DETERMINATION OF BASE-FLOW COMPONENTS FOR REZAN AT REZAN GAUGING STATION

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Abstract

Rezan River is a tributary of the Greater Zap River which is the principal source of water for domestic and agricultural use in the Barzan area. The length of the river is about 85 km with total drainage area reaches 1158 km^2 in Iraqi part. The Rezan River is of great importance for Iraqi Kurdistan Region; because it provides Greater Zab River with about 1,37 billion m^3 / year which represent about 8,2% of its total discharge. The mean daily discharges data for the last ten years are available. The result of hydrograph analysis for the water years shows better understanding of the flow characteristics of Rezan River, it is necessary to understand its base flow components characteristics and their relations to the total stream flow and geology of the river basin due to the importance of base flow in the dry season where all the water flow in the river is from base flow. Tens of villages depending on the river during the summer for irrigation as well as to supply water for domestic uses for reconstruction of destroyed villages along the river course, and have significant role in developing agricultural activity in the area. The quantitative information and analysis of base flow are also important in developing and future planning of the area where most activities are related to agriculture.

Key words: base flow, basin storage, bank storage, surface flow, water year.

Introduction

Increased demand for uses of surface water and groundwater in Iraqi Kurdistan Region during recent drought conditions lead to more studies concerning, river basins, groundwater and surface-ground water relations in face of drought danger. The Rezan River is the principal source of water for domestic and agricultural use in the Barzan area (Fig. 1). There are three main tributaries of Rezan River, 1) Haji Bak River making the natural Border between Iraq and Turkey, 2) Khuwakurk River and 3) Barazgird River. The Iraqi-Iranian border represents the water divide of the Rezan River Basin from the East. There is a gauging-station at Rezan village on Rezan River which is a tributary of the Greater Zap River. This gauging-station has been established recently. The mean daily discharges data for the last ten years are available. In order to understand the flow characteristics of Rezan River, it is necessary to understand its base flow components characteristics and their relations to the total stream flow and geology of the river basin due to the importance of base flow in the dry season where all the water flow in the river is from base flow. Better understanding of total stream flow requires quantitative analysis of base flow components during minimum and maximum water years. Moreover the minimum low flow information is very useful in determining the suitability of a river for water supply. The base flow of the Rezan River during the summer season represents the minimum low flow of the river. During summer season groundwater storage plays a crucial role by sustaining the river discharge [6].

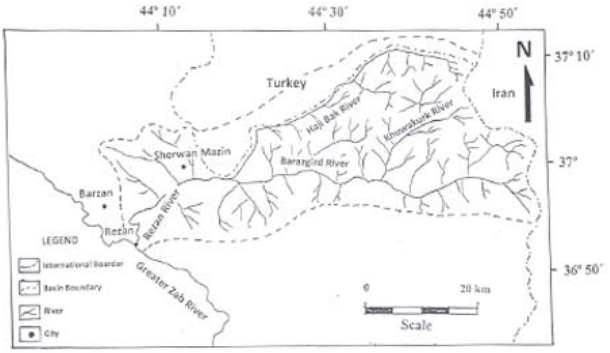

Fig. 1. Rezan River Watershed [5]

Purpose and Scope

The study aims to provide quantitative information on the contribution of surface runoff and base flow at Rezan River gauging station. Furthermore, quantitative separation of base flow into bank storage and basin storage components, and finally estimate the minimum river discharge which can be considered as the ground water discharge composed primarily of the basin storage discharge which is the main source of water flow in the river and tens of villages depending on the river during the summer for irrigation as well as to supply water for do-

mestic uses for destroyed villages along the river course.

Physiography

The Rezan River Lies within the thrust zone in northern part of Iraqi Kurdistan Region and is drained by the Barazgird, Khuwakurk and Haji Bak Rivers and their tributaries. The whole basin area is mountainous which locates at Iraqi-Turkish-Iranian boarders and characterized by the Zagros-Toros mountain range with heights up to 3600 m above sea level. The morphology of this area is rough, with steep slopes and narrow deep valleys [2]. The whole area of the basin is highly dissected, with steep slopes. Land surface altitude ranges from 800m near the Brazger narrow plain in the southern part of the basin to about 3600m north of Khuwakurk Mountain.

Hydrogeologic Setting

The Rezan River is located in northern part of Iraq. It is a tributary of Greater Zab River. This river flows from the mountain areas as high as 3000 m above sea level in Khuwakurk and north of Sherwan mazin. The length of the river is about 85 km with total drainage area reaches 1158 km^2 .The average annual precipitation of the Rezan River basin is about 1253 mm, while the average annual temperature is about 11,2 ^{o}C. [5].

