BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL, PRINCIPAL BENCH, NEW DELHI

ORIGINAL APPLICATION NO.635/2024

Sumoto matter News Item titled "2023 Delhi Floods How Govt. did not see Delhi's worst flood coming even 24 hours before it"

INDEX

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Place: New Delhi

BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL, PRINCIPAL BENCH, NEW DELHI

ORIGINAL APPLICATION NO.635/2024

Sumoto matter News Item titled "2023 Delhi Floods How Govt. did not see Delhi's worst flood coming even 24 hours before it"

Reply Affidavit on behalf of Respondent No. 1 Central Water Commission (CWC) & Respondent No.2 Ministry of Jal Shakti

I Nagendra Kumar Singh, Executive Engineer Central Water Commission having office at Kalindi Bhawan, Katwaria Sarai, New Delhi do hereby solemnly affirm and declare as under:-

1. That the competent authority has been authorized me to file the present reply on behalf of Respondent No.1/CWC and Respondent No.2/Ministry of Jal Shakti, Govt. of India.

2. That I have gone through the official records maintained by our office in the present case and competent to file the present reply.

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Advocate
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Introduction:

3. As a non-structural measure of flood management, the Central Water Commission issues station-specific flood forecasts to concerned stakeholders at identified river locations. This includes inflow forecasts at identified reservoirs for proper reservoir regulation.

4. Presently, Flood Forecasts are issued by CWC at 340 stations (140 Inflow Forecast Stations + 200 Level Forecast Stations) as per Standard Operating Procedure. The network has been established in consultation with State Govt. / Project Authorities which also includes stations on the river passing through / nearby metropolitan cities. Dissemination of flood forecasts is through a dedicated website https://ffs.india-water.gov.in/. State-wise Flood Forecasting Stations is given below at **Annexure-R1**.

5. In addition to short-range forecasts, CWC is currently providing 7-day advisory flood forecasts through basin-specific mathematical models using IMD weather forecast products. These flood advisories are disseminated through the web Portal https://all.india-water.gov.in/home.php to stakeholders.

Flood Forecasting Activities by CWC in Yamuna Basin:

6. River Yamuna is an inter-state river, the largest tributary of Ganga and thewestern most river of Ganga system. The river Yamuna originates from Banderpoonch glacier in Uttarakhand

near Yamunotri and travel about 1376 km before meeting the River Ganga at Sangam (At Prayagraj). The catchment area from Yamunotri to its confluence with river Ganga at Prayagraj is 366223 Sqkm. The line diagram of the river Yamuna is attached at **Annexure-R2**.

7. A regional office, namely, Yamuna Basin Organization (YBO), headed by a Chief Engineer, has been established by CWC in Delhi, who looks after the Hydrological Observation and Flood Forecasting (**HO & FF**) Activities in Yamuna Basin. Three divisions, namely, Upper Yamuna Division (UYD), Lower Yamuna Division (LYD) and Chambal Division (CD), covering whole Yamuna Basin, are functional under the jurisdiction of Superintending Engineer, Hydrological Observation Circle, YBO, CWC, NOIDA (UP).

8. YBO, CWC maintains 35 Flood Forecasting stations in Yamuna basin, out of which, 19 are Level Forecasting stations and 16 are Inflow Forecasting stations. Thedetails are given below:

S. No.	Name of the River	Name of Flood Forecasting Stations	State	District
1	2	3	4	5
Level Forecasting Stations				
1	Yamuna	Paonta	Himachal Pradesh	Sirmaur
2	Yamuna	Karnal	Haryana	Karnal
3	Yamuna	Mawi	Uttar	Shamli

			Pradesh	
4	Yamuna	Delhi Railway Bridge	NCT of Delhi	North
5	Sahibi	Dhansa	NCT of Delhi	South-West
6	Yamuna	Mathura (Prayag Ghat)	Uttar Pradesh	Mathura
7	Yamuna	Agra	Uttar Pradesh	Agra
8	Yamuna	Etawah	Uttar Pradesh	Etawah
9	Yamuna	Auraiya	Uttar Pradesh	Auraiya
10	Yamuna	Kalpi	Uttar Pradesh	Jalaun
11	Yamuna	Hamirpur	Uttar Pradesh	Hamirpur
12	Yamuna	Chillaghat	Uttar Pradesh	Banda
13	Yamuna	Naini	Uttar Pradesh	Prayagraj
14	Ken	Banda	Uttar Pradesh	Banda
15	Betwa	Shahijna	Uttar Pradesh	Hamirpur
16	Chambal	Dholpur	Rajasthan	Dholpur
17	Betwa	Mohana	Uttar Pradesh	Jalaun
18	Chambal	Kota City	Rajasthan	Kota
19	Chambal	Manderial	Rajasthan	Karoli

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Inflow Forecasting Station				
1	Tons	Ichari Dam	Uttarakhand	Dehradun
2	Yamuna	Juddo Dam	Uttarakhand	Dehradun
3	Yamuna	Hathnikund Barrage	Haryana	Yamuna Nagar
4	Betwa	Rajghat Dam	Madhya Pradesh	Ashok Nagar
5	Sindh	Madikheda (Atal Sagar) Dam	Madhya Pradesh	Shivpuri
6	Chambal	Panchana Dam	Rajasthan	Karauli
7	Parwati	Parwati Dam	Rajasthan	Baran
8	Betwa	Matatila Reservoir	Uttar Pradesh	Lalitpur
9	Chambal	Gandhisagar Dam	Madhya Pradesh	Neemuch
10	Kalisindh	Kalisindh Dam	Rajasthan	Jhalawar
11	Mej	Gudha Dam	Rajasthan	Shajapur
12	Banas	Bisalpur Dam	Rajasthan	Karauli
13	Chambal	Kota Barrage	Rajasthan	Kota
14	Chambal	Rana Pratap Sagar Dam	Rajasthan	Chittorgarh
15	Kalisindh	Parwan Dam	Rajasthan	Jhalawar
16	Banas	Gambhiri Dam	Rajasthan	Chittorgarh

9. There are 31 Nos. Of Hydrological Observation sites of CWC on main stem of River Yamuna upto Prayagraj on which CWC mainly observes hourly water level, daily discharge and three hourly rainfall during the Monsoon season.

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10. Out of the three Divisions stated above, UYD looks after the HO & FF activities on the upper stretch of Yamuna starting from Yamunotri to Mathura - Prayag Ghat. Hydrological Observation (HO) sites network of UYD is annexed as **Annexure-R3**.

Brief background of the FF Activities under UYD, CWC, New Delhi:

11. UYD, CWC has been issuing Level Flood Forecasts on river Yamuna at Paonta (Himachal Pradesh), Karnal (Haryana), Mawi (Uttar Pradesh), Delhi Railway Bridge (Delhi), Mathura-Prayag Ghat (Uttar Pradesh) and on river Sahibi at Dhansa (Delhi). Inflow forecasts on river Yamuna at Hathnikund Barrage (Haryana) and on river Tons at Ichari Dam (Uttarakhand) are also being issued by UYD, CWC. An additional Inflow Forecasting station namely; Juddo Dam on River Yamuna has also been included by CWC from the Monsoon-2024. Flood Forecasting being an important component in river management, the UYD, New Delhi, has been carrying out these activities for the past 65 years in the interest of public safety. In this process, CWC is issuing Level Forecasts for Delhi Railway Bridge (DRB) site since 1959. In process, CWC issues Flood Forecast when water level is expected to cross 'Warning Level' of the forecasting site.

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Methodology for Flood Forecasting:

12. The methodologies & techniques for flood forecasting are to be adopted depending upon the topographical, geological, hydrological and meteorological factors, availability of

operational data and computational facilities and purposes of forecasting.

13. Flood Forecasting: The process of estimating future flood stages / flood levels and its time sequence at selected places / sites alongwith river during flood season is called flood forecasting. The main purpose of flood forecasting work is to issue warning before time. Not only it empowers the State authorities for their flood protection efforts but also life and property are saved.

14. Flood Forecasting on River Yamuna: The method widely used for flood forecasting is gauge to gauge correlation found suitable for flood forecasting sites namely Karnal, Mawi, Delhi Railway Bridge and Mathura on river Yamuna. The past data of recent floods and historical floods are compiled and studied to calculate and develop lag-time / travel-time curve and flood forecasting diagrams / correlation graphs.

15. Calculation of Travel-Time / Lag Time Curve: The time taken by flood peak from Base station to Flood Forecasting station is called as 'travel time' like time taken to reach Delhi from Mawi. First station is taken as Base station whereas second station is taken as flood forecasting station. In this process HO Site 'Mawi' is considered as Base station for formulation of level forecasts at 'DRB', which is 86 km upstream to DRB.

16. In general, travel time does not remain constant but varies with a channel conditions as well as stage of flood. As per

observations over the period upto 2023, travel time between the reach from Mawi to DRB is given below:

Station	Gap (Kms.)	Travel Time (Hrs.)
Mawi - Baghpat	42	7-16
Baghpat - Palla	18	4-9
Palla - Delhi Railway Bridge (DRB)	26	5-10
Total	86	16-35

Standard conditions of the Channel:

The Flood Forecasts generated by CWC by using gauge to gauge correlation graph prepared for Base stations and Flood Forecasting based long series of data, requires the channel to be in free flow condition for accuracy of the forecast. If any change occurred in flow condition upstream and downstream of the flood forecasting station, the accuracy of the flood forecast is compromised.

Standard Operating Procedure (SOP) for Flood:

17. CWC has issued SOP for Flood Forecasting and have categorized the alerts to be issued during a flood situation as under:

Category	Description	Stage	Alerts to be transmitted to
Above Normal	Water Level between	Yellow	• JS(DM) & AS (DM) • Nodal officers of NDMA

	Warning and Danger Level		&NDRF • On instruction of JS (DM) be transmitted to HS
Severe	Water Level between Danger Level to HFL* attained at that location	Orange	• HS / AS (DM) / JS(DM)/PS to HM/PS to MOS • Nodal officers of NDMA &NDRF • All designated officers in PMO / Cabinet Secretariat • Concerned State / Union Territory Governments
Extreme	Water Level higher than the HFL* at that location	Red	• HS/AS (DM)/JS(DM) / PS toHM/PS to MOS • Nodal officers of NDMA &NDRF • All designated officers in PMO / Cabinet Secretariat • ESF ministries / Departments & Concerned States / UTs

*Highest Flood level - The highest flood level of the river ever recorded at theplace.

Our performance during Monsoon 2023 for Forecast issued for DRB:

18. Delhi Railway Bridge site is located just downstream of old Delhi Railway Bridge. Highest Flood Level recorded in 1978 was 207.49m, however, new HFL of 208.66m was recorded during Monsoon 2023 on 13.07.2023 due to very heavy rainfall that occurred in Himalayan region upstream of Hathnikund Barrage during 9-11 July, 2023. As a result, the flow reached the Hathnikund Barrage on 11.07.2023 and Hathnikund Barrage passes peak discharge of 3.59 Lakh cusecs at 11:00 hrs on 11.07.2023. The same flow was continued for two hours and also the flow remain more than 2.0 lakhs cusecs from 2100 hrs on 09.07.2023 to 0600 hrs on 12.07.2023. The high discharge downstream of Hathnikund Barrage created Flood situation in the river Yamuna near Delhi. Due to this, the flow of Delhi Railway Bridge site increased continuously and crossed the previous HFL of 207.49m at 13:00 hrs on 12/07/2023 and achieved the highest peak of waterlevel of 208.66m at 18:00 hrs on 13/07/2023.

19. During the period from 10.07.2023 to 01.08.2023 the water level at Delhi Railway Bridge site persisted above Warning Level i.e. 204.50m and CWC issued 52 forecasts, out of which 16 forecasts were revised. Details of the 06 Nos. of forecasts out of 52, issued by CWC were mentioned in The Hindu newspaper's article dated 27-04-2024. The same is reproduced here:

Forecast No.	Date & time of Issuing forecast	Existing Water Level / time at the time of issuing forecast	Forecasted Values				Actual Values			
			Date	Water Level (m)	Time (hrs)	Trend	Date	Water Level (m)	Time	Trend
6	12-07-2023 at 02:30 Hrs	206.95 / 02:00 Hrs	12-07-2023	207.10	11 to 13	Steady	12-07-2023	207.38	11:00	Rising
6R	12-07-2023 at 06:30 Hrs	207.14 / 06:00 Hrs	12-07-2023	207.35	11 - 13	Steady	12-07-2023	207.38	11:00	Rising
7	12-07-2023 at 10:30 Hrs	207.34 / 10:00 Hrs	12-07-2023	207.57	22 - 24	Steady	12-07-2023	208.05	22:00	Rising
7R	12-07-2023 at 13:30 Hrs	207.55 / 13:00 Hrs	12-07-2023	207.72	22 - 24	Steady	12-07-2023	208.05	22:00	Rising
8	12-07-2023 at 17:10 Hrs	207.77 / 17:00 Hrs	13-07-2023	207.99	04 - 06	Steady	13-07-2023	208.32	04:00	Rising
9	12-07-2023 at 21:30 Hrs	207.95 / 21:00 Hrs	13-07-2023	208.30	07 - 09	Steady	13-07-2023	208.46	07:00	Rising

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Factors that mandated CWC for frequent revision of forecasts:

CWC issues forecasts based on the gauge to gauge correlation graph (updated every year by incorporating previous monsoons data) for DRB site assuming free flow condition in the river in Delhi reach between Wazirabad barrage and Okhla Barrage. But for such a high flood, it is observed later that, the free flow condition were not existed in Delhi reach due to (a) non-opening of all the gates of ITO Barrage, (b) formation of islands of silt deposits, (c) growing trees in river course and (d) muck disposal at various locations due to bridge construction activities across river. All these factors resulted into congestion in the river in Delhi reach and if free flow condition of the channel is compromised, then, forecast issued will mismatch with the actual forecast.

This indicates that there was lot of congestion in Delhi reach which created unprecedented afflux at DRB site and other places. This congestion also reflected from the fact that water level at DRB crosses the Highest Flood Level (HFL) of 207.49m of 1978 and reaches upto 208.66m on 13.07.2023, however, water level at Okhla Barrage Reservoir, which is downstream of Flood forecasting site DRB, reach only 200.80m, which was 1.37m lower than the Maximum Water Level i.e. 202.17m of Okhla Barrage Reservoir. Due to the situation mentioned above, the forecasts of CWC were not so accurate as expected.

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Joint Flood Management Study of River Yamuna for its reach between Hathnikund and Okhla Barrage:

20. By taking cognizance of the extensive flooding in river Yamuna during July, 2023, Department of Water Resources, River Development & Ganga Rejuvenation (DoWR, RD & GR), Ministry of Jal Shakti (MoJS) constituted a committee under the Chairmanship of Chairman, CWC vide its order No.Z-15011/1/2020-FM Section- MoWR/I/86850/2023, dated 06.08.2023 (attached as **Annexure-R4**) to give a fresh look for flood management of the river in its reach between Hathnikund and Okhla Barrage. Final report of the committee has been prepared and circulatedon 28.08.2024 (attached as **Annexure-R5**).

21. Based on the details mentioned above, it is to submit before this Hon'ble Tribunal that, during Monsoon 2023, CWC made all out efforts in its forecasting activities, however, due to the conditions of river Yamuna in Delhi reach already mentioned above the forecasts issued by CWC were not so accurate. The committee mentioned above have also pointed out those factors in its report and have suggested the concerned departments of Delhi to take corrective measures for future.

22. That the Central Water Commission will abide by whatever direction/order passed by this Hon'ble Tribunal.

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23. That the Central Water Commission will file any further reply/report as and when directed by this Hon'ble Tribunal.

01/01/25

Deponent

अधिशासी अभियन्ता / Executive Engineer
उपरी यमुना मंडल / Upper Yamuna Division
केन्द्रीय जल आयोग / Central Water Commission
नई दिल्ली-110016 / New Delhi-110016

Verification

3 JAN 2025

Verified at New Delhi on _____ day of January, 2025 that the contents of the above reply affidavit are true and correct to the best of my knowledge and belief and nothing material has been concealed therefrom

I identified the deponent who has signed in my presence

NOTARY PUBLIC
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01/01/25

Deponent

अधिशासी अभियन्ता / Executive Engineer
उपरी यमुना मंडल / Upper Yamuna Division
केन्द्रीय जल आयोग / Central Water Commission
नई दिल्ली-110016 / New Delhi-110016

CERTIFIED THAT DEPONENT
Sh./Ms. ..... Age.....
S/o, W/o, D/o .....
R/o.....
Identified by Sh./Ms. ..... before me at Delhi
has solemnly affirmed that the
On..... contents of this affidavit have been read
& explained to him/her and are true & correct to
his/her knowledge.

NITENDRA KUMAR, NOTARY PUBLIC
Govt. of India, DELHI

ANNEXURE-R1

Statewise Flood Forecasting Stations in India during Flood Season 2024

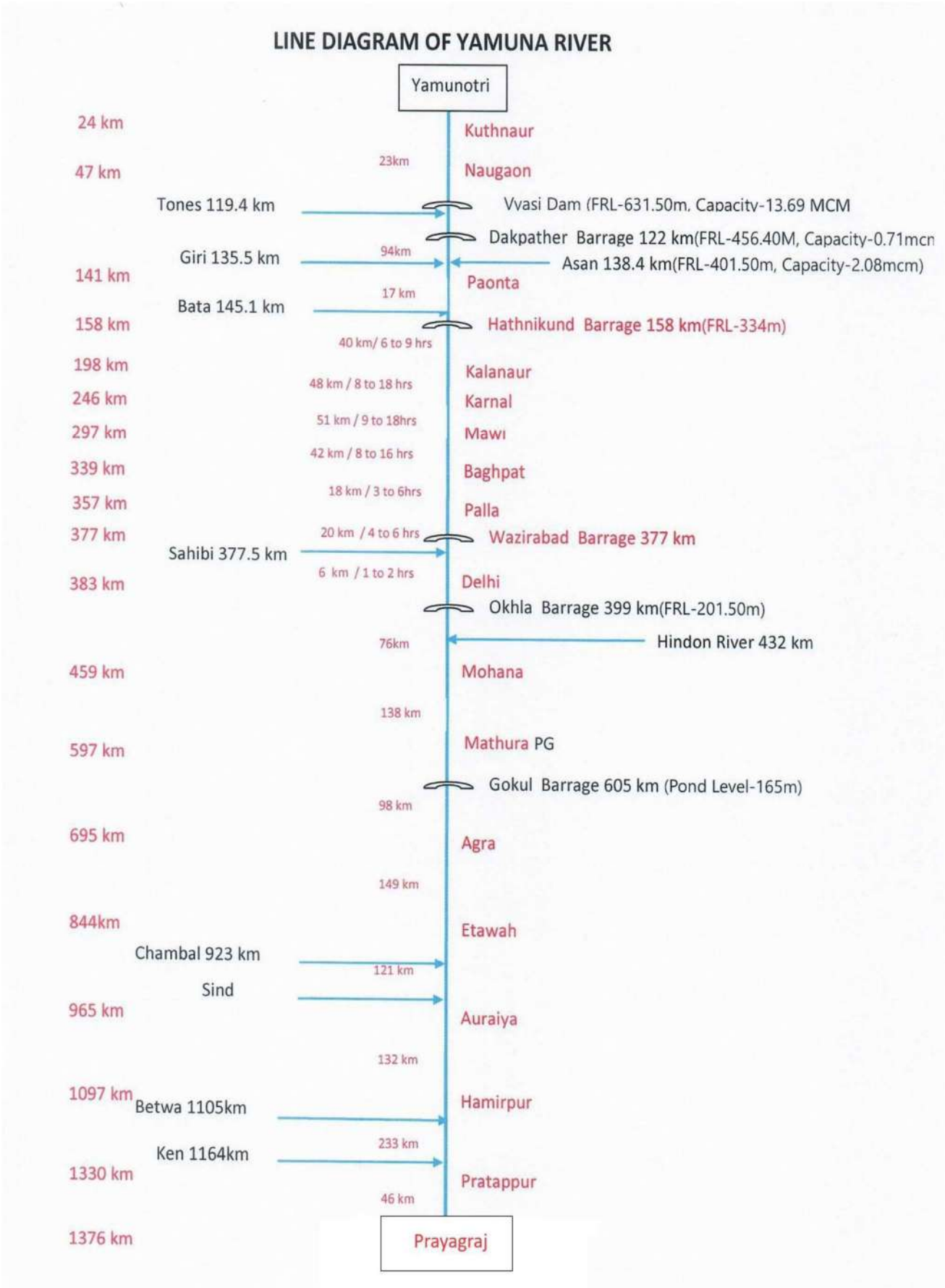
S.No.	Name of the river	Name of FF site	Name of State	District	Concerned Nodal CWC Division	Basin Name	Sub Basin	Organisation
1	2	3	4	5	6	7	8	9
(A) LEVEL FORECASTING STATIONS								
1	Sabari	Chinturu	Andhra Pradesh	Alluri Sitarama Raju	LGD, Hyderabad	Godavari Basin	Godavari Lower	KGBO
2	Godavari	Kunavaram	Andhra Pradesh	Alluri Sitarama Raju	LGD, Hyderabad	Godavari Basin	Godavari Lower	KGBO
3	Godavari	Rajahmundry	Andhra Pradesh	East Godavari	LGD, Hyderabad	Godavari Basin	Godavari Lower	KGBO
4	Godavari	Dowlaiswaram	Andhra Pradesh	East Godavari	LGD, Hyderabad	Godavari Basin	Godavari Lower	KGBO
5	Tungabhadra	Mantralayam	Andhra Pradesh	Kurnool	LKD, Hyderabad	Krishna Basin	Tungabhadra Lower	KGBO
6	Pennar	Nellore Anicut	Andhra Pradesh	Nellore	HD, Chennai	Pennar Basin	Pennar Lower	CSRO
7	Godavari	Atreyapuram	Andhra Pradesh	Kona Seema	LGD, Hyderabad	Godavari Basin	Godavari Lower	KGBO
8	Tungabhadra	Kurnool	Andhra Pradesh	Kurnool	LKD, Hyderabad	Krishna Basin	Tungabhadra Lower	KGBO
9	Krishna	Avanigadda	Andhra Pradesh	Krishna	LKD, Hyderabad	Krishna Basin	Krishna Lower	KGBO
10	Nagavali	Srikakulam	Andhra Pradesh	Srikakulam	ERD, Bhubaneshwar	EF (Mahanadi to Pennar)	Nagavali & others	MERO
11	Noa-Dehing	Namsai	Arunachal Pradesh	Namsai	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Upper	BBO
12	Siang	Yingkiang	Arunachal Pradesh	Upper Siang	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Upper	BBO
13	Siang	Passighat	Arunachal Pradesh	East Siang	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Upper	BBO
14	Brahmaputra	Dibrugarh	Assam	Dibrugarh	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Upper	BBO
15	Brahmaputra	Neamatighat	Assam	Jorhat	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Upper	BBO
16	Brahmaputra	Tezpur	Assam	Sonitpur	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Lower	BBO
17	Brahmaputra	Guwahati	Assam	Kamrup	MBD, Guwahati	Brahmaputra and its Trib	Brahmaputra Lower	BBO
18	Brahmaputra	Goalpara	Assam	Goalpara	MBD, Guwahati	Brahmaputra and its Trib	Brahmaputra Lower	BBO
19	Brahmaputra	Dhubri	Assam	Dhubri	MBD, Guwahati	Brahmaputra and its Trib	Brahmaputra Lower	BBO
20	Buridehing	Naharkatia	Assam	Dibrugarh	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Upper	BBO
21	Buridehing	Khowang	Assam	Dibrugarh	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Upper	BBO
22	Desang	Nanglamoraghat	Assam	Shivsagar	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Upper	BBO
23	Dikhow	Shivsagar	Assam	Shivsagar	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Upper	BBO
24	Subansiri	Badatighat	Assam	Lakhimpur	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Upper	BBO
25	Dhansiri (S)	Golaghat	Assam	Golaghat	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Upper	BBO
26	Dhansiri (S)	Numaligarh	Assam	Golaghat	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Upper	BBO
27	Jiabharali	Jia-Bharali NT Road Crossing	Assam	Sonitpur	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Lower	BBO
28	Kopili	Kampur	Assam	Nagaon	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Lower	BBO
29	Kopili	Dharamtul	Assam	Morigaon	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Lower	BBO
30	Puthimari	Puthimari NH Crossing	Assam	Kamrup	MBD, Guwahati	Brahmaputra and its Trib	Brahmaputra Lower	BBO
31	Pagladiya	Pagladiya NT Road Crossing	Assam	Nalbari	MBD, Guwahati	Brahmaputra and its Trib	Brahmaputra Lower	BBO
32	Beki	Beki NH Crossing	Assam	Barpeta	MBD, Guwahati	Brahmaputra and its Trib	Brahmaputra Lower	BBO
33	Manas	Manas NH Crossing	Assam	Bangaigaon	MBD, Guwahati	Brahmaputra and its Trib	Brahmaputra Lower	BBO
34	Manas	Mathanguri	Assam	Baksa	MBD, Guwahati	Brahmaputra and its Trib	Brahmaputra Lower	BBO
35	Sankosh	Golokganj	Assam	Dhubri	LBD, Jalpaiguri	Brahmaputra and its Trib	Brahmaputra Lower	T&BDBO
36	Barak	AP Ghat	Assam	Cachar	MID, Shillomg	Barak and its Trib	Barak	BOBO
37	Katakhal	Matizuri	Assam	Hailakhandi	MID, Shillomg	Barak and its Trib	Barak	BOBO
38	Kushiyara	Karimganj	Assam	Karimgunj	MID, Shillomg	Barak and its Trib	Barak	BOBO
39	Barak	Badarpurghat	Assam	Karimgunj	MID, Shillomg	Barak and its Trib	Barak	BOBO
40	Subansiri	Choldhowaghat	Assam	Lakhimpur	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Upper	BBO
41	Ranganadi	N H Crossing Ranganadi	Assam	Lakhimpur	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Upper	BBO
42	Lohit	Dholla Bazaar	Assam	Tinsukia	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Upper	BBO
43	Gaurang	Kokrajhar	Assam	Kokrajhar	MBD, Guwahati	Brahmaputra and its Trib	Brahmaputra Lower	BBO
44	Ganga	Buxar	Bihar	Buxar	LGD-2, Patna	Ganga & its tributaries	Ganga	LGBO
45	Ganga	Patna Dighaghat	Bihar	Patna	LGD-2, Patna	Ganga & its tributaries	Gandak and others	LGBO
46	Ganga	Patna Gandhighat	Bihar	Patna	LGD-2, Patna	Ganga & its tributaries	Gandak and others	LGBO
47	Ganga	Hathidah	Bihar	Patna	LGD-2, Patna	Ganga & its tributaries	Gandak and others	LGBO
48	Ganga	Munger	Bihar	Munger	LGD-2, Patna	Ganga & its tributaries	Gandak and others	LGBO
49	Ganga	Bhagalpur	Bihar	Bhagalpur	LGD-2, Patna	Ganga & its tributaries	Gandak and others	LGBO
50	Ganga	Kahalgaon	Bihar	Bhagalpur	LGD-2, Patna	Ganga & its tributaries	Gandak and others	LGBO
51	Ghaghra	Darauli	Bihar	Siwan	LGD-2, Patna	Ganga & its tributaries	Ghaghra	LGBO
52	Ghaghra	Gangpur Siswan	Bihar	Siwan	LGD-2, Patna	Ganga & its tributaries	Ghaghra	LGBO
53	Ghaghra	Chhappra	Bihar	Saran	LGD-2, Patna	Ganga & its tributaries	Gandak and others	LGBO
54	Gandak	Chatia	Bihar	East Champaran	LGD-1, Patna	Ganga & its tributaries	Gandak and others	LGBO
55	Gandak	Rewaghat	Bihar	Muzzafarpur	LGD-2, Patna	Ganga & its tributaries	Gandak and others	LGBO
56	Gandak	Hajipur	Bihar	Vaishali	LGD-2, Patna	Ganga & its tributaries	Gandak and others	LGBO
57	Burhi Gandak	Lalbeghiaghat	Bihar	East Champaran	LGD-1, Patna	Ganga & its tributaries	Gandak and others	LGBO
58	Burhi Gandak	Muzzafarpur Sikandarpur	Bihar	Muzzafarpur	LGD-1, Patna	Ganga & its tributaries	Gandak and others	LGBO
59	Burhi Gandak	Samastipur	Bihar	Samastipur	LGD-1, Patna	Ganga & its tributaries	Gandak and others	LGBO
60	Burhi Gandak	Rosera	Bihar	Samastipur	LGD-1, Patna	Ganga & its tributaries	Gandak and others	LGBO
61	Burhi Gandak	Khagaria	Bihar	Khagaria	LGD-1, Patna	Ganga & its tributaries	Gandak and others	LGBO
62	Bagmati	Benibad	Bihar	Muzzafarpur	LGD-1, Patna	Ganga & its tributaries	Kosi	LGBO
63	Bagmati	Hayaghat	Bihar	Darbhanga	LGD-1, Patna	Ganga & its tributaries	Kosi	LGBO
64	Bagmati	Dheng Bridge	Bihar	Sitamarhi	LGD-1, Patna	Ganga & its tributaries	Kosi	LGBO
65	Adhwara Group	Kamtaul	Bihar	Darbhanga	LGD-1, Patna	Ganga & its tributaries	Kosi	LGBO
66	Adhwara Group	Ekmighat	Bihar	Darbhanga	LGD-1, Patna	Ganga & its tributaries	Kosi	LGBO
67	Adhwara	Sonebarsha	Bihar	Sitamarhi	LGD-1, Patna	Ganga & its tributaries	Kosi	LGBO
68	Kamla Balan	Jainagar	Bihar	Madhubani	LGD-1, Patna	Ganga & its tributaries	Kosi	LGBO
69	Bagmati	Runisaidpur	Bihar	Muzzafarpur	LGD-1, Patna	Ganga & its tributaries	Kosi	LGBO
70	Parwan	Araria	Bihar	Araria	LGD-1, Patna	Ganga & its tributaries	Bhagirathi & others(Ganga L)	LGBO
71	Kamla Balan	Jhanjarpur	Bihar	Madhubani	LGD-1, Patna	Ganga & its tributaries	Kosi	LGBO
72	Kosi	Basua	Bihar	Supaul	LGD-1, Patna	Ganga & its tributaries	Kosi	LGBO
73	Kosi	Baltara	Bihar	Khagaria	LGD-1, Patna	Ganga & its tributaries	Kosi	LGBO
74	Kosi	Kursela	Bihar	Katihar	LGD-1, Patna	Ganga & its tributaries	Kosi	LGBO
75	Mahananda	Dhengraghat	Bihar	Purnea	LGD-1, Patna	Ganga & its tributaries	Bhagirathi & others(Ganga L)	LGBO
76	Mahananda	Jhawa	Bihar	Katihar	LGD-1, Patna	Ganga & its tributaries	Bhagirathi & others(Ganga L)	LGBO
77	Mahananda	Taibpur	Bihar	Kishanganj	LGD-1, Patna	Ganga & its tributaries	Bhagirathi & others(Ganga L)	LGBO
78	Gandak	Dumariaghat	Bihar	Gopalganj	LGD-1, Patna	Ganga & its tributaries	Gandak and others	LGBO
79	Burhigandak	Ahirwalia	Bihar	East Champaran	LGD-1, Patna	Ganga & its tributaries	Gandak and others	LGBO
80	Sone	Inderpuri	Bihar	Rohtas	LGD-2, Patna	Ganga & its tributaries	Sone	LGBO
81	Sone	Koelwar	Bihar	Patna	LGD-2, Patna	Ganga & its tributaries	Sone	LGBO
82	Sone	Maner	Bihar	Patna	LGD-2, Patna	Ganga & its tributaries	Sone	LGBO
83	PunPun	Sripalpur	Bihar	Patna	LGD-2, Patna	Ganga & its tributaries	Gandak and others	LGBO
84	Indravathi	Jagdalpur	Chhattisgarh	Bastar	LGD, Hyderabad	Godavari Basin	Indravathi	KGBO
85	Damanganga	Daman	Daman & Diu	Daman	TD, Surat	WFR Tapi to Tadri	Bhatsol & others	MTBO
86	Sabarmati	Ahmedabad Shubhash Bridge	Gujarat	Ahmedabad	MD, Gandhinagar	Sabarmati Basin	Sabarmati Upper	MTBO
87	Mahi	Wanakbori	Gujarat	Mahisagar	MD, Gandhinagar	Mahi Basin	Mahi Lower	MTBO
88	Narmada	Garudeswar	Gujarat	Narmada	TD, Surat	Narmada Basin	Narmada Lower	MTBO
89	Narmada	Bharuch	Gujarat	Bharuch	TD, Surat	Narmada Basin	Narmada Lower	MTBO
90	Tapi	Surat	Gujarat	Surat	TD, Surat	Tapi Basin	Tapi Lower	MTBO
91	Damanganga	Vapi Town	Gujarat	Valsad	TD, Surat	WFR Tapi to Tadri	Bhatsol & others	MTBO
92	Yamuna	Karnal Bridge	Haryana	Karnal	UYD, New Delhi	Ganga & its tributaries	Yamuna Upper	YBO
93	Yamuna	Paonta Sahib	Himachal Pradesh	Sirmaur	UYD, New Delhi	Ganga & its tributaries	Yamuna Upper	YBO
94	Jhelum	Rammunshibagh	Jammu & Kashmir	Srinagar	Chenab D, Jammu	Indus Basin	Jhelum	IBO

Statewise Flood Forecasting Stations in India during Flood Season 2024								
S.No.	Name of the river	Name of FF site	Name of State	District	Concerned Nodal CWC Division	Basin Name	Sub Basin	Organisation
1	2	3	4	5	6	7	8	9
95	Jhelum	Sangam	Jammu & Kashmir	Anantnag	Chenab D Jammu	Indus Basin	Jhelum	IBO
96	Jhelum	Safapora	Jammu & Kashmir	Bandipora	Chenab D Jammu	Indus Basin	Jhelum	IBO
97	Ganga	Sahibganj	Jharkhand	Sahibganj	LGD-2, Patna	Ganga & its tributaries	Bhagirathi & others(Ganga L)	LGBO
98	Subarnarekha	Jamshedpur	Jharkhand	Purba Singhbhum	ERD, Bhubaneshwar	Subarnarekha Basin	Subarnarekha	MERO
99	Bhima	Deongaon	Karnataka	Kalaburagi	LKD, Hyderabad	Krishna Basin	Bhima Lower	KGBO
100	Periyar	Neeleswaram	Kerala	Ernakulam	SWRD, Kochi	WFR Tadri to Kanyakumari	Periyar & others	CSRO
101	Bharathapuzha	Kumbidi	Kerala	Palakkad	SWRD, Kochi	WFR Tadri to Kanyakumari	Varrar & others	CSRO
102	Pamba	Malakkara	Kerala	Pathanamthitta	SWRD, Kochi	WFR Tadri to Kanyakumari	Periyar & others	CSRO
103	Kabini	Muthankera	Kerala	Wayanad	Cauvery D Bengaluru	Cauvery and its trib Basin	Cauvery Middle	MSO
104	Narmada	Mandla	Madhya Pradesh	Mandla	ND, Bhopal	Narmada Basin	Narmada Upper	NBO
105	Narmada	Narmadapuram	Madhya Pradesh	Narmadapuram	ND, Bhopal	Narmada Basin	Narmada Middle	NBO
106	Godavari	Kopergaon	Maharashtra	Ahmednagar	UGD, Hyderabad	Godavari Basin	Godavari Upper	KGBO
107	Godavari	Gangakhed	Maharashtra	Parbhani	UGD, Hyderabad	Godavari Basin	Godavari Middle	KGBO
108	Godavari	Nanded	Maharashtra	Nanded	UGD, Hyderabad	Godavari Basin	Godavari Middle	KGBO
109	Wainganga	Bhandara	Maharashtra	Bhandara	WGD, Nagpur	Godavari Basin	Wainganga	MCO
110	Wainganga	Pauni	Maharashtra	Bhandara	WGD, Nagpur	Godavari Basin	Wainganga	MCO
111	Wardha	Balharsha	Maharashtra	Chandrapur	WGD, Nagpur	Godavari Basin	Wardha	MCO
112	Krishna	Arjunwad	Maharashtra	Kolhapur	UKD, Pune	Krishna Basin	Krishna Upper	KGBO
113	Godavari	Nasik	Maharashtra	Nasik	UGD, Hyderabad	Godavari Basin	Godavari Upper	KGBO
114	Yamuna	Delhi Rly Bridge	NCT Delhi	North	UYD, New Delhi	Ganga & its tributaries	Yamuna Upper	YBO
115	Sahibi	Dhansa	NCT Delhi	South-West	UYD, New Delhi	Ganga & its tributaries	Yamuna Upper	YBO
116	Subarnarekha	Rajghat	Odisha	Baleshwar	ERD, Bhubaneshwar	Subarnarekha Basin	Subarnarekha	MERO
117	Burhabalang	NH_5 _Road Bridge	Odisha	Baleshwar	ERD, Bhubaneshwar	Subarnarekha Basin	Subarnarekha	MERO
118	Baitarni	Anandpur	Odisha	Keonjar	ERD, Bhubaneshwar	Brahmani & Baitarani	Baitarani	MERO
119	Baitarni	Akhuapada	Odisha	Bhadrak	ERD, Bhubaneshwar	Brahmani & Baitarani	Baitarani	MERO
120	Brahmani	Jenapur	Odisha	Jajpur	ERD, Bhubaneshwar	Brahmani & Baitarani	Brahmani	MERO
121	Rishikulya	Purushottampur	Odisha	Ganjam	ERD, Bhubaneshwar	EF (Mahanadi to Pennar)	Vamsadhara & others	MERO
122	Vamsadhara	Gunupur	Odisha	Rayagada	ERD, Bhubaneshwar	EF (Mahanadi to Pennar)	Vamsadhara & others	MERO
123	Vamsadhara	Kashinagar	Odisha	Gajapati	ERD, Bhubaneshwar	EF (Mahanadi to Pennar)	Vamsadhara & others	MERO
124	Mahanadi	Naraj	Odisha	Cuttack	Mahanadi D Burla	Mahanadi Basin	Mahanadi Lower	MERO
125	Mahanadi	Alipingal Devi	Odisha	Jagatsinghpur	Mahanadi D Burla	Mahanadi Basin	Mahanadi Lower	MERO
126	Mahanadi	Nimapara	Odisha	Puri	Mahanadi D Burla	Mahanadi Basin	Mahanadi Lower	MERO
127	Jalaka	Mathani Road Bridge	Odisha	Balasore	ERD, Bhubaneshwar	Subarnarekha Basin	Subarnarekha	MERO
128	Banas	Abu Road	Rajasthan	Sirohi	MD, Gandhinagar	WFR(Kutch & Saurastra)	Saraswati	MTBO
129	Chambal	Kota City	Rajasthan	Kota	Chambal D Jaipur	Ganga & its tributaries	Kalisindh & others	YBO
130	Chambal	Dholpur	Rajasthan	Dholpur	LYD, Agra	Ganga & its tributaries	Chambal Lower	YBO
131	Chambal	Manderial	Rajasthan	Karauli	Chambal D Jaipur	Ganga & its tributaries	Chambal Lower	YBO
132	Teesta	Melli	Sikkim	Namchi	SID, Gangtok	Brahmaputra and its Trib	Brahmaputra Lower	T&BDBO
133	Rangit	Rothak	Sikkim	Namchi	SID, Gangtok	Brahmaputra and its Trib	Brahmaputra Lower	T&BDBO
134	Ranikhola	Singtam	Sikkim	Pakyong	SID, Gangtok	Brahmaputra and its Trib	Brahmaputra Lower	T&BDBO
135	Cauvery	Musiri(Srirangam)	Tamilnadu	Tiruchirapalli	SRD, Coimbatore	Cauvery and its trib Basin	Cauvery Lower	CSRO
136	Cauvery	Kodumudi (Erode)	Tamilnadu	Erode	SRD, Coimbatore	Cauvery and its trib Basin	Cauvery Middle	CSRO
137	Bhavani	Savandapur(Bhavani)	Tamilnadu	Erode	SRD, Coimbatore	Cauvery and its trib Basin	Cauvery Middle	CSRO
138	Vaigai	Madurai	Tamilnadu	Madurai	SRD, Coimbatore	EFR (Pennar to Kanyakmri)	Pamba and others	CSRO
139	Godavari	Kaleswaram	Telangana	Bhopalpalli	LGD, Hyderabad	Godavari Basin	Pranhita & others	KGBO
140	Godavari	Eturunagaram	Telangana	Mulugu	LGD, Hyderabad	Godavari Basin	Godavari Lower	KGBO
141	Godavari	Dummagudem	Telangana	Bhadradri	LGD, Hyderabad	Godavari Basin	Godavari Lower	KGBO
142	Godavari	Bhadrachalam	Telangana	Bhadradri	LGD, Hyderabad	Godavari Basin	Godavari Lower	KGBO
143	Wardha	Sirpur Town	Telangana	Kumuram Bheem	WGD, Nagpur	Godavari Basin	Wardha	MCO
144	Manu	Kailashahar	Tripura	Unakoti	MD, Silchar	Barak and its Trib	Naoch Chara and others	BOBO
145	Gumti	Sonamura	Tripura	Sipahijala	MD, Silchar	Barak and its Trib	Naoch Chara and others	BOBO
146	Ganga	Kannauj	Uttar Pradesh	Kannauj	MGD-2, Lucknow	Ganga & its tributaries	Upstream of Gomti	UGBO
147	Ganga	Ankinghat	Uttar Pradesh	Kanpur	MGD-2, Lucknow	Ganga & its tributaries	Upstream of Gomti	UGBO
148	Ganga	Kanpur	Uttar Pradesh	Kanpur	MGD-2, Lucknow	Ganga & its tributaries	Upstream of Gomti	UGBO
149	Ganga	Dalmau	Uttar Pradesh	Rae-Bareilly	MGD-2, Lucknow	Ganga & its tributaries	Upstream of Gomti	UGBO
150	Ganga	Phaphamau	Uttar Pradesh	Prayagraj	MGD-3, Varanasi	Ganga & its tributaries	Upstream of Gomti	LGBO
151	Ganga	Allahabad Chhatnag	Uttar Pradesh	Prayagraj	MGD-3, Varanasi	Ganga & its tributaries	Upstream of Gomti	LGBO
152	Ganga	Mirzapur	Uttar Pradesh	Mirzapur	MGD-3, Varanasi	Ganga & its tributaries	Upstream of Gomti	LGBO
153	Ganga	Varanasi	Uttar Pradesh	Varanasi	MGD-3, Varanasi	Ganga & its tributaries	Upstream of Gomti	LGBO
154	Ganga	Ghazipur	Uttar Pradesh	Ghazipur	MGD-3, Varanasi	Ganga & its tributaries	Ganga	LGBO
155	Ganga	Ballia	Uttar Pradesh	Ballia	MGD-3, Varanasi	Ganga & its tributaries	Ganga	LGBO
156	Ramganga	Moradabad	Uttar Pradesh	Moradabad	MGD-2, Lucknow	Ganga & its tributaries	Ramganga	UGBO
157	Ramganga	Bareilly	Uttar Pradesh	Bareilly	MGD-2, Lucknow	Ganga & its tributaries	Ramganga	UGBO
158	Yamuna	Mawi	Uttar Pradesh	Shamli	UYD, New Delhi	Ganga & its tributaries	Yamuna Upper	YBO
159	Yamuna	Mathura	Uttar Pradesh	Mathura	UYD, New Delhi	Ganga & its tributaries	Yamuna Upper	YBO
160	Yamuna	Agra	Uttar Pradesh	Agra	LYD, Agra	Ganga & its tributaries	Yamuna Lower	YBO
161	Yamuna	Etawah	Uttar Pradesh	Etawah	LYD, Agra	Ganga & its tributaries	Yamuna Lower	YBO
162	Yamuna	Auraiya	Uttar Pradesh	Auraiya	LYD, Agra	Ganga & its tributaries	Yamuna Lower	YBO
163	Yamuna	Kalpi	Uttar Pradesh	Jalaun	LYD, Agra	Ganga & its tributaries	Yamuna Lower	YBO
164	Yamuna	Hamirpur	Uttar Pradesh	Hamirpur	LYD, Agra	Ganga & its tributaries	Yamuna Lower	YBO
165	Yamuna	Chillaghat	Uttar Pradesh	Banda	LYD, Agra	Ganga & its tributaries	Yamuna Lower	YBO
166	Yamuna	Naini	Uttar Pradesh	Prayagraj	LYD, Agra	Ganga & its tributaries	Yamuna Lower	YBO
167	Betwa	Mohana	Uttar Pradesh	Jalaun	LYD, Agra	Ganga & its tributaries	Gomti	YBO
168	Ken	Banda	Uttar Pradesh	Banda	LYD, Agra	Ganga & its tributaries	Yamuna Lower	YBO
169	Gomati	Lucknow HanumanSetu	Uttar Pradesh	Lucknow	MGD-2, Lucknow	Ganga & its tributaries	Gomti	UGBO
170	Gomati	Jaunpur	Uttar Pradesh	Jaunpur	MGD-3, Varanasi	Ganga & its tributaries	Gomti	LGBO
171	SAI	Rae-Bareli	Uttar Pradesh	Rae-Bareli	MGD-2, Lucknow	Ganga & its tributaries	Gomti	UGBO
172	Ghaghra	Elgin Bridge	Uttar Pradesh	Barabanki	MGD-1, Lucknow	Ganga & its tributaries	Ghaghra	UGBO
173	Ghaghra	Ayodhya	Uttar Pradesh	Ayodhya	MGD-1, Lucknow	Ganga & its tributaries	Ghaghra	UGBO
174	Ghaghra	Turtipar	Uttar Pradesh	Ballia	MGD-1, Lucknow	Ganga & its tributaries	Ghaghra	UGBO
175	Rapti	Balrampur	Uttar Pradesh	Balrampur	MGD-1, Lucknow	Ganga & its tributaries	Ghaghra	UGBO
176	Rapti	Bansi	Uttar Pradesh	Siddarthnagar	MGD-1, Lucknow	Ganga & its tributaries	Ghaghra	UGBO
177	Rapti	Gorakhpur Birdghat	Uttar Pradesh	Gorakhpur	MGD-1, Lucknow	Ganga & its tributaries	Ghaghra	UGBO
178	Rapti	Kakardhari	Uttar Pradesh	Bahraich	MGD-1, Lucknow	Ganga & its tributaries	Ghaghra	UGBO
179	Gandak	Khadda	Uttar Pradesh	Kushinagar	LGD-1, Patna	Ganga & its tributaries	Gandak and others	LGBO
180	Ganga	Fathegarh	Uttar Pradesh	Farukkabad	MGD-2, Lucknow	Ganga & its tributaries	Above Ramganga Conf	UGBO
181	Ganga	Dabri	Uttar Pradesh	Shahjahanpur	MGD-2, Lucknow	Ganga & its tributaries	Ramganga	UGBO
182	Ganga	Garhmuktheswar	Uttar Pradesh	Hapur	MGD-2, Lucknow	Ganga & its tributaries	Above Ramganga Conf	UGBO
183	Ganga	Kachla Bridge	Uttar Pradesh	Badaun	MGD-2, Lucknow	Ganga & its tributaries	Above Ramganga Conf	UGBO
184	Betwa	Shahjina	Uttar Pradesh	Hamirpur	LYD, Agra	Ganga & its tributaries	Yamuna Lower	YBO
185	Mandakini	Ganganagar	Uttarakhand	Chamoli	HGD, Haridwar	Ganga & its tributaries	Above Ramganga Conf	UGBO
186	Alaknanda	Srinagar	Uttarakhand	Pauri Garhwal	HGD, Haridwar	Ganga & its tributaries	Above Ramganga Conf	UGBO
187	Ganga	Rishikesh	Uttarakhand	Dehradun	HGD, Haridwar	Ganga & its tributaries	Above Ramganga Conf	UGBO
188	Ganga	Haridwar	Uttarakhand	Haridwar	HGD, Haridwar	Ganga & its tributaries	Above Ramganga Conf	UGBO
189	Ganga	Farakka	West Bengal	Murshidabad	LGD-3, Berhampore	Ganga & its tributaries	Bhagirathi & others(Ganga L)	T&BDBO

Statewise Flood Forecasting Stations in India during Flood Season 2024								
S.No.	Name of the river	Name of FF site	Name of State	District	Concerned Nodal CWC Division	Basin Name	Sub Basin	Organisation
1	2	3	4	5	6	7	8	9
190	Mayurakshi	Narayanpur	West Bengal	Birbhum	DD, Asansol	Ganga & its tributaries	Bhagirathi & others(Ganga L)	T&BDBO
191	Ajoy	Gheropara	West Bengal	Birbhum	DD, Asansol	Ganga & its tributaries	Bhagirathi & others(Ganga L)	T&BDBO
192	Mundeswari	Harinkhola	West Bengal	Hooghly	DD, Asansol	Ganga & its tributaries	Damodar	T&BDBO
193	Kangsabati	Mohanpur	West Bengal	Medhinipur	DD, Asansol	Ganga & its tributaries	Damodar	T&BDBO
194	Raidak-I	Tufanganj	West Bengal	Coochbehar	LBD, Jalpaiguri	Brahmaputra and its Trib	Brahmaputra Lower	T&BDBO
195	Torsa	Hasimara	West Bengal	Alipurduar	LBD, Jalpaiguri	Brahmaputra and its Trib	Brahmaputra Lower	T&BDBO
196	Torsa	Ghugumari	West Bengal	Coochbehar	LBD, Jalpaiguri	Brahmaputra and its Trib	Brahmaputra Lower	T&BDBO
197	Jaldhaka	NH-31	West Bengal	Jalpaiguri	LBD, Jalpaiguri	Brahmaputra and its Trib	Brahmaputra Lower	T&BDBO
198	Jaldhaka	Mathabanga	West Bengal	Coochbehar	LBD, Jalpaiguri	Brahmaputra and its Trib	Brahmaputra Lower	T&BDBO
199	Tista	Domohani	West Bengal	Jalpaiguri	LBD, Jalpaiguri	Brahmaputra and its Trib	Brahmaputra Lower	T&BDBO
200	Tista	Mekhliganj	West Bengal	Coochbehar	LBD, Jalpaiguri	Brahmaputra and its Trib	Brahmaputra Lower	T&BDBO
(B) INFLOW FORECASTING STATIONS								
1	Vamsadhara	Gotta Barrage	Andhra Pradesh	Srikakulam	ERD, Bhubaneshwar	EF (Mahanadi to Pennar)	Vamsadhara & others	MERO
2	Krishna	Srisailam Reservoir	Andhra Pradesh	Kurnool	LKD, Hyderabad	Krishna Basin	Krishna Upper	KGBO
3	Godavari	Indirasagar Polavaram Project	Andhra Pradesh	Eluru	LGD, Hyderabad	Godavari Basin	Godavari Lower	KGBO
4	Krishna	Prakasam Barrage (Vijayawada)	Andhra Pradesh	Krishna	LKD, Hyderabad	Krishna Basin	Krishna Lower	KGBO
5	North Pennar	Somasila Dam	Andhra Pradesh	Nellore	HD, Chennai	Pennar	Pennar Lower	CSRO
6	Krishna	Dr K L R S Pulichintala Dam	Andhra Pradesh	Guntur	LKD, Hyderabad	Krishna Basin	Krishna Lower	KGBO
7	Tungabhadra	Sunkesula Barrage	Andhra Pradesh	Kurnool	LKD, Hyderabad	Krishna Basin	Tungabhadra Lower	KGBO
8	Nagavali	Thottapalli Reservoir Scheme	Andhra Pradesh	Vizianagaram	ERD, Bhubaneshwar	EF (Mahanadi to Pennar)	Nagavali & others	MERO
9	Nagavali	Narayanapuram Anicut	Andhra Pradesh	Srikakulam	ERD, Bhubaneshwar	EF (Mahanadi to Pennar)	Nagavali & others	MERO
10	Nagavali	Madduvalasa Reservoir	Andhra Pradesh	Vizianagaram	ERD, Bhubaneshwar	EF (Mahanadi to Pennar)	Nagavali & others	MERO
11	Subansiri	Subansiri Lower Dam	Arunachal Pradesh	Lower Subansiri	UBD, Dibrugarh	Brahmaputra and its Trib	Brahmaputra Upper	BBO
12	Sone	Indrapuri Barrage	Bihar	Rohtas	LGD-II Patna	Ganga & its tributaries	Sone	LGBO
13	Gandak	Gandak Barrage	Bihar	West Champaran	LGD-I Patna	Ganga & its tributaries	Gandak and others	LGBO
14	Kosi	Kosi Barrage	Bihar	Supaul	LGD-I Patna	Ganga & its tributaries	Kosi	LGBO
15	Mahanadi	Ravishankar Sagar Dam	Chattisgarh	Dhamtari	MD, Burla	Mahanadi Basin	Mahanadi Middle	MERO
16	Hasdeo	Bango Reservoir	Chattisgarh	Korba	MD, Burla	Mahanadi Basin	Mahanadi Middle	MERO
17	Banas	Dantiwada Dam	Gujarat	Banaskanta	Mahi D Gandhinagar	WFR(Kutch & Saurastra)	Saraswati	MTBO
18	Sabarmati	Dharoi Dam	Gujarat	Mehsana	Mahi D Gandhinagar	Sabarmati Basin	Sabarmati Upper	MTBO
19	Mahi	Kadana Dam	Gujarat	Mahisagar	Mahi D Gandhinagar	Mahi Basin	Mahi Lower	MTBO
20	Tapi	Ukai Reservoir	Gujarat	Surat	TD, Surat	Tapi Basin	Tapi Middle	MTBO
21	Damanganga	Madhuban Dam	Gujarat	Valsad	TD, Surat	WFR Tapi to Tadri	Bhatsol & others	MTBO
22	Panam	Panam Dam	Gujarat	Panchmahal	Mahi D Gandhinagar	Mahi Basin	Mahi Lower	MTBO
23	Narmada	Sardar Sarovar Project	Gujarat	Narmada	TD, Surat	Narmada Basin	Narmada Middle	MTBO
24	Shetrunji	Shetrunji Dam	Gujarat	Bhavnagar	Mahi D Gandhinagar	WFR(Kutch & Saurastra)	Shetrunji & Other EFR	MTBO
25	Yamuna	Tajewala Weir (Hathnikund)	Haryana	Yamunanagar	UYD, New Delhi	Ganga & its tributaries	Yamuna Upper	YBO
26	Mayurakshi	Massanjore Dam	Jharkhand	Dumka	DD, Asansol	Ganga & its tributaries	Bhagirathi & others(Ganga L)	T&BDBO
27	Damodar	Tenughat Reservoir	Jharkhand	Bokaro	DD, Asansol	Ganga & its tributaries	Damodar	T&BDBO
28	Damodar	Panchet Reservoir	Jharkhand	Dhanbad	DD, Asansol	Ganga & its tributaries	Damodar	T&BDBO
29	Barakar	Maithon Reservoir	Jharkhand	Dhanbad	DD, Asansol	Ganga & its tributaries	Damodar	T&BDBO
30	Subarnarekha	Chandil Dam	Jharkhand	Sahebganj	ERD, Bhubaneshwar	Subarnarekha Basin	Subarnarekha	MERO
31	Barakar	Tilaiya Reservoir	Jharkhand	Hazaribagh	DD, Asansol	Ganga & its tributaries	Damodar	T&BDBO
32	Sundar	Sundar Dam	Jharkhand	Godda	DD, Asansol	Ganga & its tributaries	Gandak and others	T&BDBO
33	North_Koel	Amanat Barrage	Jharkhand	Palamau	LGD-II Patna	Ganga & its tributaries	Sone	LGBO
34	North_Koel	Annaraj Dam	Jharkhand	Garhwa	LGD-II Patna	Ganga & its tributaries	Sone	LGBO
35	Damodar	Bhairwa Dam	Jharkhand	Hazaribagh	DD, Asansol	Ganga & its tributaries	Damodar	T&BDBO
36	Batane	Batane Dam	Jharkhand	Palamau	LGD-II Patna	Ganga & its tributaries	Gandak and others	LGBO
37	Ashra nadi	Sikatia Barrage	Jharkhand	Deoghar	DD, Asansol	Ganga & its tributaries	Damodar	T&BDBO
38	Konar	Konar Reservoir	Jharkhand	Hazaribagh	DD, Asansol	Ganga & its tributaries	Damodar	T&BDBO
39	Subarnarekha	Galudih Barrage	Jharkhand	paschim Singbhum	ERD, Bhubaneshwar	Subarnarekha Basin	Subarnarekha	MERO
40	Subarnarekha	Getlasud Reservoir	Jharkhand	Ranchi	ERD, Bhubaneshwar	Subarnarekha Basin	Subarnarekha	MERO
41	Krishna	Almatti Reservoir	Karnataka	Bagalkot	LKD, Hyderabad	Krishna Basin	Krishna Upper	KGBO
42	Krishna	Narayanpur Reservoir	Karnataka	Bagalkot	LKD, Hyderabad	Krishna Basin	Krishna Upper	KGBO
43	Tungabhadra	Tungabhadra Dam	Karnataka	Ballari	LKD, Hyderabad	Krishna Basin	Tungabhadra Upper	KGBO
44	Harangi	Harangi Reservoir	Karnataka	Kodagu	Cauvery D Bengaluru	Cauvery and its Trib Basin	Cauvery Upper	MSO
45	Hemavathy	Hemavathy Reservoir	Karnataka	Hassan	Cauvery D Bengaluru	Cauvery and its Trib Basin	Cauvery Upper	MSO
46	Cauvery	Krishnarajasagar Reservoir	Karnataka	Mandya	Cauvery D Bengaluru	Cauvery and its Trib Basin	Cauvery Middle	MSO
47	Kabini	Kabini Reservoir	Karnataka	Mysore	Cauvery D Bengaluru	Cauvery and its Trib Basin	Cauvery Middle	MSO
48	Tunga	Upper Tunga Project	Karnataka	Shimoga	Cauvery D Bengaluru	Krishna Basin	Tungabhadra Upper	MSO
49	Bhadra	Bhadra Reservoir	Karnataka	Chikmagaluru	Cauvery D Bengaluru	Krishna Basin	Tungabhadra Upper	MSO
50	Karanja	Karanja Dam	Karnataka	Bidar	UGD, Hyderabad	Godavari Basin	Manjra	KGBO
51	Malaprabha	Malaprabha Dam	Karnataka	Belgaum	Cauvery D Bengaluru	Krishna Basin	Krishna Upper	MSO
52	Krishna	Hippargi Barrage	Karnataka	Bagalkot	LKD, Hyderabad	Krishna Basin	Krishna Upper	KGBO
53	Ghataprabha	Hidkal Reservoir	Karnataka	Balgaum	Cauvery D Bengaluru	Krishna Basin	Krishna Upper	MSO
54	Tungabhadra	Singatalur Barrage	Karnataka	Gadag	LKD, Hyderabad	Krishna Basin	Tungabhadra Upper	KGBO
55	Periyar	Idukki Reservoir	Kerala	Idukki	SWRD Kochi	WFR Tadri to Kanyakumari	Periyar & others	CSRO
56	Periyar	Idamalayar Reservoir	Kerala	Ernakulam	SWRD Kochi	WFR Tadri to Kanyakumari	Periyar & others	CSRO
57	Chambal	Gandhisagar Reservoir	Madhya Pradesh	Mandsaur	Chambal D Jaipur	Ganga & its tributaries	Chambal Upper	YBO
58	Sone	Bansagar Dam	Madhya Pradesh	Shahdol	MGD-III, Varanasi	Ganga & its tributaries	Sone	LGBO
59	Betwa	Rajghat Dam	Madhya Pradesh	Ashok Nagar	LYD,Agra	Ganga & its tributaries	Yamuna Lower	YBO
60	Tawa	Tawa Reservoir	Madhya Pradesh	Narmadapuram	ND, Bhopal	Narmada Basin	Narmada Upper	NBO
61	Narmada	Bargi Reservoir	Madhya Pradesh	Jabalpur	ND, Bhopal	Narmada Basin	Narmada Upper	NBO
62	Barna	Barna Reservoir	Madhya Pradesh	Raisen	ND, Bhopal	Narmada Basin	Narmada Upper	NBO
63	Narmada	Indira Sagar Reservoir	Madhya Pradesh	East Nimar	ND, Bhopal	Narmada Basin	Narmada Middle	NBO
64	Narmada	Omkareshwar Reservoir	Madhya Pradesh	East Nimar	ND, Bhopal	Narmada Basin	Narmada Middle	NBO
65	Bawanthri	Bawanthadi Reservoir	Madhya Pradesh	Balaghat	WGD, Nagpur	Godavari Basin	Wainganga	MCO
66	Wainganga	Upper Wainganga Project/SSP	Madhya Pradesh	Seoni	WGD, Nagpur	Godavari Basin	Wainganga	MCO
67	Pench	Pench	Madhya Pradesh	Chindwara	WGD, Nagpur	Godavari Basin	Wainganga	MCO
68	Sindh	Madikhera(Atal Sagar) Dam	Madhya Pradesh	Shivpuri	LYD,Agra	Ganga & its tributaries	Yamuna Lower	YBO
69	Pench	Totladoh Project	Maharashtra	Nagpur	WGD, Nagpur	Godavari Basin	Wainganga	MCO
70	Godavari	Jaikwadi Dam	Maharashtra	Aurangabad	UGD, Hyderabad	Godavari Basin	Godavari Middle	KGBO
71	Tapi	Hathnur Dam	Maharashtra	Jalgaon	TD, Surat	Tapi Basin	Tapi Middle	MTBO
72	Wainganga	Gosikhurd Dam	Maharashtra	Bhandara	WGD, Nagpur	Godavari Basin	Wainganga	MCO
73	Wardha	Upper Wardha Project	Maharashtra	Amaravati	WGD, Nagpur	Godavari Basin	Wardha	MCO
74	Mula	Mula Dam	Maharashtra	Ahmednagar	UGD, Hyderabad	Godavari Basin	Godavari Upper	KGBO
75	Penganga	Issapur R/Upper Penganga Project	Maharashtra	Yavatmal	WGD, Nagpur	Godavari Basin	Wardha	MCO
76	Godavari	N M D Weir	Maharashtra	Nasik	UGD, Hyderabad	Godavari Basin	Godavari Upper	KGBO
77	Purna	Yeldari Reservoir	Maharashtra	Parbhani	UGD, Hyderabad	Godavari Basin	Godavari Middle	KGBO
78	Koyna	Koyna Dam	Maharashtra	Satara	UKD, Pune	Krishna Basin	Krishna Upper	KGBO
79	Warna	Warna Dam	Maharashtra	Kolhapur	UKD, Pune	Krishna Basin	Krishna Upper	KGBO
80	Bhima	Ujjanai Reservoir	Maharashtra	Solapur	UKD, Pune	Krishna Basin	Bhima Upper	KGBO
81	Nira	Veer Dam	Maharashtra	Satara	UKD, Pune	Krishna Basin	Bhima Upper	KGBO

