ANNEXURE –

(Detailed Project Report of Karcham Wangtoo HEP in 6 (Six) Volumes)

VOLUME - I

JAIPRAKASH
INDUSTRIES LIMITED

HYDRO POWER DIVISION

KARCHAM-WANGTOO HYDRO-ELECTRIC PROJECT (1000 MW)

HIMACHAL PRADESH

PROJECT REPORT

(REVISED)

VOLUME I

REPORT

CONSULTANTS

IDEA
INTERNATIONAL DESIGN ENGINEERING ASSOCIATES LIMITED

NEW DELHI

DECEMBER 2000

KARCHAM-WANGTOO HYDROELECTRIC PROJECT (1000 MW)
HIMACHAL PRADESH

PROJECT REPORT

VOLUME I - REPORT

LIST OF CONTENTS

FOREWORD

Our country has immense hydro-power potential. It is estimated that identified schemes can provide 84,000 MW of power at 60% load factor. The potential developed is 22014 MW (26.2%) while the potential under development during 9th Plan is 9890 MW (11.8%).

The Government of India has now opened up the entire power sector (except Atomic power) to the private sector. For the VIII plan (1992-97) CEA had estimated a need based capacity addition of 48000 MW which was scaled down to 30538 MW taking into account availability of resources. Actual capacity addition during 8th Plan has been 16422 MW. At the end of 1997-1998, India had an energy shortage of 8.1% and peaking shortage of 11.3%. This situation is likely to worsen in the coming years. The private sector has, therefore, to play an important role to fill the gap between supply and demand. Hydropower which is a renewable source of energy is the best answer for meeting the peak loads.

Jaiprakash Industries Ltd. (JIL), who have vast experience in construction of dams, tunnels and power houses and have large resources in trained and motivated manpower, is amongst the first to enter the field of setting up Hydro Power Projects in private sector. JIL signed an agreement with Himachal Pradesh Government in October 1992 for implementation of Baspa Hydroelectric Project Stage II (300 MW) which is just upstream of Karcham-Wangtoo Hydroelectric Project. This project is now under construction and is proposed to be commissioned during the year 2003.

JIL signed an MOU with Himachal Pradesh Govt. in August 1993 and carried out detailed field investigations and techno-economic studies and submitted Detailed Project Report (DPR) in, February 1996 with Cost Estimates at Dec.1995 Price level. 'In-principle Clearance' , was accorded by CEA to the Project on 31.3.96. Subsequently, 'Implementation Agreement' for execution of this project was executed with Government of Himachal Pradesh on 18th November, 1999.

The DPR of February 1996 was revised in April 2000 to update the cost estimates on December 1999 Price level . Revision was also made due to relocation of certain project works(access adit to P.H. and tail race tunnel outfall works)due to rise in river bed after flash floods in river Satluj on 11th August 1997. The comments of CEA / CWC on the original project report of February 1996 were also duly considered in the revised DPR of April 2000.

In the night of July 31, 2000, river Satluj experienced unprecedented flash floods causing severe damages to the road and bridges in the Satluj valley. Based on the updated discharge data upto end of July 2000, the design flood at Karcham dam site has been worked out again which has increased from 5540 cumec to 8260 cumec for design of diversion dam. The DPR of April 2000 has now been further revised to account for this increase in the design flood and also to revise the cost estimates as per CWC 'Guidelines for preparation of Project Estimates for River Valley Projects- March 1997'. In preparing this revised DPR, all the comments of CWC/CEA/HPSEB on the DPR of April 2000 have also been taken into consideration. The replies to all these comments have been compiled in a separate Volume designated as Volume VI of the DPR for convenience of CWC/CEA/HPSEB.

Karcham-Wangtoo Hydroelectric Project, as now formulated based on investigations and studies carried out by JIL, utilises a gross head of 295m for power generation and comprises 98m high (above deepest foundation level), Diversion Dam, four Intakes and underground Sedimentation Chambers, 17.2 km long and 10.48m dia circular concrete lined Headrace Tunnel for design discharge of 417 cumec, 16/27m dia and 184m high Surge Shaft, four steel lined Pressure Shafts of 4.75m dia and each 290.5m in length, an Underground Power Station, and a 909m long Tailrace Tunnel and Outfall works. The power station will have installed capacity of 1000 MW (4 units of 250MW) with Francis turbines for 273.5m design head. The annual generation will be 4228.50 million units in 90% dependable year and 4651.02 million units in 50% dependable year.

The project is located in area having favourable geological conditions and hence no complex geo-technical problems are anticipated.

The project will have no adverse environmental impact as only a diversion dam and a small reservoir for diurnal storage is to be constructed. Except dam, intake, and outlet works, all other works of the project are located underground.

It is proposed to commence the work on the Project from Nov.2002 by which time it is expected that all statutory clearances and financial closure shall be in place. The Project is planned to be completed and commissioned in a period of 6 years.

The estimated cost of the project at December 1999 price level is Rs. 3784 Crores, giving the cost per MW of installed capacity as Rs. 3.78 Crores which is quite attractive.

The detailed project report is presented in 6 Volumes comprising :

- Vol. I	- Report
- Vol. II	- Electro-Mechanical Works
- Vol. III	- Engineering and Costing
- Vol. IV	- Appendices
- Vol. V	- Drawings
- Vol. VI	- Replies to comments of CWC/CEA/HPSEB on the revised DPR of April 2000.

(Jaipraakash Gaur)

Chairman

Jaiprakash Industries Ltd.

EXECUTIVE SUMMARY

Project Area

The Government of India and the State of Himachal Pradesh have identified the Satluj river as an important future source of hydropower and have initiated several hydroelectric projects along Satluj and its tributaries. The Karcham-Wangtoo Hydroelectric Project is envisaged as run-of-the-river development on the Satluj river, in the reach between Karcham and Wangtoo villages in Kinnaur district of Himachal Pradesh. The project will utilise the head available between tail waters of Baspa Hydroelectric Project Stage-II and head waters of Nathpa-Jhakri Hydroelectric Project.

The project area is about 200 km from Shimla, the state capital, on National Highway 22.

Climate

The project area is on the dividing line between Zone I and Zone III of Northern India. Zone I is tropical monsoon climate. The project area however experiences little rainfall as the mountains between the plains and project area capture most of the precipitation. Climate Zone III is characteristically cold and dry in winter and hot and dry in summer. This is also highly modified by the topography of the project area.

Satluj River Hydro Development

In the Satluj basin there are a number of projects in varying stages of planning, construction, completion and operation. These projects starting from lower reaches are :

- Bhakra-Nangal, 1164 MW (operating)
- Kol dam, 800 MW (concept stage)
- Rampur-Behna, 400 MW (concept stage)
- Nathpa-Jhakri, 1500 MW (under construction)
- Karcham-Wangtoo, 1000 MW (planning stage)
- Shongtong-Karcham. 225 MW (concept stage)
- Thopan-Powari, 200 MW (concept stage)
- Jhangi-Thopan, 175 MW (concept stage)
- Khab (concept stage).

All these projects are run-of-the-river schemes except Bhakra-Nangal which has got a storage dam.

The projects which are in operation or under construction on tributaries of Satluj are:

- Sanjay Vidyut Pariyojana, 120 MW (operating)
- Nagli, 3 MW (operating)
- Baspa-II, 300 MW (under construction).

Hydrology

There are gauging stations on Satluj river at Shongtong, Karcham, Wangtoo, Nathpa, Rampur, Kasol and Bhakra.

For the hydrological studies, the data of gauge sites at Karcham, Wangtoo and Nathpa have been analysed.

Water availability has been based on the discharge data at Wangtoo bridge site transposed to Karcham Dam site. For this site continuous data is available for 28 years. For computation of 90% and 50% dependable discharges, the non-monsoon (October-May) run-off have been considered as during monsoon period (June-September) sufficient water is available through the entire period to run the station as base load station with full installed capacity.

Design flood studies have been carried out using various methods. Based on regional flood frequency analysis for Nathpa dam site, 1000 year flood of 8260 cumec has been adopted for design of spillway.

For design of diversion tunnel non-monsoon flood of 25 years frequency which works out to 1312 cumec, has been adopted.

Power Planning

Karcham-Wangtoo Hydroelectric Project is a run-of-the-river scheme. The project upstream as well as downstream of it are also run-of-the-river schemes which will not affect the water availability and utilisation at Karcham-Wangtoo Project. Optimum tunnel diameter and installed capacity studies have, therefore, been carried out independently for this project.

The studies have been carried out for different combinations of tunnel diameter and installed capacity. The tunnel diameters considered varies from 9m dia to 10.5m dia for single tunnel option and 7m dia to 9m dia for twin tunnel option. The tunnel diameter above 10.5m dia (excavated dia about 11.5m) has not been considered as construction of long tunnel bigger than this size may pose geological problems. The installed capacity considered varies from 600 MW to 1500 MW.

The cost of generation is minimum for tunnel diameter of 10m for installed capacity of 800 MW to 950 MW for a single tunnel option.

For a tunnel diameter of 10.5m and installed capacity of 1000 MW the cost of generation is still in the optimum range, and generation benefit increases by about 120 MU.

It is, therefore, proposed to provide an installation of 1000 MW which will give the optimum cost of generation and also utilises the power potential to the maximum possible extent.

For ease of construction, it is proposed to excavate a modified horse shoe tunnel. The finished size of tunnel will be 10.48m circular so that there is no concentration of stresses at the haunches, as is the case if the finished size is of horse shoe shape. For this tunnel dia and installed capacity, tunnel discharge will be 417 cumec and corresponding velocity will be 4.83 m/sec, which is well within the acceptable limits.

The annual design energy based on 95% availability of installed capacity as per Guidelines of Government of India will be 4301.77 MU during 90% dependable year (year 73-74) and 4752.18 MU during average dependable year (year 94-95). The plant utilisation factor will be 49.11% and 54.25% respectively for 90% availability and average availability year respectively.

The yearly generation during the hydrological series of 34 years varies from 3901 MU to 6047 MU.

The installed capacity of 1000 MW will be provided in four units of configuration of 250 MW each, which is the most economical arrangement.

Geology

The project area lies in Mehbar and Maldi gneisses comprised of kyanite and psamatic gneisses with bands of schist and quartzite. These are intruded by basic and acidic rocks. All the rocks are well foliated. The general trend is N-S with moderate dips toward East. These are transected by a number of joints of which the foliation and strike joints are the most predominant followed in frequency by steeply dipping transverse joints. The rock formations within the project area going upstream from the tailrace consist of the Wangtoo, Rampur and Jutogh gneisses and granites. The Wangtoo rocks are overlaid by the Rampur followed by the Jutogh, the three series having thrusted contacts.

Rocks are generally covered by glacial deposits, rock debris, alluvial terraces and fans. The soils of the Satluj valley are relatively poor sandy loam, and exposed bedrock, rocks and gravel abound. In the valley bottom there is virtually no soil, but between elevations 1200 and 3500 m, the soils support some forest cover and are cultivable to a certain extent.

Seismicity

The project area lies in an active seismic region, zone IV of the Seismic Zoning Map of India. Available data on seismicity within a radius of 150 kms of the project shows that earthquakes having a magnitude greater than 5 on the Richter scale occur at frequent intervals. Important seismic events which have taken place in the past 150 years and caused significant damage include the 1905 Kangra quake (magnitude 8+), the 1908 Kullu quake (magnitude 6.0), the 1945 and 1947 Chamba quakes (magnitude 6.5 & 6.6), the 1975 Kinnaur quake (magnitude 6.8) and the 1991 Uttarkashi quake (magnitude 6.6).

Based on the probabilistic approach, the effective ground horizontal acceleration has been taken as 0.23g for MCE, and correspondingly the value of effective peak ground horizontal acceleration for DBE has been taken as 0.115g which has been considered for the elastic design of the dam.

Project Works

a) **Diversion Works**

Keeping in view that there is overburden of about 50m in the river bed, and relatively narrow gorge, it is considered necessary to construct a diversion tunnel to permit uninterrupted construction of the dam in its entire length during non-monsoon period.

The diversion tunnel will be 10.50m finished dia and 456m in length. The upstream coffer dam will be 20.5m high while downstream coffer dam will be 8.5m high. Both the coffer dams will be of rockfill type with impervious core. Full concrete cut-offs upto the bed rock are proposed for both the upstream and downstream coffer dams in view of the high permeability of the overburden material.

b) **Diversion Dam**

In the undeveloped reach of Satluj between Baspa-II and Nathpa-Jhakri Project, four possible dam sites were identified. Of these sites, the site situated about 300m downstream of the Baspa river confluence has been selected. The main reasons for selecting this site are suitable geological set up, availability of sufficient diurnal storage for peaking purposes and minimum submergence of populated area and the existing roads.

Due to shape of the valley, availability of materials and need of a large capacity spillway, a concrete gravity dam is proposed. The top of dam has been kept at El 1813 while the deepest level will be at El 1715. The maximum and minimum pond levels have been kept at El 1810 and El 1799 respectively. The total storage available between these pond levels is 544.97 Ham as against requirement of 484.10 Ham for 4 hour peaking, thus allowing margin for loss of storage due to silting after construction of dam.

The dam will have 6 sluice spillway bays of size 9m (W) x 9m (H) with crest at El 1782m. In addition an auxiliary surface spillway has also been provided on the left bank to pass floating debris and surplus water due to sudden closure of the power station. The auxiliary spillway will have two bays of 8m width with crest at El 1803m. The discharge capacity of the main spillway is 8260 cumec while that of auxiliary spillway is 549 cumec. The energy dissipation arrangement for both the spillways will be of ski jump bucket type. Depending upon the results of hydraulic model experiments at the design stage of the project for firming up the various features of the headworks, the auxiliary spillway may be located over the two central bays of the main spillway, if so found expedient.

c) **Intake and Sedimentation Chambers**

The intake has been designed for 521.25 cumec discharge, 417 cumec for power generation and 104.25 cumec for flushing the sediment.

Intake works have been sited on the right bank as the HRT and powerhouse complex are located on this bank. There will be four intake bays with four corresponding sedimentation chambers. The intake will have its invert at El 1786m which is 4m above the main spillway crest.

At the downstream of intake structure, intake tunnels will take the water to the sedimentation chambers.

Since the silt carried by Satluj river contains quartz particles also, all sediment coarser than 0.2 mm is proposed to be eliminated from the flow of HRT for durability of turbines against damage by silt. There will be four sedimentation chambers, i.e. one for each intake bay for settling and flushing out the suspended silt load. The length of each sedimentation chamber will be 505m which is based on fall velocity of 0.02 m/sec for 0.2 mm size particles and 95% efficiency of chamber. The width of each chamber will be 16m.

The sedimentation chambers will have 64 openings at the bottom and a flushing duct of varying depth. At the downstream of last opening the duct has been kept circular of 2.75m dia. The outfall of the flushing tunnels have been kept about 900m downstream of dam axis, which is the closest location where sufficient head is available for generating flushing velocity.

d) **Headrace Tunnel**

The length of HRT from exit end of sedimentation chambers and upto junction with surge shaft is 17198 metres. Based on optimisation studies tunnel size has been kept as 10.48m dia circular tunnel.

The maximum velocity in the tunnel will be 4.83 m/sec. It is proposed to provide uniform grade of 1 in 150 in the HRT. For construction of HRT five intermediate adits apart from adit at inlet end and adit at surge shaft end, have been provided. The length of adits varies between 100m and 600m. With the provision of these adits, the maximum length to be excavated from any face will be 2237m. This will ensure completion of tunnel in required time. The tunnel will have concrete lining in its entire length.

e) **Surge Shaft**

A restricted orifice type surge shaft has been proposed at the end of HRT.

Based on surge studies the top of surge shaft has been kept at El 1852.0. The surge shaft will be of 16m dia upto El 1755 and 27m dia above this elevation. The orifice area required is 19 sqm which will be provided by four gate grooves of size 4.3 x 0.75m and an opening at centre of 2.8m dia.

The surge shaft will be provided with reinforced concrete lining.

f) **Pressure Shafts and Penstocks**

The power house will be fed by 4 pressure shafts of 4.75m dia. Each pressure shaft will negotiate a head of 171.6m between centre line of HRT (El 1673.1) and centre line of machine at El 1501.5m. The length of each pressure shaft will be 290.5m. The pressure shafts will be provided with steel liners in the entire length, the thickness of plate varying from 14 mm to 25 mm.

The arrangement of providing four independent pressure shafts as compared to the arrangement of two pressure shafts with Y-pieces near the power house, has been adopted because in the later arrangement the required diameter of pressure shafts will be 6.5m, which is not considered practicable for transportation of ferrules on hilly project roads and will be clumsy in installation and lead to rather large size of control valves.

g) **Power House Complex**

The powerhouse and transformer hall cavities are located on the right bank of river Satluj near the junction with Bhabha river.

The access to the machine hall and transformer hall will be through a 8.5m D-shaped adit of 883m length. This adit will take off from NH-22. A 6.5m D-shaped branch adit will provide access to the control room.

The powerhouse cavity will be 21m wide, 45m high and 143m long. The service bay is located at the north end of this cavity at El 1515.0. The control block (25m long) will be located on south end of this cavity. Two 275/40/10 T EOT cranes will run on rails at El 1525 in the service bay and machine hall.

The transformer hall cavity will be 15.5m wide, 25m high, and 143m long and will be parallel to PH Cavity. It will house the single phase transformers at El 1515m and 400 kV GIS equipment at the floor at El 1526.0m.

h) **Tailrace Works**

The tailrace works will consist of a downstream surge chamber cum collection gallery of size 220m (L) x 16m (W) x 42.5m (H) and a 909m long tailrace tunnel of 10.48m dia Circular shape. An outlet structure with provision of gates has been provided at the exit end so that the tailrace works can be isolated when river is in high flood and power station is closed.

The operation of draft tube gates at the junction of unit draft tubes and collection gallery will be carried out from a D.T. gate operating gallery at El 1525.

i) **Hydraulic Gates and Valves**

The hydraulic gates and Valves as below have been provided for the dam and the water conductor system.

(i) Diversion tunnel gates (2 nos.) and electric hoists.

(ii) Top sealing type radial gates (6 nos.) with hydraulic hoists for the sluice spillway.

(iii) Radial gates (2 nos.) with hydraulic hoists for the auxiliary spillway.

(iv) Spillway stop logs along with spillway gantry crane for the main spillway and auxiliary spillway.

(v) Trash racks and trash cleaning machine at the intake structure.

(vi) Fixed wheel intake gates (4 nos.) with individual hydraulic hoists.

(vii) Stop log gate (one no.) for intake.

viii) Sedimentation chamber gates in link tunnels (4 nos.) and gantry crane.

(ix) Flushing conduit gates (4 nos.) with hydraulic hoists.

(x) Surge shaft gates (2 nos.) and radial travelling hoist.

(xi) Butterfly type emergency valves (4 nos.) in valve chamber d/s of surge shaft with hydraulic servomotors.

(xii) Main inlet valves (spherical type) in the machine hall.

(xiii) Draft tube gates (2 nos.) and gantry crane.

(xiv) Fixed wheel type outlet gates (2 nos.) with electric hoists.

(xv) Vehicle access doors (3 nos.) at plugs in inlet adit, intermediate adit 3 and surge shaft adit.

Power Plant

The powerhouse will have four vertical axis Francis turbines having rated output of 255,000 KW under a rated net head of 273.5 m at 214.3 RPM synchronous speed. The generators will be synchronous and of the vertical shaft type of 250 MW rated power at 0.9 power factor and 50 hertz frequency. The generators will have speed of 214.3 RPM and generation voltage ≥ 13.8 kV.

The electrical auxiliaries will consist of A.C. supply system, D.C. supply system, grounding system and communication equipment etc.

The mechanical auxiliaries will consist of compressed air system, oil handling system, ventilation and air-conditioning system, fire protection system, drainage and dewatering system and cooling water system etc.

The machine hall will have two 275/40/10 T EOT cranes for installation and maintenance of the heavy equipment.

The power produced at 13.8 kV will be stepped up to 400 kV by single-phase transformers of 93 MVA, 13.8/400/√3 of WF type installed in the transformer hall. The transformers will be connected to 400 kV GIS switchgear installed in the same cavern. The GIS will be connected to outdoor switchyard (GIS) through 400 kV SF6 gas insulated phase buses.

Infrastructure Works

The infrastructure works required to be carried out are creation of rail head facilities, improvement of National Highway 22 beyond Jhakri and upto Karcham for transport of heavy equipment, construction of roads to surge shaft (4.0 km) and roads to inlet adit and intermediate adits to HRT 3 & 4 (1.25 km), construction of camp sites, permanent colony, stores and workshops and construction power arrangement.

In addition, it will also be necessary to realign part of National Highway 22 and small portion of Karcham-Sangla and Karcham-Sapni roads, which will be submerged in the reservoir. It will involve construction of 9.75 km of new roads and construction of three major permanent bridges - two over river Satluj and the other over river Baspa.

It will also be necessary to provide a bridge over river Satluj near Powerhouse site to provide access to dumping areas on the left bank.

The total requirement of construction power for the project works will be 12 MVA. This will be made available by construction of two 22 kV feeders to Dam site from 66/22 kV station of HPSEB at Nathpa. Diesel sets (3 MVA at Dam site and 3 MVA at Powerhouse site) will also be provided to meet emergency power requirements in case of grid failure.

Additional Studies

Additional studies and investigations as below are proposed to be carried out for preparation of detailed designs and drawings for implementation of the project :

a) Topographical surveys.

b) Hydrological observations.

c) Silt observations.

d) Geological investigations including mapping along the tunnel alignment.

e) Further drilling at Dam site and across head race tunnel alignment at three locations.

f) Further tests for determination of insitu stresses and modulus of deformation at Dam site, sedimentation chambers site, surge shaft site and pressure shaft and powerhouse site.

g) Tests on aggregates and concrete mix designs.

h) Hydraulic model studies for Dam, Intake, Sedimentation Chambers and Surge Shaft.

Construction Planning and Management

It is proposed to complete the project and commission all the four units in a period of six years from the date of start of the project.

The head race tunnel, which is 17.2 km long of 10.48 m dia circular shape, is the most critical structure. To complete this tunnel in the required time, it has been proposed to provide five intermediate adits in addition to the adits at inlet end and surge shaft end. The maximum length of HRT to be excavated from any face will be about 2200m.

The tunnel will be excavated by conventional method of drilling and blasting. It is proposed to use most modern equipment for excavation of HRT, which will include computerised hydraulic jumbos, automatic rock bolters and wet shotcrete machines for fibre reinforced shotcrete.

The concrete lining will be placed by continuous lining system using collapsible shutters with traveller and concrete pumps with concrete distribution system.

The timely construction of efficient and reliable river diversion works including diversion tunnel and coffer dams is also very important for the construction of the dam in required period as in river bed portion it will require open excavation upto 50m or so. Keeping in view the high permeability of river bed material, it is proposed to provide positive concrete cut-off upto bed rock for both the u/s and d/s coffer dams. It is proposed to carry out this work by using slurry trench cutter suitable for boulder strata.

To achieve the objective of commissioning the project in a period of six years and also to ensure quality of all the works to the recognised Indian and International Standards, an efficient and result oriented construction organisation will be set up.

Environmental Evaluation

The Karcham-Wangtoo Project is a run-of-the-river scheme without any storage dam. All the works of the project except Dam, intake structure and outfall works are underground. Moreover, only 6.85 km of new roads are required to be constructed to approach the various work sites. As a result of these basic features, there will be nominal disturbance to the existing environment and ecology either during construction or during operation of the project.

Environment impact studies for the project have been carried out by a team comprised of Indian and Canadian biophysical and socio-cultural specialists. These studies have been carried out keeping in mind the five principal objectives as below:

i) Collect existing environmental data of the project area.

ii) Carry out site reconnaissance.

iii) Identify the potential environmental effects of the proposed project.

iv) Assess the significance of the resultant impacts.

v) Recommend the appropriate measures to minimise the environmental impact of the project and provide enhancement where possible.

The requirement of land for the works and coming in the reservoir submergence is as below :

Forest land / Govt. land	95.60 Ha
Private land	3.79 Ha

In addition, the land given below will be required for the construction period :

Forest land / Govt. land	64.41 Ha

The forest land involved in this project does not cover extensive forest or trees. In the project report, adequate provision has been proposed for afforestation, plantation, soil conservation etc. in the project area.

Estimate of Costs

The estimate of costs has been prepared in detail to arrive at the total cost of the project. The estimates are based on the prices prevailing in December 1999.

The detailed estimate of cost of civil works is based on the preliminary designs of different components of the works after review of site conditions and carrying out detailed field investigations. The layout of different works have been finalised after considering all the possible alternatives and most economical layouts have been adopted. For carrying out preliminary design, numerical methods such as FEM analysis have been carried out. Detailed analysis of rates of different items of works have been prepared as per Guidelines of CWC (Guidelines for preparation of project estimate for river valley projects- March 1997). The rates for hydraulic gates, hoists and cranes etc. are based on the prevalent market rates for such works. Apart from main civil works, the provisions under various other sub-heads are also based on the Guidelines of CWC.

Cost of generating plant and equipment is based on current budgetary prices of plant from M/s Siemens, Germany for 4x250 MW units. The cost of 400 kV gas insulated switchgear, 400 kV SF6 bus ducts and other electro-mechanical equipment are also based on budgetary offers from the manufacturers/suppliers or offers for similar equipment for other projects viz. Baspa II, Vishnuprayag, Chamera II.

Provisions for other items like establishment, audit and accounts etc. are as per norms of CEA.

The total cost of the project at December 1999 price level excluding escalation, IDC and Financing Charges works out as under :

Civil Works	Rs.	2584.00	Crores
Electrical Works	Rs.	1200.00	Crores
Total	Rs.	3784.00	Crores

The cost per MW of installed capacity works out to Rs. 3.78 Crores (at December 1999 price level). Thus, the cost per MW for this project is quite low, making the project very attractive.

		INR (Rs. Crores)		F.C. (million US$)	
Civil Works	Rs.	2584.00		-	
Electro-Mechanical Works	Rs.	525.50		155.00	
	Rs.	**3109.50**	**US$**	**155.00**	**million**

= Rs. 674.25 crores
(1 US$ = Rs. 43.50)
= Rs. 3784 Crores

C:\Usha2000\KARCHAM-DEC.00\EXESUM(C K A).wpd

KARCHAM-WANGTOO HYDROELECTRIC PROJECT

SALIENT FEATURES

LOCATION

1.	State	Himachal Pradesh
2.	District	Kinnaur
3.	River	Satluj
4.	Vicinity	Dam near Village Karcham on NH-22 and Power house near village Wangtoo on NH-22 about 186 kms from Shimla (Capital of H.P.)

