porosity	1.61	0.072	$3.13x10^{-1}$	Sigma $\sigma = S_m/S_f$ = 1 x 10^3 Lambda $\lambda = \alpha r^2 K_f / K_m$ = 0.0495 Kf= fracture permeability. Km=matrix permeability Sm= matrix storage. Sf = fracture storage.
Average	2.0175	0.0351	$2.58x10^{-1}$	

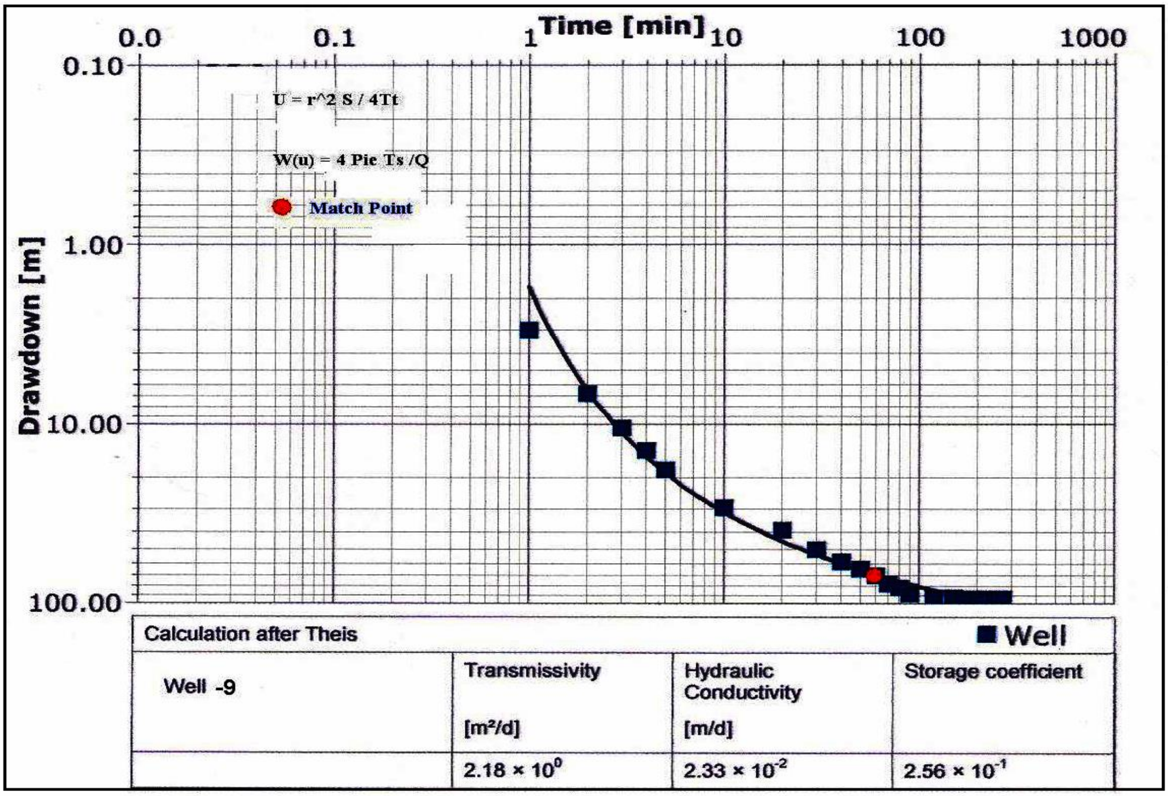


Fig -8:Pumping test results according to Theis variable discharge method at (W-9).

