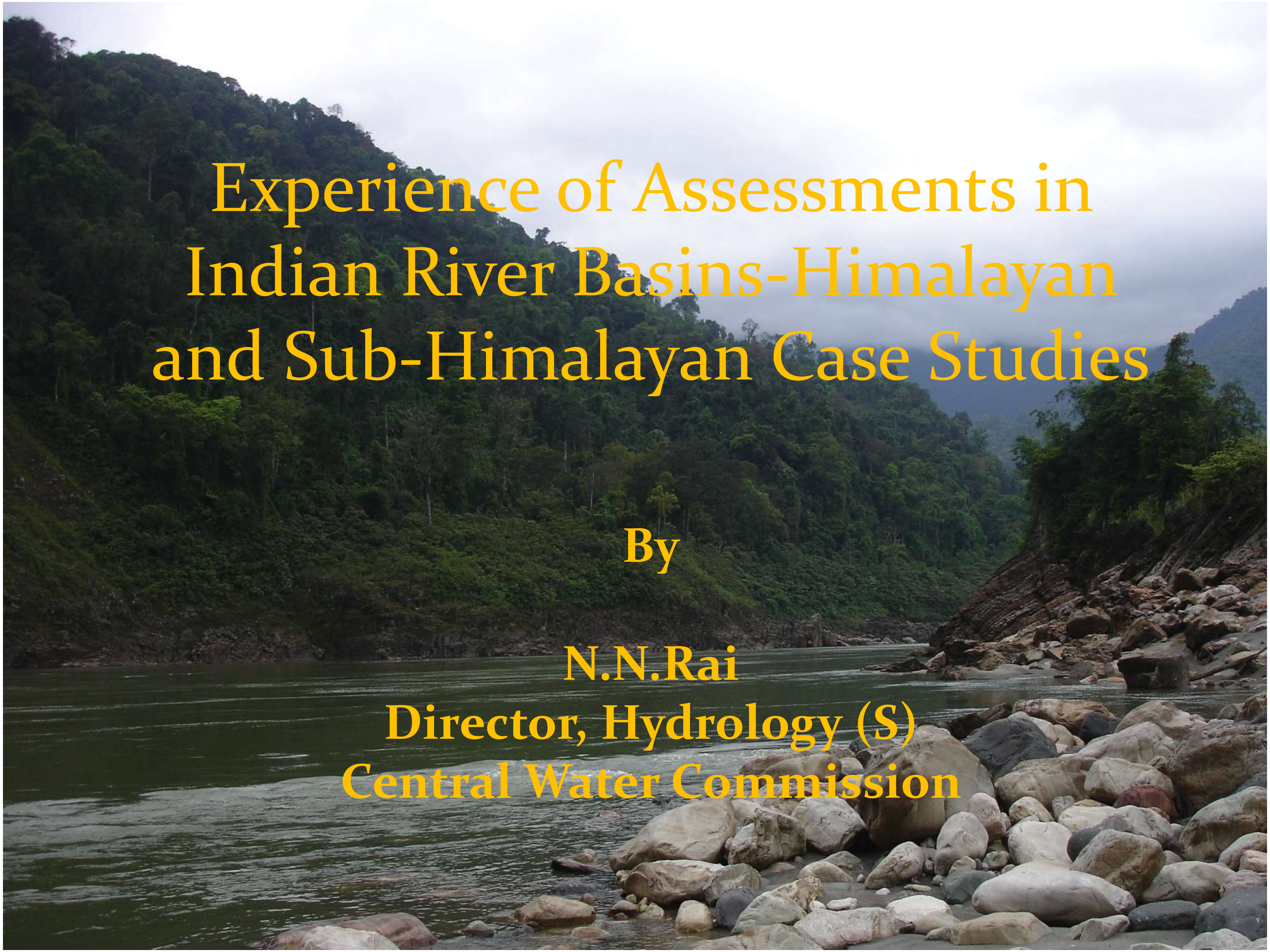

Experience of Assessments in Indian River Basins-Himalayan and Sub-Himalayan Case Studies

By

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Environmental Flow

The International Union for Conservation of Nature (IUCN) (2003) defines :

"E-Flows as the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated".

A distinction may be made between the amount of water needed to maintain an ecosystem in close-to-pristine condition, and that which might eventually be allocated to it, following a process of environmental, social and economic assessment. The latter is referred to as the 'environmental flow', and it will be a flow that maintains the ecosystem in a less than pristine condition.

A trade off between water resources development and river maintenance in healthy or reasonable condition is, in general, an inevitable compulsion. National Water Policy (2012) stipulates that ecological needs of the river should be determined, through scientific study, duly accommodating development needs.

Role of flow regime in structuring aquatic life

- Aquatic species have evolved life history strategies primarily in response to the natural flow regimes. Therefore, flow regime alterations can lead to loss of biodiversity of native species.

- All components of the hydrological regime have certain ecological significance

- High flows of different frequency are important for channel maintenance, bird breeding, wetland flooding and maintenance of riparian vegetation

- Moderate flows may be critical for cycling of organic matter from river banks and for fish migration

- Low flows of different magnitudes are important for algae control, water quality maintenance and the use of the river by local people.

Methodologies for assessment of Environmental Flow

Hydrological Methods

- Tenant and Modified Tenant method
- Flow Duration Curve Method and Shifting FDC Techniques based on EMC

Hydraulic Methods

- Hydraulic rating Method
- Habitat Simulation Method

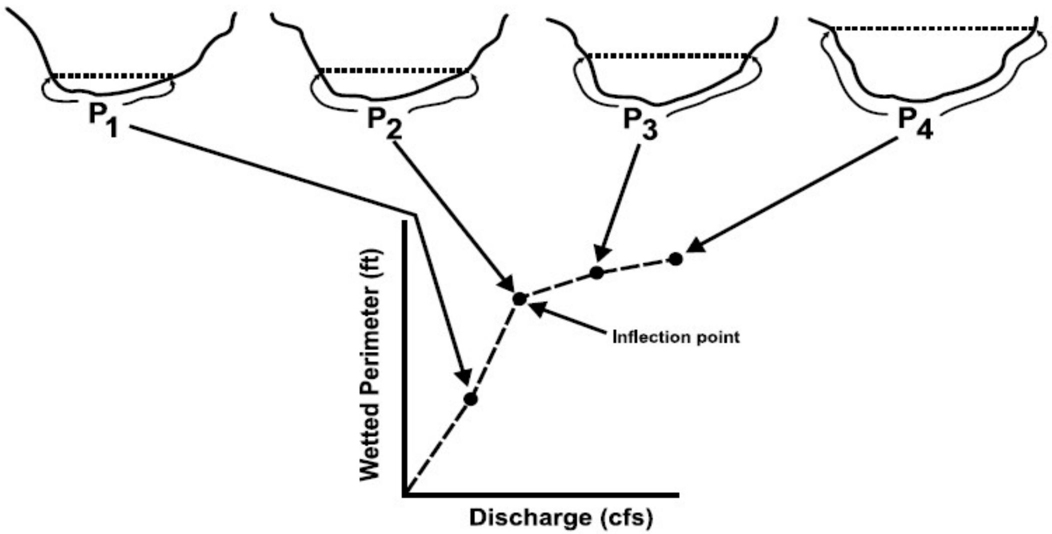
Holistic Methodologies

- Building Block Methodology (BBM)
- Downstream Response to Imposed Flow Transformation (DRIFT), which systematically addresses the downstream biophysical and socioeconomic impacts.

Hydraulic Rating Methods

- Hydraulic rating methodologies use changes in simple hydraulic variables, such as wetted perimeter or maximum depth, usually measured across single, flow-limited river cross-sections (commonly riffles), as a surrogate for habitat factors known or assumed to be limiting to target biota.

- Environmental flows are determined from a plot of the hydraulic variable(s) against discharge, commonly by identifying curve breakpoints where significant percentage reductions in habitat quality occur with decreases in discharge.



