INCOLD
Indian National Committee on Large Dams

INTERNATIONAL
DAM SAFETY CONFERENCE

DRIP
Dam Rehabilitation & Improvement Project

Central Water Commission

Two-dimensional Dam break flow analysis of Cascade of Dam using HEC-RAS

TS-1: Global Best Practices in Dam Safety Management & Governance

S. Jaiswal, **R.K. Jaiswal,** AK Lohani

National Institute of Hydrology Roorkee

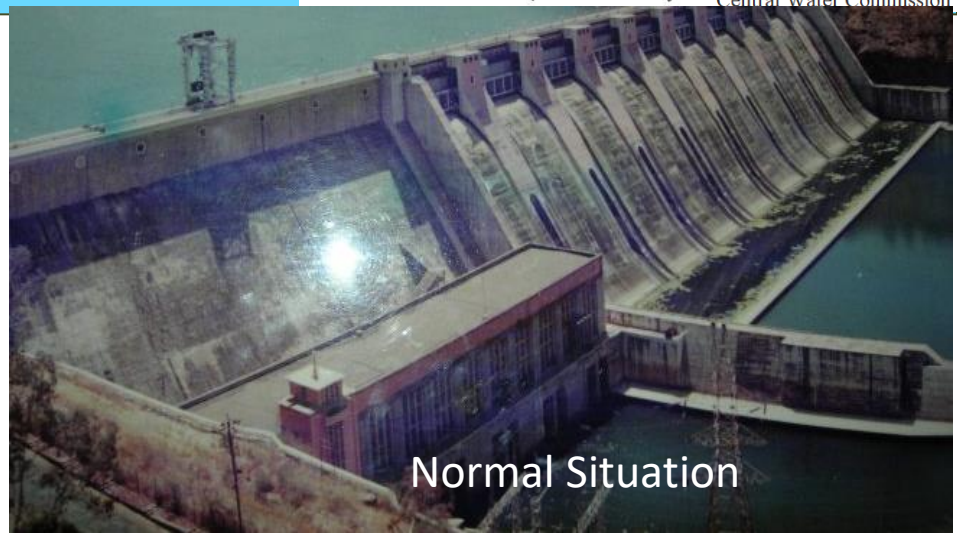
rkjaiswal.nih@gmail.com, +919425655193

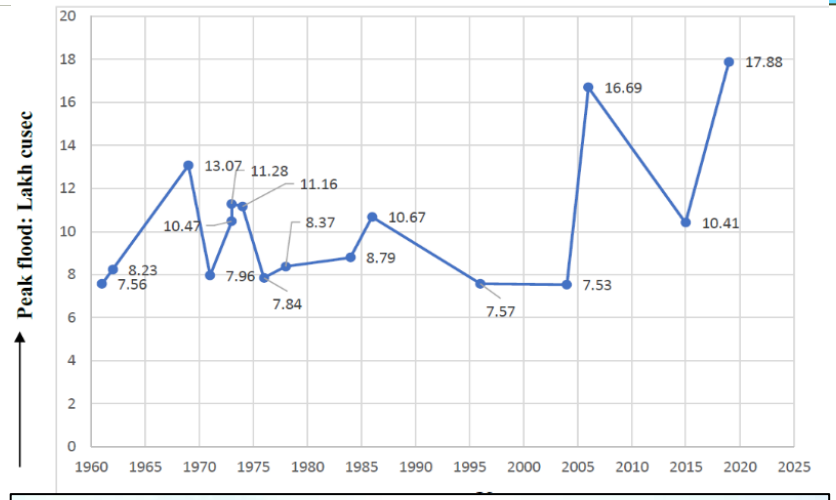
Introduction

- Dams are barrier to store water
  - Irrigation
  - Flood moderation
  - Power generation
  - Domestic WS
  - Industrial WS
- Of the country but the same dam if fails will leads high flood waves that travel along a valley at quite high speed and can cause partial or catastrophic loss of life and properties.

Motivation of the Study

- Gandhi Sagar Dam is the third largest dam of India
- First in the series of the Chambal valley project (4 dams/barrages).
- On **September 15, 2019,** one such flood disaster was faced by Dam when this dam came close to overtopping.
- Heavy rains in the catchment cause an inflow of 17.88 lakh cusec (5063.05 cumec) and outflow of approximately 5 lakh cusecs (1400 cumec) of water (CWC report).





- The situation was so menacing that the CWC called it's overtopping a "National Crises".
- RAPP is D/S of GS Sagar dam
- The topography is high undulated.
- Gandhi Sagar Dam has started experiencing floods shortly after the construction has finished.
- Change in runoff pattern due to change in ecology
- Erratic water flows have rendered the dam unsafe and arrangements for surplus storage is insufficient (Gupta and Kawadia, 2007).

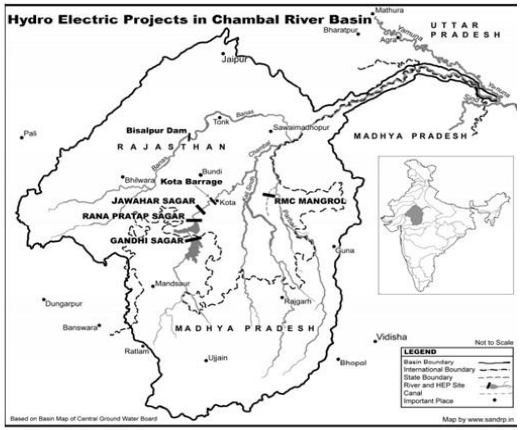
INCOLD
Indian National Committee on Large Dams