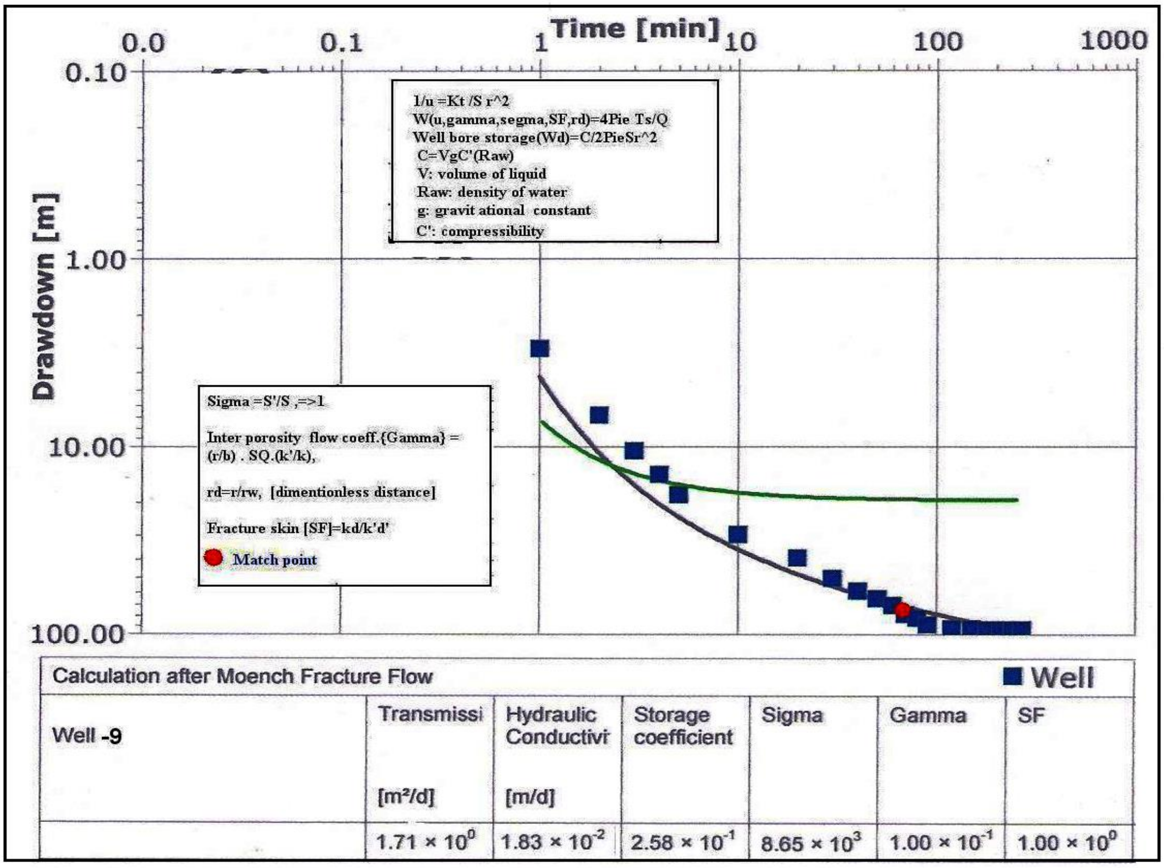


Fig -9: Pumping test results according to Monech Fracture Flow method at (W-9).

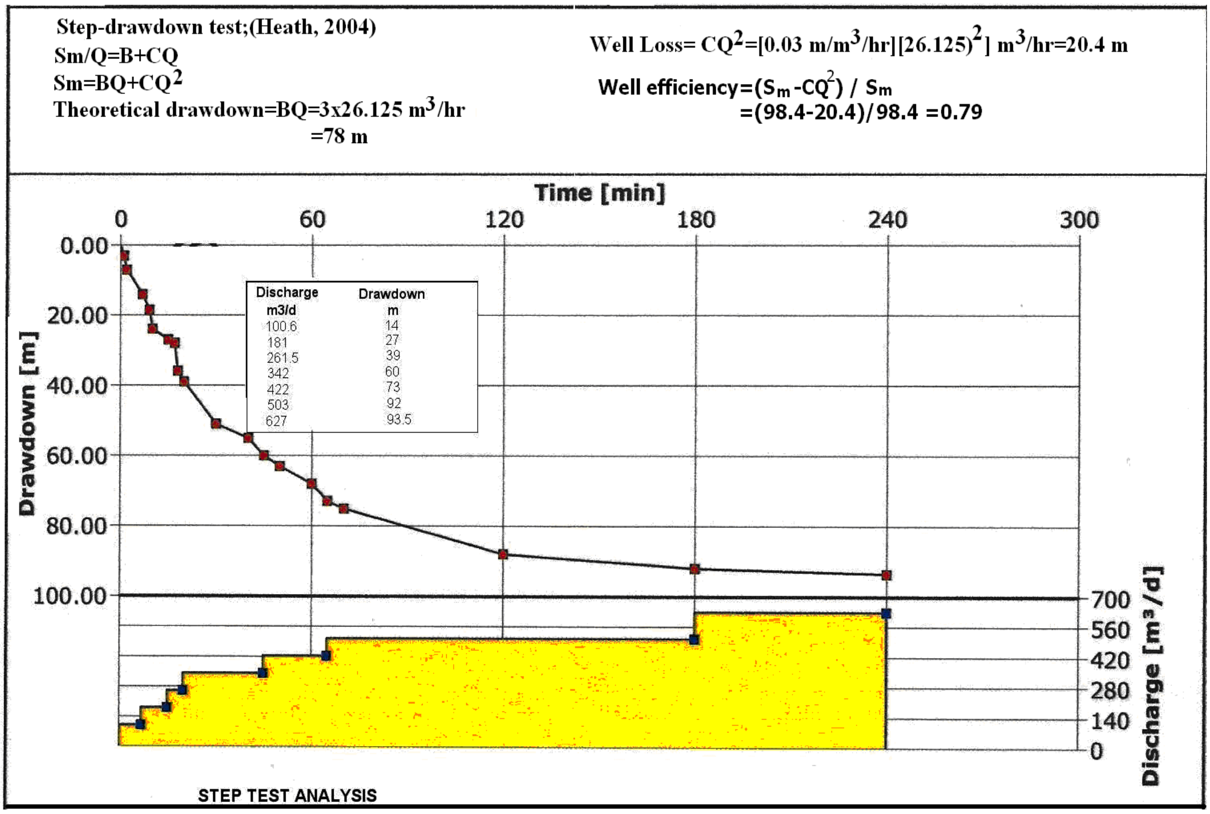


Fig -10:Interpretation of step test analysis (W-9)