HYDROLOGY

1.	Catchment Area at Dam site	48755 Sq.km
2.	Snow catchment	38760 Sq.km
3.	Maximum observed average 10 daily discharge	1870.48 cumec
4.	Design Flood	5540 cumec
5.	Average run off in 90% availability year	
	Monsoon :	112558 cumec-day
	Non Monsoon :	28586 cumec-day
	Total :	141144 cumec-day
6.	Average run off in 50% mean year	
	Monsoon :	75697 cumec-day
	Non Monsoon :	36846 cumec-day
	Total :	112543 cumec-day
7.	Discharge for 90% availability	80.8 cumec
8.	Discharge for 50% availability	176.0 cumec
9.	Percent availability corresponding to design discharge of 417 cumec	32.38%

RIVER DIVERSION WORKS

1. Diversion Tunnel

Dia	10.5m
Length	456m

2. Coffer Dams

Type	Rock fill with impervious core
Upstream	20.5m high
Downstream	8.5m high

3. Cut-off for Coffer Dams — Concrete cut-off upto bed rock

DIVERSION DAM

1.	Type	Concrete Gravity
2.	Top of dam	EL 1813.00m
3.	Height from deepest foundation level	98 m
4.	Total length at top	177.8 m
5.	No. of blocks	12
6.	Minimum river bed level at dam axis	El 1770.00m
7.	Deepest foundation level	El 1715.00m
8.	Maximum pond level	EL 1810.00 m
9.	Minimum pond level	EL 1799.00 m
10.	Live storage capacity	544.97 Ha-m

MAIN SPILLWAY (SLUICES)

1.	Location	Block nos. 5 to 10 of Dam
2.	No. of bays	6
3.	Size of each sluice	9m (W) x 9.0m (H)
4.	Crest elevation	1782.00 m
5.	Thickness of intermediate piers	7m
6.	Size of each gate	9m (W) x 9.25m (H)
7.	Type of gates	Radial Gates (top sealing type)
8.	Maximum flood level	1808 m
9.	Ski-jump bucket lip elevation	1778.00 m
3.	Discharge capacity of Sluices	8260 cumec

AUXILIARY SPILLWAY

1.	Location	Block no. 3 of Dam
2.	No of bays	1
3.	Width of each bay	8m
4.	Crest elevation	1803.00m

5.	Thickness of intermediate pier	7.0m
6.	Size of each gate	8m (W) x 7.35m (H)
7.	Type of gates	Radial gates
8.	Maximum discharge capacity	549 cumec
9.	Ski-jump bucket lip elevation	1778.80m

INTAKE

1.	No. of intake bays	4
2.	Size of each bay at trash- racks	18 m (W) x 7.5 m (H)
3.	Orientation with respect to Dam axis	90°
4.	Crest level	1786.00 m
5.	Minimum water level U/s	1799.00 m
6.	Discharge through each intake bay	130.3 cumec
7.	Number of intake gates	4
8.	Size of each gate	6.00m (W) x 5.25m (H)
9.	Size of intake tunnels	6.0m modified Horse Shoe shaped

SEDIMENTATION CHAMBERS

1.	Particle size to be excluded	+ 0.2 mm
2.	Flow through velocity	0.3 m/s
3.	Width of each chamber	16.0m
4.	Depth of each chamber	28.0m
5.	Length of each chamber	505m
6.	Design discharge	521.25 cumec
7.	Flushing discharge	104.25 cumec
8.	Fall velocity	2.3 cm/sec
9.	Size of flushing duct at start of chamber	2m (W) x 0.37m (H)
10.	Size of flushing duct at end of chamber	2m (W) x 3m (H)
11.	Velocity at start of flushing duct	0.3 m/sec
12.	Velocity of the end of flushing duct	4.3 m/sec

LINK TUNNELS

1.	Size	Four individual link tunnels of 6.0m dia

2.	Length of each tunnel	Outer link tunnels - 125.5m Inner link tunnels - 65.5m
3.	Gates at start of link tunnels	4 nos.
4.	Size	6.0m (W) x 6.0m (H)
5.	Gate operating gallery	7m D-shaped

FLUSHING CONDUITS

1.	Number	4
2.	Size	2.75m dia circular
3.	Lengths	300m, 330m, 370m and 405m

HEADRACE TUNNEL

1.	Size & Type	10.48m dia circular
2.	Length	17.2 km
3.	Velocity through tunnel	4.83 m/sec
4.	Centre line of tunnel at inlet end	1785.85 m
5.	Centre line of tunnel at junction with surge shaft	1671.195 m
6.	Design discharge	417 cumecs
7.	Slope	1:150
8.	Adits	

	Chainage from intake axis (m)	**Length (m)**
Inlet Adit	900	225
Intermediate adit 1	3104	470
Intermediate adit 2	5092	450
Intermediate adit 3	7385	250
Intermediate adit 4	11860	100
Intermediate adit 5	14310	600
Surge shaft adit	17750	140

SURGE SHAFT

1.	Type	Restricted Orifice
2.	Diameter	16m upto 1755.00m and 27m from 1755.00m to EL 1852.00m
3.	Bottom elevation	El 1667.950m

4.	Top elevation	El 1852.000m
5.	Maximum upsurge	1848.880 m
6.	Minimum down surge	1717.103 m
7.	Top	Open to Sky

PRESSURE SHAFTS

1.	No. and type	4 nos. steel lined
2.	Diameter	4.75 m
3.	Length of each penstock	290.50 m
4.	Type of steel for penstock liners	ASTM A 537 - Grade I

VALVE CHAMBER

1.	Location	Downstream of Surge shaft
2.	Size of chamber	95x10x22 m (LxBxH)
3.	Type of valves	Butterfly valves
4.	Diameter of each valve	4750mm
5.	E.O.T. Crane	1 x 65/5 t

POWER STATION COMPLEX

POWER HOUSE / TRANSFORMER CAVITY

1.	Type	Underground
2.	Installed capacity	1000 MW (4x250 MW)
3.	Size of machine hall	143 m (L) x 21 m (W) x 49 m (H)
4.	Size of transformer hall	143 m (L) x 15.5 m (W) x 25 m (H)
5.	Approach adit to machine hall	8.5 m D-shaped 883 m long
6.	Average gross head	298.73m
7.	Net head at 417 cumec tunnel discharge	275.93m
8.	Length of cable tunnel	528.71m

ELECTRO-MECHANICAL EQUIPMENT

TURBINES

1.	No. and type	4 (Four) nos., Francis turbines
2.	Rating	255,000 kW / 347,000 MHP
3.	Maximum/Minimum Head	303.50/258.20 m

8.	Design head	273.5m
5.	Design discharge	104.25 cumecs
6.	Speed	214.30 rpm
7.	Runner Discharge Dia	3870 mm
8.	Maximum Speed Rise	42 percent
9.	Maximum Pressure Rise	16 percent (excluding upsurge)

MAIN INLET VALVES

1.	No. & Type	4 Nos., Spherical type
2.	Dia	3200 mm
3.	Rated Head	365 m W c
4.	Service and Maintenance Seal	Hydraulic operated

PENSTOCK B.F. VALVES

1.	No. & Type	4 Nos., Butterfly type
2.	Diameter	4000 mm
3.	Rated head	192 m W c
4.	Opening/Closing	Hydraulic

GENERATORS

1.	No. & Type	4 nos., semi-umbrella, vertical synchronous generators
2.	Rated output	277.70 MVA
3.	Rated voltage	≥ 13.8 kV ± 10%
4.	Rated frequency	50 Hz ± 5%
5.	Power factor	0.9 lagging
6.	Speed	214.30 rpm
7.	Insulation class	F
8.	Cooling	Closed circuit air cooling
9.	Fire protection	Water sprinkler type

EXCITATION SYSTEM

1.	Type of excitation	Static
2.	Type of voltage regulator	Digital - microprocessor based
3.	Type of excitation transformer	Dry epoxy cast resin

4.	Nominal excitation system response	Not less than 2.0
5.	Ceiling voltage	Not less than 1.8 p.u.
6.	Regulator response time	Not more than 20 ms

BUS DUCTS

1.	Type	Isolated phase, continuous type
2.	Rated voltage	15 kV
3.	Rated current	15000 A / 8500 A (main/delta)
4.	Cooling	Natural

GENERATOR-TRANSFORMERS

1.	Number	13 (Thirteen), including one spare
2.	Rating	4 banks of three single phase transformers, 93 MVA, 13.8/400/√3 kV, YNd11, OFWF cooled

STATION/UNIT AUXILIARY TRANSFORMERS

1.	Capacity	1000 kVA
2.	Type	Epoxy cast resin
3.	Voltage ratio	13.8/0.415 kV (UAT), 22/0.415 kV (SST)

DC SYSTEM

1.	Batteries for P.H. and Switchyard	2 sets, 220 Volts, 2000 AH
2.	Batteries for communication system	2 sets, 48 Volts, 500 AH
3.	Batteries for DACS	1 set, 24 Volts, 400 AH

420 kV GAS INSULATED SWITCHGEAR

1.	Type	Indoor/outdoor G.I.S.
2.	Rating	420 kV, 4000/2000 A (bus bar/feeder ratings), 40 kA symm. S.C. current for one second
3.	No. of bays	11 (eleven) comprising generator-transformer and bus-coupler bays (located underground) and 6 nos. feeder bays outdoor type.

420 kV GAS INSULATED DUCTS

1.	No. of 3 phase circuits	2 (Two) for connecting double bus bars of underground and overground G.I.S.
2.	Rating	400 kV, 4000 Amp

CONTROL AND PROTECTION

1.	Type of control	Data acquisition and control system (computerised)
2.	Protections	Standard protections for generators, transformers, bus bar, feeders (Main I & II)

CRANES

POWER HOUSE

1.	No. & type	2 nos., E.O.T.
2.	Capacity	275/40/10 t
3.	Span	20.2m

B.F. VALVE CHAMBER

1.	No. and Type	1 No., E.O.T.
2.	Capacity	65/5 t
3.	Span	9.2 m

GIS CAVERN

1.	No. and Type	1 no., Pendant push button operated
2.	Capacity	10 t
3.	Span	14.7 m

COLLECTION GALLERY CUM D/s SURGE CHAMBER

1.	Size	220m (L) x 16m (W) x 42.5m (H)
2.	Maximum surge level	1523.065 m
3.	Minimum surge level	1497.812 m

TAIL RACE TUNNEL

1.	Size & Type	10.48m dia Circular shape
2.	Length	909m
3.	Invert level of tailrace tunnel at outfall	1505.000m
4.	Normal tail water level	1508.00m
5.	Maximum tail water level	1516.25m

POWER GENERATION

1.	Installed capacity	1000 MW
2.	Annual generation	
	- 90% dependable year	4228.50 GWH
	- 50% dependable year	4651.02 GWH
3.	Plant load factor	
	- 90% dependable year	49.11%
	- 50% dependable year	54.25%

COST ESTIMATE

			INR (Rs. Crores)		F.C. (million US$)	
1.	Civil Works	Rs.	2584.00		-	
2.	E-M Works	Rs.	525.50	US$	155.00	
3.	Total base cost of Project (December 1999 Price Level)	**Rs.**	**3109.50**	**+ US$**	**155.00**	**million**
		=	Rs. 3784 Crores (1 US$ = Rs. 43.50)			

C Usha2000 KARCHAM-DEC 00\salfeat C K.A.) wcd

CHECK LIST

Name of the Project	:	KARCHAM-WANGTOO HYDRO-ELECTRIC PROJECT

Location:

(a)	State	:	Himachal Pradesh
(b)	District	:	Kinnaur

Category of the Project:

(a)	Irrigation or Multipurpose	:	Run-of-the-river Hydro-Electric development
(b)	Storage or diversion	:	Diversion

Sl. No.	Item	Reference
	PLANNING	
1.	Has the Master Plan for overall development of the river basin been prepared and stages of basin development discussed briefly?	Yes, Chapter 2 (Volume I)
2.	Have the alternative proposals been studied and their merits and demerits discussed?	Yes, Chapter 5 (Volume I)
3.	Does the scheme fit in the overall development of the river basin and its priority in the overall development of the basin discussed?	Yes, Chapter 2 (Volume I)

4.	Are there any features which are not likely to fit in the overall development of the basin? Have the other Departments Concerned with the development been informed?	There are no such features
5.	Is the present scheme proposed to be executed in Stages? If so, are its various stages of execution and development discussed in the report?	The project will be executed in single stage only
6.	Are the effects of the scheme on the riparian rights existing upstream and downstream projects etc. discussed?	Not Applicable
	Interstate and International Aspects:	
7.	Are there any International/Inter-state issues involved? If so, have these issues been identified and present status of agreement indicated specially in respect of: (a) Sharing of water (b) Sharing of cost (c) Sharing of benefits (d) Acceptance of the submergence by the upstream state (e) Compensation of land coming under submergence (f) Settlement of outsees (g) Any other.	No
	SURVEYS	
8.	Have the detailed topographical surveys been carried out for the following items and maps prepared as prescribed scales	Detailed surveys of the project area have been carried out on 1:1000 scale.
	(a) River Surveys	Yes

	(b)	Reservoir surveys	Yes, Topographical surveys of the reservoir area including cross-sections have been carried out.
	(c)	Head works surveys (dams, dykes, barrages, weirs, etc. and auxiliary components)	Yes, Drawing No. 1200-04-01
	(d)	Plant site and colonies	Yes
	(e)	Water conductor system	Yes, Drawing No. 1200-07-01
	(f)	Major Canal structures	Not applicable
	(g)	Power house, switch-yard surge shafts, tailrace	Yes, Drawing Nos. 1200-08-01 and 1200-10-01
	(h)	Tunnel(s), adits, penstocks etc.	Yes, Drawing No. 1200-07-01 to 1200-07-11
	(i)	Surveys (detailed and sample of areas of the command for OFD and drainage works	Not applicable
	(j)	Soil surveys	Not applicable
	(k)	Surveys for soil conservation	Not applicable
	(l)	Any other surveys i.e. Archaeological, Right of way, Communication etc.	Yes, Chapters 19 and 20 (Volume I)

GEOLOGY

9. Have the geological surveys for the following items been carried out?

(a) Regional geology (b) Reservoir (c) Headwork and energy dissipation area (d) Power house and appurtenances (e) Intakes and regulators (f) Major Canal structures (g) Tunnel, penstock hill etc. (h) Communication routes (i) Any other	Yes, Chapter 6 (Volume I) and Appendix 1 (Volume IV)
10. (a) Has the seismicity of the region been studies and Coefficient of vertical/horizontal acceleration for the various structures discussed?	Yes, Chapter 7 (Volume I) and Appendix 2 (Volume IV)
(b) Has the approval of standing committee for recommending design of seismic Co-efficient for River Valley Project been obtained?	Suitable recommendations have been made in Chapter 7 (Volume I)

FOUNDATION INVESTIGATIONS

11. Have the detailed foundation investigations (including in situ tests and laboratory tests) for the following structures been carried out?	
(a) Earth & rockfill dam/barrage/weir etc. (b) Masonry/concrete dam/weir etc. (c) Canal	5 holes have been drilled for the Dam (details given in Appendix 1 of Volume IV)
(d) Power house, tunnel canal structures etc. (e) Any other	Drift has been constructed in power house area details given in Appendix 1 of Volume IV).

12.	Are there any special features affecting the design?	No
	MATERIAL SURVEYS	
13.	Have the surveys and laboratory tests for the following construction materials been carried out and report appended?	Yes
	(a) Soils for impervious semi-pervious and pervious zones of earth dam	Not applicable
	(b) Sand	Yes (Appendix 4 Volume IV)
	(c) Rock & aggregate	Yes (Appendix 4 Volume IV)
	(d) Bricks and tiles	Not applicable
	(e) Pozzuolana	Not applicable
	(f) Cement and limestone	No
	(g) Steel	No
	(h) Other scarce materials	No
14.	Have the sources for each of the above material been identified and need etc. indicated?	Yes, Chapter 19 (Volume I)
15.	Have the proposals for procurement of scarce materials been indicated?	No

HYDROLOGICAL AND TECHNOLOGICAL INVESTIGATIONS

16.	Have the hydrological and meteorological investigations been carried out and status of data discussed in report? (a) Rainfall (b) Gauge (c) Discharge (d) Sediment (e) Water quality (f) Evaporation and whether the above data has been appended?	Yes, Chapter 4 (Volume I) and Chapters A-1 to A-6 (Volume III)

HYDROLOGY

17.	Is the hydrology dealt with in detail in a separate volume?	Yes, Section A (Chapters A-1 to A-6) (Volume III)
	(a) Have the brief details been included in this report?	
	(b) Is an index map and bar chart showing locations of various hydrometric, climatic and rainfall stations and the data availability at those stations been attached?	Yes, Section A (Chapter A-1 and A-2) of Volume III and Figure A-1
	(c) Are brief notes about quality consistency, processing and gap filling of the data included?	Yes, Section A (Volume III)
18.	Have hydrological studies been carried out for the following:	
	(a) To establish the availability of water for the benefits envisaged.	Yes, (Chapter A-3, Volume III)

d:\karcham\vol-checklis-00

	(b) To determine design flood for the various structures (spillway, weir, barrage etc.)	Yes, (Chapter A-4 Volume III)
19.	Have the analysis for the water flows, sediment flows evaporation and catchment area rainfall been discussed?	Yes, Section A (Volume III)
20.	Have the studies regarding reservoir sedimentation been carried out and revised elevation-area capacity curves been used in the simulation studies?	There is no storage reservoir. It is purely run-of -the-river scheme. The reservoir capacity has been provided for daily peaking only.
21.	Have the other requirements such as low flow augmentation, water quality control etc. been included in the project report and incorporated in the simulation studies?	Not required
22.	(a) Have the details of the simulation studies (working tables) and conclusions arrived from the various alternative explaining the factors and assumptions been included and discussed?	Not required
	(b) Have the number of failures for the different aspects been indicated?	Not required
23.	Have the likely desirable and undesirable changes in the hydrologic regime due to the project been brought out in the report?	No such change contemplated.
24.	Is the criteria adopted for selection of the construction diversion flood discussed?	1 in 25 years flood has been considered for design of diversion tunnel.
25.	Is the basis for fixing up the storage discussed?	No, as it is a run-of-the river scheme, the storage has been provided for daily peaking.
26.	Have the flood routing studies been carried out?	Not necessary as it is a diversion dam

27.	Have the back water studies been carried out?	Not required.
	LAND ACQUISITION AND RESETTLEMENT OF OUTSEES	
28.	Have the type and quantum of land proposed to be acquired in the submerged area, project area, required for rehabilitation of the outsees been detailed?	Yes, Chapters 19 and 22 (Volume I)
29.	Is the basis for provision for land acquisition indicated?	Yes (Annexure C-2.2 of Section C, Volume III)
30.	Have the rehabilitation measures, amenities and facilities to be provided to the outsees been discussed specially for the outsees from the upstream state?	Provision has been made for compensation of houses and other property coming into submergence. Most of the houses are owned by Governmental agencies.
31.	Are the basis of land acquisition of the submerged area upon FRL/MWL etc. discussed?	Yes.
	DESIGN	
32.	Has the final location of the head works and appurtenances, in preference to the other sites investigated been discussed?	Yes, Chapter 9 (Volume I)
33.	Has the layout of the project area viz. location of headworks work-shop, sheds, offices, colonies etc. been finalised and discussed?	Yes, Chapters 9 and 19 (Volume I)
34.	Has the layout of various major components of the headworks been discussed in the light of site feature geology and foundation characteristics etc.?	Yes, Chapters 6 and 9 (Volume I).

35.	Have the designs been prepared for the following components and appended? (a) Earth or rockfill dam, masonry or concrete dam, spillway, barrage, weir etc. and appurtenances. (b) Energy dissipation arrangements,training well etc. (c) Opening through dam galleries head regulators, penstocks other outlets, sluices etc. (d) Water conductor system. (e) Power house, tunnels, surge shaft. (f) Instrumentation	Yes, Chapters 9 to 16 (Volume I) and Chapter B-1 to B-9 (Volume III)
36.	Have the assumptions made in the design of above components of the project been indicated and basis of assumption discussed?	Yes, Section B (Volume III)
37.	Have any model studies been carried out for location of the dam, spillway and other appurtenances checking the design profile of the spillway, energy dissipation arrangements, location of outlets/regulators etc.?	Model studies are proposed to be carried out for Dam, Intake and Sedimentation Chambers (Chapter 20 Volume I)

POWER

38.	Have the following points been discussed?	
	(a) Availability of the power generating capacity in the region from different sources.	Yes, Chapter 3 (Volume I)
	(b) Total energy available and peaking capacity of the system.	Yes, Chapter 3 (Volume I)

(c)	Integrated operation of the system and present status of utilisation.	Yes, Chapter 3 (Volume I)
(d)	Surplus and short falls in the system.	Yes, Chapter 3 (Volume I)
(e)	Future plans of power development from different sources in the state/ region	Yes, Chapter 3 (Volume I)
(f)	Fitment of the scheme in planning of power development of the state/region	Yes, Chapter 3 (Volume I)
(g)	Energy generated from the project, firm power, seasonal power and total power	Yes, Chapter 5 (Volume I)
(h)	Proposal for transmission connecting to the existing system/grid	Chapter 18 (Volume I)
(i)	Cost of generation per kWh installed and per kWh generated as compared to the different hydroelectric projects and different sources in the state/region to justify the power component of the project	Cost of generation and sale rate have been worked out as per guidelines issued by Govt. of India. The details are given in Chapter 24 and its Annexures (Volume I).

CONSTRUCTION PROGRAMME AND PLANT AND MANPOWER PLANNING

39.	Are the major components of work proposed to be done departmentally or through contractor?	The construction of main works will be carried out through Construction Division of Jaiprakash Industries Limited in association with any other agency(s) as required.
40.	Have the various alternative for construction programme been studied and proper justification furnished for the final programme adopted?	Yes, Chapter 21 (Volume I)

41.	Has the proposed construction programme been prepared and synchronised for timely completion of each of the major component of work.	Yes, Master Control Network Diagram for the Project has been prepared (Drawing No. 1200-12-01 in Volume V). Bar chart showing construction programme has also been prepared (Drawing No. 1200-12-02 in Volume V).
42.	Have the yearwise quantities of the following materials of construction been worked out for various components of the Project.	
	(a) Excavation - soft & hard strata (b) Earthwork in filling impervious semi pervious and pervious. (c) Rockfill dam, toe, riprap etc. (d) Stone for masonry (e) Coarse aggregate for concrete (f) Sand-filter, masonry, concrete (g) Gravel - filter (h) Steel of various sizes and type reinforcement (i) Cement - normal, quick/slow setting with or without pozzuolana (j) Lime - Surkhi - Pozzuolana (k) Scarce material - special steel (l) Other material - fuel, electricity explosive etc.	Yes, Annexure 21.2, Chapter 21 (Volume I)
43.	Have the yearwise quantities to be executed by machine/labour for each of the major component been worked out for each of the above material?	Yes, Annexure 21.2, Chapter 21 (Volume I)

44.	Have the labour intensive items of the various major components of the project been identified and the quantities of such items worked out?	Project works are highly mechanised. However, for labour intensive items or parts thereof, precise quantities to be worked out during pre-construction stage of the project.
	FOREIGN EXCHANGE	
45.	Have the details of the plant and machinery, spares, instruments scarce materials to be imported worked out and itemwise justified?	The requirement of foreign exchange will be worked out at the stage of finalisation of source of electro-mechanical and construction equipments.
46.	Has the phasing of imports and source of imports been discussed itemwise	- do -
47.	Are the imports to be affected under foreign grants/credits or internal resources of the country?	- do -
	FINANCIAL RESOURCES	
48.	(a) Has the concurrence of the finance Department been obtained?	Not required as it is a Private Sector Project.
	(b) Whether the schemes has already been started? If so, is the present stage of construction indicated?	Only preliminary studies were carried out by HPSEB.
49.	Is the scheme included in the plan? If not what is the present position, regarding its inclusion in the plant?	-----
50.	Have the yearwise requirement of funds been indicated	Yes, Annexure 24.4 (Sheet 3) Chapter 24 (Volume I)
51.	Is the scheme covered under State sector or Central Sector?	-----

52.	Is the scheme covered under any foreign assistance/aid agreement.	-----

ESTIMATE

53.	Is the separate volume of estimate attached as appendix?	Section C (Volume III)
54.	Is the year to which the rates adopted in the estimate indicated?	December 1995
55.	Have the analysis of rates for various major items of work for the major components of the project been furnished with basis for analysis?	Yes, Section D (Volume IV)
56.	Are the provision for the following items made on the basis of sample survey and sub-estimates:	
	(a) Distributaries, minor and sub minors (b) Water courses (c) Drainage	Not applicable

REVENUES

57.	Are the basis for the following sources of revenues furnished?	
	(a) Betterment levy and proposal for its recovery. (b) Irrigation Cess (c) Flood protection Cess (d) Cropwise water rates (e) Sale of water for village water supply (f) Miscellaneous	Not applicable
58.	Have these rates been compared with the existing rates at the other projects in the state/region?	No

59.	In case the rates are being enhanced has the concurrence of the concerned department been obtained?	Not applicable
60.	Have the organisational set up for the collection of revenue been indicated?	Not applicable
61.	(a) Is the area likely to have any of the following environmental and ecological problems due to the altered surface water pattern and preventive measures discussed?	
	i) Excessive sedimentation of the reservoir	No
	ii) Water logging	No
	iii) Increase in salinity of the ground water	No
	iv) Ground water recharge	No
	v) Health hazard-water borne diseases, industrial pollution etc.	No
	vi) Submergence of important minerals.	No
	vii) Submergence of monuments	No
	viii) Fish culture and aquatic life	No
	ix) Plant life-forests	No
	x) Life of migratory birds	No
	xi) National park and sanctuaries	No
	xii) Seismicity due to filling of reservoir	No
	xiii) Any other	No

	(b) Has the concurrence of the environmental appraisal committees has obtained?	Environmental and Ecology aspects have been dealt in Chapter 22 (Volume I) and Appendix 3 (Volume IV).