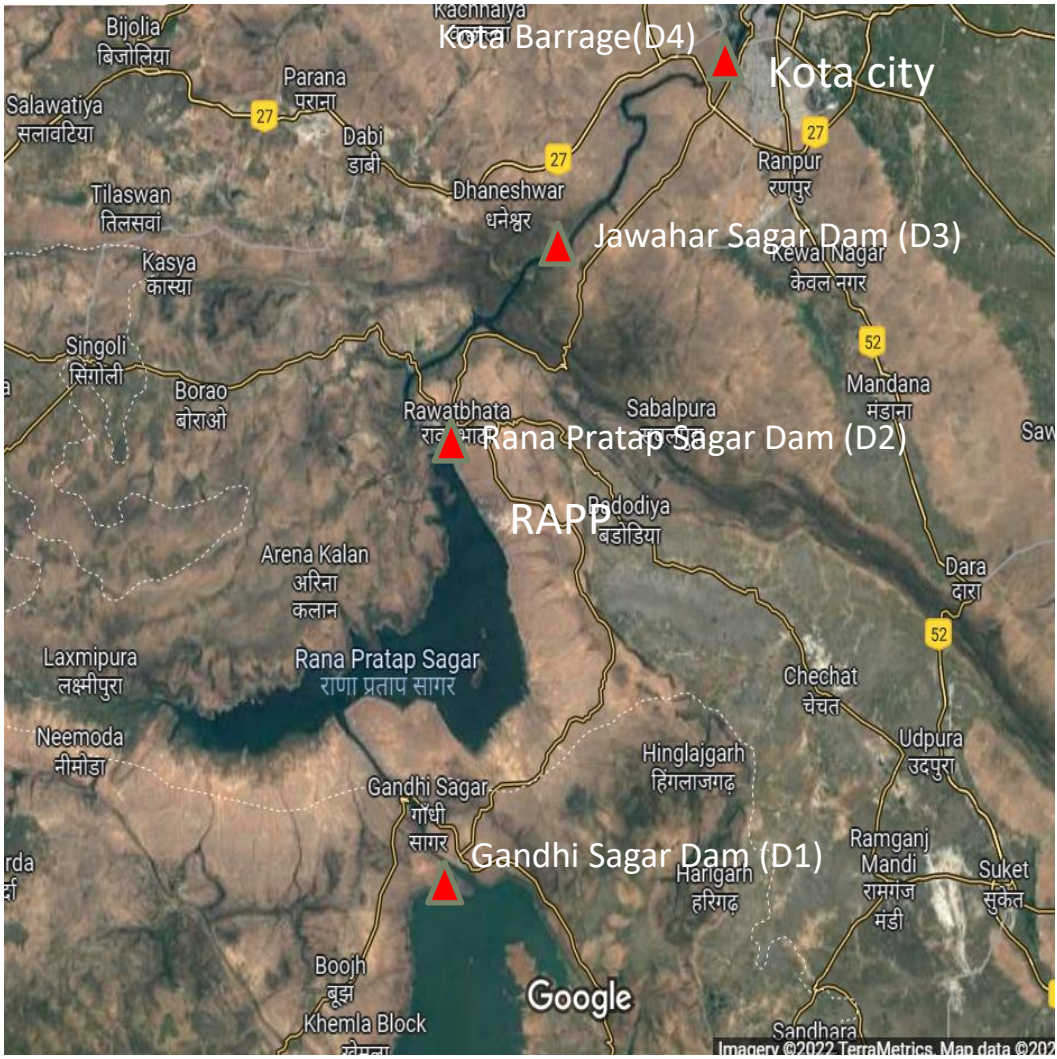
INTERNATIONAL DAM SAFETY CONFERENCE

DRIP
Dam Rehabilitation & Improvement Project

Central Water Commission

Study Area: Chambal Valley Project





Started in 1954 on the Chambal River.

1st Stage (1960): Gandhi Sagar Dam

2nd Stage (1970): Rana Pratap Sagar Dam

3rd Stage (1971-72): Jawahar Sagar dam and Kota Barrage

Salient Features of the Chambal Valley Project

S. No	Particulars	Gandhi Sagar	Ranapratap Sagar	Jawahar Sagar	Kota Barrage
1.	Lat. And Long.	24°42'24"N & 75°33'12"E	24°55'04"N & 75°34'53"E	25°2'12.796"N & 75°40'39.92"E	25°10'33.49"N & 75°49'35"E.
2.	Catchment area(sq.km)	23051	24864	27195	27454
3.	Type of dam	Gravity dam	Gravity dam	Gravity dam	Earthfill dam
4.	Road top EL (ft.)	1324	1172	1000	862
5.	Overflow crest EL (ft.)	1284	1129	936	812
6.	Dead storage (ft.)	1250	1125	NA	NA
7.	MWL (ft.)	1312	1162	990	857
8.	FRL (ft.)	1312	1157.5	980	854

9.	Sluice gate	9 Nos. (10'*25')	4 Nos. (9'*11')	NA	2 Nos. (9'*11')
10.	Crest gates (ft.)	10 Nos. (60'*28')	17 Nos. (60'*28')	22 Nos. (55'*44')	NA
11.	Gross capacity (MCM)	7165	2905	67	70
12.	Live capacity (MCM)	6605	1443	25	10
13.	Dead capacity (MCM)	560	1462	42	69
14.	Power hydel (MW)	115	172	99	0
15.	Rabi irrigation (Ha)	Rajasthan	225000		
		Madhya Pradesh	362100		

Data Used

S.NO	DATA USED	SOURCE
1.	Digital elevation model(DEM) of study area	Alaska satellite facility (12.5 m)
2.	Salient features of Gandhi Sagar Dam	MPWRD
3.	LULC of Study area	Prepared using LANDSAT 8 satellite image and survey of India toposheets using ArcGIS.
4.	Flood hydrograph (Gandhi Sagar Dam)	MPWRD
5.	Elevation storage curve of Gandhi Sagar and Ranapratap Sagar reservoir.	MPWRD
6.	Elevation storage curve of Jawahar Sagar and Kota Barrage reservoir.	MP & Raj WRD
7.	Salient features of Ranapratap Sagar Dam, Jawahar Sagar Dam and Kota Barrage respectively	http://water.rajasthan.gov.in/wrd#
8.	Satellite Image (LANDSAT 8)	https://earthexplorer.usgs.gov/

