CLIMATE-RESILIENT DAMS AND

HYDROPOWER INFRASTRUCTURE

INTEGRATING

ENVIRONMENTAL SUSTAINABILITY

IN PLANNING AND DEVELOPMENT

HEAVY WATER INGRESS IN DEEP SEATED FOUNDATION GALLERIES OF OPERATIONAL DAMS ISSUES, CHALLENGES & REMEDIAL MEASURES- A CASE STUDY OF NTPC KOLDAM

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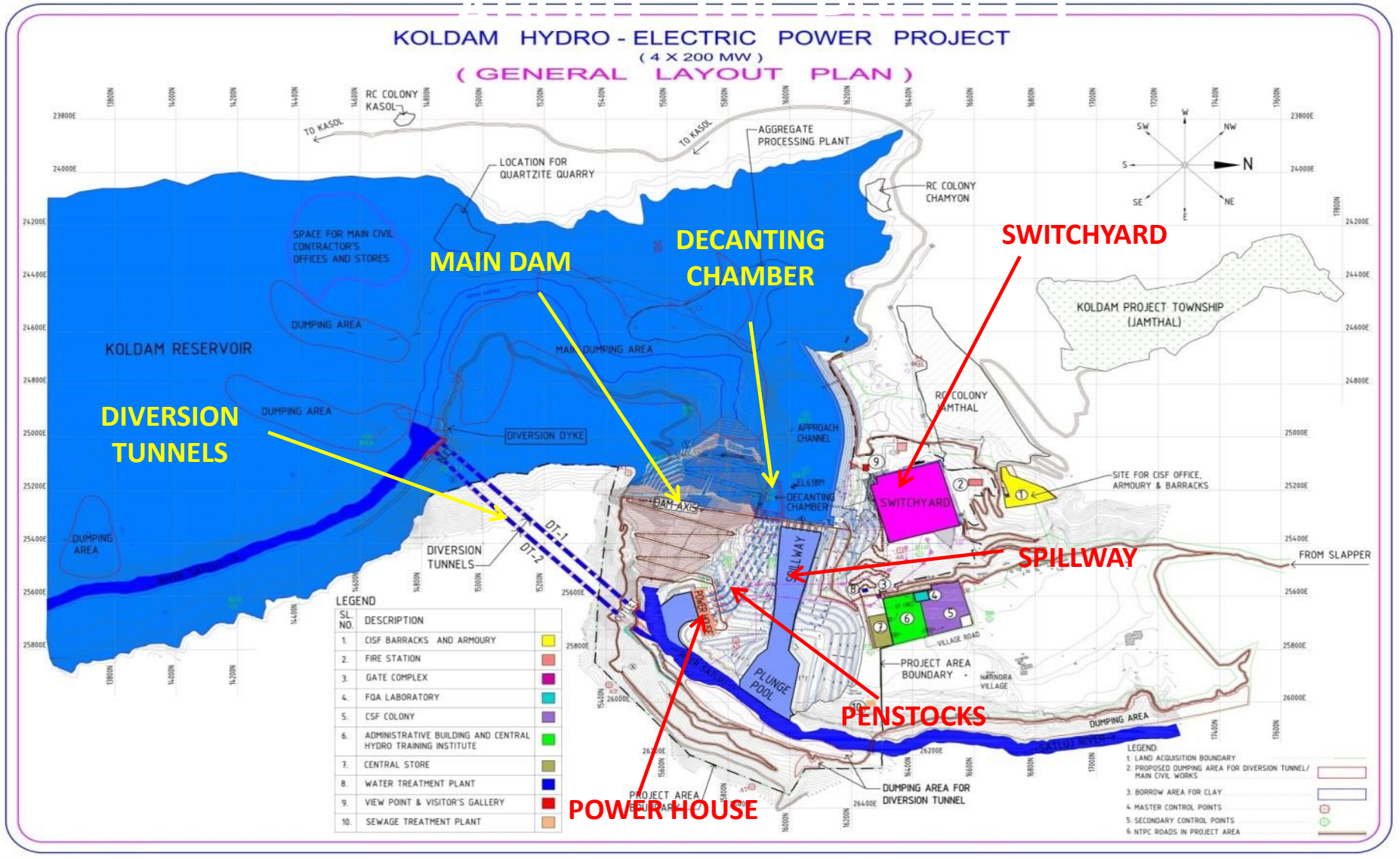
NTPC KOLDAM, INDIA

OUTLINE OF PRESENTATION

- ✓ **About NTPC Koldam**
- ✓ **A Case Study**
  - *NTPC Koldam: Dam Type, Foundation Gallery location & approach*
  - *Details about the Issue of Heavy Water Ingress*
  - *Engineering Solution*
  - *Execution*
  - *Issues/Challenges Vs availability of Guidelines/Standard*
- ✓ **Conclusions**

