Estimation of Groundwater recharge by groundwater level fluctuation method of Dibdibba aquifer at Karbala- Najaf plateau, central of Iraq

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Abstract

Groundwater recharge estimation is essential for management of groundwater systems. As groundwater is a vital source of water for domestic and agricultural activities in the study area (Karbala - Najaf plateau), where the Dibdibba aquifer represents the primary and essential aquifer, evaluation of groundwater recharge is critical in the study area. A wide range of methodologies exists for estimating recharge. The water-table fluctuation method strategy might be the most generally utilized system for estimating recharge; it requires learning of changes in water levels over time and specific yield. Advantages of this approach include its simplicity and an insensitivity to the mechanism by which water moves through the unsaturated zone. Sensitiveness in measures created by this technique relates to the compelled precision with which specific yield can be calculated and to the degree to which assumptions inherent in the strategy are valid. The primary objective of this study is to calculate the annual and monthly values of recharge for Jan. 2010 through Aug. 2017 for Dibdibba aquifer at Karbala - Najaf plateau, central of Iraq to use results in the management of groundwater in the study area later. Water levels measured in four observation wells in the study area, measurements were taken daily at the middle of the night automatically by using modern electronic devices installed on the wells (from 10 BM to 4 AM) to avoid the effect of pumping activity on the water levels and to neutralize the effect of evapotranspiration for Jan. 2010 to Aug. 2017.

Keywords: Recharge, water-table fluctuation**,** Dibdibba, specific yield

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حسـاب التغذية باستخـدام طريقة تذبذب مستوى المياة الجوفيـة في خزان الدبدبـة الجوفي ضمن هضبـة كربـلاء – نجف ، وسـط العراق

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الخلاصـة

تقدير تغذية المياه الجوفية هي عملية ضرورية لإدارة أنظمة المياه الجوفية. بما أن المياه الجوفية هي مصدر حيوي للمياه للأنشطة المنزلية والزراعية في منطقة الدراسة (هضبة كربلاء – النجف) ، حيث يمثل خزان الدبدبة الخزان الجوفي الرئيسي والمهم في المنطقة ، فإن تقييم تغذية المياه الجوفية لهذا الخزان مهمة جدا

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في الدراسة. توجد مجموعة واسعة من الطرق والتقنيات لتقدير التغذية. قد تكون استراتيجية او طريقة تذبذب
مستوى المياه هي الأكثر استخدامًا لتقدير تغذية المياة الجوفية ؛ يتطلب معرفة التغييرات في مستويات المياه
مع مرور الوقت العطاء النوعي specific yield . وتتميز هذة الطريقة او النهج بالبساطة وعدم حساسيتها
للآلية التي تنتقل بها المياه عبر المنطقة الغير المشبعة. الحساسية في هذا الاستراتيجية او الطريقة تتمثل
بمدى دقة العطاء النوعي specific yield التي تم حسابة وإلى مدى صحة الفرضيات المتأصلة في هذة
االإستراتيجية. تقنيات كثيرة تستخدم مستويات المياه (تعتمد في الغالب على معادلة دارسي). الهدف الرئيسي
من هذه الدراسة هو حساب القيم السنوية والشهرية لتغذية المياة الجوفية خلال الفترة من يناير 2010 وحتى
أغسطس 2017 في خزان الدبدبة ضمن هضبة كربلاء – هضبة وسط العراق لاستخدام هذة النتائج في ادارة
المياة الجوفية ضمن منطقة الدراسة فيما بعد. تم مراقبة وقياس مستويات المياه الجوفية تلقائي او اتوماتيكيا
في أربع آبار مراقبة موزعة في منطقة الدراسة باستخدام اجهزة مراقبة الكترونية حديثة منصبة على هذة الابار
حيث تسجل القراءات بعد منتصف الليل   (من الساعة 10 مساءاً حتى 4 صباحًا) لتجنب تأثير نشاط الضخ
على مستويات المياه الجوفية ولتحييد تأثير التبخر من يناير 2010 إلى أغسطس 2017.

1. Introduction

Water is a vital natural resource on which life and food production are based. Attention to water resource is crucial to cover all human needs of drinking and to meet the requirements of agriculture, industrial, and other usages. In recent years, it becomes more evident that the groundwater is one of the most critical natural resources. As a well-equipped source of water, groundwater has some advantageous compared to the surface water; it is less prone to seasonal and long-term fluctuations and eventually has a uniform spread over large areas. Groundwater is often essential in places and areas where surface water is not present.