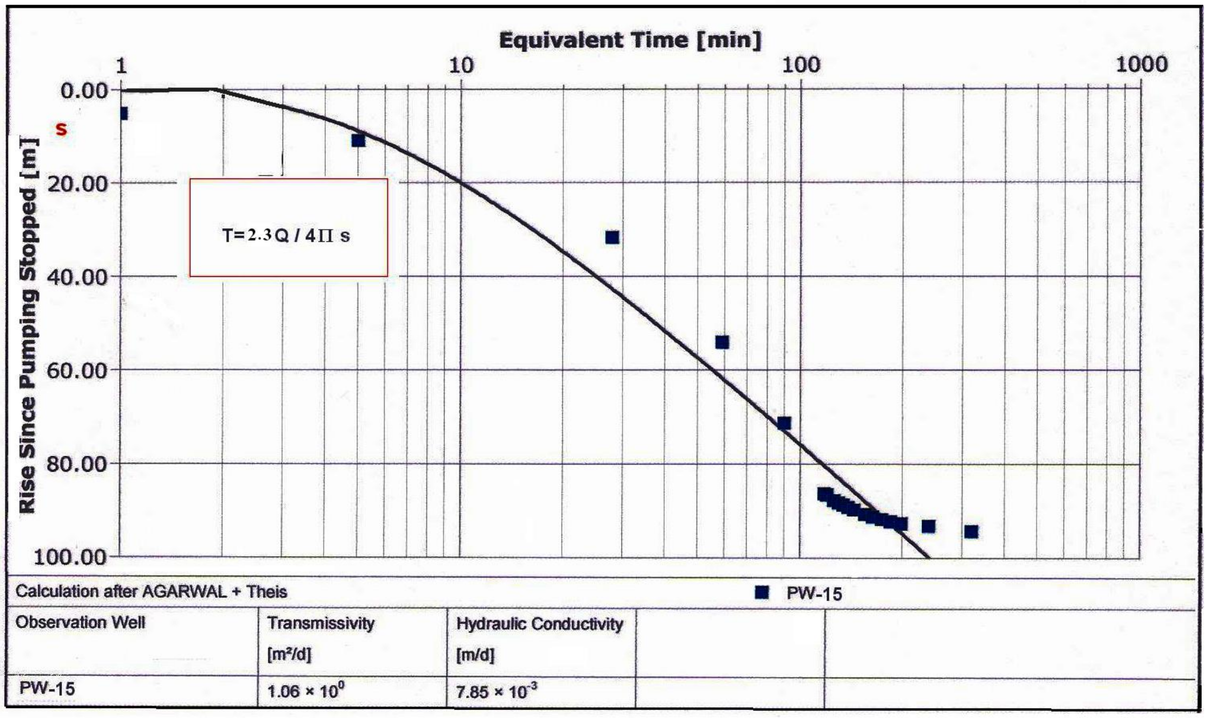


Fig-11: Recovery test analysis at (W-15)

Analysis and processing of recovery data using Agarwal-Theis recovery method of the production well (PW-15) is illustrated in (Figure-11).

The coefficient of transmissivity and permeability of Mullusi aquifer at this location are 1.06 m^2/day and 0.00785 m/day, respectively, and classified within the aquifers of low transmissivity and permeability.

3.1.4. Hydraulic Properties and Pumping Test (W-5868).

The following methods (Kruseman and Ridder, 1990) are used in the analysis of the pumping results and find the hydraulic parameters of Mullusi aquifer with the assistance of software (Aquifer Test 4.2).

1- Theis method.
2- Boulton method.
3- Hantush with Storage method.
4- Hantush method.
5- Theis method with Jacob correction.
6-Warren Root double porosity method.
7- Cooper and Jacob method.