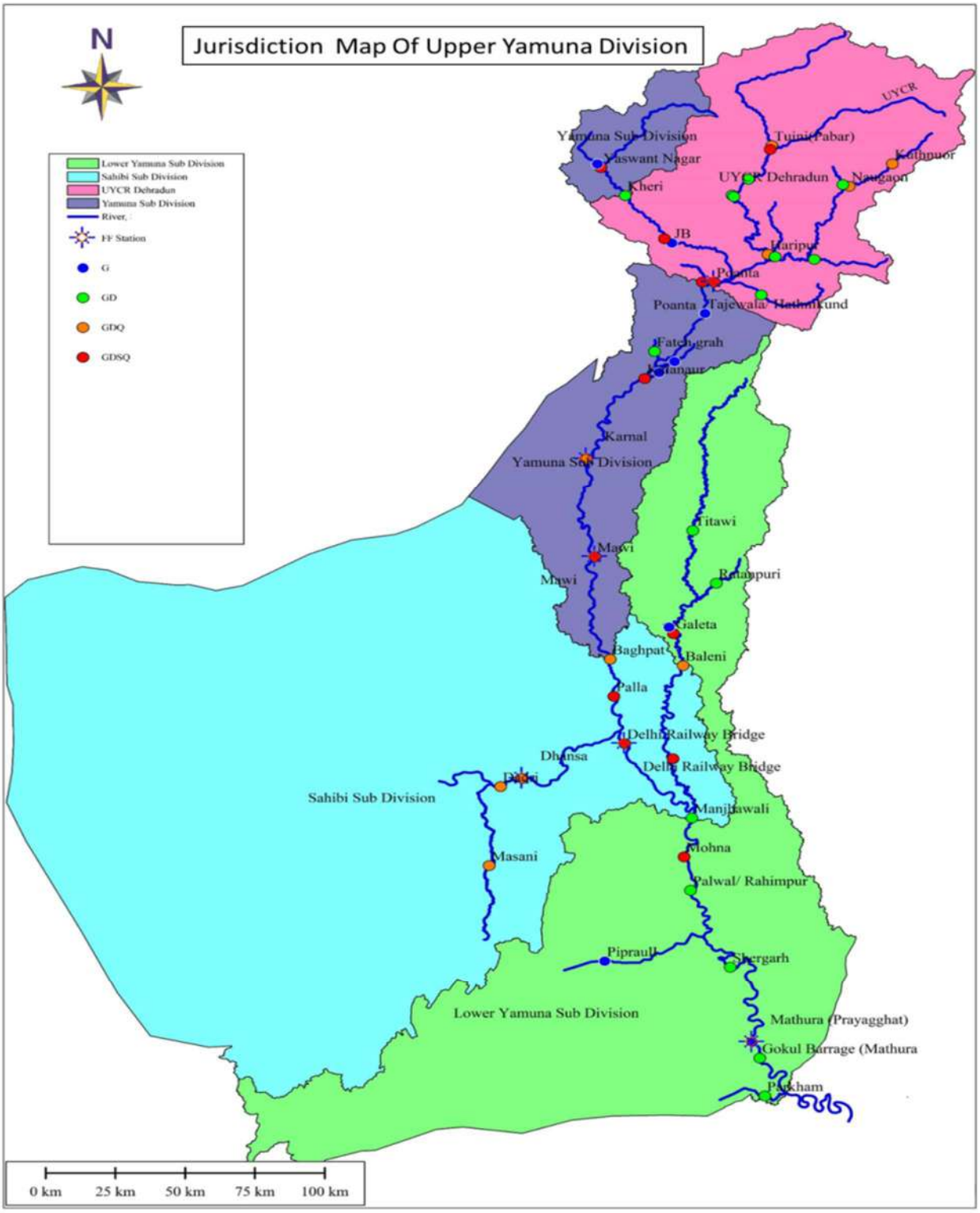
Statewise Flood Forecasting Stations in India during Flood Season 2024								
S.No.	Name of the river	Name of FF site	Name of State	District	Concerned Nodal CWC Division	Basin Name	Sub Basin	Organisation
1	2	3	4	5	6	7	8	9
82	Sindhpana	Manjlegaon Dam	Maharashtra	Beed	UGD, Hyderabad	Godavari Basin	Godavari Middle	KGBO
83	Baitarani	Salandi Reservoir	Odisha	Kendujhar	ERD, Bhubaneshwar	Brahmani & Baitarani	Baitarani	MERO
84	Indravathi	Upper Indravathi Dam	Odisha	Nabarangpur	LGD, Hyderabad	Godavari Basin	Indravathi	KGBO
85	Kolab	Kolab Dam	Odisha	Koraput	LGD, Hyderabad	Godavari Basin	Indravathi	KGBO
86	Machhkund	Machhkund Dam(Jalaput)	Odisha	Koraput	LGD, Hyderabad	Godavari Basin	Godavari Lower	KGBO
87	Sileru	Balimela Dam	Odisha	Malkangiri	LGD, Hyderabad	Godavari Basin	Godavari Lower	KGBO
88	Brahmani	Rengali Reservoir	Odisha	Angul	ERD, Bhubaneshwar	Brahmani & Baitarani	Brahmani	MERO
89	Mahanadi	Hirakud Reservoir	Odisha	Sambalpur	Mahanadi D Burla	Mahanadi Basin	Mahanadi Middle	MERO
90	Banas	Bisalpur Reservoir	Rajasthan	Karauli	Chambal D Jaipur	Ganga & its tributaries	Banas	YBO
91	Mahi	Mahi Bajajsagar Dam	Rajasthan	Banswara	Mahi D Gandhinagar	Mahi Basin	Mahi Upper	MTBO
92	Som Kamla	Som Kamla Amba Dam	Rajasthan	Dungarpur	Mahi D Gandhinagar	Mahi Basin	Mahi Upper	MTBO
93	Kalisindh	Kalisindh Dam	Rajasthan	Jhalawar	Chambal D Jaipur	Ganga & its tributaries	Kalisindh & others	YBO
94	Parwan	Parwan Dam	Rajasthan	Jhalawar	Chambal D Jaipur	Ganga & its tributaries	Kalisindh & others	YBO
95	Gambhiri	Gambhiri Dam	Rajasthan	Chittorgarh	Chambal D Jaipur	Ganga & its tributaries	Banas	YBO
96	Chambal	Panchana Dam	Rajasthan	Karauli	Chambal D Jaipur	Ganga & its tributaries	Yamuna Middle	YBO
97	Parwati	Parwati Dam	Rajasthan	Baran	Chambal D Jaipur	Ganga & its tributaries	Yamuna Middle	YBO
98	Chambal	Kota Barrage	Rajasthan	Kota	Chambal D Jaipur	Ganga & its tributaries	Kalisindh & others	YBO
99	Chambal	Rana Pratap Sagar Reservoir	Rajasthan	Chittorgarh	Chambal D Jaipur	Ganga & its tributaries	Kalisindh & others	YBO
100	Mej	Gudha Dam	Rajasthan	Boondi	Chambal D Jaipur	Ganga & its tributaries	Kalisindh & others	YBO
101	Teesta	Teesta-3 Dam	Sikkim	Mangan	SID, Gangtok	Brahmaputra and its Trib	Brahmaputra Lower	T&BDBO
102	Teesta	Teesta V Dam Singtam	Sikkim	Pakyong	SID, Gangtok	Brahmaputra and its Trib	Brahmaputra Lower	T&BDBO
103	Rongpo	Rongpo Dam	Sikkim	Pakyong	SID, Gangtok	Brahmaputra and its Trib	Brahmaputra Lower	T&BDBO
104	Rongli	Rongli Dam	Sikkim	Pakyong	SID, Gangtok	Brahmaputra and its Trib	Brahmaputra Lower	T&BDBO
105	Rangit	Rangit-3 Dam	Sikkim	Soreng	SID, Gangtok	Brahmaputra and its Trib	Brahmaputra Lower	T&BDBO
106	Cauvery	Mettur Reservoir	Tamilnadu	Salem	SRD, Coimbatore	Cauvery and its Trib Basin	Cauvery Middle	CSRO
107	Bhavani	Bhavanisagar Dam	Tamilnadu	Erode	SRD, Coimbatore	Cauvery and its Trib Basin	Cauvery Middle	CSRO
108	Cauvery	Grand Anicut	Tamilnadu	Thanjavur	SRD, Coimbatore	Cauvery and its Trib Basin	Cauvery Lower	CSRO
109	Cauvery	Upper Anicut	Tamilnadu	Tiruchirapalli	SRD, Coimbatore	Cauvery and its Trib Basin	Cauvery Lower	CSRO
110	Vaigai	Vaigai Reservoir	Tamilnadu	Theni	SRD, Coimbatore	EFR (Pennar to Kanyakmri)	Pamba and others	CSRO
111	Kosasthaliyar	Poondi Satyamurthy reservoir	Tamilnadu	Thiruvallur	HD, Chennai	EFR (Pennar to Kanyakmri)	Palar & others	CSRO
112	Kodaganar	Kodaganar Dam	Tamilnadu	Dindugul	SRD, Coimbatore	Cauvery and its Trib Basin	Cauvery Middle	CSRO
113	Vellar	Gomukhi Dam	Tamilnadu	Villupuram	HD, Chennai	EFR (Pennar to Kanyakmri)	Ponnaiyar & others	CSRO
114	Periyar Odai	Wellington Reservoir	Tamilnadu	Cuddalore	HD, Chennai	EFR (Pennar to Kanyakmri)	Ponnaiyar & others	CSRO
115	Ponnaiyar	Sathanur Dam	Tamilnadu	Thiruvannamalai	HD, Chennai	EFR (Pennar to Kanyakmri)	Ponnaiyar & others	CSRO
116	Adyar	Chembarampakkam Lake Reservoir	Tamilnadu	Tiruvallur	HD, Chennai	EFR (Pennar to Kanyakmri)	Palar & others	CSRO
117	Godavari	Sriramasagar Reservoir	Telangana	Nizamabad	UGD, Hyderabad	Godavari Basin	Pranhita & others	KGBO
118	Manjira	Singur Reservoir	Telangana	Sanga Reddy	UGD, Hyderabad	Godavari Basin	Manjra	KGBO
119	Manjira	Nizamsagar Reservoir	Telangana	Kama Reddy	UGD, Hyderabad	Godavari Basin	Manjra	KGBO
120	Krishna	Priyadarshini Jurala Project	Telangana	Mahbubnagar	LKD, Hyderabad	Krishna Basin	Krishna Upper	KGBO
121	Kaddamvagu	Kaddam Dam	Telangana	Adilabad	UGD, Hyderabad	Godavari Basin	Pranhita & others	KGBO
122	Maner	Mid Manair Dam	Telangana	Rajanna Sircilla	UGD, Hyderabad	Godavari Basin	Pranhita & others	KGBO
123	Godavari	Sripada Yellampally Project	Telangana	Karimnagar	UGD, Hyderabad	Godavari Basin	Pranhita & others	KGBO
124	Godavari	Laxmi Barrage	Telangana	Bhupalpally	UGD, Hyderabad	Godavari Basin	Pranhita & others	KGBO
125	Musi	Musi Dam	Telangana	Nalgonda	LKD, Hyderabad	Krishna Basin	Krishna Lower	KGBO
126	Godavari	PVNR Kanthapally Project	Telangana	Mulugu	UGD, Hyderabad	Godavari Basin	Godavari Lower	KGBO
127	Ganga	Narora Barrage (U/S)	Uttar Pradesh	Bulandshahar	MGD-2, Lucknow	Ganga & its tributaries	Above Ramganga Conf	UGBO
128	Rihand	Rihand Dam	Uttar Pradesh	Sonebhadra	MGD-III, Varanasi	Ganga & its tributaries	Sone	LGBO
129	Ganga	Choudhury Charan Singh Madhya	Uttar Pradesh	Bijnor	HGD, Haridwar	Ganga & its tributaries	Above Ramganga Conf	UGBO
130	Betwa	Matatilia Reservoir	Uttar Pradesh	Lalitpur	LYD,Agra	Ganga & its tributaries	Yamuna Lower	YBO
131	Ghaghra	Katerniaghat Barrage	Uttar Pradesh	Bahraich	MGD-1, Lucknow	Ganga & its tributaries	Ghaghra	UGBO
132	Ramganga	Kalagarh Dam	Uttarakhand	Pauri Garhwal	MGD-2, Lucknow	Ganga & its tributaries	Ramganga	UGBO
133	Sharda	Banbasa Barrage	Uttarakhand	Champawat	MGD-1, Lucknow	Ganga & its tributaries	Ghaghra	UGBO
134	Tons	Ichari Dam	Uttarakhand	Dehradun	UYD, New Delhi	Ganga & its tributaries	Yamuna Upper	YBO
135	Bhagirathi	Tehri Dam	Uttarakhand	Garhwal	HGD, Haridwar	Ganga & its tributaries	Above Ramganga Conf	UGBO
136	Yamuna	Juddo Dam	Uttarakhand	Dehradun	UYD, New Delhi	Ganga & its tributaries		YBO
137	Mayurakshi	Tilpara Barrage	West Bengal	Birbhum	DD, Asansol	Ganga & its tributaries	Bhagirathi & others(Ganga L)	T&BDBO
138	Damodar	Durgapur Barrage	West Bengal	Purba Bardhaman	DD, Asansol	Ganga & its tributaries	Damodar	T&BDBO
139	Kangsabati	Kangsabati Reservoir	West Bengal	Bankura	DD, Asansol	Ganga & its tributaries	Damodar	T&BDBO
140	Ajoy	Hinglow Dam	West Bengal	Birbhum	DD, Asansol	Ganga & its tributaries	Bhagirathi & others(Ganga L)	T&BDBO

Annexure – R2


LINE DIAGRAM OF YAMUNA RIVER
Yamunotri
24 km
Kuthnaur
23km
47 km
Naugaon
Tones 119.4 km
Vvasi Dam (FRL-631.50m, Capacity-13.69 MCM
Dakpather Barrage 122 km(FRL-456.40M, Capacity-0.71mcn
94km
Giri 135.5 km
Asan 138.4 km(FRL-401.50m, Capacity-2.08mcm)
141 km
Paonta
17 km
Bata 145.1 km
158 km
Hathnikund Barrage 158 km(FRL-334m)
40 km/ 6 to 9 hrs
198 km
Kalanaur
48 km / 8 to 18 hrs
246 km
Karnal
51 km / 9 to 18hrs
297 km
Mawi
42 km / 8 to 16 hrs
339 km
Baghpat
18 km / 3 to 6hrs
357 km
Palla
377 km
20 km / 4 to 6 hrs
Wazirabad Barrage 377 km
Sahibi 377.5 km
6 km / 1 to 2 hrs
383 km
Delhi
Okhla Barrage 399 km(FRL-201.50m)
76km
Hindon River 432 km
459 km
Mohana
138 km
597 km
Mathura PG
Gokul Barrage 605 km (Pond Level-165m)
98 km
695 km
Agra
149 km
844km
Etawah
Chambal 923 km
121 km
Sind
965 km
Auraiya
132 km
1097 km
Betwa 1105km
Hamirpur
233 km
Ken 1164km
1330 km
Pratappur
46 km
1376 km
Prayagraj

Annexure – R3

Hydrological Observation Site Network of Upper Yamuna Division



Annexure-R4

Z-15011/1/2020-FM Section-MOWR

I/86850/2023

Government of India
Ministry of Jal Shakti
Department of Water Resources, RD&GR
(Flood Management Wing)
Block-11, 8th Floor, CGO Complex,
Lodhi Road, New Delhi-110003.
Dated 06 August 2023

Office Memorandum

Subject: Constitution of a Committee for joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage

The extensive flooding in river Yamuna during July 2023 necessitated giving a fresh look for flood management of the river in its reach between Hathnikund and Okhla barrage. In this regard, the undersigned is directed to convey that, with the approval of the Competent Authority of DoWR, RD&GR, Ministry of Jal Shakti, a Committee is constituted for conducting a ***joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage,*** as per the following details:

2. **Composition of the Committee:**

1.	Chairman, Central Water Commission	Chairman
2.	Member (D&R), Central Water Commission	Member
3.	Member (RM), Central Water Commission	Member
4.	Commissioner (FM), DoWR, RD&GR, MoJS	Member
5.	Commissioner and Secretary, Irrigation and WRD, Government of Haryana	Member
6.	Engineer in Chief, Irrigation and WRD, Government of Haryana	Member
7.	Principal Secretary, Irrigation and WRD, Government of Uttar Pradesh	Member
8.	Engineer in Chief and HoD, Irrigation and WRD, Government of Uttar Pradesh	Member
9.	Principal Secretary, Irrigation and Flood Control Department, Government of NCT	Member
10.	Chief Engineer-Zone-1, Irrigation and Flood Control Department, Government of NCT	Member
11.	Director, Central Water & Power Research Station, Pune	Member
12.	Representative of National Remote Sensing Centre, Hyderabad	Member
13.	Representative of IMD	Member

Z-15011/1/2020-FM Section-MOWR

I/86850/2023

14.	Chief Engineer(FMO), Central Water Commission,	Member-Secretary

The Committee shall review and advice the study as per Terms of Reference given at Annexure-I.

3. The Committee will submit its final report within a period of six months from the date of its constitution. However, an interim report regarding meteorological aspects, return period floods, discharging capacity of barrages, functional requirement of ITO barrage etc along with interim measures to be taken shall be submitted within two months. The Committee may co-opt other members, if required, and may invite any officer from expert organizations to present the outcome of related technical studies carried out by them, if any.

4. The expenditure on TA/DA etc. of the officials for participating in meetings/visits shall be borne by the respective Organizations.

6/8/2023

(Rajesh Kumar)
Sr. Joint Commissioner-II, FM
Ph.No. 9650550015
E-mai: sjcer2-mowr@nic.in

To,
The Members of the Committee

Copy to:

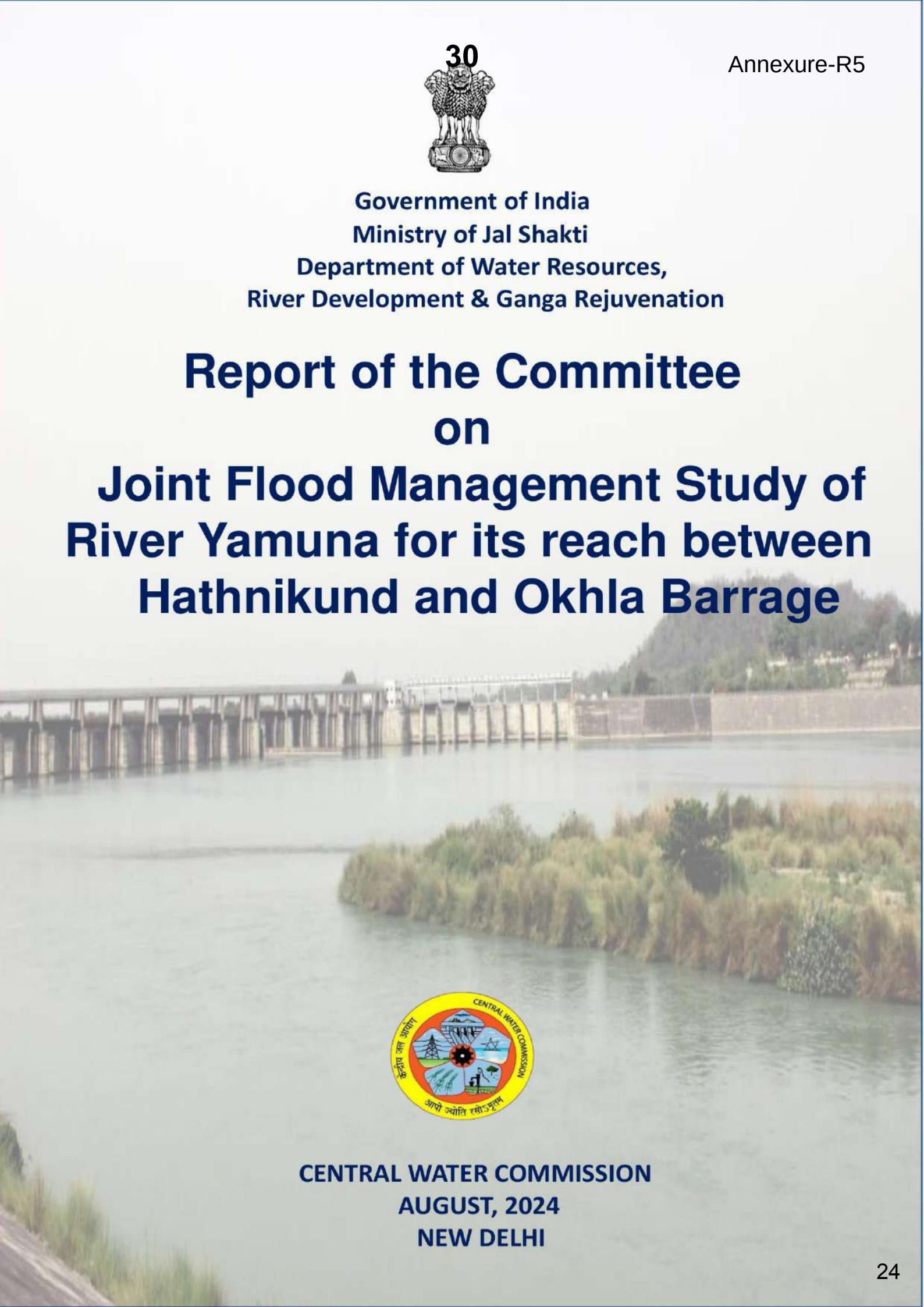
1. Chief Secretary, Government of Uttar Pradesh
2. Chief Secretary, Government of Haryana
3. Chief Secretary, Government GNCDT
4. Director General, IMD, New Delhi
5. Director, NRSC, Hyderabad.

Copy for kind information to:

1. PS to Hon'ble Minister Jal Shakti
2. Sr.PPS to Secretary (WR,RD&GR), Ministry of Jal Shakti
3. Sr. PPS to Special Secretary (WR,RD&GR), Ministry of Jal Shakti

Government of India
Ministry of Jal Shakti
Department of Water Resources,
River Development & Ganga Rejuvenation

Report of the Committee on Joint Flood Management Study of River Yamuna for its reach between Hathnikund and Okhla Barrage



CENTRAL WATER COMMISSION
AUGUST, 2024
NEW DELHI

REPORT

ON

JOINT FLOOD MANAGEMENT STUDY OF RIVER YAMUNA FOR ITS REACH BETWEEN HATHNIKUND AND OKHLA BARRAGE

Submitted to

MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES,
RIVER DEVELOPMENT AND GANGA REJUVENATION
MINISTRY OF JAL SHAKTI

AUGUST, 2024

Acknowledgement

The report of the committee on "Joint flood management study of river Yamuna for its reach between Hathnikund and Okhla Barrage" covers the various hydro metrological conditions that prevailed in July, 2023 which led to rapid rise of water level in the river Yamuna resulting in flooding in the hills and plains in its catchment. An attempt has been made in the report to look into the issue of Yamuna flooding holistically and suggest ways & means for effective management of floods in study reach of river Yamuna.

The committee has carried out the exhaustive studies and analysis on hydro metrological aspects, barrage operation, possible storage of flood water of river Yamuna and other related aspects of river Yamuna like encroachments, afflux, etc. which have been presented systematically in the report comprising of nine chapters. I am hopeful that the recommendations of the committee based upon the studies would be helpful in identifying the gaps and would act as guide for agencies involved in flood management of Yamuna.

I express my sincere thanks and gratitude to all the members of the committee for their significant contribution in bringing out this report. I also place on record the sincere and outstanding efforts made by officials of Department of Water Resources RD & GR, Central Water Commission, Central Ground Water Board, Indian Meteorological Department, Central Water and Power Research Station, National Remote Sensing Centre, Upper Yamuna River Board, Delhi Development Authority, Survey of India, I&FCD Govt. of NCT Delhi, Delhi Jal Board, Irrigation & Water Resource Department Government of Uttar Pradesh, Irrigation & Water Resource Department Government of Haryana in finalisation of the report.

In the end, I would like to thank the Member Secretary of the committee for his unwavering support, effective coordination among multiple agencies involved and organising meetings of the committee.

Kushvinder Vohra
Chairman, Central Water Commission &
Ex-Officio Secretary to the Government of India and
Chairman of the Committee.

Executive Summary

There was wide spread heavy rainfall across catchment of the river Yamuna which led to high runoff and huge discharge resulting in rapid rise of water level in the river Yamuna resulting in extensive landslides and flooding in the hills and plains of catchment of river Yamuna. The heavy rainfall was primarily due to Western Disturbances and South-West monsoon caused heavy rainfall during the period 9th to 13th July 2023, at different places in the States of Himachal Pradesh, Uttarakhand, Punjab, Delhi and Haryana in the catchment of river Yamuna. This flooding event necessitated a fresh look at the river's flood management in its reach from Hathnikund Barrage up to Okhla Barrage. Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti, vide OM dated 6th August 2023, constituted a committee for conducting a joint flood management study of river Yamuna for its reach between Hathnikund and Okhla Barrage. The committee was headed by Chairman, Central Water Commission & Ex-Officio Secretary to Government of India with members from Haryana, Uttar Pradesh, NCT of Delhi and expert Organizations. The committee was mandated to examine the meteorological aspects, return period of floods, discharging capacity of barrages, functional requirement of ITO barrage, etc.

The constituted committee was given the task to carry out various studies like detailed catchment representative rainfall analysis to compare the floods of the year 1978 and 2023, estimation of 5, 10, 25, 50, 100 and 500-year return period floods at Hathnikund Barrage, Wazirabad Barrage, Delhi old railway bridge and Okhla Barrage, carrying capacity of the river between Hathnikund barrage and Okhla barrage, maximum water level at salient locations of the study river reach for 5, 10, 25, 50, and 100-year return period floods, afflux of barrages, bridges, flood protection dykes and other structures in the study reach of the river, 2D modelling and submergence area estimation for the reach of river Yamuna from 10 km upstream of Wazirabad barrage and up to 10 km downstream of Okhla barrage, identification of possible drainage congestion in Delhi in case of high spate of river Yamuna, review the utility of ITO barrage in present context and to examine the feasibility of some innovative measures like creating underground reservoirs for flood moderation in line with Tokyo model along with examination of the feasibility of creation of storages for surplus flood water in the flood plains of Yamuna and thereafter identification of such sites.

The above studies involved collection of data, formulation of hydraulic & mathematical models, ground survey & inspection, meetings with all stake holders, etc. As all above tasks were time consuming and involved exhaustive coordination among various agencies involved in the management of floods in river Yamuna, the committee took a decision to first issue an Interim Report addressing the broader aspects of flood management of river Yamuna for its reach between Hathnikund and Okhla barrage. Accordingly, an Interim Report of the committee was issued in January, 2024 and shared

with all stake holders. The Interim Report of the committee summarized the views of the committee on various aspects as per the mandate of the committee and focussed on the cause of the event and measures for better on ground preparedness in case of such events in future.

The committee held four meetings under the chairmanship of Chairman, CWC wherein, informal groups were constituted within the Central Water Commission to monitor and to carry out studies in a time bound manner for accomplishment of tasks assigned during the course of committee meetings. The meetings of the committees were held to look into the issues of effective flood management, data requirement, data available, model studies, analysis, etc. The fifth and the final meeting of the committee was held on 14th August, 2024 wherein, the report of the committee in its form as presented here was accepted by all members of the committee.

This final report of the committee has been split into different chapters for focused attention to the topics presented under each chapter. This report has nine elaborate chapters with first chapter of introduction and subsequent chapters describing specific topics such as Catchment Representative Rainfall Analysis, Flood Frequency Analysis, Carrying Capacity of River Yamuna, 2-D Modelling and Submergence Area Estimation, Barrages on river Yamuna, Encroachments in river Yamuna, Storage Possibility of Flood Water and with concluding chapter on the conclusions and recommendations of the committee.

The final conclusions and recommendations of the committee for effective flood management of floods of river Yamuna for its reach between Hathnikund and Okhla have been described in the ninth chapter of this report based upon the studies and analysis presented in the chapters.

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List of Figures

List of Tables

1 Introduction and Background

1.1 Introduction

Floods constitute one of the major natural calamities faced by India almost every year resulting in substantial loss of life, large scale damage to property, disruption of community lifelines besides entailing untold misery to the millions. Concerted efforts have been made over the years to reduce the damage due to floods and mitigate the sufferings of the people. Various structural flood control measures were taken up in the past including construction of reservoirs, embankments, drainage channels, etc. It is, however, now realised that absolute and permanent protection to all flood prone areas and for all magnitudes of floods by structural measures alone may not be feasible. The river Yamuna originates from Banderpunch glacier in Uttarakhand near Yamunotri and travel about 1376 km before meeting the river Ganga at Sangam (at Prayagraj). River Yamuna, one of the largest tributaries of River Ganga, originates from Yamunotri Glacier on the south western slope of Banderpunch peaks of the Lower Himalayas in Uttarakhand. The river basin lies in the states of Uttarakhand, Himachal Pradesh, Haryana, Uttar Pradesh, Rajasthan and Delhi. Before its confluence with River Ganga at Sangam in Prayagraj district of Uttar Pradesh, important tributaries such as Tons, Giri, Hindon, Chambal, Sindh, Betwa and Ken join the river along its way. The basin's huge population depends upon the water of the river Yamuna.

Yamuna has six functional barrages and one proposed barrage. The functional barrages are Dakpathar Barrage, Hathnikund Barrage, Wazirabad Barrage, ITO Barrage, Okhla Barrage and Gokul (Mathura) Barrage. From Hathnikund Barrage, water is diverted to Eastern and Western Yamuna Canals. A line diagram of River Yamuna is shown in **Fig**. **1.1**. The river water takes about 2-2.5 days to travel from Hathnikund to Delhi. Central Water Commission (CWC) started flood forecasting services in the year 1958 with its first forecasting station on Yamuna at Old Delhi Railway Bridge. It’s catchment from Yamunotri to Mathura Gokul Barrage comes under the jurisdiction of Upper Yamuna Division, Central Water Commission, New Delhi. There are 46 Hydrological Observation Stations under the Upper Yamuna Division where regular monitoring of water level is being carried out. Beside the water level, daily discharge and 3 hourly rainfall are also recorded during monsoon at most of the stations. There are 6 flood forecasting stations under the jurisdiction of Upper Yamuna Division.

1.2 Background

Due to a combination of Western Disturbances and Southwest Monsoon, there was heavy rainfall in different places of Himachal Pradesh, Uttarakhand and Haryana during 09-13 July 2023, leading to extensive landslides and flooding in the hills and plains. The heavy rainfall in the catchment area of river Yamuna resulted in huge runoff in the river, due to which an earlier Highest Flood Level (HFL) of 207.49 m recorded at the CWC gauging site of old Delhi railway bridge on 6th September, 1978 got surpassed by a new HFL of 208.66 m observed on 13th July 2023. The heavy rainfall led to increased flow at Hathnikund Barrage on 11th July, 2023 as a result Hathnikund Barrage released peak discharge of 3.59 Lakh cusecs at 11:00 hrs on 11th July, 2023. The same flow was continued for two hours and after that flow reduced gradually. The high discharge downstream of Hathnikund Barrage created flood situation in the river Yamuna. Due to this, the flow of Delhi Railway Bridge site increased continuously and crossed the previous HFL of 207.49m at 13:00 hrs on 12th July, 2023 and achieved the highest peak of water level of 208.66m at 18:00 hrs on 13th July, 2023.

Above events necessitated a fresh look at the river's flood management in its reach from Hathnikund Barrage up to Okhla Barrage. In this regard, DoWR, RD&GR, Ministry of Jal Shakti, vide OM No. Z-15011 /1 /2020-FM Section-MOWR dated 6th August 2023, constituted a committee for conducting a joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage. The committee headed by Chairman CWC has members from Haryana, Uttar Pradesh, NCT of Delhi and expert organizations. It will inter-alia examine the meteorological aspects, return period of floods, discharging capacity of barrages, functional requirement of ITO barrage, etc. Constitution of committee and its terms of reference is attached as **Annexure A**

The meetings of the committees were held to look into the issues of flood management of river Yamuna joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage as per the mandated of the committee. The issues related to effective flood management, data, model studies, analysis, etc. ere discussed and deliberated in details in the five meetings of the committee under the chairmanship of Chairman, CWC. The first meeting of the committee was held on 4th September, 2023 followed by the second meeting on 13th October, 2023. Thereafter, the third and fourth meeting of the committee were held on 25th April, 2024 and 1st July, 2024 respectively. India. The representatives from DoWR, RD &GR, Central Water Commission, Irrigation & Flood Control Department Govt. of NCT Delhi, Irrigation and Water Resource Department Govt. of Haryana & Uttar Pradesh, Delhi Jal Board, Delhi Development Authority, Central Ground Water Board, Central Water & Power Research Station, Indian Metrological Department, Upper Yamuna River Board, Survey of India, etc. participated

in the proceedings of the meetings. The minutes of the four meetings of the committee are at **Annexure B to F.**

During the course of above meetings the scope of various studies as per the ToR of the committee which were required to be carried out and necessary data required for the studies was deliberated. The views and suggestions for taking up the studies have well been recorded in the minutes of the meetings. The studies as carried out have been described in detail in various chapters of the report. The conclusions and recommendations of the committee for effective management of the floods in reach between Hathnikund and Okhla Barrage based upon the studies carried out is presented in the concluding chapter of the report.

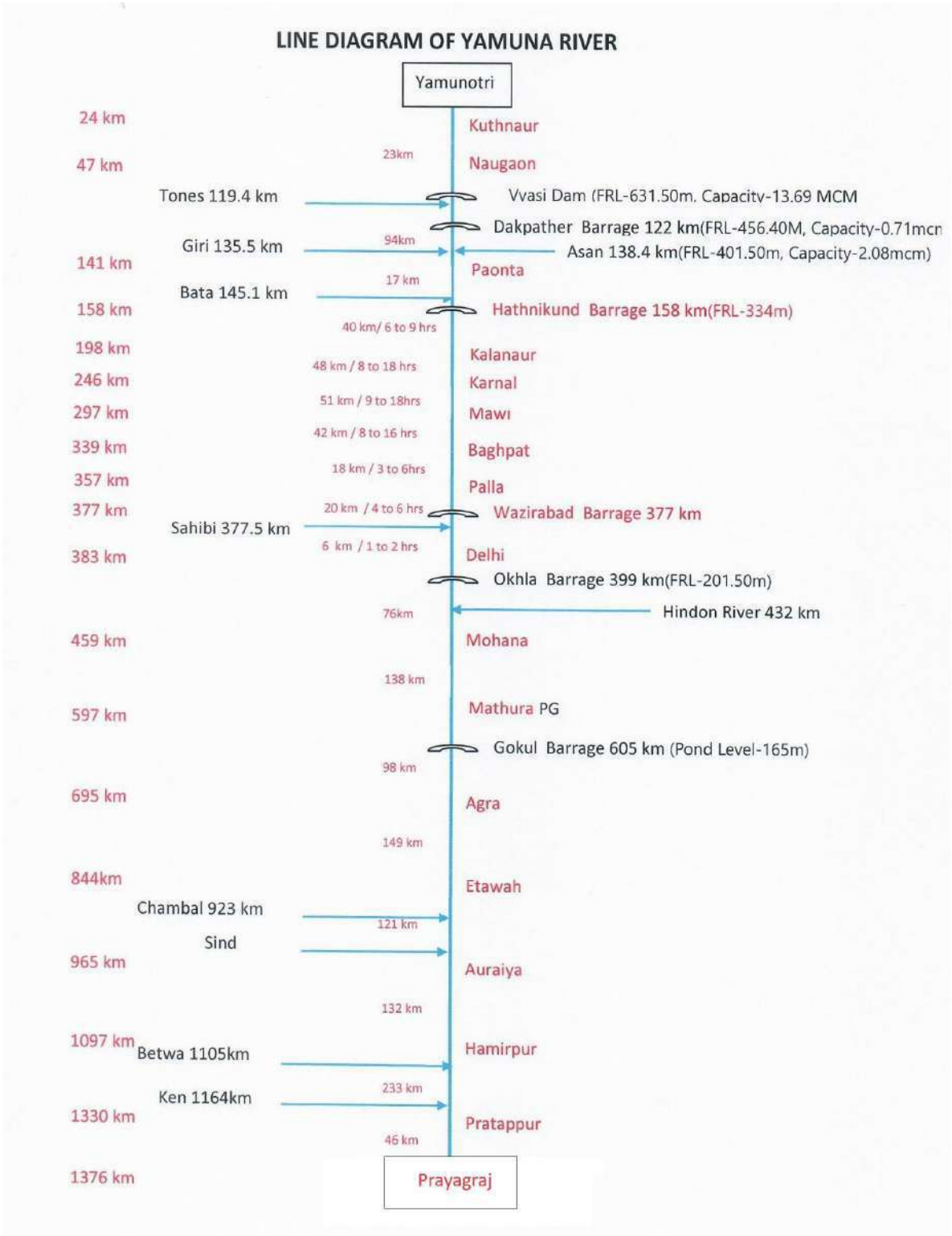


Fig. 1.1: Line Diagram of Yamuna River

2 Catchment Representative Rainfall Analysis

2.1 Detailed Catchment Representative Rainfall Analysis

Detail catchment representative rainfall analysis during the period 09-13th July, 2023 up to Old Delhi Railway Bridge is carried out by utilizing IMD Gridded Rainfall data and comparing it with catchment representative rainfall for the period 1970 to 2022.

2.2 Observed Rainfall

The catchment area of river Yamuna at Old Delhi Railway Bridge is given in **Fig. 2.1**. The estimated catchment areas at Hathnikund barrage, Mawi G&D site and Old Delhi Railway Bridge is 11397, 15683 and 17882 sq. km., respectively. Due to combination of Western Disturbances and Monsoon, heavy rainfall occurred in Himachal Pradesh and Uttarakhand during 09-13 July 2023, as shown in **Fig. 2.2 to Fig. 2.5** which led to extensive landslides and flooding in the hills and plains.

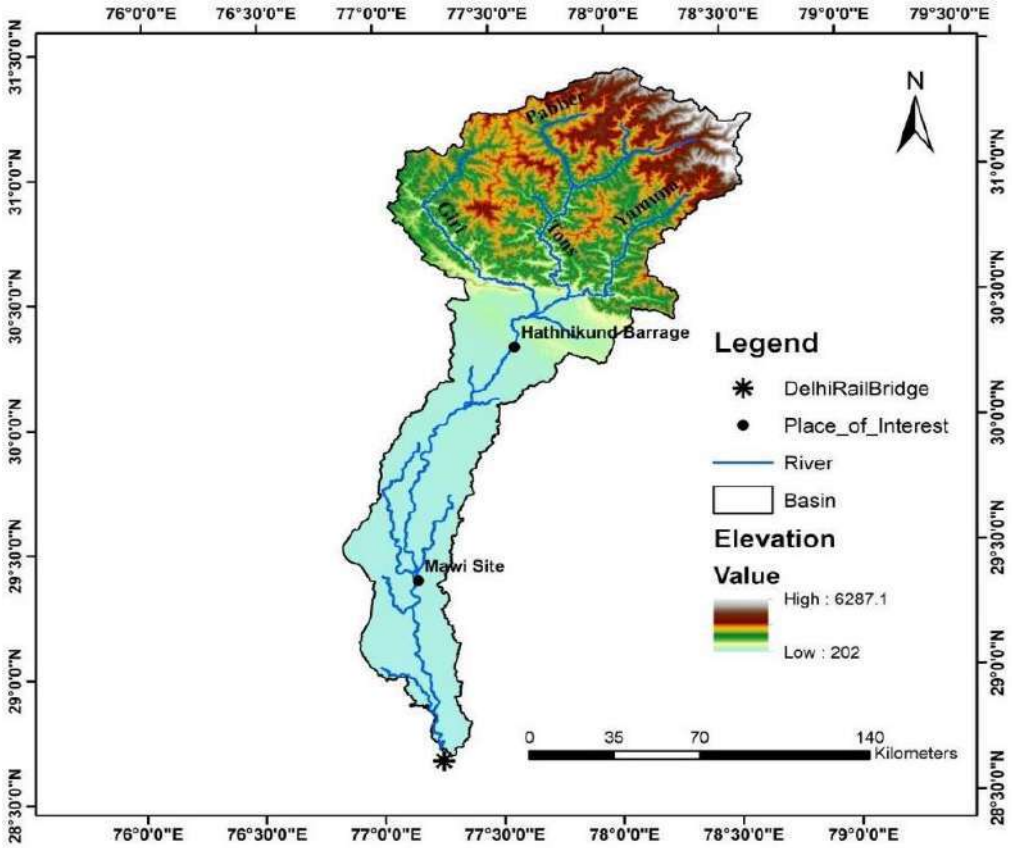


Fig. 2.1: Catchment of Yamuna (excluding Sahibi) River at Old Delhi Railway Bridge

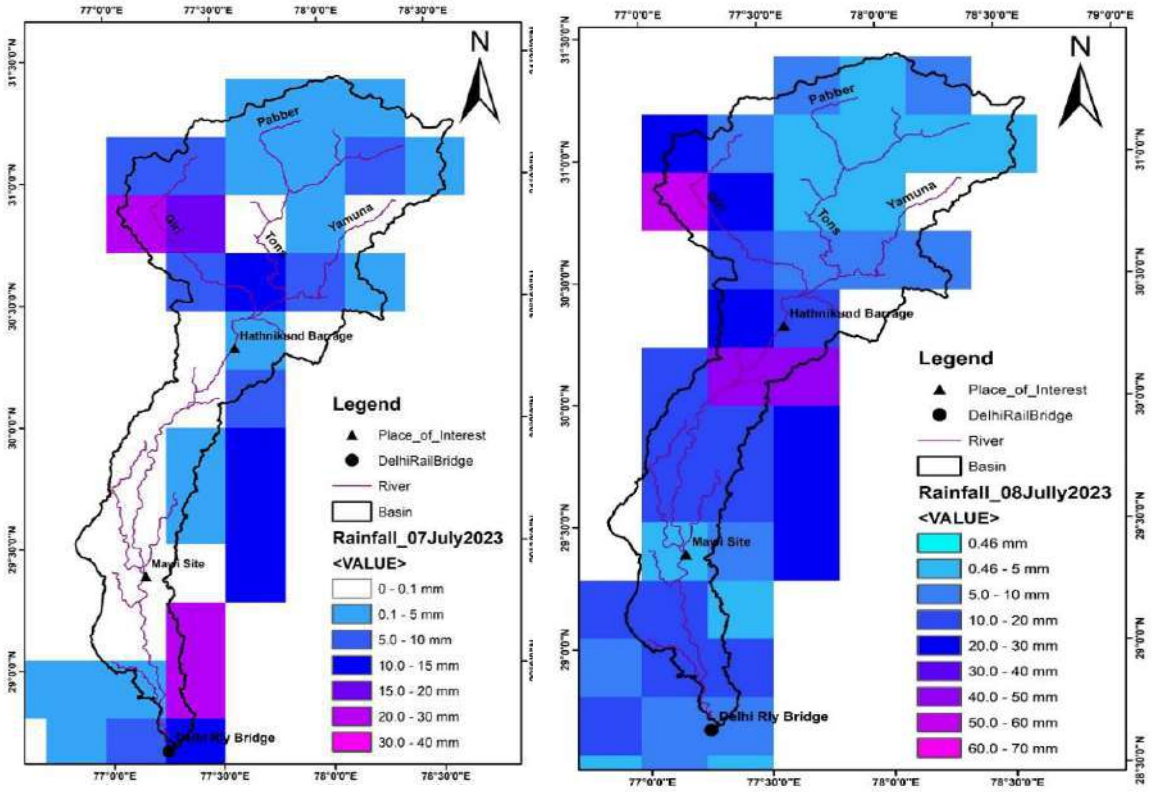


Fig. 2.2: Spatial Distribution of Rainfall on 7th & 8th July 2023

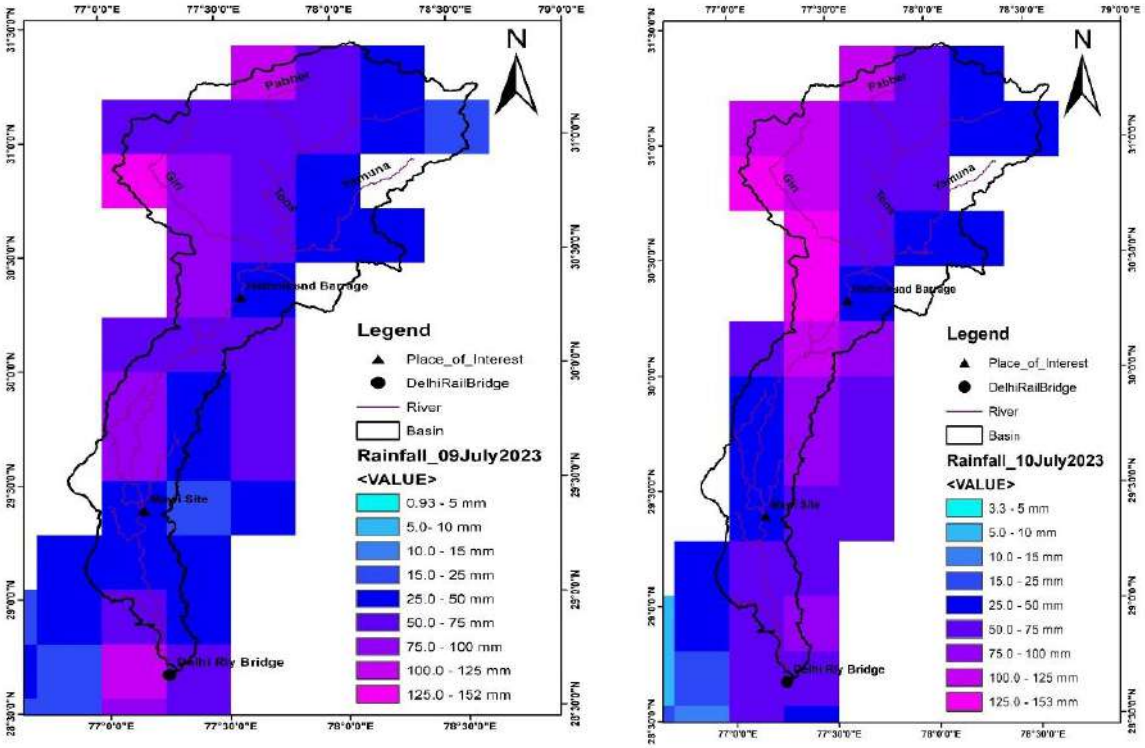


Fig. 2.3: Spatial Distribution of Rainfall on 9th & 10th July 2023

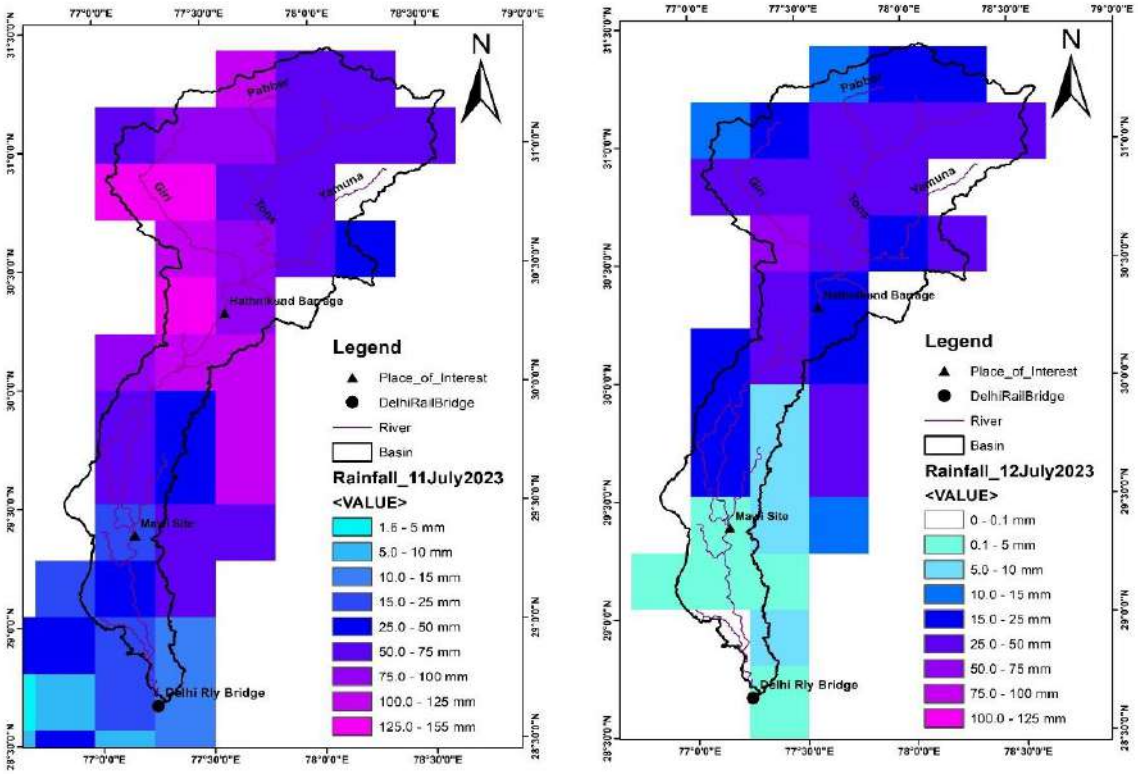


Fig. 2.4: Spatial Distribution of Rainfall on 11th & 12th July 2023

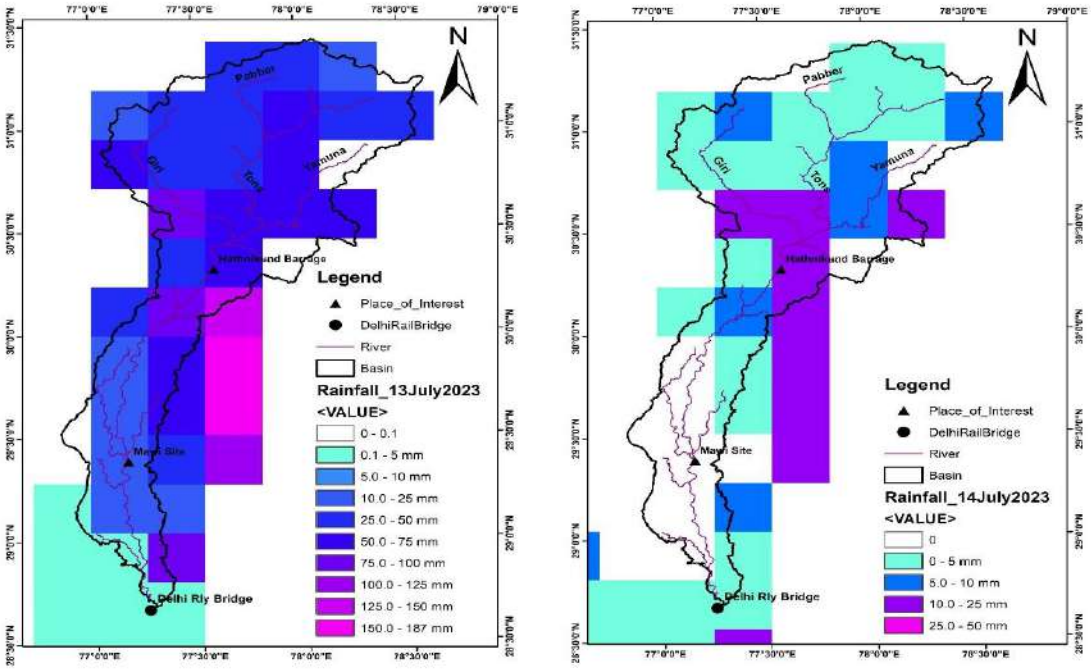


Fig. 2.5: Spatial Distribution of Rainfall on 13h & 14th July 2023

2.3 Methodology of Analysis of Rainfall

Gridded IMD Rainfall from 1970 to 2022, available on IMD website and rainfall for July 2023 (supplied by IMD) have been utilized to compute the catchment representative rainfall for the catchment upto Hathnikund and Mawi. The IMD Grids used for computation for catchment representative rainfall are given in **Fig. 2.4 & Fig. 2.6.**

An Annual Maximum series for cumulative 5-day rainfall for Hathnikund and Mawi have been computed and frequency analysis has been conducted to determine the 5, 10, 25, 50, 100 year return period of rainfall.

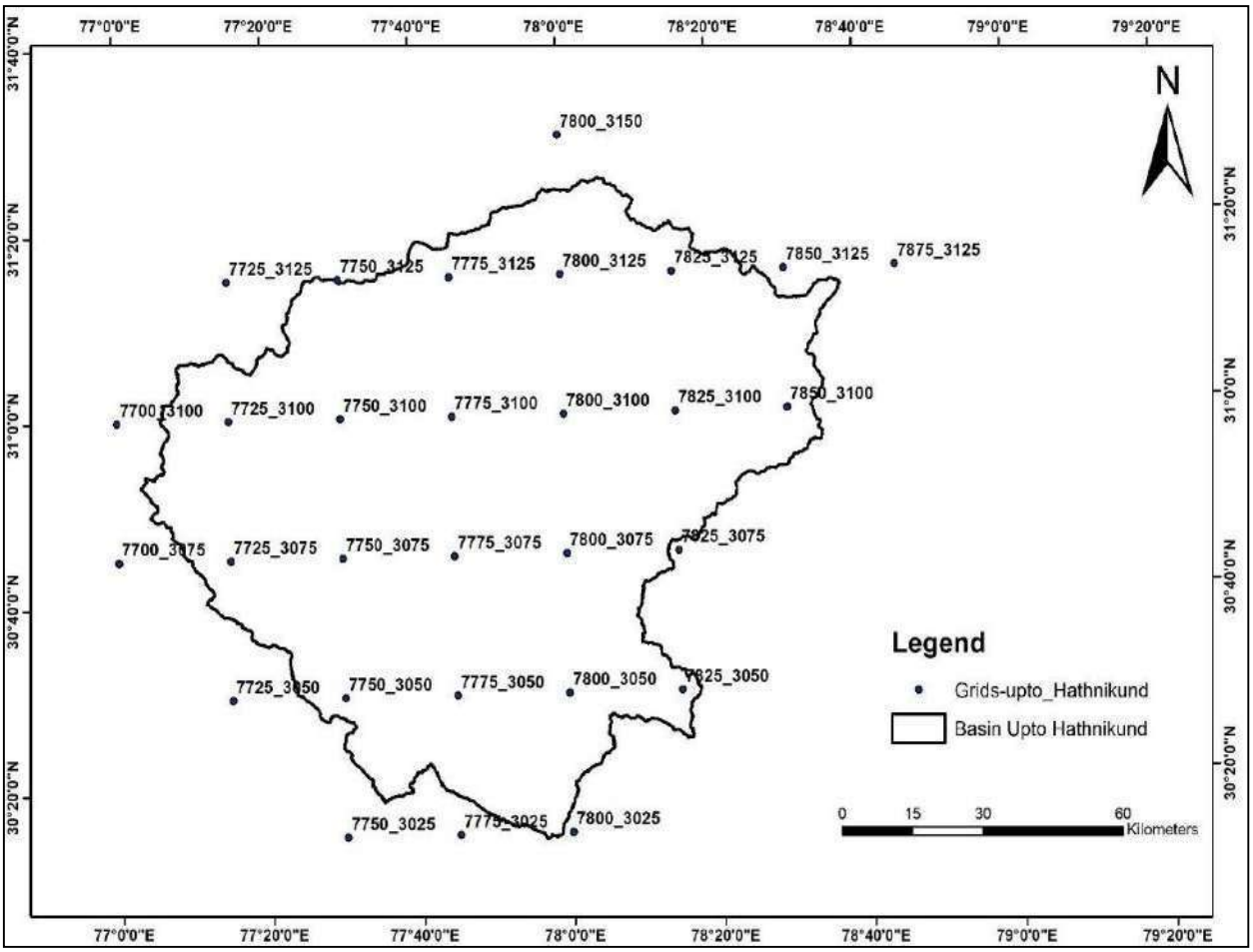


Fig. 2.4: Catchment Map of IMD Grids over Yamuna Catchment at Hathnikund

2.4 Catchment Representative Rainfall for Hathnikund Barrage

The catchment map of Yamuna River upto Hathnikund Barrage is presented in **Fig. 2.5** Physiographic parameters of Yamuna catchment at Hathnikund barrage are given in **Table 2.1**. Elevation difference between highest and lowest point along the Longest Flow Path is 5385 m.

Table 2.1: Physiographic parameters of catchment of river Yamuna at Hathnikund barrage

Catchment Area	Longest Flow Path	Centroidal Flow Path	Equivalent Stream Slope
11397 km^2	225 km	115 km	9.53 m/km

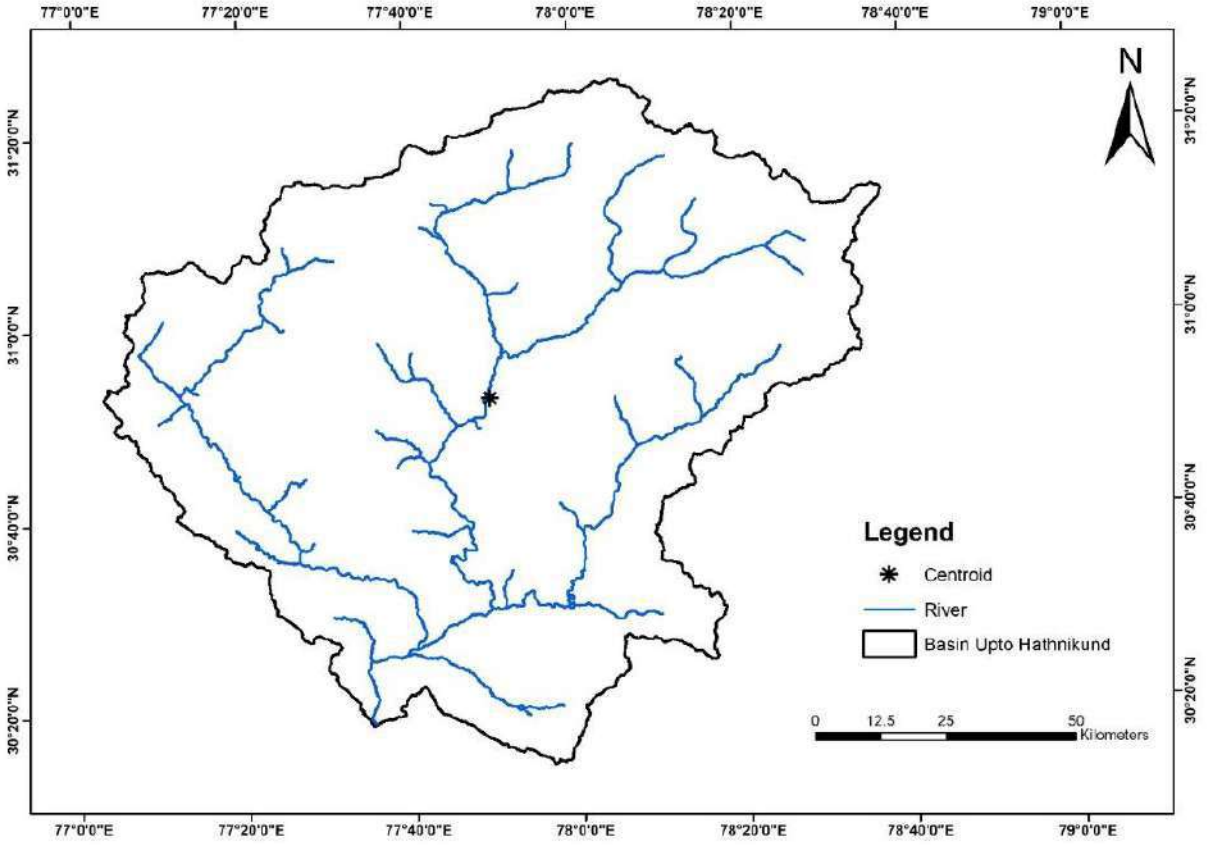


Fig. 2.5: Catchment Map Yamuna River upto Hathnikund Barrage

Based on the above physiographic parameters, it emerged that in general the entire catchment at Hathnikund barrage shall get activated in 3 days of continuous rainfall for generating the maximum runoff at Hathnikund barrage site. The Hathnikund barrage with a small pondage will be forced to release the flood water in case of rise of water upto a certain elevation and this water will travel downstream along the river. If the heavy rainfall sustains for more than the three days, then the water shall be released for a longer duration, resulting in less attenuation of flood peak in downstream reach of the river due to channel routing, resulting in higher flood peaks in the downstream reaches of the river. Considering the above aspects, the rainfall of 5 days duration has been analyzed in the present study.

