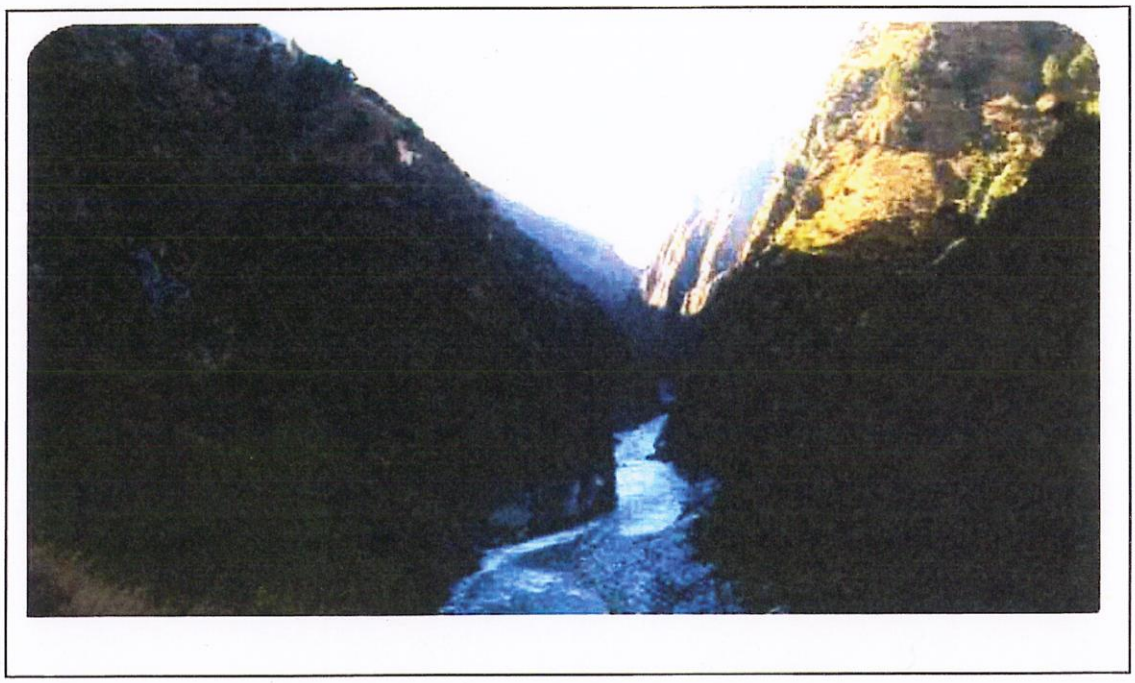
JAMMU & KASHMIR STATE POWER DEVELOPMENT CORPORATION

(A GOVT. OF J&K UNDERTAKING)

SAWALKOT HYDROELECTRIC PROJECT

JAMMU & KASHMIR

1856 MW (1406 MW STAGE - I + 450 MW STAGE - II)



DETAILED PROJECT REPORT

(Final as cleared by CEA)

VOLUME 0: EXECUTIVE SUMMARY

FEBRUARY 2018

SAWALKOTE CONSORTIUM

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

Sawalkot Hydroelectric Project (J&K)
Detailed Project Report
(Final as cleared by CEA)

List of Volumes

- **Volume 0 -- Executive Summary**
- Volume 1 -- General Chapters Including Hydrology & Power Potential
- Volume 2A -- Geology
  - Part 1(a) – Chapters
  - Part 1(b) – Plates
  - Part 2 – Bore Holes Logs & Test Reports
  - Part 3 – Previous GSI Reports
  - Part 4 – In-situ Rock Mechanics Tests
  - Part 5 -- Site Specific Design Earthquake Parameters
- Volume 2B – Construction Material
- Volume 3A -- Design and Engineering
  - Part 1 – Civil
  - Part 2 – Hydro-Mechanical
  - Part 3 – Electro-Mechanical
- Volume 3B -- Drawings
- Volume 3C -- Additional Design Studies
- Volume 4 -- Construction Methodology and Equipment Planning
- Volume 5 -- Cost Estimate and Financial Analysis

Dr. G.S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

TABLE OF CONTENTS

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

JKSPDC

No: - JKSPDC/ / P-76 (III)/9659-64
Date:- 8.03.2018

To,
The Secretary,
Central Electricity Authority,
Sewa Bhawan, R. K. Puram,
New Delhi-110066

Subject: - Submission of final DPR of 1856 MW Sawalkot HE Project, J&K

Ref: -

1. Your letter no. 2/J&K/19/CEA/03-PAC/2371-77 dated: - 27-09-2017
2. This office letter No:- JKSPDC/ / P-76 (II)/ 7143-46 dated 04.10.2017
3. Your letter No:-2/Hydro/Genl./2000-PAC/3086-3146 dated: - 07-12-2017
4. Your letter No:-2/J&K/19/CEA/03-PAC/617-618 dated: -07-03-2018

Sir,

May please refer above referred letters on the subject matter. Final DPR of the project was submitted to CEA for vetting vide JKSPDC letter referred at S.No 2. alongwith certificate to the effect that the said DPR fully incorporates all the compliances/ suggestion agreed by JKSPDC during appraisal process and is based upon the final clearance issued by various appraising groups from CEA/CWC/GSI/CSMRS.

However, vide your letter referred at S.No 3, JKSPDC was directed to get the salient features of the project vetted from Hydrology/Design Divisions of CWC and HE&TD/ PSP&A/HPA/HPP&I divisions of CEA, in accordance with the new procedure issued by CEA for concurrence vide letter 07.12.2017. On completion of the vetting process of the salient features, final/updated DPR after incorporating the vetted salient features and also modifying the DPR in compliance to the vetting letters issued by GSI vide letter dated 04.01.2018 and CSMRS vide letter dated 15.01.2018, the updated/final DPR of 1856 MW Sawalkot HEP in six hard bound copies is submitted herewith along with soft copy, as desired vide your letter referred at S.No 4.

It is again certified that all the changes/ modifications as approved/agreed upon during the detailed examination/appraisal process and all the vetted final salient features have been incorporated in the final DPR

It is requested that Techno-Economical Appraisal Letter in respect of above DPR of Sawalkote HEP may kindly be issued at earliest.

Thanking you,

Yours' faithfully,

(Shah Faesal) IAS
Managing Director

Copy to:-

1. Executive Director (E), JKSPDC
2. Executive Director (C), JKSPDC
3. Director Finance, JKSPDC.
4. Chief Engineer, Sawalkot HEP, JKSPDC
5. Director, PAC, CEA

JAMMU AND KASHMIR STATE POWER DEVELOPMENT CORPORATION LIMITED
(A Government of J&K Enterprise)
Regd. Office : Exhibition Ground, Srinagar - 190009
Ph. : 0194-2483783 Fax : 01924-2451665
Camp Office : Ashok Nagar, Satwari, Jammu - 180004
Ph. : 0191-2430548/24309039 Fax : 0191-2435403
CIN : U40101JK1999SGC001418 Website : www.jkspdc.nic.in.

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

CHAPTER – 1

BACKGROUND & INTRODUCTION

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

CHAPTER - 1

BACKGROUND AND INTRODUCTION

1.1 The Project

Sawalkot Hydroelectric Project (1856 MW) envisages harnessing hydropower potential of River Chenab in the reach downstream of Baglihar HEP and upstream of Salal HEP in the state of J&K (ref. Plate-01). The Project is being implemented by JKSPDC (A Govt. of J&K Enterprise).

The project consists of the following main components (ref. Plate-02):

- A Roller Compacted Concrete Dam of 192.5 m height from deepest foundation
- River diversion scheme for monsoon diversion consisting of 3 no. diversion tunnels on the right bank and upstream and downstream coffer dams
- 3 no. power intakes
- 3 no. short Headrace Tunnels
- 8 no. pressure shafts
- An underground power house complex housing 8 no. generating units of 225 MW each and 1 no. generating unit of 56 MW (for environmental flow) (ref. Plates - 03, 04 & 05)
- 4 no. Tailrace Tunnels
- A pothead yard

1.2 Location & Approachability

Sawalkot HEP is located in the Ramban and Udhampur Districts of Jammu & Kashmir State between Baghliar Project to its upstream and Salal Project to its downstream. Nearest village from the dam site is Sidhu which is located around 2.5km U/S of the dam axis. The project site is approachable from Jammu by NH-1A/44 up to Ramban which is the nearest important town, 150 kms away from Jammu and 144 kms from Srinagar. From Ramban, project site is approachable up to Dhamkund by a BRO road (all weather tar road), then onwards project site is approachable by an 18 km long project road. Nearest railway head is Udhampur from where project site is located at

around 100km away. Beyond Udhampur, presently construction of railway line to Srinagar valley via Katra is in progress. Both Jammu and Srinagar airports are almost equidistant from the project site and both are connected directly with Delhi.

1.3 Background information

Sawalkot hydro electric project over river Chenab was conceived by erstwhile Central Water & Power Commission (CW&PC) which is presently known as Central Water Commission (CWC). Detailed investigation for the preparation of Detailed Project Report (DPR) was initiated at their behest in early 1960's. Detailed geological investigation for the proposed project, which included a 155m high concrete gravity dam, a 5.5km long Head Race Tunnel, a surface power house on the right bank and other appurtenant structures was carried out by geologists of Geological Survey of India between F.S. 1962-'63 and 1968-'69 Afterwards for the preparation of DPR, necessary field and laboratory tests and other detailed engineering studies were carried out by different Government organisations under the guidance of CWC. Initially a DPR was prepared by CWC considering the scheme as a run of the river scheme for generation of 1200MW of hydro power from this project in two stages (Stage-I & II of each 600MW capacity). Later on, the project was handed over to NHPC for execution.

Subsequently, JKSPDC took over the project from NHPC and decided to execute the project as state sector project.

The Sawalkot consortium proposed a layout with underground powerhouse and short tail race tunnel on the left bank. Sawalkot consortium prepared and submitted the detailed project report of 1200MW in March 2006 to JKSPDC/CEA. During Examination of DPR in CEA, CWC and GSI in 2006, additional studies were sought to be carried out.

Meanwhile, based upon approved Hydrology, the installed capacity of the project has been approved by CEA in April 2012 as 1406 MW as Stage-I and 450 MW as Stage-II. The DPR for 1856 MW capacity was accordingly submitted to CEA in January 2014 for examination and accord of appraisal.

The DPR of Sawalkot Hydroelectric Project for 1856 MW capacity was accepted in CEA for examination in April 2014.

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

The DPR was subsequently examined in CEA/CWC/GSI during 2014 to 2017 and was cleared from different wings from time to time. CEA vide its letter no. 2/J&K/19/CEA/03-PAC/2371-77 dated 27.09.2017 has communicated to submit the final DPR of the project incorporating various compliances made by JKSPDC in respect of various stipulations made by various appraisal groups (viz GSI/CSMRS/CEA/CWC) and as agreed upon by JKSPDC during the appraisal process/detailed examination.

This final Detailed Project Report (DPR) is organised in following volumes:-

- Volume 0 -- Executive Summary
- Volume 1 -- General Chapters Including Hydrology & Power Potential
- Volume 2A -- Geology
    - Part 1(a) – Chapters
    - Part 1(b) – Plates
    - Part 2 – Bore Holes Logs & Test Reports
    - Part 3 – Previous GSI Reports
    - Part 4 – In-situ Rock Mechanics Tests
    - Part 5 -- Site Specific Design Earthquake Parameters
- Volume 2B – Construction Material
- Volume 3A -- Design and Engineering
    - Part 1 – Civil
    - Part 2 – Hydro-Mechanical
    - Part 3 – Electro-Mechanical
- Volume 3B -- Drawings
- Volume 3C -- Additional Design Studies
- Volume 4 -- Construction Methodology and Equipment Planning
- Volume 5 -- Cost Estimate and Financial Analysis

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

CHAPTER - 2

SALIENT FEATURES

Dr. G. S. S. H VA
Senior Manager (
NHPC

CHAPTER - 2

SALIENT FEATURES

1.	**LOCATION**		
	(i)	Country	India
	(ii)	State	Jammu & Kashmir
	(iii)	Districts	Ramban and Udhamapur
	(iv)	River	Chenab
	(v)	Location of dam & Power House site Northing Easting Topo sheet No. 43 O/4	 33°11'N 75°06'E
	(vi)	Location of dam & Power House site	Near Sedhu Village and d/s of confluence of Mandiyal and Talsuen Nalla with river Chenab
	(vii)	Nearest Rail Head	Udhampur
	(viii)	Nearest Airport	Jammu & Srinagar
2	**PURPOSE - Hydropower**		
3	**HYDROLOGY**		
	(i)	Catchment Area	19,475 km^2
	(ii)	Location of Catchment Latitude Longitude	States of Himachal Pradesh and Jammu & Kashmir Lat 32° to 34° 15' N Long 74° to 78° E
	(iii)	Design flood (PMF)	18,711 cumecs
	(iv)	Water availability Series	From 1975-76 to 2008-09
4	**RESERVOIR**		
	(i)	Full Reservoir (FRL)	EL. 695m
	(ii)	Maximum water level (MWL)	EL. 695m
	(iii)	Min. Draw down level	EL. 692.80m
	(iv)	Reservoir Area	11 km^2

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

	(v)	Length of Reservoir at FRL	30 km
	(vi)	Gross storage at FRL	530 MCM
	(vii)	Live Storage/ Operational Pondage	23.84 MCM
	(viii)	Annual Sediment Load	41.38 MCM
	(ix)	Pondage required for firm power	11.92 MCM
	(x)	Maximum Permissible Pondage	23.84 MCM
	(xi)	Pondage provided	23.84 MCM
5	**CONCRETE DAM**		
	(i)	Type	Roller Compacted Concrete (RCC) Gravity Dam
	(ii)	Dam top elevation	EL. 697.5m
	(iii)	FRL Elevation/Pond level	EL. 695 m
	(iv)	River bed level at dam site	EL. 534m
	(v)	Deepest foundation level	EL.505m
	(vi)	Height of dam (above deepest foundation level/from river bed)	192.5m/163.5 m
	(vii)	Length of Dam at top	240 m
	(viii)	Type of foundation cut off	Curtain grouting in rock
6	**SPILLWAY**		
	(i)	Design flood (PMF)	18,711 cumecs
	(ii)	Type	Sluice Spillway (5 bays) and Crest Spillway (2 bays)
	(iii)	**Crest Elevation** Lower Level Upper Level	 • EL 657.0m • EL 675.0m
	(iv)	Number and Size of Spillway Openings	➢ Lower Level • Number – five • Size (W X H) – 11 m x16.5 m ➢ Upper Level • Number - Two • Size (W X H) – 13 m x 20 m
	(v)	Energy dissipation	Ski jump bucket
	(vi)	Total length of Spillway Blocks	125m
	(vii)	Type of gate	Radial

