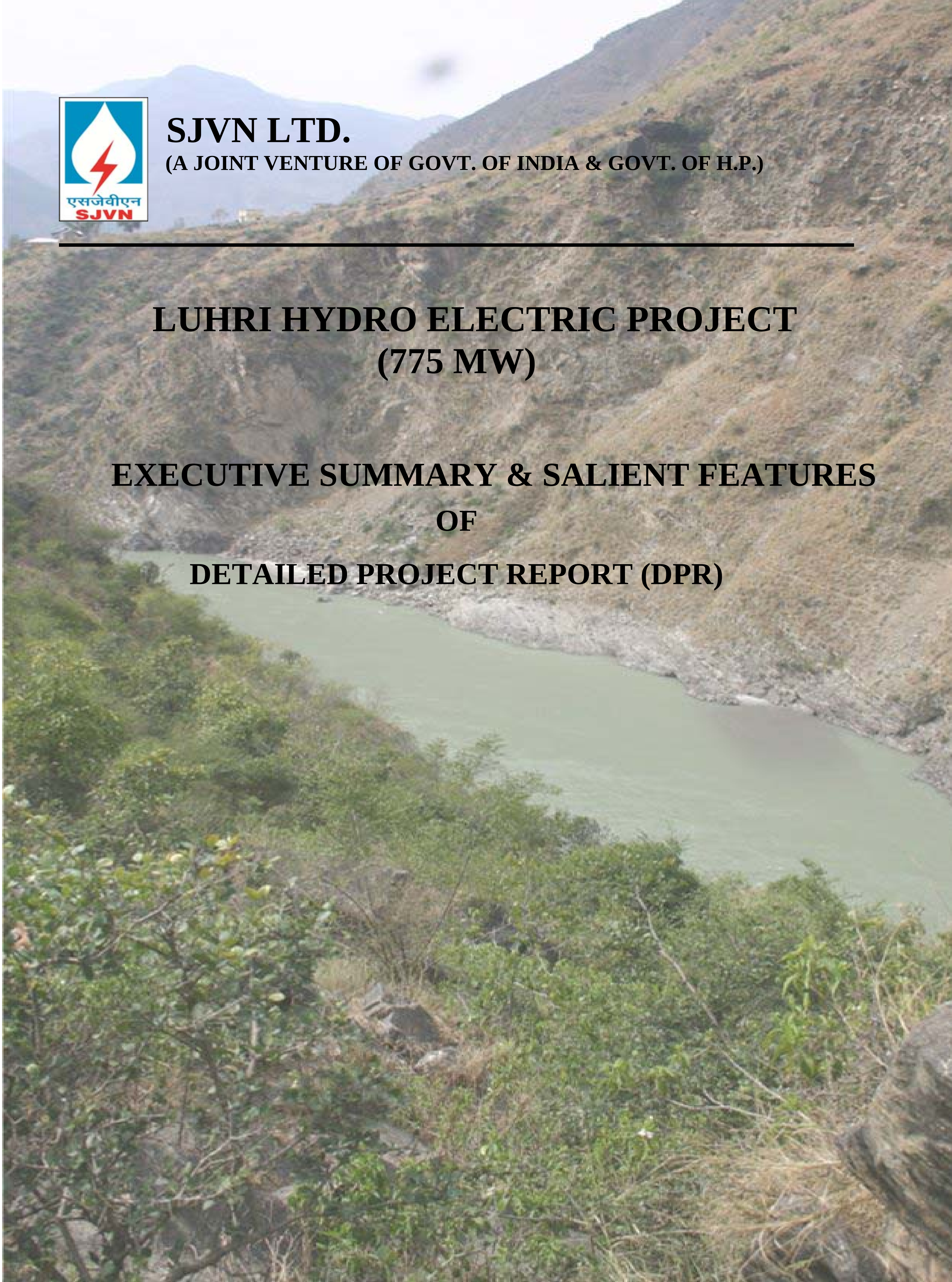

SJVN LTD.

(A JOINT VENTURE OF GOVT. OF INDIA & GOVT. OF H.P.)