The IMD Grids as shown in **Fig 2.4 & Fig 2.6** have been utilized for gridded rainfall to estimate the catchment representative rainfall from 1970-2022. The cumulative 5-day

annual maximum rainfall series has been then computed from IMD Gridded Rainfall and in case of 2023, the rainfall has been considered from 09-13 July 2023 which is maximum for 2023 till 13th July. The 5-days series is shown in **Table 2.2**

Further, the frequency analysis of Annual Maximum values of 5-day rainfall has also been carried out to estimate the 5, 10, 25, 50, 100 year return period of rainfall for series from 1970-2022 and 5-day observed rainfall till July 2023 using the best fitting frequency distribution Log Pearson Type-III. The above estimated return period rainfalls are given in **Table 2.3**.

Table 2.2 Cumulative 5-day Annual Maximum Rainfall Series from 1970-2023 for catchment up to Hathnikund

Year	Annual Max of Sum of 5 days (mm)	Year	Annual Max of Sum of 5 days (mm)
1970	104.93	1997	131.25
1971	131.66	1998	142.97
1972	93.46	1999	134.39
1973	132.70	2000	134.67
1974	93.36	2001	90.83
1975	77.35	2002	150.49
1976	101.33	2003	97.85
1977	89.97	2004	80.17
1978	222.09	2005	117.62
1979	116.58	2006	117.05
1980	163.24	2007	121.41
1981	85.67	2008	125.00
1982	123.49	2009	181.59
1983	97.11	2010	143.46
1984	102.03	2011	152.77
1985	132.22	2012	115.16
1986	86.01	2013	306.63
1987	72.77	2014	120.31
1988	233.29	2015	110.37
1989	152.92	2016	117.07
1990	147.30	2017	102.46

1991	120.85	2018	158.00
1992	110.76	2019	125.48
1993	151.12	2020	73.77
1994	155.13	2021	107.25
1995	214.43	2022	114.54
1996	101.24	2023	316.94

Table 2.3 : Return Period Rainfall for Catchment up to Hathnikund

Return Period	Rainfall (mm)
5-year	160
10-year	192
25-year	238
50-year	278
100-year	324

2.5 Catchment Representative Rainfall for Catchment up to Mawi Site

IMD grids for Yamuna river catchment up to Mawi site is shows in **Fig. 2.6**

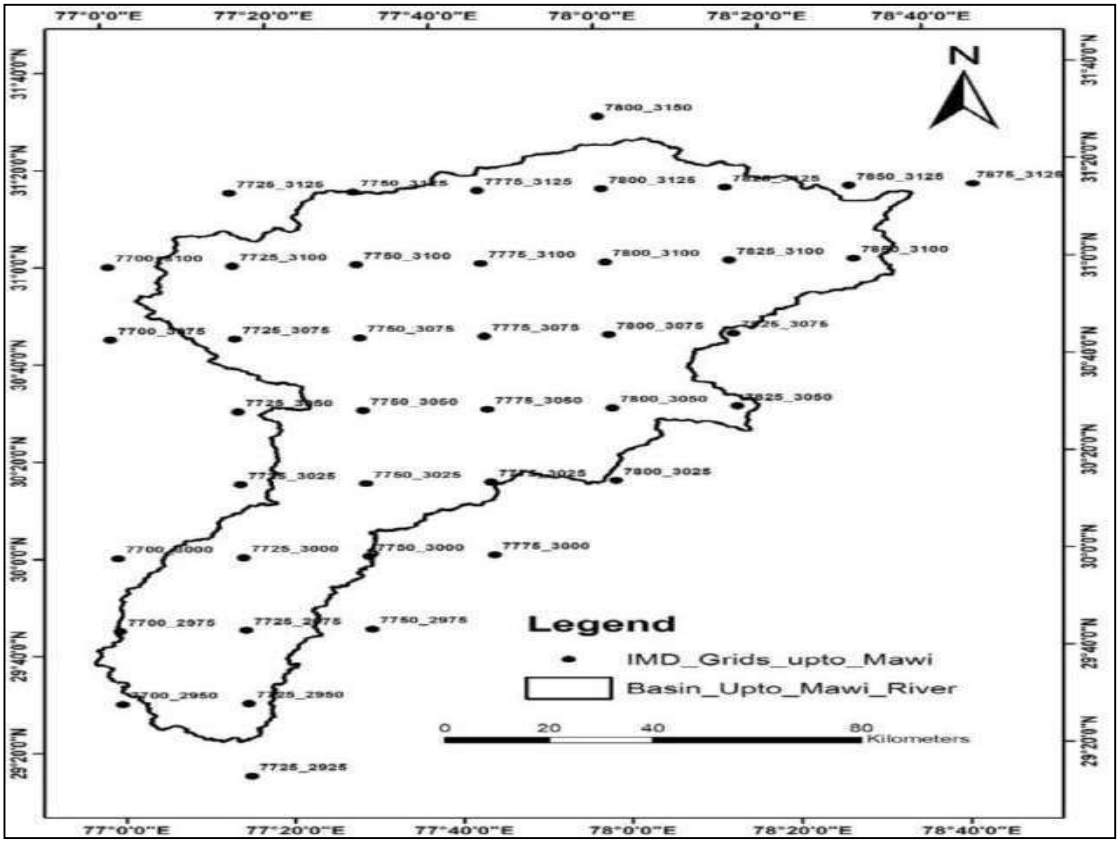


Fig. 2.6: Catchment Map of IMD Grids over Yamuna Catchment up to Mawi Base station

The catchment map of Yamuna River up to Mawi G & D Site of CWC (at $29^0$23'05"N and $77^0$09'20"E) is presented in **Fig. 2.7**

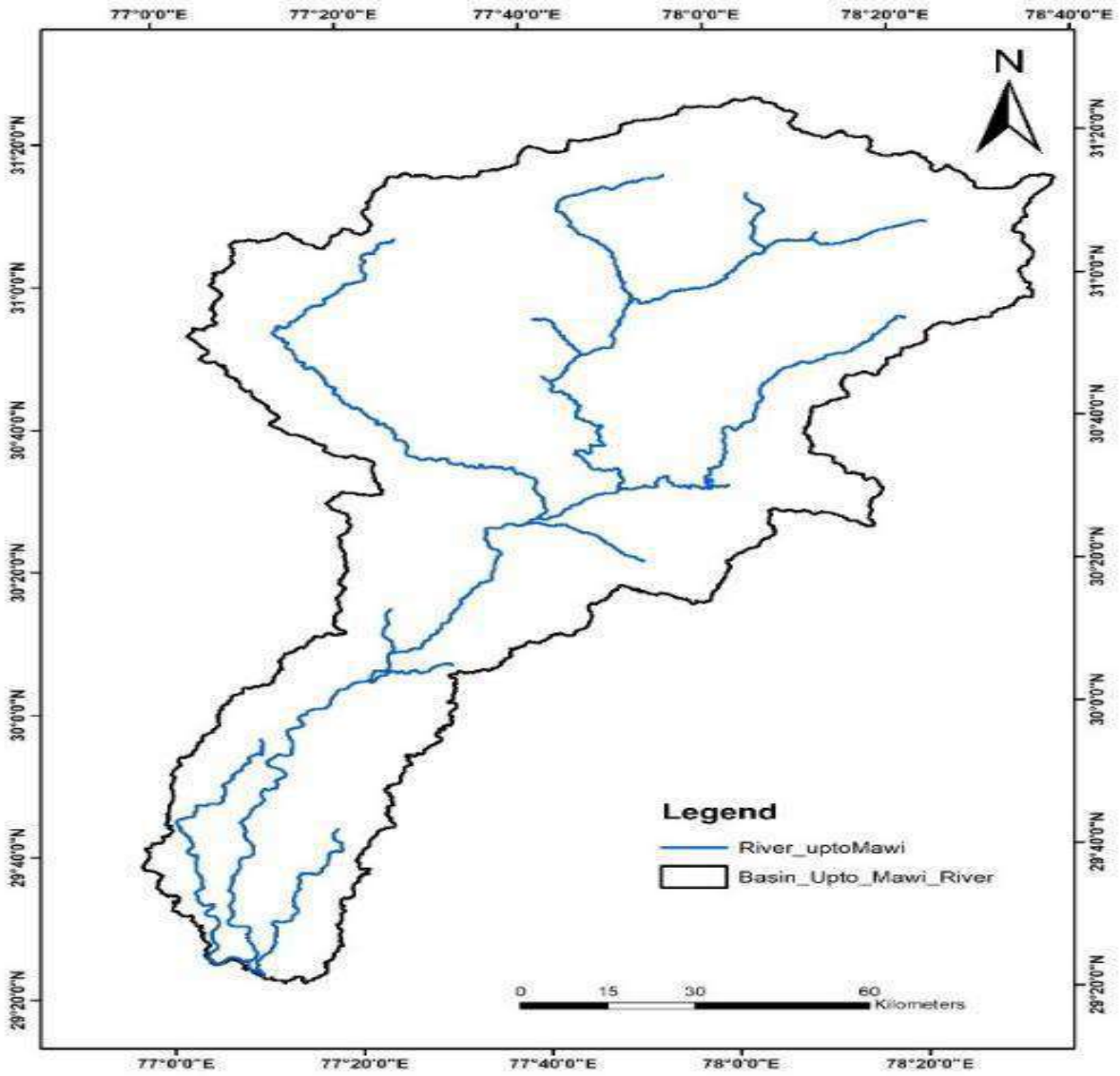


Fig. 2.7 : Catchment Map of Yamuna River upto Mawi Site

The Physiographic parameters of river Yamuna catchment at Mawi are given in **Table 2.4** . The Elevation difference between highest and lowest point along the Longest Flow Path is 5486 m.

Table 2.4 : Physiographic parameters of catchment of river Yamuna at Mawi Site

Catchment Area	Longest Flow Path	Centroidal Flow Path	Equivalent Stream Slope
15683 km^2	379.4 km	218.1 km	3.72 m/km

The IMD Grids as shown in **Fig 2.6** have been utilized for gridded rainfall to estimate the catchment representative rainfall from 1970-2022. The cumulative 5-day annual maximum series has been then prepared from IMD Gridded Rainfall. In case of 2023, rainfall has been considered from 09-13 July 2023 which is maximum for 2023. The 5-day series is shown in **Table 2.5.**

The frequency analysis of annual maximum values of 5-day rainfall has been carried out to estimate the 2, 5, 10, 25, 50, 100 year return period of rainfall for series from 1970-2022 and 5-day observed rainfall till July 2023 using the best fitting frequency distribution Log Pearson Type-III. The above estimated return period rainfalls are given in **Table 2.6**.

Table 2.5 : Cumulative 5-day Annual Maximum Rainfall Series from 1970-2023

Year	Annual Max of Sum of 5 days (mm)	Year	Annual Max of Sum of 5 days (mm)
1970	105.0	1997	123.7
1971	135.0	1998	130.4
1972	105.7	1999	120.7
1973	117.5	2000	134.8
1974	85.6	2001	102.7
1975	87.8	2002	158.0
1976	133.2	2003	89.0
1977	83.9	2004	88.8
1978	230.8	2005	112.9
1979	96.8	2006	95.9
1980	152.9	2007	103.9
1981	99.7	2008	105.2
1982	100.9	2009	186.1
1983	139.6	2010	143.3
1984	79.7	2011	146.7
1985	113.7	2012	113.7
1986	76.9	2013	255.9
1987	66.7	2014	116.1
1988	215.5	2015	115.1
1989	159.1	2016	121.4
1990	152.4	2017	99.7
1991	105.7	2018	158.4
1992	117.2	2019	120.1
1993	134.4	2020	71.2
1994	146.0	2021	103.9
1995	220.7	2022	118.5
1996	103.3	2023	303.6

Table 2.6: Return Period Rainfall for Catchment at Mawi G&D site

Return Period	Rainfall (mm)
5-year	155
10-year	184
25-year	226
50-year	261
100-year	300

2.6 Catchment Representative Rainfall for Catchment at Old Delhi Railway Bridge

CWC is maintaining a gauge site at Old Delhi Railway Bridge, where earlier HFL recorded as 207.49 m on 6th September 1978 was surpassed on 13th July 2023 and maximum water level recorded was 208.66 m. Hence, catchment representative 5-day cumulative rainfall at Old Delhi Railway Bridge has also been estimated and the same has been found as 223.12 mm during the period 31.08.1978 to 04.09.1978 and 276.25 mm during the period 9-14, July 2023.

2.7 Stage Hydrograph Analysis

Hydrological Observation (HO) network of CWC in Yamuna catchment (from Paonta to Delhi) is shown in **Fig. 2.8.** As per observations over the period up to 2023, travel time between various stations is given below in **Table 2.7**

Table 2.7: Travel Time

Station	Gap (kms)	Travel Time (Hrs.)
Hathnikund- Kalanaur	40	6-9
Kalanaur- Karnal	48	8-18
Karnal- Mawi	51	9-18
Mawi- Baghpat	42	8-16
Bagpat- Palla	18	3-6
Palla- Old Delhi Railway Bridge	26	5-8
Total	225	39-75

The water levels observed at HO sites from Paonta to Old Delhi Railway Bridge as evident from the **Fig. 2.10 to Fig. 2.16** also establishes the travel time between different locations as given at **Table 2.7**. It is observed from **Fig. 2.17** showing the flood hydrographs at Hathnikund barrage and Okhla barrage that peak flood discharge of 3,59,760 cusecs

occurred at Hathnikund barrage on 11.07.2023 at 11.07 Hrs. followed by peak flood discharge of 3,72,225 cusecs at Okhla barrage on 14.07.2023 at 13.00 Hrs.

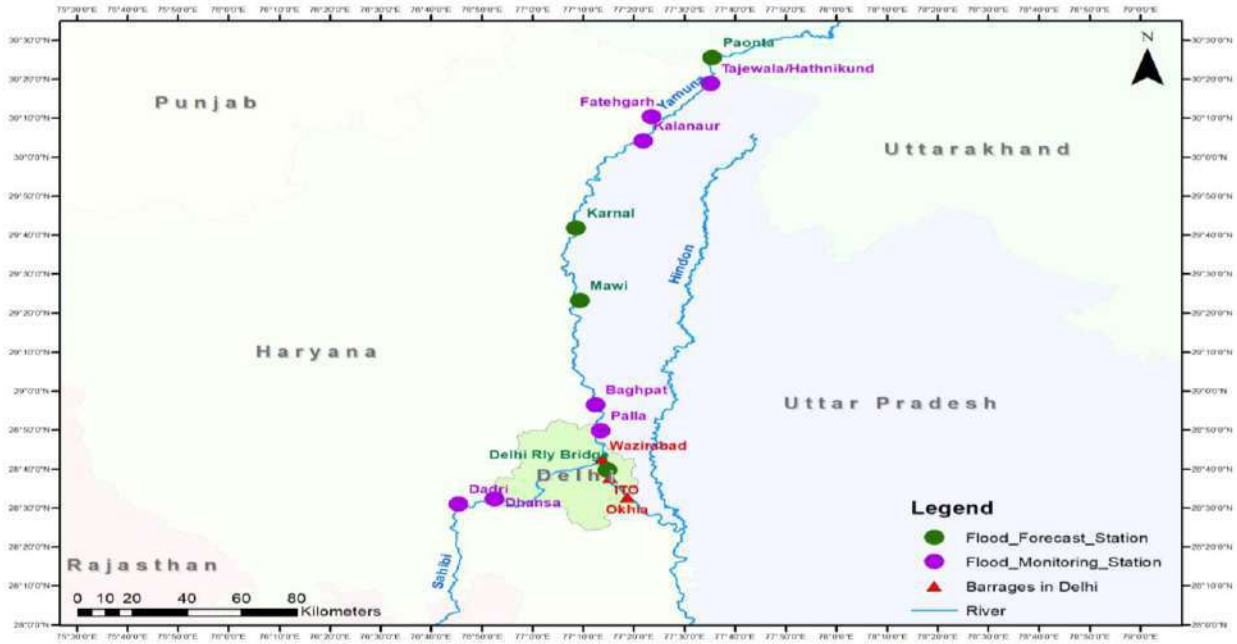


Fig. 2.8: HO Network of CWC from Paonta to Delhi

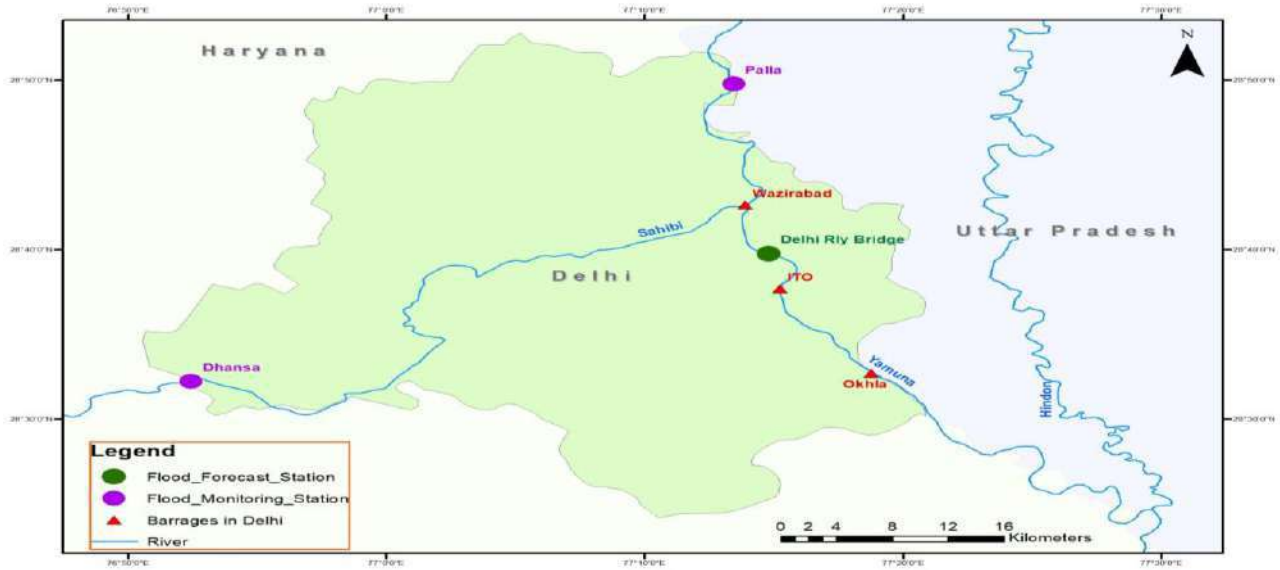


Fig. 2.9: HO Network within Delhi i.e. from Palla to Okhla

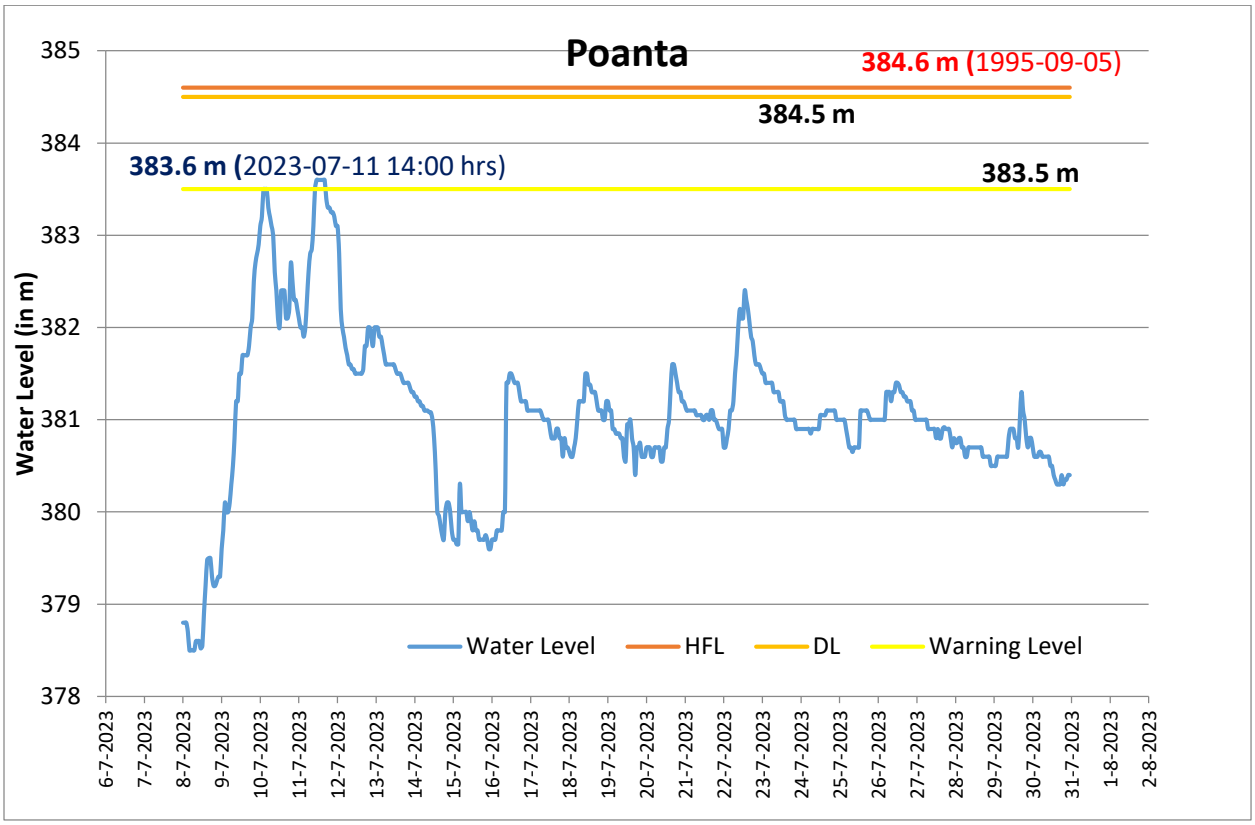


Fig. 2.10: Stage (WL) hydrograph at Paonta during July 2023

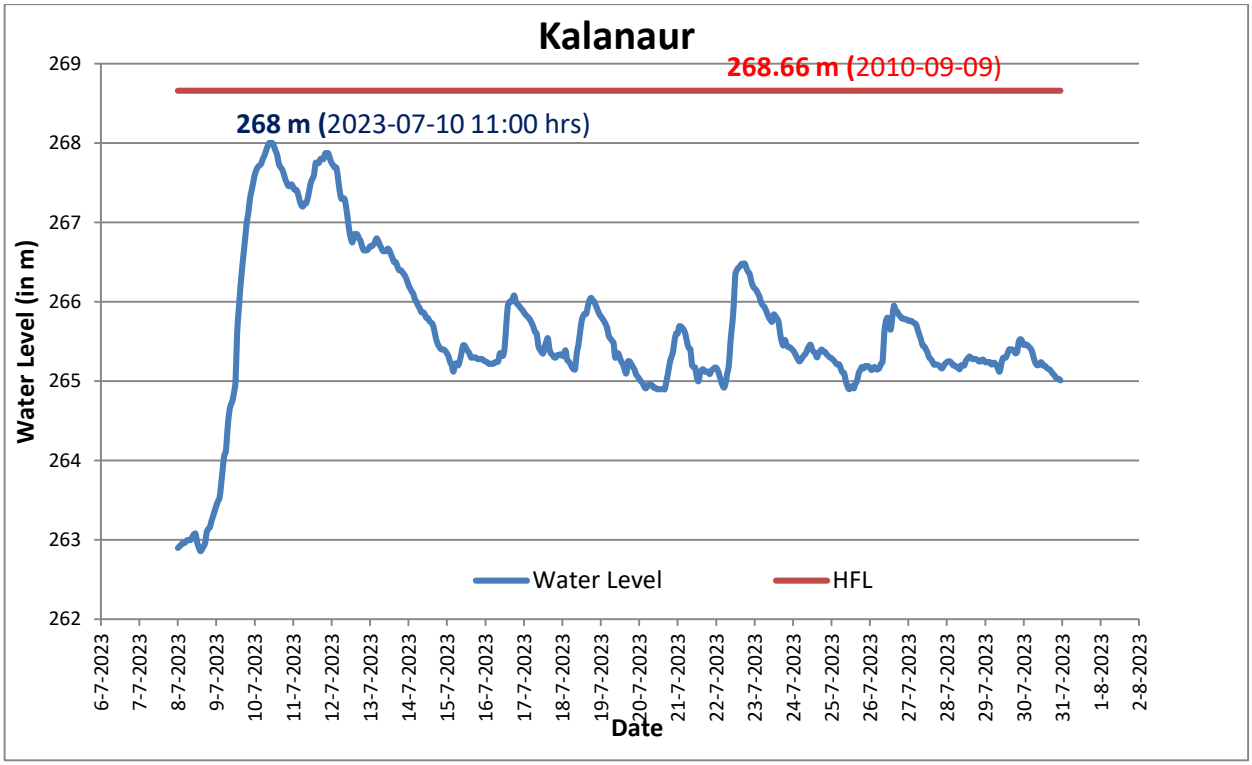


Fig. 2.11: Stage (WL) hydrograph at Kalanaur during July 2023

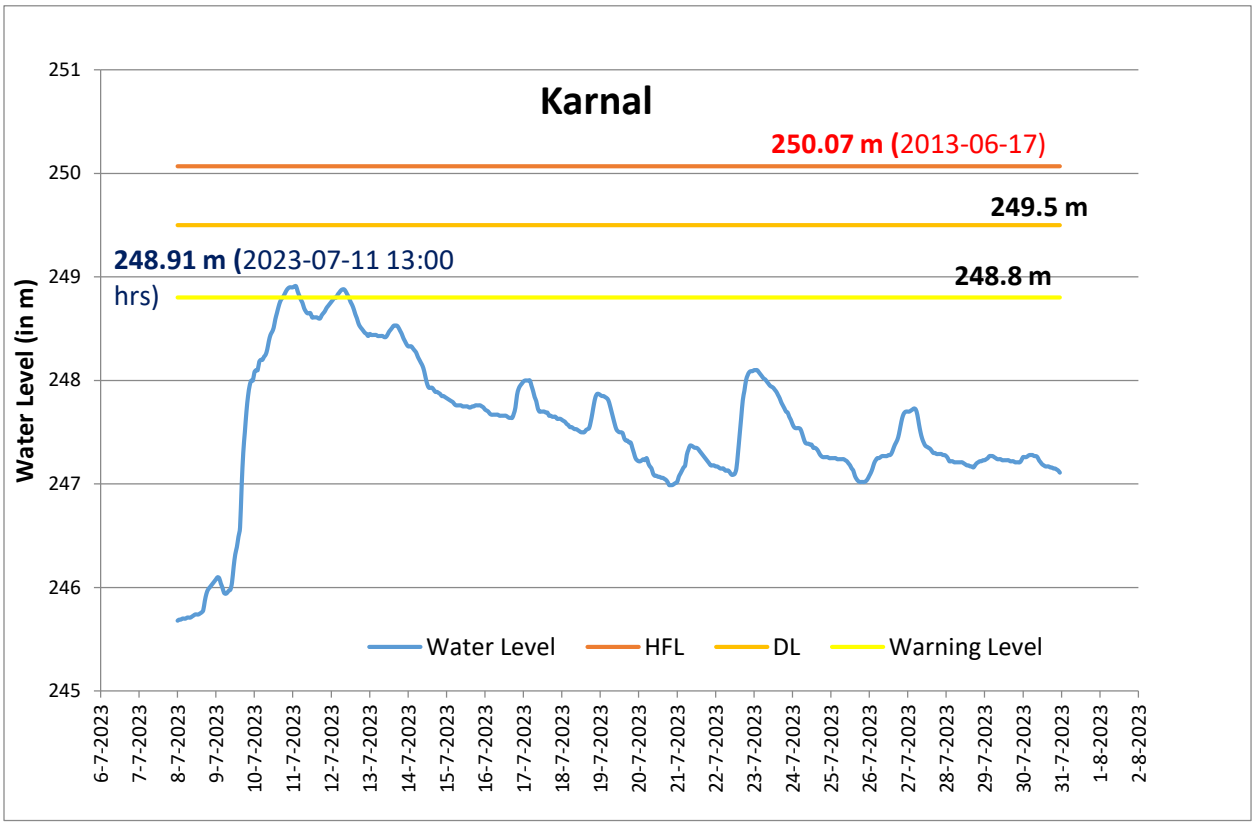


Fig. 2.12: Stage (WL) hydrograph at Karnal during July 2023

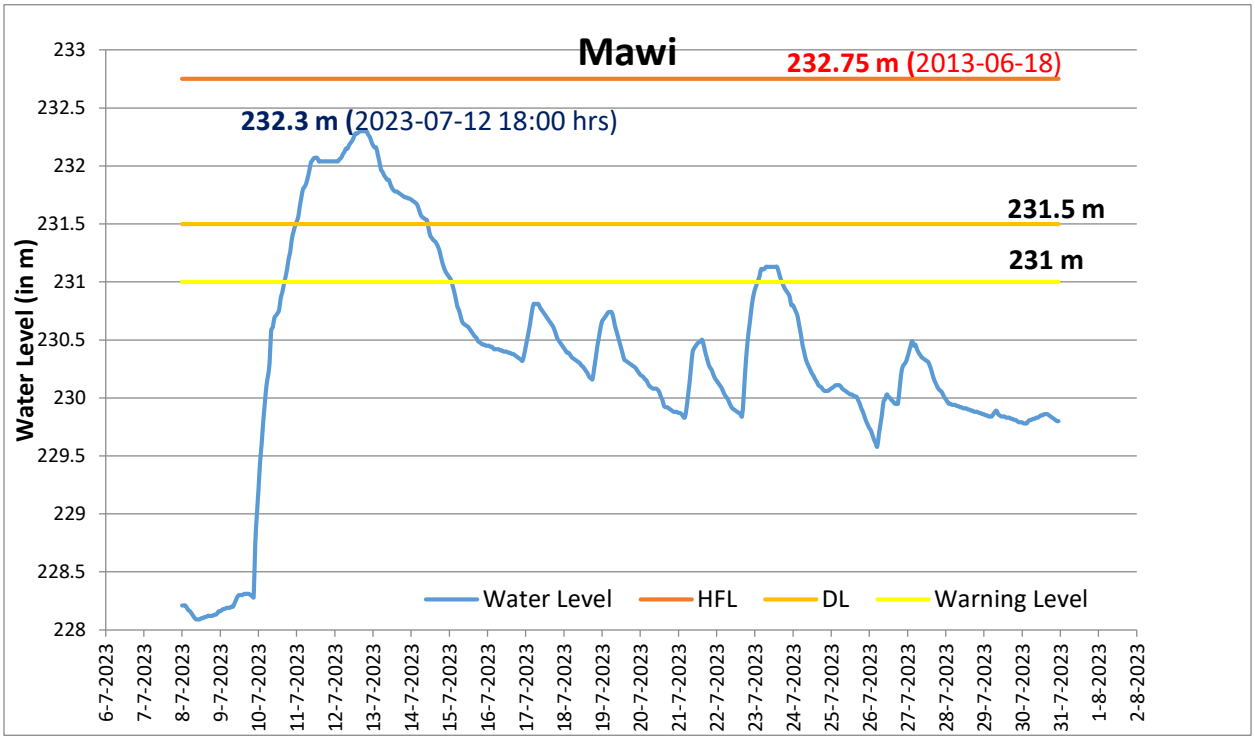


Fig. 2.13: Stage (WL) hydrograph Mawi during July 2023

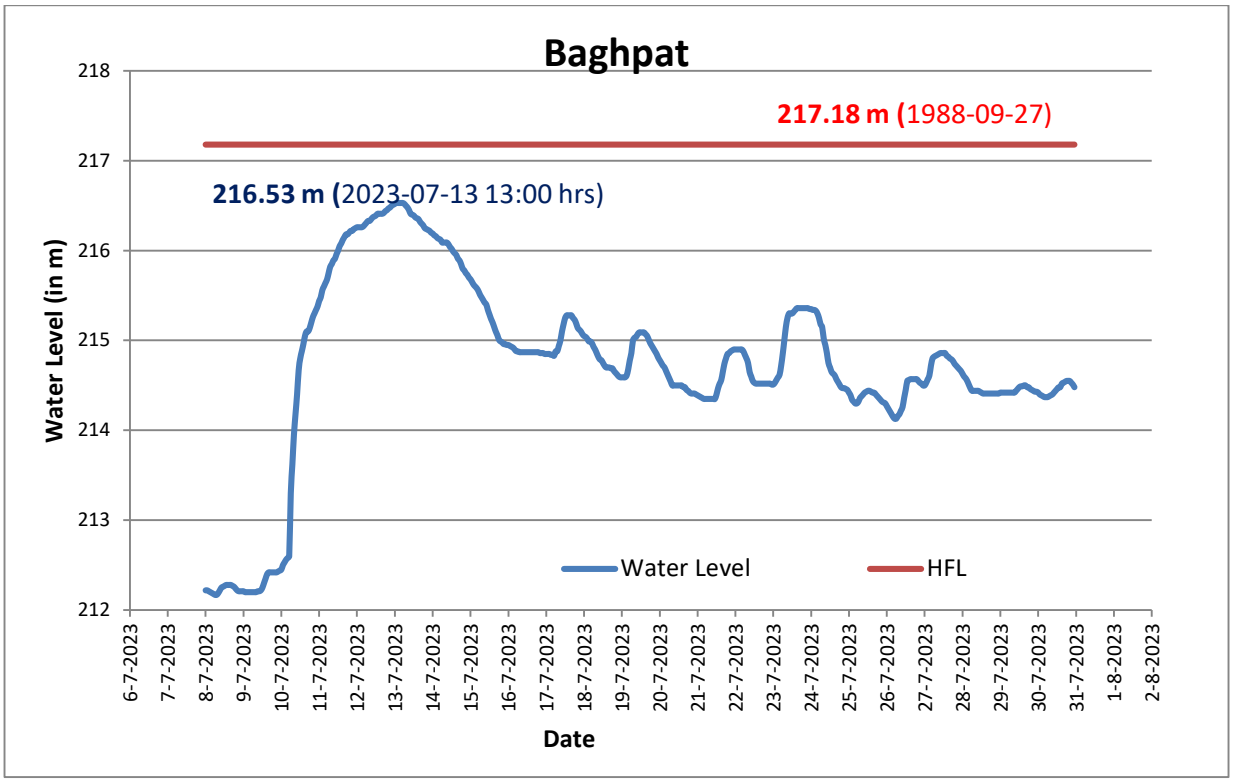


Fig. 2.14: Stage (WL) hydrograph Baghpat during July 2023

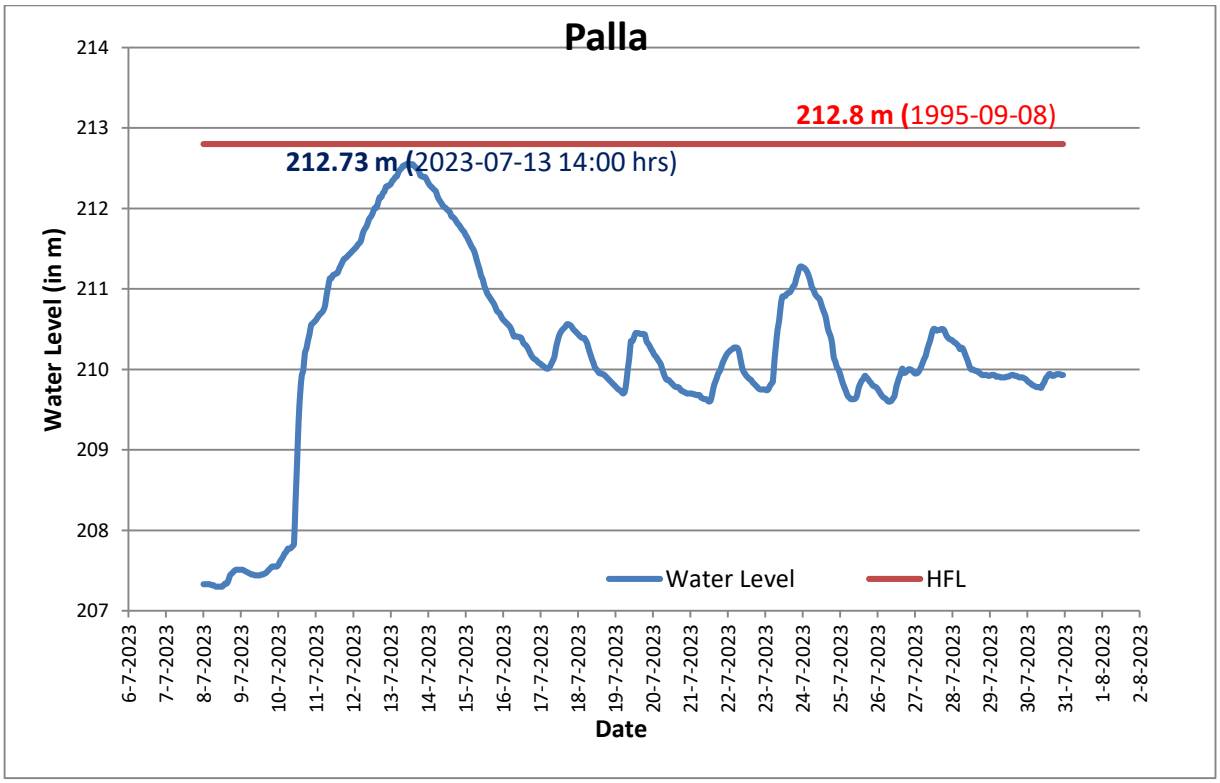


Fig. 2.15: Stage (WL) hydrograph at Palla during July 2023

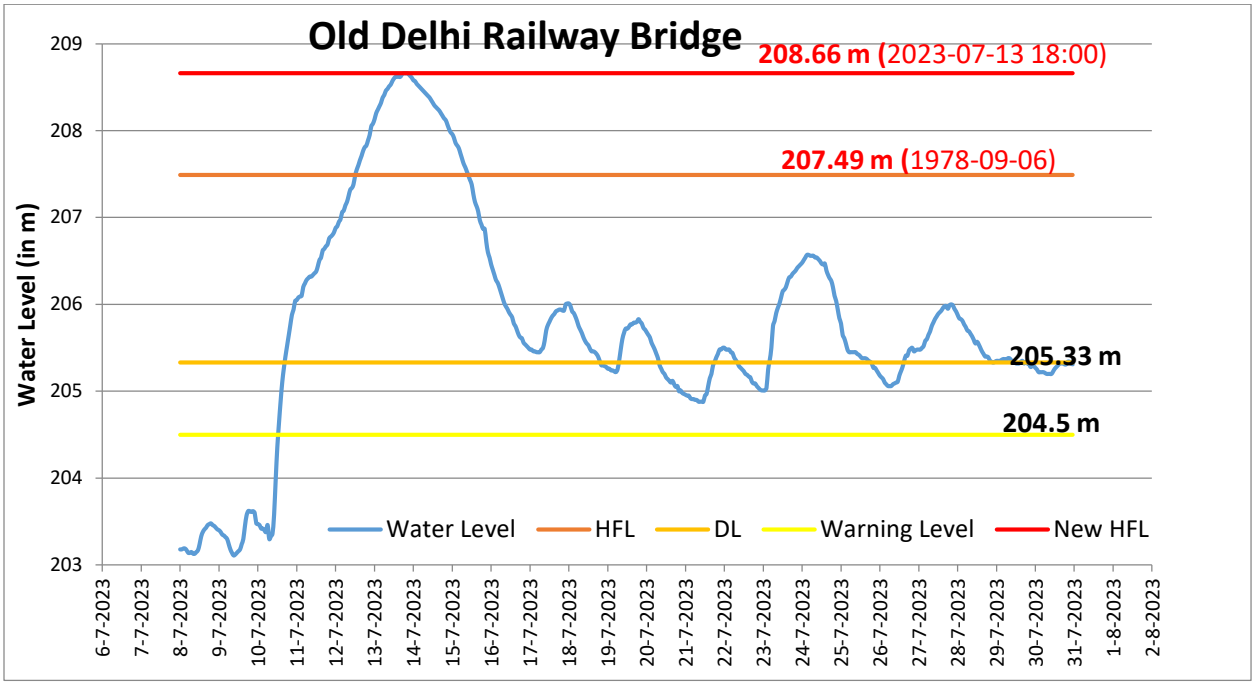


Fig. 2.16: Stage (WL) hydrograph at Old Delhi Railway Bridge during July 2023

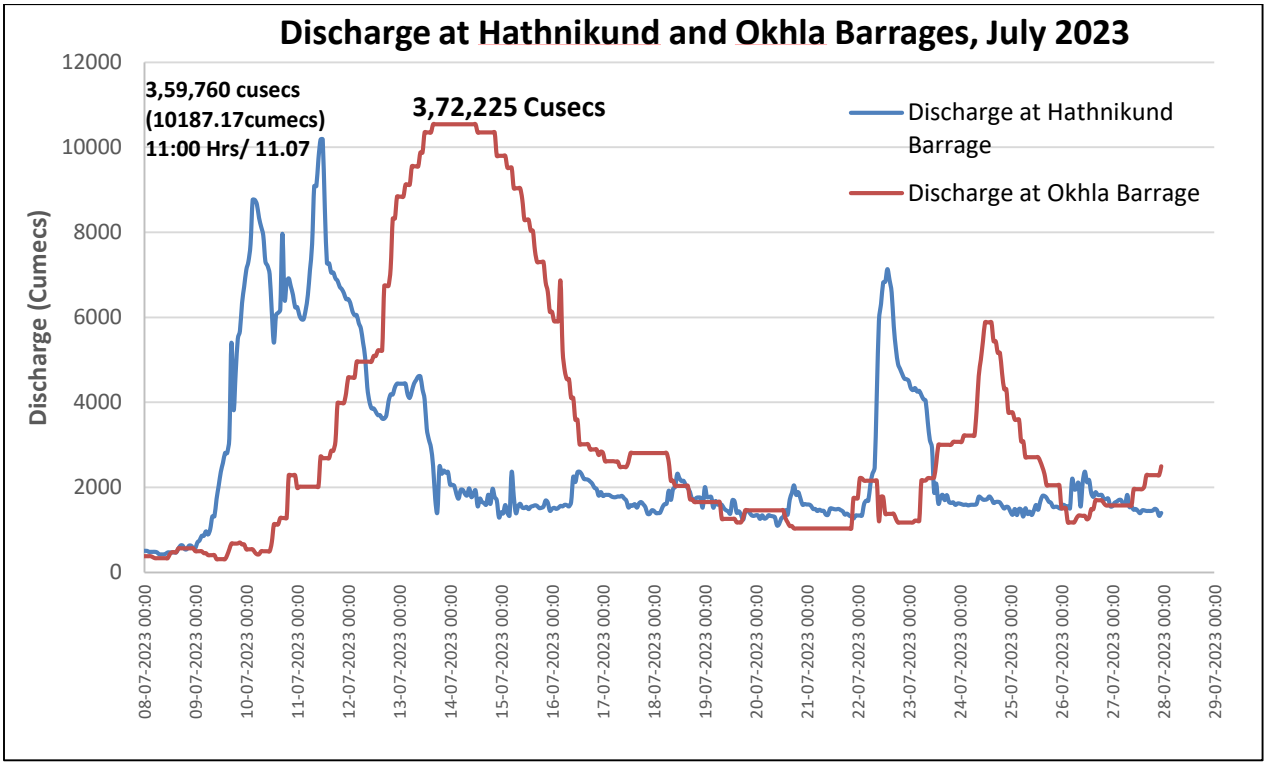


Fig. 2.17: Discharge from Hathnikund and Okhla barrages during July 2023

Note-Above are the observed reported discharge. The discharge at Hathnikund barrage has been corrected as there was some error in their computation methodology and used subsequently in the sudy. However, the above graph is useful to indicate the flood propagation at the two locations.

2.8 Conclusions

The conclusions drawn from detail catchment representative rainfall analysis during the period 09-13th July, 2023 utilizing IMD Gridded Rainfall data and comparing it with catchment representative rainfall for the period 1970 to 2023 is summarised in **Table 2.8**

Table 2.8: Analysis of the rainfall data for floods during the year 1978 and 2023

S. No.	Event	In 1978	In 2023	% Increase in 2023 w.r.t 1978
1	Annual maximum Sum of 5 days Rainfall in Catchment upto Hathnikund (mm) Catchment Area- 11397 sq km	222.09 mm (31.08.1978 to 04.09.1978)	316.94 mm (09-13, July 2023)	+42.7%
2	Annual maximum Sum of 5 days Rainfall in Catchment upto Mawi G&D site (mm) Catchment Area- 15683 sq km	230.8 mm (31.08.1978 to 04.09.1978)	303.6 mm (09-13, July 2023)	+31.5%
3.	Annual maximum Sum of 5 days Rainfall in entire catchment uptoOld Delhi railway bridge (mm) Catchment Area- 17882 sq km	223.12 mm (31.08.1978 to 04.09.1978)	276.25 mm (09-13, July 2023)	+23.8%
4.	Water Levels at Old Delhi railway bridge (m)	207.49 m 06 Sep 1978	208.66 m 13 July 2023	+ 1.17 m

From the analysis of catchment representative 5-day cumulative rainfall data as given above, it has been found that the catchment representative rainfall at old Delhi railway bridge in 2023 is 23.8% more in comparison to rainfall of year 1978. The catchment representative rainfall inyear 2023 at Mawi G&D site is about 31.5% more in comparison to rainfall of year 1978.The catchment representative rainfall in year 2023 at Hathnikund barrage site is about 42.7% more in comparison to rainfall of year 1978. The cumulative 5-day catchment representative rainfall during July 2023 at Hathnikund barrage and Mawi G&D site corresponds to rainfall of about 100 year return period.

From the Stage Hydrograph analysis at various Hydrological Observations (HO) sites on river Yamuna as well as from rainfall analysis in Yamuna catchment, it can be concluded that rainfall during 9th July, to 13th July, 2023 period was one of the major causative factor for extreme flooding in Delhi and other locations along the reach of river Yamuna.

3 Flood Frequency Analysis

The chapter is about computation of annual peak discharge at Hathnikund Barrage, Old Delhi Rail Bridge & Okhla Barrage and finding discharge corresponding to 5, 10, 25, 50,100,200 & 500 year return period flood at Hathnikund Barrage, Old Delhi Rail Bridge and Okhla Barrage.

3.1 Annual Peak Discharge at Hathnikund Barrage, Delhi Rail Bridge & Okhla Barrage

3.1.1 Hathnikund Barrage

Irrigation Department, Govt. of Haryana provided the annual maximum inflow discharge observed at Hathnikund Barrage from 1971-2023. Further, the revised discharge computations for 2014-2023 during the high flow period were submitted by BCD (N&W) Dte. CWC to Hydrology (NE) Dte. CWC, as received from project authorities. Project Authority informed that during 2020, there was no free flow (controlled flow) from the barrage due to unavailability of gate opening data. The flood frequency analysis has been conducted on data of latest 30 years that is 1994-2023 for estimation of return period floods. The annual maxima from 1994-2023 is given in **Table 3.1**

Table 3.1: Hathnikund Barrage Inflows

Year	Max Observed Peak Discharge (Cumec)	Max Observed Peak Discharge (Cusec)
1994	4247	149968
1995	15188	536338
1996	7867	277803
1997	11295	398849
1998	15340	541700
1999	7226	255168
2000	7899	278953
2001	7291	257481
2002	5875	207449
2003	1631	57607
2004	1547	54619
2005	2953	104279
2006	2950	104158
2007	2027	71564

Year	Max Observed Peak Discharge (Cumec)	Max Observed Peak Discharge (Cusec)
2008	7738	273251
2009	7938	280303
2010	14055	496338
2011	12110	427641
2012	1865	65869
2013	15225	537643
2014	9760	344642
2015	7370	260277
2016	8537	301454
2017	8537	301454
2018	13327	470634
2019	18480	652584
2020	1531	54065
2021	5222	184395
2022	6481	228854
2023	11962	422431

3.1.2 Old Delhi Rail Bridge

The monsoon peak discharge data (June to September) for period 1970 to 2020 at Delhi Railway Bridge has been considered. This data has been taken from water year book (June 2020-May 2021) of Yamuna basin shared by Yamuna Basin Organisation. The monsoon flood peak derived for period 1970 to 2020 at Delhi Railway Bridge HO site is given in **Table 3.2**

Table 3.2: Old Delhi Railway Bridge Inflows

Year	Max Observed Peak Discharge (Cusec)	Max Observed Peak Discharge (Cumec)
1970	65930	1867
1971	103516	2931
1972	89946	2547
1973	134885	3820
1974	106267	3009
1975	312827	8859

Year	Max Observed Peak Discharge (Cusec)	Max Observed Peak Discharge (Cumec)
1976	329083	9319
1977	158229	4481
1979	40714	1153
1980	106429	3014
1981	67988	1925
1982	45025	1275
1983	141691	4012
1984	43115	1221
1985	70274	1990
1986	62413	1767
1987	5239	148
1988	199245	5642
1989	153141	4337
1990	77444	2193
1991	17915	507
1992	109592	3103
1993	47486	1345
1994	97696	2767
1995	248165	7028
1996	91561	2593
1997	183877	5207
1998	119468	3383
1999	68784	1948
2000	118871	3366
2001	122758	3476
2002	75065	2126
2003	61301	1736
2004	25292	716
2005	45985	1302
2006	29195	827
2007	40364	1143
2008	74840	2119

Year	Max Observed Peak Discharge (Cusec)	Max Observed Peak Discharge (Cumec)
2009	50329	1425
2010	122413	3466
2011	71255	2018
2012	43049	1219
2013	114381	3239
2014	28012	793
2015	37868	1072
2016	42001	1189
2017	30567	866
2018	87935	2490
2019	102056	2890
2020	29275	829
2021	42376	1200
2022	67166	1902
2023	247160	6999

Note: Data consistency for year 2021-23 was done at later stages. Therefore flood Frequency analysis has been done for the values up to 2020 which make no difference as far as outcome is concerned.

3.1.3 Okhla Barrage

Irrigation Department, Govt. of Uttar Pradesh provided the annual maximum discharge observed at Okhla Barrage from 1993 to 2023 vide letter dated 20.09.2023. The same is given in **Table 3.3**

Table 3.3: Okhla Barrage Inflows

Year	Max Observed Peak Discharge (Cusec)	Max Observed Peak Discharge (Cumec)
1993	73309	2076.0
1994	92760	2626.8
1995	259854	7358.5
1996	136720	3871.6
1997	176087	4986.4
1998	165306	4681.1
1999	73858	2091.5

Year	Max Observed Peak Discharge (Cusec)	Max Observed Peak Discharge (Cumec)
2000	100730	2852.5
2001	75034	2124.8
2002	72940	2065.5
2003	44195	1251.5
2004	18522	524.5
2005	48417	1371.1
2006	24823	702.9
2007	27627	782.3
2008	105835	2997.0
2009	69206	1959.8
2010	287885	8152.3
2011	126520	3582.8
2012	56007	1586.0
2013	365573	10352.3
2014	30655	868.1
2015	44404	1257.4
2016	50009	1416.1
2017	39864	1128.9
2018	79390	2248.2
2019	174968	4954.7
2020	25604	725.1
2021	62745	1776.8
2022	116874	3309.6
2023	372225	10540.6

Note: There is some error in computational methodology at Okhla Barrage, which the project authorities are reconciling in consultation with IIT, Delhi.

3.2 Frequency Analysis

For determination of 50 year, 100 year, 200 year and 500 year return period flood at Hathnikund Barrage, Delhi Rail Bridge and Okhla Barrage, flood frequency analysis has been used.

Since frequency analysis is a univariate analysis, detection of effects of change, identification of nature of any change detected and appropriate adjustment of the data are pre-requisite steps required before frequency model can be used to make probability estimates. Therefore, this data has been subjected to Turning Point Test for checking randomness, Outlier tests & Trend test - Spearman Rho Test

The monsoon peak flood values have been subjected to flood frequency analysis using Gumble and Log-Pearson Type-III distribution. The best fit has been determined using D-index test. Distribution with lower D-index value is considered better fit.

3.3 D-Index results & return period floods

3.3.1 Hathnikund Barrage

The result of D-Index test on annual maximum discharge data on Hathnikund Barrage is given below:

Sl. No	Distribution	D-Index value
1	Gumble's	0.836
2	Log-Pearson	0.882

Therefore, Gumble distribution is a better fit. The return period floods are given in table below:

Return Period	Discharge (cumec)	90%U confidence limit	90%L confidence limit
5	11541	13752	9330
10	14327	17313	11341
25	17847	21873	13821
50	20458	25275	15641
100	23050	28661	17439
200	25633	32041	19224
500	29040	36505	21574

3.3.2 Old Delhi Rail Bridge

The result of D-Index test on annual maximum discharge data on Old Delhi Rail Bridge is given below:

S No	Distribution	D-Index value
1	Gumble's	2.073
2	Log-Pearson	2.393

Therefore, Gumble distribution is a better fit. The return period floods are given in table below:

Return Period	Discharge (cumec)	90%U confidence limit	90%L confidence limit
5	4025	4721	3330
10	5157	6096	4217
25	6587	7852	5319
50	7648	9162	6131
100	8701	10464	6934
200	9748	11763	7732
500	11131	13480	8783

3.3.3 Okhla Barrage

The return period flood at Okhla Barrage has been determined as per Gumbel distribution because Gumble distribution was best fit for both Hathnikund Barrage and Delhi Rail Bridge among Gumble and LPT-III. The return period floods are given in table below:

Return Period	Discharge (cumec)	90%U confidence limit	90%L confidence limit
5	5040	6269	3811
10	6614	8274	4954
25	8603	10841	6365
50	10079	12756	7401
100	11543	14663	8424
200	13003	16565	9440
500	14928	19078	10778

It may be noted that in comparison to Delhi Railway Bridge, the return period flood at Okhla barrage seems to be higher. This could be attributed to some errors in computations of inflow discharge at Okhla barrage.

3.4 Conclusions

The discharge corresponding to return period of 5, 10, 25, 50,100, 200 & 500 years have been computed at Hathnikund, Delhi Railway Bridge and Okhla Barrage by utilising the past hydrological data available. As Hathnikund released value have already been reconciled and discharge at Old Delhi Railway Bridge are observed, hence both are considered consistent .Further, discharge values at Okhla are to be reconciled by project authority. However, as far as the analysis of flood in Yamuna in Delhi is concerned, the discharge values at Old Delhi Railway Bridge are most important which are consistent.

The discharge of different return year period flood is utilised as a key input for carrying out 2D model study for estimation of area under submergence, drainage congestion at various drains in Delhi NCR region, knowing the afflux at various locations in river Yamuna and potential overtopping of embankments as elaborated in chapter 5 of the report. The flood discharge of different year return period would also guide in planning of bank protection and various structures of flood protection along the course of river Yamuna.

4 Carrying Capacity of River Yamuna

4.1 Introduction

The carrying capacity of flood discharge in the reach of river Yamuna has been carried out using the surveyed river cross sections supplied by Irrigation & Water Resource Department, Government of Haryana at an interval of 500 m to 1000 m. The river cross sections as supplied is given in **Table 4.1**.

Table 4.1: Cross section details of river Yamuna supplied by I&WRD, Government of Haryana

Sr. No.	Division	Cross section data supplied
1	Yamuna Nagar Division	From RD 900 m to 59900 m downstream of Hathnikund barrage
2	Karnal Division	From RD 6979 m to 70980 m
3	Panipat Division	From RD 0 m to 38500 m
4	Bega bund Rai Division	From RD 0 m to 4724 m
5	Sonipat Division	From RD 0 m to 9500 m
6	Rai Division (RD 0m to 22112 m total)	From RD 0 m to 7879 m - Mehendipur Jajjal bund From RD 500 m to 2667 m - Jajjal bund From RD 500 m to 1935 m – Jajjal Jhundpur bund From RD 500 m to 2392 m – Tanda bund From RD 500 m to 7239 m – Tanda Khurampur bund
7	Delhi Division of Haryana	From RD 0 m to 3500 m

The carrying capacity of flood discharge for each of the above reaches of river Yamuna has been carried out by 1 Dimensional water profile simulation study on HEC-RAS. As the cross sections were surveyed from bunds to bunds where bunds are existing, hence river channel and flood plain between channel and bund are envisaged in the bathymetry. Accordingly, the equivalent value of Manning's n has been adopted as 0.030. The reach of river Yamuna from Hathnikund barrage to Delhi-Haryana border is shown in **Fig. 4.1**.

