INDIA-UK Workshop on Future Ganga: Science Needs for Water Security

Dec 02 – 04, 2015

River Ganga: Energy and Environment

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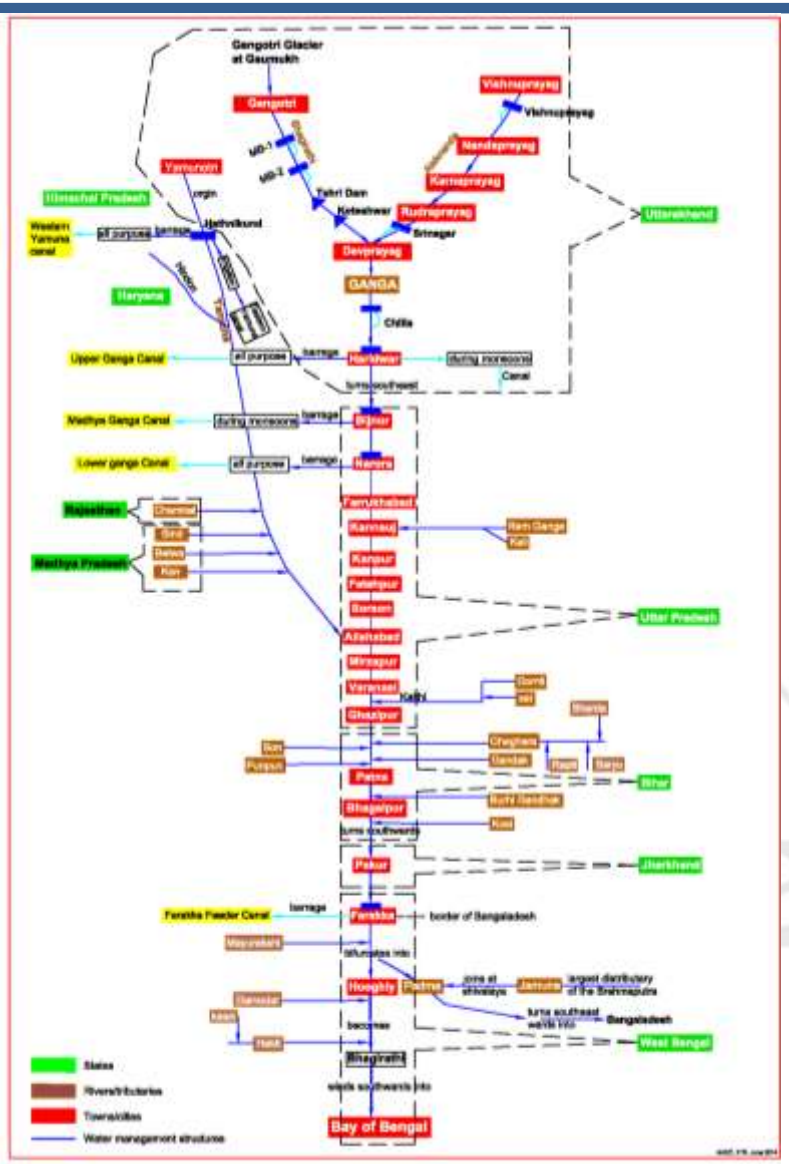
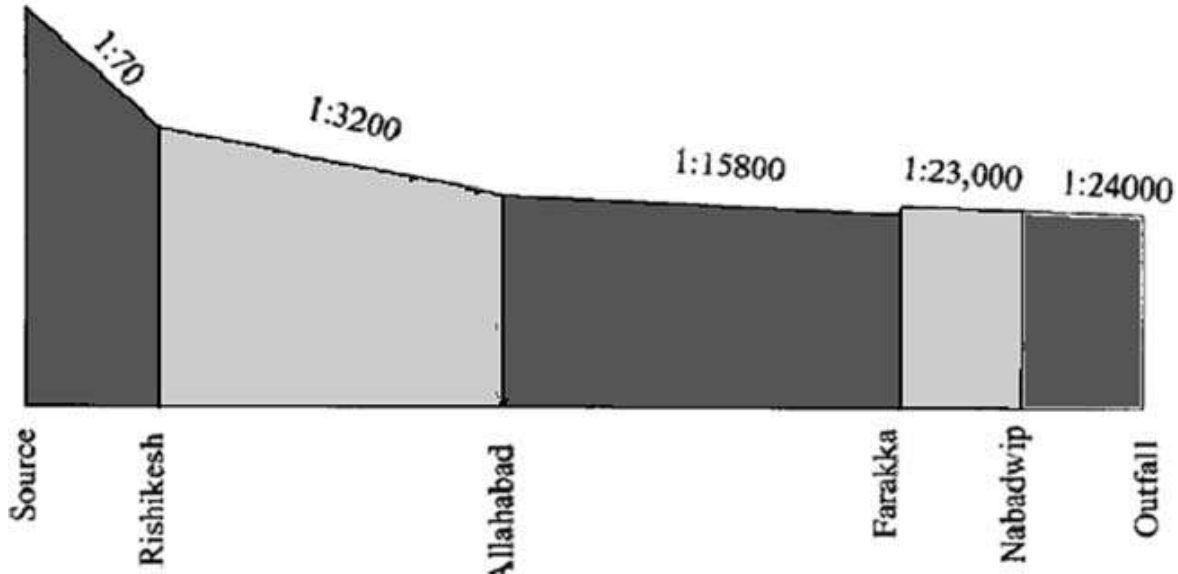
River Ganga: Energy and Environment

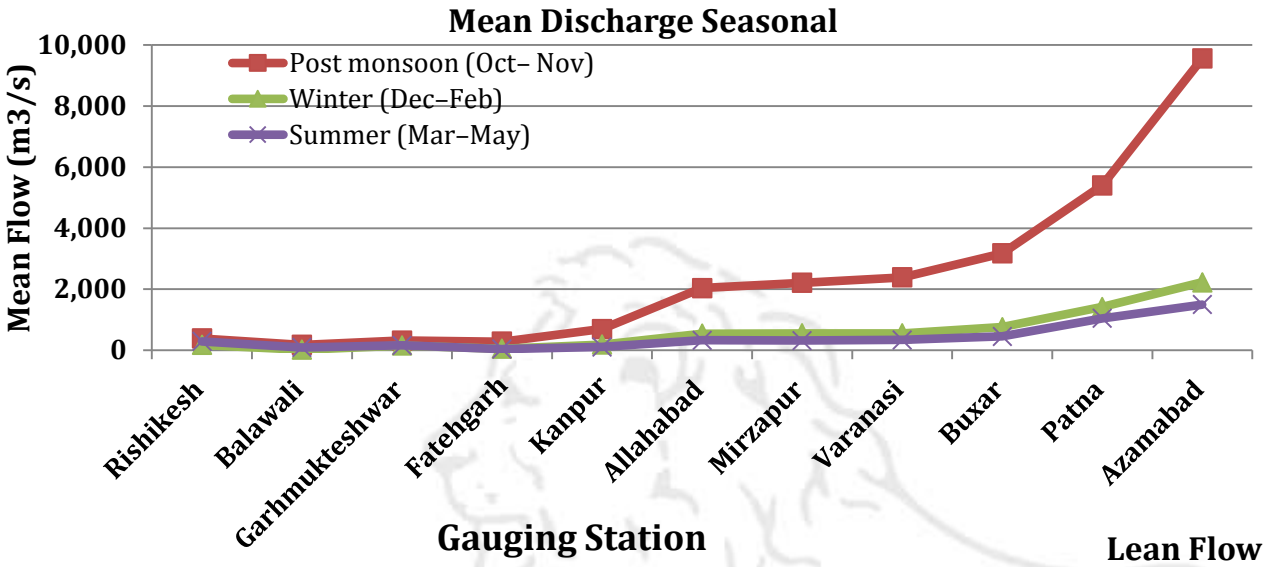
- In recent time, Energy and environment appears to be in conflict even though both are major pillars for sustainable development.
- Water in the hills, in plains or in delta have different utility and river has different characterstics. Consumptive or non consumptive.
- River Ganga being the Holy river has been supporting the man kind from its origin
- Water with drawl for irrigation and drinking make the river dry on one hand and on other hand disposal of untreated waste water are the major issues for discussion.

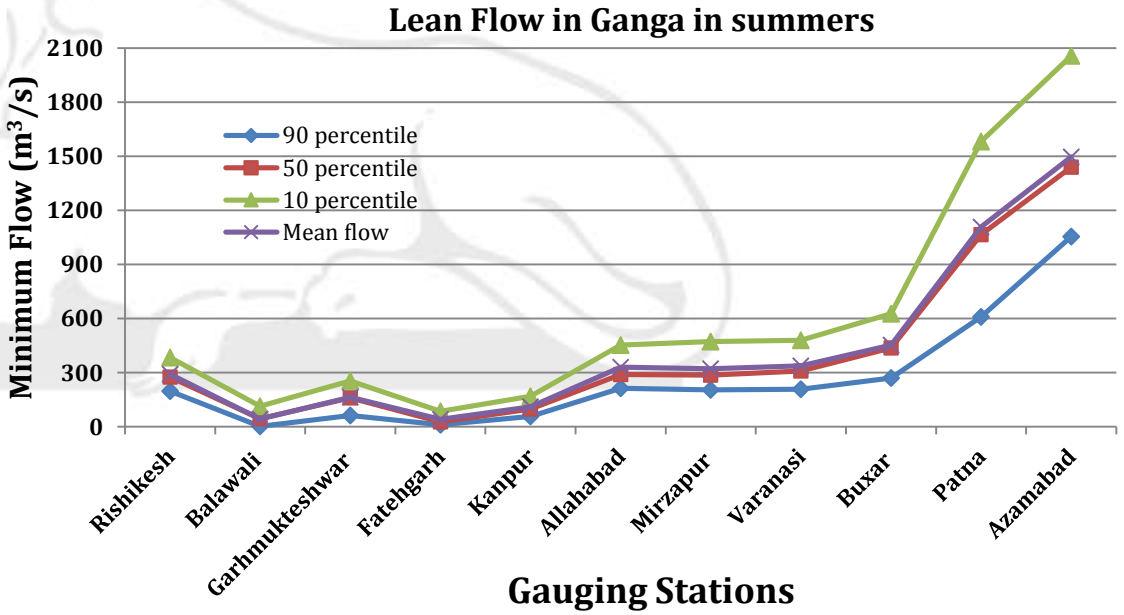

Gangotri Glacier at Gaumukh
Gangotri
Vishnuprayag
Nandeprayag
Karnaprayag
Rudraprayag
Srinagar
Devprayag
GANGA
Yamunotri
Tehri Dam
Kotleshwar
Uttarakhand
Himachal Pradesh
Western Yamuna canal
Hathnikund
Haryana
Chilla
Upper Ganga Canal
Haridwar
Madhya Ganga Canal
Bijnor
Lower ganga Canal
Narora
Rajasthan
Madhya Pradesh
Farrukhabad
Kannauj
Ram Ganga
Kanpur
Fatehpur
Bindki
Allahabad
Uttar Pradesh
Mirzapur
Varanasi
Ghazipur
Buxar
Patna
Bihar
Bhagalpur
Kahalgaon
Pakur
Jharkhand
Farakka Feeder Canal
Farakka
border of Bangladesh
Jangipur
Hooghly
Jamuna
Bangladesh
Berhampore
Nabadwip
West Bengal
Bhagirathi
Bay of Bengal
States
Rivers/tributaries
Towns/cities
Water management structures

Average bed slope of river Ganga along Bhagirathi-Hoogly



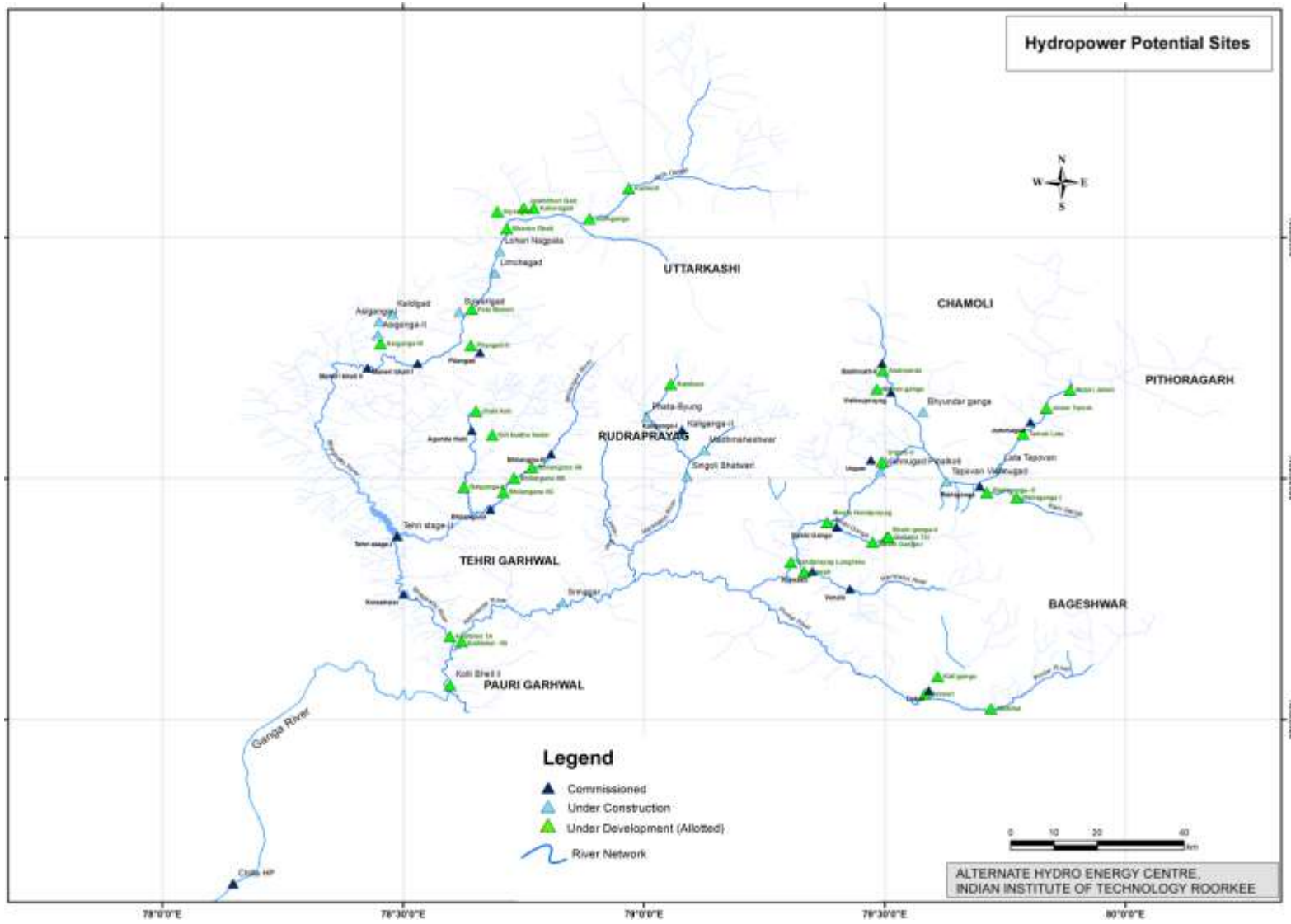
- Gaumukh to Haridwar (270 km), average bed slope of 12.8 meters per km – Himalayan stretch.
- Haridwar to Garhmuktesar (180 km), average bed slope of 0.68 meters per km – Upper Alluvial Ganga River.
- Garhmuktesar to Allahabad (670 km) average bed slope of 0. 16 meter/km.
- Allahabad to Buxar (380 km) average bed slope of 0.11 m/km –Lower Alluvial Ganga River (Middle Ganga Plain).
- Buxar to Barh (285 km) average bed slope of 0.05 m/km.
- Barh to Farakka (360 km) average bed slope of 0.06 m/km.
- Farakka to sea (380 km) average bed slope of 0.04 m/km – Delta Plain of the Ganga


