# Water Management for Dam Construction

## *Update of Bulletin 48a (1986)*

ICOLD Workshop 28 May 2022
Joint Work Group - Committees E and M

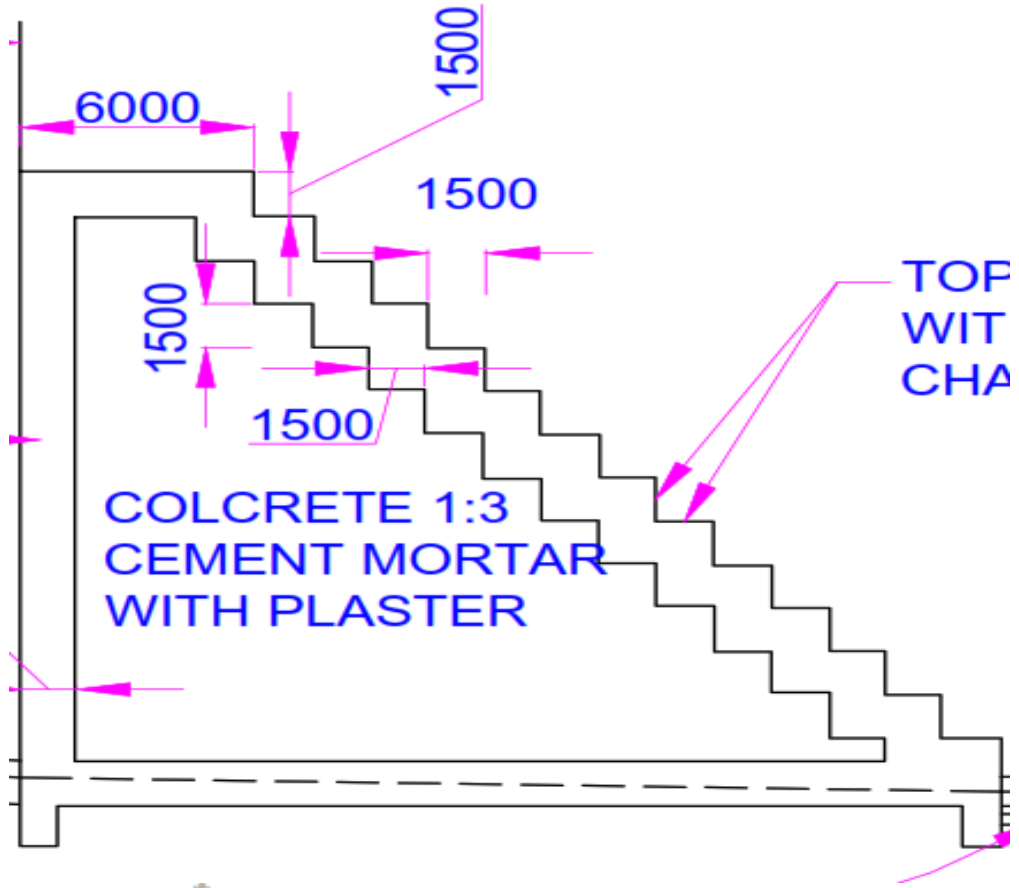
*Dan Johnson, AECOM*
*Dave Paul, Paul Geotek Engineering*
*Rachel Bisnett, Stantec*
*Jean-Pierre Tournier, HydroQuebec*
*Christine Noret, Tractebel*
*Vivek Tripathi, Central Water Commission*
*Finn Midboe, Rejlers*

