IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Comprehensive Rainfall-Runoff Analysis And Identified Flood-Prone Areas In Dibrugarh, Dhemaji, Lakhimpur And Miri Hill From 2009-2023 Using Hec-Hms And Arcgis Pro

[1]Deep Das, [1]SK Najibul Rahaman, [1]Sreeja Das, [2]Subhankar Dey, [2]Arya Banerjee

[1]Student, [2]Assistant Professor

[1,2]Civil Engineering

[1,2]Narula Institute of Technology, Kolkata, India

Abstract: Flooding and landslides remain persistent issues in Assam and Arunachal Pradesh, India, primarily due to the region's topography, irregular rainfall patterns, and human-induced activities. This study focuses on rainfall-runoff analysis in the Upper Brahmaputra Basin, particularly in flood-prone areas such as Dibrugarh, Dhemaji, Lakhimpur, and the Miri Hills. The analysis covers monsoon rainfall trends from 2009 to 2023. For various sub-basins, peak discharge values were calculated for individual years, accompanied by detailed explanations. The HEC-HMS model and the SCS-CN method were employed using DEM data and rainfall records from India WRIS within ArcGIS Pro to simulate the rainfall-runoff process. This modeling approach enabled the estimation of direct runoff along with catchment characteristics and rainfall intensity. The highest peak discharge was recorded in Subbasin-82 (Amsuk Hapa, Pelmilli, Chimir, Taya Simla, Rakar in Miri Hills, Arunachal Pradesh) with 190.1 m³/s and a runoff volume of 2208.01 mm in August 2015. Subbasin-36 (Bora Rupak, Chota Rupak, Baririjo, Kulo in Miri Hills) was even more prone to flooding, reaching a peak discharge of 254.6 m³/s and a runoff volume of 3380.09 mm in July 2020. Other subbasins, including Subbasin-26 (Bordoibam Goan, Kala Khawa Goan, Lakai Goan, Kakoti Goan in Dibrugarh, Assam) and Subbasin-1 (Subansiri, Goamukh, Krishnapur, Dakhin Nalbari in Lakhimpur and Dhemaji, Assam), experienced peak discharges of 108.8 m³/s and 168.2 m³/s, respectively, during July 2022 and July 2020. Their corresponding runoff volumes were 3129.73 mm and 3379.81 mm. Additionally, the largest drainage area, Reach-85, covering 1974.4 km², recorded a peak discharge of 932.1 m³/s in July 2020. This study provides crucial insights into flood management strategies for the most vulnerable regions. By integrating spatially distributed hydrological data, it enhances the understanding of complex hydrological processes in the Upper Brahmaputra Basin and supports effective resource management and disaster preparedness.

Index Terms **- DEM, SCS-CN, ARCGIS, UBB, USGS, Hydrological Modelling, WRIS, Peak Discharge.**

I. Introduction

Due to topographical variations, land use land cover status, and geological irregularities, erosion, sedimentation, floods, landslide problems, and shrinkage of the riverbeds are pretty familiar in Assam, a state in India. Some disastrous flood seasons in recent times had formed due to topographical features and irregularities in precipitation disparities during the monsoon season. Besides heavy amount of rainfall, the catchment area of upper Brahmaputra region also receives huge amount of snowmelt water due to its influence from the Himalayan mountains. This is another vital source of generating runoff flow at the downstream location. As a result of increased anthropogenic activities such as deforestation, agriculture, and conversion of land use into urbanization, the catchment area has, over time, seen a reduction in the total evapotranspiration. These enhanced land use activities have resulted in the generation of quick flows. The present paper focuses on the comprehensive rainfall-runoff analysis performed in four study areas, namely Dibrugarh, Dhemaji, Lakhimpur, and Miri Hills, lying in the Upper Brahmaputra Basin (UBB) of north-eastern India. Due to the geography, these areas have been facing frequent floods resulting from the amount of rainfall that usually comes in this area unpredictably; therefore, the study is approached with a view to mitigate the impact of these hazardous natural activities. HEC-HMS and the SCS-CN method under an open environment of ArcGIS Pro are implemented for a rainfall-runoff modeling framework to quantify the rainfall- runoff occurring in these study catchments. Finally, the resultant maps would provide insight into identifying the major contributors to flooding and results can be implemented by concerned organizations at local strategy levels in each area. The generated computer models build practical information to compute the flow in space-dependent ways. The Hydraulic Engineering Center, Hydrologic Modeling System (HEC-HMS) software is a National Flood Predictive Service program for simulating the performance of small, intermediate, and large watersheds. This non-proprietary modeling system uses spatially distributed hydro-logic data and software to gain, produce, and simulate effective simulations of watershed runoff. It is designed for single basin-scale investigations, and the spatial scale of the data used is watershed scale that defines each second drainage space in terms of latitude and longitude.

II. STUDY AREA

Dibrugarh, Dhemaji, Lakhimpur and Miri Hills is located in the north-eastern part of India reffering to fig. 1, at 27.48° north latitude and 94.57° east longitude, with an area of about 8,253.23 square kilometers and an altitude of 48-2090 meters above mean sea level. Since the main body of the study area is close to the hills of Arunachal Pradesh, temperature, rainfall, fog, wind etc. show great variations. Annual rainfall in the region varies between 1,500 mm and 2,600 mm. Rainfall generally starts in the month of April and continues till the end of September. Precipitation generally increases from southeast to northeast. May to September is the monsoon seasons. An average of 200 days a year sees 3.5 mm or more of precipitation. Humidity ranges from 90% to 73%. Summer temperature is 39.9°C, winter temperature is 5.9°C.