Mean Discharge Seasonal
Mean Flow (m3/s)
10,000
8,000
6,000
4,000
2,000
0
Post monsoon (Oct– Nov)
Winter (Dec–Feb)
Summer (Mar–May)
Rishikesh
Balawali
Garhmukteshwar
Fatehgarh
Kanpur
Allahabad
Mirzapur
Varanasi
Buxar
Patna
Azamabad
Gauging Station


Lean Flow in Ganga in summers
Minimum Flow (m3/s)
2100
1800
1500
1200
900
600
300
0
90 percentile
50 percentile
10 percentile
Mean flow
Rishikesh
Balawali
Garhmukteshwar
Fatehgarh
Kanpur
Allahabad
Mirzapur
Varanasi
Buxar
Patna
Azamabad
Gauging Stations

Hydropower in Ganga Basin

River	Commissioned		Under Construction		Under Development	
	Installed Capacity (MW)	Generation (MU)	Installed Capacity (MW)	Generation (MU)	Installed Capacity (MW)	Generation (MU)
Ganga	2,443	7,417	3,303	12,579	3,431	15,255
Yamuna	483	1,674	439	2,182	1,330	5,739
Other Tributaries	1,742	5,291				
Total	4,668	14,382	3,742	14,761	4,761	20,994
Total Hydro Power	13,171 MW	50,137 MU	Small hydro is about 10% of total hydro.			


Hydropower Potential Sites
N
W
E
S
UTTARKASHI
CHAMOLI
PITHORAGARH
RUDRAPRAYAG
TEHRI GARHWAL
PAURI GARHWAL
BAGESHWAR
Ganga River
Legend
Commissioned
Under Construction
Under Development (Allotted)
River Network
0 10 20 40
km
ALTERNATE HYDRO ENERGY CENTRE,
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
80°0'0"E

Evolution of Thinking

1940 Engineers

1950

1960 Economists

1970 Environmentalists

1980 Sociologists

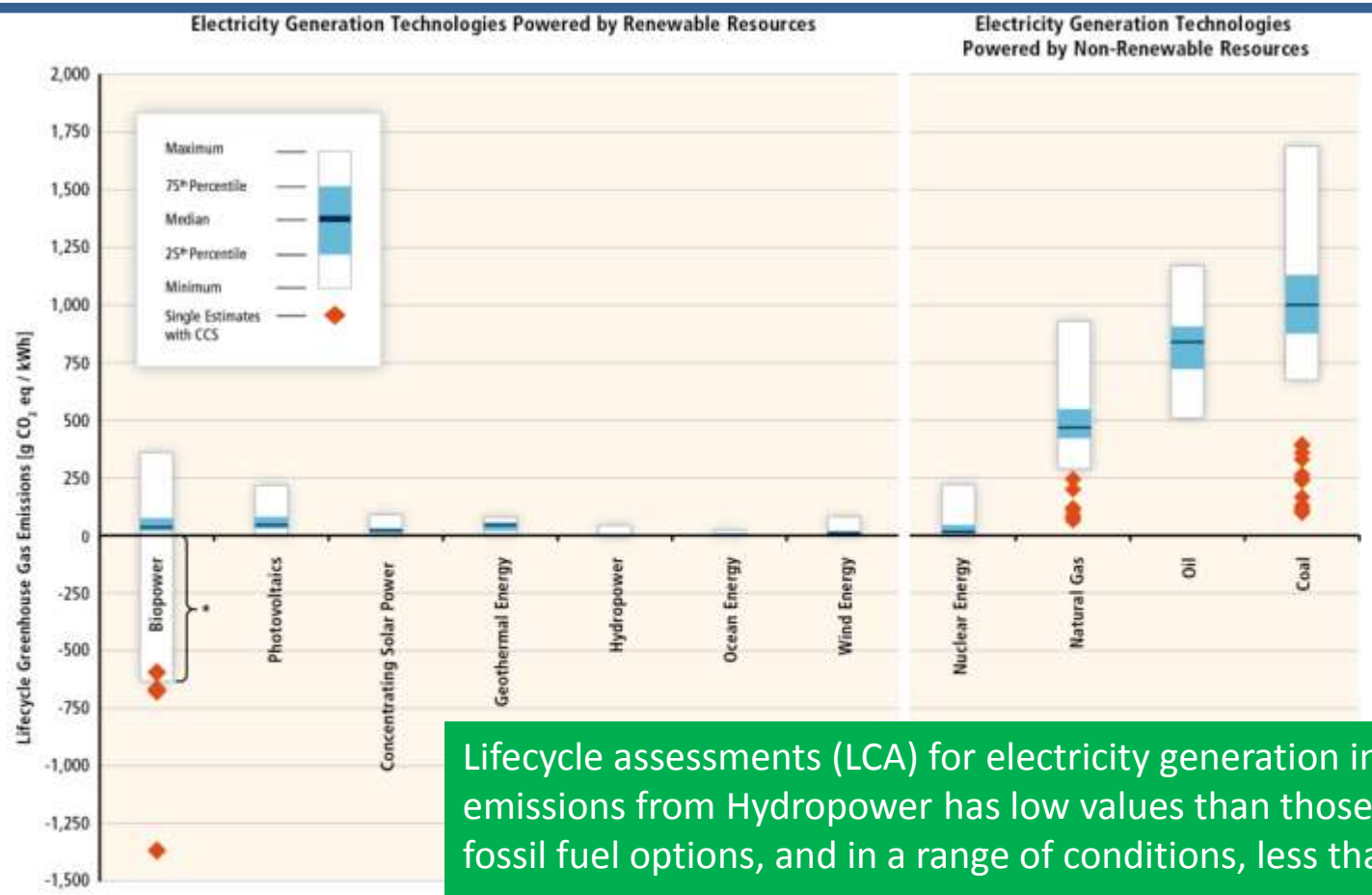
1990 Resettled People

Finally!

2000

2010 Upstream/Downstream

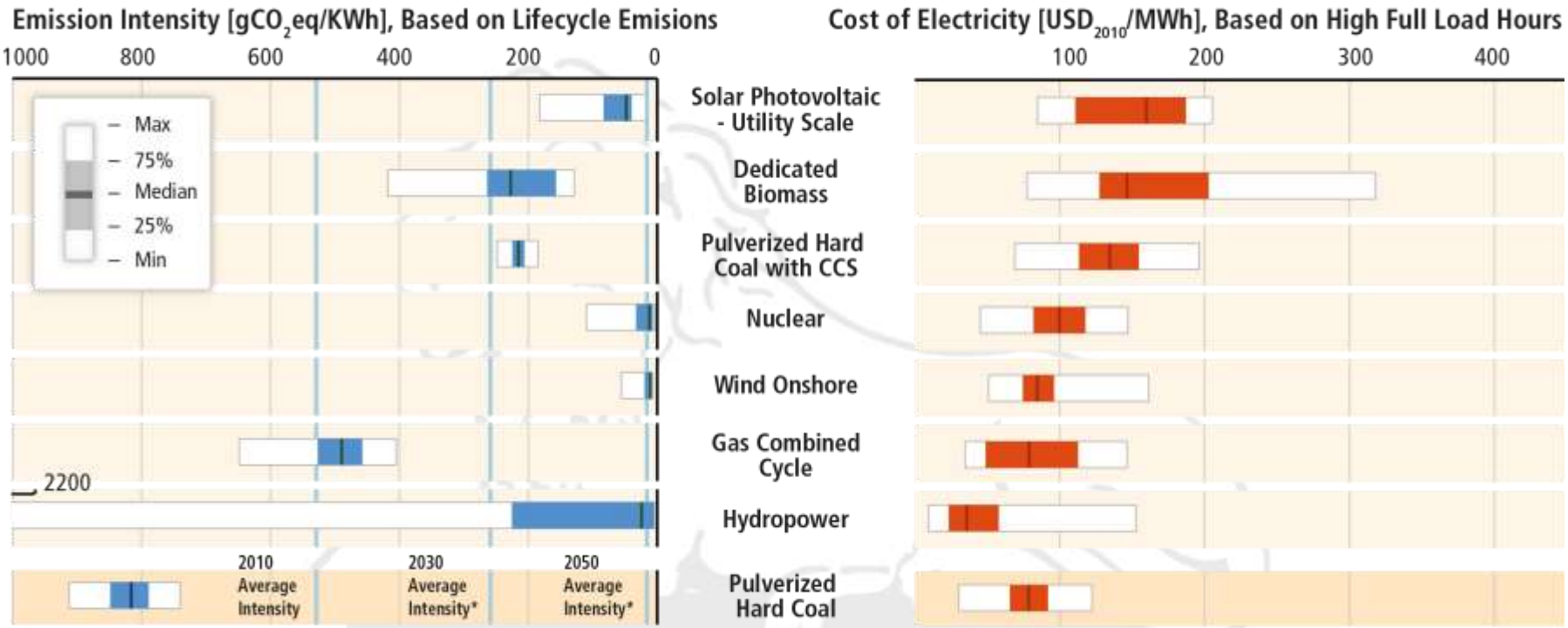
Mitigating climate change IPCC-SRREN 2011



Lifecycle assessments (LCA) for electricity generation indicate that GHG emissions from Hydropower has low values than those associated with fossil fuel options, and in a range of conditions, less than fossil fuels.

Count of Estimates	222(+4)	124	42	8	28	10	126	125	83(+7)	24	169(+12)
Count of References	52(+0)	26	13	6	11	5	49	32	36(+4)	10	50(+10)

Some Mitigation Technologies for Electricity Generation



* Median Value in Mitigation Scenarios (430-530 ppm CO_2eq by 2100)

Intended Nationally Determined Contribution (INDC) Government of India for UNFCCC, Conference of Parties (COP), Paris in December 2015.

Clean Energy Shifts and Target as per INDC of India

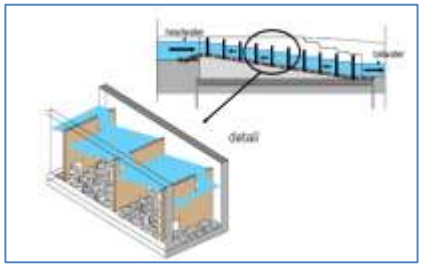
para 1.1.1.4 page 9

Sl. No.	Energy Source	Current Installed Capacity		Target		
		(MWs)	% Energy Mix	2022 (MWs)	2032 (MWs)	% Energy Mix
A)	**Non fossil fuel based**					
1.	Hydro	46,000	18.32		150,000	27.27
2.	Solar	4,060	1.62	100,000		18.18
3.	Nuclear	5,780	2.30		63,000	11.46
4.	Wind	23,760	9.50	60,000		10.91
5.	Biomass	4,400	1.76	10,000		1.82
	Sub Total (A)	**84,000**	**33.50**	**383,000**		**69.64**
B)	**Fossil fuel based**					
6.	Coal	167,000	66.50	167,000		30.36
	Sub Total (B)	**167,000**	**66.50**	**167,000**		**30.36**
7.	**Grand Total (A+B)**	**251,000**	**100**	**550,000**		**100**

Para 4 page 29: External Cooperation: A Critical Enabler

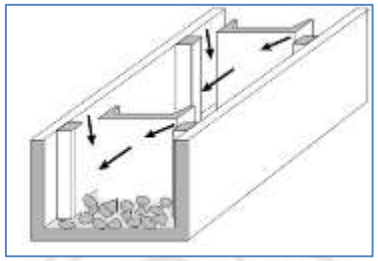
TECHNICAL FISH PASSES

Pool Passes



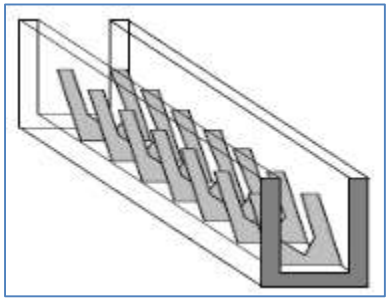
- Channel from headwater to the tailwater is divided into a number of successive pools by installing cross-walls.
- Orifices and notches in cross-walls are employed to pass the discharge

Vertical Slot Pass



- These kinds of fish passes are a variation of pool passes.
- The cross-walls in slot passes are notched over their entire height unlike pool passes.