According to reports of the Ministry of Water Resource, In the last few years the need for water in the Republic of Iraq is tremendously increasing because of population growth and economic development, This coincided with a shortage of surface water supplies mainly due to the expansion of exploitation, investment of water resource in neighboring Iraqi countries (Turkey, Iran, and Syria), and the absence of long-term agreements with these countries to regulate water quotas. In light of these challenges, uses of groundwater as an alternative resource is of importance to cope with the expected shortage of surface water. The Ministry of Water Resource of Iraq was aware of such risks and launched a campaign to re-evaluate the aquifers in Iraq and the possibility of investing them to face the scarcity of water in the future. As a part of this campaign, this study is oriented to re-assessment of the Dibdibba unconfined aquifer in the Karbala – Najaf plateau in central of Iraq. The re-assessment of the hydrogeological system in the Karbala – Najaf plateau has great importance to keep pace with the agricultural, industrial, and demographic expansion. The number of operating wells in the Dibdibba has reached more than 3000 wells according to the latest survey of water points carried out by the General Commission of Groundwater/ Karbala branch. Therefore, it became essential to calculate the annual and monthly values of recharge for this aquifer and adopted these values in the modeling process for initial estimate recharge value and then adjusted until a good match between calculated and measured heads was obtained. Recharge has been characterized as "the entry into the saturated zone of water made available at the water-table surface, together with the associated flow away from the water table within the saturated zone" [1]. Accurate evaluation of recharge rates is basic to proper management and protection of valuable groundwater resources. Many methods have been used to calculate recharge. Information on recharge methods is contained in many references such as [2-5]. The groundwater levels fluctuation is most applied methods for calculating recharge values; This is likely due to the abundance of available groundwater-level data and the simplicity of estimating recharge rates from temporal fluctuations or spatial patterns of groundwater levels. This process is named the water-table fluctuation (WTF) method and is usable only to unconfined aquifers, like Dibdibba aquifer in the study area. In addition to monitoring of water levels in one or more wells or piezometers, an estimate of specific yield is required. The current study, four piezometers wells to the monitoring of water levels were used, and specific yield was estimated from a pumping test.

2. The study area

The considered area locates in the central part of Iraq between Karbala and Najaf cities and geographically between (32°00′– 32°50′) latitude and (43°35′– 44°30′) longitude. It is a cone-shaped

plateau encompasses an area about of (2700 km^2), Figure-1. Two scraps bound the plateau; from the northeast by a Tar Al-Sayyed and in the south by Tar Al-Najaf. In the northern part of the plateau, the Razzaza lake is located, and from the east, the quaternary sediments id found. The surface of the plateau is nearly flat, dissected by some shallow flat-floor valleys, and almost covered by pebbly or gypsiferous pebbly soil or gypcrete. Aeolian sand sheets and shrub dunes are present too. The topography elevation ranges from 13 to 207 m with an average 83m. Generally, elevation decreases from west to east. From the geology point of view, the plateau covers by gypcrete deposits except where the Razzaza Lake, Ta-Alsayed and Tar-Al-Najaf are located. The stratigraphic column consists of the following formations (from older to younger): Dammam, Euphrates, Fatha, Nfayil, Injana, and Dibdibba Figure-2. Table-1 provides a brief explanation of these formations. Tectonically, the plateau lies in the northwest part of the Euphrates subzone that is the West part of the Mesopotamian zone of the stable shelf [6]. The study area is considered stable, and the sedimentary cover ranges 7 to 8 km overlying basement rocks. The area is influenced by extension deformations and tectonic tension over the Arabian plate of the Permian/Triassic-Lower Cretaceous Periods. The area is characterized by the presence of two groups of faults. The first group is trending NE-SW and includes Rhaimawi – Hilla Fault and Khanaquin - Baquba - Karbala Fault, Figure-3. There are also two faults oriented in the same direction but the basement only (not apparent on the surfaces). The second group trends NW-SE similar to Abu Jir fault zone which is represented by Heet-Abu Jir fault in the western part of the study area.

From the hydrogeological point of view, Dibdibba aquifer represents the upper main unconfined aquifer in the study area and covers an area of 1100 km^2 from the Karbala-Najaf plateau. The aquifer is fed by seasonal flow stream from direct rainfall within the Plateau [7], (Figure-4). The seasonal flow stream-oriented 40°N towards the Mesopotamian Basin. The Dibdibba alluvial fan delta formed in the early Miocene as a result of a drainage system which remains visible upstream on the Western Desert's carbonate platform [8] .
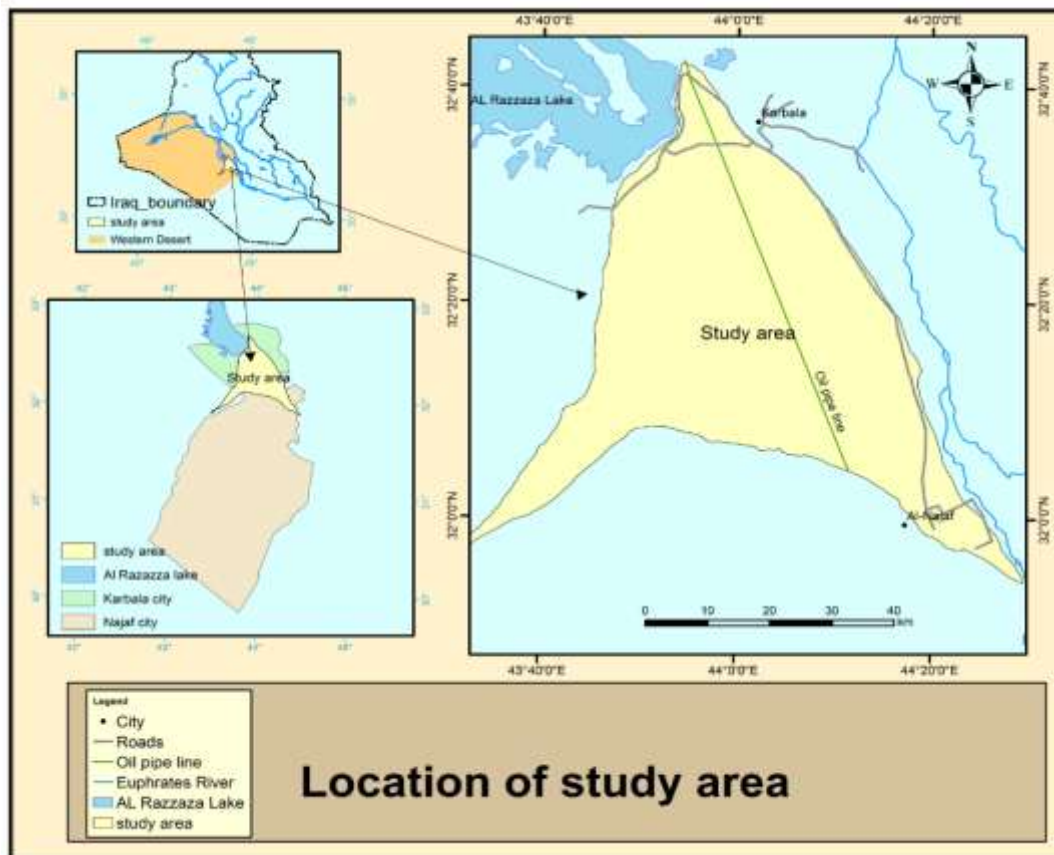