# *Initial Plan, Challenges, and Design Solution for Cofferdam of Punatsangchhu-I H.E. Project Bhutan*

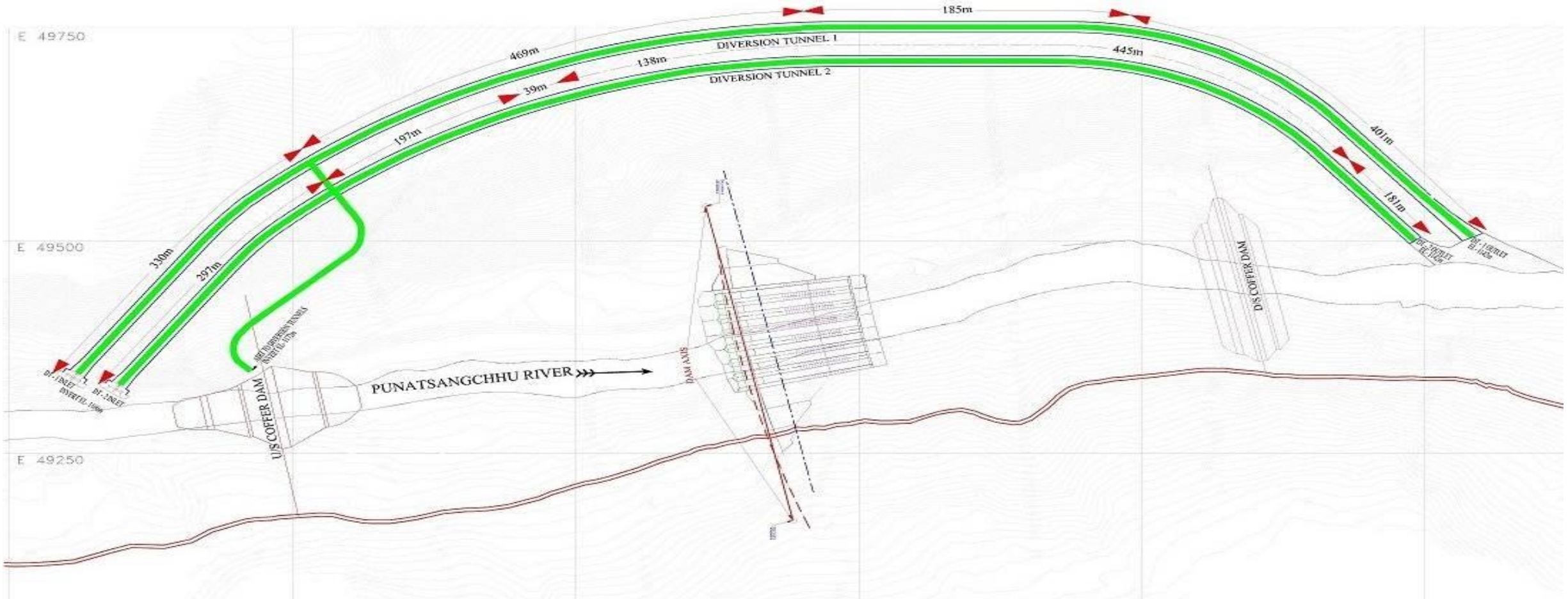
**Presented by :** Vivek Tripathi

# *Initial Features of Diversion Arrangement*

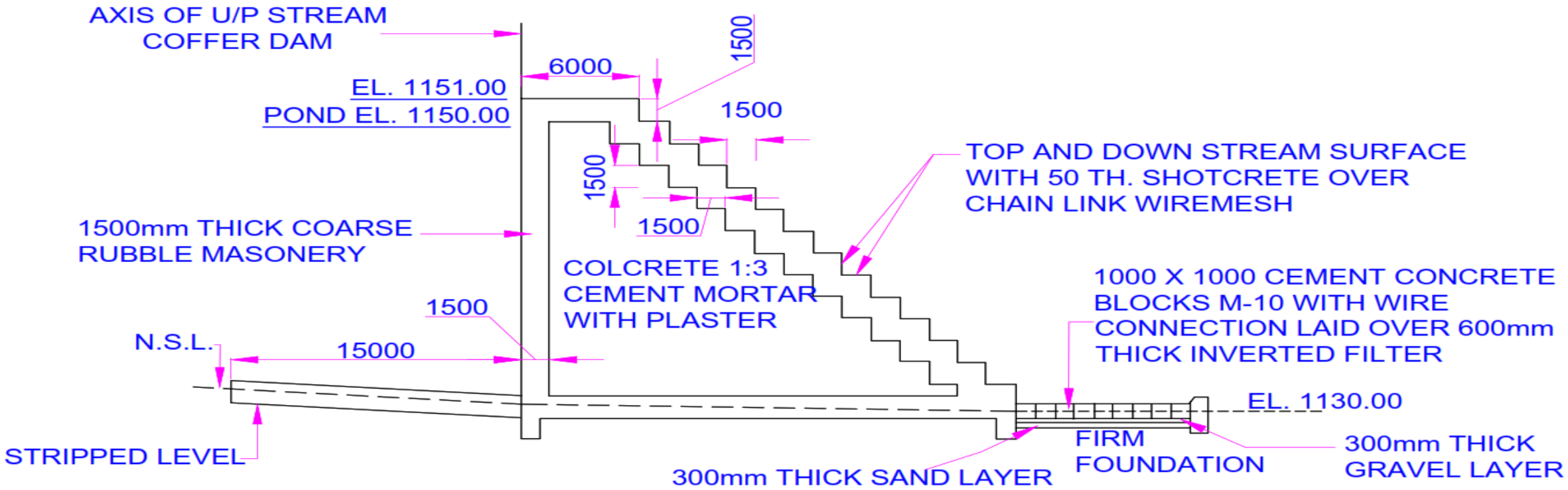
- Height: 21 m
- Length: 124.72m
- Type: Colcrete
- Location: Across the river Punatsangchhu at ± 420m upstream of main dam axis
- Purpose: To facilitate the excavation of main dam.
- Diversion Tunnel: 10m Diameter, 2724m combined length



# *Diversion Arrangement Plan*



# *Maximum Section of Upstream Cofferdam (Colcrete)*




**At DPR stage: 21m high Cofferdam**

# *Geology and Rock Mass Condition*

- The rocky boulders are of medium to coarse grained quartzo-feldspathic gneiss, quartzite and leucogranite. Most of the boulders/cobbles are of quartzo-feldspathic gneiss, which ranges from very small to maximum up to 12m size, whereas the boulders of quartzite and leucogranite are of small to medium size.
- The overburden soil is light yellowish to light brownish colored, granular from very fine to medium grained. It is the matrix of silt, sand and fine gravels but the major part of the soil is silty.