Habitat Simulation Methods

- These methods are an extension of the hydraulic methods as they also use the hydraulic conditions, which meet specific habitat requirements for biota, to determine flow requirements

- In this method the flow parameters like depth, top flow width, flow velocity etc is estimated using modelling tools and EF is quantified for the physical habitat using field data from multiple locations

Environmental Flow Norms in India

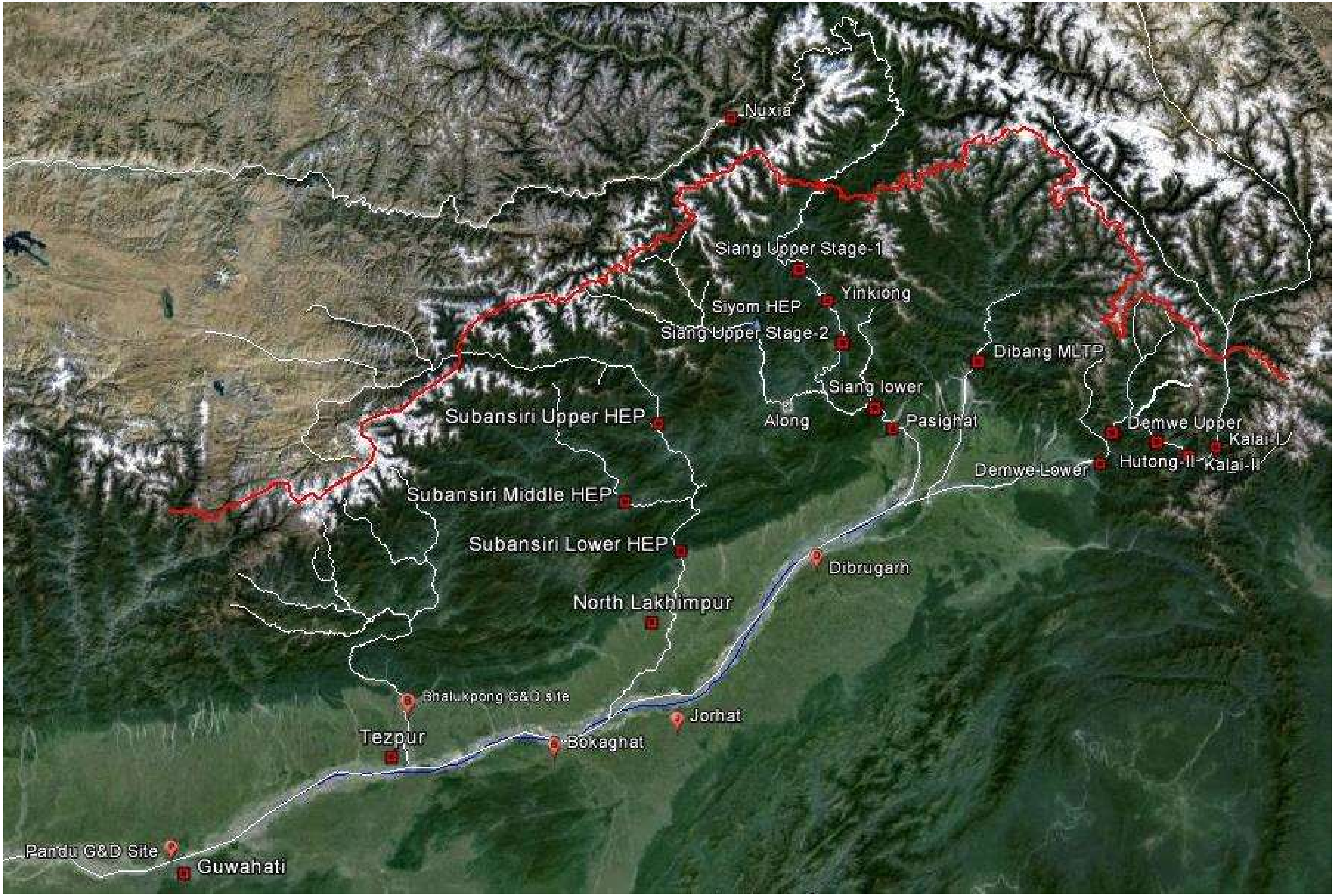
- Till early 2000, in the name of ecological flow, a provision of 5-10% of minimum flow in lean season was considered to be sufficient for the purpose

- First initiative was taken by Government of Himachal Pradesh when they issued a circular during the year 2005 making 10% of minimum lean season flow as mandatory environment release; which in 2009 was increased to 15% of average lean season flow.

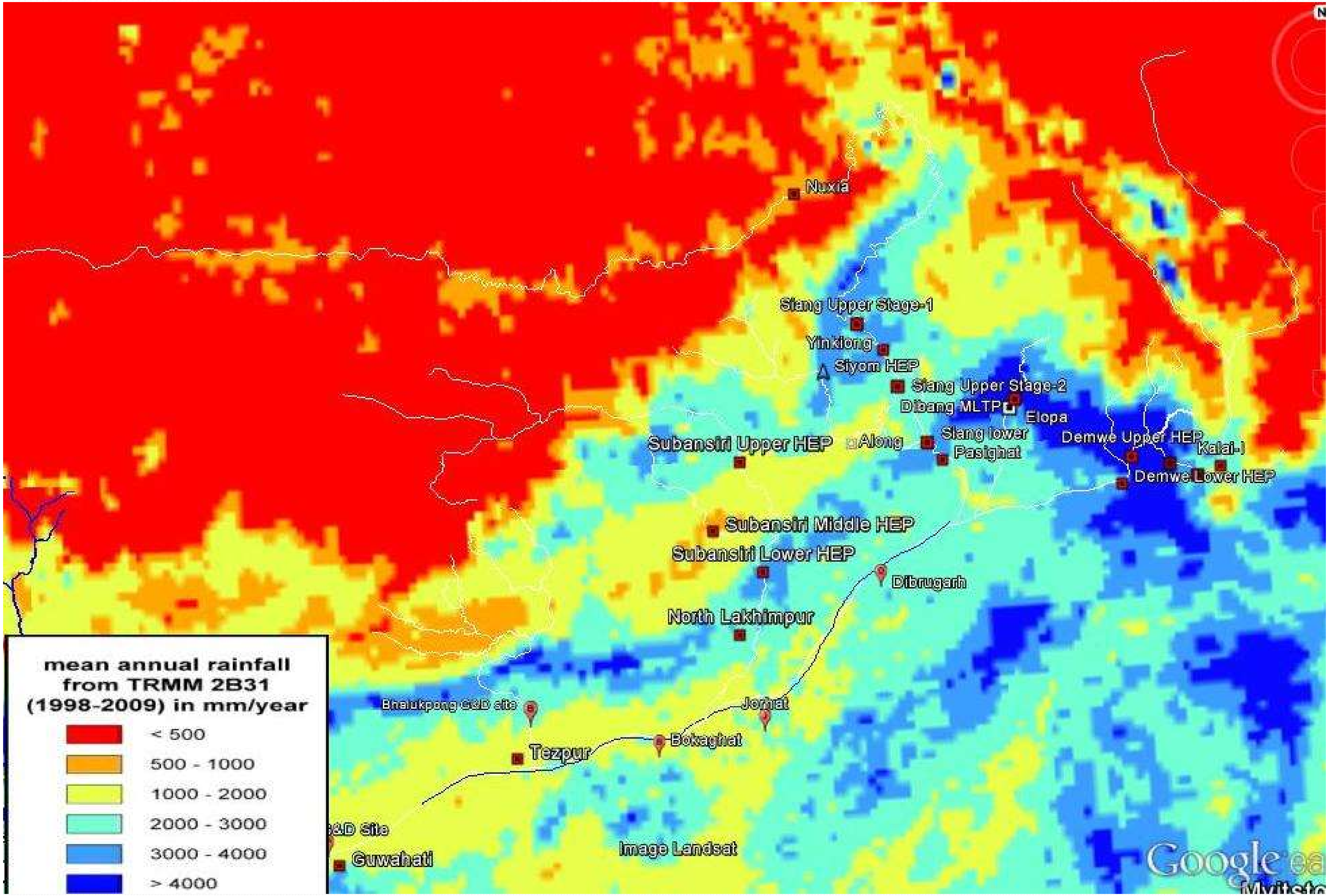
- During the period 2008-09, Expert Appraisal Committee (EAC) used to recommend, 20% of average lean season discharge (4 leanest months) in 90% dependable year to be released as environment flow

- During the next 2-3 years, concept was developed further requiring site specific studies and focus was also shifted to the varied environment flow release during the year. Lean season environmental flow requirement was kept as 20% of average flow of four leanest months in 90% dependable year; monsoon season (4 months) as 30% of inflows in 90% dependable year and other months i.e. pre-monsoon and post monsoon period as 20-30% of inflows in 90% dependable.