ABOUT NTPC KOLDAM

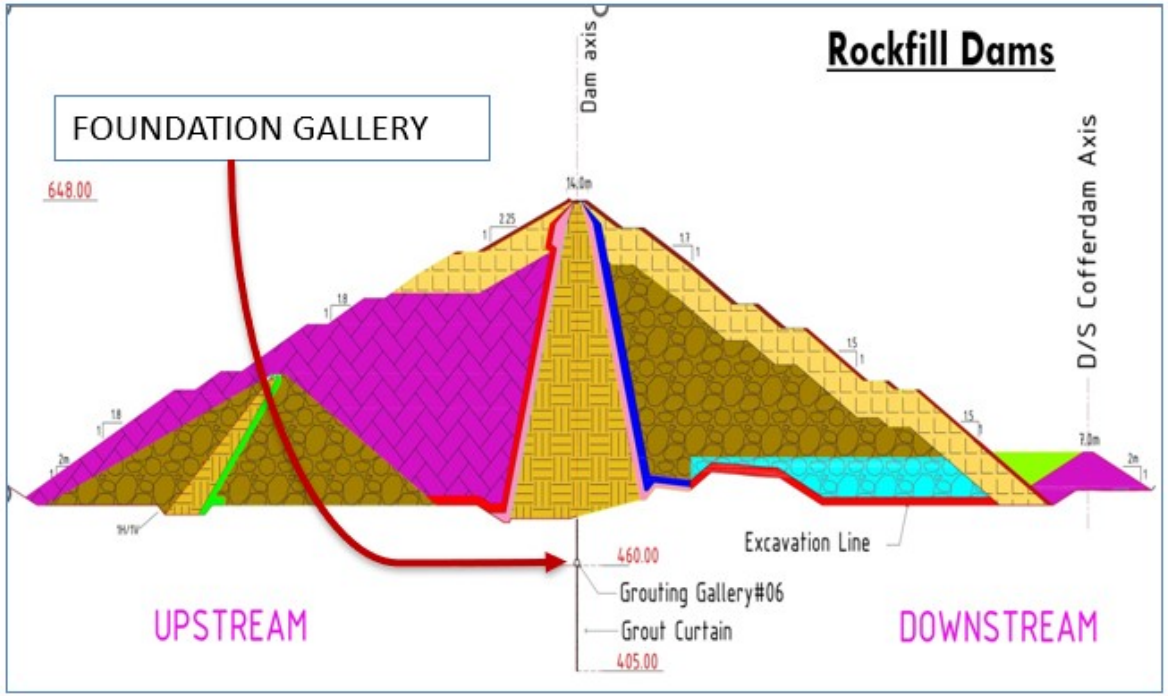


- ✓ The 2nd tallest Rockfill dam of India.
- ✓ ROR Scheme with additional Storage of 30 Yrs.
- ✓ Located on Sutlej River, Bilaspur (HP)
- ✓ Gross capacity: 576MCM
- ✓ Dead Storage: 486 MCM
- ✓ Live Storage: 90 MCM
- ✓ Installed Capacity: 4 X 200 MW
- ✓ Design Energy: 3054 MUs

- ✓ COD 18-July-2015

ABOUT KOLDAM CONTD….

Koldam Hydroelectric Plant



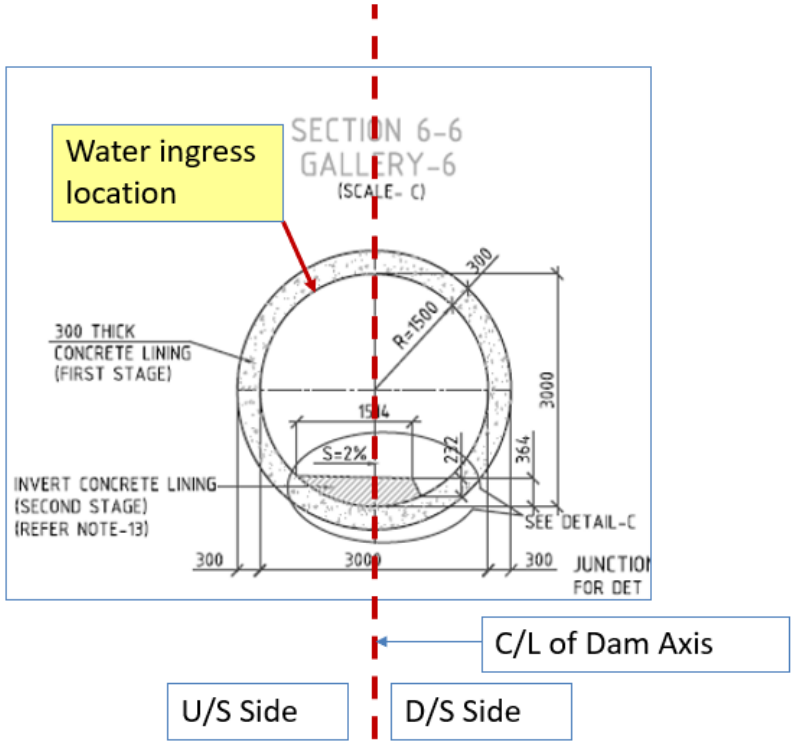
TYPICAL CROSS-SECTION OF ROCKFILL DAM SHOWING FOUNDATION GALLERY

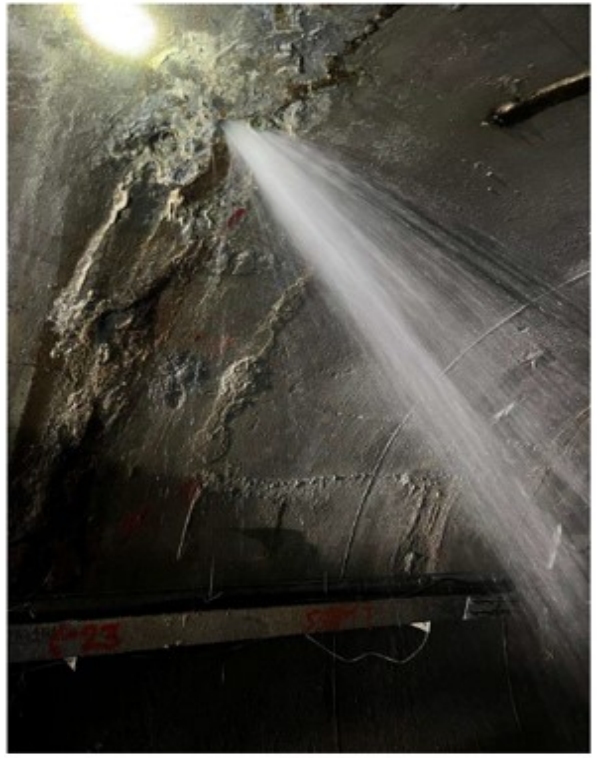
• A CASE STUDY

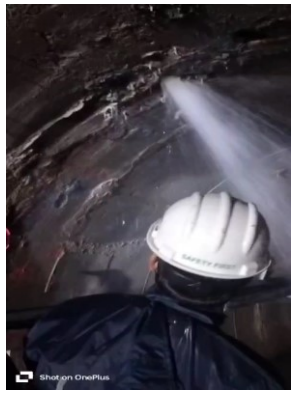
Heavy Water Ingress in Deep Seated Foundation Gallery of Dam–Challenges & Remedial Measures

DETAILS OF HEAVY WATER INGRESS IN FDN GALLERY

- ✓ Heavy water ingress in Dam foundation gallery was observed on 18.01.2025.
- ✓ This Gallery is concrete lined (Plain concrete), 3m finished diameter & 160m long .
- ✓ Water ingress was observed at RD 55M & 11 O'clock position, D/s side.
- ✓ Discharge measured was of the order of 330 to 350 lpm

