# Presentation 5: RoR HEP basics (I)

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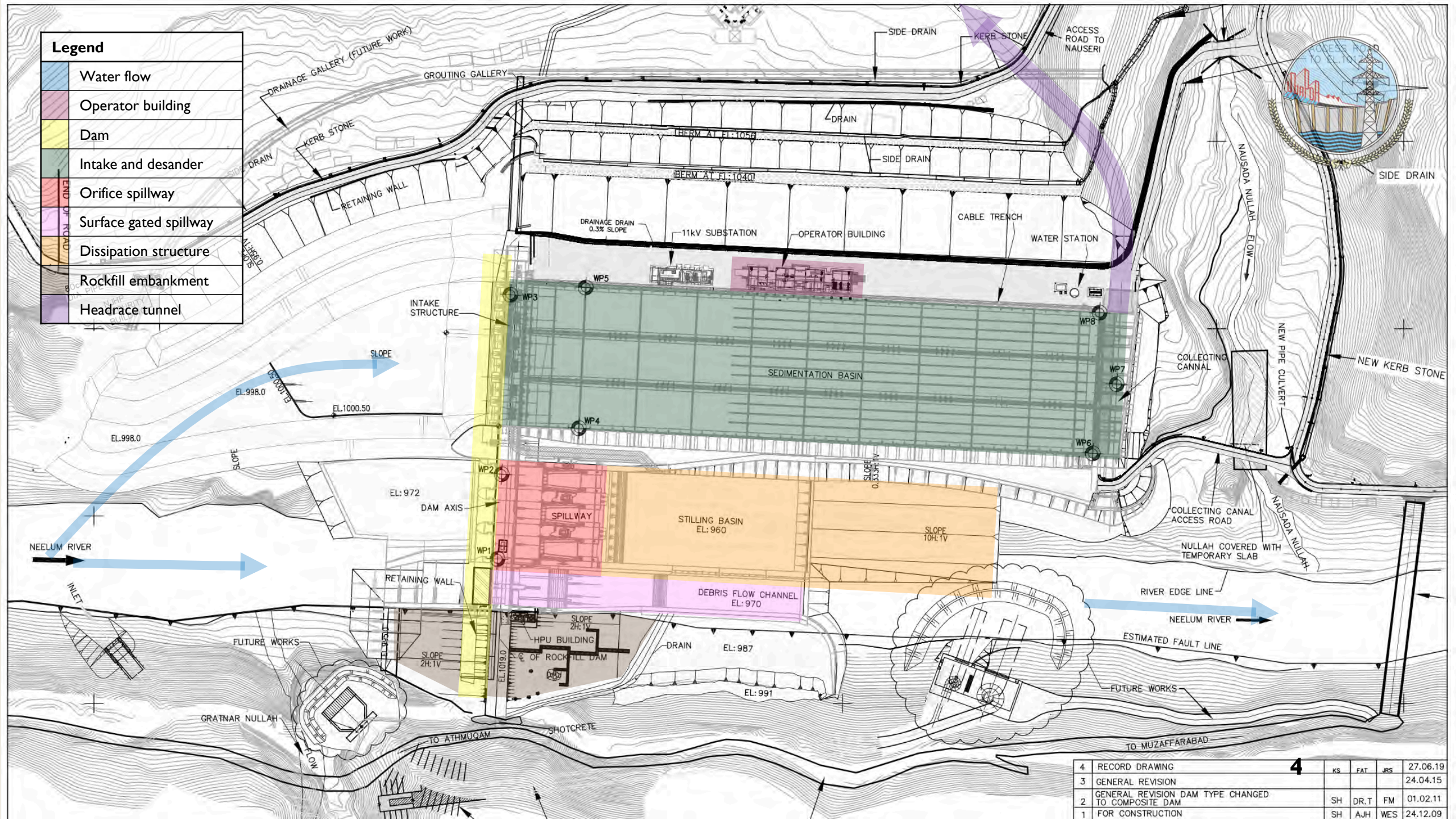
*Dr Yasir Abbas*

**26 April 2024**

# Run-of-river HEP headworks

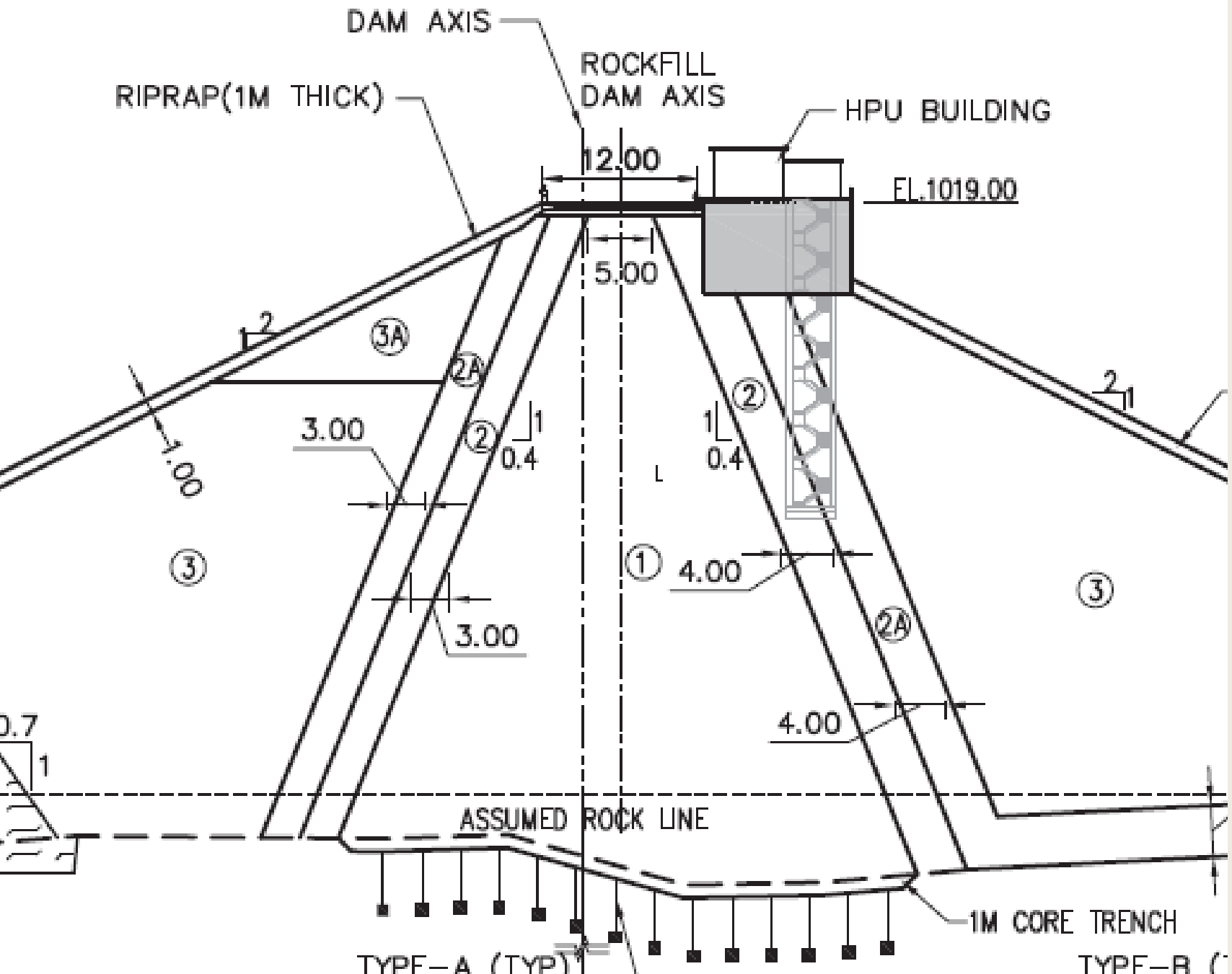
# Headworks

- The headworks in a run-of-river HEP include everything constructed at the site of the river itself.
- This includes not only the dam, but all appurtenant structures, including spillways, intakes and operational buildings.




| | | | | | |
|---|---|---|---|---|---|
| 4 | RECORD DRAWING | KS | FAT | JRS | 27.06.19 |
| 3 | GENERAL REVISION | | | | 24.04.15 |
| 2 | GENERAL REVISION DAM TYPE CHANGED TO COMPOSITE DAM | SH | DR.T | FM | 01.02.11 |
| 1 | FOR CONSTRUCTION | SH | AJH | WES | 24.12.09 |