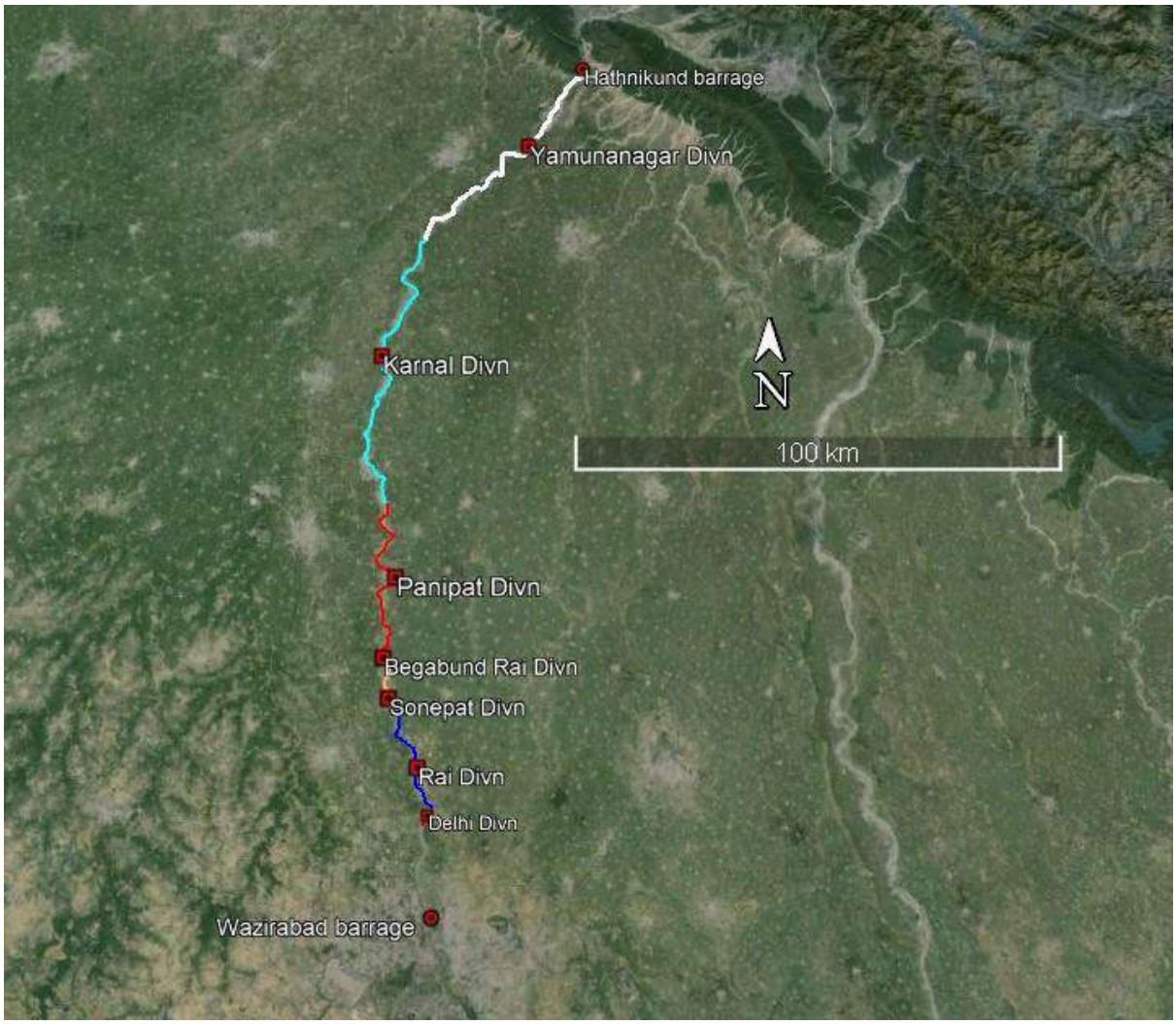


Fig. 4.1: Reach of river Yamuna from Hathnikund barrage to Delhi-Haryana border

4.2 Simulation results for the reach of river Yamuna from RD 900 m to 59900 m downstream of Hathnikund barrage of Yamuna Nagar Division

For this reach of river, using the surveyed cross sections available at every 1000 m the HEC-RAS model set up was completed for one dimensional water profile study. The discharge has been applied as upstream boundary. The normal depth has been adopted as downstream boundary applied at last cross section of the study reach. The HEC-RAS model set-up is shown in **Fig. 4.2**. From the water profile study the discharge carrying capacity has been estimated about 21000 cumec from RD 900 m to 5900 m, 11000 cumec from RD 6900 m to 15900 m, 4000 cumec from RD 16900 m to 23900 m and 3000 cumec from RD 24900 m to 59900 m. The simulation results are given in **Table 4.2**.The longitudinal profile of the river consisting of water bed profile, water surface profile, left bund profile and right bund profile is given in **Fig. 4.3.**

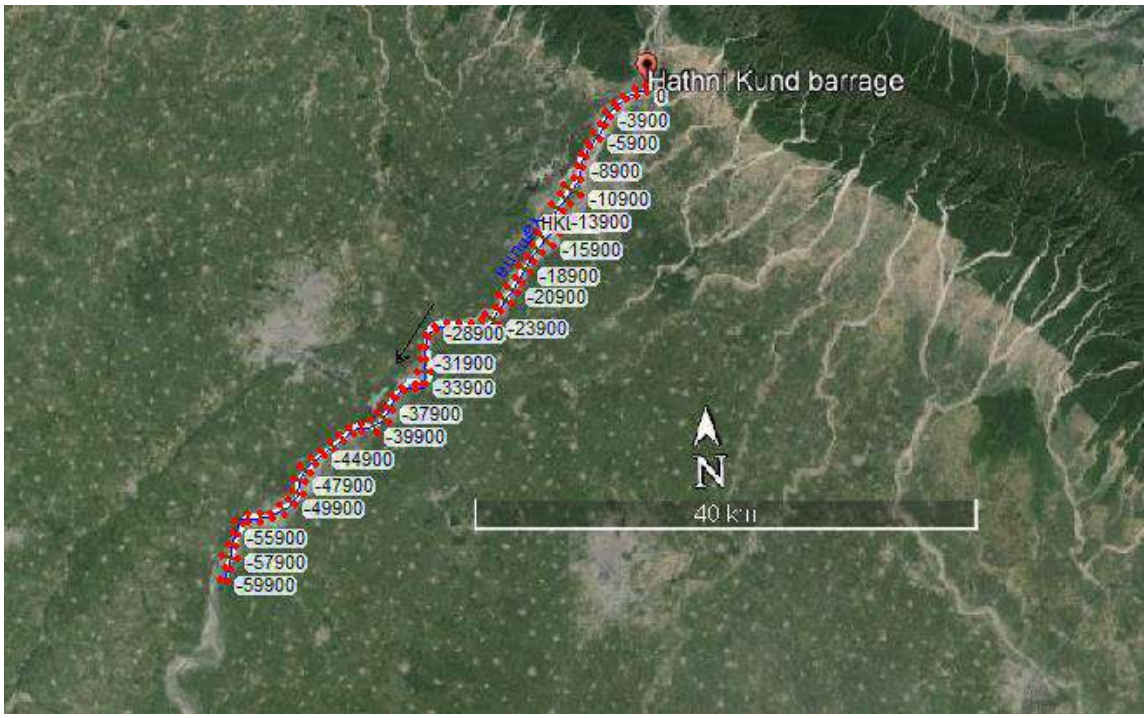


Fig. 4.2: HEC-RAS Model set up for the reach of river Yamuna from Hathnikund barrage up 59900 m downstream

Table 4.2: Water profile simulation results of river Yamuna from RD 900 m to 59900 m of Yamuna Nagar Division

(Note: LOB represents left bank/bund elevation, ROB represents righy bank/bund elevation)

Reach	River Sta	Discharge	Rive bed Elev	Water surface Elev	LOB Elev	ROB Elev	Flow width
	(m)	(cumec)	(m)	(m)	(m)	(m)	(m)
HKBDS	900	21000.0	315.84	330.53	332.81	328.94	539.34
HKBDS	1900	21000.0	313.39	326.49	329.63	328.84	328.37
HKBDS	2900	21000.0	310.54	322.12	327.46	326.42	365.00
HKBDS	3900	21000.0	307.88	320.12	322.35	327.52	542.01
HKBDS	4900	21000.0	305.45	315.39	320.00	323.81	356.99
HKBDS	5900	21000.0	303.16	311.83	318.25	319.71	670.92
HKBDS	6900	11000.0	299.92	309.20	303.71	309.87	302.26
HKBDS	7900	11000.0	297.79	307.08	307.51	305.96	484.34
HKBDS	8900	11000.0	295.77	304.07	303.08	308.44	446.36
HKBDS	9900	11000.0	292.99	299.62	300.20	299.30	602.21
HKBDS	10900	11000.0	289.67	296.69	304.20	301.61	800.61
HKBDS	11900	11000.0	286.54	294.71	297.60	297.39	520.88

Reach	River Sta	Discharge	Rive bed Elev	Water surface Elev	LOB Elev	ROB Elev	Flow width
	(m)	(cumec)	(m)	(m)	(m)	(m)	(m)
HKBDS	12900	11000.0	285.97	293.23	295.96	296.78	777.23
HKBDS	13900	11000.0	283.45	290.00	293.58	294.60	772.29
HKBDS	14900	11000.0	281.24	288.04	290.46	290.21	1362.0
HKBDS	15900	11000.0	280.28	284.37	288.41	287.14	1006.6
HKBDS	16900	4000.00	277.24	282.76	283.64	284.36	931.08
HKBDS	17900	4000.00	276.50	281.53	281.98	281.82	587.38
HKBDS	18900	4000.00	275.61	279.29	280.23	280.46	886.66
HKBDS	19900	4000.00	273.68	277.48	278.49	277.96	769.01
HKBDS	20900	4000.00	271.65	275.60	277.01	275.77	1091.1
HKBDS	21900	4000.00	269.68	274.50	275.26	276.74	1058.1
HKBDS	22900	4000.00	267.73	272.17	273.27	275.65	417.79
HKBDS	23900	4000.00	265.57	270.58	280.43	275.17	889.80
HKBDS	24900	3000.00	263.82	269.99	272.01	270.13	577.90
HKBDS	25900	3000.00	263.93	269.62	270.62	270.48	500.69
HKBDS	26900	3000.00	262.88	269.25	269.76	268.86	511.33
HKBDS	27900	3000.00	262.37	269.09	269.68	269.73	642.17
HKBDS	28900	3000.00	262.09	268.58	269.46	269.40	306.79
HKBDS	29900	3000.00	261.75	267.77	268.48	268.51	307.57
HKBDS	30900	3000.00	261.49	267.17	268.14	267.81	492.81
HKBDS	31900	3000.00	261.13	266.35	268.63	267.55	381.23
HKBDS	32900	3000.00	260.49	266.39	266.78	266.83	1097.2
HKBDS	33900	3000.00	259.67	265.96	266.53	266.30	277.24
HKBDS	34900	3000.00	259.38	265.44	265.22	266.05	420.43
HKBDS	35900	3000.00	258.92	264.98	265.22	265.26	422.05
HKBDS	36900	3000.00	258.76	264.31	263.97	264.65	340.58
HKBDS	37900	3000.00	258.44	263.39	264.81	264.44	532.61
HKBDS	38900	3000.00	257.63	262.59	264.02	263.97	1240.1
HKBDS	39900	3000.00	257.23	262.23	262.87	263.18	1239.8
HKBDS	40900	3000.00	256.84	261.69	262.58	262.65	580.24
HKBDS	41900	3000.00	255.76	261.05	262.01	260.52	521.73
HKBDS	42900	3000.00	254.63	260.75	261.74	260.04	683.02

Reach	River Sta	Discharge	Rive bed Elev	Water surface Elev	LOB Elev	ROB Elev	Flow width
	(m)	(cumec)	(m)	(m)	(m)	(m)	(m)
HKBDS	43900	3000.00	253.86	260.05	261.40	260.55	589.43
HKBDS	44900	3000.00	253.61	259.44	259.65	260.15	534.30
HKBDS	45900	3000.00	253.29	259.08	259.63	259.25	724.46
HKBDS	46900	3000.00	252.88	258.50	259.88	258.87	890.96
HKBDS	47900	3000.00	252.43	257.59	258.43	258.20	916.11
HKBDS	48900	3000.00	251.57	257.00	256.72	256.85	971.94
HKBDS	49900	3000.00	251.19	256.29	256.42	256.32	628.68
HKBDS	50900	3000.00	250.87	255.90	256.16	257.15	802.55
HKBDS	51900	3000.00	250.27	255.36	256.14	256.48	430.55
HKBDS	52900	3000.00	249.81	254.87	254.66	256.50	607.14
HKBDS	53900	3000.00	249.54	254.45	255.75	256.11	599.75
HKBDS	54900	3000.00	248.43	254.10	254.83	255.30	659.09
HKBDS	55900	3000.00	248.34	253.43	254.45	257.60	398.80
HKBDS	56900	3000.00	247.88	252.77	254.00	253.83	551.60
HKBDS	57900	3000.00	247.67	252.60	254.07	253.48	1289.8
HKBDS	58900	3000.00	247.66	252.22	254.88	254.75	430.63
HKBDS	59900	3000.00	247.18	251.72	253.13	253.38	398.74

Note:- In some reaches, spills are allowed beyond banks as informed by the I&WRD, Govt. of Haryana .Further embankment have been provided in certain reaches for protection of particular area.

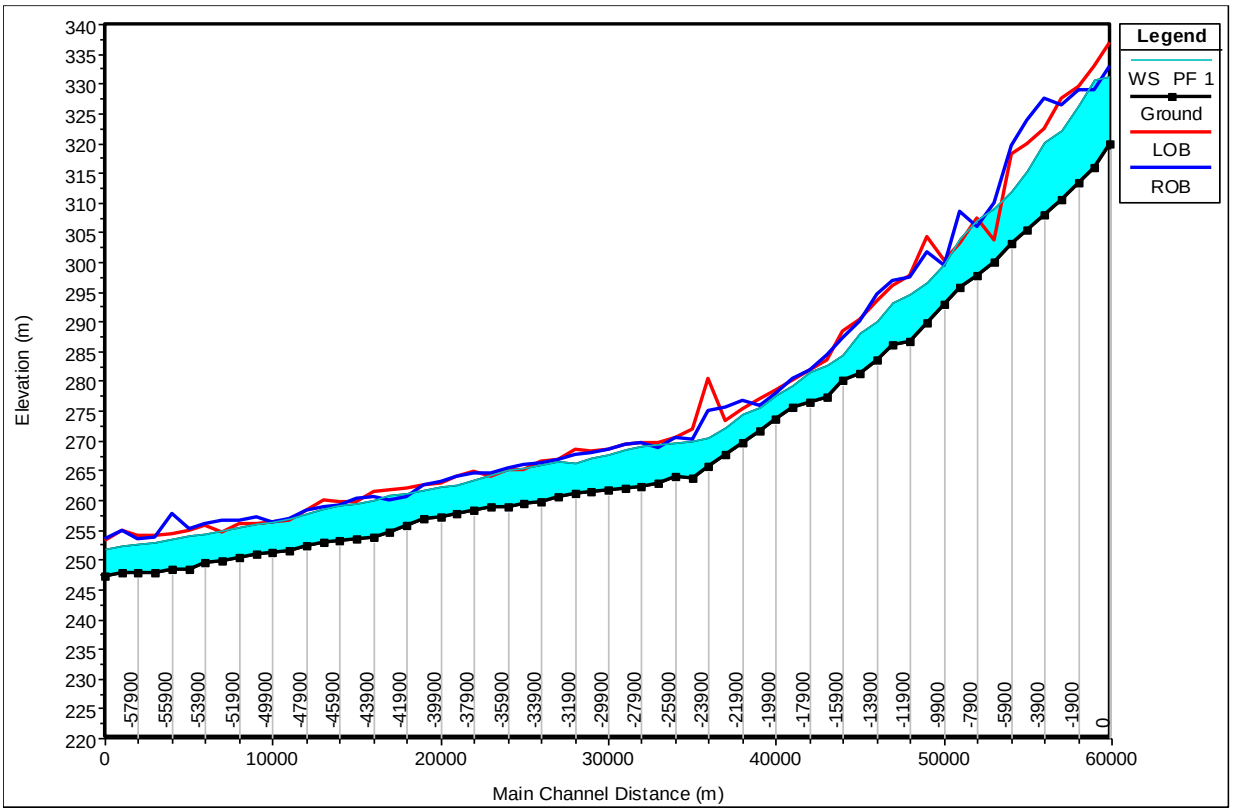


Fig. 4.3: Longitudinal profile of river Yamuna (RD 900 to 59900 m) of Yamuna Nagar Div.

4.3 Simulation results for the reach of river Yamuna from RD 6979 m to 70980 m of Karnal Division

The cross sections of river Yamuna were provideded by Yamuna Nagar Division from RD 900 m to 59900 m downstream of Hathnikund barrage. Further downstream cross sections were provided by Karnal Division from RD 6979 m to 70980 m at every 1000 m. For this reach of river, using the surveyed cross sections available at every 1000 m the HEC-RAS model set up was completed for one dimensional water profile study. The discharge has been applied as upstream boundary. The normal depth has been adopted as downstream boundary applied at last cross section of the study reach. From the water profile study the discharge carrying capacity has been estimated about 1000 cumec from RD 6979 m to 15979 m, 5000 cumec from RD 16979 m to 19979 m, 11000 cumec from RD 20979 m to 49980 m, 5000 cumec from RD 50980 m to 58980 m and 6000 cumec from RD 59980 m to 70980 m. The simulation results are given in **Table 4.3.** The longitudinal profile of the river consisting of water bed profile, water surface profile, left bund profile and right bund profile is given in **Fig. 4.4.**

Table 4.3: Water profile simulation results from RD 6979 m to 70980 m of Karnal Divn

Reach	River Sta	Discharge	Rive bed	Water surface	LOB Elev	ROB Elev	Flow width
	(m)	(cumec)	(m)	(m)	(m)	(m)	(m)
Karnal	6979	1000	252.95	257.65	260.1	258.5	1406.01
Karnal	7979	1000	252.76	257.34	259.73	258.73	1829.93
Karnal	8979	1000	253.43	256.74	260.11	259.1	1246.00
Karnal	9979	1000	252	256.36	257.71	257.47	1480.78
Karnal	10979	1000	252.67	256.16	259.51	258.03	942.96
Karnal	11979	1000	252.12	256.05	259.86	257.88	785.74
Karnal	11980	1000	252.09	255.91	258.71	255.85	2000.83
Karnal	12979	1000	251.54	255.89	258.83	256.4	476.94
Karnal	14979	1000	250.14	255.85	257.57	255.59	2721.13
Karnal	15979	1000	251.74	255.77	257.78	255.69	5009.63
Karnal	16979	5000	251.12	255.42	257.5	256.39	5778.69
Karnal	17979	5000	250.31	255.13	257.37	258.65	5954.15
Karnal	18979	5000	250.06	255.01	256.45	258.09	4709.82
Karnal	19979	5000	249.84	254.93	255.38	257.81	4685.42
Karnal	20979	11000	249.44	254.72	255.25	257.06	4399.61
Karnal	21979	11000	248.13	254.35	254.81	256.17	4558.08
Karnal	22979	11000	248.56	253.43	255.58	255.88	4155.80
Karnal	23979	11000	247	253.21	255.43	255.32	4089.64
Karnal	24979	11000	247.14	253.01	255.8	254.53	4062.67
Karnal	25979	11000	247.05	252.71	255.81	254	4358.66
Karnal	26979	11000	246.74	252.42	255.07	254.49	4640.97
Karnal	27979	11000	246.06	252.15	253.73	252.75	3355.01
Karnal	28979	11000	246.02	251.96	254.2	252.77	2399.81
Karnal	29979	11000	245.8	251.69	253.9	252.53	1961.72
Karnal	30979	11000	245.99	251.17	253.9	252.2	2581.37
Karnal	31979	11000	246.01	250.73	253.42	250.87	2966.96
Karnal	32979	11000	244.59	250.47	252.97	250.67	3296.39
Karnal	33979	11000	244.32	250.29	251.87	251.1	3408.27

Reach	River Sta	Discharge	Rive bed	Water surface	LOB Elev	ROB Elev	Flow width
	(m)	(cumec)	(m)	(m)	(m)	(m)	(m)
Karnal	34979	11000	243.93	249.99	252.09	250.89	2612.70
Karnal	35979	11000	243.72	249.64	251.45	250.67	2824.32
Karnal	36979	11000	243.84	249.27	250.92	250.57	2942.63
Karnal	37979	11000	242.22	248.74	250.21	250.38	2401.04
Karnal	38980	11000	242.31	248.32	249.2	249.76	2071.67
Karnal	39980	11000	240.97	247.92	249.45	249.16	2284.24
Karnal	40980	11000	240.73	247.5	248.43	248.16	2451.94
Karnal	41980	11000	240.57	247.17	248.19	248.05	2358.26
Karnal	42980	11000	240.04	246.79	247.71	247.81	2303.80
Karnal	43980	11000	239.85	246.4	246.76	247.23	2211.08
Karnal	45980	11000	238.7	245.97	246.89	246.31	1676.26
Karnal	46980	11000	239.46	244.74	246.76	245.31	1943.26
Karnal	47980	11000	239.3	244.3	246.08	244.91	2282.26
Karnal	48980	11000	237.7	243.87	244.83	246.3	2368.28
Karnal	49980	11000	237.42	243.15	242.81	244.71	2095.05
Karnal	50980	5000	237.42	242.57	242.81	244.71	2082.72
Karnal	51980	5000	237.28	241.98	243.9	243.74	3160.59
Karnal	52980	5000	236.56	241.62	243.63	243.58	3377.02
Karnal	53980	5000	236.02	241.44	243.62	243.17	3565.32
Karnal	54980	5000	236.24	241.16	243.2	243.25	3193.67
Karnal	55980	5000	236.19	240.82	241.63	242.95	2660.67
Karnal	56980	5000	235.52	240.53	241.02	242.94	2641.08
Karnal	57980	5000	235.35	240.29	240.79	242.34	2583.66
Karnal	58980	5000	235.01	240.14	240.36	242.34	2482.73
Karnal	59980	6000	234.5	239.94	239.79	242.12	2473.27
Karnal	60980	6000	234.45	239.56	239.63	242.12	2461.91
Karnal	61980	6000	234.35	239.14	239.87	241.53	2980.70
Karnal	62980	6000	233.94	238.89	239.46	241.03	3379.86
Karnal	64980	6000	233.21	238.73	240.05	241.13	4375.94

Reach	River Sta	Discharge	Rive bed	Water surface	LOB Elev	ROB Elev	Flow width
	(m)	(cumec)	(m)	(m)	(m)	(m)	(m)
Karnal	65980	6000	233.21	238.43	238.87	240.34	4502.48
Karnal	66980	6000	232.72	238.31	239.27	239.81	4682.89
Karnal	67980	6000	232.72	238.2	239.46	239.82	3779.09
Karnal	68980	6000	232.06	238.04	238.16	239.29	2785.05
Karnal	69980	6000	232.01	237.84	238.2	239.39	2781.97
Karnal	70980	6000	232.06	237.56	238.21	239.25	2780.29

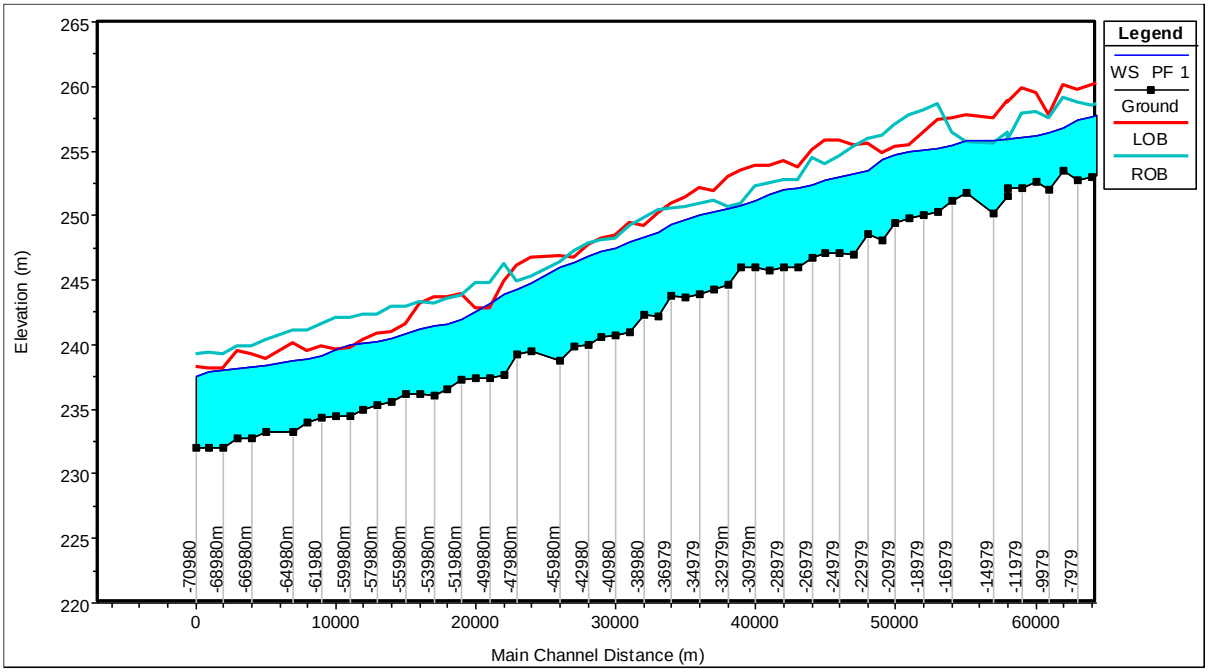


Fig. 4.4: Longitudinal profile of river Yamuna (RD 7979 m to 70890 m) of Karnal Division

4.4 Simulation results for the reach of river Yamuna from RD 0 m to 39000 m of Panipat Division

Cross sections of river Yamuna were provided by Karnal Division from RD 6979 m to 70980 m at every 1000 m. Further downstream cross sections were provided by Panipat Division from RD 0 m to 39000 m. For this reach of river, using the surveyed cross sections at every 1000 m the HEC-RAS model set up was completed for one dimensional water profile study. The discharge has been applied as upstream boundary. The normal depth has been adopted as downstream boundary applied at last cross section of the study reach. From the water profile study the discharge carrying capacity has been estimated about 11000 cumec from RD 0 m to 25000 m, 8000 cumec from RD 26000 m to 36000 m and 2000 cumec from RD 37000 m to 39000m. The simulation results are

given in **Table 4.4** The longitudinal profile of the river consisting of water bed profile, water surface profile, left bund profile and right bund profile is given in **Fig. 4.5.**

Table 4.4: Water profile simulation results of river Yamuna from RD 0 m to 39000 m of Panipat Division

Reach	River Sta	Discharge	River bed Elev	Water surface	LOB Elev	ROB Elev	Flow width
	(m)	(cumec)	(m)	(m)	(m)	(m)	(m)
Panipat	0	11000	230.67	237.25	236.45	238.12	1895.14
Panipat	500	11000	229.72	237.01	237.67	238.15	1505.08
Panipat	1000	11000	230.2	236.78	237.88	238.05	1757.81
Panipat	2000	11000	226.59	236.59	236.86	238.08	2587.27
Panipat	3000	11000	228.59	236.43	236.93	237.53	2851.39
Panipat	4000	11000	227.67	236.16	236.79	236.8	2284.92
Panipat	5000	11000	228.04	235.88	236.26	236.61	2452.32
Panipat	6000	11000	228.07	235.66	235.87	236.22	2545.71
Panipat	7000	11000	227.54	235.36	235.61	235.6	1820.64
Panipat	8000	11000	226.74	235.06	235.58	235.25	2090.86
Panipat	9000	11000	226.26	234.7	235.15	235.55	1851.48
Panipat	10000	11000	227.46	234.24	234.95	235.22	1766.62
Panipat	11000	11000	225.84	233.58	233.72	234.45	1412.30
Panipat	12000	11000	225.92	233.22	234.2	236.1	2920.75
Panipat	13000	11000	225.83	232.98	233.72	233.81	3135.25
Panipat	14000	11000	225.57	232.82	233.44	233.66	3361.74
Panipat	15000	11000	225.06	232.58	233.38	233.06	2359.43
Panipat	16000	11000	225.17	232.01	232.23	232.92	1445.31
Panipat	17000	11000	224.61	231.25	232.57	232.56	2469.14
Panipat	18000	11000	222.88	230.89	231.68	231.71	4319.75
Panipat	19000	11000	224.07	230.74	231.76	232.7	4132.86
Panipat	20000	11000	223.65	230.58	230.68	232.12	3377.41
Panipat	21000	11000	222.25	230.34	230.95	234.7	3295.57
Panipat	22000	11000	222.26	229.94	230.74	246.11	2458.30
Panipat	23000	11000	222.56	229.49	230.56	234.49	2434.16

Reach	River Sta	Discharge	River bed Elev	Water surface	LOB Elev	ROB Elev	Flow width
	(m)	(cumec)	(m)	(m)	(m)	(m)	(m)
Panipat	24000	11000	222.1	229.08	230.17	231.99	2730.64
Panipat	25000	11000	219.85	228.5	229.53	232.02	2644.19
Panipat	26000	8000	220.55	228.11	228	232.78	2336.68
Panipat	27000	8000	221.28	227.85	228.26	228.01	2515.52
Panipat	28000	8000	220.55	227.51	227.7	227.1	2663.90
Panipat	29000	8000	220.57	227.08	227.59	232.56	2536.54
Panipat	30000	8000	220.91	226.7	227.78	227.23	3172.04
Panipat	31000	8000	218.78	226.32	227.06	226.98	3654.41
Panipat	32000	8000	218.75	225.9	226.16	227.14	3126.31
Panipat	33000	8000	219.01	225.59	225.8	226.77	3863.90
Panipat	34000	8000	218.55	225.36	226.1	231.04	3992.67
Panipat	35000	8000	219.29	224.97	226.42	230.97	3567.61
Panipat	36000	8000	218.42	223.78	225.63	229.45	3066.78
Panipat	37000	2000	218.28	223.06	222.84	227.11	2117.53
Panipat	38000	2000	217.82	222.93	224.43	224.77	1593.01
Panipat	39000	2000	218.53	222.73	225.51	230.68	1869.19

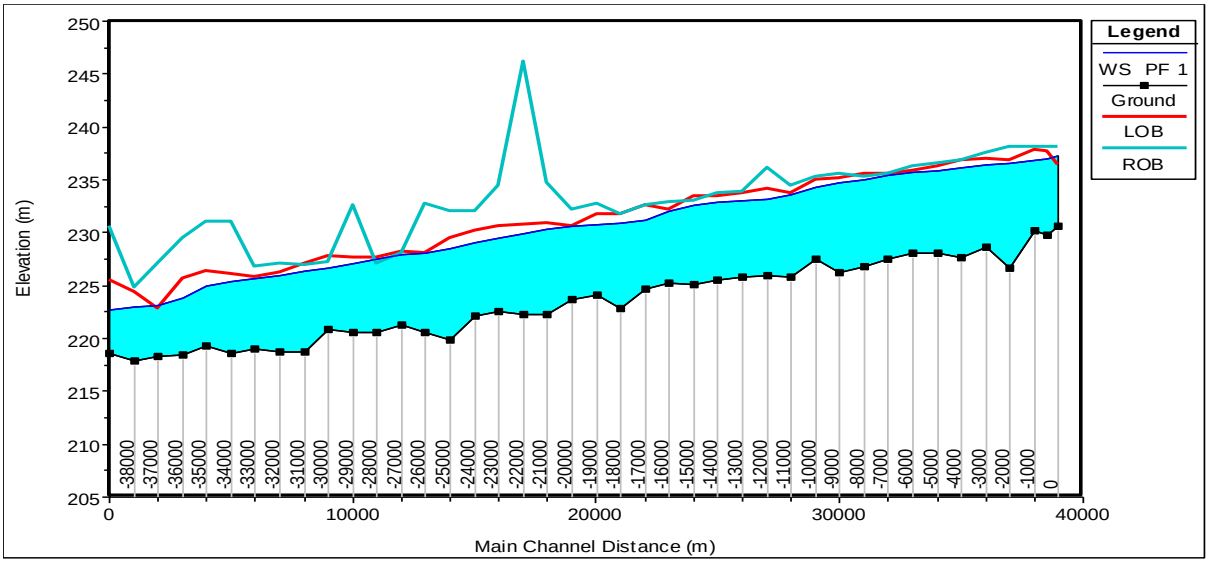


Fig. 4.5: Longitudinal profile of river Yamuna from RD 0 m to 39000 m of Panipat Division

4.5 Simulation results for the reach of river Yamuna from RD 0 m to 4724 m of Bega Bund Rai Division

For this reach of river, using the surveyed cross sections at every 500 m the HEC-RAS model set up was completed for one dimensional water profile study. The discharge has been applied as upstream boundary. The normal depth has been adopted as downstream boundary applied at last cross section of the study reach. From the water profile study the discharge carrying capacity has been estimated about 3500 cumec from RD 0 m to 2500 m and 13000 cumec from RD 3000 m to 4724 m. The simulation results are given in **Table 4.5.**The longitudinal profile of the river consisting of water bed profile, water surface profile, left bund profile and right bund profile is given in **Fig. 4.6.**

Table 4.5: Water profile simulation results of river Yamuna from RD 0 m to 4724 m of Bega Bund Rai Division

Reach	River Sta	Discharge	Rive bed Elev	Water surface Elev	LOB Elev	ROB Elev	Flow width
	(m)	(cumec)	(m)	(m)	(m)	(m)	(m)
Begabund	0	3500	214.92	222.91	223.61	223.5	1147.
Begabund	500	3500	214.48	222.66	223.97	222.87	1374.
Begabund	1000	3500	214.1	222.25	224.87	223.37	1264.
Begabund	1500	3500	214.11	222.28	225.01	223.54	2531.
Begabund	2000	3500	215.26	222.17	224.46	227.42	2350.
Begabund	2500	3500	215.2	221.84	224.63	222.49	1822.
Begabund	3000	13000	214.74	223.57	226.28	225.8	2406.
Begabund	3500	13000	216.16	223.47	224.17	224.17	4382.
Begabund	4000	13000	213.31	223.29	223.67	223.65	2955.
Begabund	4724	13000	213.31	222.99	223.64	223.86	2912.

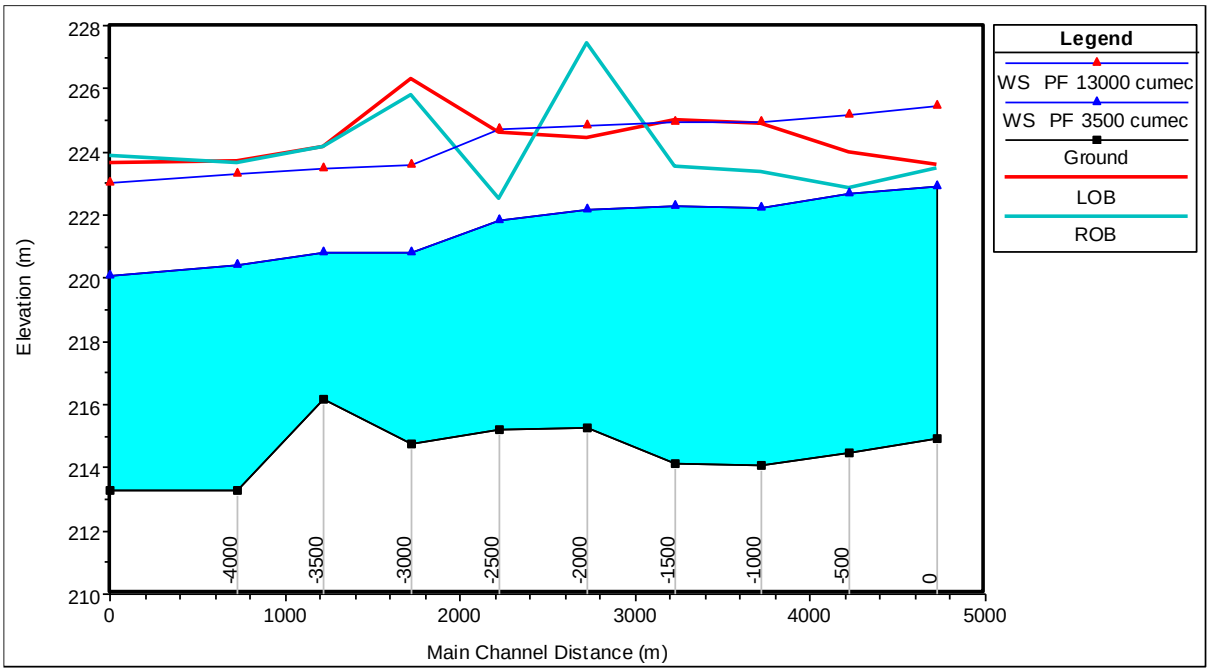


Fig. 4.6: Longitudinal profile of river Yamuna from RD 0 m to 4724 m of Rai Division

4.6 Simulation results for the reach of river Yamuna from RD 0 m to 9500 m of Sonipat Division

For this reach of river, using the surveyed cross sections at every 500 m the HEC-RAS model set up was completed for one dimensional water profile study. The discharge has been applied as upstream boundary. The normal depth has been adopted as downstream boundary applied at last cross section of the study reach. From the water profile study the discharge carrying capacity has been estimated about 9500 cumec from RD 0 m to 9500 m. The simulation results are given in **Table 4.6**. The longitudinal profile of the river consisting of water bed profile, water surface profile, left bund profile and right bund profile is given in **Fig. 4.7**.

Table 4.6: Water profile simulation results of river Yamuna from RD 0 m to 9500 m of Sonipat Division

Reach	River Sta	Discharge	Rive bed Elev	Water surface	LOB Elev	ROB Elev	Flow width
	(m)	(cumec)	(m)	(m)	(m)	(m)	(m)
Sonepat	0	9500	213.63	222.26	222.91	222.53	2979.47
Sonepat	500	9500	213.81	222.17	222.87	222.25	3056.28
Sonepat	1000	9500	214.27	222.05	222.54	223.57	3014.88
Sonepat	1500	9500	213.93	221.95	222.48	226.28	3170.57

Reach	River Sta	Discharge	Rive bed Elev	Water surface	LOB Elev	ROB Elev	Flow width
	(m)	(cumec)	(m)	(m)	(m)	(m)	(m)
Sonepat	2000	9500	215.11	221.87	222.76	224.22	3060.06
Sonepat	2500	9500	213.46	221.8	222.31	224.34	2892.21
Sonepat	3000	9500	214.22	221.73	222.38	227.92	2907.62
Sonepat	3500	9500	213.75	221.63	222.14	226.62	2801.84
Sonepat	4000	9500	213.89	221.5	221.83	222.13	2978.40
Sonepat	4500	9500	213.21	221.24	222.1	223.46	2090.36
Sonepat	5000	9500	213.77	220.95	222.41	222.28	2122.28
Sonepat	5500	9500	212.95	220.69	222.94	223.34	2080.87
Sonepat	6000	9500	213.64	220.46	221.67	222.69	1824.88
Sonepat	6500	9500	212.38	220.36	221.27	221.5	2196.06
Sonepat	7000	9500	213.52	220.22	220.88	220.81	2462.98
Sonepat	7500	9500	212.74	220	219.93	220.84	3026.42
Sonepat	8000	9500	212.14	219.71	220.18	222.32	2998.50
Sonepat	8500	9500	212.31	219.42	220.38	221.1	3061.72
Sonepat	9000	9500	212.19	219.03	220.38	223.59	3364.55
Sonepat	9500	9500	211.41	218.67	220.24	224.72	3457.08

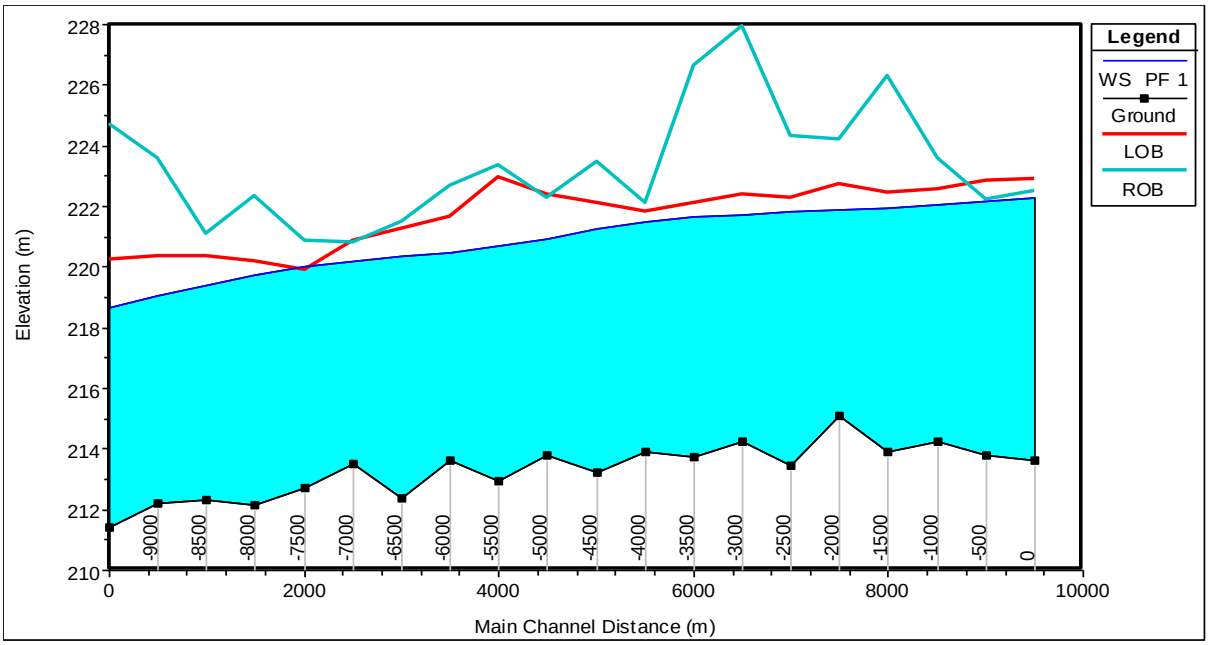


Fig. 4.7: Longitudinal profile of river Yamuna from RD 0 m to 9500 m of Sonipat Division

4.7 Simulation results for the reach of river Yamuna from RD 0 m to 22112 m of Mehendirpur Jajjal bund to Tanda bund of Rai Division

For this reach of river, using the surveyed cross sections at every 500 m the HEC-RAS model set up was completed for one dimensional water profile study. The discharge has been applied as upstream boundary. The normal depth has been adopted as downstream boundary applied at last cross section of the study reach. From the water profile study the discharge carrying capacity has been estimated about 2200 cumec from RD 0 m to 15373 m and 1200 cumec from RD 15873m to RD 22112m. The simulation results are given in **Table 4.7**. The longitudinal profile of the river consisting of water bed profile, water surface profile, left bund profile and right bund profile is given in **Fig. 4.8**

Table 4.7: Water profile simulation results of river Yamuna from RD 0 m to 22112 m of Mehendipur Jajjal bund to Tanda bund of Rai division

Reach	River Sta	Discharge	Rive bed	Water surfac	LOB Elev	ROB Elev	Flow width
	(m)	(cumec)	(m)	(m)	(m)	(m)	(m)
MJ-Tanda	0	2200	213.12	218.54	221.57	218.67	1334.04
MJ-Tanda	500	2200	212.72	218.41	221.3	218.96	1678.64
MJ-Tanda	1000	2200	212.8	218.27	221.02	220.12	1805.10
MJ-Tanda	1500	2200	212.1	218.18	221.21	219.44	1792.47
MJ-Tanda	2000	2200	211.16	218.15	220.75	218.53	1450.13
MJ-Tanda	2500	2200	211.46	218.09	220.68	218.24	755.90
MJ-Tanda	3000	2200	212.03	217.98	220.3	218.21	655.16
MJ-Tanda	3500	2200	212.03	217.65	219.9	218.19	464.91
MJ-Tanda	4000	2200	211.62	217.41	219.94	217.92	360.45
MJ-Tanda	4500	2200	211.93	217.23	219.6	217.42	755.14
MJ-Tanda	5000	2200	213	216.9	219.48	217.49	600.32
MJ-Tanda	5500	2200	212.02	216.74	219.7	218.39	1346.85
MJ-Tanda	6000	2200	211.63	216.55	219.84	218.16	1295.52
MJ-Tanda	6500	2200	210.2	216.49	217.72	220.04	2717.21
MJ-Tanda	7000	2200	210.31	216.38	217.84	220.2	2172.38
MJ-Tanda	7879	2200	210.92	216.14	219.69	223.16	759.48
MJ-Tanda	8379	2200	210.81	216.06	219.58	223.01	754.53
MJ-Tanda	8879	2200	211.04	215.99	218.9	219.26	3275.97
MJ-Tanda	9379	2200	211.16	215.87	219.02	219.38	3069.41

Reach	River Sta	Discharge	Rive bed	Water surfac	LOB Elev	ROB Elev	Flow width
	(m)	(cumec)	(m)	(m)	(m)	(m)	(m)
MJ-Tanda	9879	2200	208.05	215.85	219.11	219.12	3871.65
MJ-Tanda	10546	2200	211.25	215.79	219.11	219.47	2874.67
MJ-Tanda	11046	2200	208.95	215.72	218.65	215.73	4411.42
MJ-Tanda	11546	2200	209.06	215.66	218.46	215.64	4347.03
MJ-Tanda	12046	2200	208.95	215.59	218.35	215.73	3880.64
MJ-Tanda	12481	2200	208.83	215.52	218.43	215.62	3896.74
MJ-Tanda	12981	2200	208.92	215.43	218.52	215.81	3457.02
MJ-Tanda	13481	2200	208.77	215.34	218.8	216.95	3124.25
MJ-Tanda	13981	2200	209	215.22	218.89	215.59	2418.11
MJ-Tanda	14873	2200	209.15	214.87	216.01	215.9	1491.05
MJ-Tanda	15373	2200	209.26	214.6	216.16	215.06	959.71
MJ-Tanda	15873	1200	208.36	214.37	216.34	214.2	1612.82
MJ-Tanda	16373	1200	208.27	213.92	216.34	214.11	858.23
MJ-Tanda	16873	1200	208.39	213.75	215.88	214.18	917.18
MJ-Tanda	17373	1200	208.84	213.63	215.73	214.06	873.52
MJ-Tanda	17873	1200	208.04	213.46	215.06	213.55	893.34
MJ-Tanda	18373	1200	208.13	213.26	215.13	213.63	469.73
MJ-Tanda	18873	1200	208.31	213	215.38	213.8	546.89
MJ-Tanda	19373	1200	207.88	212.9	214.88	213.47	883.04
MJ-Tanda	19873	1200	207.2	212.67	214.81	213.95	888.69
MJ-Tanda	20373	1200	206.95	212.2	214.77	216.7	657.11
MJ-Tanda	20873	1200	207.11	212	214.53	211.65	913.23
MJ-Tanda	21373	1200	206.82	211.86	212.54	210.97	878.46
MJ-Tanda	22112	1200	205.86	211.66	214.14	210.51	1261.37

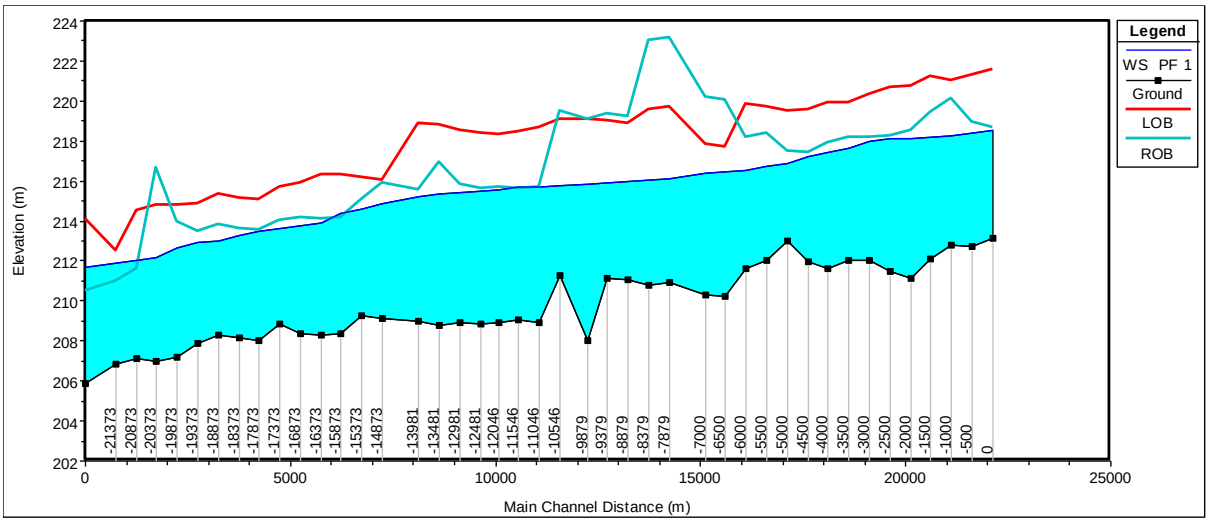


Fig. 4.8: Longitudinal profile of river Yamuna from RD 0 m to 22112 m of Mehendipur Jajjal bund to Tanda bund of Rai division

4.8 Simulation results for the reach of river Yamuna from RD 0 m to 3500 m of Delhi Division

For this reach of river, using the surveyed cross sections at every 500 m the HEC-RAS model set up was completed for one dimensional water profile study. The discharge has been applied as upstream boundary. The normal depth has been adopted as downstream boundary applied at last cross section of the study reach. From the water profile study the discharge carrying capacity has been estimated about 30000 cumec from RD 500 m to 3500 m. The simulation results are given in **Table 4.8**. The longitudinal profile of the river consisting of water bed profile, water surface profile, left bund profile and right bund profile is given in **Fig. 4.9** .

Table 4.8: Water profile simulation results of river Yamuna from RD 0 m to 3500 m of Delhi division

Reach	River Sta	Discharge	River bed Elev	Water surface Elev	LOB Elev	ROB Elev	Flow width
	(m)	(cumec)	(m)	(m)	(m)	(m)	(m)
Delhi	0	30000	207.2	216.14	215.61	225.33	4660.9
Delhi	500	30000	207.13	216.03	216.9	216.98	5264.5
Delhi	1000	30000	206.53	215.93	216.75	216.56	5085.3
Delhi	1500	30000	205.99	215.82	216.9	216.47	4848.4
Delhi	2000	30000	206.26	215.68	216.73	216.43	4646.8
Delhi	2500	30000	206.69	215.54	216.51	216.29	4624.3
Delhi	3000	30000	205.88	215.37	216.5	215.75	4402.6
Delhi	3500	30000	206.25	215.16	216.3	215.79	4284.3

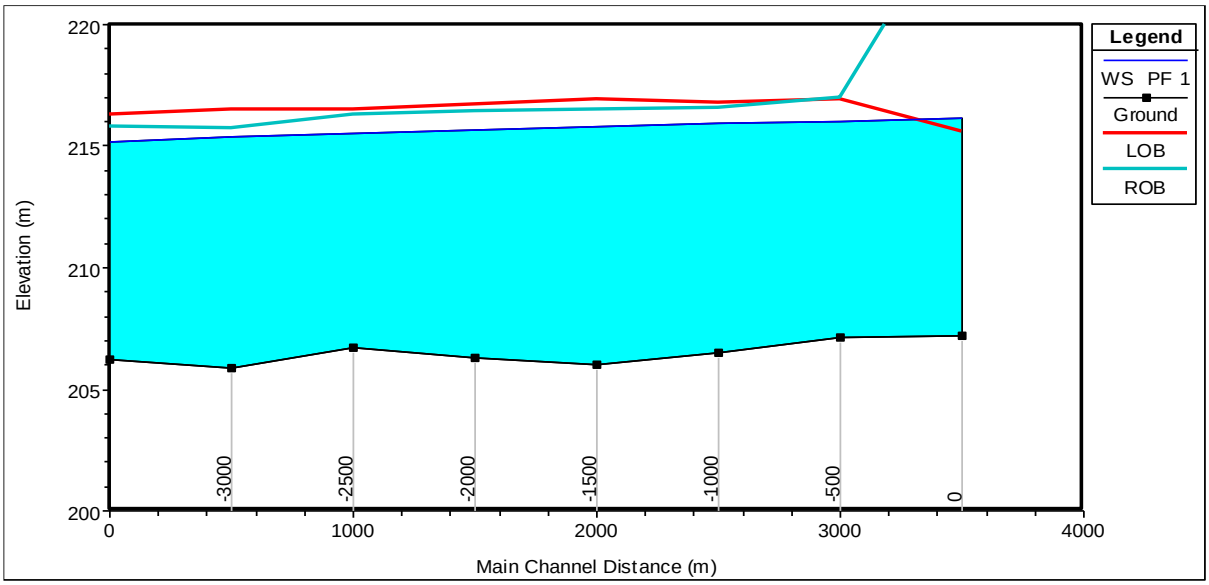


Fig. 4.9: Longitudinal profile of river Yamuna from RD 0 m to 3500 m of Delhi division

4.9 Limitations of the Study

The estimated discharge carrying capacity are indicative values only which has been estimated using the surveyed river cross section data provided by Government of Haryana. The discharge carrying capacity has been estimated with respect to bank elevations as per surveyed cross sections. Any variation in bank elevations shall result in variation of discharge carrying capacity. Further, the water surface elevation has been computed, assuming a conservative Manning's n of 0.030. A variation in Manning's n shall give slightly higher or lower value of water surface elevation.

4.10 Conclusions and Recommendations

This study is based on cross-sectional data provided by the Irrigation & Water Resource Department, Government of Haryana. As limited data of cross-section has been provided, the results looks like erratic. Therefore, Hec-Ras Model used for the study has been shared with the Irrigation and Water Resources Department, Government of Haryana, for refinement as per proper cross-sections and validation to arrive at realistic carrying capacity in various reaches.

From above, It can be seen that the carrying capacity of river Yamuna in various divisions spread across 202 Km varies from 1000 cumecs (in Karnal Division between RD 6976m to 15979m) to 30000 cumec (Delhi Division between RD 500m to 3500m) reach between RD0 to RD 3500m of Delhi division. However, at some places embankments has been provided to protect certain areas. Further, spilling beyond banks also happen during heavy flood and managed by Govt. of Haryana as per their procedures.

5 2-D Modeling and Submergence Area

5.1 Introduction

As per the ToR of the constituted committee, the studies which were required to be carried out included:

I. 2D modelling and submergence area estimation for the reach of River Yamuna from 10 km upstream of Wazirabad Barrage and up to 10 km downstream of Okhla barrage.
II. Identification of possible drainage congestion in Delhi in case of high spate of River Yamuna.
III. Afflux of barrages, bridges, flood protection and other structure in the study reach of the river.

The 2D hydrodynamic flood model studies in this regard is carried out by Hydrological Studies Organization (HSO), CWC wherein a 2D hydrodynamic model has been developed with an objective to find out-

1. Submergence area estimation-
    a. Submergence area estimation w.r.t. 2, 5, 10, 25, 50 and 100 year flood
    b. Embankment overtopping analysis
2. Identification of Drainage congestion and its operating mechanism
3. Afflux of existing structures

5.2 Two Dimensional (2-D) Modeling and Submergence Area estimation

5.2.1 Submergence area estimation w.r.t. 2, 5, 10, 25, 50 and 100 year flood

To carry out this analysis, the monsoon peak discharge data (June to September) from period 1970 to 2020 at Delhi Railway Bridge (DRB) HO site has been considered. This data has been provided by Yamuna Basin Organization, Central Water Commission. Also, the flood peak for July, 2023 at DRB was given by YBO, CWC kept as an **attachment 5a.** The monsoon flood peak derived from period 1970 to 2020 at Delhi Railway Bridge HO site is given in the **Table 5.1.**

Table 5.1: The monsoon peak discharge data from period 1970 to 2020 at Old Delhi Railway Bridge

Year	Max Observed Peak Discharge(Cumec)	Year	Max Observed Peak Discharge (Cumec)
1970	1867	**1996**	2592.82
1971	2931.34	**1997**	5207.02
1972	2547.08	**1998**	3383.09
1973	3819.66	**1999**	1947.82
1974	3009.26	**2000**	3366.18
1975	8858.59	**2001**	3476.26
1976	9318.94	**2002**	2125.69
1977	4480.71	**2003**	1735.92
1979	1152.93	**2004**	716.21
1980	3013.84	**2005**	1302.2
1981	1925.28	**2006**	826.74
1982	1275	**2007**	1143.01
1983	4012.4	**2008**	2119.32
1984	1220.93	**2009**	1425.2
1985	1990	**2010**	3466.48
1986	1767.39	**2011**	2017.78
1987	148.35	**2012**	1219.06
1988	5642.19	**2013**	3239.04
1989	4336.62	**2014**	793.25
1990	2193.06	**2015**	1072.33
1991	507.31	**2016**	1189.38
1992	3103.4	**2017**	865.58
1993	1344.7	**2018**	2490.14
1994	2766.55	**2019**	2890
1995		**2020**	829

Source: CWC-Water Year Book 2020-21

Accordingly, the estimated flood values for 2 year, 5 year, 10 year, 25 year, 50 year and 100 year return period at Delhi Railway Bridge HO site were computed. The **Table 5.2** shows the computed flood values.

Table 5.2: Estimated flood value at Old Delhi Railway Bridge HO site

S No	Return Period	Flood value at Old Delhi Railway Bridge HO site	
		Cumec	Cusec
1	2	2313	81755
2	5	4023	142082
3	10	5157	182042
5	25	6587	232521
6	50	7648	269974
7	100	8701	307145

In the 2D hydrodynamic model simulation, these flood values of different return periods were passed through Delhi Rail Bridge to get the corresponding water level at different locations and flood submergence areas over the Delhi reach of River Yamuna. The model incorporated the observed cross-section data, open drain data, bunds and embankment data as received from the Delhi Government. The results of the model simulation is tabulated in the **Table 5.3.**

Table 5.3: Submergence Area over Delhi reach of River Yamuna

Return Period (Year)	DRB Discharge (M^3/s)	DRB Water Level (m)	Submergence Area (Km^2) (within embankment)	Net Submergence Area (Km^2)
2	2316	204.2	26.42	0
5	4025	205.99	30.82	0.4
10	5157	206.9	47.11	16.7
25	6587	207.94	63.51	33.1
2023 Flood	6999	208.6	74.525	44.1
50	7648	208.75	77.76	47.3
100	8701	209.35	85.25	54.8

Net Submergence area = Submergence area- Main channel area i.e. **30.46 Km^2** (within banks)

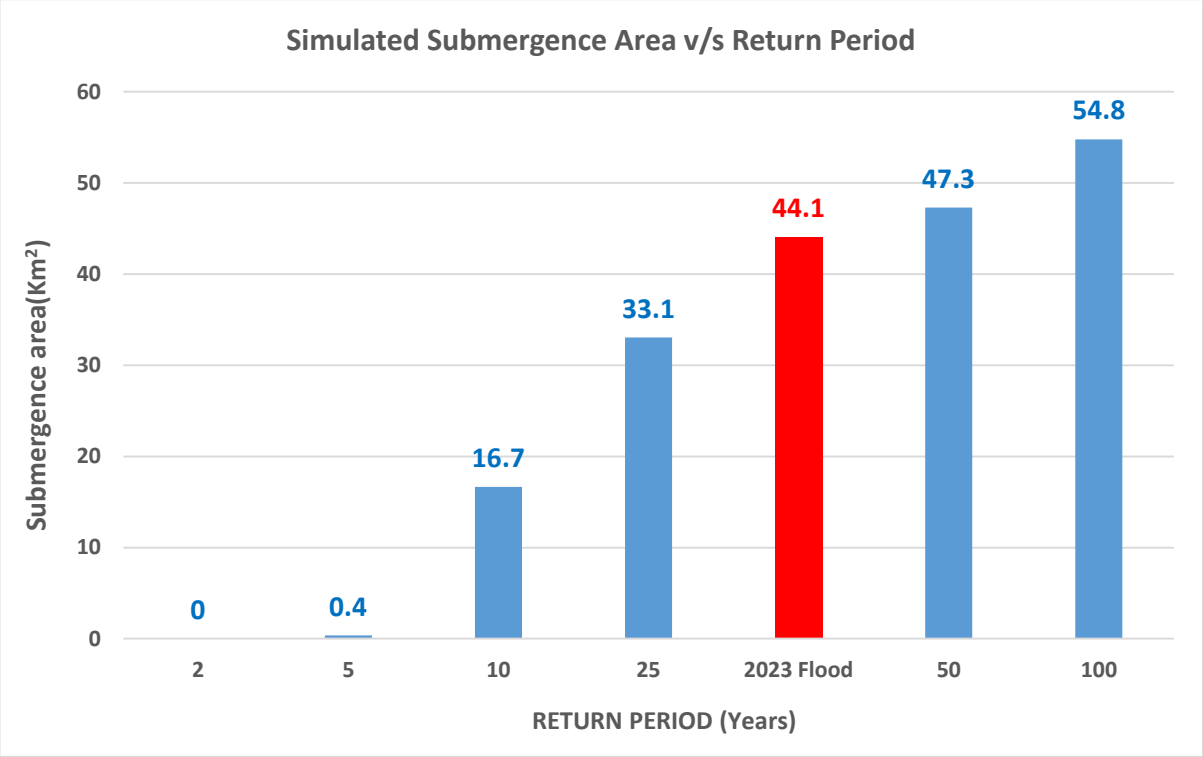


Fig. 5.1: Submergence Area v/s return Period

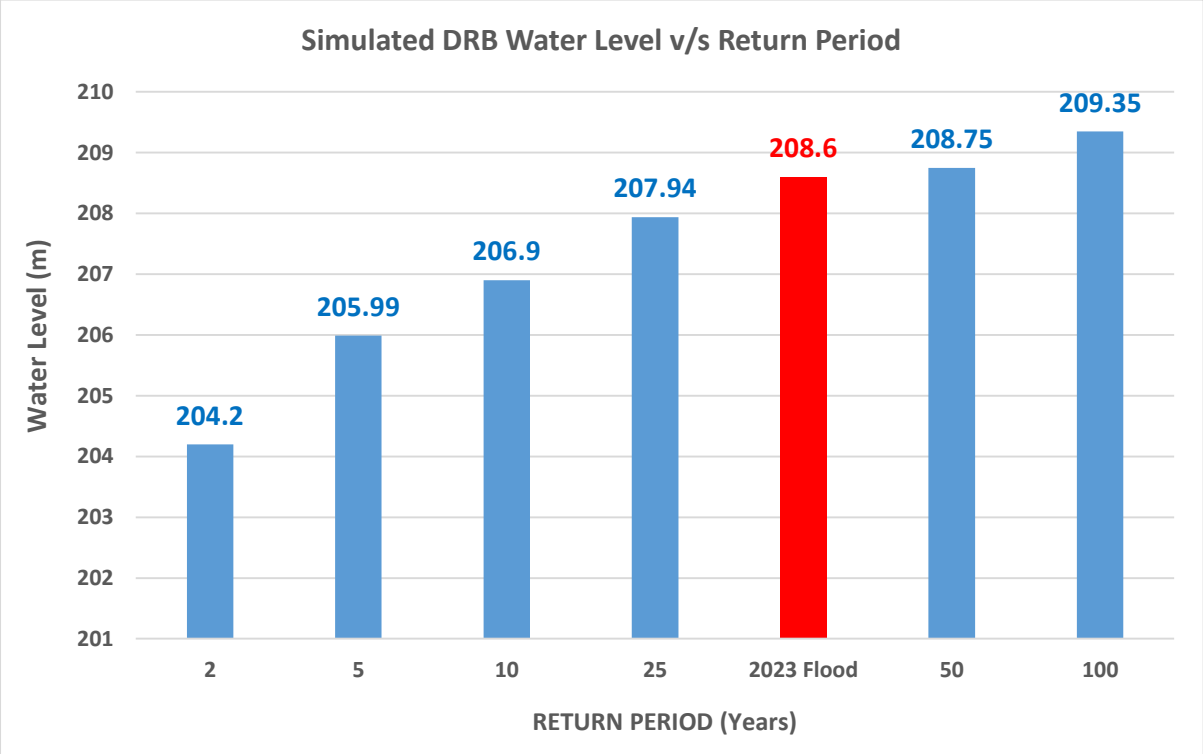


Fig. 5.2 : WL v/s Return Period

Further, the **Table 5.4** and **Fig. 5.3** below shows the Maximum longitudinal Water Surface Elevations starting from 21 km u/s of Wazirabad Barrage. The station zero is accordingly considered 21km upstream of Wazirabad Barrage. The water surface elevations is for entire 48 km reach at 1-Km interval for 2, 5, 10, 25, 50 & 100 Year Return period Floods.