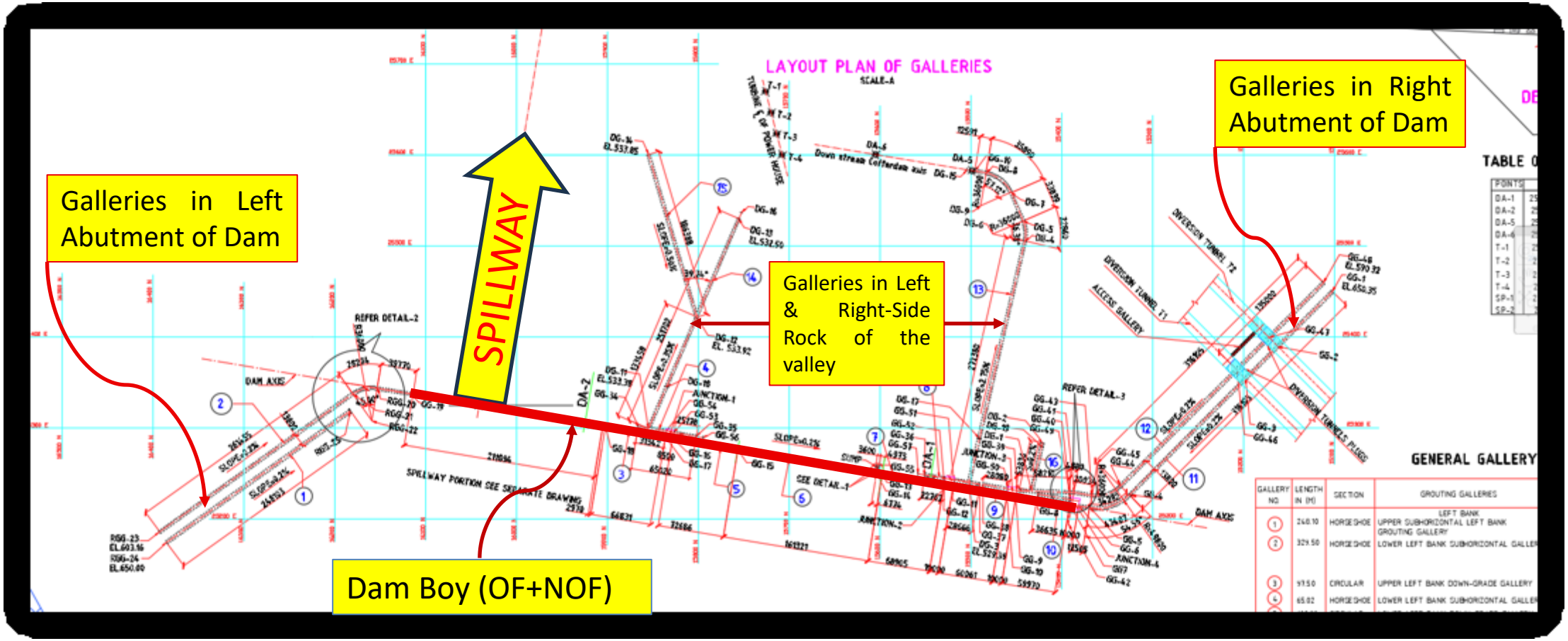




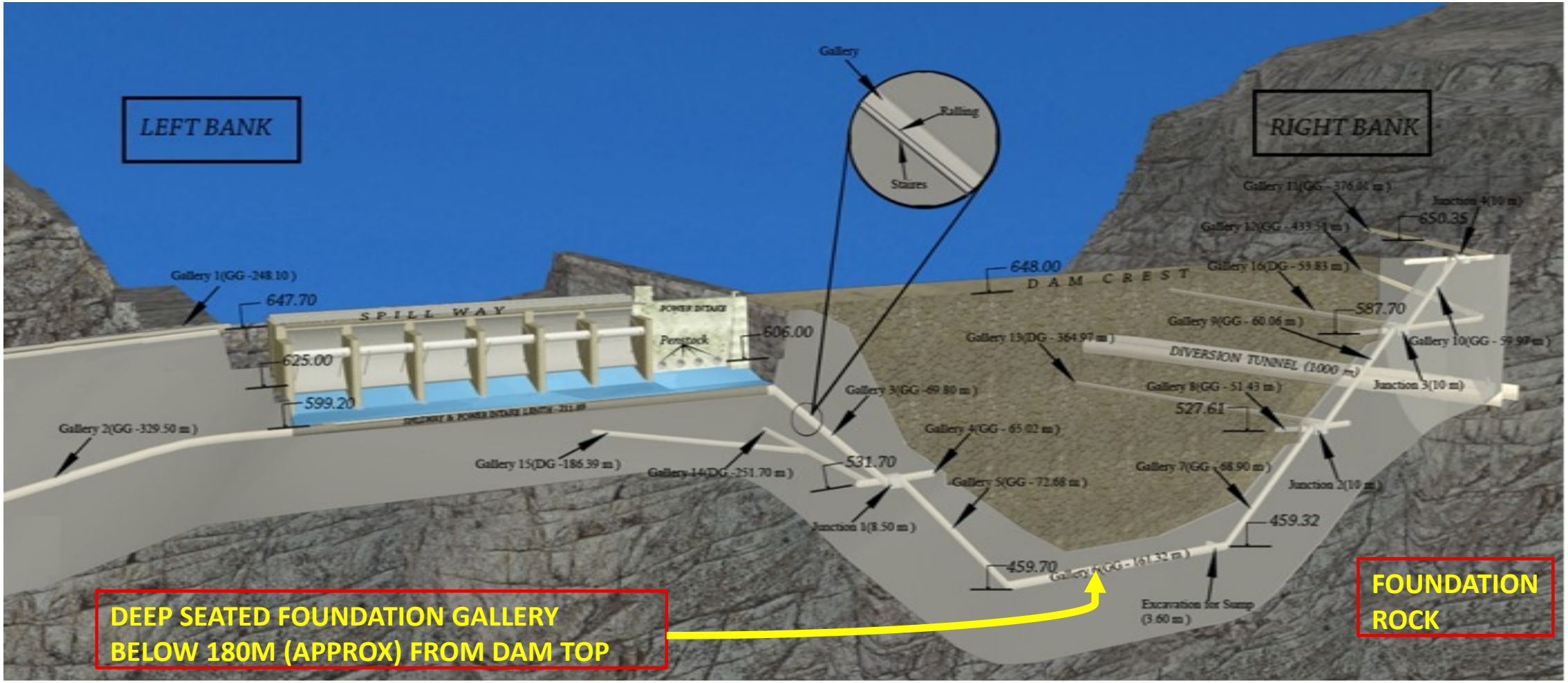


LOCATION OF FDN GALLERY –WHERE LEAKAGE OCCURED

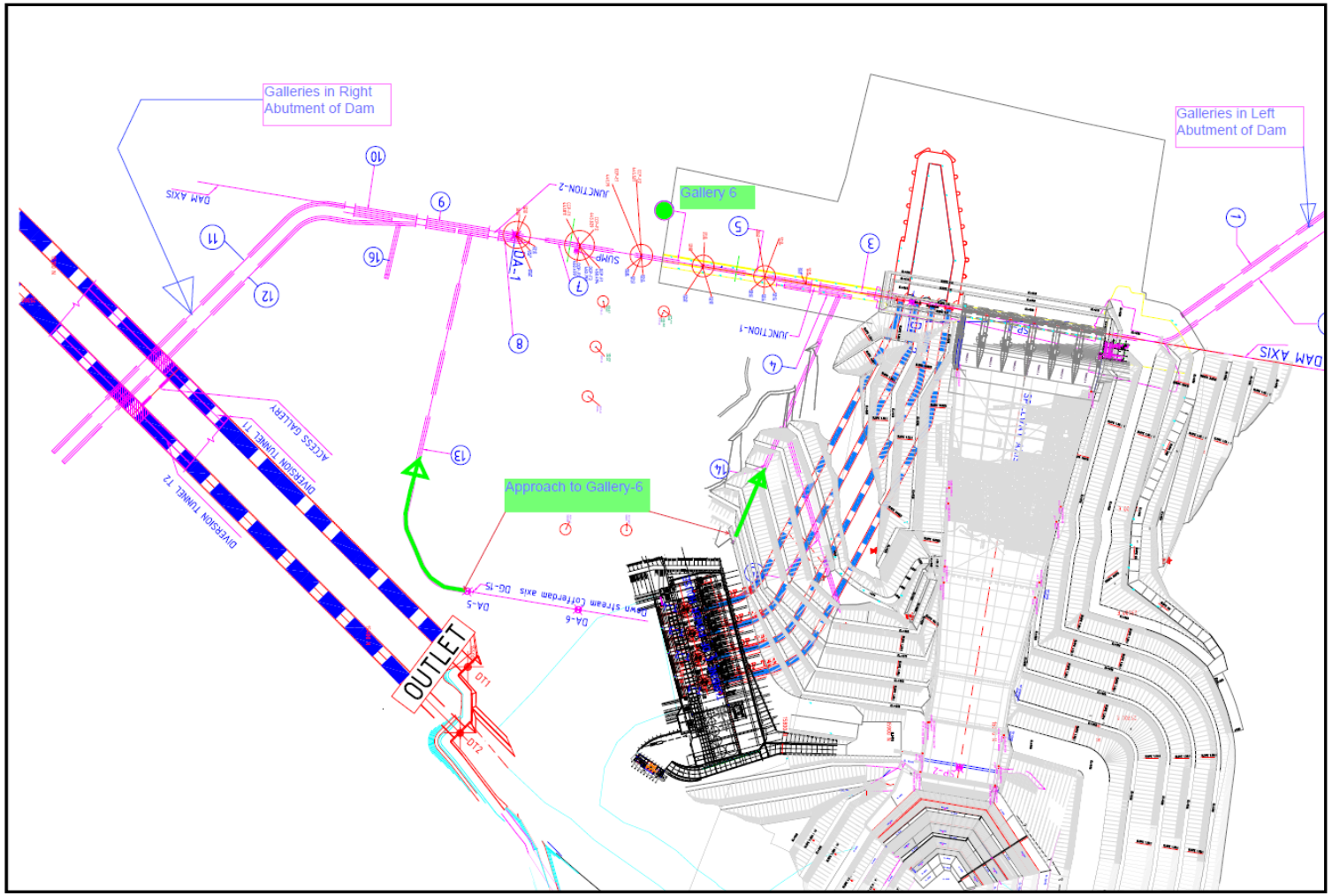
- ✓ There are 17 Drainage & Grouting Galleries in the Dam body, including deep seated foundation gallery.



LOCATION OF FDN GALLERY –WHERE LEAKAGE OCCURED



APPROACH TO FDN GALLERIES IN KOLDAM



- ✓Koldam foundation gallery is 180m below the Dam Top.
- ✓This foundation gallery can be accessed from two side (L& R Horizontal access tunnels & then 45 degree inclined tunnels with 350 steps).
- ✓Size of tunnel is 3 m dia. (finished) , concrete lined.