Figure 1-Location of the study area

Table 1-Formation description in the study area

Formation	Age	Environment	Lithology description
Dibdibba	Upper Miocene Pliocene (AP11)	Freshwater environment (Delta)	Sand, pebbles, claystone, sandstone, and silt
Injana	Upper Miocene (AP11)	Lagoon environment	Sandstone, siltstone, and claystone with thin limestone
Fatha	Middle Miocene (AP11)	deposited in broad basin following a marine transgression	Mudstone, gypsum, and silt, interbedded with limestone and marl.
Euphrates	Late lower Miocene (AP11)	Deposited reef and behind the reef	Basal breccia, limestone, and marl
Dammam	Middle-Late Eocene (AP10)	Deposited on a shallow marine shelf with high energy nummulitic shoals and deposited in a lagoonal environment in a subtropical sea.	Consists mainly of neritic shoal limestones often recrystallized and/or dolomitized, nummulitic

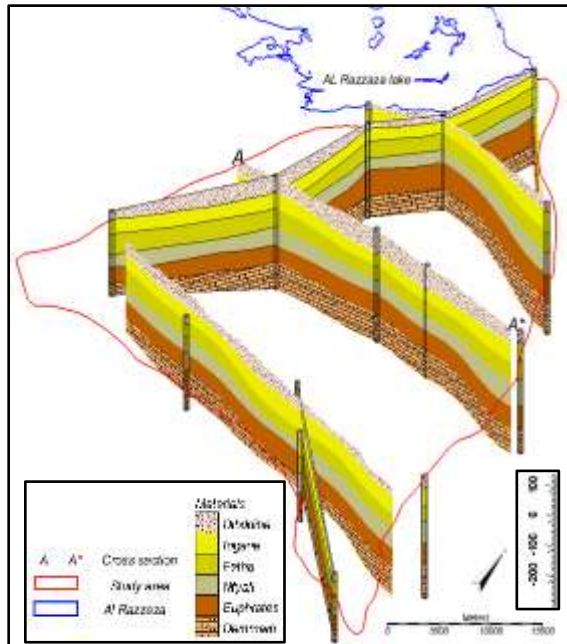*(Formations Dibdibba through Dammam are grouped under the heading TERTIARY in the Age column.)*

Figure 2-Boreholes and Cross Sections in the study area, (Three-dimensional view(
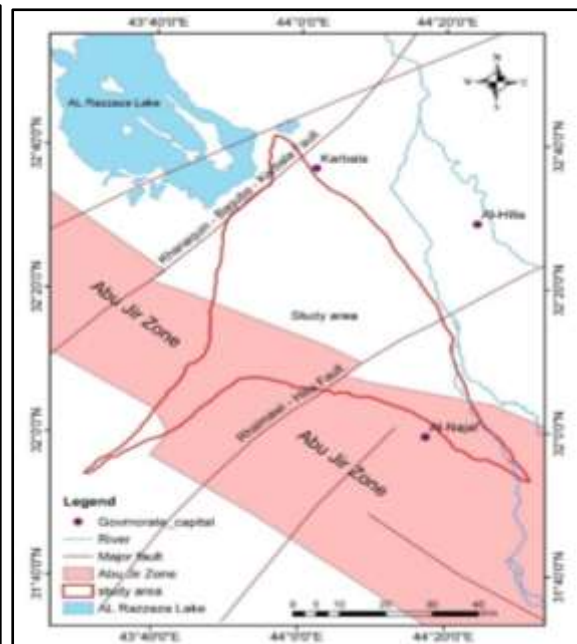

Figure 3-Structural map of the study area {modified from the tectonic map of Iraq (GEOSURV, 1996)}.