Environmental flow Assessment for Siang and Subansiri Sub-basins

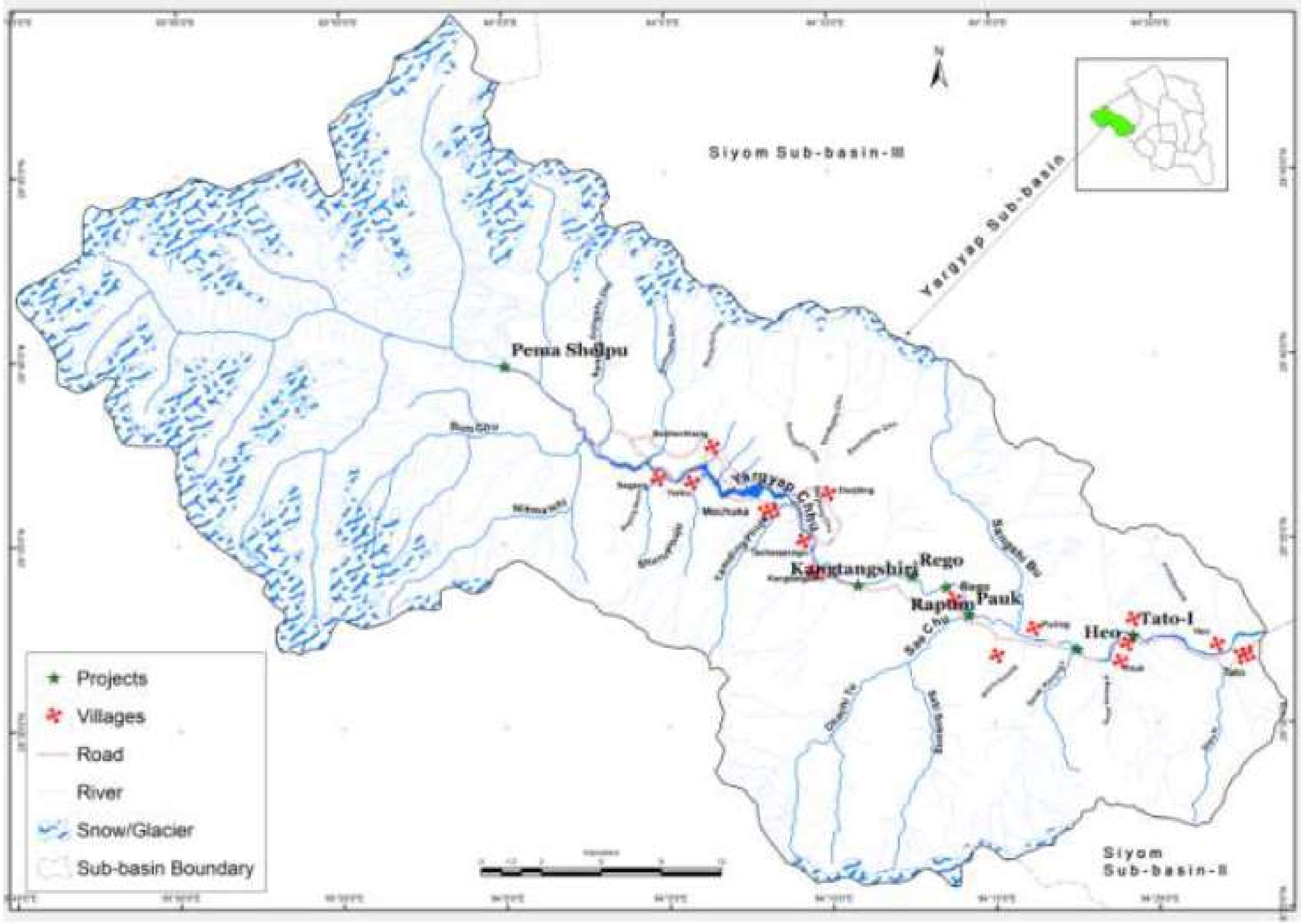


Rainfall pattern in Brahmaputra basin



Methodology adopted

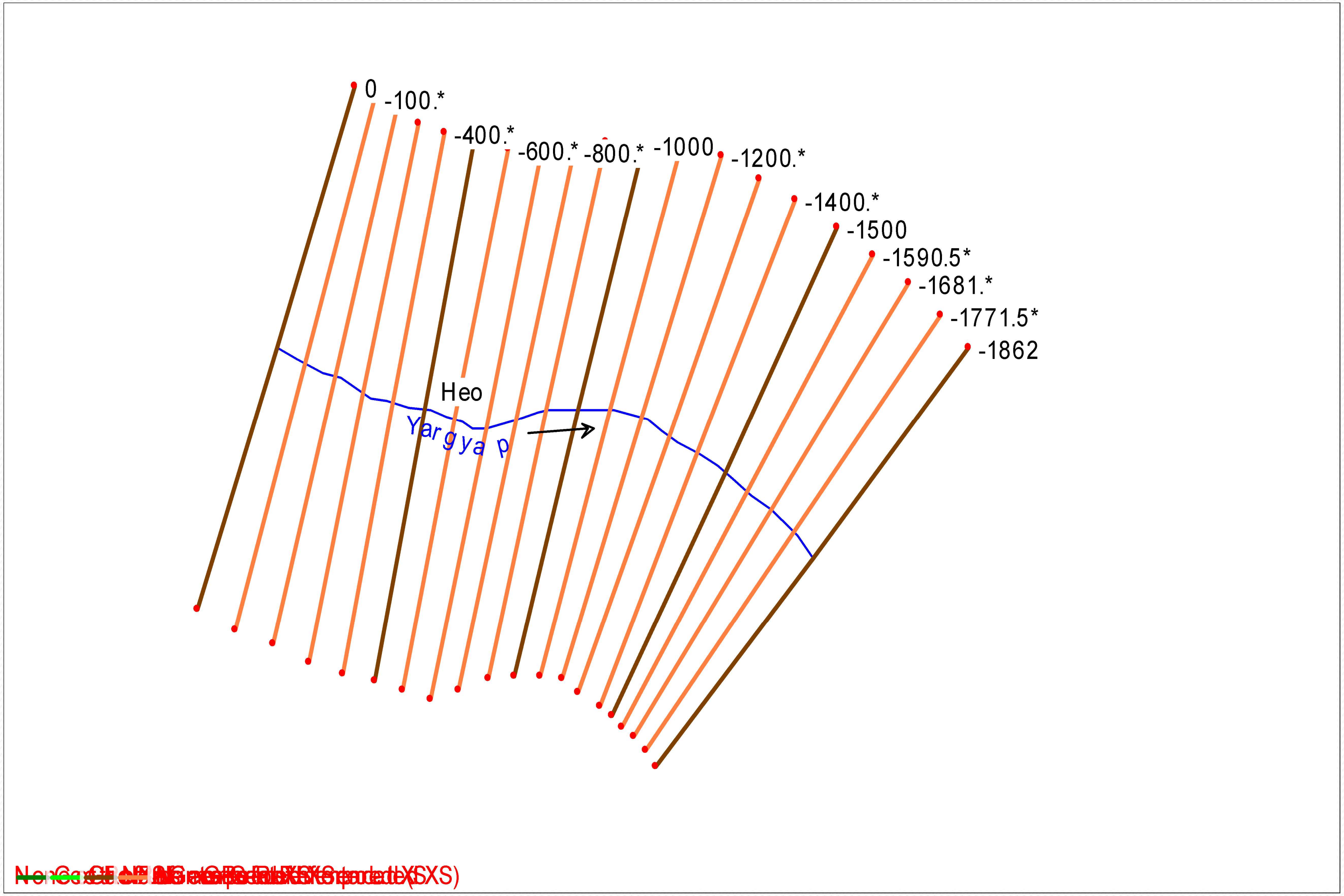
- Hydaulic rating cum Habitat simulation methodology has been adopted
- River reach from diversion site up to its confluence with the first stream has been considered most critical
- The above river reach has been represented through river cross sections and flow parameters such as depth of flow, top flow width and velocity of flow has been estimated through hydrodynamic simulations using HEC-RAS for 10, 15, 20, 25, 30, 40, 50 and 100% release of average lean, monsoon and non lean non monsoon flow of 90% dependable year



Siyom Sub-basin-III
Yargyap Sub-basin
Pema Shelpu
Yargyap Chhu
Kangtangshiri
Rego
Rapum
Pauk
Heo
Tato-I
Siyom
Sub-basin-II
Projects
Villages
Road
River
Snow/Glacier
Sub-basin Boundary

Critical river reach for Environmental Flow Assessment

Hydrodynamic model set up



Flow in Yargyapchu river at HEO HEP site in 90% dependable year

Leanest 4 months 0f 90% dep yr			Monsoon 4 months of 90% dep yr			Other 4 months of 90% dep yr		
Month	10 Daily	Flow (cumec)	Month	10 Daily	Flow (cumec)	Month	10 Daily	Flow (cumec)
Dec	I	16	June	I	97	Oct	I	111
	II	14		II	106		II	99
	III	13		III	177		III	90
Jan	I	15	July	I	158	Nov	I	20
	II	14		II	137		II	18
	III	12		III	127		III	17
Feb	I	12	Aug	I	119	Apr	I	17
	II	13		II	110		II	20
	III	13		III	155		III	23
Mar	I	12	Sep	I	141	May	I	95
	II	12		II	145		II	104
	III	16		III	120		III	88
	Avg	13.50		Avg	132.67		Avg	58.50
% release of avg			% release of avg			% release of avg		
	10	1.35		10	13.27		10	5.85
	15	2.03		15	19.90		15	8.78
	20	2.70		20	26.53		20	11.70
	30	4.05		30	39.80		30	17.55
	40	5.40		40	53.07		40	23.40
	50	6.75		50	66.33		50	29.25
	100	13.50		100	132.67		100	58.50

