SEDIMENT MANAGEMENT IN RUN-OF THE RIVER HYDROPOWER PLANTS IN HIMALAYAN REGION

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SEDIMENTATION PROBLEM

- Loss of storage capacity: Serious impact on water resources development by reducing water supply, **hydropower production, peaking capability**, the supply of irrigation water, and the effectiveness of flood control schemes.

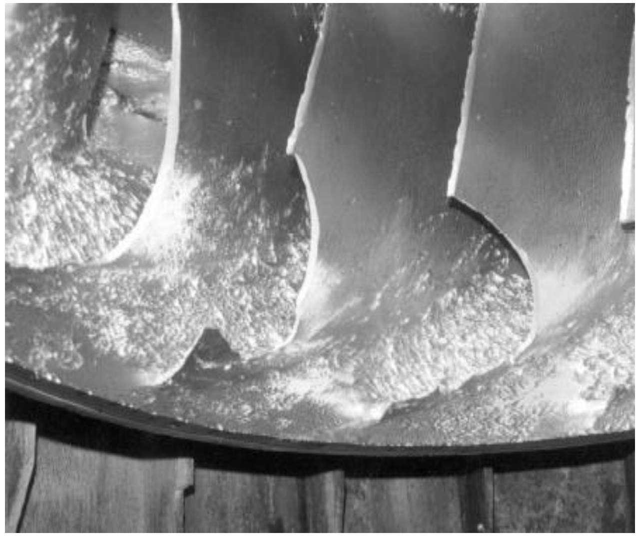
- **Growth of the delta deposits** at the upstream end of the reservoir cause **increased flooding** due to the backwater upstream.

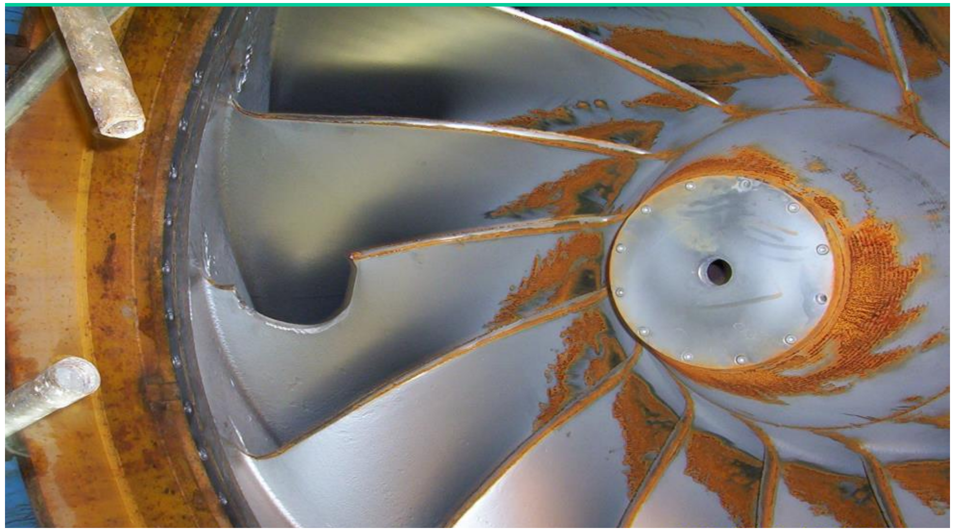
- **Damage** (erosion) of water conductor systems, turbines, spillways and other dam components, abrasion of underwater parts of turbines and eventually decrease in efficiency of turbine.

- Sedimentation at or near the dam face tend to **block the outlets** causing difficulties in operation of the gates.

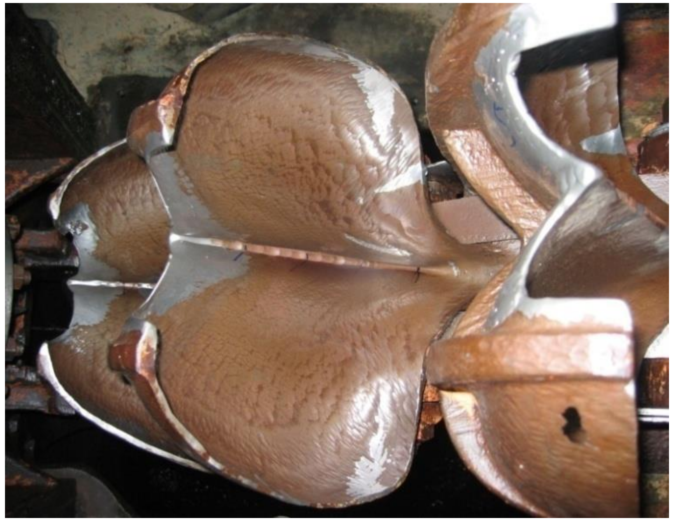
It is estimated that about 50% of the reservoir capacity shall be lost in next 50 years and entire capacity of reservoirs shall be lost in 200 years.