LUHRI HYDRO ELECTRIC PROJECT
(775 MW)

EXECUTIVE SUMMARY & SALIENT FEATURES
OF
DETAILED PROJECT REPORT (DPR)

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1 Introduction

This Detailed Project Report has been prepared by Mott MacDonald to present the development of the proposed Luhri hydroelectric project on the Satluj River. The project lies downstream of the proposed Rampur hydroelectric project and upstream of the Koldam project which is currently under construction.

2 Project Development

This study draws on the Feasibility Study Report by Mott MacDonald dated September 2006 as well as previous pre-feasibility studies and a review of possible development options considered in March 2006.

This study has concluded that there is a feasible scheme and the economic analysis indicates that the project will be viable within the current market. However, the relatively high capital cost of the scheme will require a correspondingly high tariff.

During the initial studies and following discussions with SJVN Ltd. it was apparent that there are three major issues that are of particular significance for the Luhri Project and these are:

- The high concentrations of quartzite sediments in the Satluj River
- The relatively low slope and high flows of the Satluj River require relatively large tunnels
- The region is seismically active and the tunnel route passes through thrust zones which are associated with sections of poor rock conditions.

This studies that are reported in this document have therefore concentrated on these issues and the preliminary designs that have been prepared attempt to find solutions to the resulting engineering problems.

It is anticipated that the proposed designs will provide a significant increase in the life and availability of the turbines compared to Nathpa-Jhakri. This will be achieved by a combination of:

- Significantly increased silt removal efficiency provided by the creation of a larger reservoir
- The provision of low speed turbines with coated internal surfaces
- A powerhouse that has been designed to allow easy repair of complete turbines without the need for generator dismantling.

The proposed reservoir within the river channel is expected to remove at least twice as much sediment from the water entering the headrace tunnel than the desilting chambers used at Nathpa-Jhakri. Initial studies indicate that there will be a significant reduction in the duration of interruptions to generation to allow sediment flushing compared to Nathpa-Jhakri.

If the scheme is to be developed to provide the scheme with the best rate of return then it will have an installed capacity in the order of 775 MW. This will require a headrace tunnel with a very large cross-sectional area and around 38 km long. The headrace tunnel is expected to be the aspect of the scheme that contains the greatest risks with regard to cost and programme. Single and twin tunnel designs have been examined and a comparison between these two alternatives is, as follows:

- Twin tunnels are expected to be quicker to construct than a single tunnel.
- Twin tunnels offer greater flexibility during construction to overcome unforeseen ground conditions.
- Twin tunnels offer the advantage of greater flexibility during operation of the station.
- The out-turn cost of twin tunnels is likely to be lower than a single tunnel although a theoretical cost advantage can be demonstrated in favour of a single tunnel.

It should be understood that the major feature and technical risk on the proposed scheme is the proposed desilting arrangement and the headrace tunnel. Design efforts have concentrated on addressing these issues.

3 Scope of Project

Eight project configuration options have been assessed, including two possibilities for two-stage development.

The project configuration both selected for detailed assessment during the feasibility study and developed further in DPR includes the following features:

- A concrete dam at Nirath around 86 m high above deepest foundation level with integral gated spillway.
- Use of the river channel to provide a desilting facility of much larger capacity than adopted on previous schemes.
- A headrace tunnel around 38 km long on the right bank of the river. The headrace could be constructed using either twin tunnels of 9.0 m internal diameter or a single tunnel of 11.75 m internal diameter.
- An underground power station near Marola with four turbine-generator units and an installed capacity of 775 MW.

4 Need for Project

The need for the project arises from:

- The need to fulfil a steady increase in peak electricity demand.
- The growing energy deficit in the Northern Region.
- The ranking of the Luhri project by CEA as 4th out of 93 schemes identified in the Indus basin.

It is clear that as long as the scheme can be implemented at a reasonable cost there will be a demand for the energy generated by the scheme.

5 Topography and Engineering Geology

The project lies in terrain characterised by steep narrow valleys. Rock formations have been extensively folded.

Relatively massive augen gneiss will provide good foundation conditions for the dam at Nirath.