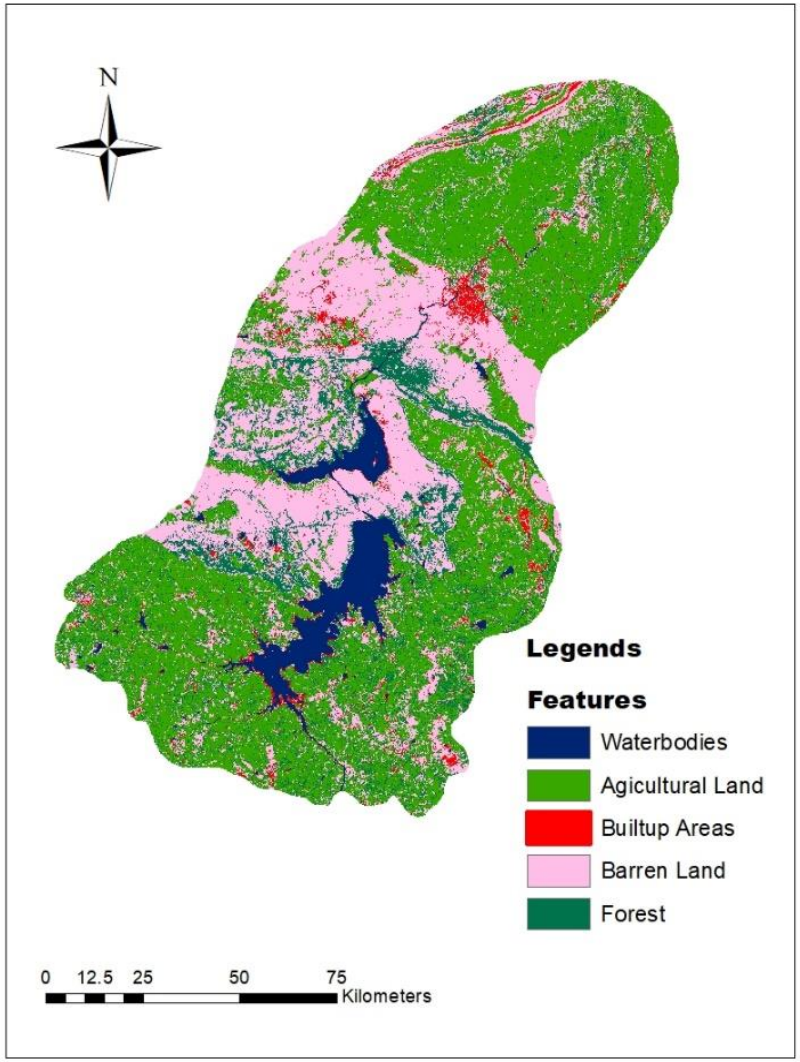


Table: LULC Features Area

Features	Area (sq.km)	Area (%)
Waterbodies	873.81539	5.459944
Agricultural Land	7211.085	45.05771
Built-up Areas	535.232	3.344341
Barren Land	5078.291	31.73117
Forest	2305.686	14.40684