COLONIES AND BUILDING

62.	Has the planning of the colony/building been done keeping in view the ultimate use for optimum utilisation of the investment?	Yes, Chapter 19 (Volume I)
63.	Has an estimate of the extent of higher cost involved been made and details discussed?	No
64.	Are the permanent buildings being constructed required for maintenance of the project only?	Yes
65.	Can the buildings other than required for maintenance of the project being constructed be put to some other use after the completion of the project by the department or any other agencies?	Yes
66.	Have the interested agencies been consulted in planning of the buildings to suit their requirements later on?	Not applicable
67.	Have the proposals for disposal of temporary buildings been discussed?	- do -

PUBLIC PARTICIPATION AND COOPERATION

68. Are the possibilities of these been discussed in:

(a) Planning (b) Construction (c) Improved agricultural practices (d) Any other	No

SOIL CONSERVATION

69. Is the need for soil conservation measures in the catchment of the project discussed?

Yes, Chapter 22 (Volume I). Provision for catchment area treatment and soil conservation works have been made in the estimate (Annexure C-2.18, Section C, Volume III).

Chapter - 1

INTRODUCTION

1.1 General

Despite the appreciable growth in energy production in India during the period 1947 to 1990, power demand has almost throughout surpassed supply. In 1990, at the end of the 7th Energy Plan, the shortfall in energy availability for India as a whole was 6.8%, while the corresponding shortfall in peak availability vis-a-vis demand was 7.6%. However, by July 1991, the shortage in energy and peak power availability jumped to 7.9% and 16.7%, respectively.

Forecasts in the 8th Energy Plan (1992-97) had estimated that an additional installed capacity of 48,000 MW, later down-scaled to 30,558 MW, was necessary to satisfy the country's energy and peak power requirements. Nevertheless even with this planned capacity addition, shortages at the end of 8th Plan are expected to continue at the 1994 levels of 8% in energy and 19% in peak power. Moreover, the situation is likely to get worse as slippages are anticipated in the plan.

In India, development of the power sector has been so far the responsibility of the Government, with a relatively small contribution of the private sector. However, it was realized that the resources needed to solve the power deficit were beyond the reach of the public sector alone. In this background, the Government of India decided to create additional power generation capacity to bridge the gap in its demand and supply by encouraging greater investment by private enterprises in the electricity sector. This decision has been implemented with the passing of legislation to allow private investors to set up generating companies which would supply bulk power to the grid and to bulk consumers as well. Due to teething troubles of transition, the new system has yet to acquire a stable regime. However, with the growing demand and increasing shortage of power in the country, a determined push is more than indicated and justified.

India is endowed with a vast hydro-power potential, assessed at 84,000 MW at 60% load factor. Of this, some 30,000 MW are located in the northern region of the country, which has a projected shortage of 27% in peak power availability for the period 1994-95.

The Karcham-Wangtoo Hydro-Electric Project with its planned installed capacity of 1,000 MW can help fill to some extent, the gap in power supply and its demand in the country and, more particularly, in the northern region.

1.2 Development of Karcham-Wangtoo Project

The Karcham-Wangtoo Project forms part of an overall plan of development of the Satluj river Basin hydro-power potential sponsored by the Government of Himachal Pradesh (GOHP).

As a result of changes in the legislation, the Government of Himachal Pradesh took an early initiative in inviting private participation in the development of projects which had been identified and investigated to a certain extent by the Himachal Pradesh State Electricity Board (HPSEB), and authorized by the Central Electricity Authority (CEA), for investigation and implementation. The Karcham-Wangtoo Project is one of these projects for which the Government of Himachal Pradesh State invited offers for its development and subsequently awarded to Jaiprakash Industries Limited (JIL), a private hydro-power developer on `Build, Own and Operate' basis.

The Karcham-Wangtoo Hydro-Electric Project is located on the Satluj river in Himachal Pradesh State (Drg. No. 1200-00-01, Vol. V) and has an estimated capacity of 1,000 MW as per the present study. Under the terms of a Memorandum of Understanding (MOU) signed with the GOHP, JIL is required to carry out the requisite detailed investigations and techno-economic studies of the project and to submit a detailed project report (DPR) to the State Government within a period of 30 months (i.e. by February 1996). The DPR was accordingly submitted by JIL to GOHP and CEA in February 1996 after carrying out required detailed surveys investigations and techno-economic studies. Implementation agreement has been entered into between GOHP and JIL on 18th November, 1998 to develop the Project.

1.3 Previous Studies

Prior to JIL's take over of the Karcham-Wangtoo, the project had been studied by the HPSEB and Geological Survey of India (GSI) for several years. As a result of this and based on a conceptual layout of development, topographical maps of the project area were prepared and geological campaigns organized to carry out geological mapping of the dam site and sub-surface geotechnical investigations in the river bed and right abutment. Measurements of river discharges near the proposed dam site were also conducted but not in a continuous manner.

These investigations have been useful but clearly insufficient to establish the feasibility of a project of the magnitude of Karcham-Wangtoo.

1.4 Field Investigations carried out for DPR

In view of the importance and size of the project, a comprehensive plan of investigations and studies was prepared and implemented. The following surveys/investigations were carried out:

1. **Topographical Survey (Scales 1:1000 and 1:500)**

    - Reservoir area
    - Dam area
    - Intermediate adits
    - Power house complex
    - Infrastructure works
    - Dumping areas.

2. **Collection of Hydrographic Data**

    - River discharge and levels
    - Suspended load sampling

3. **Geotechnical Exploration**

    - Geological mapping
    - Diamond drilling
    - Exploratory drifts
    - Test pit/trench excavation
    - Permeability tests in boreholes.

4. **Geophysical Investigations at Dam Area**

    - Seismic refraction studies
    - Electrical resistivity studies.

5. **Aerial Photo Interpretation along the Tunnel Alignment**

    - Certification of various lineaments, faults and shear zones, etc.

6. **Field Tests on Rocks**

- Determination of in situ stresses by hydro-fracturing method
- Determination of modulus of deformation by plate jacking tests
- Point load index tests.

7. **Laboratory Tests**

- Petrographical and petro-fabric analysis of sediment
- Petrographical examination of rock samples
- Tests on aggregates.

8. **Environmental and Ecological Surveys**

- Social environment
- Flora and fauna
- Impact evaluation.

A number of well-known expert organisations and individual experts were associated in carrying out these investigations. Some of the Indian institutions which were associated are as below:

(1) National Institute of Rock Mechanics (NIRM)
(2) Irrigation Research Institute, Roorkee (IRI)
(3) University of Roorkee, Roorkee (UOR)
(4) Indian Institute of Technology, Delhi (IIT)
(5) Geological Survey of India (GSI)
(6) National Remote Sensing Agency (NRSA).

1.5 Studies Carried out for DPR

The studies/analysis as below were carried out for finalisation of layouts and preparation of preliminary designs and drawings for the various components of the project:

1. **Hydrological Studies**

(a) **Flow for Power Generation**

- Computation of 90% availability and 50% availability discharges.

- Derivation of annual flow duration curve.

(b) **River Discharge and Level**

- Water profile along Satluj river upstream and downstream of tunnel outlet
- Stage discharge curve at Karcham dam site
- Stage discharge curve at outlet structure site
- Reservoir area capacity curves.

(c) **Flood Studies**

- Flood peak statistics
- Regional flood statistics
- Comparison and reconciliation
- Maximum probable flood
- River diversion design flood.

2. **Power Studies**

- Network characteristics
- Definition criteria
- Optimization of draw down
- Optimization of tailrace location
- Optimization of installed capacity
- Optimization of headrace tunnel diameter
- Potential of river diversion.

3. **Diversion Works**

- Diversion scheme
- Design flood
- Optimization of tunnel size
- Optimization of intake structure design
- Coffer dams (upstream and downstream)
- Type and extent of cut-off walls
- Coffer dam protections
- River closure.

4. **Diversion Dam**

- Spillway design flood
- Spillway variants
- Spillway optimization
- Flip bucket profile
- Stability analysis of dam (overflow and non-overflow).

5. **Reservoir**

- Reservoir sedimentation
- Sediment grain size distribution
- Bed load estimation
- Risk of land slides in reservoir.

6. **Power Intake**

- Optimization of shape and velocity at trash racks
- Computation of minimum submergence.

7. **Sedimentation Chambers**

- Determination of size of sediment to be diverted
- Optimization of shape, length and flow through velocity in the chambers
- Optimization of size of openings at bottom
- Optimization of flushing conduits.

8. **Headrace Tunnel**

- Computations of flow characteristics
- Optimization of alignment
- Optimization of location and length of intermediate adits
- Design of support system in various types of rock.

9. **Surge Shaft**

- Optimization of Location
- Oscillation characteristics

- Optimization of height / cross sections
- Structural design.

10. **Pressure Shafts**

- Optimization of diameter
- Length of steel lined penstocks
- Rock participation
- Steel liner thicknesses.

11. **Underground Power House Complex**

- Alternative arrangements and locations
- Sizing the various cavities
- Checking the stresses around cavities by FEM analysis
- Roof and wall support system for the cavities.

12. **Tailrace Works**

- Optimization of diameter of TRT
- Hydraulics at outlet structure.

1.6 Detailed Project Report

Based on the investigations and studies as detailed above, this DPR has been prepared in five volumes as below:

Vol. I	Report
Vol. II	Electro-mechanical Works
Vol. III	Engineering and Costing
Vol. IV	Appendices
Vol. V	Drawings

Chapter - 2

PROJECT AREA

2.1 Introduction

The Government of India and the State of Himachal Pradesh have identified the Satluj river as one of the main promising future sources of hydro-electric power. Development of Satluj waters was started in a big way by Bhakra-Nangal Project. Government have now initiated several hydro-electric projects along the reach of the Satluj and its tributaries. The Karcham-Wangtoo Hydro-Electric Project is envisaged as a run-of-the-river development on the Satluj river, in the reach between Karcham and Wangtoo villages in Kinnaur district of Himachal Pradesh just upstream of Nathpa-Jhakri Hydro-Electric Project presently under construction.

2.2 Location and Access

Himachal Pradesh is located in the western portion of the Great Himalayan Mountain Range of northern India, bounded by the State of Jammu-Kashmir to the North, Tibet to the East, and the plains of northern India to the South and West. The Satluj river is one of the major rivers draining this region. It rises in the Tibetan Plateau, passes via steep valleys and gorges through the Himalayan Mountains and foothills and meets the Arabian sea across the plains of Northern India.

The project site area is about 200 km from Shimla, the State capital, on National Highway 22 and is an immediate upstream development to the Nathpa-Jhakri Hydro-Electric Project (1500 MW) on the Satluj river.

2.3 Climate

The study region is on the dividing line between climatic zones I and III of northern India. Zone I, the Tropical Monsoon climate, extends from the Indian Ocean north as far as Wangtoo, with its effects modified by elevation and topography. The tropical monsoon climate involves an annual rainfall in excess of 1000 mm, occurring mostly in the months of June to October. The study region, however, experiences little rainfall as the mountains between the plains and the study region capture most of the precipitation.

Climatic Zone III, the Arid Mountain Climate, affecting the Tibetan and western China Plateau, is characteristically cold and dry in winter, and hot and dry in summer. This is highly modified by the topography of the study region. From November to May, the region experiences a generally north-easterly flow of cold continental air moving out from across the Tibetan Plateau. The effect of this flow is somewhat modified by the mountains but it can result in high winds. Winter precipitation occurs as a result of westerly disturbances. From June to September, the region experiences the south-westerly monsoon from the Indian ocean, though, once again the region's location in the heart of the Himalayas modifies the effect, and precipitation is small.

2.4 Geology

The project area lies in Mehbar and Maldi gneisses comprised of kyanite and psamatic gneisses with bands of schist and quartzite. These are intruded by basic and acidic rocks. All the rocks are well foliated. The general trend is N-S with moderate dips toward East. These are transected by a number of joints of which the foliation and strike joints are the most predominant followed in frequency by steeply dipping transverse joints. The rock formations within the project area going upstream from the tailrace consist of the Wangtoo, Rampur and Jutogh gneisses and granites. The Wangtoo rocks are overlaid by the Rampur followed by the Jutogh, the three series having thrusted contacts.

Rocks are generally covered by glacial deposits, rock debris, alluvial terraces and fans. The soils of the Satluj valley are relatively poor sandy loam, and exposed bedrock, rocks and gravel abound. In the valley bottom there is virtually no soil, but between elevations 1200 and 3500 m, the soils support some forest cover and are cultivable to a certain extent.

2.5 Seismicity

The project area lies in an active seismic region, zone IV of the Seismic Zoning Map of India. Available data on seismicity within a radius of 150 kms of the project shows that earthquakes having a magnitude greater than 5 on the Richter scale occur at frequent intervals. Important seismic events which have taken place in the past 150 years and caused significant damage include the 1905 Kangra quake (magnitude 8+), the 1908 Kullu quake (magnitude 6.0), the 1945 and 1947 Chamba quakes (magnitude 6.5 & 6.6), the 1975 Kinnaur quake (magnitude 6.8) and the 1991 Uttarkashi quake (magnitude 6.6).

2.6 Socio-economic Characteristics

The Kinnaur region has deep roots in Indian mythology, legends and literature. The kinnaur region was formerly a part of the princely state of Bushahr. The State of Himachal Pradesh came into existence in 1960 and Kinnaur became a district. Contact with the outside world accelerated when National Highway 22 was built by the Border Roads Organization, following the 1962 Sino-Indian war. One immediate consequence of the road construction was that Kinnaur became integrated into the cash economy of Himachal Pradesh. The State has continued to play a role in introducing techniques and policies that have enhanced production despite the poor soils of the area.

The people in the study area have developed a culture that is distinctive for two reasons. First, they live in a socio-economic environment officially designated as "depressed" and they were designated as "scheduled castes" and "scheduled tribes". Prior to 1960, they were semi-nomadic and sought opportunities to enhance their economic base and to forge alliances with political and religious factions. Since the 1960s, the economic base has expanded to encompass horticulture which was being promoted in the State. This has become a highly profitable growth industry in the area. Kinnaur is the most important producer of apples in a State famous for them. Secondly, the study area is home to two distinct groups with common subsistence and trade practices. Over the centuries, these groups retained their differences and developed shared values which has resulted in "scheduled castes" and "scheduled tribes", Hindus and Buddhists, with temples and monasteries existing side by side in the villages.

2.7 Satluj river Hydro-power Development

The Government of India and the State of Himachal Pradesh have identified the Satluj river as one of the main sources of hydro-electric power, and have initiated several hydro-electric projects along the reach of the river and its tributaries under their jurisdiction. These projects, in varying stages of planning, construction, completion and operation, include:

- Bhakra-Nangal, 1164 MW, operating
- Kol, 800 MW, concept stage
- Rampur-Behna, 400 MW, concept stage
- Nathpa-Jhakri, 1500 MW, under construction
- Karcham-Wangtoo, 1000 MW, preliminary planning

- Shongtong-Karcham, 200 MW, concept stage
- Suni, 225 MW, concept stage
- Thopan-Powari, 220 MW, concept stage
- Jhangi-Thopan, 175 MW, concept stage
- Khab, concept stage.

These projects are all run-of-the-river, with the exception of Bhakra-Nangal. Additional hydro projects, planned and operating, have been identified on tributaries of the Satluj, such as Sanjay Vidyut Pariyojana-Bhaba (120 MW, operating), Nagli (3 MW, operating), Ghanvi (planned), Baspa II (300 MW, under construction) and Baspa I (concept stage). Some of the potential projects listed here may not be built in near future, but it is reasonable to assume that the preliminary studies have indicated these projects to be technically feasible, there will be a strong motivation to build them as the demand for power grows and limited fuel resources tend to exhaust.

Further developments, in addition to those listed here, may at some time be seriously considered on both the Satluj and its tributaries. A program to develop small hydro projects on streams flowing through villages is also in place.

2.8 Neighbouring Projects

Two hydro projects are presently under construction near the Karcham-Wangtoo planned development.

Nathpa-Jhakri

The Nathpa-Jhakri Project, located downstream of Wangtoo, is a joint enterprise between the Central Government of India and the Government of Himachal Pradesh with the World Bank's assistance. It comprises a 60 m high concrete gravity diversion dam (above foundation level) built on the Satluj river at Nathpa, about 4 km downstream of Wangtoo village, a 28 km long circular power tunnel and an underground powerhouse located at Jhakri, with an installed capacity of 1500 MW (6x250 MW). The catchment area at Nathpa dam site is 49,820 km^2, compared with 49,175 km^2 at Karcham. The plant will utilize the available 488 m gross head between Nathpa and Jhakri under a 405 m^3/s turbine design discharge. The plant will be basically operated as peaking plant.

The development and operating scheme of Nathpa-Jhakri is very similar to that of Karcham-Wangtoo.

Baspa II

Baspa II is one of the first projects being taken up in the private sector under the new Government of India's policy guidelines. It is an upstream development to the Karcham-Wangtoo hydro project on the Baspa river, a left bank tributary of the Satluj river. The catchment area at the dam site is 968 km^2.

The Baspa II hydro project is essentially a run-of-the-river development that will be operated as a peaking station that will supply the Northern Regional Grid. The installed capacity will be 300 MW comprising three vertical axis Pelton units of 100 MW each, under a 716 m gross head (the net head is 682 m) and a 52 m^3/s design discharge. The diversion barrage is being built on the Baspa river at Kuppa village, near Sangla, while the power-house, located near Karcham, will discharge in the Satluj river. The length of the headrace tunnel is approximately 7.95 km.

2.9 Previous Project Studies

Project Layout

Development of the Karcham-Wangtoo Project was envisioned many years ago when preliminary studies of the Satluj potential identified the Karcham dam and the Wangtoo power-house sites. However, it is from the early 1980s when significant efforts to develop the project have taken place. Planning and geological studies by the Himachal Pradesh State Electricity Board and the Geological Survey of India (GSI) were carried out and, as a result, some basic information on the project became available. This work allowed investigators to formulate a conceptual layout of development for Karcham-Wangtoo (Figure 2.1) within the context of the Satluj overall hydro-power development plan.

The conceptual project layout develops the Satluj river potential between the villages of Karcham and Wangtoo, in the Kinnaur District of Himachal Pradesh. The project was conceived as a run-of-the-river development between the current sites for the Karcham dam and the Wangtoo power-house, and included a concrete gravity dam 43 m above the river bed, a 10.3 m diameter, 17.2 km long headrace tunnel, and an underground power-house with 4-250 MW installed capacity. This preliminary layout has been the basis for subsequent field investigations, and alternative studies.

Field Surveys

Before the Karcham-Wangtoo Project was awarded to JIL for further feasibility investigation, the State and the GSI had carried out investigations on various disciplines to enhance the project database. They are briefly described below:

(a) **Hydrology**

Daily measurements of river discharge at the Karcham station, located 200 m downstream from the dam site, have been conducted since 1982 to date, although not continuously.

(b) **Topography**

Survey of India carried out a topographical survey on 1:10,000 scale with 10 m contour intervals of the project area (the Satluj right bank).

(c) **Geological**

One test drift was excavated at the proposed dam site during 1984-85. The drift was excavated at elevation 1780 m in the right abutment, close to the contact between the gneiss and the quartzite. In order to investigate the shear zone contact, the drift was supplemented in 1985-86 with two branches perpendicular to the main drift, one in the upstream direction and the other in the downstream direction. The total length of the drift is 109 m.

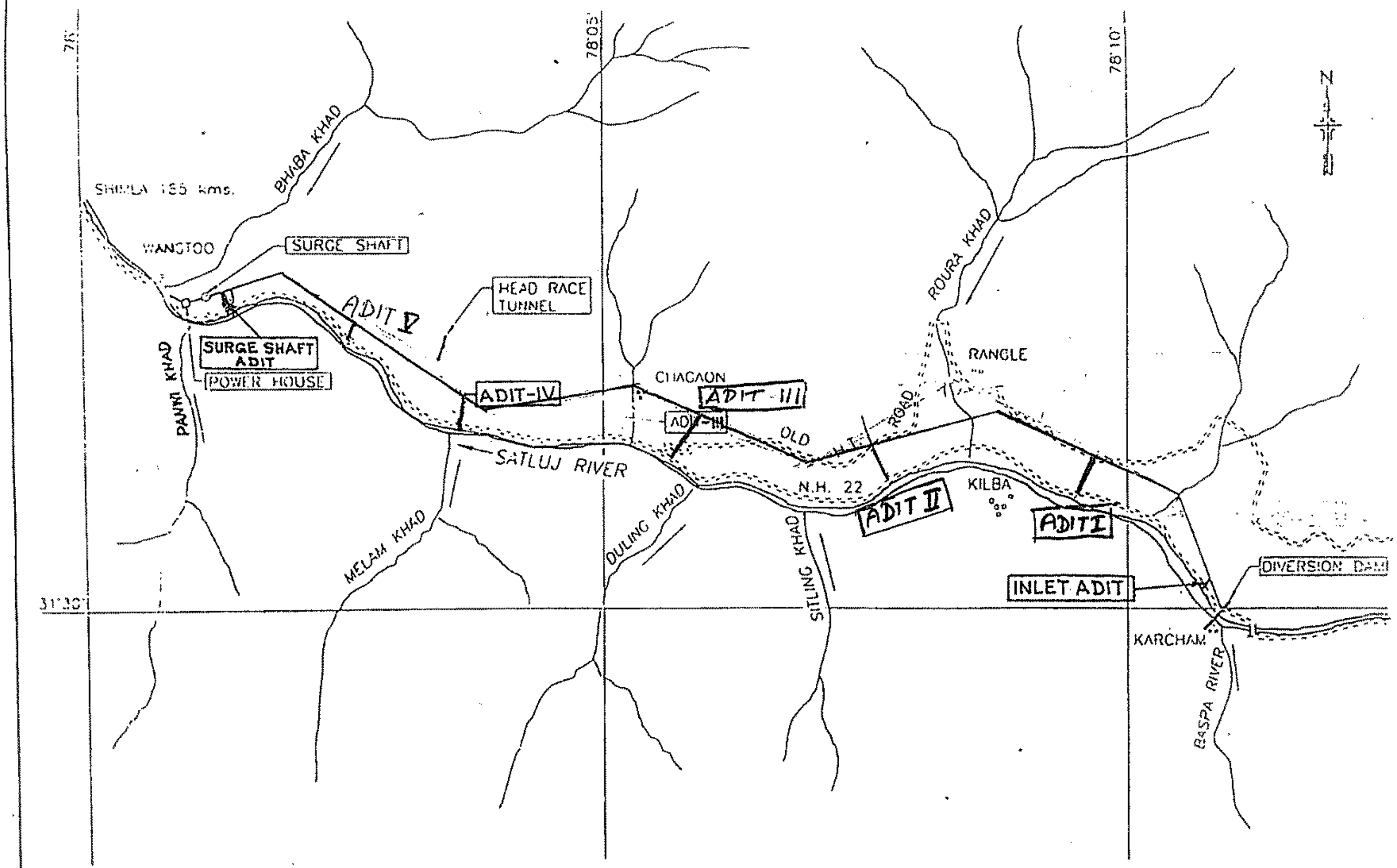
Three drill holes were carried out at the proposed dam site:

No.	Elevation	Total Depth	Depth of Rock	Year
DH-1	1773.00 m	58.25 m	39.9m	1986-87
DH-2	1784.20 m	52.40 m	30.5m	1986-87
DH-3	1786.76 m	51.29 m	log not available	1989

2.10 Drawings

Following drawings about the project area have been included in Volume V of the Report.

S. No.	Drawing No.	Title
1.	1200-00-01	Karcham-Wangtoo Hydroelectric Project - Location Map
2.	1200-00-02	Satluj river basin - Drainage area



KARCHAM-WANGTOO HYDROELECTRIC PROJECT
CONCEPTUAL PROJECT LAYOUT

FIGURE 2.1

Chapter - 3

POWER SCENARIO

3.1 Sources of Energy

India is endowed with a vast hydropower potential. As per the latest assessment carried out by the CEA, exploitable hydro potential in India has been estimated at about 84000 MW at 60% load factor, which can yield an annual power generation of over 440 TWh of electricity and with additional seasonal energy, the total energy potential is about 600 TWh a year. Only 14.5% of this potential is under operation and 7.2% of the potential is under execution. Thus the bulk of the potential amounting to 77.9% is yet to be developed (see Table 3.1).

The bulk of the potential is available in Arunachal Pradesh at 26756 MW, followed by Himachal Pradesh at 11647 MW, Uttar Pradesh at 9744 MW and Jammu & Kashmir at 7487 MW.

Table 3.1

Status of Development of Hydropower Potential

SI No	Region	Potential at 60% L.F. MW	Potential already developed		Potential under development		Total Potential Development		Potential yet to be developed	
			MW	%	MW	%	MW	%	MW	%
1	Northern	30155	3955	13.1	2308	7.6	6263	20.7	23892	79.2
2	Western	5679	1764	31.1	1585	27.9	3349	59.0	2330	41.0
3	Southern	10763	5274	49.0	1098	10.2	6372	59.2	4391	40.8
4	Eastern	5590	868	15.5	726	13.0	1594	28.5	3996	71.5
5	North-East	31857	314	1.0	305	1.0	619	2.0	31238	98.1
Total (India)		84,044.60	12175	14.5	6022	7.2	18197	21.7	65847	77.9

About 73% of India's total installed capacity is thermal-based (Table 3.2). However expansion of this energy source is encountering difficulties because of the burden it places on the infrastructure for supply (mines) and transportation (railways) of coal. Considering that the capacity of Indian Railways to carry coal effectively is limited and additional tracks are required, and the coal is of low quality and costly to transport over long distances, it appears logical to develop thermal projects in specific areas, e.g. coal-based projects in Bihar, Orissa, Eastern Uttar Pradesh and surrounding areas, and gas-based power near the port belts of Gujarat and Maharashtra, and place total emphasis on hydropower in States such as Himachal Pradesh, Punjab, Haryana, Western Uttar Pradesh and far-East India - the Himalayan belt.