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

	(viii)	Plunge Pool EL	515 m
7	**DIVERSION TUNNEL**		
	(i)	Diameter, nos. & shape	13.5m X 19m, 3 nos, Horse shoe Shaped
	(ii)	Length	965m, 1130m, 1280m
	(iii)	Diversion discharge (Monsoon in 25 years return flood)	9,292 cumecs (Monsoon) 2,977 cumecs (Non Monsoon)
	(iv)	Invert Level at Entry	• DT-1 : El. 535m • DT-2: EL. 539m • DT-3: EL. 543 m
	(v)	Invert Level at Exit	• DT-1: El. 532 m • DT-2: EL. 536 m • DT-3: El. 540 m
	(vi)	Diversion Tunnel Gate (Type of Gate)	Fixed Wheel Type
	(vii)	Size of Opening	6 m x 19 m each
	(viii)	Design Head	122m
8	**COFFER DAM**		
	(i)	Type of u/s Coffer Dam/ d/s Coffer Dam	Earth & Rock fill coffer dam
	(ii)	Max. height of u/s Coffer Dam	53m
	(iii)	Top of upstream cofferdam	588m
	(iv)	Max. height of d/s Coffer Dam	38m
	(v)	Top of d/s coffer dam	570m
9	**POWER INTAKE**		
	(i)	Numbers	Three (Two for Stage-I & One for Stage-II)
	(ii)	Design discharge per Intake	• Intake – 2: 519.16 m^3/s, (Including Environment flow 39.97 cumec)) • Intake – 1: 479.19 m^3/s, • Intake Stage II: 319.46 m^3/s (Stage-II)
	(iii)	Invert Level	• El. 675.4 m (Intake 1 & 2) • EL. 677.4 m (Intake stage II)
	(iv)	Centre Line of Intake	• Intake 1 & 2: 679.75m each • Intake stage II: 681.25m

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

	(v)	Trash Rack Dimension Number	• Stage-I 35 (excl. piers)x22.78 (inclined) • Stage-II 22.5 (excl. piers)x22.78 (inclined) • Stage –I (2 nos) • Stage –II (One number)
	(vi)	Type of Gate	Vertical
	(vii)	Design Head	Stage -I 20m Stage-II 18m
10	**HEAD RACE TUNNEL**		
	(i)	Numbers and type	Two for Stage-I & one for Stage-II (Circular type)
	(ii)	Size	• 12.8 m for Stage-I • 10.8 m for Stage-II
	(iii)	Length	• About 200m each
	(iv)	Design discharge	• Stage-I i. 519.16 m^3/s, (Including Environment flow) ii. 479.19 m^3/s • Stage-II 319.46 m^3/s
11	**PRESSURE SHAFT / PENSTOCK**		
	(i)	Numbers	6 No. for Stage - I & 2 no. for Stage - II
	(ii)	Type	Steel lined
	(iii)	Diameter	• PS-1 to PS-5:- 6 m dia. Each • PS-6:- 6.7 m dia. • 2.75 m dia penstock for 56 MW Environmental unit (EU)
	(iv)	Length Inclined Horizontal	 130m - 140m 50m to 115m
	(v)	Design Discharge (each penstock)	• 159.73 cumecs (PS 1,2,3,4,5,7 and 8 each) • 199.70 cumecs (PS 6), including discharge for EU

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

	(vi)	Velocity (penstock)	• 5.65 m/s (PS 1,2,3,4,5,7 and 8 each) • 5.67 m/s (PS 6)
12	**POWER HOUSE**		
	(i)	Type	Underground
	(ii)	Size	• 23m (W) x 46.5m (H) x 218m (L) for Stage-I • 23m (W) x 46.5m (H) x 64m (L) for Stage-II
	(iii)	Type of turbine	Vertical Francis
	(iv)	Unit installed capacity	6 x 225 MW + 1 x 56 MW (Stage-I) 2 x 225 MW (Stage–II) Total Capacity 1856MW
	(v)	Unit discharge	• 159.73 cumecs (Units 1,2,3,4,5,6,7 and 8 each) • 39.97 cumecs (for Environmental Unit)
	(vi)	Net Rated head	• 155.7m for Unit-1, 2, 3, 4, 7 and 8 • 153.5m for Unit 5, 6 and EU
	(vii)	Head Loss	• 4.565 m (Unit 1, 2, 3, 4, 7 & 8) • 3.765 (Unit 5, 6 & EU)
	(viii)	Normal TWL (all units running)	***Stage-I*** • For units-1, 2,3 & 4= 534 m • For units -5 & 6 and environment unit =537 m. ***Stage-II*** • For units- 7 & 8= 534 m
	(ix)	Minimum TWL (One machine running at 50% load)	***Stage-I*** • For units-1, 2,3 & 4= 531 m • For units -5 & 6 and environment unit =533.5 m. ***Stage-II*** • For units- 7 & 8= 531 m
	(x)	Maximum Tail Water Level (during July, August considering a spillway discharge of 1000 cumecs)	***Stage-I*** • For units-1, 2,3 & 4= 537 m • For units -5 & 6 and environment unit =545 m. ***Stage-II*** • For units- 7 & 8= 537 m
	(xi)	Turbine Axis Elevation	El. 525 m

Dr. G.S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

13	**TRANSFORMER CAVERN**		
	(i)	Type	Underground
	(ii)	Size	• 15m (W) x 23.5m (H) x 211m (L) for Stage - I • 15m (W) x 23.5m (H) x 56m (L) for Stage – II.
	(iii)	Number	Single continuous cavern
	(iv)	Transformer details	536.10 m
14	**POWER HOUSE COMPLEX**		
	(i)	Type of Power House (Underground/Surface/Semi)	Underground
	(ii)	Scheme of Hydro Electric Project (ROR/Storage)	RoR
	(iii)	Installed Capacity No. of Units	• 1406 MW (Stage-I) • 450 MW (Stage-II) Total = 1856 MW 6 x 225 MW + 1 x 56 MW (Stage-I) 2 x 225 MW (Stage–II)
	(iv)	Status of Overload capability of Unit	10%
	(v)	Status of Butterfly Valve Chamber (Yes/No)	No
	(vi)	Status of Desilting Chamber (Yes/No)	No
	(vii)	Rated Head including Maximum Net Head & Minimum Net Head.	*Rated Net Head* • 155.7m for Unit-1, 2, 3, 4, 7 and 8 • 153.5m for Unit 5, 6 and EU *Maximum Net Head* • 163m for unit 1,2,3,4,7 and 8 • 160.50m for units 5, 6 and EU *Minimum Net Head* • 154.30m for unit 1,2,3,4,7 and 8 • 152.20m for units 5, 6 and EU
	(viii)	Type of turbine	Vertical Francis
	(ix)	Turbine Efficiency	93% for unit size 225MW capacity 92% for unit size 56MW capacity
	(x)	Synchronous speed	• 166.67 rpm (225 MW machine)

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

			• 300 rpm (56 MW machine)
	(xi)	Power Factor	0.85
	(xii)	Generator Efficiency	• 98.5%
	(xiii)	Generation Voltage	• 16kV for 264.7 MVA • 11kV for 65.9 MVA
	(xiv)	Generator Bearing Arrangement (type)	Combined thrust and guide bearing arrangement
	(xv)	Bus Duct (type, rating)	Type:- Isolated Phase Bus Duct Rating:- • 12500Amps, 24KV (for 16KV generation voltage for 225MW generating units) • 12500Amps, 12KV (for 11KV generation voltage for 56MW generating units)
	(xvi)	Generator Step Up Transformer (type, rating)	Single Phase OFWF (Oil forced water forced) 97.1 MVA for 225 MW units Three phase OFWF (Oil forced water forced) 72.5 MVA, for 56MW unit)
	(xvii)	EOT Cranes (Nos, Capacity & Location)	*Power House:-* • 2 No. cranes each of 450/50/10 T capacity *GIS building* • 1 No. crane of capacity 10 T
	(xviii)	Transport Limitation.	4.5m (W) x 4.5(H) x 10m(L) (Heaviest component is Transformer of size 4.0m(W) x 4.2m(H) x 6m(L) and weight 115 T
	(xix)	Type of Switchyard (GIS/AIS, rating)	420KVA, 6000A of GIS
	(xx)	Bus-bar Arrangement.	In stage-I, 17 No. of bays provided (6+1 bays for generator incoming, 8 bays for outgoing lines, one bay for bus coupler and one bay for reactor. In stage-II, 2 no. bays shall be provided for generator incoming of stage-II units
15	**POWER SYSTEM PLANING**		
	(i)	Generator Commissioning Schedule	Unit # 1 - 89th month & Unit # 8 - 96th month with June 2018 as zero date.
	(ii)	Generating Voltage	• 16kV for 225 MW • 11kV for 56 MW

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

	(iii)	Transmission Voltage	400 kV
	(iv)	Transformer (GT): • Transformation Capacity (MVA) • Voltage ratio (KV/KV) • No. of Transformers • Single Phase/Three Phase unit	 • 3 X 97.1 MVA for each 225 MW unit & 1 X 72.5 MVA for 56MW unit. • 16/400 kV for 225 MW units & 11/400 kV for 56 MW unit • 26 nos. (incl. spares) for 225 MW units & 01 no. for 56 MW unit • Single Phase for 225 MW units & Three Phase for 56 MW units
	(v)	Switchyard: • Type • No. of Bays including Generator bays (at different voltages level) • Switching scheme • Switchyard Coordinates (latitude/longitude) • Switchyard Equipment Rating	 420kV GIS (Indoor) 19 ((6+1) nos. generator bays, 1 no. bus coupler bay, 8 nos. of 400kV line bays and 1 no. bus reactor bay in the Stage-1 and 2 nos. generator bays in Stage-II) Double Busbar Scheme with bus coupler 33°11'N 75°06'E 420 kVrms ; 50 kA
	(vi)	Transmission System: • Details of Transmission System (indicating no. of circuits, type of Conductor and length (in km) etc.)	400 kV GIS Double main bus switching arrangement has been proposed at power house. Provision of total 19 nos., 400 kV bays, consisting of (6+1) nos. generator bays, 1 no. bus coupler bay, 8 nos. of 400kV line bays and 1 no. bus reactor bay in the Stage-1 and 2 nos. generator bays in Stage-II, has been kept. Out of total 19 no. 400 kV bays, 8 nos. 400 kV line bays are provided in pothead yard and others are in the underground GIS bus. GIS bus will be connected to 400 kV pothead yard (GIS)

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

			through 400 kV GIB bus duct for further transfer of power to the grid. The transmission system for the project along with bus reactor rating would be firmed up after grant of connectivity/ LTA.
	(vii)	Interconnection between Indoor Switchyard and Pothead Yard	Through 400 kV GIB bus duct
	(viii)	Bus Reactor: • Voltage level • MVAR capacity • Type(single/three phase units)	• 400kV • Would be firmed up after grant of connectivity/ LTA.
	(ix)	Whether applied for connectivity/LTA to CTU	JKSPDC shall approach CTU to seek connectivity/Long Term Access (LTA) as per CERC regulations at least five years before the anticipated commissioning of the project.
	(x)	All Generating units at the main power house incl. environment unit should be capable of operating in Synchronous Condenser mode.	
16	**SURGE ARRANGEMENT D/S POWER HOUSE**		
	(i)	Number & Type	Three Nos, type underground
	(ii)	Size	• 18m (W) x 42m (H) x 170m (L) combined for units 1, 2, 3 and 4 • 10m (W) x 57m (H) x 75m (L) combined for unit 5, 6 and EU • 18m (W) x 42m (H) x 85m (L) combined for units 7and 8 of Stage - II
17	**TAIL RACE TUNNEL (TRT)**		
	(i)	Numbers & type	Three for Stage-I & one for Stage-II
	(ii)	Diameter & shape	10.8 m dia (Circular) each
	(iii)	Design discharge	319.46 cumecs in TRT 1 & 2 and TRT in Stage II 359.43 cumecs in TRT-3
	(iv)	Length (excluding outlet structure)	TRT-1 = 1743m TRT-2 = 1720m TRT-3 = 199m TRT Stage-II = 1915m
	(v)	Adit to TRT	6.5 m dia, D-shaped

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

	(vi)	No. of gates and their size	Six No. for Stage-I and two No. for Stage-II Size 12 m (W) x 7.0 (H)
	(vii)	Type of Gate	Vertical lift roller gate
	(viii)	Sill level	530m for TRT 1, 2 and TRT Stage II 532.5m for TRT 3
	(ix)	Design Head (m)	39.50 M
	(x)	Outlet invert level	EL. 530m (TRT 1, 2 and TRT- Stage-II) El.532.5m (TRT - 3)
	(xi)	• TWL at Rated discharge at TRT Outlet (TRT-1, 2 and TRT-Stage II) • TWL at Rated discharge at TRT Outlet (TRT-3)	• EL.534 m • El 537 m
18	**POWER GENERATION**		
	(i)	Installed capacity	1406 MW (Stage-I) 450 MW (Stage-II) Total = 1856 MW
	(ii)	• Annual Energy Generation in 90% dependable year • Design Energy in 90% Dependable year with 95% machine availability	8196.10 MU (7711.03 MU for main plant both Stage-I & Stage-II and 485.07 MU for auxiliary plant) 7994.73 MU (7533.91 MU for main plant both Stage-I & Stage-II and 460.82 MU for auxiliary plant)
	(iii)	• Corresponding Annual Load Factor • Corresponding Daily Peaking Duration (Minimum) • Environmental Flow	• 49.17% (for all units including environmental unit) • 3 hours • 39.97 cumec
	(iv)	E&M Cost	Rs. 3100.64 crore at February 2016 price level.
19	**Construction Period**		96 Months (excluding 24 months of pre-construction)
20	**Cost (February 2016 Price Level) including IDC & FC**		Rs. 20,317.66 Cr.
21	**Tariff**		1st year Tariff – Rs. 6.81 per unit Levelised Tariff - Rs. 5.06 per unit

Dr. G. S. S. H VARA PRASAD,
Senior Manager (Environment)
NHPC Ltd

CHAPTER - 3

HYDROLOGY

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

CHAPTER - 3

HYDROLOGY

Hydrology of the project (water availability, design flood and diversion flood) was cleared by CWC/CEA in the year 2011.

The catchment area at Dam site is 19,475 m^2.

Water availability studies have been carried out based upon the data availability at Dhamkund, Premnagar and Akhnoor G&D sites.

The design flood has been estimated by different approaches i.e. flood frequency method as well as hydro-meteorological approach.

A design flood of 18,711 cumec has been approved as the design flood for planning of spillway capacity.

The diversion flood has been studied both for monsoon period as well as non-monsoon period. Diversion flood for the project has been approved as 9,292 cumec for monsoon period and 2,977 cumec for non-monsoon period.

Dr. G. S. S. H VARA PRASAD
Senior Mana[illegible]vironment)

CHAPTER - 4

POWER POTENTIAL STUDIES

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

CHAPTER - 4

POWER POTENTIAL STUDIES

Based upon the approved water availability series, the approved power potential of project was considered by CEA as 1856 MW with 1406 MW installed capacity in Stage-I (including 56 MW Environmental Unit) and 450 MW in Stage-II.

Various data considered for power potential estimation are given below:

- FRL = 695m & MDDL = 692.8m
- Pondage = 23.84 MCM as approved by HP & I division vide letter dated 21.07.14
- TWL = 534m (all machines running)
- Head losses considered = 5.8m
- Rated Head = 155.7m (for units 1 to 4, 7 & 8)
- Rated Head = 153.5m (for units 5, 6 & EU)
- Discharge of one unit (159.73 cumecs) corresponds to the firm discharge available during lean months.
- To limit the transport size and weight of the electro mechanical package especially the single phase step up transformer unit.
- Non monsoon environmental flow is 39.97 cumecs
- To comply with the requirement of monsoon environmental flows, two units of 225 MW each of the main power plant shall discharge at the dam toe through a separate tail race tunnel. The discharge through these units shall be 33% of the design discharge for the power plant. These units shall operate in monsoon all 24 hours. Any excess discharge over and above the design discharge shall be spilled through spillway arrangement.