# *Geology and Rock Mass Condition*

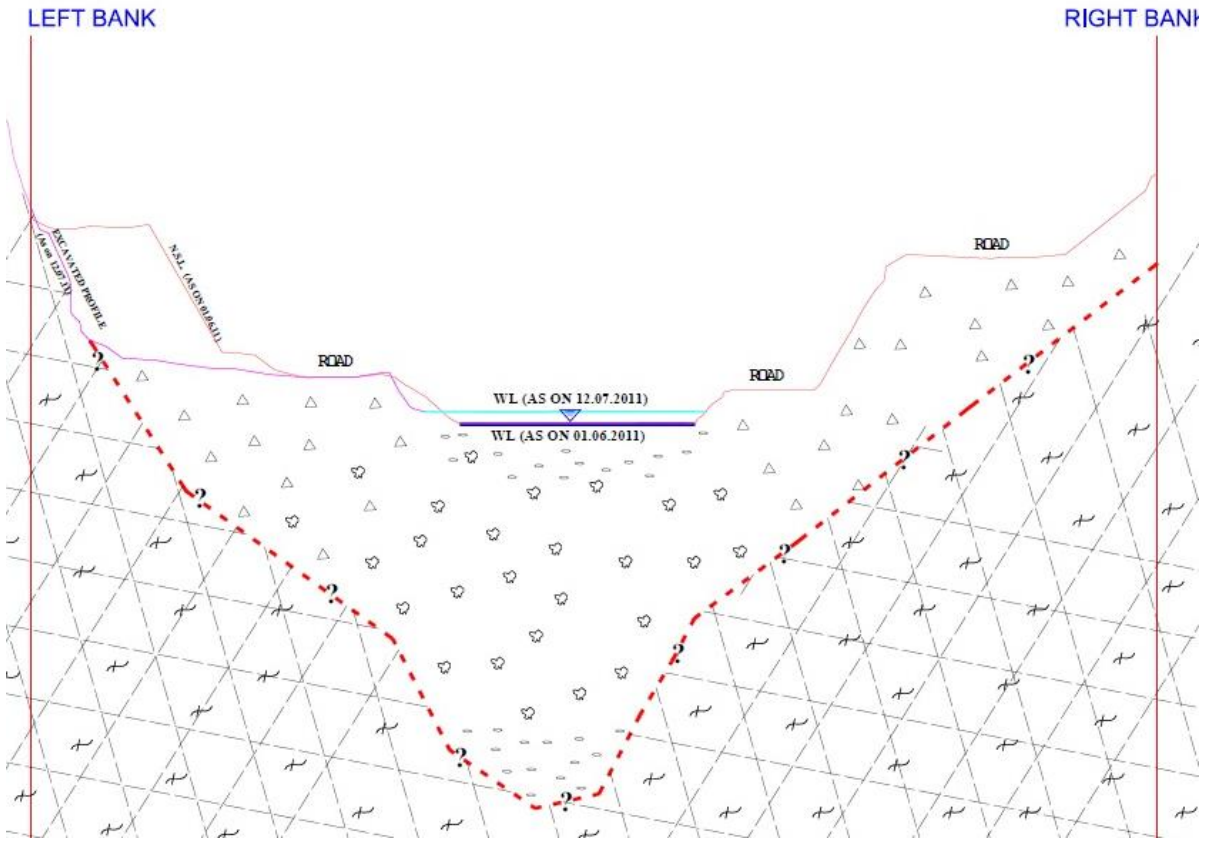
- The river valley at dam site is characterized by steep rocky cliffs on the left bank and gentle abutments on the right bank with alternate ridge and geomorphic depressions. Both the banks and riverbed comprises thick and wide colluvium/hill wash material with some zones of river borne material (RBM).
- The exploratory drill holes and on-going open excavation has revealed that the foundation of the coffer dam in riverbed comprises colluvium/hill wash material consisting of rocky boulders, cobbles and gravels set in overburden soil (silty and sandy matrix).

# *Geology and Rock Mass Condition*

- The borehole data also revealed that, the riverbed area comprises ≈ 20 - 25m wide zone of river borne material (RBM) at certain depths below El 1125m, comprising of sandy layers and well-polished pebbles of gneiss, quartzite and leucogranite
- The encountered colluvium material is assorted and not well graded due to varying size and shapes of boulders, but it is observed that this material is compact, cohesive and moderately denser in majority of the places, which has been witnessed by its angle of repose acquired during excavation on either abutment.