Much of the headrace tunnel will lie in competent rock. However, a significant length will pass through a thrust zone of very weak, highly fractured carbonaceous shale and highly deformed phyllites where tunnelling conditions are likely to be extremely difficult.

The proposed location for the powerhouse lies in interbedded dolomite, limestone and shale which are anticipated to provide good conditions for construction, although there is some risk that karstic formations could be encountered.

6 Seismo-tectonics

An assessment has been made of the regional geology in terms of the seismotectonic behaviour of the project area. It has been concluded that the works should take account of the following design criteria:

- Maximum Credible Earthquake: magnitude 8 earthquake with peak ground acceleration of 0.39 g
- Design Base Earthquake: peak ground acceleration of 0.21 g

7 Reservoir Stability

Studies included in the preparation of DPR have shown that there are areas around the proposed reservoir site which will require further stabilisation.

8 Hydrology

Relevant records of discharges in the Satluj River are available from 1963. These provide a high quality basis for assessment of the energy available for hydropower generation. High flows are experienced during the June to September monsoon period. Flood frequency analysis has concluded that a flood discharge of 8000 m^3/s should be adopted for the design of the permanent works and that the diversion works should be designed for a non-monsoon flood of 1000 m^3/s.

9 Sedimentation

A detailed numerical analysis has been undertaken to model the deposition and flushing of the proposed Nirath reservoir. The model has been run for three different cases:

- A reservoir without diversion tunnels
- The same reservoir with diversion tunnels
- Desilting chambers similar to those at Nathpa-Jhakri

The results indicate that the reservoir will be around twice as effective as the sedimentation chambers. Itr is also anticipated that this will also increase the life of the turbines by a similar factor. In addition, there are indications that improvements in sediment deposition performance may be possible in practice.

10 Power and Energy Studies

A detailed spreadsheet based model has been prepared for the power and energy studies. For the base case of twin 9 m diameter headrace tunnels, 3117 GWh design energy will be generated in a 90% dependable hydrological year for 95% installed capacity.

11 Optimisation Studies

The optimisation analysis carried out during the feasibility study was reviewed and found to continue to be valid following the further design development undertaken as part of DPR.

Key conclusions are:

- Installed capacity confirmed at 775 MW with four machines
- No significant difference in the IRR for twin 9.0 m tunnels compared to single 11.75 m tunnel
- Out-turn cost of twin 9.0 m tunnels likely to be less than a single 11.75 m tunnel when appropriate allowances are made for relatively greater risk of delay and disruption in constructing the larger tunnel.
- There is no financial advantage from having "spare" machines unless the outage period required for runner maintenance is greater than 31 days.

12 Conceptual Layout and Planning: Civil Works

12.1 Headworks

For the base scheme, the headworks consist of four main components:

- A concrete gravity diversion dam to form a reservoir with a top water level equal to the tailwater level of the upstream Rampur project. The diversion dam will include gates to allow the passage of flood flows and for silt flushing.

- A pair of diversion tunnels to allow construction of the diversion dam and to allow flows in excess of generation flows to bypass the downstream section of the reservoir and thereby improve its desilting performance.
- An intake structure for the headrace tunnel(s).
- Turbine within the dam to utilise compensation (environmental) flows.

12.2 Headrace Tunnel

It is proposed that the headrace tunnel will be located on the right bank of the river. The study has examined alternative schemes with either a single 11.75 m diameter tunnel or twin 9.0 m diameter tunnels. The proposed designs incorporate short steel lined sections to allow the tunnel to pass below low valleys. It is anticipated that the tunnels will be constructed using the drill and blast technique and it is currently proposed that there will be a total of 8 construction adits.

The use of tunnel boring machines was examined but it is considered that these are not preferred as they will be close to the largest ever made and their additional cost cannot be offset by a route length reduction. Further there is a potential with the single tunnel option for squeezing ground conditions and rock bursts due to high rock cover.

12.3 Powerhouse

The powerhouse was designed around several key issues. One important issue was the high silt load in the Satluj River. Experience at the upstream hydropower station of Nathpa-Jhakri indicated that runner damage is likely due to these high silt loads, even when measures are incorporated into the design to reduce the silt passing through the power station. As such, the Luhri powerhouse has been designed to facilitate easy runner removal for maintenance and replacement as well as to provide significant storage space on the machine floor for machine components during these maintenance periods.

