Design Flood Review of Gandhi Sagar Dam using Multi Storm Analysis

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Gandhi Sagar Dam

- On Chambal river in Madhya Pradesh
- Masonry gravity dam- 62.17 m high
- Gross storage-7.322 BCM
- Completed in 1960
- 115 MW –HEP and Irrigation –Kota Barrage

- FRL/ MWL - EL 1312 ft (399.90 m)
- Top of dam - EL 1324 ft (403.56m)
- Storage between FRL and top of dam is about 2.5 BCM

- Spillway – gated ogee type, crest- EL 1284 ft
- Sluices- 9 nos. of sluices at EL 1193.50 ft

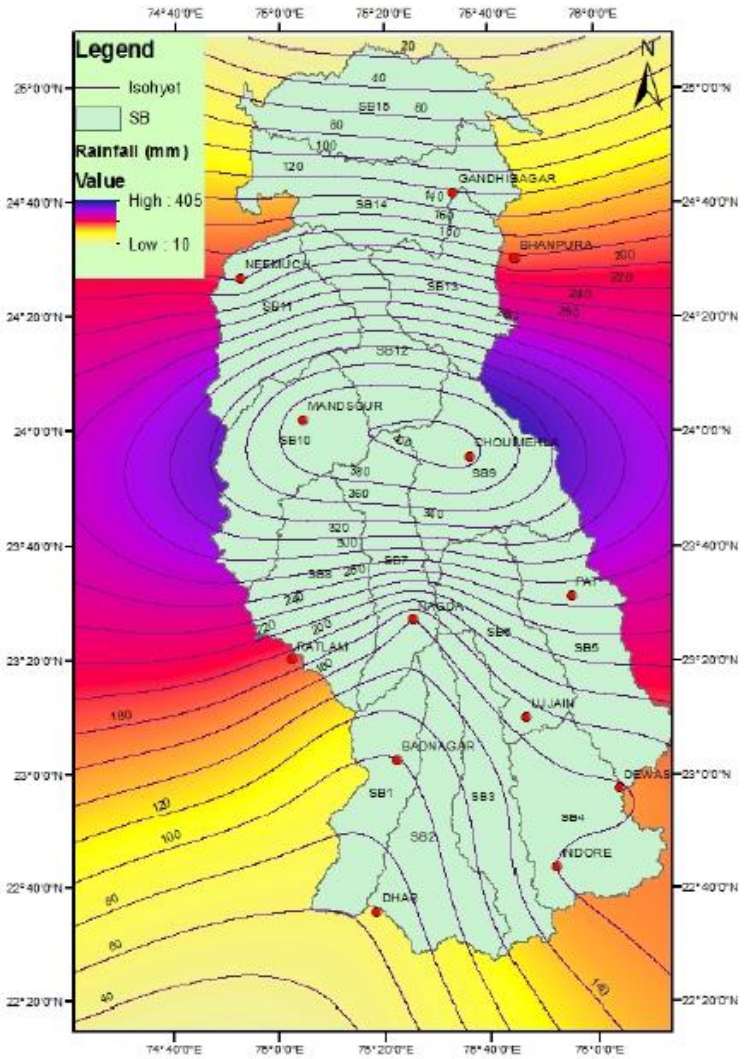
Flooding at Gandhi Sagar Dam

- Dam originally designed for a flood of 21,237 cumec in 1960.
- Combined discharging capacity of spillway and sluices at FRL as per latest computations carried out by CWC is about 13104 cumec (4.63 lakh cusec).
- Design flood of 21237 cumec exceeded a number of times in past including in year 2019.