Denil Pass



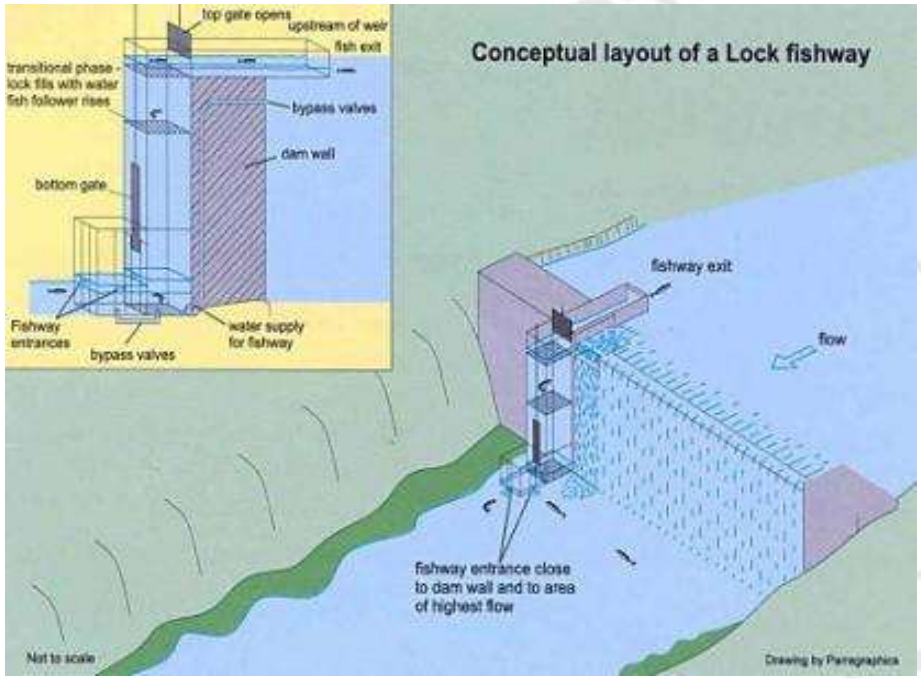
- Use backflows for energy dissipation to allow steeper slopes than other fish passes.
- Baffles placed at relatively short intervals bent against the flow direction.
- Installed generally by retrofitting of the existing hydraulic structures

Eel Ladders

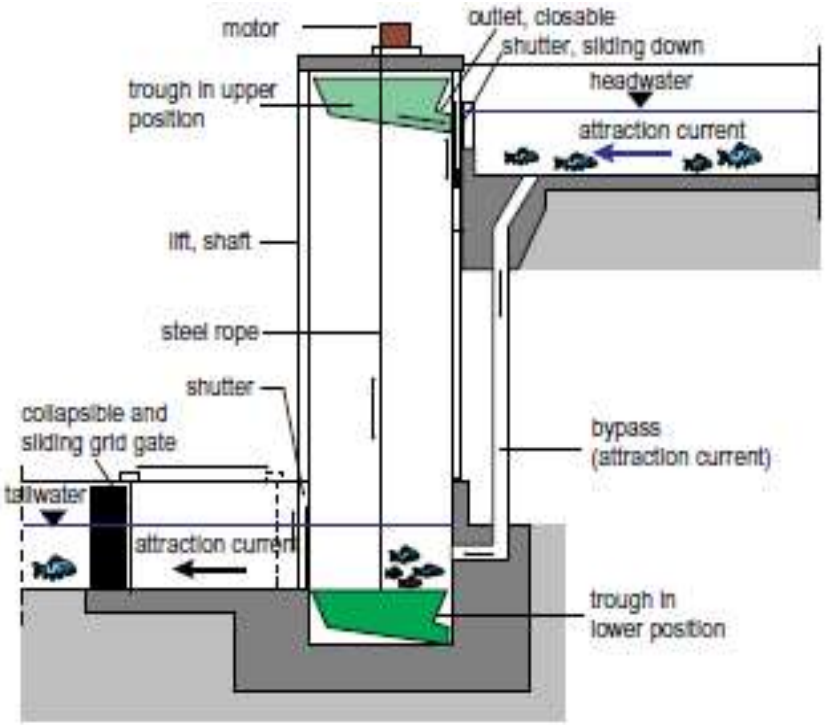
Main Components:
Eel ascending ramp
Supporting Structure
Water feeding system
Side gutter

MECHANISED FISH PASSING STRUCTURES FOR HIGH HEAD (H>20m)

FISH LOCKS

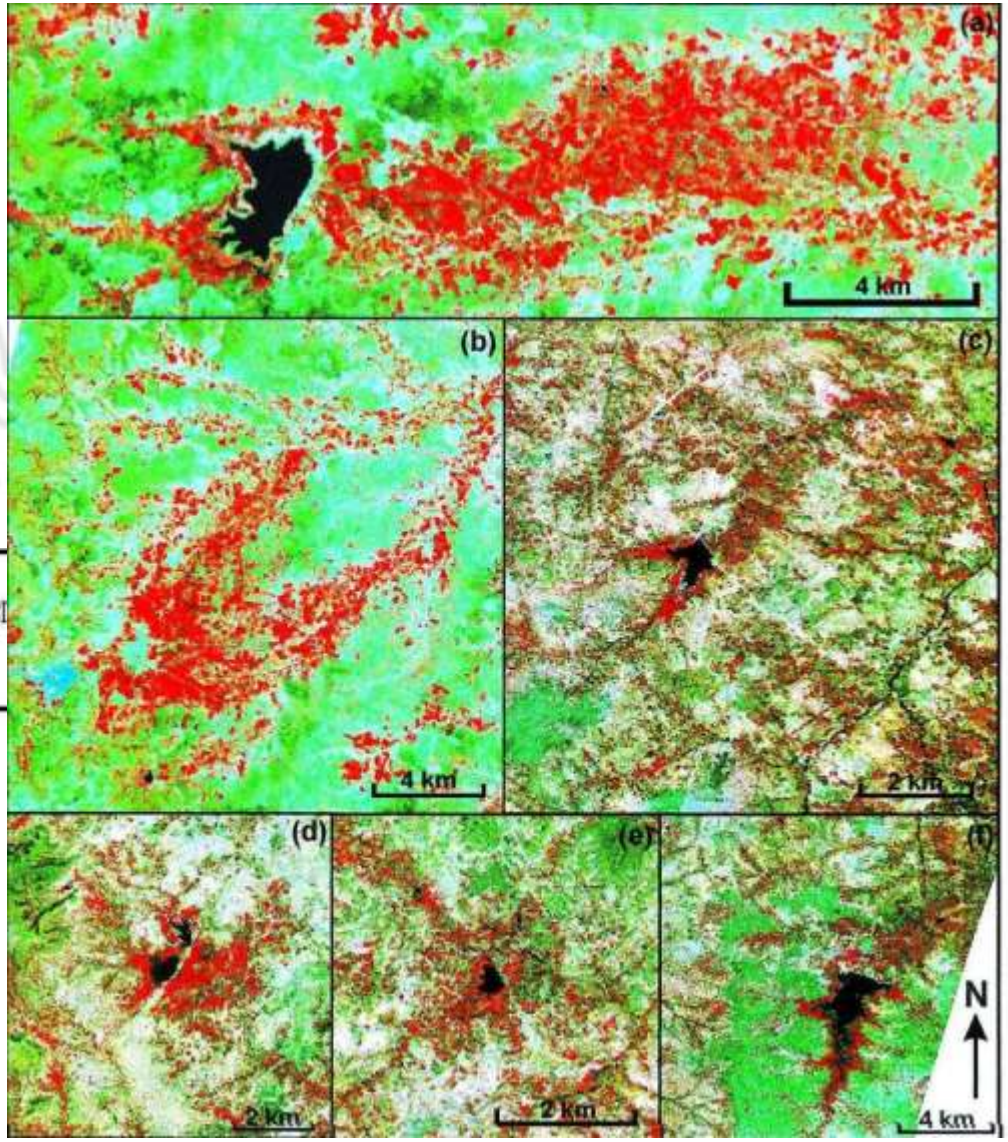


FISH LIFTS



Impacts of Reservoirs on Groundwater and Vegetation

Name of the reservoir	Benefited area (km^2)	Submerged area (km^2)	Benefited/submer areas ratio
Jhaloni & Burera	21.5	1.2	17.92
Jakhaura	8.4	0.3	28.00
Kharkhari	19.5	0.8	24.3
Govind Sagar	53.6	11.6	4.62
Sironj	31.7	2.8	11.32
Naren	41.2	5.3	7.77



Cumulative Impact Study of Hydropower Projects on Alaknanda and Bhagirathi Rivers including Tributaries

Sponsored by:

UJVN Limited on behalf of Government of Uttarakhand

Prepared by:

Alternate Hydro Energy Centre
Indian Institute of Technology Roorkee
Roorkee.

In Collaboration with

National Institute of Hydrology, Roorkee.

Department of Forestry and Natural Resources,
HNB Garhwal University, Srinagar.

Jan 2015

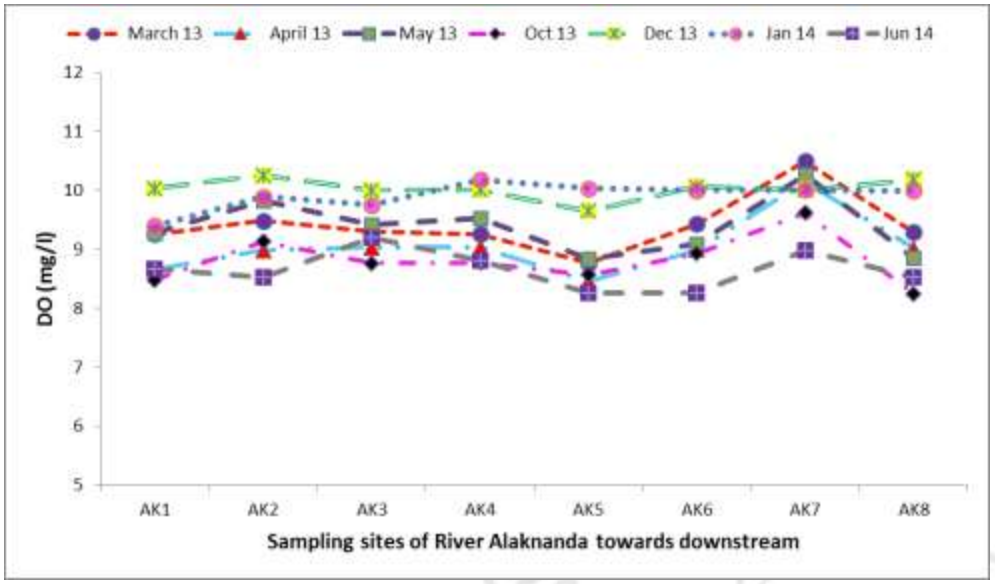
Components Studied For Assessment of Impact of Hydropower Projects

- Land Use/Land Cover changes
- Water Quality
- Socio-economic Environment
- Aquatic Biodiversity
- Terrestrial Biodiversity
- Water resources and Hydrology
- Springs and Drinking Water
- Sedimentation
- Environmental Flow
  - Flow regime of the stream
  - Whether the impact is remediable
  - Impact of ensuring environmental flow on power generation.
- Hydropower Development
  - Submergence
- Natural Disasters

WATER QUALITY

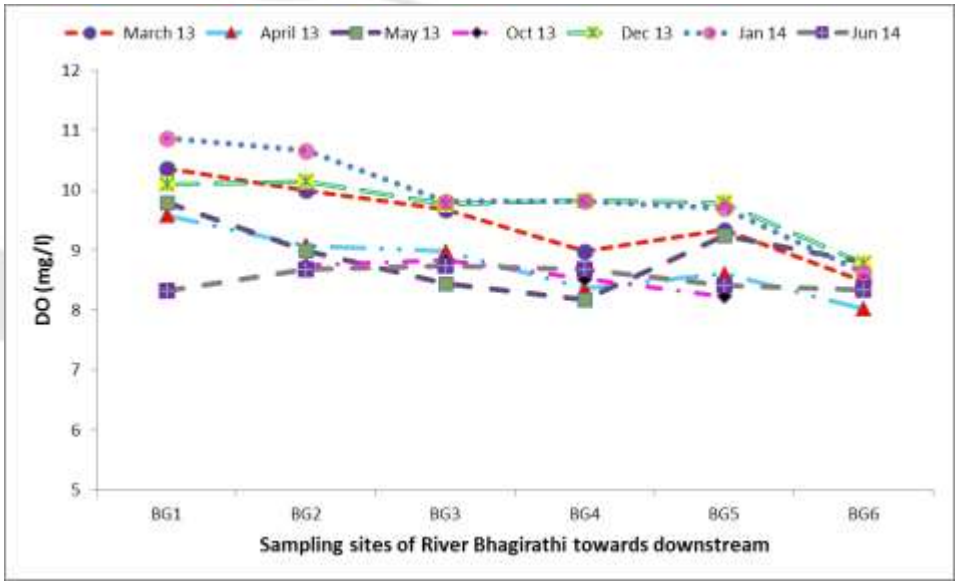
- The water quality in the study area in general is good and by and large conforms to the designated best use Class 'A' (Designated Best Use for drinking) with a few exceptions.
- The DO values throughout are well above the minimum specified limit for Class A.
- The BOD values are also within limits for Class A at most stations but marginally exceed the upper limit at a few stations for few samplings.
- The total coliform, while within the limits for Class A at most of the locations, exceeds the limits at more locations than the BOD.
- The parameters at the locations where the BOD and Coliform values exceed the limits are still well within the limits specified for Class B(Designated Best Use for bathing).
- The water quality parameters do not show any appreciable change between stations on the upstream and downstream of hydropower plants – commissioned or under construction – indicating that the hydropower plants do not have any adverse impact on the water quality.