Simulation results leanest four months

Reach	Ch d/s of Heo HEP	Profile	Q Total	Bed Elevation	Water surface Elevation	Water depth	Flow Velocity	Flow Top Width
			(m3/s)	(m)	(m)	(cm)	(m/s)	(m)
Yargyap	0	PF 20% release	2.7	1384.2	1384.93	73	0.84	8.85
Yargyap	-100.*	PF 20% release	2.7	1383.76	1384.49	73	0.84	8.84
Yargyap	-200.*	PF 20% release	2.7	1383.32	1384.05	73	0.83	8.91
Yargyap	-300.*	PF 20% release	2.7	1382.88	1383.6	72	0.86	8.78
Yargyap	-400.*	PF 20% release	2.7	1382.44	1383.2	76	0.77	9.27
Yargyap	-500	PF 20% release	2.7	1382	1382.64	64	1.07	7.9
Yargyap	-600.*	PF 20% release	2.7	1380.94	1381.58	64	1.31	6.4
Yargyap	-700.*	PF 20% release	2.7	1379.88	1380.62	74	1.12	6.44
Yargyap	-800.*	PF 20% release	2.7	1378.81	1379.49	68	1.5	5.28
Yargyap	-900.*	PF 20% release	2.7	1377.75	1378.59	84	1.08	6
Yargyap	-1000	PF 20% release	2.7	1376.69	1377.35	66	1.83	4.47
Yargyap	-1100.*	PF 20% release	2.7	1370.62	1371.27	65	1.8	4.66
Yargyap	-1200.*	PF 20% release	2.7	1364.55	1365.18	63	1.77	4.9
Yargyap	-1300.*	PF 20% release	2.7	1358.49	1359.09	60	1.74	5.17
Yargyap	-1400.*	PF 20% release	2.7	1352.42	1352.99	57	1.71	5.49
Yargyap	-1500	PF 20% release	2.7	1346.35	1346.9	55	1.66	5.92
				Avg for 20% release		67.94	1.30	6.71
				Avg for 100% release		126.25	1.84	12.51

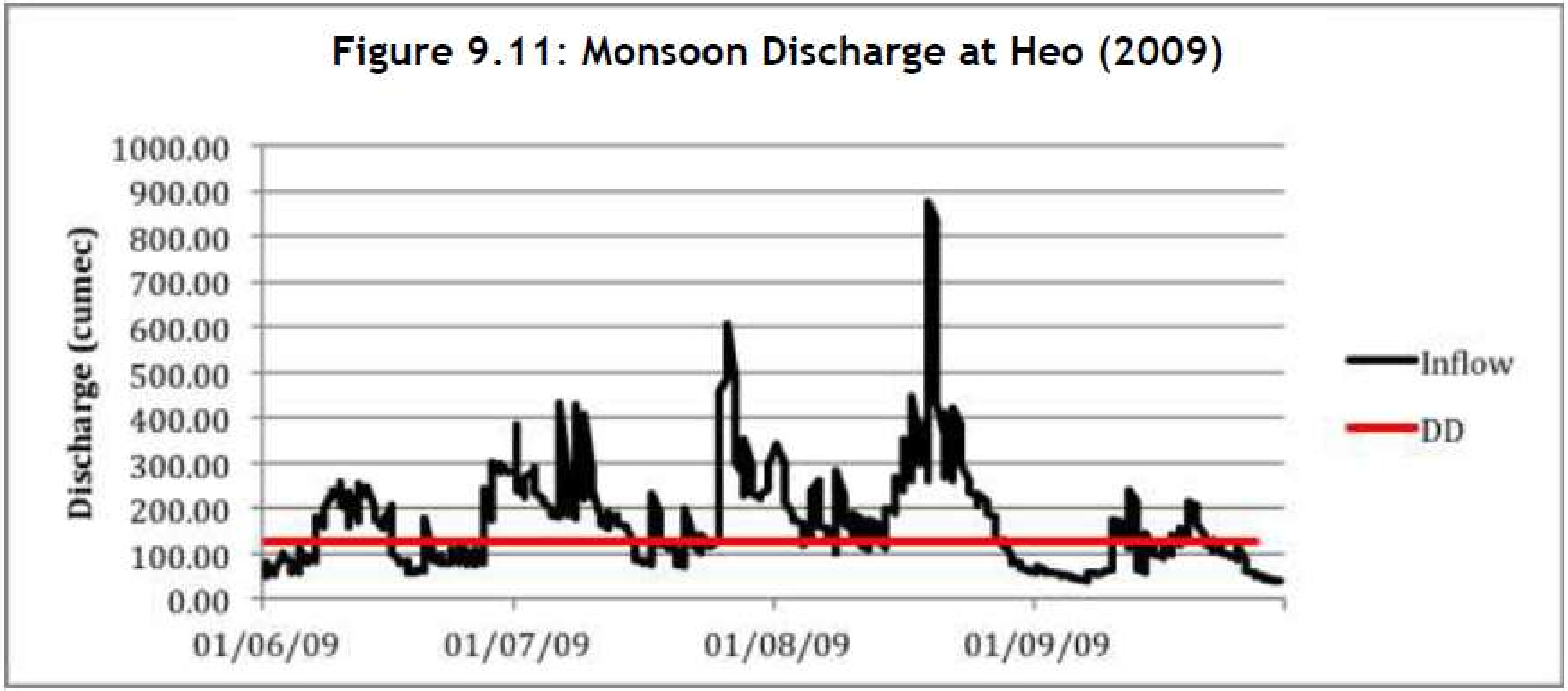
Simulation results monsoon four months

Reach	Ch d/s of Heo HEP	Profile	Q Total	Bed Elevation	Water surface Elevation	Water depth	Flow Velocity	Flow Top Width
			(m3/s)	(m)	(m)	(cm)	(m/s)	(m)
Yargyap	0	PF 15% release	19.9	1384.2	1385.74	154	1.38	18.69
Yargyap	-100.*	PF 15% release	19.9	1383.76	1385.3	154	1.38	18.91
Yargyap	-200.*	PF 15% release	19.9	1383.32	1384.86	154	1.37	19.15
Yargyap	-300.*	PF 15% release	19.9	1382.88	1384.42	154	1.36	19.47
Yargyap	-400.*	PF 15% release	19.9	1382.44	1384	156	1.31	20.14
Yargyap	-500	PF 15% release	19.9	1382	1383.35	135	1.75	17.39
Yargyap	-600.*	PF 15% release	19.9	1380.94	1382.36	142	1.98	14.12
Yargyap	-700.*	PF 15% release	19.9	1379.88	1381.42	154	1.94	13.27
Yargyap	-800.*	PF 15% release	19.9	1378.81	1380.33	152	2.22	11.8
Yargyap	-900.*	PF 15% release	19.9	1377.75	1379.47	172	1.87	12.35
Yargyap	-1000	PF 15% release	19.9	1376.69	1378.17	148	2.7	9.98
Yargyap	-1100.*	PF 15% release	19.9	1370.62	1372.06	144	2.66	10.42
Yargyap	-1200.*	PF 15% release	19.9	1364.55	1365.95	140	2.62	10.93
Yargyap	-1300.*	PF 15% release	19.9	1358.49	1359.82	133	2.59	11.5
Yargyap	-1400.*	PF 15% release	19.9	1352.42	1353.71	129	2.52	12.27
Yargyap	-1500	PF 15% release	19.9	1346.35	1347.57	122	2.48	13.15
				Avg for 20% release		146.44	2.01	14.60
				Avg for 100% release		303.31	3.06	30.71

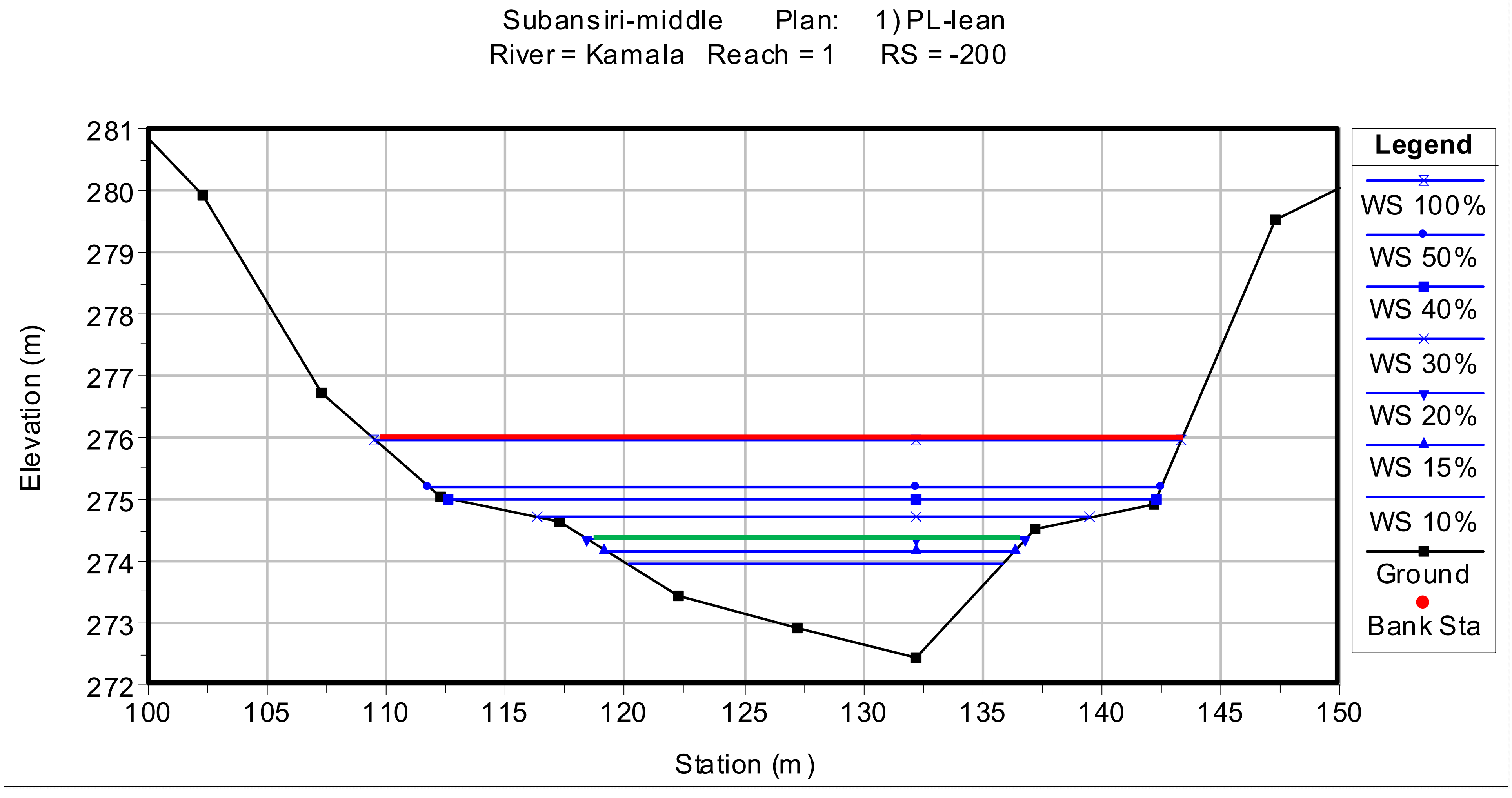
Simulation results non-monsoon non-lean four months