4

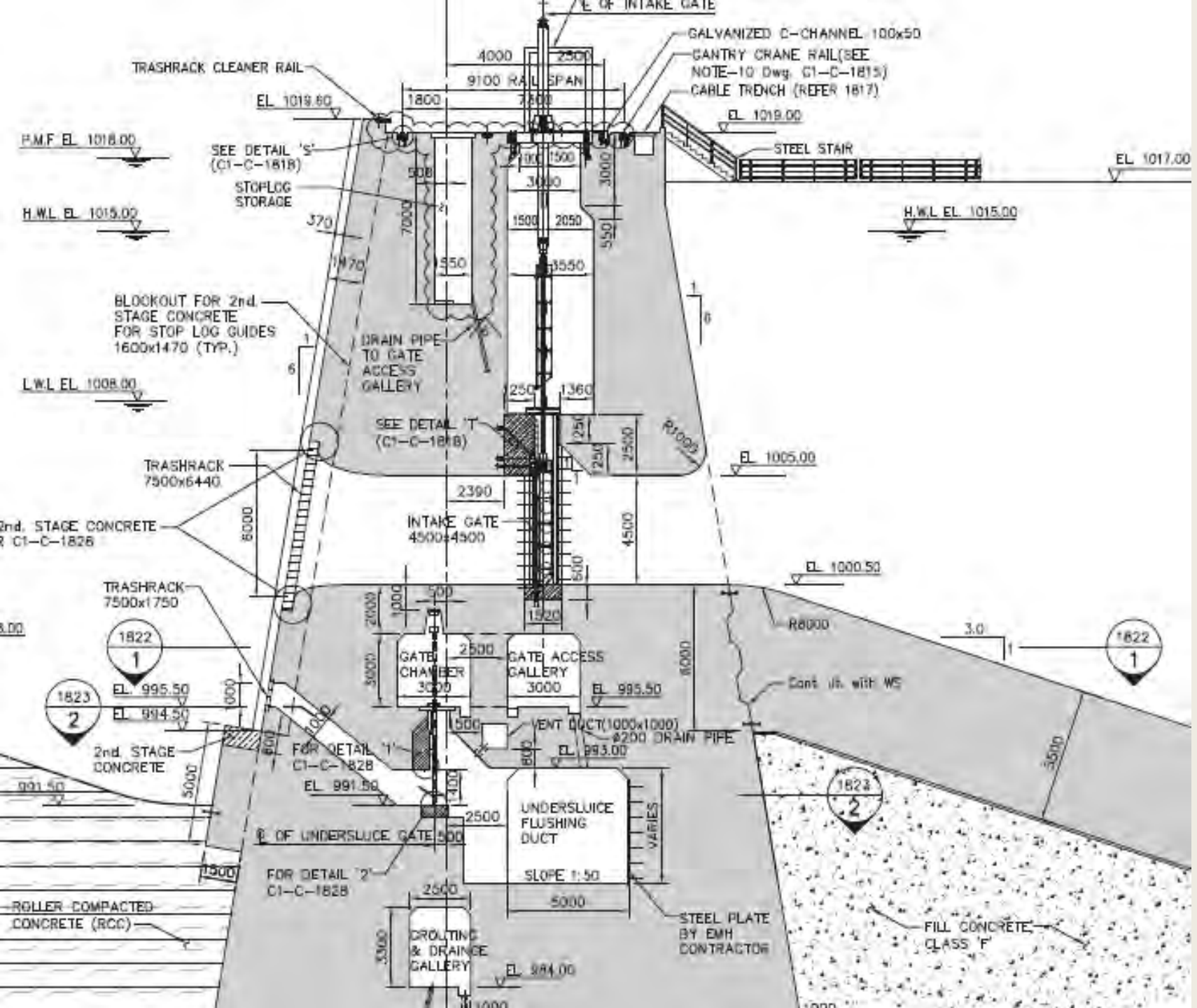



# Dam

- For a run-of-river HEP, the dam is usually situated in a valley, allowing a narrow reservoir to fill behind it. This creates head for power generation.
- The dam structure will vary depending on location – the three major types are earthen concrete, and rock-filled dams.
- NJHEP is a hybrid: the main dam is concrete with a rock-filled section straddling a geological fault (the main boundary thrust).

# Spillway

- The spillway is the principal structure by which water is passed through the dam – particularly in times of flood. It may also have other applications (e.g. sediment management).
- Multiple spillway structures may be included in the same dam.
- Usually includes a structure to prevent erosion of the riverbed at the foot of the dam.




# Intakes

- The intakes allow water to be abstracted from the reservoir into the headrace – and thence on to the turbines.
- Need to be carefully designed to minimize sediment ingress and prevent vortexing.
- May include special structures to achieve either or both of these aims, e.g. desanders.

# Reservoir

- Not part of the headworks per se, but an important component of the HEP.
- A run-of-river HEP can function without a reservoir – but its power generation potential would be limited.
- Run-of-river HEPs tend to have small reservoirs for the purpose of developing head and improving power production in the dry season.

# Live and dead storage

**Storage HEP**

- Massive storage (in the order of months or even years).
- Designed to permit flexible operation of the HEP year-round, as well as provide flood control.
- Notable example: Tarbela HEP, Khyber Pakhtunkhwa.

**Run-of-river HEP with no storage**

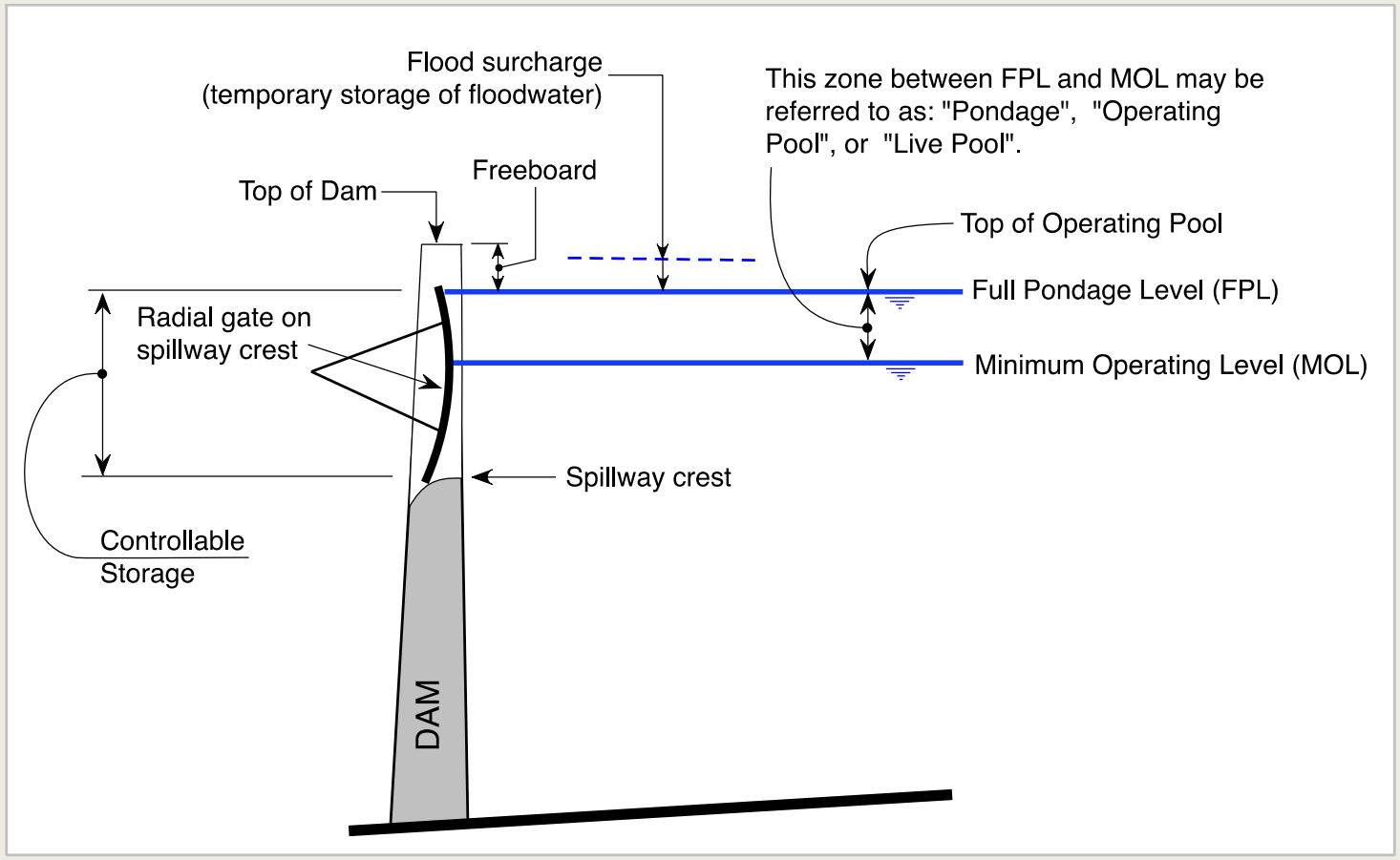
- No storage at all; effectively a turbine placed in the river or on an adjoining canal. Usually a smaller HEP.
- Entirely dependent on the river flow on a particular day and used only as base load power. Relatively primitive.
- Notable example: Shadiwal HEP, Punjab.

**Run-of-river HEP with storage**

- Small reservoir constructed in narrow valley to improve head and power generation.
- Typically used for baseload power in the wet season and peaking power in the dry season.
- Notable example: NJHEP, Kashmir.