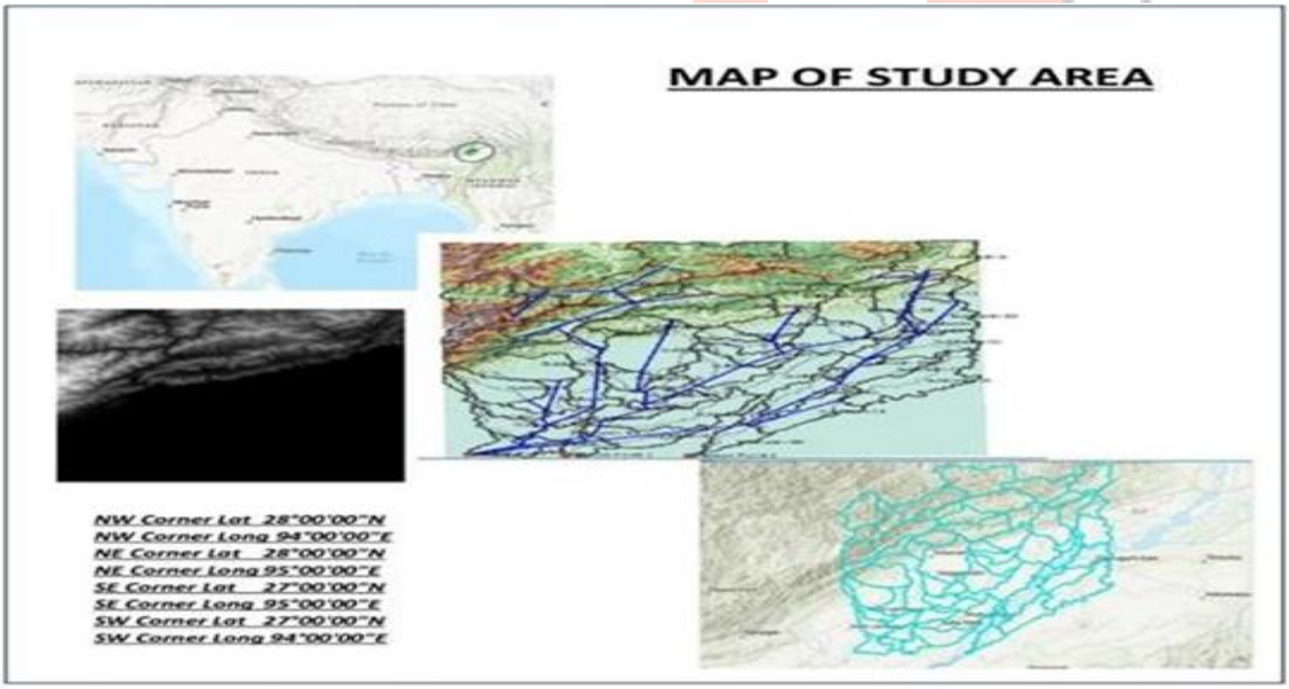

Fig. 1- Sub-basin generated by HECHMS

III. OBJECTIVE

The main objective of the research study is to evaluate and compare the trends in the annual monsoon rainfall pattern of the study area for the period of 2009 to 2023 and calculate the peak discharge in the respective year of the subbasin model. In this paper, an attempt has been made to relate rainfall with satellite data of the Upper Brahmaputra region and peak discharge observed during the same period in monsoon i.e., May to September.

IV. METHODOLOGY

The methodology of this study included various methods to analyse the rainfall patterns in Dibrugarh, Dhemaji, Lakhimpur and Miri Hills. Digital Elevation Model (DEM) data of the study area were obtained from USGS Earth Explorer and imported into HEC-HMS (Hydrologic Engineering Center- Hydrological Simulation System). After that, the boundaries of the river were annotated on the HEC-HMS platform referring to fig. 1 and the discharge points were selected at i) North Lakhimpur, ii) Majuli Island, ii) Disangmukh on Brahmaputra River. The Soil Conservation Service (SCS) Curve Number (CN) method is a widely used empirical approach for estimating direct runoff from rainfall events. This method is often employed in hydrology and engineering for predicting runoff in different land use and soil cover scenarios. The CN method is part of the Natural Resources Conservation Service (NRCS) of the United States Department of Agriculture (USDA). In our basin model curve number is varying from 56.1 to 94. Use HEC-HMS to create subbasins and calculate curve numbers based on the "Hydro-Soil Group B" assumption and follow the criteria outlined in the USDA TR-55.It's known as the Soil Conservation Service (SCS) referring to fig 2. Environmental Protection Agency (NRCS). The lag time was then determined using the formula given below:

$$LLAG = L^{0.8} [(S+1)^{0.7} /(1900*Y^{0.5})]$$

Where,
TLAG = lag time in hours
L = hydraulic length of watershed in feet Y = watershed slope in percent
S = maximum retention in the watershed in inches as defined by:

$$S = (1000/ CN) - 10$$

Where, CN = SCS curve number for the watershed as defined by the loss method.

Subsequently, the calculated curve number and lag time were incorporated (referring to table 1) into HEC-HMS along with rainfall data collected from India-WRIS (Water Resource Information System). HMS uses these integrated data to provide values such as catchment area, peak elevation and the relevant year in which the flow occurred. This integration enables a comprehensive analysis of rainfall and hydrological conditions in the northern Brahmaputra, including topographic and meteorological conditions.

SUBBASIN	LAG TIME (MIN)	SUBBASIN	LAG TIME(MIN)	SUBABASIN	LAG TIME(MIN)	SUBBASIN	LAG TIME(MIN)
Subbasin-82	1710.37	Subbasin-4	4870.46	Subbasin-30	5986.04	Subbasin-34	1799.39
Subbasin-29	1456.08	Subbasin-40	7456.52	Subbasin-13	8416.67	Subbasin-51	2977.88
Subbasin-10	1464.8	Subbasin-35	7904.75	Subbasin-8	13876.09	Subbasin-18	1811.54
Subbasin-36	2777.99	Subbasin-50	1627.4	Subbasin-52	3313.98	Subbasin-32	9317.5
Subbasin-38	17825.41	Subbasin-43	5870.99	Subbasin-65	1560.53	Subbasin-2	4977.16
Subbasin-20	1191.42	Subbasin-76	6446.63	Subbasin-1	6816.85	Subbasin-16	6872.04

Subbasin-28	3702.89	Subbasin-66	1015.13	Subbasin-19	6450.58	Subbasin-22	6013.24
Subbasin-3	2245.21	Subbasin-27	4381.58	Subbasin-58	6077.06	Subbasin-159	4868.93
Subbasin-178	2127.76	Subbasin-67	6387.51	Subbasin-17	4582.61	Subbasin-31	8841.05
Subbasin-5	4538.39	Subbasin-37	10294.2	Subbasin-60	5131.37	Subbasin-61	7559.56
Subbasin-45	1621.88	Subbasin-14	1682.75	Subbasin-55	5175.68	Subbasin-26	13798.86
Subbasin-53	2425.59	Subbasin-12	3190.73	Subbasin-21	12382.59	Subbasin-11	9308.55
Subbasin-24	1400.14	Subbasin-15	2723.69	Subbasin-9	8659.14	Subbasin-72	3207.02
Subbasin-77	9119.33	Subbasin-25	1256.16	Subbasin-39	2357.58	Subbasin-98	6487.78
Subbasin-23	3442.18	Subbasin-7	6914.77	Subbasin-6	2227.11	Subbasin-62	6347.14
Subbasin-81	4408.87						