Dissolved Oxygen (DO)

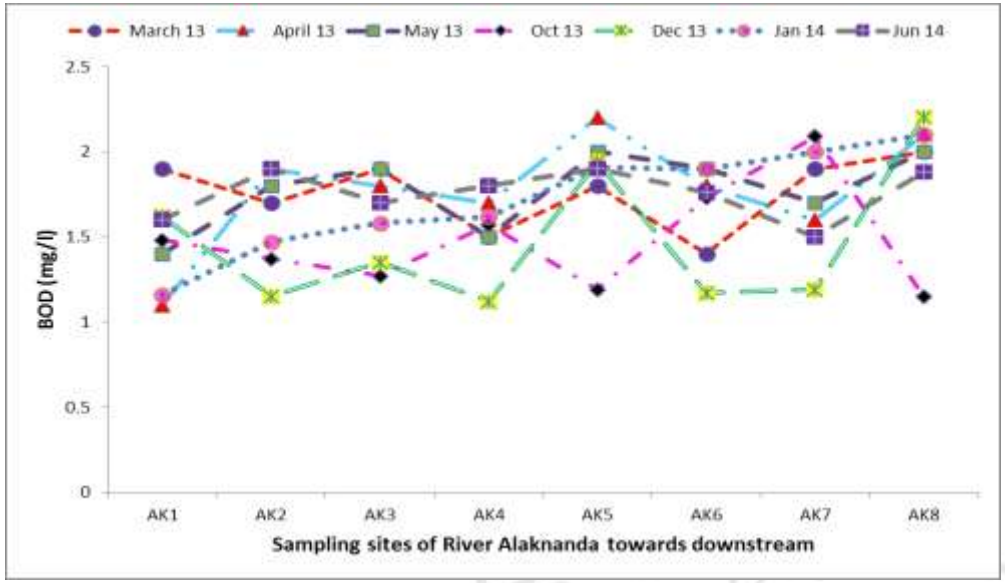


Variation of DO in river Alaknanda

Variation of DO in river Bhagirathi

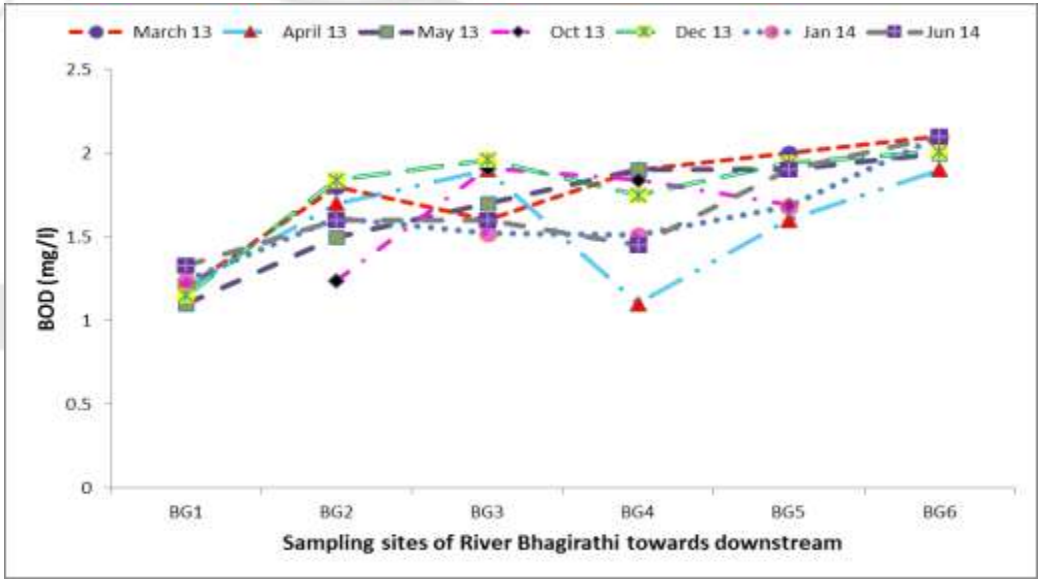


Biochemical Oxygen Demand (BOD)



Variation of BOD in river Alaknanda

Variation of BOD in river Bhagirathi



Fish Zone in Alaknanda and Bhagirathi Basins

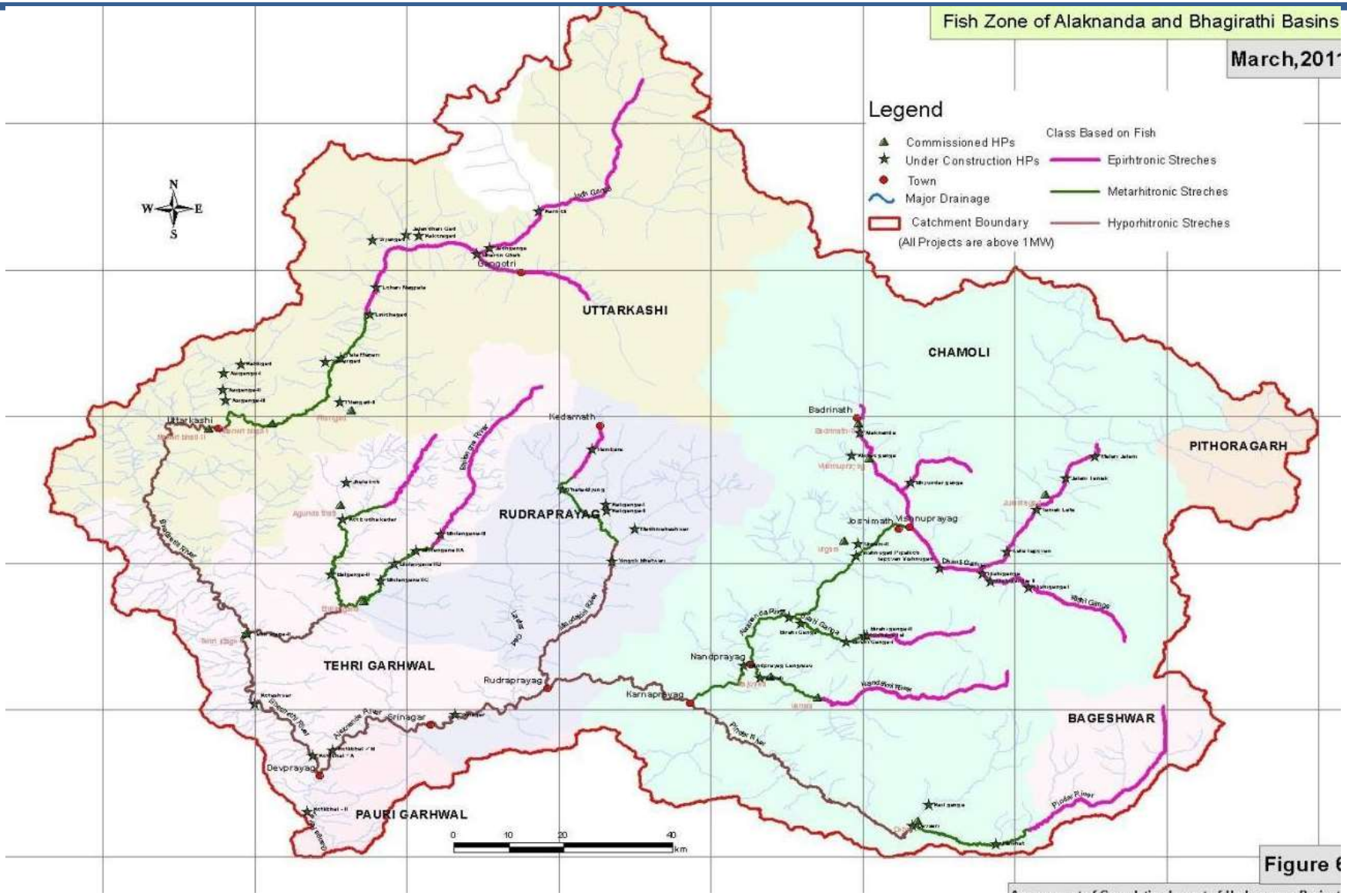
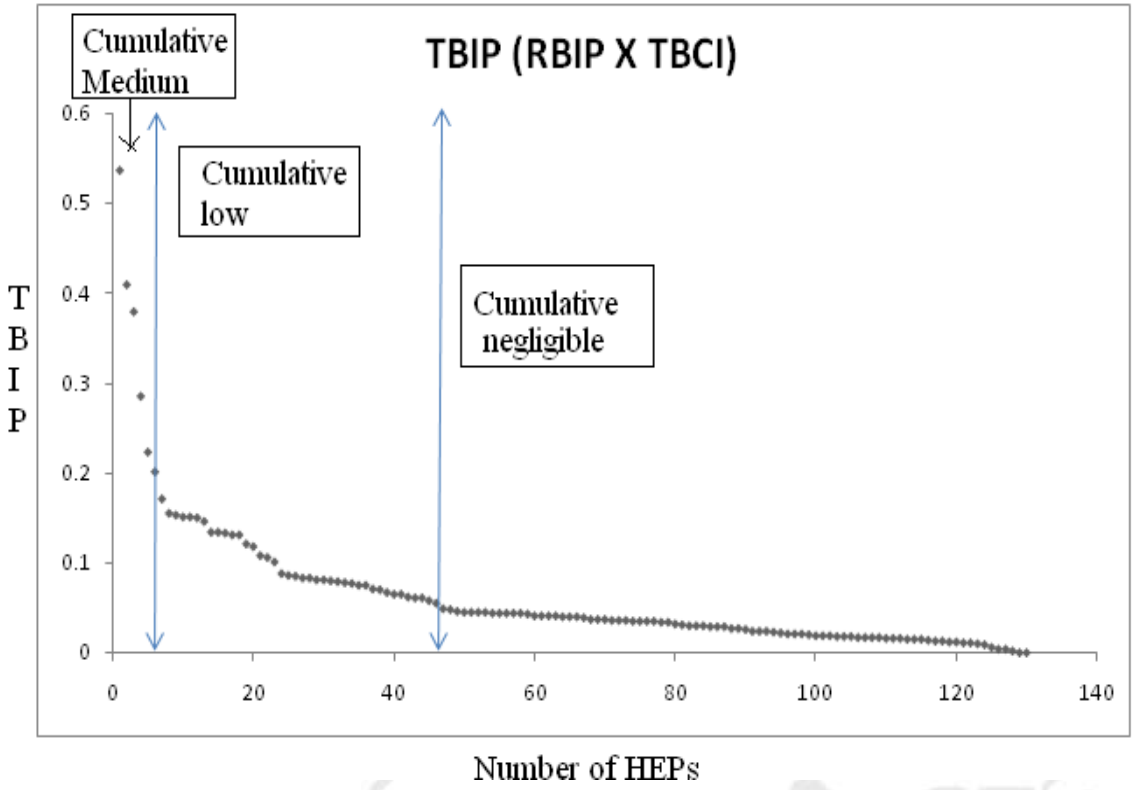


Figure 6

Terrestrial biodiversity

Terrestrial Biodiversity Impact Potential (TBIP) (RBIP X TBCI)



Based on the scatter graph of TBIP:
Relative Biodiversity Index Potential (TBIP)
Terrestrial biodiversity conservation importance(TBCI)

Cumulative medium : TBIP > 0.2

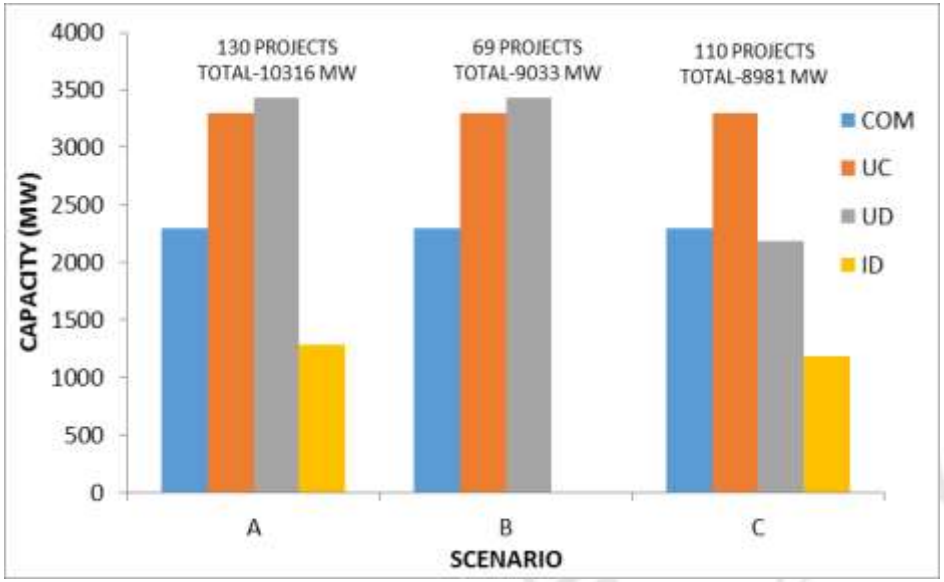
Cumulative low : TBIP: 0.05 – 0.2

Cumulative negligible : TBIP <0.05. I)

As one can observe that these values are very low, does not imply to their potential interms of localized impact.