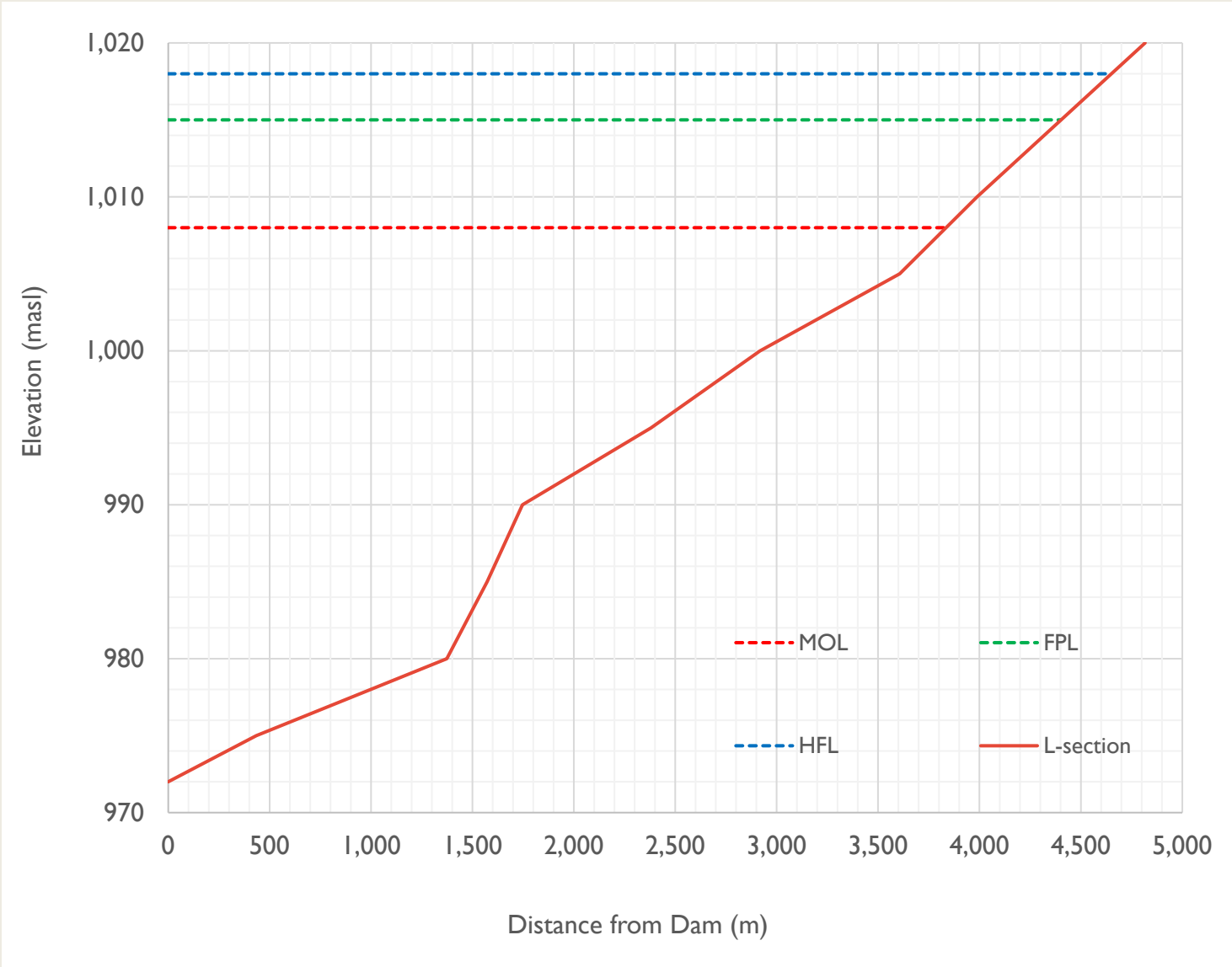
# Types of HEP

- HEPs can be divided into categories depending on how much **storage** they have – i.e. the size of the reservoir.
- Storage can be used to raise head and increase power generation.



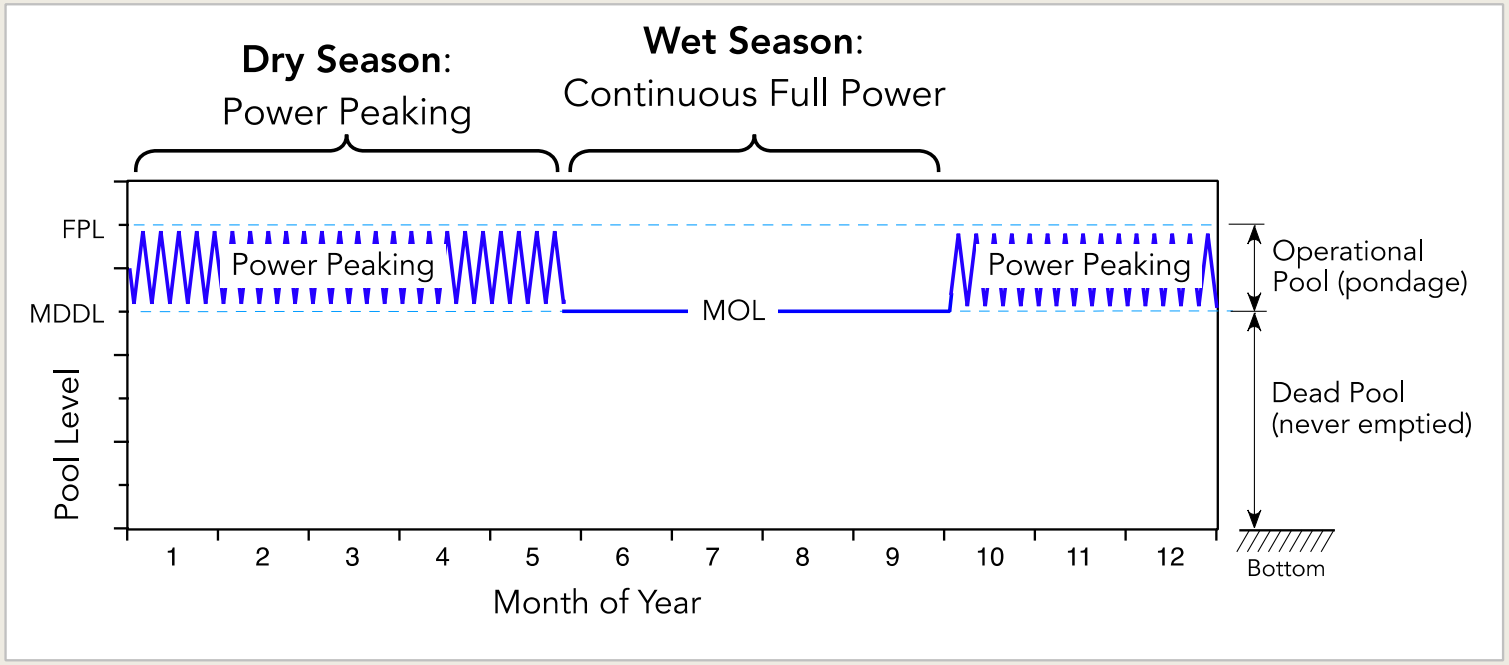

# Reservoir levels

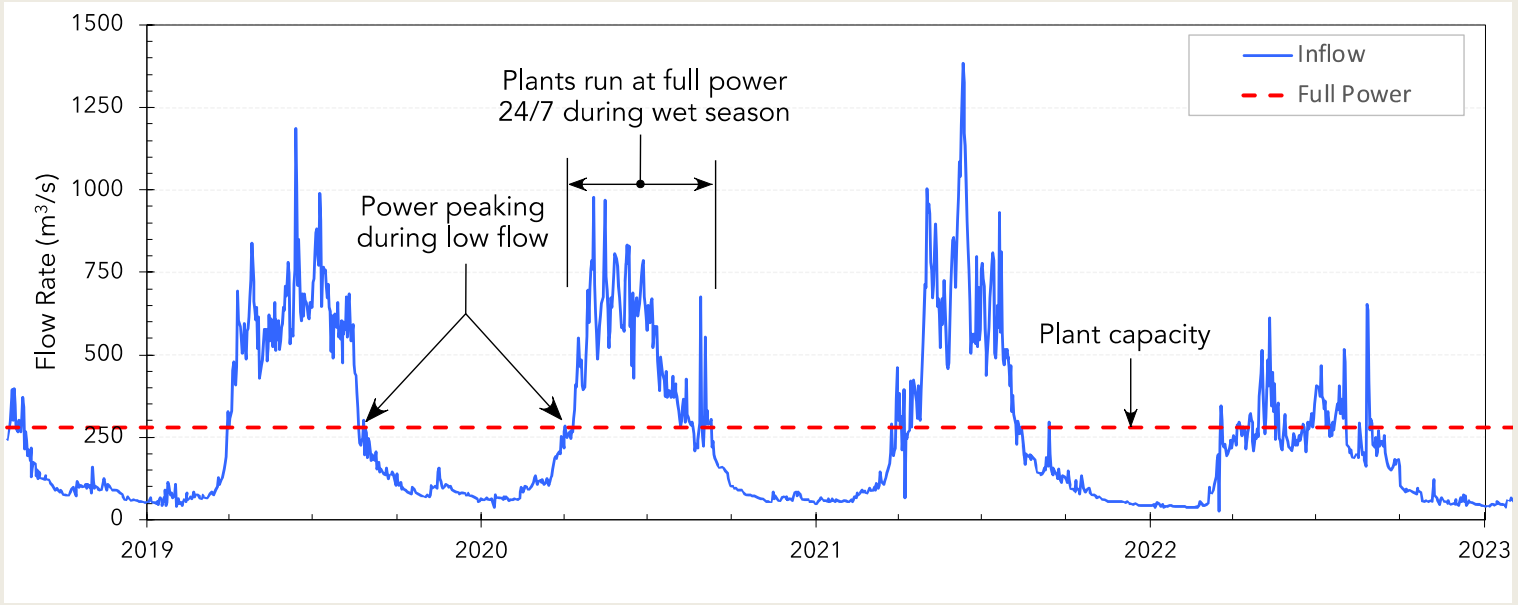
- Storage in a HEP reservoir is determined by the **invert of the lowest outlet**
- Anything below that point is **dead storage** in that it cannot be evacuated through the dam via gravity. Reservoir space below this level is often used for **sediment storage**.
- Anything above that point is **live or controllable storage** that can be used for operational purposes such as power production.
- Pondage is stored in the HEP's **operating pool**, i.e. it is live storage the top of which is the **full pondage level** (FPL). The bottom of the operating pool is the **minimum operating level** (MOL).




# NJHEP reservoir

- Longitudinal view (L-section) of the NJHEP reservoir with the dam at 0m. River slope in reservoir is 1% or 1/100.
- Demonstrates the Minimum Operating Level (MOL), Full Pondage Level (FPL) and High Flood Level (HFL).