The geological formations that exist in the study area belonging to Paleocene-Late Jurassic (Fig. 2). These formations consist of clay, siltstone, sandstone, marl, limestone and dolomitic limestone, as well as of igneous and metamorphic rocks belonging to Early Cretaceous.

Generally, the limestone forms the aerial skeletons of the folds within the basin. The limestone is highly jointed, fractured and karstified due to the intensive tectonic forces which can be attributed to the subduction of the Neo-Tethyan oceanic plate beneath the Iranian lithosphiric plates during (E-L Cretaceous) and collision of Afro-Arabian continental lithosphere with the Iranian plates in Late Cretaceous and later times [1].

Accordingly, this area is characterized by a highly transmissive groundwater flow system, developed through fractures, solution canals and karst processes in the limestone formations. These fractures and karsts make the aquifers to be extremely productive as the result of high rates of recharge from snow and rainfall and through the interaction between the aquifers and Rezan River tributaries. The highly fractured and canal solution of the limestone transmit large amounts of groundwater from the aquifers to springs that discharge along Rezan River. This phenomenon is quite obvious in Dorea area near Rezan village.

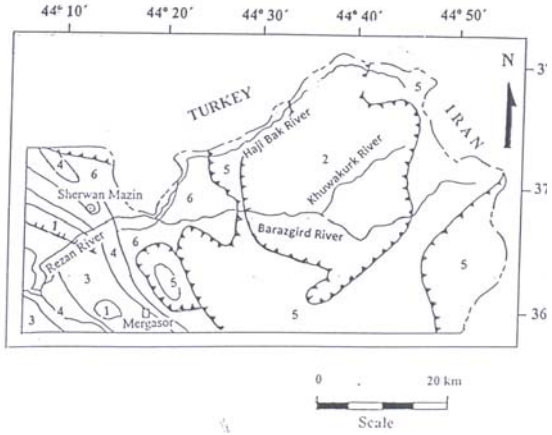

Fig 2. Lithostratigraphic map of Rezan Watershed (modified after [3])

Legend:

Unit No.	*Geological Unit*	*Age*
6	*Red Bed Series,Covanda Fn.*	*Palcoccne-Mioccene*
5	*Naopurdan Series, Walash Series*	*Palcoccne-M. Eoccne*
4	*Tanjero Fn.*	*Late Cretaccous*
3	*Bekhme Fn., Aqra Fn., Qamchuqa Fn., Sarmord Fn.*	*Middle Cretaccous*
2	*Qulqula Group*	*Late Jurassic-M.Cretaccous*
1	*Chbia Gara Fn., Naokelekan Fn., Barsaria Fn., Sargelu Fn.*	*Late Jurassic*
	Thrust Fault	
	Reverse Fault	

Methodology and Discussion

The Kunkle method (1962), is the hydrograph separation of base and surface runoff, furthermore, it can separate base runoff into discharge from bank and basin storage. The method is based on several assumptions, for the separation of basin-storage discharge; first the minimum-discharge values at the beginning and end of a groundwater year are assumed to represent groundwater discharge from basin storage, because the bank storage has been depleted and, provided that there has been no recent precipitation, therefore, all the discharge is coming from basin storage, second the minimum discharge values at the beginning and end of the groundwater year are very nearly equal due to the close balance between the amount of discharge and the amount of recharge. The minimum-discharge

values at the beginning and end of groundwater year are connected by straight line representing the separation of basin-storage discharge from other runoff components (Fig. 3, 4 and 5). For the separation of bank storage discharge, it is obvious that the discharge from bank storage takes place only during periods when river discharge is below the level of saturated banks. The recession period is easily recognized when the minimum discharge values can be connected by a straight line on semi logarithmic paper. Since the recession slop is essentially constant at each gauging station, the true recession line is verified when two or more recession periods on the same hydrograph yield the same slope. Recorded discharge lying above the recession line represents the influence of surface runoff during the recession period. Bank-storage discharge begins after the crest of a significant rise in river stage and continues until the beginning of another significant rise or until bank storage is depleted, bank storage discharge is assumed to begin instantaneously at the start of the recession period and to end instantaneously when another significant rise is meet, the separation is made by vertical separation lines as illustrated in Fig. 3, 4 and 5.

