Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 7, July 2021: 5111- 5121

Research Article

An Optimum Approach to generate Unit Hydrograph using various Geomorphological techniques: An Immense Review

Abhishek Agrawal*, Dr. Basant Kumar**

ABSTRACT

This paper critically analyse the popular flood hydrograph modelling techniques which are used for gauged and un-gauged basins to develop Unit hydrograph (UH) and Synthetic Unit Hydrograph (SUH). Under the present study, various models have been referred. Different data were collected and with the help of hydrologic modelling software, Geomorphological model was tracked down, which is most useful and intriguing to generate the essential data for unit hydrograph and flood forecasting as well. The study shows that system developed by the Hydrologic Engineering Centre (HEC-HMS), hydrologic modelling is highly accurate and helps in restricting the job of the calibration and validation parameters and saves a lots of time.

KEYWORDS : Synthetic Unit Hydrograph (SUH), Unit Hydrograph (UH), Flood Forecasting, Geomorphological model, Geomorphological Instantaneous Unit Hydrograph (GIUH), Hydrologic Modelling System developed by the Hydrologic Engineering Centre (HEC-HMS).

1. INTRODUCTION

Unit hydrograph (UH) and Synthetic Unit Hydrograph (SUH) concept is a doubtlessly effective tool in watershed hydrology. More than seventy five years on account that the inception of UH principle with the aid of Sherman (1932), it is nevertheless one of the techniques most extensively used for development of Flood Prediction and Warning Systems for gauged basins with located rainfall–runoff data. Sherman paved the way for the development of watershed rainfall–runoff evaluation with his UH technique. In its development, Sherman made assumptions that are the ground work for a good deal of modern-day hydrology.

Now Days, SUH methods is growing very fast. The fundamental cause of this paper is to keep in knowledge the growth in the development of UH and SUH methods in the previous and to furnish rapid reference information for researchers exploring new techniques that can be used for hydrological prediction in gauged and un-gauged basins. In this study, the accessible UH and SUH models have been categorised into Geomorphological models. The Geomorphological classification makes use of basin to develop IUH for flood hydrograph modelling for un-gauged

[1]PhD. Scholar, Department of Civil Engineering, SIRT, SAGE University Indore (MP) India, abhidrakchas@gmail.com

[2]Professor, Department of Civil Engineering, SIRT, SAGE University Indore (MP) India, basantkumarochani@gmail.com

basins. The following sections deal with the models grouped and severely evaluation and talk about their applicability and limitations, and their future applications.

2. OBJECTIVES OF THE STUDY

Following are the objectives of the study:

- To review various Geomorphological techniques used for Unit Hydrograph generation.
- To find out an optimum technique for developing Unit Hydrograph in a region.

3. DATA COLLECTION

Various data of different basin with geographical location, characteristics and period of rainfall in rainy season etc. have been collected for different models. Table 1 shows basin & characteristics properties of Myntdu-Leska River**.** Table 2,3,4 and 5 show basin & characteristics properties of Ajay River, Sakleshpura, tributary of Hemavathi River, and Shuiji River, tributary of Minjiang River, Koraiyar River respectively. Table 6 shows observed peak flow (m^3/s) and observed flood volume (mm) for Koraiyar River.

Table 1: basin characteristics of Myntdu-Leska River

S.no.	Parameters	Properties or Value
1	Study Area	The Myntdu-Leska river catchment is located in the north-eastern part of India
2	Geographical Location	92^0 15' to $92^0$30'E longitude
		25^0 10' to 25^0 17'N latitude
3	Characteristics	The area is narrow and steep
4	Main Rainy Season	May to October
5	Maximum Monthly Rainfall	715 mm
6	Catchment Area	350 km^2
7	Elevation Ranges	595 to 1372 m above mean sea level (msl)

