Water Surplus for Umm Er Radhuma Aquifer – West of Iraq

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Abstract :

Water surplus (WS) is calculated for Umm Er Radhuma aquifer using different methods. The data include monthly averages of nine stations and daily averages for Nukhaib and Salman stations which are located in the middle of western desert.

The averages of climatic elements for twenty consecutive years (from the water year of 1985-1986 to the water year of 2005-2006) were determined from the climate information recorded at these stations. Water surplus (WS) was found to form (29.34%) of rainfall. This reflects the portion of rainfall that recharges the aquifer. Water deficit, on the other hand, was found to be (70.66%). The natural recharge of groundwater in the desert was found to be (5%) of total rainfall. The natural recharge of Umm Er Radhuma aquifer is in the order of (3.8×10^8 m^3/year).

الخلاصة

الفائض المائي تم حسابه لمكمن أم أرضمة باستخدام عدة طرق. تضمنت البيانات المستخدمة المعدلات الشهرية من تسع محطات مناخية ومعدلات يومية لمحطتي النخيب والسلمان الواقعتين وسط الصحراء الغربية.

معدلات العناصر المناخية لعشرين سنة متتالية (من السنة المائية 1985-1986 إلى السنة المائية 2005-2006) اعتمدت في تحديد المعلومات المناخية التي سجلت في هذه المحطات. الفائض المائي شكل (29.34%) من الساقط المطري وهذا يعكس جزء من الساقط المطري الذي يغذي المكمن . العجز المائي من الناحية الأخرى شكل (70.66%). التغذية الطبيعية للمياه الجوفية في الصحراءِ الغربية شكلت (5%) من الساقط المطري الكلي . قيمة معدل التغذية الطبيعية لمكمن أم أرضمة يصل إلى (3.8×10^8) م^3 / سنة.

Introduction :

The studied area is located between the Euphrates river and the Saudi Arabian borders, it forms about (151,834) km^2 of the Iraqi Western Desert covering Umm Er Radhuma geological formation inside Iraq, figure (No.1).

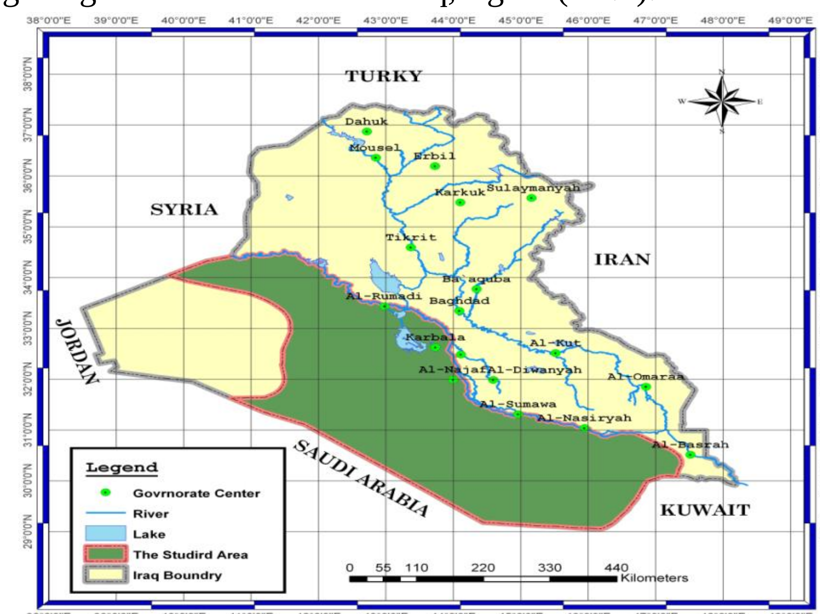

Figure (No.1) Location map

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Umm Er Radhuma formation contains two types of aquifers: The first one is an unconfined aquifer that covers an area of (60,068) km^2, while the second one is a confined aquifer that covers an area of (91,766) km^2 , figure (No.2).