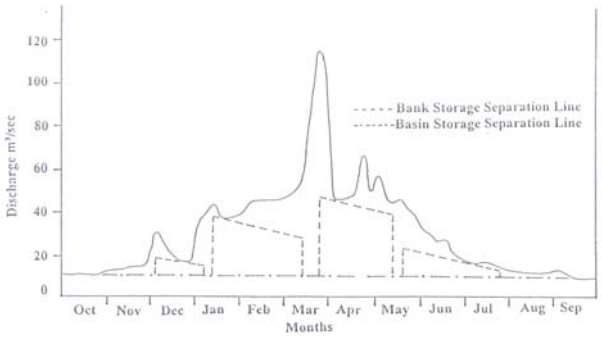

Fig. 3. Hydrograph Analysis of Rezan River for Water year (2001)

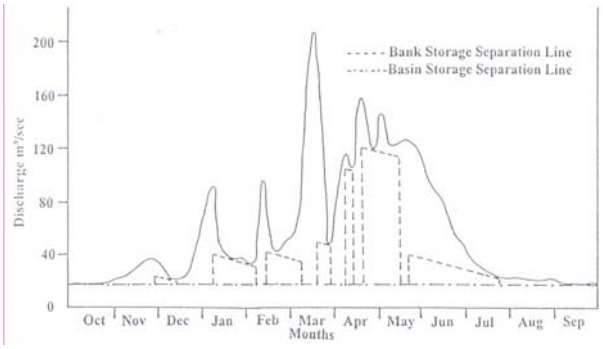

Fig. 4. Hydrograph Analysis of Rezan River for Water year (2002)

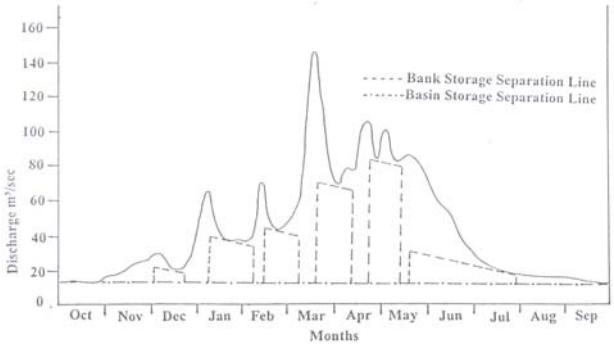

Fig. 5. Hydrograph Analysis of Rezan River for Water year (2001-2002)

Table 1. The discharge components amount of Rezan River at Rezan gauging station for the water year 2001

Type of Discharge	Discharge Discharge amount m^3x109	Discharge %
Bank Storage	0,31199	32,5
Basin Storage Discharge	0,29056	30,3
Total Base Flow Discharge	0,60255	62,8
Surface Runoff	0,35788	37,2
Total River Discharge	**0,96043**	**100**

Table 2. Groundwater contribution for Rezan River components at Rezan gauging station for water year 2001

Type of Discharge	Average Discharge of groundwater Components (m^3/sec/km^2)x10^3 -
Bank Storage	8,54322
Basin Storage Discharge	7,95656
Total Base Flow Discharge	**16,49978**

Table 3. The discharge components amount of Rezan River at Rezan gauging station for the water year 2002

Type of Discharge	Discharge amount m^3x109	Discharge %
Bank Storage	0,42438	23,8
Basin Storage Discharge	0,54433	30,6
Total Base Flow Discharge	0,96871	54,4
Surface Runoff	0,81229	45,6
Total River Discharge	**1,78100**	**100**

Table 4. Groundwater contribution for Rezan River components at Rezan gauging station for water year 2002

Type of Discharge	Average Discharge of groundwater Components (m^3/sec/km^2)x10^3-
Bank Storage	11,62242
Basin Storage Discharge	14,90562
Total Base Flow Discharge	**26,52804**

Table 5. The discharge components amount of Rezan River at Rezan gauging station for the water year 2001-2002

Type of Discharge	Discharge amount m^3x109	Discharge %
Bank Storage	0,43137	31,5
Basin Storage Discharge	0,40040	29,2
Total Base Flow Discharge	0,83177	60,7
Surface Runoff	0,53974	39,3
Total River Discharge	**1,37151**	**100**

Table 6. Groundwater contribution for Rezan River components at Rezan gauging station for water year 2001-2002

Type of Discharge	Average Discharge of groundwater Components (m^3 /sec/km^2)x 10 $^{-3}$
Bank Storage	11,8122
Basin Storage Discharge	10,9642
Total Base Flow Discharge	**22,7764**

Table 7. Average daily discharge (m^3/sec) for Rezan River at Rezan station for the minimum water year discharge 2001 [5]

#	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1-5	10,8	12,7	31	36,7	38,9	46,5	46,1	58	31,2	17,2	13,3	12,9
6-10	10,8	13,4	28,5	38,6	44,8	49	45,3	45,6	29,3	16,2	12,9	11,8
11-15	10,7	13,4	21	44,1	45	53,9	46	43,5	25,5	17,1	12,4	10,3
16-20	10,8	14,7	18,1	37,1	45,1	83,9	46,8	45,9	27,4	16,9	11,8	9,9
21-25	10,9	15	17	36,6	45,6	115,5	66,4	40,8	20,8	15,4	11,7	9
26-30	10,9	14,7	16,2	38,4	45,6	110,6	47,8	37,9	19,3	13,9	11,4	8,4