Considering this criteria, **Tehri I is likely to have cumulative medium impact on the terrestrial biodiversity,** followed by **Rishiganga I, Utyasu –II, Srinagar, Bhairo Ghati** and **Devasari.**

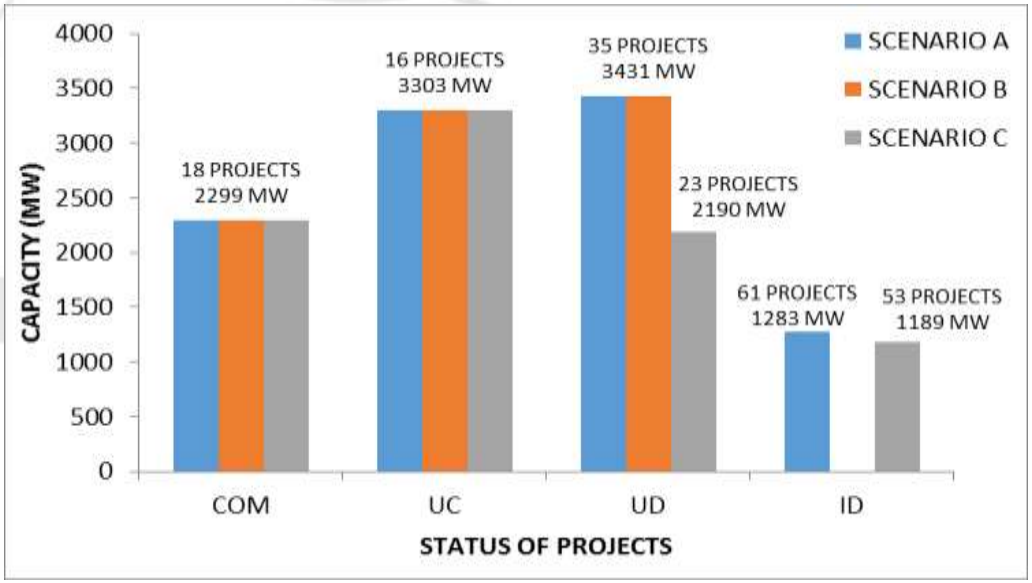
Installed Capacity under Different Scenarios of Development



Scenario A - All projects including those that are identified irrespective of their location (130 HPs)

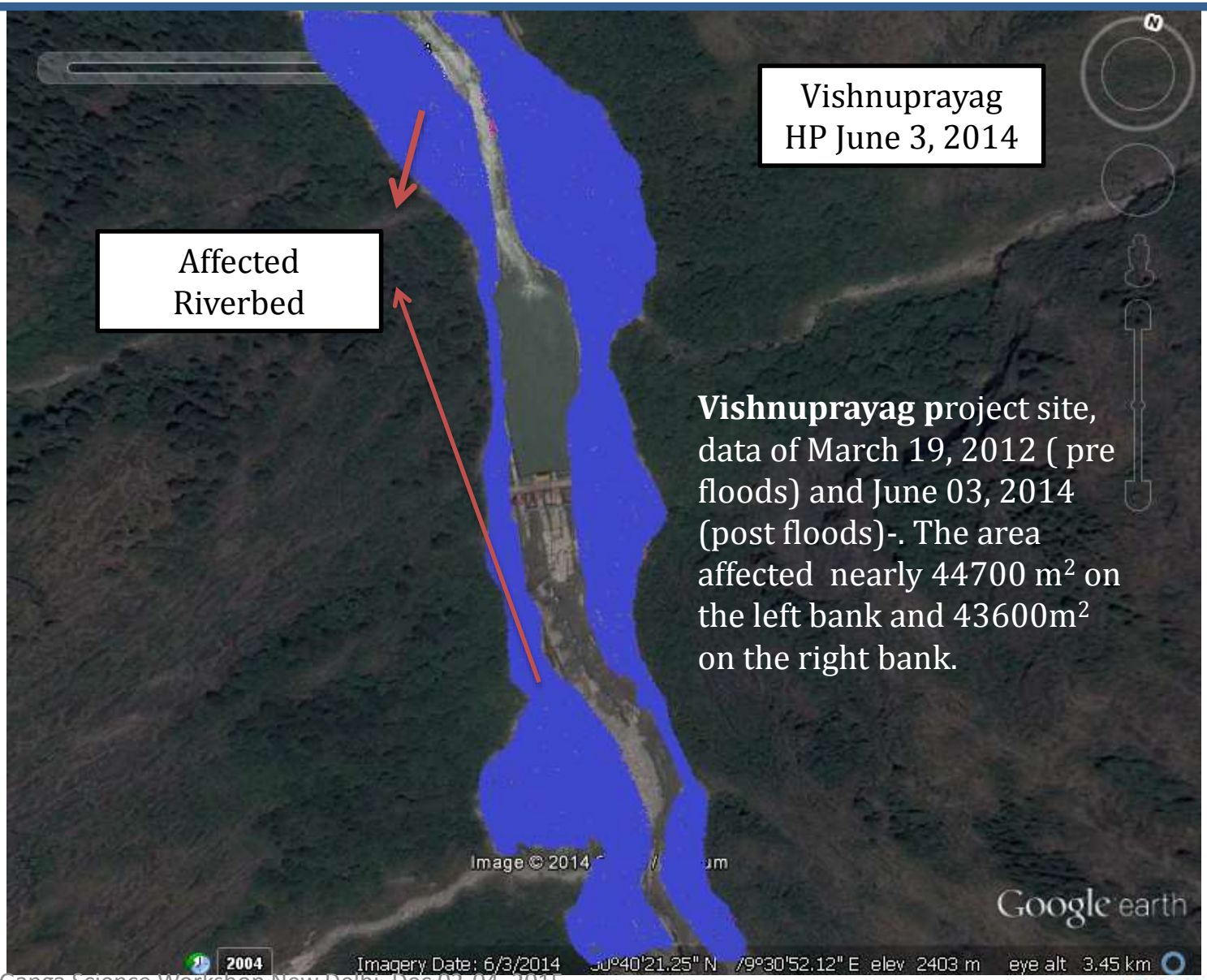
Scenario B - Projects excluding those that are identified and not yet allotted (69 HPs)

Scenario C- Projects excluding those which are in protected areas and within 2 km of buffer zone, except those which are already commissioned as well as under construction (110 HPS)




3/19/2012
2004
2014
Vishnuprayag HP
March 19, 2012
Image © 2014 DigitalGlobe
Google earth
2004
Imagery Date: 3/19/2012 30°40'21.25" N 79°30'52.12" E elev 2403 m eye alt 3.45 km


6/3/2014
Vishnuprayag HP
June 3, 2014
Image © 2014 CNES / Astrium
Google earth
2004
Imagery Date: 6/3/2014 30°40'21.25" N 79°30'52.12" E elev 2403 m eye alt 3.45 km


Vishnuprayag
HP June 3, 2014
Affected
Riverbed
Vishnuprayag project site, data of March 19, 2012 (pre floods) and June 03, 2014 (post floods)-. The area affected nearly 44700 m2 on the left bank and 43600m2 on the right bank.
Image © 2014
Google earth
2004
Imagery Date: 6/3/2014
eye alt 3.45 km

Small or Large – Example from China

Small hydropower (< 50 MW):

- More than **1000** plants built
- Producing **2.5 TWh/a**

Extra Large Three Gorges:

- **1** huge plant
- Producing **96 TWh/a**

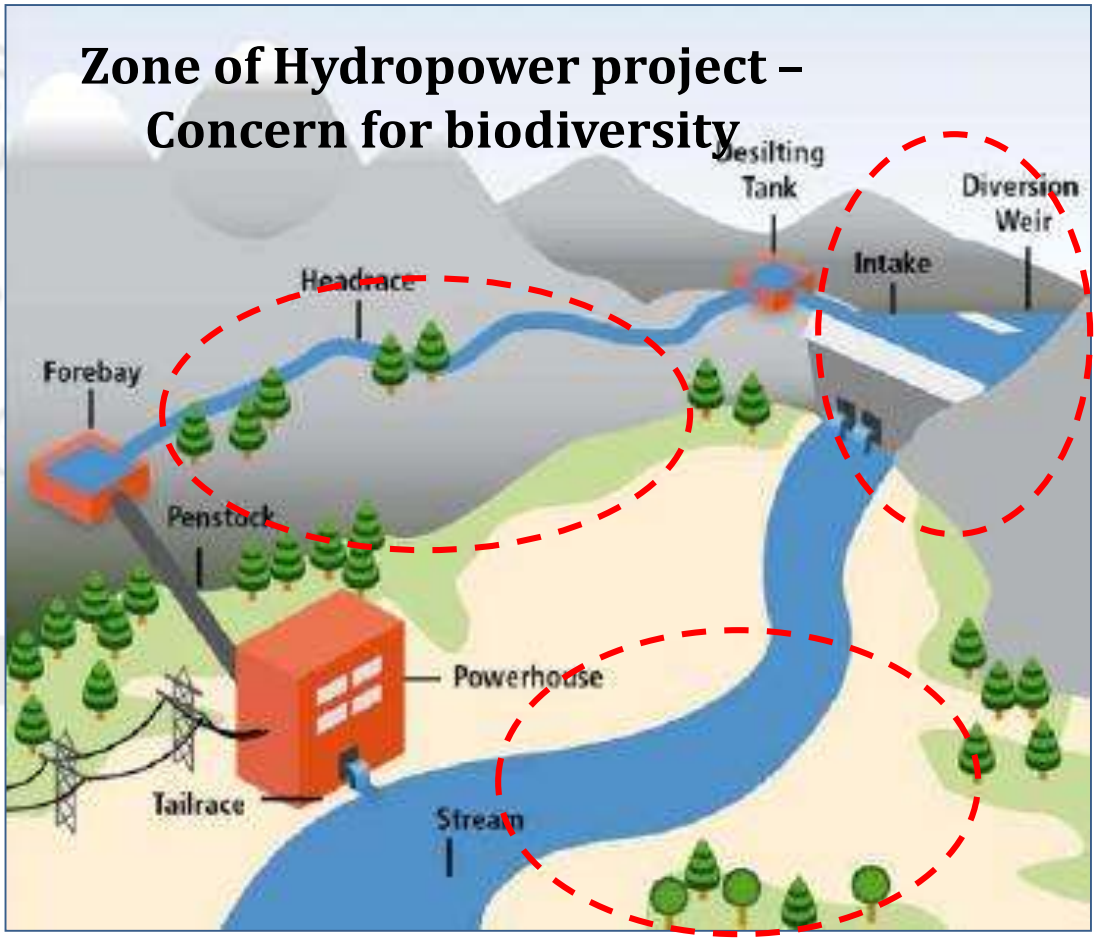
In order to produce the same energy output from Three Gorges project, approximately **40 000 small** hydropower plants (< 50 MW) must be constructed.

What are the accumulated environmental (and social) impacts?

(source: Atle Harby, SINTEF)

Bio- Diversity and Hydropower

- Flora - Terrestrial
  - Aquatic
- Fauna- Terrestrial
  - Avian
  - Aquatic



Society is concerned?

ESTIMATION AND IMPLEMENTATION OF Environmental Flow -- absence of regulation

Honesty?

LEGISLATIVE PERSPECTIVE

Section-3(3) of the Environment(Protection) Act, 1986:

- Central Govt. empowered to constitute an authority or authorities for the purpose of exercising and performing such powers and functions of the Central Govt. under the Act;

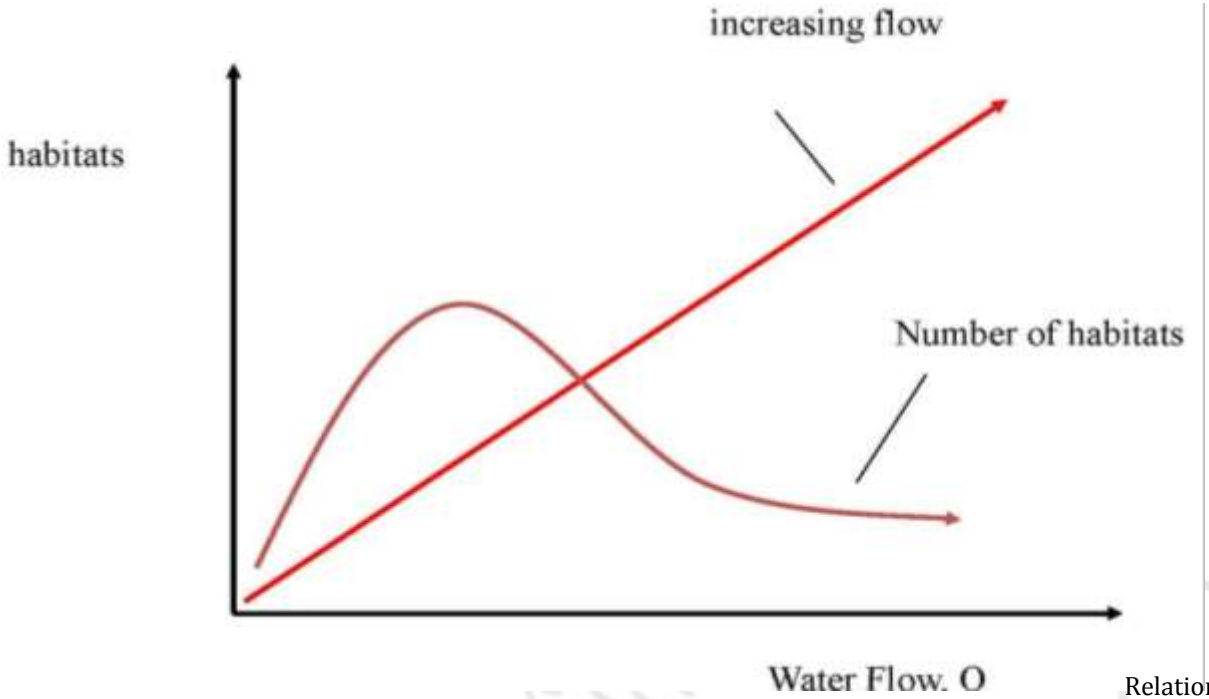
Environment Protection Act, 1986
Water Quality Assessment Authority