Table 1- Sub-basin vs minimum Lag time data

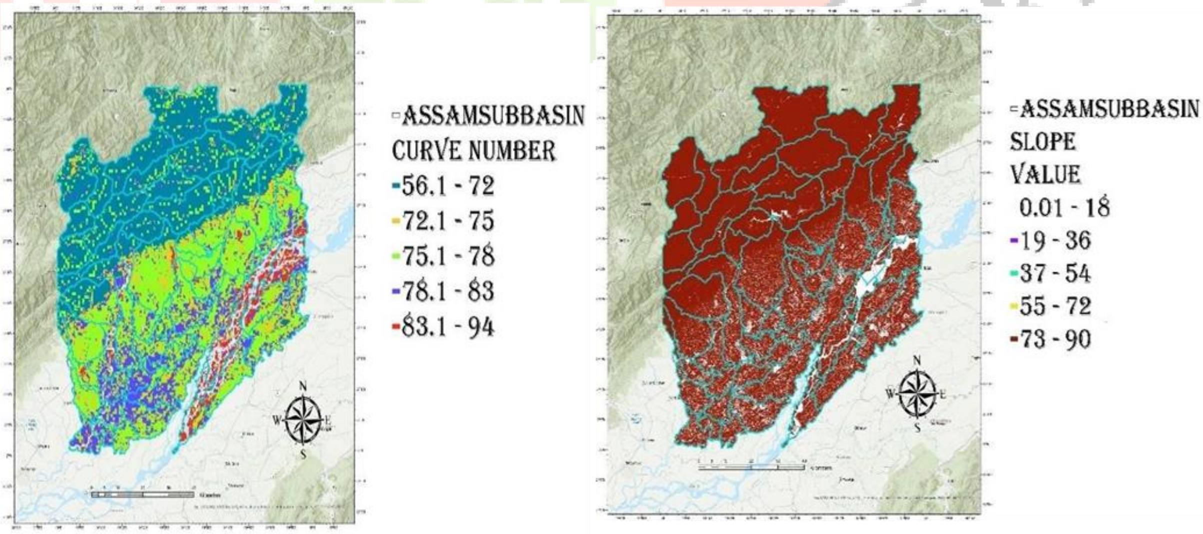

Fig. 2- Curve Number and Slope Value

V. RESULTS AND DISCUSSION

The following data was collected from India-WRIS and the whole project is based upon this referring to table 2,

Year	April	May	June	July	August	September
2009	132.51	178.32	286.13	390.71	486.75	198.14
2010	417.59	361.53	448.22	414.63	423.5	384.64
2011	110.65	194.93	311.34	571.46	299.79	247.97
2012	283.5	234.69	453.94	547.24	355.27	0
2013	132.2	337.02	338.37	459.92	401.88	173.64
2014	51.36	360.14	352.97	364.92	469.73	333.88
2015	229.09	324.77	509.82	360.63	471.85	224.85
2016	413.5	287.56	380.48	532.9	222.47	369.87
2017	253.10	303.09	324.89	551.83	302.16	374.18
2018	136.54	194.97	436.34	529.14	340.11	329.38
2019	132.76	432.51	297.14	609.00	178.98	347.45
2020	94.65	336.64	569.56	256.89	277.71	342.95
2021	52.57	266.21	314.80	291.91	373.26	136.2
2022	353.05	305.49	546.86	334.53	272.29	250.3
2023	152.09	242.00	422.22	546.49	371.15	187.41

Table -2: Rainfall Data for Monsoon Period of upper Brahmaputra Region (2009 – 2023)

After importing the DEM file in HEC-HMS and putting the rainfall data the below results are generated-

Hydrologic Element	*Subbasin 82*	*Subbasin 26*	*Subbasin 37*	*Subbasin 76*	*Subbasin 8*	*Subbasin 1*	*Subbasin 36*	*Subbasin 14*	*Subbasin 81*	*Subbasin 18*
Drainage Area (KM^2)	*216.2*	*293.1*	*201.7*	*98.7*	*254.0*	*352.2*	*361.8*	*121.0*	*63.8*	*73.5*
Peak Dis-charge (May)	*132.6*	*65.4*	*50.0*	*29.3*	*55.6*	*102.0*	*181.3*	*75.7*	*22.9*	*43.4*
Peak Dis-charge (June)	*158.8*	-	-	-	-	*168.2*	*235.0*	*89.3*	*35.7*	*52.9*
Peak Dis-charge (July)	*168.2*	*108.8*	*83.3*	*48.6*	*92.3*	*168.2*	*254.6*	*94.6*	*37.8*	*56.0*
Peak Dis-charge (August)	*190.1*	*83.7*	*61.0*	*32.4*	*71.6*	*113.9*	*254.0*	*106.7*	*23.9*	*63.8*
Peak Dis-charge (Sept)	*84.2*	*84.6*	*68.5*	*44.6*	*71.6*	*153.3*	-	-	*35.9*	*28.5*
Time of Peak (May)	*2012*	*2019*	*2019*	*2019*	*2019*	*2019*	*2012*	*2012*	*2012*	*2012*
Time of Peak (June)	*2022*	-	-	-	-	*2022*	*2022*	*2022*	*2022*	*2022*
Time of Pea	*2020*	*2022*	*2022*	*2020*	*2022*	*2020*	*2020*	*2020*	*2020*	*2020*

k (July)										
Time of Peak (August)	*2015*	*2021*	*2021*	*2021*	*2021*	*2021*	*2021*	*2015*	*2021*	*2015*
Time of Peak (September)	*2011*	*2015*	*2015*	*2015*	*2015*	*2015*	-	-	*2015*	*2011*
Volume (May)	*1593.26*	*2162.70*	*2159.86*	*2160.07*	*1619.28*	*2160.06*	*1654.54*	*1618.14*	*1619.83*	*1601.54*
Volume (June)	*3149.25*	-	-	-	-	*3135.71*	*3147.53*	*3136.71*	*3149.29*	*3143.03*
Volume (July)	*3380.09*	*3129.73*	*3129.26*	*3379.87*	*3136.05*	*3379.81*	*3380.09*	*3380.03*	*3380.05*	*3380.09*
Volume (August)	*2208.01*	*2204.29*	*2201.70*	*2201.98*	*2210.55*	*2202.01*	*2201.97*	*2208.01*	*2202.00*	*2208.01*
Volume (Sept)	*1664.41*	*2208.42*	*2206..98*	*2207.98*	*2214.54*	*2207.87*	-	-	*2208.01*	*1611.50*