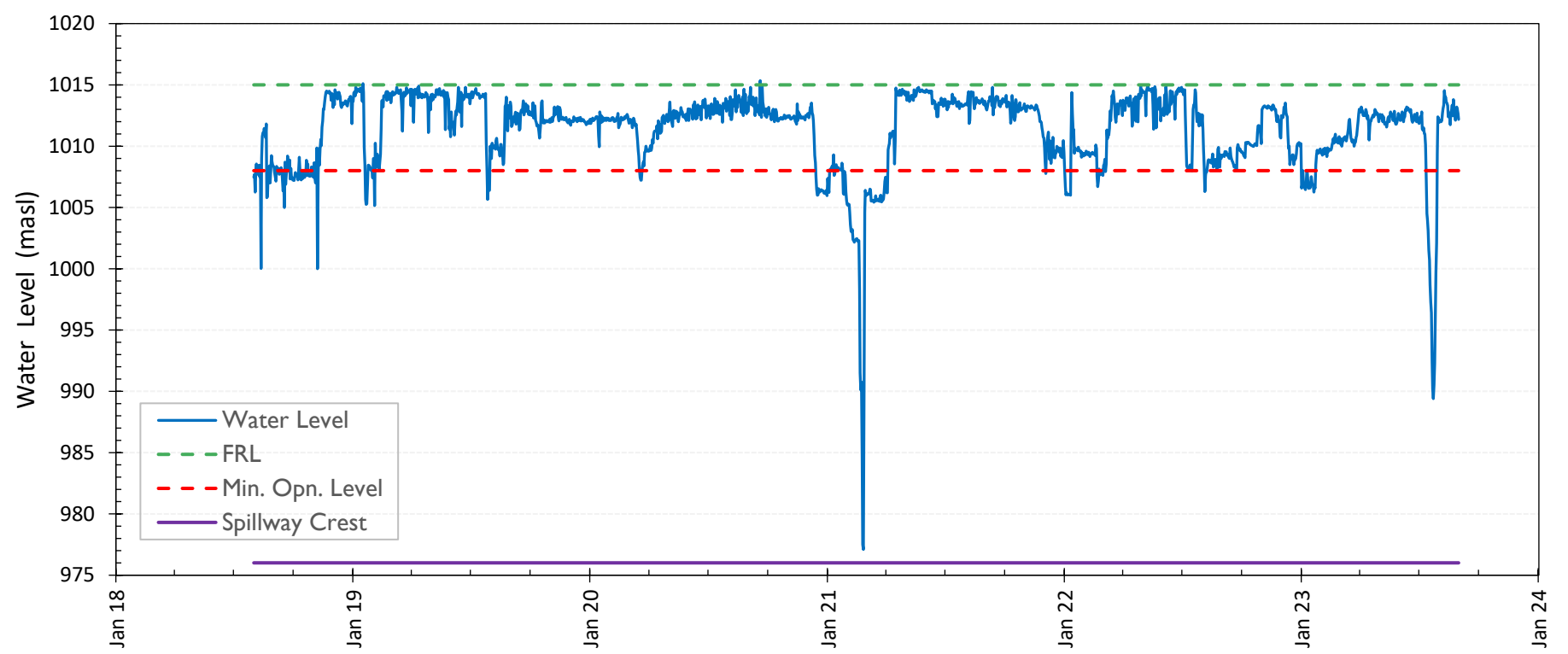



# Run-of-river HEP operation

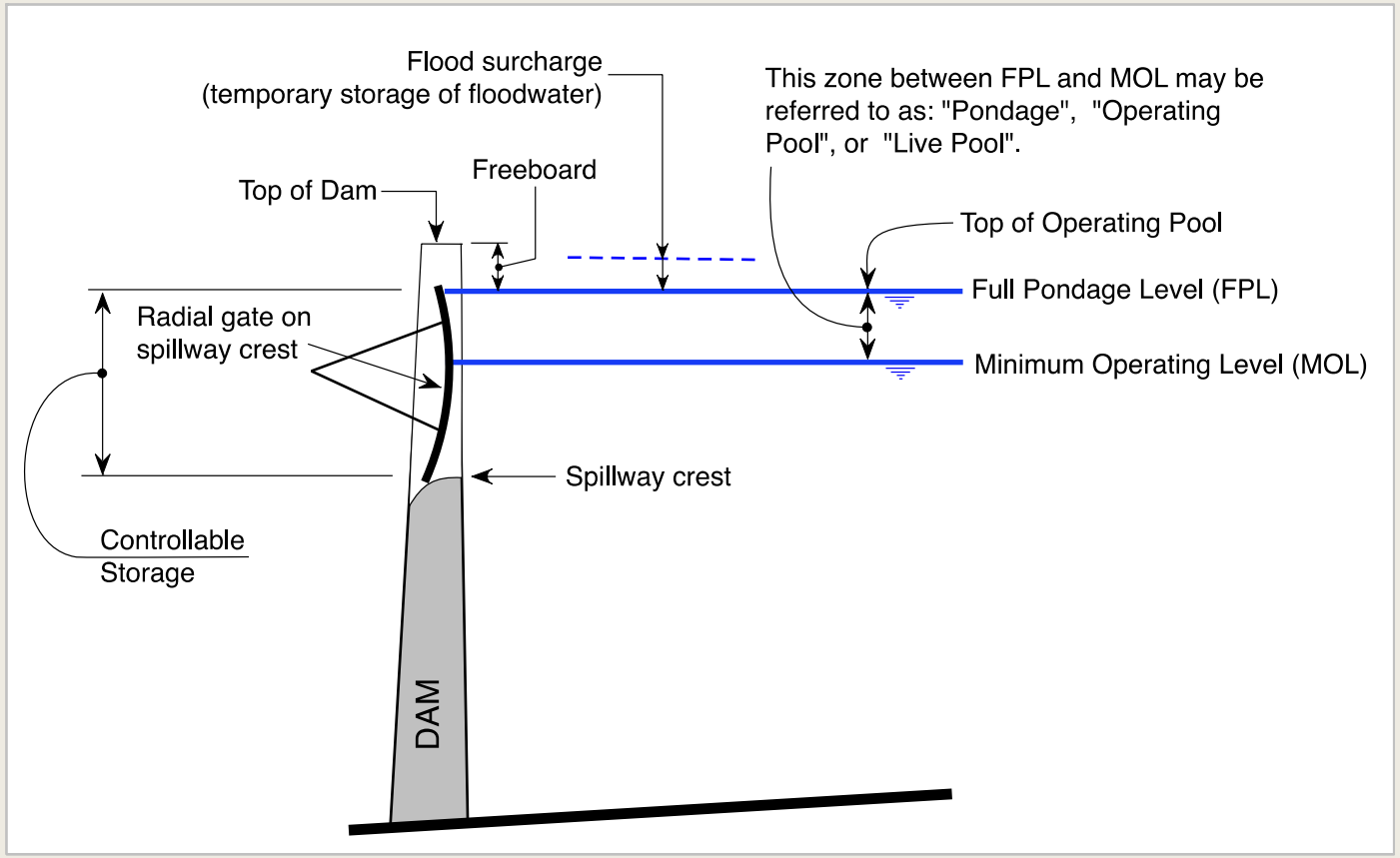
- Himalayan run-of-river plants are designed to operate at full power through the **wet summer months**, supplying base load 24/7.
- To minimize sedimentation, they may operate at the **minimum operating level** (MOL) during the wet season.
- During the dry winter months they can only produce limited amounts of energy.
- If **pondage** is available, during the dry season the HEP can be turned off to allow water to be stored in the operating pool for part of the day up to the **full pondage level** (FPL), releasing stored water (i.e. pondage) to produce power during hours of peak demand.

