

## ESTIMATION SURFACE RUNOFF CHARACTERISTICS OF HISHKARO BASIN, DUHOK GOVERNORATE USING SOME HYDROLOGICAL APPROACHES

RAMADHAN HAMZA MOHAMMED

Institutional Research Center (IRC) – University of Duhok, Kurdistan Region-Iraq

*(Received: March 29, 2021; Accepted for Publication: July 25, 2021)*

### ABSTRACT

An analysis of some hydrological characteristics specifically surface runoff of Hishkaro stream basin located in Duhok Governorate-Kurdistan Iraq was conducted. The available historical recorded rainfall data in Duhok and Zawita meteorological stations were used to calculate maximum daily rainfall using probability distribution for number of return periods. Natural resources conservation service method (NRCS) is used to estimate daily surface runoff at the outlet of the basin. Then runoff coefficient, monthly and annual surface runoff volume were predicted. A maximum daily surface runoff for different probability distribution and number of return period was calculated too which is an essential parameter in the design process of any future required hydraulic structures on Hishkaro stream.

### (1) INTRODUCTION

The proper planning of storage structures, waterways, irrigation schemes, water harvesting, erosion control structures, and groundwater development strategies requires accurate estimation of surface direct runoff (Hussein A., et al ,2000) .However, hydrologists in Iraq face serious challenges, specifically due to the rare availability of surface runoff data. To overcome water scarcity challenges that most arid and semi-arid regions, decision-makers in that region must come up with strategies to explore new water resources or optimize the usage of the available resources.

Kurdistan region of Iraq lie within the semi-arid region. The climate of the region is characterized by its fluctuation in rainfall and periods of droughts (Al-Ansari, 1998). Recently, the water scarcity issue is becoming more serious due to several factors.

Water demand, high population rate, effect of global warming and poor management and planning of the water resources during the last four decades. In addition, water policies of the neighboring countries enforced another burden where huge dams were built on the upper parts of the Tigris and Euphrates Rivers in Syria and Turkey. And this led to the reduction of the flow rate of both rivers inside of Iraq. So it is important

to build dams in suitable areas to guarantee water reserving for drought seasons (Al-Ansari, 2011).To meet the scarcity of water shortage In Iraq, the accurate information of runoff is not available in most areas and is limited. The Soil Conservation Services Hydrologists constantly face the problem of estimating direct runoff in which no available records for a specific watershed.

Different researchers interested in estimating direct runoff using SCS method (Liu, X.; Li, J,2008, Topno, A.; Singh, A.K.; Vaishya, R.C.,2015, Gitika, T.; Ranjan, S.,2014, Zahraa M. Klari , Sayran A. I.,2021 )

In this study, the soil conservation service method was utilized to estimate the direct runoff depth and its volume for Hishkaro river basin in Duhok Governorate, north of Iraq in Kurdistan region using NRCS approach in addition their maximum values for different return periods.

### (2) THE STUDY AREA

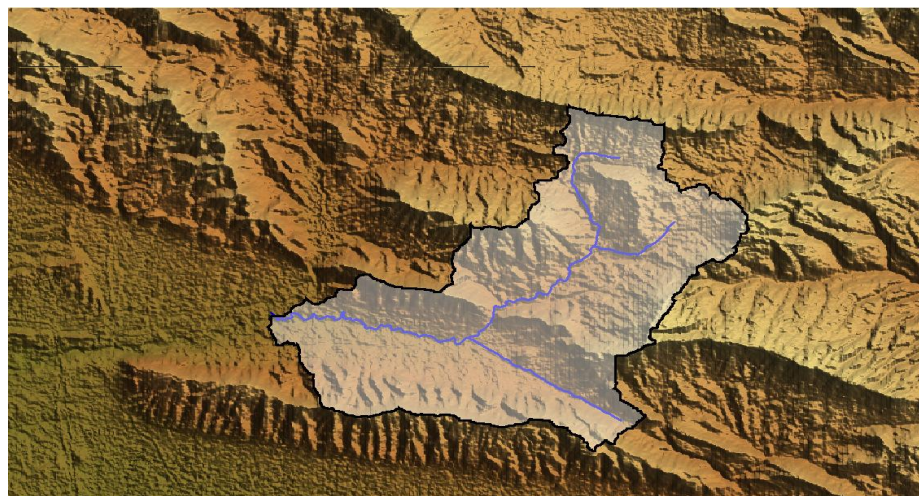
Hishkaro stream is an ephemeral and located in the Duhok Governorate in Kurdistan Iraq. A watershed area analysis for the stream basin was conducted (Su Yapi Engineering& construction,2014) using ASTER DEM as shown in Figures 1 and 2. The total area of the basin is 79.2 km. The total drainage area of the Hishkaro