Table -3: Results generated from HEC-HMS for Sub basin

From this above data Table No-3, it can be seen Subbasin-82 having drainage area 216.2 square km have most peak discharge 190.1 m3/s in 2015. Subbasin-26 having drainage area 293.1 square km have most peak discharge 108.8 m3/s in 2022. Subbasin-37 having drainage area 75.4 square km, observed most peak discharge 83.3 m3/s in 2022. Subbasin-76 having drainage area 98.7 square km, observed most peak discharge 48.6 square km in 2020. Subbasin-8 having drainage area 254.0 square km, observed peak discharge 92.3 m3/s in 2022. Subbasin-1 having drainage area 352.2 square km, observed most peak discharge 168.2 m3/s in 2020. Subbasin-36 having drainage area 361.8 square km, observed peak discharge 254.6 m3/s in 2020. Subbasin-14 having drainage area 121.0 square km, having peak discharge 106.7 m3/s in 2015. Subbasin-81 having drainage area 63.8 square km, observed most peak discharge 37.8 m3/s in 2020. Subbasin-18 having drainage area 73.5 square km, observed peak discharge 63.8 m3/s in 2015. So, from our analysis it appears that Subbasin-82 area along Amsuk Hapa, Pelmilli, Chimir, Taya-Simla , Rakar (Arunachal Pradesh) mostly stands out with an exceptional run off discharge volume of 2208.01 mm over the course of the year with peak discharge 190.1 m3/s in August of 2015. Subbasin-26 area along Bordoibam Gaon, Kalakhowa Gaon, Lakai Gaon, Kakoti Gaon mostly stands out with an exceptional run off discharge volume of 3129.73 mm over the course of the year with peak discharge 108.8 m3/s in July of 2022. Subbasin-37 area along Jongaon Nepali, Dormuria Deori, Lachit Nagar, Gandhi Nagar, Kulamua Bengali, Ayengia Patri, etc. mostly stands out with an exceptional run off discharge volume 3129.26 mm over the course of the year with peak discharge 83.8 m3/s in July of 2022. Subbasin-76 along area Bakal, Panigaon, Bocha Gaon, Hatimora, Hatilung, Singaramari mostly stands out with exceptional run off discharge volume of 3379.89 mm over the course of the year with peak discharge 48.6 m3/s in July of 2020. Subbasin -8 area along Siring Gaon, Rupahi Miri, Dhenukhana Gaon, Sisisiri Kal, Borchapori, Bambuk Kalabari, Sitalmari, Kareng Gaon, etc. mostly stands out with exceptional run off discharge volume of 3136.05 mm over the course of the year with peak discharge 92.3 m3/s in July of 2022. Sub- basin-1 area along Subansiri, Goamukh, Krishnapur, Dakhin Nalbari, Bogipung etc. mostly stands out with an exceptional run off discharge volume 3379.81 mm over the year with peak discharge 168.2 m3/s in July of

2020. Subbasin-36 area along Bora Rupak, Chota Rupak, Kulo, Baririjo etc. mostly stands out with an exceptional run off discharge volume of 3380.09 mm over the year peak discharge 254.6 m3/s in July of 2020. Subbasin-14 area along Likabali, New Bonte etc. mostly stands out with an exceptional run off discharge volume of 2208.01 mm over the year peak discharge 106.7 m3/s in August of 2015. Subbasin-81 area along Majuli, Karkichuk, Goborchuk, Jengrai NC, Polongani etc, mostly stands out with an exceptional run off discharge volume of 3380.05 mm over the year peak discharge 37.8 m3/s in July of 2020. Subbasin-18 area along Manikpur, Kherani, Hosong, Rangpuria Rural etc. mostly stands out with an exceptional discharge volume of 2208.01 mm over the year peak discharge 63.8 m3/s in August of 2015 (referring to fig 3 & 4).