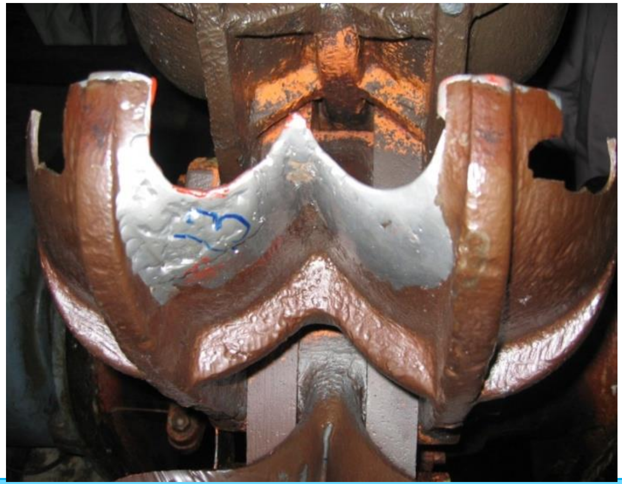
DAMAGE TO RUNNERS AND RUNNER BLADE

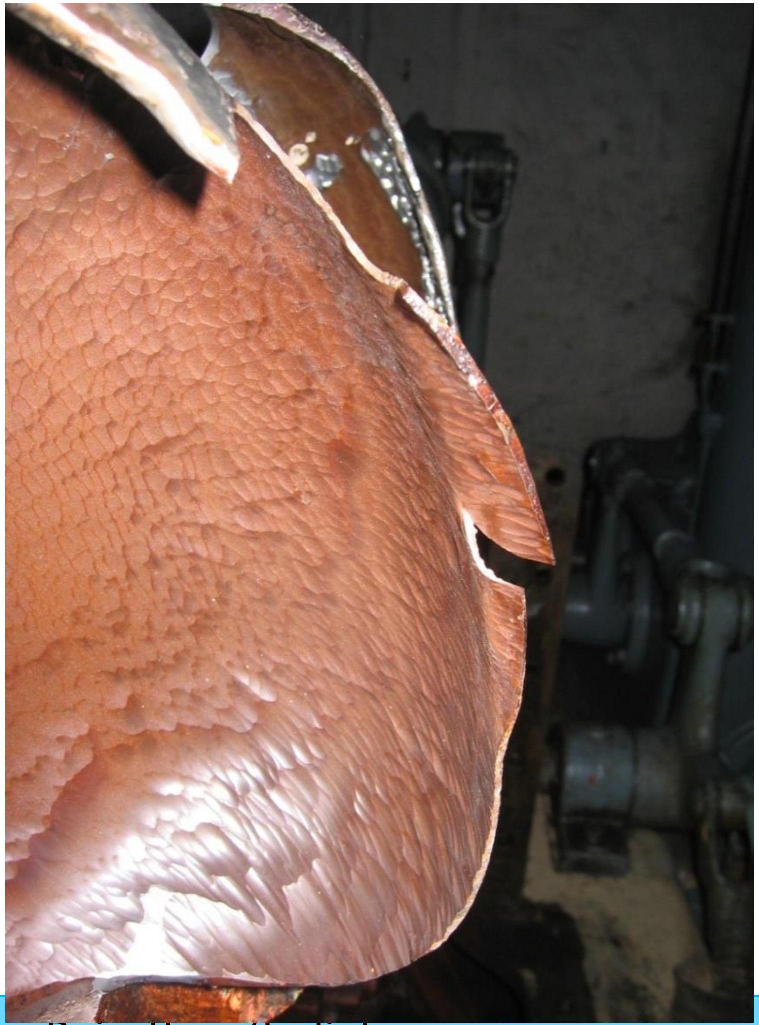




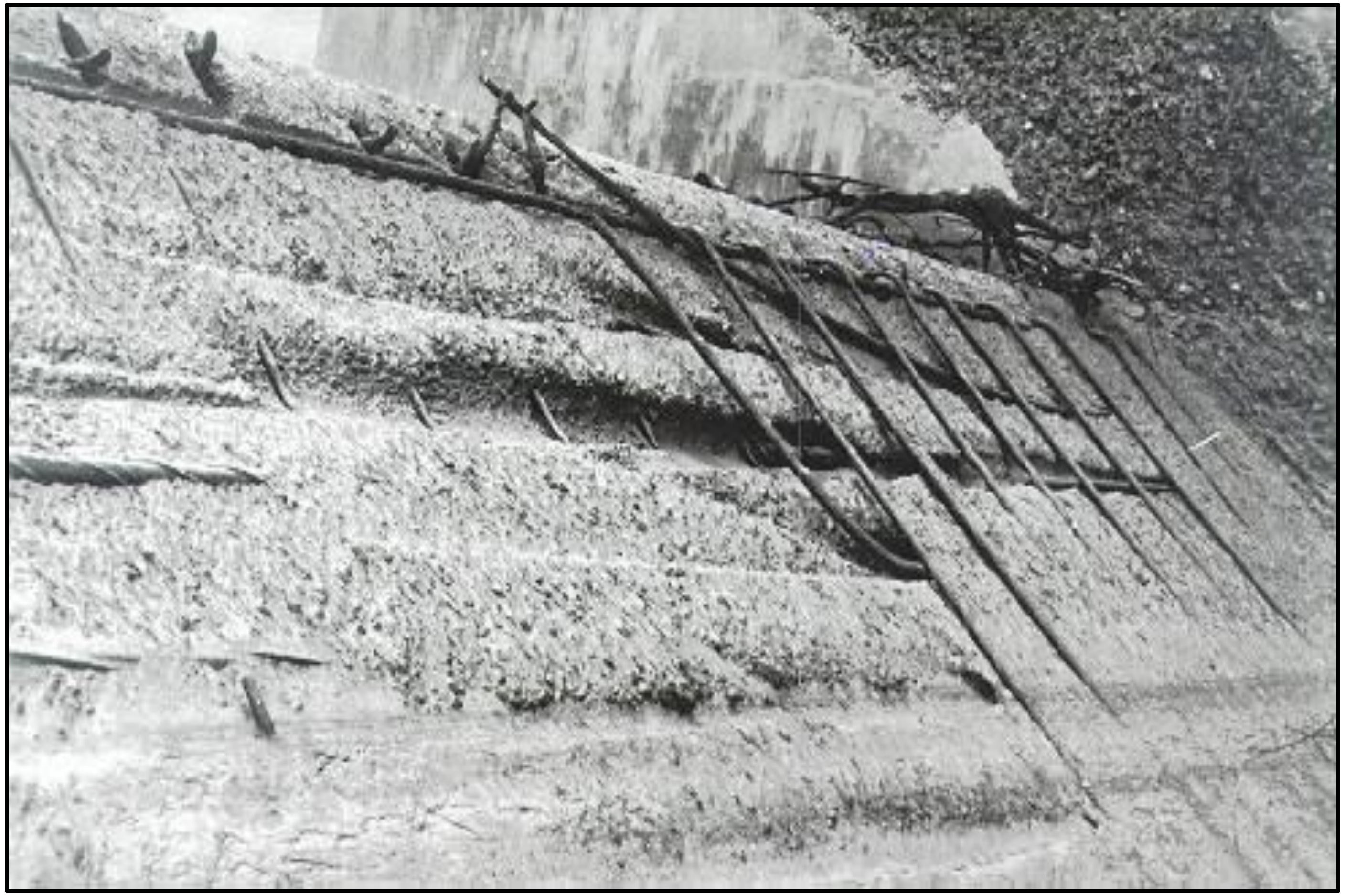
WEAR IN PELTON TURBINES
BUCKET SURFACE







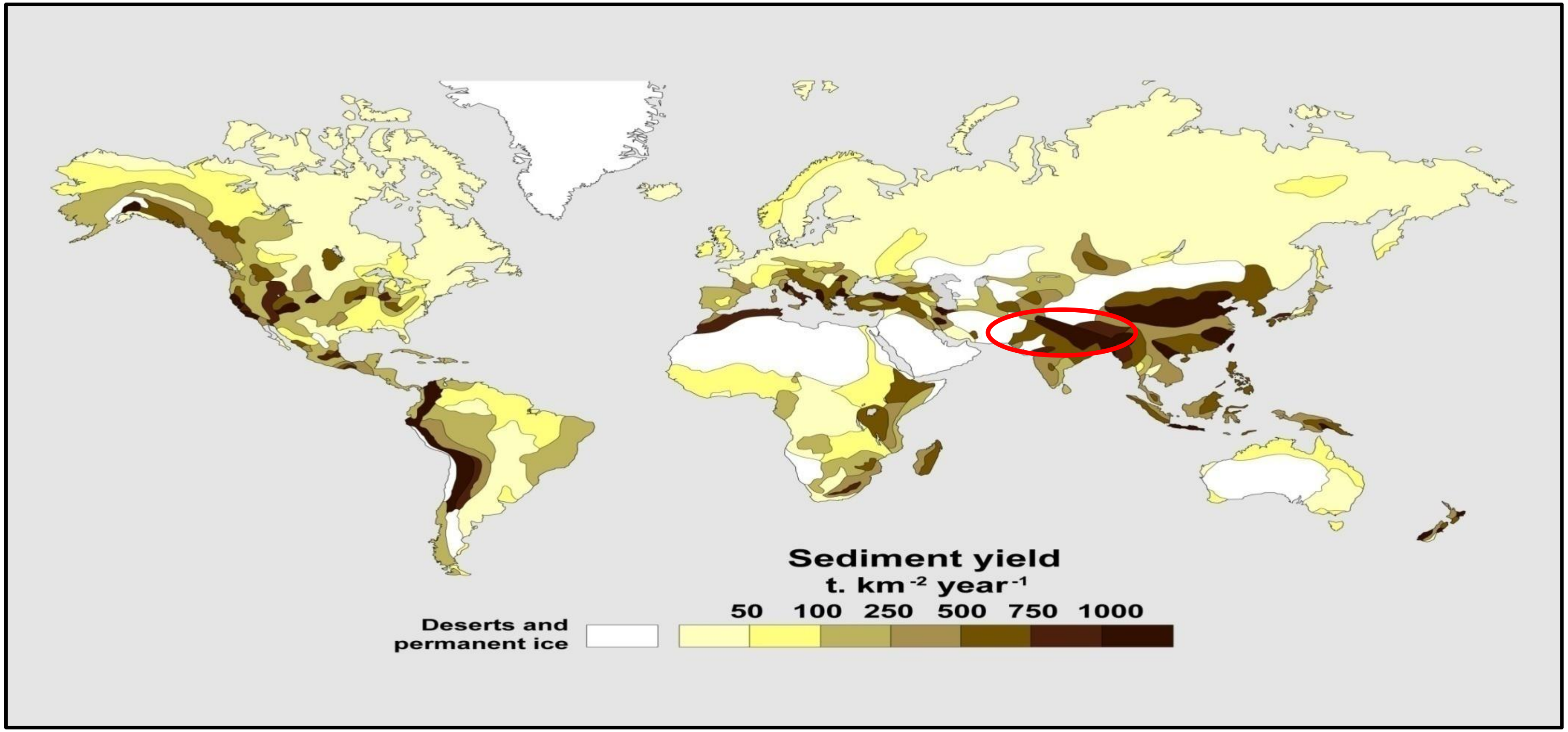
EROSION IN THE SPILLWAY BUCKET



LEAN SEASON
Clear Water

FLOOD SEASON
Muddy Water

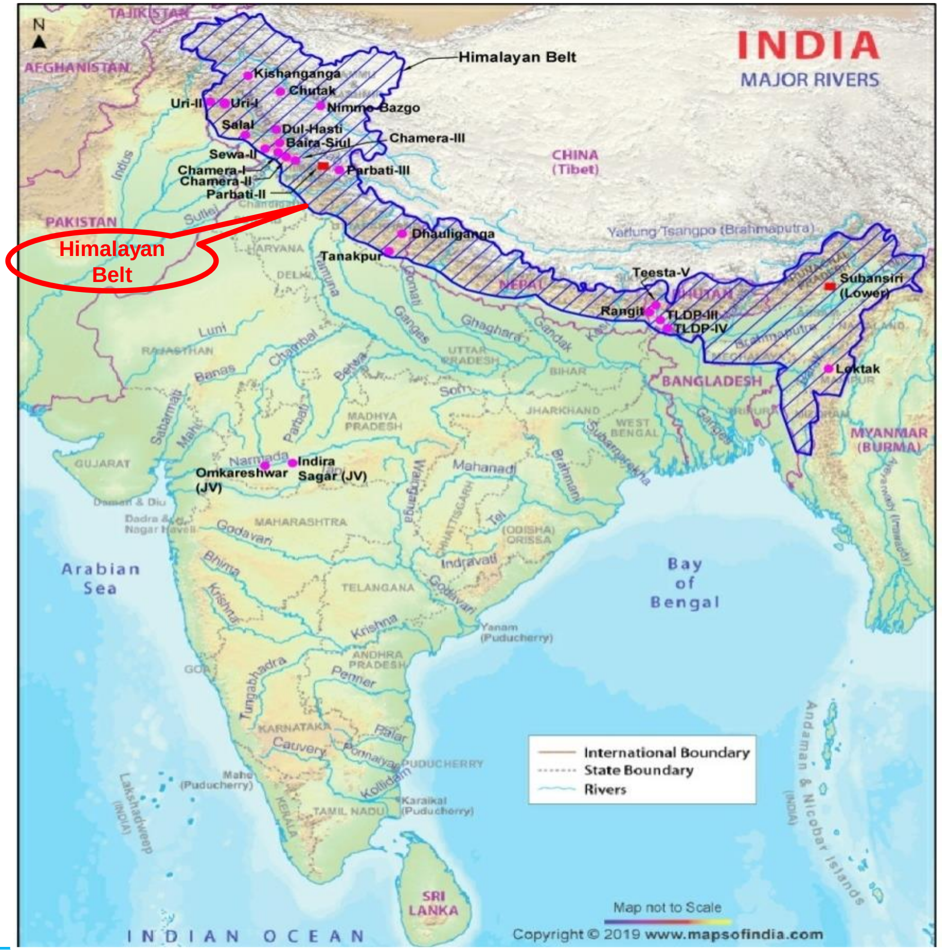
SEDIMENT YIELD IN DIFFERENT PARTS OF THE WORLD



Source : Walling and Web (1983)

SEDIMENTATION PROBLEM

PROJECTS/POWER STATIONS OF NHPC LIMITED



MOST OF THE PROJECTS /POWER STATIONS ARE LOCATED IN HIMALAYAS WHERE RIVERS CARRY FAR MORE SEDIMENT LOAD THAN NON-HIMALAYAN RIVERS .

More than 80% of Annual sediment load comes in Monsoon Season.

SEDIMENT MANAGEMENT TECHNIQUES

A) SEDIMENT YIELD REDUCTION:

- Catchment Area Treatment (CAT), afforestation etc are generally adopted in NHPC's Project as a part of EIA/EMP study. Integrated approach is adopted under CAT plan which includes various biological, engineering, and bio-engineering measures.
- Also lots of protection works are done to stabilize hill slope in the vicinity of reservoir and adjoining hill road sides, which reduces sediment inflow into reservoir.

B) DESILTING BASINS/CHAMBERS :

- Desilting basins are provided in the water conductor system of ROR hydropower projects to minimize the impact of damage due to suspended sediment on water conductor systems, turbine and other underwater parts.
- **However, providing desilting basin/chambers alone cannot help in maintaining the live storage of the plant. Generally, desilting basins are designed for 90 % removal of suspended sediment particles of size 0.2 mm and above**

SEDIMENT MANAGEMENT TECHNIQUES

C) SLUICING : (*Maintaining reservoir level at Lower* Level during Monsoon)

- To pass a large quantum of the incoming sediment through the spillway and reduced trap efficiency (due to reduction in capacity inflow ratio).