Reach	Ch d/s of Heo HEP	Profile	Q Total	Bed Elevation	Water surface Elevation	Water depth	Flow Velocity	Flow Top Width
			(m3/s)	(m)	(m)	(cm)	(m/s)	(m)
Yargyap	0	PF 15% release	8.78	1384.2	1385.33	113	1.13	13.75
Yargyap	-100.*	PF 15% release	8.78	1383.76	1384.89	113	1.12	13.79
Yargyap	-200.*	PF 15% release	8.78	1383.32	1384.45	113	1.13	13.8
Yargyap	-300.*	PF 15% release	8.78	1382.88	1384.01	113	1.13	13.8
Yargyap	-400.*	PF 15% release	8.78	1382.44	1383.6	116	1.06	14.36
Yargyap	-500	PF 15% release	8.78	1382	1382.99	99	1.46	12.18
Yargyap	-600.*	PF 15% release	8.78	1380.94	1381.97	103	1.66	10.24
Yargyap	-700.*	PF 15% release	8.78	1379.88	1381.02	114	1.56	9.84
Yargyap	-800.*	PF 15% release	8.78	1378.81	1379.91	110	1.88	8.52
Yargyap	-900.*	PF 15% release	8.78	1377.75	1379.03	128	1.5	9.18
Yargyap	-1000	PF 15% release	8.78	1376.69	1377.76	107	2.29	7.19
Yargyap	-1100.*	PF 15% release	8.78	1370.62	1371.66	104	2.26	7.51
Yargyap	-1200.*	PF 15% release	8.78	1364.55	1365.56	101	2.22	7.88
Yargyap	-1300.*	PF 15% release	8.78	1358.49	1359.45	96	2.18	8.32
Yargyap	-1400.*	PF 15% release	8.78	1352.42	1353.35	93	2.14	8.84
Yargyap	-1500	PF 15% release	8.78	1346.35	1347.24	89	2.09	9.52
				Avg for 20% release		107.00	1.68	10.55
				Avg for 100% release		221.19	2.55	22.17

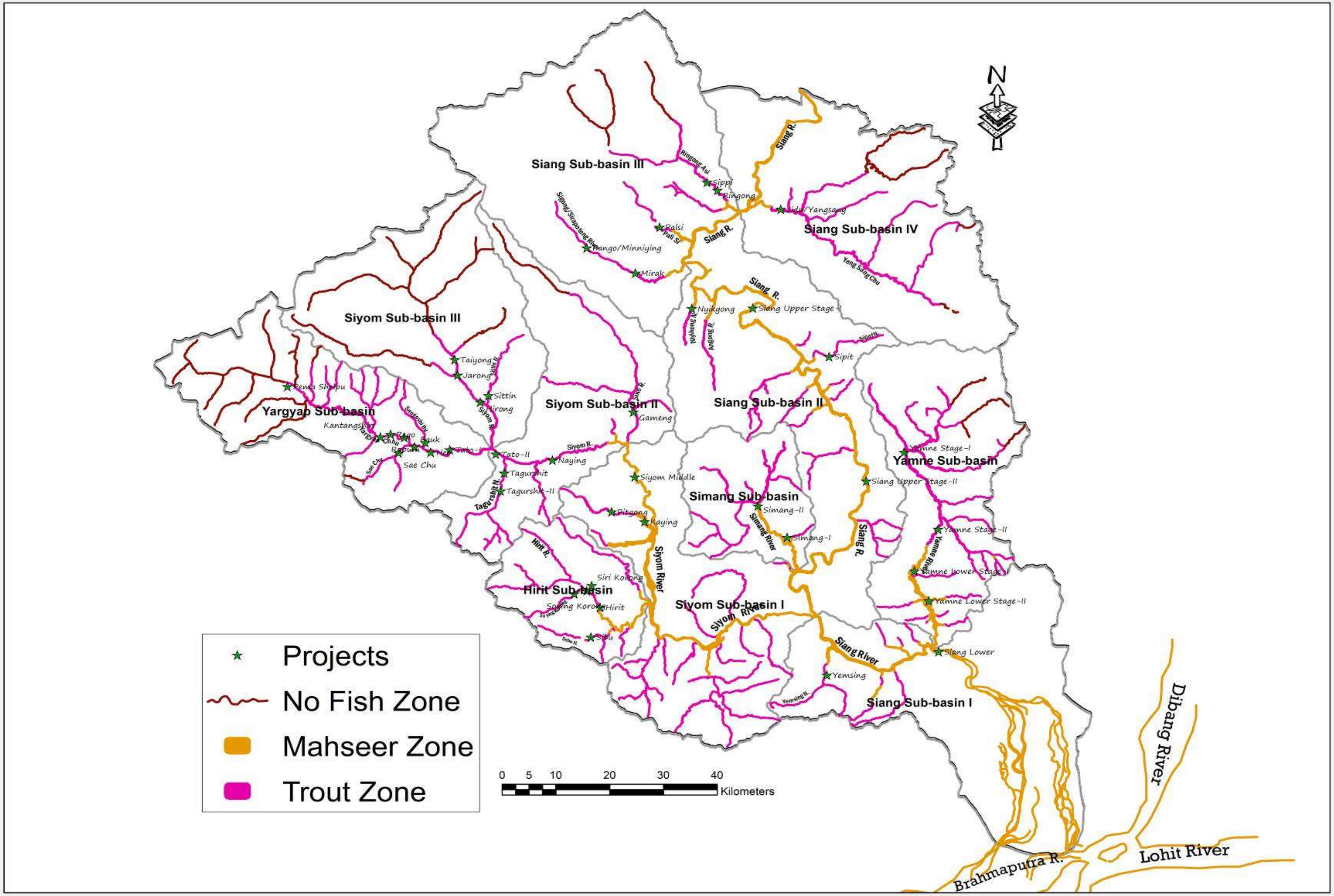
Monsoon spill from hydroelectric projects in NE Region



Flow Profile of Kamala river at 200 m d/s of Subansiri middle HE Project for different % release of average lean flow of 90% dependable year



Habitat Simulation



HABITAT REQUIREMENT

Snow trout

	Adults	Juveniles	Spawning	Incubation & Larval development
Depth	>0.5 m	0.1 - 1 m	0.5 - 1.00 m	0.1 - 1.00 m
Velocity	Low to high (0.5-1.5 m/s)	Low to medium (0.5-1.0 m/s)	Low to medium (0.5 - 1.0 m/s)	Low (0.1-0.5 m/s)
Habitat	Riffles, pools, glides,	Riffles, glides, closer to the banks	Low gradient riffle Glides	Backwater pools and bank undercuts
Substratum	Boulders, Cobbles, Pebbles, Gravel	Cobbles, boulders, pebbles, gravel	Cobbles, pebbles, gravel	Cobbles, gravel
Temperaure	4-20 ° C	4-20 ° C	<15 ° C	4-15° C
Dissolved Oxygen (mg/l)	8-12 mg/l	8-12 mg/l	8-12 mg/l	8-12 mg/l
Food	Large portion of periphytic algae and diatoms. Also feed on benthic invertebrates	Periphytic algae and diatoms.	Not applicable	Diatoms
Breeding Period	April to September			
Passage requirement	This species is a migrant species, moves from river to upstreams and adjoin streams for spawning.			
Migration timing	April to September			
Migration Cues	Movement is believed to be triggered by the variation in water temperature and flow			

HABITAT REQUIREMENT

Golden Mahseer (*Tor putitora*)

