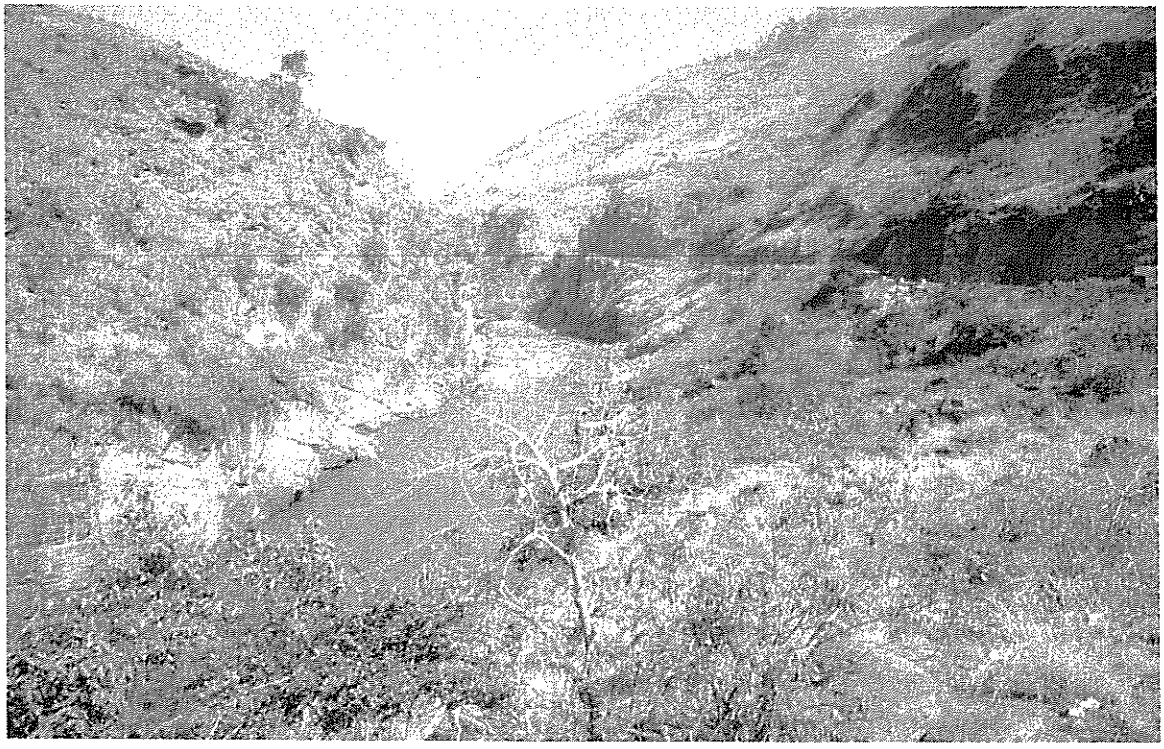
SJVN LIMITED

(A Joint Venture of Govt. of India & Govt. of Himachal Pradesh)

Luhri HEP Stage-II



Chapter on

General Layout

(For First Consultation Meeting)

(January, 2018)

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List of Annexures

Drawing Annexures

1. Introduction

1.1. Type of Project

Luhri Hydro Electric Project-II is a run of the river type development proposed to harness the hydel potential of river Satluj. The project envisages construction of a concrete gravity dam of ±71 m high above deepest foundation level across river Satluj near Nanj village and underground power house on the left bank.

1.2. Location of Project

The proposed project is situated on Satluj River in Shimla, Mandi and Kullu Districts of Himachal Pradesh. The dam is located near Nanj village in district Mandi at Longitude 77°20'58.46"E and Latitude 31°20'22.5"N. On the upstream of the project lies the 412 MW Rampur HPS, which utilises water discharged from the further upstream 1500 MW Nathpa-Jhakri project. On the downstream of Luhri Hydroelectric project-II lies the proposed Sunni Dam Project (23Km d/s) and 800 MW Kol Dam Project. In between Rampur HPS and proposed Luhri H.E Project-II, Luhri HEP Stage-I (nearly 27 km upstream).**(Refer Plate A).**

1.3. Access to Project Area

The project site is located at about 178 km from the nearest railhead at Kalka in Haryana and can be approached by NH-5 followed by SH-13and MDR-22 via Shimla, Naldhera and Chaba. The nearest airport is at Jubbar Hati (Shimla) about 93 km from project site. The nearest international airport is located at Chandigarh at a distance of 205 km from the project site.**(Refer Plate B).**

2. Need for the Project

Himachal Pradesh is blessed with vast hydroelectric power potential in its five major rivers. Gurgling rivers and their tributaries with steep gradient continue to challenge planners and engineers for optimal exploitation of hydropower potential. Numbers of hydroelectric projects are under execution in the state by central, state, joint and private sector developers. The only strategy followed in Himachal Pradesh for exploitation of hydroelectric power resources is to produce as much energy as possible, as fast as possible, with minimum cost and with minimum environmental negative impacts. The speedy exploitation of hydroelectric power potential will definitely improve the economic health of the State because 12 percent free power plus 1% LADF on all new installations will increase the resources of the state to a significant extent. The need for the project also arises from the need to fulfil a steady increase in peak electricity demand and the growing energy deficit in the Northern Region.

3. Alternatives Studies

The following alternative studies were carried out before the selection of Project at Nanj site:

i) Alternative-I: Dam and Surface toe Power House on Right bank at 250m u/s of Steel Bridge on narrow gorge near Nanj Village.

ii) Alternative-II: Dam and Underground Power House near Village Nathan about 3.5 km downstream of Dam site at Nanj village.

iii) Alternative-III: Dam and Underground toe Power House on Left Bank at 700m u/s of Steel Bridge on narrow gorge near Nanj Village.

Alternative-I: Dam and surface toe Power House on Right bank at 250m u/s of Steel Bridge on narrow gorge near Nanj Village.

An option of dam ±300 m downstream of Alternative-I dam site with surface power house has been studied. The dam and power house are likely to be housed in limestone and dolomite. Backwater effect from narrow gorge 300 m d/s can flood the surface power house, so this site was rejected for further study. **.(Refer Plate C).**

Alternative-II: Dam and Underground Power House near Village Nathan about 3.5 km downstream of Dam site at Nanj village.

An option of dam ±3.5 Km downstream of Alternative-I dam site with underground power house has been studied. The dam and power house are likely to be housed in limestone and dolomite. Issue of road (MDR-22) submergence approximately 5 Km is involved in this site, so this is less attractive option. **.(Refer Plate D).**

Alternative-III: Dam and underground toe Power House at left bank at 700m u/s of Steel Bridge on narrow gorge near Nanj Village

An option of Dam Site, ±15 Km downstream of Luhri Town with underground power house has been studied. The dam and power house are likely to be housed in limestone and dolomite. This site has been considered for detailed study on account of availability of space for power house and transformer hall. **(Refer Plate E).**

4. Environment Releases

The environmental discharge that will be released from the dam as per MOEF guidelines and the same is given in table below. It is proposed that the environmental release is used to generate electricity in an appropriately sized turbines situated in toe-powerhouse.

Environmental Releases as Suggested by MOEF

Season	Environment Flows (in cumecs)
Monsoon Period(June-Sep)	160.58 (30% of avg, Monsoon Flow)
Non-Monsoon and Non-Lean Period (Oct-Nov.-April-May)	67.89 (25% of avg. NM-NL flow)
Lean Period(Dec.-March)	19.69 (20% of avg. Lean flow)

5. Main Components of the Projects

5.1. River Diversion Works

The diversion tunnel is expected to be constructed in right side of the river valley. 10.5m dia, horse shoe shaped diversion tunnel is designed to pass diversion flood up to 765 m^3/s. The height of upstream cofferdam shall be ±17.50m and the height of downstream coffer dam shall be ±6.0m.

5.2. Dam and Spillway

A ±71m high, concrete gravity dam from deepest foundation level ±688m, with integral 6 nos. gated spillways having size of 9.5m (W) X 17.60m (H) have been proposed . The spillway has been designed to pass design flood corresponding to Probable Maximum Flood of 14287 cumec. The Full Reservoir Level has been kept at 754.0m and Minimum Draw Down Level at El. 748.0m. The dam would provide a gross pondage of 12.26 MCM and live storage of 5.71 MCM. The length of the dam at top shall be ±147.00 m. The proposed dam is divided in 9 blocks as tabulated in **Table 5.1** below:

Table 5.1: Details of Dam Blocks

Sl. No.	Description	Total Length (m)	No. of blocks	Block no.	Remarks
1.	NOF section on left bank	36.00	3	9 ,10 &11	Total Blocks = 11
2.	Over flow blocks	93.00	6	2 to 7	
3.	NOF section on right bank	18.00	2	1 to 2	

5.3. Intake Structure

Intake structure is proposed on right bank for diverting the design discharge of 646.28 m^3/sec from the reservoir to the underground power house. The centre line of intake shall be at ±728.70m. Trash screens will be provided to prevent coarse floating or submerged debris being drawn into the pressure shafts. Trash rack cleaning facilities should be provided. The velocities through the trash screens shall be limited to 1.5 m/s as mentioned in IS: 9761-1995- Hydropower Intakes- Criteria for Hydraulic Design.

Discharge from intake-1 and 2 (249.79 m^3/sec each) shall be utilized for main units and discharge through intake-3 (146.70 m^3/sec) shall be utilized for environment units.

Intake gates with stoplog gates are provided to enable inspection and maintenance whilst the reservoir is impounded and to prevent heavily sedimented water depositing sediment within the pressure shaft entrance area during extreme floods.

5.4. Pressure Shaft and Penstocks

For flexibility of operation and maintenance, 3 nos. pressure shaft have been proposed which shall further bifurcated into four to pass total discharge of 646.28 m^3/sec.

5.5. Power House and Transformer Hall

Due to non-availability of space for surface power house an Underground power house having with size of 167.0m (L) x 23.0m (W) x 50.0m (H) shall be provided on left bank (In the Shimla district) with installed capacity of 163 MW (4 x 31.5 MW – Main Units, 2 x 18.5 MW- Environmental Units).The power house cavern is proposed ±130m inside the hill with as top cover of ±80m. Further, minimum 50.0m rock cover is available between transformer hall and machine hall. The Transformer cavern proposed is 130(L) x 16(W) x 23 (H).