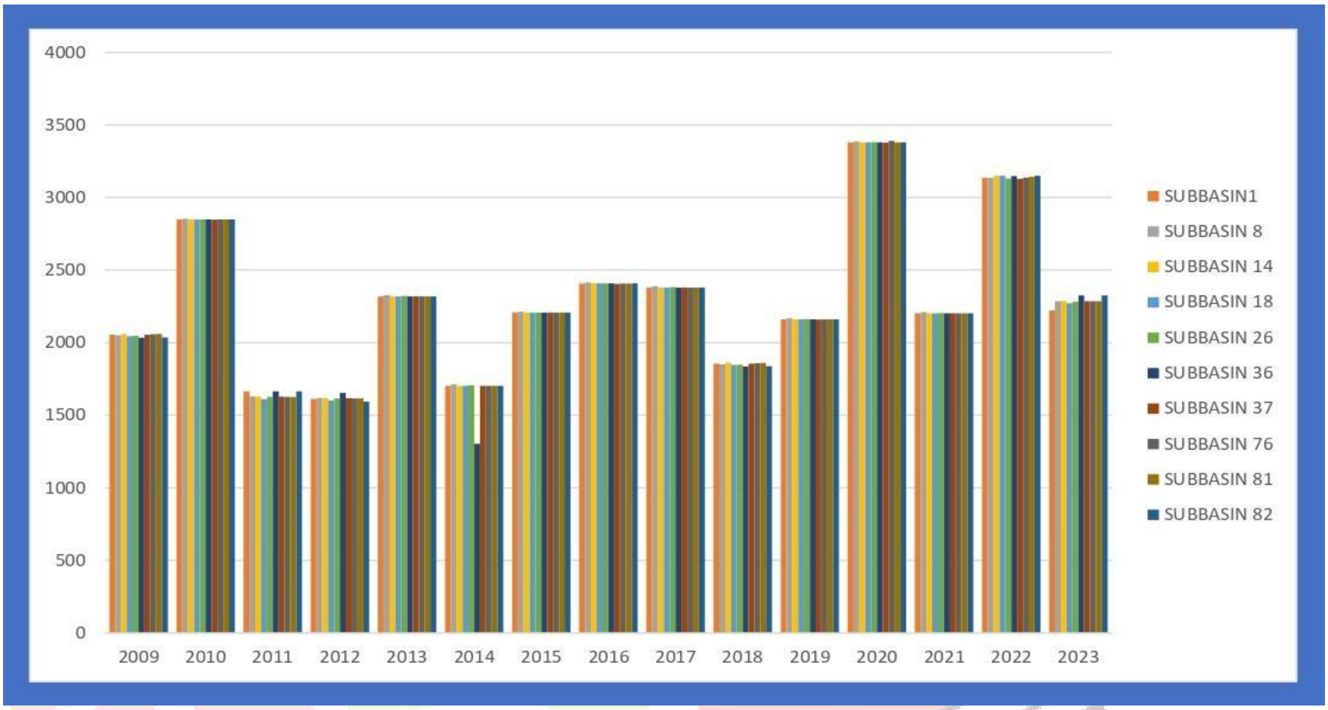

Fig. 3- Discharge Volume Graph of Subbasins

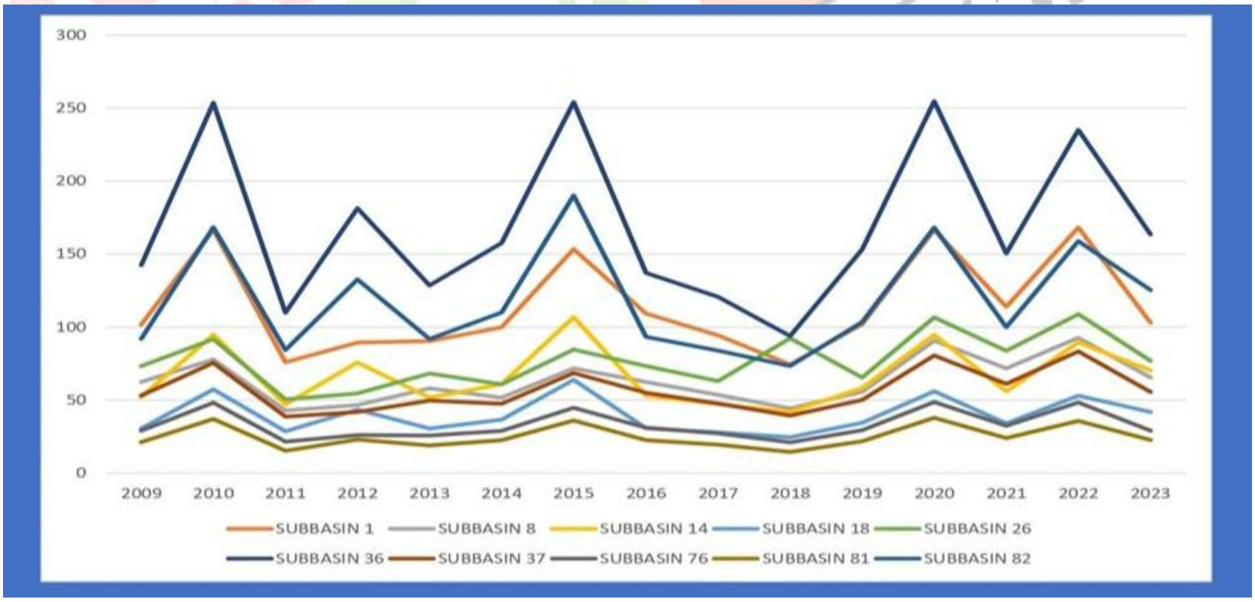

Fig. 4. Peak Discharge Graph of Subbasins

Hydrologic Element	Reach 5	Reach 72	Reach 40	Reach 86	Reach 66	Reach 50	Reach 10	Reach 14	Reach 85	Reach 31
Drainage Area (KM^2)	216.2	293.1	449.4	98.7	1409.0	686.9	361.8	121.0	1974.4	73.5
Peak discharge (April)	169.5	91.6	195.4	48.2	571.7	336.9	253.3	94.8	830.6	57.7
Peak Dis-charge (May)	102.9	65.4	127.1	29.3	385.7	207.6	178.9	75.3	558.6	43.1
Peak Dis-charge (June)	158.2	-	209.5	-	-	344.2	235.4	89.1	930.7	52.7
Peak Dis-charge (July)	167.6	108.8	212.5	48.6	635.3	353.7	254.4	94.3	932.1	55.9
Peak Dis-charge (Au-gust)	190.7	83.7	145.1	32.4	442.8	323.0	255.4	107.2	846.3	63.9
Peak Dis-charge (Sept)	84.9	84.6	188.2	44.6	-	-	-	47.7	-	28.7
Time of Peak (April)	2010	2010	2010	2010	2010	2010	2010	2010	2010	2010
Time of peak (may)	2019	2019	2019	2019	2019	2019	2012	2012	2019	2012
Time of peak (June)	2022	-	2022	-	-	2022	2022	2022	2022	2022
Time of peak (July)	2020	2022	2020	2020	2020	2020	2020	2020	2020	2020
Time of peak (august)	2015	2021	2021	2021	2021	2015	2015	2015	2015	2015
Time of peak (September)	2011	2015	2015	2015	-	-	-	2011	-	2011
Volume (April)	2848.77	2848.82	2848.91	2848.61	2850.11	2848.65	2848.74	2848.92	2850.11	2848.47
Volume (May)	2160.13	2162.70	2160.67	2160.07	2162.11	2160.08	1592.12	1628.04	2162.12	1601.75
Volume (June)	3149.50	-	3138.02	-	-	3141.42	3147.74	3149.40	3139.89	3149.77
Volume (July)	3390.11	3129.71	3380.28	3379.81	3381.62	3379.95	3380.09	3380.10	3381.51	3380.15
Volume (Au-gust)	2208.06	2204.29	2202.58	2201.98	2203.99	2202.05	2208.04	2208.04	2209.55	2208.16
Volume (Sept)	1603.77	2208.41	2208.23	2207.91	-	-	-	1628.04	-	1611.69

Table -4: Results generated from HEC-HMS for Reach

Now from this above Table No-4, fig 5 & 6, it can be seen Reach-5 having drainage area 216.2 square km and have most peak dis- charge 190.7 m3/s and its drainage volume is 2208.06 mm in August of 2015. Reach-72 having drainage area 293.1 square km and have most peak discharge is 108.8 m3/s and its drainage volume is 3129.71 mm in July of 2022. Reach-40 having drainage area 449.4 square km and have most peak discharge is 212.5 m3/s and its drainage volume is 3380.28 mm in July of 2020. Reach-86 having drainage area 98.7 square km and have most peak discharge is 48.6 m3/s and its drainage volume is 3379.86 mm in July of 2020. Reach-66 having drainage area 1409.0 square km and have most peak discharge is 653.3 m3/s and its drainage volume is 3381.62 in July of 2020. Reach-50 having drainage area 686.9 square km and have most peak discharge is 353.7 m3/s and its drainage volume is 3379.95 in July of 2020. Reach-10 having drainage area 361.8 square km and have most peak discharge is 255.4 m3/s and its drainage volume is 2208.04 in August of 2015. Reach-14 having drainage area 121.0 square km and have most peak discharge is 107.2 m3/s and its drainage volume is 2208.04 mm in August of 2015. Reach-85 having drainage area 1974.4 square km and have most peak discharge is 932.1 m3/s and its drainage volume is 3381.51 mm in July of 2020. Reach-31 having drainage area 73.5 square km and have most peak discharge is 63.9 m.3/s and its drainage volume is 2208.16 in August of 2015.