# *Detailed Investigation at Tender Stage*

- To ascertain the riverbed rock:
  - 05 drill holes along the axis
  - 03 vertical holes on right bank and one inclined at 300 angle and one vertical hole drilled at left bank
  - All holes terminated after 30-40 m in fresh bedrock
  - Deepest bedrock encountered was at 70 m below the riverbed at upstream coffer
  - PLT= 37 t/m2



# *Important Findings*

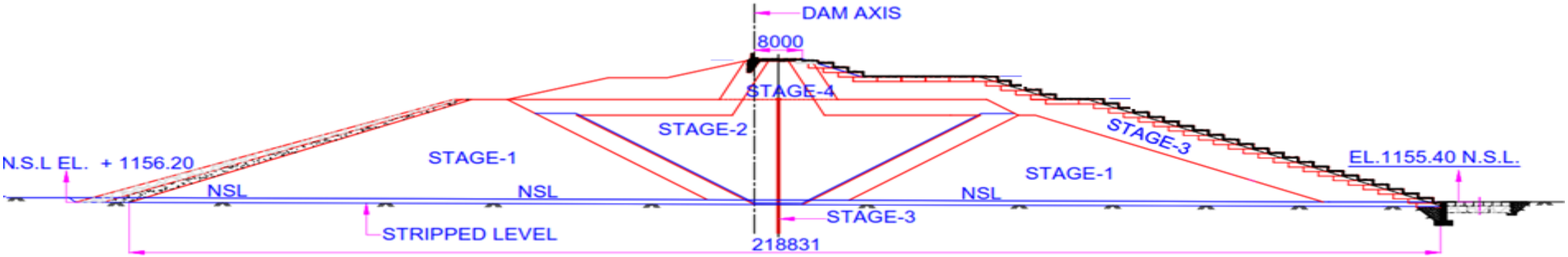
- River borne material had marginally low safe bearing capacity
- Deepest rock level at approx. 70m at cofferdam and at main dam

*This meant that the excavation at main dam site would require more time and be deeper.*

# *Change in Dam Type after Detailed Investigations*

- 21m Colcrete type dam was changed to **21m rock fill with combination of clay core** and jet grouting wall to stop seepage, to allow the bearing stresses withing permissible limits
- Initially Diversion Dam was designed for discharge of  1960 cumecs and was kept same.

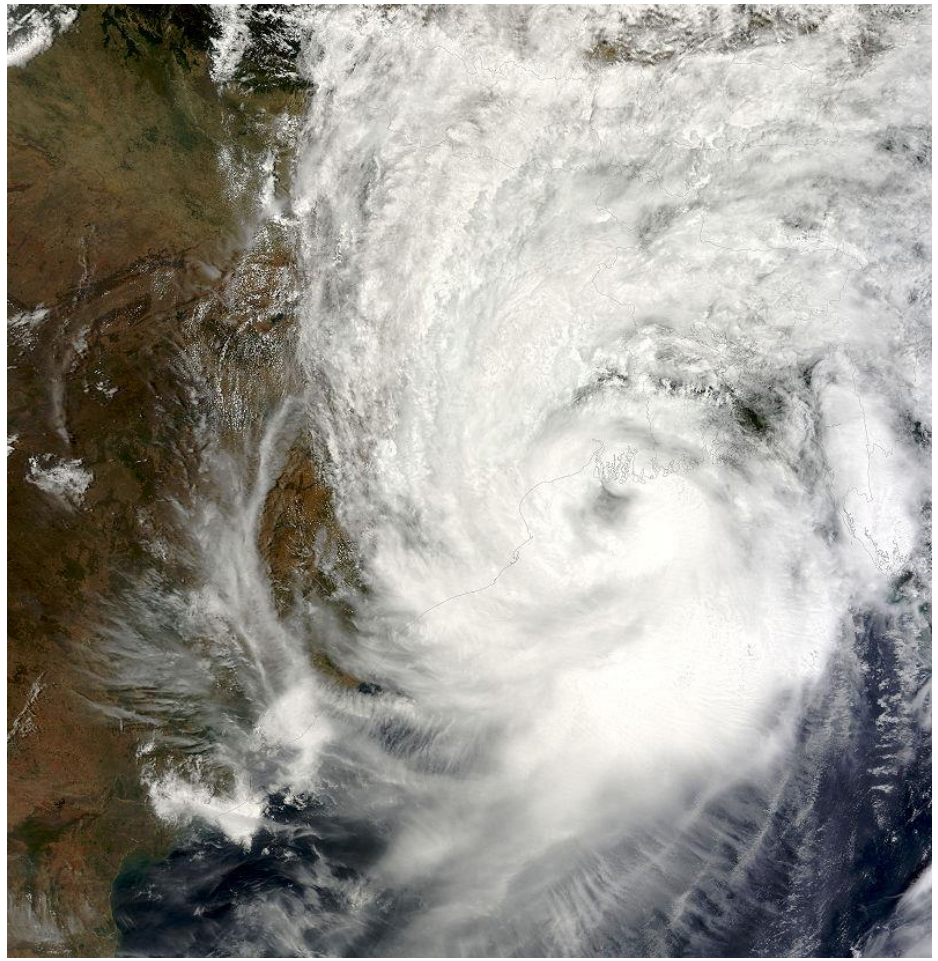
# *Maximum Section of Upstream Coffer Dam (Rockfill) at Tender Stage*



# *On the verge of construction…*

**Cyclone Aila**

- On 26 May 2009, Punatsangchhu River received maximum ever recorded discharge of 2430 cumecs due to Cyclone Aila.
- This led to revision of design.
- In new design, Coffer Dam top EL increased to 29m and diameter of diversion tunnels increased to 11m.