5.6. Tail Race Tunnel and Outfall Structures

Water exiting from the turbines will be discharged through the draft tubes into the 2 nos., 10.5m and 6.5m dia horse shoe shaped tail race tunnels. The length of tail race tunnels shall be ±280.0m and ±280m respectively. The TRT outfall gated structure after TRT has been proposed with crest level of El ±723.0m for discharging water from TRT to Satluj River.

5.7. Access Tunnels

The access tunnels to the machine hall and transformer hall and penstock have been determined based on the size of the vehicles and equipment required to be transported through them, a maximum slope of 1 in 15 and making them as straight as possible for ease of maneuvering large vehicles. Access tunnel for construction only have been sized to pass two dump trucks side by side.

5.8. Main Access Tunnel (MAT)

The main access tunnel will be approximately ±700m long with a maximum slope of 1 in 15. It is anticipated that an enlarged section will be created at the junction between the tunnel and the machine hall loading and erection bay to form a parking area.

5.9. Secondary Access Tunnel and Cable Tunnel

The secondary access and cable tunnel provides access for delivery of transformers, switchgear and draft tube gates. A parking bay may also be included in this tunnel, just outside the transformer hall. This tunnel will also act a cable tunnel, with the cable buried in ducts in the tunnel invert for safety reasons.

6. Interstate/International Aspects

The project lies in Satluj basin, which is a part of Indus Basin, and is to be governed by relevant provision of Indus water Treaty signed between India and Pakistan in 1960. Since Satluj is an Eastern flowing river of Indus Basin, hence India has exclusive right over its water sharing.

7. Cost Estimate and Financial Aspects

The project is estimated to cost around 1882.90 Cr. including IDC and financing charges at March, 2017 price level. The design energy of the project calculated as 604.00 GWh.

8. Construction Period

LHEP Stage-II project is proposed to be completed in 5 years.

9. Sailent Features of Luhri HEP-II

Tentative Salient features of Luhri HEP-II are mentioned below

LUHRI HEP STAGE-II (163 MW)

1.0 Location	
State	Himachal Pradesh
District	Shimla, Mandi and Kullu
Tehsil	Kumarsen, Karsog and Anni
River	Satluj
Nearest Village (Dam Site)	Nanj (Mandi district)
Rail Head	Kalka (Haryana) 178km
Latitude of Dam Site	31° 20' 22.5" N.
Longitude of Dam site	77° 20' 58.46" E
2.0 Hydrology	
Catchment Area at Diversion Site	52231 km^2
90% dependable year	2001-2002
Flood discharge for river diversion	765.00m^3/sec (Approved)
Probable Maximum Flood (PMF)	14287.00m^3/sec
3.0 Reservoir	
Full Reservoir Level (FRL)	EL754.00 m
Minimum Draw Down Level (MDDL)	EL 748.00 m
Gross Storage at FRL	12.26 X 10^6 m^3
Dead Storage	6.55X 10^6 m^3
Live Storage at FRL	5.71 X 10^6 m^3
Length of Reservoir	$\pm$6.00 km(approx.)
Desilting Basin	Reservoir will act as Desilting basin
4.0 Dam	
Type of Dam	Concrete Gravity
Top of the Dam	EL759.00 m
Average River Bed Level at Dam Site	EL718.00 m
Dam Height above River bed	41.00m
Length of Dam at Top	147.00 m
Top Width of Dam	8.00 m
Length of Overflow Blocks	93.00 m
Length of Non-Overflow Blocks	54.00m
5.0 Spillway	
Design Flood(PMF)	14287.00m^3/sec
Type of Spillway	*Combination of Upper Level Spillway(ULS) and Low Level Spillway(LLS) (sluice spillway)*
Energy Dissipation System	Stilling Basin

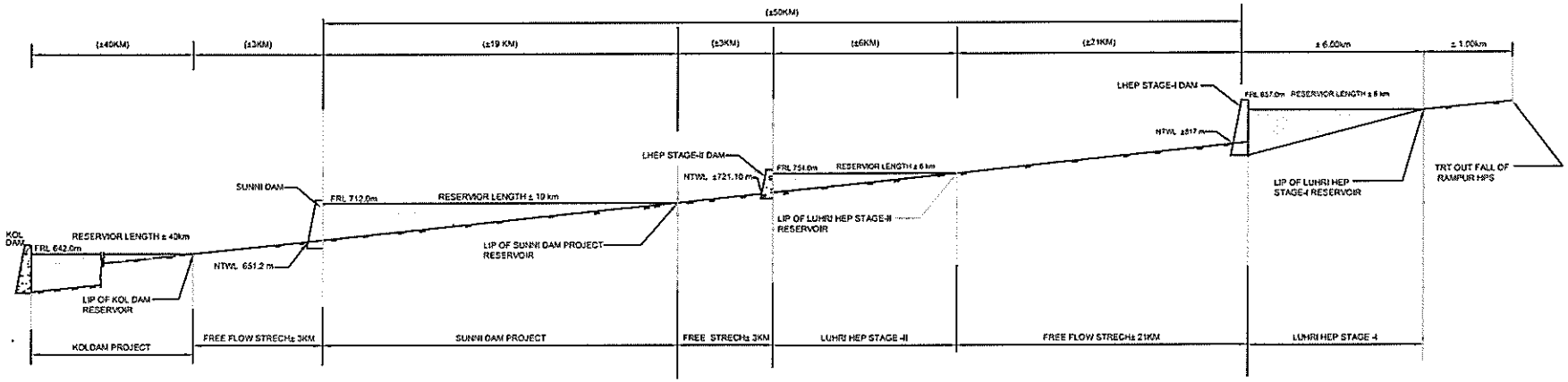
Low Level Spillway(LLS)(Under sluice Spillway)	
Type	Sluice type
No. of Bays	Six
Size of opening	9.5 m (W) X 17.6m (H)
Type & No. of gate	Radial, Six (06)
Width of each sluice block	15.5 m
Total width of LLS Blocks	93.00m
Crest Level	EL ±724.00 m
Upper Level Side Spillway(ULS) (Overflow Spillway)	
Type	Ogee with open crest overflow
No of Bays	One(01) (Block No. 2)
Size	9.0m (W) X 3.0m (H)
Type and No of gates	Flap Gate, One(01)
Crest of ULS	EL 748.00 m
6.0 River Diversion	
River Diversion Discharge (1 in 25 years)	765.00m^3/sec (Approved)
Diversion Scheme	Through Diversion Tunnel(DT) and coffer dams
Location of Diversion Tunnel	Right Bank
No. of Tunnel	One(01)
Diameter and shape of DT	10.5 m, Horse Shoe Shape
Length of Tunnel	±793.0 m
7.0 Power Intake	
Number of Intake	Three (03)
Invert level	EL 728.70 m
Discharge Capacity of Intake 1 and 2 (for Main Units)	249.79 m^3/sec
Discharge Capacity of Intake 3 (for Environment Units)	146.70 m^3/sec
8.0 Pressure Shaft	
Number of Pressure Shaft	Three (03) further bifurcated into six
Design Discharge for Pressure Shaft-1 and 2 (for Main units)	249.79 m^3/sec
Design Discharge for Pressure Shaft-3 (for Environment units)	146.70 m^3/sec
Diameter of Penstock	7.2 m and 4.5m
Length of Penstock	± 100.0 m
9.0 Power House	
Type	Underground
Location	Left Bank
Size of machine Hall	167m (L) X 23m(W) X 50(H)
Normal Tail Water Level	EL 721.10 m
Minimum Tail Water Level	EL 718.80 m

Gross Head	30.90 m
Rated Head/Design Head	28.40 m
Turbine Type	Kaplan
No of Unit	Six (06)
Design Discharge	646.28m^3/sec
Installed Capacity for main units	4X31.50MW
Installed Capacity for environment units	2X18.5MW
Total Installed Capacity	163 MW
10.0 Tail Race Tunnel	
Number	Two (02)
Size of Tunnels	10.5m and 6.5m dia., Horse Shoe Shaped
Length of Tunnels	±280m (both)
11.0 Power Generation	
Design Energy	604.00 GWh
Annual Load Factor (Main Unit)	40.10%
Annual Load Factor (Environment Unit)	54.55 %
12.0 Estimated Cost	
Total Hard Cost at March'17 Price Level	1521.88 Crore
Interest During Construction	347.73 Crore
Financial Charges	13.29 Crore
Total Project Cost	1882.90 Crore
13.0 Financial Aspects	
1st year tariff at Power House bus bars (including IDC) during 90% dependable year as per CERC guidelines	Rs 7.21
Levelised tariff at Power House bus bars (including IDC) during 90% dependable year as per CERC guidelines	Rs 6.85
14.0 Construction Period	
Total construction period	5 years

NOTE

1. ALL DIMENSIONS ARE IN MILLIMETER AND ELEVATIONS ARE IN METER UNLESS OTHERWISE SPECIFIED

SCHEMATIC SKETCH SHOWING L-SECTION OF SATLUJ FROM LUHRI HEP STAGE-1 TO KOL DAM



LUHRI HEP STAGE-II (Envisaged as RoR)	
FRL	754 m
NORMAL TWL	721.10 m
RESERVOIR LENGTH	± 6 km

KOL DAM PROJECT (800MW) (UNDER OPERATION STAGE)	
FRL	642 m
NORMAL TWL	-
RESERVOIR LENGTH	±40 km

SUNNI DAM PROJECT (Envisaged as RoR)	
FRL	712 m
NORMAL TWL	651.2 m
RESERVOIR LENGTH	±19 km