The Dibdibba fan delta appears disconnected today from this drainage system, most likely because of recent tectonic movement along the active Abu Jihr fault. The delta of Dibdibba alluvial fan might have also received water from discharging aquifers in the Ma'ania depression located 100 km from the SW, outside the area[8]. The gravels and sand of the Dibdibba formations date from the end of the

Pliocene have been altered by calcite and gypsum[9]. Figure-5 shows the Three-dimensional view of a hydrogeological section of the water table in the Dibdibba aquifer in the study area. The flow direction of groundwater for Dibdibba aquifer in the study area generally from southwest to northeast (i.e., towards Euphrates River) which it is within the regional groundwater flow direction of Iraq as observed in flow net map (Figure-4). The value of the hydraulic gradient as calculated in the study area ranges from (0.0011) to (0.0005).
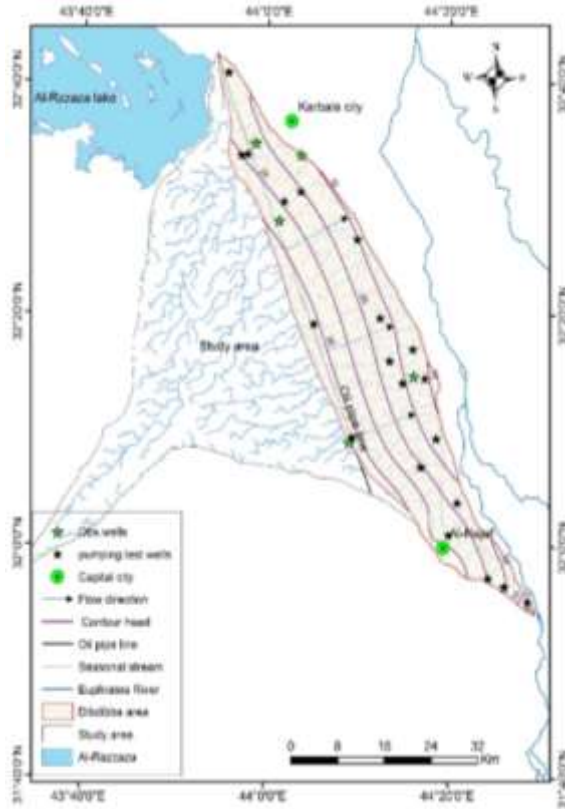

Figure 4-The flow net, seasonal flow stream, Obs. wells and selected wells for pumping test of the Dibdibba aquifer in the study area.
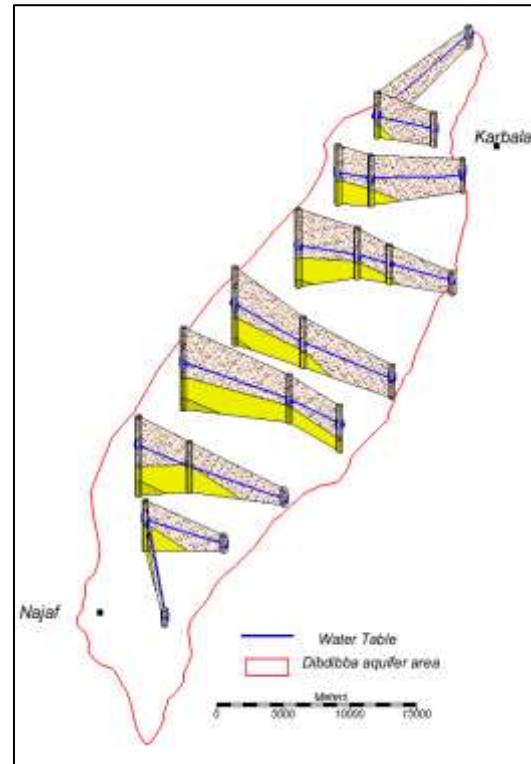
Figure 5-A Hydrogeological section shows the water table in Dibdibba aquifer in the study area,(Three-dimensional view)

3. Materials and methods
3.1 Methodology

The area of Dibdibba aquifer receives an average of annual precipitation of 91.92 mm in Karbala station and 111.29 mm in Najaf station [10], (Table-2). Water levels were measured in four observation wells (Figure-4) daily at midnight. The data logger of type Aqua TROLL 200 was used to measure levels automatically, and the data were analyzed using the Win-Situ V.5 software. The recorder system is programmed to take a reading in the middle of the night (from 10 AM to 4 AM) to avoid the effect of pumping activity on the water levels and to neutralize the effect of evapotranspiration.

Table 2-Mean monthly records of the climatic parameter (Rainfall) at Karbala station and Najaf station for the period (1980-2016) (Iraqi Meteorological organization 2016).

Months	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July.	Aug.	Sep.	Total
Rainfall in Karbala	4.18	10.59	14.16	16.48	15.3	15.14	12.57	3.19	0	0	0	0.309	91.92 (mm)
Rainfall in Najaf	5.30	17.92	16.53	18.03	15.81	14.21	18.03	5.25	0	0	0	0.2	111.28 (mm)

3.2 Water-Table Fluctuation Method (WTF)

As background, consider the groundwater budget for a basin. Changes in subsurface water storage can be attributed to recharge, and groundwater flows into the basin minus base flow (groundwater discharge to streams or springs), evapotranspiration from groundwater and groundwater flows out of the basin [11]. The budget can be written as:

$$R = \Delta S^{gw} + Q^{bf} + ET^{gw} + Q^{gw}off - Q^{gw}on \tag{1}$$

where R is recharge, ΔS^{gw} is changed in subsurface storage, Q^{bf} is baseflow, ET^{gw} is evapotranspiration from groundwater, and $Q^{gw}off - Q^{gw}on$ is net subsurface flow from the study area and includes pumping; all terms are expressed as rates (e.g., mm/year).