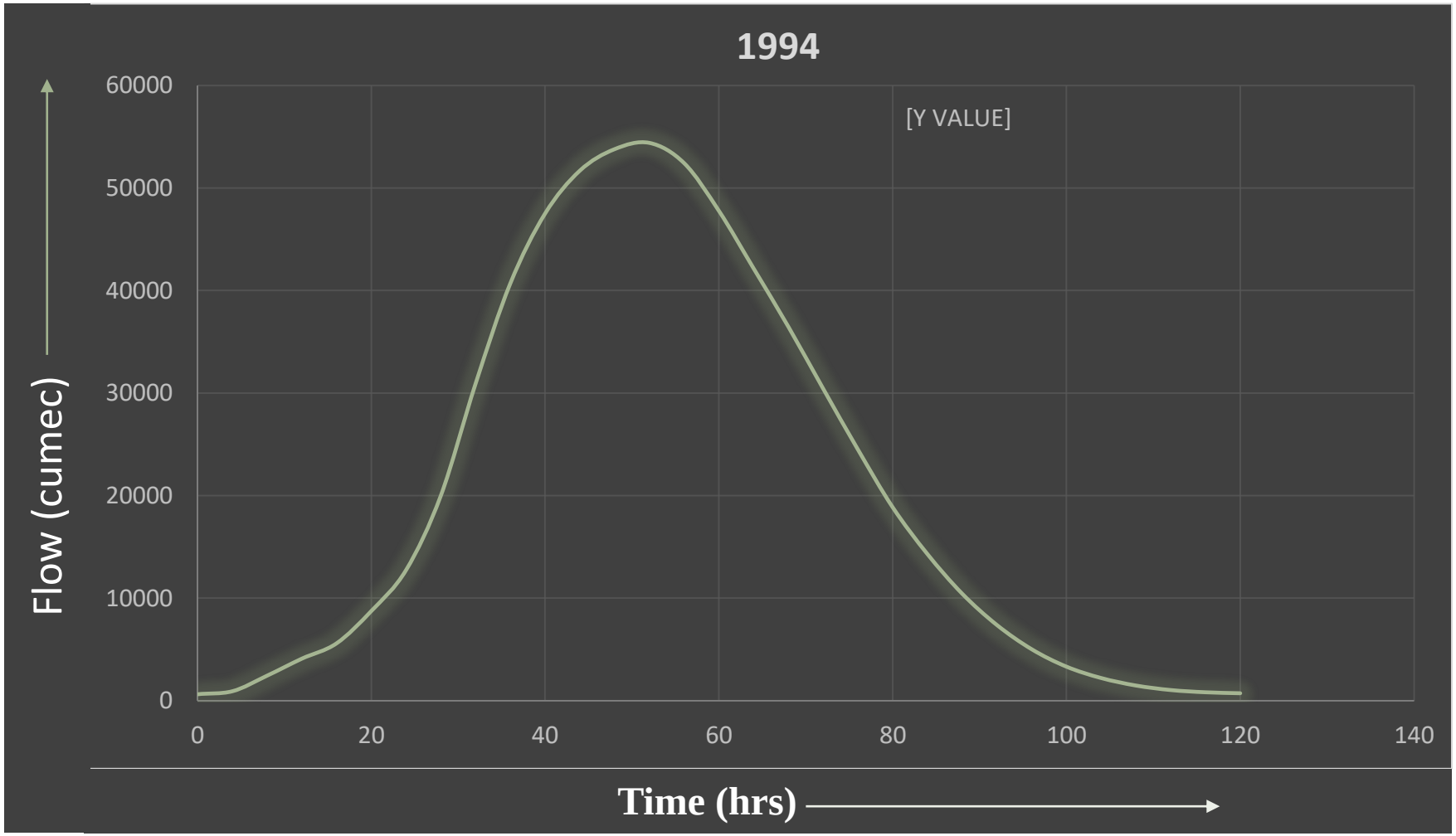


Fig. Design Flood Hydrograph of Gandhi Sagar Dam

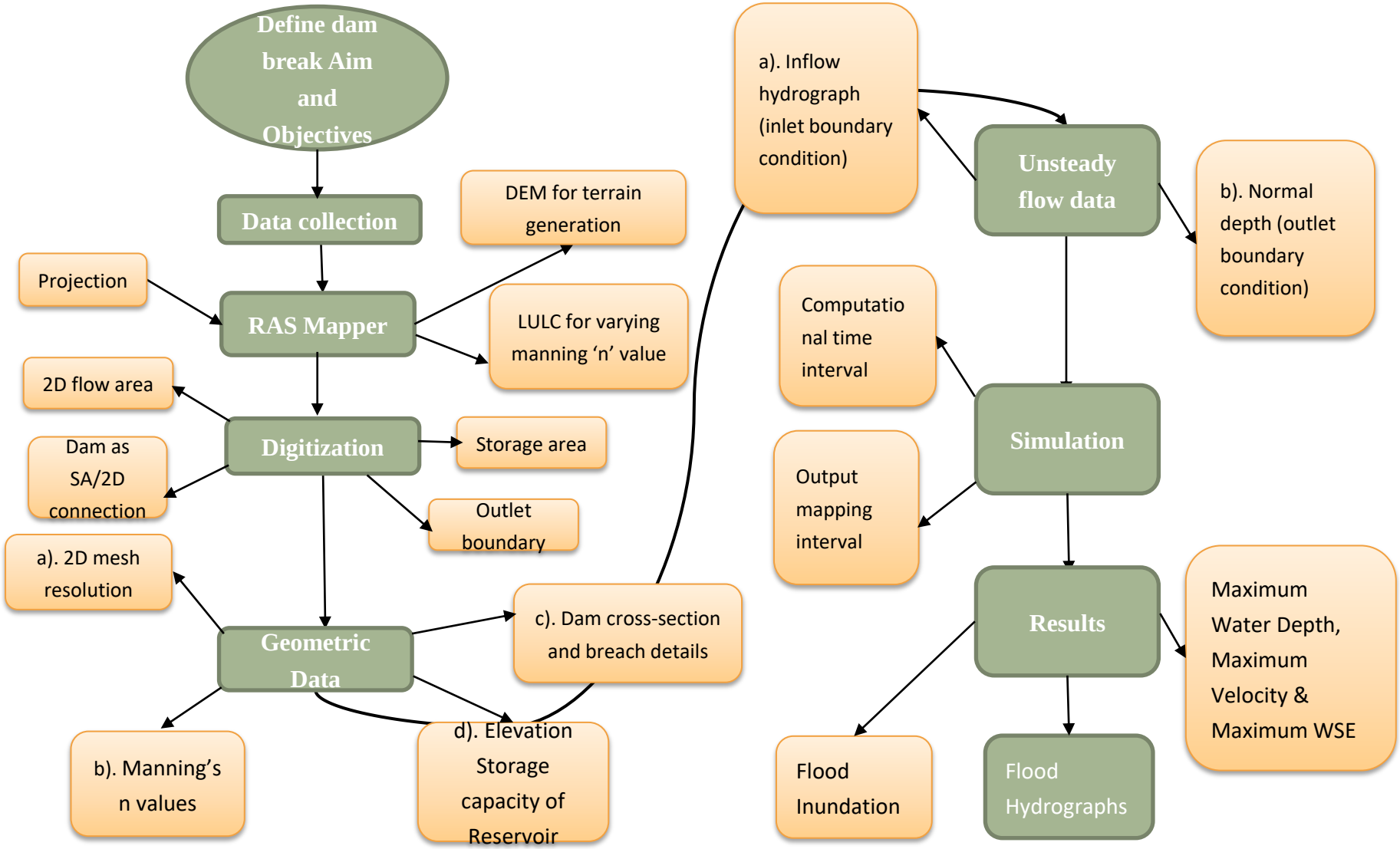
METHODOLOGY

INCOLD
Indian National Committee on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE

DRIP
Dam Rehabilitation & Improvement Project

Central Water Commission



10-12 October 2022 at Jaipur, Rajasthan (India)

Model Setup

- A two-dimensional mesh was created for the expected flood area due to the dam break. The cell size of the mesh is 50 m X 50 m.
- LANSAT 8 satellite is used to prepare LULC map for the study area to provide varying manning's n values.
- The whole study area has been divided into 5 features classes viz. Water bodies (0.04), Agriculturr (0.035), Built-up Areas (0.1), Barren Land (0.025) & Forest (0.16) (Chow, 1959).
- Storage area is digitized and the elevation versus storage curve obtained as an input
- SA/2D flow connection and was used to represent dam body in the model.
- The breach plan was computed using USACE 2007 guidelines for Gravity Dam and Froehlich 2008 empirical equation for earth fill dam.