Design energy for 90% dependable year:

Energy corresponding to Main Plant	=	7,533.91 MU
Energy corresponding to Environmental Unit	=	460.82 MU
Total Design energy (1856 MW)	=	7,994.73 MU

Dr. G. S. S. H VARAPRASAD
Senior Manager (Environment)
NHPC Ltd

CHAPTER - 5

GEOLOGY & SEISMICITY

Dr. G.S. S. H VARAPRASAD
Senior Manager (Environment)
NHPC Ltd

CHAPTER 5

GEOLOGY & SEISMICITY

5.1. Background information

Detailed geological investigation for the proposed project, which included a 155m high concrete gravity dam, a 5.5km long Head Race Tunnel, a surface power house on the right bank and other appurtenant structures was carried out by officers of Geological Survey of India between F.S. 1962-'63 and 1970-'71. Afterwards for the preparation of DPR necessary field and laboratory tests and other detailed engineering studies were carried out by different Government organisations under the guidance of CWC. Initially a DPR was prepared by CWC for generation of 1200 MW of in two stages (Stage-I & II of each 600MW capacity). Later on this project was handed over to National Hydroelectric Power Corporation (NHPC) in 1984 for execution. Subsequently, JKSPDC took over the project from NHPC and decided to execute the project as state sector project and entrusted the work to 'Sawalkote Consortium.'

The Sawalkote Consortium proposed a layout with underground powerhouse and short tail race tunnel on the left bank. Sawalkote Consortium prepared and submitted the detailed project report of 1200 MW in March 2006. During examination of DPR in CEA, CWC and GSI during 2006, additional studies were sought to be carried out.

5.2. Investigation Works

The project area was geologically investigated in great details between 1962 and 1971 by Geological Survey of India. Of the total geological investigation carried out at that period, following works are still relevant for the present proposal:-

1. Geological mapping of the dam area on 1:1000 scale.
2. Sub- surface exploration of the dam area through 9 bore holes.
3. Excavation of three drifts in each abutment at different elevations.
4. Geological map of the reservoir area.

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
[illegible] Ltd

At the time of preparation of DPR of this project by different organizations, at different time, some additional geological and geotechnical investigations such as surface geological mapping covering dam, new power house and tail race tunnel alignment and laboratory tests were carried out. This is to mention here that no additional sub-surface investigations through drilling or drifting at any of the sites especially at the underground power house site were undertaken at that time.

During preparation of Geological details, adequate attention was given for both surface and subsurface investigation covering the unexplored areas of latest layout. As a result following geological and geotechnical investigations were carried out:-

1. Slope stability study along the reservoir rim.
2. Drilling of 6 additional bore holes covering toe, plunge pool, upstream coffer dam, in the abutments etc. to complete residual sub surface investigation to know geology and permeability of rock mass.
3. Large scale geological mapping of the powerhouse complex on 1:2000 scale
4. Excavation of 180m long exploratory drift to get an idea on the actual rock condition at the power house site.
5. Necessary in situ rock mechanics tests such as flexible dilatometer test (for determination of deformation modulus and modulus of elasticity of rock mass), direct shear test (to determine pick and residual shear strength of the rock mass) and hydro fracture test (to determine both magnitude and direction of maximum and minimum horizontal stresses of the rock mass) were conducted within the power house drift.
6. Detailed geological mapping of the Tail Race Tunnel alignment on 1:5000 scale.
7. Detailed geological mapping of the construction material site on 1:2000 scale.
8. Drilling of 6 bore holes in the Quarry site to get necessary information on the thickness of overburden and weathered rock in this part.
9. Laboratory test of the construction material both rock and soil samples to check their suitability.
10. Laboratory test of rock core samples such as unconfined compressive test, tri axial shear test, Poisson's ratio, water absorption, specific gravity etc. from around tentative foundation grade of the rock mass.

Summary of cumulative exploration carried out for project is presented in the table below:-

Component	Surface Geological mapping	Sub-surface exploration
Dam	0.3 km^2 on 1:2000 scale	**Drilling** Total drilling : 1549.23 m of which 548.73 m between 1965-1969 and 1000.5m between 2011-2013 **Drifting** 6 nos Drifts (3 on each abutment) totalling 287m length (between 1966-1969)
Diversion tunnel	1.3 line km on 1:2000 scale	-
Intake-HRT-Pressure shafts	0.5 line km on 1:2000 scale	-
Power house	0.5 line km on 1:2000 scale	**Drifting** 180 m long drift and 10m each long cross cuts at RD 160m and further extended drift for length 384m including 3 cross cuts of 25m length each. **Drilling** 4 nos Holes of cumulative length155m (one 65m deep Nx size drill hole and three 30m deep EX size drill holes). 2 nos EX size holes in cross cuts of 45m depth each.
Tailrace Tunnel	3 line km on 1: 5000 scale	–
Reservoir area	11 km2 in 1:15000 scale	-
Construction Material survey	0.25 km2 on 1:2000 scale	**Drilling** 135m through 6 no. Holes (between 2011-2012)

Dr. G. S. S. H VARAPRASAD
Senior Manager (Environment)
NHPC Ltd

Brief details of project geology and seismicity are given below:-

5.3. Regional Geology

Himalayas stretch over an approximate length of 2900 km in a roughly East-West direction along the border between India and Tibet. This immense mountain range was formed by huge tectonic forces and sculptured by powerful denudation processes. The Himalayan range has been sub divided into four broad tectonic units by Blanford & Medlicott, 1879 and Heim & Gansser, 1939, that can be followed for more than 2400 km along the belt:-

i. The Outer or Sub Himalaya,
ii. The Lesser Himalaya (LH),
iii. The Central Himalayan Domain, CHD (or High Himalaya),
iv. The Indus Suture Zone, ISZ

The Northwest Himalayas have been subdivided into a number of laterally continuous, east-west trending tectonometamorphic belts, each supposedly with distinct geological attributes and separated by major tectonic surfaces.

The majority of rocks found in the Lesser and Higher Himalayan Belts of Jammu and Kashmir sector are Proterozoic in age. These comprise a sequence of metapelites, metapsammites, metacarbonaceous sediments, carbonates, calc-silicates, with penecontemporaneous volcanics and localised diamictites. In view of their unfossiliferous nature, age determination and correlation has become difficult. Lithostratigraphic classification has been done on the basis of gross lithological association, presence of stromatolites, identifiable magmatic and metamorphic events and available radiometric data.

The rock formations in the project area are Murrees, Nummulitic limestone and Sirban limestone. The river flows in this area in a general from north easterly to south westerly direction. The contact between the Murrees with the Sirban limestone and the Sirban limestone with the Nummulitic limestone are faulted in nature. The fault between the Murrees and Sirban limestone is known as Sawalkot fault, whereas, the fault between the Sirban limestone and Nummulitic limestone is known as Chakka fault. The Sirban limestone unit is present as an "inlier" having the Murrees in the upstream side and Nummulitic limestone in the downstream side.

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

5.4. Geology in and Around Dam area

Predominantly, dolomites of Sirban Limestone formation are exposed at the dam site. Within the dolomites, minor bands of limestone, thinly bedded puckered limestone and splintery carbonaceous shale are also exposed in the upstream of dam axis. The dolomites of Sirban formation within the mapped area in general are bluish grey to grey, reasonably hard, slightly weathered (W1) to fresh (W0) and well jointed to massive in nature. Moreover, within the dolomite, black thin bands of cherts (2 to 4mm thick) were also noticed (Photo. 3.1).

In and around the dam area, the average strike of dolomite i.e. the bed rock is $N70^0W$ - $S70^0E$ and it dips steeply, varying from 60^0 to 80^0 in $N20^0E$ direction i.e. towards the U/S direction. This is also to mention here that in places wide swing in the strike and dip direction was also noticed in the rock mass. For this reason broad warping in the rock mass was noticed. Bedding is very prominent due to colour banding. Bedding joint is most prominent in this part. These are closely spaced, continuous and often open in nature. Besides this bedding joint, two other prominent joint sets along with random joint sets have dissected the rock mass.

5.5. Geology around Diversion Tunnels

Based on the observations made during field traverses, it can be concluded that the diversion tunnels will mostly pass through well jointed competent dolomite. The exposed dolomite is traversed by eight sheared dolomite bands i.e. SD-1 to SD-8 (bedding shears) of different thickness. Shearing is expected to extend at least 10m on either side of the boundary of individual sheared dolomite bands. Moreover, thinly jointed and friable dolomite bands at random are expected intermittently within the competent dolomite.

RBM covers the bed rock and part of Chenab river bank from the confluence point between Chenab and Talsyuin nala up to 150m D/S and also intermittently. Moreover, a 20m wide scree covered hill slope is present around 450m D/S from the confluence zone. An interbanded sequence of thinly laminated splintery carbonaceous shale band, thinly laminated puckered limestone and limestone band covers both the banks of Chenab from 250m D/S of the confluence point. This assemblage covers around 80m to 100m D/S along the river bank. In rest of the part

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

competent dolomites are exposed along hill slope both in U/S and D/S direction of this scree covered zone.

5.6. Geology around Power Intakes, HRTs and Pressure Shafts:

These structures will be located within dolomite forming the steep hill slope along the left bank of Chenab. Dolomites, belonging to Sirban limestone Formation, exposed here are almost fresh to slightly weathered, hard but well jointed in nature. Broadly dolomites are traversed by three prominent sets of joints and the joint spacing varies frequently within the study area. Besides dolomite nine sheared dolomite bands / bedding shears (SD-4 to SD-8) of average thickness varying between 2 & 6m have dissected the dolomite between Intake and surge gallery.

SMR values of the rock between Dam axis and U/S 160m of the left abutment has been consulted to get an idea on the probable rock condition at the proposed intake locations. The study reveals that normal, partially stable rock mass is exposed surrounding the present proposed location of Intake 2 of Stage- I and the lone Intake of Stage II. Rock mass exposed surrounding Intake1 of Stage-I is unstable in nature as a 5 to 6m thick sheared dolomite band (SD-4) is passing through this area. It has been decided to keep the Intake 1 of Stage-I at the present proposed location because from the consultation of geological map it has been found that if Intake-1 location is changed then there is every probability that location of one of the other two intakes will fall within the adverse geological condition. Thus instead of changing the location of Intake-1 an elaborate plan of treatment has been envisaged to stabilise the distressed hill slope surrounding it. These will consist of a) benching of the hill slope from the top, b) systematic close spaced & rock bolting and reinforced shotcreting with drainage holes, c) construction of toe and gravity walls along the lower most bench, d) development of a drainage network and e) provision for pre stressed cable anchoring if situation warrants.

At the intake-2 location, also benching will be done from top to prepare a suitably wide bench to accommodate the Intake structure.

Detailed study of the geological sections along the proposed HRT and pressure shafts alignments revealed that competent jointed dolomite will basically be the host rock for these structures. Both these alignments have to negotiate on an average 8 to 9 sheared dolomite bands of thickness varying from 2m to 6m within their entire

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

length. Besides sheared dolomite bands, thinly jointed friable dolomite bands and thin shears are expected to occupy around 20% cumulative length within the competent dolomite. It can be anticipated that the competent rock will cover about 75% and rest about 25% by incompetent rock mass within HRT + Inclined pressure shaft + Horizontal shaft. Thus major lengths of the HRT and pressure shafts are expected to pass through Class-III upper part to Class-II lower part rock mass and shorter lengths will pass through Class-IV to Class-V rock mass. Necessary supports to the rock mass will be provided depending up on their rock quality and water inflow condition. Study of geological sections revealed that sheared dolomite bands will be intercepted within HRT, in both inclined and horizontal pressure shafts and between power house and transfer hall cavern. No sheared dolomite band is expected to be intercepted surrounding the surge gallery location.

5.7. Geology of Powerhouse:

The proposed underground power house cavern will be located tentatively between D/S 320m and 500m with respect to the dam axis along the left bank of Chenab. This area is covered with rugged high hills where dolomite is exposed throughout along the hill slope. Traverse geological map (on 1:2000 scale), surrounding the power house area revealed presence of competent, hard and compact but well jointed dolomite in this part. Broadly there are three prominent sets of joints leaving aside other random and discontinuous joint sets. Dolomites are traversed by four major sheared dolomite bands (SD-7 to SD-9) of different thickness. Within this competent dolomite intermittently thinly jointed and friable dolomites bands along with thin shears are present at random. Based on the characteristics of joints, dolomite exposed surrounding power house area can be grouped between fair to good quality rock mass i.e. Class-III to Class-II. It is expected to cover around 80% of the mapped area. In the rest of the area poor quality rock mass is expected to be encountered (areas where sheared dolomite bands, thinly jointed friable dolomite bands and thin shears are exposed).

A 180m long and 2m dia exploratory drift having 10m long cross cuts at RD 160m has been excavated around 15m above the crown of the actual power house cavity to get a firsthand knowledge on the tentative rock condition surrounding the proposed power house cavern. Direct shear test, flexible dilatometer test and hydro fracture test have been conducted within this drift. Further this drift was extended upto actual

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

location of power house with three cross-cuts. Study of 3-D geological log of this drift indicates presence of four major sheared dolomite bands within the excavated section. As these sheared dolomite bands are occurring between SD-7 & SD-8 these have been numbered as SD 7A to SD 7D. Thickness of these bands varies from 1m to 5m. Areas surrounding the sheared dolomite bands are accompanied with moderate seepage (water loss ranges in between 10lit/min to 25lit/min.

From the analysis of water inflow data derived from drift logging it can be expected that water inflow condition within the powerhouse and all other adjacent caverns will be mostly low water inflow (between 5 & 10 lit/min), in the form of dripping. But mostly adjacent to sheared dolomite bands and thinly jointed dolomite bands moderate water inflow i.e. water inflow between 25 and 125 lit/min can be expected.

As the rocks are well jointed in nature, chances of all types of rock failures i.e. wedge, planar and rock fall within the cavern cannot be ruled out. This may cause formation of cavities beyond the pay line of excavation. Thus to avoid it as far as practicable, necessary precautions such as providing of primary support to the rock mass within stand up time will be provided.

Study of the geological section through the centre line of the proposed machine hall cavern revealed that four sheared dolomite bands (SD 7A to SD 7D, thickness varying from 1 to 5m) are expected to be encountered within the power house cavern. Moreover, due to very steep dip of these bands it is also expected that all these sheared dolomite bands will cover the power house cavity from its invert to crown. Besides these four sheared dolomite bands another sheared dolomite band (SD-8) is also expected to be encountered at just downstream invert end of the machine hall cavity (Refer Geol. Plate-6.2). Leaving aside these major sheared dolomite bands chances of encountering thin shears and thinly jointed and friable dolomite bands at random within the competent dolomite bands cannot be ruled out.

'Q' and RMR values of the rock mass within the drift have been determined. It shows that the drift has passed through broadly middle to upper part of Class-III rock mass and lesser length through poor quality rock mass i.e. Class-IV. Expected rock class within the power house and probable support required for stability are provided below.

This drift was further extended up to PH cavern length with three intermediate cross cuts. The drift was excavated for 269m u/s and 40m d/s of existing drift, with three cross cuts of 25m length each. In one of the cross cuts, hydro-fracture test conducted for confirmation of test already done in existing drift. During 3D logging of drift, it is recorded that 66% length of drift (from Ch. 124 to 269m) passing through Fair rock class, 34% length of drift passing through Poor rock class.