- Removal of fine/cohesive sediment prohibits consolidation of cohesive sediment particle which is difficult to scour once deposited.

D) DRAWDOWN FLUSHING

- **It re-mobilises the deposited sediment which passes through spillway.**
- Most effective if the reservoir is drawn down to the extent that the flow condition over the deposits approaches that of the original river.
- Recommended in the small size of the reservoirs preferably once in a month during monsoon.
- The flushing discharge : on the basis of 50% probability of occurrence of that discharge using inflow records.
- Also helps in clearing the trash collected in front of power intakes, which in turn improves the head available for power generation.

E) PROVIDING LARGE SIZED DEEP OUTLETS

Providing deep outlets in dam body of sufficient capacity at a level close **to original river bed and lower than intake crest level**, help in effective sediment management in reservoirs. The design consideration for shape, size and location of such outlets should be part of planning stage itself.

Benefits of Large Sized Deep Outlets (Guidelines)

ICOLD Bulletin 144 (Cost Savings in Dams) states ***"*****Where the siltation problems** may be important, these problems should be taken into account for the general layout of the various structures, such as; **water intake, bottom gates, spillways** and even possibly for the choice of the dam site and of the overall river utilization…"

ICOLD Bulletin 115 (Dealing with Reservoir Sedimentation) states"…**the ideal elevation of bottom outlets is at original river bed level, preferably not higher than relative water depth 0.15 to 0.2 from bed**."

"..low-level bottom outlets have been used as well, especially when the structure was also used for river diversion and/or if discharge of accumulated sediment in the reservoir was required."