Table 2: basin characteristics of Ajay River

S.no.	Parameters	Properties or Value
1	Study Area	The Ajay River Basin at the Jamtara gauging site. It is a tributary of the Bhagirathi River, in the Ganga Basin of northern India.
2	Geographical Location	$86^0$16'E and $86^0$57'E longitude
		$23^0$57'N and $24^0$37'N latitude
3	Characteristics	mild terrain having small patches of steep slope
4	Main Rainy Season	June to September
5	Catchment Area	2881.65 km^2

Table 3: basin characteristics of Sakleshpura, tributary of Hemavathi River

S.no.	Parameters	Properties or Value
1	Study Area	The head water catchment of the Hemavathi
2	Geographical Location	$75^0$30'0" to $75^0$50'0"E longitude
		$12^0$50'0" to $13^0$10'0" N latitude
3	Characteristics	The area is narrow and steep
4	Maximum Annual Rainfall of Hemavathi river	5080 mm

Table 4: basin characteristics of Shuiji River, tributary of Minjiang River

S.no.	Parameters	Properties or Value
1	Study Area	The Minjiang River is located in southeast China
2	Geographical Location of Minjiang River	$116^0$23' E and $119^0$43' E longitude
		$25^0$23'N to $28^0$19' N latitude
3	Characteristics of Minjiang River	The area is narrow and steep
4	Main Rainy Season of Minjiang River	April to September
5	Average Annual Runoff Volume of Minjiang River	1980 m^3/s
6	Catchment Area of Shuiji watershed	3470.5 km^2
7	annual average temperature of Minjiang River	15^0C to 20^0C
8	Temperature in summer of Minjiang River	it can be higher than 40^0C
9	The runoff in rainy season of Minjiang River	70% to 80% of the total annual runoff
10	land slope of Shuiji watershed	0.0009 to 0.77

Table 5: basin characteristics of Koraiyar River

S.no.	Parameters	Properties or Value
1	Study Area	Located in Tiruchirappalli city region, India
2	Geographical Location	$78^0$32’23.94”–$78^0$39’48.58”E longitude
		$10^0$32’40.24”–$10^0$48’16.81”Nlatitude
3	Characteristics	slope is mild and somewhere steep
4	Main Rainy Season	October and December
5	The average annual rainfall	757.40–866.70 mm
6	Catchment Area	1498 km^2

Table 6: observed peak flow (m^3/s) and observed flood volume (mm)

Flood no.(Date and year)	Observed peak flow (m^3/s)	Observed flood volume (mm)
30-Jul-2000	39.2	0.92

4-May-2004	39	0.9
24-Sep-2005	86.3	1.36
21-Aug-2006	23.3	0.66
9-Dec-2007	62.2	1.48
11-May-2008	64.1	1.32
28-Nov-2010	38.9	0.87
29-Nov-2012	33.8	0.81
17-Nov-2013	37	1.21

4. METHODOLOGY AND DATA ANALYSIS

Under the suggested methodology total six models were analysed: Two-parameter gamma distribution (2PGD), Two-parameter Weibull distribution (2PWD), Geomorphological Instantaneous Unit Hydrograph (GIUH) based Clark Model, Geomorphological Instantaneous Unit Hydrograph (GIUH) based Nash Model, Integrating XAJ Model with GIUH Based on Nash Model, Hydrologic Modelling System developed by the Hydrologic Engineering Centre (HEC-HMS).

4.1 Two-parameter gamma distribution (2PGD)

Hydrograph derived using the 2PGD method with the numerical approach performs marginally better than the other two methods i.e. Analytical approach and Rosso approach. Table 7 shows parameters and their values evolved from 2PGD model and Fig. 1 shows Synthetic Unit Hydrograph (SUH) developed from 2PGD model.