The design was also optimised to simplify the powerhouse construction in order to minimise the costs. Such considerations included:

- Preferences for long and narrow caverns as these are generally cheaper to construct than shorter wider caverns.
- Careful consideration of optimal construction tunnel locations in order to ensure sufficient space is allowed for.
- A preference for surge tunnels over surge shafts or chambers as tunnels are easier and cheaper to construct for a given volume.
- All tunnels and caverns were sized to ensure adequate space for equipment transport and assembly.

13 Conceptual Layout and Planning: Electrical and Mechanical Works

The appropriate machines for the scheme will be vertical Francis turbines and generators. Four machines have been selected as this number provides adequate operational flexibility and they are not too large for the available transport facilities. The turbines will be specified with split head-covers to allow fast dismantling to allow the relatively easy repair of damage due to erosion. To minimise the effects of the high silt content the turbine speed and setting has been selected to minimise relative water velocity and cavitation.

Butterfly type turbine inlet valves are proposed as they provide an optimal balance between first cost, head loss and are less susceptible to the effects of silt.

Following standard SJVNL practice, the generator transformers will be underground within a separate cavern.

The drainage and dewatering system has been designed to provide adequate redundancy and to cope with the failure of the largest pipe connected to either of the upstream or downstream waterways.

14 Hydraulic Transients

Studies of the behaviour of the hydraulic system during operation of the power plant have been undertaken to identify behaviour during stopping and starting of the project. It is concluded that surge protection facilities are required both upstream and downstream of the power plant, consisting of:

- Surge tunnels at the downstream end of the headrace tunnel connected to the tunnel by a short shaft.
- Surge tunnels at the upstream end of the tailrace tunnel.

15 Instrumentation

Proposals have been developed for instrumentation of the dam and underground structuresto monitor their behaviour during construction to confirm design assumptions and to confirm continuing ground stability.

16 Power Evacuation

Due to the lack of a suitable site for an open terminal surface switchyard it is proposed that a double bus-bar gas insulated switching facility be installed underground above the generator transformers. The connection to the surface will be by XLPE insulated cables that will be installed in ducts. Air insulated terminal equipment will be provided to allow the connection to two double circuit 400 kV transmission lines close to the mouth of the cable tunnel.

17 Environmental and Social Issues

The environment impact assessment and environmental management plan carried out by CISHME fall outside the scope of this study. However, the proposed designs have attempted to minimise potential negative impacts. The main effects of the proposed scheme will be due to two factors:

- The inundation due to the creation of the reservoir.
- The reduction of the flow in the Satluj River downstream of the diversion dam.

With regard to inundation the area where most people are currently living and will be displaced is in the reach between the proposed discharge from the Rampur scheme and the entrance to the proposed diversion tunnel. The reach between the diversion tunnel entrance and the diversion dam is steeply sided and the ground submerged will be small. We consider that it would be difficult to develop a scheme design that did not require the submergence of the upstream area.

An alternative design that takes water directly from the Rampur scheme has also been suggested. Although the review of this is considered to currently be outside the scope of this study we would comment as follows:

- An additional length of headrace tunnel approximately equal to 8 km would have to be constructed instead of the dam at Nirath, thereby increasing the hydraulic losses. It may also increase the total cost of the project.
- The water from Rampur would have significantly higher silt content than is anticipated to be available with the proposed design. Turbine erosion will therefore be more significant.
- The available flows for the scheme will be less as it will not be possible to take advantage of the catchment's downstream from Nathpa-Jhakri.
- The flexibility to operate the scheme independently will be lost.

18 Infrastructure

A number of major hydro electric schemes have already been developed on the Satluj River and the majority of the regional infrastructure is already in place. The most significant work that will be required to allow the project to be constructed will be associated with improvements to the road system local to the scheme. The National Highway will need to be upgraded to allow the passage of construction plant and equipment. Furthermore a number of bridges will need to be built across the Satluj River to allow access to the right bank headrace tunnel construction adits.

The local electricity and water supply systems will need to be developed and upgraded to provide facilities for construction.