The nine stations lies in the western desert, figure (No.3). Early studies concerning the water surplus in term of groundwater recharge and surface runoff were those of Ahmed and Kraft (1972) and Consortium-Yugoslavia (1977). The given value of such surplus is in the order of (5%) of annual rainfall It is clear that corrected potential evapotransipiration which was calculated by using.

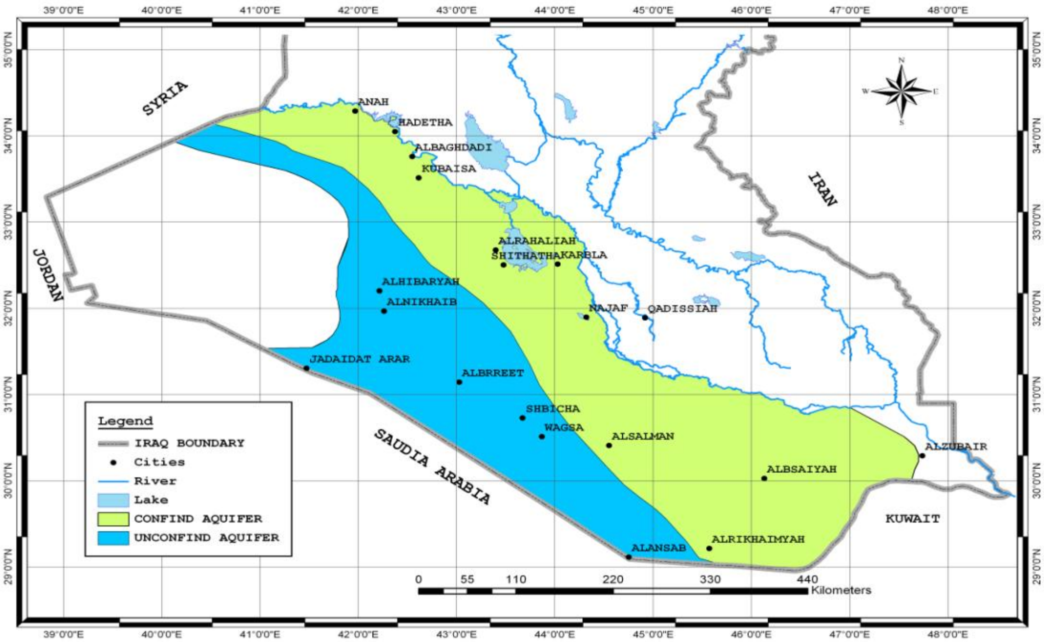

Figure (No.2) Extents of the two types of aquifers inUmm Er Radhuma formation

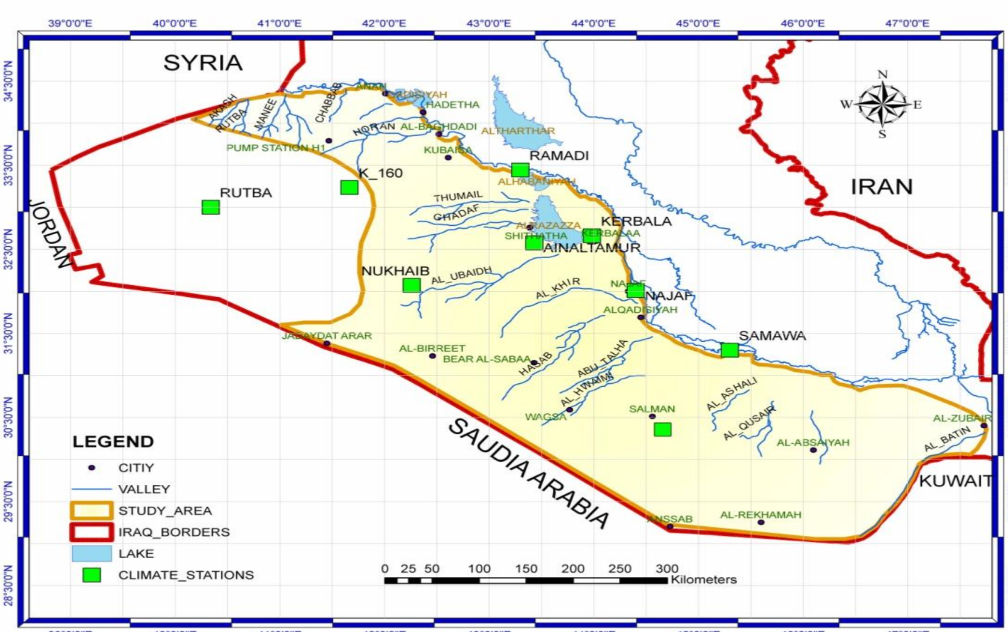

Figure (No.3) Location of Climatic stations Water Surplus (WS) and Water Deficit (WD):

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Thornthwait method represents monthly values (Thornthwait, 1948). Certain terms of water balance can be determined from these values among which are water surplus and water deficit. Water surplus is defined as the excess of rainfall over the corrected potential evapotransipiration values during specific months of the year, while water deficit is the excess of corrected potential evapotransipiration values over rainfall during the remaining months of that year. According to Lerner, et al.,(1990) the Potential evapotransipiration (PE) could be expressed as follows:

PE = PEc when $P \geq PEc$

PE = P when $P < PEc$

Where:

P = Rainfall depth (mm).

PE = Potential evapotranspiration (mm / month).

PEc : Corrected potential evapotranspiration (mm).

In the first case, potential evapotranspirtion is equal to the corrected potential evapotranspirtion. In the second case it is equal to rainfall depth. Water surplus and water deficit can be expressed as:

$WS = P - PEc$; $P > PEc$ $PEc = PE$ ……………………..(1)

$WD = PEc - P$; $P < PEc$ $P = PE$ ……..........................(2)

However, at the presence of appreciable wet soil due to rainfall or to irrigation, actual evapotranspiration value is complemented by an amount from the available moisture in that soil reaching at some times to the value of potential evapotranspiration; otherwise it remains lesser than potential evapotranspiration.