Table 3.2

Share of Hydropower in India's Installed Capacity

Year	Total Installed Capacity (MW)	Hydropower Capacity (MW)	Share of Hydropower (%)
1962-63	5801	2936	50.6
1969-70	14102	6135	43.5
1979-80	28448	11384	40.0
1989-90	63636	18308	28.8
1991-92	69070	19189	27.8
1993-94	76718	20366	26.6

In the Northern Region, hydropower is the most suitable source of power since both thermal/nuclear or other fuel-based source of energy involve carriage of raw material over long distances making the cost of development uneconomical. There are no thermal-based power projects in Himachal Pradesh.

3.2 Hydropower Potential of Himachal Pradesh

Himachal Pradesh along with the States of Jammu & Kashmir and Punjab form part of the Great Indus Basin. This basin comprises six major rivers, viz., Indus, Jhelum, Chenab, Ravi, Beas, and the Satluj, and drains a total area of 1.16×10^6 km^2 of which 0.17×10^6 km^2 lies in India. A total of about 190 hydropower schemes have been identified in the Great Indus Basin having a firm hydropower potential of 11993 MW at 60% load factor.

According to the CEA in its publication "Hydro Electric Power Potential of India", December 1988, in various States and river basins in the country. As per this publication, the total potential in Himachal Pradesh is 11578 MW at 60% load factor, with an installed capacity of 18715 MW.

The Satluj basin in Himachal Pradesh has a hydropower potential of 6272 MW, which represents approximately 33% of the likely installed capacity in Himachal Pradesh. Five schemes in the Satluj are already in operation and total 1290 MW. The remaining 4980 MW potential is yet to be developed. Two major projects in the basin have been taken up for construction recently: the 1500 MW Nathpa-Jhakri, a joint enterprise between the Central Government and the Government of Himachal Pradesh, and the 300 MW Baspa II Project, a privately-financed development sponsored by the State Government.

Besides Nathpa-Jhakri and Baspa II, the following projects in the Satluj basin have been identified and form part of the river unexploited potential.

Kol Dam	800 MW
Suni	225 MW
Rampùr-Behna	400 MW
Karcham-Wangtoo	1000 MW
Shongtong-Karcham	200 MW
Thopan-Powari	220 MW
Jhangi-Thopan	175 MW
Ghanvi	22.5 MW

The proposed Karcham-Wangtoo Hydroelectric Project has a capacity of 1000 MW and is located on the Satluj River, between the Nathpa-Jhakri and the Baspa-II Projects.

In addition to the Satluj, other rivers which are part of the Great Indus Basin and pass through the State of Himachal Pradesh, also contribute to the power potential of the State. The most important are : Beas River, 3880 MW; Ravi River, 1250 MW, Chenab River, 1024 MW.

Himachal Pradesh thus has considerable hydropower potential. In the long run, it is more economical for development than thermal power, as it utilises perennial natural resource which otherwise goes to waste. For the prosperity of the state and benefit of the country the hydro-power development in Himachal Pradesh needs a renewed thrust. The hydroelectric potential of Himachal Pradesh, however, is not likely to be consumed in the State, and therefore will be available for meeting the requirements in other parts of the country, and particularly in the Northern Region.

3.3 **Thermal Power Potential in Himachal Pradesh**

Himachal Pradesh being located in the far North end of the country and considerably away from the coal fields, does not have any prospect of having thermal projects. The same consideration applies to other northern states.

3.4 **Demand and Supply**

3.4.1 **Power Scenario in India**

The installed capacity in India increased from 1362 MW in 1947 to 64,729 MW in 1990 at the end of the 7th Plan. During that period energy jumped from 4 to 264 TWh. However, despite that appreciable growth, power demand has almost throughout outstripped the supply.

At the end of the 7th Plan, the shortfall in energy availability on an " all India " basis was 6.8%. The corresponding shortfall in peak availability vis-a-vis demand was about 7.6%. In the Northern Region, the shortage with regard to peak availability was 19%. In July 1991, the peaking shortage for the country as a whole increased to 16.7% from 7.6% in March 1990 while the energy shortage rose to 7.9% from 6.8%.

For the 8th Plan(1992-97), the Central Electricity Authority (CEA) had estimated a need based capacity addition of 48000 MW,which was scaled down to 30 558 MW taking into account the availability of resources. At the end of 1997-98 India had an energy shortage of 8.1% and a peaking shortage of 11.3%. Even with the planned capacity addition of more than 30,000 MW, the shortages in the terminal year of the 8th Plan, i.e. 1997, would continue to be at the same level. As a matter of fact the situation is likely to be worse as slippages are anticipated in the planned capacity addition.

3.4.2 **Demand and Supply in Himachal Pradesh State**

Himachal Pradesh, being mostly a hilly terrain State and located in the far North end of the country, considerably away from the coal fields, has little prospect of having thermal projects. Having considerable hydropower potential, which is generally found to be more economical for development than thermal power, power generation in the future for Himachal Pradesh has to be essentially from hydro-power sources.

As per the 14th Electric Power Survey of India, carried out by the Central Electricity Authority (CEA), the energy requirement of Himachal Pradesh for 1990-91 was 1487 GWh. This demand was projected to increase to 2536 GWh in 1994-95. Similarly, the peak load requirement for 1990-91 was 325 MW, which was expected to increase to 541 MW in 1994-95.

Table 3.3 shows the supply of energy and power as well as future demand during the period 1990-91 to 1994-95 as projected by Central Electricity Authority (CEA) in the 14th Electric Power Survey of India.

An examination of the above figures indicates that while there will not be any deficits as far as energy demand and supply are concerned; however, there would be a deficit of 5.3% in the supply of peak load in 1991-92, which would increase to 12.2% in 1994-95.

Table 3.3

POWER SUPPLY AND DEMAND FOR HIMACHAL PRADESH, PERIOD 1990-95

Item	Unit	1990-91	1991-92	1992-93	1993-94	1994-95
Installed Capacity	MW	274	274	296	301	301
Peak Availability	MW	340	347	379	458	475
Peak Load	MW	325	366	415	477	541
Surplus/Deficit	MW %	15 4.6	- 19 - 5.2	- 36 - 8.7	- 19 - 4.0	- 66 - 12.3
Energy Availability	GWh	2013	2047	2147	2521	2711
Energy Requirement	GWh	1487	1688	1925	2224	2536
Surplus/Deficit	GWh %	526 35.4	359 21.3	222 11.5	297 13.4	175 6.9

During the period 1990-95, the total addition to the State's installed capacity would be 27 MW through three projects: Baner (12 MW); Gaj (10.5 MW), and Thirot (4.5 MW).

The future demand scenario for the period 1995-2010 as projected by the CEA in the 14th Electric Survey Report with respect to Himachal Pradesh is as depicted in Table 3.4.

Table 3.4

Energy and Peak Load Demand for Himachal Pradesh
Period 1995 to 2010

Period	Energy Demand (GWh)	Peak Demand (MW)
1995-96	2879	609
1996-97	3254	683
1997-98	3662	763
1998-99	4103	848
1999-2000	4576	939
2004-05	7378	1457
2009-10	10606	2020

It can be observed that energy requirements are likely to increase during the period 1991-2000 from 1487 GWh in 1990-91 to 4576 GWh in 1999-2000, and the peak load demand would do increase from 325 MW to 939 MW during the same span. The deficit would be mostly met by H.P's share from Central Sector Projects i.e. Chamera II and Nathpa-Jhakri.

3.4.3 Demand and Supply in the Northern Region

The hydro-power potential of Himachal Pradesh, is obviously surplus to its own requirement. However, it will be usefully made available to meet the power and energy requirements in other parts of the country, and very particularly, the Northern grid. This is the case of major projects such as Bhakra and Beas, which supply power to the Northern grid. Another example is the 540 MW Chamera Project, situated in the north-western part of the State, which started operating in 1994 and supplies New Delhi through a 510km long transmission line. For planning purposes it is therefore necessary to study the energy and power requirements of the Northern region as a whole, since the region will be the recipient of any hydropower project likely to be developed in Himachal Pradesh in the future.

On the basis of the addition of capacity during the 8th Plan period, the CEA has estimated the requirements of the Northern Region as shown in Table 3.5.

Table 3.5

Power Demand and Supply for the Northern Region in the Period 1990-95

Item	Unit	1990-91	1991-92	1992-93	1993-94	1994-95
Installed Capacity	MW	19203	20581	22195	24274	26681
Peak Availability	MW	11408	11291	12777	14008	15271
Peak Load	MW	14908	16259	17721	19240	20814
Surplus/Deficit	MW %	- 3500 - 23.5	- 4338 - 26.7	- 4944 - 27.9	- 5232 - 27.2	- 5543 - 26.6
Energy Availability	GWh	80803	82755	88165	95959	106143
Energy Requirement	GWh	79338	86553	93396	102416	110841
Surplus/Deficit	GWh %	1465 1.8	- 3798 - 4.4	- 6231 - 6.6	- 6457 - 6.3	- 4698 - 4.2

It is observed that by 1994-95 although there will be marginal deficit in energy availability, the deficit in peak availability is likely to increase from the present level of 23.5% to 26.6%, despite the addition of installed capacity of about 7400 MW in the five-year period in the Northern Region. Table 3.6 lists the future energy and load requirements for the Northern Region.

Table 3.6

Energy and Peak Load Demand for the Northern Region
Period 1995-2010

Period	Energy (GWh)	Peak Load (MW)
1995-96	119887	22466
1996-97	129587	24234
1997-98	139976	26124
1998-99	151086	28143
1999-2000	162954	30295
2005-06	248332	45634
2009-10	318715	58117

From Tables 3.5 and 3.6, it can be seen that the peak demand over a period of 10 years is likely to double from 14908 MW in 1990-91 to as much as 30295 MW in 1999-2000.

3.5 Private Participation in the Power Sector

From the aforesaid, it will be seen that power and energy potential of Karcham-Wangtoo can be effectively used to reduce deficit in Northern States.

In India, development of the Power Sector has so far been primarily the responsibility of the Government, with a relatively small contribution from private enterprises. However, it is now realised that the resources needed to set up enough capacity to make a dent in the power deficit are enormous to be mobilised by the public sector alone. As mentioned previously even with the planned addition of over 30000 MW, shortages by 1997 are expected to continue and even to get worse.

In this background, the Government has resolved to mobilise additional resources to help bridge the gap in the demand and supply by encouraging greater investment by private enterprises in the electricity sector. In order to implement this decision the Government has amended the legislation governing the electricity sector, allowing private investors to set generating companies which would supply power in bulk to grid and to bulk consumers as well. The policy on private sector development has been enhanced with a number of incentives to make electricity generation, supply and distribution attractive to private entrepreneur in India and abroad.

The Government of Himachal Pradesh, having a large hydropower potential, took an early initiative in inviting private participation in the development and utilisation of its untapped potential. Thus, several projects with a combined potential of over 2000 MW have been awarded to private developers for study and/or implementation. The 1000 MW Karcham-Wangtoo is one of these projects to be implemented in the private sector, which can meet power and energy requirement of northern states.

Chapter - 4

HYDROLOGY

4.1 General

The Satluj river originates from Mansarovar Lake in Tibetan Plateau at an elevation of about 4570m above sea level. The river first passes through the Tibetan province of Nari Khorsam, most of which lies in the plateau situated between the Zaksar and Ladakh ranges of Himalayas. As there is no vegetation in the area, the water resulting from snow melt forms deep channels on the surface of the plateau. The Satluj river enters India near Shipkila after having flowed about 300 km in Nari Khorsam province.

Just after entering India, the Satluj receives its biggest tributary, the Spiti river, whose morphology is similar to that of Tibetan plateau. Other main tributaries downstream of the Spiti confluence down to Wangtoo are the Kashming, Baspa and Bhaba. The Baspa river joins the Satluj about 250m upstream of Karcham dam site, while the Bhaba river discharges into the Satluj near the tailrace of the planned Wangtoo underground powerhouse about 100m upstream of Wangtoo bridge.

The fall of Satluj from its source to plains of India is very uniform. The height of bed is about 4570m near Rakas Tal, 2530m near Shipkila, 915m at Rampur, 460m at Bilaspur and 350m at Bhakra dam site.

The total catchment area of the Satluj above the Bhakra dam site is about 56875 sq.km and above the Karcham diversion dam site is about 48755 sq.km. From Bhakra to Wangtoo the drainage area is comparatively narrow with an average width of about 35 km. The river Satluj drains an area of about 49750 sq.km at Wangtoo discharge site.

The reservoir at Karcham dam site will extend for about 4.4km along Satluj river and 1.2km along the Baspa tributary.

4.2 Availability of Data

There are river gauging stations in Satluj basin at Shongtong, Karcham, Wangtoo, Nathpa, Jhakri, Rampur, Kasol, Bhakra and on some of the tributaries of river Satluj namely Spiti, Baspa, Bhaba, Sholding, Ghanvi, Sir, Sukar etc. The longest length of record is available at Bhakra (Olinda) from 1909 (continuous since 1926). At Rampur and Wangtoo the observations are available since 1963 and 1966 respectively. The Karcham gauge site has been collecting gauge discharge readings since 1985. For present study the data of Karcham, Wangtoo and Nathpa have been obtained and checked for consistency. The data of Nathpa is based on long term data available from Rampur gauge site. It is seen that the average non-monsoon runoff at Nathpa and Wangtoo stations are similar. By comparison, the Karcham data for the same period is significantly lower. A comparison of Karcham and Wangtoo discharges during April-May by actual discharge measurement shows that Karcham flows are about 90% of flows at Wangtoo.

By the observations and regression tests carried out it has been considered that Wangtoo bridge data is consistent with the Nathpa flow data and the same can be adopted for design purposes.

4.3 Water Availability

Ten daily discharges at karcham site are available for a continuous period of 34 hydrologic years (1966-67 to 1999-2000). For computation of 90% and 50% dependable discharges, the full year (October to September) run off volumes of hydrologic years have been arranged in descending order of magnitude and exceedence frequency computed using Weibull's plotting position formula $\frac{m}{N+1}$.

The hydrologic years 1973-74 and 1994-95 have been adopted as 90% dependable and 50% dependable years respectively. The ten-daily discharges for these years are presented in Table 4.1.

4.4 Design Flood

Flood estimation for Karcham dam site has been carried out using following methods:-

1. Gumbel's Method
2. Gumbel's Method with confidence limit
3. Chow's Method

Annual flood peaks are available for a period of 34 years (1966-67 to 1999-2000). These values of observed flood magnitudes have been analysed using different flood frequency distributions.

The results of these studies are provided in Table 4.2

It will be read from Table 4.2 that for a return period of 1 in 100 year magnitude of flood will be of the order of 6097 cumec while for 1 in 1000 return period the flood will be of the order of 8260 cumec since about 80% catchment area of Satluj is in China for which hydrological data is not available, it is proposed to use design flood of 8260 cumec for design of spillway at Karcham Dam.

4.5 Non-monsoon Flood

To provide protection during construction of the diversion dam, river diversion works have to be carried out. The magnitude of the flood to be diverted depends upon the number of months in the year for which protection is desired. After a comparison, it has been observed that a flood protection work effective for 8 months period (from 16th September to 15th May) is an optimum alternative.

Non-monsoon observed flood peaks for 34 years period have been analysed by Gumbel's Method of frequency distribution. From the analysis a 25 year flood of 1312 cumec has been obtained and adopted for the design of river diversion works.

4.6 Hydrological Studies

The detailed hydrological studies carried out for determination of water availability, spillway design flood, and design flood in river diversion works are covered in chapters A-1 to A-6 of Volume III of the project report.

TABLE 4.1

90% and 50% Dependable Discharges at Karcham

Ten-Daily Period		10-DAILY DISCHARGE, CUMEC	
		90% Dependable Year (1973-74)	50% Dependable Year (1994-95)
Oct	I	267.71	222.04
	II	208.52	187.19
	III	161.68	170.19
Nov	I	137.40	154.70
	II	123.94	139.82
	III	111.66	125.30
Dec	I	95.98	112.46
	II	87.71	102.88
	III	82.06	94.41
Jan	I	76.57	84.94
	II	69.35	79.93
	III	71.15	75.10
Feb	I	67.18	75.57
	II	68.56	75.34
	III	68.90	76.47
Mar	I	73.16	77.08
	II	79.60	80.89
	III	107.39	108.93

Ten-Daily Period		10-DAILY DISCHARGE, CUMEC	
		90% Dependable Year (1973-74)	50% Dependable Year (1994-95)
April	I	102.79	97.09
	II	116.27	111.68
	III	147.42	159.88
May	I	262.82	241.96
	II	228.36	740.82
	III	191.93	407.75
Jun	I	284.89	818.34
	II	454.87	1125.35
	III	422.16	604.96
July	I	505.60	988.15
	II	962.68	1029.43
	III	868.79	1006.74
Aug	I	891.40	959.96
	II	804.59	868.66
	III	593.46	743.83
Sept	I	402.59	599.60
	II	271.61	414.18
	III	209.55	298.52

Table 4.2

COMPARISON OF FLOOD DISCHARGES OBTAINED BY DIFFERENT METHODS

Sl. No.	Method	Discharge in cumec for different return periods				
		Return Period (year)				
		5	20	50	100	1000
1.	Gumbel's Method	3119	4531	5427	6097	8260
2.	Gumbel's method with 95% confidence band (upper limit)		5581	6778	7676	
3.	Chow's Method	2992	4210	4982	5560	7472

Chapter - 5

POWER PLANNING

5.1 General

Karcham-Wangtoo Hydroelectric Project is a run-of-the-river scheme utilising the hydro potential of river Satluj for power generation. The project will utilise the water head available between tail water of Baspa Hydroelectric Project Stage II and head water of Nathpa-Jhakri Hydroelectric Project.

It is proposed to have an installed capacity of 1000 MW, comprising of 4 units of 250 MW, at this project. The project will utilise a gross head of 295m.

The project will operate in Northern regional grid and will meet the energy requirements of Northern states.

5.2 Hydrology

Based on discharge of Satluj river at Karcham discharge site from 1966-67 to 1999-2000, 10 days daily 90% dependable and 50% dependable discharges have been worked out which are given in Table 5.1.

Annual run off, as well as run-off from June to September and October to May at the Dam site have been tabulated in Table 5.2. Corresponding annual generation for various hydrological years based on installed capacity of 1000 MW and 10.48m dia finished circular tunnel are given in Table 5.3. The figures of generation for non-monsoon period and monsoon period are also given in this table. The details of ten daily generation for 90% dependable year and 50% dependable years are given in Tables 5.4 and 5.5 respectively.

The energy generation in a hydrological year has been based on 95% availability of installed capacity of the station as per guidelines given in Notification dt. 12.1.95 of Govt. of India.

5.3 **Design Head**

A tail water rating curve has been developed for the outlet site which is based on the water levels of Wangtoo bridge gauge site. This curve is given in Fig. 5.1. Gross head between average pond level at the diversion dam and normal tail water level is 295m. Corresponding to the design discharge of 417 cumec, the net head works out as 273.70m. The design head adopted for the turbines has been taken as 276.0m.

The basic parameters are as below :-

Maximum pond level at Dam	=	El 1810m
Minimum pond level at Dam	=	El 1799m
Weighted Average pond level	=	El 1806.73m
Normal tail water elevation	=	El 1508m
Gross Head	=	El 298.73 m
Losses in water conductor system at 417 cumec discharge	=	22.80 m
Net head (corresponding to 1000 MW rated capacity)	=	275.93 m
Design Head for turbines	=	276m

The design head of 276m and the maximum/minimum head range is well within the range permitted for Francis type turbine from cost and efficiency considerations.

5.4 **Power Studies**

Karcham-Wangtoo Hydroelectric Project is a run-of-the-river scheme. The project upstream of it as well as downstream of it are also run-of-the-river schemes, which will not effect its performance. The studies for optimum tunnel diameter and installed capacity have, therefore, been carried out independently for this project.

These studies have been carried out for different combinations of tunnel diameter and discharge as given below :

Tunnel dia (m)	Discharge (cumec)
8	175, 200, 225, 250
8.5	200, 225, 250, 275
9	225, 250, 275, 300, 325
9.5	250, 275, 300, 325, 350
10	275, 300, 325, 350, 375, 400
10.5	300, 325, 350, 375, 400, 425, 450
11	325, 350, 375, 400, 425, 450, 475
11.5	375, 400, 425, 450, 475, 500, 525
12	400, 425, 450, 475, 500, 525, 550, 575
13	575, 600, 625, 650
14	600, 625, 650, 675, 700

These combinations have been chosen such that the velocity in tunnel is within 5 m/sec.

For these studies the following parameters have been considered :

Gross Head	295 m
Length of Tunnel	17198 m
Length of each penstock	291 m
Overall Efficiency	89.5%

The maximum power generated and total energy produced for each combination of tunnel diameter and discharge have been worked out for 90% dependable year and are given in Table 5.6.

This study indicate that an installation of 800 MW to 1725 MW is feasible for single tunnel of size 8m to 14m. Considering the tunnelling problems in Himalayas, it has been considered prudent to limit the tunnel size to 10.5m which is close to what has actually been tried at Nathpa-Jhakri Project. For this diameter or equivalent, the installed capacity gets limited to 1000 MW.

5.5 Optimum Installed Capacity and Tunnel Diameter

In order to optimise the power generation from this project, studies have been conducted for the cost of generation and increment cost of generation for different tunnel diameter and different installed capacities.

Since a construction of tunnel above 10.5m dia (excavated about 11.25m) is not considered practicable in the available rock along the tunnel alignment, studies have been carried out for single tunnel and two tunnel options as per following combinations :

Single tunnel option

Tunnel Dia	Installed Capacity
8m dia	450 MW, 500 MW, 550 MW, 600 MW
8.5m dia	500 MW, 550 MW, 600 MW, 650 MW
9m dia	600 MW, 650 MW, 700 MW, 750 MW
9.5m dia	650 MW, 700 MW, 750 MW, 800 MW, 850 MW
10m dia	700 MW, 750 MW, 800 MW, 850 MW, 900 MW, 950 MW
10.5m dia	800 MW, 850 MW, 900 MW, 950 MW, 1000 MW, 1050 MW

Twin tunnel option

2x7m dia	650 MW, 700 MW, 750 MW, 800 MW, 850 MW
2x7.5m dia	750 MW, 800 MW, 850 MW, 900 MW, 950 MW, 1000 MW
2x8m dia	900 MW, 950 MW, 1000 MW, 1050 MW, 1100 MW, 1150 MW, 1200 MW
2x8.5m dia	1000 MW, 1150 MW, 1200 MW, 1250 MW, 1300 MW, 1350 MW
2x9m dia	1100 MW, 1150 MW, 1200 MW, 1250 MW, 1300 MW, 1350 MW, 1400 MW, 1450 MW, 1500 MW, 1550 MW

For these studies the following parameters have been assumed :-

a) Estimated cost of the Project — Cost of civil works and electrical works based on 17.2km long HRT, 2.2km adits, fixed and variable costs involved in construction of dam, intake sedimentation chambers, surge shaft, power house, generator and turbine units and contingencies.

b)	Interest during construction	It has been worked out on loan capital (80% cost of the project) @ 18% per annum
c)	Depreciation	Advance against depreciation has been assumed as per guide lines of Govt. of India
d)	O&M Charges	1.5 percent per year as per guidelines of Govt. of India
e)	Interest on Loan Capital	Computed on the outstanding loans @ 18%
f)	Interest charges on Working Capital	Worked out @ 20% per annum on O&M expenses for one month, maintenance spares for one year and receivable equal to two months of average billing
g)	Return on equity	As per Govt. of India guidelines which is 16% on equity
h)	Annual energy for sale	This has been worked out on the following basis:- - Energy computed in 90% dependable year with 95% availability of installed capacity - Auxiliary consumption as 0.5% of energy generated - Transformation losses from generation voltage to transmission voltage as 0.5% of energy generated - 12% free power to State government as per MOU

These studies for 90% dependable year are given in Table 5.7 and Table 5.8 for single tunnel and twin tunnel options respectively.

5.6 Selection of tunnel diameter and installed capacity

From Table 5.5, the indication is that for a single tunnel option, the range for minimum generation cost corresponds to installation of 950MW to 1050MW. However, in consideration of the limitation in velocity of flow, installed capacity of 1000 MW has been chosen which is well within the optimum range.

Nominal diameter of 10.5m has been adopted on the basis of power studies.

However for ease of construction, a modified horse shoe section will be excavated. The finished size will be 10.48m circular.

Tunnel discharge required for 1000 MW installed capacity will be 417 cumec and corresponding flow velocity in tunnel will be 4.83 m/sec which is within the permissible limit.

5.7 Incremental Energy and Cost of Incremental Energy

Annual energy generation for different installed capacities has been given in Fig. 5.2. The incremental energy and cost of incremental energy are also given in Table 5.7.

For a tunnel diameter of 10.5m the incremental energy varies from 142 MU to 127 MU for increase in installed capacity in steps of 50 MW.

Cost of incremental generation for different installed capacities has been given in Fig. 5.5. It is observed that there is a rise in cost of incremental generation from 2.00/kWh to 2.28/kWh from 900 MW to 1000 MW. However cost of incremental energy increases from Rs. 2.28 to Rs. 2.65 per unit if the installed capacity is increased from 1000 MW to 1050 MW. Therefore the installed capacity of 1000 MW is justified from considerations of lower range of incremental cost of energy.

5.8 Sale Rate of Power

Sale rate of power for 90% dependable year is given in Table 5.7. Sale rate of power for different installed capacities is presented in Fig. 5.4. It is seen that sale rate of power Rs. 3.05/kWh for installed capacity of 1000 MW is one of the lowest in the range.

5.9 Benefit cost ratio and incremental benefit cost ratio

Benefit cost ratio and incremental cost ratio are important parameters to check economic viability of the project.

$$\text{Benefit - cost ratio} = \frac{Annual\ Benefit\ (B)}{Annual\ Cost\ (C)}$$

Incremental Benefit/Incremental Cost Ratio

$$= \frac{\textit{Increase in Annual Benefit } (\Delta B)}{\textit{Increase in Annual Cost } (\Delta C)}$$

Benefit - Cost computations are presented in Table 5.9 and 5.10 for different installed capacities for a tunnel diameter of 10.5m for 90% dependable discharge and 50% dependable discharge respectively.

In Fig. 5.6, benefit-cost ratio for different installed capacities for 90% dependable year has been presented. A benefit-cost ratio of 1.29 has been obtained for 800 MW to 1050 MW of installed capacities. Since there is practically no change in B-C ratio, it is better to provide a higher capacity plant to maximise the net benefits. Because of high velocities in water conductor system, an installed capacity of 1000 MW is considered practical.