The water table fluctuation WTF method is based on the premise that rises in groundwater levels in unconfined aquifers are due to recharge water arriving at the water table, (Freeze and Cherry1979). Recharge is calculated as:

$$R = SY\ dh/dt = SY\ \Delta h/\Delta t \tag{2}$$

Where *h* is water-table level, $\underline{Sy}$ is specific yield, and *t* is time deduction of Eq. (1) suppose that water arriving at the water table goes instantly into storage and that all other components of Eq. (2) Are zero during the period of recharge. A time lag occurs between the arrival of water during a recharge event and the redistribution of that water to the other components of Eq. (2), [12]. If the method is applied during that time lag, all of the water going into recharge can be accounted. This assumption is most valid over short periods (hours or a few days), and it is this period for which application of the method is most appropriate. The length of the time lag is critical to the success of this method. If water is transported away from the water table at a rate that is not significantly slower than the rate at which recharge water arrives at the water table, then the method is of little value [13]. For the WTF method to produce a value for total or "gross" recharge requires the application of Eq. (1), For each water level rise. Equation (2), can also be applied over longer time intervals (seasonal or annual) to produce an estimate of change in subsurface storage, ΔS^{gw} [14] ‹To tabulate a total recharge estimate, Δh is set equal to the difference between the peak of the rise and low points of the extrapolated antecedent recession curve at the time of the peak. The antecedent recession curve is the trace that the well hydrograph would have followed in the absence of the rise-producing precipitation Figure-6. Drawing that trace is a somewhat subjective matter. If long-term hydrograph records are available, many recession curves should be used to trace the pattern. For an estimate of the net recharge, Δh is the difference in head between the second and first times of water-level measurement ‹ (Healy and Cook, 2002). The difference between total and net recharge is equal to the sum of evapotranspiration from groundwater, base flow, and net subsurface flow from the site. With some additional assumptions, the WTF method can be used to estimate any of these parameters [15-17].
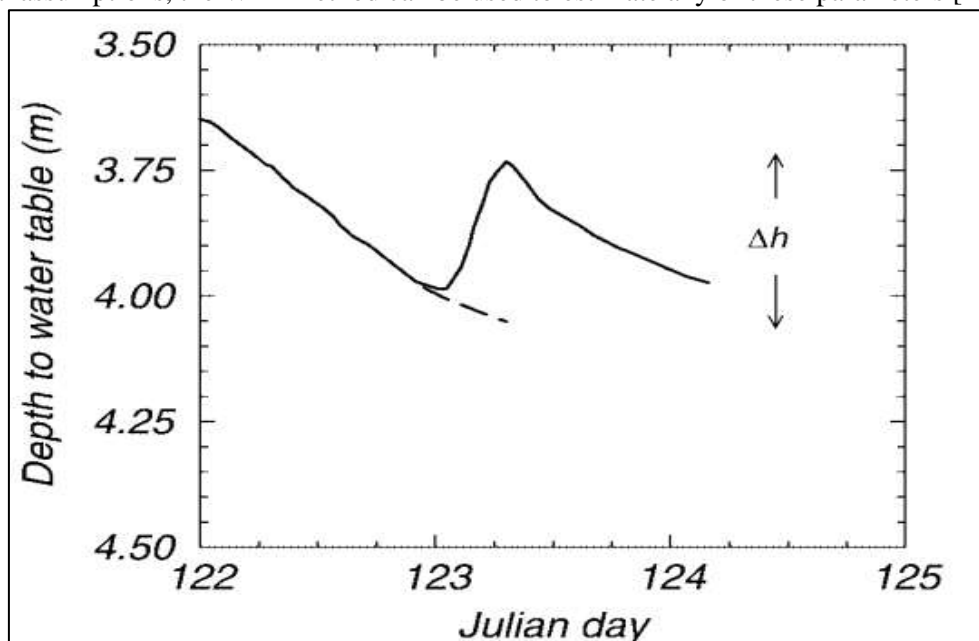

Figure- 6 Hypothetical water-level rise in a well in response to rainfall.

3.3 The water table fluctuation (WTF) method limitations

The fascination with the WTF method lies in its simplicity and facilitating of use. No speculation is made on the details by which water travels through the unsaturated zone; thus, the presence of preferential flow paths within the unsaturated zone in no way restricts its application. Since the water level measured in an observation well is representative of a zone of no less than a few several square meters, the WTF strategy can be seen as a coordinated approach and less a point estimation than those strategies that depend on information in the unsaturated zone. The method, however, does have its limitations [12-13] :

1. The technique is best connected to shallow water tables that show sharp water-level rises and declines.

2. Commonly, recharge rates change considerably inside a basin, owing to contrasts in elevation, land-surface slope, geology vegetation, and other factors.

3. The method cannot provide a calculation for a steady rate of recharge. For example, if the rate of recharge equal to the rate discharge, water levels would not change and the WTF method would predict no recharge.

4. Other snags relate to identifying with recognizing the reason for water-level fluctuations and calculating a value for specific yield.

3.4 Reasons for Water-Table Fluctuations in Unconfined Aquifers

The water table Fluctuations changes are not generally demonstrative of groundwater recharge or discharge (14). Changes in the water level can be attributed to naturally occurring changes in climate and anthropogenic activities (12). The fluctuations in groundwater levels, which occur during the seasons, are prevalent in numerous regions due to the seasonality of precipitation, evapotranspiration, and irrigation.