	Adults	**Juveniles**	**Spawning**	**Incubation & Larval development**
Depth	Deep (>1 m) 0.5 - 1.5 m	Shallow (<0.75 – 1.5m)	Shallow to high (0.5-2.0m)	Shallow to high (0.3 - 2.00 m)
Velocity	Medium to high (0.5 - 1.5 m/s)	Low to medium (0.1-1.5 m/s)	Low to medium (0.1 -1.0 m/s)	Low to medium (0.1-0.5 m/s)
Habitat	Riffles, pools, glides	Pools, backwater pools closer to the banks and run habitats	Low gradient riffles, backwater pools, secondary channel	Backwater Pools and secondary channels
Substratum	Bed rock, Boulders, Cobbles, gravel to sandy bottom	Cobbles, gravel to sandy bottom Bed rock undercut	Boulder undercut Gravel bed	Cobbles, gravel to sandy bottom, leaf litter
Temperaure	12-30 ° C	12-20 ° C	<12 ° C	10-15° C
Dissolved Oxygen (mg/l)	8-12 mg/l	8-12 mg/l	8-12 mg/l	8-12 mg/l
Food	Omnivorous: small fishes, benthic invertebrates larvae, mollusc, crab, fronds and seeds, etc.	Benthic invertebrates larvae, worms etc.	Not applicable	Periphytic algae and diatoms
Breeding Period	March – April; October to December			
Passage requirement	Moves long distance to streams associated with main river, nearby side channels, shallow water and pools to breed			
Migration timing	March – April; October -December			
Migration Cues	Change in flow pattern and water temperature may be a factor which trigger the breeding migration			

HABITAT REQUIREMENT

Silver Mahseer (*Tor putitora*)

	Adults	Juveniles	Spawning	Incubation & Larval development
Depth	Deep (>1 m) 0.5 - 1.5 m	Shallow (<0.75 – 1.5m)	Shallow to high (0.5-2.0m)	Shallow to high (0.3 - 2.00 m)
Velocity	Medium to high (0.5 - 1.5 m/s)	Low to medium (0.1-1.5 m/s)	Low to medium (0.1 -1.0 m/s)	Low to medium (0.1-0.5 m/s)
Habitat	Riffles, pools, glides	Pools, backwater pools closer to the banks and run habitats	Low gradient riffles, backwater pools, secondary channel	Backwater Pools and secondary channels
Substratum	Bed rock, Boulders, Cobbles, gravel to sandy bottom	Cobbles, gravel to sandy bottom Bed rock undercut	Boulder undercut Gravel bed	Cobbles, gravel to sandy bottom, leaf litter
Temperaure	12-30 ° C	12-20 ° C	<12 ° C	10-15° C
Dissolved Oxygen (mg/l)	8-12 mg/l	8-12 mg/l	8-12 mg/l	8-12 mg/l
Food	Omnivorous: small fishes, benthic invertebrates larvae, mollusc, crab, fronds and seeds, etc.	Benthic invertebrates larvae, worms etc.	Not applicable	Periphytic algae and diatoms
Breeding Period	March – April; October to December			
Passage requirement	Moves long distance to streams associated with main river, nearby side channels, shallow water and pools to breed			
Migration timing	March – April; October -December			
Migration Cues	Change in flow pattern and water temperature may be a factor which trigger the breeding migration			

Estimated Environmental Flow Release from HEO HEP

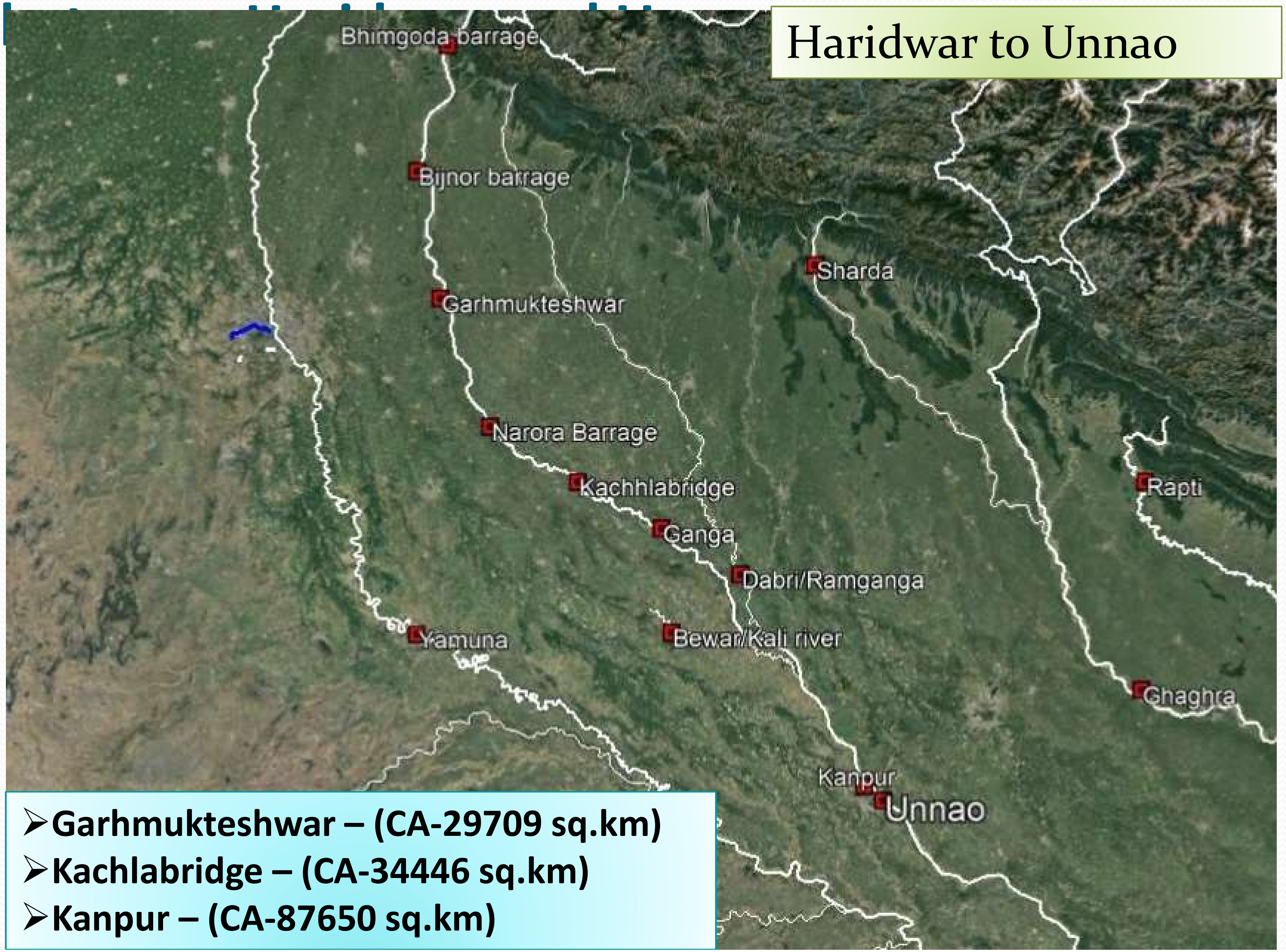
- **Monsoon months (Jun-Sep) – 19.9 cumec (20% of 90% dep flow)**

- **Non-monsoon, non-lean month (Oct, Nov, Apr, May) – 8.8 cumec (15% of 90% dep flow)**

- **Lean months (Dec –Mar) – 2.7 cumec (15% of 90% dep flow)**

Eflow assessment for the reach of river Ganga

Haridwar to Unnao



- Garhmukteshwar – (CA-29709 sq.km)
- Kachlabridge – (CA-34446 sq.km)
- Kanpur – (CA-87650 sq.km)

Important facts

- At Haridwar, Ganga opens to the Gangetic Plains, where Bhimgoda barrage diverts a large quantity of its waters into the Upper Ganga Canal, to provide water for irrigation and other consumptive uses.

- Further, about 76 km downstream of Haridwar, at Bijnore, another barrage diverts water into the Madhya Ganga Canal but only during monsoon months.

- At Narora, there is further diversion of water into the Lower Ganga Canal from Narora barrage. Narora barrage is about 155 km downstream of Bijnor barrage.

- At about 215 km downstream of Narora barrage, Ramganga a left bank tributary of river Ganga joins the river. River Kali a right bank tributary of river Ganga joins the river about 242 km downstream of Narora barrage.

- The culturable command area of Upper Ganga Canal is 9.07 lakh hectares, out of maximum irrigated area so far during kharif and rabi seasons are 3.63 lakh hectares and 3.07 lakh hectares. At present, the Middle Ganga Canal is providing the Kharif irrigation for about 57000 hectares command area. The Lower Ganga Canal System is meeting the irrigation requirements of about 4.07 lakh hectares of command area. From the barrage at Kanpur, Ganga water is being diverted to meet the drinking water requirements.