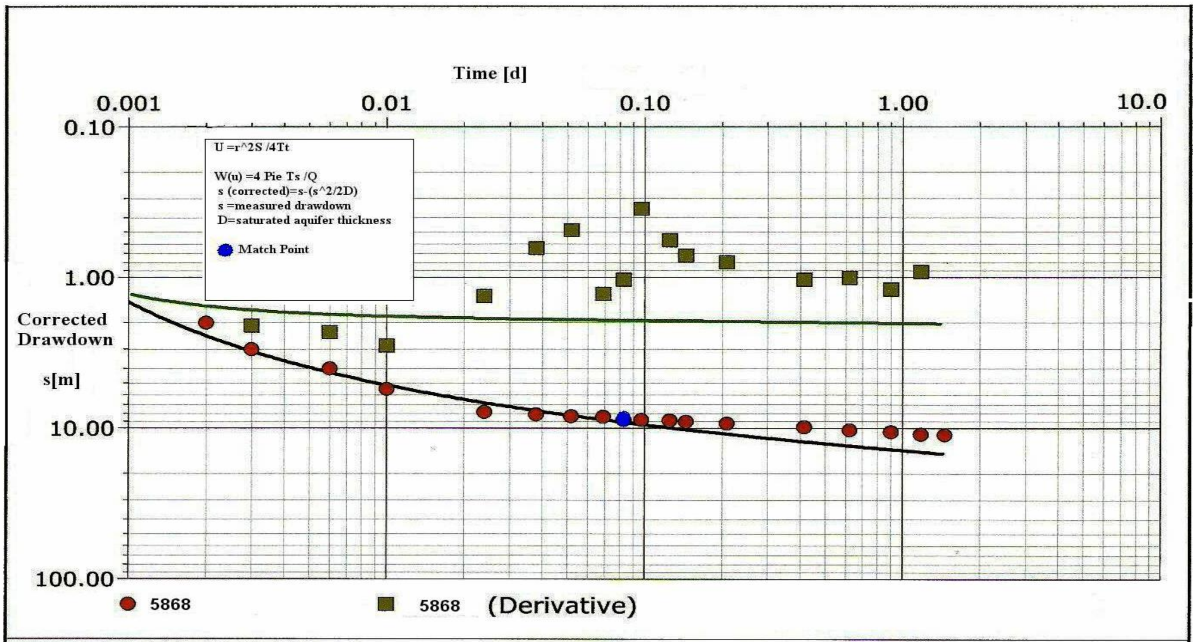
The results of the hydraulic parameters for Mullusi aquifer in the site of well (W-5868), which include values of transmissivity, permeability and storage coefficients, derived from different methods of analysis (Table 4), ranged between (1.12-4.04) m^2/day (0.0086-0.171) m/day and ($1.0x10^{-4}$-$18.6x10^{-2}$), at average of (2.27) m^2/day, (0.0366) m/day and (2.73 $x10^{-2}$), respectively.

Table -4: Hydraulic parameters of Mullusi aquifer at Dhabaa site (W-5868).

Method	T(m^2/day)	K (m/day)	S	Remark
Theis	1.650	0.012	0.0164	
Theis with Jacob	2.22	0.171	0.0082	
Cooper and Jacob	3.14	0.024	0.0027	
Boulton	1.12	0.0086	0.1680	Ratio (Sy/S) =11.9 Drainage Factor = 0.0117 Sy= drainage storage. S=elastic storage.
Hantush with Storage	2.16	0.0166	0.0074	Hydraulic Resist.(C) = b'/K'=46.4 Storage Coef. of Aquitard = 0.0016 L =Leakage factor =$(T*C)^{½}$
Hantush (Leaky)	2.19	0.0168	0.0076	Hydraulic Resist.(C) =b'/K' = 49.8
Monech Fracture Flow	1.65	0.0127	0.0082	Sigma $\sigma = S_m/S_f$ =11.2 Gamma (Inter porosity flow Coef.) $\Gamma = r/b \times K_f /K_m$ = 0.525 SF= Fracture Skin SF= Kb/K'b'= 200
Warren Root double porosity	4.04	0.0311	0.0001	Sigma $\sigma = S_m/S_f$ = 100 Lambda $\lambda=\alpha r^2 K_f / K_m$ = 0.1 Kf= fracture Permeability. Km=Matrix Permeability Sm= Matrix Storage. Sf = Fracture Storage.
Average	2.271	0.0366	$2.73x10^{-2}$	

It is noted that the results obtained from Thies – Jacob, Fig (12) in addition to Hantush (Leaky) method Fig (13) are of closest results to the amount of average for hydraulic parameters followed by the results of Thies , Monech (fracture flow) and Hantush (Storage) methods, while the results of the rest methods are far away than average value. The results of Thies-Jacob and Hantush (leaky) methods are accredited in determining the type and conditions of storage, which confirmed the type of aquifer is of semi-confined conditions of double storage in the rock pores with small margin of fractures storage. The value of coefficient of storage in aquitard, depending on Hantush (Storage) is of about (0.0016), while the coefficient of storage in aquifers is of about (0.0058).

The results of Monech method (fracture flow) indicates that most depleted water caused by pumping moves through the pores of rocks by (99.51%) compared with water moving through fractures by (0.49%), which reflected by the value of (SF=Kb/K'b'=200). This explains the low productivity of the aquifer at this site compared to a record obtained from the well (W-1), since the value of (SF= Kb/Kb'=0.631),where (38.68%) percent from the value of transmissivity coefficient related to storage in the fractures and (61.32%) percent is due to pores storage. Depending on Laboutka classification (Laboutka, 1974), Mullusi aquifer in this location considered within the aquifers of low conductivity and permeability.