Table 7: Parameters and their values evolved from 2PGD model

S.no.	Parameters	Unit	Value evaluated
1	Catchment order = Ω	-	6
2	Area of catchment= A_{Ω}	km^2	350
3	Length of catchment= L	km	52.0
4	Area ratio = R_A	-	4.61
5	Bifurcation ratio = R_B	-	4.27
6	Length ratio = R_L	-	2.12
7	Peak time = t_p	hr	5
8	$v L^{-1}$	h^{-1}	0.243
9	Peak discharge = Q_p	Cumec	11.8
10	$q_p = Q_p/A$	mm/h/mm	0.122
11	$\beta = q_p x\ t_p$		0.574
12	Shape parameter = n	-	3.26
13	Scale parameter = k	hr	2.09

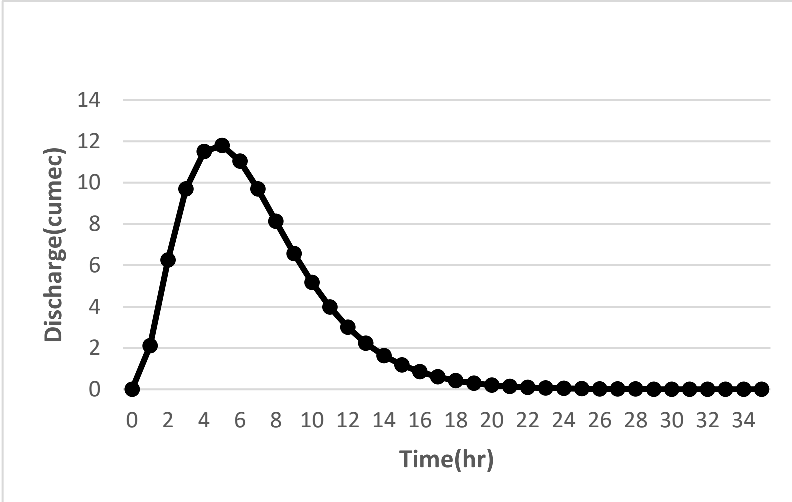

Figure 1: SUH developed from 2 PGD model

4.2 Two-parameter Weibull distribution (2PWD)

Hydrograph derived using the 2PWD method with the numerical approach performs better than the analytical approach. Table 8 shows parameters and their values evolved from 2PWD model and Fig. 2 shows Synthetic Unit Hydrograph (SUH) developed from 2PWD model.

Table 8: parameters and their values evolved from 2PWD model

S.no.	Parameters	Unit	Value evaluated
1	Catchment order = Ω	-	6
2	Area of catchment= A_{Ω}	km^2	350
3	Length of catchment= L	Km	52.0
4	Area ratio = R_A	-	4.61
5	Bifurcation ratio = R_B	-	4.27
6	Length ratio = R_L	-	2.12
7	Peak time = t_p	hr	5
8	$v L^{-1}$	h^{-1}	0.243
9	Peak discharge = Q_p	Cumec	11.8
10	$q_p = Q_p/A$	mm/h/mm	0.122
11	$\beta = q_p x\ t_p$		0.574
12	Shape parameter = a, (a>1)		1.93
13	`Scale parameter = b, (b>0)		6.88

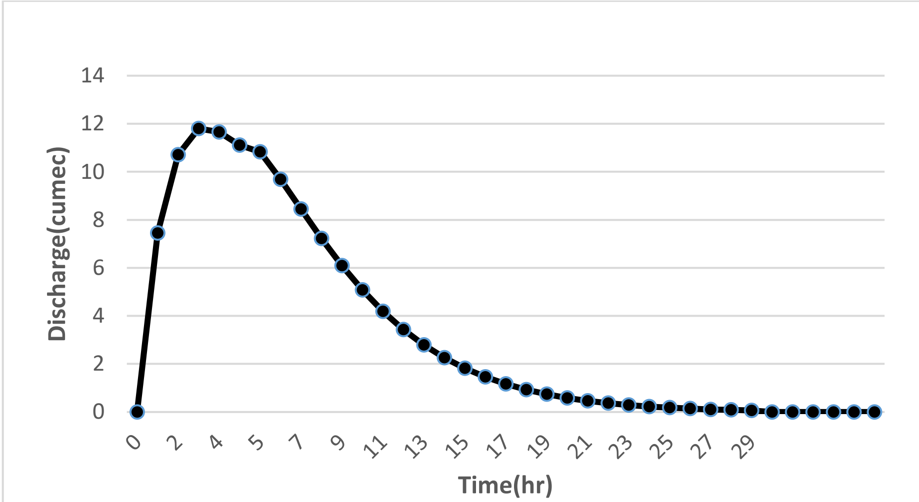

Figure 2: SUH developed from 2PWD model.