RESULTS and ANALYSIS

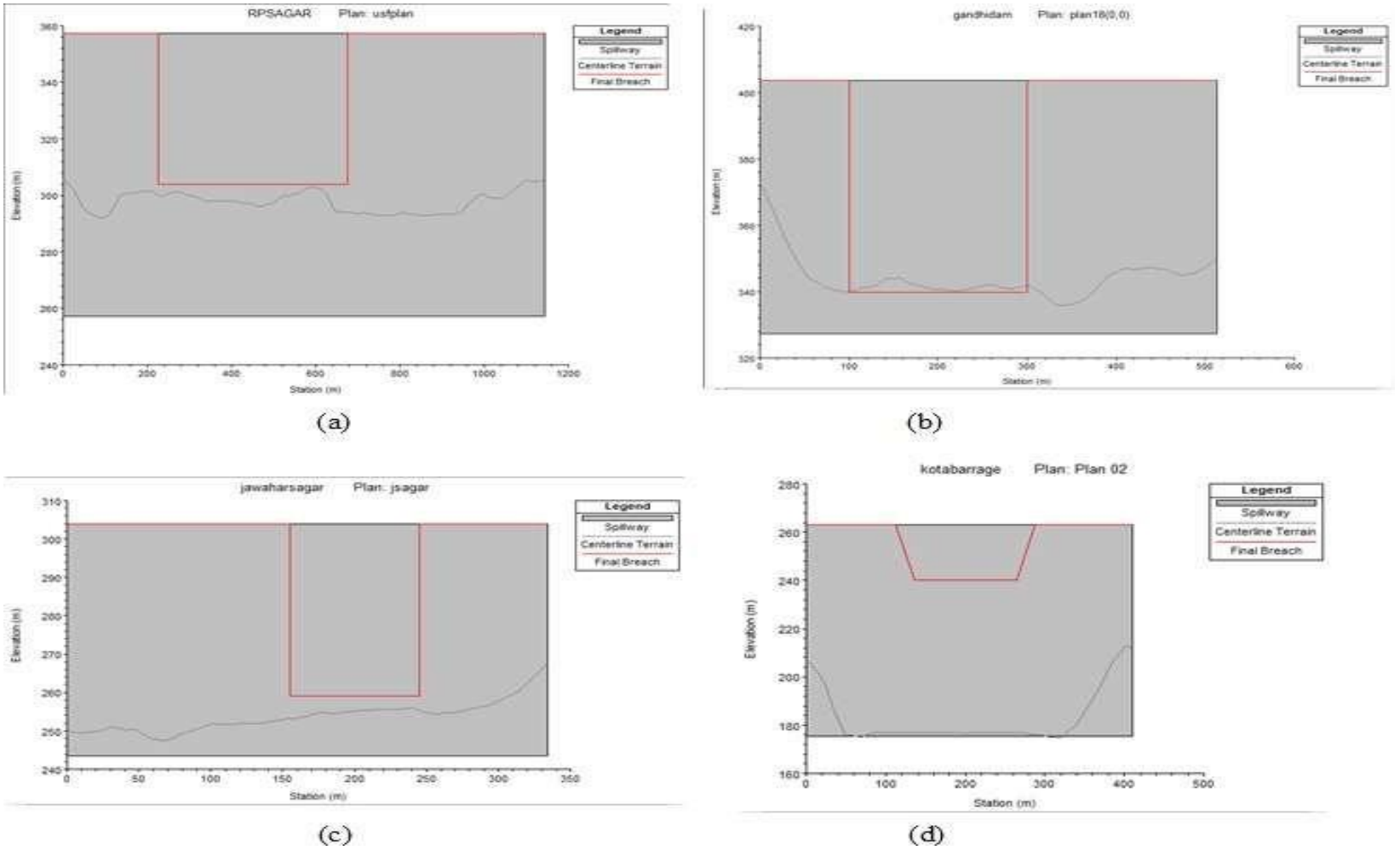


Fig. Breach Plot for a) Gandhi Sagar dam b) Ranapratap Sagar dam c) Jawahar Sagar Dam and d) Kota Barrage

- In this HEC-RAS model setup, each dam's lateral inflow flood hydrograph ***is given as the inflow boundary condition and normal depth as an outflow boundary condition.***
- Computation interval : 5 seconds
- Mapping output interval : 30 seconds,
- Hydrograph output interval : 1 hour,
- Detailed output interval : 1 hour
- The analysis of each dam is proceeded subsequently based on the preceding Dam break scenario.
- Equation set used for unsteady flow modeling is diffusion wave equation and the initial condition time for 2D flow analysis is set to 8 hrs.