Table 5.4 Max Longitudinal Water Surface Elevation

Station (m)	WSE 2-year (m)	WSE 5-year (m)	WSE 10-year (m)	WSE 25-year (m)	WSE 50-year (m)	WSE 100-year (m)	WSE-100-year With elevated bund levels at Nili chhatri
0	210.767	212.289	213.092	213.822	214.389	214.52	214.864
1000	210.331	211.852	212.685	213.435	214.009	214.4	214.493
2000	210.097	211.637	212.476	213.219	213.78	214.2	214.256
3000	209.983	211.509	212.339	213.069	213.622	213.95	214.091
4000	209.72	211.27	212.105	212.836	213.391	213.6	213.866
5000	209.425	210.962	211.793	212.528	213.089	213.3	213.575
6000	209.206	210.731	211.556	212.279	212.829	213.3	213.31
7000	209.05	210.562	211.378	212.083	212.618	213.03	213.089
8000	208.947	210.45	211.259	211.953	212.481	212.88	212.947
9000	208.813	210.307	211.112	211.798	212.322	212.73	212.79
10000	208.656	210.145	210.948	211.633	212.16	212.57	212.636
11000	208.357	209.874	210.696	211.416	211.967	212.43	212.466
12000	208.064	209.603	210.45	211.219	211.81	212.43	212.338
13000	207.92	209.458	210.315	211.107	211.726	212.43	212.273
14000	207.756	209.326	210.196	211.003	211.643	212.1	212.205
15000	207.555	209.148	210.029	210.852	211.52	212.05	212.103
16000	207.379	209.004	209.898	210.741	211.432	211.9	212.03
17000	207.238	208.877	209.78	210.641	211.346	211.85	211.95
18000	207.095	208.74	209.655	210.534	211.251	211.74	211.86
19000	206.896	208.568	209.507	210.415	211.15	211.6	211.77
20000	206.492	208.259	209.244	210.198	210.964	211.46	211.6
21000	206.053	207.903	208.921	209.907	210.693	211.3	211.34
22000	205.813	207.71	208.741	209.733	210.516	211.05	211.16
23000	205.547	207.428	208.454	209.456	210.25	210.79	210.91
24000	205.089	206.963	207.984	208.981	209.78	210.32	210.41
25000	204.764	206.589	207.594	208.576	209.384	210	210.1
26000	204.486	206.315	207.32	208.3	209.105	209.6	209.79
27000	204.196	205.998	206.986	207.954	208.752	209.55	209.68
28000	203.98	205.732	206.693	207.643	208.427	209.05	209.1
29000	203.863	205.589	206.537	207.475	208.252	208.89	208.915
30000	203.525	205.267	206.221	207.161	207.937	208.48	208.59
31000	203.2	204.896	205.83	206.773	207.574	208.25	208.25

32000	202.954	204.605	205.52	206.454	207.26	207.8	207.95
33000	202.855	204.501	205.411	206.341	207.145	207.7	207.84
34000	202.557	204.134	205.012	205.91	206.689	207.3	207.36
35000	202.104	203.557	204.38	205.227	205.966	206.5	206.609
36000	201.44	202.784	203.57	204.386	205.102	205.46	205.73
37000	201.041	202.309	203.073	203.868	204.567	205	205.18
38000	200.889	202.111	202.861	203.643	204.333	204.84	204.93
39000	200.661	201.801	202.524	203.284	203.955	204.5	204.54
40000	199.988	200.84	201.503	202.222	202.862	203.35	203.42
41000	199.664	200.323	200.971	201.692	202.339	202.8	202.9
42000	199.51	200.049	200.697	201.428	202.085	202.5	202.65
43000	199.473	199.975	200.62	201.353	202.01	202.4	202.57
44000	197.943	199.46	200.261	201.065	201.751	202.2	202.33
45000	197.728	199.213	199.996	200.782	201.452	201.87	202.02
46000	197.207	198.64	199.39	200.141	200.776	201.229	201.32
47000	196.481	197.753	198.427	199.102	199.682	200.102	200.19
48000	195.597	196.756	197.364	197.972	198.492	198.871	198.94

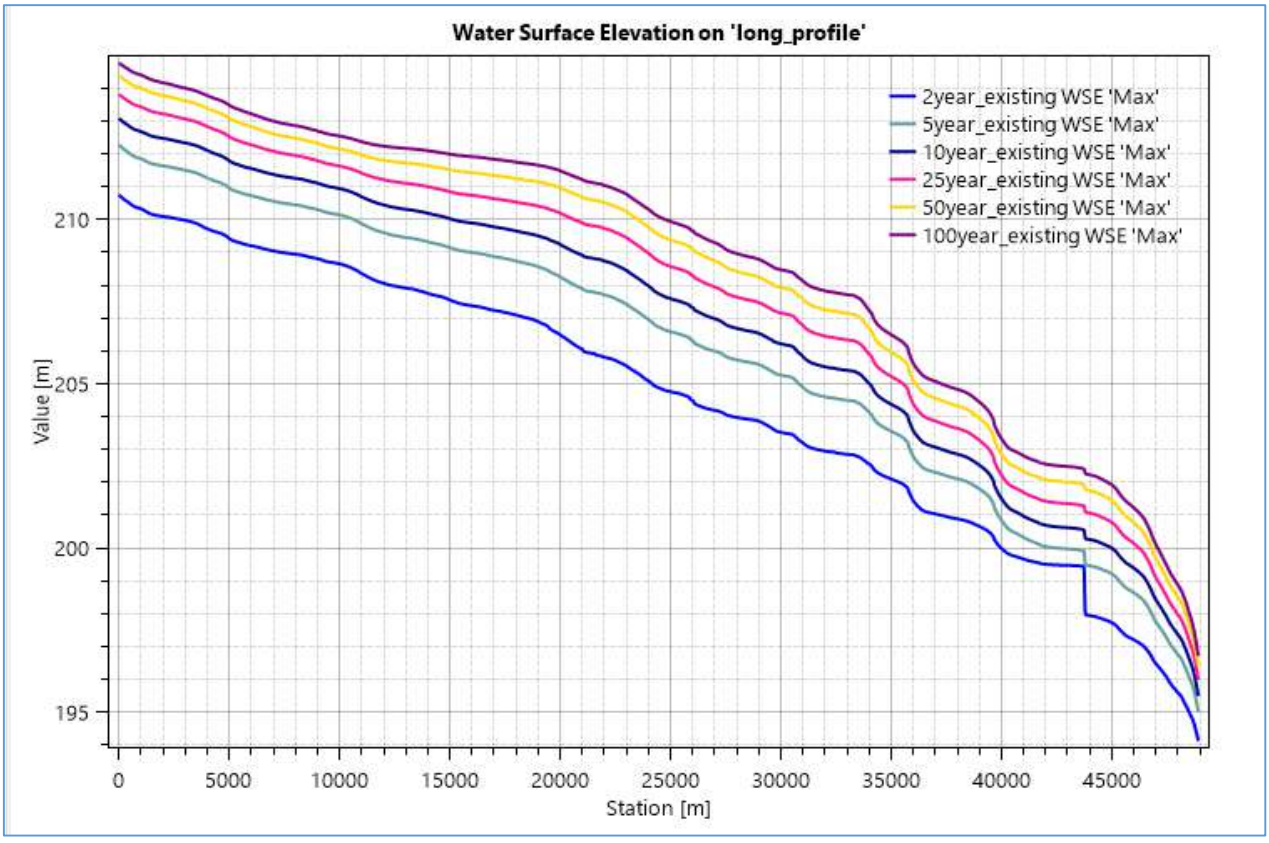


Fig. 5.3 Longitudnal WSE : 2, 5, 10, 25, 50 & 100 Year return Period Flood

5.2.2 Embankment Overtopping Analysis

In the Interim Report, 14 embankment locations were identified by preliminary model runs as potential overtopping zones. These locations were further sent to respective State Governments for ground-verification. The report on ground-verification submitted by the State Government shows that none of the identified locations by the model got overtopped during the 2023 floods is attached as **attachment 5b**.

The model was further corrected by not only incorporating the actual embankment levels provided at these 14 locations but also by incorporating the revised embankment levels provided by the state government for all other locations along the reach.

Subsequent runs on the revised model were carried out for different return period floods, the result of which is shown in **Table 5.5** .

Table 5.5: Embankment opertopping analysis

Return period	Passing Discharge at DRB (cumec)	Simulated WL at DRB (m)	Embankment Overtopping locations			Remark
2-year	2316	204.2	No Overtopping			
5-year	4025	205.9	No Overtopping			
10-year	5157	206.9	No Overtopping			
25-year	6587	207.94	No Overtopping			
July, 2023 Flood [Between 25 -50 year return period]	6999	208.7	**Location**	**Bank**	**Max WL reached**	Overtopping at Nili chhatri area is observed in simulation. The same is Verified on ground by the Delhi Government during July, 2023 floods. Max water level of 208.88m is reached which is above the existing bund level. No overtopping at any other location shown by the model.
			Nili Chhatri	Right	208.88	
50-year	7648	208.75	**Location**	**Bank**	**Max WL reached**	At Nili chhatri area, max water level of 208.98m may be reached which is above the existing bund level. No overtopping at any other location shown by the model.
			Nili Chhatri	Right	208.98	
			Location	**Bank**	**Max WL reached**	At Nili chhatri area, max water level of 209.55m may be reached which is above the existing bund level. No overtopping at any other location shown by the model.
100-year	8701	209.35	Nili Chhatri	Right	209.55	
100-year With elevated Nili Chhatri bund in the model	8701	209.44	Nili Chhatri	Right	209.68	

Table 5.6 below shows Maximum Longitudinal Water Surface Elevations for 100-year flood starting 21 km u/s of Wazirabad Barrage at every 1-Km interval against both the Right & the Left Bank Elevations.

Table 5.6: WL v/s Bank Elevations for 100-year Flood

Chainage	Right Bank Elevations (m)	Centreline WL (m)	Left Bank Elevations (m)	Right Bank elevation difference wrt WL (m)	Left Bank elevation difference wrt WL (m)
0	215.9	214.52	215.72	1.380	1.200
1000	215.25	214.4	215.3	0.850	0.900
2000	215.2	214.2	215.3	1.000	1.100
3000	214.6	213.95	214.8	0.650	0.850
4000	214.55	213.6	214.7	0.950	1.100
5000	214	213.3	214.5	0.700	1.200
6000	214.3	213.3	214.3	1.000	1.000
7000	213.6	213.03	214.01	0.570	0.980
8000	213.4	212.88	213.9	0.520	1.020
9000	213.4	212.73	213.7	0.670	0.970
10000	213.5	212.57	213.3	0.930	0.730
11000	213.3	212.43	213.1	0.870	0.670
12000	213.3	212.43	213.1	0.870	0.670
13000	213.3	212.43	213.1	0.870	0.670
14000	213.2	212.1	212.97	1.100	0.870
15000	213.1	212.05	212.5	1.050	0.450
16000	213.1	211.9	212.4	1.200	0.500
17000	212.4	211.85	211.96	0.550	0.110
18000	212.12	211.74	211.77	0.380	0.030
19000	211.77	211.6	211.77	0.170	0.170
20000	211.69	211.46	211.81	0.230	0.350
21000	212.37	211.3	211.6	1.070	0.300
22000	213.35	211.05	211.12	2.300	0.070
23000	212.25	210.79	211	1.460	0.210
24000	211.45	210.32	210.55	1.130	0.230
25000	211.25	210	210.25	1.250	0.250
26000	211.25	209.6	212	1.650	2.400
27000	208.5	209.55	212	-1.050	2.450
28000	210.56	209.05	209.75	1.510	0.700
29000	209.75	208.89	209.55	0.860	0.660
30000	210.1	208.48	210.4	1.620	1.920
31000	209.75	208.25	209.58	1.500	1.330
32000	208.76	207.8	208.55	0.960	0.750

Chainage	Right Bank Elevations (m)	Centreline WL (m)	Left Bank Elevations (m)	Right Bank elevation difference wrt WL (m)	Left Bank elevation difference wrt WL (m)
33000	208.35	207.7	208.55	0.650	0.850
34000	208.45	207.3	208.05	1.150	0.750
35000	208.8	206.5	207.43	2.300	0.930
36000	208.8	205.46	206.75	3.340	1.290
37000	206.05	205	206.75	1.050	1.750
38000	206.6	204.84	206.6	1.760	1.760
39000	207.35	204.5	208.5	2.850	4.000
40000	205.4	203.35	206.65	2.050	3.300
41000	204.2	202.8	204.5	1.400	1.700
42000	203.9	202.5	203.52	1.400	1.020
43000	203.99	202.4	203.52	1.590	1.120
44000	203.5	202.2	204.46	1.300	2.260
45000	203.4	201.87	204.4	1.530	2.530

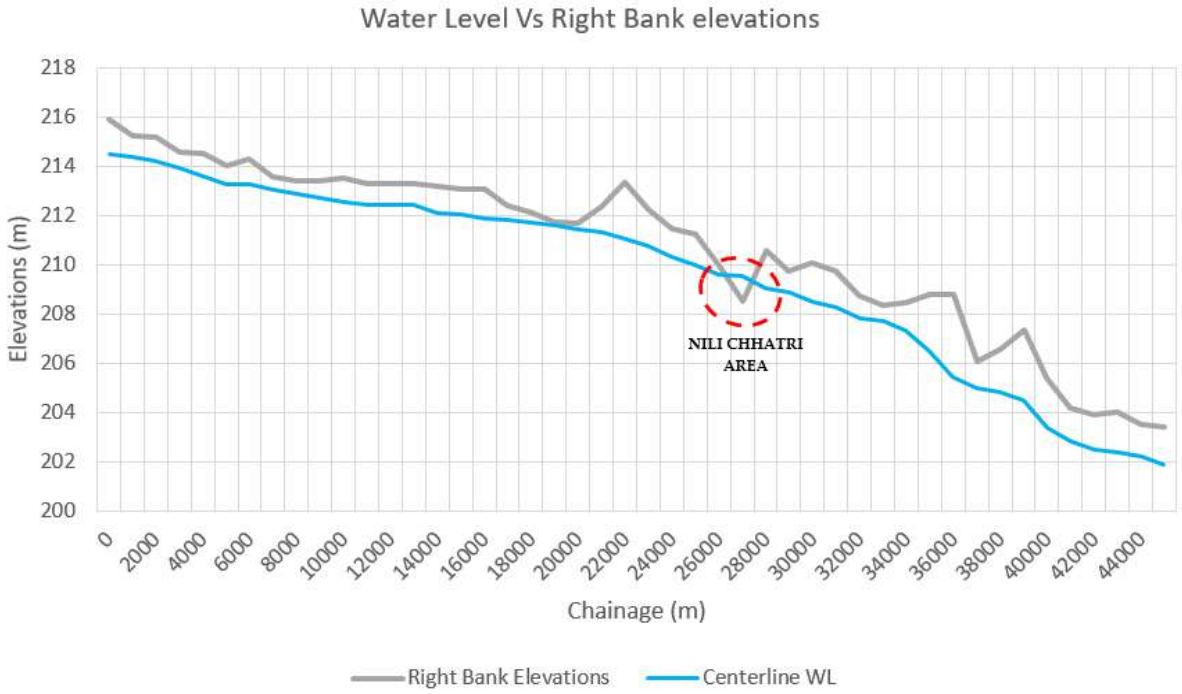


Fig. 5.4: WL v/s Right Bank Elevation

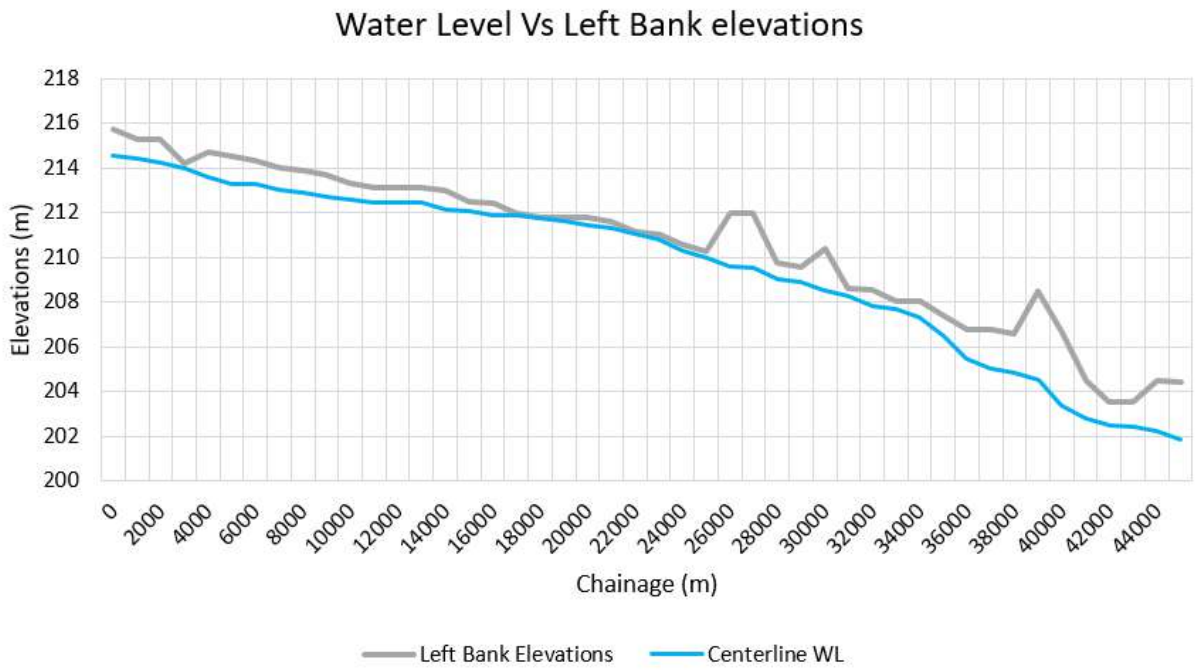


Fig. 5.5: WL v/s Left bank Elevation

5.2.3 Submergence Area analysis Conclusion

1. The flood of July, 2023 was in between1-in-25-year and 1-in-50-year flood.
2. Bottom Girder level at Old Railway Bridge in Delhi is 207.4m. As per the model simulation, this level may be attained as the flow at DRB crosses 5974 cumec. Further for 100-year flood the water level may reach 209.35m. In such condition, there may be slightly more afflux due to girder. Further, appropriate study may be carried out by the Indian Railways to know the effect of such high flood on the Old Delhi Railway Bridge structural stability.
3. Up to 1-in-25-year flood (6587cumec), no overtopping of embankments is shown by the model along the entire Delhi reach. Further, model study indicate that there shall be no overtopping for discharge up to 6700 cumec.
4. Simulated water level for 2023 flood at DRB is found to be 208.6m against the observed 208.65m. Also, simulated submergence area for 2023 flood is found to be 44.1 Km^2 which is slightly less than the simulated submergence area for 50-year flood at DRB. The model shows overtopping from Metcalf house to Nili Chhatri/ Yamuna Bazar Ring road area on right bank of river Yamuna with max water level reaching upto 208.88m. The same has been verified on ground by the Delhi Government.
5. For 50-year flood i.e. flow of 7648 cumec, the water may rise up to 208.75m resulting in submerging 47.3 Km^2 which is 7.3% more than the area submerged in July 2023 Flood. This magnitude of flood, may cause

embankment overtopping at Metcalf house to Nili Chhatri/ Yamuna Bazar Ring road area on right bank of river Yamuna with max water level reaching upto 208.98m.

6. For 100-year flood ie. flow of 8701 cumec, (which is equivalent to the design discharge of ITO/Okhla/Wazirabad barrage, the water level may rise upto 209.35m resulting in submerging 54.8 Sqkm which is 24.0% more area as compared to the area submerged in July 2023 Flood. This magnitude of flood, may cause embankment overtopping at Metcalf house to Nili Chhatri/ Yamuna Bazar Ring road area on right bank of river Yamuna with max water level reaching upto 209.55m
7. Further, for 100-year flood ie. Discharge of 8701 cumec at DRB, the max Water Level at the Nili Chhatri area under existing conditions is simulated as 209.55m by the model. Now raising the embankment height beyond this level (say to 210.55m) in the model and again running shows that the max water Level now reached is 209.68m which may be taken as the maximum Water Level reaching for 100-year flood. Suitable flood protection may be provided against it keeping in view the design norms and actual ground conditions. Water Surface Elevation profile with raised embankment height at Nili Chhatri area is given in last column of table 4 above.
8. **Table 5.6, Fig 5.4 & Fig. 5.5** shows the simulated water levels for 100-year flood with respect to the right and the left embankment levels. Up to 100-year flood, no overtopping at any other location is shown by the model. However, the simulated water levels given in Table 5.6 may be matched with the actual bund levels by I&FC Department, Govt. of NCT Delhi to find the possible overtopping locations and raising the same with free board as per the codal provision.

5.3 Identification of Drainage congestion and its Operating Mechanism

There are 20 drains falling into river Yamuna in the Delhi reach. These drains are operated and maintained by Delhi Government. Details of these 20 drains as provided by the Delhi Government is used to do the analysis. The analysis is done to find out the return period flood for which the drain starts getting congested.

Drainage congestion seems to start occurring when the Water Level in the River Yamuna gets higher than the outfall sill level of a particular drain. The **Table 5.7** shows the list of drains along with their outfall Sill levels and the River Water levels reached for different return period floods. The table finally shows the return period flood at DRB for which the drains start getting congested.

Table 5.7: Drainage Congestion

Sl.No	Drain	Outfall Sill Level	River Water Level at Drain outfall for various Return period flood			Return period flood at which the congestion starts in the Drains
			2-year	5-year	10-year	
1	Najafgarh Drain (un regulated)	203	206.5	207.8	209.0	2-Year (2316 m^3/s)
2	Shahadra Drain (un regulated)	193.58	197.9	199.3	200.2	2-Year (2316 m^3/s)
3	Magzine Road Drain	206.4	-	207.5	208.7	5-Year (4025 m^3/s)
4	Old Chandrawal Drain	206.4	-	207.4	208.6	5-Year (4025 m^3/s)
5	Khyber Pass Drain	206.5	-	207.3	208.5	5-Year (4025 m^3/s)
6	Metcalf House Drain	204.76	204.9	206.7	207.8	2-Year (2316 m^3/s)
7	ISBT/Mori gate/Qudsia Ghat Drain	204.37	204.5	206.2	207.4	2-Year (2316 m^3/s)
8	Tonga Stand Drain	204.25	204.3	206.0	207.1	2-Year (2316 m^3/s)
9	Vijay Ghat	203.065	204.1	205.7	206.8	2-Year (2316 m^3/s)
10	Civil Military Drain	203.173	203.3	204.9	206.0	2-Year (2316 m^3/s)
11	Delhi Gate	202.154	203.0	204.5	205.6	2-Year (2316 m^3/s)
12	Sen Nursing Home Nalla 12 No.12	202.64	--	204.4	205.5	5-Year (4025 m^3/s)
13	Nalla No.12 (A)	201.45	202.9	204.4	205.5	2-Year (2316 m^3/s)
14	Nalla No.14	202.09	202.3	203.7	204.7	2-Year (2316 m^3/s)
15	Nalla No.15	203.124		203.3	204.3	5-Year (4025 m^3/s)
16	Barapullah Drain (un regulated)	199.046	200.8	201.9	202.9	2-Year (2316 m^3/s)
17	Nalla No.17	201.1	-	-	201.1	10-Year (5157 m^3/s)
18	Taimur Nagar (un regulated)	201.1	-	-	201.1	10-Year (5157 m^3/s)

5.3.1 Drainage congestion conclusion

1. For Drain No. 1, 2, 6, 7, 8, 9, 10, 11, 13, 14 and 16 congestion starts with 2-years return period flood.
2. For Drain 3, 4, 5 and 12 congestion starts with 5-years return period flood.
3. All the above drains start to get congested for 10-year and above return period flood

5.3.2 Operating Mechanism of out falling drains

The I&FCD, Govt. of NCT Delhi submitted a report regarding the operating mechanism of these drains and the adequacy of the pumping mechanism adopted during floods. The report is at **attachment 5c.**

5.4 Afflux of Structures in the study reach

To study the afflux of the structures in the study reach, following two scenarios of generating the longitudinal Water Surface Elevation (WSE) Profile were simulated in the 2D Hydrodynamic model as shown in **Fig. 5.6 & Fig. 5.7.**

- **Existing Scenario**: Terrain with existing structures including Muck i.e. as per current condition
- **Pier Scenario**: Terrain with existing structures raised on Piers i.e. Embankment replaced by Piers and muck removed.

Fig. 5.6: Existing Scenario: with existing structures i.e. as per current condition

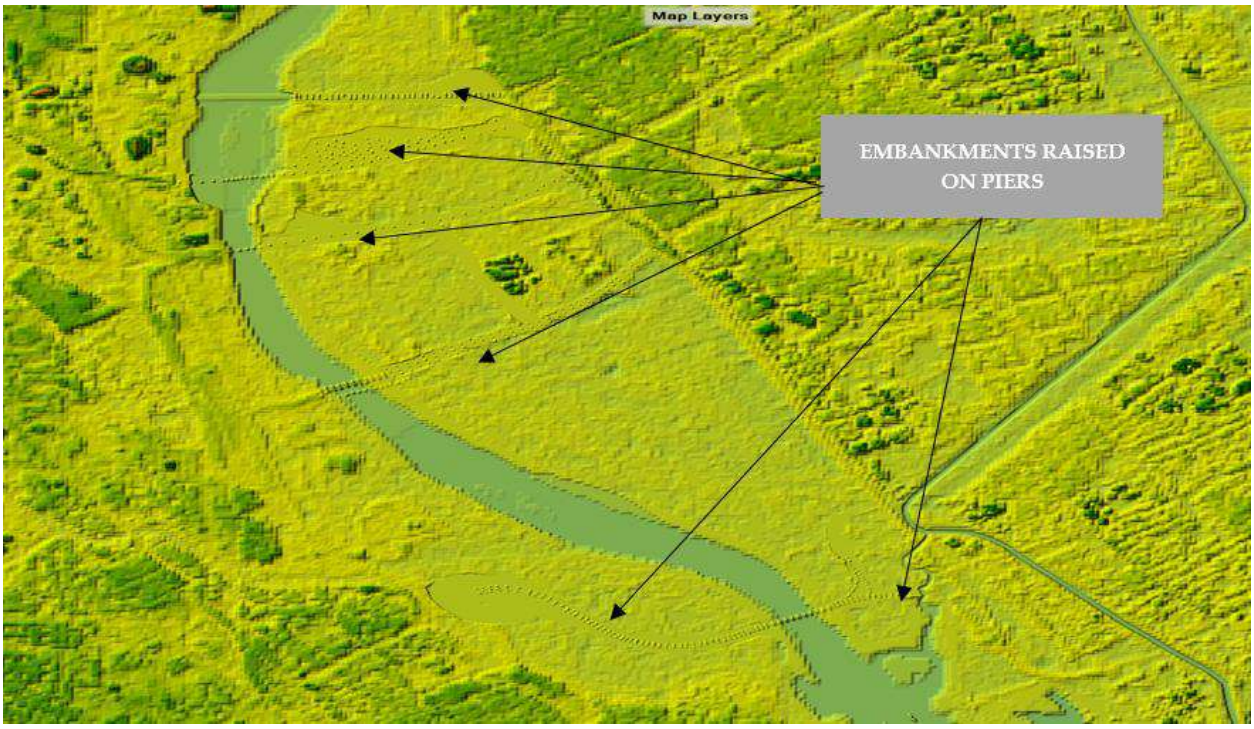


Fig. 5.7: Pier Scenario: Existing lateral structures raised on Piers

Existing structures mentioned above mainly include all the lateral embankments into floodplain that are possibly obstructing the flow excluding the three existing Barrages.

5.5 Simulation Results

The **Fig. 5.8** shows the longitudinal WSE profile along with the longitudinal bed level profile of the Delhi reach for all the three scenarios mentioned above. The above simulation is done for the 100-year flood (i.e. discharge of 8701 cumec passing through Old Delhi Railway Bridge).

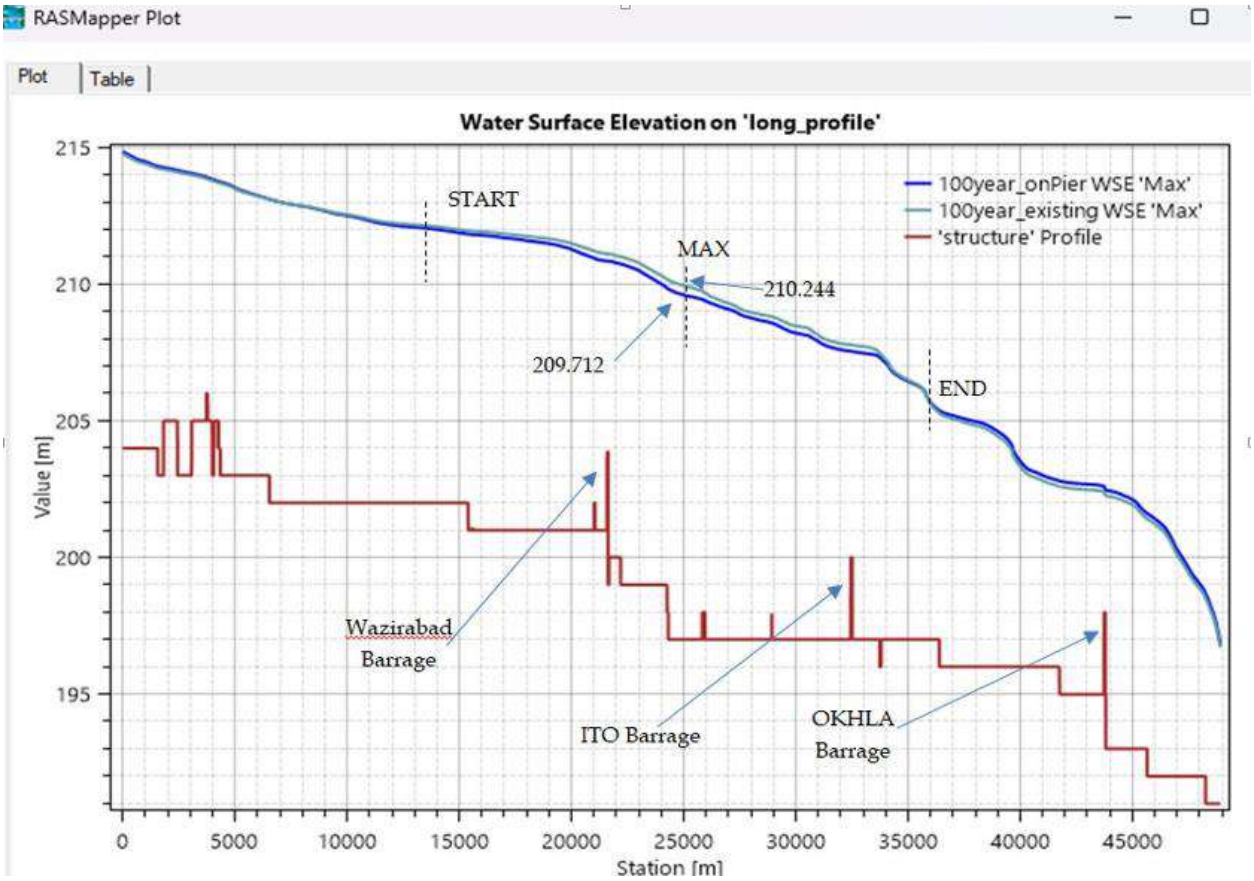


Fig. 5.8: Longitudinal water surface elevation (WSE) Profile

5.5.1 Conclusion for afflux Analysis

After running the above mentioned two simulations, following observations could be made

Taking both scenarios together it is observed that the longitudinal water surface profile shows a marked difference in the water elevations in the middle reach only. This difference starts appearing around 12Km U/s from Wazirabad Barrage to 16Km D/s. The Water Surface Elevation profile for the existing Terrain is higher than the Pier Terrain which has all the lateral embankments raised on Piers. The maximum difference between the two Water Surface Elevations is found to be **0.536 meters** at around **26.404 Km** which lies between Wazirabad and ITO Barrage. This possibly indicates the afflux produced due to the lateral embankments and muck lying downstream of Wazirabad Barrage. However this afflux is indicative only based on data available and actual values might vary.

The simulated Water Surface Elevations for both the existing structural arrangements and scenario where embankments at ends are replaced with piers is graphically shown in the **Fig. 5.9.**

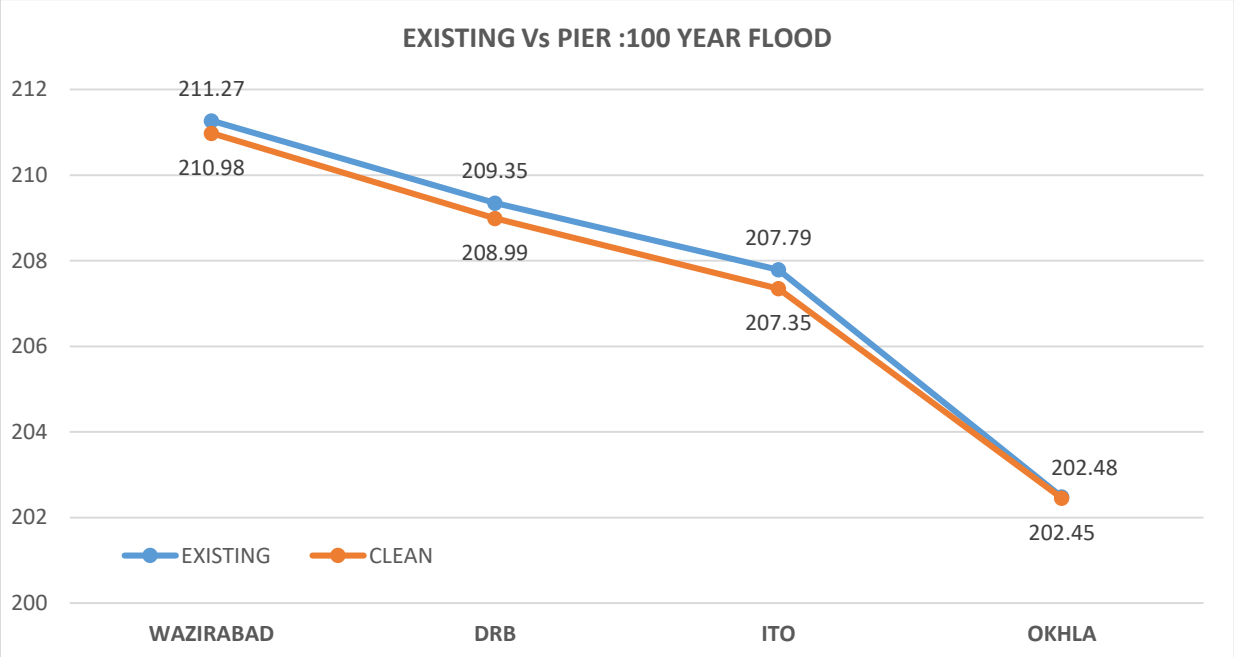


Fig. 5.9 : Simulated Water Surface Elevations for both the existing and pier scenario

5.6 Limitations of the Study

1. The obtained values of levels and flows in the study are indicative and subject to the errors and uncertainties present in the data and the model.
2. The DEM used in the model has horizontal resolution of 30m which is relatively coarse for such a study. All the levels, depths and extents simulated by the model is subject to the inherent errors present in the DEM and its limitation because of its coarser resolution.
3. The errors in the outcome of the model, if any, are due to the uncertainties already present in other input data like flow hydrograph, land use land cover data, structure details etc.
4. For the sake of model stability and shorter simulation period diffusive wave equation is used as the solver. In Diffusive wave equation gravity and friction are assumed to be dominating forces and the acceleration terms, as well as the eddy viscosity and Coriolis terms are neglected.

5.7 Summary, Conclusions/Recommendations

Based upon the 2D Model studies, following conclusions are drawn-

<u>Drainage Congestion</u>

a. The assessment of capacities of various drains to carry sewage and storm water may be carried out in order to avoid congestion during floods of various return period in river Yamuna.

b. The I&FCD, Govt of NCT Delhi may ensure that all the entries/exit which are leading to river Yamuna may be raised above the maximum water level of river Yamuna during floods of various return period in order to avoid spilling of flood waters through these entries/exit points.

c. I&FCD, Govt. of NCT Delhi to ensure adequate pumping arrangement for discharging of water from drains to river Yamuna at higher level during floods in river Yamuna wherever the drains gets congested due to high stage floods in river Yamuna.

d. The committee observed that the drainage network within the Delhi NCR region is being maintained by different agencies like, I&FCD, Govt.NCT of Delhi, MCD, NDMC, etc. and there is no coordination among various agencies for operation of these drains. A SoP for operation of these drains in Delhi NCR region may be prepared with clear guidelines defining the procedures to be followed for operating these drains depending upon the water level in river Yamuna. There should be one nodal agency which should be responsible for operation of drains in Delhi NCR region. The nodal agency may be entrusted with the task of monitoring of proper maintenance and regular desilting of drains. The SoP for drains should also clearly define the details of pre monsoon and post monsoon inspections that are required to be carried out for the drains.

<u>Submergence in varying return periods and adequacy of embankments</u>

a. The flood of July, 2023 was in between1-in-25-year and 1-in-50-year flood.

b. Bottom Girder level at Old Railway Bridge in Delhi is 207.4m. As per the model simulation, this level may be attained as the flow at DRB crosses 5974 cumec. Further for 100-year flood the water level may reach 209.35m. In such condition, there may be slightly more afflux due to girder. Further, appropriate study may be carried out by the Indian Railways to know the effect of such high flood on the Old Delhi Railway Bridge structural stability.

c. Up to 1-in-25-year flood (6587cumec), no overtopping of embankments is shown by the model along the entire Delhi reach. Further, model study indicate that there shall be no overtopping for discharge up to 6700 cumec.

d. Simulated water level for 2023 flood at DRB is found to be 208.6m against the observed 208.65m. Also, simulated submergence area for 2023 flood is found to be 44.1 Km2 which is slightly less than the simulated submergence area for 50-

year flood at DRB. The model shows overtopping from Metcalf house to Nili Chhatri/ Yamuna Bazar Ring road area on right bank of river Yamuna with max water level reaching upto 208.88m. The same has been verified on ground by the Delhi Government.

e. For 50-year flood i.e. flow of 7648 cumec, the water may rise up to 208.75m resulting in submerging 47.3 Km2 which is 7.3% more than the area submerged in July 2023 Flood. This magnitude of flood, may cause embankment overtopping at Metcalf house to Nili Chhatri/ Yamuna Bazar Ring road area on right bank of river Yamuna with max water level reaching upto 208.98m.

f. For 100-year flood ie. flow of 8701 cumec, (which is equivalent to the design discharge of ITO/Okhla/Wazirabad barrage, the water level may rise upto 209.35m resulting in submerging 54.8 Sqkm which is 24.0% more area as compared to the area submerged in July 2023 Flood. This magnitude of flood, may cause embankment overtopping at Metcalf house to Nili Chhatri/ Yamuna Bazar Ring road area on right bank of river Yamuna with max water level reaching upto 209.55m

g. Further, for 100-year flood ie. Discharge of 8701 cumec at DRB, the max Water Level at the Nili Chhatri area under existing conditions is simulated as 209.55m by the model. Now raising the embankment height beyond this level (say to 210.55m) in the model and again running shows that the max water Level now reached is 209.68m which may be taken as the maximum Water Level reaching for 100-year flood. Suitable flood protection may be provided against it keeping in view the design norms and actual ground conditions. Water Surface Elevation profile with raised embankment height at Nili Chhatri area is given in last column of table 4 above.

h. **Table 5.6, Fig. 5.4 & Fig. 5.5** shows the simulated water levels for 100-year flood with respect to the right and the left embankment levels. Up to 100-year flood, no overtopping at any other location is shown by the model. However, the simulated water levels given in **Table 5.6** may be matched with the actual bund levels by I&FC Department, Govt. of NCT Delhi to find the possible overtopping locations and raising the same with free board as per the codal provision.

<u>Afflux Condition</u>

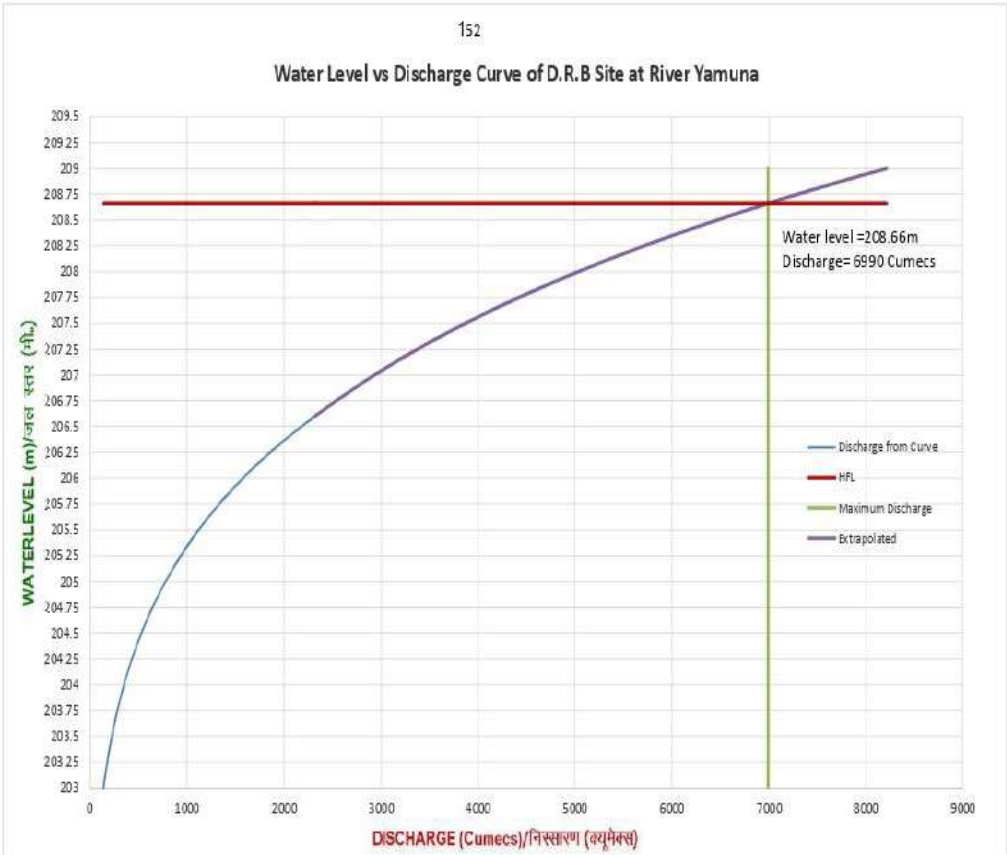
a. The simulations results indicate that replacing lateral embankments with piers leads to lower water surface elevations in the middle reach of the river compared to the existing terrain. An afflux of 0.536 meters has been observed at around 26.404 km. This suggests that the current embankments of structures and muck contribute to higher water levels.

Attachment 5a

GD Curve of Delhi Railway Bridge Site on River Yamuna

Zero of Gauge 197m

Water Level (m)	Discharge (Cumecs)	Water Level (m)	Discharge (Cumecs)
203.00	138.98	206.00	1575.34
203.10	153.44	206.10	1683.10
203.20	169.13	206.20	1796.93
203.30	186.13	206.30	1917.10
203.40	204.54	206.40	2043.90
203.50	224.44	206.50	2177.60
203.60	245.92	206.60	2318.51
203.70	269.10	206.70	2464.47
203.80	294.06	206.80	2615.33
203.90	320.92	206.90	2770.89
204.00	349.80	207.00	2933.88
204.10	380.81	207.10	3104.58
204.20	414.08	207.20	3283.24
204.30	449.73	207.30	3470.16
204.40	487.90	207.40	3665.62
204.50	528.74	207.50	3869.90
204.60	572.38	207.60	4083.32
204.70	618.98	207.70	4306.16
204.80	668.70	207.80	4538.75
204.90	721.71	207.90	4781.40
205.00	778.17	208.00	5034.44
205.10	838.26	208.10	5298.19
205.20	902.17	208.20	5573.00
205.30	970.09	208.30	5859.21
205.40	1042.21	208.40	6157.16
205.50	1118.75	208.50	6467.22
205.60	1199.91	208.60	6789.75
205.70	1285.91	208.70	7125.13
205.80	1377.00	208.80	7473.72
205.90	1473.39	208.90	7835.92
		209.00	8212.11



Attachment 5b

ZONE	Long.	Lat.	EMBANKMENT	Place		Levels at the top of embankments/ bund	Weather flood water over topped	
							Yes	No
1	77.249328	28.654831	RIGHT	MG Marg, Near Raj Ghat, Vijay Ghat		209.480		No
2	77.254095	28.647295	RIGHT	MG Marg, Near Raj Ghat		209.960		No
3	77.264990	28.654292	LEFT	Geeta colony Shamshan ghat		207.775		No
4	77.236482	28.886787	LEFT	Alipur Bandh, Mavikala	Pertains to UP Irrigation			
5	77.236959	28.888090	LEFT	Alipur Bandh, Mavi Kala				
6	77.237171°	28.831976	LEFT	Near Allipur				
7	77.234262	28.825883	LEFT	Near Allipur				
8	77.229920	28.821415	LEFT	Near Allipur				
9	77.228268	28.819780	LEFT	Near Allipur				
10	77.215168	28.806133	LEFT	Near Pachayara Police chowki				
11	77.243285	28.776001	LEFT	Tronica City Road				
12	77.243389	28.776901	LEFT	Tronica City Road				
13	77.206890	28.771060	RIGHT	Bund Road, near SCADA center DJB		213.225		No
14	77.209419	28.740487	RIGHT	Raj Marg, Milan Vihar		212.486		No

CE(FM)...अनु./Sec./निदे./Dte.
डा.सं./Dy. No....282.....
दिनांक/Date...30/5/24.....

कार्यालय अधिशासी अभियन्ता
हैड वर्क्स खण्ड ,आगरा नहर
ओखला, नई दिल्ली–25

पंत्राकः– /है0व0ख0/बाढ़/ दिनांकः–

विषयः– 3rd Meeting of the committee for joint flood management study of river Yamuna for its reach between hathnikund and okhla barrage.

अधीक्षण अभियन्ता, तृतीय मण्डल सिंचाई कार्य, आगरा।
महोदय,

उपरोक्त विषयक के सम्बन्ध में अवगत कराना है कि अधीक्षण अभियन्ता, सिंचाई कार्य मण्डल, सहारनपुर के पत्रांक सं0 511 /सिंकामस/दिनांक 26.04.2024 के बिन्दु सं0 1 द्वारा ओखला बैराज से सम्बन्धित जी0डी0 टैबल की अद्यतन सूचना एवं बिन्दु सं0 2 द्वारा बजीराबाद बैराज के अपस्ट्रीम में निर्मित सिंचाई विभाग के अलीपुर तटबन्ध के निम्नलिखित तालिका 11 के अनुसार स्थलों के Longtitude & Latitide के Levels उपलब्ध कराने की वांछना की गई है। उक्त के सम्बन्ध में सूचना निम्नानुसार है।

1. ओखला बैराज से सम्बन्धित जी0डी0 टैबल की अद्यतन सूचना (छायाप्रति संलग्न) है।
2. अलीपुर तटबन्ध के निम्नलिखित तालिका 11 के अनुसार स्थलों के Longtitude & Latitide के Levels निम्नानुसार है।

Table 11: Idenfied Locations

ZONE	Long.(°E)	Lat.(°N)	EMBANKMENT	LEVELS
8	77.22992	28.821415	LEFT	213.960
9	77.228268	28.81978	LEFT	213.940
10	77.215168	28.806133	LEFT	213.270
11	77.243285	28.776001	LEFT	211.810
12	77.243389	28.776901	LEFT	211.830

अवगतनीय है कि बिन्दु सं0–2 से सम्बन्धित Table 11 में अंकित Zone 1 से 7 , 13 एवं 14 इस खण्ड से अच्छादित नही है।

सूचनार्थ एवं अग्रिम आवश्यक कार्यवाही हेतु प्रेषित है।

संलग्नकः– उपरोक्तानुसार।

अधिशासी अभियन्ता
हैड वर्क्स खण्ड ,आगरा नहर
ओखला, नई दिल्ली–25

पत्रांक : 1968 /है0व0ख0/बाढ़/तदिनांक :– 22-5-2024

प्रतिलिपि–निम्नलिखित को सूचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषित हैः–

1. श्री समीर कुमार शुक्ला, निदेशक, BCD (N&W), केंद्रीय जल आयोग, नई दिल्ली।
2. मुख्य अभियन्ता (यमुना), सिंचाई एवं जल संसाधन विभाग, उ0प्र0, ओखला।
3. श्री बी0के0 कारजी0, मुख्य अभियन्ता (FMO), केंद्रीय जल आयोग, नई दिल्ली।
4. अधीक्षण अभियन्ता, सिंचाई कार्य मण्डल, सहारनपुर।
5. सहायक अभियन्ता प्रथम, हैड वर्क्स खण्ड आगरा नहर, ओखला को उनके पत्रांक सं0 462/स0अ0पंचम0/दिनांक 18.05.2024 के कम में।
6. सहायक अभियन्ता– पंचम, हैड वर्क्स खण्ड आगरा नहर, ओखला को उनके पत्रांक सं0 247/स0अ0पंचम0/दिनांक 15.05.2024 के कम में।

अधिशासी अभियन्ता
हैड वर्क्स खण्ड आगरा नहर
ओखला, नई दिल्ली–25

कार्यालय अधिशासी अभियन्ता
सिंचाई खण्ड बडौत, बागपत

पत्रांकः– 345 /सि0ख0ब0बा0/बाढ़. दिनांकः 28/5/24

विषयः– 3rd Meeting of the committee for joint flood managment study of river Yamuna for its reach between hathnikund and okhla barrage.

अधीक्षण अभियन्ता, सिंचाई कार्य मण्डल, सहारनपुर।

उपरोक्त विषयक आपके पत्रांकः 511/सिंकामस, दिनांकः 26.04.2024 के बिन्दु संख्या–01 द्वारा बजीराबाद बैराज के अपरस्ट्रीम में निर्मित सिंचाई विभाग के अलीपुर तटबन्ध के निम्नलिखित तालिका 11 के अनुसार स्थलों के Longtitude & Latitide के Levels उपलब्ध कराने की वांछनरा की गई है। उक्त के सम्बन्ध में सूचना निम्नानुसार है।

1– अलीपुर तटबन्ध के निम्नलिखित तालिका 11 के अनुसार स्थलों के Longtitude & Latitide के Levels निम्नानुसार है।

Table11: Idenfied Locations

ZONE	Long.(^{O}E)	Lat.(^{O}N)	EMBANKMENT	LEVELS
4	77.1410	28.5311	LEFT	216.130
5	77.1404	28.5252	LEFT	215.970

अवगतनीय है कि बिन्दु संख्या–02 से सम्बन्धित टेबिल 11 में अंकित जोन 1 से 3 एवं 6 से 14 इस खण्ड से अच्छादित नही है।

रिपोर्ट सूचनार्थ एवं अग्रिम आवश्यक कार्यवाही हेतु प्रेषित है।

अधिशासी अभियन्ता
सिंचाई खण्ड बडौत
बागपत

पत्रांकः– /सि0ख0ब0बा0/बाढ़,दिनांकः

प्रतिलिपि निम्नलिखित को सूचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषित हैः–

1:– श्री समीर कुमार शुक्ला निदेशक, BCD (N&W), केन्द्रीय जल आयोग, नई दिल्ली।
2:– मुख्य अभियन्ता(यमुना), सिंचाई एवं जल संसाधन विभाग, ओखला।
3:– श्री वी0के0 कारजी0, मुख्य अभियन्ता (FMO), केन्द्रीय जल आयोग, नई दिल्ली।
4:– अधीक्षण अभियन्ता, तृतीय मण्डल सिंचाई कार्य, आगरा।
5:– सहायक अभियन्ता चतुर्थ, सिंचाई खण्ड बडौत, बागपत।

अधिशासी अभियन्ता
सिंचाई खण्ड बडौत
बागपत

Attachment 5c

Operating Mechanism of out falling drain in River Yamuna (As per IFCD, national Capital of Delhi)

The River Yamuna enters in Delhi from Palla and flows upto Jaitpur by travelling aprox. 48 Kms. There are 20 drains which are outfalling into River Yamuna in Delhi region from D/S of Wazirabad Barrage to Jaitpur. The detailed parameters of these drains are given in **Table 5.8**

(A) These drains outfalling into the river Yamuna do not have any regulatory mechanism.

- Najafgarh Drain (Sahibi River)
- Barapulla Drain.
- Shahdara Outfall Drain
- Taimur Nagar Drain

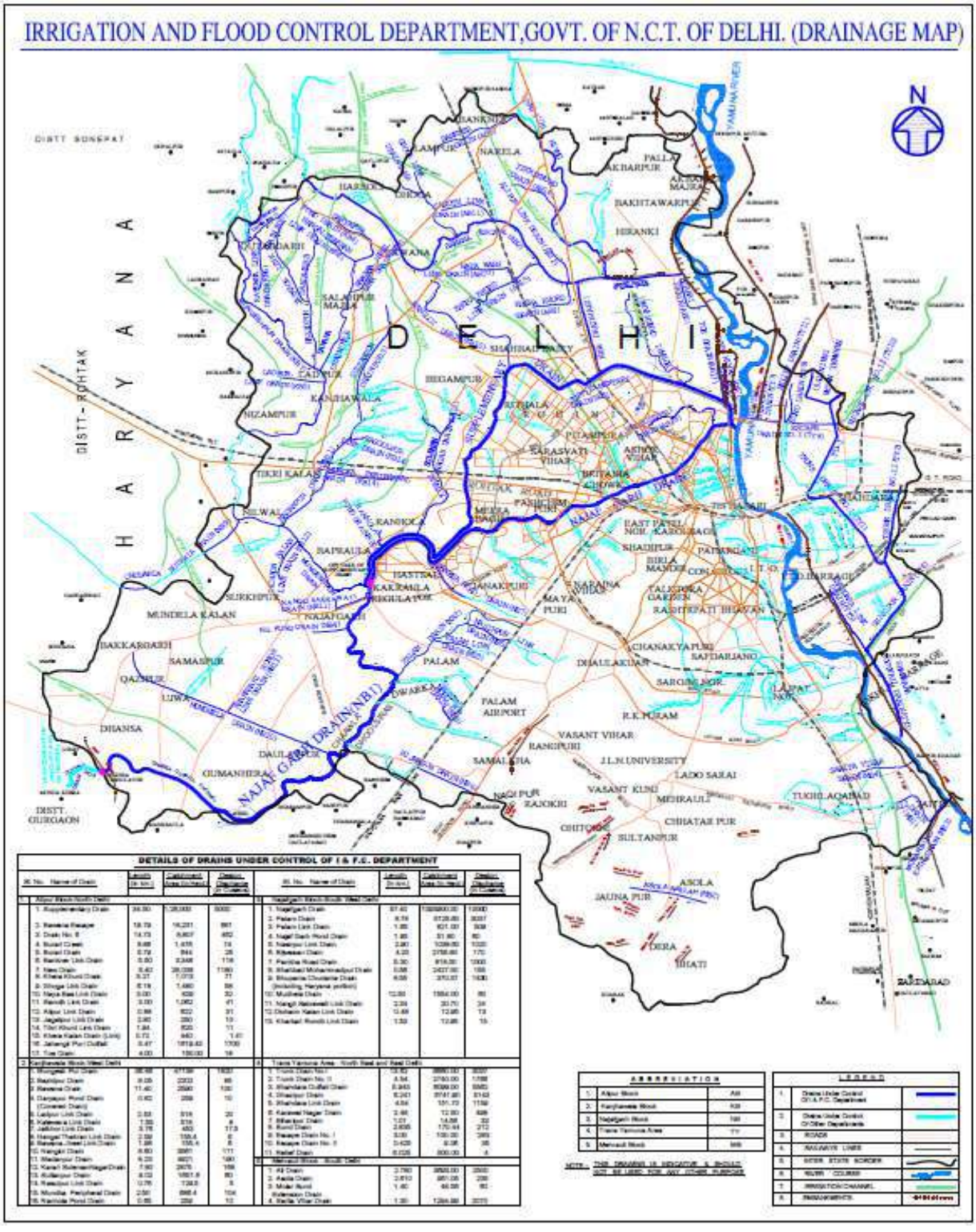
These three drains do not have any regulator at its outfall however a regulators have been provided on outfall of some of the identified vulnerable inlets in these drains and which are affected by backflow during the floods in River Yamuna. During the high flood, when there is backflow in these drains all these regulators are closed and necessary pumping started to pump out the drain water towards River so as to avoid any water logging on city side. Details of pumps deployed at each regulators are also given in the Annexure 'A'. The pumping arrangement seems to be adequate as per past experience during the high floods to pump out the drain water. The additional pumps may also be deployed as per requirement, considering the quantum and extent of rainfall in catchment area of inlets/ drains.

(B) The other drains outfalling into the river Yamuna which have proper regulatory mechanism at its outfall are as under:

- Magazine Road Drain
- Old Chandrawal Drain
- Khyber Pass Drain
- Metcalf House Drain
- Qudsia Ghat Drain
- Tonga Stand Drain
- Vijay Ghat Drain
- Civil Military Drain
- Delhi Gate Drain/Power House
- Sen Nursing Home Nallah/Nallah No. 12

- Nallah No. 12 A
- Nallah No. 14
- Nallah No. 15
- Nallah No. 17
- Abul Fazal Drain
- RME 180 Madanpur Khadar

These drains have proper Regulatory System at its outfall to operate it during the high flood to prevent back flow of River water towards the city side. During the high flood, when there is backflow in the drain all these regulators are closed and necessary pumping started to pump out the drain water towards River so as to avoid any water logging on city side. Details of pumps deployed at each regulator also given in the Annexure 'A'. The pumping arrangement seems to be adequate as per past experience during the high floods to pump out the drain water. The additional pumps may also be deployed as per requirement.