MONITORING OF WATER INGRESS OBSERBED IN FDN GALLERY

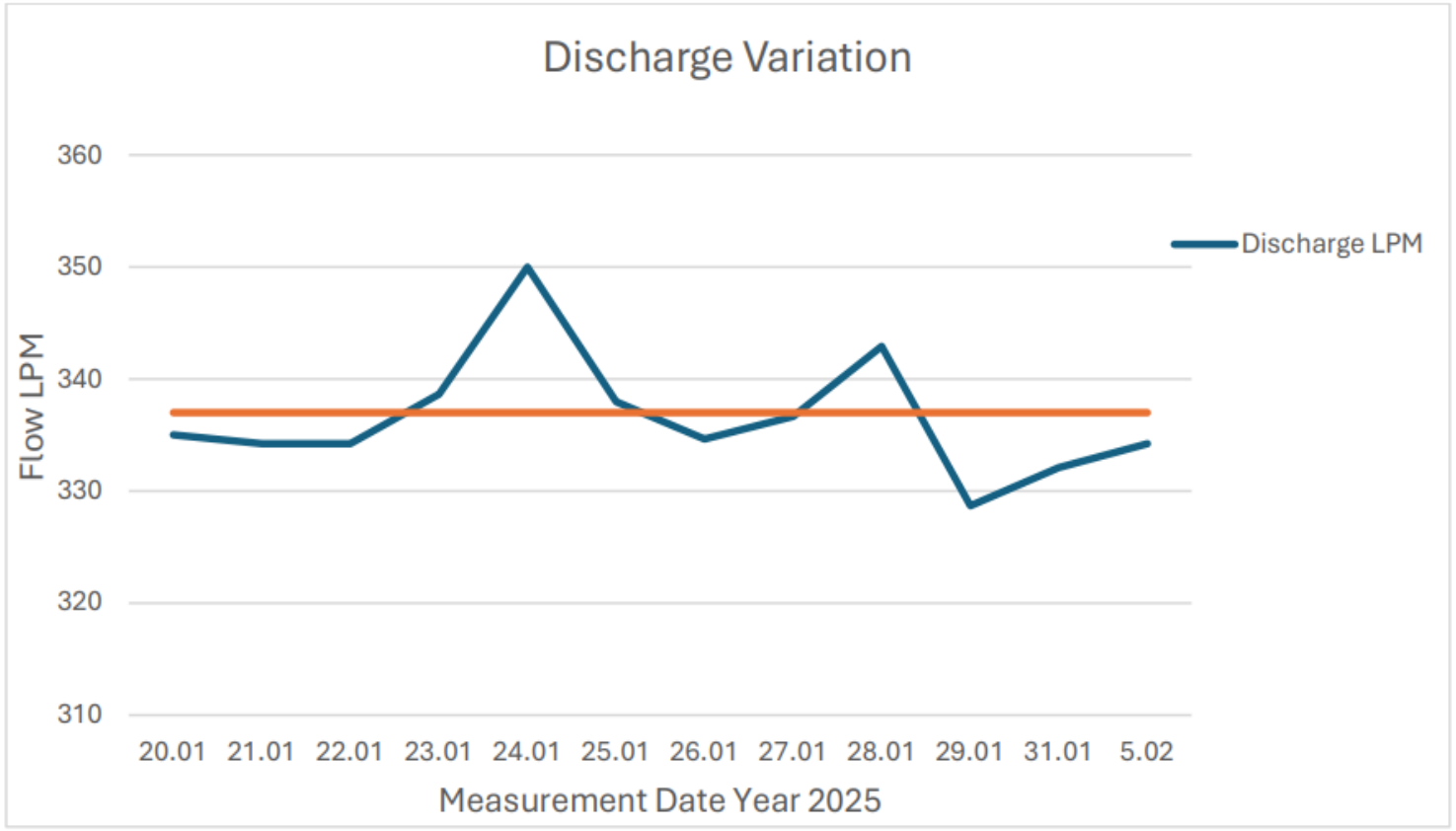


Fig: 2 Chronological discharge variation pattern

- ✓ Immediately after the occurrence of the leakage, as the solution to the problem was being discussed/ finalization by Engineering, leakage monitoring campaign for monitoring quantum and quality of water was started.
- ✓ No large variation in leakage rate and properties could be observed till the solution of problem- a great sigh of relief, as this leakage has very high hazard potential.
- ✓ Average discharge of about 300 to 350 lpm

Typical Graph showing Leakage Rate & Monitoring practice

MONITORING OF WATER INGRESS OBSERBED IN FDN GALLERY

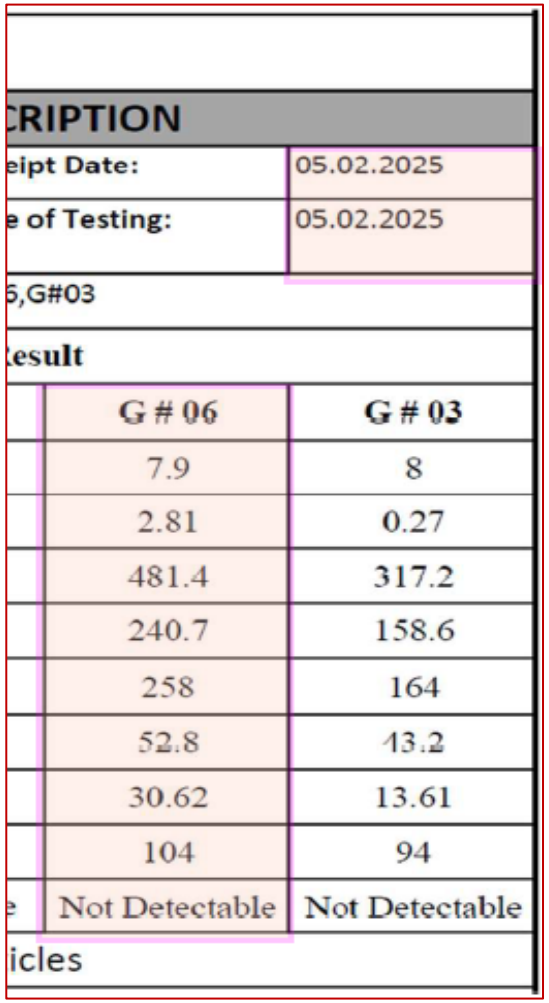
Water Analysis Report

CUSTOMER DATA		SAMPLE DESCRIPTION			
Name of Client:	In House Samples.	Sample No:	39	Receipt Date:	31.01.2025
Address:	NTPC Koldam HPP.	Date of Sampling :	31.01.2025 (11:45 hrs)	Date of Testing:	31.01.2025
		Sample Location:	Gallery No -03/06 & 14		

S.No.	Parameter	Analysis Result		
		Sample No -01 (Gallery-03)	Sample No -02 (Gallery-06)	Sample No -03 (Gallery-14)
1	pH	8.1	7.9	8
2	Turbidity (NTU)	0.32	1.06	0.45
3	Conductivity (µS/cm)	313	478	323
4	Total Dissolved Solids (TDS) (ppm)	156	239	161
5	Total Hardness as $CaCO_3$ (ppm)	168	248	172
6 (a)	Calcium hardess as Ca (ppm)	42.4	48.8	41.6
6 (b)	Magnesium hardess as Mg (ppm)	15	30.62	16.52
7	Total Alkalinity as $CaCO_3$ (ppm)	92	106	84
8	TSS	Not detectable	Not detectable	Not detectable

Recommendations: Gallery water samples tested is free of any substantial grain particles

Fig: 5 Comparison of water properties in different Galleries (3, 6, 14) 31 Jan 25



CRIPTION

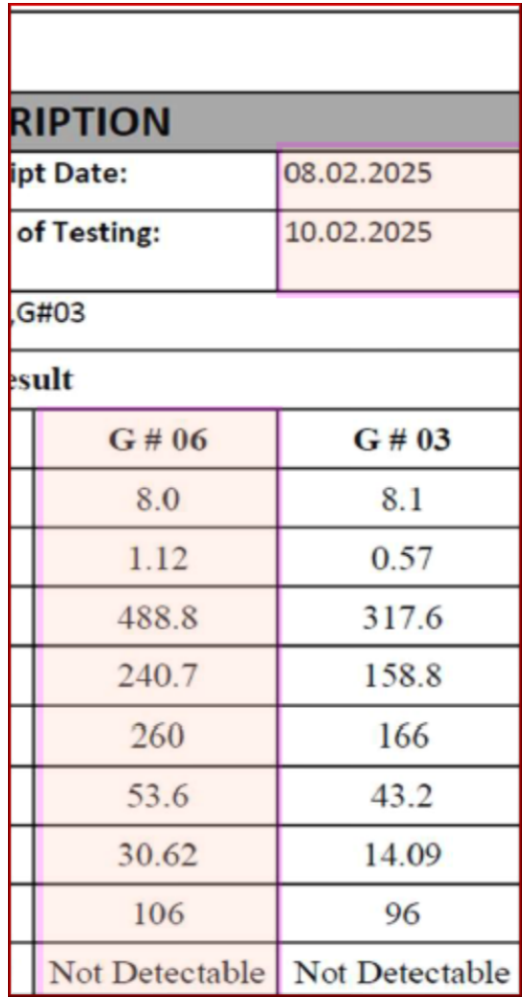
eipt Date:	05.02.2025
e of Testing:	05.02.2025