4.3 <u>Geomorphological Instantaneous Unit Hydrograph (GIUH) based Clark Model</u>

Table 9 shows parameters and their values evolved from GIUH based Clark Model and Fig. 3 shows Synthetic Unit Hydrograph (SUH) developed from GIUH based Clark Model.

Table 9: Parameters and their values evolved from GIUH based Clark Model

S.no.	Parameters	Unit	Value evaluated
1	Catchment Area	km^2	2881.65
2	largest flow path length of the stream	km	125.06
3	the drainage density	km^{-1}	1.424
4	the maximum relief	meter	345
5	relief ratio	-	0.0016
6	Observed Peak discharge	Cumec	351.700
7	duration	hr	3
8	Total rainfall excess	mm	4.949
9	Bifurcation ratio = R_B	-	4.208
10	Area ratio = R_A	-	4.748
11	Length ratio = R_L	-	2.204
12	Time of concentration (T_c)	hr	16.780
13	storage coefficient of the Clark IUH model (R)	hr	0.711

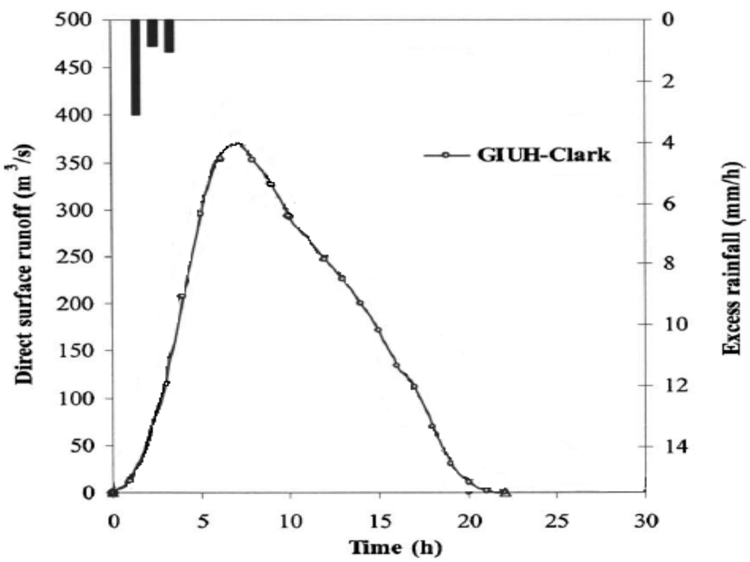

Figure 3: SUH developed from GIUH based Clark Model

4.4 Geomorphological Instantaneous Unit Hydrograph (GIUH) based Nash Model

Table 10 shows parameters and their values evolved from GIUH based Clark Model, Table 11 shows coordinate evolved for Hydrograph and Fig. 4 shows Synthetic Unit Hydrograph (SUH) developed from GIUH based Clark Model.

Table 10: parameters and their values evolved from GIUH based Nash Model

S.no.	Parameters	Unit	Value evaluated
1	Shape parameter = n	-	3.9
2	dynamic velocity = V	m/s	4
3	Scale parameter = k	Hr	2.3667
4	Peak discharge = Q_p	Cumec	166.43
5	Peak time = t_p	hr	9

And the coordinate evaluate are as below

Table 11: coordinate evolved for Hydrograph

t_p (hr)	u(t) in cumec	t_p (hr)	u(t) in cumec	t_p (hr)	u(t) in cumec
0	0	9	164.3171	18	34.0895
1	6.2104	10	154.1544	19	26.6365
2	30.3815	11	138.7321	20	20.6049
3	64.5324	12	116.0654	21	15.7968
4	97.41	13	99.1028	22	12.0136
5	121.94	14	80.2202	23	9.0704
6	139.6049	15	66.3128	24	6.8033
7	151.9712	16	53.8811	25	5.0723
8	160.2041	17	43.1353	26	3.7611