The water-table fluctuations in short-term happen in light of rainfall, pumping, barometric-pressure Fluctuations, or other phenomena. The WTF method is best connected for short-term water-level rises that happen in light of individual storms (12). These conditions usually happen in areas with shallow depths to the water table. Application of the WTF method for estimating recharge requires identification of the water-level rises that are attributable to precipitation.

4. Results and discussion

4.1 The specific yield measurement

Values of specific yield، Sy, and transmissivity, T, for the Dibdibba unconfined aquifers in the study area are commonly obtained from the analysis of pumping tests conducted over a period of hours (Table-3). Many wells were selected in the Dibdibba aquifer to carry out pumping tests. The distribution of these well was taken to be even as possible as to complete the picture of the spatial distribution of these characteristics over the study area (Figure-4). The software AQTESOL 4.5 were used to analysis the pumping test database on the curve matching technique by Neuman (1974) Solution,[18] . Two test types were used to get data namely, the multi-well test (drawdown and recovery in an observation well) that include seven wells, (Figure-7), and a single-well test (drawdown and recovery in a pumped well only) that include six wells, (Figure-8), Aquifer parameters such as transmissivity and hydraulic conductivity were estimated from specific capacity(SC), for four wells (Table-3) . The drawdown was observed in the observation wells that located at a distance of 15 and 35 m from the pumped well. The pumping well-screen occupied the lower 60% of the aquifer. The degree of matching between curves of the field data with Neuman's standard curves in the early and intermediate time of test is a measure of the influence of partial penetration of pumping well. The influence of partial penetration in some wells in Dibdibba aquifer is imperceptible. Hence, the late time data is most important to obtain accurate transmissivity and specific yield parameters. The analysis of drawdown in some wells is considerably less than expected for consistency with the other wells. This suggests the difference in the saturated thickness and primary porosity values in this part of the aquifer. The specific yield data used to estimate recharge values to the Dibdibba aquifer in the study area were imported from the multi-well test by average values (0.073), (Table-3).

Table 3-The hydraulic parameters of the Dibdibba aquifer.

| ID Well	Elev. (m)	Depth (m)	S.W.L (m)	Head (m)	Q m³/d	T m²/day	K m/day	Sy	Sat. Thick (m).	distance cone depression (m)	Type of test
No.4	41.5	50	18.5	23	864	581	18.15	0.008	31.5	390	Single well Test
No.16	71	80	40	31	691.2	638	13.58	0.07	40	130	Multi well test
No.20	23	30	6	17	691.2	610	18.5	0.04	24	150	Multi well test
No.24	35	40	18	17	864	265	16.56	0.05	22	110	Multi well test
No.25	30	18	8	22	518.4	288	16	0.08	10	130	Multi well test
No.27	27	36	15	12	691.2	410.1	19.53	0.5	21	40	Single well Test
No.29	50	54	33	17	864	350.1	16.67	0.07	21	90	Multi well test
No.33	40	42	23	17	648	350	18.92	0.02	19	40	Multi well test
No.40	25	25	7.5	17.5	691.2	280	17.5	—	17.5	—	From SC
No.41	35	30	15.5	12.5	691.2	266.6	18.39	0.041	14.5	130	Single well Test
No.43	42	50	26	16	864	375	16.3	0.015	24	290	Single well test
No.50	38	30	15	23	57.6	13.5	0.3	0.001	15	250	Single well Test
No.51	27	24	10	17	57.6	25	0.625	—	14	—	From SC
No.55	67	55	36	31	57.6	16	0.58	0.001	19	260	Single well Test
No.58	20	26	15	5	57.6	45	1.425	—	11	—	From SC
No.60	42	50	22	20	691.2	336	12	—	28	—	From SC
No.61	22	18	4	18	432	168	14	0.06	14	115	Multi well test
No.62	33	22	7	26	345.6	144	10.2	—	15	—	From SC
Obs.S.	59	49	29.88	29.12	172.8	27.07	1.47	0.009	19.12	220	Multi well test
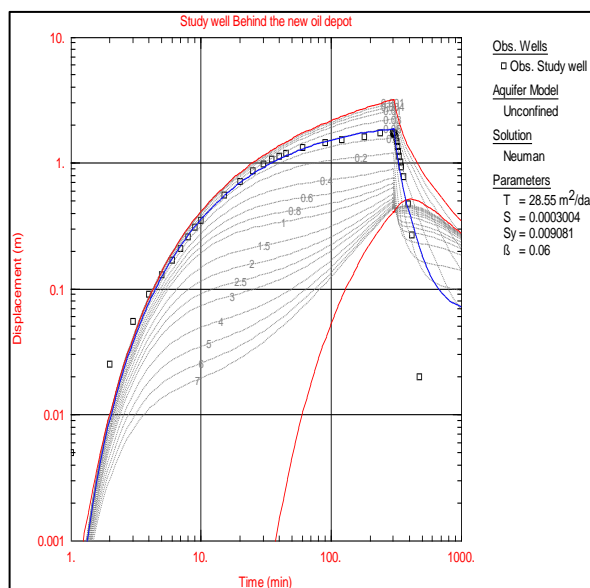
Figure-7 Analysis of pumping test data in case of the multi-well test (Dibdibba aquifer).
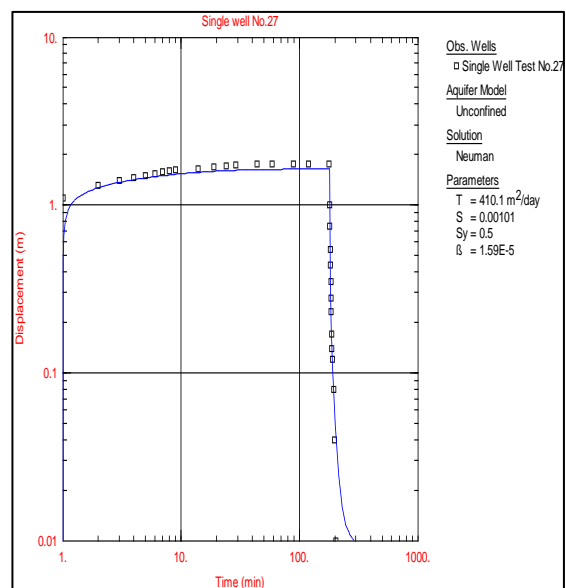
Figure-8 Single-well test in the Dibdibba aquifer (High efficiency) in the study area.