5.8. Geology around Tailrace Tunnel Alignment:

Within the TRT alignment area, exposed dolomite up to TR-35 survey point is slightly weathered to fresh (W0 to W1), hard and compact but well jointed rock mass. These dolomites dip steeply (70^0 to 80^0) towards upstream direction and average strike of these trend $N75^0W$ - $S75^0E$. Bedding joint is most prominent and persistent in nature. Besides bedding joints there are two other prominent sets of joints in addition to discontinuous and random joints. Considering weathering index of the rock mass and joint characteristics these dolomites have been grouped as a fair quality rock mass.

The host dolomite has been traversed by 11 prominent sheared dolomite bands along the mapped stretch. The thickness of these bands varies from 5m to 50m. These sheared dolomite bands has been designated as bedding shears, as their strike is parallel to sub parallel to strike of the host dolomite. Sheared dolomite bands are made up of thinly jointed friable dolomite. Along the joint planes occasionally clay gouge and thin argillaceous bands are also present. These bands are a distinctive feature along the hill slope. Each of these bands are continuously present along the slope almost maintaining the same thickness from the river edge to the top and even can be traced continuously in the opposite river bank along their strike continuity. Due to thinly jointed and friable nature of the rock mass these sheared dolomite bands have been categorized as poor quality rock mass.

Between TR-35 and TR-38 survey points exposed dolomites are thinly jointed, to some extent sheared, soft and friable in nature. Further downstream between TR-38 and just beyond TR-40 an assemblage of highly deformed, sheared and brecciated limestone and quartzite is exposed. Nummulitic limestone and sandstone, shale, siltstone of Murrees are exposed further downstream. Chakka fault is passing through the contact between Nummulitic limestone and rock assemblage of Murrees.

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

As all exposed rocks beyond TR-35 point are highly jointed, sheared, brecciated and friable in nature these have been grouped within poor quality rock mass.

Study in and around TRT alignment area reveals that rocks exposed close to Chakka Fault are closely jointed, sheared, friable and soft in nature. The rock mass expected to fall within Class V to VI. Within this rock mass excavation of three TRT'S of 10.5m diameter will be a very difficult proposition as there will be chances of low stand up time, water ingress with pressure, high convergence and even flowing conditions in the sheared mass. Due to these, chances of formation of big cavities and overbreak cannot be ruled out. The combined effect of all these may lead to collapse of the underground cavities which shall be unmanageable. Considering all these facts, it has been decided to terminate all the TRT'S upstream of the Chakka fault.

5.9. Geology of the Reservoir Area:

Traverse geological mapping of the reservoir area was originally carried out by Geological Survey of India during FS. 1965 – '66 on 1:15,000 scale contour plan. During present preparation of Geology Volume of DPR traverses encompassing the reservoir area were taken up basically to review/assess on the slope stability condition along the reservoir periphery and also to get acquainted with the distribution of rock mass in this part. Within the studied area different rock types of different geological formations are exposed overlain by Recent to Sub Recent depositions.

Regional geological mapping surrounding the project area was done by C.S. Middlemiss in the late 19th century. The rocks exposed within the reservoir area range from Lower Paleozoic Dogra slates to Lower Miocene Muree Formation, which covers the major area. All rock units are intensely folded, sheared and deformed in nature, due to the effect of tectonic movement at different geological era. As a result of these tectonic movements the contacts between each formation are not normal contacts but invariably marked by either a thrust or a fault. Within the reservoir area two distinct thrusts and one fault is present.

Dr. G. S. S. H VARAPRASAD
Senior Manager (Environment)
NHPC Ltd

5.10. Seismicity and Seismotectonics:

The proposed dam site lies in seismic zone IV as per the seismic zoning map of India as incorporated in Indian Standard Criteria for Earthquake Resistant Design of Structures IS:1893-(Part I) 2002.

The proposed 192.5m high Sawalkot Dam on Chenab River shall be located within the Himalayan frontal Tertiary Siwalik- Murree fold belt. The height of the dam shall be between those of operational Bhakra (226m) over Satluj and Thein (148m) over Ravi, both located further southeast but within the same tectonic domain, i.e., south of the MBT defined by the contact between the Tertiary rocks in the south and Pre-Tertiary domain in the north. Relative to Bhakra and Thein dam, the Sawalkote dam is located much upstream within gorge section, thus with less reservoir volume (550 million meter cube) in comparison to Thein (3300 million meter cube) and Bhakra (9868 million meter cube).

The entire foothills belt shows abundant signature of neotectonic activity; the Thein dam located on the Surinsar-Mastgarh fault propagation fold while the Bhakra dam located over the hanging wall of a south dipping back thrust. The proposed Sawalkote dam shall be located on the hanging wall of the Riasi Thrust, the northwest continuation of the Jwalamukhi Thrust. Evidence of recent movement along the Riasi Thrust has been documented from Dugla, Aghar and Mari Nala sections (GSI Sp. Pub 26, 1989, p. 124). The seismotectonic status of the Riasi-Jwalamukhi thrust is same as that of the Tanda Thrust that has been reactivated to produce the Balakot- Bagh surface rupture from the 2005 Kashmir earthquake.

Closest (56 km) to the proposed dam the large earthquake is the 1555 event of Mw 7.6, which is also the characteristic earthquake. To the southeast locate the Mw 7.8, 1905 Kangra earthquake at a distance of 101 km and to the northwest locate the 2005 earthquake (Mw 7.6) at larger distance of more than 200 km. From seismotectonic consideration the MCE should be Mw 7.8. As sufficient period of earthquake data is available, both deterministic and probabilistic approach could be adopted for seismic design.

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

5.11. Limitations of Geotechnical Investigation at site

The proposed Sawalkote project site has some inherent constraints causing partial to severe limitations in carrying out geological and geotechnical investigations in the entire project area.

The foremost limitation is the approachability towards the right abutment of the dam area. Due to limitations of approach to the right bank, present geological and geotechnical investigations are almost entirely concentrated along the left bank of Chenab.

Along left abutment also, approachability to every nook and corner of the project site for detailed study is also a very difficult proposition. The proposed dam site is located within a very remote tight gorge section. The abutments of the dam are very steep (ranging between 65^0 and 75^0). As a result project site presently is approachable only along one narrow footpath that has been developed along the middle level (around EL 610 & 620m) of the dam and it is practically impossible to move up and down of this footpath due to the steepness of the slope. For this reason geological data in general are only collected in and around the footpath i.e. along a single elevation and in the rest portion this same data has been used for geological interpretation.

Similarly for sub-surface exploration, the bore holes could not been drilled covering entire dam area due to nonexistent accesses. As Chenab is a turbulent river and carries enormous discharge even during lean period, drilling in the river section is practically impossible and thus river section has been attempted to be explored through angular drilling only. The other holes have been drilled wherever a proper location has been found to bring and install drill rigs. For this reason adjacent to dam axis the holes are broadly concentrated in two to three locations.

Exploratory drift to the power house has been excavated from an elevation around 570m which is around 15m above the crown of the power house cavern (which is 555m). In general the exploratory drift is excavated around 10m below the crown of the power house i.e. in ideal condition it should have been excavated at an elevation around 545m & 540m but as the HFL of Chenab may reach even up to 560m during monsoon, to avoid this hazard, the drift has been excavated at 570m elevation i.e. 15m above the crown of the proposed power house cavity.

CHAPTER - 6

DESIGN AND ENGINEERING

(CIVIL, HM & EM)

Dr. G. S. S. H VARAPRASAD
Senior Manager (Environment)
NHPC Ltd

CHAPTER - 6

DESIGN AND ENGINEERING
(Civil, HM & EM)

6.1 River Diversion, Diversion Tunnels and cofferdams

The river diversion scheme designed for monsoon diversion flood of 9292 cumecs consists of:

- Three large diversion tunnels on right bank (13.5m x 19m size)
- Upstream Rockfill cofferdam with top at El. 588m
- Downstream Rockfill cofferdam with top at El. 570m

6.2 Diversion Tunnels

Maximum water level behind upstream cofferdam has been restricted to El. 586.2m to pass the monsoon diversion flood of 9292 cumecs. Area of each diversion tunnel is estimated approx. 220.70 m^2. The velocity in diversion tunnels works for maximum discharge works out to be about 15 m/sec (varying from 14.50 m/sec to 15.25 m/sec). The diversion tunnels are concrete lined.

6.3 Upstream and downstream cofferdams

The upstream cofferdam shall be rockfill type with impervious core. The top of upstream cofferdam has been kept at El. 588 m. General River bed at upstream cofferdam location is El. 535 m. Thus height of upstream cofferdam is 53m. Since the diversion scheme has been designed to cater to maximum observed instantaneous flood peak at dam site (9292 cumecs), the cofferdam shall be in place without overtopping during construction phase of the project.

Similar to upstream cofferdam, the downstream cofferdam shall also be rock fill type with impervious core. The top of upstream cofferdam has been kept at El. 570m. General River bed at downstream cofferdam location is El. 532m. Thus height of upstream cofferdam is 38m. Since the diversion scheme has been designed to cater to maximum observed instantaneous flood peak at dam site (9292 cumecs), the cofferdam shall be in place without overtopping during construction phase of the project.

6.4 DAM

The proposed dam is a roller compacted concrete dam about 166.5m above river bed level and approximately 192.5m from deepest foundation level. Dam axis is slightly curved with a radius of 600 m in plan.

The length of dam at the top is 240m. The spillway structure occupies 125 m length in the central part, while the non- overflow RCC sections on either sides are about 59 m and 56m each.

The full reservoir level and minimum drawdown level has been fixed at El. 695 m and El.692.8m respectively.
Free Board has been provided as 2.5m. Top of the dam has accordingly been provided as El. 697.5m.

A design flood (PMF) of 18711 cumecs has been approved by CWC.

Alternative studies were carried out to fix the crest at its optimum level taking into consideration the height of the gate, height of breast wall, intake crest level, discharge intensity, etc. Based on the alternatives proposed, the crest Level for sluice spillways has been proposed at El. 657m, while the crest level for surface spillways has been provided at EL. 675m.

The spillway crest and the chute will be a separate concrete structure with special high quality of concrete, heavily reinforced and bolted to the RCC structure.

Three central bays of the spillway are separated by sidewalls all the way down from the pillars to the flip bucket. This allows for safe maintenance work in these bays.

Roller-compacted concrete (RCC) dams combine the best of the concrete dam, i.e. a small cross-section of erosion-resistant material, together with the best of the fill dam, i.e. a plant-intensive method of construction. Rather than the concrete being placed in a series of individual monoliths, as with traditional concrete gravity dams, the roller compacted concrete is placed in thin layers from one abutment to the other. Contraction joints are cut through the RCC after placement. Because of simplicity of the method of

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

construction, the RCC can be placed very much more rapidly than the concrete in traditional concrete gravity dams.

6.5 Water Conductor System

Water conductor system for Sawalkot HEP (Stage-I and Stage-II) consists of the following components:

a) Upstream water conductor System comprising of

- Power Intakes
- Short HRTs
- Pressure shafts / Penstocks

b) Downstream water conductor System comprising of

- Draft Tube Tunnels
- Surge gallery
- Tail Race Tunnels
- Tail Race Outlets

The underground powerhouse houses the following generating units:

Stage - I: 6 Generating units of 225 MW each
1 Environmental unit of 56 MW each
Stage - II: 2 Generating units of 225 MW each

6.6 Headrace Tunnel Intakes

The headrace tunnel intakes are located close to the main dam on the left bank. A three intake (Two for Stage -I and one for Stage -II) arrangement is proposed for the project.

In the three intake layout, the design discharge is 319.46 cumecs for Stage-II intake, 479.19 cumecs for Stage-I, Intake no.1 and 519.16 cumecs for Stage-I, Intake no. 2. Higher discharges in three intake layout require quite large sized structures, but are considered acceptable.

6.7 Head race Tunnels

There are two short headrace tunnels for Stage -I and an additional headrace tunnel for Stage-II. Each of Stage-I HRT further trifurcates into three pressure shafts. The Stage-II HRT however, bifurcates into two pressure shafts.

The HRT feeding the three pressure shafts further feeding to Unit 1, 2 and 3 is termed as HRT1 and takes off from Power Intake 1. The HRT feeding the other three pressure shafts (feeding unit 4, 5, 6 and Environment Unit) is termed as HRT2 and takes off from Power Intake 2. The HRT catering to unit 7 and unit 8 of Stage-II is termed as HRT-Stage-II.

6.8 Pressure Shafts

The Head race tunnels at their downstream ends branch off into small sized steel lined conduits to feed each generating unit.

The HRT1 branches off into three pressures shafts (PS1, PS2 and PS3) to feed Units 1, 2 and 3. The HRT2 also branches off into three pressure shafts (PS4, PS5, and PS6) to feed unit 4, 5, 6 and environmental unit. The stage 2 HRT branches off into pressure shafts PS7 and PS8 to feed Unit 7 and unit 8 of Stage-II.

Steel liner for PS shall be designed for both for internal pressure (equal to static head plus the induced water hammer due to normal gate operation) as well as external pressure. The steel lined pressure conduit shall be backfilled with concrete. It is seen that most of the portion of steel lined pressure shaft is governed by external pressure. Stiffener rings of suitable height at 1.25m spacing have been provided. The thickness of liner shall ranges from 18mm to 34mm.

The material of steel pressure conduit liner including specials shall conform to ASTM-537-Class-I.

6.9 Tailrace System

There are three Tail race tunnels (10.8m dia circular) for Stage-I and an additional Tailrace tunnel for Stage-II.

The draft tube tunnels (downstream of surge gallery) DT1 and DT2 carrying discharge from Unit 1 and Unit 2 join to form the Tail Race tunnel 1. Draft tube tunnels DT3 and DT4 carrying discharge from unit 3 and unit 4 combine to form Tail Race Tunnel 2. Draft tube tunnels DT5, DT6 and DT-EU carrying discharge from Unit 5, 6 and Environment unit join together to form Tail Race Tunnel 3. Draft tube tunnels DT7 and DT8 of Stage-II join together to form Tail Race Tunnel –Stage II.

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

On account of environmental considerations, the outfall of TRT3 is close to dam toe just downstream of plunge pool dam. The Outfalls of TRT1, TRT2 and TRT-stage 2 are located about 2km downstream, just upstream of Chakka fault.

6.10 Power House complex

Underground Powerhouse complex of Sawalkot HEP shall accommodate the provisions and facilities for 6 units of 225 MW and one unit of 56 MW during Stage-I and additional provision of two units of 225 MW during Stage-II. Planning has been done keeping both Stage-I and Stage-II of the project in view.

Civil works pertaining to underground power house complex are:

- Power House cavern
- Penstock tunnels (in the upstream wall of powerhouse cavern)
- Bus Duct Tunnels
- Transformer cum GIS cavern
- Draft tube tunnels, Surge gallery and draft tube gate operating chambers
- The cable tunnel (GIB tunnel)
- Pothead yard

The Permanent access tunnels to powerhouse caverns and transformer caverns as well as construction tunnels are also part of the powerhouse complex, but have been separately discussed for sake of simplicity. Various structures are described in detail in the subsequent paragraphs:

Size of power house cavern has been fixed based upon Electro-mechanical considerations. The excavated span of the powerhouse cavern is 23m. However, the excavated span of the arch above crane beam is 25 m.

Length of the power house cavern works out to be 218m for Stage-I powerhouse and additional 64m for Stage-II powerhouse. The 218m length of Stage-I powerhouse include 42m long service bay and 21m long control block. Length of powerhouse machine hall for Stage-I is 155 m which accommodates six plus one units. The centre to centre spacing of units has been kept as 21m. Height of the powerhouse cavern works out to be 46.5 m.