LHEP STAGE- I (210 MW) (UNDER DPR EXAMINATION)	
FRL	857 m
NORMAL TWL	817 m
RESERVOIR LENGTH	6 km

NOT TO BE SCALED

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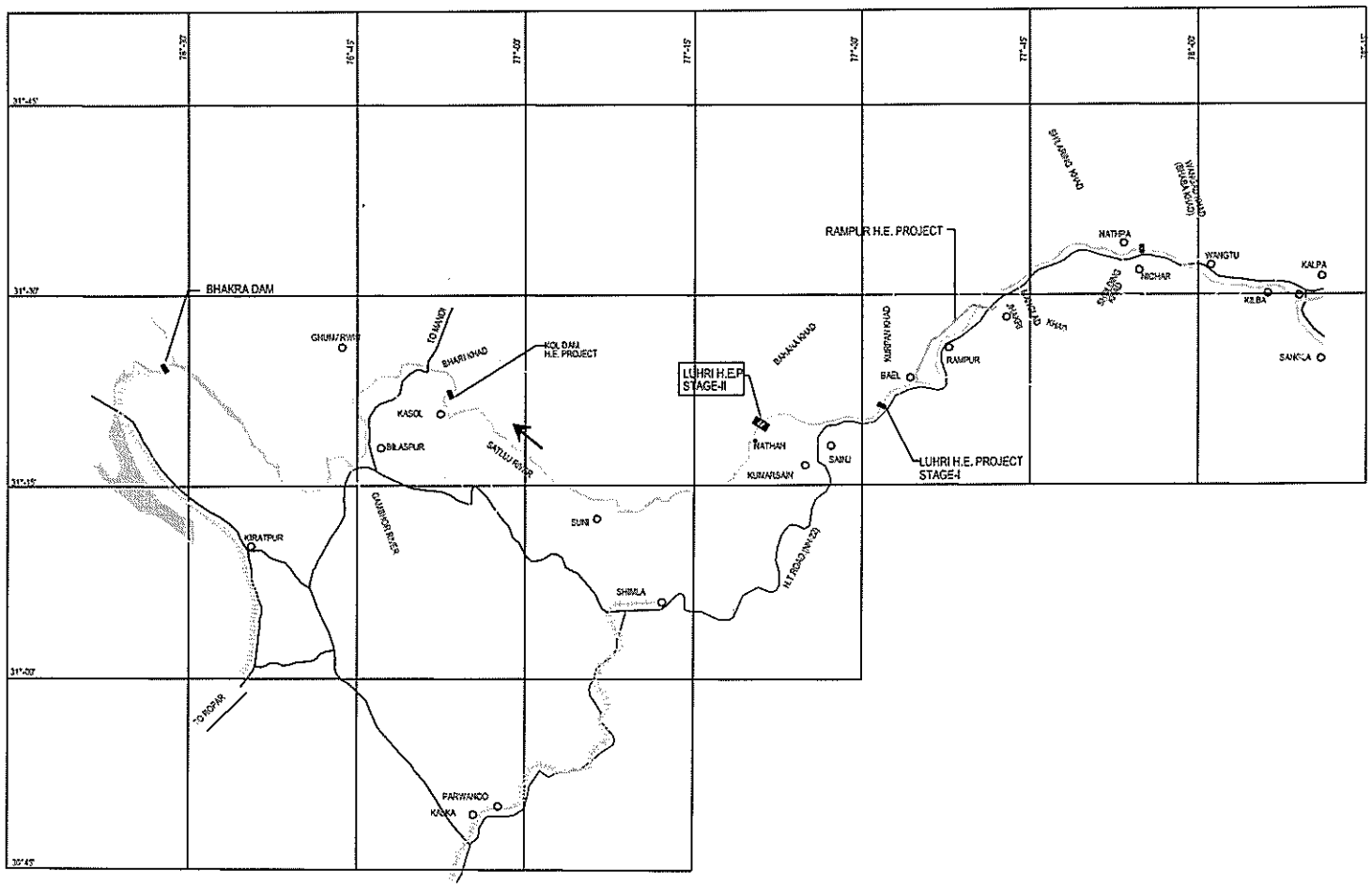
सतलुज जल विद्युत परियोजना डिएपी
LUHRI HEP STAGE-II

SCHEMATIC SKETCH SHOWING L-SECTION OF SATLUJ FROM LUHRI HEP STAGE-1 TO KOL DAM (CASCADE DEVELOPMENT)

अभिकल्पित DSGN.	परीक्षित CHKD.	संस्तुत RECM.
रेखांकित DRWN.	प्रस्तुत SUBM.	

PLATE B



KEY TO SYMBOLS:-

RAILWAY

NATIONAL HIGHWAY

RIVER/NALA

TOWNS

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लूहरी जल विद्युत परियोजना स्टेज-II
LUHRI HEP STAGE-II (H.P.)

LOCATION MAP

अभिकल्पक DSGN.	जाँचकर्ता CHKD.	संस्तुत RECM.
ड्राफ्टसमैन DRWG.	पास्ता SUBM.	

(8)

PLATE B1

INDIA
REFER TO THIS MAP AS 1:50,000
SHEET 53 E/7 FIRST EDITION

HIMĀCHAL PP.ADESH

KULU, MAHĀSU & MANDI DISTRICTS. Surveyed 1964-65.

NO. 53 E/7

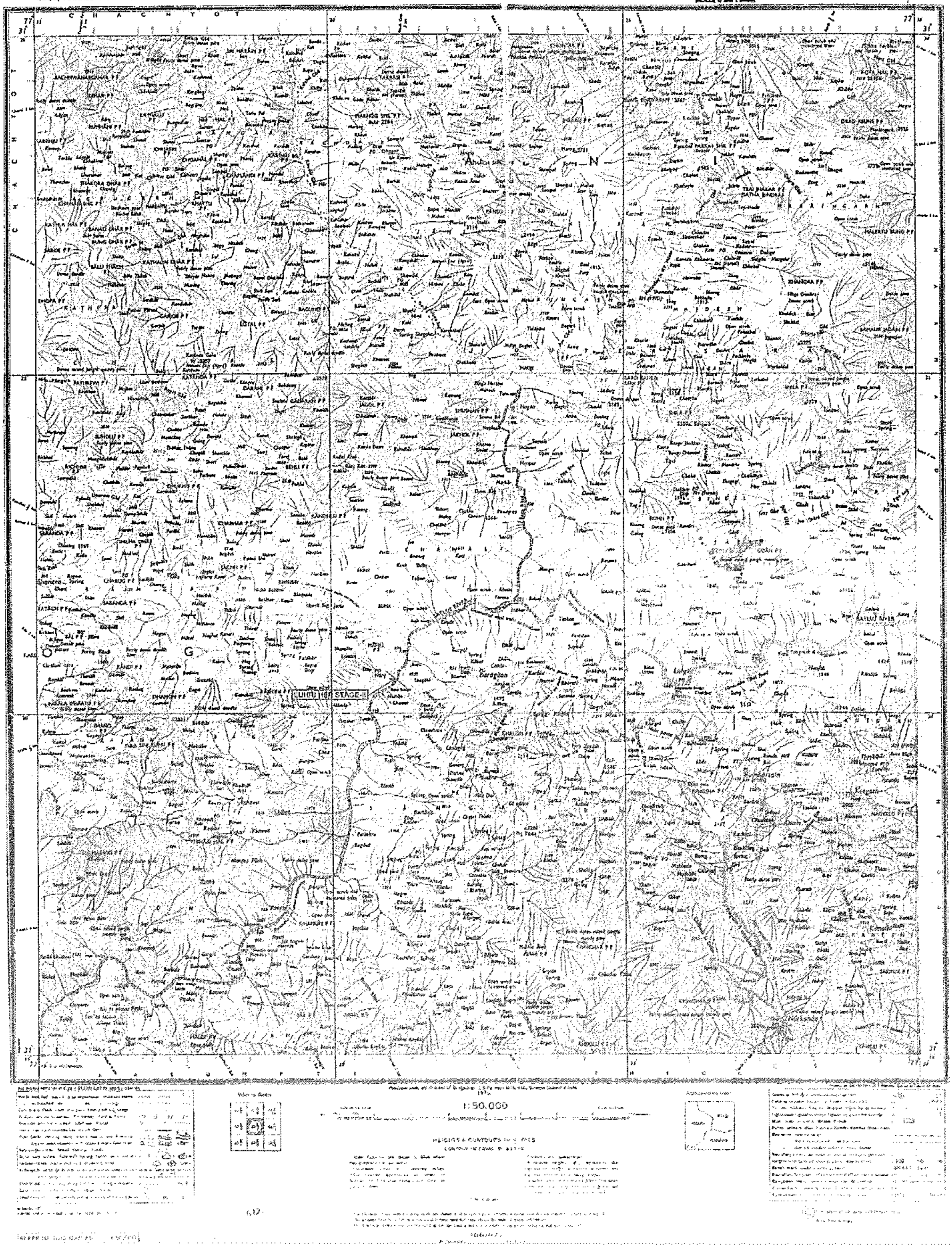
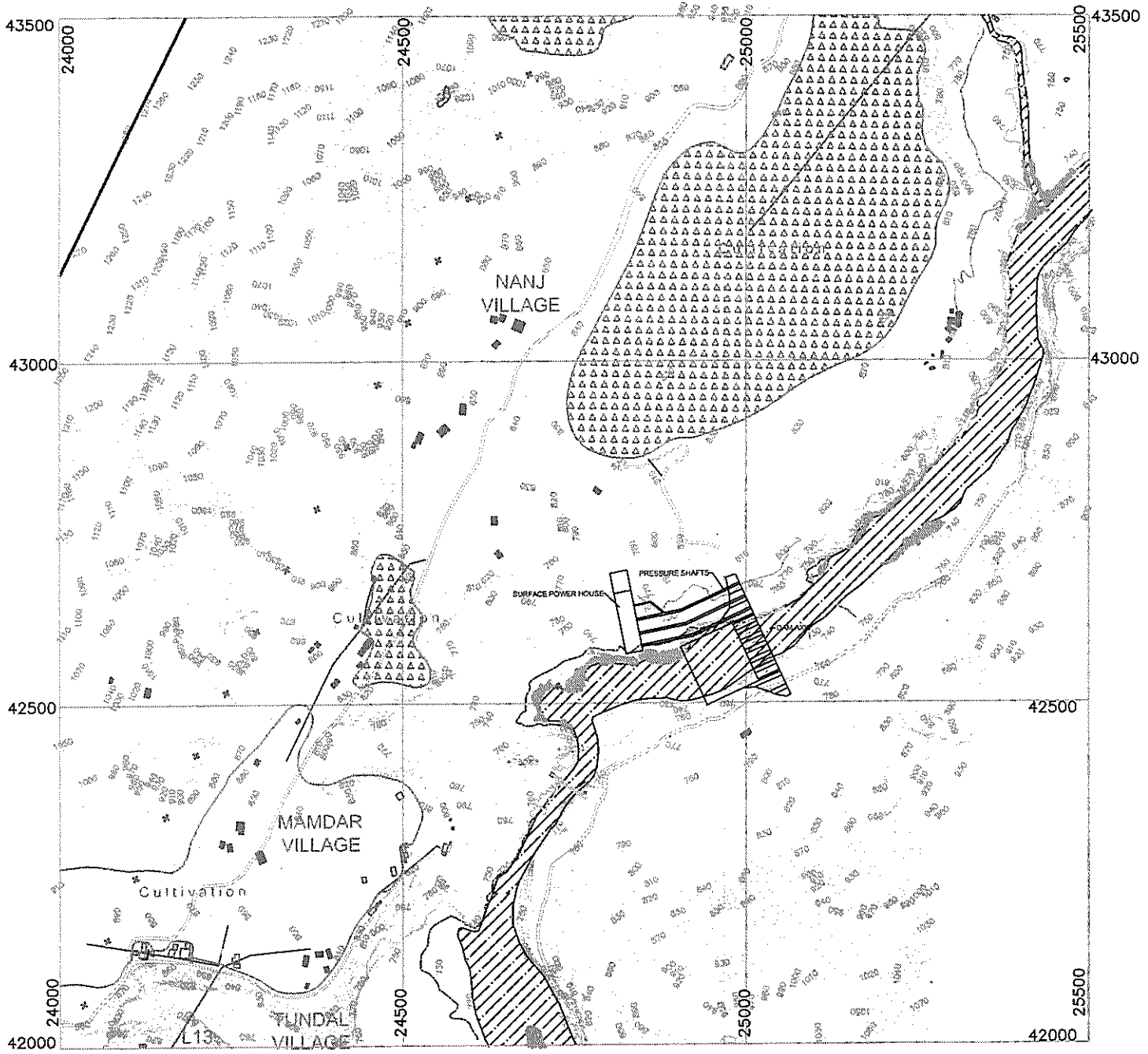