stream basin was divided into two sub-catchments called as: Upper Hishkaro and Lower Hishkaro catchment area to ensure representation of the

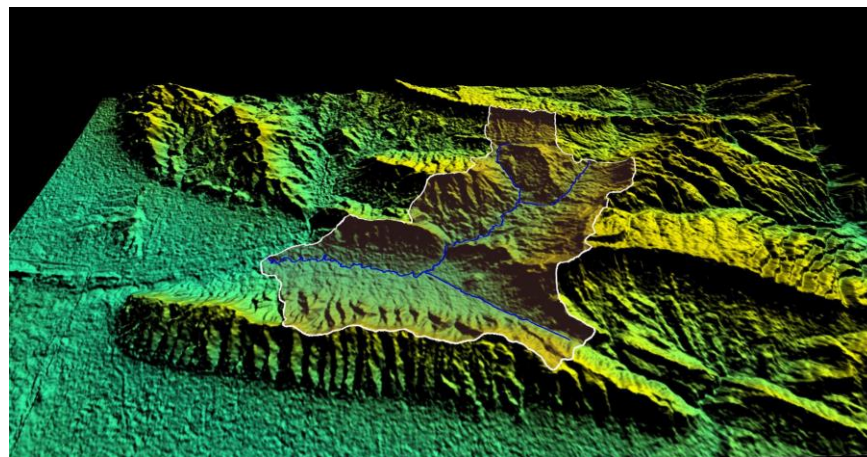
hydrological process. in which table 1 shows their topographical characteristics.

**Table( 1):-** Topographical characteristics of Upper and Lower Hishkaro catchment.

Upper Hishkaro catchment				Lower Hishkaro catchment			
Area (km <sup>2</sup> )	Basin Length (km)	Average Elevation (m.a.s.l.)	Average Slope	Area (km <sup>2</sup> )	Basin Length (km)	Average Elevation (m.a.s.l.)	Average Slope
58	10.9	866	25.1%	21.2	8.3	682	22%