# NJHEP reservoir level: 2018–2023



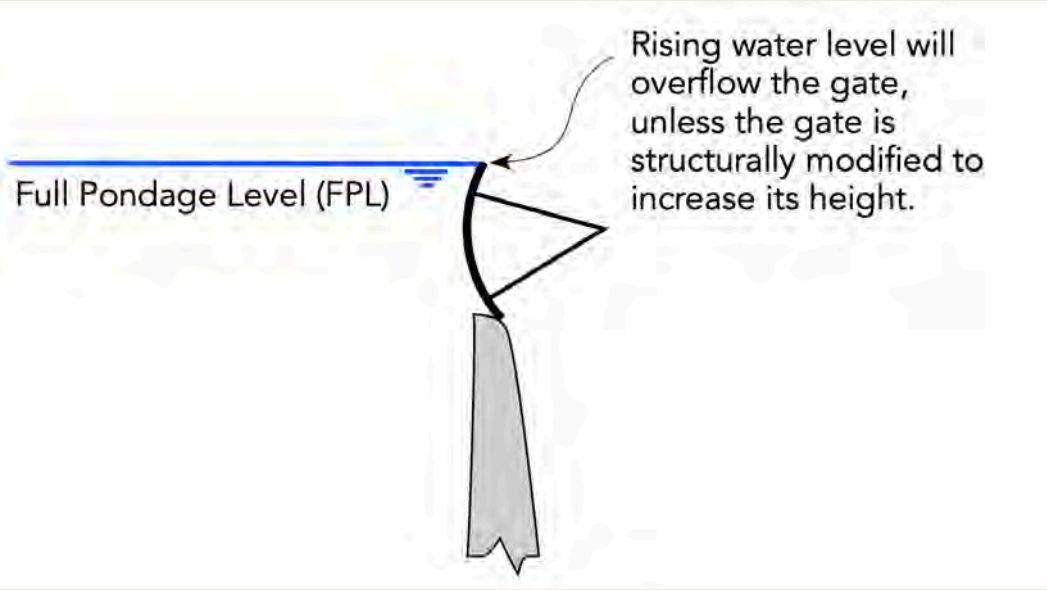
# Spillways and freeboard

# Spillway and freeboard configuration



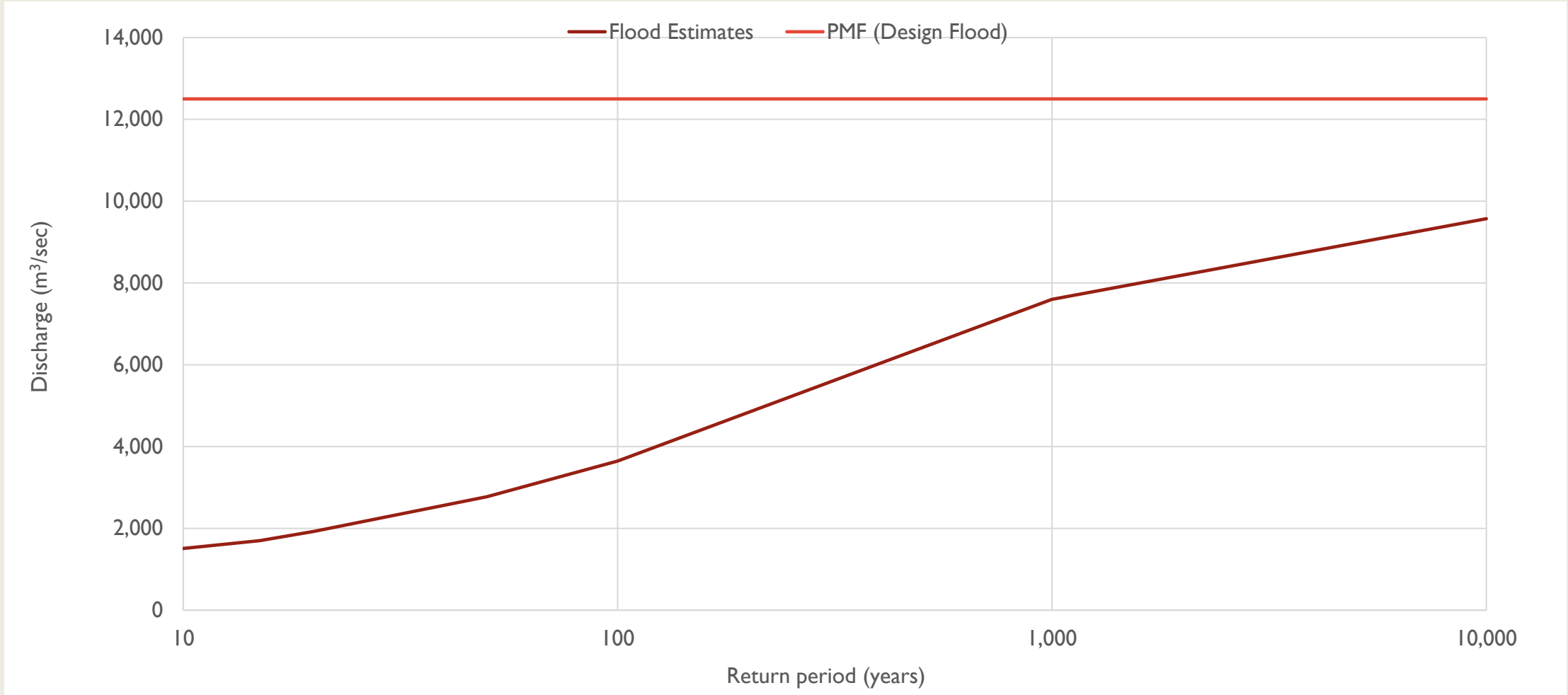

- The spillway is the principal means of releasing water to the river below the dam during floods.
- It is designed to safely pass the **design flood**, which is assessed based on location.
- In the Himalaya, the design flood is usually assessed on a 10,000-year basis.
- Spillway placement may be relevant to the freeboard, being the portion of the dam that extends above the top of the operating pool and protects the dam from **overtopping**.

# Freeboard height

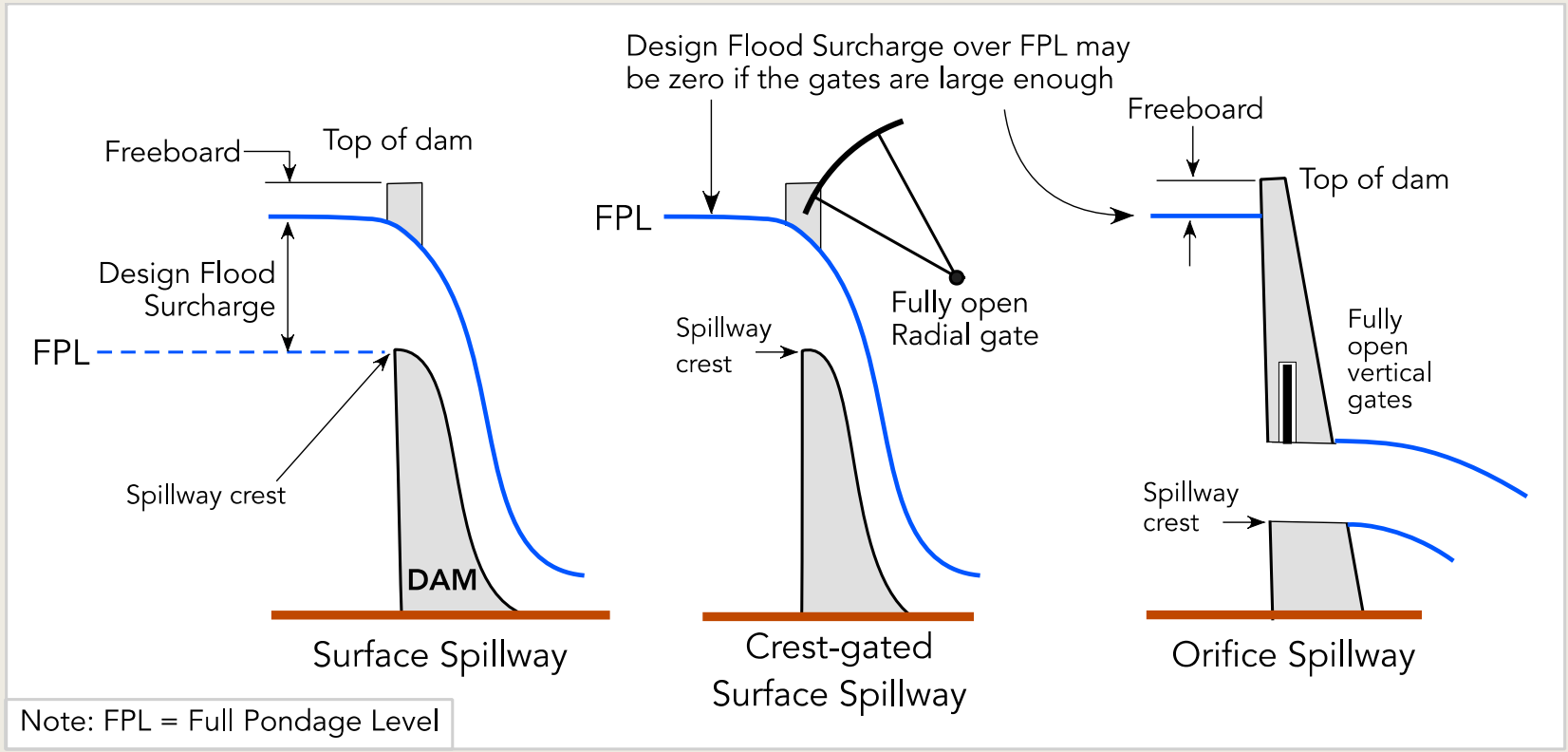



- Freeboard height above the full pondage level (FPL) is provided to account for several factors:
- Flood surcharge;
- Wave action;
- Type of dam;
- Operational reliability.

# NJHEP design flood



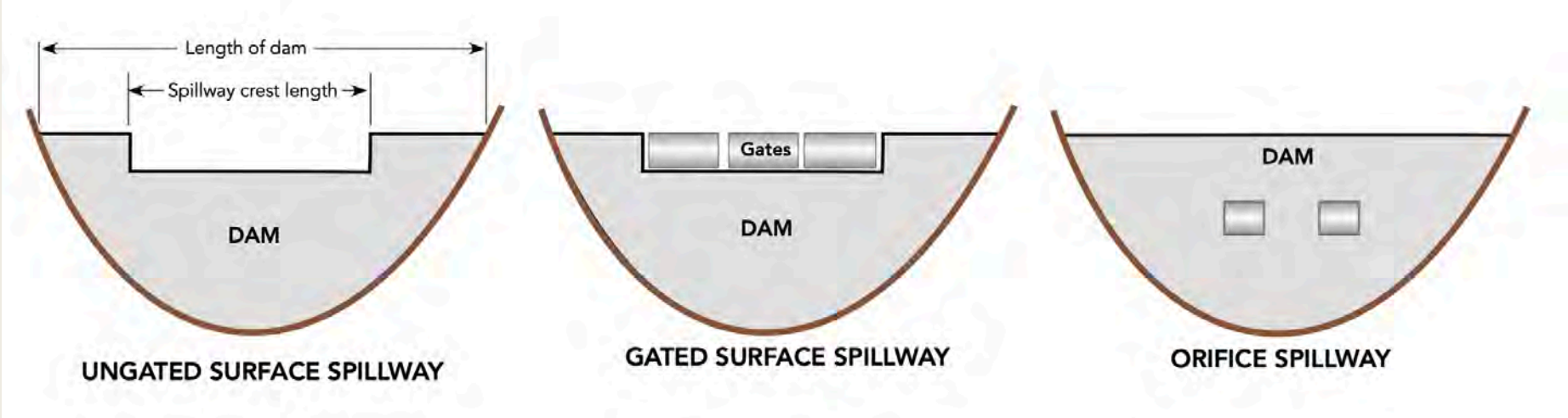
# Spillway configurations




Note: FPL = Full Pondage Level

- Multiple spillway configurations can be used.
- Several different configurations may be incorporated into a single dam.