# *Design Challenges*

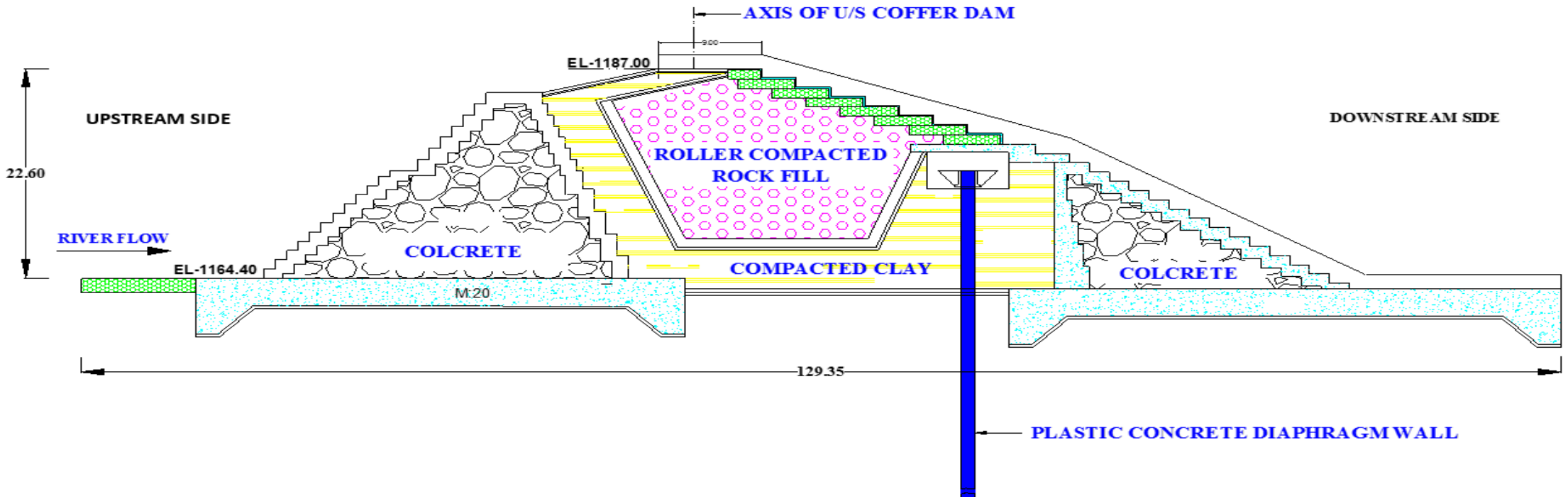
**Increase in height created some other challenges**

- Higher safe- bearing capacity requirement of the foundation soil as otherwise settlement cracks would be developed in the structure.
- The construction of U/s coffer dam had to be completed up to safe height before start of monsoon of 2012.
- Energy dissipation of spilling water in the event of overflow would be difficult to manage.
- The stiff junction between the jet grout curtain and type of Dam to be adopted as that would crack resulting in heavy seepage.

# *Design Solutions*

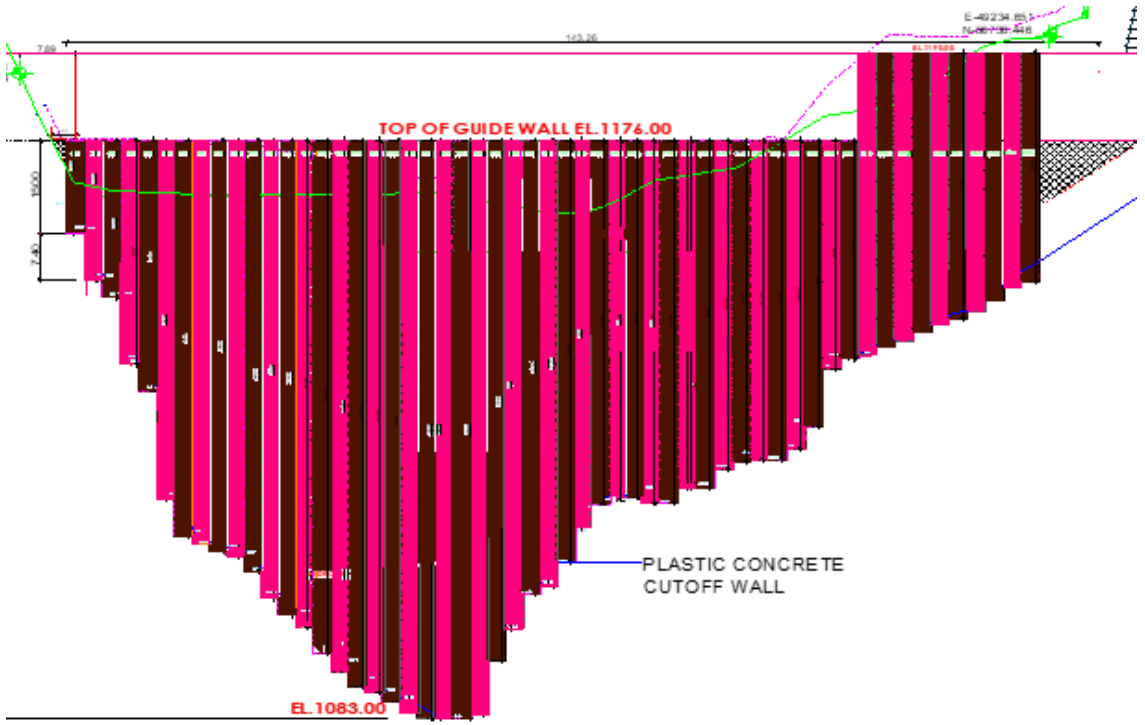
To achieve such height before monsoon, the coffer dam was conceptualized to be made in parts:

**Two colcrete dams of each 18m height founded on raft foundation and sandwiching central portion of rockfill type with lined compacted clay.**



# *Design Solutions*

An 8m to 9m pedestal of larger base width was proposed so that an 18m Colcrete Dam of normal dimension can leave a sufficient wide Colcrete berm down-stream of the 18m height portion of the dam and settlement can be taken care of appropriately.




This served two purposes:

- The construction of dam could be achieved at a desirable height before the first monsoon.
- The work was done at faster rated compacted clay.

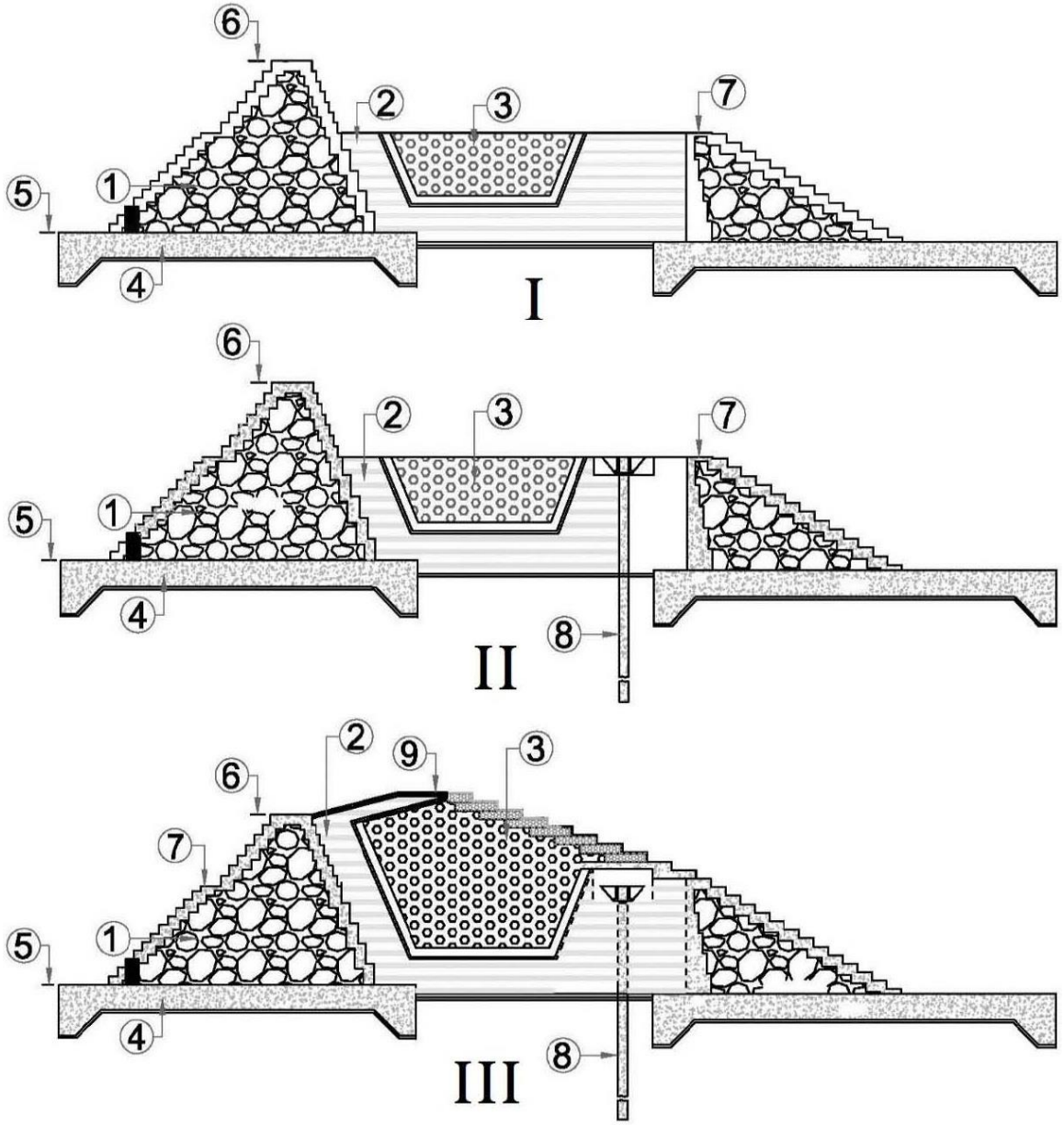
# *Design Solutions*

Considering the unprecedented event of Cyclone Aila, designers decided to provide an energy dissipation arrangement in the downstream slope of the coffer dam by providing the steps along with a provision of 5x1x1m blocks of gabion boxes covered by 150mm thick concrete of M20 grade with expansion joints and PVC seal provision at 6.0m c/c.