**Fig.( 1):** -The Hishkaro stream watershed boundaries and the main channel.



**Fig.(2):** -Hishkaro stream watershed in Three dimension (Su Yapi Engineering& construction,2014)

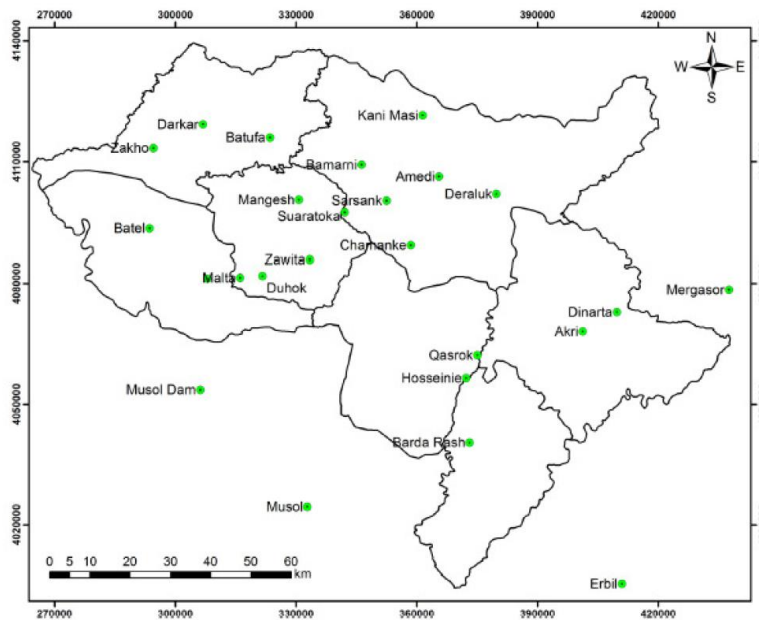
### (3) METROLOGICAL DATA ANALYSIS

The available rainfall data for Duhok and Zawita meteorological stations located within Hishkaro basin (Figure 3) for the years (2003-

2019) was depended. The maximum daily rainfall recorded for these two stations are shown in table (2) after arranging in a water year form for the rainfall season of each water.

**Table (2):-** Maximum daily rainfall recorded in Duhok and Zawita stations.

Duhok Station		Zawita Station	
Water year	Maximum daily rainfall (mm)	Water year	Maximum daily rainfall (mm)
19/4/2004	65	19/04/2004	76.5
23/1/2005	64	23/01/2005	69.0
17/4/2006	71.6	03/02/2006	96.0
25/10/2007	54	28/01/2007	70.0
28/1/2008	34	28/01/2008	75.0
29/11/2009	38.5	31/12/2009	42.0
19/12/2010	57.5	30/12/2010	66.0
22/4/2011	62.7	22/04/2011	95.0
4/3/2012	36.7	31/01/2012	54.0
28/1/2013	70.4	08/01/2013	133.0
8/11/2014	101.5	27/01/2014	149.0
16/10/2015	48.4	26/11/2015	69.0
31/12/2016	44.1	31/12/2015	79.0
13/4/2017	39.3	14/12/2016	88.0
5/5/2018	65.2	19/01/2018	58.0
28/1/2019	75.4	15/11/2019	111



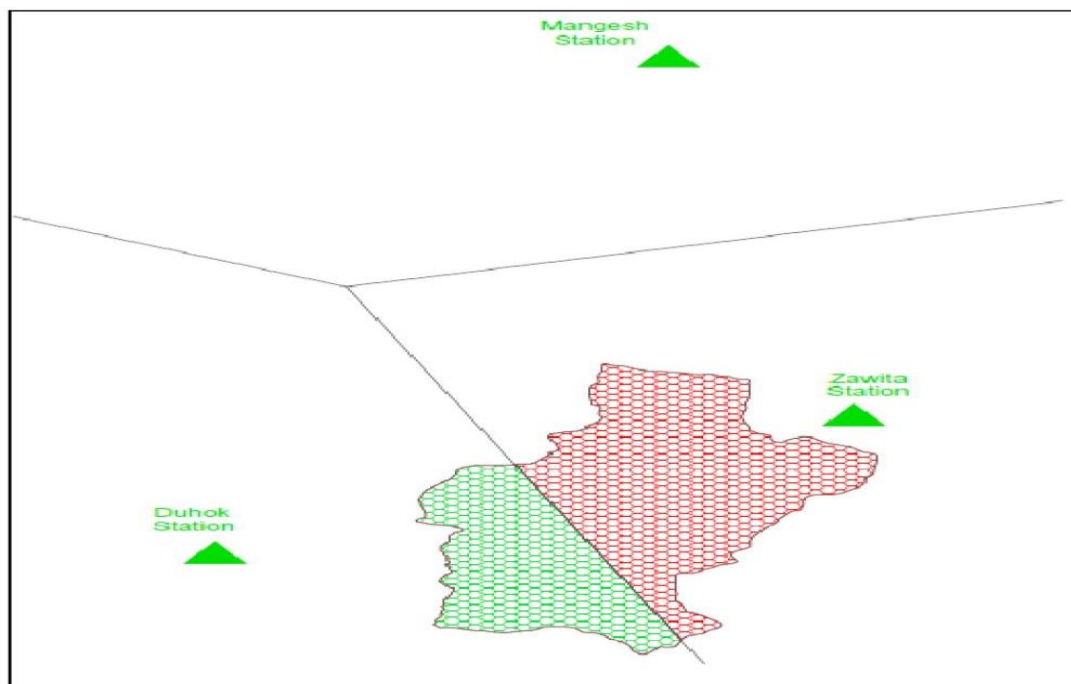
**Fig.( 3):-** The locations of the meteorological stations

According to the Thiessen polygon method Table 3 and Figure 4 shows the influence of each meteorological station of Duhok and Zawita in the

Hishkaro basin (Su Yapi Engineering& construction,2014).