- Water Quality Assessment Authority notified by Central Govt. mandated: "***to maintain minimum discharge for sustenance of aquatic life forms in riverine systems***"
- EIA, 1994/2006 vested powers with the Govt. of India for granting Environmental Clearance.
- Sectiion-24(1-b) of the Water(P&CP) Act, 1974 **restricts entry into any stream of matter which may tend, either directly or in combination with similar matters, to impede the proper flow of the water of the stream in a manner leading or likely to lead to a substantial aggravation of pollution due to other causes or of its consequences.**

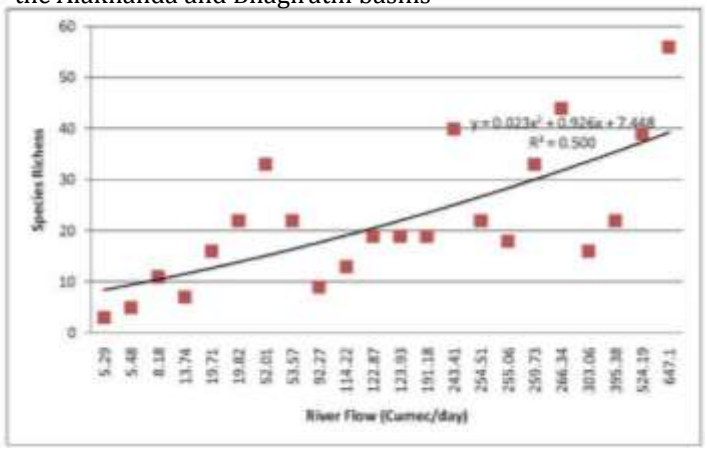
Current Practice for E-flows in India

- **Himachal Pradesh** started maintenance of E-flows since 2005 through its pollution control board
- 15% of the minimum inflow downstream of diversion structure
- Conventional methods of flow measurement using gauge readings
- Since 2009 Real-time online continuous flow measurement and data logging made mandatory for all hydro projects
- **Uttarakhand**
- 10% of the minimum inflow downstream of diversion structure but only for new projects.
- State owned project still no release
- No effective monitoring mechanism
- **EAC recommendations**
- 20% during non monsoon season and 30% during 4 months of monsoon season on cumulative basis

More water does not necessary result in more or larger living species



Relationship between river flow and species richness in the Alaknanda and Bhagirathi basins

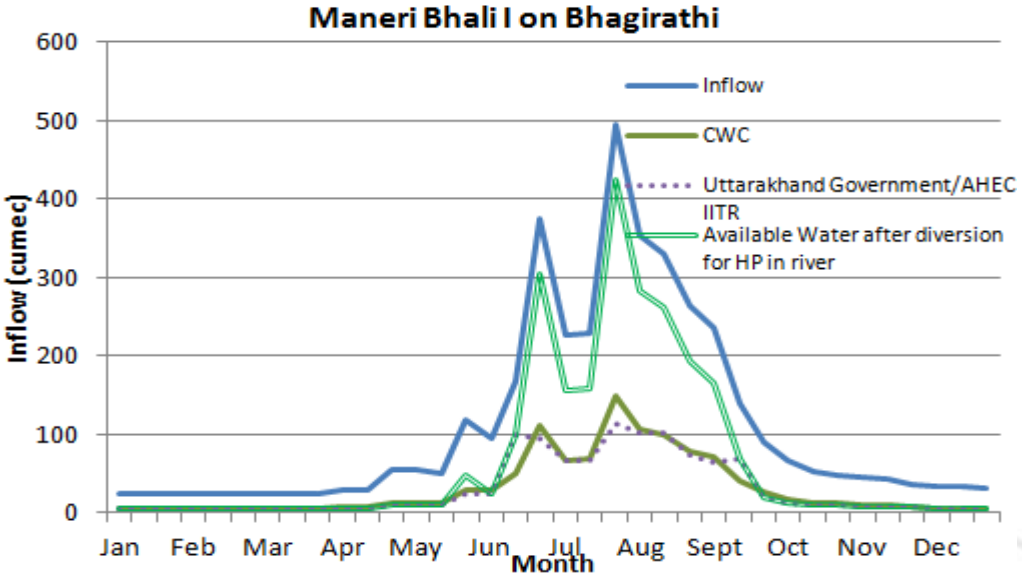


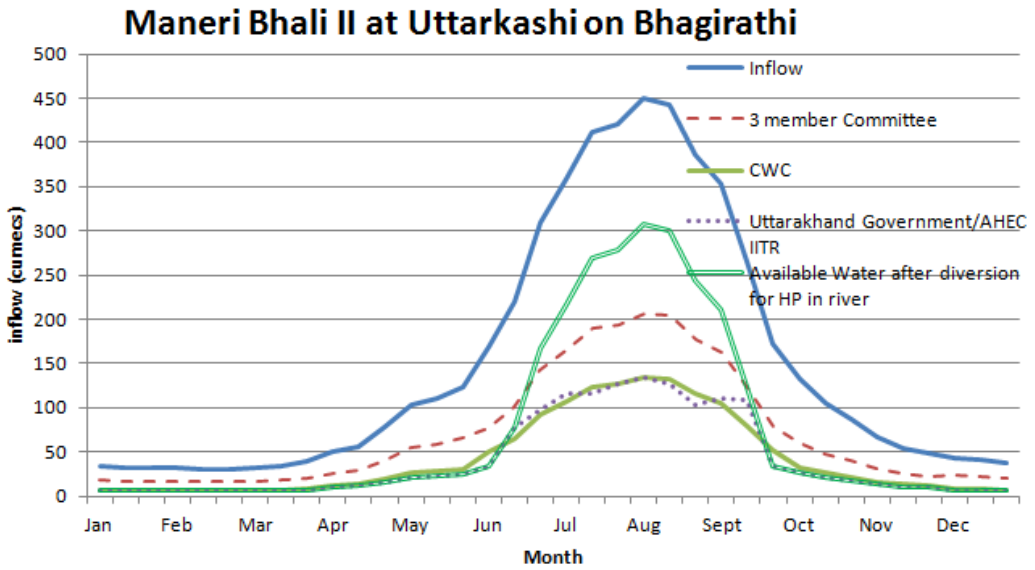
In adequate understanding some time leads to wrong perceptions. “there is a strong correlation between the flow and species richness (R2 = 0.5007)”.

EFR Estimation

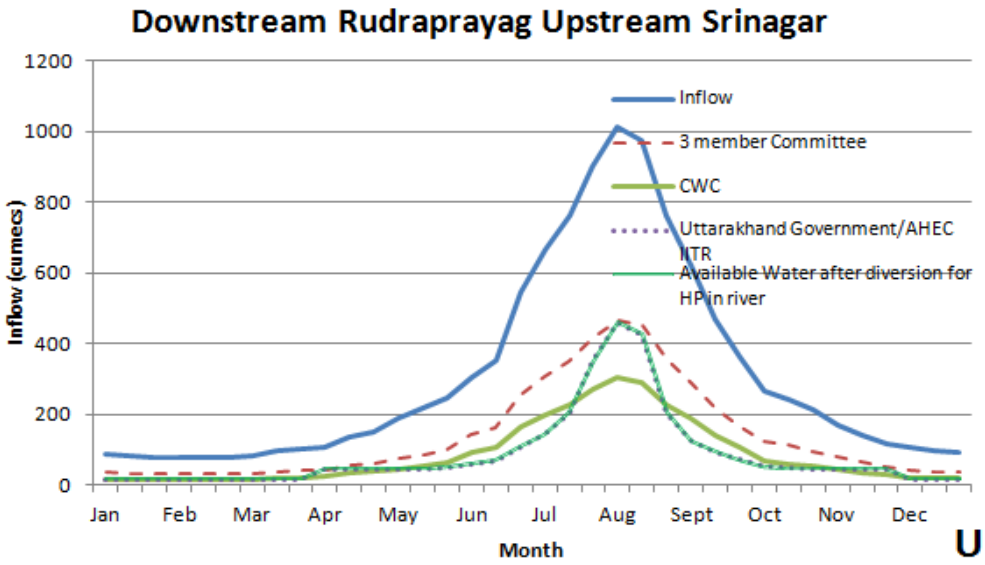
HPs in the No Fish Zone		
Months	EFR Requirements	Remarks
Dec, Jan, Feb	20% of the mean lean season (Dec-Jan-Feb) flow	
March, April, May, Oct and Nov	20% of the inflow	.
June, July, August & Sept.	30% of the cumulative flow	_
HPs in the Fish Zone		
Months	EFR Requirements	Remarks
Dec, Jan, Feb, March	20% of the mean lean season (Dec-Jan-Feb) flow	_
April, May, Oct and Nov	20% of the inflow or 25 cm of water depth required for fish migration whichever is more (Subject to 90% dependable flow)	These are the months in which the fishes migrate from lower reaches to higher reaches or reverse
June, July, August, and Sept.	30% of the cumulative flow	_

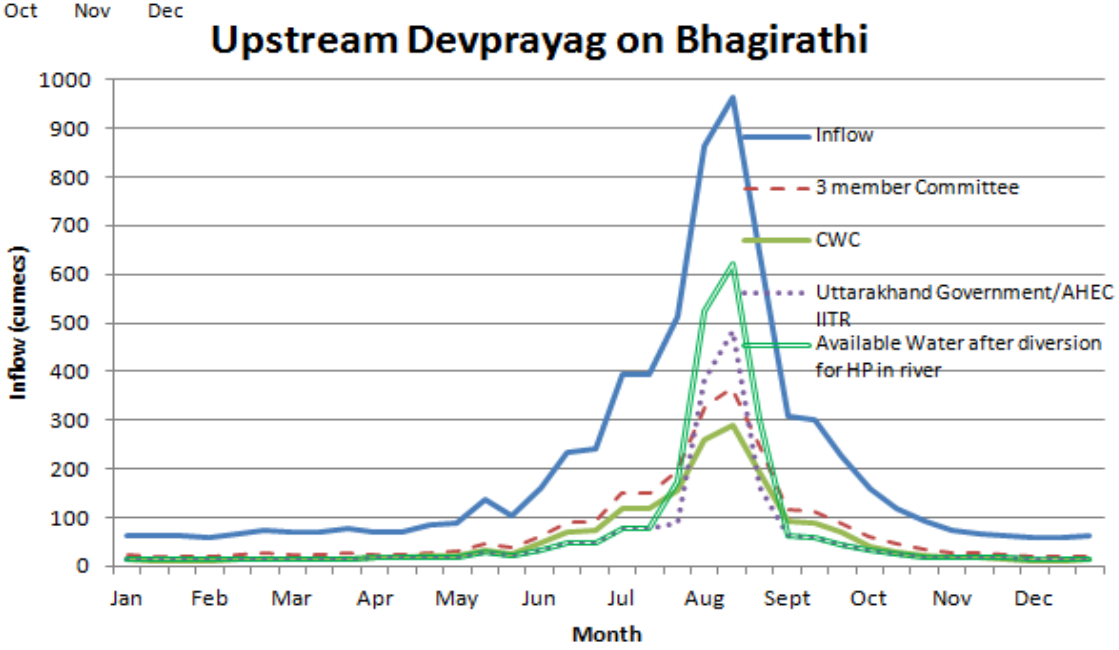
Estimated EFR by different groups at two existing HEP plants





Estimated EFR by different groups at two locations





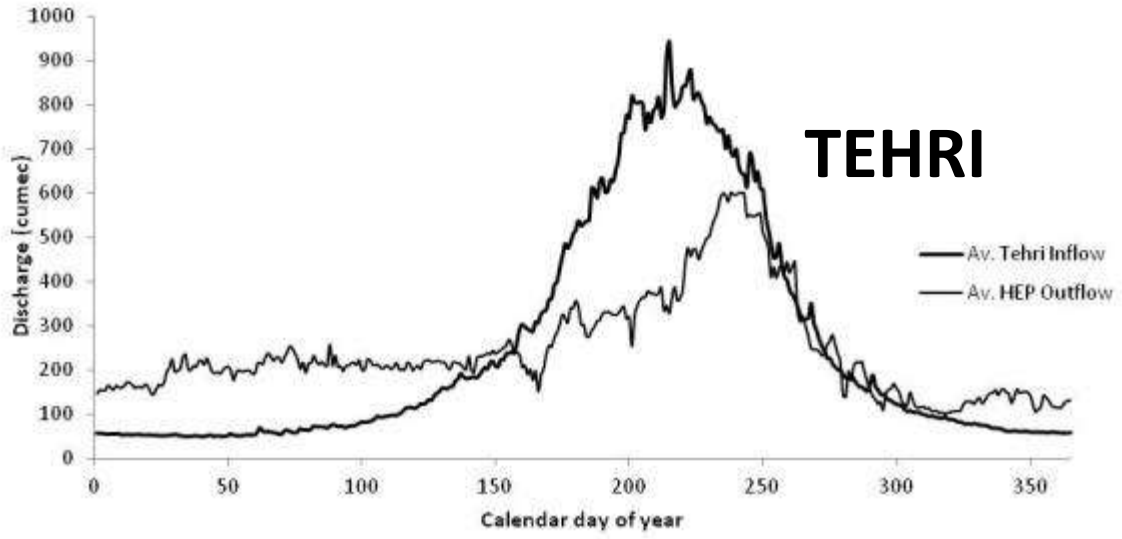
Flashiness Index

Flashiness Index (FI): Flashiness, or rate of change, refers to how quickly flow changes from one condition to another. FI reflects the frequency and rapidity of short term changes in runoff values. FI used to detect changes in the hydrological regime of rivers and is obtained.