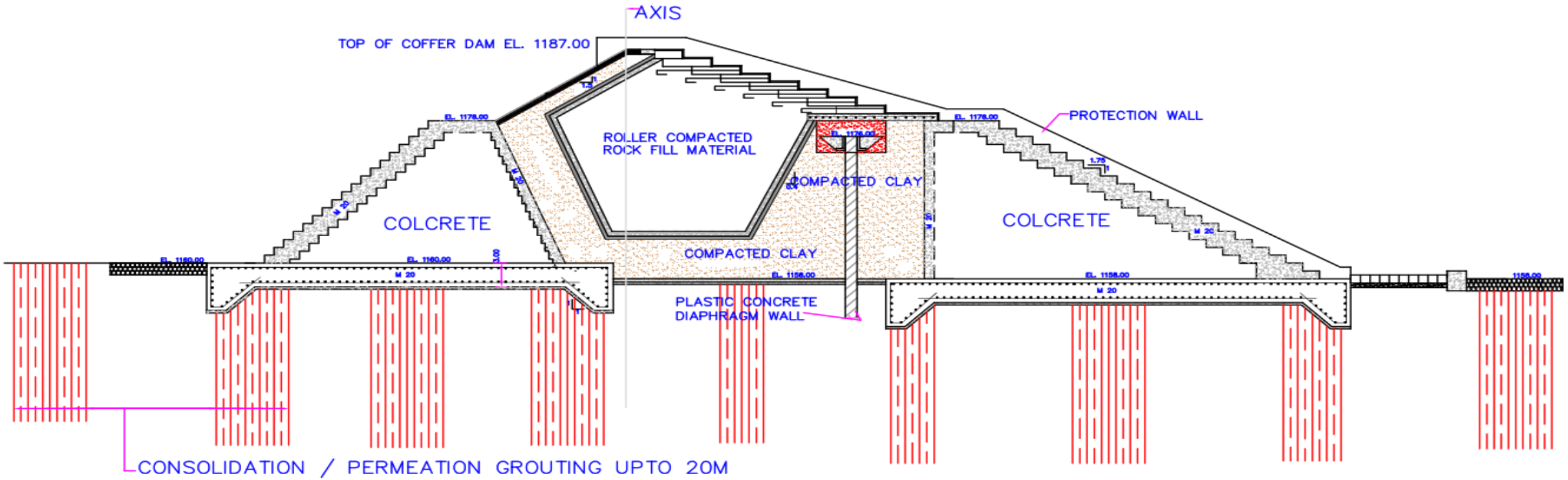
The grout curtain and the Colcrete Dam, the problem of possible cracking is eliminated as the curtain below the Coffer Dam has been revised from "jet grouting" to "plastic concrete cutoff wall" to accommodate for the deformations.

# *Sequence of Construction of Cofferdam*

1. Colcrete
2. Clay
3. Rockfill
4. Raft
5. EL. 1164.40m
6. EL. 1184.40m
7. EL. 1176.00m
8. Plastic concrete cutoff wall
9. EL. 1187.00m



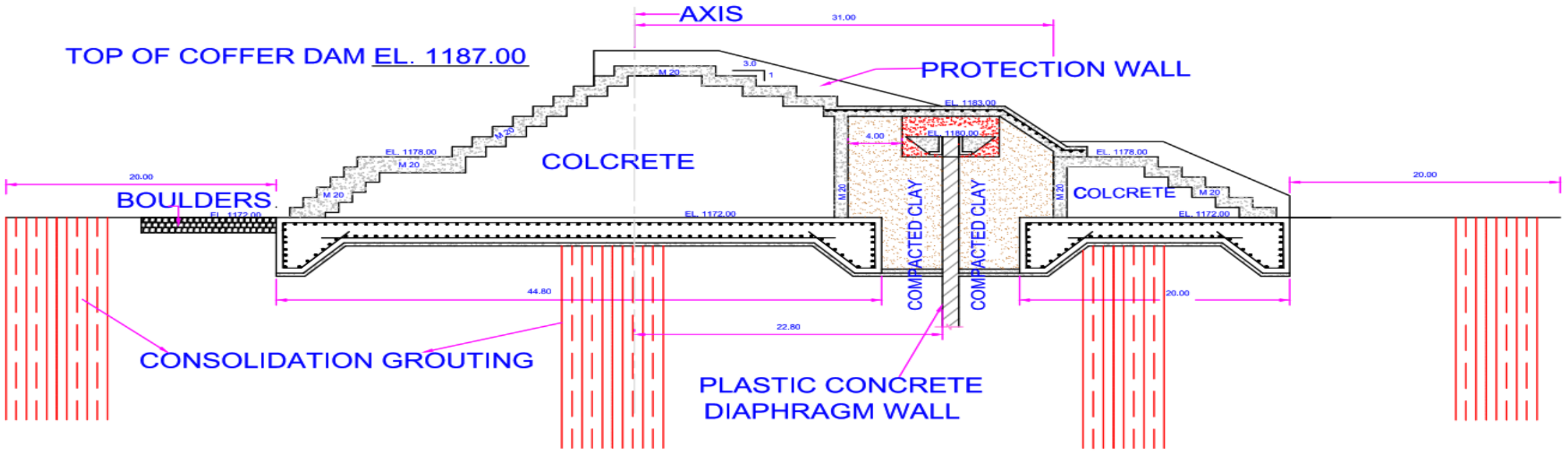
# *Maximum Section of Upstream Cofferdam at Centre (colcrete type) with Clay and Plastic Cut Off Wall*