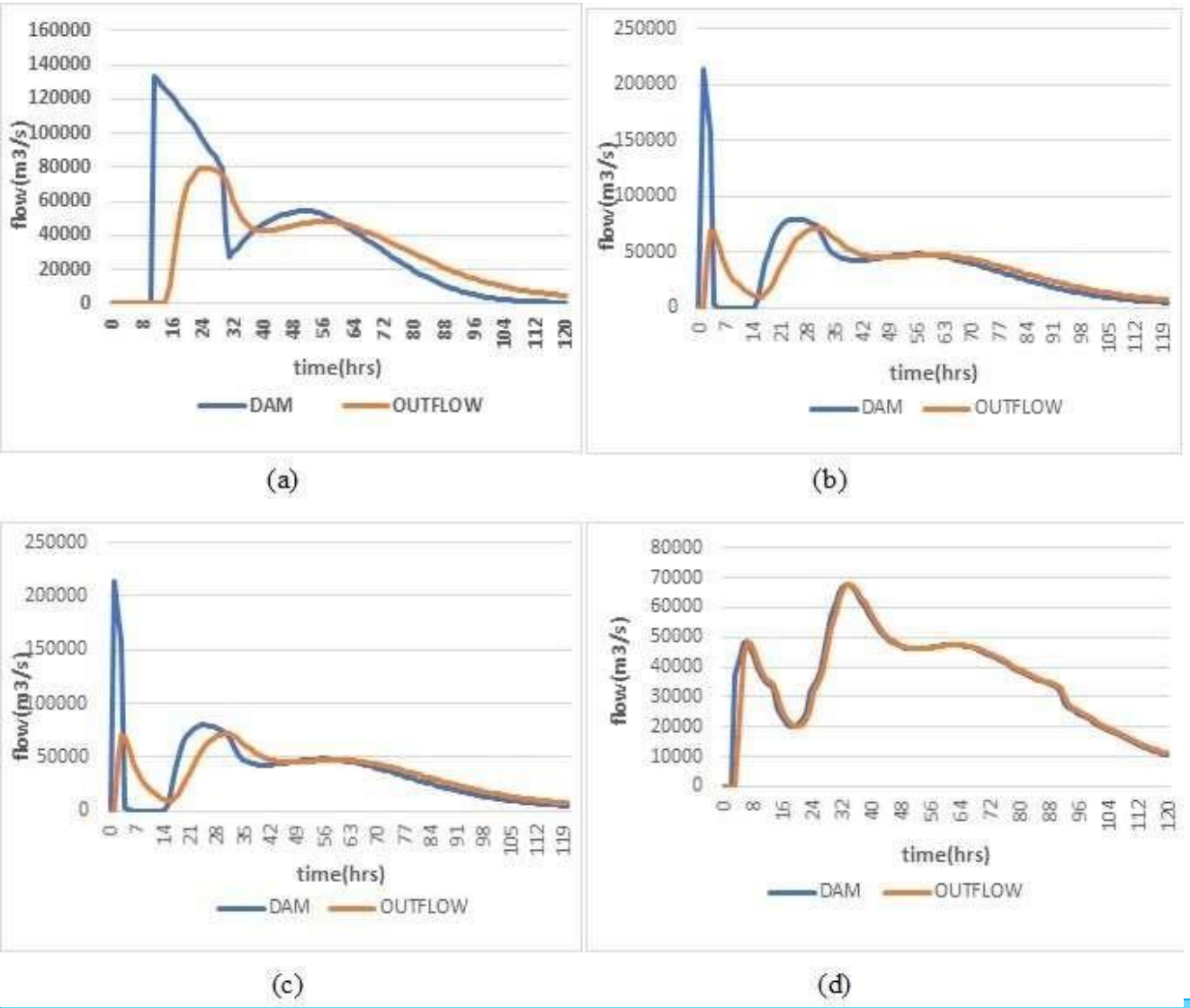


Fig. Flood Hydrograph Obtained downstream of (a) Gandhi Sagar Dam, (b) Ranapratap Sagar Dam, (c) Jawahar Sagar Dam, and (d) Kota Barrage

Table. Maximum Depth, Mean Depth, and Maximum velocity at villages/Town nearby Kota Barrage

Affected Villages/town	Area of Village/town (km^2)	Maximum Depth (m)	Mean Depth (m)	Minimum Arrival Time (h:mm:ss)
Gaonri	1.957846	16.2616	2.65624	**2:34:30**
Ram Kherli	0.752624	12.0499	3.41774	**6:04:30**
Kherli Pande	2.435877	11.3177	2.51794	**5:56:30**
Pipalda Shekhan	1.129614	11.9434	3.75197	**5:51:30**
Daslana	1.266168	10.9623	2.79948	**6:10:00**
Borkhandi	2.642331	10.9771	2.71592	**5:47:30**
Hanuwant Khera	2.274345	10.9751	3.22904	**6:53:30**
Rajnagar	1.218089	10.9739	2.70612	**8:41:00**
Kota (RJ)	**155.4487**	**24.1414**	**8.14137**	**0:11:03**
Badoonda	8.634013	12.2791	5.75863	**6:02:30**
Chhapawada	2.337028	13.7337	5.5022	**5:48:00**
Bajar	5.334004	10.5155	4.66389	**7:25:00**

Affected Villages/town	Area of Village/town (m^2)	Maximum Depth (m)	Mean Depth (m)	Minimum Arrival Time (h:mm:ss)
Teetarwasa	3.006049	11.7879	3.9787	**4:30:00**
Gamach	4.298826	13.1289	3.54735	**4:09:00**
Keshonagar	3.472765	15.6864	2.03918	**2:06:30**

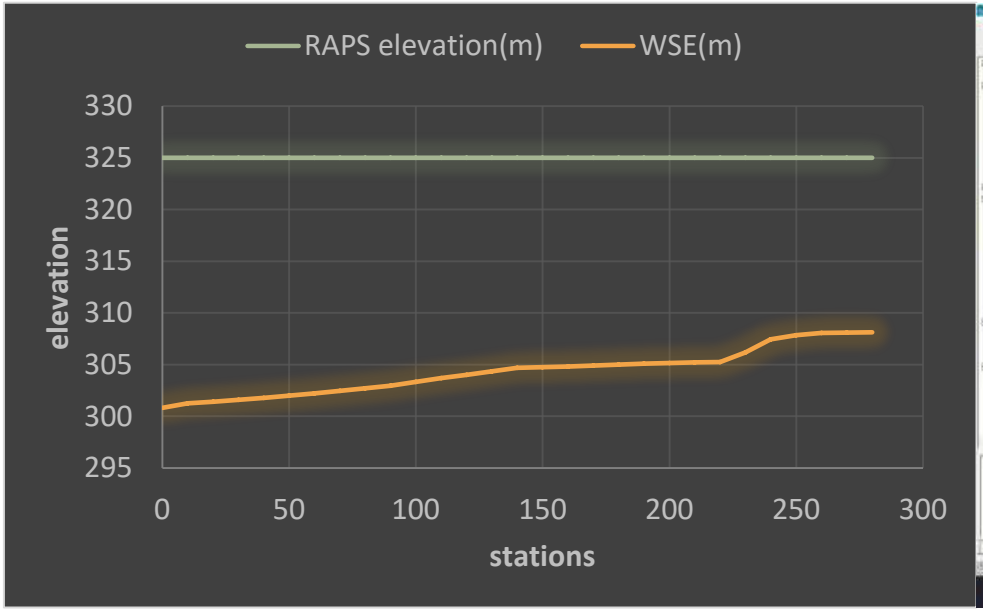
Effect of Flood on Rawatbhata Atomic Power Station (RAPS)