Calculation after Theis with Jacob Correction

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Storage coefficient	Radial Distance to PW [m]	
5868	2.22×10^{0}	1.71×10^{-2}	8.26×10^{-3}	0.61	

Fig:12: Pumping test results (Theis with Jacob method)

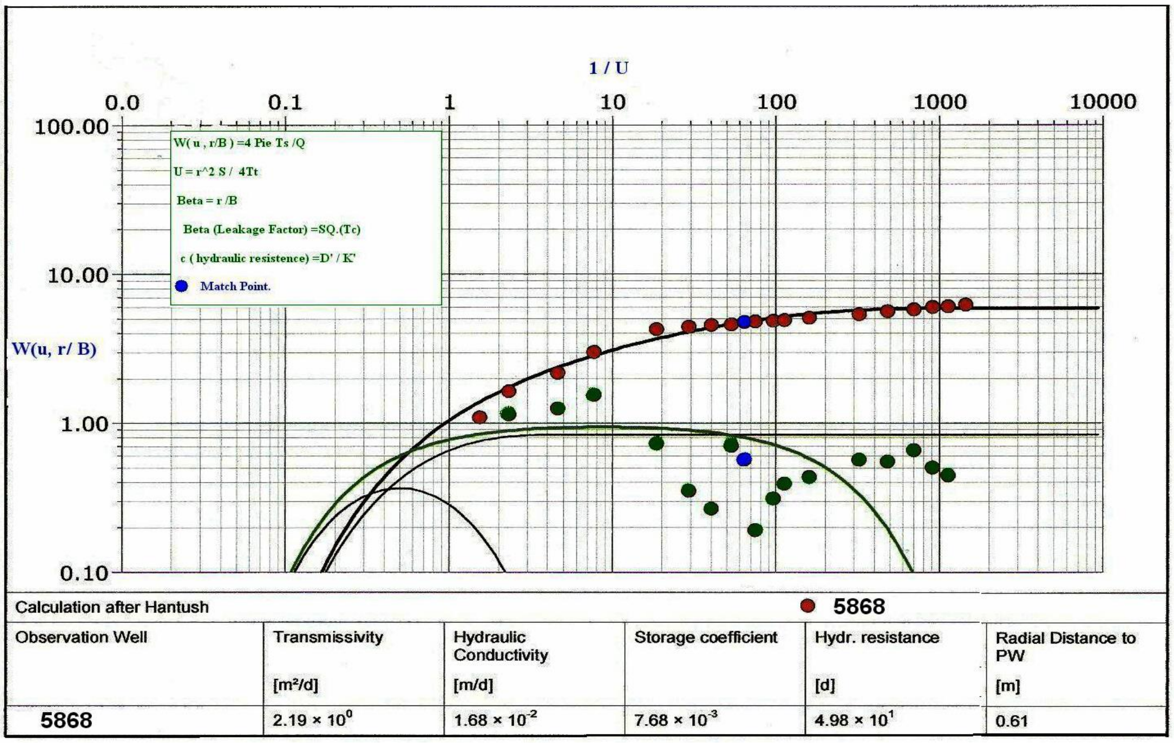


Fig -13: Pumping test results (Hantush method at W-5868).

Finally, the values of hydraulic parameters for Mullusi aquifer within Dhabaa site can be summarized in table (5), which proves that the aquifer is characterized by certain types of aquifers with medium transmissivity and permeability under semi-confined conditions.

The radius of influence in the four test groups are (400, 259.7, 190.12 and 33.6) meters with an average of (220.85) meters, resulting in a discharge of (777, 627, 375 and 50) m^3/day and at a rate of (457) m^3/day.

3.2. Groundwater Movement

The ground water moves in trends of (NE, E and SE) in the sector limited by equipotential lines of (595-485 m asl.)

Table -5: Hydraulic parameters of Mullusi aquifer within Dhabaa site

WELL NO.	T(m^2/day)	K(m/day)	S	Remark
W-5868	2.271	0.0366	2.73x 10^{-2}	R=575 x s √ T =575 x11.4 √2.6x$10^{-5}$$m^2$/sec R=33.6 m.(calculated.),Q=50 m3/day
W-1	36.057	0.286	2.64 x 10^{-4}	R (effective radius) = 400 m. (field). Q=777 m^3/day
W-9	2.0175	0.0351	0.285 x 10^{-2}	R=575 x s √T =575 x93.5√2.3x10^{-5} R=259.7 m.(calculated.),Q=627 m^3/day
W-15	1.06	0.00785	/	R=575 x s √T =575 x94.4√1.2x10^{-5} R= 190.12 m.(calculated.),Q=375 m^3/day
Average	10.351	0.091	10.14x10^{-3}	R=220.85 m. (average).Q=457 m^3/day