PLATE C



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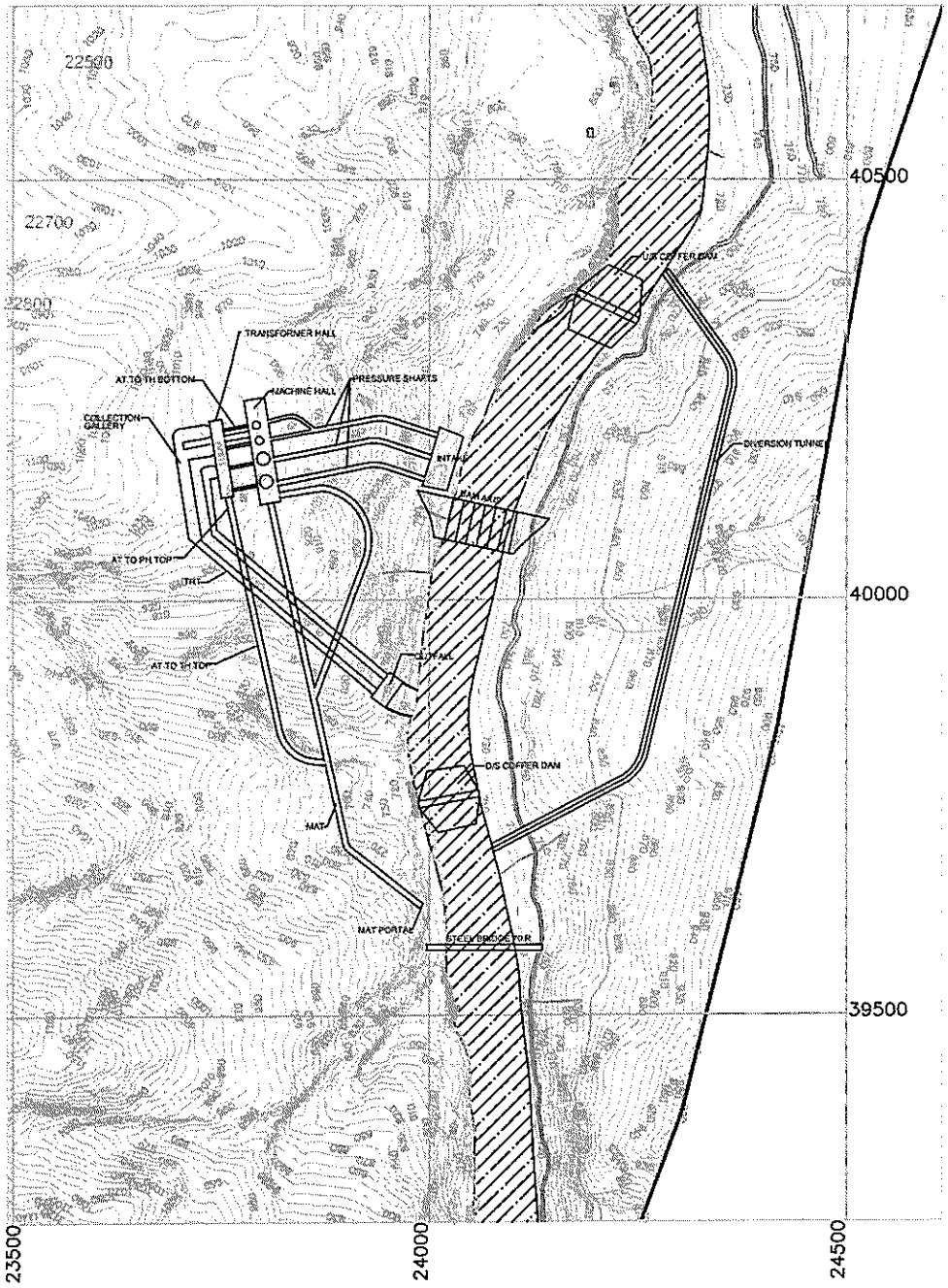
LUHRI STAGE II (H.P.)

LAYOUT PLAN
ALTERNATIVE-I

	JANUARY 2015	

PLATE D



NOTES

1. THE DRAWING SHALL BE USED FOR PLANNING PURPOSE ONLY.
2. THE LAYOUT PLAN IS TENTATIVE AND IS SUBJECT TO CHANGE AS PER SITE CONDITIONS

TENTATIVE CO-ORDINATES OF PROPOSED DAM AXIS AT EL 760.00M (NATHAN SITE)

BANK	EASTING	NORTHING
LEFT	24143.2095	40096.4732
RIGHT	23985.9365	40131.1087

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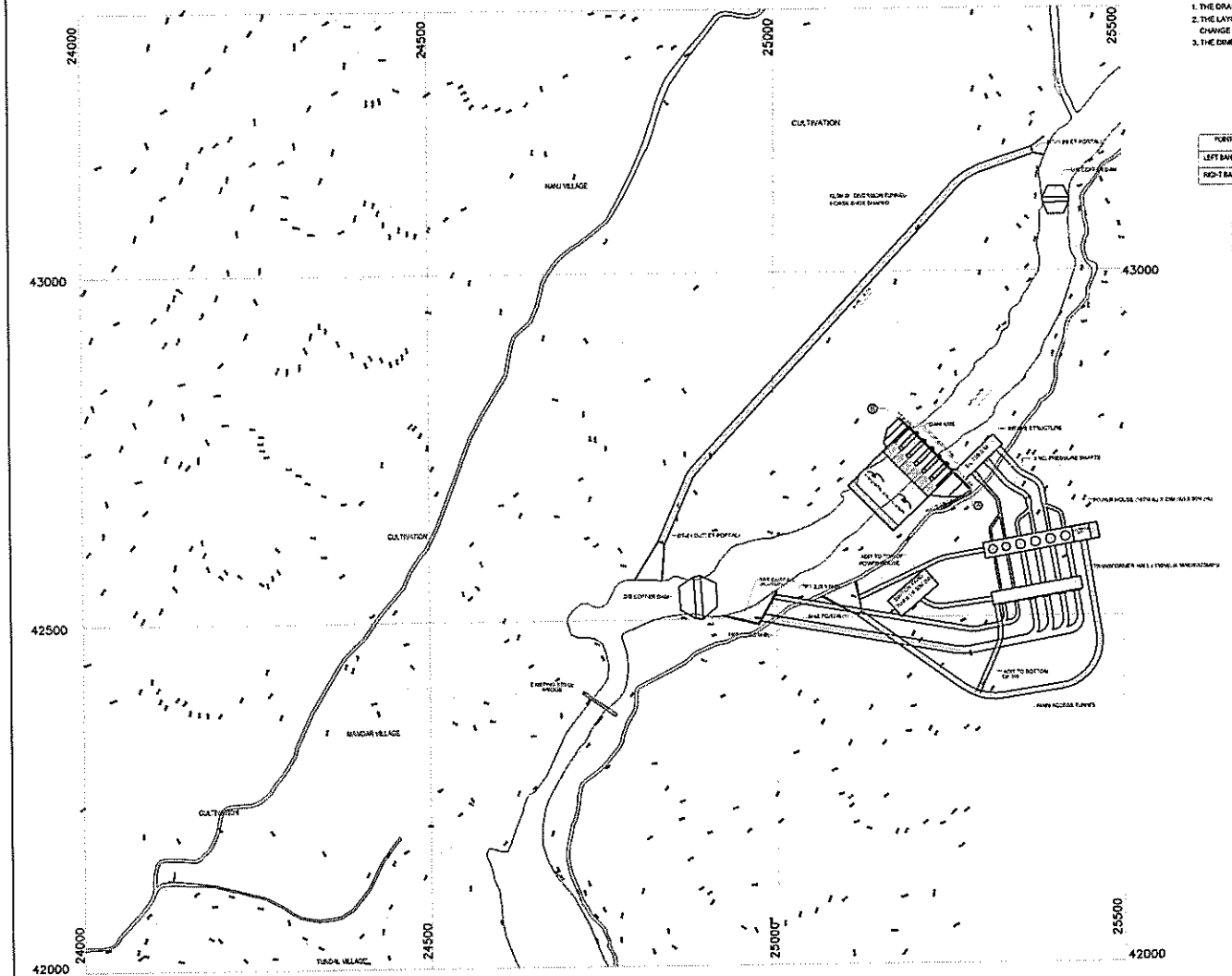
LUHRI STAGE II (H.P.)