"Large bottom outlets are normally used when the flushing of sediment is required…"

ICOLD Bulletin-67 (Sedimentation Control of Reservoirs) states ***"*****Outlet work must possess sufficient capacity for passing inflows through without excessive deposition of cohesive material taking place and / or to scour deposited material at suitable stages.*"***

" Sediment can only be passed through effectively if adequate discharge capacity is provided in the outlet work of a dam. **Ideally** it would be **possible** to pass the **biggest floods** through with the dam offering no resistance to the flows. *"*

SEDIMENT MANAGEMENT BY LARGE SIZED DEEP OUTLETS

EXAMPLES AROUND THE WORLD

The Three Gorges Project (22500 MW)(on Yangtze river, largest multipurpose project)

To satisfy this requirement for preserving the long term storage capacity for such a huge reservoir which is about 700 kms of length, the **23 bottom outlets have been provided at 85 m below the FRL.**

The Sanmenxia Reservoir (400 MW) located in middle reaches of the Yellow river.

- Maximum water level (MWL) is at El 340 m and dam top is at El 353 m.
- Due to heavy sediment deposition, the elevation of the riverbed at Tongguan (upstream town) increased by 4.5 m within 18 months of commissioning (1975).
- **Changed mode of operation** as a first step, and **started reconstruction** of outlets. Since then several steps have been taken to improve the sluicing capacity.
- **Two tunnels** were dug along the left bank at an elevation of **290m (50 m below MWL)** and **four of the eight penstocks were converted to sluiceways**.
- **8 of 12 diversion outlets of 280 m** elevation, which were used during construction, **were reopened**.
- After tunnel excavation and penstock conversion, 82.5 percent of the incoming sediment was released by lowering the water level within the reservoir during flood season.

SEDIMENT MANAGEMENT BY LARGE SIZED DEEP OUTLETS (INDIAN EXAMPLES)

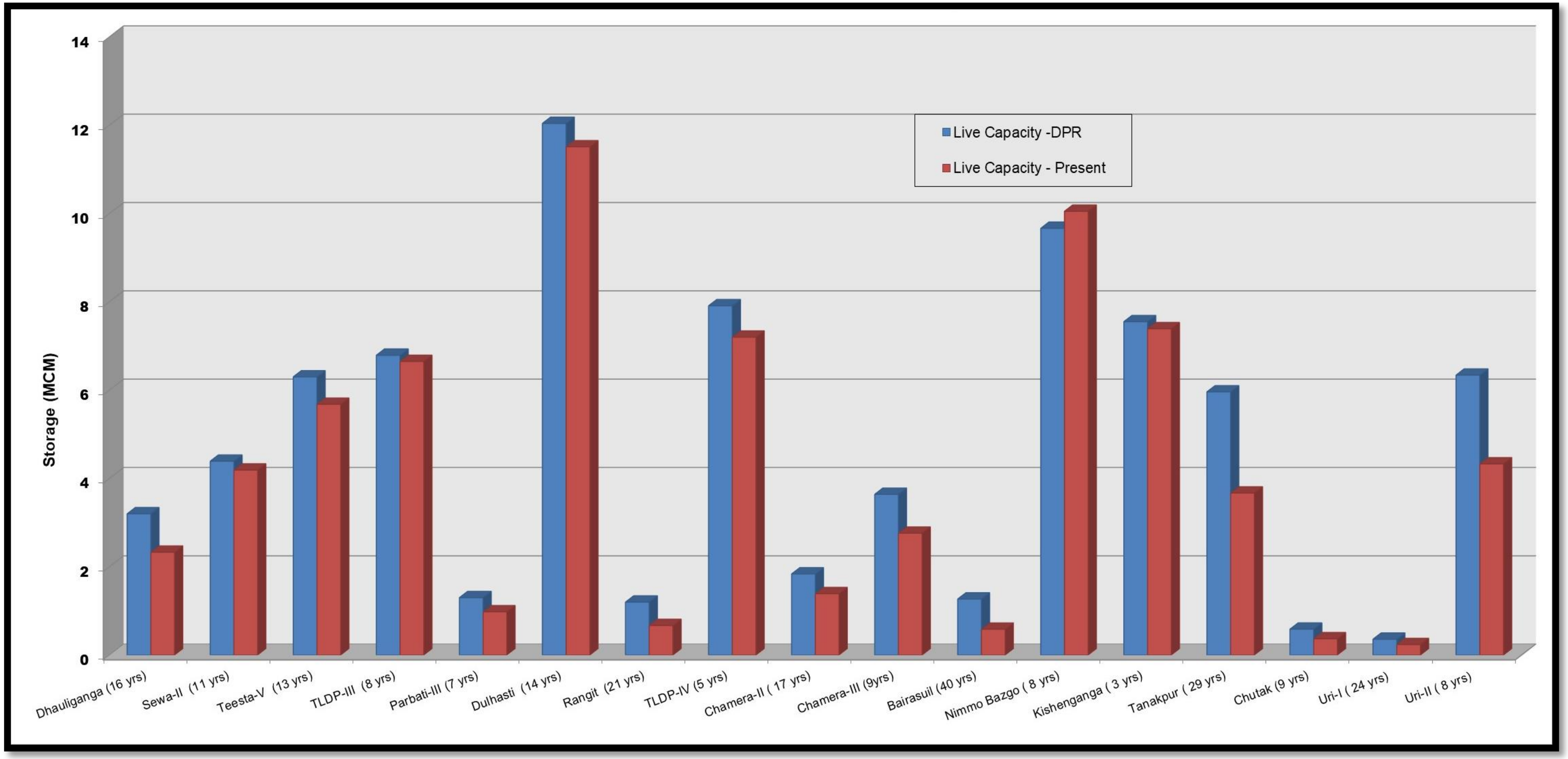
Salal Power station (690 MW)

- Large sized deep outlets not provided

- Capacity reduced drastically (with avg annual load of 30 MCM) in initial few years of operation by about **97%.**