IRRIGATION AND FLOOD CONTROL DEPARTMENT,GOVT. OF N.C.T. OF DELHI. (DRAINAGE MAP)
H A R Y A N A
D E L H I
N
DISTT SONEPAT
DISTT - ROHTAK
DISTT GURGAON
YAMUNA RIVER
NAJAFGARH DRAIN(NBI)
BANKNER
NARELA
BAKHTAWARPUR
HIRANKI
SAJAPUR MAZRA
BEGAMPUR
KANJHAWALA
NIZAMPUR
TIKRI KALAN
BEGUMPUR
KESHAV PURAM
SARASWATI VIHAR
ASHOK VIHAR
BRITANIA CHOWK
PASCHIM PURI
EAST PATEL NGR.
SHADIPUR
PATELNAGAR
RANHOLA
NAIMAULA
KAKROLA
NAJAFGARH
MUNDELA KALAN
BAKKARWALA
SAMALKHA
PALAM
DHANSA
DAULATPUR
GUMANHERA
PALAM AIRPORT
R.K.PURAM
VASANT VIHAR
RANGPURI
J.L.N.UNIVERSITY
LADO SARAI
VASANT KUNJ
MEHRAULI
CHHATAI PUR
SULTANPUR
NAGLI RAJOKRI
ASOLA
JAUNA PUR
DERA
BHATI
TUGHLAQABAD
DETAILS OF DRAINS UNDER CONTROL OF I & F.C. DEPARTMENT
ABBREVIATION
LEGEND
NOTE : THIS DRAWING IS INDICATIVE & SHOULD NOT BE USED FOR ANY OTHER PURPOSE

LIST OF OUTFALLING DRAIN IN DELHI
Regulator operated during the last & past floods

Table 5.8: List of Out falling Drain in Delhi

S. No.	REGULATOR NUMBERING	Name of Regulator	Discharge / Flow during flood	Size / Width (in Mtr.)	Sill Level/ Bottom (in Mtr.)	HFL (in Mtr.)	Operation Level w.r.t. ORB	Requirement Capacity Pump / (in HP)
		(N.G. Drain)						
1.	R1	Hakikat Nagar Inlet (54700m)	11 cusec	3.30x4.90r	205.87	209.70	204.90	12 HP (02 Nos.)
2.	R2	MES Inlet (55050m)	02 cusec	4.10x4.5	206.00	209.60	204.90	05 HP (01 Nos.)
3.	R3	Nehru Vihar Inlet (56014m)	15 cusec	2.35x4.40m	204.00	209.375	203.80	12 HP (02 Nos.)
4.	R4	Podina Inlet (56014m)	15 cusec	2.35x4.4	204.00	209.375	204.95	12 HP (02 Nos.)
5.	R5	J.P Drain regulator	35 cusec	3x5.00m 1x7.70m	203.400	209.00	204.56	72 HP - 2 No. 60 HP - 2 No. 32 HP - 1 No. 25 HP - 3 No. 21 HP - 3 No.
		(Supplementary Drain)						
6.	R6	RD 1170m (Wazirabad)	36 cus	1.50m	206.05	210.21	207.55	32 HP
7.	R7	RD 2683m (Jharoda Majra)	15 cus	900mm dia pipe	205.30	209.56	206.20	32 HP (2 No.)
8.	R8	RD 4170m (Burari)	40 cus	1200mm dia pipe	204.80	209.36	206.00	32 HP (3 No.)
9.	R9	RD 4250m	36 cusec	1.50m	205.50	209.66	207.00	20 HP

		(Burari)						
10.	R10	RD 5194m (Mukundpur)	15 cusec	900mm Dia pipe	205.40	209.46	206.30	32 HP
11.	R11	RD 5690m (Mukundpur, Peer Baba)	15 cusec	900mm Dia pipe	205.85	209.41	206.75	32 HP
12.	R12	RD 5780m (Mukundpur)	15 cusec	900mm Dia pipe	205.65	209.41	206.55	20 HP
13.	R13	RD 5890m (Mukundpur Golf)	15 cusec	900mm Dia pipe	205.55	209.41	206.55	32 HP
14.	R14	RD 7500m (Bhalswa)	15 cusec	900mm Dia pipe	205.10	209.41	206.60	20 HP
15.	R15	Toe Drain	18	1 x 1.50 Meter	205.03	209.18	205.50	32 HP (3 Nos.) 8 HP (02 Nos.) 7.50 HP (02 Nos.) 20 HP (04 Nos.)
16.	R16	Link drain No. II	10	1 x 2.50 Meter	204.00	209.18	205.48	32 HP (01 No.) 50 HP (01 No.) 20 HP (04 Nos.) 20 HP (01 No.) 25 HP (01 No.)
17.	R17	New Course of Burari Creek drain at RD 640 m	74 cusecs	5 to 8 M	205.57	209.185	205.640	32 H.P. (03 Nos.) 7.5 H.P. (08 Nos.) 20 HP (04 Nos.)
		Yamuna river						
18.	R18	Magazine road drain	2.59 cusec	1 x 3.00 Meter	206.400m	209.676 Meter	207.150m	25 HP
19.	R19	Old Chandrawal drain	1.92 cusec	2 x 2.00 Meter	206.400m	209.640 Meter	207.150m	25 HP
20.	R20	Khyber pass drain	2.39 cusec	1 x 3.00 Meter	206.500m	209.605 Meter	207.120m	25 HP

21.	R21	Metcalf house drain	2.71 cusec	1 x 1.98 Meter	204.176m	209.450 Meter	205.550m	32 HP
22.	R22	Qudsia Ghat drain (Now Vasudev Ghat)	16.12 cusec	1 x 6.00 Meter	204.370m	209.132 Meter	205.740m	60 HP
23.	R23	Tonga stand drain	2.71 cusec	1 x 2.00 Meter	204.250m	208.803 Meter	204.700m	60 HP
24.	R24	Vijay Ghat		5.00x5.70	202.90	207.36	204.00	82 HP(2No.) 62 HP(2Nos.)
25.	R25	Civil Military Drain		5.10x 6.00	202.64	207.21	206.45	82 HP(2Nos.) 32 HP(2Nos.) 25 HP(2Nos.)
26.	R26	Delhi Gate/ Power House		7.62x 5.48	202.22	206.22	205.36	82 HP(3Nos.) 62 HP(3Nos.)
27.	R27	Sen Nursing Home Nallah / Nallah No. 12		10.90x 4.70	202.78	205.80	205.60	82 HP(4Nos.)
28.	R28	Nallah No. 12A		1.20x 4.75	201.73	205.80	205.20	5 HP(2Nos.)
29.	R29	Nallah No. 14		9.00x 4.30	202.31	205.39	205.96	82 HP(1Nos.) 32 HP(3Nos.) 10 HP(2Nos.)
30.	R30	Nallah No. 15		2.50x 3.80	201.86	204.91		7.5 HP(1Nos.)
31.	R31	Chilla Regulator L/S			198.78	200.75		If required
32.	R32	Chilla Regulator D/S			198.78	200.60		
33.		Barapulla Nallah	No regulator					

34.		Maharani Bagh Nallah / Nallah No.17 / Taimur Nagar Drain	No regulator	
35.		Abdul Fazal Drain	Maintained by UP Irrigation	

S. No.	REGULATOR NUMBERING	Regulator	Size (m)	Top level of regulator	Sill Levels (m)
		SHAHDARA OUTFALL DRAIN			
36	I1	Shahdara outfall drain RD 5680 L/S	2.00x1.50	202.917	198.140
37	I2	Shahdara outfall drain RD 5620 R/S	1.00m Dia Pipe Circular	204.100	199.390
38	I3	Shahdara outfall drain RD 5450 L/S	2.45x1.50 Rectangular	201.160	198.700
39	I4	Shahdara outfall drain RD 5445 L/S	2.75x1.50 Rectangular	202.615	199.520
40	I5	Shahdara outfall drain RD 5440 L/S	1200mm dia pipe	203.786	201.732
41	I6	Shahdara outfall drain RD 3875 R/S	0.60x1.00 Rectangular	202.975	199.440
42	I7	Shahdara outfall drain RD 3150 L/S	1.00m dia pipe circular	200.480-U/s 202.235-D/s	197.245
43	I8	Shahdara outfall drain RD 2600 R/S	0.90m dia pipe circular	206.126	199.505
44	R33	RME 180 Mtr. Madanpur Khadar			

6 Barrages on River Yamuna

6.1 Salient Features of Barrages on River Yamuna in Study Area

There are four barrages across Yamuna River namely Hathnikund Barrage, Wazirabad Barrage, Yamuna (ITO) Barrage and Okhla Barrage in the study reach. The salient features of these barrages as provided by project authorities are given in **Table 6.1**:

Table 6.1: Details of the barrages on river Yamuna

Particulars	Hathnikund Barrage	Wazirabad Barrage	ITO Barrage	Okhla Barrage
Year of Construction	1999	1959	1965-66	1982
Owner	I&WRD, Haryana	DJB, Delhi	I&WRD, Haryana	I&WRD, UP
River Bed Level (m)	329	201.47	199.217	195.85
Design Flood (Cumec)	22,000 (1 in 100 yr)	-	8,495	8,495
HFL (m)	342.35	208.178	206.289	202.17
PL (m)	334.32	205.6	202.23	201.35
Total Gates (Nos.)	18	29	32	27
Under-Sluice/US (Nos.)	8	12	10	5
US Width (m)	18	8.36	8.38	18.3
US Crest (m)	329	201.47	199.217	195.85
Spillways/SP (Nos.)	10	17	22	22
SP Width (m)	18	17.68	18.3	18.3
SP Crest (m)	330	202.692	200.131	196.75

Note: In addition to the above structures, Okhla weir is a defunct/abandoned submerged weir constructed in 1874 and located in upstream of Okhla Barrage.

A layout depicting the existing and planned structures in Yamuna Basin is presented in **Fig. 6.1.**

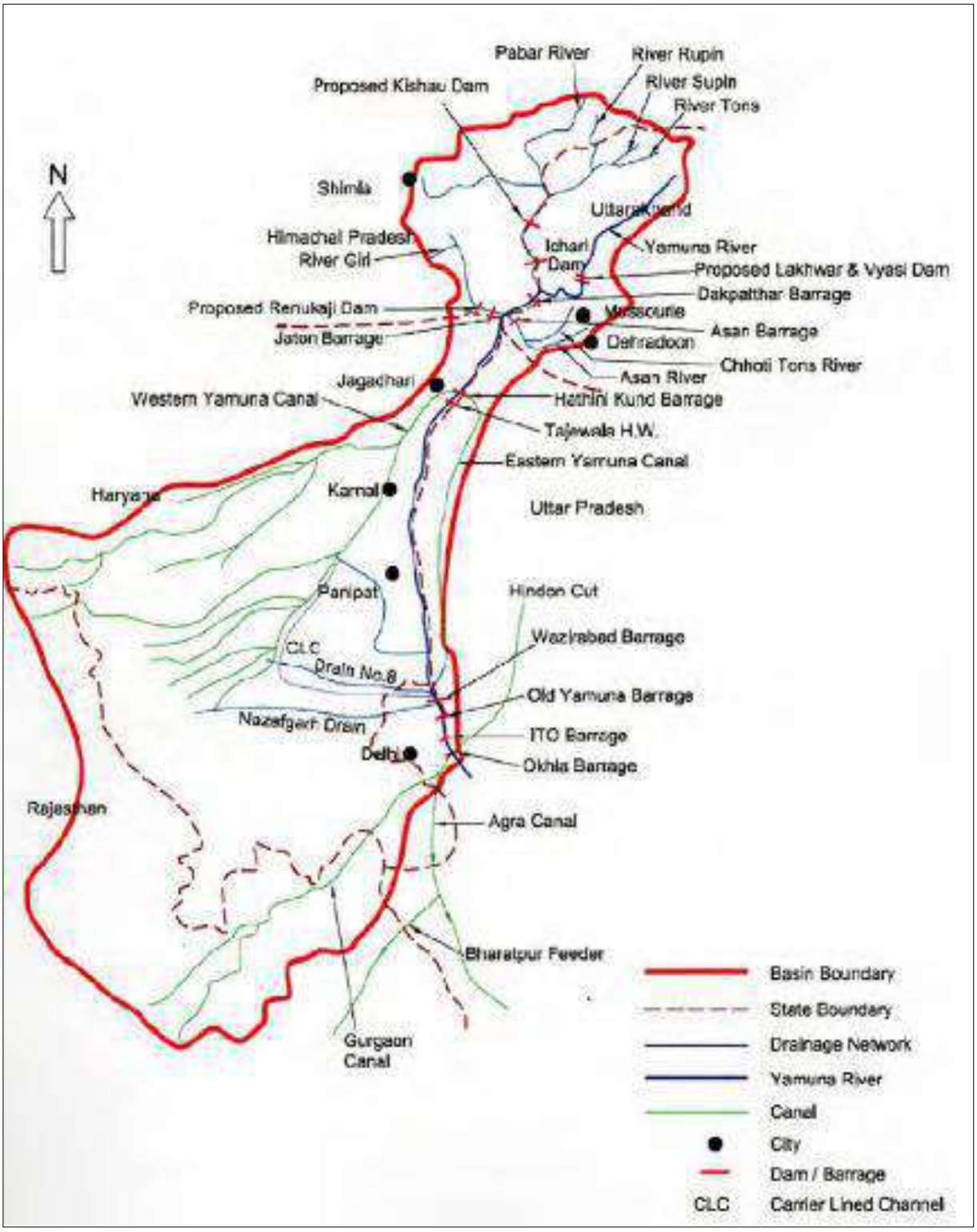


Fig. 6.1: Map depicting the existing and planned structures on Yamuna Basin

6.2 Summary of observations vis-à-vis discharge computation by project authorities during the visit to Barrages on River Yamuna in Study Area

As decided in the 2nd meeting held on 13th November, 2023 of the Committee for joint flood management study of river Yamuna that officers of CWC will visit the barrages on Yamuna River from Hathnikund to Okhla.

Accordingly, the barrages on river Yamuna from Hathnikund to Okhla were visited by CWC officials along with concerned officials of the respective barrages to assess the discharge computation methodologies being adopted by the project authorities and the overall operation of the barrages.

The summary of observations vis-à-vis discharge computation methods being adopted by project authorities during the visit to Barrages on River Yamuna in study area are summarized below:

6.2.1 Hathnikund Barrage

- The peak discharge as reported by the project authority during the flood was **3,59,760 cusecs** corresponding to u/s water level 336.35 m recorded on 11.07.2023 at 11.00 AM at Hathnikund Barrage.
- It was observed that the discharge computation methodology being adopted by the project authority was erroneous and the correct method of computation as per IS codes was conveyed to them during the visit of CWC team on 18.11.2023.
- Accordingly, as per above recommendation, the project authorities have corrected their computation and peak discharge for 11.07.2023 has now been reported to be **4,22,431 cusecs** against the originally reported discharge of 3,59,760 cusecs. The modified final peak discharge for the period of 2014-2023 is given in **Table 6.2**

Table 6.2 Final peak discharge as reported by the project authority

Year	Final peak discharge (Cusecs)
2014	3,44,642
2015	2,60,277
2016	3,01,454
2017	3,01,454
2018	4,70,634
2019	6,52,584
2020*	54,065*
2021	1,84,395
2022	2,28,854
2023	4,22,431

*Controlled flow from barrage as informed by project authority hence this discharge could not be verified as the gate openings are not available.

- The present calculation has been carried out using the weir coefficient as per IS 6966. Project authority has been advised to undertake model studies for determination of actual coefficient of discharge. The discharge computation will need to be accordingly modified by the project authority.

6.2.2 Wazirabad Barrage

- The peak discharge as reported by the project authority during the flood was **11,37,020 cusecs** corresponding to u/s water level 209.43 m recorded on 13.07.2023 at 01.00 PM at Wazirabad Barrage.

- However, for the same scenario the estimated discharge (by standard calculation method) from all the gates in fully opened position, is found to be **2,89,000 cusecs.** Here, it is also pertinent to mention that there is siltation in upstream and downstream which may further affect the discharge passing capacity of the structure.

- The correct method of computation as per IS codes has also been conveyed to project authority of Wazirabad Barrage.

- Project authority has been advised to undertake model studies at least up to ITO barrage to have better accuracy in discharge computation. Accordingly, it has been informed that project authority has approached IRI, Roorkee for model studies for updated tail water rating curve. The discharge computation will need to be accordingly modified by the project authority.

6.2.3 ITO Barrage

- During the peak flow, out of 32 gates of ITO barrage which is downstream of Old Delhi Railway Bridge, some of gates were reportedly non-operational till 13th July 2023 (as per the media reporting). During this time the peak flood was passing through Old Delhi Railway Bridge and ITO Barrage leading to higher afflux and subsequent water levels.

- The estimated maximum discharge from the barrage in free flow condition (all gates fully open) at HFL 206.289 m is **3,23,000 cusecs** as per IS Code.

- The estimated discharge from the barrage gates in the scenario as observed during the visit on 27.07.2023 is 2,29,000 cusecs at HFL of 206.289 as per design calculations. Here, it is also pertinent to mention that there is siltation in upstream and downstream which may further affect the discharge passing capacity of the structure.

- The correct method of discharge computation to be adopted by the project authority as per IS codes has been conveyed to the project authority of ITO barrage.

- However, as the requirement of ponding is yet to be established after decommissioning of Indraprastha Power Station and Rajghat Power House of Delhi Thermal Power Control Board (DTPCB) and there being no withdrawals from the barrage pond, the project authority has been advised to keep all the gates fully open at all times. They have also been advised to clear all the obstructions in the waterway of barrage to avoid any congestion during flood.

- The basic structure of ITO barrage comprising of piers with gate grooves and deck slab is in place. The gates of the barrages are kept open during flood period so that the original condition of river is maintained and the barrage structure has a minimum impact on river flow during floods. Further, the barrage is linked with Road Bridge. Therefore, the only matter to be considered is whether gates are to be dismantled or not. It is observed that in lean season, the gates could be useful to impound some water for various purposes including recreational activities. Hence, it is recommended to operate ITO barrage with all gates open during floods in coordination with operation of Wazirabad barrage and Okhla barrage. It is also recommended that regular maintenance of all hydro-mechanical equipment of barrage be conducted as per the operation and maintenance manual of the barrage/codal provisions.

- The matter of handing over of the ITO barrage to Government of Delhi can be taken up separately by appropriate authority.

6.2.4 Okhla Barrage

- The peak discharge as reported by the project authority during the flood was **3,72,225 cusecs** corresponding to u/s water level 200.80 m and d/s water level 200.75 m recorded on 13.07.2023 at 05.00 PM at Okhla Barrage. It is pertinent to mention here that the design capacity of the barrage is 3,00,000 cusecs at HFL of 202.17 m.

- Observing that the discharge computation methodology being adopted by the project authority was erroneous, the correct method of computation as per IS codes was conveyed to them during the visit of CWC officers to barrage site on 09.01.2024.

- The estimated discharge in above mentioned scenario (by standard calculation method) in free flow condition (all gates fully open) as per the upstream and downstream levels reported by project authority is **1,77,421 cusecs.**

- Project authority has been advised to undertake model studies for determination of actual coefficient of discharge. The discharge computation will need to be accordingly modified by the project authority.

- The Project Authority have informed that they engaged IIT Delhi to correct their methodology for the discharge computation of Okhla barrage. Furthermore, they have agreed to adopt the discharge computation methodology suggested by CWC in consultation with IIT Delhi. CWC has also advised the project authorities to

modify the historical discharge data of the Okhla barrage according to corrected methodology.

6.3 Conclusions

The discharge computations have been reconciled for Hathnikund Barrage in consultation with project authorities and may be used in future. Discharge computations for Wazirabad Barrage and Okhla Barrage are being revised by project authorities in consultation with IRI, Roorkee and IIT, Delhi respectively and same may be expedited.

I. Discharge Computation:

- Project authorities should also regularly review their discharge computation vis-à-vis:

  a. Upstream and downstream water levels
  b. Changes in Cd over the years
  c. Morphological Changes
  d. Tail Water Rating Curve

It is pertinent to mention that project authorities have not updated the charts and tables being used for the purpose since the commissioning of the barrages and the same may not be applicable anymore due to changes in river morphology along the river stream.

- Integrated numerical and physical models of the river reach from Wazirabad to Okhla including all such structures like barrages, bridges and other such interventions in the river, needs to be maintained for actual assessment of afflux.

II. Obstruction in Waterway:

- Obstructions in waterway due to silt deposition need to be removed in upstream and downstream of the barrage on a regular basis and the channel and barrage should be maintained regularly to ensure their flow capacities. The agencies involved in construction of structures across the river should be made responsible for removal the debris accumulated during the work in the river floodplains, and clear the obstruction across the river due to the same.

III. Updation /Integration of Benchmark

- Due to frequent construction activities, there are chances of dislodging of Benchmarks (BMs) for measuring river water levels/gauges. Hence there is a need of regular cross checking of these BMs with the permanent BMs of Survey of India. Further, all the barrages i.e. Hathnikund, Wazirabad, ITO, Okhla should have common benchmark to avoid discrepancies during correlation of water levels.

IV. Integrated Operation of Barrages

- The integrated operation of barrages on Yamuna River will be helpful in avoiding any flow congestion.

- SOPs for integrated operation of barrage may be prepared for flood conditions. Coordination of barrage operation by I & FC Dept. Govt. of NCT Delhi with all three barrage/project authorities.

V. Gate Operation:

- Project authority should ensure all hydraulic gates of the barrages in proper working condition before onset of monsoon season and ensure unrestricted passage of flood**.**

VI. Training of Staff:

- Engineers and staff posted at the barrage and involved in recording the data and discharge calculations may be trained suitably by approaching training institutes such as National Water Academy, Pune or any other suitable training center for their capacity building.

7 Encroachments in the River Yamuna

7.1 Restoration and Rejuvenation of River Yamuna Flood Plains

The issue of encroachments in river was highlighted in the Interim Report of the committee and thereafter Delhi Development Authority (DDA) has taken up the restoration and rejuvenation of River Yamuna Flood Plains in 22 Kms urban stretch in Delhi spanning from Wazirabad Barrage to Okhla Barrage (Both eastern and western Banks). The primary objective of DDA's Restoration Plan is to restore, revive and rejuvenate the floodplains of River Yamuna to their pristine state and make them accessible to the public at large. DDA has been working as per the directions of the Hon'ble NGT and recommendations of the Principal Committee constituted by the Hon'ble NGT for the development of Flood plains. The entire 22 Kms stretch of river Yamuna in Delhi (Western Bank & Eastern Bank) has been sub divided into 10/11 Projects for the ease of Execution.

7.2 Protection of Yamuna Flood Plains

The actions planned by DDA involved in protection of Yamuna Flood Plains have been further categorized under following activities

7.2.1 Repossession of land

I. Protection of Yamuna Flood Plains
II. Repossession of Land
III. Identification of Encroachments
IV. Status of Land ownership /Legal Status verification
V. Physical Demolition drives with the assistance of Local Police
VI. Identification of Malba and C&D waste of Infrastructure Agencies
VII. Quantification and Type of debris such as malba, C&D, municipal waste, silt etc. and intimation to the agencies about their removal plan
VIII. Coordination with Animal husbandry- Deptt. of Municipal corporation of Delhi for removal of Cattles and their sheds.
IX. Immediate Fencing of re-possessed land Deployment of Security Guards
X. Issue of Challans for illegal parking, Malba disposal and banned activities as per H'NGT

7.2.2 DDA being the land owning agency of Zone O, is consistently engaged in protection of Yamuna Flood Plains.

I. Demarcation of 1:25 year flood plains has been done by DDA. Presently 591 Bollards duly marked with GPS Co-ordinates, 375 Nos. Flag posts and 27 Nos. of sign boards have been installed for the demarcation of flood plains.
II. 134 Security Guards and patrolling vehicles have been engaged for protection of Flood Plains to stop illegal dumping of Malba and to stop further encroachment.
III. 93 nos. CCTV cameras have also been installed at 27 locations for protection of flood plains.

7.3 Action taken Report on Removal of Encroachments/Muck/Temporary Structures in River Yamuna by DDA

Encroachment Removal Drive as carried out by DDA is mentioned in **Table 7.1**

Table 7.1: Encroachment Removal Drive as carried out by DDA

Sl. No.	Location/Project	Date of encroachment removal	Area Freed from Encroachment (in Acre)	Type of Encroachment	Remarks
1	'O' Zone area between NH24 and Railway line, behind CWG Flats, Eastern Bank (Amrut Biodiversity park)	27.06.2022, 28.06.2023	110.00	Cultivation	Re-possessed Area taken up for restoration in Amrut Biodiversity Park project
		10.09.2023	1.50		
		05.07.2024	1.20	50 jhuggies	
2	DDA land in Yamuna Floodplains between ITO bridge and Railway Line, near south of Yamuna Bank Metro Station	21.09.2022	5.00	Cultivation	Compensatory plantation to be done in reclaimed area
		23.02.2023	4.94		
3	DDA land from NH24 to Barapullah drain (Kalindi Aviral Entn) 163 Ha.	19.06.2022,	66.70	Jhuggi/ Cultivation	Baansera Bamboo Park developed on reclaimed area.
		20.06.2022,	-		
		23.06.2022,	-		
		07.07.2022, 22.07.2022,	-		
		27.08.2022,	-		
		24.11.2022	-		
		21.02.2023	4.94		

		05.07.2024	5.00	100 Jhuggies, 10 Cattle sheds, 50 Kabadi Shops	
		26.07.2024	0.50	Ragpicker	
4	Mayur Nature Park	22.02.2023	7.41	Jhuggi/ Cultivation	Re-possessed Area will be taken up for restoration in Mayur Nature Park project
		21.03.2023	4.95		
		24.03.2023	7.00		
		24.04.2023	5.00		
		28.04.2023	4.00		
		02.05.2023	20.00		
		08.05.2023	20.00		
		12.05.2023	20.00		
		15.05.2023	20.00		
		16.05.2023	10.00		
		18.05.2023	20.00		
		22.05.2023	20.00		
		23.05.2023	10.00		
		26.05.2023	30.00		
		19.06.2023	5.00		
		23.06.2023	6.00		
		20.10.2023	8.00		
		21.10.2023			

		26.10.2023			
		27.10.2023			
		24.06.2024	10.00	Cricket Ground	
		05.07.2024, 18.07.2024 to 22.07.2024	963.70	6000 Jhuggies, 200 cattle shed, 20 nurseries, 40 Bore well	
5	Hindon Sarovar (NH-24 to DND Flyway) Yamuna Flood Plain area	11.04.2023	12.50	-	Re-possessed Area will be taken up for restoration in hindon Sarovar Project
6	DDA Land between ITO Barrage and Railway line (Eastern Bank) near Yamuna Bank Metro Station	12.10.2023	11.00	Cultivation	Compensatory plantation to be done in reclaimed area
		13.10.2023	9.00		
7	Kalindi Biodiversity park	30.10.2023	2.00	-	The reclaimed area falls in O-Zone .
8	Taimur Nagar, Joga Bai Extension	09.02.2024 and 14.02.2024	0.49	Cattle sheds, Parking and Rickshaw charging stations	
9	Restoration and Rejuvenation of River Yamuna Flood Plains.	22.06.2022	Nil		Re-possessed Area taken
		27.12.2022	30.00		

	SH: Old Rly. Bridge to ITO Barrage (Eastern Bank) U.P.Portion. (86 Hact. area)	20.01.2023	Nil	Cultivation/ Nursery/ Jhuggi	up for restoration in Asita East (UP Portion) project
		14.02.2023	20.00		
		16.02.2023	4.00		
		17.02.2023	3.41		
		21.03.2023	5.00		
		15.06.2023	5.00		
		24.09.2023	0.91		
		14.06.2024	0.57	Temple cluster	
10	Restoration and Rejuvenation of River Yamuna Flood Plains. SH: Old Rly. Bridge to ITO Barrage (Western Bank) Asita- West (Development of Land beyond Geeta Colony Bridge to Shantivan drain). (107ha)	11.01.2023	Nil	Jhuggi/ Cultivation	Re-possessed Area taken up for restoration in Asita West project
		17.01.2023	Nil		
		24.03.2023	13.00		
		27.03.2023	5.67		
		02.12.2023	0.01		
11	Restoration and Rejuvenation of River Yamuna Flood Plains. SH: Development of land beyond Wazirabad Barrage to ISBT Bridge (Eastern Bank) Garhi Mandu. (236.50 Hact.	28.06.2022	3.00		Re-possessed Area to be taken up for restoration in Yamuna Vansthali project
		29.06.2022	5.00		
		01.12.2023	0.70		

	area)				
12	Yamuna River Ghat Area	Till Dec-23	12.72		Re-possessed Area taken up for restoration in Ghat Area project
		28.05.2024	0.60	Religious Structure, Wrestling Ground	
		01.06.2024	0.30	Religious Structure & pucca structure	
Total			**1535.772**		

7.4 Undergoing Activities and Initiatives by Development Authority

It has been apprised by DDA, that currently 36 court cases pertaining to encroachment in Flood Plains is pending in Hon'ble High Court. 28 matters related to encroachment are pending in Hon'ble District Courts. DDA will take immediate action for re- possession of land as per the judgment of the Hon'ble Courts.

DDA has nominated nodal officers for each project of the flood plain who would be responsible for sustained upkeep of their jurisdictional area free from encroachment and free of construction & demolition waste.

DDA has taken up the matter with concerned authorities, such as Irrigation and Flood Control, National Ganga Mission etc., for carrying out controlled and scientific dredging for removal of silt both upstream and downstream. D.O letters have been written to both the agencies requesting for the plan for dredging of the river. VC/DDA has also chaired a meeting on 24.04.2024 in this regard.

Challans valuing Rs 7.8 Cr have been issued to the violators for Dumping of Malba and unauthorized parking in Yamuna Flood Plains from 2018 to till date.

7.5 Co-ordination of Delhi Development Authority with Infrastructures Agencies

All the infrastructures agencies such as PWD, DMRC, NCRTC, MCD, NHAI & I&FC have been intimated about the Malba, C&D Waste and other materials lying in Flood Plains through letters supported by Pictures. A meeting was held on 24th April 2024, under the chairmanship of VC, DDA for a discussion on actionable points of Hon'ble High Court order dated 8th April 2024 in WP(C) 7594/2018 and 9617/2022 on Storm Water Drain management. Representative of PWD, DMRC, NCRTC, MCD, NHAI, NMCG & I&FC attended the meeting. A brief presentation was made by DDA, wherein agency wise

influence of Malba and C&D waste dumping and/or encroachment by each was identified on various DDA projects in the Yamuna flood plains.

7.6 SoP for Restoration & Rejuvenation Works being undertaken by DDA in Flood Plains

Restoration and Rejuvenation of the floodplains of River Yamuna by DDA is an initiative to enhance the ecological character of the floodplains and to make them accessible to public by providing nature friendly spaces near the river. Each project site is being developed based on the following the universal principles of ecological restoration.

I. Restoration of natural depressions
II. Creation of catchment zones
III. Revival of floodplain forests and grasslands
IV. Creating favourable habitats, especially for water and terrestrial birds, and
V. Identifying target actions to tackle the root cause of degradation through engagement of all stakeholders.

The above projects are being taken up with respect to these principles and divided into following three zones:

i. Buffer Zone: Spanning up to 300 meters from the river edge, this zone is planted with species of Riverine grasses conducive to floodplain ecology connected with kaccha walking trails up to the river.

ii. Ecological Zone:

Plantation: Characterised with trees of native variety that are endemic to the Yamuna floodplains. These varieties have been strategically chosen and planted in multi-tier plantation as upper storey, middle storey and lower storey to promote ecological succession which is helping in nurturing floodplain biodiversity. Plantation is based on individual site topographies.

Low-lying areas: These areas have been restored as per H'NGT directions by deepening (as per site feasibility) for catchment of Flood Waters during floods that serve as water bodies after flood recedes back.

iii. Greenway: Up to 150 meters along the existing roads/ embankments have been developed as 'Public zone' with kacchha trails connecting active and passive congregation public spaces like multi-purpose area, kid's play, seating areas along with Entrance plazas and other public utilities.

7.7 Projects that have been taken up on ground by DDA

I. Lying on the eastern bank of River Yamuna and spanning from Old Delhi Railway Bridge to ITO Barrage, Asita which is another name for 'Yamuna' in ancient literature measures approximately 197 Hectares. A part of the project is in the jurisdiction of UP Irrigation Department along the Pushta Road, which has also been developed by DDA.

II. About 31,500 native trees of flood plain ecology and 3.9 million of riverine grasses have been planted so far. An existing depression measuring around 2 hectares has been restored into a water body for the catchment of flood waters. This water body has the capacity to store about 50,000-60,000 cubic metres of water during monsoon.

III. It has become home to a range of resident birds like Spotbilled Duck, Indian Moorhen, Purple Swamphen and migratory birds like Indian Paradise Flycatcher, Verditer Flycatcher, Grey Headed Canary Flycatcher, Asita East, has proved to be a bird lovers' delight. After restoration, more than 170 species of resident and migratory birds have been spotted here alone by the birding community. It is being utilised as a leisure space for all age groups.

IV. As a part of Yamuna River Rejuvenation, and directions of the H'NGT one of the old Ghats located between Aarti Sthal and Nigam Bodh Ghat has been restored and renovated by DDA as Vasudev Ghat on 5 Ha of land on the western Bank near ISBT Kashmiri Gate. The Ghat, was previously inaccessible due to steep slope, was a garbage disposal place, had 1.5-foot-deep silt deposits from floods and was mostly encroached. The 145-metre Ghat has 25 steps to descend to the river and has three entrances with ample parking space. The design combines amenities like lawns, cycling tracks, and walking areas with historic elements in Charbagh style with Baradaris and Chhatris. Unique attractions include a 250-kg metal bell sourced from Rajasthan and elephant structures made of red sand stone. Yamuna Statue is being installed here and face mound sculpture has been made which attracts tourist. Ruins of Old Ghats have been found and DDA is in the process to conserve it and make it accessible in continuity with the renovated Ghat. In collaboration with an agency DDA has ensured that Yamuna Aarti is being undertaken at the restored Ghat. Spread over 16 hectares, Vasudev Ghat's rejuvenation is part of DDA's initiative to revitalize 66 hectares of Ghats from Wazirabad to the Old Railway Bridge on the western bank. Further development/restoration of Ghats includes the Sur Ghat project, Yamuna Bazar and Eco-trail area.

V. One of the projects recently restored at Sarai Kale Khan, spreading over an area of 40 hectares on the western bank of the Yamuna River has been developed as the Capital's first Bamboo themed public space.

VI. More than 35000 bamboos of 15 different varieties procured from different parts of India have been planted here that are spread across 12 hectares of the site that was degraded due to huge amounts of C&D waste from infrastructure activities. The site has been developed with a 2 MW solar plant that will feed 134 parks of DDA through net metering. Area along the river has been planted with around 27000 native trees and more than 3 lakh riverine grasses of floodplain ecology. Other spaces like kids play area, seating shelters etc have been designed in bamboo along with kaccha pathway amidst bamboo groves. The greenway has some attractions like Musical Fountain, lotus ponds, small café in eco-friendly materials etc.

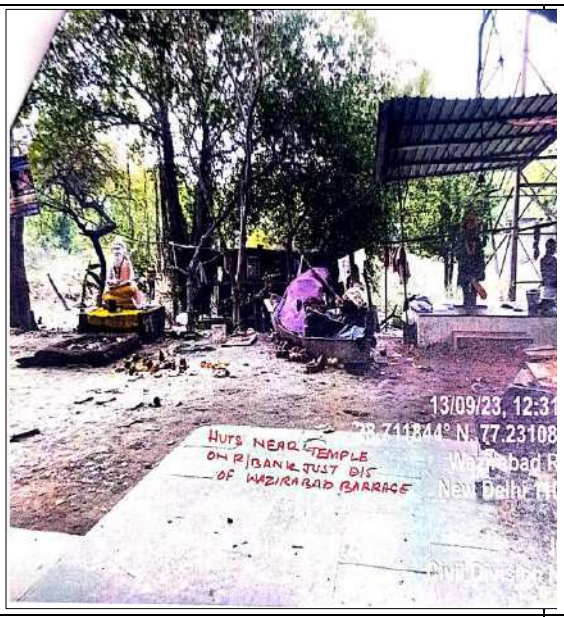
VII. Similarly, Yamuna Vatiika, Kalindi Aviral and Amrut Biodiversity park are being restored and developed by DDA for enhancing the native floodplain Bio- diversity, to provide public recreational activities and reviving the lost river-people connect.

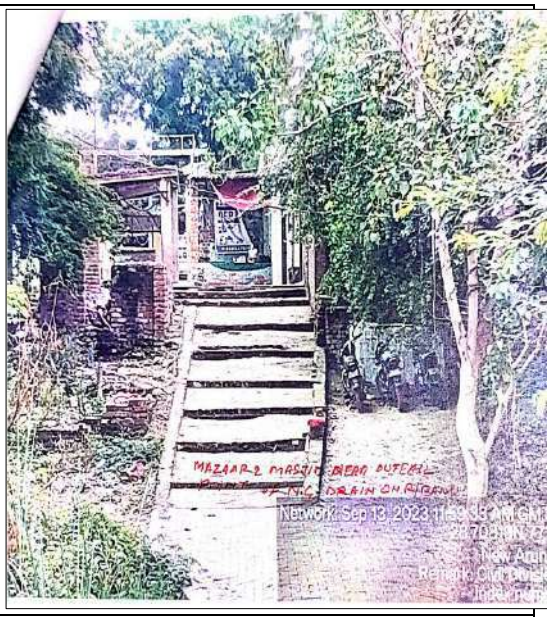
7.8 Details of Temporary structure/muck disposal clearance from the river bed/bank

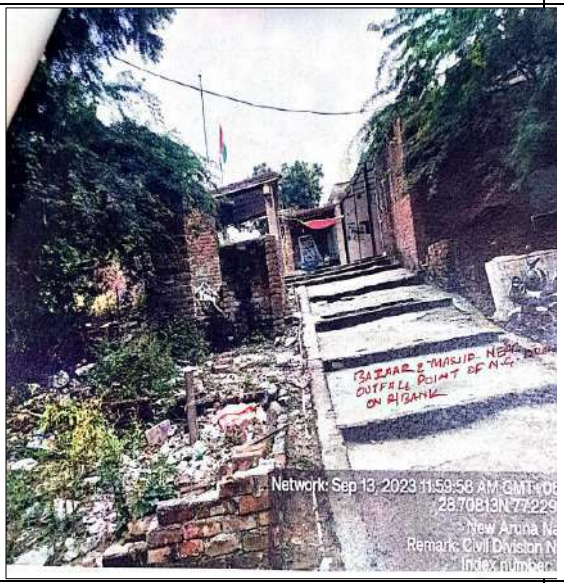
I&FC Department, Govt. of NCT Delhi has indicated the following encroachments & obstructions in the bed of river Yamuna between Wazirabad Barrage and Signature Bridge:

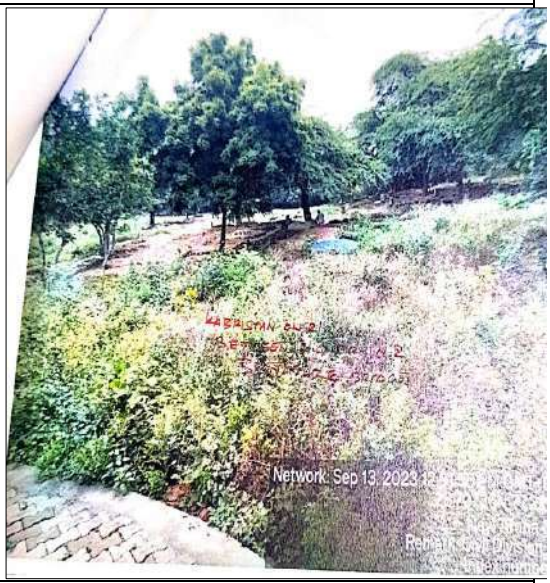
- A pucca room between Wazirabad Barrage & Signature Bridge of Yamuna.
- A temple between Wazirabad Barrage and Signature Bridge on the left bank of river Yamuna.
- Two temples & Huts just Downstream of Wazirabad Barrage on right bank of river Yamuna.
- A Mazaar and Masjid near outfall point of N.G. Drain on right bank of river Yamuna.
- A Kabristan between N.G. Drain & Signature Bridge on right bank of river Yamuna.
- Earthen Bund construction by DMRC.
- DMRC precast RCC Girders are lying in the river flood plains of river Yamuna.
- Debris and other construction waste material left under Signature Bridge by the bridge construction agency of DTDC.

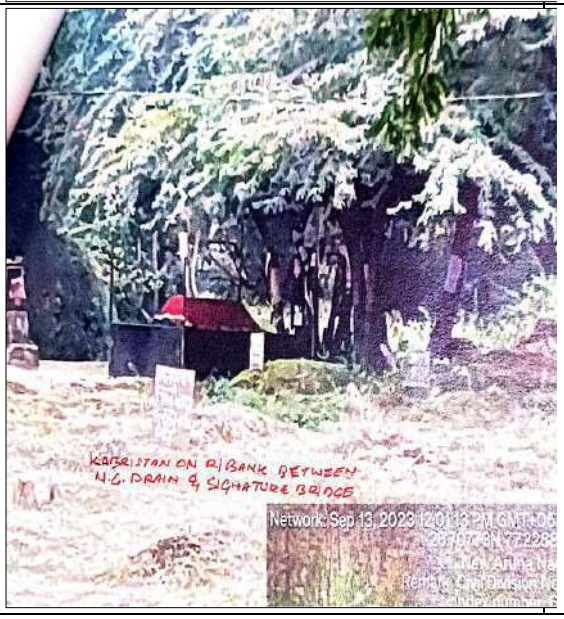
The photographs of encroachment & obstructions are shown below.

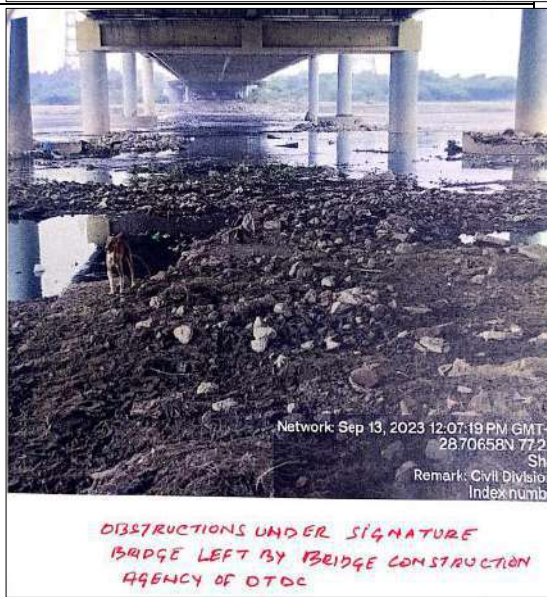




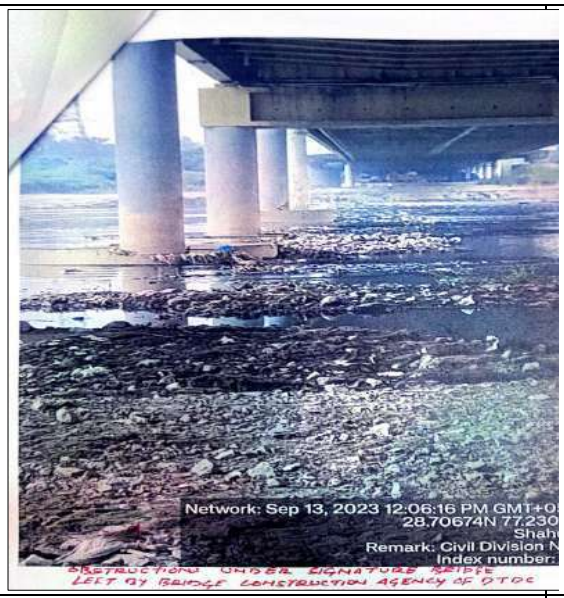








OBSTRUCTIONS UNDER SIGNATURE BRIDGE LEFT BY BRIDGE CONSTRUCTION AGENCY OF DTDC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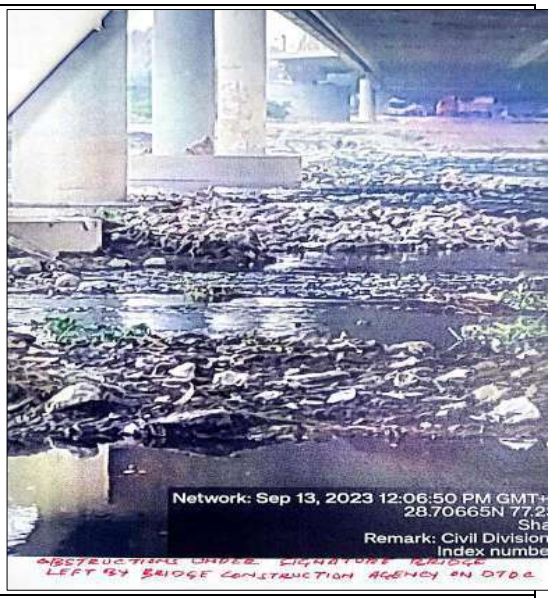
LEFT BY BRIDGE CONSTRUCTION AGENCY OF DTDC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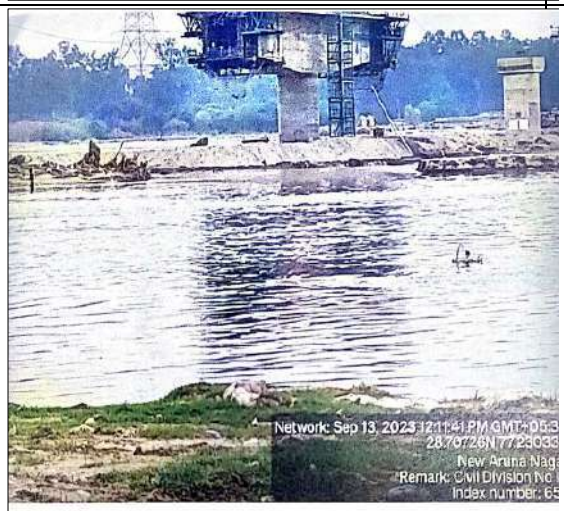
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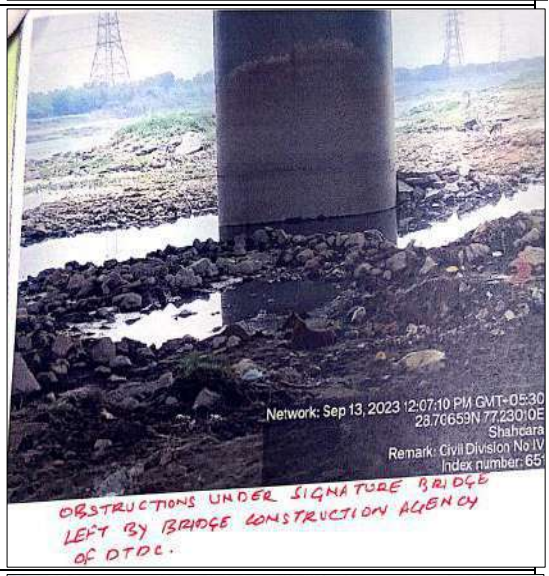
New Aruna Nag
Remark: Civil Division No
Index number: 65
EARTHEN BUNDI CONSTRUCTED BY DMRC
DURING FLOOD SEASON 2023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28.70659N 77.23010E
Shahdara
Remark: Civil Division No IV
Index number: 65
OBSTRUCTIONS UNDER SIGNATURE BRIDGE
LEFT BY BRIDGE CONSTRUCTION AGENCY
OF DTDC.


RCC GIRDERS OF DMRC LYING IN
FLOOD PLAIN AREA OF RIVER YAMUNA
Network: Sep 13, 2023 11:39:12 AM GMT+05:
28.70658N 77.2356
Remark: Civil Division N
Index number:


Network: Sep 13, 2023 11:43:57 AM GMT+05:30
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Shahdara
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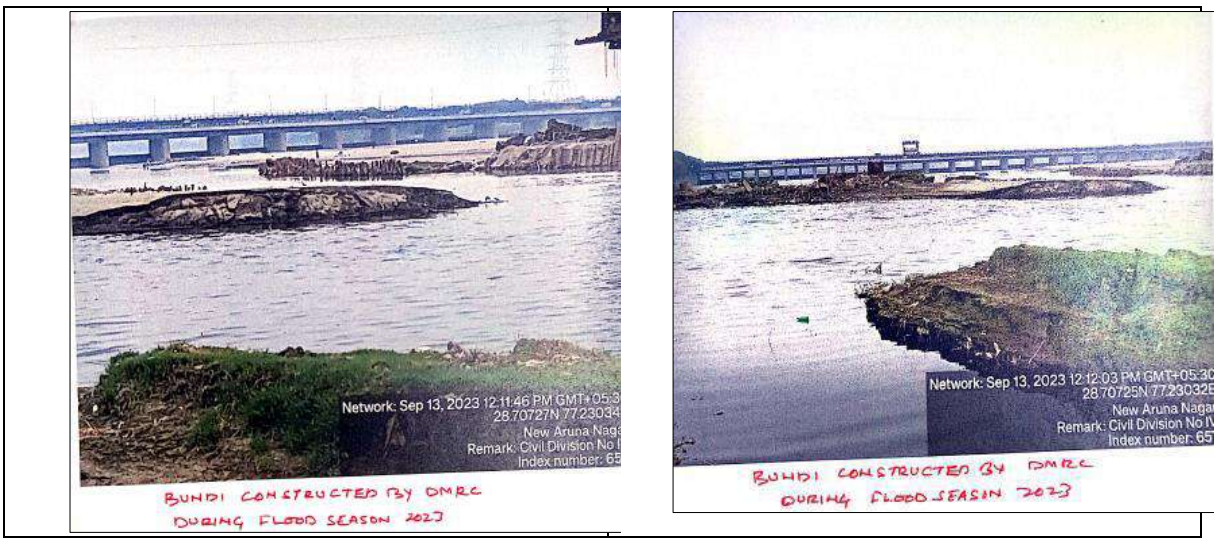
BUNDI CONSTRUCTED BY DMRC
DURING FLOOD SEASON



The committee was of the view that construction of temporary structures and muck disposal in the right of way of river during the construction led to the increased afflux during a flooding event. Hence, after construction the temporary structures should be properly dismantled and muck should be properly disposed away from the river bed/bank. The Irrigation & Flood Control Department (I&FCD) of the Government of NCT Delhi has raised concerns regarding the proposed widening of certain bunds and the addition of new bunds. Given the current carrying capacity of the river, it may not be advisable.

7.9 Status Report in this regard been taken by I&FCD, Govt. of NCT Delhi

The status report in this regard by I&FCD, Govt. of NCT Delhi is as under

Desilting Status

- Total Number of Drains - 57 (382 KM)
- Departmental machines deployed - 59
- Proposed Quantity of de-silting
  By departmental machines / by contract - 15, 05,438 MT
  (6, 61,438 MT + 8, 44,000 MT special drive)
- De-silting achieved - Total 13, 18,839 MT

Some of the issues on which action has been taken by I&FCD, Govt. of NCT Delhi on River Yamuna from Wazirabad to Okhla Barrage are shown in the **Table 7.2.**

7.10 Review of Warning Levels and Danger Levels in Delhi

Danger level and warning level are important parameters utilized for flood forecasting services. These levels are fixed in consultation with State Govt. and depends upon the threat perception in the area corresponding to those levels. It was informed by IFCD, Govt. of Delhi that the Danger Level considered presently at Old Delhi Railway Bridge needs to be re-ascertained as this level is attained even at a very low discharge/flood, thereby, causing panic to citizens of NCT of Delhi. Earlier, warning & danger levels at Old Railway Bridge were 204.00 m & 204.83 m, respectively. However, in the year 2019, the warning & danger levels were raised by 0.5 m which is 204.50 m & 205.33 m,

respectively. Delhi Govt. officials informed that they are now contemplating to change warning & danger levels further to 205.00 m and 205.75 m, respectively.

As per IFCD, Govt. of NCTD, at Warning Level which is 204.50m, gates at inlets of some drains are required to be closed. Further, after attaining danger level (205.33m) water of the active river course starts spreading on the area within the embankments, affecting the activities of inhabitants/dwellers residing therein. Further, some villages like, Ghari Mandu, Usmanpur, Madanpur Khadar and other unauthorized colonies also exist within river embankments. The backflow of the drains at the time of high stages of river Yamuna needs to be studied and the committee emphasized the regular Inspection, desilting and maintenance schedule of drains need to be ensured by Government NCT.

It was informed by I&FCD, Govt of Delhi that a study has been awarded to Central Water and Power Research Station (CWPRS) for ascertaining the Warning and Danger level of river Yamuna in Delhi and currently that study is under progress.

7.11 Conclusion

(a) The efforts are being made by DDA as well as I&FCD, Government of NCT Delhi for removal of encroachments, muck, temporary construction materials from water way of river Yamuna. However, an integrated approach by a Nodal Agency by involving all agencies like DMRC, DDA, Delhi PWD, I&FCD, Delhi Jal Board and other Government agencies carrying out construction activities in river Yamuna should be adopted to make river Yamuna free from such encroachments.

(b) The drainage network of Delhi NCR region should be cleaned/ desilted and a separate SoP for regular maintenance and inspection of drains may be prepared.

(c) I&FCD, Govt. of NCT Delhi may take up matter with Delhi Development Authority (DDA) for the levels of approach roads in use as per the water levels indicated in simulation study.

(d) The appropriate Warning and Danger levels may be arrived at byI&FCD, Govt. of NCT of Delhi after completion of CWPRS studies.

Table 7.2: Action Taken Report By IFCD

S. No.	Location	Obstructions	Agency	Earlier Photographs	Current Status Photographs	Remarks
1.	Downstream of Wazirabad Barrage	Temporary structures, malba, sheet piles, pile heads, C&D waste, earthen bundies etc.	DMRC		 	• **Construction work still in progress within the river course. Approx. 20% obsruction in river course is still there.** • **Widening of River course by width more than the obstruction to be created on eastern side.** • 70% water way clear between metro piller No. 194 & 195. • Temporary office in form of porta cabin surrounded by barricades still present on eastern side.

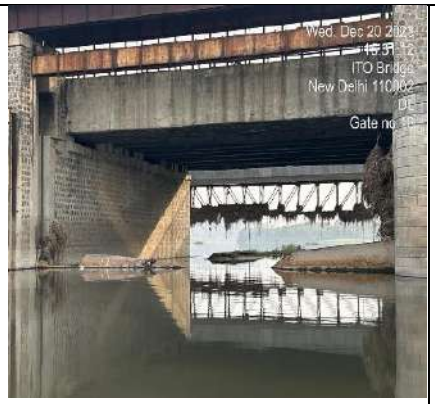
2.	Signature Bridge	Temporary structures, malba, sheet piles, pile heads, C&D waste, earthen bundies etc.	DTTDC		 	Waterway has been cleared below the bridge. However obstructions are still in waterway between DTTDC and DMRC site. Excavated earth/C&D waste dumped on the banks of river, needs to be excavated and disposed off outside of floodplain. **Work is halted with the wrong plea that it does not pertain to them.** **No further progress till there.**

3.	Pontoons are laying near Flood Plain area Signature Bridge	Pontoons	PWD		 	Pontoons has been removed from western bank but Pantoons **still lying along eastern bank and one number within the River course behind Guru Dwara (Majnu ka Tila)**.

4.	Manholes from the IGL station to Metcalf House drain	Raising of height of Manholes and there capping	PWD			The damaged slab has been repaired.
						**Work in progress.** In stretch of 160 meter manholes height has been raised but placing of M.H covers yet to be done.

5.	Toe wall along Outer Ring Road IGL station	Gaps in the toe wall & Shorter toe wall	PWD / I&FC		 	**Work completed**.
6.	Outer Ring Road	Damaged parapet wall and Open Bell Mouths	PWD			60% work of Bell mouth cleaning has been completed. Work in progress.

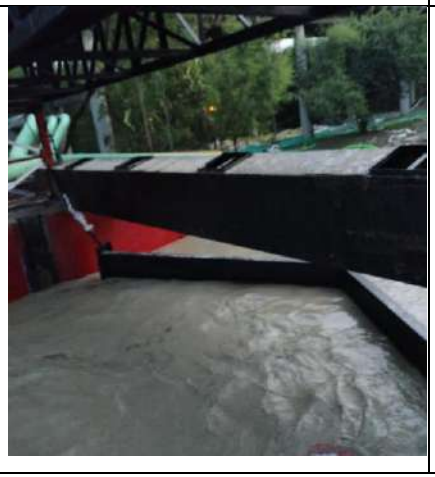
7.	Constructions of railway bridge u/s of existing Old Railway Bridge (ORB)	Temporary structures, malba, sheet piles, pile heads, C&D waste, earthen bundies etc.	Northern Railway			• Work of demolition of two abandoned well upto NSL completed. • 80% Waterway between three piers has been cleared. • Work is in progress on western side. • Construction material, C&D waste, machinery, site office, approach on eastern bank yet to be removed and taken away from flood plain. • **Arrangement of CC Blocks made by Railway to plug the entry points towards Ring Road in case of Flood.**
						

8.	ITO Barrage	Silt up / damaged gates	Haryana Irrigation			**All gates opened.**
9.	PWD Bridge	Temporary structures, malba, sheet piles, pile heads, C&D waste, earthen bundies etc.	PWD			Obstructions from water course yet to be removed Construction work by PWD are still in progress. Increase in active course/ waterway is required as around 50 mtr. portion on left bank side is obstructed by approach path. Further, around 50 mtr. width is obstructed by mid pier. PWD need to expedite the removal of obstruction. Only 10m(approx). wide channel has been created on left bank side to increase the active corse /waterway

10.	NCRTC Bridge	Temporary structures, malba, sheet piles, pile heads, C&D waste, earthen bundies etc.	NCRTC			The waterway has been cleared completely below the bridge. Island / platform created/formed downstream side is still to be cleared. 80% obstructions removed from flood plain. However, the removed earth has been levelled on the banks, which needs to be removed and taken out of flood plain. The approach path/road made in flood plain also to be removed and excavated material be taken out of flood plain. **No further improvement.**
						

11.	Bombay-Baroda Expressway	Obstructions Exist in flood plain along western bank.	NHAI	 	 	Obstructions in Yamuna flood plain on western side. Approximately 180000 sq mt. area occupied in form of site office, yard, approach to bridge approach to pillar etc.
12.	NHAI - Delhi to Dehradun Expressway	Restoration of retaining wall/ Parapet wall on left side embankment from Akshardham to Khazoori Chowk.	NHAI			The work in critical portion near Gandhi Nagar Market has been completed. However, work is in progress on L.M. Bund (around 5% work completed, of the total parapet wall to be restored).

						**No further progress.** A letter has been received on dated 29/07/2024 from Project Director NHAI stating that work of boundary wall on LM Bund is started by the EPC Contractor M/s. Gawar construction Ltd. and shall be completed as early as possible.
Measures taken by I&FC Department to improve carrying capacity of river and prevent entry/overtopping of flood water into city						
13.	Deepening of waterway at following locations: (i) U/S ITO Bridge (ii) D/S ITO Bridge/ Barrage (iii) D/S ORB Bridge (iv) in front of Vasudev Ghat (L/ Bank of Yamuna U/s of Yudhishthir setu (v) upstream of ORB	Temporary measure to create additional passage to pass additional discharge during flood.				Work **completed**

	(vi) D/s of Wazirabad Barrage					
14.	Restoration of gate at Nallah No.12	To prevent entry of flood water into city				Work **completed**.

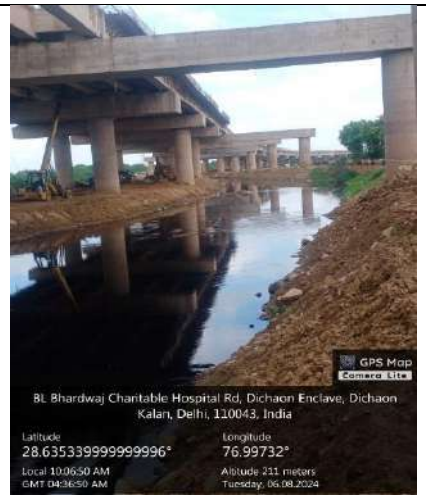
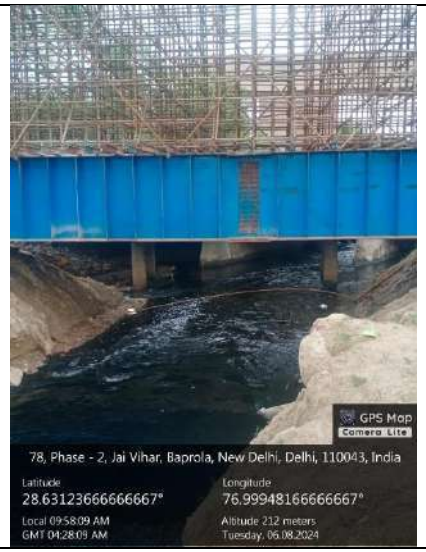
15.	Tanga Stand Regulator Raising the height of gates.	To prevent overtopping of gates.		 **Previous** **Gate Height -3.45m** **Width- 2.04m**	 **Now** **Gate Height – 4.45m** **Width- 2.04m**	Work **completed**.
16.	Metcalf House Regulator			 **Previous** **Gate Height -3.25m** **Width- 2.05m**	 **Now** **Gate Height – 4.25m** **Width- 2.05m**	Work **completed**.

17.	Installation of Flap door at Magazine drain.	Fabrication and Installation of Flap door at the opening of regulator.				Work **completed**.

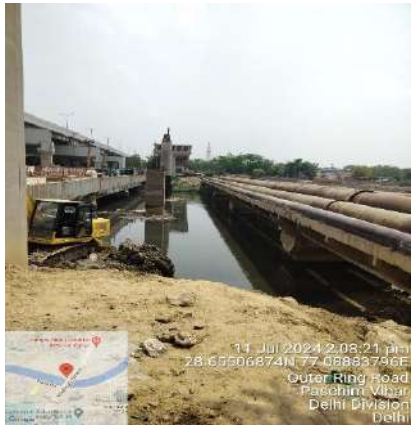
18.	Raising of existing parapet wall along Ring Road.	Raising of existing parapet wall from Khybar pass to Chandgi Ram Akhahra at Ring Road.				Work **completed**.
19.	Ramp at Entry point at Boat Club	Raising of height of ramp from 208.66 meter to 209.30 meter.				Work **completed**
20.	Restoration of existing Yamuna Bazar wall.	At Yamuna bazar wall the gaps are provided at stair case location for pedestrian movement. The gaps are plugged by constructing brick work.				Work **completed**.