The Transformer cum GIS cavern has been provided downstream and parallel to the powerhouse cavern. The clear distance between downstream wall of powerhouse cavern and upstream wall of transformer cavern has been kept as 46m. The clear distance is more than vertical height of the larger (i.e. powerhouse cavern) and which is almost twice the width of powerhouse cavern.

The transformer cum GIS cavern is provided 46m downstream of the powerhouse cavern. The width of cavern is 15m and height is 23.5m. Length of transformer cavern is provided almost similar to the powerhouse cavern. The Stage-I length is 211m and Stage-II length is 56 m.

Draft Tube tunnels emerge from the downstream wall of the powerhouse. The Draft tube at its exit is of 7m horse shoe shape.

The Draft tube Gates are provided from the Gate operating Chamber at El. 575 m. The length of the chamber including provision for Stage-II is 240m. Size of the chamber is 11.5m (W) x 11.5m (H).

The Gate shafts are 3.9 m x 7m, size in plan in elliptical shape.

From the transient considerations, a surge gallery is provided just downstream of the draft tube gates. The common surge gallery has been for unit 1, 2, 3 and 4. This surge gallery is 18 m wide, 42.26m high and 170m long. The surge gallery for unit 5, 6 and environment unit is 10m wide and 75m long. For stage II works, the surge gallery will be about 85m long.

6.11 The GIB Shaft and GIB Tunnel

The power cables from underground GIS cavern shall be taken to pothead yard through an arrangement of a GIB shaft followed by a GIB tunnel. The GIB shaft, 6.5m dia, is provided between EL. 553.1m and EL. 690m.

The GIB tunnel at EL. 690m is also of 6.5m diameter and takes the cables further to pot head yard (EL. 690m).

6.12 Pothead yard

Pot head yard is proposed to be located downstream of dam at EL. 690 m. The approach for pothead yard has been provided from dam top on the left bank by a road of about 700m length.

Size of the pot head yard works out to be 260m (L) x 40m (W) as per electrical requirements.

6.13 Hydro-Mechanical Equipment

Five nos. submerged type radial gates for opening size of 11m (W) x 16.5m (H) and two nos crest type radial gates for opening size 13m (W) x 20m (H) shall be provided to control the discharge through the spillway.

The stop log gate for sluice bays shall be fabricated in 8 units for opening size 11m wide x 19.4m high. Also the stoplog gate for crest bays shall be fabricated in 9 units for the opening size 13m (W) x 20.30m (H) including 300mm of free board.

Six numbers diversion tunnel fixed wheel gates of size 6m (W) X 19m (H) have been envisaged for three diversion tunnels each requiring two gates.

On upstream face of the Power intake, trash rack with inclination of 15° from vertical axis shall be provided. Each Power intake (Stage-I) consists of 5 bays of 7m width, separated by intermediate piers. Each bay shall contain three trash rack screen of size approximately 3m wide x 22.78m high (inclined height) and shall be fabricated in panels of suitable height. Fifteen set of such screens are provided in each intake structure.

Independent D/s draft tube gate at the outlet have been proposed for each of the six generating units and also for the environmental unit (56 MW). Each D/s draft tube flume has been provided with one gate of clear opening size 7.0m wide X 7.0m high to enable isolation of each generating unit from tail water for maintenance purpose.

The size of draft tube gate for 56 MW Unit shall be 3.5m (W) x 4m (H).

Dr. G. S. S. H VARAPRASAD
Senior Manager (Environment)
NHPC Ltd

The outlets of tailrace channels shall be equipped with bulk head gates for closure during high flood. It will be possible to lower or lift the bulkhead gates at any tail water level with the help of Dedicated Rope Drum Hoist.

6.14 Electro-Mechanical Equipment

The Electro-mechanical equipment envisages installation of 6 (six) generating units of 225 MW with 10% continuous overload capacity, operating under a rated head of 154.4m in an underground Powerhouse and 1 no. 56 MW additional generating unit utilizing environment flow. In Stage-II, two no. generating units of 225MW with 10% continuous overload capacity are proposed.

The main equipment for 225 MW units shall include:

- Vertical Shaft Francis Turbines with Butterfly Valve, complete with all unit auxiliaries like governing system, Pressure oil System, cooling water system, Low Pressure Compressed Air System, Grease Lubrication System, Drainage and Dewatering System etc.. (An additional turbine 56 MW for Environment unit shall also be required).

- 250 MVA Synchronous Generators, complete with static excitation system etc. (An additional 62.5 MVA generator for environment unit shall be required)

- 92 MVA, 16/400/√3kV Single Phase OFWF (Oil forced water forced) Generator step up transformers, 3 nos. for each unit (total 20 + 6 including spares). (A three phase 69 MVA, 11/400/√3kV transformer for environment unit shall also be required)

- 12000 Amps, 24kV Isolated Phase Bus ducts including delta connection for interconnection between Generator phase terminals & Generator Transformers along with terminal equipment for phase as well as for neutral side for 225MW Generating Units (Additional 12kV bust duct shall be required for environment unit.)

- SCADA System for Computerized Control and Monitoring for the Main Plant

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

and Plant Auxiliaries

- 420 kV GIS and 420kV GIB
- Common Station Auxiliaries
- Relay and Protection System'
- 415 V Station and Unit Auxiliary Power Supply System
- Station D.C. System comprising of 220V and 48 V D.C Supply including Batteries, Battery Charging Equipment and D.C. Distribution System
- Plant UPS system
- Power, Control and Instrumentation Cables, Cable Trays, Cable supporting racks, Hardware fittings etc.
- Electric Overhead Travelling Cranes for Power House
- Elevator/Lifts
- Plant Communication System
- PLCC Equipment
- 80 MVAr Shunt Reactor
- Earthing System
- Fire Fighting System
- Workshop Equipment
- Oil Purification System
- Heating, Ventilation and Air Conditioning System
- Diesel Generating Sets for Emergency Power Supply

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

CHAPTER - 7

INFRASTRUCTURE WORKS

Dr. G. S. S. H VARAPRASAD
Senior Manager (Environment)
NHPC Ltd

CHAPTER 7

INFRASTRUCTURE WORKS

7.1 INFRASTRUCTURE AND CONSTRUCTION FACILITIES

Infrastructure and construction facilities for the project have been divided into the following components:-

(a) External Access Roads , Road Tunnel and bridges

(b) Internal Project Roads

(c) Project Headquarter: Offices and Residential / Non-Residential Complexes.

(d) Liaison Office, Transit Camp and Transit Stores.

(e) Workers camps

(f) Workshops and equipment yard

(g) Ferrule Fabrication shop

(h) Warehouses/Stores Complex

(i) Plant installation areas

(j) Explosive magazine

(k) Construction Power

(l) Telecommunication

(m) Security & Safety Arrangements

The proposed 1856 MW Sawalkote HEP is located about 32.00 Km from the Ramban town. The main access to the project named as External Access Road (EAR) takes off at

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

Ch. 17.62 Km of Ramban-Gul Road. The External Access Road is about 18.3 Km long and passes through villages like Tanger and Pari.

Approx. 17 km long internal construction roads shall be constructed. These construction roads shall be minimum 6.5 m wide excluding drains and parapet to cater to double lane construction traffic. Slope protection of hill sides and valley sides shall be provided as per requirement. Proper drainage shall be provided to channelize the flow of rains and other waters. Cross drainage works shall be provided by causeways, pipe culverts or RCC culverts as per the site requirement.

Construction of Sawalkot HEP is proposed to be undertaken through mechanized operations will latest construction methodology. The residential complex shall include both permanent and temporary accommodations. Non-residential accommodation shall include administrative building, dispensary, guest house, canteen, model room, fire station, workshop, DG building, quality control laboratory etc.

Location of explosive magazine has been proposed near Mandiyal Khad. It is proposed to install a 50 T magazine to cater to requirement of project works. Sufficient numbers of explosive vans shall be provided for transportation of explosives.

Presently, the project site is connected with mobile networks from various service providers. In order to boost mobile connectivity, it is proposed to add three number mobile network towers. For additional communication facilities, following is proposed:

a) V – SAT systems for field offices and headquarter
b) Local EPBAX system of 100 incoming lines which shall have provision for further distribution to project users.

7.2 CONSTRUCTION POWER

The requirement of peak construction power requirement of the project is 15 MW. Construction power will be provided from J&K grid by tapping 132 kV line between village Digdol & Marog on Jammu-Srinagar National highway. 18 Km, 132kV transmission line would be constructed upto Mandiyal Nalla besides 132/11 kV substation at Mandiyal Nala. The availability of grid power has been taken as 90% and balance 10% shall be met with DG sets.

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

7.3 CONSTRUCTION MATERIAL

Total requirement of coarse and fine aggregates (including reserve and wastage) for the Project components is as given below:-

Description	Volume (Lakh cum)	
	Excluding 38% wastage	Including 38% wastage
Coarse Aggregate	35.7	49.3
Fine Aggregate	17.05	23.53
Total	**52.75**	**72.83**

Above concrete requirement can be sub-divided in two heads: namely wearing as well as non-wearing surfaces of the project. Out of total requirement of coarse aggregate of 35.7 lac cum, approximately 70% will be for non-wearing surface and balance 30% will be for wearing surface. Though suitable excavated muck shall be utilised for production of aggregates, however, sufficient rock material is available in the identified quarry.

To get an idea in the quarry area, about thickness of overburden, weathered rock profile and depth of occurrence of fresh rock mass within the slope; six bore holes were drilled. All these bore holes have been logged and fresh rock samples were collected from the designated quarry site and from the power house drift for necessary laboratory tests to check their suitability for using them as ingredients of concrete as coarse and fine aggregates.

Analysis of all the results indicated that, all the samples collected from a) quarry sites and b) from within the exploratory power house drift are suitable for using as coarse and fine aggregate in concrete of the proposed dam.

In addition, following quantities of rock fill and impervious material are also required for coffer dams:

Description	U/s Coffer Dam	D/s Coffer Dam	Mandiyal Nalla Coffer Dam	Total
	(Quantity in cum)			
Rock fill	317450	135370	284320	**737140**
Filter Material	5750	3270	15370	**24390**
Impervious material	80610	40290	76820	**197720**

Dr. G S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

Samples collected from four soil quarry (after removing of top soil) two from Pari and two from Tangar, for the necessary laboratory tests.

Considering all aspects on the engineering characteristics of the soil samples determined through laboratory tests from all four locations it can be concluded that soils in these four locations are suitable for using as impervious core material for the proposed coffer dams.

7.4 POWER EVACUATION

As per the current information available, evacuation of power would be done by LILO of Two double circuits of 400 kV transmission lines

(i) 400 kV Kishenpur-Wagoora double circuits line

(ii) 400 kV Kishenpur-New Wanpoh double circuits line

Provision of bays for the same has been made in the Pothead yard in the current DPR of Sawalkot Hydroelectric Project.

CHAPTER - 8

CONSTRUCTION PLANNING

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

CHAPTER - 8

CONSTRUCTION PLANNING

The construction schedule has been worked out keeping in view the various components of the project, the construction activities required to complete each component and the project as a whole and logical relationship between these activities. Duration of various activities has been assessed on the basis of cycle times, experiences of similar works and production capacities of equipment and plants. Equipment and plants have been selected to achieve their optimum utilization.

Considering the magnitude and complexity of the project, the working out construction schedule of the project results in a construction period of 96 months (8 years) excluding two year of infrastructure development and investigation phase. This shall be further optimized during the Preconstruction period.

8 years construction schedule of the project has been necessitated in view of the following specific factors.

- River Diversion scheme involving diversion of 9292 cumecs discharge for the narrow and steep dam site on Chenab River.
- It is attempted to achieve diversion of river in lean period only.
- Height of dam being of the order of 192.5m
- Very large spillway
- Serious limitation of accesses in view of unusual & very steep topography on the both banks and narrow gorge at Dam site restricting working space.
- Reservoir filling schedule in accordance with Indus treaty provisions and large (530 million m^3) capacity of reservoir.
- Time required for commissioning of 6 units of 225 MW each of Stage-I, 2 units of 225 MW each of Stage-II and one environmental unit of 56 MW capacity
- Execution of all necessary civil and hydro-mechanical and electro-mechanical works for Stage-II to be carried out during execution of Stage-I itself.

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

The Project being in the Himalayas, weather conditions at the project site are harsh particularly during monsoon season. The monsoon season becomes active during the middle of the June and continues till end of September. It would be difficult to continue open works during the peak monsoon season due to heavy rains and related disruptions. Accordingly open works are expected to slow down during peak monsoon spreading over four months i.e. June, July, August and September. Other works are mostly underground which are not much affected by the monsoon and can be carried out even during the monsoon period.

Start of the infrastructure development and investigation phase (24 months) has been taken with effect from 01.06.2016. Various investigations suggested by CEA/ CWC/ GSI/ CSMRS shall be carried out during infrastructure development and investigation phase.

In order to save time, works on construction of adit to diversion tunnel and construction left bank construction access tunnel is proposed to be taken up concurrent with infrastructure development. Work on various project roads shall also be started during this phase of project.

After completion of dam works, the diversion tunnels are plugged and reservoir filling is commenced. The timing of reservoir filling should however match in accordance with provision of Indus waters treaty and other applicable guidelines.

After filling the downstream and upstream water conductor system, the commissioning of electromechanical unit take place.

The commissioning of units for Stage-I & II are carried out from 89th month to the end of 96th month.

CHAPTER - 9

COST ESTIMATE AND FINANCIAL ANALYSIS

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

CHAPTER 9
COST ESTIMATE AND FINANCIAL ANALYSIS

9.1. INTRODUCTION AND BASIS OF COST ESTIMATE

The project cost estimate has been presented separately for 1406 MW Stage-I works and 450 MW Stage-II works and then combined for total capacity of 1856 MW.

The project cost estimate has been framed broadly on the basis of "Guidelines for preparation of project estimate for River Valley Projects" (second revised edition, March 1997) published by CWC, New Delhi and "Guidelines for formulation of Detailed Project Reports for Hydro Electric Schemes, their acceptance and Examination" (Revision 5.0 - January 2015) Published by CEA, New Delhi. Experience gathered during preparation of cost estimates of other projects has also been utilized to arrive at a these cost estimate.

Cost estimate is inclusive of cost of further investigations at the project, land acquisition, buildings and roads required for the project, measures to mitigate impact on environment and other services, cost of civil structures and Hydro-mechanical works. Based on investigations carried out so far at the project, preliminary designs including layout of the project have been prepared. These drawings form strictly the basis of quantities to arrive at cost of civil structures. The rates for principal items used in the estimate have been analyzed.

The rates are based on the following:-

i) Analysis of Rates
   a) Analysis of hourly use rate of major construction equipments which shall be used during execution of Project has been prepared on the basis of "Guidelines for preparation of project estimate for River Valley Projects" and on the basis of experience gathered during DPR preparation of other projects.
   b) Basic rates of construction materials and man power are the basis of rate analysis of various items. Analysis for basic rates has been prepared on the basis of prevailing market rates. Transportation charges have been worked out considering the place of material supply and distance of the place of material supply from the project site.

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

c) Labour rates have been taken as per prevailing J&K State PDC rates. However, the wages applicable for the project workers shall be higher than the normal wages applicable in other projects because of projects location, site conditions, and climate conditions and due to other considerations.

ii) The receipts and recoveries on capital account have been deducted from total cost of the project. The indirect charges like audit and account charges have been included in the total estimated cost.

iii) Establishment charges for civil and electrical works have been considered as per CEA guidelines.

iv) Contractor's overhead and profit @ 20% has been considered.

v) In addition, provisions of maintenance, special T&P, Communication and Environment and ecology have also been provided.