4.2 Estimated recharge of the Dibdibba aquifer

   The average water level in the observation wells and the total precipitation on a monthly basis for Jan. 2010 to Aug. 2017 are shown in Figure-9. Water levels are highest in late winter and early spring. Precipitation almost happens in just four months throughout the year. Recharge was calculated using Eq. (2), On a monthly basis. As previously mentioned, Sy was estimated by [18] method to be 0.073; Δh was taken as the cumulative rise in water level for the month (i.e., the sum of all rises that occurred). To account for drainage from the water table that takes place during rises in water levels, water levels before rises were extrapolated to their expected positions had there been no precipitation. The rising was then estimated as the difference between the peak level and the extrapolated antecedent level at the time of the peak [12] . The dashed lines in (Figure-10), Represent the extrapolations. Table-(4, 5) show annual and monthly estimates values of recharge for Jan. 2010 through Aug. 2017. These values are adopted in the modeling process for initial estimate recharge value and then adjusted until a good match between calculated and measured heads was obtai
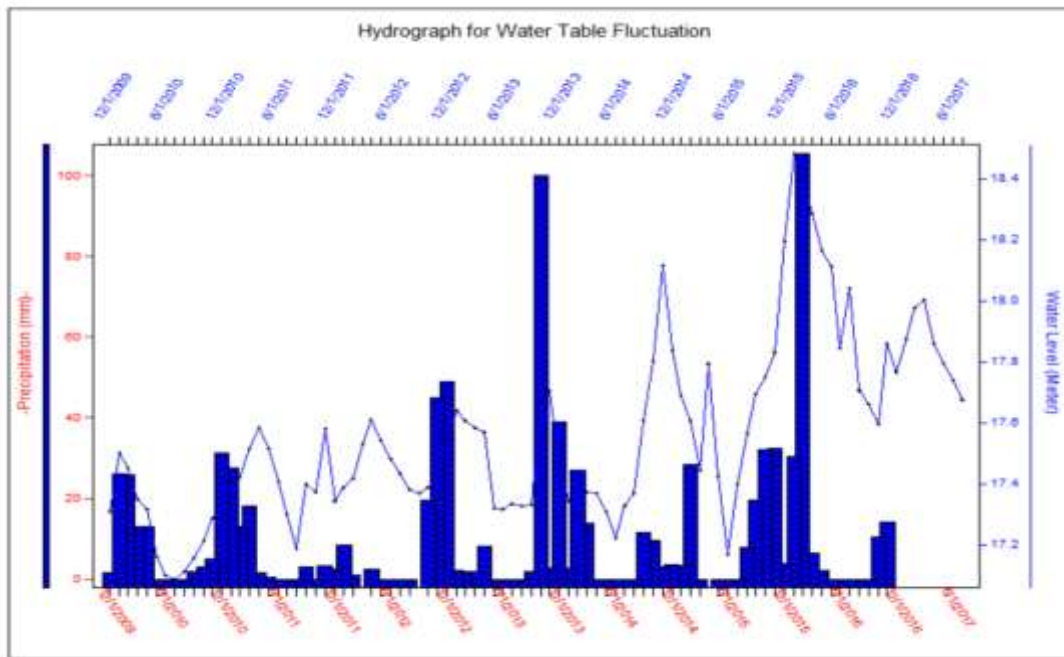