# Advantages of spillway designs

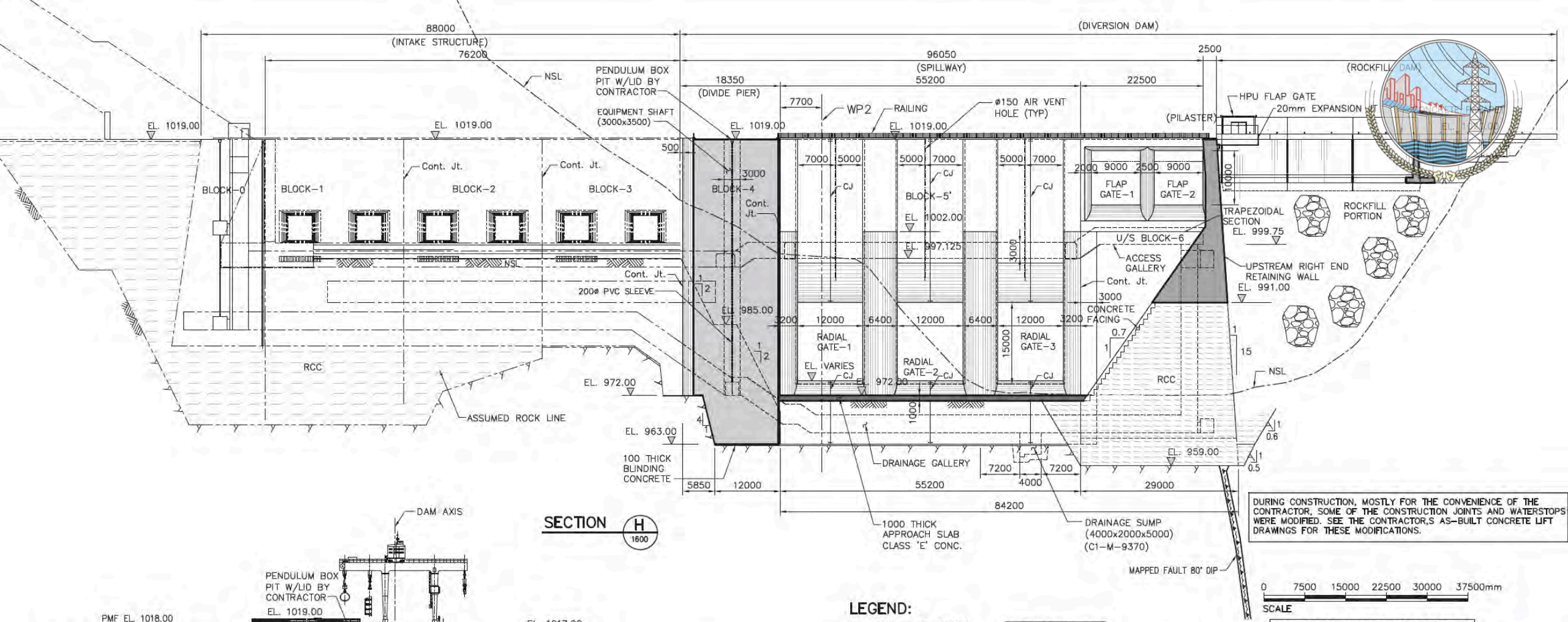



# Multiple spillway design

# NJHEP spillways

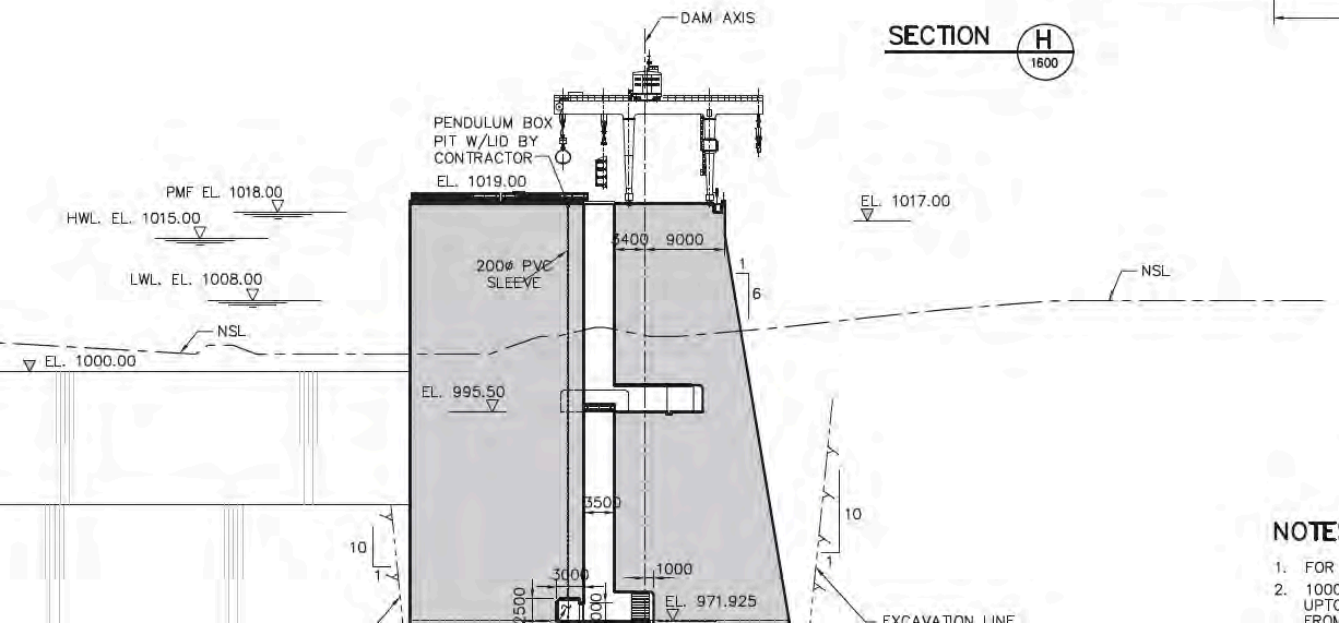
- Spillways can be combined in different configurations to meet different challenges at the HEP site (e.g. flood or sediment management). If one design is not possible, a workaround may be developed.
- For example, an orifice spillway may be included as the main spillway, with a surface spillway incorporated for use if the discharge capacity of the main spillway is exceeded.
- The NJHEP is one such design, incorporating orifice and surface gated spillways – together with undersluices built into the intake structure for sediment management.


# Upstream elevation




SECTION H 1600

DURING CONSTRUCTION, MOSTLY FOR THE CONVENIENCE OF THE CONTRACTOR, SOME OF THE CONSTRUCTION JOINTS AND WATERSTOPS WERE MODIFIED. SEE THE CONTRACTOR,S AS-BUILT CONCRETE LIFT DRAWINGS FOR THESE MODIFICATIONS.




## LEGEND:

- MBT FAULT LINE MAPPED AFTER RIVER DIVERSION
- 1st STAGE CONCRETE (CLASS 'A' 20MPa)
- 1st STAGE CONCRETE (CLASS 'C' 30 MPa)
- 1st STAGE CONCRETE (CLASS 'E' 50 MPa)
- ROLLER COMPACTED CONCRETE (RCC)
- ROCKFILL

## NOTES:

1. FOR GENERAL NOTES REFER DRAWING NO. C1-C-1600.
2. 1000 THICK CLASS 'E' CONCRETE LAYER IN WALL/PIERS UPTO 15000 HEIGHT FOR PROTECTION AGAINST ABRASION FROM HIGH VELOCITY WATER IN SPILLWAY AREA.

**RECORD DRAWING**

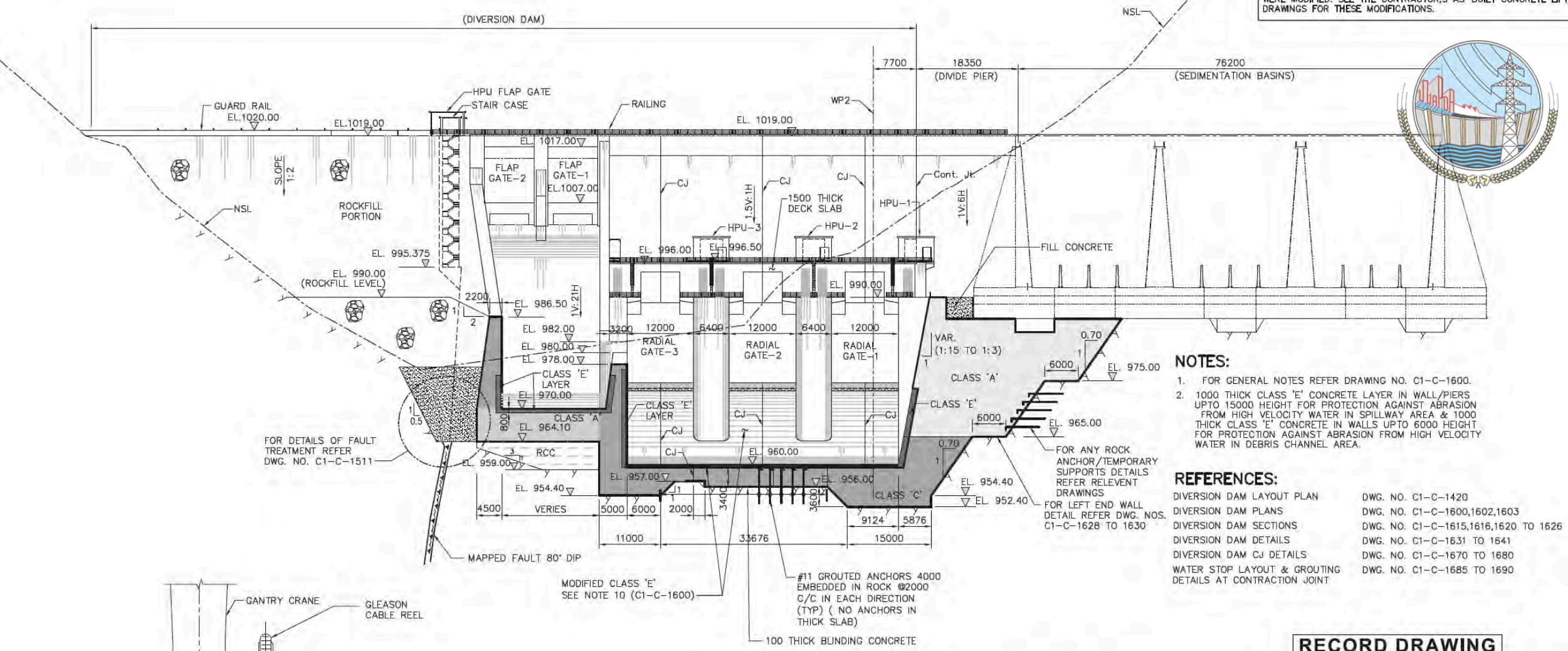
| Rev. | Description | Submit | Check | Appr. | Date |
|---|---|---|---|---|---|
| 9 | RECORD DRAWING. | | | | 18.07.19 |
| 8 | RAFT FOR GANTRY CRANE AS REQUESTED BY CONTRACTOR'S LETTER GZBZJ-NJC-8435. (INDICATING A SOLUTION) | MDH | SR | SR | 01.06.15 |
| 7 | REVISED AS SHOWN. | SKA | SIR | SR | 18.11.14 |
| 6 | RCC BEHIND INTAKE REVISED. | SKA | SIR | SR | 25.08.14 |
| 5 | Cont. Jt. OF PIERS REMOVED, CJ & APPROCH SLAB ADDED. | SH | SR | JRS | 13.12.12 |
| 4 | AIR VENT REMOVED BLINDING CONC. ADDED & AS SHOWN. | – | SH | SR | 20.09.12 |
| 3 | REVISED AS SHOWN. | – | T.R | SR | 20.04.12 |
| 2 | REVISED AS SHOWN. | – | T.R | SR | 02.03.12 |
| 1 | GENERAL REVISION | – | SR | JRS | 16.12.11 |

PAKISTAN WATER & POWER DEVELOPMENT AUTHORITY

NEELUM JHELUM HYDRO-POWER COMPANY

**NEELUM JHELUM HYDROELECTRIC PROJECT**

# Downstream elevation



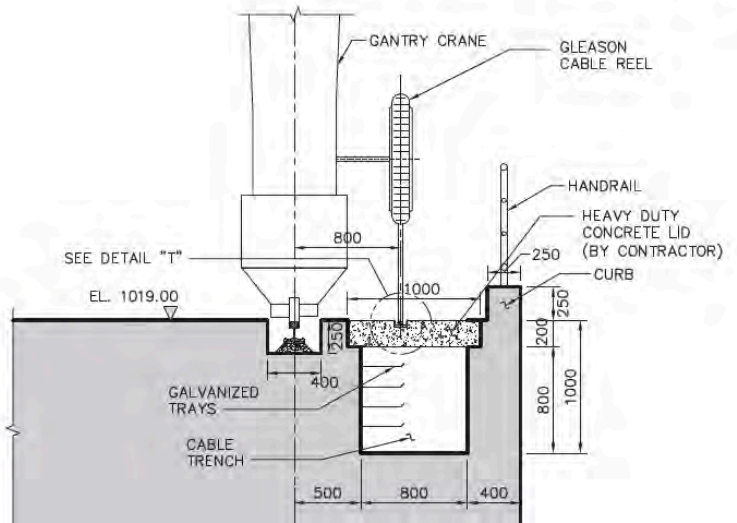

ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE NOTED.
HERE MODIFIED. SEE THE CONTRACTOR'S AS BUILT CONCRETE LIFT DRAWINGS FOR THESE MODIFICATIONS.