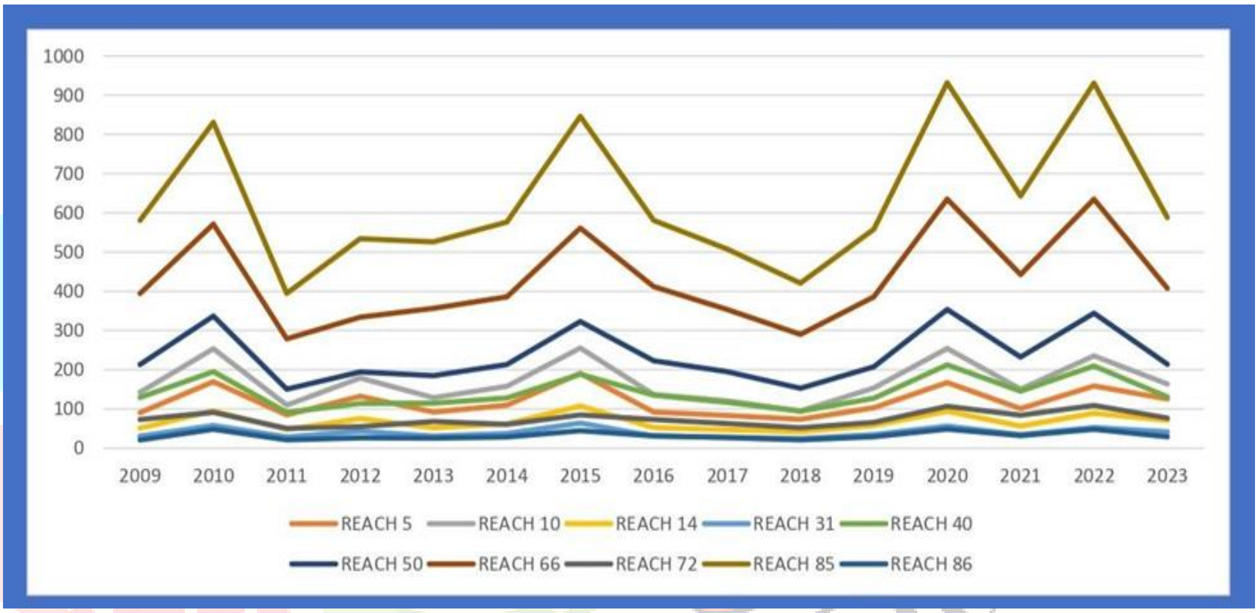

Fig. 5 Peak Discharge Graph of Reaches

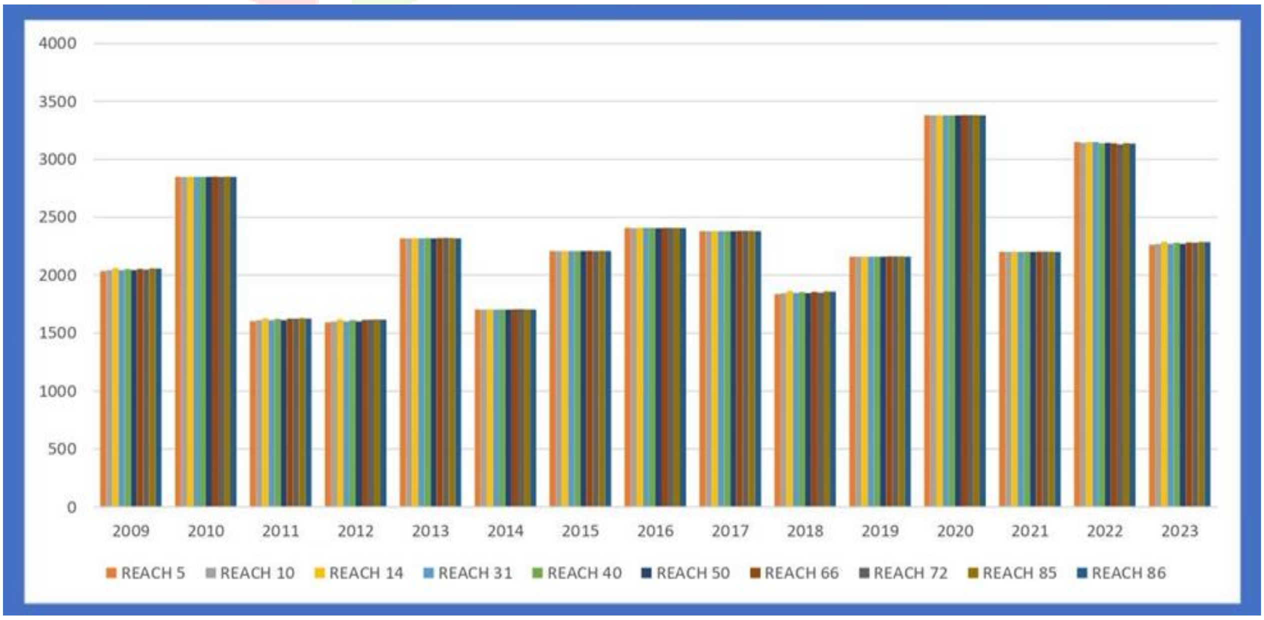

Fig. 6 Discharge Volume Graph of Reaches

Year	Drainage Area	Peak Discharge	Time of Peak	Volume
2009	8253.2	2522.1	August	2050.04
2010	8253.2	3759.7	April	2850.70
2011	8253.2	1700.9	July	1619.64
2012	8253.2	2424.9	May	1609.84
2013	8253.2	2258.7	July	2320.56
2014	8253.2	2535.7	August	1705.06
2015	8253.2	3803.3	August	2209.44
2016	8253.2	2534.1	April	2409.19
2017	8253.2	2204.6	July	2382.03
2018	8253.2	1790.9	July	1851.05
2019	8253.2	2447.6	May	2161.94
2020	8253.2	4146.2	July	3381.55
2021	8253.2	2726.5	August	2203.83
2022	8253.2	4081.5	June	3141.50
2023	8253.2	2592.3	July	2278.38

Table -5: Results generated from HEC-HMS for SINK-1

Now, from this above Table No-5, fig 7,8 & 9, it can be seen Sink-1 having drainage area 8253.2 square km and have most peak discharge 4146.2 m3/s and its maximum drainage volume is 3381.55 mm in July of 2020.