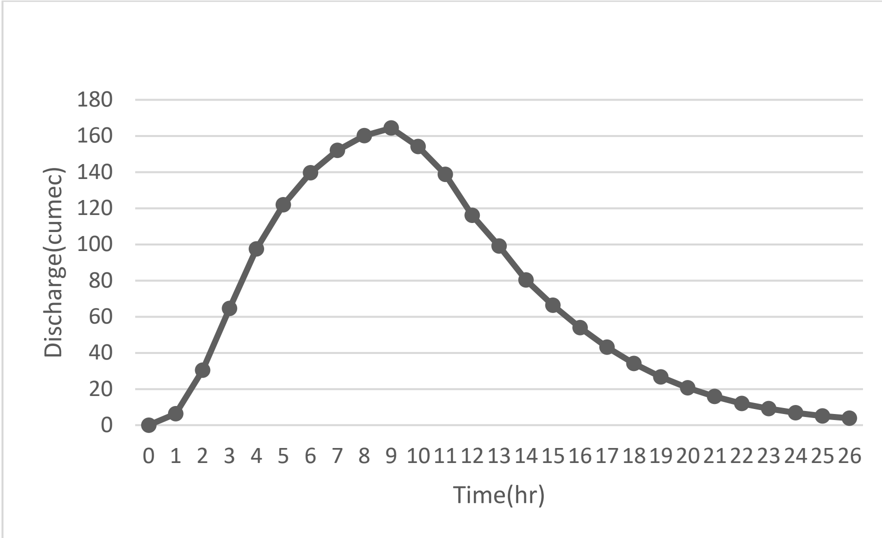

Figure 4: SUH developed from GIUH based Nash Model

4.5 Integrating XAJ Model with Geomorphological Instantaneous Unit Hydrograph (GIUH) Based on Nash Model

Table 12 shows parameters and their values evolved from Integrating XAJ Model with GIUH Based on Nash Model and Fig. 5 shows Unit Hydrograph (UH) developed from Integrating XAJ Model with GIUH Based on Nash Model.

Table 12: Parameters and their values evolved from Integrating XAJ Model with GIUH Based on Nash Model

S.no	Parameters		Units	Range	Value evaluated
1.	largest flow path length of the stream		km	-	86.93
2.	Bifurcation ratio = R_B		-		4.209
3.	Area ratio = R_A		-		4.326
4.	Length ratio = R_L		-		2.187
5.	Evaporation	potential evaporation / pan evaporation (KC)	-	0.8-1.2	1.35
6.		Volume of upper layer soil moisture storage capacity (UM)	mm	5-20	20
7.		Volume of lower layer soil moisture storage capacity (LM)	mm	60-90	80
8.		Conversion coefficient of deep layer evaporation (C)	-	0.1-0.2	0.16
9.	Runoff generation	Volume of average soil moisture storage capacity (WM)	mm	120-200	163
10.		The power in the curve of soil moisture storage capacity(B)	-	0.1-0.4	0.79

11.		A ratio impervious area/the area of saturated zone(IM)	-	0.01-0.04	0.01
12.	Runoff partition	Free water capacity in the soil surface(SM)	mm		20
13.		The power in the curve of free water capacity in the soil surface (EX)	-	1.0-1.5	1.5
14.		Outflow coefficient of free water storage to ground water(KG)	-		0.45
15.		Outflow coefficient of free water storage to subsurface runoff(KI)	-		0.4
16.	The mean slope of whole basin = S_m(for method II)		-		0.032
17.	Length of Flow Concentration = L_c (for method II)		km		130.692
18.	Time of Concentration = t_c(for method II)		min		635.0
19.	Mean Flow Velocity = v(for method II)		m/sec		3.43
	For method I (Code of Flood event)		Average Effective Rainfall Intensity, ie (mm/h)		Mean Flow Velocity, v (m/s)
20.	19880520		2.43		1.16
21.	19950425		2.36		1.15
22.	19930615		1.83		1.10