## NOTES:

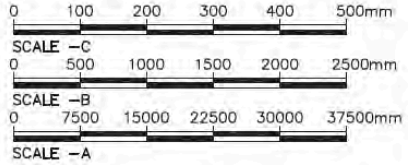
1. FOR GENERAL NOTES REFER DRAWING NO. C1-C-1600.
2. 1000 THICK CLASS 'E' CONCRETE LAYER IN WALL/PIERS UPTO 15000 HEIGHT FOR PROTECTION AGAINST ABRASION FROM HIGH VELOCITY WATER IN SPILLWAY AREA & 1000 THICK CLASS 'E' CONCRETE IN WALLS UPTO 6000 HEIGHT FOR PROTECTION AGAINST ABRASION FROM HIGH VELOCITY WATER IN DEBRIS CHANNEL AREA.

## REFERENCES:

| | |
|---|---|
| DIVERSION DAM LAYOUT PLAN | DWG. NO. C1-C-1420 |
| DIVERSION DAM PLANS | DWG. NO. C1-C-1600,1602,1603 |
| DIVERSION DAM SECTIONS | DWG. NO. C1-C-1615,1616,1620 TO 1626 |
| DIVERSION DAM DETAILS | DWG. NO. C1-C-1631 TO 1641 |
| DIVERSION DAM CJ DETAILS | DWG. NO. C1-C-1670 TO 1680 |
| WATER STOP LAYOUT & GROUTING DETAILS AT CONTRACTION JOINT | DWG. NO. C1-C-1685 TO 1690 |




SECTION L (1600)
SCALE -A



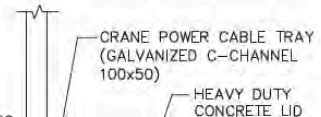

## LEGEND:

MBT FAULT LINE MAPPED AFTER RIVER DIVERSION

1st STAGE CONCRETE (CLASS 'A' 20 MPa)

1st STAGE CONCRETE (CLASS 'C' 30 MPa)

1st STAGE CONCRETE (CLASS 'E' 50 MPa)

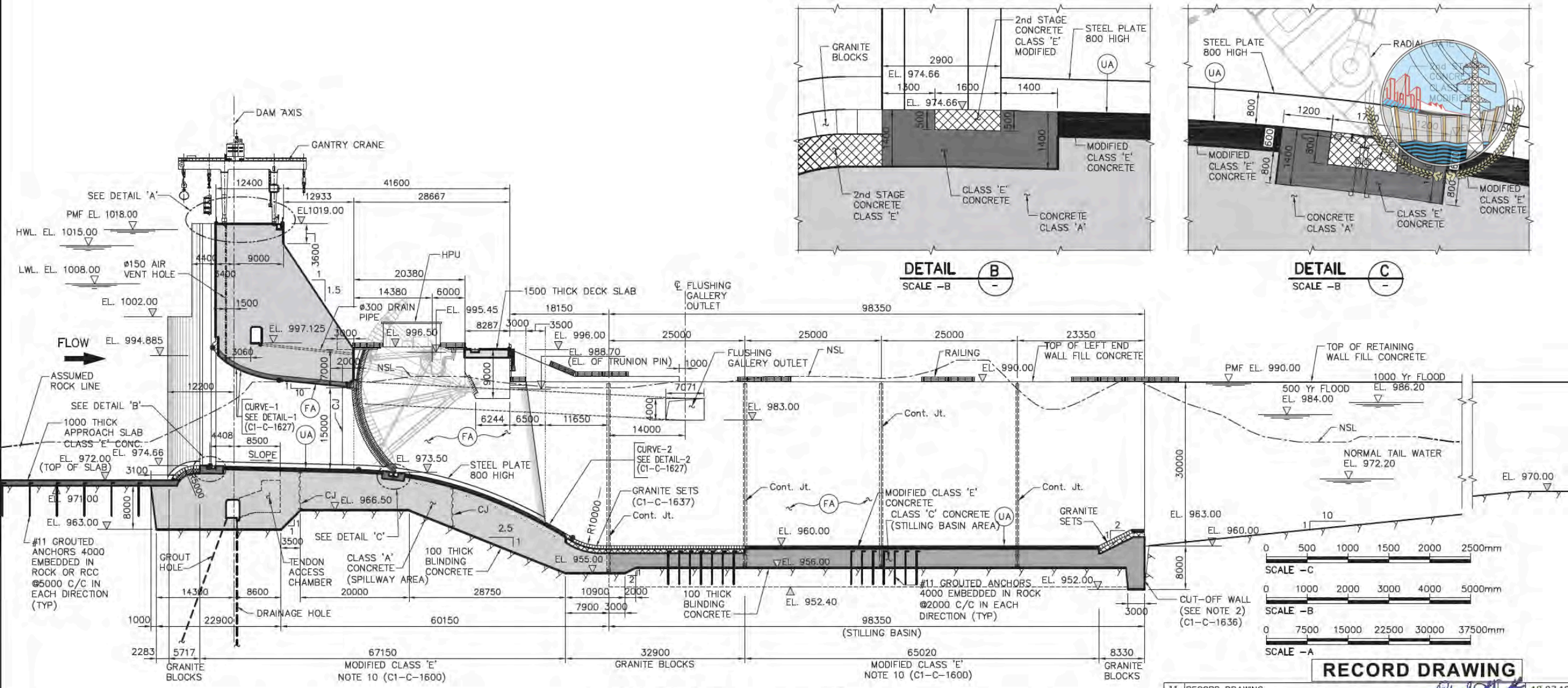



**RECORD DRAWING**

| Rev. | Description | Drawn | Check | Appr. | Date |
|---|---|---|---|---|---|
| 9 | RECORD DRAWING | | SIR | SR | 18.07.19 |
| 8 | REVISED AS SHOWN. | SKA | SIR | SR | 18.11.14 |
| 7 | DRAINAGE GALLERY REMOVED, LEFT END WALL REVISED, RIGHT END WALL CORRECTED & CABLE TRENCH REVISED AS PER DWG. NO. 278E66-01-3-5(2/4)-R5 SUBMITTED THROUGH GZBZJ-NJC-6813 OF JULY 24-2014. | SKA | SIR | SR | 25.08.14 |
| 6 | LEFT END WALL REVISED, HPU LEVELS RAISED AS PER CMEC REQUIREMENT. | SH | SR | JRS | 04.02.14 |
| 5 | Cont. Jt. OF PIERS REMOVED, CJ & CONCRETE CLASS MARKED & TENDONS ARRANGEMENT REVISED. | SH | SR | JRS | 13.12.12 |
| 4 | ROCK ANCHORS REVISED, DIVIDE WALL REMOVED, BASE ANCHORS EXTENT SHOWN. | – | SH | SR | 20.09.12 |
| 3 | REVISED AS SHOWN. | – | T.R | SR | 20.04.12 |
| 2 | REVISED AS SHOWN. | – | T.R | SR | 02.03.12 |
| 1 | GENERAL REVISION | – | SR | JRS | 16.12.11 |

PAKISTAN WATER & POWER DEVELOPMENT AUTHORITY

# Orifice spillway



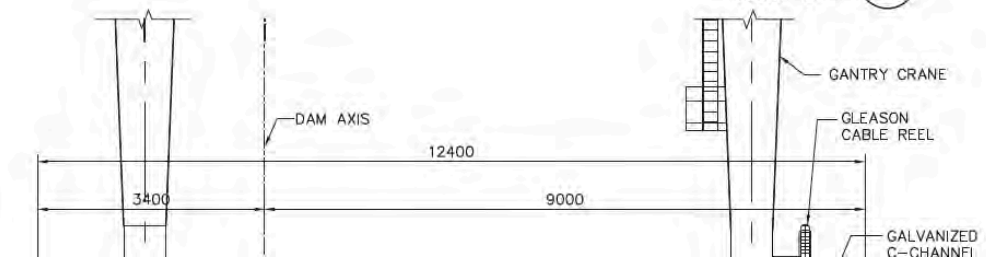




**DETAIL B** SCALE –B




**DETAIL C** SCALE –B




## NOTES:

1. FOR GENERAL NOTES REFER DRAWING NO. C1–C–1600.
2. 1000 THICK CLASS 'E' CONCRETE LAYER IN WALL/PIERS UPTO 15000 HEIGHT FOR PROTECTION AGAINST ABRASION FROM HIGH VELOCITY WATER IN SPILLWAY AREA.