Since our studied area is part of the desert, irrigation practices are rare; however, it may contain some natural vegetation at locations where soil is present. The unconfined part of Umm Er Radhuma aquifer is mainly recharged at the western part of the desert where the exposed outcrop having no soil cover; therefore, it is assumed that the actual evapotranspiration is only a function of rainfall (equations 1 and 2).

Accordingly, water surplus and water deficit were calculated for our studied area using the above presented climatic data for Ramadi, Kilo160, Rutba, Karbala, Nukhaib, Ain Al Tamour, Najaf, Samawa, and Salman stations recorded during the period of 1985 - 2006. Two attempts were made for such calculation using monthly averages in the first attempt and daily values in the second one.

Calculation of water surplus :

1- Calculation of water surplus using monthly data :

The means of the monthly corrected potential evapotranspirtion (PEc) values calculated according to Thornthwiat method, Table (1), were used to determine the means of the monthly potential evapotranspirtion (PE) and the means of the monthly water surplus and water deficit as shown in Table (2). It is obvious from Table (2) that there is a distinct water deficit from the beginning of March to the end of November because PEc exceeds rainfall, and consequently the utilization of soil moisture. From the beginning of December to the end of February, rainfall exceeds PEc. The result is the recovering of soil moisture to its capacity and the additional or the exceeded water may become groundwater recharge (GR) and surface runoff (SR) (Fetter, 1980) as:

$WS = SR + GR$ ……………………………. (3).

Where:

WS: Water Surplus

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SR: Surface Runoff
GR: Groundwater Recharge

Because the land of the studied area is stony, soil moisture could be neglected (Hassan and Al-Kubaisi, 2002).

Table (1) Potential evaporation-transpiration values calculated using Thornthwaite method.