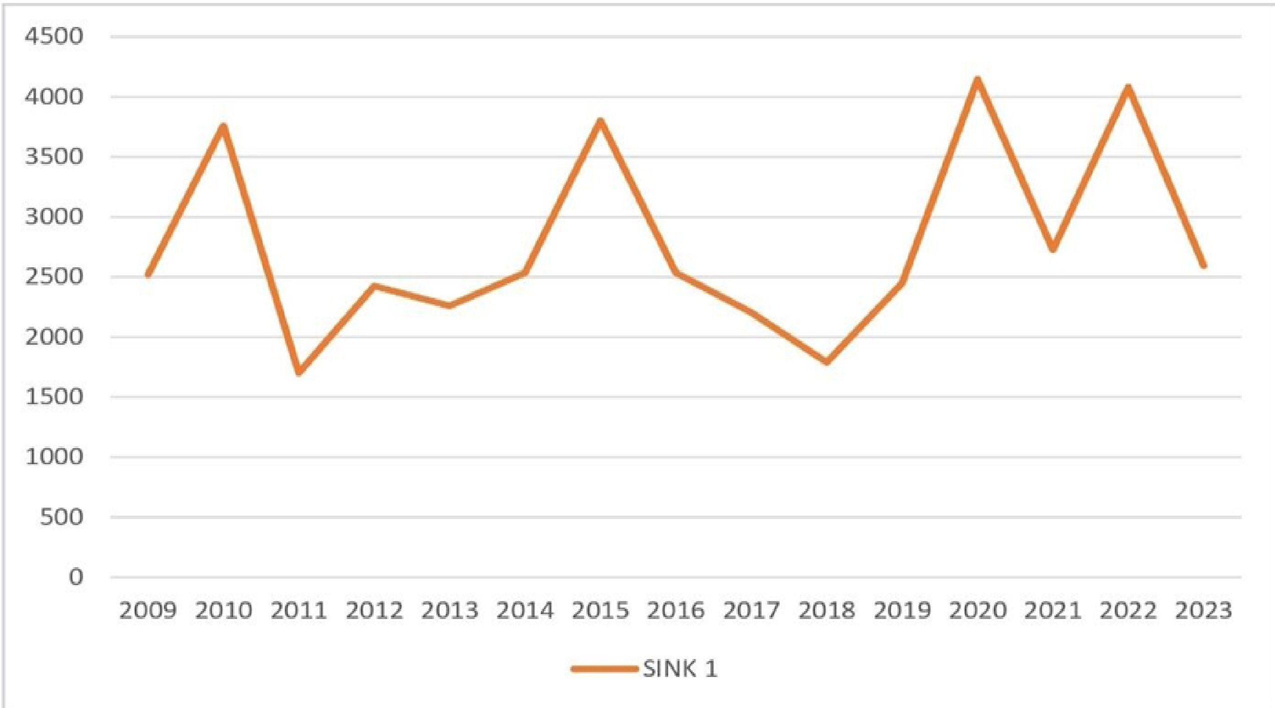

Fig. 7 Peak Discharge Graph of Sink

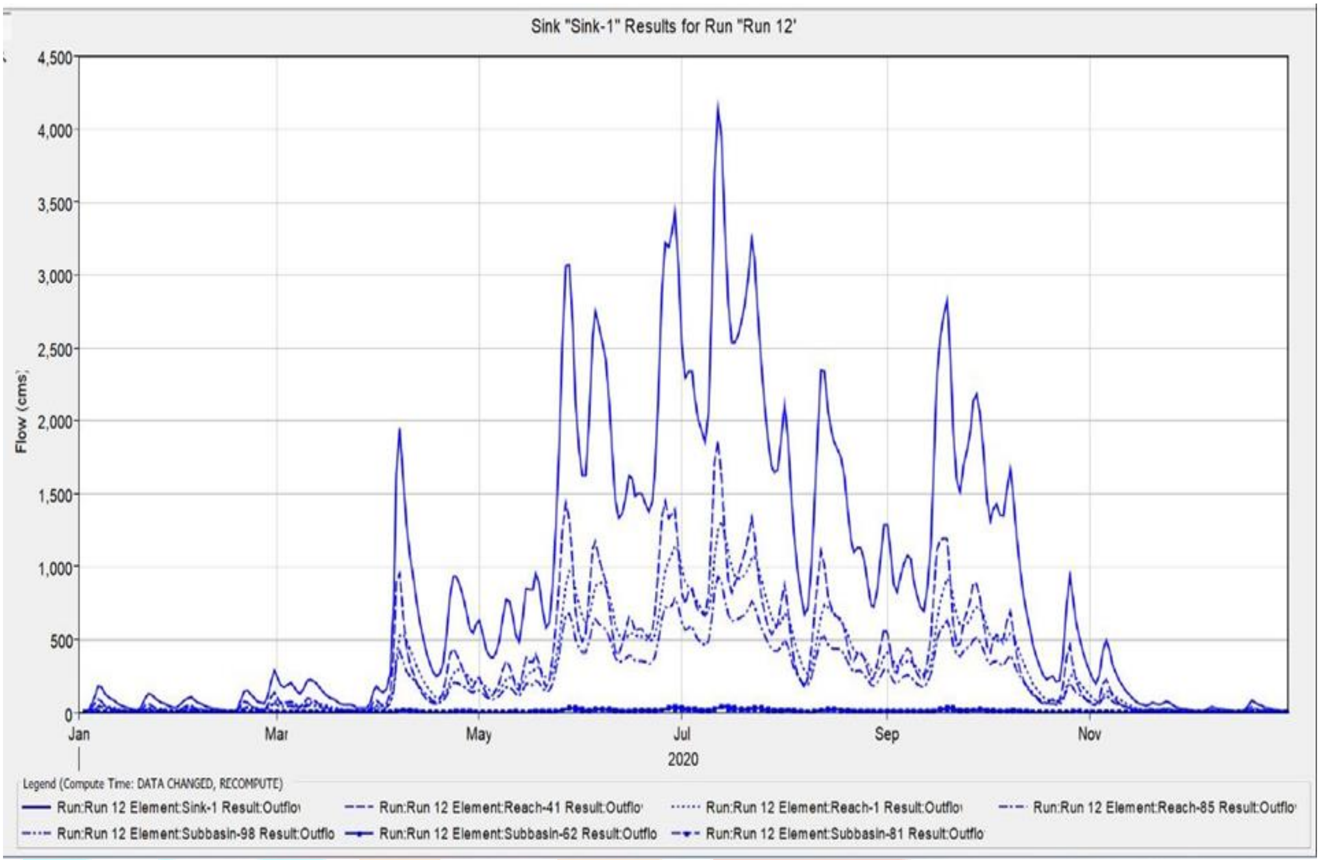

Fig. 8 Peak Discharge Graph in 2020

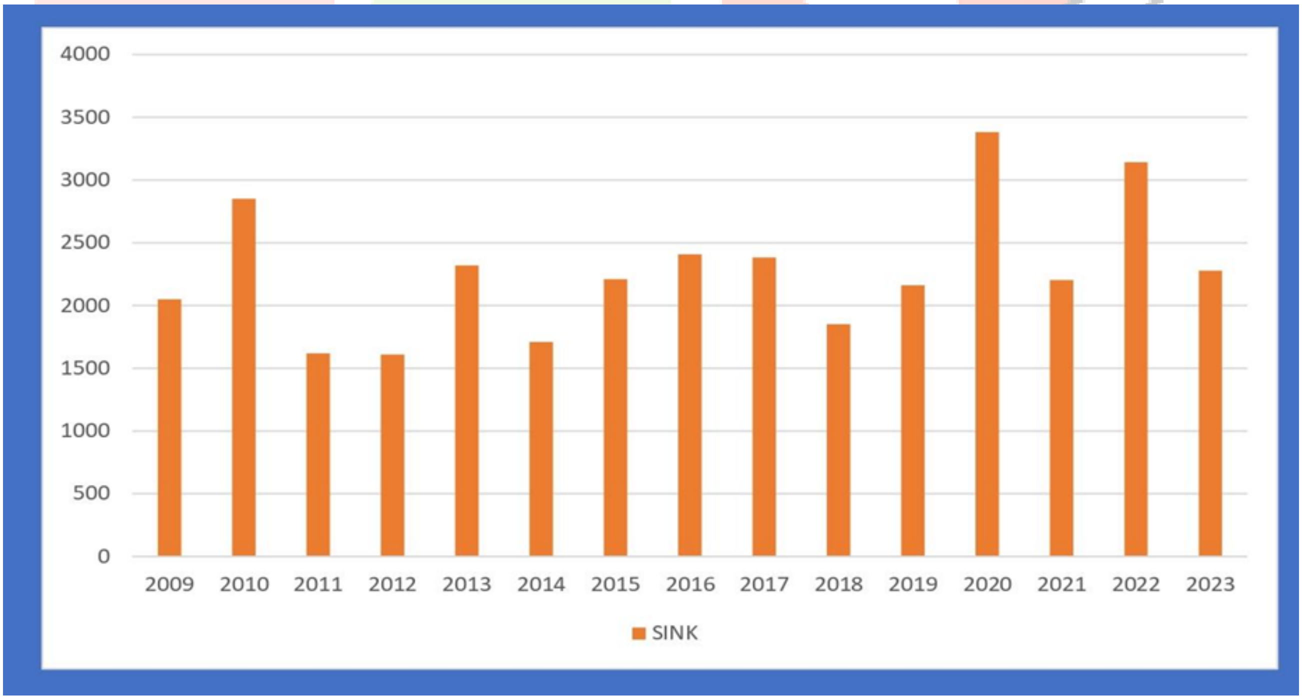

Fig. 9 Discharge Volume Graph of Sink

VI. CONCLUSIONS

Critical values in peak discharge exhibited extreme ranges for values between the subbasins. The highest peak discharge of 190.1 m³/s was recorded in the year 2015 for Subbasin-82, Amsuk Hapa, Pelmilli, Chimir, Taya-Simla, Rakar in August, except the exceptional runoff volume of 2208.01 mm. That reflected the subbasin's susceptibility to severe floods caused during the monsoon season. Sub- basin-36 has the highest peak discharge of 254.6 m³/s during July 2020, with a corresponding volume of run-off at 3380.09 mm; hence, the subbasin is very vulnerable to floods despite its moderate drainage area of 361.8 km². Variability in peak discharges therefore reflects the complexity of hydrological processes involved, which depends on the topography and land cover, intensity of rainfall, and character of drainage. Such information is invaluable for determining high-risk sub-basins in flood prediction as well as water management. Higher drainage areas are not necessarily accompanied by a greater peak discharge. For Peak discharges reached as high as 168.2 m³/s in July 2020 in the huge drainage area 352.2 km² of subbasin-1. Subbasin-36 was relatively small, 361.8 km², but with a very high peak discharge which is much higher than that of 254.6 m³/s. For instance, whereas at Subbasin-18 the drainage area was significantly smaller at about 73.5 km², it peaked in August 2015 to be 63.8 m³/sec . This implies that flood prediction models should not be based on the size of the drainage area but rather on the intensity and then the temporal distribution of rainfall. The extreme events of rainfall indicate high contributions to peak discharges and volumes of runoff. Years like 2015, 2020, and 2022 were very peculiar in such a way that they incurred very high peak discharges. Subbasin-26 reached a maximum value of 108.8 m³/s in July 2022 caused by heavy monsoon rain volume of runoff with 3129.73 mm. The highest recorded peak discharge of Subbasin-76 was 48.6 m³/s in July 2020, the highest runoff of 3379.89 mm that falls within that year due to intense heavy precipitation. Such findings imply the need for continuous real-time monitoring of rainfall and improved models of forecast to predict and manage flood risks during monsoons. In general, some of its subbasins and reaches flood due to a high peak discharge and big volumes of runoff as shown by the study. Since peak discharges in subbasin-82, subbasin-36, and subbasin-1 were impressive, these are thus identified as focal areas that require prompt flood management measures. Reach-66 drainage area of 1409.0 km², peak discharge of 653.3 m³/s in July 2020, it was one of the most exposed sites for large-scale flooding. The highest drainage area is 1974.4 km², and the maximum peak discharge is 932.1 m³/s in the year 2020. Reach-85 will therefore be placed in the high-priority list for flood-mitigation measures. There, flood barriers, embankments, and a proper drainage system have to be built up to minimize the threat of flooding in these areas. The annual runoff volumes calculated for each subbasin represented movement of water and, of course, flood risks incorporated in the region. Some notable subbasins that have achieved very high runoff volumes include Subbasin-36 with 3380.09 mm, and Subbasin-81 of 3380.05 mm, These areas comprise huge water runoff, and therefore, there is a need to manage their water flow management towards utilization of excess flow especially during peak discharge periods.