**Table (3)** :-Percent of influence of meteorological Duhok and Zawita stations in the hydrological analysis.

Station Name	Drainage area	Percent of Influence
Duhok	21.23 km <sup>2</sup>	30.60 %
Zawita	36.77 km <sup>2</sup>	63.40 %
Mangesh	0.00 km <sup>2</sup>	0.00 %
Total	58.00 km <sup>2</sup>	100.00 %

**Fig.( 4)**:- Area distribution of the Hishkaro watershed according Thiessen method

#### (4) SOIL CONSERVATION METHOD FOR ESTIMATING SURFACE RUNOFF

Daily surface runoff for Hishkaro basin was estimated using Soil Conservation Service (SCS) approach, using available recorded rainfall data for the water years (2004-2019) for Duhok and Zawita hydrological stations. The present hydrological analysis is focused on estimating the maximum daily runoff, which is important in the design of any hydraulic structures required in the catchment of the Hishkaro stream.

The Soil Conservation Service (1972) developed a method for computing abstractions

from storm rainfall. For the storm as a whole, the depth of excess precipitation or direct runoff ( $P_e$ ) is always less than or equal to the total depth of precipitation likewise, after runoff begins, the additional depth of water retained in the watershed ( $F_a$ ) is less than or equal to some potential maximum retention  $S$  as shown in figure (5). There is some amount of rainfall initial abstraction before ponding for which no runoff will occur, so the potential runoff is ( $P - I_a$ ). The hypothesis of the SCS method is that the ratios of the two actuals to the two potential quantities are equal, that is:

$$\frac{Fa}{s} = \frac{Pe}{P-Ia} \text{-----(1)}$$

From the continuity principle:

$$P = Pe + Ia + Fa \text{----- (2)}$$

Combining these two equations to solve for  $Pe$  gives

SCS method of rainfall

Where:

- $Pe$  = rainfall excess
- $Fa$  = continuing time
- $P$  = total rainfall.
- $Ia$  = initial abstraction

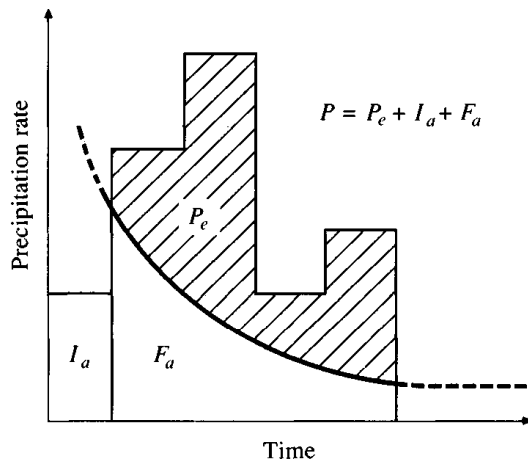


Figure 5. Variables in the abstractions

abstraction,

$$Pe = \frac{(P-Ia)^2}{P-Ia+S} \text{.....(3)}$$

which is the basic equation for computing the depth of excess rainfall or direct runoff from a storm by the SCS method.