Months	Temp. C°	j	PE (mm)	DT/360	PEc (mm)
Oct.	24.4	11.02	107.6	0.72	77.47
Nov.	16.7	6.21	36.79	0.61	22.44
Dec.	11.5	3.53	12.8	0.53	6.78
Jan.	9.9	2.81	8.38	0.55	4.61
Feb.	11.6	3.58	13.12	0.58	7.61
Mar.	15.9	5.76	32.02	0.72	23.05
Apr.	22.3	9.62	83.4	0.74	61.72
May	27.3	13.07	147.85	0.88	130.11
Jun.	32.1	16.7	233.83	1.04	243.18
Jul.	34.4	18.54	284.41	1.08	307.16
Aug.	34	18.21	275.15	1.05	288.91
Sep.	30.4	15.38	200.45	0.86	172.39
		J= 124.43	1435.8		1345.43

Table (2) Calculated monthly averages of water surplus and water deficit for the studied area.

Months	P mm	PEc mm	Ws(P-PEc)	PE mm	WD(PEc-P)
Oct.	8.2	77.47	0	8.2	69.27
Nov.	15.7	22.44	0	15.7	6.74
Dec.	16.2	6.78	9.42	6.78	0
Jan.	17.6	4.61	12.99	4.61	0
Feb.	16.8	7.61	9.19	7.61	0
Mar.	13.7	23.05	0	13.7	9.35
Apr.	14.7	61.72	0	14.7	47.02
May	4.8	130.11	0	4.8	125.31
Jun.	0	243.18	0	0	243.18
Jul.	0	307.16	0	0	307.16
Aug.	0	288.91	0	0	288.91
Sep.	0	172.39	0	0	172.39
∑	107.7	1345.43	31.6	76.1	1269.33

Where:
j = Monthly temperature parameter (C°).
D: number of days in the month.
T: average number of hours between sunrise and sunset in the month.

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The results of applying this method using evapotranspiration values are shown in Table (2). It shows that water surplus is realized during three months: December, January and February with an annual value of 31.6 mm. Water surplus as a % of rainfall is found to be:

WS% = (31.6/107.7)×100= 29.34% and PE % = 70.66% .

2- Calculation of water surplus using daily data :

A- The homogeneous method (N):

This method aims to discard evaporation of non rainy days from the calculation of monthly water surplus. This is done by multiplying the daily average evaporation from free surface (Epan) for a given month by the number of rainy days in that month. Water surplus and water deficit are obtained from the difference between the monthly rainfall and the total evaporation of the rainy days in that month. The use of evaporation instead of evapotranspiration is due to the fact that the latter is normally calculated on monthly basis only, (Hassan and Al Kubaisi,1998):

………………………….(4) PE = (E pan/ D)×N

Where :

Epan / D: Average of daily evaporation (from free surface). N: number of rainy days in any month.

D: number of days in each month. Here there are two cases :

- The first case is when the rainfall exceeds Potential evaporation (PE) as determined by equation No. (4) , WS is therefore equal to P – PE

- The second case is when the value of the Potential evaporation exceeds or equals the amount of rainfall, hence there is no water surplus

$PE \geq P$ PE = P ; WS = 0

This method was applied on the available daily climatic data of two stations which are located in the middle of western desert in the studied area:

1. Nukhaib station which represents the northern desert.
2. Salman station which represents the southern desert.

The results are presented in Table (3) for Nukhaib station and Table (4) for Al-Salman station which show the annual water surplus is (9.7mm) for Nukhaib station and (5.2mm) for Salman station and at an average of (7.45mm) for the two stations.

B- Methods of recording rainfall in one day (n):

This method depends on the amount of recorded rainfall in one day. Daily evaporation from free surface is calculated as in the previous method and is compared with daily rainfall during the rainy days only, thus the water surplus was calculated according to the following equation (Hassan and Al Kubaisi,1998):

………………….. (5) n (Epan / D) pd -∑WS = Where:

Pd: total rainfall, which is in every day higher than the value of daily evaporation (in 20 years).

n: number of days where the rainfall is higher than the daily evaporation.