Temporary construction facilities will be required including quarries and batching plants.

None of the infrastructure issues would appear to be problematic within the context of the overall project development.

19 Construction Schedule and Planning

The time required for construction schedule has been calculated for both the single and twin tunnel options. The time required for construction of these options is 84 months and 90 months respectively including preliminary works. In order to achieve these construction periods, it will be necessary to make physical and contractual arrangements to enable driving of the headrace tunnel to commence as rapidly as possible after any decision to proceed with the implementation of the project. The construction time to complete the project will be determined by the time required to drive the headrace tunnel between adits 3 and 4 and adits 4 and 5.

Before construction can start it will be necessary to obtain all statutory approvals, prepare tender specifications and award the contracts. This will take at least 12 months and construction is therefore unlikely to begin before 2008.

20 Cost Estimate

The cost estimates have been prepared for the base case for the single and twin headrace tunnel options. A cost estimate has also been prepared for a two stage scheme.

It may be noted that the detailed cost estimates prepared for the single scheme for twin 9.0 m diameter headrace tunnels has been used as the basis for developing the cost estimates for the two stage scheme with the assumption that the head-works at Nathan and powerhouse at Luhri will be similar to head-works at Nirath and powerhouse at Chaba respectively. In the event that reservoir desilting is not an option and underground desilting chambers are considered for the lower scheme, the cost estimates for the lower scheme will be affected accordingly.

The cost estimate has been developed assuming use of Indian materials and equipment where possible and hence Indian rates have generally been used. In some cases, either where the required equipment was not expected to be available in India or where accurate cost estimates were not available from India, international prices have been used is US dollars and converted to Rupees. The electrical and mechanical costs were based on the costs of plant and equipment procured recently for similar projects in India.

The cost estimate showed that for the base case, the twin tunnel option (Total project cost of Rs. 4795 crores) was approximately Rs. 563 crores more expensive to construct than the single tunnel option (Total project cost of Rs. 4232 crores), approximately 13.30% more. However, as discussed in the optimisation analysis, the increased tunnel driving risk involved with the single tunnel option is likely to result in unexpected additional project costs and significant delays in project programme. As such, although a single tunnel appears financially preferable at this stage, by the completion of construction a twin tunnel arrangement may have actually been cheaper. The optimisation analysis deals with this issue in more detail.

The cost estimate for the two stage scheme (Total project cost of Rs. 5468 crores) was approximately Rs 673 crores more expensive compared to the base case with twin tunnel option (Total project cost of Rs. 4795 crores), approximately 14% more. **However, it is important to note that the two stage scheme has not been optimised.**

21 Economic Evaluation

Tariff calculations have been done for the recommended single stage scheme for both the single and twin tunnel alternatives.

For the option with twin tunnels the sale rate of power per unit during the first year of operation and levellised tariff will be Rs. 2.87 and Rs 2.53 respectively. For the single tunnel option the sale rate of power per unit during the first year of operation and levellised tariff will be Rs. 2.52 and Rs. 2.22 respectively.

These results have been determined for the construction periods determined during these studies. If these periods, or the project costs are changed as a result of further optimisation then these tariff rates will change accordingly.

The tariff for the recommended twin tunnel project has been estimated on the basis of likely out-turn costs which take into account the possible construction risks of driving the larger single tunnel. The tariff for twin tunnel option cannot therefore be compared with the preliminary tariffs generally quoted in DPRs which do not take into account the construction risks. Further considering the size and long length of headrace tunnel and corresponding higher costs than conventional schemes, the tariff for single scheme is considered reasonable.

22 Salient Features

The salient features of Luhri Hydroelectric Project in tabular form for quick reference are as given below.