Incremental Benefit Cost ratio as given in Fig. 5.7 drops after 550 MW of installed capacity. Benefit-cost ratio and incremental benefit-cost ratio in range of 950 MW to 1000 MW change by small margins. To take advantage of higher energy output, 1000 MW of installed capacity has been adopted.

5.10 Net Annual Benefits

Net annual benefits have also been computed in Tables 5.9 and 5.10 for 90% and 50% dependable discharges respectively.

5.11 Plant Utilisation Factor

Plant utilisation factor for different installed capacities are given in Table 5.7. For installed capacity of 1000 MW the plant utilisation factor is 49.11% for 90% availability basis and 54.25% for 50% availability, as worked out in Table 5.3, which is reasonable.

5.12 Unit Size

The unit size has been selected after due consideration of the following factors:

a) The installed capacity should be delivered by units of same capacity to minimise costs and reduce the spare parts and special tools required for operation and maintenance.

b) The units should be as large as possible to obtain the benefits of scale.

c) The penstocks, turbines and generators should not be so large that their components cannot be transported and assembled at site.

d) There should be an even number of units to reduce excavation and equipment costs and to provide maximum operating flexibility.

e) The Francis turbines should not be so large that they have to run at low efficiencies for long periods of time.

After due consideration of all these factors a unit size of 250 MW in a four unit configuration has been selected.

5.13 Net Head

Due to relocation of project components on account of rise in river bed after flash floods on 11.8.97, the length of tailrace tunnel has been increased from 162m to 909m so as the benefits from the project do not change.

With this changes the net head works out as below:

Maximum Pond Level	1810m
Minimum Pond Level	1799m
Weighted Average Pond Level	1806.73m
Normal Tailwater Level	1508m
Gross Head	298.73m
Total Head Loss	22.8m
Net Head	275.93

The tail rating curve at the new site is given in Annexure 5.1 (This supercedes Figure 5.1).

5.14 Firm Power

The firm power has been worked out as per procedure suggested by CEA.

The total flow for the lean period (December to March) for 34 years for which data is available, has been arranged in descending order. On this basis the 90% dependability year is 1970-71 (Annexure 5.2).

Based on average inflow during the 90% dependable year (year 1970-71) during lean period (Dec-March) the firm power works out to 169.91 MW (Annexure 5.3). As the power house will be used as peaking station during non-monsoon months, the diurnal storage for 4 hours peaking has been provided.

5.15 Annual Design Energy

As advised by CEA the `annual design energy' has been worked out on the basis of complete hydrological inflows (monsoon + non-monsoon) for each year. The annual energy generation for all the 34 years for which hydrological data is available has been worked out and arranged in descending order (Annexure 5.4). The 90% dependable year is 1984-85 and the energy generated during this year which is 4215.2 million units. However, 4228.50 million units has been considered as design energy.

The computations for design head / net head for working out design energy have been based on the weighted average reservoir level and tailwater level with all the four machines running.

Table 5.1

90% AND 50% DEPENDABLE DISCHARGES AT KARCHAM DAM SITE

Ten-Daily Period		90% Dependable Discharge (cumec)	50% Dependable discharge (cumec)
Oct	I	267.71	222.04
	II	208.52	187.19
	III	161.68	170.19
Nov	I	137.40	154.70
	II	123.94	139.82
	III	111.66	125.30
Dec	I	95.98	112.46
	II	87.71	102.88
	III	82.06	94.41
Jan	I	76.57	84.94
	II	69.35	79.93
	III	71.15	75.10
Feb	I	67.18	75.57
	II	68.56	75.34
	III	68.90	76.47
Mar	I	73.16	77.08
	II	79.60	80.89
	III	107.39	108.93
April	I	102.79	97.09
	II	116.27	111.68
	III	147.42	159.88
May	I	262.82	241.96
	II	228.36	740.82
	III	191.93	407.75
Jun	I	284.89	818.34

Ten-Daily Period		90% Dependable Discharge (cumec)	50% Dependable discharge (cumec)
	II	454.87	1125.35
	III	422.16	604.96
July	I	505.60	988.15
	II	962.68	1029.43
	III	868.79	1006.74
Aug	I	891.40	959.96
	II	804.59	868.66
	III	593.46	743.83
Sept	I	402.59	599.60
	II	271.61	414.18
	III	209.55	298.52

Table 5.2

ANNUAL RUN-OFF AT KARCHAM DAM SITE

Sl. No.	Year	Non-Monsoon (Oct-May) (cumec day)	Monsoon (June-September) (cumec-day)	Total of the year (cumec-day)
1.	1966-67	30065	113516	143581
2	1967-68	51768	98597	150365
3	1968-69	28707	116805	145512
4	1969-70	34933	54625	89558
5	1970-71	25839	72628	98467
6	1971-72	31382	79620	111002
7	1972-73	56488	135351	191839
8	1973-74**	30557	68184	98741
9	1974-75	42258	114153	156411
10	1975-76	40232	91582	131814
11	1976-77	28664	94897	123561
12	1977-78	35718	100583	136301
13	1978-79	39746	98729	138475
14	1979-80	33101	80124	113225
15	1980-81	36846	75697	112543
16	1981-82	29706	103093	132799
17	1982-83	37485	109277	146762
18	1983-84	41732	83586	125318
19	1984-85	30115	94762	124877
20	1985-86	33386	115527	148913
21	1986-87	28586	112558	141144
22	1987-88	50266	120372	170638
23	1988-89	45438	59558	104996

Sl. No.	Year	Non-Monsoon (Oct-May) (cumec day)	Monsoon (June-September) (cumec-day)	Total of the year (cumec-day)
24	1989-90	47848	105964	153812
25	1990-91	46365	109275	155640
26	1991-92	42995	84333	127328
27	1992-93	46950	69396	116346
28	1993-94	40190	145554	185744
29	1994-95*	38727	96328	135055
30	1995-96	53417	84905	138322
31	1996-97	32719	67010	99729
32	1997-98	44631	117447	162078
33	1998-99	64000	104682	168682
34	1999-2000	49136	57846	106982

* 50% dependable year

** 90% dependable year

Table 5.3

POWER GENERATION IN HYDROLOGIC YEAR (OCTOBER TO SEPTEMBER)
(BASED ON INSTALLED CAPACITY OF 1000 MW)

Sl No	Year	Power Generation in GWH			Plant Utilisation Factor %
		Non-Monsoon	Monsoon	Total	
1	1966-67	1733.96	2706.64	4,440.60	50.69
2	1967-68	2045.47	2537.61	4,583.08	52.32
3	1968-69	1575.81	2710.64	4,286.45	48.93
4	1969-70	1908.72	2508.25	4,416.97	50.42
5	1970-71	1490.25	2561.91	4,052.16	46.26
6	1971-72	1628.47	2643.61	4,272.08	48.77
7	1972-73	2150.49	2781.60	4,932.09	56.30
8	1973-74**	1762.36	2539.41	4,301.77	49.11
9	1974-75	2121.32	2724.00	4,845.32	55.31
10	1975-76	2125.45	2730.30	4,855.75	55.43
11	1976-77	1653.19	2574.73	4,227.92	48.26
12	1977-78	1771.18	2675.82	4,447.00	50.76
13	1978-79	2292.30	2615.32	4,907.62	56.02
14	1979-80	1894.22	2634.82	4,529.04	51.70
15	1980-81	2045.62	2605.40	4,651.02	53.09
16	1981-82	1713.23	2691.95	4,405.18	50.29
17	1982-83	1940.46	2776.71	4,717.17	53.85
18	1983-84	2187.82	2629.55	4,817.37	54.99
19	1984-85	1557.98	2657.22	4,215.20	48.12
20	1985-86	1864.38	2471.42	4,335.80	49.50
21	1986-87	1644.92	2756.91	4,401.83	50.25

Sl No	Year	Power Generation in GWH			Plant Utilisation Factor %
		Non-Monsoon	Monsoon	Total	
22	1987-88	2416.21	2781.60	5,197.81	59.34
23	1988-89	2620.58	2428.41	5,048.99	57.64
24	1989-90	2051.67	2734.81	4,786.48	54.64
25	1990-91	2403.61	2781.60	5,185.21	59.19
26	1991-92	2479.66	2690.46	5,170.12	59.02
27	1992-93	2609.61	2661.32	5,270.93	60.17
28	1993-94	2305.33	2715.06	5,020.39	57.31
29	1994-95*	2026.42	2725.76	4,752.18	54.25
30	1995-96	2860.34	2097.60	4,957.94	56.60
31	1996-97	1887.01	2658.40	4,545.40	51.89
32	1997-98	2267.61	2781.60	5,049.21	57.64
33	1998-99	3265.56	2781.60	6,047.16	69.03
34	1999-2000	2510.32	1390.80	3,901.12	44.53
AVERAGE		**2082.69**	**2610.67**	**4693.36**	**53.58**

* 50% Dependable year

** 90% Dependable year

Table 5.4

KARCHAM-WANGTOO PROJECT
POWER AND ENERGY GENERATION
90% DEPENDABLE YEAR

Installed Capacity	= 1000.00 MW
Gross Head	= 295.00 m
Tunnel Discharge	= 417.00 cumec
Overall Efficiency	= 89.50 %
Total Head-Loss	= 21.30 m
Length of Tunnel	= 17198 m
Velocity in Tunnel	= 4.83 m/sec
Tunnel Diameter	= 10.48m dia circular

Period		Discharge (cumec)	Power (MW)	Avail. Power (MW)	Energy (GWH)
Oct	I	267.71	643.33	643.33	154.40
	II	208.52	501.09	501.09	120.26
	III	161.68	388.53	388.53	93.25
Nov	I	137.40	330.18	330.18	79.24
	II	123.94	297.84	297.84	71.48
	III	111.66	268.33	268.33	64.40
Dec	I	95.98	230.65	230.65	55.36
	II	87.71	210.77	210.77	50.59
	III	82.06	197.20	197.20	47.33
Jan	I	76.57	184.000	184.000	44.16
	II	69.35	166.65	166.65	40.00
	III	71.15	170.98	170.98	41.03
Feb	I	67.18	161.44	161.44	38.75
	II	68.56	164.75	164.75	39.54

Period		Discharge (cumec)	Power (MW)	Avail. Power (MW)	Energy (GWH)
	III	68.90	165.57	165.57	39.74
Mar	I	73.16	175.81	175.81	42.19
	II	79.60	191.28	191.28	45.91
	III	107.39	258.07	258.07	61.94
April	I	102.79	247.08	247.08	59.28
	II	116.27	279.41	279.41	67.06
	III	147.42	354.26	354.26	85.02
May	I	262.82	631.58	631.58	151.58
	II	228.36	548.77	548.77	131.70
	III	191.93	461.22	461.22	110.69
Jun	I	284.89	684.61	684.61	164.31
	II	454.87	1000.00	950.00	228.00
	III	422.16	1000.00	950.00	228.00
July	I	505.60	1000.00	950.00	228.00
	II	962.68	1000.00	950.00	228.00
	III	868.79	1000.00	950.00	250.80
Aug	I	891.40	1000.00	950.00	228.00
	II	804.59	1000.00	950.00	228.00
	III	593.46	1000.00	950.00	250.80
Sept	I	402.59	967.45	950.00	228.00
	II	271.61	652.70	652.70	156.65
	III	209.55	503.56	503.56	120.86

Non-monsoon Energy = 1762.36
Monsoon Energy = 2539.41
Net Energy Generation = 4301.77
Plant Utilisation Factor = 49.11%

Table 5.5

KARCHAM-WANGTOO PROJECT
POWER AND ENERGY GENERATION
50% DEPENDABLE YEAR

Installed Capacity	= 1000.00 MW
Gross Head	= 295.00 m
Tunnel Discharge	= 417.00 cumec
Overall Efficiency	= 89.50 %
Total Head-Loss	= 21.30 m
Length of Tunnel	= 17198 m
Velocity in Tunnel	= 4.83 m/sec
Tunnel Diameter	= 10.48m dia circular

Period		Discharge (cumec)	Power (MW)	Avail. Power (MW)	Energy (GWH)
Oct	I	222.04	533.58	533.58	128.06
	II	187.19	449.84	449.84	107.96
	III	170.19	408.97	408.97	98.15
Nov	I	154.70	371.75	371.75	89.22
	II	139.82	335.99	335.99	80.64
	III	125.30	301.11	301.11	72.27
Dec	I	112.46	270.24	270.24	64.86
	II	102.88	247.22	247.22	59.33
	III	94.41	226.87	226.87	54.45
Jan	I	84.94	204.11	204.11	48.99
	II	79.93	192.09	192.09	46.10
	III	75.10	180.46	180.46	43.31
Feb	I	75.57	181.60	181.60	43.58
	II	75.34	181.06	181.06	43.45
	III	76.47	183.76	183.76	44.10

Period		Discharge (cumec)	Power (MW)	Avail. Power (MW)	Energy (GWH)
Mar	I	77.08	185.23	185.23	44.46
	II	80.89	194.38	194.38	46.65
	III	108.93	261.77	261.77	62.83
April	I	97.09	233.30	233.30	55.99
	II	111.68	268.38	268.38	64.41
	III	159.88	384.19	384.19	92.21
May	I	241.96	581.44	581.44	139.54
	II	740.82	1000.00	950.00	228.00
	III	407.75	979.85	950.00	228.00
Jun	I	818.34	1000.00	950.00	228.00
	II	1125.35	1000.00	950.00	228.00
	III	604.96	1000.00	950.00	228.00
July	I	988.15	1000.00	950.00	228.00
	II	1029.43	1000.00	950.00	228.00
	III	1006.74	1000.00	950.00	250.80
Aug	I	959.96	1000.00	950.00	228.00
	II	868.66	1000.00	950.00	228.00
	III	743.83	1000.00	950.00	250.80
Sept	I	599.60	1000.00	950.00	228.00
	II	414.18	995.31	950.00	228.00
	III	298.52	717.35	717.35	172.16

Non-monsoon Energy = 2026.42
Monsoon Energy = 2725.76
Net Energy Generation = 4752.18
Plant Utilisation Factor = 54.25%

Table 5.6

POWER GENERATION FOR DIFFERENT TUNNEL DIAMETER AND DISCHARGES
(90% DEPENDABLE YEAR)

Dia m	Disch. m^3/s	Vel m/s	Head Loss m	Power MW	Non-Monsoon GWH	Mon-soon GWH	Total GWH	PUF %
8.00	175.00	3.48	15.80	426.59	1456.05	1186.61	2642.66	70.72
8.00	200.00	3.98	20.64	479.09	1481.50	1332.63	2814.14	67.05
8.00	225.00	4.48	26.12	528.21	1493.08	1469.27	1962.35	64.02
8.00	250.00	4.97	32.24	573.53	1474.75	1595.33	3070.08	61.11
8.50	200.00	3.52	14.93	489.05	1512.29	1360.33	2872.62	67.05
8.50	225.00	3.97	18.90	542.38	1533.14	1508.69	3041.83	34.02
8.50	250.00	4.41	23.33	592.97	1524.75	1649.41	3174.16	31.11
8.50	275.00	4.85	28.24	640.50	1511.84	1781.61	3293.45	58.70
9.00	225.00	3.54	13.94	552.14	1560.71	1535.82	3096.54	64.02
9.00	250.00	3.93	17.20	606.35	1559.15	1686.63	3245.78	61.11
9.00	275.00	4.32	20.82	358.32	1553.89	1831.17	3385.06	58.70
9.00	300.00	4.72	24.77	707.80	1546.26	1968.82	3515.08	56.69
9.00	325.00	5.11	29.07	754.58	1536.20	2098.93	3635.13	54.99
9.50	250.00	3.53	12.89	615.76	1583.34	1712.80	3296.14	61.11
9.50	275.00	3.88	15.60	670.83	1583.44	1865.99	3449.43	58.70
9.50	300.00	4.23	18.57	724.05	1581.76	2014.02	3595.78	56.69
9.50	325.00	4.59	21.79	775.24	1578.28	2156.42	3734.70	54.99
9.50	350.00	4.94	25.27	824.24	1572.93	2292.70	3865.64	53.54
10.00	275.00	3.50	11.87	679.80	1604.60	1890.93	3495.53	58.70
10.00	300.00	3.82	14.12	735.69	1607.19	2046.40	3653.59	56.69
10.00	325.00	4.14	16.58	790.04	1608.40	2197.58	3805.98	54.99

Dia m	Disch. m^3/s	Vel m/s	Head Loss m	Power MW	Non-Monsoon GWH	Mon-soon GWH	Total GWH	PUF %
10.00	350.00	4.46	19.22	842.72	1608.20	2344.11	3952.31	53.54
10.00	375.00	4.77	22.07	893.60	1606.56	2483.51	4090.07	52.25
10.00	400.00	5.09	25.11	942.56	1603.44	2606.28	4209.72	50.98
10.50	300.00	3.46	10.89	744.17	1625.71	2069.97	3695.68	56.69
10.50	325.00	3.75	12.78	800.82	1630.34	2227.55	3857.90	54.99
10.50	350.00	4.04	14.82	856.18	1633.89	2381.55	4015.43	53.54
10.50	375.00	4.33	17.01	910.16	1636.32	2529.51	4165.83	52.25
10.50	400.00	4.62	19.36	962.65	1637.61	2661.82	4299.44	50.98
10.50	425.00	4.91	21.85	1013.56	1636.16	2789.99	4426.14	49.85
10.50	450.00	5.20	24.50	1062.78	1620.31	2907.83	4528.14	48.64
11.00	325.00	3.42	9.97	808.78	1646.56	2249.72	3896.28	54.99
11.00	350.00	3.68	11.56	866.13	1652.87	2409.22	4062.09	53.54
11.00	375.00	3.95	13.27	922.40	1658.32	2563.53	4221.85	52.25
11.00	400.00	4.21	15.10	977.50	1662.87	2702.88	4365.76	50.98
11.00	425.00	4.47	17.05	1031.37	1664.91	2839.02	4503.92	49.85
11.00	450.00	4.74	19.11	1083.93	1652.54	2965.68	4618.23	48.64
11.00	475.00	5.00	21.30	1135.09	1639.46	3081.14	4720.60	47.47
0.50	375.00	3.61	10.47	931.57	1674.82	2589.02	4263.84	52.25
11.50	400.00	3.85	11.92	988.63	1681.81	2733.67	4415.48	50.98
11.50	425.00	4.09	13.45	1044.72	1686.46	2875.77	4562.23	49.85
11.50	450.00	4.33	15.08	1099.78	1676.71	3009.05	4685.76	48.64
11.50	475.00	4.57	16.80	1153.74	1666.39	3131.75	4798.15	47.47
11.50	500.00	4.81	18.62	1206.53	1655.51	3251.61	4907.12	46.43
11.50	525.00	5.05	20.53	1258.11	1644.09	3368.49	5012.57	45.48

Dia m	Disch. m^3/s	Vel m/s	Head Loss m	Power MW	Non-Monsoon GWH	Mon-soon GWH	Total GWH	PUF %
11.50	400.00	3.54	9.50	997.08	1696.19	2757.04	4453.23	50.98
1.00	425.00	3.76	10.72	1054.86	1702.82	2903.67	4606.50	49.85
12.00	450.00	3.98	12.02	1111.81	1695.05	3041.96	4737.01	48.64
12.00	475.00	4.20	13.39	1167.89	1686.83	3170.16	4857.00	47.47
12.00	500.00	4.42	14.84	1223.04	1678.17	3296.10	4974.27	46.43
12.00	525.00	4.64	16.36	1277.22	1669.05	3419.64	5088.69	45.48
12.00	550.00	4.86	17.95	1330.38	1659.50	3540.71	5200.21	44.62
12.00	575.00	5.08	19.62	1382.47	1649.50	3659.15	5308.65	43.84
13.00	575.00	4.33	12.80	1416.70	1690.34	3749.75	5440.09	43.84
13.00	600.00	4.52	13.94	1472.33	1683.52	3877.30	5660.82	43.12
13.00	625.00	4.71	15.13	1527.21	1676.42	3997.49	5673.91	42.41
13.00	650.00	4.90	16.36	1581.29	1669.03	4107.44	5776.47	41.70
14.00	600.00	3.90	9.39	1496.18	1710.79	3940.09	5650.88	43.12
14.00	625.00	4.06	10.19	1554.17	1706.01	4068.05	5774.06	42.41
14.00	650.00	4.22	11.02	1611.61	1701.03	4186.19	5887.21	41.70
14.00	675.00	4.38	11.88	1668.50	1695.85	4303.07	5998.82	41.04
14.00	700.00	4.55	12.78	1724.82	1690.48	4418.67	6109.15	40.43

Table 5.7

STATEMENT OF COST OF GENERATION, INCREMENTAL COST AND PLANT UTILISATION FACTOR IN 90% DEPENDABLE YEAR (SINGLE TUNNEL)

Sl No	Tunnel Dia (m)	Discharge (cumec)	Power Output (MW)	Estimated Cost of Project (Rs. In Crores)	Cost of Project Including IDC (Rs. In Crores)	Average Annual Interest on Loan (Rs. In Crores)	Depreciation per year (Rs. In Crores)	Total Annual Generation (GWH)	Annual Energy for Sale (GWH)	Capacity Charges (Rs./kWh)	O&M Expenses @ 1.5% / year (Rs. In Crores)	Interest Charges on Working Capital (Rs. In Crores)	Returns on Equity Capital (Rs. In Crores)	Total 12+13+14 (Rs. In Crores)	Energy Charges (Rs./kWh)	Sale rate of Power (11 + 16) (Rs./kWh)	Incr. Energy (MW)	Cost of Incr. energy (Rs./kWh)	Plant Utilisation Factor (%)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	8.00	185.96	450	1955.82	2827.79	407.2	188.52	2721.93	2371.35	2.51	42.42	21.44	90.49	154.35	0.65	3.16	-	-	69.05
2	8.00	210.42	500	2031.02	2936.5	422.86	195.77	2877.89	2507.22	2.47	44.05	22.54	93.97	160.56	0.64	3.11	156	1.867	65.71
3	8.00	236.75	550	2108.89	3049.1	439.07	203.27	3015.59	2627.18	2.44	45.74	23.52	97.57	166.82	0.63	3.08	137.7	2.178	62.59
4	8.00	265.79	600	2190.68	3167.35	456.1	211.18	3129.08	2726.05	2.45	47.51	24.33	101.36	173.19	0.64	3.08	113.5	2.756	59.53
5	8.50	205.04	500	2079.21	3006.19	432.89	200.41	2907.66	2533.15	2.5	45.09	22.76	96.2	164.05	0.65	3.15	-	-	66.38
6	8.50	228.68	550	2153.23	3113.2	448.3	207.55	3063.15	2668.62	2.46	46.7	23.86	99.62	170.18	0.64	3.1	155.5	1.844	63.58
7	8.50	253.59	600	2229.08	3222.87	464.09	214.86	3192.05	2780.91	2.44	48.34	24.77	103.13	176.25	0.63	3.08	128.9	2.263	60.73
8	8.50	280.21	650	2307.38	3336.08	480.4	222.41	3316.79	2889.59	2.43	50.04	25.66	106.75	182.46	0.63	3.06	124.7	2.41	58.25
9	9.00	224.03	550	2205.58	3188.9	459.2	212.59	3089.91	2691.93	2.5	47.83	24.06	102.04	173.94	0.65	3.14	-	-	64.13
10	9.00	247.02	600	2278.65	3294.55	474.41	219.64	3228.59	2812.74	2.47	49.42	25.04	105.43	179.89	0.64	3.11	138.7	2.034	61.43
11	9.00	270.92	650	2353.05	3402.11	489.9	226.81	3362.94	2929.8	2.45	51.03	26	108.87	185.89	0.63	3.08	134.4	2.134	59.06
12	9.00	295.97	700	2429.09	3512.05	505.74	234.14	3494.77	3044.64	2.43	52.88	26.93	112.39	192	0.63	3.06	131.8	2.22	56.99
13	9.00	322.49	750	2507.24	3625.04	522.01	241.67	3623.53	3156.82	2.42	54.38	27.85	116	198.22	0.63	3.05	128.8	2.332	55.15

Sl No	Tunnel Dia (m)	Discharge (cumec)	Power Output (MW)	Estimated Cost of Project (Rs. in Crores)	Cost of Project Including IDC (Rs. in Crores)	Average Annual Interest on Loan (Rs. in Crores)	Depreciation per year (Rs. in Crores)	Total Annual Generation (GWH)	Annual Energy for Sale (GWH)	Capacity Charges (Rs./kWh)	O&M Expenses @ 1.5% / year (Rs. in Crores)	Interest Charges on Working Capital (Rs. in Crores)	Returns on Equity Capital (Rs. in Crores)	Total 12+13+14 (Rs. in Crores)	Energy Charges (Rs./kWh)	Sale rate of Power (11 + 16) (Rs./kWh)	Incr. Energy (MW)	Cost of Incr. energy (Rs./kWh)	Plant Utilisation Factor (%)
14	9.50	265.45	650	2407.29	3480.54	501.2	232.04	3391.65	2954.81	2.48	52.21	26.21	111.38	189.8	0.64	3.12	-	-	59.57
15	9.50	288.59	700	2480.59	3586.51	516.46	239.1	3529.87	3075.22	2.46	53.80	27.19	114.77	195.76	0.64	3.09	138.2	2.046	57.56
16	9.50	312.54	750	2555.06	3604.18	531.96	246.28	3666.45	3194.21	2.44	55.41	28.16	118.21	201.78	0.63	3.07	136.6	2.102	55.81
17	9.50	337.49	800	2630.95	3803.9	547.76	253.59	3801.13	3311.54	2.42	57.06	29.11	121.72	207.9	0.63	3.05	134.7	2.17	54.24
18	9.50	363.65	850	2708.59	3916.16	563.93	261.08	3933.58	3426.94	2.41	58.74	30.05	125.32	214.11	0.62	3.03	132.5	2.255	52.83
19	10.00	283.96	700	2539.15	3671.18	528.65	244.75	3552.81	3095.21	2.5	55.07	27.37	117.48	199.92	0.65	3.14	-	-	57.94
20	10.00	306.51	750	2611.6	3775.92	543.73	251.73	3693.84	3218.07	2.47	56.64	28.37	120.83	205.84	0.64	3.11	141	1.984	56.22
21	10.00	329.66	800	2684.91	3881.92	559	258.79	3833.76	3339.97	2.45	58.23	29.36	124.22	211.81	0.63	3.08	139.9	2.023	54.71
22	10.00	353.52	850	2759.23	3989.38	574.47	265.96	3972.42	3460.78	2.43	59.84	30.34	127.66	217.84	0.63	3.06	138.7	2.068	53.35
23	10.00	378.21	900	2834.76	4098.58	590.19	273.24	4105.81	3576.98	2.41	61.48	31.28	131.15	223.92	0.63	3.04	133.4	2.18	52.08
24	10.00	403.89	950	2911.71	4209.84	606.22	280.66	4227.74	3683.21	2.41	63.15	32.15	134.71	230.01	0.62	3.03	121.9	2.422	50.8
25	10.50	324.64	800	2745.98	3970.22	571.71	264.68	3855.56	3358.96	2.49	59.55	29.53	127.05	216.13	0.64	3.13	-	-	55.02
26	10.50	347.18	850	2818.41	4074.95	586.79	271.66	3997.9	3482.97	2.46	61.12	30.53	130.4	222.06	0.64	3.1	142.3	1.967	53.69
27	10.50	370.25	900	2891.6	4180.77	602.03	278.72	4139.38	3606.23	2.44	62.71	31.53	133.78	228.03	0.63	3.07	141.5	1.998	52.5
28	10.50	393.91	950	2965.65	4287.82	617.45	285.85	4267.37	3717.73	2.43	64.32	32.44	137.21	233.97	0.63	3.06	128	2.226	51.28
29	10.50	418.26	1000	3040.69	4396.33	633.07	293.09	4393.69	3827.78	2.42	65.94	33.34	140.68	239.97	0.63	3.05	126.3	2.284	50.16
30	10.50	443.42	1050	3116.89	4506.5	648.94	300.43	4503.8	3923.71	2.42	67.60	34.12	144.21	245.93	0.63	3.05	110.1	2.65	48.97