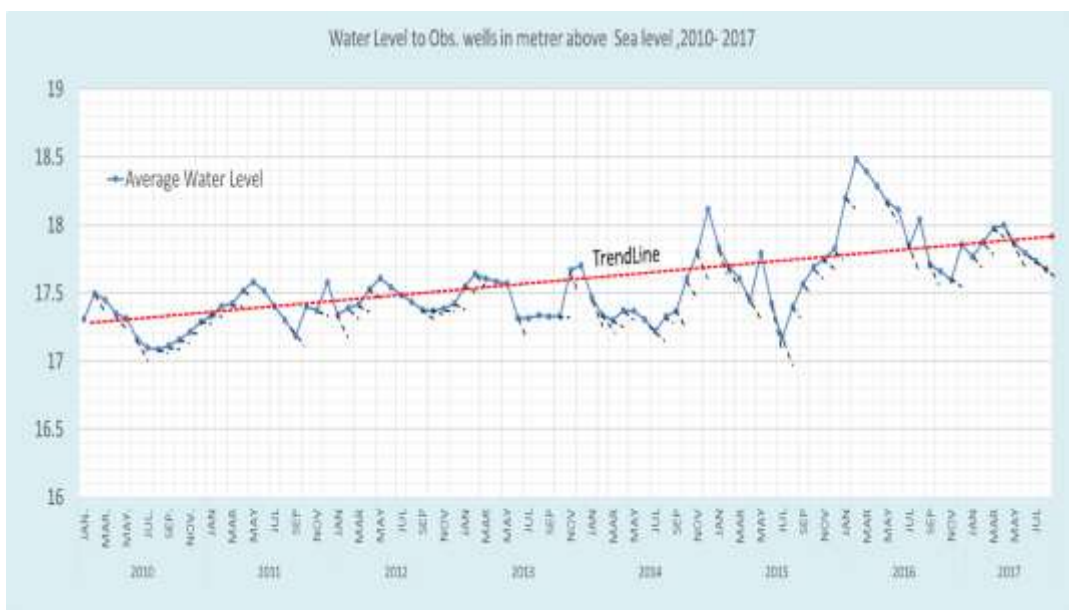**Figure 9-**Time series hydrograph of average monthly water levels and precipitation.

Figure-10 Recharge estimating from the difference between the peak of the rise and low points of the extrapolated antecedent recession curve at the time of the peak.

Table 4-Monthly change in water level and groundwater recharge of Dibdibba aquifer in the study area from the year 2010 to 2017

Month	2010		2011		2012		2013		2014		2015		2016		2017	
	ΔH (cm)	R (cm)	ΔH (cm)	R (cm)	ΔH (cm)	R (cm)	ΔH (cm)	R (cm)	ΔH (cm)	R (cm)	ΔH (cm)	R (cm)	ΔH (cm)	R (cm)	ΔH (cm)	R (cm)
JAN.	30	2.19	10	0.73	22	1.606	10	0.73	5	0.365	5	0.365	40	2.92	20	1.46
FEB.	3	0.219	0	0	10	0.73	5	0.365	5	0.365	5	0.365	0	0	20	1.46
MAR.	4	0.292	10	0.73	10	0.73	0	0	15	1.095	0	0	0	0	10	0.73
APR.	0	0	10	0.73	10	0.73	0	0	5	0.365	50	3.65	0	0	0	0
MAY.	10	0.73	0	0	0	0	0	0	0	0	0	0	10	0.73	10	0.73
JUN.	5	0.365	0	0	0	0	10	0.73	0	0	5	0.365	0	0		
JUL.	0	0	0	0	0	0	0	0	15	1.095	40	2.92	30	2.19		
AUG.	2	0.146	0	0	0	0	0	0	5	0.365	22	1.606	0	0		
SEP.	5	0.365	30	2.19	4	0.292	0	0	30	2.19	20	1.46	10	0.73		
OCT.	10	0.73	0	0	2	0.146	40	2.92	30	2.19	10	0.73	0	0		
NOV.	10	0.73	25	1.825	2	0.146	15	1.095	50	3.65	10	0.73	30	2.19		
DEC.	10	0.73	0	0	13	0.949	0	0	0	0	50	3.65	0	0		
Total		6.497		6.205		5.329		5.84		11.68		15.84		8.76		4.38

Table 5-Annual recharge of Dibdibba aquifer in the study area

Year	R (cm/year)	R (m/day)	R (m/year)	The volume of water to recharge Dibdibba aquifer area (1100 km²), in m³ /year
2010	6.497	0.000178	0.06497	71467000
2011	6.205	0.00017	0.06205	68255000
2012	5.329	0.000146	0.05329	58619000
2013	5.84	0.00016	0.0584	64240000
2014	11.68	0.00032	0.1168	128480000
2015	15.841	0.000434	0.15841	174251000
2016	8.76	0.00024	0.0876	96360000
2017	4.38	0.00012	0.0438	48180000

It is clear from the Figure-10 that there is a gradual increase in the level of groundwater in the Dibdibba aquifer in the study area for the following reasons:

1. Increasing the annual rainfall rate in the years 2013 and 2015 as shown in Figure -9.
2. The establishment of a lot of large projects in the Karbala - Najaf plateau after 2010, such as the refinery of Karbala oil, refinery Al-Najaf oil and large oil reservoirs as well as the establishment of Karbala airport and sizeable urban expansion, this led to many wells go out from service.
3. The reluctance of many farmers to work because of the impact of imported products on local agriculture

5. Conclusion

The water-table fluctuation technique depends on the premise that rises in groundwater levels in unconfined aquifers are because to recharge arriving at the water table. The WTF method is best used in systems with shallow water tables that display sharp rises and declines. Annual groundwater recharge was calculated from Jan. 2010 to Aug. 2017 by using water table fluctuation WTF method in four observation wells was water table levels measured daily on midnight basis. The data logger of

type Aqua TROLL 200 was used to measure levels automatically. The specific yield data used to estimate recharge values to the Dibdibba aquifer in the study area were imported from the multi-well pumping test by Neuman (1974) method. The average values of specific yield for seven years is (0.073). The average annual groundwater recharge for seven years is 8.0665 cm/year.

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