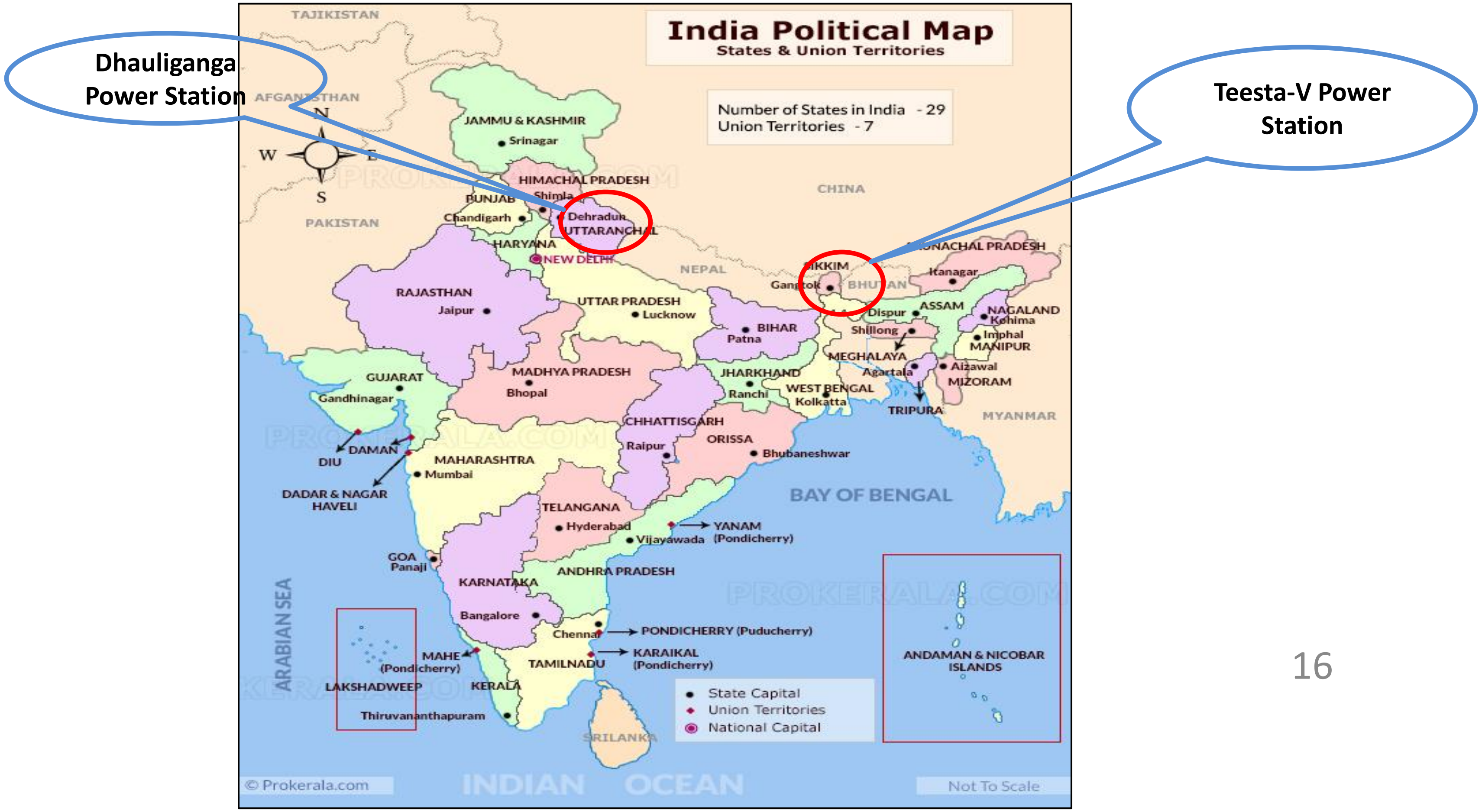
Name of the Project	Height of the dam in (m)	FRL in (m)	Spillway Crest Level in (m)	Spillway gate Nos and Size (WXH)(m)
Chamera II (300 MW)	43	1162	1141	4 Nos , 15 X 21.5
Dhauliganga (280 MW)	55	1345	1307	3 Nos , 6 X 10
Teesta V (510 MW)	52.2	579	540	5 Nos , 9 X 12
Subansiri Lower (2000 MW)	125	205	145	9 Nos , 11.5 X 14
Chamera III (300 MW)	68	1397	1360/1381	3 Nos , 12.5 X 16 1 No , 9 X20
Parbati III (520 MW)	43	1330	1298	2 Nos , 7.2 X 14
Chamera III (231 MW)	55	1397	1360	3 Nos , 12.5 X 16.5
Sewa II (120 MW)	53	1197.5	1168	4 Nos , 7 X 10.8
Dulhasti (390 MW)	65	1266.5	1225	4 Nos , 9 X 9.5
Rangit (60 MW)	43	639	620	3 Nos , 9 X 12
Nimmo Bazgo (45 MW)	59	3093	3065	5 Nos, 7 X 9
TLDP III(132 MW)	32	208	183	7 Nos, 14 X 14
TLDP IV (160 MW)	30	182.3	157	7Nos , 11X 17
Kishanganga (330 MW)	37	2390	2370	3 Nos, 7 X 9.5

COMPARISON OF RESERVOIR CAPACITIES IN NHPC's POWER STATIONS



LOCATION OF POWER STATIONS UNDER STUDY

NHPC



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CASE STUDY- TEESTA-V POWER STATION

(Gross - 13.52 MCM, Live-6.28 MCM, initially)
Gross – 10 MCM , Live- 5.33 MCM , 2021)
and length of reservoir at FRL is 5.1 km.

Average annual sediment load	10 MCM

TEESTA-V POWER STATION

RESERVOIR OPERATION AND SEDIMENT MANAGEMENT

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- Teesta-V power station (commissioned in 2008), is in Teesta Basin, of North East India.
- The Dam top, FRL, MDDL and river bed levels of project are El 583.2 m, 579.0 m, 568.5 m and El 531 m respectively.
- The Concrete Gravity Dam is 52 m high with five spillways of size 9.0m x 12.0 m at EL 540.0m i.e. **39 m below** Full Reservoir Level (FRL) acting as **large size low level outlets** to safely pass flood and sediment**.**
- During flood season, the reservoir level is brought down from FRL (EL 579 m) to **0.5 m above MDDL i.e. EL 568.5 m**.
- Considering the size of the reservoir, inflow and quantity of sediment, **drawdown flushing along with sluicing** is practiced through low level spillway.
- **4 flushings**, 1 in each monsoon month, are carried out from June to September.

TEESTA-V POWER STATION

NHPC

PROPOSED FLUSHING DISCHARGES IN DIFFERENT MONTHS

Period	Flushing to be done when discharge (cumec) exceeds
1st June to 30th June	800
1st July to 31st July	1000
1st’ Aug to 31st Aug	800
1st’ Sep to 30th Sep	700

Note: If discharge does not exceed the specified discharge, flushing to be carried out on the last day of the month, irrespective of discharge so that majority of sediment deposited during the month gets flushed out from the reservoir.

SEDIMENT SIZE

RESERVOIR FLUSHING

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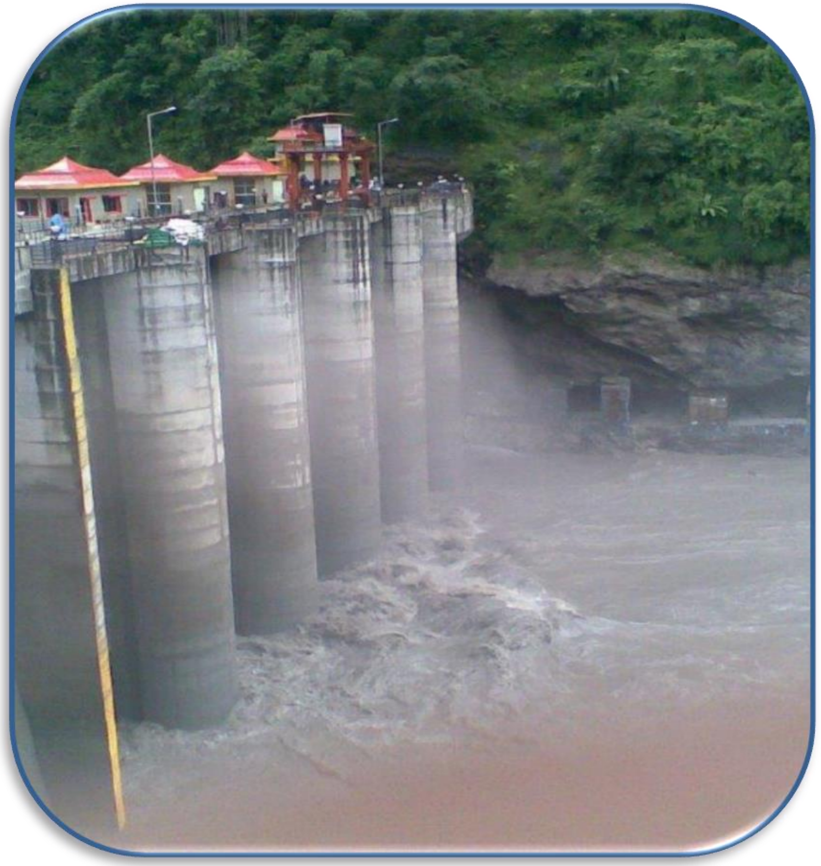


Huge Sediment deposition at Intake (2020-21)

TEESTA-V POWER STATION

RESEROIR SEDIMENTATION

- The sediment got deposited within first year and reduction in gross and live capacity was 21% and 10.3% respectively. **This loss in capacity was majorly due to full deposition upto spillway crest, as expected as there was no opening below this level.**

- Due to present practice of sedimentation management **with low level outlets and drawdown flushing and sluicing,** after 14 years of operation, the live capacity is maintained at 5-6 MCM as compared to initial live capacity of 6.3 MCM.