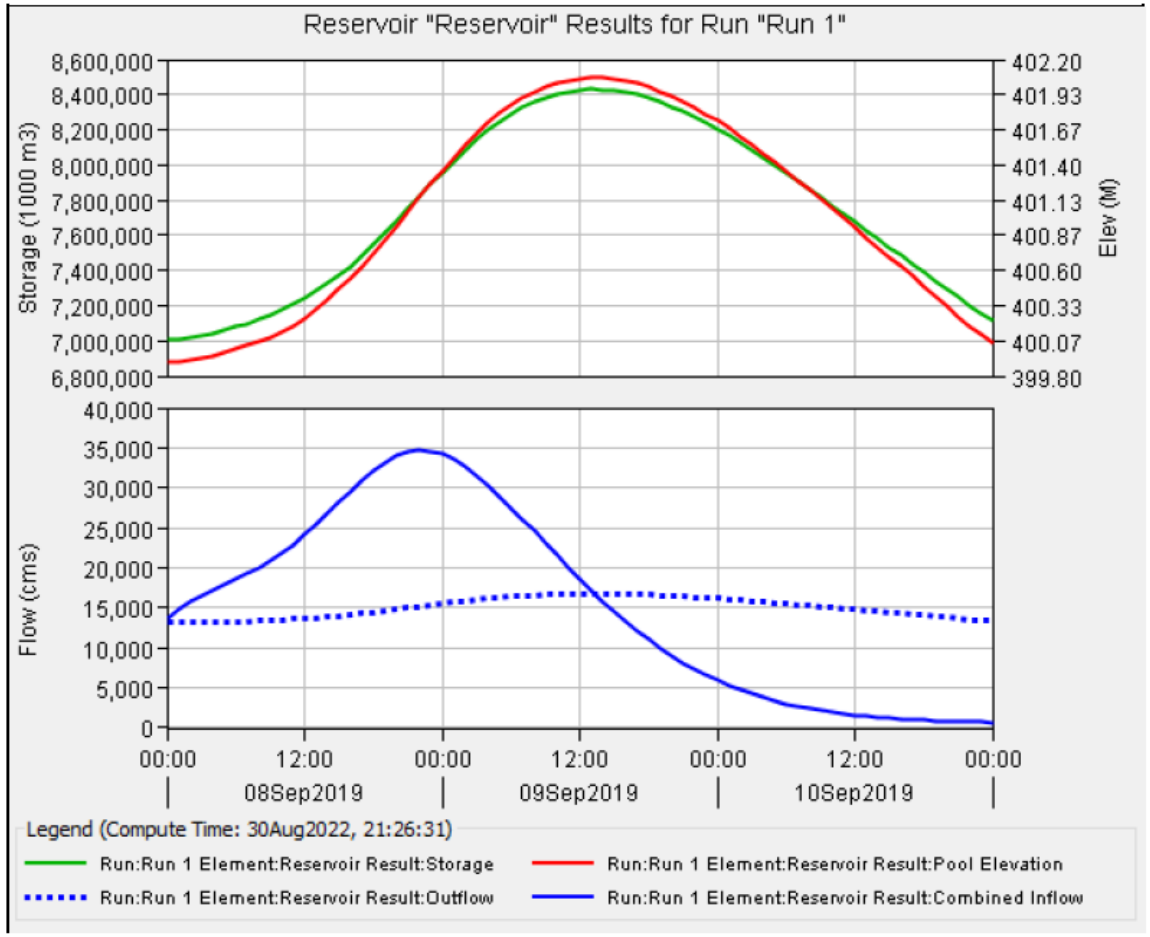
- During 13-15, September 2019 very severe rainfall occurred in Gandhi Sagar catchment. Due to this rainfall and consequent flood, the water level of reservoir reached till EL 1318.87 ft (401.99 m) on 15.09.2019 and it remained at the same level for about 7 hours.

Flood event of September 2019 of Gandhi Sagar Dam

- 4 hourly rainfall data of 13 rain gauge stations for the September 2019 rainfall – 3 day storm isohyets prepared
- Catchment representative rainfall of 51.34 mm, 83.38 mm and 91.97 mm on 13th , 14th and 15th September 2019 respectively.
- Using SUH and observed hourly TD coefficient, the flood hydrograph was simulated using a quasi-distributed hydrological model setup on HEC-HMS
- Reservoir routing also carried out to simulate observed reservoir levels
- From the routing results, it was concluded that during September 2019 flood, the peak inflow into Gandhi Sagar reservoir was of the order of 33000 to 35000 cumec.