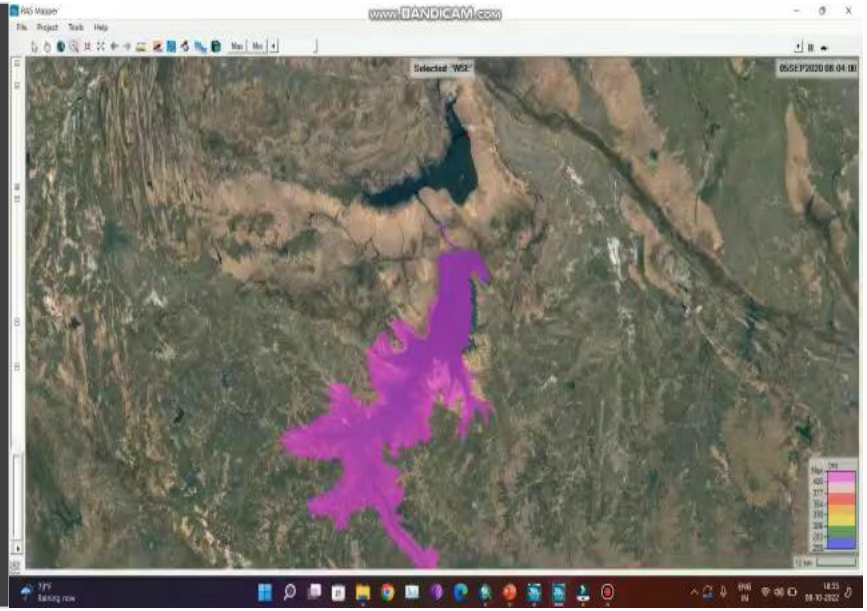
The effect of the flood on RAPP due to Gandhi Sagar Dam break is analyzed for two cases.

i) When upstream dam reservoir, Ranapratap Sagar reservoir is empty.

ii) When upstream dam reservoir, Ranapratap Sagar reservoir is full.