9.2. PROJECT COST

Cost of the project has been estimated at February 2016 Price Level is termed as present day cost (ref. **Annexure-9.1**). The summary of present day cost in the form of major heads of expenditure has been provided in the abstract of cost, which is inclusive of Civil Works including HM Works & EM Works.

The total project cost has been divided into two Heads i.e. A – Civil and HM works and B- EM Works. Further A - Civil and HM Works & B - EM Works have been divided into sub-heads, which are explained herein below:-

9.2.1. A – Civil and Hydro-mechanical Works

Total cost under this head consists of Direct charges and Indirect charges. Direct charges consist of charge of I-works, Establishment, Tools and Plants, Suspense and Receipt & Recoveries and Indirect charges include Audit & accounts charges.

All the above mentioned sub-heads are explained herein below:

9.2.1.1. I – Works

Under this head, the cost of A-preliminary, B-Land, C-works, J-Civil works of Power Plant, HM works, K-Building, M-Plantation, O-Miscellaneous, P-Maintenance during construction, Q-Special tools and plants, R-communication, X-Environment and Ecology and Y-Losses on stock during construction has been considered.

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

i) **A – Preliminary**

This covers the cost of expenditure already incurred on survey and investigation works.

In addition, this also covers the cost of additional survey & investigations to be carried out, cost of preparation of DPR including layout planning and design studies, Hydrological Studies & Power Studies and Consultancy services for detailed design and engineering & design review.

ii) **B – Land**

Provisions under this head have been made to cover the expenditure on acquiring land required for construction of project structures, infrastructure works & stores etc.

iii) **C – Works**

This covers the cost of construction of diversion tunnels, cofferdams, concrete dam and plunge pool. This also covers costs related to Mandiyal nalla diversion works and right bank access tunnels. This also includes the cost of Hydro-Mechanical works associated with diversion tunnels and concrete dam.

iv) **J – Power Plant**

Works under this head consist of following:-

a) **Civil works**

i) Construction of Head race tunnel intakes,
ii) Construction of HRTs and Pressure shafts,
iii) Construction of Power House complex including machine hall, service bay, control room, draft tubes, transformer hall and bus ducts,
iv) Downstream surge galleries,
v) Access Tunnels/ Adits in power house complex,
vi) GIB tunnel (Cable tunnel) & GIB shaft,
vii) Pothead Yard (Switchyard),
viii) Tail race tunnels,
ix) Outlet works including outlet structures

Dr. G. S. S. HVARA PRASAD
Senior Manager (Environment)
NHPC Ltd

b) **H-M works**

Cost of fabrication, supply and erection of hydro-mechanical components associated with power intakes, draft tubes and tailrace outlets have been included under this head.

v) **K – Buildings**

Under this head, provision has been made to cover the expenditure to be incurred both on residential and non-residential buildings (Temporary and Permanent).

vi) **M – Plantation**

The provisions under this head covers the plantation programme including gardens etc. required for beautification as considered necessary around power house and other important structures. A token provision of Rs. 4.98 crores has been made under this head.

vii) **O – Miscellaneous**

Under this head provision has been made to cover the cost of following miscellaneous works:-

a) Capital cost of electrification, Hospital equipment, sewage disposal, fire fighting- equipments etc.

b) Repair and maintenance of buildings, guest house, electrification, water supply, sanitation and drainage facilities, fire fighting equipments, transport vehicles, telecommunication systems, workshops & stores etc.

c) Other services such as laboratory testing, recreation facilities, hospital & expenditure on maintenance of different amenities for staff, petrol/ diesel pumps & expenditure on inauguration visit of VIP's.

viii) **P – Maintenance**

Under this head, provision has been made to cover the cost of maintenance of all civil works. The provision has been made @1% of C-works, J-Power Plant Civil works (including cost of HM Works), K-Buildings & R-Communication.

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

ix) **Q – Special T&P**

As all the major equipment shall be procured by main contractor at works, provision has been made under this head only for minimal equipment needed for infrastructure works at project. A lump-sum provision of Rs. 3.68 cr. has been kept under this head.

x) **R – Communication**

The provision under this head covers the construction of main approach roads, up-gradation/ realignment of existing roads.

xi) **X – Environment & Ecology**

The provision under this head covers the cost of catchment area treatment. Muck disposal & quarry area development, construction of retaining walls/ wire crates & other environmental issue.

xii) **Y – Losses on Stock**

Provision has been made under this head @0.25% of cost of C-Works (including HM. Works), J-Power Plant Civil Works (including H.M. Works), K-Building and R-Communication.

9.2.1.2. II – Establishment

Provision under this head has been made based on CEA guidelines.

9.2.1.3. III – Tools and Plants

A token provision of Rs. 2 crore under this head has been made to cover the expenditure on survey instruments, camp equipment, office furniture, office equipments and other small tools.

9.2.1.4. IV – Suspense

There will be no provision under this head as all the outstanding suspense accounts are expected to be cleared by adjustment to appropriate heads on completion of the project.

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

9.2.1.5. V – Receipts and Recoveries

Under this head, estimated recoveries by way of resale of Q-special T&P and temporary buildings @15% of cost has been provided.

9.2.1.6. Insurance during construction

Provision towards the cost of insurance during the project execution phase has not been kept in cost estimate as the same is not provided for in CEA guidelines.

9.2.1.7. Security cost

Provision for security during the project execution stage has not been considered.

9.2.1.8. Indirect Charges - Audit & Accounts Charges

Under this head, a provision @ 0.25% of the cost of I-works has been made for Audit & Accounts Charges.

The provision for capitalized value of abatement of land revenues has been kept as approx. Rs. 3.48 Cr.

9.3. Electro-mechanical Works

The cost of electro-mechanical works includes the cost of Turbine-Generator sets, Transformers, electrical and mechanical auxiliary equipment, switchyard equipment and Transmission lines etc. The hard cost of main electro-mechanical equipments (Supply, erection, testing & commissioning) has been estimated as per present market rates (i.e. Price Level Feb'16).

9.4. Total Project Cost Excluding IDC

The hard cost of project Rs. 13,670.43 cr. (present day cost at Feb'16 price level) for civil works (including HM works) and E&M works has been separately worked out both for 1406 MW stage-I works and 450 MW stage-II works.

The above project cost does not include IDC and financing charges. No escalation during construction has been considered in the calculation of Project Cost.

Dr. G. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

9.5. IDC Calculations and Financial Analysis/ Tariff

IDC calculations and tariff calculations have been done considering various options of funding both as per CERC guidelines and JKSERC guidelines.

Total project duration is considered as 96 months with start date (Zero date) as 01.06.2018 excluding 24 months of pre-construction period. Fund flow for the project has been derived on the basis of schedule of various activities for the project for this period. Jammu and Kashmir State Electricity Regulatory Commission, (Terms and Conditions for Determination of Hydro Generation Tariff) Regulations, 2011No.:JKSERC/11/2011 Dated: April 20, 2011.

Out of the total cost of project, 30% will be in the form of equity and 70% shall be met through long term loan.

Following assumptions, based on the latest guidelines of CWC have been considered in working out the tariff:-

Sl.	Description	Value
1.	Debt: Equity ratio @	70:30
2.	Equity	Rs. 6095.31 Cr.
3.	Debt	Rs. 14222.38 Cr.
4.	Total Project Cost (Price Level February 2016)	Rs. 20317.69 Cr.
5.	Rate of Interest (during operation period) - Interest on loans - Working capital loan	 11.15% p.a 14 % p.a.
6.	O & M Expenses	@ 1.5% of Project cost
7.	Escalation on O & M Expenses	4 % p.a.
8.	Maintenance Spares of the historical cost	1 %
9.	Return on Equity (ROE)	14%
10.	Rate of Income Tax / Corporate Tax:- a) Rate of Income Tax	 34.61% (30% +12% + 3%)

Dr. S. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

Sl.	Description	Value
	b) Corporate Tax	34.61 % (30% + 12% + 3%)
11.	Discounting Factor for levelised tariff	10.74%
12.	Auxiliary Energy consumption (AUX) & transformation losses	1.20%
13.	Design Energy	7994.73 million unit (in 90% dependable year)
14.	Free power a) State b) for Local Area Development **c) Total free power**	 12% 1% **13%**

The present day cost of the Project is as under:

Sl.	Items	Amount (Rs. Crore)
1.	Hard Cost of the Project without Escalation, IDC & Financing charges (at Feb.'16 Price level)	13,670.43
2.	IDC	6348.56
3.	Financing charges	298.67
4.	**Total Present Day Cost**	**20,317.66**

Tariff calculation for 35 years operation period has been done and summary is given below:-

Sl.	Description	Tariff (Rs. / kWh)
1.	1st Year Tarff	6.81
2.	Levelised Tariff for 35 years	5.06

Dr. G. S. S. H VA PRASAD
Senior Manager (
NHPC L

SAWALKOT HE PROJECT (1856 MW), J&K

ABSTRACT OF COST

(Feb'2016 Price Level) (Amounts in Rs. Crore)

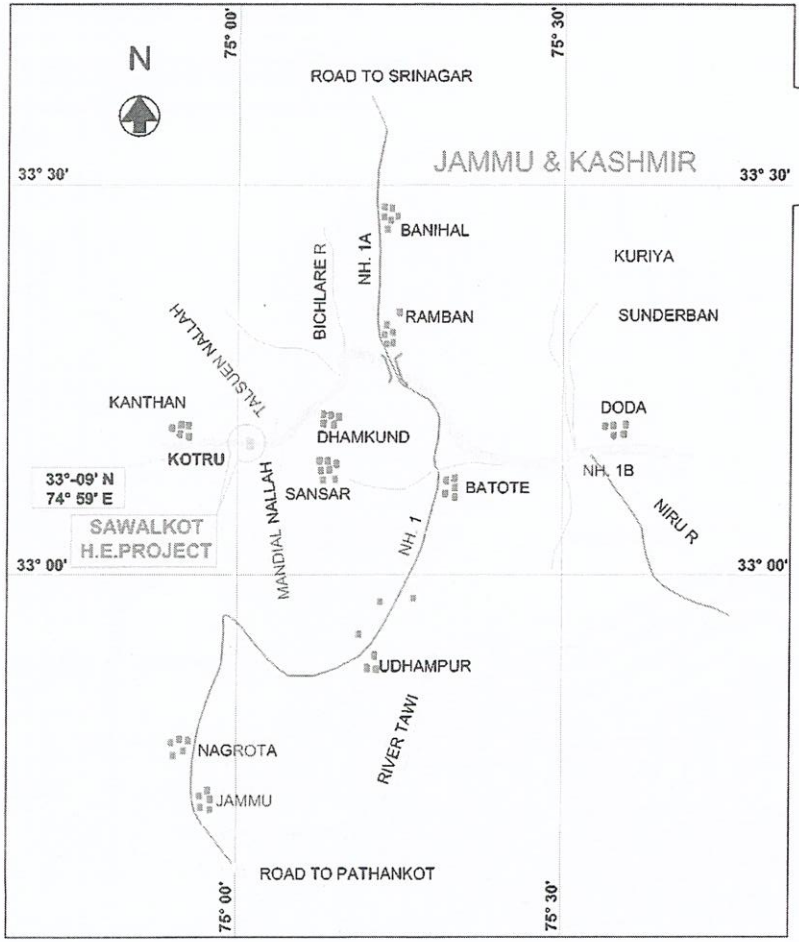
Sl. No.	Description	Stage - I (1406 MW)	Stage - II (450 MW)	Total
A.	**CIVIL & H-M WORKS**			
(i)	**Direct Charges**			
	I - Works			
	A - Preliminary	188.00		188.00
	B - Land - Part 1- Land including R&R	796.28		796.28
	B - Land - Part 2- cost of relocation/ realligment	287.25		287.25
	C - Works	3,805.52		3,805.52
	J - Power Plant Works	3,122.87	838.59	3,961.46
	K - Buildings	185.90		185.90
	M - Plantation	4.98		4.98
	O - Miscellaneous	81.22		81.22
	P - Maintenance During Construction (1% of C-Works, J-Works, K-buildings & R-Communication)	71.14	8.39	79.53
	Q - Special Tools and Plants	3.68		3.68
	R - Communication	656.02		656.02
	X - Environment and Ecology	209.53		209.53
	Y - Losses on Stock (0.25% of C-Works, J-Works, K-buildings & R-Communication)	19.43	2.10	21.52
	Total I - Works	**9,431.82**	**849.08**	**10,280.90**
	II - Establishment	249.88	22.50	272.38
	III - Tools and Plants	2.00		2.00
	IV - Suspense	0.00		
	V - Receipt & Recoveries (-)	-14.67		-14.67
	Total Direct Charges	**9,669.03**	**871.58**	**10,540.61**
(ii)	**Indirect Charges**			
	I - Audit & Accounts Charges (0.25% of I - Works)	23.58	2.12	25.70
	II - Charges for capitilization of abatement of land revenue	3.48		3.48
	Total Indirect Charges	**27.06**	**2.12**	**29.18**
	TOTAL CIVIL & H-M WORKS	**9,696.09**	**873.70**	**10,569.79**
B	ELECTRICAL WORKS	**2,424.06**	**676.58**	**3,100.64**
D	**BASIC HARD COST (A+B) - Without Escalation, IDC & Financing Charges**	**12,120.15**	**1,550.28**	**13,670.43**

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

PLATES

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

PLATE-01



SAWALKOT HEP

LONGITUDE = 75° 06' E

LATITUDE = 33° 11' N

MAP OF INDIA AND
LOCATION OF THE PROJECT

NOTE:

1. ALL DIMENSIONS ARE IN MILLIMETER AND LEVELS IN METER.

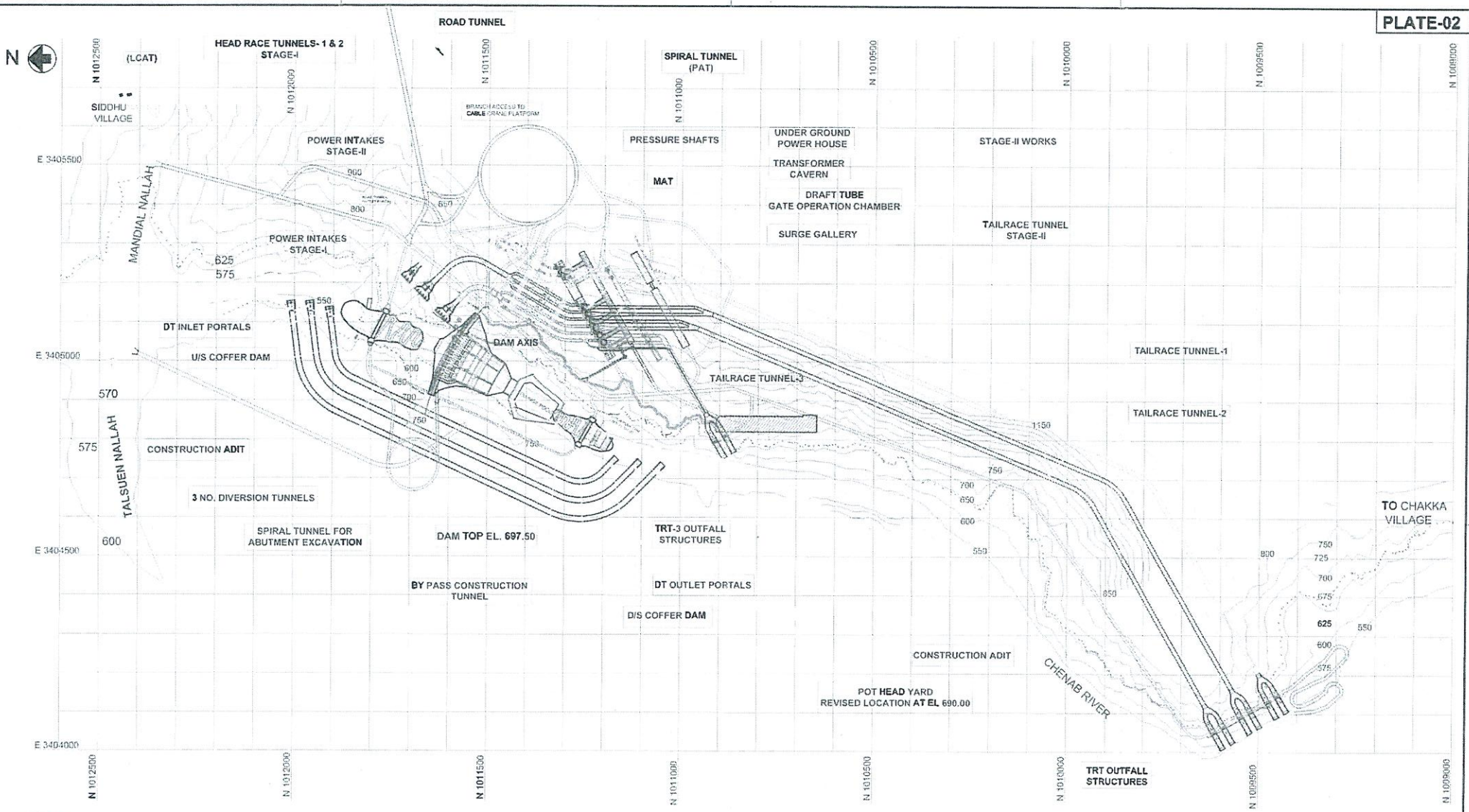
DPR DRAWING

N.B : MAP IS NOT TO THE SCALE

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

JAMMU & KASHMIR STATE POWER DEVELOPMENT CORP.
SAWALKOTE CONSORTIUM
SAWALKOT HYDROELECTRIC PROJECT (J & K) 1406 MW (STAGE - I) & 450 MW (STAGE - II)
INDEX PLAN
JUNE - 2017 | SWKT-DPR-GA-01-00

PLATE-02



NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETER AND LEVELS IN METER
2. FOR COMPLETE DEFINITION OF ACCESSES/ CONSTRUCTION ADITS REFER DRGS NO. SWKT-DPR-ACS-01-00 & 02-00
3. CONTOUR LAYERS OF 5m, 10m & 25m HAS BEEN SWITCHED OFF FOR CLARITY

SCALE:

0 100 200 300 400 500m

DPR DRAWING

Dr. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

JAMMU & KASHMIR STATE POWER DEVELOPMENT CORP.

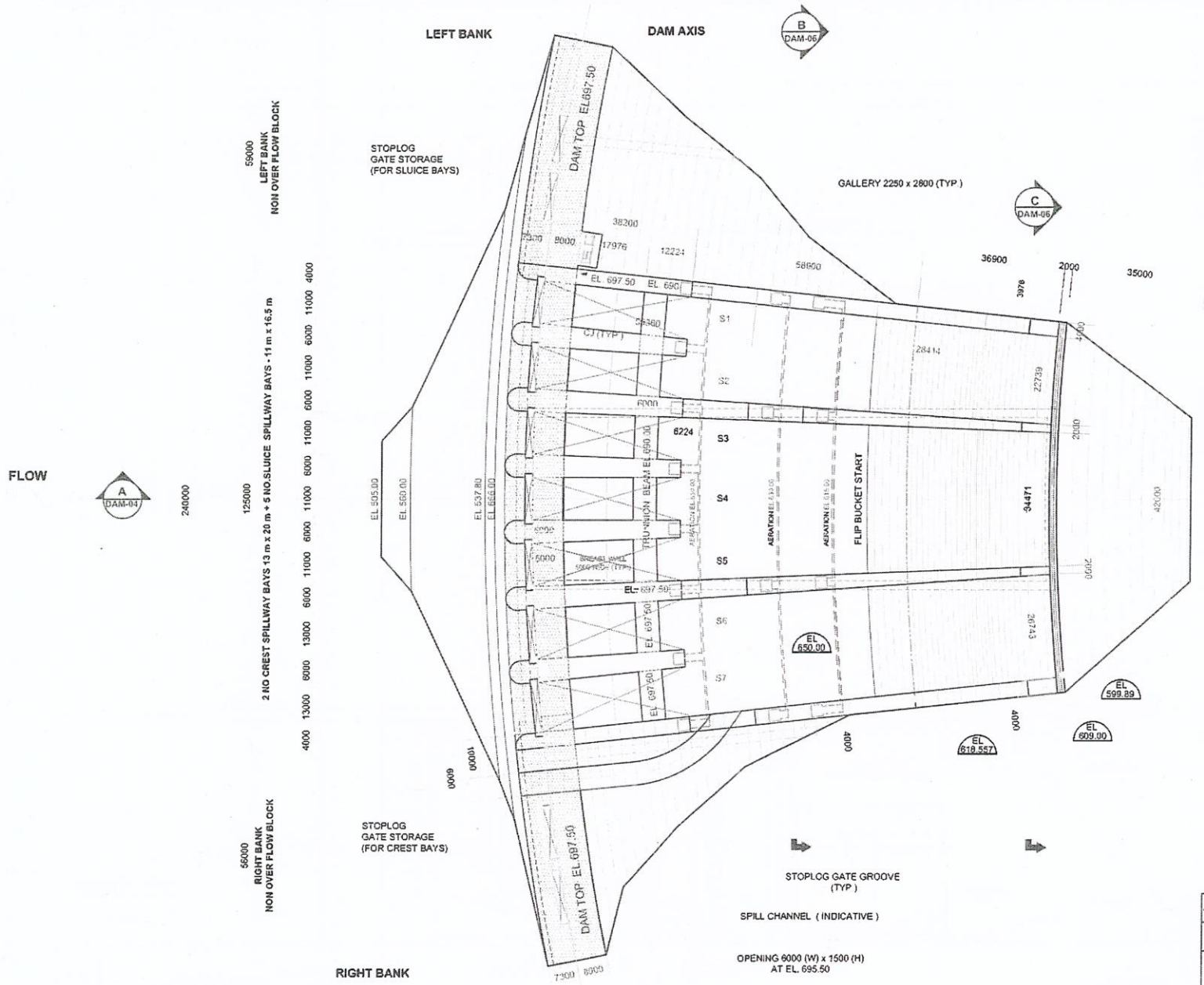
SAWALKOTE CONSORTIUM

SAWALKOT HYDROELECTRIC PROJECT (J & K)
1406 MW (STAGE - I) & 450 MW (STAGE - II)

PROJECT GENERAL LAYOUT PLAN

JUNE - 2017 | SWKT-DPR-GA-02-00

PLATE-03



NOTE:

1. ALL DIMENSIONS ARE IN MILLIMETER AND LEVELS IN METER.

DPR DRAWING

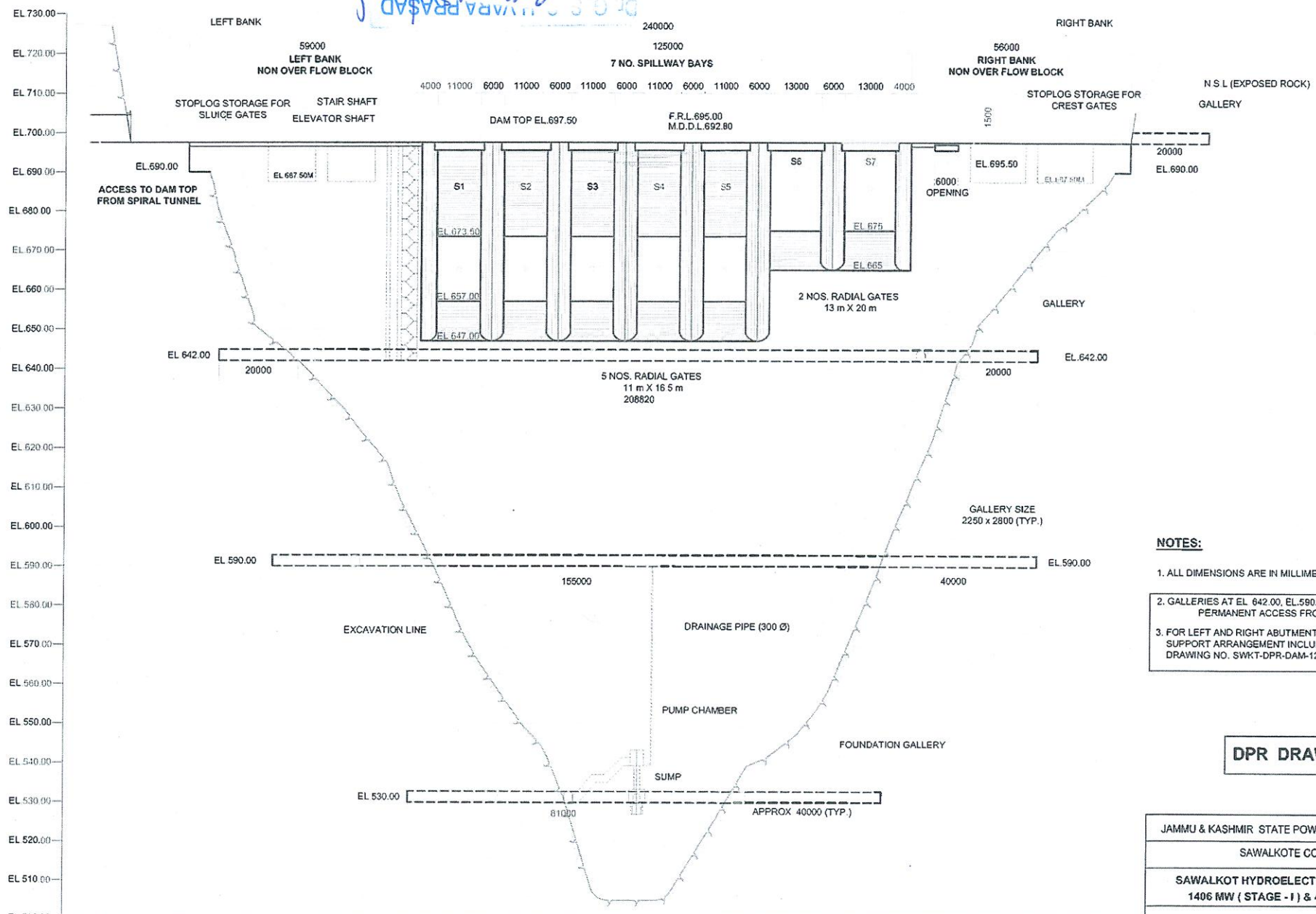
SCALE:

0 10 20 30 40 50m

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

JAMMU & KASHMIR STATE POWER DEVELOPMENT CORP.
SAWALKOTE CONSORTIUM
SAWALKOT HYDROELECTRIC PROJECT (J & K) 1406 MW (STAGE - I) & 450 MW (STAGE - II)
CONCRETE GRAVITY DAM PLAN (WITHOUT CONTOURS)
JUNE - 2017 | SWKT-DPR-DAM-02-00

PLATE-04



NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETER AND LEVELS IN METER.
2. GALLERIES AT EL. 642.00, EL.590.00 & EL. 530.00 SHALL HAVE PERMANENT ACCESS FROM SPIRAL TUNNEL
3. FOR LEFT AND RIGHT ABUTMENTS EXCAVATION AND ROCK SUPPORT ARRANGEMENT INCLUDING BENCHES, REFER DRAWING NO. SWKT-DPR-DAM-12

DPR DRAWING

SCALE:

0 10 20 30 40 50m

JAMMU & KASHMIR STATE POWER DEVELOPMENT CORP.

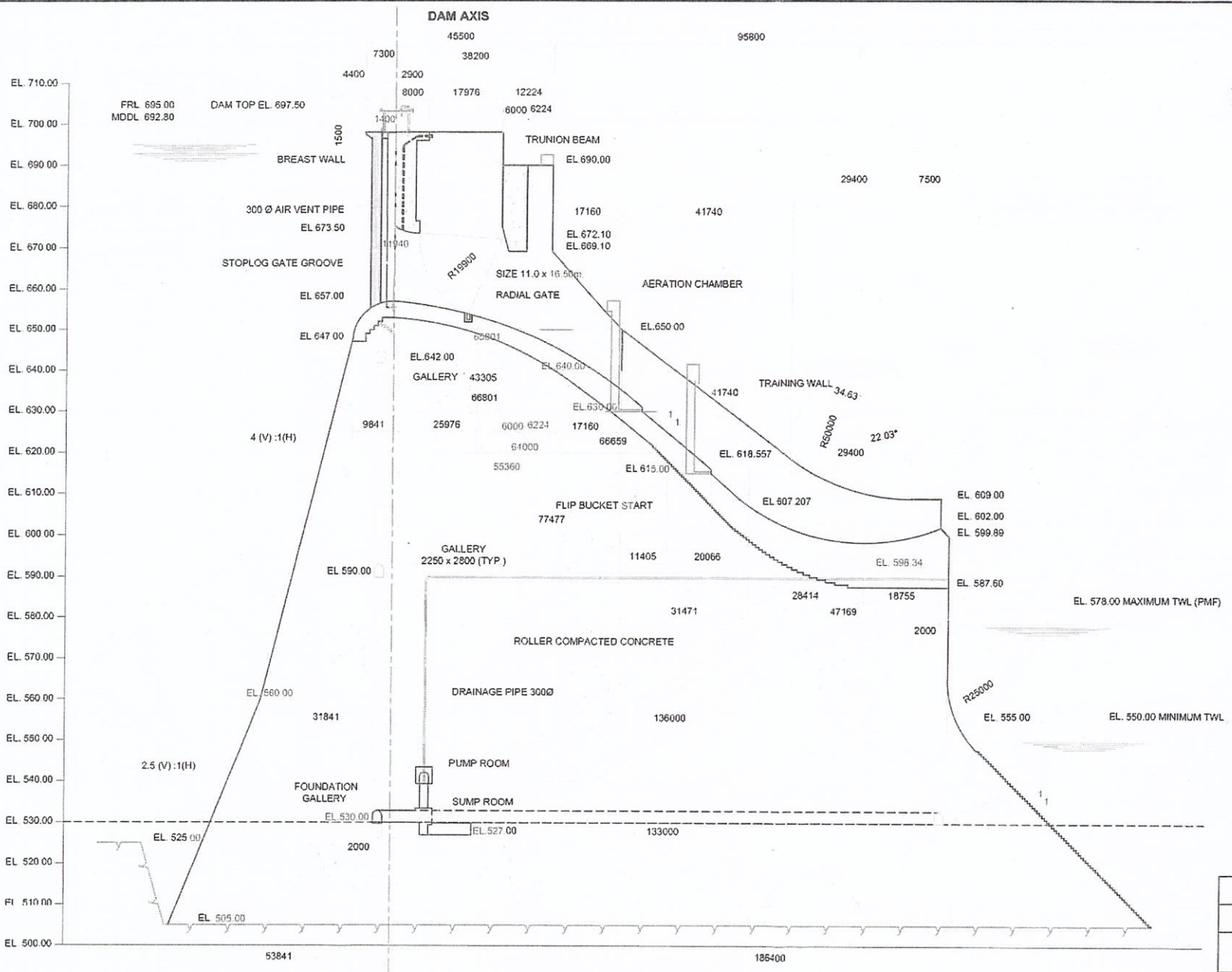
SAWALKOTE CONSORTIUM

SAWALKOT HYDROELECTRIC PROJECT (J & K)
1406 MW (STAGE - I) & 450 MW (STAGE - II)