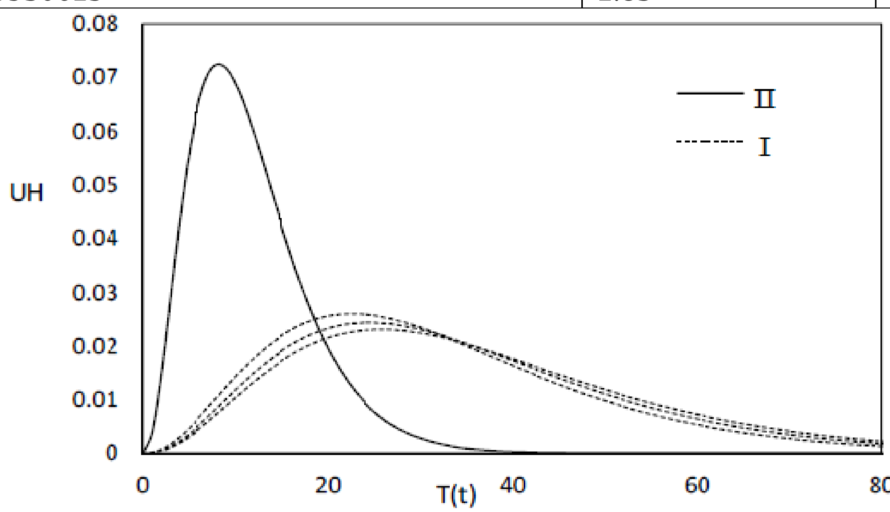

Figure 5: Unit Hydrograph developed from Integrating XAJ Model with GIUH Based on Nash Model

4.6 Hydrologic Modelling System developed by the Hydrologic Engineering Centre (HEC-HMS)

Table 13 shows parameters and their values evolved from Hydrologic Modelling System developed by the Hydrologic Engineering Centre (HEC-HMS) and Fig 6 shows Unit Hydrograph (UH) developed from Hydrologic Modelling System developed by the Hydrologic Engineering Centre (HEC-HMS).

Table 13: parameters and their values evolved from HEC-HMS

Process of simulation	Flood no. Date and year	Observed peak flow (m^3/s)	Simulated peak flow (m^3/s)	Observed flood volume (mm)	Simulated flood volume (mm)	Relative peak flow error (%)	Nash	SCS CN	Optimized (I_a)
Validation	30-Jul-2000	39.2	39.1	0.92	1.07	-0.1	0.584	0.01	19.7
	4-May-2004	39	32.7	0.9	0.98	-6.3	0.531	0.01	11.47
	24-Sep-2005	86.3	69.1	1.36	1.52	-17.2	0.515	0.01	32.22
	21-Aug-2006	23.3	24.4	0.66	0.76	1.1	0.559	0.01	11.47
	9-Dec-2007	62.2	54.7	1.48	1.64	-7.5	0.598	0.01	32.29
	11-May-2008	64.1	54.8	1.32	1.46	-0.93	0.55	0.01	32.29
	28-Nov-2010	38.9	34.7	0.87	1.02	-4.2	0.519	0.01	19.70
	29-Nov-2012	33.8	32.5	0.81	0.94	-1.3	0.564	0	19.70
	17-Nov-2013	37	40	1.21	1.34	3	0.622	0.01	32.29