GENERAL LAYOUT PLAN
ALTERNATIVE-II (NATHAN SITE)

PLATE E



GENERAL LAYOUT PLAN

NOTES

1. THE DRAWING IS USED FOR PLANNING PURPOSE ONLY.
2. THE LAYOUT PLAN IS TENTATIVE AND IS SUBJECT TO CHANGE AS PER SITE CONDITIONS.
3. THE DIMENSIONS AND ELEVATIONS OF COMPONENTS ARE TENTATIVE.

TENTATIVE COORDINATES OF DAM AXIS

POINTS	EASTING	NORTHING
LEFT BANK (A)	25279.814	42663.071
RIGHT BANK (B)	25177.925	42787.568

COORDINATES OF DAM SITE

LONGITUDE	LATITUDE
77° 20' 56.48"	31° 29' 22.5"

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LUHRI HEP STAGE II (H.P.)	
GENERAL LAYOUT PLAN ALTERNATIVE-III	
SCALE	DWG. NO.
DRAWN	CHECKED
	JANUARY 2019

GEOLOGY OF PROJECT

1. Introduction

Luhri Stage-II project is proposed on the River Satluj and falls in districts of Shimla and Mandi of Himachal Pradesh. The project is located in the inner lesser Himalaya between Dhauladhar range in the south and higher Himalaya in the north. The project envisages construction of a concrete gravity dam ±71m high from deepest foundation level across river Satluj near Nanj village. The underground power house and its appurtenant structures (±163MW) are proposed on left bank.

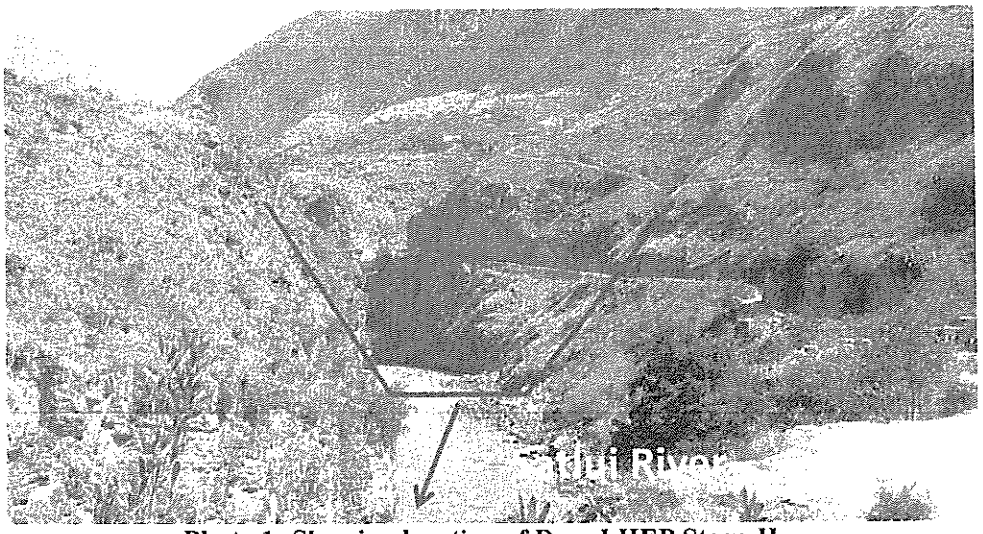


Photo 1: Showing location of Dam LHEP Stage-II.

2. Accessibility:

The project site is located at about 178 km from the nearest railhead at Kalka in Haryana and can be approached by NH-5 followed by SH-13and MDR-22 via Shimla, Naldhera and Chaba. The nearest airport is at Jubbar Hati (Shimla) about 93 km from project site. The nearest international airport is located at Chandigarh at a distance of 183km from the project site.

3. Physiography and Geomorphology:

The project lies in the Inner Lesser Himalaya between the Dhauladhar range in the south and the Higher Himalayan Range in the north. The Satluj River is the main drainage in the catchment area with headwaters located in the highlands of Tibet. Geomorphologically the area is located in a young mountain chain which is characterized by rapid down-cutting valley. Hence, most of the valley slopes are steep and the Satluj River is confined within narrow V-shaped valleys on the higher reaches. The area forms part of the drainage basin of Satluj, which flows in nearly southwest direction. Behnakhad, Kotlukhad, are important tributaries of the river Satluj.The drainage in the area exhibits sub-dendritic to trellis pattern controlled both by structure and lithology.

4. **Regional Geology:**

The project area lies in Inner Lesser Himalayas SSW of main central thrust. The stratigraphy established in the SatlujValley (after Sharma, 1977) is enumerated below in Table-1.:

Table-1: Stratigraphy of Lesser Himalaya in Satluj Valley (after Sharma, 1977 and Unified Legend, GSI).

Geological Age	Group	Formation	Lithology
Holocene		Newer Alluvium	Boulder, pebbles, coarse sand – younger terraces (T1) and river channel
Middle to Upper Pleistocene		Older Alluvium	Boulder, pebbles, coarse sand – older terraces (T2)
Palaeocene to Early Eocene	Sirmur	Subathu (Kakra)	Basal pisolitic laterite, quartz arenite, variegated shales and massive to thin bedded Limestone.
Mesoproterozoic to Neoproterozoic	Kullu	Khokhan	Quartzite, quartz chlorite and quartz biotite schist; slate, phyllite and schist, garnetiferous schist; locally associated with amphibolites.
		Gahr	Streaky mylonite gneiss, banded and augen gneisses
		Khamrada	Carbonaceous to graphitic schist and phyllitelocallygarnetiferous; lenticular grayish blue and cream coloured platy limestone and calcschist.
	Shimla		Quartzite-shale-limestone at the base, shale siltstone alternations with limestone interbeds;shale and siltstone alternations with ortho-quartzite and greywacke; greywacke sandstone, siltstone, shale alternation, orthoquartzite; quartzite, arkosic sandstone, protoquartzite, grey and purple shale at top
Palaeoproterozoic	Rampur		Quartzite withpenecontemporaneous mafic meta-volcanics intruded by BandalGranitoid Gneiss.
	Shali/ Larji	Bandla	Green and purple shale/ slate, siltstone sporadic limestone, thinly bedded orthoquartzite, interbeds green brecciated rock and a fairly persistent band of white quartzite at the base.
		Parnali	Cherty dolomite, grey limestone and white quartz-arenit
		Makri	Grey, green, black and purple shale and slate, thin bedded limestone, thin bedded quartzarenite with or without dolomite.
		Tattapani	Cherty dolomite, grey and pink colour with grey phyllitised shale.
		Sorghwari	Pink and grey cream textured limestone with shale parting
		Khatpul	Massive dolomite with sporadic quartz arenite and a thin red shale band at the base.
		Khaira	Mainly pink and purple, white quartz arena
		Ropri	Brick red shale and siltstone with grey dolomite in the lower horizon; local development of salt, salt grit and the

			marlylithocomplex "Lokhan"
	Sunderna gar Group		Quartzite with penecontemporaneous mafic volcanics (Mandi – Darla Volcanic), grey slate, phyllite, shale, limestone
Archaean	Jeori – Wangtu Granitoid		Augen gneiss, mylonitic gneiss, porphyroblasticbiotite gneiss with intercalated biotite-garnet-kyanite-sillimanite-schist bands intruded by porphyritic and tourmaline granite, pegmatite and aplite

The project area lies in Khatpul/Tatapani Formation of Shali/Larji Group of rocks.

4.1 Tectonics:

Four distinct patterns of folding are identifiable in the vicinity of the project area. Chamba Syncline and Rampur Anticline are main structure features whereas Main Central Thrust and Jutogh Thrust are major thrusts in the far Upstream. The nearest structural feature being Kotlu thrust is in the vicinity of the (u/s 500m) of the project.

5. Alternate Studies:

On the basis of reconnaissance survey and geological mapping of the designated area, various alternatives were studied stretching from the confluence of Satluj & Kotlu Khad (near Nanj Village) to Nathan village (situated on left bank) in an area of 3 km length along the river.All possible locations in this stretch were studied from geological view point. On the basis of various traverses taken by SJVN Geologist & Design Team and joint visit with Geological Survey of India, Chandigarh, three alternative were identified ,the detail study and conclusion are given below:-

Alternate-1 – This alternate is located 250m u/s of the Nanj bridge. The alternate was studied for dam toe surface power house. The site was inspected from Geological and design point of view. The dolomite /limestone of Khatpul formation are exposed at both banks along the proposed dam axis up to Elevation ±760 m. Above El ± 760m right bank is occupied by overburden comprises of river borne material and continued to the flat terrace (El ±810 m).At left bank above road (± 755m) there is no exposure of rock along the proposed dam axis. There is narrow gorge 250 m d/s from proposed dam site. It is opined by Design department that flood (PMF) could not pass through this narrow gorge, therefore site is not feasible.

Alternate-2 (Near Nathan Village) - The location was identified and studied for Dam /Toe sub-surface power house. The river section at this site was wider than alternate -1. Geologically, the area around the proposed dam axis is comprised of sound rock. Dolomite /limestone are exposed at both the banks. At this alternate reservoir lip of Sunni dam is supposed to be overlapped the proposed dam axis of stage -II. As per guidelines of MOEF& CC it is necessary to maintain 1Km free flow stretch between two projects so project at this alternate is not feasible.

Alternate-3 (700m u/s the Nanj Bridge) – This alternate is located near the Nanj Village & is about 700 m u/s of the Nanj Bridge. The grayish pink dolomites belonging to Shali/larji Group (Khatpul/Tattpani Formation) are exposed on both the banks (with very thin overburden on the left bank) at the proposed dam axis. However, very thick terrace deposits resting over the dolomite/limestone was observed on the right bank from El ± 820m. It was apprehended that terrace formed due to ancient river channel. At left bank the same rock type is observed from the river bank to the road (±760m). The rock above the road is covered under thin overburden.

On the basis of various aspects and to check the feasibility of the project site from geological point of view point the Alternate -3 is consider for further geological studies.