CONCRETE GRAVITY DAM
UP STREAM ELEVATION

JUNE - 2017 | SWKT-DPR-DAM-03-00

PLATE-05



REVISED MAXIMUM OVERFLOW SECTION

NOTE:

1. ALL DIMENSIONS ARE IN MILLIMETER AND LEVELS IN METER

DPR DRAWING

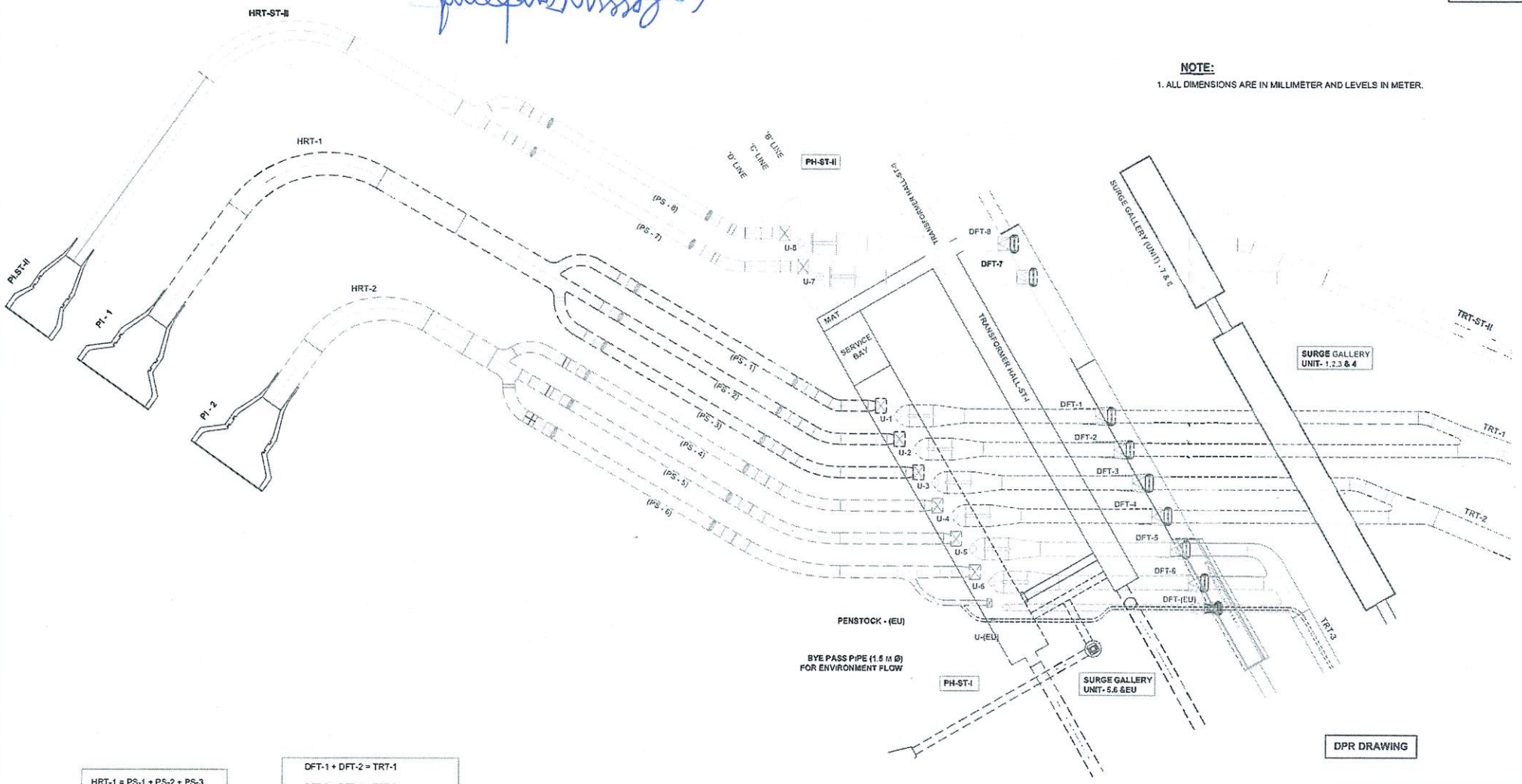
SCALE:

0 10 20 30 40 50m

Dr. G. S. S. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

JAMMU & KASHMIR STATE POWER DEVELOPMENT CORP.
SAWALKOTE CONSORTIUM
SAWALKOT HYDROELECTRIC PROJECT (J & K) 1406 MW (STAGE - I) & 450 MW (STAGE - II)
CONCRETE GRAVITY DAM SECTION THROUGH CREST SPILLWAY AT EL. 657 M
JUNE -2017 | SWKT-DPR-DAM-04-00

PLATE-06



NOTE:

1. ALL DIMENSIONS ARE IN MILLIMETER AND LEVELS IN METER.

HRT-1 = PS-1 + PS-2 + PS-3

HRT-2 = PS-4 + PS-5 + PS-6

HRT-ST-II = PS-7 + PS-8

DFT-1 + DFT-2 = TRT-1

DFT-3 + DFT-4 = TRT-2

DFT-5 + DFT-6 + DFT-EU = TRT-3

DFT-7 + DFT-8 = TRT-ST-II

DPR DRAWING

ARRANGEMENT FOR BYE PASS FOR ENVIRONMENT FLOW INDICATED

SCALE:

0 20 40 60 80 100m.

JAMMU & KASHMIR STATE POWER DEVELOPMENT CORP.

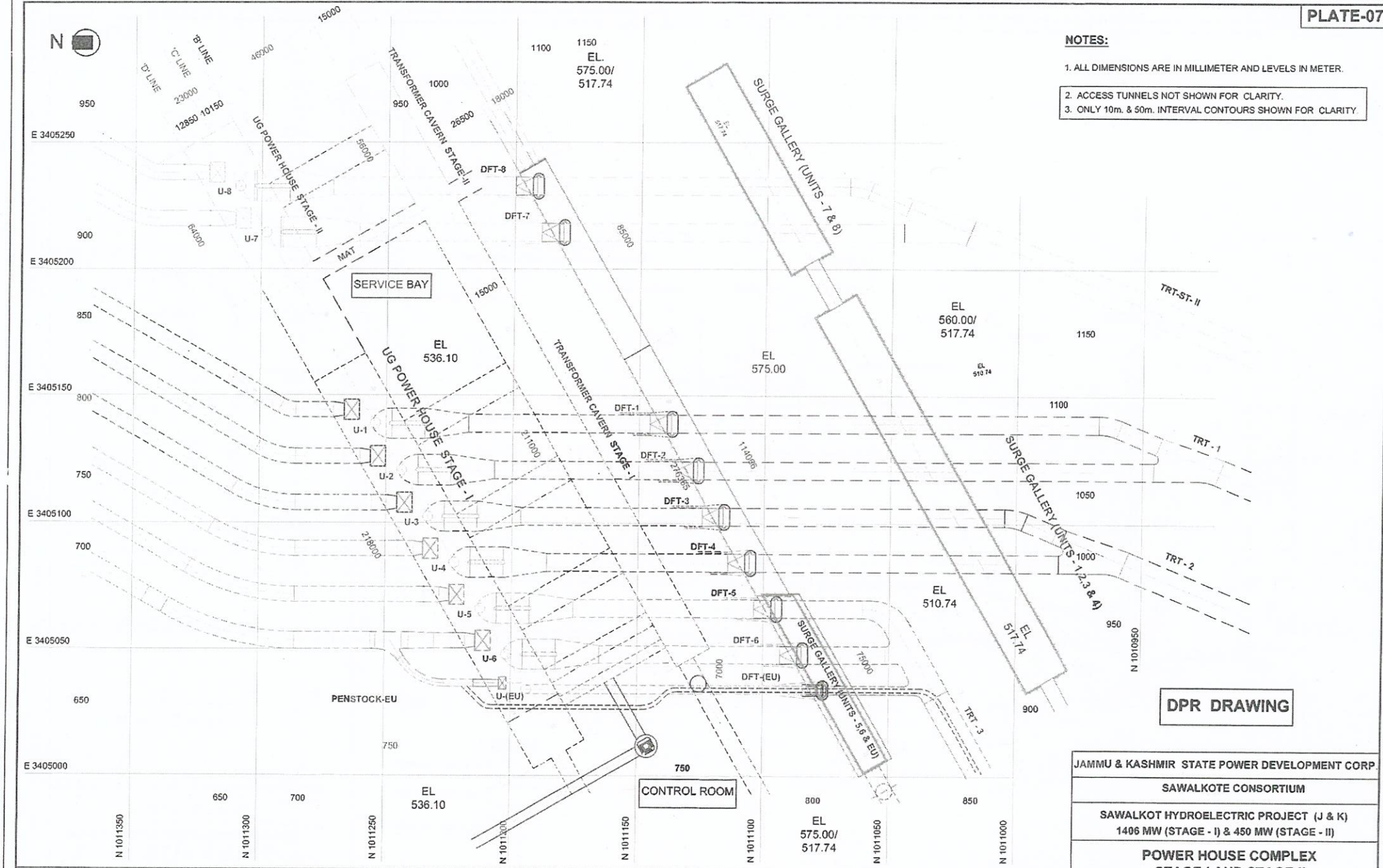
SAWALKOTE CONSORTIUM

SAWALKOT HYDROELECTRIC PROJECT (J & K)
1406 MW (STAGE - I) & 450 MW (STAGE - II)

DEFINITION PLAN
WATER CONDUCTOR SYSTEM

JUNE - 2017 | SWKT-DPR-GA-03-01

PLATE-07



NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETER AND LEVELS IN METER.
2. ACCESS TUNNELS NOT SHOWN FOR CLARITY.
3. ONLY 10m. & 50m. INTERVAL CONTOURS SHOWN FOR CLARITY.

DPR DRAWING

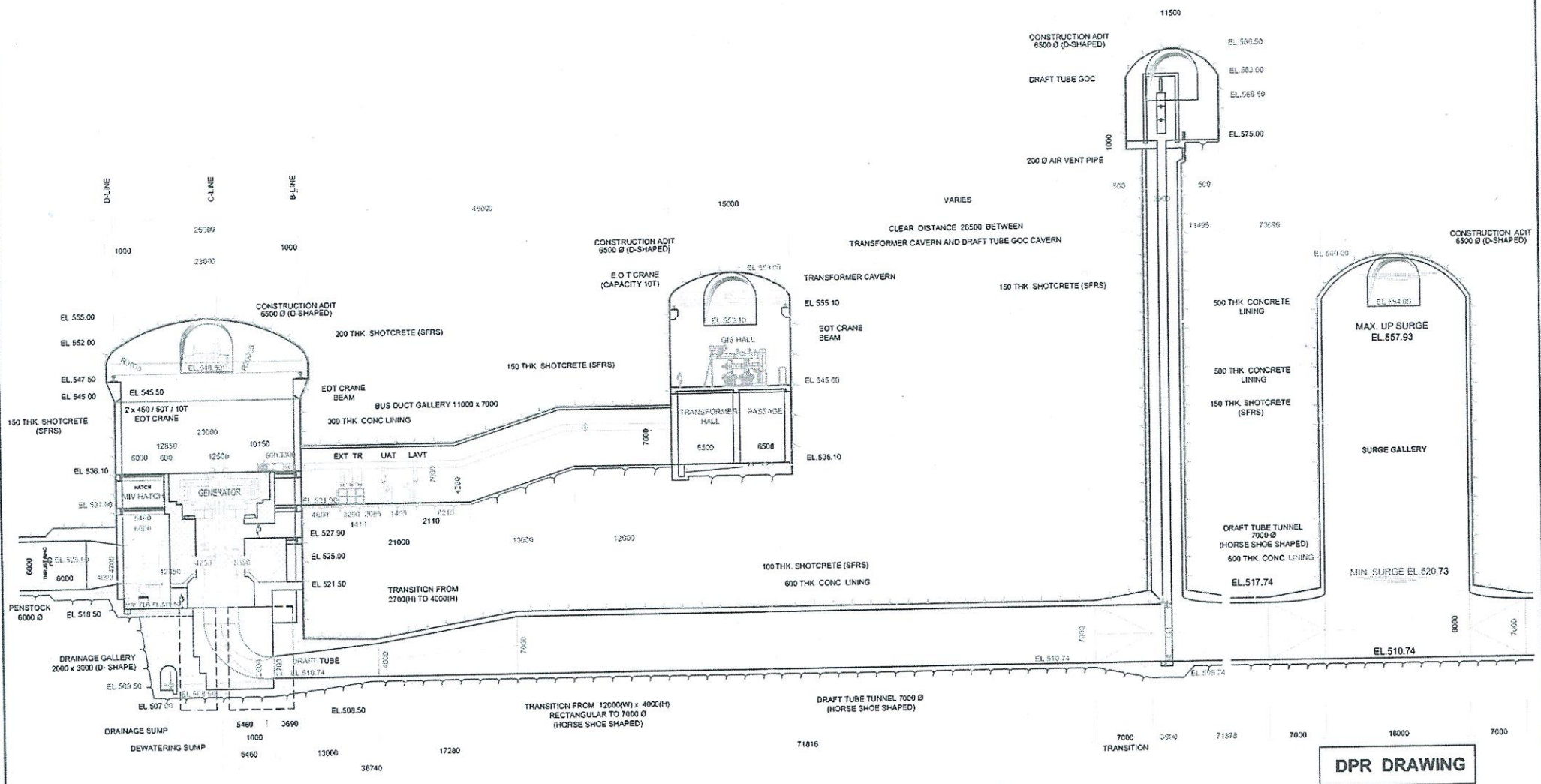
SCALE:

0 15 30 45 60 75m.

Dr. H VARA PRASAD
Senior Manager (Environment)
NHPC Ltd

JAMMU & KASHMIR STATE POWER DEVELOPMENT CORP.
SAWALKOTE CONSORTIUM
SAWALKOT HYDROELECTRIC PROJECT (J & K) 1406 MW (STAGE - I) & 450 MW (STAGE - II)
POWER HOUSE COMPLEX STAGE-I AND STAGE-II LAYOUT PLAN (WITH CONTOURS)
JUNE - 2017 | SWKT-DPR-PH-01-01

PLATE-08



DPR DRAWING

LEGEND :

- 1st STAGE CONCRETE
- 2nd STAGE CONCRETE
- 3rd STAGE CONCRETE

NOTE:

1. ALL DIMENSIONS ARE IN MILLIMETER AND LEVELS IN METER.

SCALE:

0 5 10 15 20 25m

Dr. G. S. S. H VARAPRASAD
Senior Manager (Environment)
NHPC Ltd

JAMMU & KASHMIR STATE POWER DEVELOPMENT CORP.
SAWALKOTE CONSORTIUM
SAWALKOT HYDROELECTRIC PROJECT (J & K) 1406 MW (STAGE - I) & 450 MW (STAGE - II)
POWER HOUSE COMPLEX CROSS SECTION THROUGH PH, TRANSFORMER HALL DRAFT TUBE GOC & SURGE GALLERY
JUNE - 2017 | SWKT-DPR-PH-04-00