$$FI_{day} = \frac{\sum_{i=1}^{n} Abs(q_i - q_{i-1})}{\sum_{i=1}^{n} q_i}$$

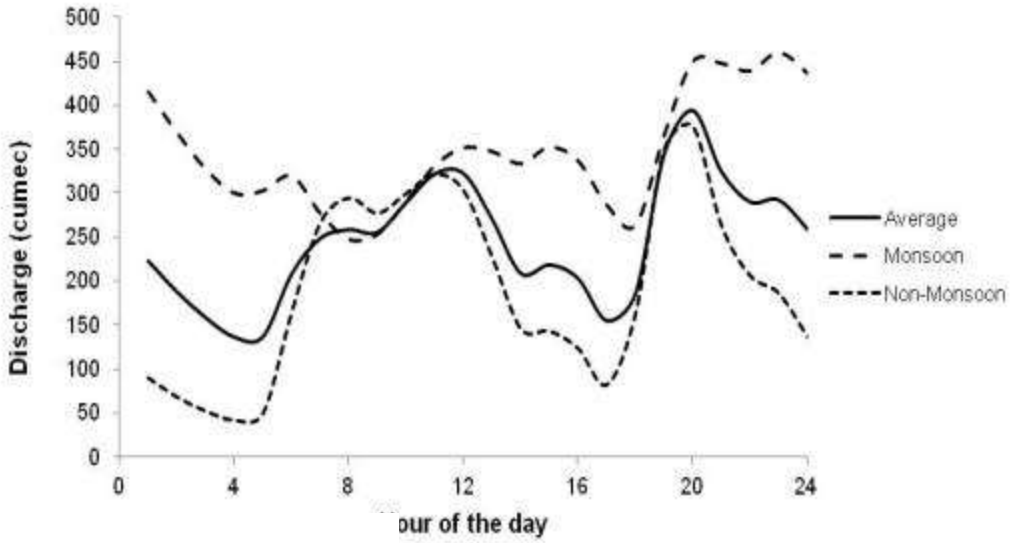
(Baker et al. (2004))

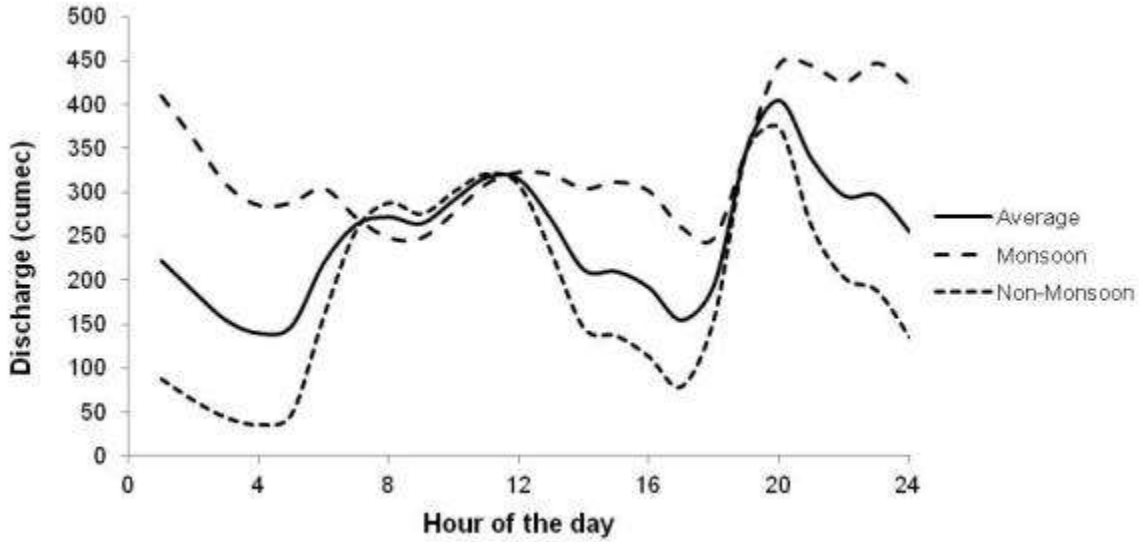
where q_i and q_{i-1} are the average daily discharges ($m^3 s^{-1}$) on day i and day i - 1, respectively.



Average Hourly Variation of Discharge

Average hourly variation of discharge from TEHRI HP on Weekdays





Average hourly variation of discharge from TEHRI HP on Weekends

Free flowing riparian distance between HPs in cascade

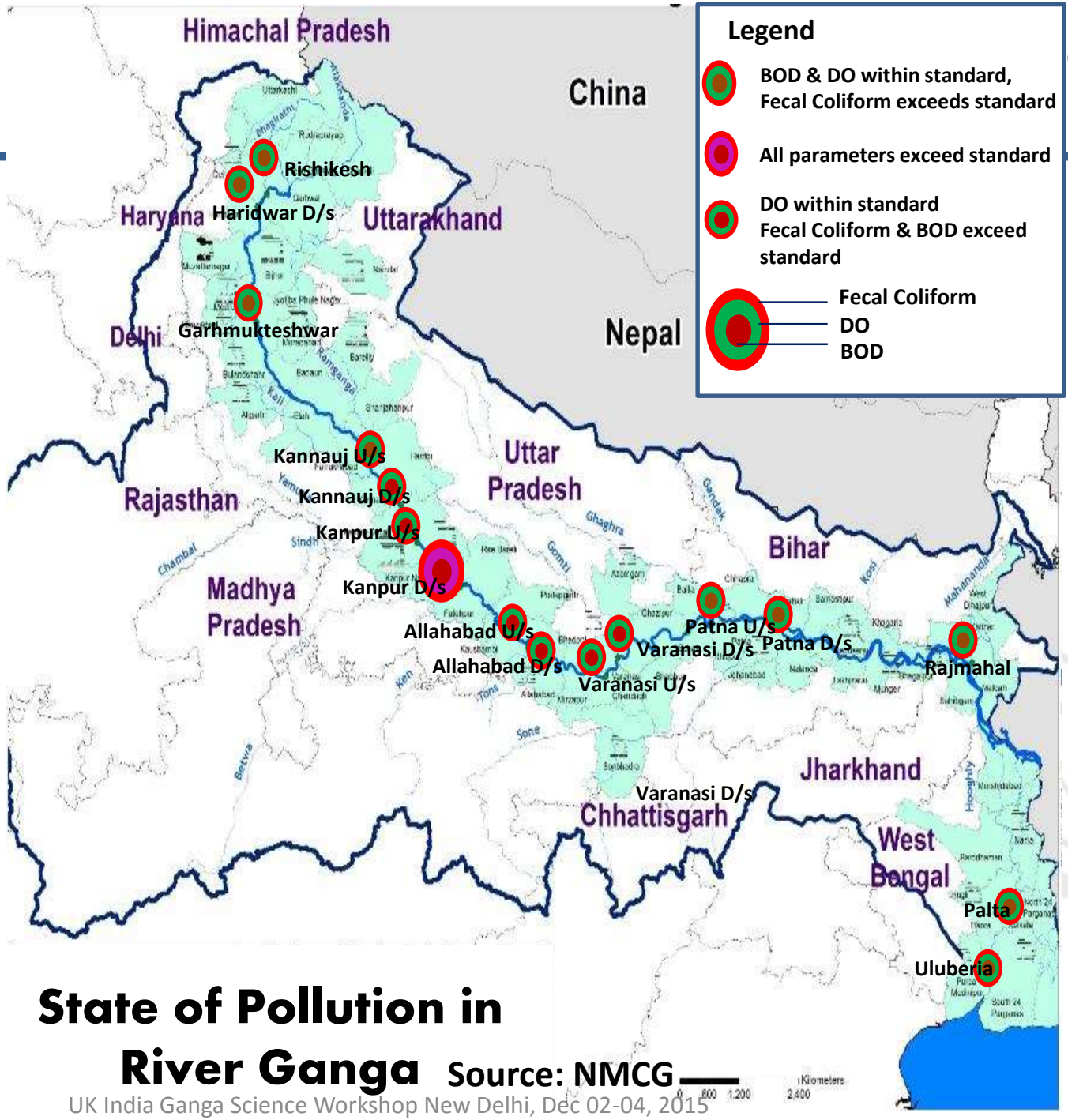
- Providing distance between tail race level of upstream and full reservoir/pond level downstream HEP shall help to regain any lost DO.
- Following is recommended

Elevation of the proposed HP	Minimum Difference between levels of the tail race of u/s HP and FRL of the d/s HP
Above 2000 m	Elevation difference of 20 m
Between 2000m and 1000 m	Elevation difference of 10 m
Between 1000m and 500 m	Elevation difference of 5 m

- Providing this distance will result in reduction in head for some projects and consequent reduction in installed capacity/annual generation. *This reduction has been computed to be 25.9MW/97MU for Bhagirathi and 82.3 MW/313 MU for Alaknanda basins*.

Science for Developing Sustainable Hydropower

- Effective monitoring using IT
- Effective governance and strict enforcement of provisions
- Effective catchment development
- Effective involvement and benefit sharing
- Effective awareness among media, legal, leadership, entrepreneurs and engineers about today's need.



CPCB Standard for Bathing (Class 'B')

Total Coliforms Organism MPN/100ml shall be **500 or less**
Dissolved Oxygen (**DO**) **5mg/l or more**
Biochemical Oxygen Demand (**BOD**) 5 days 20°C **3mg/l or less**

Critical Hotspots in terms of BOD

- Kannauj D/s to Varanasi D/s – **critically polluted stretch**
- Kanpur D/s to Allahabad U/s (**Max at Kanpur D/s – 6.60 mg/l**)

Critical Hotspots in terms of DO

- Kanpur D/s (**Min DO in Ganga – 4.0 mg/l**)
- All other locations indicate DO much above the standard

Critical Hotspots in terms of Fecal Coliform

At all monitoring stations, coliform exceeds the standard

State of Pollution in River Ganga

Source: NMCG

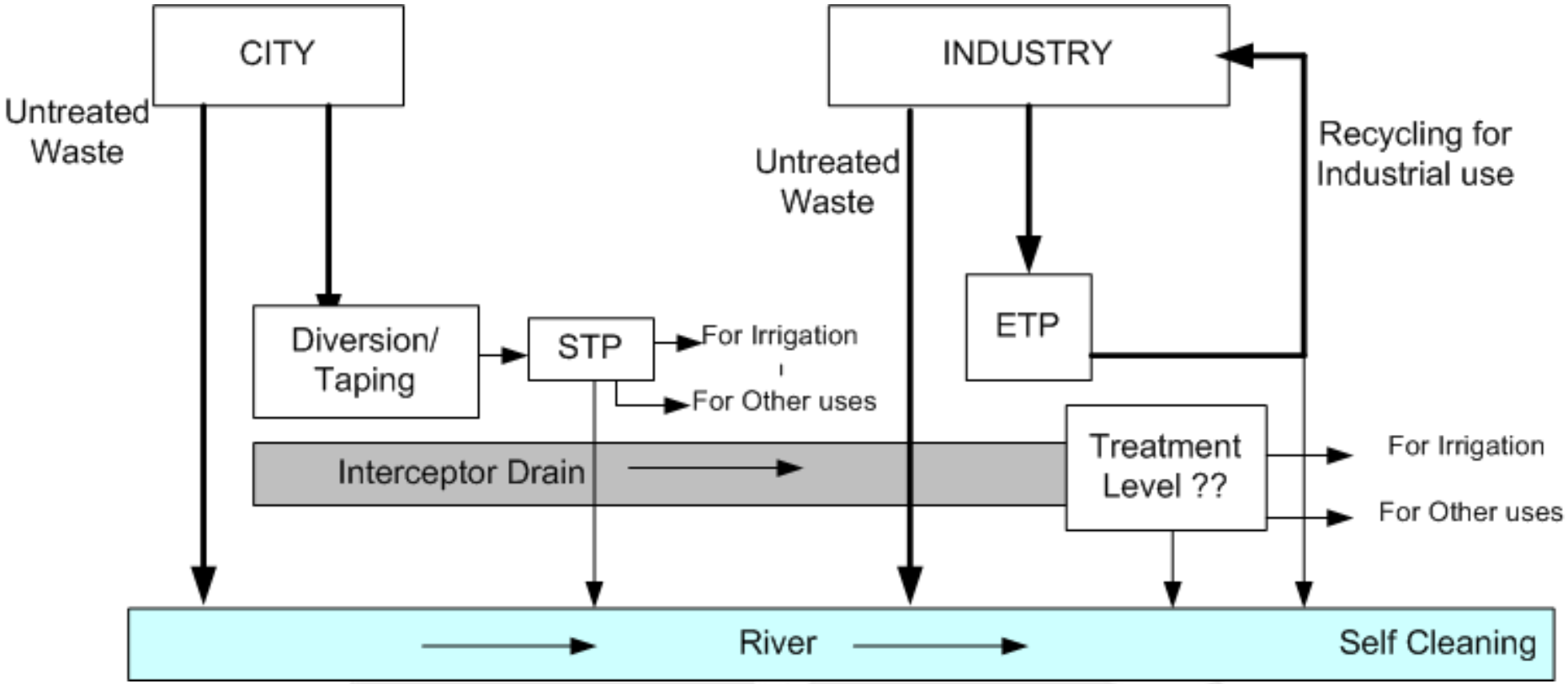
Revised Effluent Standards
(CPCB's notification dated Oct 9, 2015)