Table 5.8

STATEMENT OF COST OF GENERATION, INCREMENTAL COST AND PLANT UTILISATION FACTOR ON 90% DEPENDABLE YEAR (TWIN TUNNEL SYSTEM)

Sl No	Tunnel Dia (m)	Discharge (cumec)	Power Output (MW)	Estimated Cost of Project (Rs. In Crores)	Cost of Project including IDC (Rs. In Crores)	Average Annual Interest on Loan (Rs. In Crores)	Depreciation per year (Rs. In Crores)	Total Annual Generation (GWH)	Annual Energy for Sale (GWH)	Capacity Charges (Rs./kWh)	O&M Expenses @ 1.5% / year (Rs. In Crores)	Interest Charges on Working Capital (Rs. In Crores)	Returns on Equity Capital (Rs. In Crores)	Total 12+ 13+14 (Rs. In Crores)	Energy Charges (Rs./kWh)	Sale rate of Power (11 + 16) (Rs./kWh)	Incr. Energy (MW)	Cost of incr. energy (Rs./kWh)	Plant Utilisation Factor (%)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	7.00	269.88	650	2509.72	3628.63	522.52	241.91	3368.29	2934.46	2.61	54.43	26.09	116.12	196.64	0.67	3.28	-	-	59.16
2	7.00	294.56	700	2585.22	3737.79	538.24	249.19	3501.36	3050.39	2.58	56.07	27.03	119.61	202.71	0.66	3.25	133.1	2.185	57.1
3	7.00	320.54	750	2662.61	3849.68	554.35	256.65	3631.7	3163.94	2.56	57.75	27.96	123.19	208.89	0.66	3.22	130.3	2.283	55.28
4	7.00	348.24	800	2742.46	3965.13	570.98	264.34	3758.66	3274.55	2.55	59.48	28.86	126.88	215.22	0.66	3.21	127	2.414	53.63
5	7.00	378.24	850	2825.63	4085.38	588.29	272.36	3877.58	3378.15	2.55	61.28	29.71	130.73	221.72	0.66	3.2	118.9	2.677	52.08
6	7.50	309.48	750	2746.22	3970.57	571.76	264.7	3680.25	3206.23	2.61	59.56	28.32	127.06	214.94	0.67	3.28	-	-	56.02
7	7.50	333.48	800	2820.76	4078.34	587.28	271.89	3817.64	3325.93	2.58	61.18	29.29	130.51	220.98	0.66	3.25	137.4	2.092	54.48
8	7.50	358.42	850	2896.64	4188.05	603.08	279.2	3953.36	3444.17	2.56	62.82	30.26	134.02	227.09	0.66	3.22	135.7	2.154	53.09
9	7.50	384.49	900	2974.16	4300.12	619.22	286.67	4079.96	3554.46	2.55	64.5	31.16	137.6	233.26	0.66	3.2	128.6	2.352	51.75
10	7.50	411.97	950	3053.69	4415.12	635.78	294.34	4197.07	3656.49	2.54	66.23	31.99	141.28	239.5	0.66	3.2	117.1	2.602	50.43
11	7.50	441.24	1000	3135.81	4533.86	652.88	302.26	4299.03	3745.31	2.55	68.01	32.72	145.08	245.81	0.66	3.21	102	3.072	49.08
12	8.00	371.92	900	3061.78	4426.82	637.46	295.12	4132.54	3600.27	2.59	66.4	31.55	141.66	239.61	0.67	3.26	-	-	52.42
13	8.00	395.99	950	3136.41	4534.72	653	302.31	4258.93	3710.38	2.57	68.02	32.45	145.11	245.58	0.66	3.24	126.4	2.271	51.18
14	8.00	420.84	1000	3212.17	4644.25	668.77	309.62	4383.95	3819.3	2.56	69.66	33.33	148.62	251.61	0.66	3.22	125	2.328	50.05
15	8.00	446.61	1050	3289.25	4755.7	684.82	317.05	4489.07	3910.88	2.56	71.34	34.08	152.18	257.6	0.66	3.22	105.1	2.803	48.8

Sl No	Tunnel Dia (m)	Discharge (cumec)	Power Output (MW)	Estimated Cost of Project (Rs. In Crores)	Cost of Project including IDC (Rs. In Crores)	Average Annual Interest on Loan (Rs. In Crores)	Depreciation per year (Rs. In Crores)	Total Annual Generation (GWH)	Annual Energy for Sale (GWH)	Capacity Charges (Rs./kWh)	O&M Expenses @ 1.5% / year (Rs. In Crores)	Interest Charges on Working Capital (Rs. In Crores)	Returns on Equity Capital (Rs. In Crores)	Total 12+ 13+14 (Rs. In Crores)	Energy Charges (Rs./kWh)	Sale rate of Power (11 + 16) (Rs./kWh)	Incr. Energy (MW)	Cost of Incr. energy (Rs./kWh)	Plant Utilisation Factor (%)
16	8.00	473.49	1100	3367.92	4869.45	701.2	324.63	4581.1	3991.05	2.57	73.04	34.75	155.82	263.61	0.66	3.23	92.03	3.257	47.54
17	8.00	501.70	1150	3448.52	4985.97	717.98	332.4	4670.4	4068.85	2.58	74.79	35.39	159.55	269.73	0.66	3.24	89.31	3.434	46.36
18	8.00	531.57	1200	3531.5	5105.95	735.26	340.4	4756.42	4143.8	2.6	76.59	36.01	163.39	275.99	0.67	3.26	86.02	3.666	45.25
19	8.50	410.08	1000	3308.57	4783.63	688.84	318.91	4425.43	3855.43	2.61	71.75	33.65	153.08	258.48	0.67	3.28	-	-	50.52
20	8.50	433.43	1050	3382.18	4890.06	704.17	326	4548.23	3962.41	2.6	73.35	34.53	156.48	264.36	0.67	3.27	122.8	2.304	49.45
21	8.50	457.35	1100	3456.59	4997.65	719.66	333.18	4652.48	4053.24	2.6	74.96	35.27	159.92	270.16	0.67	3.26	104.3	2.73	48.28
22	8.50	481.90	1150	3531.92	5108.56	735.34	340.44	4752.4	4140.29	2.6	76.8	35.98	163.41	275.99	0.67	3.26	99.92	2.88	47.17
23	8.50	507.19	1200	3608.3	5216.99	751.25	347.8	4850.94	4226.14	2.6	78.25	36.69	166.94	281.89	0.67	3.27	98.54	2.959	46.15
24	8.50	533.32	1250	3685.89	5329.18	767.4	355.28	4947.92	4310.63	2.6	79.94	37.39	170.53	287.86	0.67	3.27	96.98	3.052	45.19
25	8.50	560.43	1300	3764.9	5443.41	783.85	362.89	5043.16	4393.6	2.61	81.65	38.07	174.19	293.91	0.67	3.28	95.24	3.163	44.28
26	8.50	588.70	1350	3845.58	5560.06	800.65	370.67	5136.39	4474.82	2.62	83.4	38.74	177.92	300.06	0.67	3.29	93.23	3.206	43.43
27	9.00	448.07	1100	3561.3	5149.04	741.46	343.27	4695.88	4091.05	2.65	77.24	35.61	164.77	277.61	0.68	3.33	-	-	48.73
28	9.00	470.85	1150	3634.08	5254.26	756.61	350.28	4801.21	4182.81	2.65	78.81	36.36	168.14	283.31	0.68	3.32	105.3	2.645	47.66
29	9.00	494.04	1200	3707.45	5360.34	771.89	357.36	4905.78	4273.92	2.64	80.41	37.1	171.53	289.04	0.68	3.32	104.6	2.685	46.67
30	9.00	517.68	1250	3781.47	5467.37	787.3	364.49	5009.55	4364.32	2.64	82.01	37.84	174.96	294.81	0.68	3.31	103.8	2.729	45.75
31	9.00	541.84	1300	3856.23	5575.46	802.87	371.7	5112.43	4453.95	2.64	83.63	38.58	178.41	300.63	0.67	3.31	102.9	2.779	44.89
32	9.00	566.57	1350	3931.81	5684.74	818.6	378.98	5214.38	4542.76	2.64	85.27	39.31	181.91	306.49	0.67	3.31	101.9	2.834	44.09
33	9.00	591.94	1400	4008.32	5795.35	834.53	386.36	5315.28	4630.67	2.64	86.93	40.03	185.45	312.41	0.67	3.31	100.9	2.896	43.34
34	9.00	618.04	1450	4085.87	5907.47	850.68	393.83	5413.48	4716.23	2.64	88.61	40.74	189.04	318.39	0.68	3.31	98.2	3.014	42.62
35	9.00	644.97	1500	4164.62	6021.33	867.07	401.42	5497.69	4789.59	2.65	90.32	41.34	192.68	324.35	0.68	3.33	84.21	3.556	41.84
36	9.00	672.86	1550	4244.74	6137.17	883.75	409.14	5580.25	4861.52	2.66	92.06	41.94	196.39	330.39	0.68	3.34	82.56	3.688	41.1

Table 5.9

BENEFIT-COST STUDY FOR 90% DEPENDABLE YEAR

Sl. No.	Dia (m)	Installed Capacity	Cost (Rs.Cr)	Annual Cost (Rs.Cr)	Energy (Gwh)	Net Energy (GWh)	Benefit (Rs.Cr)	Net Benefit (Rs.Cr)	B/C	ΔB/ΔC
1.	10.50	800	2745.98	925.47	3855.56	3817.00	1194.72	269.25	1.29	1.29
2	10.50	850	2818.41	950.10	3997.90	3957.92	1226.96	276.86	1.29	1.31
3	10.50	900	2891.60	974.99	4139.38	4097.99	1258.08	283.09	1.29	1.25
4	10.50	950	2965.65	1000.06	4267.37	4224.70	1292.76	292.70	1.29	1.38
5	10.50	1,000	3040.69	1025.44	4393.69	4349.75	1326.67	301.23	1.29	1.34
6	10.50	1,050	3116.89	1015.09	4503.80	4458.76	1359.92	308.83	1.29	1.30

Table 5.10

BENEFIT-COST STUDY FOR 50% DEPENDABLE YEAR

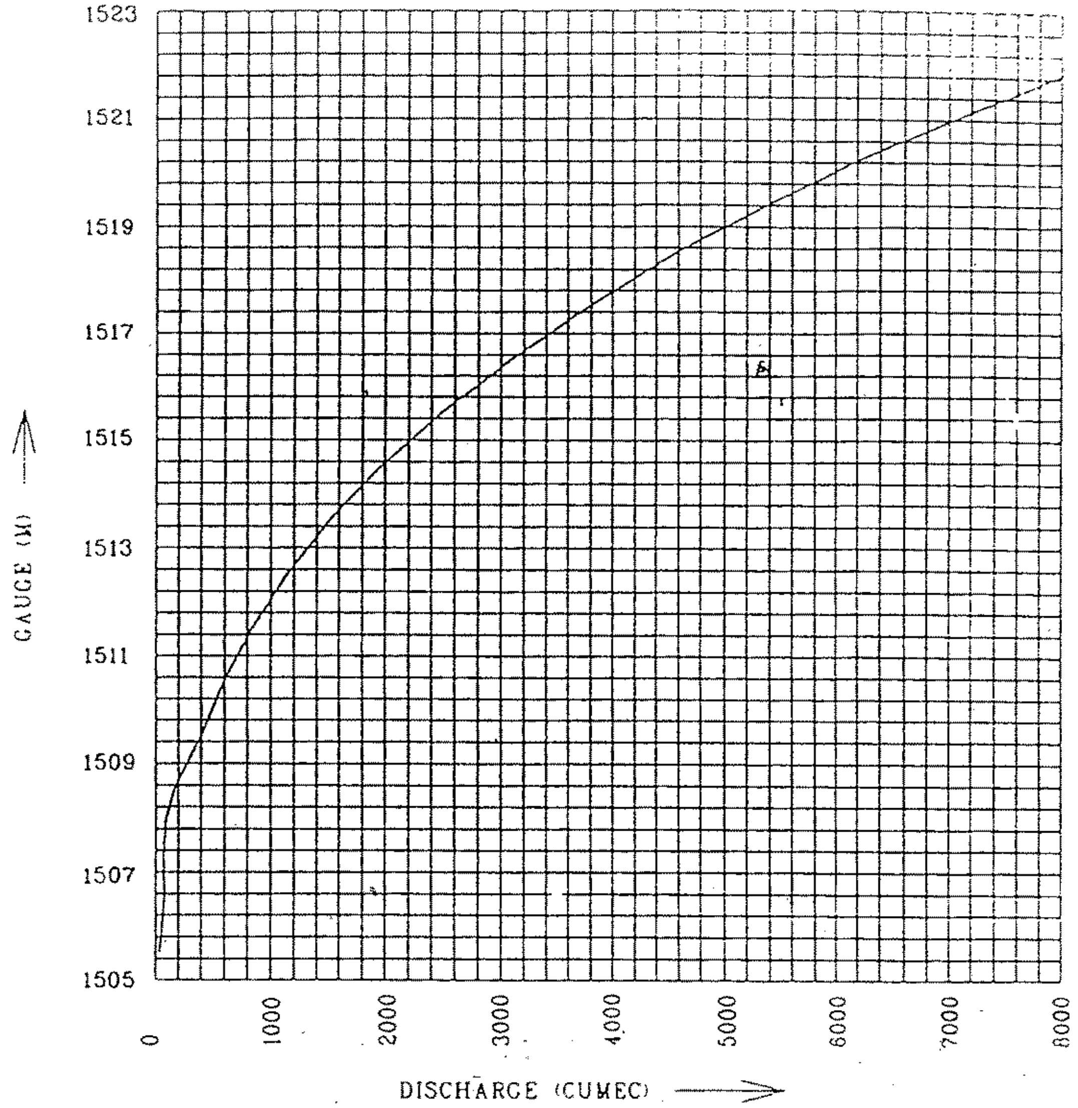
Sl. No.	Dia (m)	Installed Capacity	Cost (Rs.Cr)	Annual Cost (Rs.Cr)	Energy (Gwh)	Net Energy (GWh)	Benefit (Rs.Cr)	Net Benefit (Rs.Cr)	B/C	ΔB/ΔC
1.	10.50	800	2745.98	925.47	4090.62	4049.71	1267.56	342.09	1.37	1.37
2	10.50	850	2818.41	950.10	4231.43	4189.12	1298.63	348.53	1.37	1.26
3	10.50	900	2891.60	974.99	4371.24	4327.53	1328.55	353.56	1.36	1.20
4	10.50	950	2965.65	1000.06	4509.97	4464.87	1366.25	366.19	1.37	1.50
5	10.50	1,000	3040.69	1025.44	4640.45	4594.05	1401.18	375.74	1.37	1.38
6	10.50	1,050	3116.89	1015.09	4735.20	4687.85	1429.79	378.70	1.36	1.12

Note:-

(1) Auxiliary consumption has been considered at 0.5% of total energy generation at Power House.

(2) Transformation losses have been taken as 0.5%.

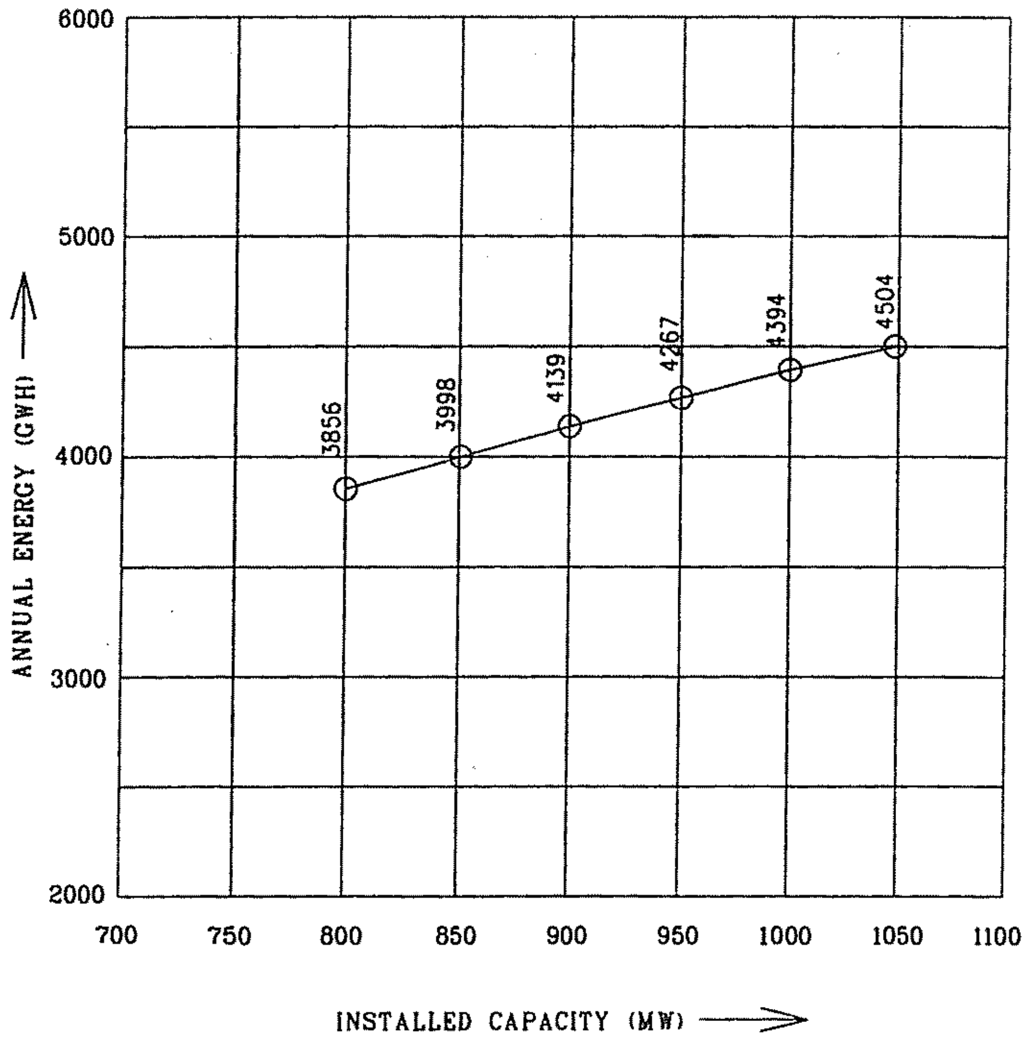
FIGURE 5.1



NORMAL WATER LEVEL (417 CUMEC)	= 1509.5 M
MAXIMUM TAIL WATER LEVEL (5540 CUMEC)	= 1519.5 M

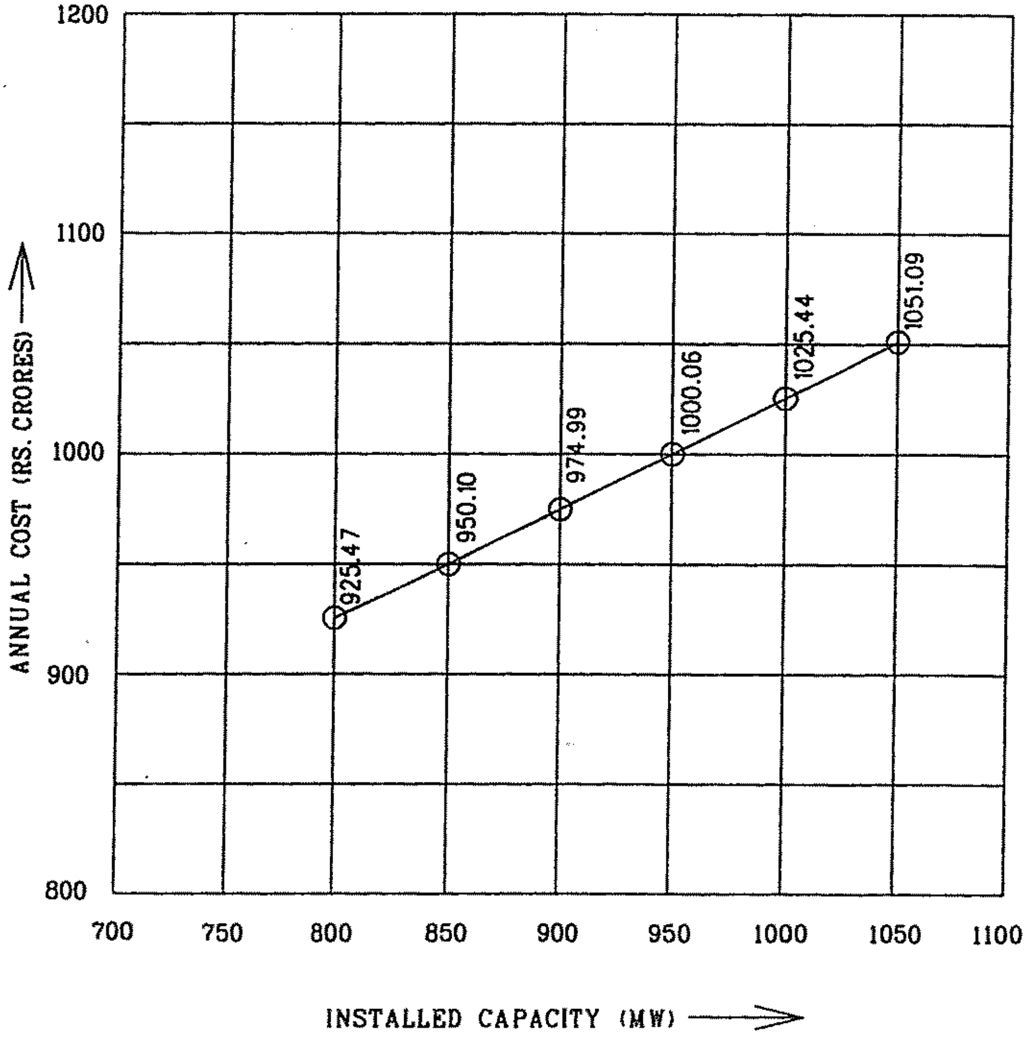
GAUGE-DISCHARGE RELATIONSHIP AT TAIL RACE OUTLET

FIGURE 5.2



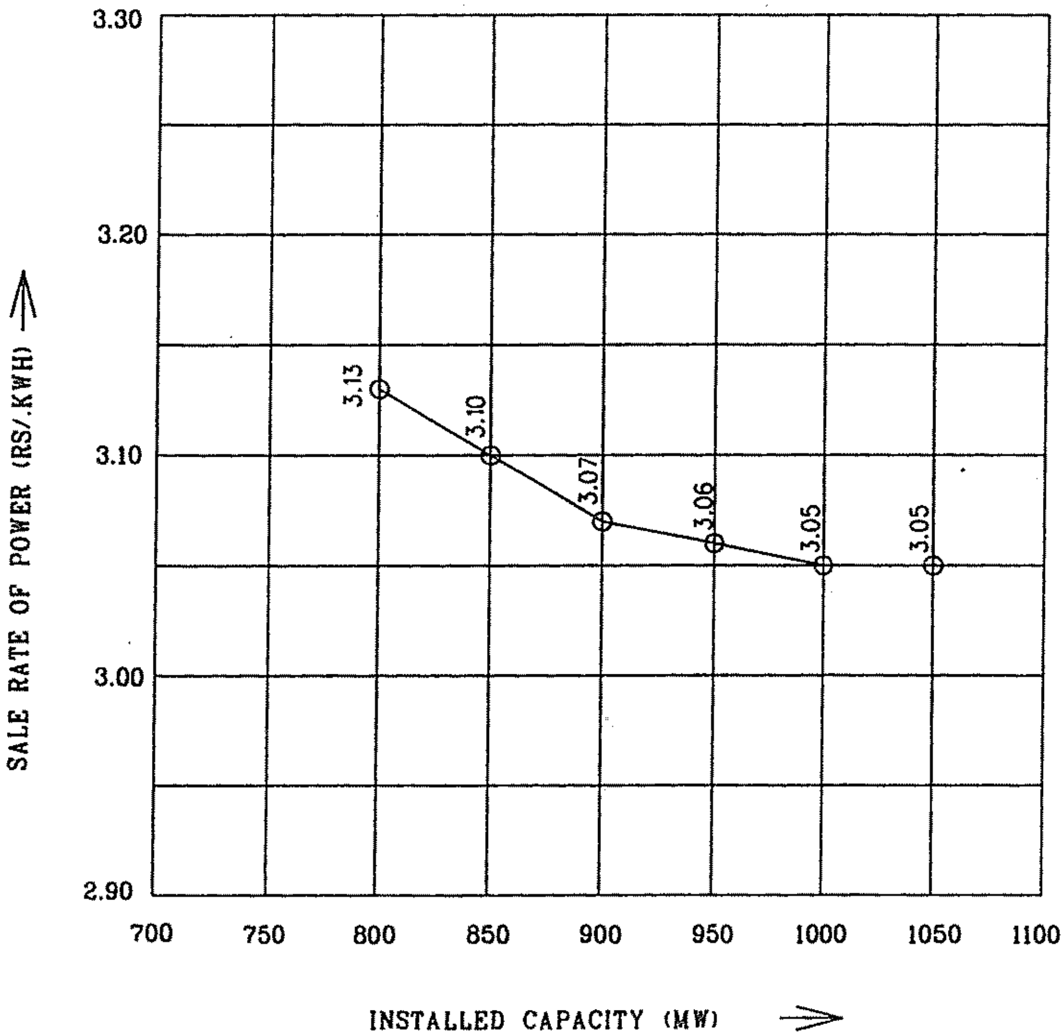
ANNUAL ENERGY GENERATION AT DIFFERENT INSTALLED CAPACITIES
(90% DEPENDABLE YEAR)