- Due to adopted sediment management technique, stable regime could be attained in the shape of pseudo–river. Sediment bed remains below spillway crest level i.e EL 540 m, indicating the effectiveness of low level spillway provided in dam body and effectiveness of drawdown sluicing and drawdown flushing.

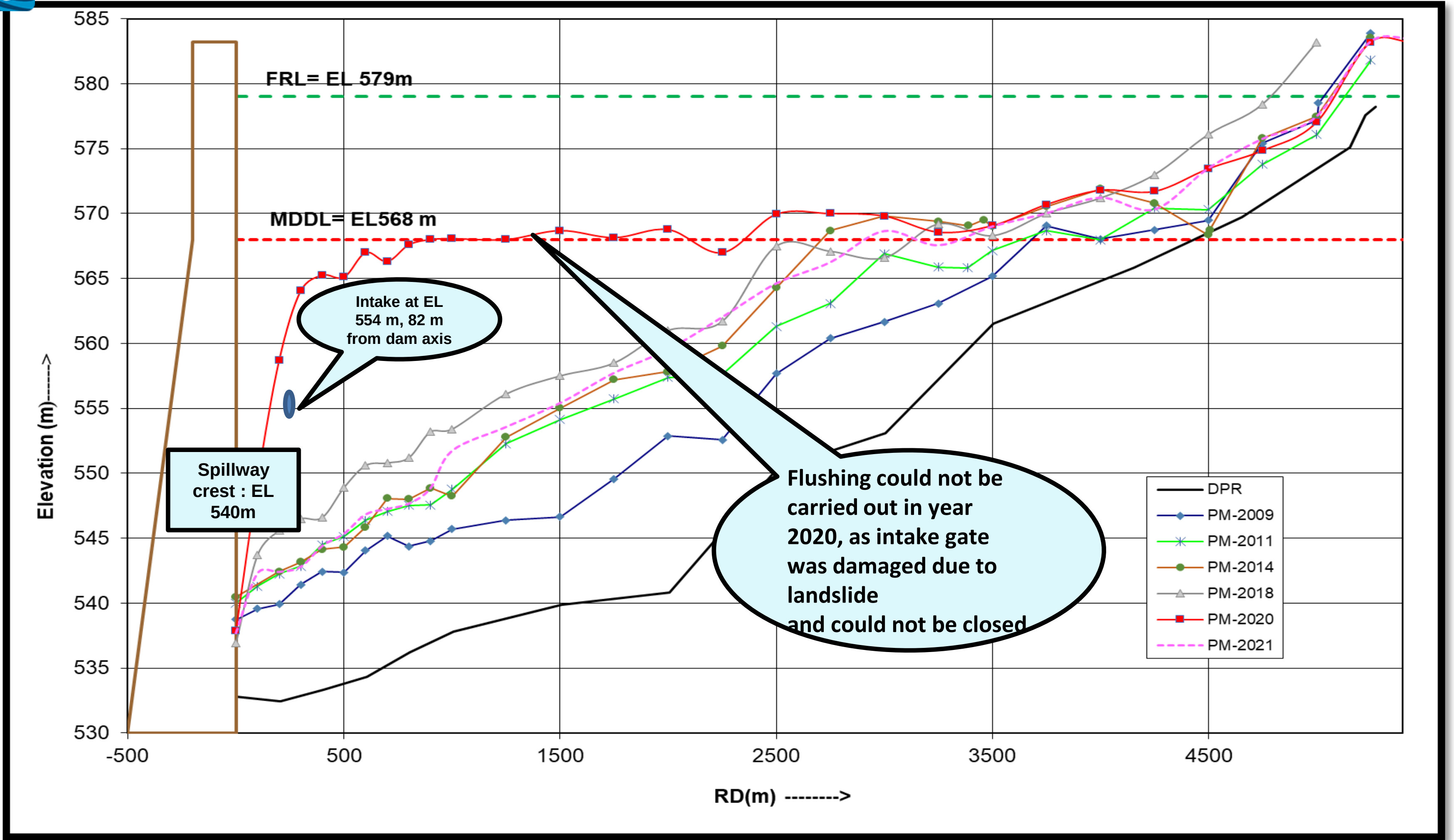
NHPC

TEESTA-V POWER STATION

- Drawdown flushing in combination with sluicing **could not be carried out in the year 2020**, as intake gate was damaged due to landslide and could not be operated.
- It was seen that due to non-application of proper sediment management techniques in 2020 Monsoon (flushing & sluicing) **there is a reduction in capacity by about 40%.** It also led to more damages to underwater parts.
- **Subsequently during 2021 monsoon aggressive drawdown flushing was carried out, which helped in recouping the reservoir capacities (gross and live) to great extent.**

SURVEY YEAR	GROSS CAPACITY (MCM)	LIVE CAPACITY (MCM)
DPR	13.52	6.28
PM-2009	10.71	5.62
PM-2010	9.85	5.50
PM-2011	9.79	5.43
PM-2014	9.61	5.44
PM-2016	8.50	5.40
PM-2017	8.70	5.32
PM-2018	9.30	5.60
PM-2020	5.90	5.26
PM-2021	10.00	5.68