6,G#03

Result

	G # 06	G # 03
	7.9	8
	2.81	0.27
	481.4	317.2
	240.7	158.6
	258	164
	52.8	43.2
	30.62	13.61
	104	94
e	Not Detectable	Not Detectable

icles



RIPTION

ipt Date:	08.02.2025
of Testing:	10.02.2025

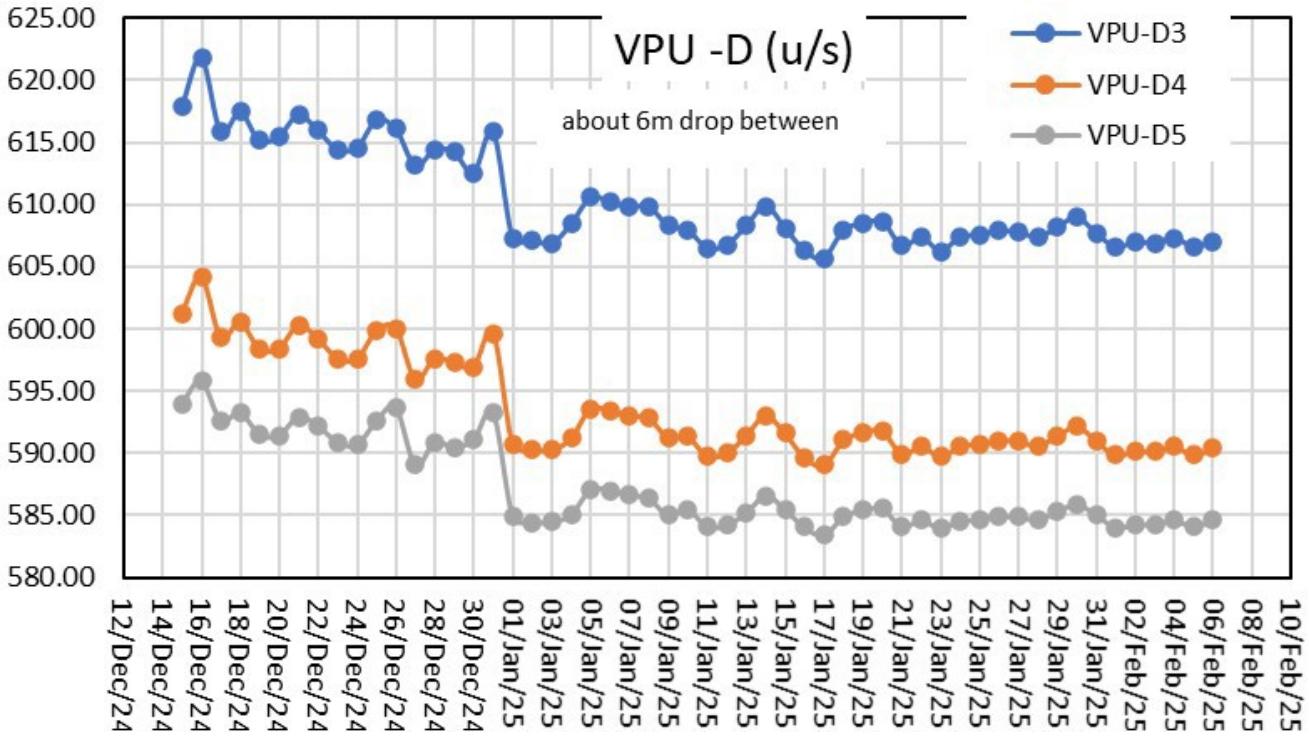
,G#03

esult

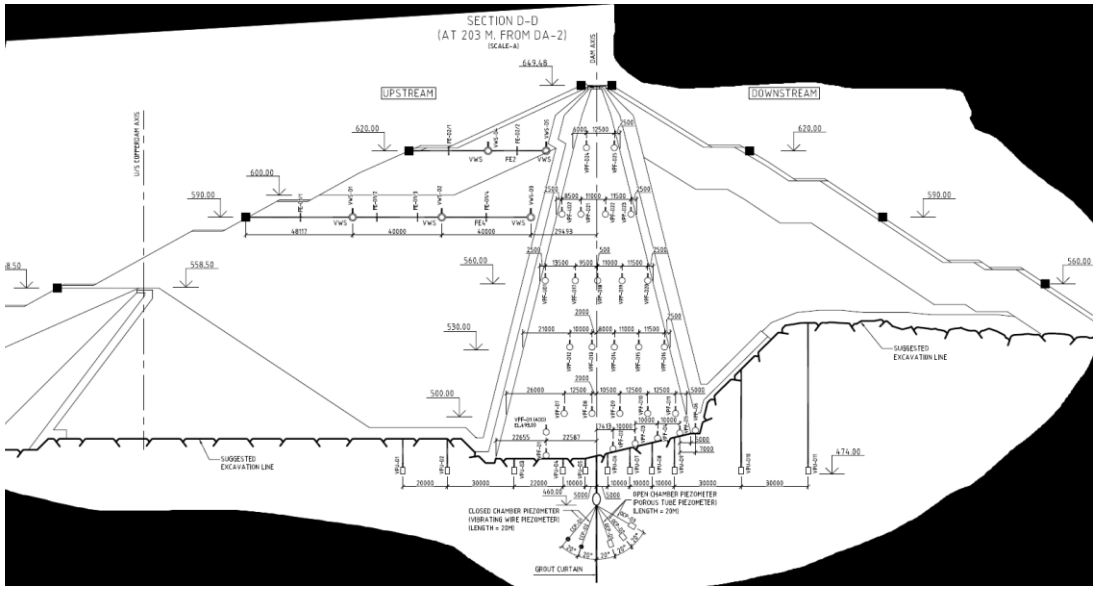
	G # 06	G # 03
	8.0	8.1
	1.12	0.57
	488.8	317.6
	240.7	158.8
	260	166
	53.6	43.2
	30.62	14.09
	106	96
	Not Detectable	Not Detectable

Table Showing the Typical Details of Monitoring the water Quality Parameters during the issue. No major change in parameters were observed.