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In this method, if the amounts of rainfall recorded in a station are (20) mm or more, then these amounts will be selected , these amounts can cause flow in the valleys and an increase in the recharge of water (Rafiq, H.R., 1993).

Applying the above equation to calculate the water surplus is shown in tables (5) and (6).

Table (3) Calculation of water surplus using homogeneous method (N) for Nukhaib station

Months	N day	P mm	E_{pan} mm	E_{pan}/D	$N \times E_{pan}/D$	Ws_{mm}	PE_{mm}
Oct.	1	10.3	228	7.4	7.4	2.9	7.4
Nov.	8	17	119	4	32	0	17
Dec.	5	18.1	72.2	2.3	11.5	6.6	11.5
Jan.	4	9.6	76.3	2.5	10	0	9.6
Feb.	4	15.4	105.3	3.8	15.2	0.2	15.2
Mar.	3	13.7	191.3	6.2	18.6	0	13.7
Apr.	5	19.9	274.2	9.1	36.4	0	19.9
May	0	3.7	392.7	12.7	0	0	3.7
Jun.	0	0	453.6	15.1	0	0	0
Jul.	0	0	524.5	16.9	0	0	0
Aug.	0	0	469.6	15.1	0	0	0
Sep.	0	0	350	11.7	0	0	0
						9.7	

Table (4) Calculation of water surplus using the homogeneous method (N) for Salman station.

Months	N day	P mm	E_{pan} mm	E_{pan}/D	$N \times E_{pan}/D$	Ws_{mm}	PE_{mm}
Oct.	2	6	247	8	16	0	6
Nov.	9	14	132	4.4	39.6	0	14
Dec.	4	16	83	2.7	10.8	5.2	10.8
Jan.	10	22	81	2.6	26	0	22
Feb.	9	17	112	4	36	0	17
Mar.	4	12	187	6	24	0	12
Apr.	2	14	268	8.9	17.8	0	14
May	0	4	373	12	0	0	0
Jun.	0	0	457	15.2	0	0	0
Jul.	0	0	517	16.7	0	0	0
Aug.	0	0	467	15.1	0	0	0
Sep.	0	0	352	11.7	0	0	0
						5.2	

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Table (5) shows how to calculate water surplus by using the method of daily data (n) at Nukhaib station (for 20 years).

Month	P mm	n day	Pd mm	E_{pan} /D	n×E_{pan} /D	WS
Oct.	10.3	1	16	7.4	7.4	8.6
Nov.	17	8	133.8	4	32	101.8
Dec.	18.1	5	70.9	2.3	11.5	59.4
Jan.	9.6	4	50.5	2.5	10	40.5
Feb.	15.4	4	50	3.8	15.2	34.8
Mar.	13.7	3	53.3	6.2	18.6	34.7
Apr.	19.9	5	101.5	9.1	45.5	56
May	3.7	0	0	12.7	0	0
Jun.	0	0	0	15.1	0	0
Jul.	0	0	0	16.9	0	0
Aug.	0	0	0	15.1	0	0
Sep.	0	0	0	11.7	0	0
						335.8

Table (6) shows how to calculate water surplus using the method of daily data (n) at Al-Salman station (for 20 years).

Months	P mm	n Day	Pd mm	E_{pan} /D	n×E_{pan} /D	WS
Oct.	6	2	20.2	8	16	4.2
Nov.	14	9	185.5	4.4	39.6	145.9
Dec.	16	4	49.1	2.7	10.8	38.3
Jan.	22	10	173.9	2.6	26	147.9
Feb.	17	9	102.9	4	36	66.9
Mar.	12	4	120.9	6	24	96.9
Apr.	14	2	25.9	8.9	17.8	8.1
May	4	0	0	12	0	0
Jun.	0	0	0	15.2	0	0
Jul.	0	0	0	16.7	0	0
Aug.	0	0	0	15.1	0	0
Sep.	0	0	0	11.7	0	0
	105					508.2

By dividing the results of water increase per 20 years for the two stations, the average of water surplus in one year will be as follows :

335.8 / 20 = 16.79 mm for Nukhaib station.