Luhri Hydroelectric Project

Salient Features

LOCATION		
1.	State	Himachal Pradesh
2.	Districts	Kullu-Mandi-Shimla
3.	River	Satluj
4.	Vicinity	Dam near Village Nirath on NH-22 and Powerhouse near village Chaba (Marola)on Sainj – Sunni Road
HYDROLOGY		
1.	Catchment Area at Dam site	51600 Sq.km
2.	Design Flood	8000 cumec
3.	Percent availability corresponding to design discharge of 480 cumec	28%
RIVER DIVERSION WORKS		
1.	Diversion Tunnel	
	Dia	10.0m
	Length	2680 m (Average)
	No. of tunnels	2
2.	Coffer Dams	
	Type	Rock fill with cut-off wall
	Upstream	12.0m high
	Downstream	9.0m high
3.	Cut-off for Coffer Dams	Soil – Cement – Bentonite core walls
DIVERSION DAM		
1.	Type	Concrete Gravity
2.	Top of dam	EL 866.00m
3.	Height from deepest foundation level	86 m
4.	Total length at top	231.5 m
5.	No. of blocks	17
6.	Minimum river bed level at dam axis	El 811.20m
7.	Deepest foundation level	El 780.00m
8.	Full Reservoir Level (FRL)	EL 862.90 m
9.	Minimum Drawdown Level (MDDL)	EL 855.0 m
10.	Gross Reservoir Capacity	35 Million m^3

MAIN SPILLWAY (SLUICES)

1.	Location	Block nos. 5 to 11 of Dam
2.	No. of bays	7
3.	Size of each sluice	7.5m (W) x 10m (H)
4.	Sluice crest elevation	El. 822.00 m
5.	Thickness of intermediate piers	4m
6.	Type of gates	Radial Gates (top sealing type)
8.	Ski-jump bucket lip elevation	El. 816.00 m
9.	Discharge capacity of Sluices	8000 cumec

REGULATING SPILLWAY

1.	Location	Block no. 4 of Dam
2.	No of bays	1
3.	Width of bay	11m
4.	Crest elevation	El. 860.50m
5.	Size of opening	11.0m (W) x 5.5 m (H)
6.	Maximum discharge capacity	73 cumec
7.	Ski-jump bucket lip elevation	El. 816.00m

INTAKE

1.	No. of intake bays	2
2.	Inclination of Trash rack with Horizontal	63°
4.	Crest level	El. 836.00 m
5.	Minimum Drawdown Level (MDDL)	El. 855.00 m
6.	Discharge Capacity of each intake bay	276 cumec (15% additional capacity)
7.	Number of intake gates	2
8.	Size of opening	9.0m (W) x 9.0m (H)
9.	Size of intake tunnels	9.0m Circular

SEDIMENTATION ARRANGEMENTS

1.	Particle size to be excluded	+ 0.1 mm
2.	Type of arrangement	Reservoir sedimentation with bye pass tunnels (diversion cum desilting tunnels)
3.	Flushing discharge	500 cumces - 1500 cumecs

HEADRACE TUNNELS

1.	Size & Type	9.0m dia circular (twin tunnels) or 11.75m dia circular (Single)
2.	Length	38.138 km
3.	Velocity through tunnel	3.77 m/s (9m dia twin) or 4.43 m/s (11.75m dia single)
4.	Invert of tunnel at inlet end	El. 836 m
5.	Invert of tunnel at junction with surge shaft/tunnel	El. 700 m
6.	Design discharge	480 cumecs
7.	Slope	1V:281H

8.	Adits		
		Chainage from intake axis (m)	Length (m)
	Intermediate adit 1	3571	623
	Intermediate adit 2	7780	529
	Intermediate adit 3	12368	710
	Intermediate adit 4	17059	494
	Intermediate adit 5	22649	637
	Intermediate adit 6	27080	592
	Intermediate adit 7	30928	196
	Intermediate adit 8	35863	380

U/S SURGE TUNNEL

1.	Type	Inclined surge tunnels with expansion galleries
2.	Diameter	9.0 m
3.	Elevation of the Invert	El 819.0m and 839.0m
4.	Top elevation	EL 900.0m

PRESSURE SHAFTS

1.	No. and type	4 nos. steel lined
2.	Diameter	5.0 m
3.	Length of each penstock	173.5 m
4.	Type of steel for penstock liners	Pressure Vessel grade steel

PENSTOCK VALVE CHAMBER

1.	Location	Downstream of Surge tunnel
2.	Type of valves	Butterfly valves
4.	Diameter of each valve	5000mm
5.	E.O.T. Crane	150 t