Table 8. Average daily discharge (m^3/sec) for Rezan River at Rezan station for the maximum water year discharge 2002 [5]

#	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1-5	17,9	21,4	30,5	73,7	33,1	55	89,6	146,7	99,9	35,8	23,1	18,3
6-10	18	23,2	26,2	92,3	35,4	71,9	114,6	120,5	86,4	31,3	21,7	18,3
11-15	17,5	26,4	20,1	44,7	96,9	174,6	105,5	120,3	83,3	27,3	20,8	18,1
16-20	17,3	30,7	22,5	38,3	51	208,2	158,8	125,9	66,7	24	20,2	18,2
21-25	18	35,5	28	37	40	104,2	146,2	123,2	52,5	20,9	19,7	17,8
26-30	18,1	36,3	49,9	37,4	49,2	46,9	117,7	118,1	46,2	20,8	22,8	17,5

Table 9. Average daily discharge (m^3/sec) for Rezan River at Rezan station for the average water year discharge 2001-2002

#	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1-5	14.4	17.1	30.8	55.2	36	50.8	67.8	102.3	65.6	26.5	18.2	15.6
6-10	14.4	18.3	27.4	65.5	40.1	60	80	83.1	57.8	23.8	17.3	15.1
11-15	14.1	19.9	20.6	44.4	71	114.3	75.8	81.9	54.4	22.2	16.6	14.2
16-20	14.1	22.7	20.3	37.7	48.1	146.1	102.8	85.9	47.1	20.5	16	14.1
21-25	14.5	25.3	22.5	36.8	42.8	109.9	106.3	82	36.7	18.2	15.7	13.4
26-30	14.5	25.5	33.1	37.9	47.4	78.8	82.8	78	32.8	17.4	17.1	13

Results and Conclusion

The Rezan River is of great importance for Iraqi Kurdistan Region; because it provides Greater Zab River with about 1,37 billion m^3/year which represent about 8,2% of its total discharge. The total drainage area of Rezan River which locates within Iraqi Kurdistan Region is about 1158 km^2, while the other parts locate within Turkey and Iran. The hydrograph of Rezan River for the water year 2001 (minimum discharge water year) which is shown in Fig. 3 and the results of the hydrograph analysis are shown in Tables 4 and 5. The contribution amount of the base flow into river discharge is extremely more than that of the direct surface runoff because the groundwater is the main source of the river flow where the precipitation amount is less than the average annual precipitation, while the amount of basin storage discharge is little less than that of the bank storage discharge. During the maximum discharge water year (2002), Figure 4 and Tables 6 and 7 the contribution amount of base flow into the river discharge is moderately more than that of direct surface runoff because the amount of the annual precipitation is high, while the amount of basin storage discharge is more than that of the bank storage. But the amount of total base flow discharge is more than the surface runoff for the two mentioned water years. Usually during the maximum water year discharge the amount of bank storage discharge should be more than the amount of basin storage discharge and during minimum water year discharge the amount of basin storage should be less than the amount of basin storage discharge. But the results of the hydrographs analysis of the Rezan River for the maximum and minimum water year discharges as mentioned before do not match with this fact.

Therefore, it is necessary to use the average water year of the maximum and minimum water years, which is the real representative of the river discharge system and its components. The hydrograph analysis of the average water year (2001-2002) as illustrates in Figure 5 and Tables 8 and 9, shows that the base flow discharge into the river is more than the direct runoff discharge into the river, this can be attributed to the slow melting of huge snow cover in the upstream area, where the melting water seeps directly through the fractures and discontinuities into the aquifers which are hydraulically in connection with the river course along the deep gulley and valleys in mountainous areas. The amount of bank storage discharge into the river is more than that of basin storage discharge; this can be attributed to the structural geology of the area where the bedding planes and fractures as well as the channels of solution along the river banks stores the water rapidly during the flood stage of the river and gives it back to the river temporarily during the low stage of the river discharge. This process repeats it self several times during the water year. According to Fetter [4], if the flood-crest depth in the channel is greater than the local water-table elevation, the hydraulic gradient in the aquifer next to the stream is reserved, water flows from the stream into the ground. The result is a temporary storage of flood water in the aquifer next to the stream. When the flood crest passes, the hydraulic gradient again reverses. The Rezan River discharge system characterizes by peaks discharge during March, April, and May. The maximum peak flow discharge occurs during March where the precipitation amount is more than the other months; moreover the snow cover in the downstream area begins to melt in the beginning of March. While the peaks of flow discharge during April and May can be attributed to the late period of snow melting in the high mountainous areas of the upstream.

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