6. Geology of the Dam and Power House:

6.1 Dam site

The geological mapping at Luhri Hydroelectric Project Stage II proposed dam site was carried out on 1:2500 scale covering an area of 2.23 sq.km with special emphasis on right bank of the dam site. The mapped area on both the abutment exposes rocks belonging to Makri Formation (Shali Group) comprising grayish pink cherty dolomite with thin bands of quartzite, Kulu Group comprising foliated augen gneiss, banded and streaky gneiss with minor quartzite and undefined Older and Newer Alluvial terraces. The general trend on the right bank is E-W with 50°-75° dip due northern and southern direction, and on the left bank, it is N30°W-S30°E with 40° dip due N60°E direction. The litho units are traversed by 3 sets of joint including bedding joints and are tabulated in Table 2 & 3. The joints are open on the left bank and the cavernous rock was observed on the right bank at the proposed dam site. It is observed that a very thick terrace deposit is present on the right bank from El ± 830m.

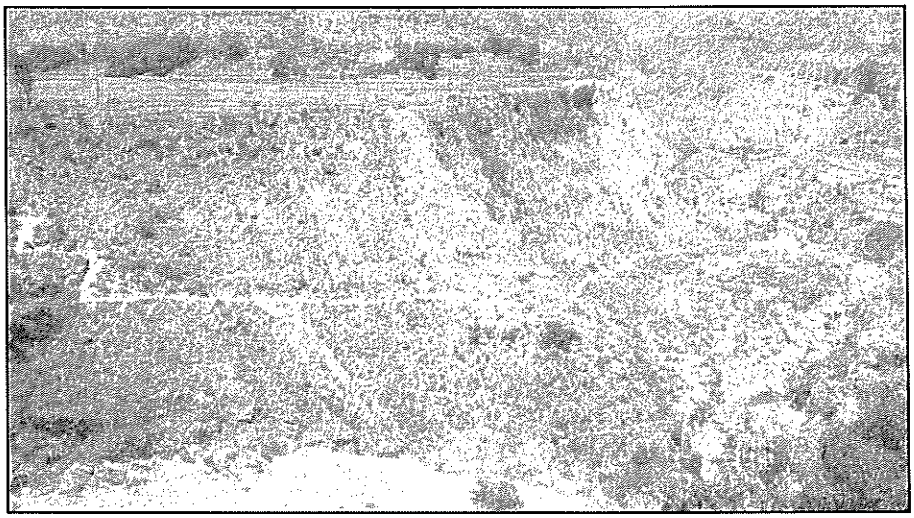


Photo. 2 : Showing terrace deposits (T) on the right bank of Satluj River at El ± 830m

Table 2: Details of joint sets observed on the left abutment:

Sl. No.	Joint Nos.	Orientation Strike/amount/dip direction	Characteristics	Remarks
1.	S0 / J1	N30^{O}W – S30^{O}E /40°/ N60°E	Spacing 2-40cm, continuity >5m, opening 1-2cm, clay coating, planar smooth	Foliation joint, clay coated and stained at places.
2.	J2	N10W – S10E /65°/ S80°W	Spacing 3-20cm, continuity >3m, opening 1-3cm, rough and undulatory	
3.	J3	N60^{O}W – S60^{O}E /80°/S30°W	Spacing 30-50cm, continuity >3m, tight, rough, undulatory	

Table 3: Details of joint sets observed on the right abutment:

Sl. No.	Joint Nos.	Orientation Strike/amount/dip direction	Characteristics	Remarks
1.	S0 / J1	N60^{O}E – S60^{O}W /30°/N30°W	Spacing 3-60cm, continuity >5m, tight, rough, planar	Due to folding dip direction varies
2.	J2	N-S /80°/E	---	
3.	J3	N70^{O}E – S70^{O}W /45°/N20°W	Spacing 2-12cm, continuity 50cm, rough planar, tight	

During the geological mapping it has been noted/observed that the pink dolomite on right bank overlain by thick alluvial deposits at EL. ± 820m. The signature of paleo channel has also been noticed approximately 500m u/s of proposed dam axis in the vicinity of confluence of Koltu Khad and Satluj River. To confirm the signature of paleo channel Geological survey of India (GSI), Chandigarh has suggested to carryout geophysical survey along the right bank extending upto the confluence of Kotlukhad with Satluj River.

Project authority has been carried out the geophysical survey through AIMIL Ltd. The findings of geophysical survey are summarized in the following paragraphs.

Overall 74 Nos. of ReMi Points along with MASW survey and Eleven (11) Electrical Resistivity profiles were conducted on Nanj Terrace at Nanj village.

Based on the findings of geophysical survey, it can be concluded that the subsurface strata of the Nanj Terrace area covered is composed of three layers in general and are classified as follows:

i. Overburden Soil strata varies in thickness from 1.0m to 60m.

ii. Highly weathered rock rests below the upper layer of soil/highly weathered rock has been Projected to a maximum depth of 100m.

iii. Moderately weathered rock with joints/Fractures below 100m depth.

On the basis of geophysical survey two geological sections (Plate –2& Plate-3)have been prepared. From the geological section A-A' along the proposed dam axis it is observed that the maximum thickness of RBM on the right bank below NSL ±835m (midpoint of the terrace) is about 51m which is further decreasing towards uphill and towards the river channel. The maximum thickness of RBM below the river bed is considered to be ±30m which is tentative. The grayish pink dolomites belonging to Makri formation are exposed on both the abutments. The bed rock is dissected by 2 to 3 numbers of joint sets including bedding joints. The rock mass is folded may be due to Kullu&Kotlu thrust passing in the vicinity of project area.

The Geological section along B-B' at 100m d/s of proposed dam axis has almost similar geological conditions as found along the proposed dam axis. As per geophysical survey the maximum thickness of the terrace material on the right abutment is ±45m.

On the basis of geological and geophysical data it is apprehended that there is adequate lateral rock ledge (at NSL and TOD level) at the proposed dam axis as well as along the whole right bank upto Kotlu Khad.

Further it is suggested to carryout subsurface exploratory drilling to cross check/validate the geophysical survey data.

6.2 Power House Site:

The power house complex area comprising of PH cavern, TH cavern TRT & their approach tunnels are placed on the left bank &are occupied by dolomites/limestone belonging to Shali /Larji Group (Tattapani/Khatpul Formation) under thin cover of debris. The power house cavern is proposed ±150m inside the hill with a top cover of ±100m. The bed rock has same nature as in dam and has same set of joints continuing to the power house area. The litho units are traversed by 3 sets of joint excluding bedding joints and are tabulated in Table 2. The bedding joint/foliation joints in general dip towards N60°E direction with amount varying from 30°-40°. The power house and transformer hall cavern are proposed to be aligned N80°E-S80°W direction. Considering the general strike of foliation/bedding joints as N30°W-S30°E, both the caverns are favorably aligned with intersection angle of alignment of cavities and that of bedding is 60° (Plate-4).

The above locations of dam axis and Power House complex have been visited by Director GSI Chandigarh also.

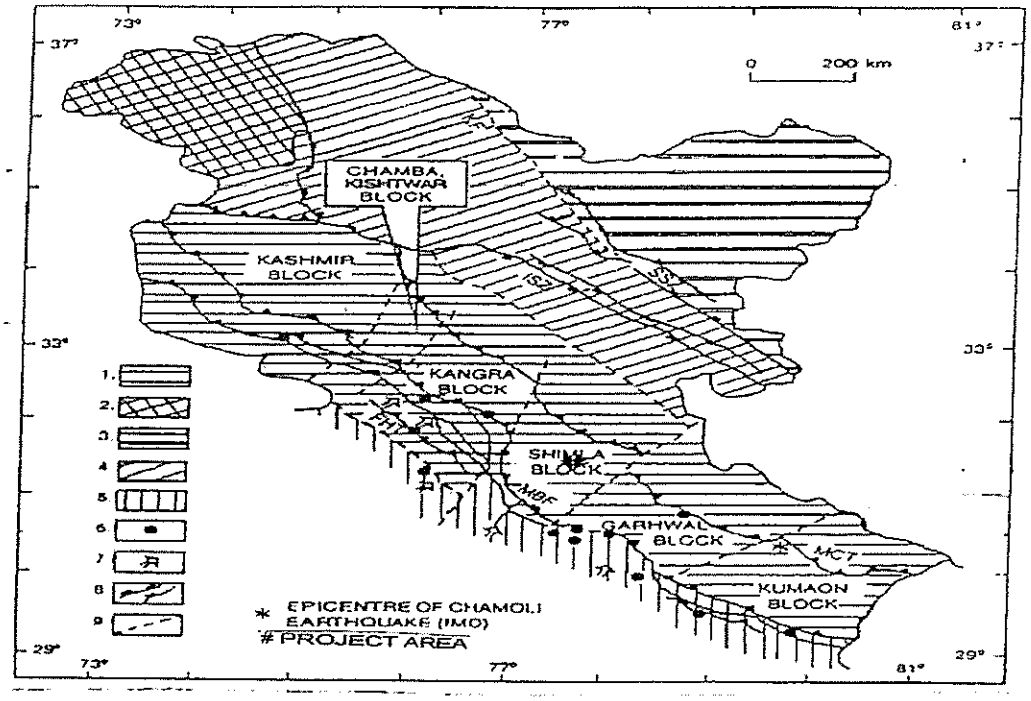
7. Reservoir Area:

Due to proposed ±41m high dam, a reservoir ±6 km in length will be created. Rock types along the reservoir are dolomite /limestone, phyllite, & gneisses. In general flat terrace observed on the both banks. No major structural feature and no major slide sare noticed in the Reservoir area. Reservoir area proposed to be mapped for Reservoir Rim Stability and Reservoir Competency.

8. Seismicity

Himachal Pradesh falls in the Himalayan region, which is one of the more seismically active regions in the world. The Project area lies in the Shimla Block of the Main Himalayan Seismic Zone domain of NW Himalayan seismic belt (Narula et al. (2000) the project falls in Earthquake Zone V in accordance with the Seismic Map of India (IS:1893:1984). It is demarcated by the Main Central Thrust in the north and the Main Boundary Fault/Thrust (MBF/MBT) in the south, and limited in east and west by interpretative fundamental transverse faults. The Kangra Block lies to its west and the Garhwal Block in the east (Figure-1).