L-SECTION OF TEESTA-V RESERVOIR FOR DIFFERENT YEARS

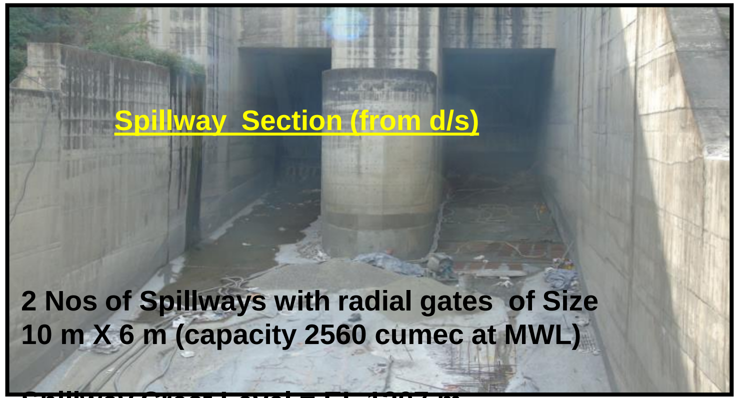


CASE STUDY

NHPC

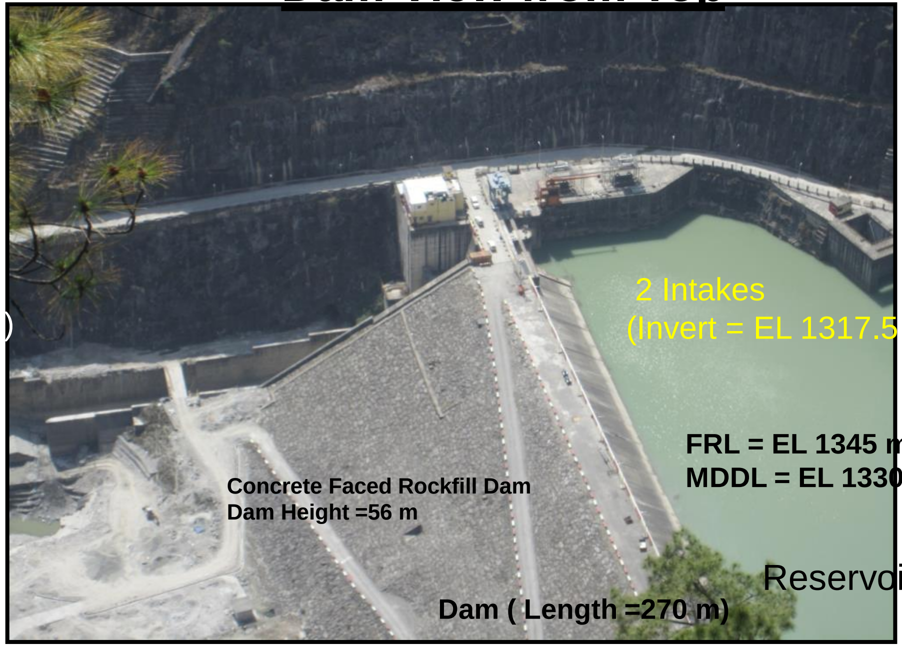
DHAULIGANGA POWER STATION (280 MW)
COMMISSIONED IN 2005, IN UTTARAKHAND

Dam View from Downstream



Spillway Crest Level = EL 1307 m

Dam View from Top



Gross Storage at FRL (MCM)	6.2 (Original); 3.24 (PM 2018)
Live storage (MCM)	3.2 (Original) ; 2.33 (PM 2018)

DHAULIGANGA POWER STATION

RESERVOIR OPERATION AND SEDIMENT MANAGEMENT

- Dhauliganga power station, commissioned in 2005, is in Sharda Basin, of India. Dhauliganga dam is a 55 m high CFRD dam with two spillways of size 6.0m x 10.0 m at EL 1307.0m i.e. 38 m below Full Reservoir Level (FRL) **acting as low level outlets.**

- For effective **sluicing** during monsoon, the reservoir is being maintained at near MDDL (EL 1330 m) for discharges more than the design discharge requirement of machines.

- If the inflow in the river is less than design discharge, reservoir level is kept between EL 1330 m to EL 1340 m.

- Further due to heavy inflow of sediment load and small size of reservoir, at present 7 nos. of **drawdown flushings** per year is in practice for effective management of sediment

DAMAGES CAUSED BY SEDIMENT DURING YEAR 2013 FLOOD

SCOURING AND EROSION BELOW APRON AREA

TRT OUTLET IN COMPLETELY CHOKED CONDITION

EROSION IN GLACIS OF DHAULIGANGA DAM SPILLWAY

EROSION IN PIER OF DHAULIGANGA DAM SPILLWAY

RBM filled in Reservoir Near Dam

RBM filled at Reservoir Tail end

SEDIMENT FILLED IN RESERVOIR DURING YEAR 2013 FLOODS

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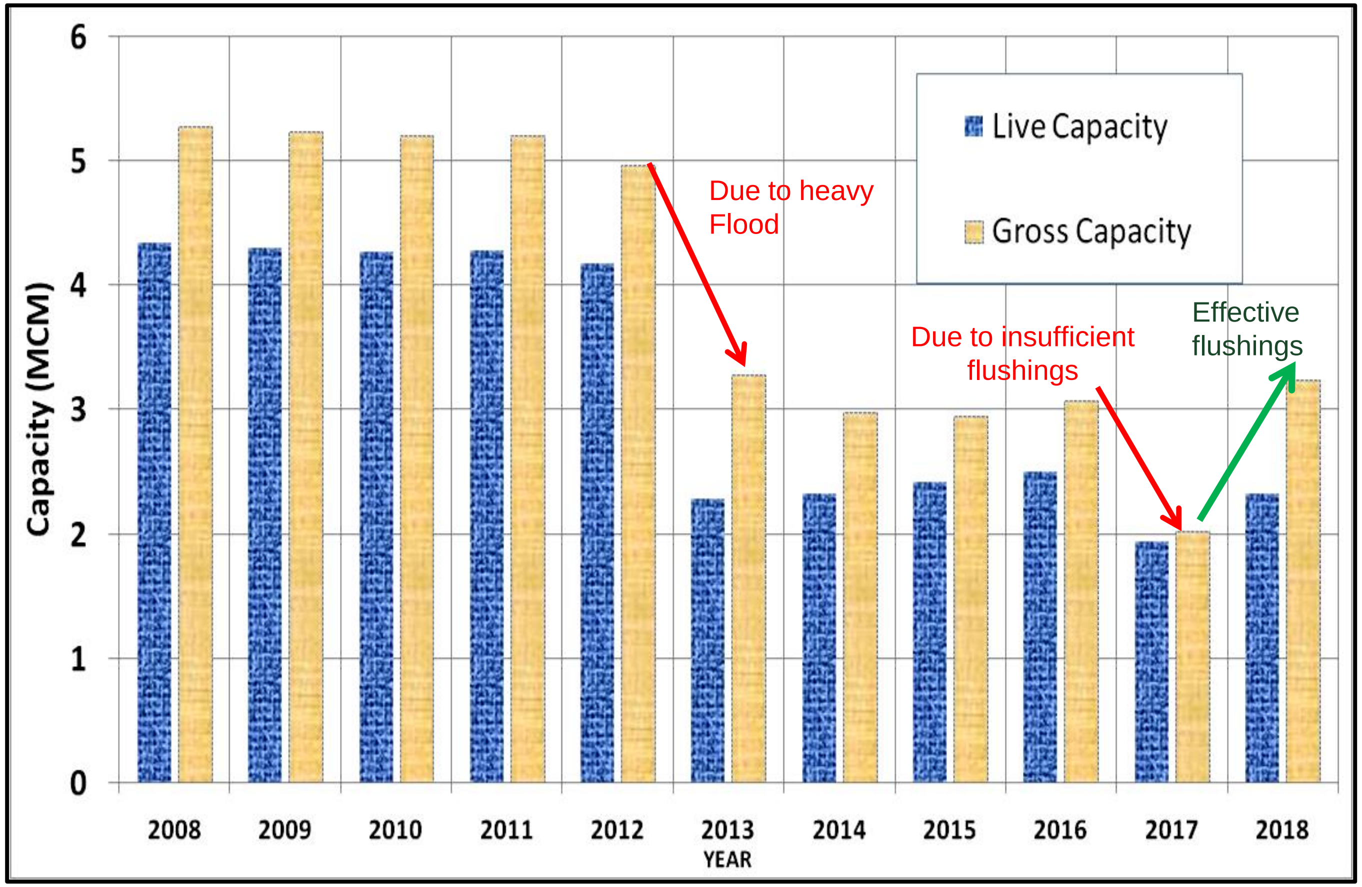
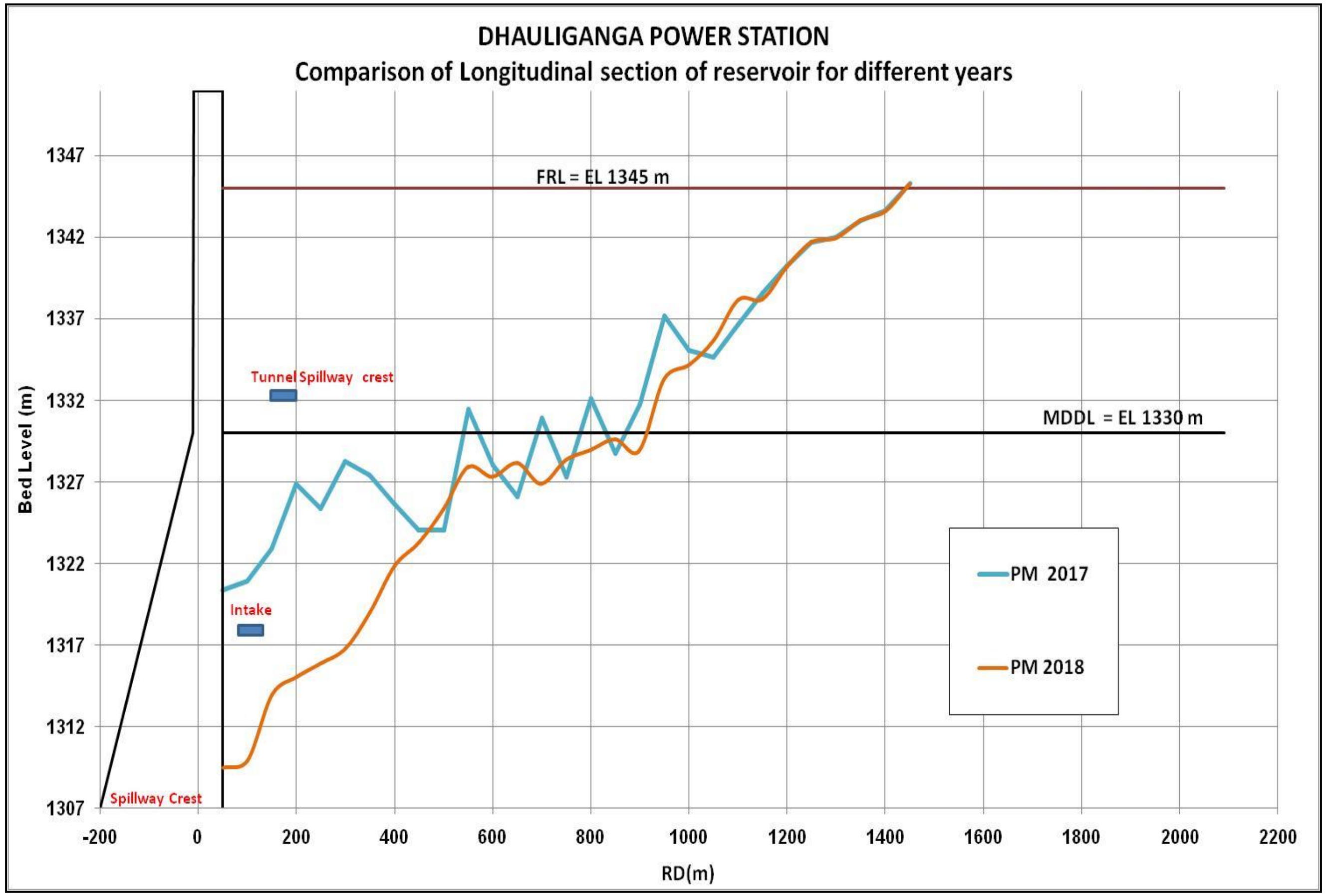
DHAULIGANGA POWER STATION
RESERVOIR CAPACITIES OVER THE YEARS