Through studying the results from many small experimental watersheds, an empirical relation was developed as follows:

$$Ia = 0.2S \text{.....(4)}$$

On this basis:

$$Pe = \frac{(P-0.2S)^2}{P+0.8S} \text{.....(5)}$$

Where :

$S$  is the abstraction coefficient, it represents the upper infiltration in soil .

shown in Figure 6 to standardize these curves, a dimensionless curve number  $CN$  is defined such that  $0 < CN < 100$ . For impervious and water surfaces  $CN = 100$ ; for natural surfaces  $CN < 100$

Plotting the data for  $P$  and  $Pe$  from many watersheds, the SCS found curves of the type

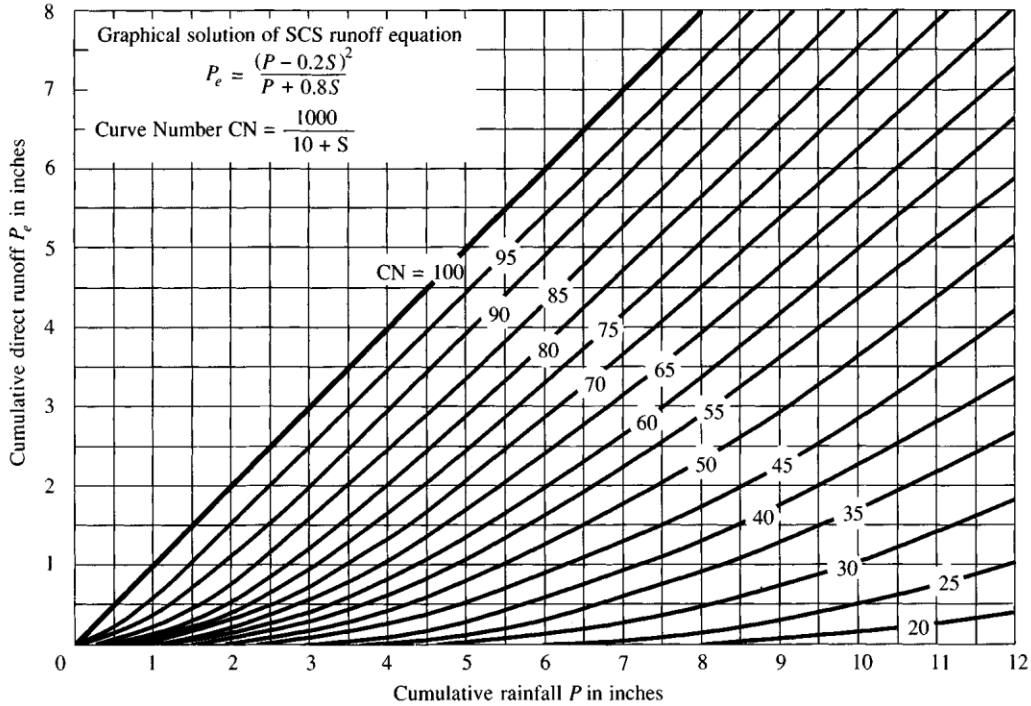


Fig.( 6):- Dimensionless Curve number curve for different surfaces.

The curve number and  $S$  are related by:

$$S = \frac{25400}{CN} - 254 \quad \dots \dots (6)$$

The curve numbers shown in Figure 6 apply for normal *Antecedent moisture conditions* (AMC II). For dry conditions (AMC I) or wet Conditions

(AMC III), equivalent curve numbers can be computed by

$$CN(I) = \frac{4.2CN(II)}{10 - 0.058CN(II)} \quad \dots (7)$$

And

$$CN(III) = \frac{23CN(II)}{10 + 0.13CN(II)} \quad \dots \dots (8)$$

Classification of antecedent moisture classes (AMC) for the SCS method of rainfall abstractions is shown in Table 4.

Table( 4):- Total 5-day antecedent rainfall (mm).

AMC group	Dormant season	Growing season
I	Less than 0.5	Less than 0.4
II	0.5 to 1.1	1.4 to 2.1
III	Over 1.1	Over 2.1

**(5) APPLICATION OF SCS METHOD FOR ESTIMATING SURFACE RUNOFF**

For topography elaborations, ASTER GDEM ver.2 data were used. ASTER GDEM ver.2 maintains the geotiff format and gridding with 30-m postings and 1x1 degree tiles. According to the soil group type and land use, the curve number for Upper Hishkaro Basin is selected to be CN=85.