508.2 / 20 = 25.41mm for Salman station.

The average will be =21.1 mm.

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The value of (WS%) in this case is higher than its value in the previous method. This method is considered more realistic and it depends on the rainfall recorded on that day and not on the average.

Runoff:

Runoff events in the studied area are few since they normally require intense and abundant rainfall. The number of these events varies from year to another depending on the rainfall pattern of that year. Nedeco (1956) and Consortium (1977) estimated that the average number of days in a year in which runoff observed in the western desert valleys were 15 and 20 days respectively. Thus for example, the number of flows in wadi Al Ubiyaidh that occur annually range between (3-5) times. The volume of water which flows when the rainfall continued for one hour is estimated between 38.3 and 47.7 million m^3. This could happen within a period ranging between (10-30) years (Al Furat Center for Studies and Design of Irrigation Projects,1995).

However, the volume of water recorded for the three main valleys in the studied area during the years 1975- 1976 is as follows : (3.5) million m^3 in wadi Al Ubiyaidh in Nukhaib location, (22.2) million m^3 in the basin of wadi Al Ghadaf, and (6.14) million m^3 in wadi Tabbel (Consortium, 1977). Runoff as a percentage of water surplus varies according to the hydrologic condition of the basin and the nature of the ground surface. Impermeable beds on surface cause higher runoff percentage, while fissured bed rocks reduce it . Hassan & Al Kubasi, 2002 suggested that runoff forms 70% of water surplus.This would mean that only 30% of water surplus will replenish groundwater through available cracks, fissures, and seepages from valley beds and depressions.

The carbonate beds of Umm Er Radhuma formation are exposed near the Iraqi-Saudi Arabian border zone, This area could be a good zone to recharge Umm Er Radhuma aquifer which extends further to the east under younger formations. Most probably, part of the flowing water in the valleys near the Iraqi-Saudi Arabian border penetrates through the fissured carbonate beds causing occasional groundwater recharges and causing a diminish of runoff downstream.

The portion of water surplus that constitutes groundwater recharge is important in determining the renewable groundwater resources of Umm Er Radhuma aquifer. This portion equals water surplus minus the runoff, or 30% of the calculated water surplus. As an average for the whole area, water surplus equals 21.1 mm, however it varies from one location to another according to local meteorological data. Thus, for example water surplus has the following values at the given locations:

WS (Nukhaib) = 16.79 mm

WS (Salman) = 25.41 mm

Average water surplus for the two locations is 21.1 mm

Groundwater recharge constitutes 30% of the mentioned values and therefore it could be calculated as in the following:

$VGR = A \times Ws \times 0.3$

$VSR = A \times Ws \times 0.7$

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Where as:

A: Area of recharge zone

VGR: Volume of groundwater recharge

VSR: Volume of surface runoff.

Considering a recharge zone area (A) = 60068 km^2 , the volume of groundwater recharge (aquifer renewable resources) will be:

$VGR = 0.3 * 21.1 * 10^{-3} \times 60068 \times 10^{6}$

$= 3.8 \times 10^{8}\ m^3/year$

Conclusions :

- Corrected potential Evapotranspiration (PEc) was determined according to Thornthwait (1948), where its total amount is (1345.43) mm, while the total amount of (PE) is (1435.8) mm. Two periods are recognized here :

• The first period starts from September to May and is characterized by the following relation: PEc < PE < Epan .

• The second period starts from June to August and is characterized by the following relation: Epan > PEc > PE .

-Water surplus (WS) was found to form (29.34%) of the rainfall. This reflects runoff and the portion of rainfall that recharges the aquifer. Water deficit, on the other hand, was found to be (70.66%).

- The natural recharge rate value of Umm Er Radhuma aquifer is in the order of (3.8×10^{8}) m^3/year.

- The nature groundwater recharge in the desert was found to be (5%) of the total rainfall.

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