FIGURE 5.3



ANNUAL COST FOR DIFFERENT INSTALLED CAPACITIES

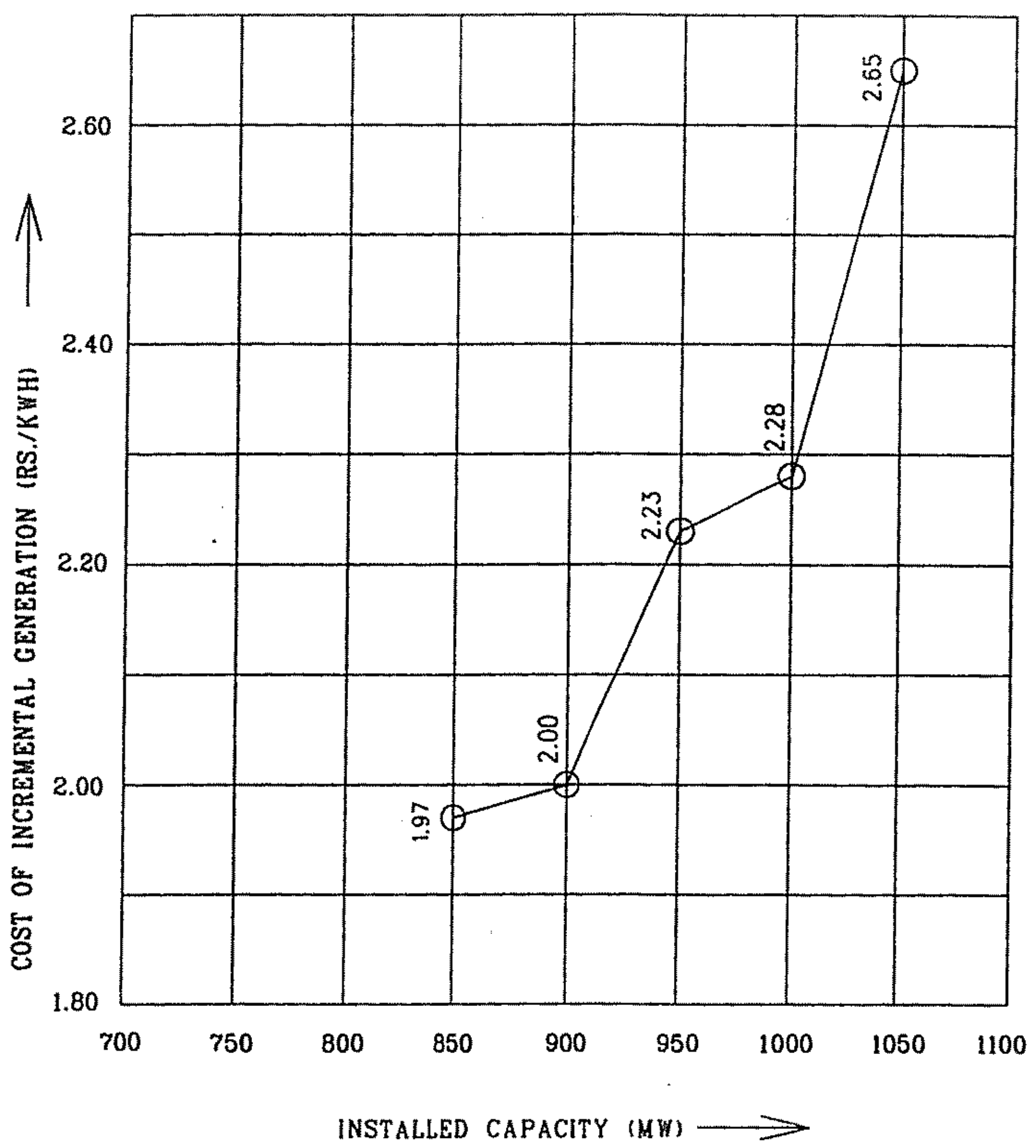
FIGURE 5.4



SALE RATE OF POWER FOR DIFFERENT INSTALLED CAPACITIES

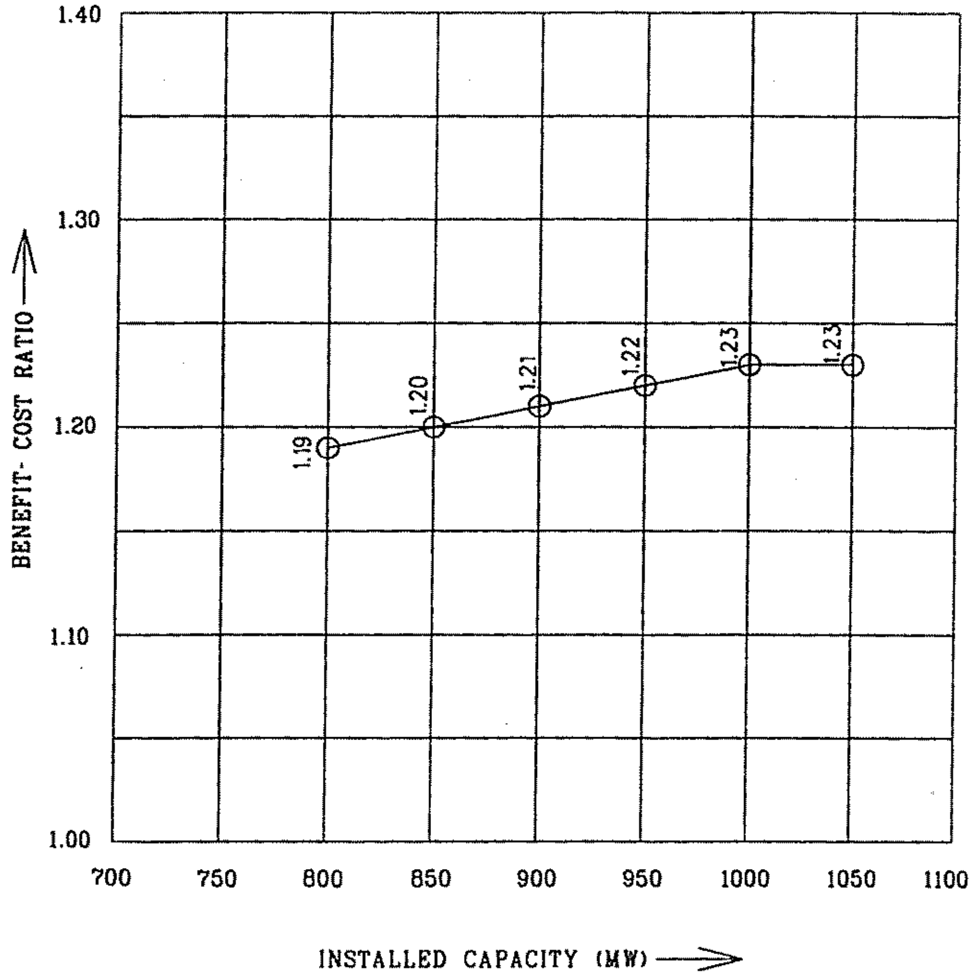
d:\prakash\karcham\gen\CHAP5.wpd

FIGURE 5.5



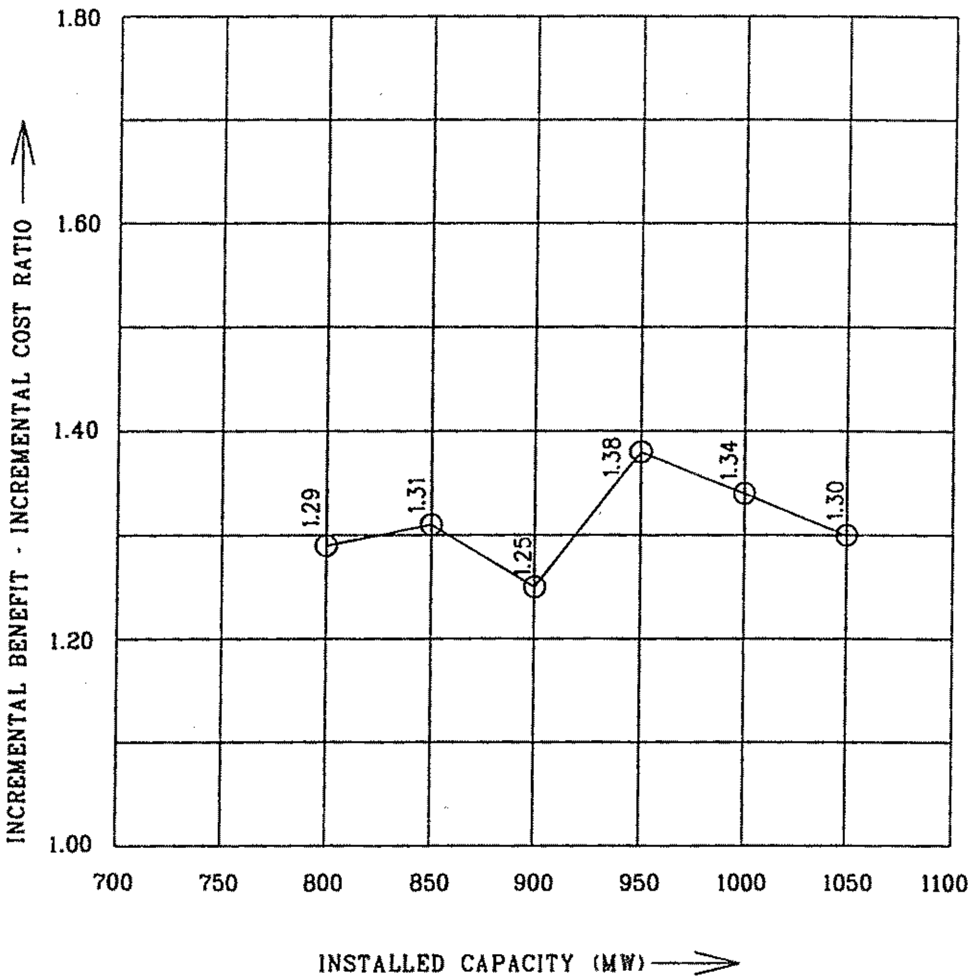
COST OF INCREMENTAL GENERATION FOR DIFFERENT INSTALLED CAPACITIES

FIGURE 5.6



BENEFIT COST RATIO FOR DIFFERENT INSTALLED CAPACITIES

FIGURE 5.7



INCREMENTAL BENEFIT INCREMENTAL COST RATIO
FOR DIFFERENT INSTALLED CAPACITIES

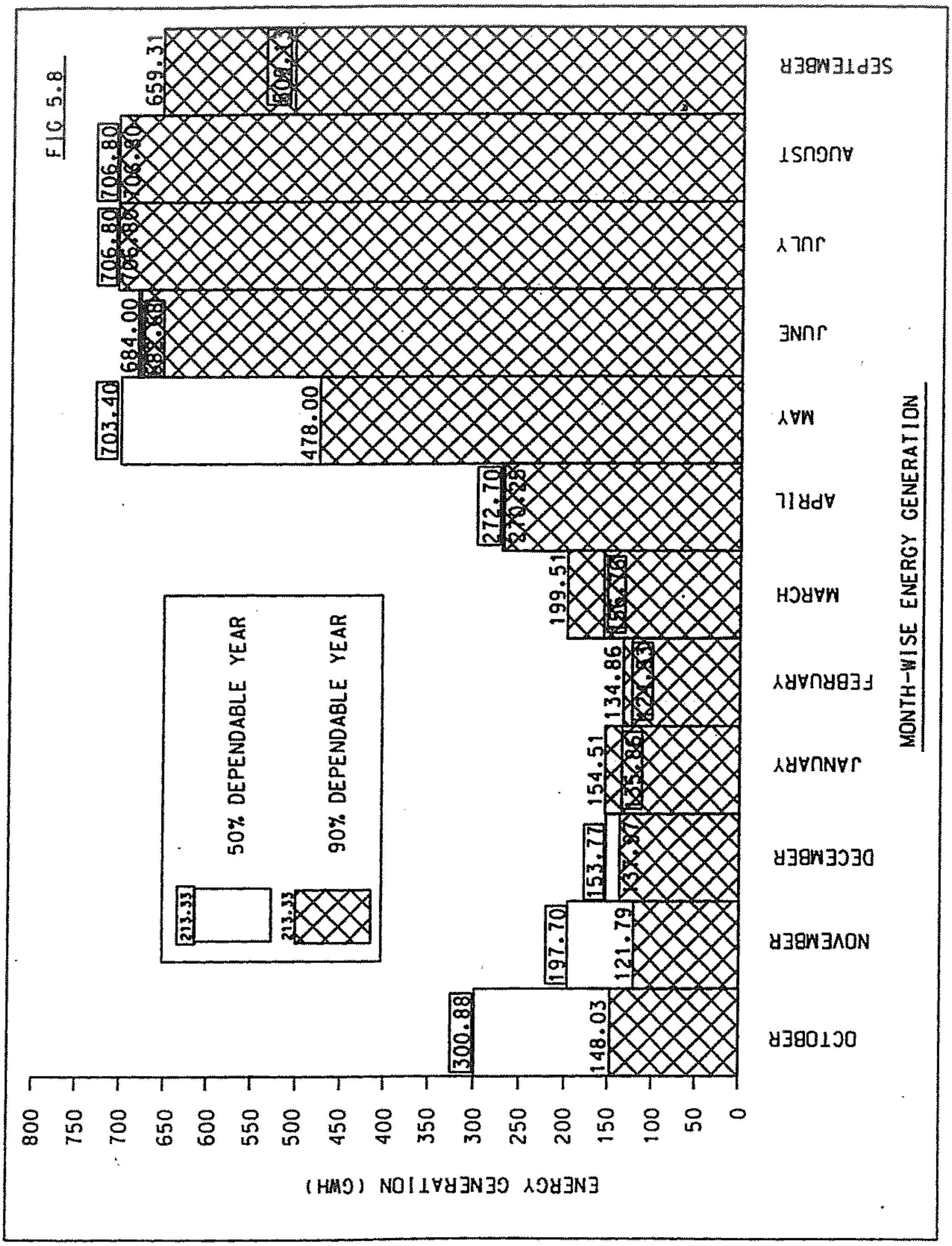
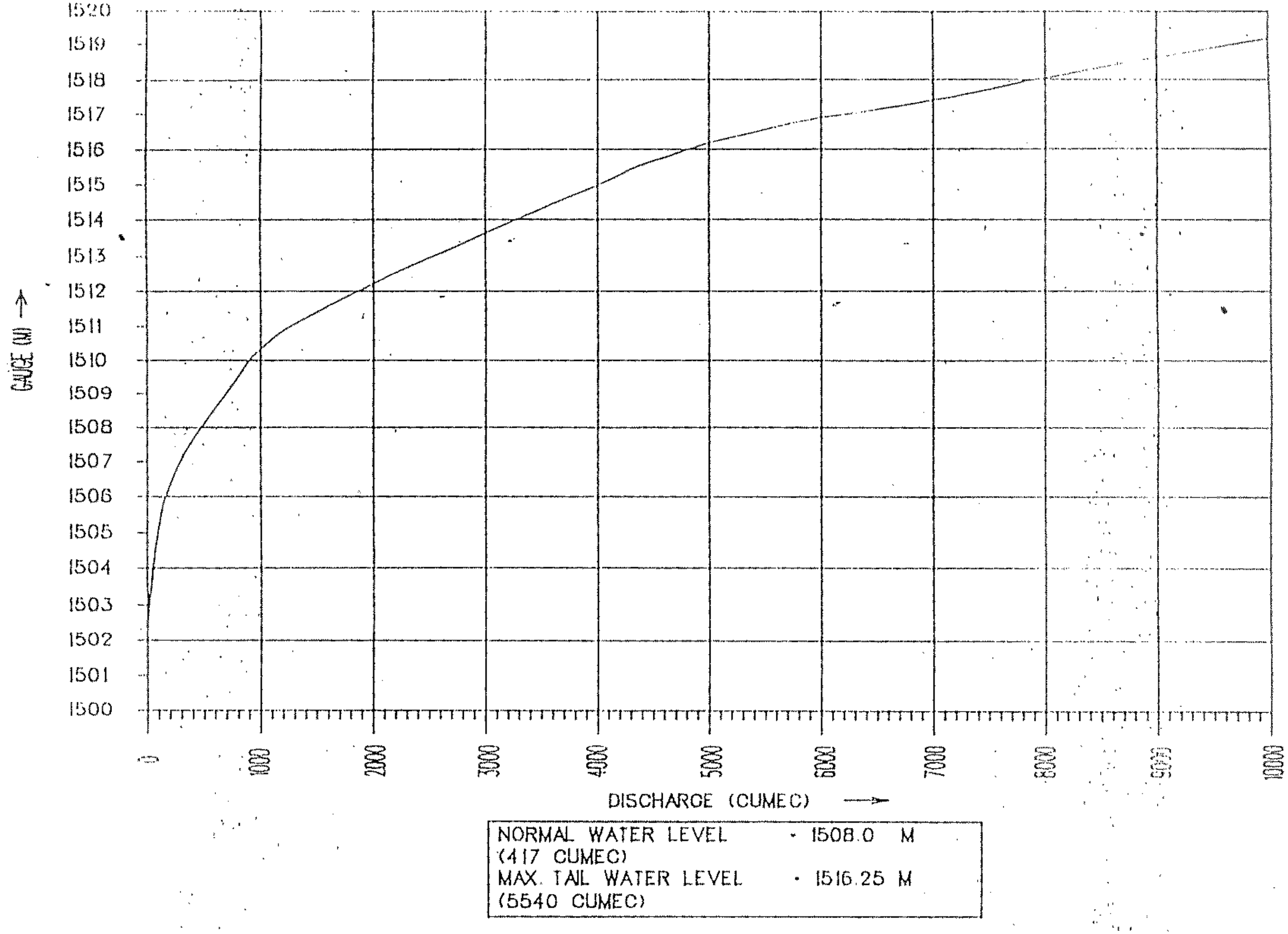


FIG 5.8
MONTH-WISE ENERGY GENERATION
ENERGY GENERATION (GWH)
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
50% DEPENDABLE YEAR
90% DEPENDABLE YEAR
213.33
213.33
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
300.88
148.03
197.70
121.79
153.77
154.51
135.86
134.86
199.51
272.70
703.40
478.00
684.00
706.80
706.80
706.80
706.80
659.31



GAUGE-DISCHARGE RELATION AT TAIL RACE OUTLET

Computation of Exceedence Probability
(Based on December-March run-off)

Sl. No.	Year	Run-off (cumec-day)	Run-off Ha-m	Probability	
1	1992-93	18141	156738.2	2.86	
2	1988-89	17098.5	147731	5.71	
3	1998-99	16291.5	140758.6	8.57	
4	1995-96	16189.57	139877.9	11.43	
5	1991-92	15859.3	137024.4	14.29	
6	1993-94	15723.8	135853.6	17.14	
7	1999-2000	13593.7	117449.6	20.00	
8	1978-79	12694.8	109683.1	22.86	
9	1990-91	12271.7	106027.5	25.71	
10	1996-97	11933.8	103108	28.57	
11	1987-88	11525.6	99581.18	31.43	
12	1966-67	11329.2	97884.29	34.29	
13	1974-75	11093.2	95845.25	37.14	
14	1997-98	11072.1	95662.94	40.00	
15	1986-87	10723.9	92654.5	42.86	
16	1994-95	10439.98	90201.43	45.71	
17	1967-68	10369.9	89595.94	48.57	
18	**1983-84**	**10268.3**	**88718.11**	**51.43**	**50% dependable year**
19	1989-90	10248	88542.72	54.29	
20	1976-77	10031.2	86669.57	57.14	
21	1969-70	9939.1	85873.82	60.00	
22	1980-81	9803.7	84703.97	62.86	
23	1985-86	9688.1	83705.18	65.71	
24	1975-76	9635.5	83250.72	68.57	
25	1973-74	9476.1	81873.5	71.43	

Sl. No.	Year	Run-off (cumec-day)	Run-off Ha-m	Probability
26	1981-82	9361.1	80879.9	74.29
27	1982-83	9294.9	80307.94	77.14
28	1984-85	9291.8	80281.15	80.00
29	1972-73	9220.7	79666.85	82.86
30	1979-80	9004	77794.56	85.71
31	1977-78	8929.6	77151.74	88.57
32	**1970-71**	**8416**	**72714.24**	**91.43**
33	1971-72	8117	70130.88	94.29
34	1968-69	8113.4	70099.78	97.14

90% dependable year

KARCHAM-WANGTOO HYDROELECTRIC PROJECT
FIRM POWER
90% DEPENDABLE YEAR (1970-71)

(Based on flow during lean period i.e. December to March)

Installed Capacity	=	1000.00 MW
Gross Head	=	298.73 m
Tunnel Discharge	=	417.00 cumec
Overall Efficiency	=	89.50 %
Total Head-Loss	=	22.80 m
Length of Tunnel	=	17198 m
Velocity in Tunnel	=	4.83 m/sec
Tunnel Diameter	=	10.48m dia circular

Ten-Daily Period		Discharge	Power	Energy
Dec	I	76.82	186.11	44.67
	II	74.98	181.65	43.60
	III	70.69	171.26	45.21
Jan	I	68.82	166.73	40.01
	II	67.00	162.32	38.96
	III	65.25	158.08	41.73
Feb	I	34.12	155.34	37.28
	II	65.92	159.70	38.33
	III	65.01	157.71	30.28
Mar	I	63.46	153.74	36.90
	II	67.57	163.70	39.29
	III	91.87	222.57	58.76
		Average	**169.91**	**41.25**

KARCHAM WANGTOO HYDROELECTRIC PROJECT

Annual Energy Generation in Descending Order

Sl. No.	Year	Energy (GWH)	Exceedance (%)
1.	1998-99	6047.16	2.86
2.	1992-93	5270.93	5.71
3.	1987-88	5197.81	8.57
4.	1990-91	5185.21	11.43
5.	1991-92	5170.12	14.29
6.	1997-98	5049.21	17.14
7.	1988-89	5048.99	20.00
8.	1993-94	5020.39	22.86
9.	1995-96	4957.94	25.71
10.	1972-73	4932.09	28.57
11.	1978-79	4907.62	31.43
12.	1975-76	4855.75	34.29
13.	1974-75	4845.32	37.14
14.	1983-84	4817.37	40.00
15.	1989-90	4786.48	42.86
16.	1994-95	4752.18	45.71
17.	1982-83	4717.17	48.57
18.	1980-81	4651.02	51.43
19.	1967-68	4583.08	54.29
20.	1996-97	4545.40	57.14
21.	1979-80	4529.04	60.00
22.	1977-78	4747.00	62.86
23.	1966-67	4440.60	65.71
24.	1969-70	4416.97	68.57
25.	1981-82	4405.18	71.43
26.	1986-87	4401.83	74.29
27.	1985-86	4335.80	77.14
28.	1973-74	4301.77	80.00
29.	1968-69	4286.45	82.86

Sl. No.	Year	Energy (GWH)	Exceedance (%)
30.	1971-72	4272.08	85.71
31.	1976-77	4227.92	88.57
32.	1984-85	4215.20	91.43
33.	1970-71	4052.16	94.29
34.	1999-00	3901.12	97.14

Chapter - 6

GEOLOGY

6.1 Regional Geology

Rock types in the Karcham-Wangtoo Hydro-Electric Project area belong to Pre-Cambrian age and consist of ortho and para gneisses of Jeori Wangtoo Gneissic Complex forming basement of Rampur Group of rocks. This rock group is surrounded by Salkhala and Jutogh Group of rocks having thrusted contacts and is called Rampur Window. The formations are largely non-fossiliferous meta-sediments as a result of which difficulty has been experienced in establishing chronological succession and correlation of various litho units. On the basis of regional geological studies carried out by Geological Survey of India. Dr. O.N. Bhargava and others have put forward a geological model and chronological succession as given below from east to west (Bhargava O.N. - 1987).

Geological succession of rocks from east to west in the Satluj Valley, Rampur-Karcham area.

LITHOLOGY	GROUP
EAST	
Sillimanite Kyanite bearing schist and gneiss Calc silicate and migmatites.	Vaikrita
.... MCT / Vaikrita Thrust	
Pale white to grey quartzite, amphibolite, subordinate, schist, locally carbonaceous quartz mica schist, gameteferous schist, phyllite and amphibolite.	Jutogh
.... Jutogh Thrust	
Garnet biotite schist, quartzite and Gneiss, augen to streaky gneiss, carbonaceous schist, quartzite and limestone.	Salkhala
.... Salkhala Thrust	
Quartzite - interstratified basic flows, chlorite phyllite.	Rampur
Jeori-Wangtoo Gneiss	Jeori-Wangtoo-Gneiss
WEST	
Glacial debris	Sub-Recent.

Three thrusts namely Salkhala Thrust, Jutogh Thrust and Main Central Thrust put forward in the above model lie 90 m, 300 m and 10 km upstream of dam site respectively. These thrusts have a general N-S trend and dip upstream side i.e. easternly. It is interesting to indicate that, at the locations of the thrusts, the rocks have uniform strike and dip and no large scale shearing normally associated with Himalayan Thrust is present at the site. The Karcham-Wangtoo Hydroelectric Project and the dam site lie in the stable gneissic basement rocks or the rock zone not involved in the overthrusting movements as per the geological model given above.