CASE 1: When Ranapratap reservoir storage is empty

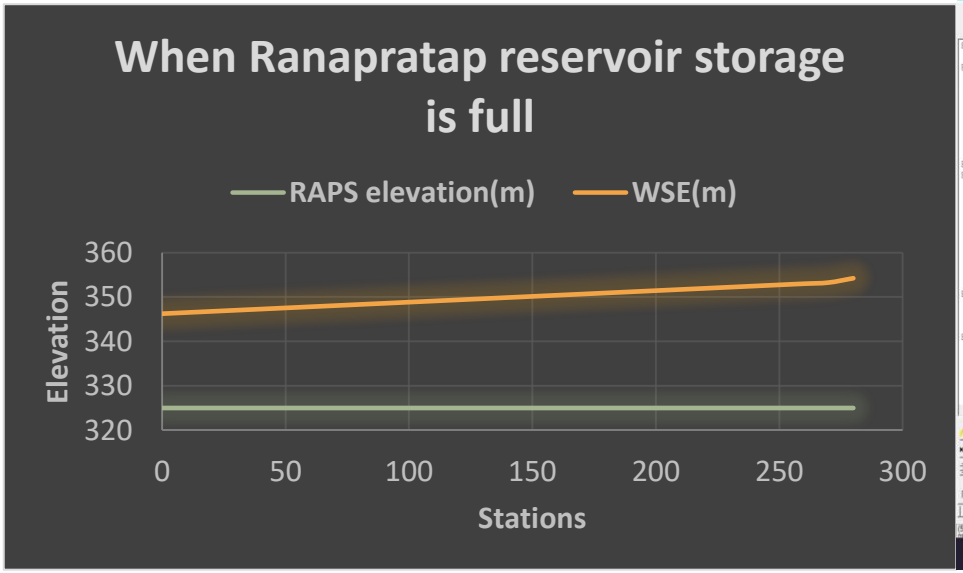


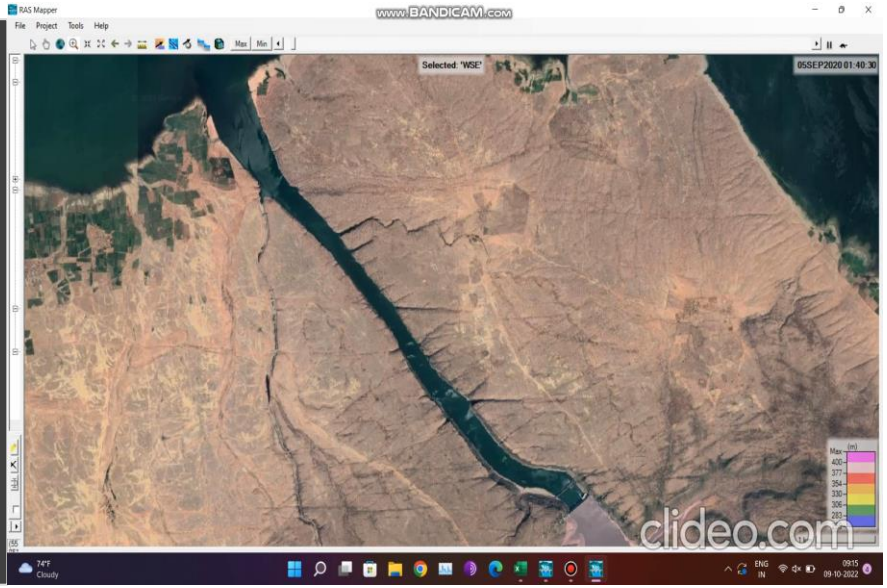


- Max water surface elevation due to Gandhi Sagar dam break flood near the power plant found out is 308.2 is less than 325 m RL of Rawatbhata Nuclear Power Plant
- floodwater will not reach up to the nuclear power station. But a proper site visit is necessary to take precautionary measures to keep the power plant safe.

there is a chance of flood at that

CASE 2: When Ranapratap reservoir storage is full.





- Max water surface elevation due to Gandhi Sagar dam break flood near the power plant found out is 354 m which is more than 325 m RL of Rawatbhata Nuclear Power Plant
- floodwater will may cause significant damage to many of the plant's reactors. This situation may be more devastating than the Chornobyl Disaster of Japan.

CONCLUSIONS

1. The max discharge D/S of Gandhi Sagar Dam (D1) is 79822.26 cumec is higher than the PMF of Ranapratap Sagar Dam (D2) (18400 cumec) may cause Failure of Ranapratap Sagar dam (D2).
2. Similarly, the maximum discharge of D2 is 71822.19 m^3/sec which is higher than PMF of Jawahar Sagar Dam (D3) (21225 cumec) may cause Failure of D3.
3. The dam break of Gandhi Sagar dam may lead to break all the structures including Kota barrage (D4).
4. Dam break time of Gandhi Sagar dam (D1) is 14:37:25 Flood arrival time from Gandhi Sagar dam (D1) to Ranapratap Sagar dam (D2) is 1:16:30 hrs and Ranapratap Sagar dam (D2) to Kota (D4) is 3:47:00 hrs.
5. The elevation of RAPP is 325 m will be affected severely when D1 is broken and D2 is full may cause may cause significant--damage to many of the plant's reactors.

References

- Amini A., Arya A., Eghbalzadeh A., Javan M. 2017. Peak Flood Estimation under Overtopping and Piping conditions at Vahdat Dam, Kurdistan, Iran, *Journal of Geoscience: 1-11*.
- Anderson D.A., Tannehill J.C., Pletchar R.H. 1984. Computational Fluid Mechanics and Heat Transfer Hemisphere, *McGraw-Hill*, NY.
- Aravind V, Muthiah P, Rai N. N. 2017. Performance Analysis of Three Dam Failure Analysis Modules, *Third National Dam Safety Conference*. IIT Roorkee.
- Balogun O.S, Ganiyu H.O. 2017. Development of Inundation Map for Hypothetical ASA Dam Break using HEC-RAS and Arc GIS, *Journal of Engineering, Technology, and Environment 13(6)*: 831-839.
- Chow, V.T. 1959. Open-channel hydraulics: New York, *McGraw-Hill Book Co*.
- Daily Flood Situation Report cum Advisories 15-09-2019, Ministry of Jal Shakti, Deptt. of Water Resources, RD & GR, Central Water Commission.

- Gee Michael D. and Brunner W. Gary. 2005. Dam Break Flood Routing using HEC-RAS and NWS-FLDWAV, *American Society for Civil Engineering (ASCE)*: 1-9.
- Georgea C. A. & Nair T. B. 2015. Dam Break Analysis Using BOSS DAMBRK, *International Conference on Water Resources, Coastal and Ocean Engineering*: 853 – 86
- Gupta R.P. and Kawadia G. 2007. Rainfall and Run-Off: Changing Trends in Gandhi Sagar Dam, *Economic and Political Weekly* 38(33): 3457-3459
- Khattak M.S., Anwar F., Saeed T.U., Sharif M., Sheraz K., Ahmed A. 2016. Floodplain Mapping Using HEC-RAS and ArcGIS: A Case Study of Kabul River, *Arabian Journal for Science and Engineering, Springer publication*.
- Kilania S. & Chahar B.R. 2019. A Dam Break Analysis Using HEC-RAS, World Environmental and Water Resources Congress, *American society of civil engineering (ASCE):* 382-389
- Kumar Sunil, Jaswal Anil, Pandey Ashish, Sharma Nayan, (2017), Literature Review of Dam Break Studies and Inundation Mapping using Hydraulic Models and GIS,

International Research Journal of Science and Technology 4(5): 55-61.

- Song L., Zhou J., Qingqing Li Q., Yang X. and Zhang Y. 2010. An unstructured finite volume model for dam-break floods with wet/dry fronts over complex topography, *International Journal for Numerical Methods in Fluids*: 960-961.
- Xu F., Zhou H., Zhou J., and Yang X., 2012. A Mathematical Model for Forecasting the Dam- Break Flood Routing Process of a Landslide Dam, *Hindawi Publishing Corporation, Mathematical Problems in Engineering:* 1-16
- Yochum E, Goertz A, Jones H. 2008. Case Study of the Big Bay Dam Failure: Accuracy and Comparison of Breach Predictions, *Journal of Hydraulic Engineering* 139(9): 1285-1293.
- Zhou R. D., Judge D. G., and Donnelly C. R. 2005. Comparison of HEC-RAS with FLDWAV And DAMBRK Models for Dam Break Analysis, *Canadian Dam Association*: 1-13.

INCOLD
Indian National Committee on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE

DRIP
Dam Rehabilitation & Improvement Project

Central Water Commission

10-12 October 2022 at Jaipur, Rajasthan (India)