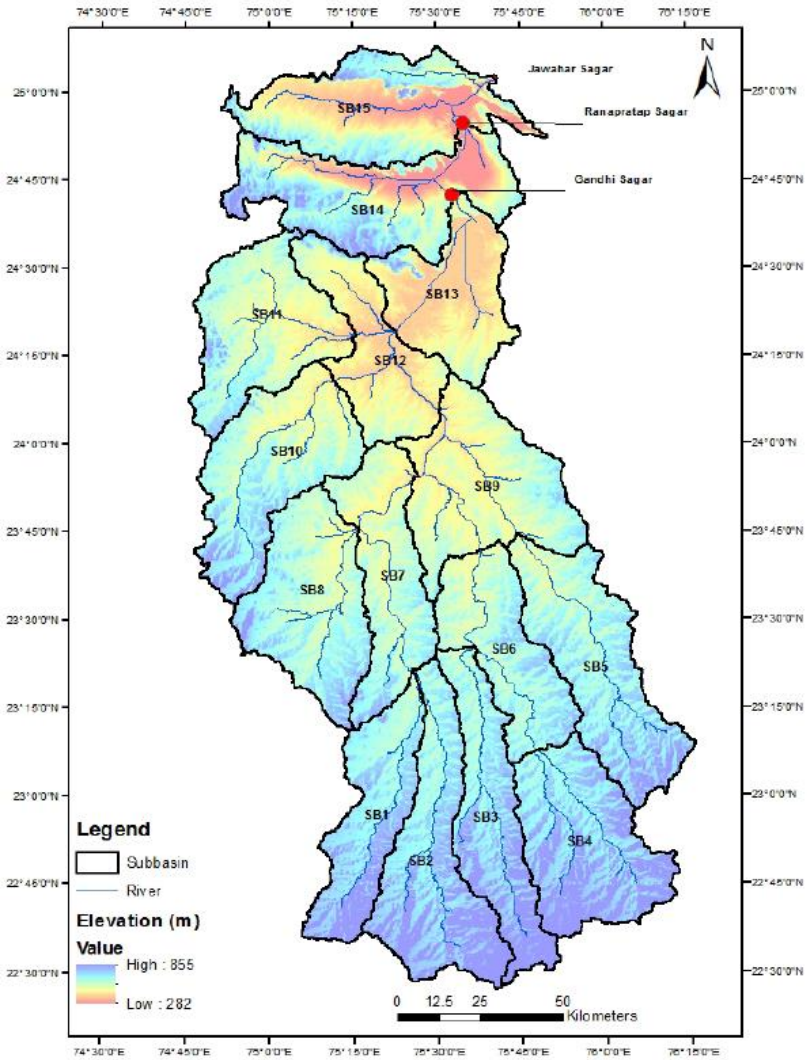


Reservoir routing plots of September 2019 flood of Gandhi Sagar dam

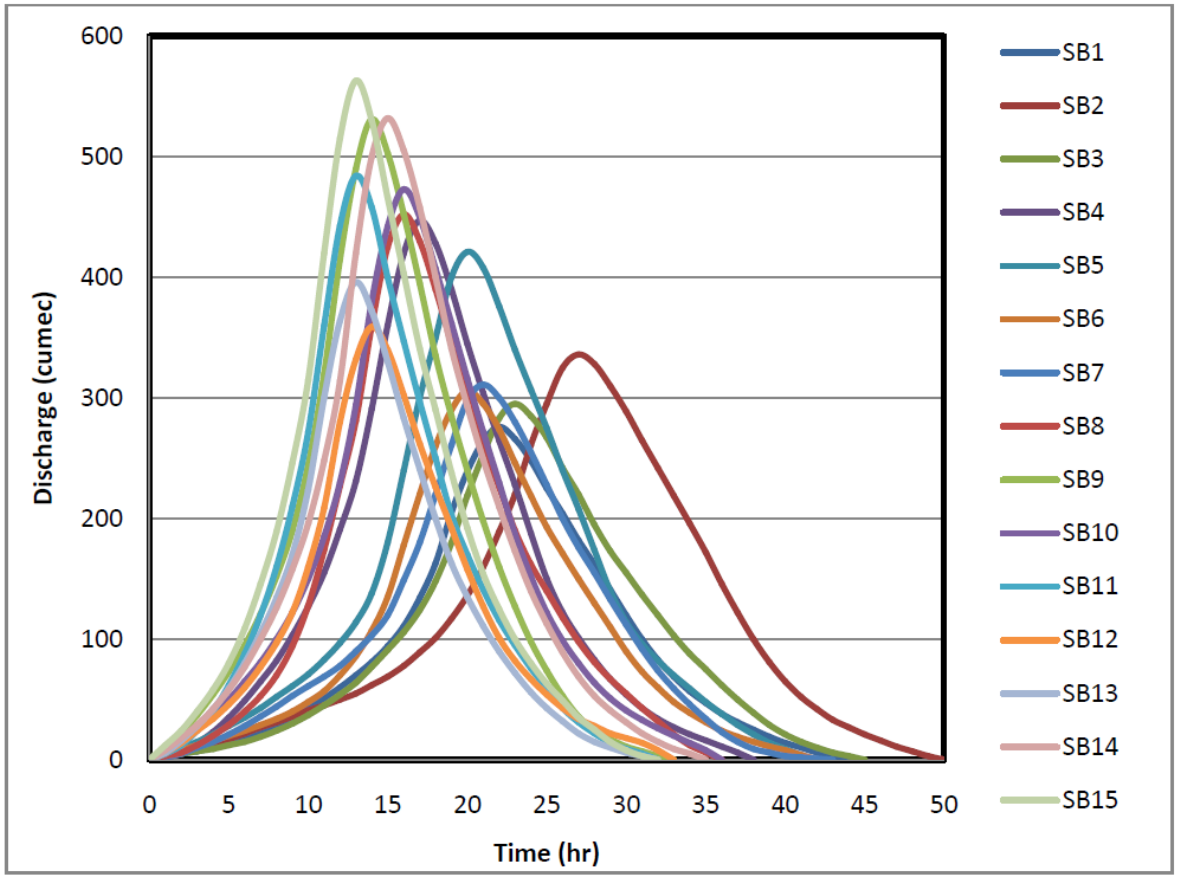


Design Flood Estimation

- As per IS:11223-1985 Gandhi Sagar qualifies for PMF as its design flood
- Catchment area - 22805 sq.km
- Divided into 13 sub-catchments
- A, L, Lc, S determined from GIS
- Synthetic Unit hydrographs (SUH) prepared using CWC FER Chambal sub-zone 1(b)



