COMPARISON OF HYDROLOGICAL CHARACTERISTICS IN KARSTIC AND NON-KARSTIC LANDSCAPES (CASE STUDY: MOJEN AND GORGDAREH CATCHMENTS IN IRAN)

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Karst topography is a landscape shaped by the dissolution of a layer or layers of soluble bedrock, usually carbonated rock such as limestone or dolomite. Investigation and comparison of these landscapes with another landscape that have non-karstic topography for is necessary watershed managers. The main objective of this research is to compare hydrological characteristics of two types of catchments including karstic and non-karstic catchments. Mojen catchment has a karstic topography that mostly covered by limestone, and Gorgdareh as a non-karstic topography in west side of Mojen catchment where both are located in central Alborz Mountain in Semnan province, with the similar climate, area, slop and annual rainfall. Thses two catchments are compared in view of maximum discharge, runoff coefficient, specific discharge and relationship between maximum instantaneous discharge and maximum daily mean discharge. Results indicate that runoff coefficient for Mojen's karstic catchment is 1.28 and for Gorgdareh that is Non- karstic catchment is 0.35. Specific discharge for Mojen on a concurrent period is 0.0174 $m^3/sec/km^2$ when for the Gorgdareh it is $0.051 m^3/sec/km^2$. Relationship between maximum instantaneous discharge and maximum daily mean discharge for Mojen is 1.145 and for Gorgdareh is 1.380. Finally this research showed that application of rational and empirical formulas for karstic catchment is unreliable.
Keywords: Karst topography, Calcareous landscape, Non-calcareous landscape, Discharge, Runoff Coefficient

INTRODUCTION

Karastic water reservoirs have been under consideration of the researchers and people from long years ago. In Iran several research projects have been carried out on evaluation of Karastic areas water resources. Geological surveys indicate that there are Karastic resources in three chains of Iran highlands that are included of central Alborz highlands and the Zagros areas. About 10000 km^2 of Karastic area exist in Alborz regions, about 5000 km^2 in central parts of Iran, and about 40000 km^2 in Zagros region. The best type of karast aquifers are located in Zagros highland especially in southern regions. Investigation on hydrological characteristics of two calcareous landscape and non-calcareous landscape in Zagros highlands has indicated that runoff coefficient in calcareous landscape is about 4 -5 folds of non- calcareous catchment. Climate changes can have remarkable effect on the water resources, as well as the rate and volume of

running water can be changed under effect of atmosphere condition, and these types of changes can be occurred by Karastic water reservoirs. Felton [4] has performed hydrological analyze on a Karastic catchment located in Woodford, USA, and has prepared an equation for the river pick runoff for these type of catchments, by analyzing the runoff for 312 days. After this investigation he has concluded that the presented common equations are not generally applicable to Karastic catchments. Atkinson et al. [1] and Brown *et al.* [2] believe that in order to study Karastic catchments, many field studies shall be done which are included of a large number of samplings, estimation of water drained on the land surface by the springs, investigation on underground water runoff velocity and water level variations etc. Kovalevsky and Dublyanskii and Kiknadze [3] and Kovalevsky and Efermenko [5] have stated that discharge of underground water is under effect of climate condition and holes and small cracks.

Surface runoff quantity of ungauged catchments is normally calculated via methods which usually are provided based on appearance characteristics such as area, length of main waterway, catchments slope and runoff coefficient. Runoff coefficient is also obtained from the tables in which geological formations were not generally pointed out. This issue results in invalidity of application of these methods for Karastic catchments. In this research the aim is to compare calcareous landscape and non- calcareous landscapes in terms of water resources and also evaluation of the empirical formulas in calcareous landscapes.

MATERIALS AND METHODS

In order to do this research, first several calcareous and non- calcareous landscapes were studied and evaluated to select two catchments with the heist similarity in terms of climate conditions, area and average slope, but one completely calcareous and the other one non-calcareous landscape. After selection of the catchments, these catchments were precisely evaluated from the view of from average annual rainfall, rainfall variations and characteristics and also other climate conditions as well as average daily discharges, maximum daily discharge and instantaneous peak discharge. For the available data record period, water quantity resulted from rainfall were calculated and then using annual average rainfall and the related annual runoff (using measured discharge data) , runoff coefficient was calculated for each one of the catchments and finally these values have been compared to each other. Meanwhile, optimized statistical distribution was selected for processing and estimation of instantaneous peak discharges and daily maximum average discharge with different return periods, applying HYFA software. The difference between discharges of the catchments for different return periods has been compared. Mojen catchment is a mountainous and a Karastic catchments whic is located on the Alborz mountain range and has general western-eastern slope. Gorgdareh catchment is a non- calcareous catchment which is located in west side of the Mojen catchment and has general eastern-western slope. Area of Mojen catchment is 734.7km^2 and area of Gorgdareh catchment is 816km^2. Both catchments were evaluated in terms of shape and

shape. The values of form factor and compression coefficient is 0.297 and 1.130 respectively for calcareous catchment and for non- calcareous catchment these are 0.453 and 1.262 respectively.

Average height of the calcareous and non- calcareous catchments is 2626m and 2455m from sea level respectively. Both catchments have similar conditions for many factors effective on runoff coefficient and specific discharge including extension, area, slope and rainfall amount.