INSTRUMENTATION DETAILS



Graph Showing Monitoring & Analysis of Situation by Geotechnical Instruments installed



Typical Section of Dam Showing the Location of Instruments

ENGINEERING PROPOSED GROUTING OF AREA

- ✓ Grouting of the area was to be done using two-component **PU based grouting material**.
- ✓ Pressure of grouting should not be more that could cause damage to already stable strata (limit 15 bars)
- ✓ Before grouting, packer – mechanical/pneumatic shall be used to regulate the leakage water.
- ✓ **After regulating the leakage with packer, grouting of the area shall be done using some foaming type grouting material.**

- ✓ After plugging the leakage with foaming compound, consolidation grouting of the area shall be done with non-foaming grout.
- ✓ **Compressive strength of PU foaming & NON foaming** materials should **not be less than M35 grade of concrete**.
- ✓ **Foaming ratio for foaming material should be more than 20.**
- ✓ Two-component polyurethane grout should have **short reaction-start-time (about 10 sec)**,
- ✓ It should have good adhesion to concrete/rock.
- ✓ Material should have low viscosity close to the viscosity of water**,** so that it percolates even in smallest crevasses of rock/concrete.
- ✓ The material should have long pot life such that it is suitable for filling the cracks.
- ✓ Grout/ compound material should have the long durability and should not be losing the strength under variation of temperatures inside gallery.

Flow Chart

INNOVATIVE KIND OF FLOW CONTROL ARRANGEMENT (AS ALTERNATIVE OF PACKER) DESIGNED AND MANUFACTURED BY KOLDAM ENGG & SITE

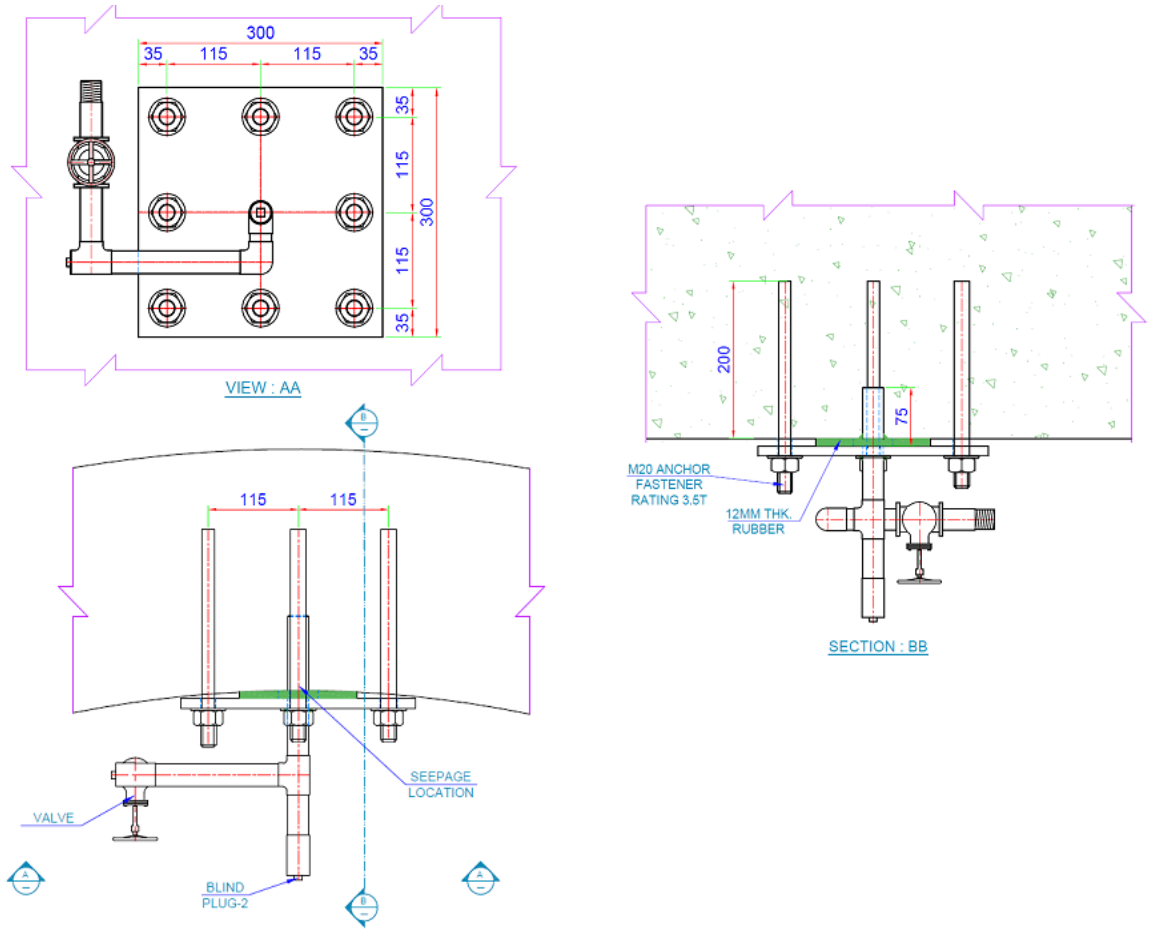


Fig. 9. Flow Control Device Designed as per Site Conditions

- ✓ As per methodology, packer was to be installed before grouting.
- ✓ No suitable agency could be find out in India to provide the packer for such kind problem.
- ✓ Here comes the innovative design & fabrication of alternative arrangement. Engineering provided the drawing/ design & the packer was fabricated at site by MMD.

This way we could save months of time and lakhs of rupees expenditure on this account.

EXECUTION METHODOLOGY

- ✓ Drilling of Holes for Grouting: : 1000mm in Rock as per drawing . These holes are to be drilled using NRV as area is fully charged.

- ✓ Grout Material : Two Component PU Resin with fast reaction time.

PU Grouting materials:

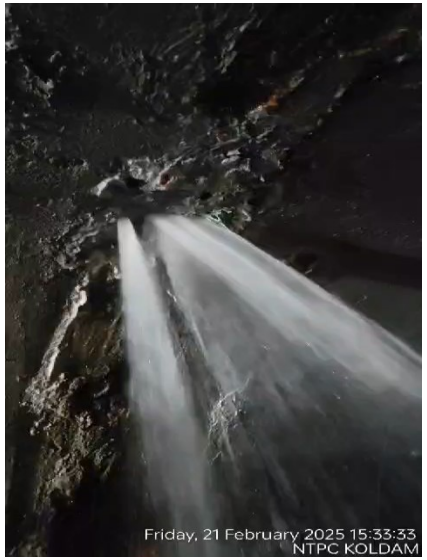
(1) Step-I : For arresting heavy water Leakage –Using **TamPur 125** PU Resin with Foaming properties

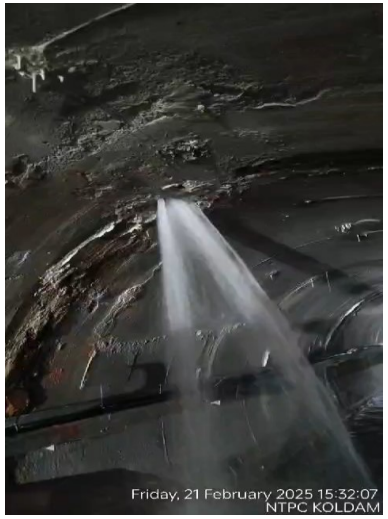
Step-II : For treating further leakages, if observed - Using **TamPur 116** PU Resin , non- foaming properties