POWER STATION COMPLEX

POWER HOUSE / TRANSFORMER CAVITY

1.	Type	Underground
2.	Installed capacity	775 MW (4x193.75 MW)
3.	Size of machine hall	156.4 m (L) x 23.5 m (W) x 44 m (H)
4.	Size of transformer hall	120 m (L) x 19 m (W) x 21 m (H)
5.	Main Access Tunnel to machine hall	8m D-shaped 530m long
6.	Average gross head	220.9m

ELECTRO-MECHANICAL EQUIPMENT

TURBINES

1.	No. and type	4 (Four) nos., Francis turbines
2.	Unit Rated Capacity	193.75 MW
3.	Unit maximum capacity	223 MW
4.	Rated net head	181 m
5.	Discharge at rated capacity	480 cumecs
6.	Speed	200 rpm
7.	Runner Discharge Dia	3790 mm

MAIN INLET VALVES

1.	No. & Type	4 Nos., Butterfly valves
2.	Dia	4400 mm

GOVERNORS

1.	No. & Type	4 Digital PID Electro-Hydraulic
2.	Stability	Speed Oscillation not to exceed ±0.15%
3.	Dead Time	0.2 Seconds
4.	Speed Dead Band	0.02%
5.	Speed Regulation	0 to 10%

GENERATORS

1.	No. & Type	4 nos., vertical, salient pole, synchronous generators
2.	Rated output	248 MVA
3.	Rated voltage	15.75 kV
4.	Rated frequency	50 Hz
5.	Power factor	0.9 lagging
6.	Speed	200 rpm
7.	Insulation class	F, Temperature rise as per Class B.
8.	Cooling	Closed circuit air cooling
9.	Fire protection	Water sprinkler/CO_2

EXCITATION SYSTEM

1.	Type of excitation	Static Excitation System
2.	Type of voltage regulator	Duplicate Static AVR
3.	Type of excitation transformer	Dry type or epoxy resin insulated

BUS DUCTS

1.	Type	Isolated phase busbars
2.	Rated Voltage	15.75 kV
3.	Cooling	Natural

GENERATOR TRANSFORMERS

1.	Number	13 (Thirteen), including one spare
2.	Rating	4 banks of three single phase transformers, 83 MVA, 15.75/400/√3 kV, ODWF cooled

UNIT AUXILIARY TRANSFORMERS

1.	Capacity	1500 kVA
2.	Type	Dry Type or resin encapsulated
3.	Voltage ratio	15.75 / 0.415 kV

400 kV GAS INSULATED SWITCHGEAR

1.	Type	G.I.S.
2.	Rating	400 kV
3.	No. of bays	12 comprising 4 generator-transformer bays, 4 bus-coupler bays and 4 feeder bays.

400 kV CABLES		
1.	No. of 3 phase circuits	4 Circuits for connecting underground G.I.S to surface Pot Yard
CONTROL AND PROTECTION		
1.	Type of control	Supervisory Control and Data Acquisition (SCADA)
2.	Protection	Standard protections for generators, transformers, bus bar, feeders (Two sets of static distance relays)
CRANES		
POWER HOUSE		
1.	No. & type	2 nos., E.O.T.
2.	Capacity	Main Hoist: 250 t
		Auxiliary Hoist 25 t
PENSTOCK VALVE CHAMBER		
1.	No. and Type	1 no. Pendant Push Button Operated
2.	Capacity	150 t
TRANSFORMER / GIS CAVERN		
1.	No. and Type	1 no. Pendant Push Button Operated
2.	Capacity	50 t
DRAFT TUBE GATE		
1.	No. and Type	4 no., Rope Hoist
2.	Capacity	60 t
D/S SURGE TUNNEL		
1.	Type	Circular
2.	Dia	9.0 m
3.	Length	380 m
4.	Maximum surge level	El. 652.5 m
5.	Minimum surge level	El. 642 m
TAIL RACE TUNNEL		
1.	Size & Type	9.0m dia Circular shape
2.	Length	454m (Average)
3.	Invert level of tailrace tunnel at outfall	El. 641.0m
4.	Maximum tail water level	El. 642.0m