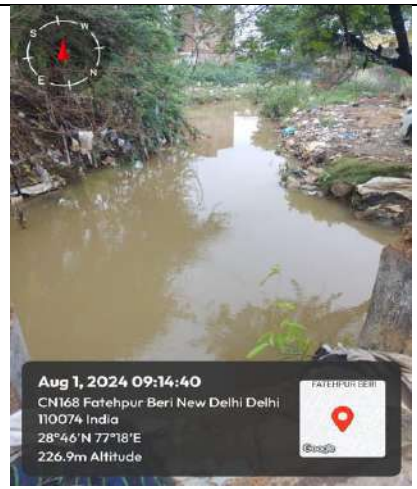
						
21.	Yamuna River right bank near Neeli Chatri.	Raising of parapet wall along footpath up to 209.00 meter.				Work **completed**.
22.	Hakikat Nagar Inlet at NG Drain	Inlet of Najafgarh drain - repair, restoration and testing				Work **completed**.

23.	Bhalaswa Lake Inlet at Supplementary Drain	Providing Flap Shutter				Work **completed**.
24.	Ramp in front of Neem Karoli Mandir	To prevent the flood water coming to Ring Road				Work **completed**.
25.	Raising the level of right bank d/s of the Ring Road of Metcalf House Drain	To prevent the flood water coming to Ring Road (Top level – 209.500m)				Work **completed**.

S. No.	Location	Obstructions	Agency	Earlier Position	Latest Position	Remarks
26.	Mungeshpur Drain (RD 2700m)	**Regarding removal of obstruction from Mungeshpur drain in reference to NHAI work "Development of 6-lane Urban Extension Road (UER-II)"**	NHAI		 	• All (31 nos.) pipe diversions removed. Work completed. • At one location, water way of drain is restricted to 10m out of 24m as such NHAI has been asked to make alternative contingency arrangements.

27.	Najafgarh Jheel and Drains of Haryana (L-2 & L-3)	Construction of Drains embankment across the Najafgarh Jheel by Govt. of Haryana	Govt. of Haryana	 		• The request has been made to stop the work in Jheel portion at various levels of GMDA and I&WRD, Govt. of Haryana. • DO letter dated 27.05.2024 has been written to Chief Secretary (Haryana) by ACS (I&FC) to stop the work in Jheel area. • DO letter dated 05.06.2024 has been written to Chief Secretary (Haryana) by worthy Chief Secretary, GNCTD to stop the work in Jheel area. However, work **has not been stopped** by Govt. of Haryana.

28.	Najafgarh Drain at u/s of outer ring road, Keshopur	Removal of obstruction (Earthen bundi) across Najafgarh Drain	DMRC	 		• Obstruction in the form of earthen bund across Najafgarh Drain on Janakpuri-Majlish Park Metro Line has been removed**.** • Obstruction below the PWD bridge by DMRC in the form of **earthen bags is yet to be removed**. • **Obstruction in the form of large size pile cap above the designed bed level is to be dismantled and removed.**

29.	Basaidarapur near ring road	Removal of pipeline bridge obstructing waterway of Najafgarh Drain and shifting the pipeline to adjacent bridge after strengthening . Plugging of abandoned pipeline	DJB			Work completed.
30.	Fatehpur Beri	Asola Drain has no outfall but outfalling in private land.	I&FC Deptt.			• Asola drain has no outfall, terminates into depression area leading to flooding in the surroundings. • Consultant appointed on the recommendation of the Committee constituted by Hon'ble High Court. • Accordingly, proposal submitted on 03.06.2024 to Revenue Deptt. to verifying the Khasra wise draft plan in order to initiate the land acquisition process. • As short term measures I&FC deptt. regularly cleaning the drain and keeping pumps available to meet any contingency in the area.

31.	Najafgarh Drain from outer ring road (RD 40680m) to Ranhola Bridge(RD 34350m)	Dredging of hump no. 2	I&FC	  		• Target Qty. of Silt to be removed: 3.48 Lac Cum • Silt removed till upto 30.06.2024: 3.10 Lac Cum • Balance Silt will be removed after Monsoon season. • Disposal work is in progress.

32.	Najafgarh Drain down - stream to Basaidarapur Bridge RD 45350m	Blockage of water way for flyover construction	PWD	  		The PWD filled earth in the water-way of Najafgarh Drain to facilitate construction of flyover. 80% of the obstruction removed and balance to be removed.

33.	Supplementary drain u/s of Wazirabad road	Obstructions and Inadequate diversion arrangement leading to afflux and water logging in U/s areas.	DMRC			Work **completed**.
34.	Barapullah drain	Obstructions in drain bed.	NCRTC			• 62% of waterway obstruction removed. However, removal of muck, C&D waste, pile heads, concrete blocks and silt / excavated earth from drain is required, which is lying on the bank of the drain. • Further, demolition and removal of test piles, pile heads, concrete blocks lying in bed is also required. • No further progress.

35	Ghazipur Drain	Obstructions in drain bed.	NCRTC		 	• Around 80% obstruction removed from waterway. • Silt is placed on the bank, of which disposal is required. • Removal of muck, C&D waste, construction material, shuttering, pile heads, concrete blocks etc. from balance portion is required. • **No further progress.**

8 Storage Possibility of Flood water

8.1 Introduction

The committee examined the possibility of storage of excess flood water by creation of underground reservoirs, storages in flood plains of river Yamuna for surplus flood water and the possibility of storing flood waters in Asola Bhatti wildlife Sanctuary where number of mining pits are available and might serve for ground water recharge through these pits.

8.2 Creation of Underground Storage

There are examples of underground reservoirs created for flood moderation purpose in Japan. The Metropolitan Area Outer Underground Discharge Channel is an underground water infrastructure project in Kasukabe, Saitama, Japan. It is the world's so called largest underground flood water diversion facility, built to mitigate overflowing of the city's major waterways and rivers during rain and typhoon seasons. It is located between Showa in Tokyo and Kasukabe in Saitama prefecture, on the outskirts of the city of Tokyo in the Greater Tokyo Area, Japan. Work on the project started in 1992 and was completed by early 2006 at an approximate cost of 2.6 billion US$ (2006). It consists of five concrete containment silos/ shafts with heights of 65 m and diameters of 32 m, connected by 6.4 km of tunnels, 50 m beneath the surface, as well as a large water tank with a height of 25.4 m, with a length of 177 m, with a width of 78 m, and with 59 massive pillars each weighing 500 ton connected to 7810 MW (13,000 hp) pumps that can pump up to 200 tons of water into the Edo River per second. These shafts and underground tunnel will divert the flood water in the rivers Oootoshifurutene, Koumatsu, Kuramatsu, Naka and No 18 Channel to the Edo River. The capacity of this arrangement is 6,70,000 cubic meter. The tank adjusts the water pressure for the pumps to operate smoothly in order to pump the water into Edo River.

The flood water diversion facility described above seems to be technically feasible. However, the following issues need to be considered:

Magnitude of flooding- The last flood sustained for about 2 days with discharge of about 3.7 lakh cusecs which is quite high.

Siltation- There are issues of heavy silt load in Indian rivers. Hence, handling silt load for an underground storage will pose a major challenge.

Financial considerations- Japanese experts themselves claim that the work began on the facility here in Kasukabe in the early 1990s, at a time when Japan was pouring funds, and concrete, into huge public works projects. But now, the country is less able to muster the resources to fund such ambitious projects. They consider now it as a one time feat, not to be repeated.

8.3 Storage of Flood waters in Flood Plains of River Yamuna

I&FC Department, Govt. of NCT Delhi has conducted a study where 6 probable locations have been identified in river Yamuna flood plains for recharging using flood water.

The physical parameters of the proposed reservoirs are given in **Table 8.1**

Table 8.1: Physical parameters of the proposed reservoirs

Sl. No.	Location	Surface Area (Sq.m)	Average Depth (m)	Storage Volume (Cubic.m)
1	Right Bank, north of Old Bawana Escape [Sheet No. 33]	9,00,000	1.5	1,350,000
2	Right Bank, south of Old Bawana Escape [Sheet No. 33]	1,170,000	1.5	1,755,000
3	Left Bank, west of Sabapur, [Sheet No. 33]	8,40,000	1.5	1,260,000
4	Left Bank, south of Wazirabad Barrage [Sheet No. 34]	2,500,000	1.5	3,750,000
5	Left Bank, between Railway Bridge and ITO Bridge [Sheet No. 41]	6,05,000	1.5	9,07,500
6	Left Bank, opp. Mayur Vihar [Sheet No. 41]	3,120,000	1.5	4,680,000
	Total			13,707,500

The locations of probable reservoirs are highlighted in Maps given in **Fig. 8.1,Fig. 8.2&Fig. 8.3**

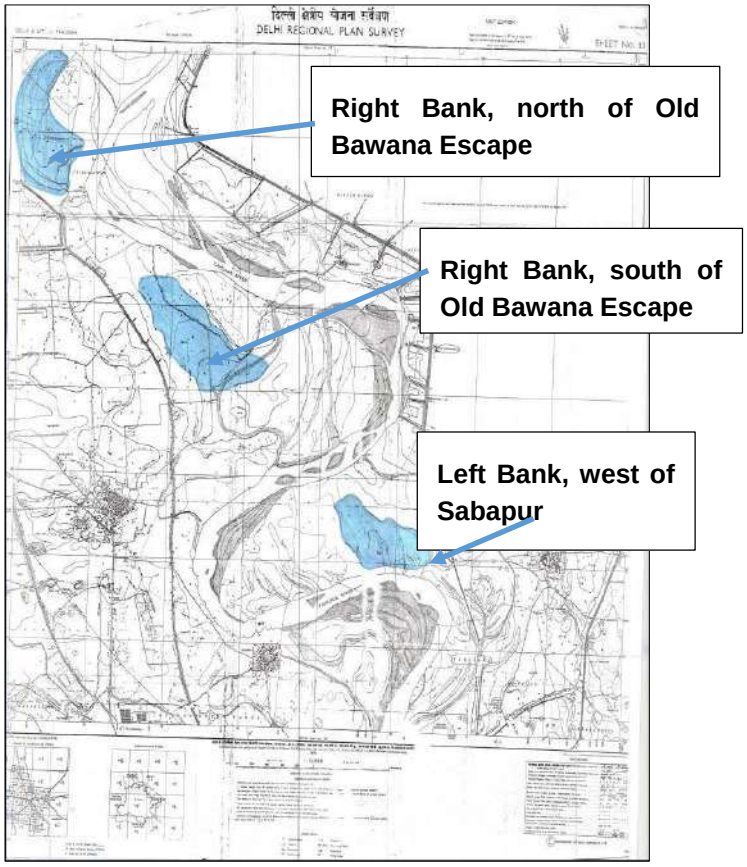


Fig. 8.1 Locations of probable reservoirs

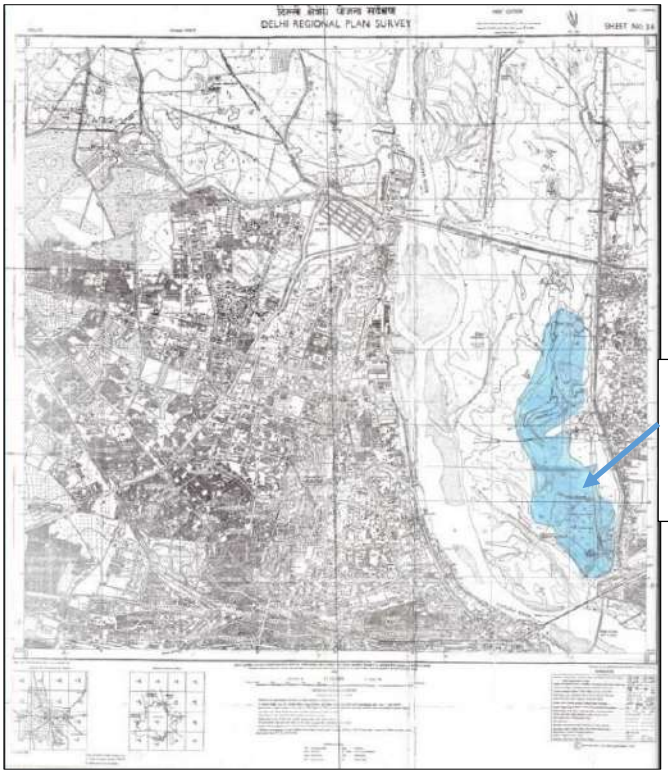


Fig. 8.2: Locations of probable reservoirs

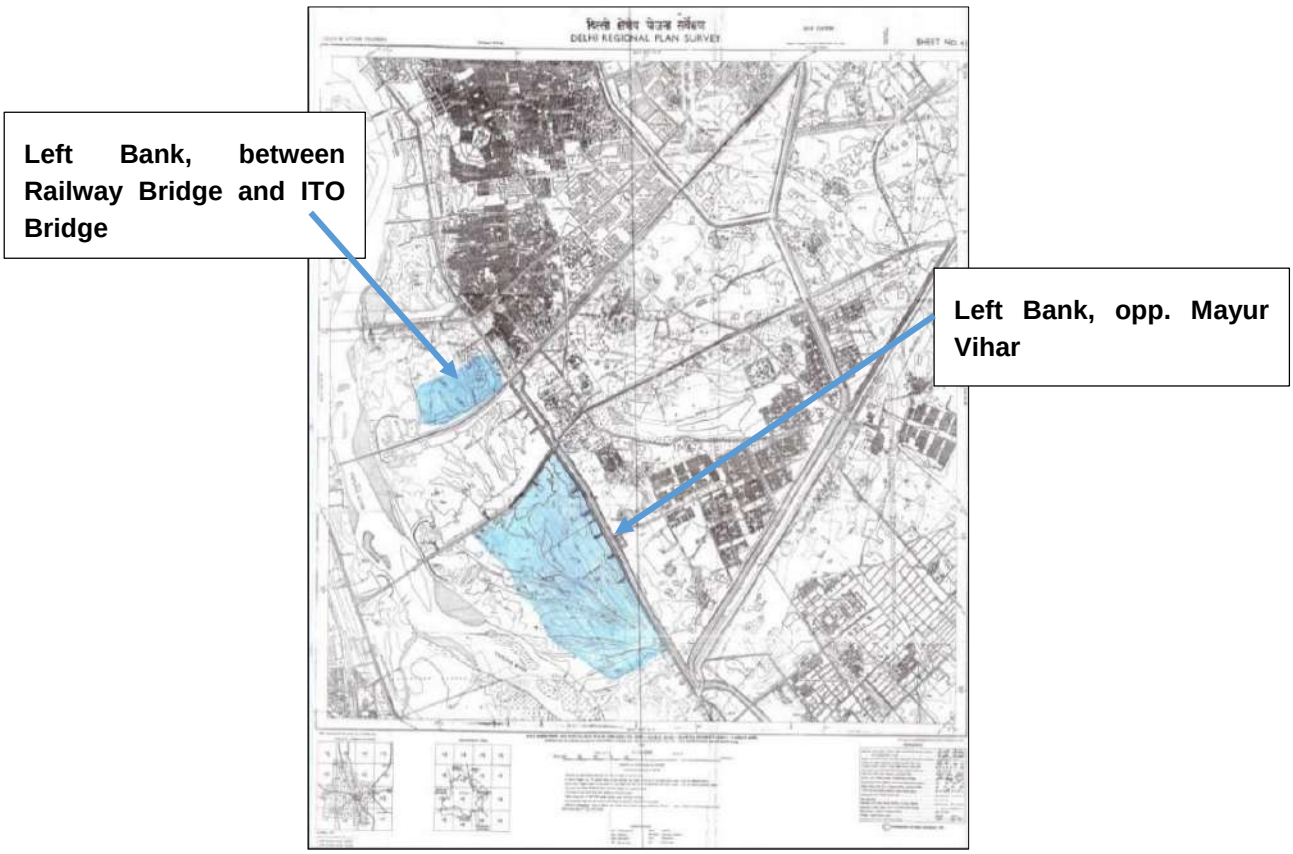


Fig. 8.3: Locations of probable reservoirs

The committee was of the view that prima facie, the above sites may not be adequate to accommodate high flows during flood period. However, further study may be conducted by Govt. of NCT of Delhi for suggesting any further potential location for detention of flood waters in Delhi region and this aspect will be discussed in the final report.

8.4 Storage of flood waters of Delhi in Bhatti Mines area

Govt. of Delhi has also identified Bhatti Mines area to store floodwaters in the pits of Bhatti Mines and to recharge the groundwater table in the area is described in detail in succeeding paras.

The genesis of exploring the any possibility of ground water recharge in Bhatti Mines area of NCT, Delhi was initiated in a meeting held under the chairmanship of Hon'ble Lieutenant Governor of Delhi to discuss about the possibilities of Artificial recharge to ground water in abandoned Bhatti mines area of NCT, Delhi by diverting the surplus monsoon runoff which is otherwise goes waste as non-committed flow. A preliminary study in this respect has been carried out by Central Ground Water Board (CGWB).

The project area is Asola Bhatti wildlife Sanctuary where number of mining pits are available and incepted an idea for ground water recharge through these pits. As per Central Ground Water Board (CGWB), there are 15 major pits which can be utilized for recharge to ground water. Total capacity of these pits is about 5200 MLD i.e. 52, 00,000 cubic meters per day. These pits can be filled with 4200 Million litres of water by pumping the surplus monsoon runoff from river Yamuna for 60 days in a year.

Fig. 8.4: Picture of one of the mine in Bhatti area

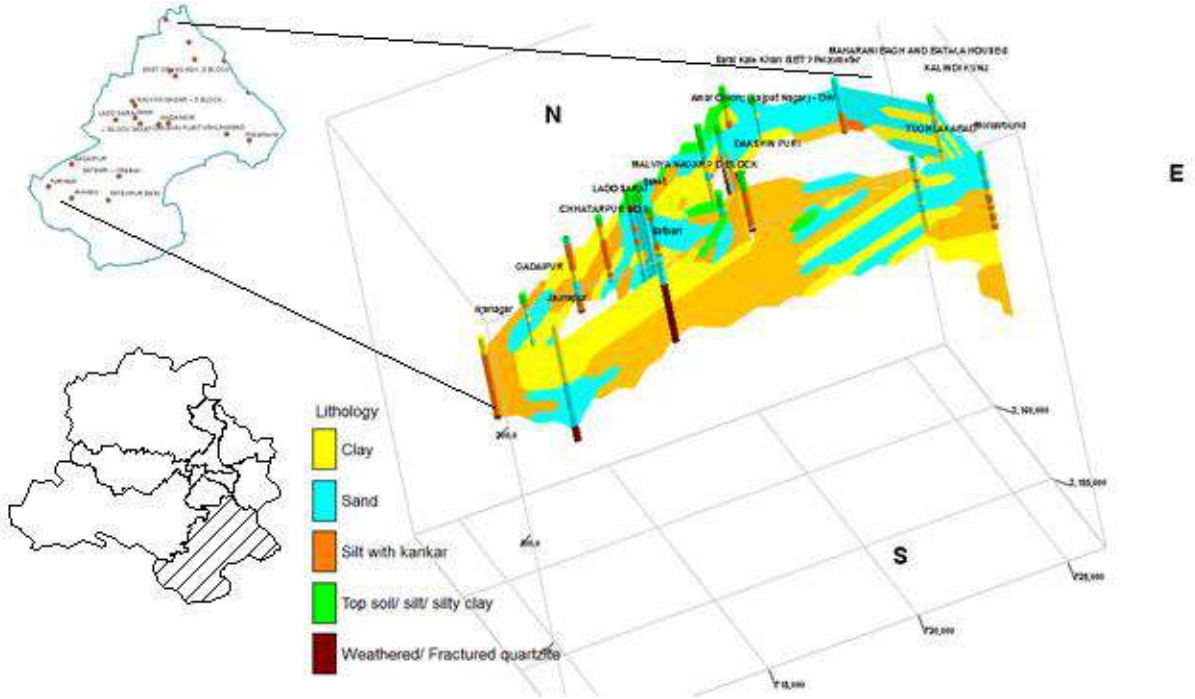
Fig. 8.5: Location of Bhatti mines where the AR project need to be implemented.

8.4.1 Rainfall in NCT Delhi

The normal rainfall of NCT Delhi is 794 mm. The rainfall increases from west to east. About 80% of the annual rainfall is received during the monsoon months July, August and September. The rest of the annual rainfall is received in the form of winter rain. Long-term rainfall data 1984 to 2021 shows that the rainfall in Delhi is highly variable and which in turn affects the natural recharge to ground water from year to year. The probability of rainfall exceeding normal rainfall of 794 mm is up to 62% whereas there are 90% chances that rainfall would limit to 450mm.

8.4.2 Hydrogeology and Depth to Water Levels of Bhatti Mines area

Bhatti mines are located in southern most part of NCT, Delhi in Southern Ridge area. The mines are underlain by Alwar quartzite of Delhi System exposed in the area belonging to Pre-Cambrian age. The quartzites are pinkish to grey in colour, hard, compact, highly jointed/ fractured and weathered. These occur with interbeds of mica-schists and are intruded locally by pegmatites and quartz veins. The strike of these rocks varies northeast southwest to north-northeast south southwest with steep dips towards southeast and east except for some local variations due to folding. The prominent joint sets are strike joints, bedding joints and dip joints. Quartzite are ferruginous and gritty types on weathering and subsequent disintegration give rise to coarse sand (Badarpur sands). Ground water occurs in weathered formation as well as in fractures and joints which are prolific in the area. Chemical weathering of deeper horizons is also common which acts good repository of ground water. Yield of tubewells of depth about 100 to 150 m below ground level varies from 100 to 200 LPM. Transmissivity of Delhi Quartzite varies from 5 to 135 m2/ day.



8.4.3 Depth to Water Levels:

Central Ground Water Board is monitoring the ground water in Bhatti mines area through a piezometer located at Bhatti mines. Pre-monsoon depth to water levels during 2022 is 48.64 m bgl and post monsoon water level is 39.17 m bgl. The **Table 8.2** the depth to water levels in Bhatti mines area for the last one decade i.e. 2012 to 2022.

Table 8.2: Depth to water levels in Bhatti mines area

Year	Depth to water levels (Pre-monsoon period) m. below ground level	Depth to water levels (Prost-monsoon period) m. below ground level
2012	49.27	43
2013	47.98	44.68
2014	48.07	48.16
2015	49.18	43.01
2016	48.74	47.56
2017	50.61	49.02
2018	50.95	49.61
2019	54.1	53.16
2020	55.16	49.1
2021	54.72	40.55
2022	48.64	39.17

From above table, it can be seen, that there is no much variations in ground water levels in the area except brief period of 2019 and 2020 where groundwater levels reached to 55 m bgl (below ground level). In rest of the years, the ground water levels are in between 48 to 51 m bgl during pre-monsoon period.

8.4.4 Demarcation of Areal extent and impact of recharge to ground water in Bhatti mines area:

Central Ground Water Board has carried out Artificial Recharge to Ground water in JNU-Sanjay Van area during 1996 to 1998 under Central Sector Scheme. Under this scheme, four check dams were constructed in JNU-Sanjay Van watershed. The impact of these check dams on ground water regime has been studied in detail. The finding of these studies are utilized in estimation of area to be benefitted through recharge to ground water in Bhatti mines areas as these two areas are hydrogeological similar in nature.

- The recharge efficiency of pondage created through check dams is 95 to 99.7% based on the fracture zones encountered and aquifer zones present in the area.
- The evaporation losses are very minimal and vary from 0.3 to 5%.
- The rise in water level varied from 0.33 to 13.70. The rise is highest in the area surrounding the check dams and away from the ponds, the rise in less. On an average the water level rise of about 2.5 m is observed in the area.
- Due to repetitive filling, capacity utilization up to 300% is achieved in the check dams.

- During 1998, the total recharge from these check dams was of the order of 76000 cubic meters and benefitted area is 74 Ha.
- In the zone of benefit, the yield of wells has been increased in the form of more pumping hours and availability of more water in wells during summer after construction of check dams.
- Based on the above observation, the following interpretation can be drawn for the recharge project in Bhatti mines area:

The pits can be filled repeatedly at least 3 times in a year. Thus the total water can be filled in these pits will be about 12600 ML if surplus monsoon water is available. With moderate estimates considering two filling of these pits, about 8400 ML of water can be filled in these pits. Considering the 5% evaporation loses, about 8000 ML water can be recharged to ground water. Considering the average rise in water levels will be about 2.5 m and Specific yield of about 0.04, it is estimated that about 8000 Ha area will be benefitted if 8400 ML water is released into the pits. Exact area can only be demarcated by construction of piezometers in the area for monitoring purposes after implementation of the project.

8.4.5 Number of tube wells to be constructed in the area and hours of operation:

It is estimated that about 8000 ML of water (80,00,000 Cu.mts) is available throughout the year to be used for drinking purposes. Considering the discharge of one tubewell about 6 Cu.mt/hour and taking 8 hours of pumping, one tubewell will yield about 48 Cu.mt/day water. Considering about 300 days of water supply in a year, one tubewell can supply about 14400 Cu.mts. As there is 80,00,000 Cu.mts of recharged additional water is available, it can be estimated that about 555 tubewells can be constructed in the area for water supply to the villages. As the ground water flow is both towards, Delhi and Haryana side, safely 200 tubewells can be constructed by NCT Delhi to exploit the additional water available in the area.

8.4.6 Quality of water to be recharged

The pits are located in highly fractured quartzite, and fractured aquifer is directly exposed in the pits, the water to be recharged should be of good quality without pollution. Polluted water need to be avoided for recharge purpose in the mines area. Desiltaiton also required to be taken up before diverting the water into the recharge pits. Water quality monitoring stations need to be established for proper monitoring of ground water in the area. The silt and top soil layer which is already present in the pits need to be cleaned before implementing the recharge project in the area. The periodic removal of silt to be deposited in the mine pits also need to be taken up.

8.5 Conclusions

a. The six probable locations that have been identified by IFCD, Govt. of Delhi in river Yamuna flood plains for recharge using flood water are concerned, prima facie, these sites may not be adequate to accommodate high flows during flood period.

However, further study may be conducted by Govt. of NCT of Delhi for suggesting any further potential location for detention of flood waters in Delhi region.

b. Regarding storage of floodwaters in the pits of Bhatti Mines and recharging the groundwater table in the area is concerned, there are several concerns which have to be carefully addressed. The foremost concern is the water quality entering into pits as the pits are located in highly fractured quartzite, and fractured aquifer is directly exposed in the pits. Polluted water need to be avoided for recharge purpose in the mines area. Desiltaiton is also required to be taken up before diverting the water into the recharge pits. Water quality monitoring stations need to be established for proper monitoring of ground water in the area. The silt and top soil layer which is already present in the pits need to be cleaned before implementing the recharge project in the area. The periodic removal of silt to be deposited in the mine pits also need to be taken up. Keeping in view the above concerns a separate studies may be undertaken by Govt. of Delhi

c. The examples of underground reservoirs created for flood moderation purpose in Japan for flood water diversion facility may be technically feasible. However, considering the issues in context to Indian rivers like high magnitude of flooding, excessive silt load of rivers and huge financial investments, prime facie the same may not be techno-economically viable in flood mitigation.

9 Summary of Conclusions and Recommendations

The committee constituted for “Joint Flood Management Study of River Yamuna for its reach between Hathnikund and Okhla Barrage” based upon the studies, deliberations in the meetings of committee, site inspections of barrages, model studies, collection & analysis of data led to some conclusions and recommendations for effective flood management which are presented in following headings-

9.1 Catchment Rainfall Analysis

The analysis of catchment representative 5-day cumulative rainfall, it has been found that the catchment representative rainfall at old Delhi railway bridge in 2023 is 23.8% more in comparison to rainfall of year 1978. The catchment representative rainfall inyear 2023 at Mawi G&D site is about 31.5% more in comparison to rainfall of year 1978.The catchment representative rainfall in year 2023 at Hathnikund barrage site is about 42.7% more in comparison to rainfall of year 1978. The cumulative 5-day catchment representative rainfall during July 2023 at Hathnikund barrage and Mawi G&D site corresponds to rainfall of about 100 year return period.

From the Stage Hydrograph analysis at various Hydrological Observations (HO) sites on river Yamuna as well as from rainfall analysis in Yamuna catchment, it can be concluded that rainfall during 9th July, to 13th July, 2023 period was one of the major causative factor for extreme flooding in Delhi and other locations along the reach of river Yamuna.

9.2 Flood Frequency Analysis

For determination of 5, 10, 25, 50, 100 200 and 500 year return period flood at Hathnikund Barrage, Delhi Rail Bridge and Okhla Barrage, flood frequency analysis has been carried out on the basis of past historical flood data.The return period floods as found out from the analysis is as under-

Hathnikund Barrage

Return Period	Discharge (cumec)	90%U confidence limit	90%L confidence limit
5	11541	13752	9330
10	14327	17313	11341
25	17847	21873	13821
50	20458	25275	15641
100	23050	28661	17439
200	25633	32041	19224
500	29040	36505	21574

Old Delhi Rail Bridge

Return Period	Discharge (cumec)	90%U confidence limit	90%L confidence limit
5	4025	4721	3330
10	5157	6096	4217
25	6587	7852	5319
50	7648	9162	6131
100	8701	10464	6934
200	9748	11763	7732
500	11131	13480	8783

Okhla Barrage

Return Period	Discharge (cumec)	90%U confidence limit	90%L confidence limit
5	5040	6269	3811
10	6614	8274	4954
25	8603	10841	6365
50	10079	12756	7401
100	11543	14663	8424
200	13003	16565	9440
500	14928	19078	10778

As Hathnikund discharge values have already been reconciled and discharge at Old Delhi Railway Bridge are observed, hence both are considered consistent .Further, discharge values at Okhla are to be reconciled by project authority. However, as far as the analysis of flood in Yamuna in Delhi is concerned, the discharge values at Old Delhi Railway Bridge are most important which are consistent.

9.3 Discharge carrying capacity of River Yamuna up to Delhi Border

With an objective to find out discharge carrying capacity of river Yamuna, 1D water profile simulation studies carried were out in HEC-RAS based on the water profile simulations using surveyed cross sections of river Yamuna from Hathnikund barrage up to Delhi-Haryana border for a reach of about 202 km has been carried out by CWC. The details of the study is described in chapter 4 of this report.

This study is based on cross-sectional data provided by the Irrigation & Water Resource Department, Government of Haryana. As limited data of cross-section has been provided, the results looks like erratic. Therefore, Hec Ras Model used for the study has been shred with the Irrigation and Water Resources Department, Government of Haryana, for refinement as per proper cross-sections and validation to arrive at realistic carrying capacity in various reaches.

From above, It can be seen that the carrying capacity of river Yamuna in various divisions spread across 202 Km varies from 1000 cumecs (in Karnal Division between RD 6976m

to 15979m) to 30000 cumec (Delhi Division between RD 500m to 3500m) reach between RD0 to RD 3500m of Delhi division. However, at some places embankments has been provided to protect certain areas. Further, spilling beyond banks also happen during heavy flood and managed by Govt. of Haryana as per their procedures.

9.4 Monsoon Peak Discharge and Submergence Area in Delhi

In the 2D hydrodynamic model simulation, these flood values of different return periods were passed through DRB to get the corresponding water level at different locations and flood submergence areas over the Delhi reach of River Yamuna. The model incorporated the observed cross-section data, open drain data, bunds and embankment data as received from the Delhi Government. The results of the model simulation is given in **Table 9.1.**

Table 9.1: Submergence Area over Delhi reach of River Yamuna

Return Period (Year)	DRB Discharge (M^3/s)	DRB Water Level (m)	Submergence Area (Km^2) (within embankments)	Net Submergence Area (Km^2)
2	2316	204.2	26.42	0
5	4025	205.99	30.82	0.4
10	5157	206.9	47.11	16.7
25	6587	207.94	63.51	33.1
2023 Flood	6999	208.6	74.525	44.1
50	7648	208.75	77.76	47.3
100	8701	209.35	85.25	54.8

Net Submergence area = Submergence area- Main channel area ie. 30.46 Km^2 (within its banks)

The maximum water levels in the river corresponding to 2, 5, 10, 25, 50 and 100 year return period floods as per the 2D model study are mentioned in **Table 5.4 and Fig. 5.3** of Chapter 5 of the Report.

9.5 Embankment Overtopping

In order to find potential overtopping zones of embankment, the 2D Model studies was simulated with different return period floods, the result of which is tabulated below-

<table>
<tr><th>Return period</th><th>Passing Discharge at DRB (cumec)</th><th>Simulated WL at DRB (m)</th><th colspan="3">Embankment Overtopping locations</th><th>Remark</th></tr>
<tr><td>2-year</td><td>2316</td><td>204.2</td><td colspan="3">No Overtopping</td><td></td></tr>
<tr><td>5-year</td><td>4025</td><td>205.9</td><td colspan="3">No Overtopping</td><td></td></tr>
<tr><td>10-year</td><td>5157</td><td>206.9</td><td colspan="3">No Overtopping</td><td></td></tr>
<tr><td>25-year</td><td>6587</td><td>207.94</td><td colspan="3">No Overtopping</td><td></td></tr>
<tr><td rowspan="2">July, 2023 Flood [Between 25 -50 year return period]</td><td rowspan="2">6999</td><td rowspan="2">208.7</td><td>Location</td><td>Bank</td><td>Max WL reached</td><td rowspan="2">Overtopping at Nili chhatri area is observed in simulation. The same is Verified on ground by</td></tr>
<tr><td>Nili Chhatri</td><td>Right</td><td>208.88</td></tr>
</table>

						the Delhi Government during July, 2023 floods. Max water level of 208.88m is reached which is above the existing bund level. No overtopping at any other location shown by the model.
50-year	7648	208.75	**Location**	**Bank**	**Max WL reached**	At Nili chhatri area, max water level of 208.98m may be reached which is above the existing bund level. No overtopping at any other location shown by the model.
			Nili Chhatri	Right	208.98	
			Location	**Bank**	**Max WL reached**	At Nili chhatri area, max water level of 209.55m may be reached which is above the existing bund level. No overtopping at any other location shown by the model.
100-year	8701	209.35	Nili Chhatri	Right	209.55	
100-year With elevated Nili Chhatri bund in the model	8701	209.44	Nili Chhatri	Right	209.68	

The 2D Model studies shows that during floods of 2023 (with discharge 6999 cumec) overtopping at Nili Chhatri area is observed and the same was verified on ground by the I&FCD Govt. of NCT Delhi during July, 2023 floods. Max water level of 208.88m was reached at Delhi Railway Bridge which is above the existing bund level in that area. No overtopping at any other location shown by the model which has also been confirmed by Government of Uttar Pradesh and I&FCD, Govt. of NCT Delhi. However, for floods of magnitude 1 in 50 years and above, the Nili Chatri Area gets flooded therefore, it is recommended to adopt appropriate structural measures to avoid flooding in this area.

9.6 Implications with floods of various return period in River Yamuna in Delhi

The implications of floods of various return period as found out from 2 D Model Studies are as under-

i. Flood up to 1-in-25-year flood (6587cumec)

- No overtopping of embankments is shown in the model along the entire Delhi reach.

ii. Flood corresponding to discharge of 6700 cumec.

- The discharge of 6700 cumec and above at Delhi Rail Bridge may cause overtopping of embankment at Nili Chatri area on the right bank of river Yamuna.

iii. Flood of year 2023 (6999 cumec)

- Simulated water level for 2023 flood at DRB is found to be 208.6m against the observed 208.65m. Also, simulated submergence area for 2023 flood is found to be 44.1 Sq. km which is slightly less than the simulated submergence area for 50-year flood at DRB. The model shows overtopping from Metcalf house to Nili

Chhatri/ Yamuna Bazar Ring road area on right bank of river Yamuna with max water level reaching upto 208.88m. The same has been verified on ground by the Delhi Government.

iv. Flood of 1-in-50 years(7648 cumec)

- The water may rise up to 208.75m at DRB resulting in submerging 47.3 Sq km which is 7.3% more than the area submerged in July 2023 Flood. This magnitude of flood, may cause embankment overtopping at Metcalf house to Nili Chhatri/ Yamuna Bazar Ring road area on right bank of river Yamuna with max water level reaching upto 208.98m.

v. Flood of 1-in-100-year flood (8701 cumec)

- The water level may rise up to 209.35m at Delhi Railway Bridge resulting in submerging 54.8 Sq km which is 24.0% more area as compared to the area submerged in July 2023 Flood. This magnitude of flood, may cause embankment overtopping at Metcalf house to Nili Chhatri/ Yamuna Bazar Ring road area on right bank of river Yamuna with max water level reaching up to 209.55m at Delhi railway Bridge. Now, raising the embankment height beyond this level (say to 210.55m) in the model and again running shows that the max water Level now reached is 209.68m which may be taken as the maximum Water Level reaching for 100-year flood.

vi. **Table 5.6**, **Fig. 5.4 & Fig. 5.5** shows the simulated water levels for 100-year flood with respect to the right and the left embankment levels. Up to 100-year flood, no overtopping at any other location is shown by the model. However, the simulated water levels given in **Table 5.6** may be matched with the actual bund levels by I&FC Department, Govt. of NCT Delhi to find the possible overtopping locations and raising the same with free board as per the codal provision.

9.7 Identification of Drainage congestion

As per the results of 2D Model Studies, the Drain No. 1, 2, 6, 7, 8, 9, 10, 11, 13, 14 and 16 congestion starts with 2-years return period flood (i.e. discharge of 2316 cumecs), the Drain 3, 4, 5 and 12 congestion starts with 5-years return period flood (i.e. 4025 cumecs) and all drains start to get congested for 10-year and above return period flood.

The committee observed that the drainage network within the Delhi NCR region is being maintained by different agencies like, I&FCD, Govt. of NCT Delhi, MCD, NDMC, etc. and there is no coordination among various agencies for operation of these drains. A SoP for operation of these drains in Delhi NCR region may be prepared with clear guidelines defining the procedures to be followed for operating these drains depending upon the water level in river Yamuna. There should be one coordinating agency which should be responsible for operation of drains in Delhi NCR region. The agency may be entrusted with the task of monitoring of proper maintenance and regular desilting of drains. The SoP for drains should also clearly define the details of pre monsoon and post monsoon inspections that are required to be carried out for the drains.

As 2D Model studies shows that all the drains in Delhi NCR start congesting in a flow of 10 and above years return period. Therefore, clear guidelines for operating these drains

may be formulated and proper pumping arrangement for ungated drains with detail SoP may be prepared. The overall coordinating agency should be made responsible for enforcing uniform SoP of drains in Delhi NCR region. Further, the capacity for pumping the water of each drain and passing it over embankment during flood may be reviewed and appropriately enhanced, if required.

9.8 Afflux in River Yamuna and Review of Warning and Danger Level at Old Delhi Railway Bridge

As elaborated in the 2 D Model studies by considering both scenarios with existing structures (terrain with existing structures & muck) and pier scenario (terrain with existing structures raised on piers), it is observed that the longitudinal water surface profile shows a marked difference in the water elevations in the middle reach only. This difference starts appearing around 12Km U/s from Wazirabad Barrage to 16Km D/s. The Water Surface Elevation profile for the existing Terrain is higher than the Pier Terrain which has all the lateral embankments raised on Piers. The maximum difference between the two Water Surface Elevations is found to be **0.536 meters** at around 26.404 Km station which lies between Wazirabad and ITO Barrage. This possibly indicates the afflux produced due to the lateral embankments and muck lying downstream of Wazirabad Barrage. The committee recommends, the muck, encroachments and other restrictions in the right of way of river to be minimised in order to reduce the afflux in the river Yamuna.

It was informed by I&FCD, Govt of NCT Delhi that a study has been awarded to Central Water and Power Research Station (CWPRS) for ascertaining the Warning and Danger level of river Yamuna in Delhi and currently that study is under progress. The committee was of the view that for the time being the Delhi Govt. may adopt the existing Warning and Danger levels till the time the study by CWPRS is complete. The issues related to dredging and siltation of river Yamuna may also be taken in the hydraulic model studies being undertaken by CWPRS.

9.9 Barrages on river Yamuna

The Central Water Commission Officers along with the concerned officers of State Government visited the barrages on river Yamuna. The detail site visit reports of CWC and observations thereon have already been shared with respective barrage operating authorities.

The correct method of discharge computation through barrages to be adopted by the project authority as per IS codes has been conveyed to the project authorities of all barrages.

The committee observed that there are various agencies of State Governments which are involved in operation of barrages on river Yamuna and there is a lack of coordination among various agencies. The committee recommends preparation of a detailed Standard Operating Procedures (SOP) for coordinated operation of barrages during flood with clear directions of operating barrages under different inflow conditions. The effective communication system between all stake holders may be established for operation of all

barrages in a coordinated and integrated manner. I&FCD, Govt. of NCT Delhi, may act as nodal agency, which should be responsible of operation of various barrages on river Yamuna during flood time in consultation with them. The prominent levels in all barrages should be corrected and connected with respect to a permanent bench mark of Survey of India so as to eliminate any scope discrepancy in observed discharges through barrages. The SOP for integrated operation of barrages must include details about operations & maintenance, communication, responsibilities of personal, evacuation plan, actions to be taken in case of extreme inflows, etc. may be prepared and implemented by nodal agency. There should be well established mechanism of measuring discharges through modern automatic equipment like SCADA etc.

Besides above, the other recommendations of the committee in respect of all barrages is as under-

- Discharge capacity of gates at various levels has been reconciled for the Hathnikund Barrage. The project authorities of Wazirabad barrage and Okhla barrage may also do the same as per studies being carried out by them through IRI, Roorkee and IIT, Delhi respectively.
- Regular maintenance/overhauling of hydraulic gates, stop logs and hoisting equipment installed in barrages may be undertaken as per the Operation and Maintenance manual of the barrage/ codal provisions. The gates and operating equipment/ structure of barrages, canals should be inspected thoroughly for their structural strength and safety.
- Any distress noticed in the gate and hoisting structure should be promptly repaired/ replaced. If any part of the hydro-mechanical equipment is found to be beyond economical repair, it may be replaced.
- Seals of the spillway gates, under sluice gates and stoplogs of barrages may be inspected by the project authority and replaced, wherever required.
- The Logbook for hydro-mechanical equipment operation and maintenance should be meticulously maintained. Hydraulic gates and their hoisting mechanisms, and water pumping system on various streams/ nallas entering into the Yamuna River should be checked for their proper functionality and adequacy. Repair/ replace wherever required before the onset of monsoon season.
- Power back-up at barrages and pumping stations should be ensured.
- De-siltation in the vicinity of hydraulic gates to be ensured wherever siltation is blocking the gate operation for smooth functioning of the gates.
- The charts being used for obtaining the discharge corresponding various gate openings may be updated at the earliest as per the existing conditions and anticipated possible conditions upstream and downstream of the barrage.
- Clearance of waterways may be taken care of with due precautions to restore the carrying capacity of river Yamuna.

- The option of installing automatic flow measurement devices along the river for accurate assessment of flows may also be explored in order collect the data for gauge, velocity and discharge accurately.
- The barrages, weirs and canals may be operated as per the Operation Manual and Rule curves and depending on past flood experience, if any modifications need to be done, it may be done immediately.
- The Tail Water Rating curves in respect of all the barrages need to be revised considering the changed morphological conditions.
- It may be ensured that rainfall & discharge measuring equipment (raingauges, gauges, current meters, stop watches, boats, O. B. Engines, bridge outfits, cable tower & trolleys etc.) are working properly. All gauge posts/markings are properly painted, marked and connected with GTS Bench mark. Any uprooted/damaged gauge posts may be re-erected/ replaced as the case may be, properly. Communication systems such as wireless networks, internet facilities, video conferencing, phones, mobile phones, telemetry systems, are to be in readiness for the transmission of various data in real time.
- The rain gauges including the self-recording type are in working condition with proper stationery available at each site. Also, the pre-monsoon cross-Sections of sites are completed and rating curves are updated. Telephone/cell numbers, emails of nodal officers/Important officers of all concerned authorities are readily available & displayed at respective stations / control rooms, etc

9.10 ITO Barrage

The basic structure of ITO barrage comprising of piers with gate grooves and deck slab is in place. The gates of the barrages are kept open during flood period so that the original condition of river is maintained and the barrage structure has a minimum impact on river flow during floods. Further, the barrage is linked with Road Bridge. Therefore, the only matter to be considered is whether gates are to be dismantled or not. It is observed that in lean season, the gates could be useful to impound some water for various purposes including recreational activities. Hence, it is recommended to operate ITO barrage with all gates open during floods in coordination with operation of Wazirabad barrage and Okhla barrage. It is also recommended that regular maintenance of all hydro-mechanical equipment of barrage be conducted as per the operation and maintenance manual of the barrage/codal provisions.

The matter of handing over of the ITO barrage to Government of Delhi can be taken up separately by appropriate authority.

9.11 Encroachments in the river Yamuna

The committee was of the view that construction of temporary structures and muck disposal in the right of way of river during the construction led to the increased afflux during a flooding event as evident from the results of 2D Model Studies. Hence, after

construction the temporary structures should be properly dismantled and muck should be properly disposed away from the river bed/bank.

The efforts are being made by DDA as well as I&FCD, Government of Delhi for removal of encroachments, muck, temporary construction materials from water way of river Yamuna. The committee recommends that an integrated approach by a Nodal Agency by involving all agencies like Delhi Metro, DDA, Delhi PWD, I&FCD, Delhi Jal Board and other Government agencies carrying out construction activities in river Yamuna should be adopted to make river Yamuna free from such encroachments. The encroachment free Yamuna will safeguard any further increase in afflux in river Yamuna.

9.12 Storage of flood water

The six probable locations that have been identified by I&FCD, Govt. of NCT Delhi in river Yamuna flood plains for recharge using flood water are concerned, prima facie, these sites may not be adequate to accommodate high flows during flood period. However, further study may be conducted by Govt. of NCT of Delhi for suggesting any further potential location for detention of flood waters in Delhi region.

Regarding storage of floodwaters in the pits of Bhatti Mines and recharging the groundwater table in the area is concerned, there are several concerns which have to be carefully addressed. The foremost concern is the water quality entering into pits as the pits are located in highly fractured quartzite, and fractured aquifer is directly exposed in the pits. Polluted water need to be avoided for recharge purpose in the mines area. Desiltaiton is also required to be taken up before diverting the water into the recharge pits. Water quality monitoring stations need to be established for proper monitoring of ground water in the area. The silt and top soil layer which is already present in the pits need to be cleaned before implementing the recharge project in the area. The periodic removal of silt to be deposited in the mine pits also need to be taken up. Keeping in view the above concerns a separate studies may be undertaken by Govt. of Delhi

The examples of underground reservoirs created for flood moderation purpose in Japan for flood water diversion facility may be technically feasible. However, considering the issues in context to Indian rivers like high magnitude of flooding, excessive silt load of rivers and huge financial investments, prime facie the same may not be techno-economically viable in mitigation of high quantum of floods.

9.13 The above recommendations may be read with detailed observations/Recommendations in each chapter of the Report.

The details of above recommendations have been described in detail in the chapters of the report and while referring to above recommendations the details thereon may be read in respective chapters of the Report.

****

10 Annexures

Sl no	Description	
1.	Constitution of Committee and ToR	Annexure A
2.	Minutes of 1st Meeting of Committee	Annexure B
3.	Minutes of 2nd Meeting Committee	Annexure C
4.	Minutes of 3rd Meeting Committee	Annexure D
5.	Minutes of 4th Meeting Committee	Annexure E
6.	Minutes of 5th Meeting Committee	Annexure F

Annexure A

Z-15011/1/2020-FM Section-MOWR

I/86850/2023

Government of India
Ministry of Jal Shakti
Department of Water Resources, RD&GR
(Flood Management Wing)
Block-11, 8th Floor, CGO Complex,
Lodhi Road, New Delhi-110003.
Dated 06 August 2023

Office Memorandum

Subject: Constitution of a Committee for joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage

The extensive flooding in river Yamuna during July 2023 necessitated giving a fresh look for flood management of the river in its reach between Hathnikund and Okhla barrage. In this regard, the undersigned is directed to convey that, with the approval of the Competent Authority of DoWR, RD&GR, Ministry of Jal Shakti, a Committee is constituted for conducting a ***joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage***, as per the following details:

2. **Composition of the Committee:**

1.	Chairman, Central Water Commission	Chairman
2.	Member (D&R), Central Water Commission	Member
3.	Member (RM), Central Water Commission	Member
4.	Commissioner (FM), DoWR, RD&GR, MoJS	Member
5.	Commissioner and Secretary, Irrigation and WRD, Government of Haryana	Member
6.	Engineer in Chief, Irrigation and WRD, Government of Haryana	Member
7.	Principal Secretary, Irrigation and WRD, Government of Uttar Pradesh	Member
8.	Engineer in Chief and HoD, Irrigation and WRD, Government of Uttar Pradesh	Member
9.	Principal Secretary, Irrigation and Flood Control Department, Government of NCT	Member
10.	Chief Engineer-Zone-1, Irrigation and Flood Control Department, Government of NCT	Member
11.	Director, Central Water & Power Research Station, Pune	Member
12.	Representative of National Remote Sensing Centre, Hyderabad	Member
13.	Representative of IMD	Member

Z-15011/1/2020-FM Section-MOWR

I/86850/2023

14.	Chief Engineer(FMO), Central Water Commission,	Member-Secretary

The Committee shall review and advice the study as per Terms of Reference given at Annexure-I.

3. The Committee will submit its final report within a period of six months from the date of its constitution. However, an interim report regarding meteorological aspects, return period floods, discharging capacity of barrages, functional requirement of ITO barrage etc along with interim measures to be taken shall be submitted within two months. The Committee may co-opt other members, if required, and may invite any officer from expert organizations to present the outcome of related technical studies carried out by them, if any.

4. The expenditure on TA/DA etc. of the officials for participating in meetings/visits shall be borne by the respective Organizations.

6/8/2023

(Rajesh Kumar)
Sr. Joint Commissioner-II, FM
Ph.No. 9650550015
E-mai: sjcer2-mowr@nic.in

To,
The Members of the Committee

Copy to:

1. Chief Secretary, Government of Uttar Pradesh
2. Chief Secretary, Government of Haryana
3. Chief Secretary, Government GNCDT
4. Director General, IMD, New Delhi
5. Director, NRSC, Hyderabad.

Copy for kind information to:

1. PS to Hon'ble Minister Jal Shakti
2. Sr.PPS to Secretary (WR,RD&GR), Ministry of Jal Shakti
3. Sr. PPS to Special Secretary (WR,RD&GR), Ministry of Jal Shakti

Annexure-I

TERMS OF REFERENCE

FOR

FLOOD MANAGEMENT STUDY OF RIVER YAMUNA FOR ITS REACH BETWEEN HATHNIKUND AND OKHLA BARRAGE

1.0 Background

River Yamuna, one of the largest tributaries of River Ganga, originates from Yamunotri Glacier on the southwestern slope of Bandarpunch peaks of the Lower Himalayas in Uttarakhand. The Yamuna River basin lies in Uttarakhand, Himachal Pradesh, Haryana, Delhi and Uttar Pradesh. Before its confluence with River Ganga at Sangam in Prayagraj district of Uttar Pradesh, important tributaries such as Hindon, Tons, Pabbar, Chambal, Sindh, Betwa and Kenjoin the river. The country's huge population depends upon the water of the river Yamuna. There are six barrages constructed on the main course of the river. These barrages are Dakpathar Barrage, Hathnikund Barrage, Wazirabad Barrage, ITO Barrage, Okhla Barrage and Mathura Barrage. From Hathnikund Barrage, water is diverted to Eastern and Western Yamuna Canals. The river water takes about 2-2.5 days to travel from Hathnikund to Delhi. Central Water Commission started flood forecasting services in 1958 with its first forecasting station on Yamuna at Delhi's old railway bridge.

Due to a combination of Western Disturbances and Southwest Monsoon, heavy rainfall in different places of Himachal Pradesh, Uttrakhand and Haryana occurred during 09-13 July 2023, leading to extensive landslides and flooding in the hills and plains. The heavy rainfall in the catchment area of river Yamuna resulted in huge runoff in the river, due to which an earlier HFL of 207.49 m recorded at the CWC gauging site of Delhi's old railway bridge on 6th September 1978 surpassed and a new HFL of 208.66 m was observed on 13th July 2023. This necessitated giving a fresh look at the river's flood management in its reach from Hathnikund Barrage up to Okhla Barrage.

2.0 Scope of the Study

For any flood management intervention by structural or non-structural measures, an in-depth understanding of the hydrological and hydro-dynamic aspects of the river/stream is essential. Hence, for the reach of river Yamuna from Hathnikund barrage up to Okhla barrages, the following studies are proposed:

i. Detailed catchment representative rainfall analysis to compare the floods of the year 1978 and 2023 and other years as decided

ii. Estimation of 5, 10, 25, 50, 100 and 500-year return period floods at Hathnikund Barrage, Wazirabad Barrage, Delhi old railway bridge and Okhla Barrage

iii. Carrying capacity of the river between Hathnikund barrage and Okhla barrage

iv. Maximum water level at salient locations of the study river reach for 5, 10, 25, 50, and 100-year return period floods

v. Afflux of barrages, bridges, flood protection dykes and other structures in the study reach of the river

vi. 2D modelling and submergence area estimation for the reach of river Yamuna from 10 km upstream of Wazirabad barrage and up to 10 km downstream of Okhla barrage.

vii. Identification of possible drainage congestion in Delhi in case of high spate of river Yamuna.

viii. To review the utility of ITO barrage in present context.

ix. Examine the feasibility of some innovative measures like creating underground reservoirs for flood moderation in line with Tokyo model.

x. Examine the feasibility of creation of storages for surplus flood water in the flood plains of Yamuna and thereafter identification of such sites.

3.0. Tasks to be performed

a. Review of Data availability, Data Collection and Compilation

b. Collection and compilation of all the requisite information/data for the study as suggested

c. Delineation of river catchment and estimation of physiographic parameters

d. Preparation of DTM up to 200 m on either side of the river from river banks using a combination of Drone and hydrographic survey and merging this DTM with other available DTM/DEM for the study purpose

e. Catchment representative rainfall analysis using IMD gridded rainfall data to estimate 1-day, 3-day and 5-day maximum rainfall depths from the year 1970 to Year 2023.

d. Estimation of 5, 10, 25, 50, 100 and 500-year return period floods at Hathnikund barrage, Wazirabad Barrage, Delhi old railway bridge and Okhla barrage

e. Development of a 1-D mathematical model of the study river reach to estimate water level at salient locations for 5, 10, 25, 50 and100-year return period

floods and channel carrying capacity

f. Development of a 2-D mathematical model for the reach of river Yamuna from 10 km upstream of Wazirabad barrage and up to10 km downstream of Okhla barrage for submergence area estimation.

g. Identification of drainage congestion in Delhi in case of high spate of river Yamuna

Annexure B

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन नदी विकास एवं गंगा संरक्षण विभाग
केन्द्रीय जल आयोग
बाढ़ प्रबंधन संगठन

सत्यमेव जयते

Government of India
Ministry of Jal Shakti
Deptt. of Water Resources, RD & GR
Central Water Commission
Flood Management Organisation

दिनांक: 07/09/2023

विषय : Minutes of 1st meeting of the Committee for joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage.

महोदय,

Please find enclosed herewith the minutes of 1st meeting of the Committee for joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage held on 04/09/2023 at 1500hrs in the Committee Room, CWC, 2nd Floor, Sewa Bhawan, RK Puram, New Delhi-110066.

Encls: As above.

भवदीय,

बी के कारजी
मुख्य अभियंता (FMO) एवं मेम्बर सेक्रेटरी

प्रति,

1. PPS to Chairman, CWC
2. PPS to Member (D&R), CWC
3. PPS to Member (RM), CWC
4. Commissioner, FM, DoWR, RD&GR, MoJS
5. Commissioner & Secretary, Irrigation & WRD, Govt. of Haryana.
6. Engineer in Chief, Irrigation & WRD, Govt. of Haryana.
7. Principal Secretary, Irrigation & WRD, Govt. of Uttar Pradesh.
8. Engineer in Chief, Irrigation & WRD, Govt. of Uttar Pradesh.
9. Principal Secretary, Irrigation & Flood Control Deptt., Govt of NCT.
10. Chief Engineer-Zone-1, Irrigation & Flood Control Deptt., Govt of NCT.
11. Director General, IMD.
12. Director, CW&PRS, Pune.
13. Director, NRSC, Hyderabad.
14. Vice-chairman, Delhi Development Authority
15. Surveyor General of India, Survey of India, Dehradun

16. Director General, Central Public Works Department, New Delhi
17. Chief Engineer, P&D, CWC
18. Chief Engineer, YBO, CWC
19. Chief Engineer, HSO, CWC
20. Director, Hydrology (NE)/BCD (N&W), CWC

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जल संरक्षण – सुरक्षित भविष्य

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Conserve Water Save Life

Minutes of 1st meeting of the Committee for Joint Flood Management Study of River Yamuna for its reach between Hathnikund and Okhla barrage

The 1st meeting of the Committee constituted vide Z-15011 /1 /2020-FM Section-MOWR dated 06thAugust 2023 for Joint Flood Management Study of River Yamuna for its reach between Hathnikund and Okhla barrage was held on 04/09/2023 at 1500hrs in the Committee Room, CWC, 2nd Floor, Sewa Bhawan, RK Puram, New Delhi-110066 under the chairmanship of Sh. Kushvinder Vohra, Chairman, Central Water Commission. The list of the participants is attached as **Annexure**.

Chairman, Central Water Commission while welcoming the participants introduced about the backdrop of the constitution of the committee. He further directed Director (FFM), CWC for presentation on terms of reference of the committee, data requirement and finalization of interim report and final report as per timeline given. After detail discussion, it was decided that the following task need to be completed for finalization/preparation of reports.

- Data requirement

Sl. No.	Task/Assignment	Agency	Timeline
a.	***Station RF in the catchment***	IMD	1 week
b.	***Annual Flood Peak (Discharge/ Water Level)***		
1.	Hathnikund Barrage	Govt of Haryana	10 days
2.	Wazirabad Barrage	Delhi Jal Board (Govt of NCT, Delhi will collect the information)	10 days
3.	Delhi Railway Bridge site	CWC	Already collected by HSO, CWC
4.	ITO Barrage	Govt of Haryana	10 days
5.	Okhla Barrage	Govt of Uttar Pradesh	10 days
c.	***DTM***		
1.	Hathnikund to u/s Shamli (1000 sqkm)	Survey of India	1 week
2.	U/s Shamli to Shamli (500 sqkm)	Survey of India	1 month
3.	Upto Okhla Barrage	Survey of India	15th Nov, 2023 (without Quality Control) 30th November, 2023 (with Quality Control)
d.	***X-section (with Lat/Long along the centre line)***		
1.	Haryana Reach embankment to embankment	Govt of Haryana	45 days
2.	Delhi reach upto Jaitpur (d/s of Okhla) embankment to embankment	Govt of NCT, Delhi	45 days
3.	Existing x-section of Yamuna (Delhi Reaches) surveyed during 2021	Govt of NCT, Delhi	1 week
e.	***Information/salient features of Structures including drawings***		
1.	Bridges	Govt of NCT, Delhi to coordinate and collect information from different	Within 10 days

		agencies.	
2.	Hathnikund Barrage	Govt of Haryana	Within 10 days
3.	Wazirabad Barrage	Govt of NCT, Delhi	Within 10 days
4.	ITO Barrage	Govt of Haryana	Within 10 days
5.	Okhla Barrage	Govt of Uttar Pradesh	Within 10 days
f.	***Review of Danger Level and Warning Level of Delhi Railway Bridge***	Govt of NCT, Delhi	One month
g.	***Review of utility of ITO Barrage***	Govt of Haryana, Govt of NCT, Delhi	One month
h.	***Details of Temporary structure/muck disposal clearance from the river bed/bank***	Govt of NCT, Delhi	One month
i.	***Salient features/ layout of drains***		
1.	Level/sections/discharges and its functioning details of drains in Delhi	Govt of NCT, Delhi	10 days
2.	Level/sections/discharges and its functioning details of Jasola drains	Govt of Uttar Pradesh	10 days
j	**LULC map**	NRSC	10 days
k.	**Information for examining the feasibility of creation of underground reservoirs as well as storages in flood plain for surplus flood water.**	Govt of NCT, Delhi DDA	One month

- X-section data available with IIT Roorkee/NIH need to be collected and utilized for this work.
- It has been decided that the report prepared on meteorological data (rainfall) analysis may be shared with IMD.
- Regular Inspection and maintenance schedule of drains need to be ensured by Govt of NCT, Delhi.
- It has been decided to construct a booklet comprising of all data collected for this study for its utilization for any study in future.
- Chairman of the committee desired that state representatives should convey message to their respective Principal Secretary to attend or have full authorization to his representative to attend the meeting. He further requested to provide data as per the timeline.

Meeting ended with vote of thanks to chair.