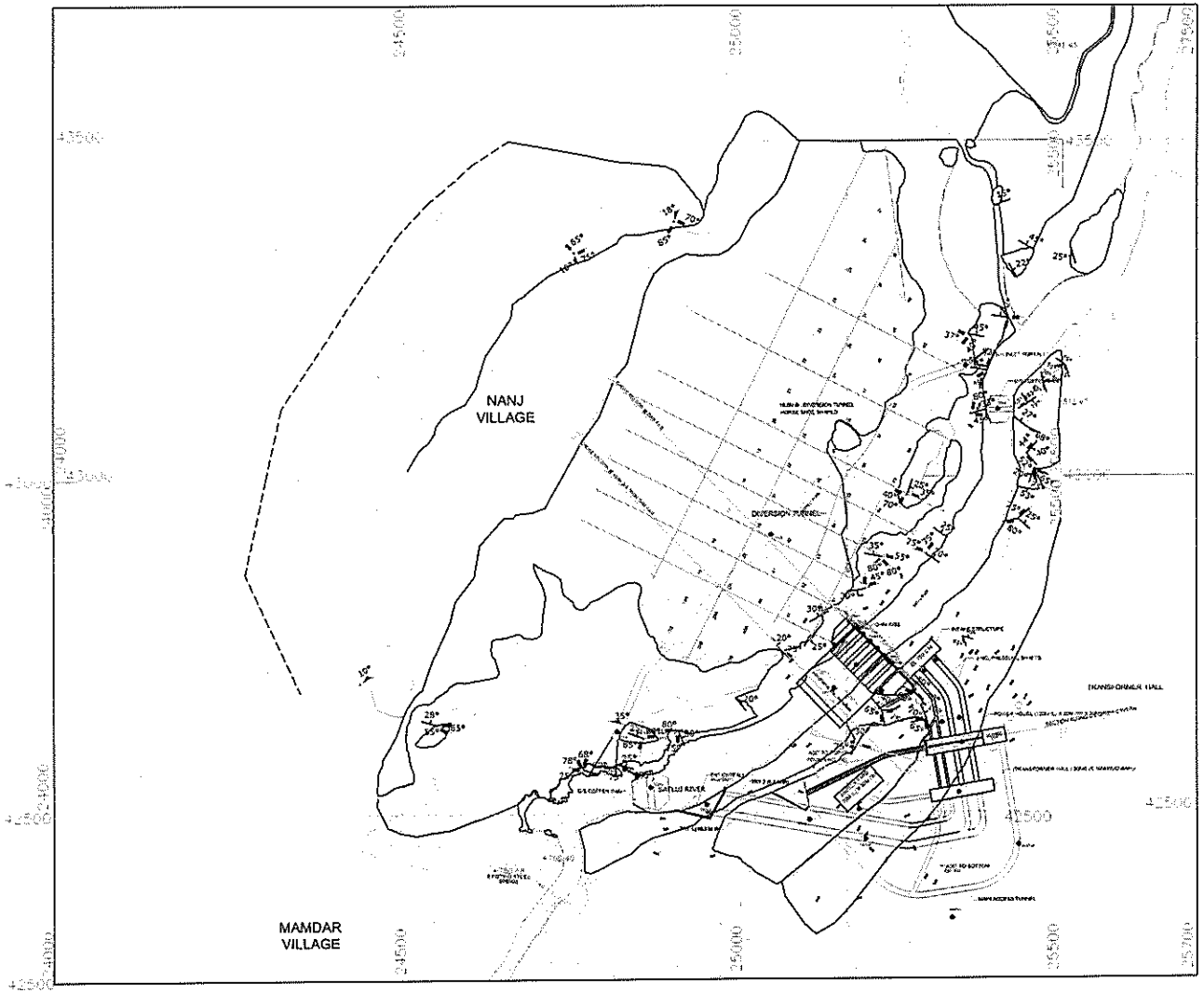
Figure-1 Seismotectonic Domains of NW Himalayan Seismic Belt (after Narula et.al.)



Seismotectonic domains of NW Himalayan seismic belt. 1. Main Himalayan Seismic Zone (MHSZ); 2. Kashmir Svantaxial Seismic Zone (KSSZ); 3. High Plateau Seismic Zone (HPSZ); 4. High Himalayan Seismic Zone (HHSZ); 5. Foot Hill Seismic Zone (FHSZ); 6. Specific locations where neotectonic activity has been recorded; 7. Direction of crustal shortening during Quaternary; 8. Suture Zone; 9. Block boundary based on geological/geophysical/tectonic flux attributes. SSZ- Shyok Suture Zone; ISZ- Indus Suture Zone; KF- Karakorum Fault; MCT- Main Central Thrust; MBF- Main Boundary Fault; FHT- Foot Hill Thrust. (After Narula et al. 1999)

PLATE-1

GEOLOGICAL MAP OF PROPOSED DAM SITE AREA, LUHRI HEP STAGE II, DISTRICT SIMLA & MANDI DISTRICTS, HIMACHAL PRADESH



N

INDEX

- SCREE / RBM
- DEBRIS / COLLUVIUM
- LIMESTONE / DOLOMITE
- GNEISS
- OLD / ABANDONED CHANNEL
- TERREACE / CULTIVATION LAND
- ROAD
- BEDDING/JOINT/FOLIATION/VERTICAL JOINT
- LITHOLOGICAL CONTACT
- SECTION LINES
- GEOPHYSICAL SURVEY LINES
- PROPOSED DRILL HOLES
- EXPLORATORY DRIFT WITH CROSS CUTS

NOTE

- Layout and survey support has been provided by the project authority.
- Due to inaccessibility area selected reaches could not be taken up.

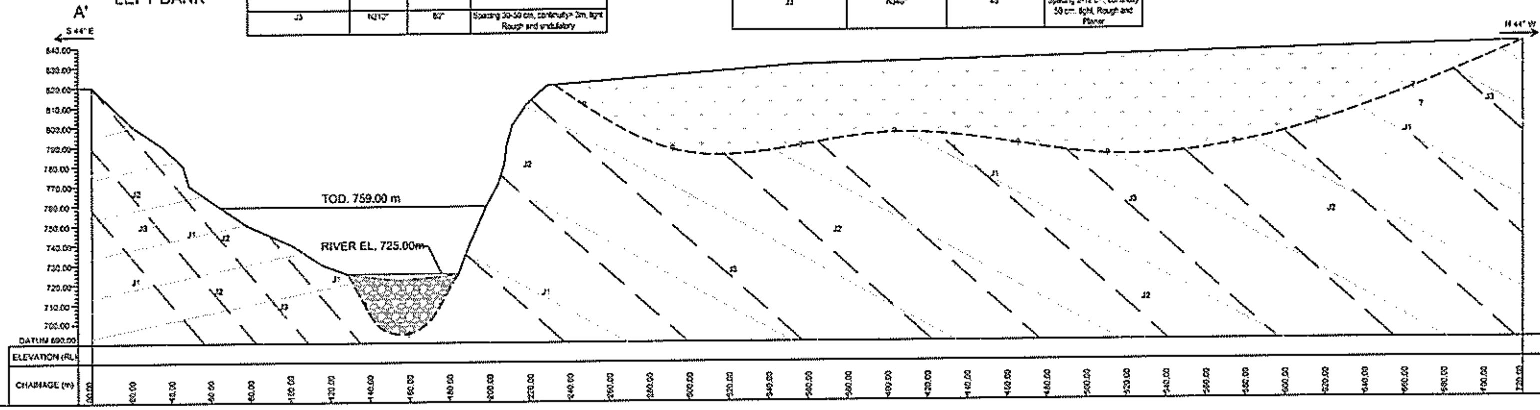
SCALE : 1:2500

100 50 0 50 100 150 200 250

SJVN LIMITED		
LUHRI STAGE II (H.P.)		
GEOLOGICAL MAP OF PROPOSED DAM SITE AREA, LUHRI HEP STAGE II, DISTRICT SIMLA & MANDI HIMACHAL PRADESH		
MAPPED BY	GSI, CHANDIGARH Prashant T. Sarkar Parveen Kumar Sr. Geologists	SJVN LIMITED Sunil Singh Ajay Kumar Sr. Geologists
GSI, EG Division, SU: PSHP, Chandigarh F.S. 2016-17		

Prominent Fol./Joint Sets at Left Bank			
Foliation/Joint Set	Dip Direction	Dip Amount	Characteristics
J1 (Fol.)	N60°	42°	Spacing 2-40 cm, continuity > 5m, opening 1-2 cm, clay coating, planar smooth
J2	N260°	85°	Spacing 3-20 cm, continuity > 3m, opening 1-3 cm, Rough and undulatory
J3	N210°	80°	Spacing 30-50 cm, continuity > 3m, tight Rough and undulatory

Prominent Fol./Joint Sets at Right Bank			
Foliation/Joint Set	Dip Direction	Dip Amount	Characteristics
J1 (Fol.)	N330°	30°	Spacing 3-60 cm, continuity > 5m, tight, Rough and Planar
J2	E	80°	-
J3	N340°	45°	Spacing 2-12 cm, continuity 50 cm, tight, Rough and Planar



INDEX

PLATE 2

- RIVER ALLUVIUM
- DEBRIS / COLLUVIUM
- LIMESTONE / DOLOMITE
- RBM/TERRACE MATERIAL
- INFERRED CONTACT
- Joint Traces

NOTE

1. Profile and survey support has been provided by Civil Design Department SJVN.
2. Discontinuities are schematically Plotted
3. True attitude of discontinuities have been shown on the joint traces whereas apparent dip have been plotted.
4. The thickness of river borne material below riverbed is tentative and will be verified by exploratory drilling.
5. The variation in the orientation of bedding has been observed which may be due to the presence of thrust in the vicinity of project area. Therefore the general trend of bedding has been followed.
6. The overburden depth depicted on the right bank is based on the geophysical survey and may require confirmation by exploratory drilling.