DHAULIGANGA POWER STATION: RESERVOIR CAPACITIES POST MONSOON 2017 AND POST MONSOON 2018



In 2017, power station could manage to conduct **only 3 flushings** and sluicing, thereby decreasing gross capacity again from **3.08 MCM to 2.03 MCM** in year 2017.

In year 2018, power station conducted almost **all proposed flushing** during the monsoon, thereby increasing the gross capacity from **2.03 MCM to 3.24 MCM**, which proved the effectiveness of sediment flushing (in combination with sluicing) in removing the deposited sediment from the reservoir.

CONCLUSION

- Himalayan rivers carry much more sediment load than the capacities available in the reservoirs of run of the power stations located in this region.
- NHPC is operating several power stations in Himalayan region and has been successful in maintaining gross/live capacity of reservoirs of these power stations satisfactorily **by way of low-level spillway, drawdown flushing and sluicing.**
- Due to present practice of sedimentation management, reduction in live capacity in Tessta-V is only 9% in 13 years and 27% in Dhauliganga in 16 years .
- In **Teesta-V PS**, **drawdown flushing and sluicing** could not be carried out in the year **2020**, due to technical reasons, which led to **reduction of capacity by about 40%** and more damages to underwater parts**, which was recouped in 2021 by aggressive flushing.**
- In **Dhauliganga PS, drawdown flushing and sluicing** could not be carried out in the year **2017, which reduced reservoir capacity by about 34%,which was recouped in 2018 by aggressive flushing.**
- In Salal Power station, due to non availability of low-level outlets the reservoir **capacity got reduced by about 97% in** only few years which indicated need of deep and wide outlets for maintaining useful life of reservoir.
- **Hence, combinations of large sized low-level spillways drawdown sluicing/reservoir flushing during monsoon season is found to be the most optimum, practical techniques with least cost involved to manage the reservoir sedimentation.**


THANK YOU
धन्यवाद

COMPARISON OF RESERVOIR CAPACITIES IN NHPC's POWER STATIONS

Name of the Power Station	DPR Storage		Present Storage		Year of Latest Reservoir Survey	Years since commissioning	% loss in live capacity since commissioning
	Gross Storage (MCM)	Live Storage (MCM)	Gross Storage (MCM)	Live Storage (MCM)			
Bairasuil	3.8	1.3	0.9	0.6	PM 2018	40	54%
Rangit	1.9	1.2	0.7	0.7	PM 2021	21	44%
Chamera-II	2.2	1.8	1.7	1.4	PM 2018	17	24%
Dhauliganga	6.2	3.2	3.2	2.3	PM 2018	16	27%
Dulhasti	13.0	12.0	12.5	11.5	PM 2021	14	4%
Teesta-V	13.5	6.3	10.0	5.7	PM 2021	13	10%
Sewa-II	7.1	4.4	5.9	4.2	PM 2021	11	5%
Chamera-III	5.5	3.6	3.2	2.8	PM 2020	9	24%
TLDP-III	18.4	6.8	10.7	6.7	PM 2021	8	2%
Nimmo Bazgo	52.8	9.7	20.7	10.1	PM 2021	8	-4%
Parbati-III	1.7	1.3	1.2	1.0	PM 2018	7	25%
TLDP-IV	36.6	7.9	16.0	7.2	PM 2021	5	9%
Kishenganga	18.6	7.6	14.57	7.39	PM 2020	3	2%
Tanakpur	6.0	_	3.7	_	PM 2021	29	
Chutak	0.6	_	0.4	_	PM 2021	9	
Uri-I	0.4	_	0.2	_	PM 2021	24	
Uri-II	6.3	_	4.3	_	PM 2018	8	
Salal	284.1	_	12.8	_	PM 2020	27	