Data used for the Eflow study

- Govt of Uttar Pradesh: Inflow, outflow and release from Bhimgoda, Bijnor and Narora Barrages for last 10 to 15 years on daily / 10 daily basis

- CWC: 10 daily discharge data of river Ganga at:
  - *Garhmukteshwar (CA- 29709 sq.km)*
  - *Kachlabridge (CA-34446 sq.km)*
  - *Kanpur (CA-87650 sq.km)*
  - At least 5 Cross sections of river Ganga at each of the location viz Garhmukteshwar, Kachlabridge and Kanpur

- CIFRI: Habitat data of the river reach between Haridwar and Unnao

Habitat data from CIFRI, Kolkata

Sr. No.	*Species*	Common name	Weight range	Depth (Lean period)	Velocity
1	*Labeodyocheilus*	Kharat	30-800	60-80 cm	0.8-1.5m/s
2	*Labeodero*	Moyli	94-563		
3	*Cyprinuscarpio*	Golden	120-563		
4	*Schizothoraxrichardsonii*	Noyla	80-500g		
5	*Crossocheiluslatius*				
6	*Botialohachata*	Chittodha	10-175		
7	*Bariliusbendelisis*	Ral			
8	*Tor putitora*	Golden mahaseer	30-800g		

Analysis of data

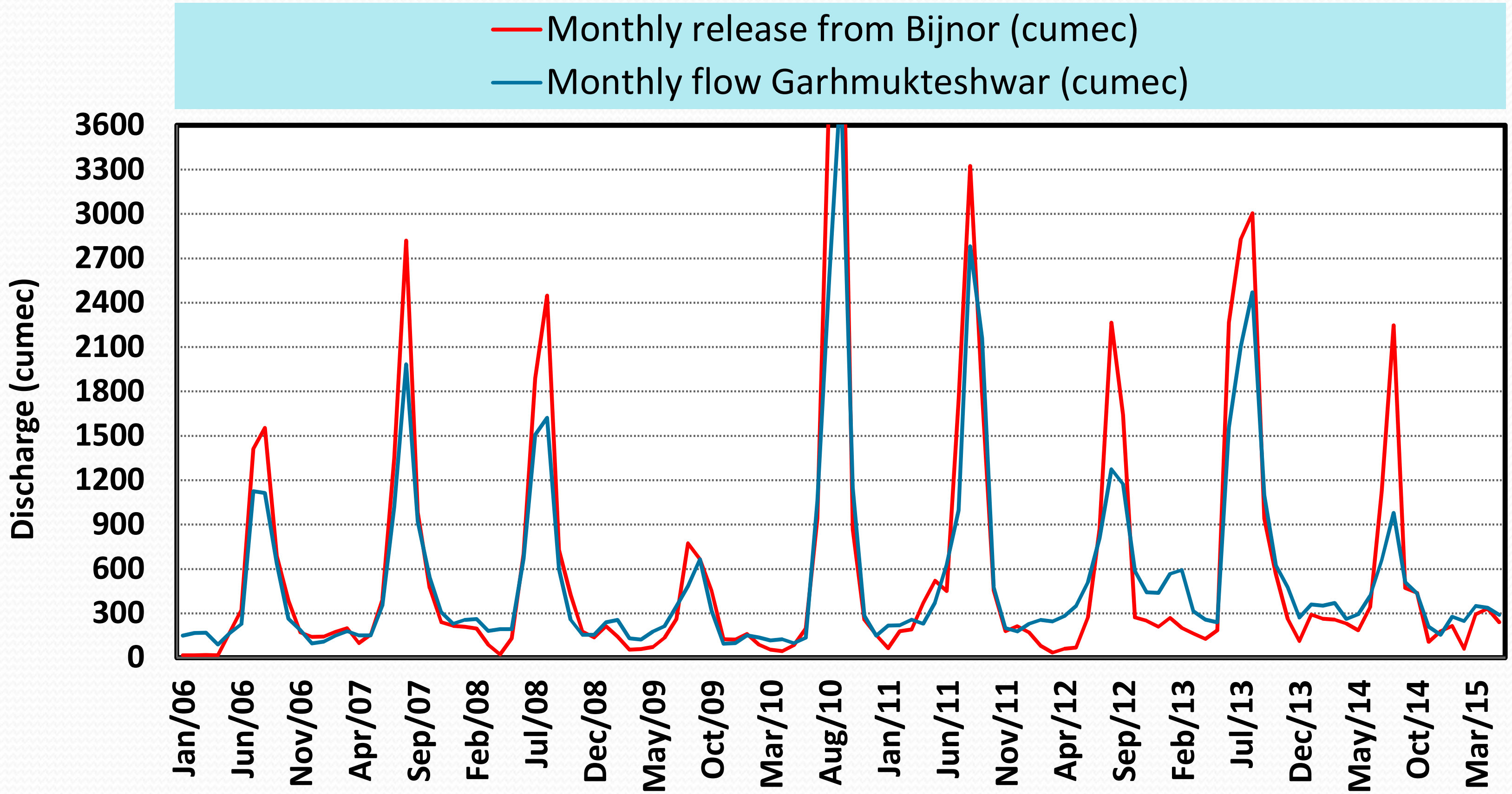
- The discharge received from Govt of Uttar Pradesh and CWC has been analysed. From the data it has been found that release from Haridwar is generally more than 20% of the barring few exceptions.

- Release from Bijnor barrage is more than 20% of the inflow

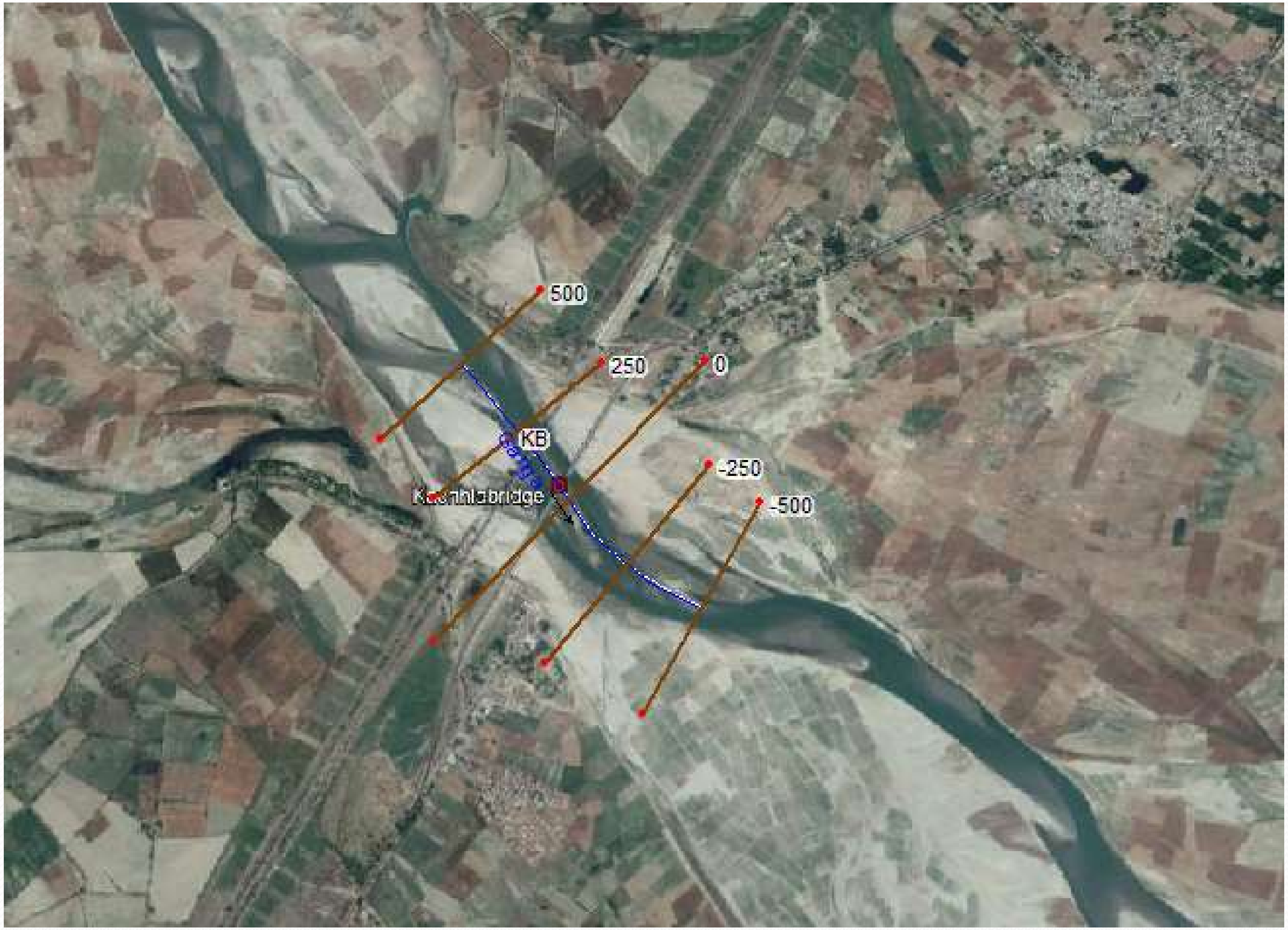
- Release from Narora barrage during the non-monsoon period is 5 to 10% in significant number of days

- The river cross section data has been utilised HEC-RAS model simulation to estimate the depth of flow, top flow width and velocity for different discharges in the river. The same have been correlated with habitat data provided by CIFRI for Eflow recommendations