VII. REFERENCES

1. Maharana, P., Agnihotri, R., & Dimri, A. P. (2021). Changing Indian monsoon rainfall patterns under the recent warming period 2001–2018. Climate Dynamics, 57(9), 2581-2593.
2. Kulkarni, A., Kripalani, R. H., & Singh, S. V. (1992). Classification of summer monsoon rainfall patterns over India. International Journal of Climatology, 12(3), 269-280.
3. Kumar, K. R., Pant, G. B, Parthasarathy, B., & Sontakke, N. A. (1992). Spatial and subseasonal patterns of the long-term trends of Indian summer monsoon rainfall. International Journal of climatology, 12(3),257-268.
4. Lakshmi Kumar, T. V., Koteswara Rao, K., Barbosa, H., & Uma, R. (2014). Trends and extreme value analysis of rainfall pattern over homogeneous monsoon regions of India. Natural hazards, 73, 1003-1017.
5. Maktav, D., Erbek, F. S., & Jürgens, C. (2005). Remote sensing of urban areas. International journal of remote sensing, 26(4), 655-659.
6. Nicótina, L., Alessi Celegon, E., Rinaldo, A., & Marani, M. (2008). On the impact of rainfall patterns on the hydrologic response. Water Resources Research, 44(12).
7. Webster, P. J. & Hoyos, C. Prediction of monsoon rainfall and river discharge on 15–30-day time scales. Bull. Am. Meteor- ol.Soc.

8. Al-Ghobari, H., Dewidar, A., & Alataway, A. (2020). Estimation of surface water runoff for a semi-arid area using RS and GIS- based SCS-CN method.
9. Gupta, L., & Dixit, J. (2022). A GIS-based flood risk mapping of Assam, India, using the MCDA-AHP approach at the regional and administrative level.
10. Pal, I., & Singh, S. (2018). Disaster risk governance and response management for flood: A case study of Assam, India. In I. Pal & R. Shaw (Eds.), Disaster risk governance in India and cross cutting issues. Disaster risk reduction (pp. 143–163). Springer.
11. Raghukanth, S. T. G., Dixit, J., & Dash, S. K. (2011). Ground motion for scenario earthquakes at guwahati city. Acta Geodaetica et Geophysica Hungarica, 46(3), 326–346.
12. Debbarma A, Deen S (2020) Flood disaster management in Assam. Shodh Sanchar Bull 10(40):105–109.
13. Shrestha M. S., Artan G. A., Bajracharya S. R., Gautam D. K., and Tokar S. A., Bias-adjusted satellite-based rainfall estimates for predicting floods: Narayani Basin, Journal of Flood Risk Management. (2011) 4, no. 4, 360– 373.
14. D. Halwatura et al. Application of the HEC-HMS model for runoff simulation in a tropical catchment.
15. A.Y. Dubey et al. Evaluation of satellite-altimetry-derived river stage variation for the braided Brahmaputra River.
16. Schumann A, Funke R, Schultz G (2000) Application of a geographic information system for conceptual rainfall–runoff modelling.
17. Priya, S, Young, W, Hopson, T. & Avasthi, A. Flood risk assessment and forecasting for the Ganges- Brahmaputra-Meghna river basins (2017).
18. Werner, M. et al. The Delft-FEWS flow forecasting system. Environ. Model. Softw. 40, 65–77 (2013).
19. Wu, H., Adler, R. F., Tian, Y., Gu, G. & Hufman, G. J. Evaluation of quantitative precipitation estimations through hydrological modeling in Flood river basins.
20. Kumar, P. S., Praveen, T. V., & Prasad, M. A. (2016). Rainfall–runoff modelling using modified NRCS-CN. RS and GIS–A Case Study.