Considering to outcome discharges from catchments, also annual rainfal and the runoff coefficient is calculated via following equations:

$$V_n = H_p A \tag{1}$$

where V_n is annual rainfall volume per million cubic meter, H_p is average rainfall height per meter and A is catchment area per km^2. Annual runoff amount can also be calculated via the following formula:

$$V_{ro} = 31.54 Q_m \tag{2}$$

where V_{ro} is annual runoff volume per million cubic meters and Q_m is average annual discharge per m^3 /s.

$$C_r = \frac{V_{ro}}{V_p} \tag{3}$$

C_r is catchment runoff coefficient and catchments specific discharge is also calculated via the following equation:

$$q = \frac{Q_p}{A} \tag{4}$$

q is catchment specific discharge per m^3/s/ km^2, A is catchment area and Q_p is instantaneous peak discharge of the catchment per m^2/sec.

RESULTS AND DISCUSSION

Both under consideration catchments have flow gauging station in their outlet. According to the performed measurements, average annual discharge of Mojen catchment in its outlet is 1297 m^3/sec and average annual runoff volume is equal to 409.02 million m^3. Average annual discharge of Gorgdareh catchment in its outlet has been measured equal to 4.19 m^3/sec, therefore average annual runoff volume of this catchment is 132.14 million m^3. As it was mentioned, compression coefficient and equivalent rectangle of both catchments are near to each other and it can be said that both catchments have extended shape and almost similar form factors. Also average height and slope of both catchments are not very different from each other. But since area of both catchments are not fully equal, runoff coefficient and specific discharge have been calculated for each catchment in order to be able to compare catchments runoff more precisely. With

increase of a catchment height (from sea level), rainfall and runoff values of both have are increased and vise versa , so the role of the catchment area is not so important in runoff coefficient according to equitation (3). Thus specific discharge calculated from equitation (4), as well as runoff coefficient obtained from equitation (3) both are parameters logically comparable.

According to the obtained results, runoff coefficient for the Gorgdareh catchment is 0.345 and for Mojen catchment the runoff coefficient is 1.206, therefore the runoff coefficient of Mojen Karastic catchments is about 3.7 times greater than Gorgdareh non-Karastic catchment runoff coefficient. This is because of unusual runoff coefficient of the calcareous catchment. According to this run off coefficient, the runoff is about 1.206 times of rainfall in Mojen catchment. It is clear that for a catchment where is not any looses for rainfall, thus runoff coefficient can be equal to 1, so there should be another reason which considerably increase discharge value in this catchment, and it must be underground calcareous waterways which bring water to this catchment from neighboring catchments. Average annual rainfall and its distribution for both catchments in a similar record period is nearly the same (Fig 1), but correlation between rainfall and run off discharge and volume is perfectly different for the both catchments.

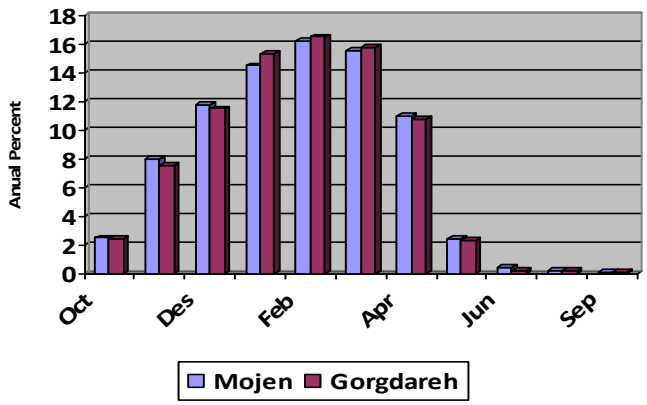

Figure 1. Comparison of average annual rainfall in Mojen and Gorgdareh catchments

According to equitation [5], correlation coefficient between rainfall and annual average discharge value of Mojen catchment is 0.11 that is perfectly insignificant while the correlation coefficient between rainfall and annual average discharge value of Gorgdareh catchment is 0.81 which is perfectly significant.

$$d=0.0058+ 11.06 \quad (r=0.11) \tag{5}$$

$$d= -4.66 + 0.02P \quad (r=0.81) \tag{6}$$

In the above equations, d is annual average discharge per m^3/s, p is annual average rainfall per mm and r is the correlation coefficient. Weak correlation coefficient between annual average rainfall and discharge in Mojen catchment also indicates the important

role of calcareous waterways in this region and also indicates that a large amount of catchment water is provided from Karastic sections. Also this low correlation for Mojen in comparison to Gorgdareh non-calcareous catchment indicates that empirical equations for discharge calculation which normally use rainfall data are not applicable in Karastic catchments.

According to equation (4), specific discharges obtained for Mojen and Gorgdareh catchments equal to 17.4 and 5.12 lit/s/km^2 respectively.

As it is clear in equitation (4) and in the situations in which average slope, height and extension of both catchments are nearly similar, specific discharge shall be more in a catchment in which there is more rainfall. According to these two arguments, in usual condition Gorgdareh catchment specific discharge shall be more than Mojen catchment, but actually specific discharge value of calcareous Mojen catchment is about 3.4 times more than the non-calcareous Gorgdareh catchment because of present Karast phenomenon. Therefore in Karastic catchments, water resources can be divided into two parts one from rainfall and the other one from Karastic water resources. Despite to non-Karastic regions in which approximately whole water are provided from rainfall, in Karastic catchment water from rainfall is forms only a part of whole present water in the catchment. These resources have binary procedure, that is water from rainfall which penetrates severely into cracks and clefts obtained by Karast phenomenon in some Karastic catchments and leads to unusual reduction of runoff coefficient and in contrast, a big amount of water are drained into the catchment through Karastic springs in neighboring catchments and leads to increase total runoff value.

Results of this research indicate that in Mojen calcareous catchment about 70% of outcome water volume is provided through Karastic resources ,therefore recognition of Karastic whole catchments is fully necessary in order to optimize consumption. Also, topography borders can not be used to calculate discharge in Karastic catchments.

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