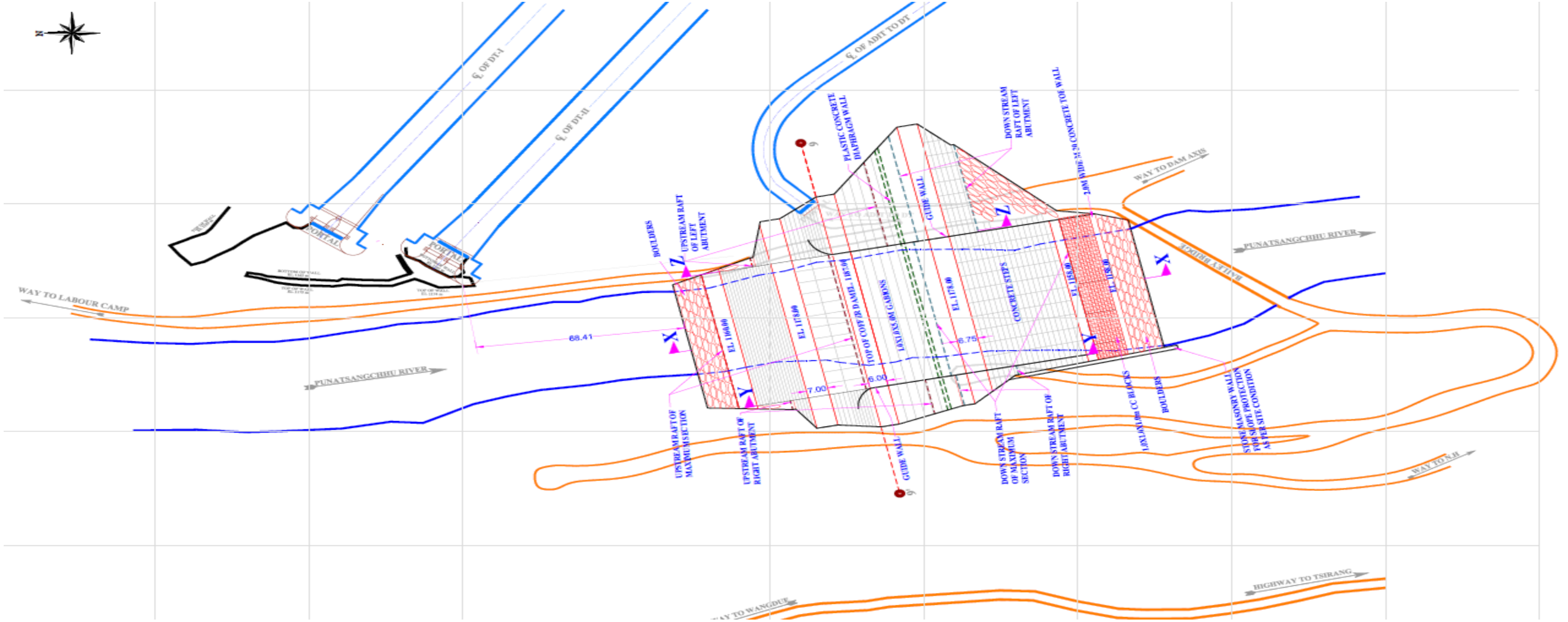
# *Final Features of Diversion Arrangement*

- **Height:** 29 m
- **Length:** 124.72m
- **Type:** Colcrete-cum-rockfill type with plastic concrete wall
- **Location:** Across the river Punatsangchhu at ± 420m upstream of main dam axis
- **Purpose:** To facilitate the excavation of main dam.
- **Diversion Tunnel:** 11m Diameter, 2724m combined length

# *Section of Upstream Coffer Dam at Abutments (Colcrete type) with Clay and Plastic Cut Off Wall*



# *Plan of Cofferdam*



# *Questions*

- Why provide a cut off wall the cofferdam, which is a temporary structure?
- What is the purpose of using colcrete in the cofferdam structure?

# *Thank You*