between recharge zone in Horan valley and discharge zone in the area of Dhabaa project, (Hussien, 2010). The amount of hydraulic gradient ranged between (0.00059-0.04597) with an average of (0.0233), where the groundwater flux and groundwater pore velocity are reached (0.0160 m/day) and (1.60 m /day), respectively. And to shed light on decline phenomenon, Fig (14), shows a distribution model of groundwater levels in three dimensions within Dhabaa site represented by (17) water wells produced from Mullusi aquifer. The model indicates that the groundwater in Dhabaa site moves in different directions and heavily influenced by depletion and reached its peak in the wells (W-10, 11). Hydraulic gradient ranged between (0.00009-0.026) with groundwater flux of (0.000008-0.0023) m/day and groundwater pore velocity of (0.0008-0.23) m/day. These variations are occurred as a normal result of pumping operations from the water wells.

3.3. Groundwater Observations:

3.3.1. Groundwater Temperature

Groundwater temperature of Mullusi aquifer within Dhabaa site ranged between (17.9-21.6) ^{o}C with an average of (18.6) ^{o}C. The groundwater classified as cold water according to the classification of (Hem, 1970). The variation in groundwater temperature observed at significance level of (19.8%), which calculated according to the following statistic equation: Significant level % = [(max. temp – min. temp) / average temp.] x 100 = [(21.6 -17.9) / 18.61] x 100 = 19.8%

These variations observed through the values of heat flow gradient in the groundwater of Dhabaa site, reached between (0.00001-0.0016)^{o}C/meter, which increased in general direction from the southern part to the northern part, with spot deviations trends to NW and NE. It is noted that the distribution of the increasing phenomenon of groundwater temperature which measured on the same time of water level measuring in wells, however, caught up to some extent with the distribution o

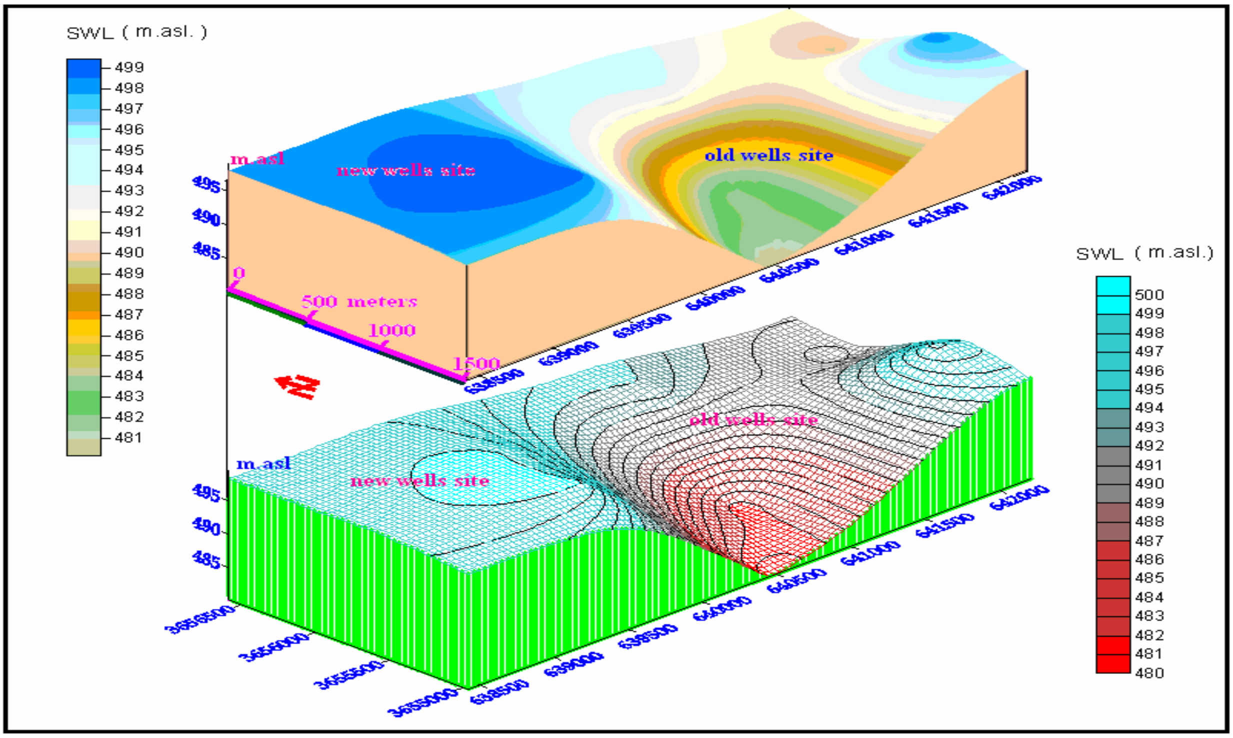


Fig-14: 3D model of static water level within Dhabaa site

low water table phenomenon in the eastern and north eastern portions, and not synchronized with the other sectors (indicates the impact of dewatering on the groundwater characteristics).