But, for the lower part of the basin, there are some residential areas that need to be considered (Figure 7), so the CN value is updated for the whole Hishkaro Basin. The hydrologic soil group for the whole basin is selected as type “C” according to number of site investigations and soil tests (Su Yapi Engineering & construction, 2014).



**Fig.( 7):- Residential areas in the Hishkaro Basin**

The residential area in the lower Hishkaro basin cover about 11.6 km<sup>2</sup>. Then curve number for these residential areas is selected to be CN =

98. The final value of the whole basin calculated according to the weight of each catchment as follows:

$$CN = \frac{\sum_{i=1}^n A_i CN_i}{\sum_{i=1}^n A_i} = \frac{(11.6 * 98) + (67.6 * 85)}{79.2} = \frac{1136.8 + 5746}{79.2} = 87 \quad \dots (9)$$

Applying the SCS method using above calculation, the daily runoff for each day of the water years for the period (2004-2019) were calculated, then the maximum daily rainfall in addition to maximum daily runoff for each water

year were estimated for the Hishkaro basin area as shown in Table (5). Then the total annual runoff depth and volume for each season was estimated as shown in Table 6.

**Table (5):-** Maximum daily runoff (mm) and volume for Hishkaro basin during the years (2004-2019).

Day	Season	Max. runoff (mm)	Max. Volume (m <sup>3</sup> )
19/4/2004	2003-2004	39.03	16.40
23/1/2005	2004-2005	57.24	1.16
25/1/2006	2005-2006	81.93	52.89
3/2/2007	2006-2007	31.71	20.92
3/2/2008	2007-2008	31.71	40.49
31/12/2008	2008-2009	8.07	4.27
19/1/2010	2009-2010	81.68	37.14
22/4/2011	2010-2011	50.1	4.5
17/12/2011	2011-2012	7.72	3.5
8/1/2013	2012-2013	138.14	82.90
28/1/2014	2013-2014	115.14	60.52
26/11/2014	2014-2015	65.76	38.50
1/1/2016	2015-2016	67.38	36.05
12/12/2016	2016-2017	54.63	36.67
5/5/2018	2017-2018	24.94	10.83
15/11/2018	2018-2019	60.93	35.27

**Table( 6):-** Total annual runoff depth (mm) and volume for each depended water year.

Season	Annual runoff depth (mm)	Max. Volume (m <sup>3</sup> )
2003-2004	396.44	176.36
2004-2005	310.93	31.25
2005-2006	600.41	317.34
2006-2007	410.43	202.4
2007-2008	435.31	140.2
2008-2009	232.35	94.27
2009-2010	479.88	246.92
2010-2011	420.5	48.62
2011-2012	160.91	68.51
2012-2013	891.35	442.60
2013-2014	473.14	241.99
2014-2015	464.4	220.10
2015-2016	518.43	258.87
2016-2017	300.18	145.25
2017-2018	390.97	175.45
2018-2019	887.59	458.53

**6. APPLICATION OF V.T. CHOW METHOD FOR ESTIMATING RAINFALL AND RUNOFF FOR DIFFERENT RETURN PERIODS**

V.T. Chow has shown that the most frequency distribution functions applicable in hydrologic studies can be expressed by the following equation:

$$R_T = \bar{R} + K_T \cdot \sigma \dots\dots\dots(9)$$

Where:

R<sub>T</sub>=Daily reduce variates (rainfall or daily runoff) for the return period T

R=Average maximum daily reduce vitiates (rainfall or maximum daily runoff) for the

recorded rainfall or estimated daily runoff in mm for the recorded rainfall data of estimated daily runoff respectively.

KT=Frequency factor which is a function of return period and depend on the probability distribution used.

σ=Standard deviation of the daily rainfall or maximum daily runoff for the recorded rainfall or estimated daily runoff in mm for the recorded rainfall data of estimated daily runoff respectively.