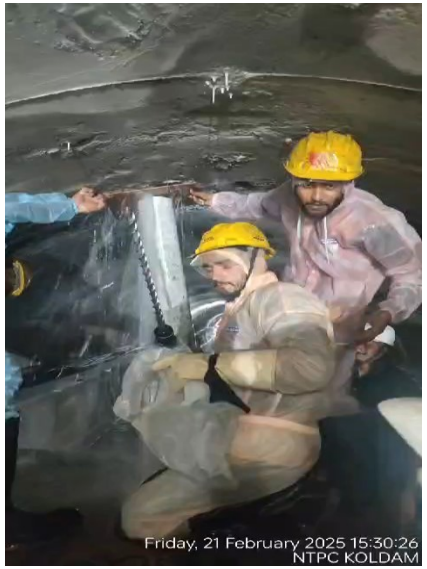
- ✓ Compressive Strength of grout materail : Minimum 35 MPa,

EXECUTION AT SITE: ATTEMPT- 1

- ✓ Due to area fully surcharged & wet, lots of safety issue in execution. Considering this suitable execution plan like pneumatic drilling etc. were used.
- ✓ The work of fixing of leakage channelization arrangement by drilling of M20 bolts as per the sketch was attempted on 22.02.2025
- ❖ 1st hole was drilled up to 200 mm in the concrete, and no water was observed.
- ❖ 2nd hole was drilled and water started coming out of that drilled hole. (Photographs and videos attached), then further hole drilling was stopped at site.
- ❖ During drilling, not much of difficulty was felt and penetration rate was high, shows that concrete is weaken at that location.







ATTEMPT-2

1. No response from packer agencies. And first attempt of site made packer got failed.

2. Hence, directly Grouting of area using was non-foaming compound was attempted. But it was not successful, as within no time that gout material was coming out due to flow of water etc.

3. Grouting expert was contacted to change the composition in view to change the setting time, and with revised grouting material, grouting was re-attempted. And some of the grouting could be done but leakage was not controlled.

4. Having understood that area have got some consolidated, installation of site evolved packer was re-attempted with the help of anchors and jacks, and this time it could be installed.

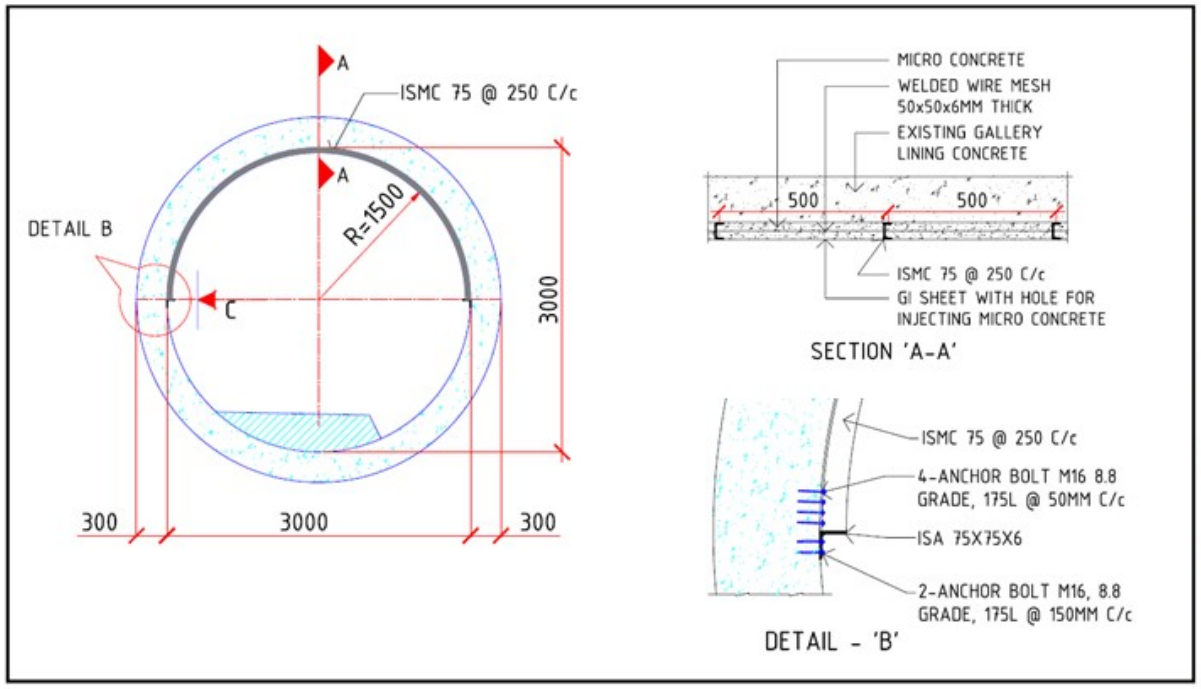
5. Water was then channelized with the help of packer, and decided grouting was done.

6. After injecting adequate grout, water leakage stopped.

7. After that consolidation grouting using TAMPUR 116 non-foaming material & secondary drill holes, was done.

SITE PICTURES DURING WORK

STRENGTHENING OF TUNNEL LINING (OVERT PORTION)



Details of Overt Jacketing (in affected area) in Foundation Gallery

Keeping in view the durability aspect of grouting and the structural health of tunnel overt at the affected location, following was also implemented as strengthening measures:

- ✓ Jacketing of overt portion of tunnel lining with the help of micro concrete and ribs.
- ✓ After completion of work, there is no further distress/deformation has been observed in the area.

Before

After completion

CONCLUSION

- ✓ India is the third-largest dam-owning country in the world, with hundreds of dams that are over a century old. Given this context, similar issues may arise in other dams in the future. These problems pose extremely high hazard potential due to the locational challenges of deep-seated galleries and limited accessibility. Therefore, **it is imperative to develop comprehensive national-level guidelines or IS codes to address such issues (Grouting Materials/ Techniques etc)**.

- ✓ Additionally, a **centralized data repository should be established at the country level**, enabling dam owners to access preliminary leads and best practices for resolving complex and hazardous problems swiftly.

- ✓ The **use of hydraulic and mechanical packers is critical** when performing grouting under conditions involving high water tables or saturated media.

- ✓ **There is a need to evolve grouting chemicals with enhanced durability, long service life, fast reaction** time under low temperature conditions.


Thank You