3.3.2. Electrical Conductivity

Electrical conductivity of groundwater of Mullusi aquifer in Dhabaa site ranged between (1030-1350) micro Siemens/cm at an average of (1186) micro Siemens/cm. The variation in electrical conductivity is observed at a significance level of (26%). These variations observed with increasing of groundwater EC grade at Dhabaa site by (0.003-0.463) micro Siemens- cm/meter and up to maximum limits in three wells (W-3,W-11 and W-17). New Dhabaa site characterized by low EC values, which is consistent with the lower temperature phenomenon and a lower decline in water table.

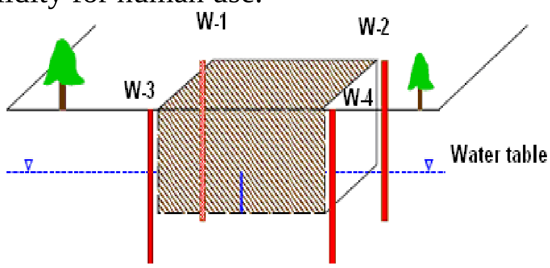
3.3.3. Acidity

PH values of groundwater in Mullusi aquifer within Dhabaa site ranged between (7.21-7.65) pH at an average of (7.4) pH. The variation in pH is observed at a significance level of (5.9%). These small changes observed where the degree of pH increase within Dhabaa site (pH grade) ranged between (0.00074-0.000002) pH/m and reaching up to maximum in wells (W-14 and W-15). The groundwater of new wells site in Dhabaa project, relatively characterized by low values of pH compared to groundwater of old wells site. There is a possibility of existence phenomenon related to mixing water from two sources, first from the west sector and the second from the SW sector. The scope of mixing includes the designated area in the N and NE part of the study area (site of the old wells). The mixing zone is determined based on the scientific function of increasing pH values with the direction of groundwater movement in carbonate aquifers.

4. DISCUSSION

Pumping System Design and Distribution of Wells

Based on the hydraulic information obtained from pumping test at Dhabaa site , depending on the main specific conditions related to radius of influence reaching (1000) meters. A best design was made for the number and distribution of the wells to ensure the best productivity from the wells without exposing the aquifer to the case of critical depletion that displays degradation in quality of groundwater or to mix with ground water of bad quality and less validity for human use.



The average values of discharge, transmissivity and storage coefficients have been used in the equations below (Dawson, etal, 1991), which includes the distribution of four to five wells to determine the amount of the drawdown in groundwater level (depth of depletion) in the area of (1) km^2, discharge rate of (457.28) m^3/day, coefficient of transmissivity (10.35) m^2/day, coefficient of storage ($1.01X10^{-2}$) and radius of influence (1000) meters.

First case: system of four wells:

The value of decline in groundwater level referred to SWL is (85.18) meters, means, the amount of depletion in the area of influence is (165.18) meters from the land surface, as following calculation.

4 wells $s = [2.3\,Q / 4\pi T]\,[\log_{10}(2.25^4\,T^4 t^4 / S^4 r_1^2 r_2^2\, r_3^2\, r_4^2)]$

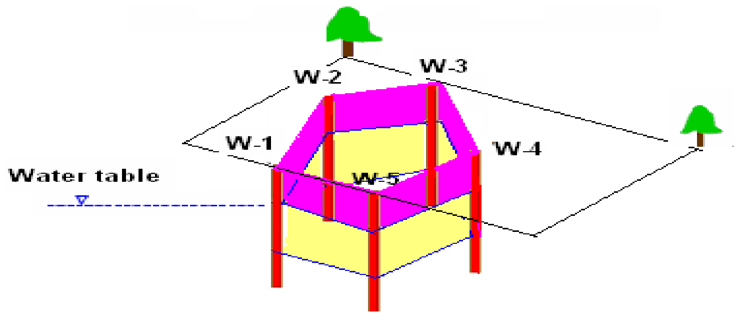
$=[(2.3\,x457.28) / (4x\,3.14\,x\,10.35)]\quad[\log\{(2.25^4 x10.35^4 x1^4) / (0.01^4\,x\,1000^8)\}]$

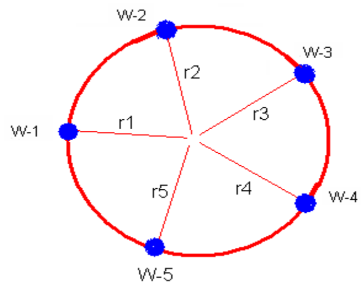
Dewatering = 85.18 meters

Depth of dynamic water level during dewatering= 85.18 + 80 =165.18 meters from land surface.