Scale: 0 10 20 30 40 50 60 m

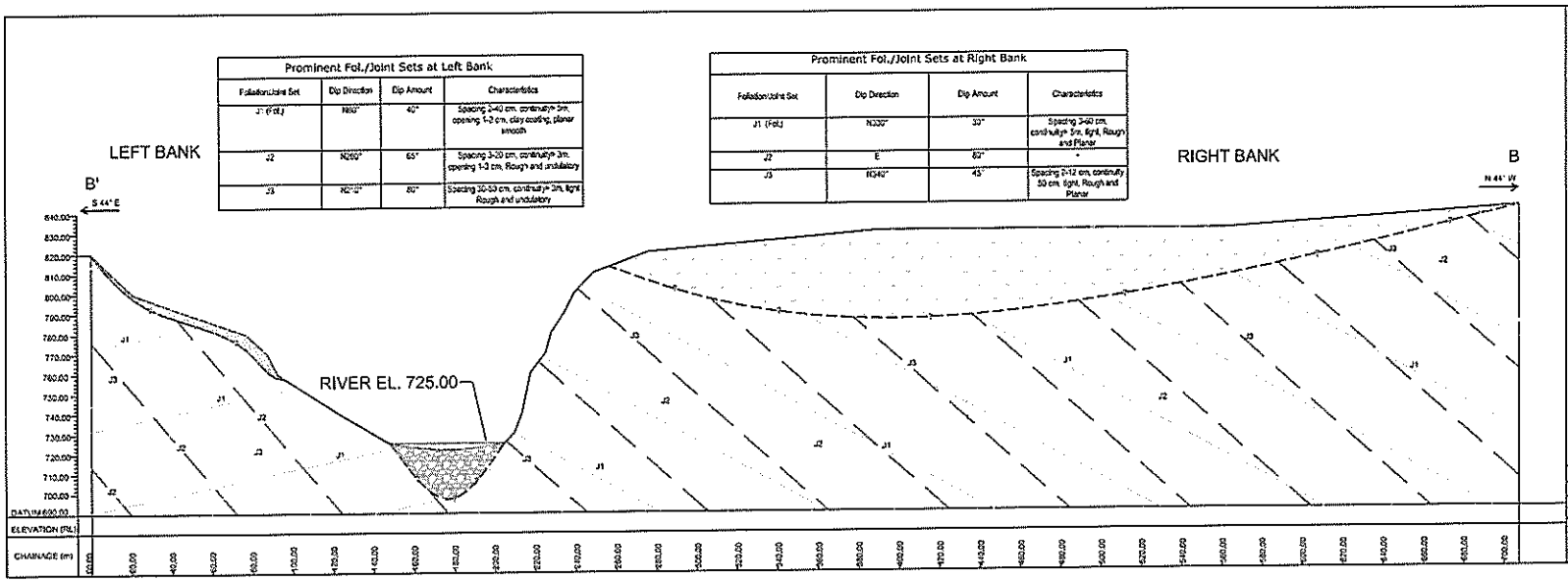
SJVN LIMITED

LUHRI HYDROELECTRIC PROJECT LHEP STAGE-II

Geological section (A-A') ALONG PROPOSED DAM AXIS LHEP STAGE-II

Supervised	Checked by	Drawn by
Dr. Naveen Kanyan, Dy. Manager (Dharmendra Kan), Asst. Manager	Mahesh Dutt, Manager (SJVN)	K. S. Chauhan, AGM (Geology)

PLATE 3



Prominent Fol./Joint Sets at Left Bank

Foliation/Joint Set	Dip Direction	Dip Amount	Characteristics
J1 (Fol.)	N80°	40°	Spacing 2-40 cm, continuity> 5m, opening 1-3 cm, clay coating, planar smooth
J2	N260°	65°	Spacing 3-20 cm, continuity> 3m, opening 1-3 cm, Rough and undulatory
J3	N210°	80°	Spacing 30-50 cm, continuity> 3m, tight, Rough and undulatory

Prominent Fol./Joint Sets at Right Bank

Foliation/Joint Set	Dip Direction	Dip Amount	Characteristics
J1 (Fol.)	N330°	30°	Spacing 3-60 cm, continuity> 5m, tight, Rough and Planar
J2	E	80°	"
J3	N240°	45°	Spacing 2-12 cm, continuity 50 cm, tight, Rough and Planar

INDEX

- RIVER ALLUVIUM
- DEBRIS / COLLUVIUM
- LIMESTONE / DOLOMITE
- RIVER TERRACE MATERIAL
- INFERRED CONTACT
- J1 J2 J3 Joint Traces

NOTE

1. Profile and survey support has been provided by project authority.
2. Discontinuities are schematically Plotted
3. True attitude of discontinuities have been shown on the joint traces whereas apparent dip have been plotted.
4. The thickness of river borne material below riverbed is tentative and will be verified by exploratory drilling.
5. The variation in the orientation of bedding has been observed which may be due to the presence of thrust in the vicinity of project area. Therefore the general trend of bedding has been followed.
6. The overburden depth depicted on the right bank is based on the geophysical survey and may require confirmation by exploratory drilling.

Scale:

0 10 20 30 40 50 60 m

SJVN LIMITED

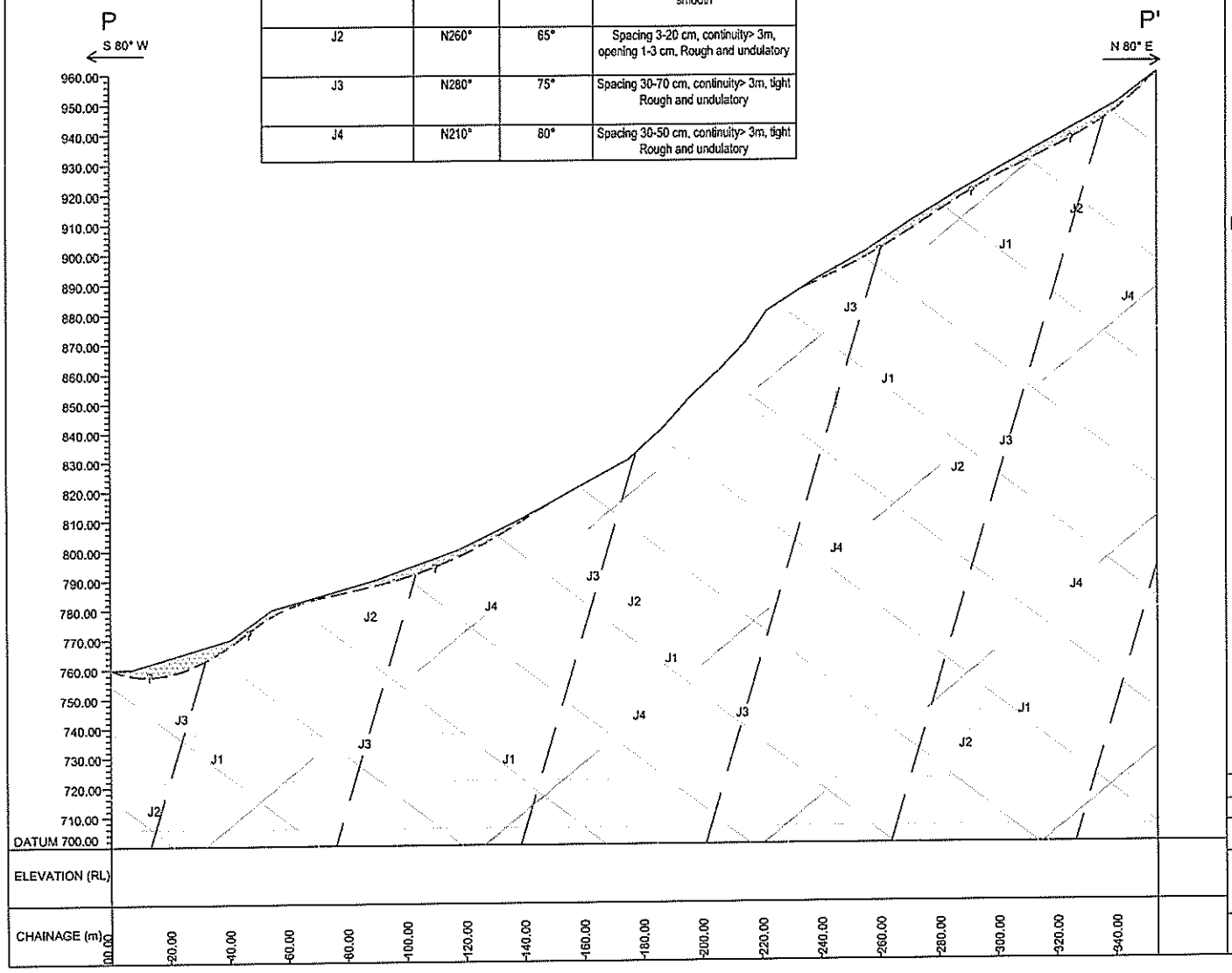
KAMA HYDROELECTRIC PROJECT (HEP STAGE-II)

Geological section (B-B') Across River (100 m D/S) of Proposed Dam Axis- (HEP Stage-II)

Submitted by	Checked by	Prepared by
Dr. Praveen Kashyap, Dy. Manager (Geology), Kam. Manager	Mukesh Dua, Manager (CPP)	R.N.Chauhan, AGM (Geology)

PLATE 4

Prominent Fol./Joint Sets at PH Area.			
Foliation/Joint Set	Dip Direction	Dip Amount	Characteristics
J1 (Fol.)	N60°	40°	Spacing 2-40 cm, continuity> 5m, opening 1-2 cm, clay coating, planar smooth
J2	N260°	65°	Spacing 3-20 cm, continuity> 3m, opening 1-3 cm, Rough and undulatory
J3	N280°	75°	Spacing 30-70 cm, continuity> 3m, tight Rough and undulatory
J4	N210°	80°	Spacing 30-50 cm, continuity> 3m, tight Rough and undulatory



INDEX

- Slope wash Material/ Talus
- LIMESTONE / DOLOMITE
- RBM/TERREACE MATERIAL
- INFERRED CONTACT
- Joint Traces (J4, J1, J2, J3)

NOTE

1. Profile and survey support has been provided by project authority.
2. Discontinuities are schematically Plotted
3. True attitude of discontinuities have been shown on the joint traces whereas apparent dip have been plotted.
4. The thickness of overburden along profile is tentative and will be verified by exploratory drilling.
5. The variation in the orientation of bedding has been observed which may be due to the presence of thrust in the vicinity of project area. Therefore the general trend of bedding has been followed.

Scale:

0 10 20 30 40 50 60 m

SJVN LIMITED

LUHRI HYDROELECTRIC PROJECT LHEP STAGE-II

Geological section Along Power House Covern (P-P').

MAPPED BY	Checked by	Recm. by
Dr. Naveen Kanyan Dy. Manager Dharmendra Giri Asstt. Manager	Mahesh Dutt Manager (SJVN)	K.S.Chauhan AGM (Geology)