## REFERENCES:

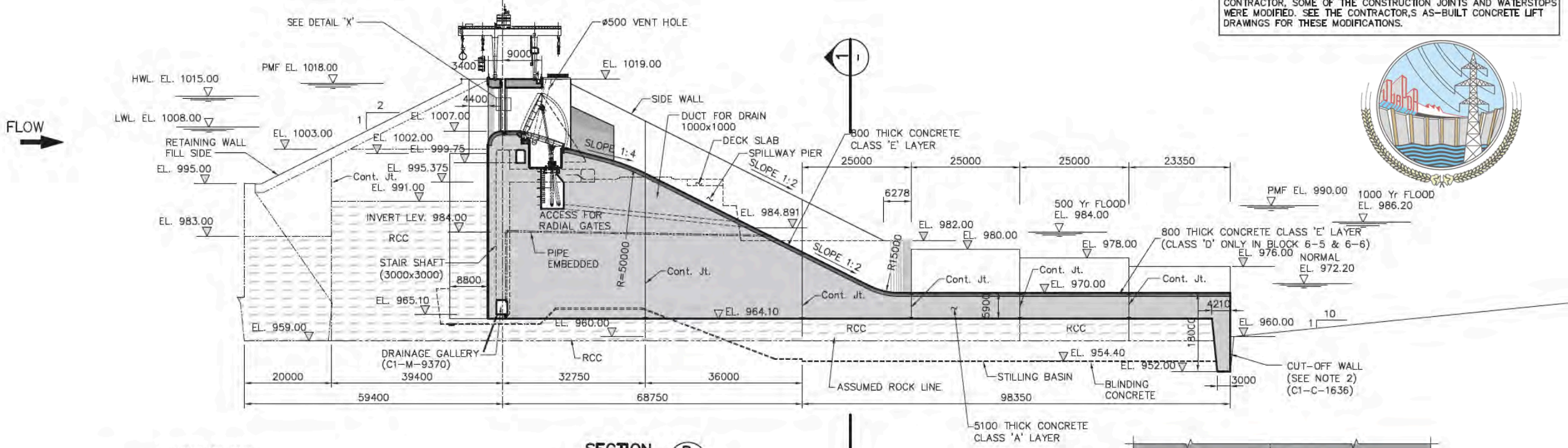
| | |
|---|---|
| DIVERSION DAM LAYOUT PLAN | DWG. NO. C1–C–1420 |
| DIVERSION DAM PLANS | DWG. NO. C1–C–1600,1602,1603 |
| DIVERSION DAM SECTIONS | DWG. NO. C1–C–1615,1616 1620 TO 1626 |
| DIVERSION DAM DETAILS | DWG. NO. C1–C–1631 TO 1641 |
| PRESTRESSING TENDON DETAILS | DWG. NO. C1–C–1631 TO 1633 |
| DIVERSION DAM C.I. DETAILS | DWG. NO. C1–C–1670 TO 1680 |

**RECORD DRAWING**

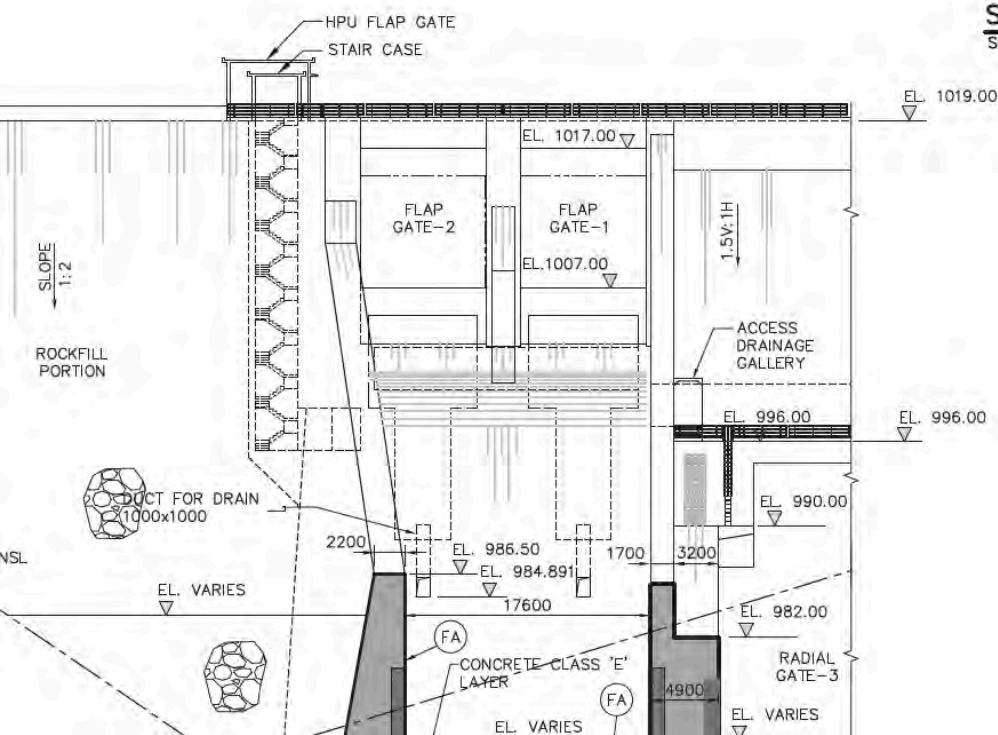
| | | | | | |
|---|---|---|---|---|---|
| 11 | RECORD DRAWING | | | JRS | 18.07.19 |
| 10 | CABLE TRENCH REVISED AS PER DWG. NO. 278E66–01–3–5(2/4)–R5 SUBMITTED THROUGH GZBZJ–NJC–6813 OF JULY 24–2014. | SKA | SIR | SR | 25.08.14 |
| 9 | –DRAINAGE GALLERY FROM LEFT END WALL REMOVED. –ø150 AIR VENT HOLE REMOVED. | SA | SIR | SR | 11.06.14 |
| 8 | C/C DIMENSION BETWEEN GANTRY CRANE REVISED, REF. DCN NO.001 | SH | SR | SR | 01.04.14 |
| 7 | GRANITE BLOCKS REPLACED WITH CONCRETE AT SOME LOCATIONS, HPU LEVEL REVISED AS PER CMEC | SH | SR | SR | 19.12.13 |
| 6 | FLUSHING GALLERY OUTLET, END SILL REVISED & APPROACH SLAB ADDED. | SH | SR | JRS | 13.12.12 |
| 5 | AIR VENT REMOVED BLINDING CONC. ADDED. | – | SH | SR | 07.09.12 |
| 4 | HOLD REMOVED & REVISED AS SHOWN. | | T.R | SR | 20.04.12 |
| 3 | REVISED AS SHOWN. | | T.R | SR | 02.03.12 |
| 2 | GENERAL REVISION | – | SR | JRS | 16.12.11 |
| 1 | GENERAL REVISION. DAM TYPE CHANGED TO COMPOSITE DAM | | SR | FMM | 01.03.11 |

# Surface gated spillway

CONTRACTOR, SOME OF THE CONSTRUCTION JOINTS AND WATERSTOPS WERE MODIFIED. SEE THE CONTRACTOR,S AS-BUILT CONCRETE LIFT DRAWINGS FOR THESE MODIFICATIONS.




SECTION B (1600, 1652)
SCALE –A




## NOTES:

1. FOR GENERAL NOTES REFER DRAWING NO. C1–C–1600.
2. FOR ROCKFILL DAM SECTIONS SEE RELEVANT DRAWINGS.
3. 1500 THICK CLASS 'E' CONCRETE LAYER IN WALL/PIERS UPTO 15000 HEIGHT FOR PROTECTION AGAINST ABRASION FROM HIGH VELOCITY WATER IN SPILLWAY AREA & 1500 THICK CLASS 'E' CONCRETE IN WALLS UPTO 6000 HEIGHT FOR PROTECTION AGAINST ABRASION FROM HIGH VELOCITY WATER IN DEBRIS CHANNEL AREA.

## REFERENCES:

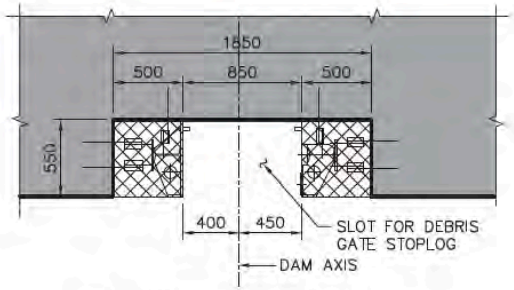
| | |
|---|---|
| DIVERSION DAM LAYOUT PLAN | DWG. NO. C1–C–1420 |
| DIVERSION DAM PLANS | DWG. NO. C1–C–1600,1602,1603 |
| DIVERSION DAM SECTIONS | DWG. NO. C1–C–1615,1616,1620 TO 1626 |
| DIVERSION DAM DETAILS | DWG. NO. C1–C–1631 TO 1641 |
| DIVERSION DAM CJ DETAILS | DWG. NO. C1–C–1670 TO 1680 |
| WATER STOP LAYOUT & GROUTING DETAILS AT CONTRACTION JOINT | DWG. NO. C1–C–1685 TO 1690 |

## LEGEND:

MBT FAULT LINE MAPPED AFTER RIVER DIVERSION

1st STAGE CONCRETE (CLASS 'A' 20 MPa)

1st STAGE CONCRETE




## SECTION OF DETAIL 'X'
SCALE –B

0 500 1000 1500 2000 2500mm
SCALE –B

0 10000 20000 30000 40000 50000mm
SCALE –A

## RECORD DRAWING

| | | | | | |
|---|---|---|---|---|---|
| 8 | RECORD DRAWING | | SIR | SR | 18.07.19 |
| 7 | HPU SIZE & LAYOUT REVISED AS SHOWN. | SKA | SIR | SR | 18.11.14 |
| 6 | DIMENSIONS OF FLAP GATE MODIFIED AS PER CMEC LATEST SUBMISSION THROUGH REF. NO. GZBZJ-NJC-5616 (R-11618). | SKA | SIR | SR | 08.05.14 |
| 5 | CUT-OFF WALL REVISED & CONCRETE CLASS SHOWN. | SH | SR | JRS | 13.12.12 |
| 4 | DIVIDE WALL IN SECTION B REMOVED. | | SH | SR | 07.09.12 |
| 3 | REVISED AS SHOWN. | | T.R | SR | 20.04.12 |
| 2 | REVISED AS SHOWN. | – | T.R | SR | 02.03.12 |
| 1 | GENERAL REVISION | | SR | JRS | 16.12.11 |