Second case: system of five wells:

The value of drawdown in groundwater level referred to SWL is (106.46) meters, in other words, that the amount of depletion in the area of influence is (186.46) meters from the land surface. This forms depth of high depletion caused irregular flow of the pumps or to stop discharge after a short period of startup. The drawdown may leads deepening of wells to preserve continuous discharge and thus approaching the upper limits of Gaara aquifer, which may cause deterioration in groundwater quality .Therefore the best number and distribution of the wells to ensure proper fit for discharge processing is displayed in the first case.





5 wells :

$s = [2.3\,Q / 4\pi T]\,[\log_{10}(2.25^5\,T^5 t^5 / S^5\, r_1^2 r_2^2 r_3^2 r_4^2 r_5^2)$

$=[(2.3 \times 457.28) / (4\times 3.14 \times 10.35)][\log\{(2.25^5 \times 10.35^5 \times 1^5) / (0.01^5 \times 1000^{10})\}]$

Dewatering =106.46 meters.

Depth of dynamic water level during dewatering = 106.46+80 = 186.46 meters from land surface. The population of Rutba city is of about (32000) people, and if take into consideration the district affiliated with the ports and border posts and travelers to the neighbor countries should be planning for a population of (35000) people. Depending on standards for the individual's need of water per day for drinking and domestic purposes reached (135) liters/day per capita (Chenoweth, 2008), therefore 35000 people, should be obtained a volume of water of (135x35000 = 4725000) liters per day, or (4725) m^3/day.

Comparing the volume of required water (4725) m^3/day with total capacity of (17 wells) in Dhabaa project of (6515) m^3/day, it is sufficient and covers the need required by (15) wells and maintains two standby wells. Looking at the distribution map of wells within Dhabaa project Fig (1) and comparing with the results obtained from the paragraph of design and distribution, shows unsuitable distribution of wells, where the hydrogeological situation of the aquifer is in a degradation trend and if it stays on this case, the alternative solves may be difficult and costly, as it should be left the site entirely with all wells and its facilities.

5. CONCLUSIONS

- Two phenomena of groundwater depletions are indicated by increasing values of hydraulic gradient, the first in the form of a circular area, where the hydraulic gradient values ranging between (12-17) m/km, as it was falling of groundwater level at Dhabaa site from level 520 to level 505 meters asl, with drawdown of 15 m. The second increase phenomenon in hydraulic gradient values range between (7-12) m/km, in the form of flume moving toward Dhabaa from area east of Rutba by (7) kilometers, as it was falling groundwater level from level 560 to level 555 meters asl, with drawdown of 5 m. Therefore, any possible increase in drawdown of groundwater level in Dhabaa site would lead to capture groundwater in the vicinity, causing the expansion of the scope of depletion, which in turn increases the possibility of mechanical mixing laterally and vertically. The mixing case may lead to water deterioration, where groundwater salinity of Gaara aquifer is higher than in Mullusi aquifer.
- The groundwater movement map indicates that the groundwater in Dhabaa site moves in different directions influenced by depletion process in a hydraulic gradient ranged between (0.00009-0.026) with

groundwater flux of (0.000008-0.0023) m/day and groundwater pore velocity of (0.0008- 0.23) m/day. These variations are occurred as a normal result of pumping operations from the water wells.

- Mullusi aquifer is characterized by certain types of aquifers with medium transmissivity and permeability under semi-confined conditions, where the values of permeability, transmissivity and storage coefficients are ranged between (0.00785-0.286) m/day, between (1.063-6.057) m^2/day and between (2.64 $x10^{-4}$-2.73$x10^{-2}$) respectively.
- Pumping system and distribution of wells is designed using system of four wells to solve the impact of depletion in Dhabaa site.
- The plan is ideal for processing must be applied according to the following proposals:

- Pumping from the first group , which includes wells (W-1,3,6,7,10,12,15 and16) operated in one shift every six hours, alternating with the wells of the second group, which includes wells (W-4,5,8,9,11,13 and 17). While the wells (W-2 and 14) can be operated in case of stop pumping from any well or be under maintenance period.
- This process will achieve groundwater discharge of (2875) m^3/day, conforms to the terms of right pumping without water depletion in aquifer or quality deterioration.
- In order to reach the water demand for Rutba people in accordance with international standards, that should obtained additional water reaches (1850) m^3/day, and can be provided through drilling five boreholes with space interface of not less than (1000) meters. Polygonal or line battery system is preferred for wells distribution. The depth of wells ranges between (210-235) meters, diameter of casing and screen pipes are of (10) inches, and the screen pipes installed at a depth ranging between (110-220) meters from the land surface.
- The choice of five wells site is open to large distance extends between Dhabaa site and Msad el Rutba Valley, but the best option is closest to Dhabaa and Dhalaa valley, depending on the hydrochemical characteristics of groundwater.

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