The above hydrologic equation using Gumbel and Person type three distributions can be applied to get the extremes values for rainfall data recorded in Duhok and Zawita stations leading to



calculate the extremes values for the runoff in Hishkaro basin as follows:

**6.1 Application of V. T. chow for Estimating Maximum Expected Daily Rainfall data:**

Two probability distribution were used for Estimating Maximum Expected Daily Rainfall data for the two meteorological stations under study, the procedure of these distributions are:

**a- Applying Gumbel distribution method:**

The procedure of this distribution method is:

**a-** Find the average and standard deviation of maximum daily rainfall for the recorded maximum daily rainfall series.

**b-** Find the value of the frequency factor (  $K_T$  ) for the required return period from the relation:

$$K_T = \frac{Y_T - Y_n}{S_n} \dots\dots(10)$$

Where:

$\bar{y}_n$ = reduced mean, a function of sample size [n] and is given in table10 for  $N \rightarrow \infty$ ,

$S_n$  = reduced standard deviation, a function of sample size  $n$  and is given in the related table ( Subramanya, K., 2013.,Chow,1988).

$y_T$  =reduced variate

**c-** Estimate the maximum expected rainfall depth for required rainfall return periods.

To estimate the Maximum expected daily rainfall for Duhok station, the values of average and standard deviation of maximum daily rainfall for the period under study equal to 58.02 and 17.8mm respectively , and the Maximum expected daily rainfall for Zawita station, the values of average and standard deviation of maximum daily rainfall for the period under study equal to 83.15mm and 28.39mm respectively.

Maximum rainfall depth values for different return period for Duhok and Zawita station using Gumbel distribution were shown in table 7.

**Table (7):-** Maximum rainfall depth for different return periods rainfall for Duhok and Zawita stations applying Gumbel distribution.

Station	Return period				
	50	100	200	500	1000
Duhok	116.4	128.5	135.6	156.28	168.29
Zawita	176.27	195.57	214.59	239.86	259.026

**b- Pearson Type III distribution method:**

The same procedure of Gumbel probability distribution can be follow, but in step (b) the value of frequency factor (  $K_T$  ) is a function the data skewness coefficient beside the required return period.

Skewness Coefficient be estimate from the relation:

$$C_s = C_v + 3C_v \dots\dots(11)$$

$C_v$  = Coefficient of variation

The value of the  $K_T$  for different return periods can be estimated from the related table ( Subramanya, K., 2013.,Chow,1988 ), with a coefficient of variation and skewness equal to 0.3 and 1.2 respectively for Duhok station and 0.34 ,1.36 respectively for Zawita station.

Rainfall values for different return period for Duhok station using Person type III distribution were shown in table 8.

**Table (8):-** Maximum rainfall depth for different return periods rainfall for Duhok and Zawita stations applying Pearson type III distribution.

Station	Return period				
	50	100	200	500	1000
Duhok	104.7628	114.0722	123.1858	130.911	143.816
Zawita	159.4509	175.2641	190.8219	208.6621	226.4627

## 6.2 Application V. T. Chow method for Estimating maximum direct Runoff for different return period

The same procedure for estimating maximum daily rainfall can be used for estimating the expected maximum daily runoff for the two mentioned distributions.

### a- Applying Gumble probability distribution method:

To estimate the maximum expected daily runoff for the basin, the values of average and

standard deviation of maximum daily runoff for the period under study equal to 18.52mm and 13.02 mm respectively, and the Maximum expected daily rainfall for Zawita station, the values of average and standard deviation of maximum daily rainfall for the period under study equal to 43.48mm and 30.22 mm respectively.

Maximum runoff depth values for different return periods for Duhok and Zawita station using Gumble distribution were shown in table 9.

**Table (9) :-** Runoff depth values for different required return periodsfor Duhok and Zawita stations using Gumble distribution.

Station	Return period (year)	50	100	200	500	1000
Duhok	Runoff (mm)	57.62	68.45	74.56	86.32	89.32
Zawita	Runoff (mm)	61.22	70.079	78.8	90.39	99.18

### b- Pearson Type III distribution method:

The same procedure of Gumbel probability distribution, also, can be follow, but in step (b) the value of frequency factor ( $K_T$ ) is a function the data skewness coefficient beside the required return period.

The value of the  $K_T$  for different return periods can be estimated from the related table

(Subramanya, K., 2013), with a coefficient of variation and skewness equal to 0.703 and 2.8 respectively for Duhok station and 0.695, 2.78 respectively for Zawita station.