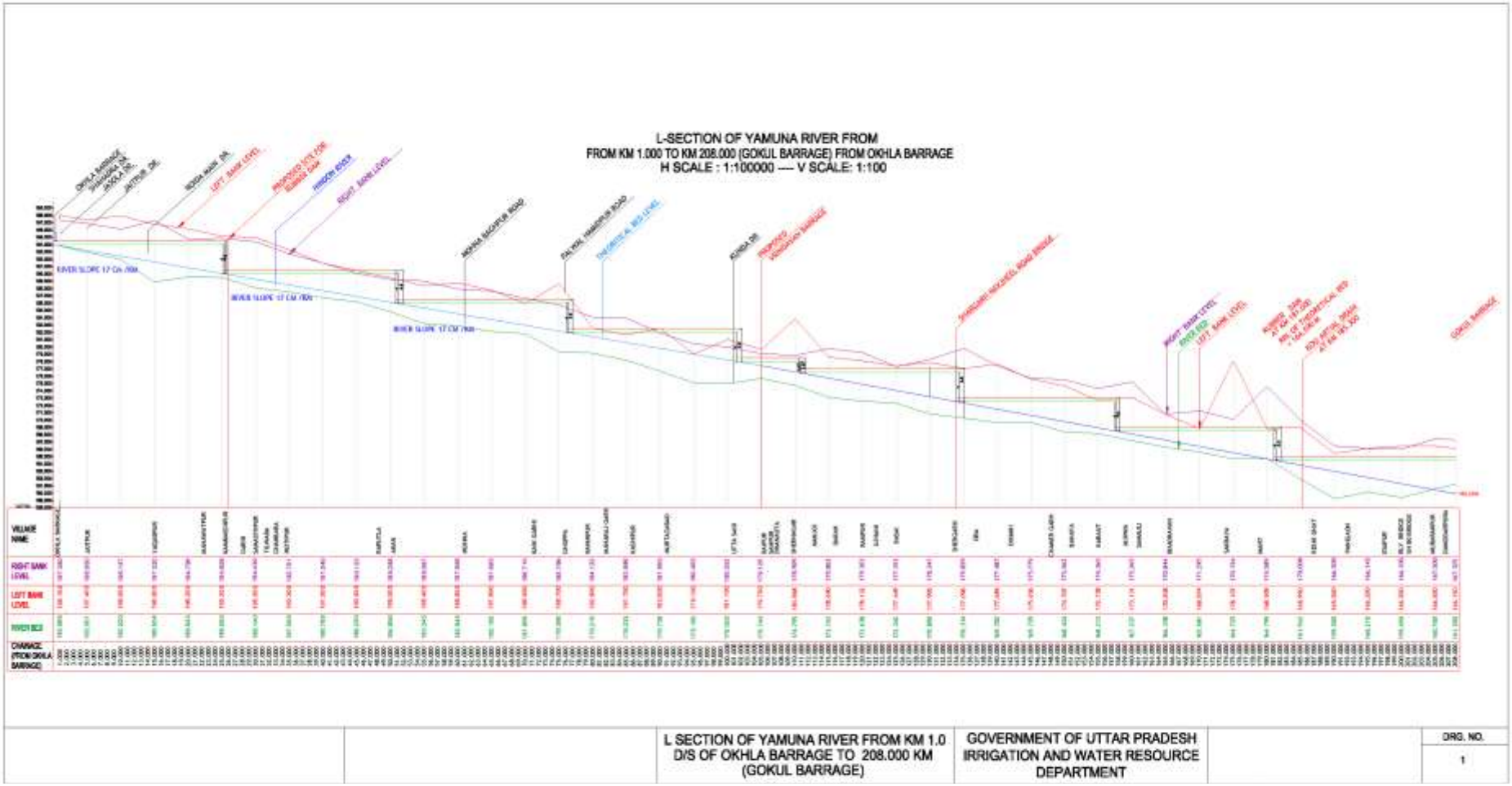
Parameters	Parameters Limit
pH	6.5 – 9.0
BOD, mg/l	10
COD, mg/l	50
TSS, mg/l	20
NH4-N, mg/l	5
Total N, mg/l	10
Faecal Coliform MPN/100 ml	< 230
PO_4–P, mg/l	2

Note:

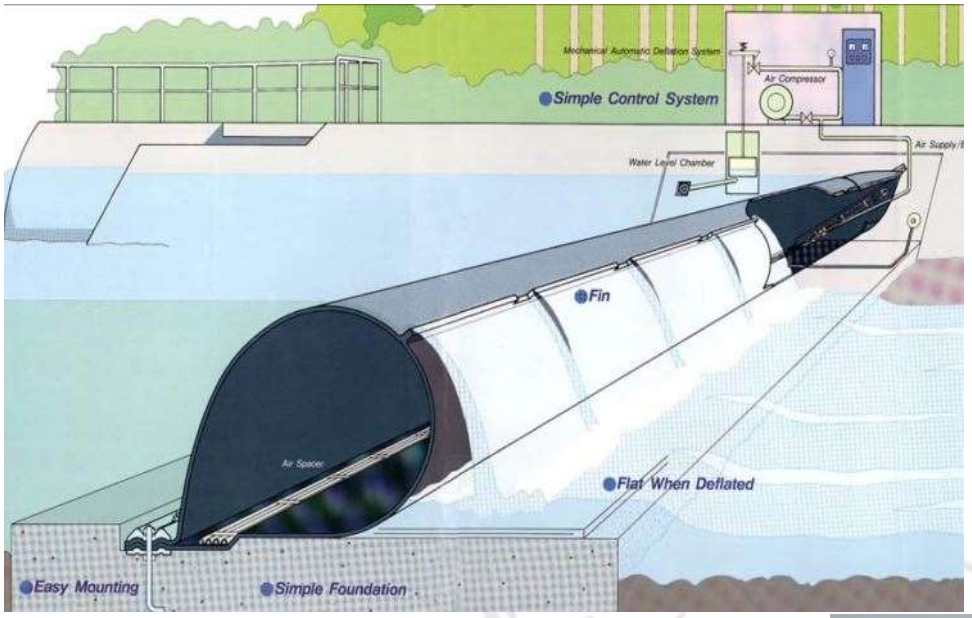
- These standards will be applicable for discharge in water resources as well as for land disposal. The standards for Faecal Coliform may not be applied for use of treated sewage in industrial purposes.
- Achievements of Standards for existing STPs within 05 years from the date of notification.

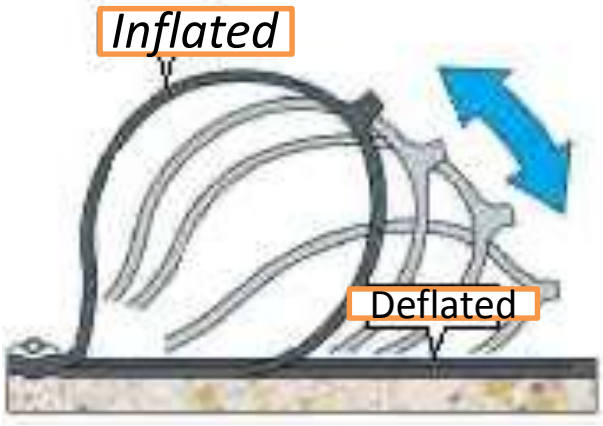
Rejuvenation of River




L-SECTION OF YAMUNA RIVER FROM
FROM KM 1.000 TO KM 208.000 (GOKUL BARRAGE) FROM OKHLA BARRAGE
H SCALE : 1:100000 ---- V SCALE: 1:100
L SECTION OF YAMUNA RIVER FROM KM 1.0 D/S OF OKHLA BARRAGE TO 208.000 KM (GOKUL BARRAGE)
GOVERNMENT OF UTTAR PRADESH
IRRIGATION AND WATER RESOURCE DEPARTMENT
DRG. NO.
1

TYPICAL RUBBER DAM





No higher quality water, unless there is a surplus of it, should be used for a purpose that can tolerate a lower grade

United Nations Economic and Social Council – 1958

Types of Reuse of treated water

- Urban Reuse - Toilet flushing , Cleaning and maintenance, including vehicle washing, Fire protection
- Gardening and horticulture purposes.
- Agricultural Reuse
- Wetland and River/Stream flow Augmentation
- Industrial Reuse and Industrial processing
- Reuse by Construction Industry
- Ground Water Recharge
- Indirect and Direct Potable Use

Is water a economic good or human right??

High time to value water and use all kind of social and business model

Issues Influencing Outcome of Ganga Rejuvenation Plan

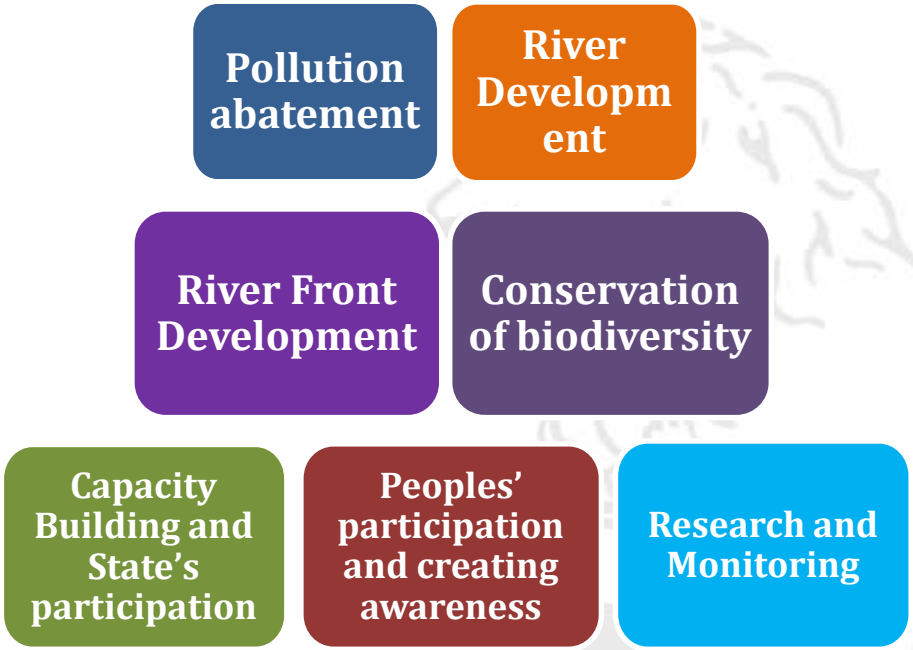
- Rejuvenation of river Ganga is a multi-dimensional activity involving social, economic, management, infrastructural and scientific and technological issues.

- aspects related to science and technology; management (regulatory; physical; financial and human resources), Operation and Maintenance (O&M) and awareness among stakeholders and training of personnel.

Issues Influencing Outcome of Ganga Rejuvenation Plan -contd

- **Awareness Generation. :** The stakeholders the affected population, the institutions involved, involved in appreciation the awareness and the ownership of the conservation programme.
- **Regulatory Framework:**
  - **Land use in the flood plain of Ganga and its major tributaries**: strict regulation is needed.
  - **Uninterrupted Supply of Electricity**
  - **Land acquisition of sewage pumping stations** and sewage treatment plants is a serious impediment in timely completion of Ganga works.
  - **Monitoring of the parameters of performance:** Selected parameters need to be monitored through automatic monitoring instruments. Such instruments can be online that enable round the clock monitoring and effective use.
  - **Strict enforcement of the regulatory provisions**
- **Critically Polluted Stretch:** from Haridwar to Allahabad Minimum flows For these stretches conservation of fresh water may be stored by using flexible inflatable weirs (rubber dams) of 3-4 m high.
- **Bio-monitoring of River Ganga with** Biological communities like macroinvertebrates and algae

Namami Gange- Thrust Areas



Essentials

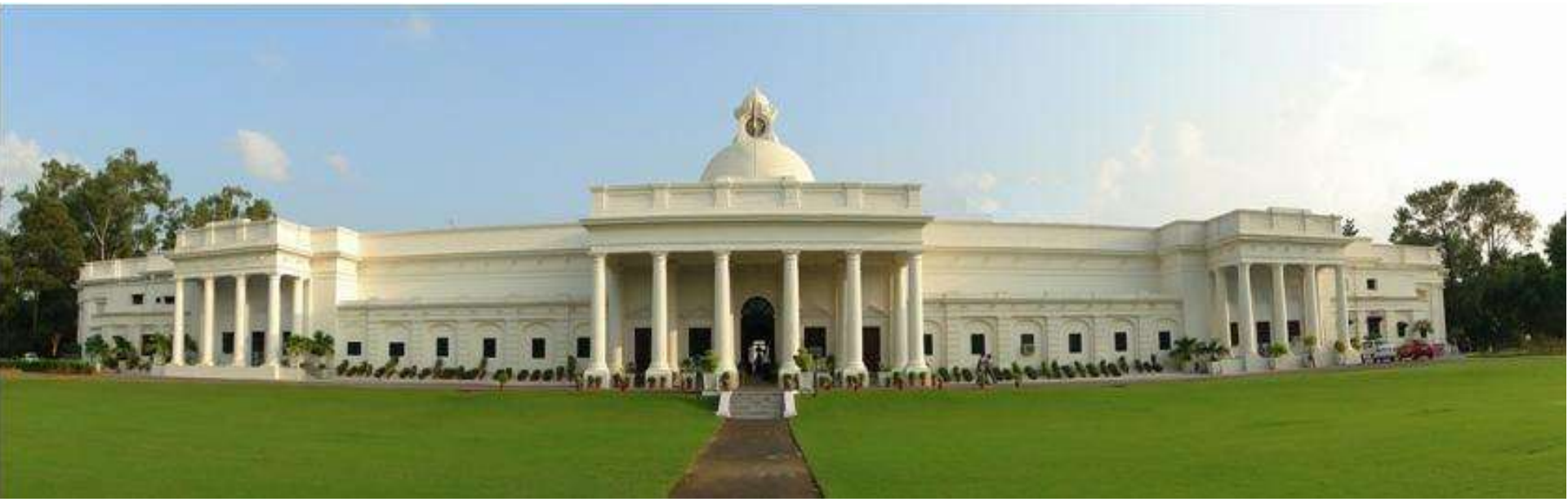
- Learning from previous GAP programmes
- Major role of States in implementation
- New interventions like biodiversity etc.
- Sustainability through communication, public outreach & participation
- Includes all tributaries and sub-tributaries of Ganga
- Dovetail with the schemes of other Ministries

Human Resource Development

Trained manpower required to

- monitor the environmental status of rivers and lakes,
- prepare and implement programme/projects/schemes of environmental conservation and
- operate and maintain the assets created for conservation of the water bodies

- We have rich reservoir of trained man power capable of dealing with various activities involved in this endeavor however conservation measures will become much more effective if the bodies such as the Municipalities/Municipal Corporations, State and Central Governments, consultants, Executing bodies and financial institutions etc have personnel who have been specially trained.
- Conventional programmes in environmental science and engineering are not adequate to offer this comprehensive requirement.



THANK YOU