Unit Hydrographs



Design Storms Analysed

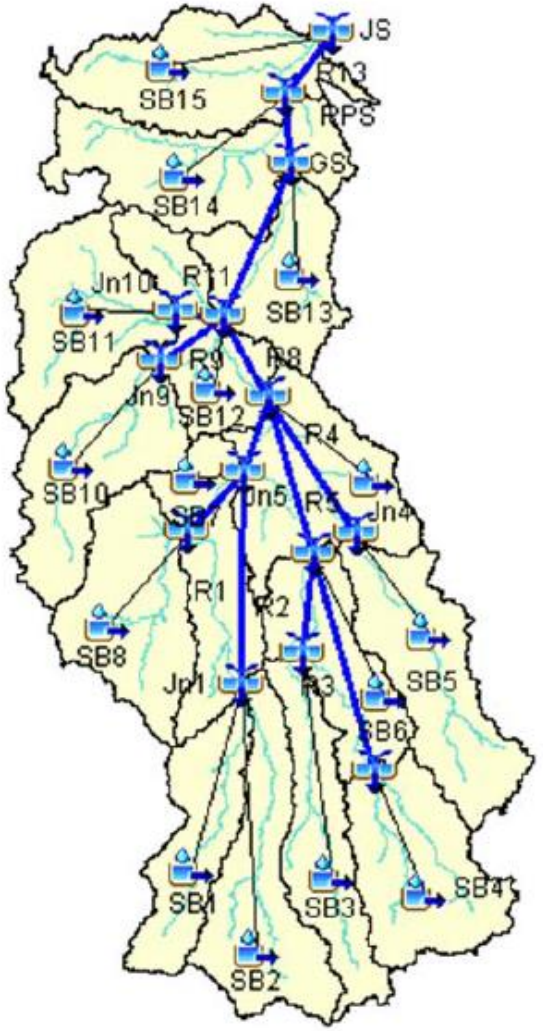
- 26-28, July 1927 with eye at Dakor (lat 22.75º, long 73.15º) and peak depth of 1289 mm – taken in 1994 design flood review study
- 18-20, August 1974 with eye at Tarana (lat 23.33º, long 76.03º) and peak depth of 525 mm – critical storm for area more than 20,000 sq.km. in PMP Atlas of Ganga basin
- 05-07 September, 1932 with eye at Agar (lat 23.72º, long 76.02º) and peak depth of 522 mm – critical storm in PMP Atlas of Ganga basin
- Rainfall of 13-15 September 2019 in Gandhi Sagar catchment