Release from Bijnor barrage and flow observed at Garhmukteshwar

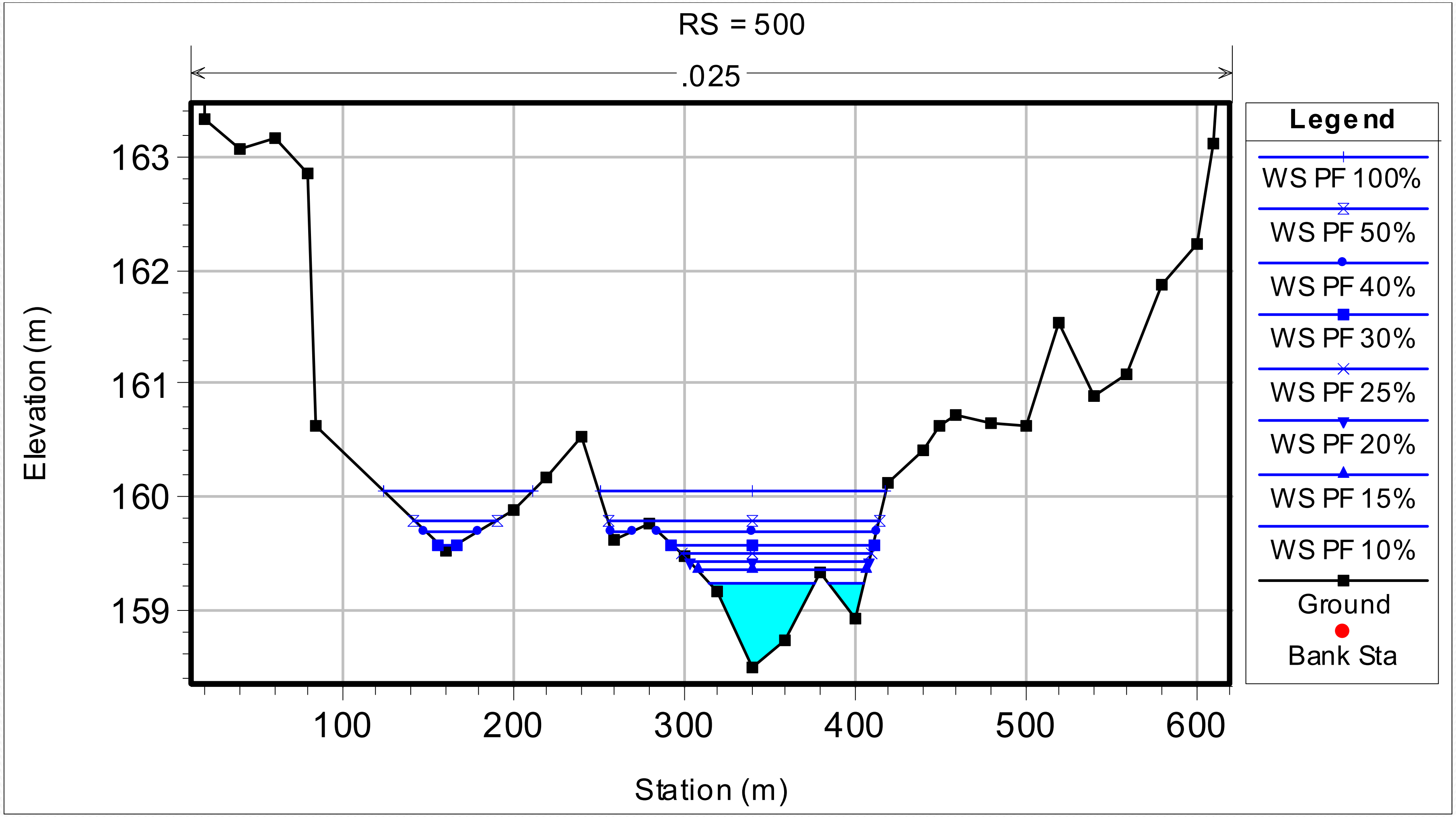


The flow pattern shows that between Bijnor and Garhmukteshwar certain amount of flow is getting added into the river from intermediate catchment, from ground water and irrigation return flow.

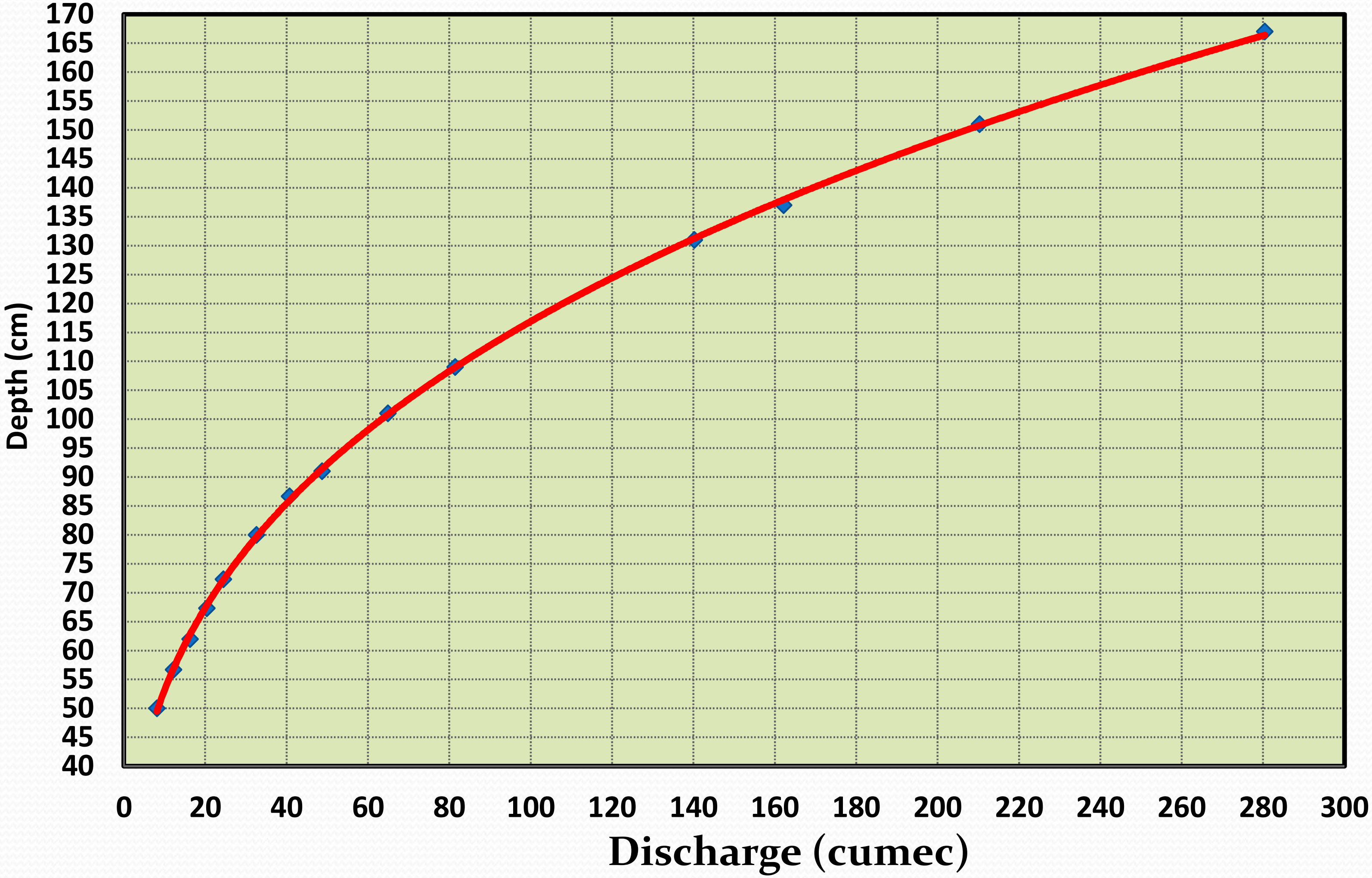


HEC-RAS Model set up for Kachlabridge

River cross section at Kachhlabridge and water surface profile



Simulation results Kachhlabridge



Summary of E-flow recommendations

Place	Eflow release during non-monsoon (Oct to May)	Eflow release during -monsoon (Jun to Sep)
Haridwar barrage	36 cumec (1270 cusec)	57 cumec (2000 cusec)
Bijnor Barrage	24 cumec (850 cusec approx).	48 cumec (1700 cusec approx)
Narora Barrage	24 cumec (850 cusec approx).	48 cumec (1700 cusec approx)
Kanpur Barrage	24 cumec (850 cusec approx).	48 cumec (1700 cusec approx)

- The above releases are the minimum releases only to ensure that discharge in the river reach in no case should be less than the above mentioned quantities.

- Ganga river has a special place in Indian culture and at numerous occasions, lakhs of pilgrims gather on its banks for bathing. Flow requirements are high during these short periods of typically one or two days.

- Such requirements can be met from natural flows, supplemented by additional water from Tehri dam or by reducing diversions.

Conclusion

- There is substantial variation in the yield of Indian rivers due to varied rainfall scenario

- Due to different yield conditions Environmental flow releases should be site specific, based on scientific computations

- Hydraulic rating cum habitat simulation methodology can be considered to quantify the EFR

- For the terminal HE projects in each sub basin normally located near the foothills one turbine can be considered to run continuously on partial or full load to release the adequate environmental flow in the downstream reaches of the river during the non-monsoon period


Thank You