Annexure

First meeting of the Committee for joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage on 04.09.2023 at 1500 hrs in the Committee Room, CWC, 2nd Floor, SewaBhawan, New Delhi.

Sl. No.	Name (Shri)	Designation	Department	Remarks
DoWR, RD&GR and CWC				
1.	Sh. Kushvinder Vohra	Chairman	CWC	Chairman of the Committee
2.	Sh. S. K. Sibal	Member (D&R)	CWC	Member
3.	Sh. Atul Jain	Commissioner (FM)	DOWR, RD&GR	Member
4.	Sh. G. K. Agarwal	Chief Engineer	YBO, CWC	Special Invitee
5.	Sh. B. K. Karjee	Chief Engineer (FMO)	CWC	Member Secretary
6.	Sh. D.P. Mathuria	Chief Engineer	P&DO, CWC	Special Invitee
7.	Sh. N. N. Rai	Director, Hydrology (NE)	CWC	Special Invitee
8.	Sh. H. S. Sengar	SE (HOC), YBO, Vaishali	CWC	Special Invitee
9.	Sh. Sharad Chandra	Director (FFM)	CWC	Special Invitee
10.	Sh. Rajesh Kumar	Senior Joint Commissioner (FM)	DOWR, RD&GR	Special Invitee
11.	Sh. Samir Kumar Shukla	Director, BCD (N&W)	CWC	Special Invitee
12.	Sh. Manoj Kumar	Deputy Director	FFM, CWC	Special Invitee
13.	Sh. Akshat Jain	Deputy Director	Hydrology, CWC	Special Invitee
14.	Sh. Piyush Kumar	Deputy Director	FCA-2, CWC	Special Invitee
15.	Sh. Suneet Bansal	Deputy Director	FCA-2, CWC	Special Invitee
16.	Sh. Parmod Kumar	Deputy Director	FFM, CWC	Special Invitee
17.	Sh. Ghanshyam	Deputy Director	Gates(N&W), CWC	Special Invitee
CW&PRS				
18.	Dr. R.S. Kankara	Director	CW&PRS, Pune	Member
UYRB				
19.	Dr. JakirHussain	Specialist Environment	UYRB, New Delhi	Member representative
Survey of India				
20.	Sh. S.V. Singh	Director	Survey of India	Special Invitee
CPWD				
21.	Sh. Manoj Kumar	SE, CPWD	CPWD	Special Invitee
IMD				
22.	Dr. A. K. Das	Scientist 'E'	IMD	Member representative
23.	Sh. S.K Manik	Scientist 'D'	Hydromet Division, IMD	Member representative
DDA				
24.	Sh. Rajeev Kr. Tiwari	Pr. Commissioner (Horticulture)	DDA	Special Invitee
NRSC				
25.	DR. K.H.V Durga Rao		NRSC	Member representative
Govt of NCT, Delhi				
26.	Sh. Anil Kumar	Chief Engineer	I & FC, Delhi	Member
27.	Sh. Shiv Kumar	EE CD XIV	I & FC, Delhi	
28.	Sh. N. S.P. Patwal	SSW	I & FC, Delhi	
Govt of Haryana				
29.	Sh. Rakesh Chauhan	Engineer in Chief	Irrigation & Water Resource Department, Haryana	Member
30.	Sh. Birender Singh	Engineer in Chief, HOD (special)	Irrigation & Water Resource Department, Haryana	Member

Annexure C

File No.T-11075/2/2023-FFM

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन नदी विकास एवं गंगा संरक्षण विभाग
केन्द्रीय जल आयोग
बाढ़ प्रबंधन संगठन

सत्यमेव जयते

Government of India
Ministry of Jal Shakti
Deptt. of Water Resources, RD & GR
Central Water Commission
Flood Management Organisation

दिनांक:28/11/2023

विषय : Minutes of the 2nd meeting of the Committee for joint flood management study of river Yamuna for its reach between Hathnikund and Okhla Barrage.

महोदय,

Please find enclosed the Minutes of 2nd meeting of the Committee for joint flood management study of river Yamuna for its reach between Hathnikund and Okhla Barrage held on 13/11/2023 at CWC, Sewa Bhawan, RK Puram, New Delhi-110066.

Encls: As above.

भवदीय,

Signed by Bijoy Kumar Karjee
Date: 28-11-2023 13:13:28
Reason: Approved

बी के कारजी
मुख्य अभियंता (FMO) एवं मेम्बर सेक्रेटरी

प्रति,

1. PPS to Chairman, CWC
2. PPS to Member (D&R), CWC
3. PPS to Member (RM), CWC
4. Commissioner, FM, DoWR, RD&GR, MoJS
5. Commissioner & Secretary, Irrigation & WRD, Govt. of Haryana.
6. Engineer in Chief, Irrigation & WRD, Govt. of Haryana.
7. Principal Secretary, Irrigation & WRD, Govt. of Uttar Pradesh.
8. Engineer in Chief, Irrigation & WRD, Govt. of Uttar Pradesh.
9. Principal Secretary, Irrigation & Flood Control Deptt., Govt of NCT.
10. Chief Engineer-Zone-1, Irrigation & Flood Control Deptt., Govt of NCT.
11. Director General, IMD.
12. Director, CW&PRS, Pune.
13. Director, NRSC, Hyderabad.
14. Vice-chairman, Delhi Development Authority (Special Invitee)
15. Sh. P.K.G. Mishra, OSD to Hon'ble LG, Delhi (Special Invitee)
16. Director General, CPWD, New Delhi (Special Invitee)

17.Surveyor General of India, Dehradun (Special Invitee)
18.Chief Engineer, P&D (Special Invitee)

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जल संरक्षण – सुरक्षित भविष्य

Conserve Water Save Life

Minutes of 2nd Meeting of the Committee for Joint Flood Management Study of River Yamuna for its reach between Hathnikund and Okhla barrage

The 2nd meeting of the Committee constituted vide Z-15011 /1 /2020-FM Section-MOWR dated 06th August 2023 for Joint Flood Management Study of River Yamuna for its reach between Hathnikund and Okhla Barrage was held on 13/10/2023 at 1430 hrs in the CWC Committee Room, 2nd Floor, Sewa Bhawan, RK Puram, New Delhi-110066 under the chairmanship of Sh. Kushvinder Vohra, Chairman, Central Water Commission and ex-officio Secretary to the Govt. of India.

The list of participants is attached as **Annexure**.

At the outset, Chairman, Central Water Commission welcomed all the participants and gave a brief of the agenda items to be discussed in the meeting. He stated that during 1st meeting of the committee, various data requirement was discussed. A lot of data was expected from concerned agencies for modelling and other studies to see the capacity of Yamuna at various places. Some of the data have been received but some are still awaited from the concerned. As per TOR of the Committee, an Interim report has to be submitted to DoWR, RD&GR, MoJS. For this, preliminary issues have been identified to highlight in the Interim Report and same will be discussed threadbare. He also stressed upon the need to look at the discharge data discrepancy at the barrage location.

Further, Chairman of the committee directed Director, FFM to give brief presentation pointwise on the status of data reception and other relevant issues.

***a.* Station RF in the catchment**

Director FFM stated that catchment rainfall analysis has been done on the basis of gridded rainfall. Since the station rainfall has been received from IMD, the analysis will be updated by HSO, CWC using station rainfall data.

[Action: HSO, CWC]

***b.* Annual Flood Peak (Discharge/ Water Level)**

The data has been received for all the 4 barrages in respect of annual flood peak.

c. DEM/DTM

(i) Director FFM stated that DEM data from Hathnikund to u/s Shamli (1000 sqkm) has already been received from SoI. Data from U/s Shamli to Okhla Barrage are expected by 31st Dec, 2023 except for No Flying Zone. Chairman of the committee requested to representative from Survey of India to update the information related to DEM data.

(ii) Survey of India stated that permission from Civil Aviation authority is awaited for flying in certain stretches of Yamuna River along with its flood plain. Chairman of the committee suggested Survey of India to assess the extent of area falling under no flying zone and also to request for permission to fly along and nearby the river course only and not in flood plain for preparation of DEM/DTM. Survey of India will provide the same within a week.

[Action: SoI]

***d.* X-section (with Lat/Long along the center line)**

Director, FFM informed that surveyed cross-sections for Haryana Reach (embankment to embankment) for Yamuna River has been received of late. For Delhi reach, I&FC Deptt, Govt of NCT Delhi has already shared the old cross-section details (surveyed in 2021). Further the latest cross-sections which are being surveyed by I&FC Deptt will be shared by **30th November, 2023**.

[Action: Govt of NCT Delhi]

e. Information/salient features of Structures including drawings

(i) Director, FFM informed that complete data has not been received in respect of bridges. Further, Chairman of the committee highlighted the importance of this information as the pier of the bridges will be used as obstruction to the flow during flood routing using mathematical modelling. Essential data such as number of piers, shape and size along with deck slab height, etc. are required. I&FC Deptt, Govt of NCT Delhi agreed to share this information in 15 days.

[Action: Govt of NCT Delhi]

(ii) Chairman of the committee stated that discharge reported during recent flood and the water level attained is not consistent. Therefore, the discharge -stage curve which barrage authorities follow needs to be understood. Director, BCD (N&W) requires the barrage operation manual so as to understand the situations and suggest suitable measures. Chairman of the committee directed to Director, BCD (N&W) and Gates (N&W) to review the discharges from the barrages and to see the operating procedure of barrages. Also, he directed to visit the barrage locations. Further, it was decided that additional data required, if any, may be obtained by BCD (N&W), CWC directly from the barrage authorities.

[Action: BCD (N&W) & Gates (N&W), CWC]

f. Review of Danger Level (DL) and Warning Level (WL) of Delhi Railway Bridge

(i) Chairman of the committee queried I&FC Deptt, Govt of NCT Delhi on the rationality of suggesting change in danger level and warning level for Old Delhi Railway Bridge. He further suggested that it should be based on the level when the water is overtopped from the bank and not focusing on the encroachment nearby. IMD also suggested that the media persons may be sensitized on the correct interpretation of Danger level.

(ii) Chief Engineer, I&FC Deptt, Govt of NCT Delhi stated that presently fixed WL and DL may continue until completion of the model study by CWPRS.

(iii) OSD to Hon'ble LG raised the issue of ownership of Yamuna floodplain in Delhi. He also highlighted that there was no flooding issue upstream of Wazirabad as there are no bridges in that reach.

(iv) DDA stated that the encroachment is being removed from the flood plains in a phased manner. DDA in a presentation stated that as per the judgment of Hon'ble NGT dated 13 January 2015, the key issues which are being addressed for River Yamuna are:

- Reclamation, Restoration and Rejuvenation of the riverbed and its floodplains
- Removal of Encroachments on the floodplains
- Check on pollution in the river and large-scale dumping of solid waste/spoils etc.

DDA also informed that in Delhi Master Plan, A to O zones are defined, in which O Zone is for flood plain along with active channel from Palla to Jaitpur.

Chairman of the Committee stated that vegetative growth in the floodplain may impede the smooth passage of flood discharge along the river and increase the afflux upstream. This important aspect should have been pointed out and highlighted by the concerned stakeholders.

(v) Director, Hydrology (NE) enquired about the design return period for main embankment and marginal bunds. In reply to that CE, I&FC Deptt informed that the embankment has been designed based on 12,500 cumec discharge and this study was conducted by CWPRS, Pune.

g. Review of utility of ITO Barrage

Presently, ITO barrage has no specific use. However, Govt of NCT Delhi is of the view that it can be utilised for storage for recharge purpose during lean period. They are of the view that its operation may be handed over to Govt of NCT Delhi. DDA also aired the same view. Govt

of Haryana informed that, ITO barrage had not been operated since 2014. Chairman of the committee directed to invite **Member Secretary (UYRB) during next meeting.**

[Action: CWC/I&FC Deptt. Govt of NCT delhi]

h. **Salient features/ layout of drains**

It was informed that out of 18 major drains, 14 drains are regulated. During flood season it is being regulated through pumping arrangement u/s of the regulator. Chairman of the committee stated that the information like capacity of drain, the return period used while designing the drain in respect of storm water, etc are essential to use in the model as inputs. I&FC Deptt agreed to share these information within one week. Further, it was desired that SOP for operating the drains when danger level at DRB is attained, may be shared. CE, I&FC Deptt agreed to share the SOP within 10 days. Chairman of the committee also directed Director, **Hydrology (Urban), CWC to co-ordinate with concerned agencies of drains to understand the problem in holistic way.** The status of implementation of the recommendations of the Drainage master plan prepared by IIT, Delhi was also discussed. It was informed that PWD is further studying these recommendations for implementation. Chairman of the committee desired that in the next meeting the concerned agency may be invited as special invitee.

[Action: Director Hydrology (Urban) CWC/Govt of NCT Delhi]

i. **Details of Temporary structure/muck disposal clearance from the river bed/bank**

The issues of encroachment/ temporary structures/ muck disposal, etc. was discussed in detail and Chairman of the committee suggested that an SOP in this regard may be formulated by DDA. It was also suggested to prepare an SOP for further development in Yamuna flood plain in Delhi region.

[Action: DDA]

j. **Embankment details, raising required, if any**

Director, Hydrology (Urban) presented a preliminary 2D model setup/run of Yamuna River in Delhi reach which showed water overtopping or leakage through the embankment at some locations for 1 in 100 year flood. Also, Chairman of the committee directed Director Hydrology (Urban) to co-ordinate with I&FC Deptt. Delhi in this regard and get it physically verified.

[Action: Director Hydrology (Urban) CWC/ I&FC Deptt.]

k. **LULC map**

Chairman of the committee directed Director Hydrology (Urban) to co-ordinate with the DDA regarding the present land use in flood plain of Yamuna.

[Action: Director Hydrology (Urban) CWC/DDA]

l. **Information for examining the feasibility of creation of underground reservoirs as well as storages in flood plain for surplus flood water.**

It was prima facie felt that creating storages at probable locations in the flood plain may not achieve the sufficient flood moderation. It has been suggested by OSD to LG, Delhi that the abandoned Bhatti mines can be a site for diverting the surplus water for ground water recharge. However, this volume is not significant for flood water storage and can bring about the possible contamination of ground water. Chairman of the Committee suggested that **CGWB may be invited for the next meeting as special invitee.**

[Action: CWC]

The meeting ended with vote of thanks to and from the chair.

Annexure

2nd meeting of the Committee for joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage on 13.11.2023 at 1430 Hrs in the Committee Room, CWC, 2nd Floor, Sewa Bhawan, New Delhi.

Sl. No.	Name	Designation	Department	Remarks
DoWR, RD & GR and CWC				
1.	Sh. Kushvinder Vohra	Chairman	CWC	In Chair
2.	Sh. P.M. Scott	Member (RM)	CWC	Member
3.	Sh. D.P. Mathuria	Chief Engineer (P&DO)	CWC	Special Invitee
4.	Sh. B.K. Karjee	Chief Engineer (FMO)	CWC	Member Secretary
5.	Sh. Rajesh Kumar	Sr. Joint Commissioner.	DoWR, RD&GR	Member Representative
6.	Sh. H.S. Sengar	Superintending Engineer	YBO, CWC	Special Invitee
7.	Sh. N.N.RAI	Director, Hydrology (NE)	CWC	Special Invitee
8.	Mohd. Faiz. Syed	Director, Hydrology (Urban)	CWC	Special Invitee
9.	Sh. Ritesh Khattar	Director, FCA-1 Dte	CWC	Special Invitee
10.	Sh. S.K. Kamboj	Director, Gates (N&W)	CWC	Special Invitee
11.	Sh. Manoj Kumar	Deputy Director (FFM Dte)	CWC	Special Invitee
12.	Sh. Varid Gupta	Assistant Director, B.C.D (N&W)	CWC	Special Invitee
CWPRS				
13.	Dr. R. S. Kankara	Director	CWPRS, Pune	Member
Survey of India				
14.	Sh. Arvind Kumar	Superintending surveyor	Survey of India	Member Representative
IMD				
15.	Dr. Ashok Kumar Das	Scientist 'E'	IMD	Member Representative
16.	Sh. Swapan Kumar Manik	Scientist 'D'	IMD	Member Representative
Members from Hon'ble LG office and DDA				
17.	Sh. P K G Mishra	OSD to Hon'ble LG	Govt of NCT Delhi	Special Invitee
18.	Sh. Ashwani Kumar	Chief Engineer (Horticulture)	DDA	Member Representative
19.	Ms. Neelima Soni	Director (Landscape)	DDA	
20	Md. Shahnawaz Alam	EE (EZ)	DDA	
NRSC (Through VC)				
21.	DR. K.H.V Durga Rao		NRSC	Member Representative
Govt. of NCT delhi				
22.	Sh. Anil Kumar	Chief Engineer	I&FC Deptt, Govt of NCT Delhi	Member

23.	Sh. Shiv Kumar	EE CD XIV	I&FC Deptt. Govt of NCT Delhi	
24.	Sh. Manish Agarwal	EE CD VI	I&FC Deptt. Govt of NCT Delhi	
25.	Sh. Ravinder Kumar	Superintending Engineer	DJB, Govt of NCT Delhi	
26.	Sh. Devinder	A.E	DJB, Govt of NCT Delhi	
27.	Sh. Narender Singh		DJB, Govt of NCT Delhi	
28.	Sh. N S P Patwal	SSW	&FC Deptt. Govt of NCT Delhi	
Govt of Haryana				
29.	Sh. Birender Singh	Engineer in Chief	Irrigation & Water Resource Department, Haryana	Member
30.	Sh. R.S. Mittal	SE	Irrigation & Water Resource Department, Haryana	
31	Sh. Tarun Agarwal	SE	Irrigation & Water Resource Department, Haryana	
32.	Sh. Manoj Kumar	EE	Irrigation & Water Resource Department, Haryana	
33.	Sh. Sandeep Taneja		Irrigation & Water Resource Department, Haryana	
Govt of Uttar Pradesh				
34.	Sh. K.P. Singh Verma		Irrigation & Water Resources Department, Uttar Pradesh	Member Representative

Annexure D

File No.1-112/12/2023-FFM | 361-383

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन नदी विकास एवं गंगा
संरक्षण विभाग
केंद्रीय जल आयोग
बाढ़ पूर्वानुमान प्रबोधन निदेशालय

Government of India
Ministry of Jal Shakti
Dept. of Water Resources, RD&GR
Central Water Commission
Flood Forecast Monitoring Directorate

Dated. 29.04.2024

विषय: Minutes of the 3rd Meeting of the Committee for joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage.

महोदय,

Please find enclosed the approved Minutes of the 3rd meeting of the Committee for joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage held on 25/04/2024 at CWC, New Delhi for information and kind necessary action.

Encls: As above.

भवदीय,

बी के कारजी
मुख्य अभियंता (FMO) एवं मेम्बर सेक्रेटरी

प्रति:

1. PPS to Chairman, CWC
2. PPS to Member (D&R), CWC
3. PPS to Member (RM), CWC
4. Chairman, CGWB.
5. Commissioner, FM, DoWR, RD&GR, MoJS
6. Commissioner & Secretary, Irrigation & WRD, Govt. of Haryana.
7. Member Secretary, Upper Yamuna River Board
8. Engineer in Chief, Irrigation & WRD, Govt. of Haryana.
9. Principal Secretary, Irrigation & WRD, Govt. of Uttar Pradesh.
10. Engineer in Chief, Irrigation & WRD, Govt. of Uttar Pradesh.
11. Principal Secretary, Irrigation & Flood Control Deptt., Govt of NCT.
12. Chief Engineer-Zone-1, Irrigation & Flood Control Deptt., Govt of NCT.

13.Director General, IMD.

14.Director, CW&PRS, Pune.

15.Director, NRSC, Hyderabad.

16.Vice-chairman, Delhi Development Authority (Special Invitee)

17.Sh. P.K.G. Mishra, OSD to Hon'ble LG (Special Invitee)

18.Director General, CPWD, New Delhi (Special Invitee)

19.Surveyor General of India, Dehradun (Special Invitee)

20.Chief Engineer, FMO, CWC

21.Chief Engineer, HSO, CWC (Special Invitee)

22.Chief Engineer, P&D, CWC (Special Invitee)

23.Chief Engineer, YBO, CWC (Special Invitee)

पश्चिमी खंड-2 विंग-7 (भूमि तल)
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E-mail: fmdte@nic.in
s Conserve Water- Safe Future s

Minutes of the 3rd Meeting of Committee for joint flood management study of River Yamuna for its reach between Hathnikund and Okhla barrage held on 25th April, 2024 under the chairmanship of Chairman, CWC

The 3rd meeting of the Committee for joint flood management study of river Yamuna for its reach Between Hathinikund and Okhla Barrage was held on 25th April, 2024 at New Delhi under the chairmanship of Shri Kushvinder Vohra, Chairman, Central Water Commission and Ex-Officio Secretary to Government of India. The list of participants is at **Annexure-I.** At the outset, Chairman, Central Water Commission welcomed the participating officers from CWC, DoWR, RD &GR, Survey of India, CWPRS, Governments of Harayna, Uttar Pradesh, NCT Delhi, DDA, Delhi Jal Board, CGWB and others present. In his opening remarks, Chairman, CWC presented the aspects of flood management which have already been covered in the Interim Report of the committee and the way forward towards finalisation of the report of the Committee. Chairman, CWC appreciated the efforts of all the Committee members towards the timely finalisation of Interim Report in January, 2024.

Introducing the agenda of the meeting, Chairman of the committee directed Director, FFM to give a brief presentation on the ToRs of the committee and progress made so far in respect of each ToR. The status of progress of each ToR was deliberated in order to decide the future course of action towards firming up the Final Report.

A. Proceedings of the Meeting

The proceedings of the meeting started with status of Action Taken Report on various tasks which were assigned to various Organisations as mentioned in the Interim Report and ToRs of the committee. The discussions and deliberations during the course of meeting are described as under.

1. Revision of Warning Level (WL) and Danger Levels (DL) at Old Delhi Railway Bridge.

In the meeting, the representative of IFCD, Government of NCT of Delhi brought out that DL& WL are important parameters utilized for activating the mechanism of evacuation, relief, revenue, police, closure of drains in Delhi, issuing of flood forecasts by CWC etc. These levels are fixed in keeping into consideration the threat perception in the area corresponding to those levels. The danger level considered presently at Old Delhi Railway Bridge needs to be re-looked as this level is attained even at a very low discharge/flood, thereby, causing panic to citizens of Delhi. Earlier, warning & danger levels at Old Railway Bridge were 204.00 m & 204.83 m, respectively. However, in the year 2019, the warning & danger levels were raised by 0.5 m which is 204.50 m & 205.33 m, respectively. Delhi Govt. officials informed that they are contemplating to change warning & danger levels further to 205.00 m and 205.75 m, respectively. It was informed that CWPRS, Pune is carrying out the 2D modelling analysis to determine the WL & DL for which data related to this has been supplied to

CWPRS. The report of CWPRS is expected shortly.It was also suggested to prepare a habitation map of vulnerable areas for a fair assessment of DL/WL.

It was deliberated that WL/DL are from the point of view of ensuring the safety of inhabitants in the low lying areas as well as from technical consideration. Therefore, it was directed to carry out detail study on justifying the revision WL/DL w.r.t threat perception as well as from technical consideration of sill levels of out-fall of drains discharging into river Yamuna. The IFCD, Government of NCT is to furnish this report by 5th of May, 2024.

2. Network of Drains in Delhi

Delhi Government officials informed that there are total 18 drains which are connected to the Yamuna River and out of these, 14 drains are regulated and the remaining 4 are unregulated. IFCD, Govt. of NCT was suggested to prepare a complete report mentioning the details of each drain like bed level, FSL, bed cross section, crest level, SoP of operation of drains/pumping, embankment details of drains, etc., with proper line diagrams and maps and send it to CWC as same is required for Annual Report by 5th May, 2024. The backflow of the drains at the time of high stages of river Yamua needs to be studied in the hydraulic model. Chairman of the committee emphasised the regular Inspection, desilting and maintenance schedule of drains need to be ensured by Government NCT of Delhi.

3. DEM/ DTM data of the Yamuna River

It was apprised by representative of Survey of India (SoI) that under NHP, final data Lot#5(sublot_1to sublot_6) i.e 05.m DEM with ortho rectified imageries of Yamuna river upto Okhla Barrage has already been supplied to CWC and NWIC. However, the areas under "No Flying Zone" comprising of Delhi Region (approx. 200 sq Km), Mathura Refinery Region (approx. 350sq. km) and Taj Mahal region (approx. 250 sq. km) have not been covered in Yamuna DEM. It was also informed that for taking up the aerial survey of these left out areas by UAVs under NHP, a proposal has already been sent to NPMU but, in view of directions of DoE that no new work would be undertaken under NHP after March, 2024, the proposal for undertaking survey of left out areas has not been accepted by NPMU. Further, it was apprised by the representative of SoI that if the above proposal of generating DEM in No fly Zones is not accepted by NPMU, then in that case, SoI intends to carry out this work through their own resources. Chairman, CWC directed Director, FFM, CWC to take up the issue with NPMU, DoWR so as to move forward on this issue.

4. Utility of ITO Barrage

Representative of Irrigation and WRD, Government of Haryana informed that maintenance work of ITO barrage and its gates is currently under progress and is likely to be completed by 30thMay and as suggested by the committee in its Interim Report, all gates of the barrage would be kept open during monsoon season.

Chairman, CWC emphasised that all operations and maintenance issues related to proper functioning of ITO barrage should be in place well before the onset of 2024 monsoon. The pre-monsoon necessary preparedness activities for all barrages should be in place before the ensuing monsoon.

5. Encroachment and removal of muck in river Yamuna

The Committee in its Interim Report has highlighted the issue of temporary structures and muck disposal within the right of way of the river during the construction time and this has led to the increased afflux during a flooding event. Therefore, the committee opined that all temporary structures should be properly dismantled and muck should be properly disposed away from the river bed/bank.

Representative of DDA informed that Hon'ble Delhi High Court has ordered the removal of encroachments from Yamuna floodplains and ordered DDA to file a report on the development of biodiversity parks/wetland, saying green development of the banks is necessary. The recent Court Order pressed for "rejuvenation" of the river by removal of construction debris and directed DDA to take up the issue of its "controlled and scientific dredging" on a war footing.

The representative of DDA informed that Department is aggressively carrying out encroachment removal and an Office order has been issued to various Government/Non-Government agencies for removal of all construction debris and muck from the river reach latest by 30thMay, 2024.

6. Regarding Underground storage and recharge of flood water

CGWB representative informed that there is some scope of water recharge in Bhatti mines. CGWB also stated that the flood water of Yamuna needs to be desilted first before discharging into the mines for recharge. There are 40 mines out of which only 15 of them are feasible for ground water recharge with an estimated recharging capacity of about 8000m^3 annually. Chairman, CWC on inquiring about the feasibility for flood moderation point of view, CGWB representative informed that this amount of recharge capacity will not help in flood moderation. However, the ground water recharge activity through Bhatti Mines can be explored separately by CGWB.

7. Observed discharge on Barrages

CWC officials brought out the issue of discrepancy found in reported discharge on Hathnikund, Wazirabad, ITO) and Okhla barrages vis-à-vis the discharge calculated by BCD Directorate, CWC. It was pointed out that discharge calculation at Hathnikund barrage needs correction as there is an error in the formula used in computation of discharge by project authority. It was explained that non-consideration of 2/3 factor and of approach velocity in discharge computation are the main reasons behind the discrepancy in the discharge figures. Similar discrepancies in the observed discharge v/s the computed discharge was also presented in the meeting by Director, BCD,

CWC. Chairman, CWC directed Director, BCD to share the discharge computation with respective barrage operating authorities and to seek their comments on the specimen discharge computation of CWC. It was also brought out that this would also have an implication on past historical discharge data of barrages and might need reconciliation of past historical data.

Director BCD,CWC suggested that there is need of revision of GD curve of barrages due to change in river morphology. In this regard, the representative of Delhi Jal Board informed that the task of preparing the GD curve at Wazirabad barrage has been assigned to IRI, Roorkee and is expected to be completed soon.

Chairman CWC suggested that the observation of discharge through ADCP may also be explored upstream of Wazirabad by guiding the ADCP through cable erected across the river during high flows in the river. He also suggested the possibility of exploring the discharge measurement with the help of Catamaran boats during floods.

8. Ground verification of potential overtopping zones along the river embankments

It was brought out in the meeting that in the Interim Report, a two dimensional (2D) hydrodynamic model of river Yamuna from Palla to Okhla barrage has been developed on HEC-RAS and simulation run of this model has identified 14 potential overtopping zones for a 100-year return period flood (8636 Cumec). The identified locations in 14 zones are listed in Table 11 of the Interim Report.

It was discussed in the meeting, that prima facie there is a need to raise the left and right embankment at the above locations and the Govt. of NCT of Delhi as well as Irrigation & WRD, Govt. of Uttar Pradesh may undertake ground verification in this regard to identify the exact such locations and send details of verification/status by 5th May, 2024. A hard copy the Interim Report was handed over to the representative of the I&WRD, Govt. of Uttar Pradesh in the meeting.

9. Preparedness for the forthcoming monsoon.

Chairman, CWC requested the officers involved in barrage operation to take all necessary steps of preparedness well before the onset of monsoon in accordance with their SoP.The functioning of all hydro-mechanical equipment (including Gates) of barrages in Yamuna as well as the effective coordination among the various barrage operating agencies may be ensured for better flood moderation. The correctness of graduations/water level markings on barrages and gauges may be ensured along with calibration of gate opening of barrages. Chairman, CWC directed Director, FFM, CWC to issue a letter to all barrage operating authorities in this context.

B. Points for taking Action

Chairman, CWC and chairman of the committee after discussions in the meeting on various aspects related to flood management of river Yamuna, the following tasks were assigned to various organization in order to complete the report of committee as per the ToRs of the Committee.

(i) Detail Report on fixing of Warning Level and Danger Level and rationale behind their fixing taking into consideration all aspects like engineering, preparedness of mitigation agencies, threat perception to the inhabitants, response of disaster managers, etc., by 5th May, 2024.**[Action :IFCD, Govt. of NCT Delhi].**

(ii) Report on estimation of 1 in 5, 10, 25, 50, 100 and 500-year return period floods at Hathnikund Barrage, Wazirabad Barrage, Old Delhi Railway bridge and Okhla Barrage. **[Action: HSO, CWC]**

(iii) Report on carrying capacity of the river between Hathnikund barrage and Okhla barrage. **[Action: HSO,CWC]**

(iv) Report on maximum water level at salient locations of the study river reach for 1 in 5, 10, 25, 50, and 100-year return period floods based upon latest DEMs. **[Action : HSO, CWC]**

(v) Study related to afflux in river due to barrages, bridges, flood protection dykes and other structures in the study reach of the river under various scenarios. **[Action : HSO, CWC]**

(vi) 2D modelling and submergence area estimation for the reach of river Yamuna from 10 km upstream of Wazirabad barrage and upto 10 km downstream of Okhla barrage. **[Action: HSO, CWC]**

(vii) Identification of possible drainage congestion spots in Delhi during high spate of river Yamuna and Report by IFCD, Govt of Delhi on details of drains in NCR their operation as mentioned at point A(2) by 5th May, 2024.**[Action: HSO, CWC / IFCD, Govt of Delhi].**

(viii) Report on removal of encroachments/muck/temporary constructions in river Yamuna **[Action:DDA].**

(ix) Report on Ground verification of potential overtopping zones along the river embankments by 5th May, 2024. **[Action: IFCD, Govt of Delhi / I&WRD, Govt. of Uttar Pradesh].**

(x) Sharing of discharge computations for Hathnikund, Wazirabad, ITO and Okhla barrages with Barrage operation Organisations and seeking their views by 5th May, 2024.**[Action: BCD (N&W), CWC / I&WRD, Govt. of Uttar Pradesh / DJB / Irrigation and WRD, Government of Haryana / IFCD, Govt. of Delhi].**

(xi) Revision of historical data of discharge from barrages in view of discrepancies which surfaced in calculation of observed discharge of barrages 5th May, 2024.**[Action: I&WRD, Govt. of Uttar Pradesh / DJB / Irrigation and WRD, Government of Haryana / IFCD, Govt. of Delhi].**

(xii) Report on discharge computation of Okhla Barrage as carried out by IIT, Delhi by 5th May, 2024.**[Action: I &WRD, Government of Uttar Pradesh].**

(xiii) Report on development of G& D curve of Wazirabad barrage by IRI, Roorkee by 5th May, 2024.**[Action : DJB].**

(xiv) Taking up issue of generating DEM for left out zones in river Yamuna by SoI under NHP **[Action: FFM Dte, CWC].**

(xv) Facilitating transfer/sharing of data and preparation of data sheet for exchange of data/information amongst various Organisations. **[Action: FFM Dte, CWC].** [The data sheet enclosed as **Annexure-II** was prepared and sent on email on 25.04.2024]

(xvi) Preparation of draft Final Report of the Committee. **[Action FFM Dte, CWC].**

(xvii) Ensuring proper operation of gates and hydro mechanical equipment of ITO barrage by 31st May, 2024.**[Action: Irrigation & WRD, Government of Haryana].**

(xvii) Flood Preparedness activities before ensuing Monsoon of 2024 by 31st May, 2024.**[Action: I&WRD, Govt. of Uttar Pradesh / DJB / Irrigation and WRD, Government of Haryana / IFCD, Govt of Delhi].**

After long-drawn deliberations during the meeting on all above aspects, Chairman CWC directed that all above tasks and exchange of data/ information between various agencies shall be accomplished by **5th May, 2024** and all sincere efforts shall be made to finalise the 1st draft of the Final report of the Committee by **20th May, 2024.**

After reviewing the progress of work in the 3rd meeting and making an assessment of the work still left, the Committee felt that a formal extension of the tenure of the committee may be sought from DoWR, RD & GR upto 15th June, 2024 and accordingly DoWR may be requested to extend the tenure of the Committee by **15th June, 2024.**

The meeting ended with a vote of thanks to and from the Chair.

Annexure-I

Participants in the 3rd meeting of committee constituted for joint flood management study of River Yamuna for its reach between Hathnikund and Okhla barrage.

A. Department of Water Resources, River Development and Ganga Rejuvenation and Central Water Commission.

1. Shri Kushvinder Vohra, Chariman& Ex-Officio Secretary to Government of India.
2. Shri P.M.Scott, Member (RM),CWC
3. Shri S.K. Sibbal, Member (D&R),CWC
4. Shri B.K Karjee, Chief Engineer (FMO),CWC
5. Shri Atul Jain, Commissioner,(FM), DoWR, RD&GR
6. Shri Rajesh Kumar, Sr. Joint Commissioner, FM
7. Shri Manoj Tiwari ,Chief Engineer,HSO, CWC
8. Shri N.N.Rai, Director (NE), CWC
9. Shri H.S. Sengar, Superintending Engineer, CWC
10. Shri Rakesh Toteja, Director, FFM Dte. CWC
11. Shri Satish Kamboj, Director, Gates (N&W), CWC
12. Shri Mohd.Faiz Syed, Director, Hydrology (Urban), CWC
13. Shri Ritesh Khattar, Director, FCA-II Dte. CWC
14. Shri Samir Kumar Shukla, Director, BCD (N&W) Dte. CWC
15. Shri Rajesh kumar Gulati, Deputy Diector, FFM Dte. CWC
16. Shri Ganshyam Patel, Deputy Director, Gates (N&W) Dte. CWC
17. Shri Gaurav Singhal, Deputy Director, Hydology (Urban) CWC
18. Shri Paritosh Kumar Singh, Assistant Director FFM Dte. CWC

B. CWPRS

1. Shri R S Kankara, Director
2. Shri Prasad Kunjeer, Scientist E

C. Survey of India

1. Shri S.V Singh, Director

D. IMD

1. Shri S.K Manik, Scientist 'D'

E. DDA

1. Shri Ashwani kumar, Chief Engineer
2. Shri M. Zaid, Assistant Director

F. Govt. Of NCT of Delhi

1. Shri Anil Kumar, Chief Engineer
2. Shri N.S.P Patwal, Chief Engineer
3. Shri Y.K Sharma, Superintending Engineer

G. Govt of Haryana(WRD)

1. Shri Pankaj Agarwal, Commissioner& Secretary (Through V.C)
2. Shri M.L. Rana, Chief Engineer
3. Shri Sandeep Taneja, Chief Engineer
4. Shri Tarun Agarwal, Superintending Engineer

H. Delhi Jal Board

1. Shri K.C. Meena, Chief Engineer

I. UYRB

1. Shri Ravi Bhushan, Member-Secretary

Annexure E

File No.T-112/12/2023-FFM

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन नदी विकास एवं गंगा
संरक्षण विभाग
केंद्रीय जल आयोग
बाढ़ पूर्वानुमान प्रबोधन निदेशालय

Government of India
Ministry of Jal Shakti
Dept. of Water Resources, RD&GR
Central Water Commission
Flood Forecast Monitoring Directorate

दिनांक: 04.07.2024

विषय: Minutes of the 4th meeting of the Committee for joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage.

महोदय,

Please find enclosed the approved Minutes of the 4th Meeting of the Committee for joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage held on 01/07/2024 at CWC, New Delhi-110066.

Encls: As above.

भवदीय,

बी के कारजी
मुख्य अभियंता (FMO) एवं मेम्बर सेक्रेटरी

प्रति,

1. PPS to Chairman, CWC
2. PPS to Member (RM), CWC
3. PPS to Member (D&R), CWC
4. Chairman, CGWB.
5. Commissioner, FM, DoWR, RD&GR, MoJS
6. Commissioner & Secretary, Irrigation & WRD, Govt. of Haryana.
7. Member Secretary, Upper Yamuna River Board
8. Engineer in Chief, Irrigation & WRD, Govt. of Haryana.
9. Principal Secretary, Irrigation & WRD, Govt. of Uttar Pradesh.
10. Engineer in Chief, Irrigation & WRD, Govt. of Uttar Pradesh.
11. Principal Secretary, Irrigation & Flood Control Deptt., Govt of NCT of Delhi.
12. Chief Engineer-Zone-1, Irrigation & Flood Control Deptt., Govt of NCT of Delhi.
13. Director General, IMD.

14.Director, CW&PRS, Pune.

15.Director, NRSC, Hyderabad.

16.Vice-chairman, Delhi Development Authority (Special Invitee)

17.Sh. P.K.G. Mishra, OSD to Hon'ble LG (Special Invitee)

18.Director General, CPWD, New Delhi (Special Invitee)

19.Surveyor General of India, Dehradun (Special Invitee)

20.Chief Engineer, HSO, CWC (Special Invitee)

21.Chief Engineer, P&D, CWC (Special Invitee)

22.Chief Engineer, YBO (Special Invitee)

पश्चिमी खंड-2 विंग-7 (भूमि तल)
आर के पुरम नई दिल्ली
दूरभाष: 011-26106523,26105274
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s जल संरक्षण – सुरक्षित भविष्य s

West Block-2, Wing-7 (Ground floor),
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Tel: 011-26106523,26105274
E-mail: fmdte@nic.in
s Conserve Water- Safe Future s

Minutes of Fourth meeting of the committee for Joint Flood Management Study of River Yamuna for its reach between Hathnikund and Okhla barrage

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The 4th meeting of the committee constituted for "Joint Flood Management Study of River Yamuna for its reach between Hathnikund and Okhla barrage" was held on 1st July, 2024 in the Committee Room, CWC, 2nd Floor, Sewa Bhawan, RK Puram, New Delhi-110066 under the chairmanship of Sh. Kushvinder Vohra, Chairman, Central Water Commission and Ex-Officio Secretary to the Government of India. The list of the participants attended the meeting is attached as **Annexure**.

At the outset, Chairman, CWC welcomed the members of the committee and expressed urgency for finalization of the report of the committee. Chairman, CWC informed the members of the committee that 1D and 2D hydraulic modelling study as per the ToRs of the committee is under progress and few more finer inputs like details of major encroachments in the form of raised platforms, coffer dams, temporary construction structure in the river Yamuna, gaps in the embankments/low height portion embankments along the river are further needed as an input in the hydraulic model in order to fine tune the ongoing studies in CWC. Chairman, CWC emphasised that most of the issues as per the ToRs of the committee have already been addressed and this meeting has been specifically called for addressing the data requirement for completion of model studies.

The discussion and the directions given on each agenda item of the of the meeting are as under-

***Agenda 1*: Detail Report regarding the possible drainage congestion in Delhi and pumping arrangement in operation of drains. Levels of drains, details of bunds in kml format, inundation map of flood of year 2023.**

Officers of IFCD, Govt. of Delhi informed that the information in tabular form regarding the details of the drains have been provided. However,it was brought out that the description details like operational details of pumping arrangement along with SoP for operation of pumps, bunds detail along the drains and SoP for closure of gates in regulated drains have not be provided. It was informed that these inputs are vital for carrying out simulation in the hydraulic model studies.

It was discussed in the meeting that details like raised platforms, coffer dams, temporary construction structure in the river Yamuna, gaps in the embankments/low height portion embankments along the river, wall built on the Yamuna bank in the Akhara and NeeliChatri area where spilling of yamuna water occurred during the last year flood are also required in order to generate hydraulic simulation in the model.

IFCD, Govt of Delhi informed that for finding the levels and extent of encroachment in the river Yamuna, an agency would be engage by them which would carry out the field survey of encroachment and submit all these details in a period of 8 to 10 days.

Officials of the IFCD also informed that inundation flood map of year 2023 and kml file of embankment has also been provided to the Hydrology Unit of CWC.

Director, CWPRS informed that IFCD Govt of Delhi has requested CWPRS to carry out a study to assess the impact on flood prone areas along river Yamuna at Delhi from Wazirabad barrage to Okhla. However, sanction of the estimate is still awaited from IFCD side to take up the study.

Chairman, CWC was of the view that the ToR of study by CWPRS as proposed by IFCD, Govt. of Delhi is more or less similar to the studies which are currently being carried out by CWC as per the ToR of the committee and duplicity of study should be avoided. Chairman directed that in order to avoid any duplication, Director, CWPRS shall be made as a special invitee to this committee and CWPRS will involve CWC in their study so as to avoid any duplicity of work which has already been carried by CWC.

Chairman, CWC directed the officials of Hydrology (Urban) and IFCD, Govt of Delhi to indulge in regular interactions and share necessary data for completion of model studies.

[Action: IFCD, Govt. of Delhi & HSO, CWC]

***Agenda 2*: Location of overtopping of river Yamuna during floods of year 2023**

IFCD, Govt. of Delhi and WRD Uttar Pradesh confirmed that there was no overtopping through the 14 potentials location identified by CWC in its Interim Report. However, IFCD, Govt. of Delhi informed that there was aprox 1.5 km stretch of low level embankment from where flood water had overtopped and entered in Delhi during the floods of 2023. Chairman, CWC directed Director Urban Hydrology to do necessary modifications in the hydraulic model as per IFCD findings and coordinate with IFCD, Delhi and WRD Govt. of Uttar Pradesh for further necessary data, if any required for the completion of the study.

[Action: IFCD, Govt. of Delhi/WRD, Govt. of Uttar Pradesh/ HSO, CWC]

***Agenda 3*: Observations of IWRD, Haryana on carrying capacity studies of river Yamuna**

Director, FFM, CWC informed that report regarding carrying capacity of Yamuna from Hathnikund to Delhi was shared with Govt of Haryana and comments thereon are awaited from IWRD, Govt. of Haryana. Chairman, CWC stated that as per the findings of the study, the carrying capacity of Yamuna is on lower side, therefore, it can be inferred that either flooding is allowed in some reaches of Yamuna or there could be some discrepancies in the cross section data provided by Govt of Haryana. Chairman, CWC directed the officials of Govt Haryana to submit their views about the report at earliest.

Regarding discharge carrying capacity of Hathnikund barrage, officials of Govt of Haryana informed that modifications in the discharge calculations through Hatnikund barrage have been carried out as per the suggestions of BCD Dte. of CWC. The revised discharge calculation and the modified discharges have been shared with BCD Dte. It was further informed that from this year onwards, the modified formula for discharge calculations as suggested by CWC would be adopted for discharge computations.

[Action: I&WRD, Govt. of Haryana/BCD, Dte, CWC/HSO, CWC]

Other Agenda Items ; The other Agenda items discussed during the course of meeting with the permission of chair are as under-

(i) Officials of Delhi Jal Board informed that that discharge study of Wazirabad Barrage has been completed by IRI Roorkee and the report would be shared shortly.

[Action: DJB/BCD, Dte, CWC]

(ii) Officials of WRD, Govt of Uttar Pradesh informed that discharge study of Okhla Barrage is being done by IIT Delhi and there is some disagreement by IIT Delhi regarding the formula used for discharge calculation by BCD Dte.

On this issue, Chairman CWC directed Director, BCD to convene a meeting with IIT Delhi and WRD Uttar Pradesh officials to settle this issue.

[Action: WRD, Govt. of Uttar Pradesh /BCD,CWC]

(iv) Regarding revision in Danger and Warning Level of river Yamuna, Chairman CWC suggested that for the time being committee may accept the Danger and Warning levels as proposed by IFCD, Govt of Delhi and any revision in these levels will be done after completion of study by CWPRS.

[Action: IFCD, Govt. of Delhi]

(v) Representative from Survey of India informed that SoI is in process of seeking approval of LIDAR survey in the No Flying Zone of Delhi and it might take some time. However, once it gets approved, SoI will do the LIDAR survey in minimum possible time. Chairman, CWC requested SoI to expedite the process of seeking necessary permissions for LIDAR survey in Delhi's No Flying Zone.

[Action: Survey of India]

(vi) Representative from DDA informed that as per the directives of Hon'ble High Court, various agencies undertaking construction activities in the river have been directed by DDA to remove encroachments from the river with in time frame as ordered by Ho'ble High Court. Chairman, CWC emphasised that the right of way of river Yamuna should be cleared of all obstacles and encroachments as the monsoon season has already commenced.

Representative of DDA was of the view that the problem of flooding in Yamuna should be studied in holistic manner rather than a piece meal approach as adopted by IFCD wherein, localised strengthening of flood protection wall at certain locations have been carried out by IFCD, Govt. of Delhi.

[Action: DDA]

In his concluding remarks Chairman, CWC expressed the need of completing the studies at earliest and asserted that organisations as well as officials of the

committee involved in the studies may proactively exchange information among themselves in order to finish the studies in a time bound manner.

The meeting ended with vote of thanks to the chair.

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Annexure

Participants of fourth meeting of the committee for Joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage on 01st July 2024 at 1100 in the Committee Room, CWC, 2nd Floor, Sewa Bhawan, RK Puram, New Delhi-

A. Department of Water Resources, River Development and Ganga Rejuvenation and Central Water Commission.

1. Shri Kushvinder Vohra, Chariman & Ex-Officio Secretary to Government of India.
2. Shri P.M Scott, Member (RM), CWC
3. Shri Manoj Tiwari ,Chief Engineer, HSO,CWC
4. Shri Bhopal Singh, Chief Engineer,YBO, CWC
5. Shri V.D. Roy , Director,Morphology & CC,CWC
6. Shri Satish Kamboj, Director, Gates (N&W),CWC
7. Shri Samir Kumar Shukla, Director, BCD (N&W) Dte.,CWC
8. Shri H.S Sengar, Superintending Engineer, CWC
9. Shri Mohd. Faiz Syed , Directo, Hydrology (Urban),CWC
10. Shri Rakesh Toteja, Director,FFM, CWC
11. Shri Vivek Kumar Soni, BCD (N&W) Dte.CWC
12. Shri Rajesh kumar Gulati, Deputy Director, FFM Dte, CWC
13. Shri Ghanshyam Patel, Deputy Director, Gates (N&W) Dte. CWC
14. Shri Gaurav Singnai, Deputy Director, Hydrology (Urban) CWC
15. Shri Varid Gupta, Deputy Director, CWC
16. Shri Paritosh kumar Singh, Assistant Director, FFM Dte.

B. Upper Yamuna River Board

1. Ravi Bhushan kumar, Member Secretary

C. IMD

1. Shri S.K Manik, Scientist 'D'
2. Shri Dr. Shrawan Muppa, Scientist 'E'

D. Irrigation &WRD Department Uttar Pradesh

1. Shri D.S Phaugat, Superintending Engineer
2. Shri Rajat Gupta, AE
3. Shri Dheeraj Kumar, AE

E. Haryana

1. Shri Rakesh Chauhan, Enignner-in-Chief I&WRD
2. Shri M.L.Rana, CE, I& WRD
3. Shri Tarun Agarwal, SE, I&WRD
4. Shri Sanjay, SE, I&WRD
5. Shri R.S. Mittal, SE, I&WRD

F. Delhi Jal Board

1. Shri.K.C. Meena, Chief Engineer.
2. Shri Devindra, AE

G. Govt. of NCT of Delhi

1. Shri Anil Kumar, CE, I&FCD
2. Shri Y.K Sharma, SE, I&FCD
3. Shri Shiv Kumar, EE, I&FCD

H. DDA

1. Smt. Neelima Soni, Deputy Director,
2. Shri Rajnish Kumar, Deputy Director,

I. Survey of India

1. Shri Sandeep Shrivastava, Director, Survey of India

J. CWPRS

1. Shri R.S Kankara, Director, (Joined through V.C)

Annexure-II

Data sharing among Agencies for Joint Flood Management Study of River Yamuna for its reach between Hathnikund and Okhla barrage

(As per directions of Chairman, CWC during the 3rd Meeting of the Committee held on 25.04.2024).

Sl. No.	Task/Assignment	Data to be shared	Agencies	
			From	to
1.	Hathnikund Barrage	Corrected Observed Discharge data	Haryana Irrigation Department	BCD(N&W), CWC
		Specimen mathematical calculation of Discharge from Barrage	BCD(N&W), CWC	Haryana Irrigation Department
2.	Wazirabad Barrage	Corrected Observed Discharge data	Delhi Jal Board	BCD(N&W), CWC
		Specimen mathematical calculation of Discharge from Barrage	BCD(N&W), CWC	Delhi Jal Board
4.	ITO Barrage	Corrected Observed Discharge data	Haryana Irrigation & Water Resources Dept	BCD(N&W), CWC
		Specimen mathematical calculation of Discharge from Barrage	BCD(N&W), CWC	Haryana Irrigation Department
5.	Okhla Barrage	Corrected Observed Discharge data	Irrigation & Water Resources Dept, Govt of UP	BCD(N&W), CWC
		Specimen mathematical calculation of Discharge from Barrage	BCD(NNW), CWC	Irrigation & Water Resources Dept, Govt of UP
4.	High resolution DEM	Hathnikund to Okhla Barrage	FCA –II Dte.CWC	GNCTD, Delhi
5.	14 Zones mentioned in Interim Report	Embankment levels, Water level, etc. to be intimated after physical verification at 14 identified location mentioned in Interim Report.	GNCT, Delhi Irrigation & Water Resources Dept, Govt of UP	Urban Hydrology Dte, CWC
6	Report on Drains in NCT, Delhi	Complete report on each drain with details like bed level, FSL, bed cross section, crest level, SoP of operation of drains / pumping, embankment details of drains, etc.	GNCTD, Delhi	Urban Hydrology Dte, CWC
7.	Rationale of firming	Rationale of firming DL & WL	GNCTD, Delhi	FFM, DTE, CWC

	DL & WL	of NCT Delhi with scientific Study		
8..	Encroachments in river	Details of river encroachment in river on a GIS Platform	GNCTD, Delhi	Urban Hydrology Dte, CWC
9.	Pre Monsoon preparedness activities	Complete Report on Pre Monsoon preparedness activities like Gates functioning of barrages, connecting gauge with nearest MSL, mechanism of dissemination of information, markings of HFL,	GNCTD, Delhi Irrigation & Water Resource Dept, Govt of UP Haryana Irrigation Department	FFM, DTE, CWC
10.	Removal of encroachments	Details of encroachment removal being accrued out as per Hon'ble Court's Directions	DDA	FFM, Dte. CWC
11.	Report of IIT Delhi	Report of IIT Delhi on computation discharge through Okhla barrage.	Irrigation & Water Resources Dept, Govt of UP	BCD(N&W), CWC

Notes

1. The above data are to be exchanged between the agencies **within 7 days.**
2. For any clarification, kindly contact **Shri Rajesh Gulati, Deputy Director, FFM Dte. CWC[Mobile :9922238820]**
3. A set of data exchanged may be shared with FFM, Dte, CWC also
4. The e mail ids are as under

S. No.	Agency	E mail
1.	FFM, Dte, CWC	fmdte@nic.in
2.	Hydrology (Urban), CWC	hyddsr-cwc@nic.in
3.	BCD(N&W), CWC	bcdnw-cwc@nic.in
4.	GNCT, Delhi	fciwrd@gmail.com, ceifcd@gmail.com
5.	FCA -II Dte. CWC	dirfca-cwc@nic.in
6.	Irrigation & Water Resources Department, Government of Uttar Pradesh	ceyokhalaup@gmail.com iwcsre@rediffmail.com eincididuplu-up@nic.in
7.	Haryana Irrigation Department	eic.irrigation@hry.nic.in hodspecial@yahoo.com
8.	Delhi Development Authority	vcdda@dda.org.in
9.	Delhi Jal Board	cewaterworks@gmail.com

Annexure F

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास और गंगा
संरक्षण विभाग
केंद्रीय जल आयोग
बाढ़ पूर्वानुमान प्रबोधन निदेशालय

Government of India
Ministry of Jal Shakti
Department of Water Resources,
River Development and Ganga
Rejuvenation
Central Water Commission
Flood Forecast Monitoring Directorate

File No. T-112/12/2023-FFM

दिनांक: 21.08.2024

विषय: Minutes of 5th meeting of the Committee for joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage.

महोदय,

Please find enclosed the approved Minutes of 5th Meeting of the Committee for joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage held on 14/08/2024 at CWC, New Delhi-110066.

Encls: As above.

भवदीय,

बी के कारजी
मुख्य अभियंता (FMO) एवं मेम्बर सेक्रेटरी

प्रति,

1. PPS to Chairman, CWC
2. PPS to Member (D&R), CWC
3. PPS to Member (RM), CWC
4. Chairman, CGWB.
5. Commissioner, FM, DoWR, RD&GR, MoJS
6. Commissioner & Secretary, Irrigation & WRD, Govt. of Haryana.
7. Member Secretary, Upper Yamuna River Board
8. Engineer in Chief, Irrigation & WRD, Govt. of Haryana.
9. Principal Secretary, Irrigation & WRD, Govt. of Uttar Pradesh.
10. Engineer in Chief, Irrigation & WRD, Govt. of Uttar Pradesh.
11. Principal Secretary, Irrigation & Flood Control Deptt., Govt of NCT.
12. Chief Engineer-Zone-1, Irrigation & Flood Control Deptt., Govt of NCT.
13. Director General, IMD.
14. Director, CW&PRS, Pune.
15. Director, NRSC, Hyderabad
16. Vice-chairman, Delhi Development Authority (Special Invitee)
17. Sh. P.K.G. Mishra, OSD to Hon'ble LG (Special Invitee)
18. Director General, CPWD, New Delhi (Special Invitee)
19. Surveyor General of India, Dehradun (Special Invitee)
20. Chief Engineer, HSO (Special Invitee)
21. Chief Engineer, P&D (Special Invitee)
22. Chief Engineer, YBO (Special Invitee)

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Conserve Water – Save Live

Minutes of the Fifth meeting of the committee for "Joint Flood Management Study of River Yamuna for its reach between Hathnikund and Okhla barrage" held on 14th August, 2024 at New Delhi

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The Fifth meeting of the committee constituted for "Joint Flood Management Study of River Yamuna for its reach between Hathnikund and Okhla barrage" was held on 14th August, 2024 in the Committee Room, CWC, 2nd Floor, Sewa Bhawan, RK Puram, New Delhi-110066 under the chairmanship of Sh. Kushvinder Vohra, Chairman, Central Water Commission and Ex-Officio Secretary to the Government of India. The list of the participants attended the meeting is attached as **Annexure**.

At the outset of the meeting, Chairman, Central Water Commission, extended a warm welcome to the committee members. He informed that the draft report of the committee had been circulated well in advance of the meeting. Expressing his satisfaction with the committee's progress, the Chairman commended the team for fulfilling the tasks outlined in the Terms of Reference (ToRs) of the committee. He provided an overview of the report's structure, highlighting that the document is organized into nine detailed chapters. The first chapter serves as an introduction, while the subsequent chapters deals into specific topics such as Catchment Representative Rainfall Analysis, Flood Frequency Analysis, Carrying Capacity of River Yamuna, 2-D Modelling & Submergence Area Estimation, Barrages on River Yamuna, Encroachments in River Yamuna and Storage Possibility of Flood Water. The final chapter summarizes the committee's conclusions and recommendations, reflecting the comprehensive studies and analyses conducted as per the committee's mandate.

Thereafter, a presentation on report of the committee was made covering the objective, results and conclusions of various studies like rainfall analysis, flood frequency analysis, carrying capacity of river Yamuna, 2-D modelling, etc.

During the deliberations of the meeting, the committee members reviewed the draft report in detail and discussed its contents thoroughly. Some minor suggestions were proposed to enhance the clarity of the report. These suggestions included adjustments to the data presentation, minor revisions to the language for improved readability and updates to certain figures, tables, etc.

The committee considered these suggestions and agreed that such minor changes may be useful and incorporated them into the draft report. After making these adjustments, the final version of the report was accepted unanimously by the committee members.

In his concluding remarks Chairman, CWC expressed his sincere appreciation and recognition to the dedicated committee members for their valuable contributions and commendable efforts to address the flood management of river Yamuna for its reach

between Hathnikund and Okhla barrage as per the mandated ToRs of the committee. Chairman, CWC expressed that final conclusions and recommendations of the committee for effective flood management of floods of river Yamuna for its reach between Hathnikund and Okhla would be pivotal in responding to the severe challenges as posed during the unprecedented rainfall events of July, 2023 in the catchment of Yamuna.

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Annexure

Participants of the Fifth meeting of the committee for "Joint Flood Management Study of River Yamuna for its reach between Hathnikund and Okhla barrage" held on 14th August, 2024 at New Delhi

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A. Department of Water Resources, River Development and Ganga Rejuvenation and Central Water Commission.

1. Sh. Kushvinder Vohra, Chariman & Ex-Officio Secretary to Government of India.
2. Sh. D.P Mathuria Chief Engineer, P&DO, CWC
3. Sh. Manoj Tiwari, Chief Engineer, HSO CWC
4. Sh. H.S Sengar, Superintending Engineer, CWC
5. Sh. Sharad Chandra, Director RDC-1, CWC
6. Sh. N.N Rai, Director (NE)
7. Sh Rakesh Toteja, Director, FFM,CWC
8. Sh. Mohd. Faiz Syed, Director, Hydrology (Urban),CWC
9. Sh. Piyush Kumar, FMP, CWC
10. Sh. Akshat Jain, Deputy Director, Hydrology CWC
11. Sh. Rohit Gupta, Deputy Director, Hydrology Dte. CWC
12. Sh. Vivek Kumar Soni, BCD, (N&W) Dte. CWC
13. Sh. Ganshyam Patel, Deputy Director Gates (N&W) Dte.
14. Sh. Rajesh Kumar Gulati, Deputy Director FFM Dte.
15. Sh. Paritosh Kumar Singh Assistant Director FFM Dte.

B. Delhi Jal Board

1. Sh. Ravinder Kumar,Superintending Engineer.
2. Sh. Devinder, Assistant Engineer.

C. DDA

1. Sh. Mukesh Kumar, Chief Engineer (Civil).
2. Smt. Neelima Soni, Director (Landscape).

D. Survey of India

1. Sh. Ajay Kumar, Officer Surveyor.

E. IMD

1. S.K. Manik, Scientist 'D' Hydromet Division.

F. I&WRD, Govt of Haryana

1. Sh.Birender Singh, Cheif Engineer, HOD (Special),
2. Sh.Tarun Agarwal, Superintending Engineer.
3. Sh.R.S.Mittal, Superintending Engineer HKB.
4. Sh. A.S Lathwal, Superintending Engineer.

5. Sh. Pankaj Kumar, Executive Engineer.
6. Sh. Ved Pal, Executive Engineer.
7. Sh. Ashish Kaushik, Executive Engineer.
8. Sh.Suresh Kumar Saini Ex. En., Panipat Water Service Division

G. I&FC, Govt of NCT of Delhi

1. Sh. Anil kumar,Chief Engineer.
2. Sh. Mukesh Kumar,Chief Engineer II.
3. Sh. Y.K Sharma, Superintending Engineer.
4. Sh. Shiv Kumar, Executive Engineer.

H. I & WRD, Govt of Uttar Pradesh

1. Sh. Dharmendra Singh Phaugat, Superintending Engineer, Agra
2. Sh. Binod Kumar, Executive Engineer, Okhla.
3. Sh. Rajender Javitri,AE.
4. Sh. Dheeraj Kumar,AE,.

I. UYRB

1. Sh. Ravi Bhushan kumar, Member-Secretary.

J. CWPRS

1. Shri R.S.Kankara, Director, (Joined through VC)