Maximum expected runoff values for different return period for Duhok station using Person type III distribution were shown in table (10).

**Table (10):-** Runoff depth values for different required return periods for Duhok and Zawita stations using Person type III distribution

	Return period (year)	50	100	200	500	1000
Duhok station	Runoff (mm)	57.62	68.45	74.56	86.32	89.32
Zawita Station	Runoff (mm)	137.45	163.22	189.17	220.94	252.66

It is worth mentioning that the time of concentration of the area unded study were estimated to be equal to almost 24hr using Kirpch relation, also the percentage area influenced by Duhok station and Zawita stations are 30.6% and 63.4%. The resulted runoff depth for different return periods and the two applied probability

distributions from the whole area of Hishkaro are calculated and estimated as shoen in tables (11). Table 11 shows that Pearson type III gives a higher value for maximum runoff depth for all return period as compare to that of Gumbel's method.

**Table (11) :-** resulted runoff depth (mm) for different return periods applying Gumbel and Pearson type III probability distributions for the whole area of Hishkaro

Distribution	Return period				
	50	100	200	500	1000
Gumbel	56.45	91.02	101.16	116.28	216.12
Pearson type III	103.87	123.37	141.55	165.08	185.97

## (7) CONCLUSION

Gumble and Person type III probability distributions were used in this study to estimate both daily rainfall and daily runoff applying V. T. Chow hydrologic relation after estimating daily runoff using soil conservation Service (SCS) method.

Those probability distributions represent the more accurate distributions that simulate the peak extremes values of the hydrologic event (rainfall and runoff). This is due to the skewness coefficient values for the daily rainfall data and daily run data. The estimation results of the daily rainfall and runoff for different return periods can be used in the design of any required hydraulic structure over Hishkaro stream and also in any stream located within the study area due to the hydrological homogenously state.

## REFERENCES

- Chow, V., Maidment, D. & Mays, L. J. N. Y. 1988. Applied Hydrology McGraw-Hill Book Company.
- Subramanya, K.. Engineering hydrology, 4e, Tata McGraw-Hill Education, 2013.
- Su Yapi Engineering & Consulting Inc., Çankaya/Ankara – Turkey, Construction of Watercourse for Hishkaro River and Main Sewerage Collector Project. Report Prepared ,2014
- Al-Ansari, N.A., Water Resources in the Arab countries: Problems and possible solutions. UNESCO International Conference, Paris, 367-376,1998.
- Al-Ansari, N.A., and Knutsson, S., Toward prudent management of water resources in Iraq. Journal of Advanced Science and Engineering Research, 1, 53-67. Conference, IWTC 13, Hurghada, Egypt,2011.
- Hussein A., Ahmed D., Abed A., Estimation of Surface Water Runoff\_ for a Semi-Arid Area Using RS and GIS-Based SCS-CN Method, Water, 12, 1924; doi:10.3390/w12071924,2020
- USDA. Hydrology. In National Engineering Handbook; United States Department of Agriculture, Soil Conservation Service, US Government Printing O\_ce: Washington, DC, USA, 1972.
- Liu, X.; Li, J. Application of SCS model in estimation of runo\_ from small watershed in Loess Plateau of China. Chin. Geogr. Sci., 18, 1235–1241,2008.
- Topno, A.; Singh, A.K.; Vaishya, R.C. SCS-CN Runo\_ estimation for Vindhyaçal region using remote sensing and GIS. Int. J. Adv. Remote Sens. GIS, 4, 1214–1223,2015.
- Gitika, T.; Ranjan, S. Estimation of surface runo\_ using NRCS curve number procedure in Buriganga Watershed, Assam, India-a geospatial approach. Int. Res. J. Earth Sci., 2, 1–7,2014.
- Zahraa M. Klari , Sayran A. I. , Application of SCS-Curve Number Method to estimate Runoff using GIS for Gali-Bandawa Watershed, Academic Journal of Nawroz University (AJNU), Vol.10, No.1, 2021