- Different combination of time distribution coefficient, loss rate and base flow adopted as per PMP Atlas of Ganga Basin and FER for Subzone-1(b) respectively.

HEC-HMS model setup

Table: Muskingum routing parameters

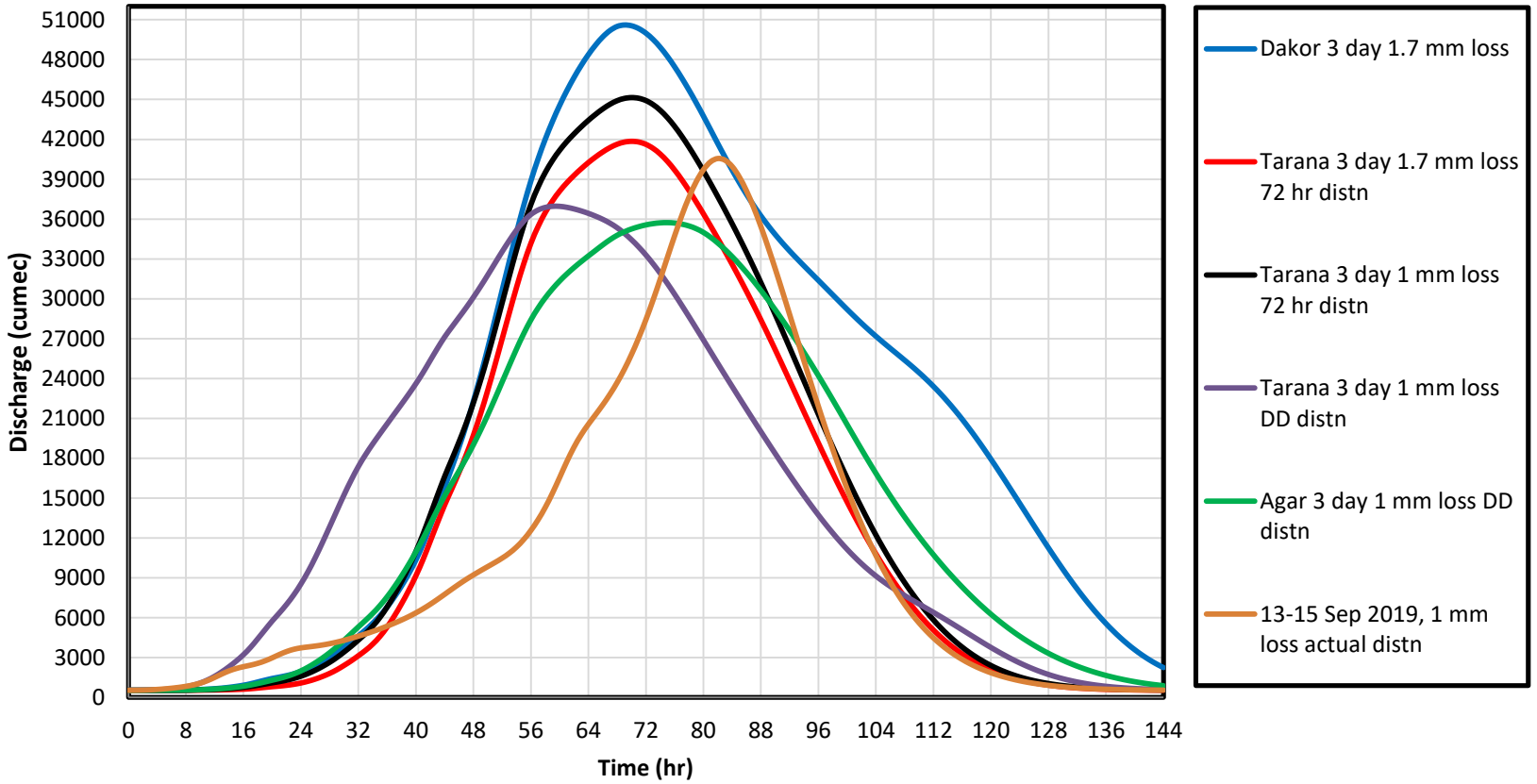
Reach	Length (km)	Muskingum 'K' (hr)	Muskingum 'X'	Sub reaches
R1	92.4	16	0.20	7
R2	43.2	7.20	0.20	3
R3	96.25	16	0.20	7
R4	53.74	9	0.20	4
R5	63.24	10.5	0.20	5
R6	27.0	4.5	0.20	2
R7	31.4	5.2	0.20	3
R8	45.9	7.6	0.20	4
R9	36.2	6	0.20	3
R10	16.8	2.8	0.20	2
R11	53.8	9	0.20	4
R12	31.6	5	0.20	2
R13	22.1	3.5	0.20	2