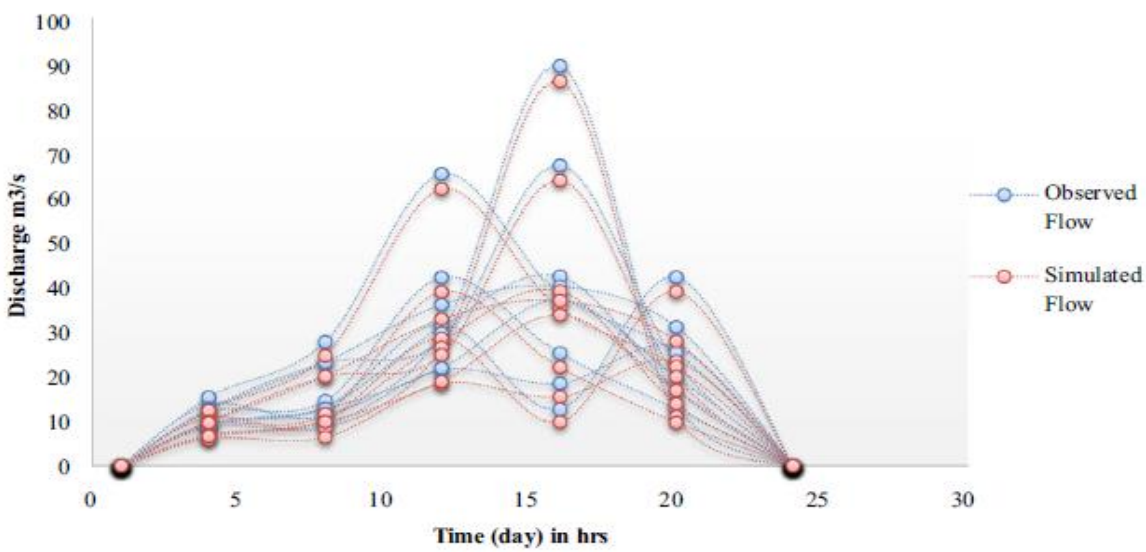

Figure 6: Unit Hydrograph (UH) developed from HEC-HMS

5. CONCLUSION

1- The study shows that Six Geomorphological techniques as suggested were highly helpful for Unit Hydrograph generation and flood forecasting.

2- This study shows that Hydrologic Modelling System developed by the Hydrologic Engineering Centre (HEC-HMS) hydrologic modelling is highly accurate and helps in restricting the job of the calibration and validation parameters and saves a lot of time.

6. References

1. S. Natarajan & N. Radhakrishnan, “Simulation of rainfall–runoA process for an ungauged catchment using an event-based hydrologic model: A case study of koraiyar basin in Tiruchirappalli city, India” J. Earth Syst. Sci. 130 30, 2021.
2. Y. Chen, P. Shi, S. Qu, X. Ji, L. Zhao, J. Gou, S. Mou, “Integrating XAJ Model with GIUH Based on Nash Model for Rainfall-Runoff Modelling” MDPI, 2019.
3. P. K. Bhunya, R. Berndtsson, P. K. Singh, and P. Hubert, “Comparison between Weibull and gamma distributions toderive synthetic unit hydrograph using Horton ratios” Water Resour. Res., 44, W04421, 2008.
4. B. Ashwini & Mamatha, “Development of Geomorphological Instantaneous Unit Hydrograph – A Case Study of Hemavathi Catchment”International Journal of Innovative Research in Science, Engineering and Technology, 2019.
5. S. Bhabagrahi, C. Chandranath, N. S. Raghuwanshi, R. Singh and R. Kumar, “Flood Estimation by GIUH-Based Clark and Nash Models”Journal of Hydrologic Engineering, 2006, pp. 515-525.
6. Singh, P.K., Mishra, S.K., and Jain, M.K., “A review of the Synthetic Unit Hydrograph: from the empirical UH to advanced geomorphological methods.” Hydrological Sciences Journal, 59 (2), 2013, pp. 239–261.
7. Riccardo Rigon, Marialaura Bancheri, Giuseppe Formetta and Alban de Lavenne, “The geomorphological unit hydrograph from a historical-critical perspective.” Earth Surf. Process. Landforms 41, 2016, pp. 27–37.
8. B Supraja, T Hemalatha and C Mahesh Babu, “Estimation of Peak Discharge in an Ungauged Watershed Using GIUH Model Supported With GIS and RS.” International Journal of Applied Research, 2016; pp. 754-759.