Comparison of estimated PMF for different storms

Storm	Loss rate	Estimated peak	Total Volume of flood hydrograph	Volume of flood hydrograph > 13104 cumec	Initial level of Gandhi Sagar Reservoir	Reservoir level attained after PMF routing
	(mm/hr)	(cumec)	(BCM)	(BCM)	(m)	(m)
26-28, July 1927 Dakor storm	1.7	50604	10.84	5.99	399.90	405.59
18-20, Aug 1974 Tarana storm with 72 hr distribution coefficient	1.7	41850	7.33	3.44	399.90	403.98
18-20, Aug 1974 Tarana storm with 72 hr distribution coefficient	1	45142	8.09	4.27	399.90	404.54
18-20, Aug 1974 Tarana storm with DD distribution	1	36959	7.86	3.44	399.90	403.65
05-07, Sep 1932 Agar storm with DD distribution	1	35733	7.64	3.25	399.90	403.61
13-15, Sep 2019 rainfall in Gandhi Sagar with actual dist of 12 RG Stations	1	40557	5.89	2.32	399.90	402.74

Plot of PMF hydrographs for different storms

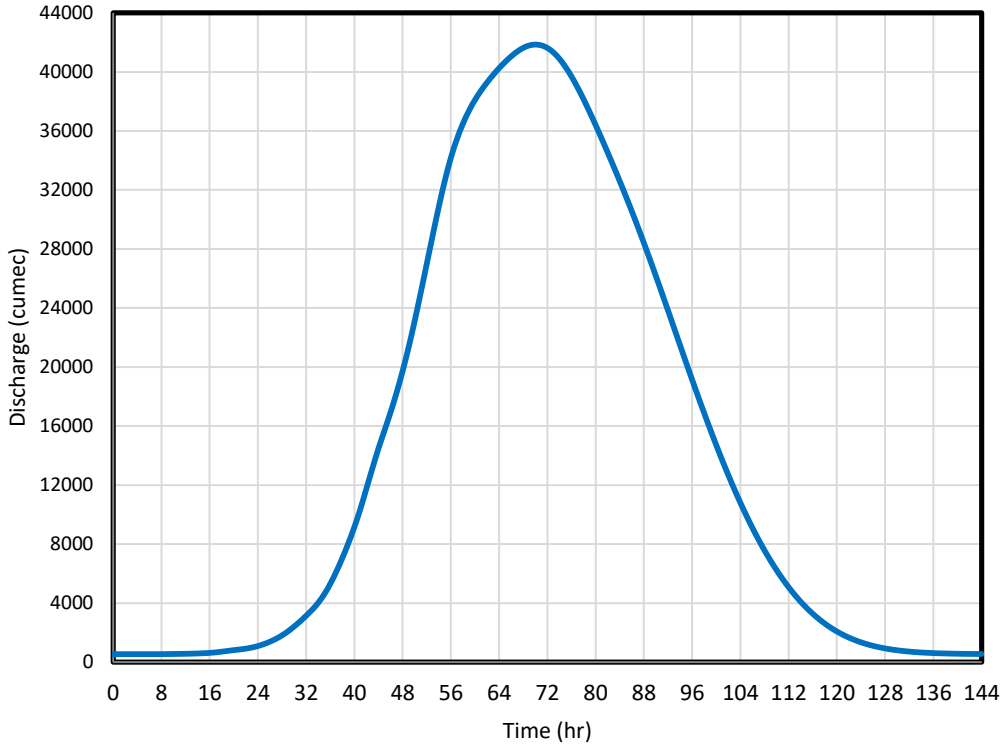


Key Findings On Simulated PMF Peaks And Hydrograph Volume

- The flood event of 13-15 September 2019, assuming the flood peak of the order of 34000 cumec for September 2019 flood, estimated total hydrograph volume is about 4.99 BCM and volume above 13104 cumec is about 1.64 BCM.
- Dakor storm (not considered in the PMP Atlas of Ganga basin for Grid PMP estimation) if placed till the western boundary of Gandhi Sagar Catchment- the estimated flood peak is about 50600 cumec, with total hydrograph volume of 10.84 BCM and hydrograph volume of 5.99 BCM above discharge of 13104 cumec. On comparing the volume with the flood event of September 2019, the total hydrograph volume is about 2.17 times and volume above 13104 cumec discharge is about 3.65 times. Hence, volume of flood hydrograph due to Dakor storm seems too high.
- The PMF estimated using the 13-15 September 2019 storm and actual time distribution -a flood peak of about 40500 cumec with total flood hydrograph volume of 5.89 BCM and flood hydrograph volume of about 2.32 BCM above 13104 cumec discharge. On comparing the volume with the flood event of September 2019, the total hydrograph volume is about 1.18 times and volume above 13104 cumec discharge is about 1.41 times.

Key Findings On Simulated PMF Peaks And Hydrograph Volume

- PMF corresponding 18-20, August 1974 Tarana storm with estimated peak of 41850 cumec, yields total flood hydrograph volume of 7.33 BCM and flood hydrograph volume of about 3.44 BCM above 13104 cumec discharge. For this PMF hydrograph, total hydrograph volume is about 1.47 times and volume above 13104 cumec discharge is about 2.10 times in comparison to September 2019 flood.
- The estimated PMF for Gandhi Sagar dam lies between average envelope (28137cumec) and upper envelope (53130 cumec) of envelope curves.



Plot of PMF hydrograph of Gandhi Sagar Dam

Conclusion

- For large reservoirs, estimation of appropriate design flood sometimes becomes very challenging, when a number of severe storm records are available in and around the catchment in transposable limits.
- In case of large reservoirs with signification storage not only the flood peak but the volume of flood hydrograph also becomes governing factor for estimating the appropriate design flood.
- In order to analyze the impact of flood peak and volume associated with the estimated flood hydrograph, the estimated flood hydrograph for different storms should be reservoir routed considering a critical condition of initial impingement level in the reservoir.

Thank You