The ellipsoidal shape of the rocks of Rampur Window is mainly due to erosion by the Satluj River along a major anticline which is considered to be the south-eastern extension of Kistwar antiformal axis. The formations have a general easternly dip at the dam site i.e. towards upstream, the foliation dip direction changes to N.W. in the middle part and northernly at the power house site indicating that the right bank of the river Satluj or the tunnel area forms northern limb of the antiform. The closure of the outcrops at Karcham is due to easternly plunge of the antiform.

The project area is located in Lesser Himalaya which lies south of snowclad peaks and is characterised by presence of hill ranges seldom rising above 4000 m and having rugged topography, the river Satluj flows through narrow and deep gorges with steep cliffs and escarpments.

The studies carried out earlier have indicated that thermal springs are present in a stretch of 150 km, length in Satluj and Spiti valleys from Tattapani in the south-west and Chuza-Samdo in the north-east. There are in all 12 spring localities out of which *two are in the project area namely Karcham (44°C) and Tapri (73°C).*

6.2 Geology of various works

6.2.1 Diversion Dam

Karcham dam site is located about 300 m downstream of confluence of Baspa river with Satluj. This location has been primarily selected so that the wider valley of Satluj at the confluence and the valley of Baspa River is available for the storage of water keeping the FRL at 1810 m. This limitation of FRL is obligatory because the tail water of Baspa Hydroelectric Project under construction has its outfall at El 1807 m in the river Satluj some 700 m upstream of the confluence.

The dam area is occupied by Gneisses of Jeori-Wangtoo Group. Towards the upstream side of the axis, these gneisses have been successively overlain by 65-70 m wide quartzite band (Rampur), mica schist and quartzite gneiss or streaky gneiss interbanded sequence (Salkhala). The rocks show a dip of 45°in an easternly direction having N-S strike direction. The geological map of the dam site is given in Drawing No. 1200-01-01.

Barring some 20-25 m thick gravel deposit above the river bed on the left bank and debris accumulation on the right bank below road, gneissic rocks are well exposed on both the abutments. However, on the right bank, an extensive glacial debris is present which starts from 20-25 m downstream of the axis and continues for some 400 m length, it rises 80-85 m above the river bed. The debris accumulation has apparently taken place in an embayment developed by erosion of rock.

Explorations

The dam site has been explored by five drill holes aggregating 190.43m drilling and two drifts including cross cuts aggregating a length of 138 m.

Drilling

The five drill holes proved bed rock as given in Table 1.

Table 1

DETAILS OF EXPLORATORY HOLES AT DAM SITE AND THEIR RESULTS

Bore Hole No.	Collar Elevation (m)	Location	Depth of over-burden	Bed Rock Elevation (m)	Total Depth of Hole (m)	Remarks
DH-1	1773.00	Left bank water edge along dam axis.	39.93	1773.0	58.21	Slightly weathered rock below over-burden for 3m depth.
DH-2	1784.00	Left bank gravel terrace top, dam axis.	30.48	1753.7	52.40	Slightly weathered rock below over-burden for 4.7m depth.
BH-1	1783.81	Right bank, dam axis.	22.20	1761.6	32.60	Below 22.20 m rock is fresh and hard.

Bore Hole No.	Collar Elevation (m)	Location	Depth of over-burden	Bed Rock Elevation (m)	Total Depth of Hole (m)	Remarks
BH-2	1781.16	Right bank 50m downstream of axis	47.22	Not proved up to El 1734	47.22	Hole abandoned due to mechanical trouble.
BH-3	1783	Left bank of river Satluj along dam axis	23.00	1760	32	Slightly weathered rock below over-burden for 7m depth.

Water percolation tests conducted in BH-1 between 22.6-24.6 m, 24.6-26.6 m, 26.6-28.6 m and 28.6-30.6 m depth gave permeability values as 7.5, 11.75, 13.3 and 11.0 Lugeons respectively indicating necessity for foundation grouting.

Drifts

Two drifts, one at road El. 1794.60 m and the other at El. 1781.0 m, have been made to explore the abutment rock conditions. From the lower drift, two cross cuts have been made from R.D. 25 m in upstream and downstream directions to explore the rock conditions across the strike, the bottom contact of the quartzite band and the condition of quartzite band in view of the anticipated Salkhala Thrust at the top of the quartzite. Abstract log of the drifts is given in Table 2.

Table 2

ABSTRACT LOG OF DRIFTS

Drift and cross-cut	Excavated Length (m)	Remarks		Depth of Stripping along axis
Drift El. 1794.6m	20	0-11.5 m	Schistose gneiss moderately weathered	
		11.5-20 m	Rock is fairly fresh and hard, open slump cracks/ joints present at R.D. 11 m and 15 m.	12.5 m
Drift El. 1781.0m	35	0-12.5 m	Deeply stained schistose gneiss.	
		11.5-20 m	Fairly fresh rock with stained joints.	12.5 m

Drift and cross-cut	Excavated Length (m)	Remarks		Depth of Stripping along axis
		20-35 m	Schistose gneiss, fairly fresh rock with stained joints.	
Upstream cross-cut at R.D. 25m	50	0-6 m	Schistose gneiss, 15-30 cm thick shear zone at the contact with overlaying quartzite.	
		6-50 m	Quartzite band, stained, closely jointed, 3-10 cm thick shear seams met at R.D. 3, 14, 30, 32.5, 35 and 37.5 dipping at 42°-45° in easternly direction.	Intake structure foundation area
Downstream cross-cut at R.D. 25m	32m (southernly)	0-15 m	Fairly fresh schistose gneiss except between 6-12 m where augen gneiss is present.	30 m (15-32 m downstream of axis)
		15-32 m	Schistose gneiss, blocky and stained on river side wall bounded by two slump cracks dipping 50° W and 70° N. The slumped rock has to be removed.	

Both the drifts have indicated depth of stripping 12.5 m, which will extend to 25m about 15m downstream of the dam axis. This is due to turn of rock line to right along the rock embayment occupied by glacial debris. Sound rock line also turns to right following rock contours below overburden.

Beyond 12.5 m depth, the rock is fairly fresh but, it contains open cracks upto excavated depth of 35 m developed due to slope adjustment initiated by deep river erosion extending down to El. 1720 m proved by geophysical survey or 61 m below the drift level. This rock zone 12.5-35 m can be thoroughly grouted through two drainage and grouting galleries at El. 1770 m and 1795 m on each abutment.

On the left abutment, the depth of stripping can be taken as about 12.5 m.

Geophysical Survey

Geophysical survey of the Karcham dam site was conducted by the Department of Earthquake Sciences, University of Roorkee at the request of M/s Jaiprakash Industries Ltd. Results of seismic refraction survey has indicated that the deepest rock level exists at El. 1720 m close to left bank of the river along the dam axis. Exploration by drilling has indicated presence of weathered and stained rock from 3 m to 4.7 m depth. Therefore, lowest sound bed rock for placement of dam foundation has been taken at 1715 m elevation.

6.2.2 Diversion Tunnel

The proposed tunnel alignment is such that it is across the strike of schistose gneiss which is a favourable orientation in so far as tunnelling conditions are concerned. The rock shows widely spaced joints. `Q' values are expected to range from 4 to 10.

Upstream portal site lies where quartzite debris is present. This material has to be removed for establishment of the portal which is expected to be in gneiss underlying the quartzite band. River bed gravel and sand has to be removed for establishment of downstream portal which will lie in schistose gneiss.

6.2.3 Coffer Dams

At the upstream and downstream cofferdam sites, the river bed contains sand and gravel which is expected to be around 50 m thick as revealed by geophysical survey. The gravel is expected to have rather high permeability. It would be necessary to provide concrete cut off in the river bed material to prevent heavy seepage into the operational area.

6.2.4 Reservoir Area

43 m high dam above the river bed having its FRL at 1810 m will spread its reservoir for 4.4 km along the river Satluj and 1.6 km along Baspa river.

Satluj gorge in the reservoir area has steep valley slopes. At places, there are narrow strips of river gravel deposits and accumulations of talus at the base, while at places, the river hugs against rocky banks. Talus accumulations have stable slopes. The talus and gravel materials is free draining. Therefore, construction of reservoir of limited height is not expected to cause any instability in the talus material as well as the rocky valley walls.

Baspa valley within the limits of the reservoir area has steep rocky slopes which are stable, except two zones of debris accumulations, one on the left bank and the other on the right bank. On the left bank from 0.7 km to 1.6 km upstream of the confluence, an old slide debris mixed with fluvio-glacial debris accumulation is present; it rises to 400-500m above the river bed. The debris is resting at an angle of repose and the area from 0.7 to 0.9 km is fairly stable where scattered trees are present. In the remaining upstream part i.e. 0.9-1.6 km the debris shows presence of slump seams and is unstable. This slumping is due to slow removal of the loose material at the base of the debris slope by river erosion, the toe removal causes slumps. After the construction of dam and during reservoir operation, this area being in the upper reach of the reservoir, will start deposition of the river bed material and toe erosion will reduce and a self stabilising process would set in. No special measures are therefore presently indicated.

On the right side from 400-600m upstream of the confluence, there is slide debris which rises to several hundred meters above the river bed. The debris consists of rock blocks of various sizes and shapes embedded in micaceous fine silt. The debris is resting at a stable slope and road to Baspa valley is constructed through this material. It would present no problem of stability of reservoir rim.

6.2.5 Intake and Intake Tunnels

The intake structure is proposed on the right bank immediately upstream of the dam axis where quartzite and overlying schist and gneisses are well exposed on the hill slope occurring at 50°. The structure has been located by suitable cutting of hill and providing necessary slope protection measures such as rock bolts and shotcrete etc. which would be sufficient for slope protection & stability.

The structure will be founded mainly on the quartzite band, a part of it will be on the underlying gneiss and the overlying schist, all dipping at 45° due east. The foliation strike is almost across the axis of the intake. The quartzite is highly jointed and contains 3-10 cm thick shear zones parallel to foliation as revealed in upstream cross cut of the exploratory drift, the crown of which lies at the foundation level of the intake. The foundation area may expose certain open slump cracks and open joints which may need treatment. For proper stability of the intake structure, the following remedial measures have been proposed to be adopted which would be sufficient and adequate.

1. Cement grouted rock bolts be provided on the rock slope below the intake bench. This treatment will cover the existing slope as well as additional rock slope exposed by removal of river bed gravel material to expose the bed rock in the dam area pit.

2. The intake foundation area will be grouted with cement to seal open joints and fractures.

3. Upstream cross-cut will be plugged with concrete, if it does not fall in excavation zone, in which case it will be automatically removed.

6.2.6 Sedimentation Chambers

Four sedimentation chambers of 505 m long, 16 m wide and 30 m high are proposed on the right bank aligned in N38°W - S38°E direction. These chambers are required in order to exclude the sediment coarser than 0.2 mm entering the water conductor system. The sedimentation chamber no. 1 is 100m away from the river edge at the upstream end and 200 m away at the downstream end. Maximum rock cover above the chamber no. 1 is 145 m and chamber no. 4 is 260 m. The chambers lie in Jeori Wangtoo Gneissic Complex, but the starting position of the chambers are so fixed that they lie in quartzite band and underlying gneiss. A part of the curved portion of intake tunnels for chamber nos. 3 and 4 cross the supposed Salkhala Thrust zone and mica schist along it. This schist band has no visible indication of shearing and tunnelling is expected to involve no abnormal problems of tunnelling through schistose rocks due to their fissile and soft character.

505m long chambers are expected to contain steeply dipping shear zones of 1-3 m thick oriented in N-S direction occurring at 75-100 m interval and having ground water seepage. In addition, the area shows two sets of joints trending N-S or E-W with varying amount of dip in direction east or west, south or north with a variation of 10° in strike direction as well as in the angle of dip. Another set dipping 60°S : 60°W is also present.

The orientation of the long axis of the sedimentation chambers is kept N 38°W - S38°E which is fairly oblique to the strike of long continuity features and is favourable position as far as effect of stability of side walls is concerned.

The intersection of the various joint sets given above form wedges in the arch portion of the chambers. Wherever, three sets are present and they have a long continuity, the roof will need a support pressure of 0.66 kg/cm².

Computation of 'Q' values in the exploratory drifts at the dam site has revealed that the average of minimum and maximum values of 'Q' are 4 and 9 respectively which indicates likely support pressure of 0.68 kg/cm².

The sedimentation chambers of 16m wide would, therefore, be provided with tensioned and grouted expansion shell type spot rock bolts 25 mm dia, 5000/7000 mm long at 1500 mm c/c staggered both ways and 150 mm fibre reinforced shotcrete in arch portion and extended to sides, as required. The shear zone portions would be provided with ISHB 150 at 34.6 kg/m at 750 c/c to 500 c/c and 150 mm fibre reinforced shotcrete.

About 400 m upstream of beginning of sedimentation chambers, a hot spring is present on NH22 at Karcham. Hot water generally rises through shear zones, faults and thrusts etc. The sedimentation chambers though not very far from the hot spring, may experience incidence of hot water. Therefore, proper provision has been kept for this eventuality.

6.2.7 Head Race Tunnel

General

The total length of the head race tunnel from the exit of sedimentation chamber upto the junction with surge shaft is 17198 m. The tunnel alignment is kept on the right side of the river due to presence of National Highway No. 22 which follows this bank of the river and provides easy approach for construction of the Project.

Geology along the Tunnel Alignment

Detailed geological mapping along the tunnel alignment and Regional Geological Studies carried out by Geological Survey of India have revealed that the entire tunnel alignment is occupied by gneissic rocks of Pre-Cambrian Age. They form the northern limb of an anticlinal fold plunging to east i.e. upstream. The fold axis trends almost E-W and lies along the flow of the river. At the intake end, the formations have N-S strike and dip at 45° to east i.e. upstream. The dip direction changes to N-W in the middle part of the tunnel length and at the power house site, the foliation dip is 70° to north. The angle between tunnel alignment and the strike of foliation varies from 10°-25° in 40% and 30°-70° in 60% length of the tunnel. Special care will be needed during tunnelling where the angle between tunnel alignment and strike of foliations is small.

The rock types along the tunnel alignment have been classified into three broad lithological zones as given below:-

Zone I (R.D. 0 - 7.750 km)

This zone contains mainly altemate bands of porphyroblastic gneiss, augen gneiss, medium grained gneiss and quartz mica schist with bands of mica schist, amphibolite schist and intrusion of pegmatite (1-2 m thick).

Zone II (R.D. 7.750 - 9.450 km)

Zone II rocks contain fine grained quartzitic gneiss with bands of biotite schist and muscovite schist 50-100 cm thick.

Zone III (R.D. 9.450 - 17.198 km)

Zone III rocks contain mainly massive Wangtoo gneiss, which is classified as ortho gneiss. The upper contact of this zone with overlying Zone II rocks is not sharp but gradational i.e. there is a considerable part where both rock units are present.

Wedge analysis of joints present in the tunnel area was carried out for estimation of rock loads and support requirement. In addition, Rock Mass classification according to Q-System was also done. The details are given in Table 3.

Table 3

THE LITHOLOGICAL ZONES ALONG THE TUNNEL ALIGNMENT AND THEIR RANGE OF `Q' VALUES

Sl No	Length along HRT (m)	Q Value and Rock Class	Structural and Lithological Description
1.	1150	0.01-0.1 Extremely poor	1) Shear zones 3-5m thick with ground water flow, oriented N-S, N20°W-S20°E, and N20°E-S20°W i.e. running across the tunnel alignment occurring at 75-100m interval; assumed aggregate length 1133m 2) Choling khad fault with ground water 17m Total 1150m
2.	850	0.1-1 Very poor	1) Foliation shear zones, mica schist, biotite schist zones etc. 600m 2) Very poor rock reaches in Zone II 250m Total 850m
3.	13198	1-4 Poor rock	3 to 3+ random joint sets, closely spaced, average RQD ranging from 50-80% forming wedges in the crown having gravity fall conditions as well as sliding conditions in gneissic rock
4.	2000	4-10 Fair to good rock	Massive Wangtoo gneiss, normally two to 2+ random sets of joints and widely spaced. RQD - 70-100%

6.2.8 Surge Shaft

Surge shaft is proposed on the E-W trending ridge occurring between Bhaba river on the north and Satluj river on the south. The hill top is a narrow hillock at El 1857m, its northem slope varies from 65°-80° with two narrow benches. The southem slope is uniform at an angle of 57°. Massive Wangtoo granite gneiss is well exposed in the larger part of the hillock. The rock shows three sets of long continuity joints which are widely spaced viz. 74°:N, 74°:N65°W and 20°:SW.

Open to sky surge shaft is proposed having finished diameter of 16m between El 1678.25m - 1755m and 27m between El 1755m - 1852m. The top portion of the surge tank would thus be practically a built-up shaft. Due to narrowness of the ridge, the side rock cover above elevation 1755m is hardly 2D at this elevation which reduces to nil at El 1852m. Below El 1755 the rock cover around the surge shaft varies from 60-170m (>3D). The surge shaft will be provided reinforcement for internal pressure without any rock sharing above El 1755. Below El 1755m, rock sharing can be adopted. A sandwitched steel lining in partial replacement of reinforcement will be a useful provision to make the lining watertight.

6.2.9 Power House Complex

Wangtoo power house is underground in the rock ridge between the river Satluj and its tributary Bhaba. The ridge rises for 295m height from the river bed elevation with steep slopes which range from 50°-80°. Wangtoo granite gneiss is present in the area having a general dip of foliation parting 60°-70° in northernly direction. Other important sets of joints are (i) 60°:S60°W, (ii) 70°:N70°W. A low angle shear zone 5-10cm thick is exposed on the road side having rolling dip of 14°-16° in S 70°E to S 55°W direction. Geological map of the power house area along with engineering layout is given in Drg. 1201-01-04.

Exploration

Powerhouse area has been explored by 186.3m long drift and at the end of this drift six drill holes of 40m each aggregating 240m have also been drilled. The results of explorations are given below :

Exploration by drift

A drift of 2.5m D-shaped size with arch roof and 186.3m long leading to powerhouse cavern area has been made. Granite gneiss met in the entire drift is fresh hard and tough except from portal to RD 5m which shows slight staining and open joints at RD 5m. The drift has shown intrusion of pegmatite veins at places which show folding in plastic stage without any shearing. The axial plane shows a dip of 40°:N20°E indicating N20°E-S20°W direction of force that caused folding. The drift is generally dry, it shows minor seepage from the open crack at 5m and near 180-186 close to powerhouse cavern face. The rock in the entire drift is self supporting, blast holes can be seen in the roof and walls indicating no overbreak or rock fall.

Exploration by Drill Holes

Six holes of 40m depth each have been made in the powerhouse drift close to cavity area aggregating 240m. These holes are made for hydrofracturing tests. First set of these holes are made from a 3m long cross cut at RD 125m. All the three holes are oriented in mutually perpendicular directions corresponding to three x, y, z axis. The second set of three holes in mutually perpendicular directions are made at RD 186m i.e. at the end of the drift where powerhouse cavern starts.

One almost horizontal hole is oriented in N 30°E direction i.e. the direction of powerhouse cavern and is about 30° oblique to the strike direction of foliation in gneiss. Second hole is also horizontal and aligned in N 60° direction i.e. perpendicular to the above hole. The third hole is vertical.

The core recovery in the holes generally varies from 80-90% though few short zones of 70-80% and 90-100% are also present.

RQD generally varies from 50-90%. Some short zones of poor RQD i.e. 10-50% seem to be due to poor drilling and AX size of core drilling.

Orientation of Power House Cavity

The orientation of powerhouse cavity is kept N32°E-S32°W which is 30°-70° oblique to strike of long continuity joint which is a favourable position as far as the stability of powerhouse walls is concerned except one joint set oriented N20°E-S20°W. Whenever, this joint is present it would need precautions by way of rock bolts, of adequate length.

Support Requirement of Power House Cavity

Wedge analysis of joints met at surface and exploratory drift has revealed that under worst conditions a support pressure of 0.5 kg/cm^2 would be needed to stabilise the wedges.

Observations of 'Q' values in the powerhouse drift was carried out at every 5m interval. The drift is dry but some seepage condition was observed near the powerhouse face. Therefore, assuming some seepage conditions in the powerhouse cavity area, minimum 'Q' value is computed as 4 and mean 'Q' value as 7-14. Taking minimum 'Q' value 4, the support pressure amounts to about 0.48 kg/cm^2 as computed by wedge analysis.

The powerhouse roof has been provided support system taking 'Q' value as 4. Systematic bolting and fibre reinforced shotcrete has been provided in the arch support.

Stress Conditions in the Powerhouse Area

Himalayan rocks have undergone mountain building processes and tectonic activities reflected by thrusts, folds, faults, and shear zones etc. The rocks of the project area show a regional antiform, the fold axis of which trends E-W roughly following the river course indicating principal compressive force in N-S direction. The minor folds seen in the powerhouse drift indicate a compression in N20°E - S 20°W direction. Since the powerhouse is located at the end of the narrow ridge deeply cut up by Bhaba and Satluj rivers, the regional tectonic stresses are believed to have been released. On the other hand the area is believed to be containing toe stresses due to rock cover of the order of 300m which may amount to 8-10 MPA.

Insitu stress measurement by Hydro-fracturing method has been done in the powerhouse drift by the National Institute of Rock Mechanics (NIRM), Kolar Gold Field (KGF), Bangalore. The direction of maximum horizontal stress as computed from the tests is N 5°E and N 10°E, which tallies well with the stress direction N-S to N 20°E - S 20°W by tectonic analysis as given above.

The test results are given below :

Insitu Stress

TESTS	SITE I RD 1006m	SITE II, RD 125
Vertical stress (S_1) Calculated with overburden = 269m and density of rock = 2.86 gm/cc	7.56 MPa	7.56 MPa
Maximum Horizontal Stress (S_H)	3.79 + 0.3796 MPa	3.56+0.6586 MPa
Minimum Horizontal Stress (S_h)	1.89 + 0.1898 MPa	1.78 + 0.3293 MPa
Direction of Maximum Horizontal Stress	N5°E	N 10°E
$K = S_H/S_v$	0.501	0.47

6.3 Test Results

Deformability modulus tests were conducted by NIRM at RD 125m and 186m in the powerhouse drift and at RD 30m in the drift at El 1788.80 on the right bank at the Karcham dam site.

Uniaxial compressive strength and tensile strength for the powerhouse and dam site rocks have been computed by determining Point Load Strength Index from cores of drill holes as per IS 8764-1978.

Point Load Tests were performed on cores of drill hole nos. H-1, H-2, H-3 and H-4 drilled in the powerhouse area and cores of BH-1 at dam site.

The results are given below :

TEST		POWERHOUSE GRANITE GNEISS	DAM SITE (Schistose Gneiss)
Deformability Modulus	Minimum	9.462 GPa	3.395 GPa
	Maximum	23.889 GPa	12.675 GPa
	Average	17.267 GPa	8.196 GPa
Modulus of Elasticity	Minimum	15.319 GPa	5.796 GPa
	Maximum	26.809 GPa	13.484 GPa
	Average	21.570 GPa	10.635 GPa
Uniaxial Compressive Strength	Minimum	876.30 kg/cm^2	429.00 kg/cm^2
	Maximum	1280.00 kg/cm^2	682.00 kg/cm^2
Tensile Strength	Minimum	51.50 kg/cm^2	22.25 kg/cm^2
	Maximum	76.44 kg/cm^2	33.50 kg/cm^2

6.4 Drawings

Following drawings about the geology of the Project Area have been included in Volume V of the Report.

S.No.	Drawing No.	Title
1.	1200-01-01	Geological Map of Karcham Dam Site
2.	1200-01-02	Geological Map along Karcham-Wangtoo tunnel alignment
3.	1200-01-03	Geological Sections along intermediate adits 2 to 4 and surge shaft adit
4.	1200-01-04	Geological Map of Wangtoo Power House Site

Chapter - 7

EARTHQUAKE ENGINEERING STUDIES

7.1 Introduction

Extensive regional and local earthquake engineering studies relative to both the Nathpa-Jhakri and Baspa II projects were carried out and approved by Central Water Commission. Both projects are now under construction according to designs which incorporate the earthquake parameters established for them.

Professor L.S. Srivastava, an authority on earthquake evaluation, carried out a similar study for the Karcham-Wangtoo Project. This report titled "Earthquake Parameters for Design of Karcham-Wangtoo Dam and other Structures of the Karcham-Wangtoo Hydroelectric Project. Himachal Pradesh. May 1995." is included unabridged in Appendix 2, Volume IV.

7.2 Contents of the Report

The report described available data on earthquake occurrence, geology tectonic and seismotectonics of the area around the Karcham-Wangtoo Project. Much of the recent data was obtained from a network of seismic recording stations, established at strategic locations in northern India. The report also presents recommendations on seismic parameters to be adopted for earthquake resistant design and dynamic analysis of Karcham Dam and appurtenant structures as well as design of underground rock structures and other components of the project.

- **Reference Document**

  The Karcham-Wangtoo Site lies in seismic zone IV, based on the seismic zoning map of India, which is part of the official Indian Standard criteria for earthquake resistant design of structures known as IS:1983-1984, Fourth Revision.

- **Historical Data**

Data on earthquake occurrences around the project in the Himalayan belt, exhibit seismic activities on considerable higher scale compared to the area in the Indo-Gangetic plains and shield regions of India.

All available data on earthquake occurrences pertinent to the region of the project were catalogued and are presented in tabular form in Srivastava's report. The table on major earthquake events which affect the project area, is included in Table 7.1 of this report.

The data shows events having Richter's magnitude 5 and greater, occurring at frequent intervals and affecting the Karcham site. These events originated from various parts of Jammu & Kashmir, Himachal Pradesh and adjoining parts of Uttar Pradesh and Tibet.

Some of the most important seismic events causing considerable damage in the region in the last 100 years, include the following:

1905	Kangra	EQ magnitude	8+
1906	Kullu	EQ magnitude	6.0
1945	Chamba	EQ magnitude	6.5
1947	Chamba	EQ magnitude	6.6
1975	Kinnaur	EQ magnitude	6.8
1991	Uttarkashi	EQ magnitude	6.6.

- **Geology**

The geology of the area was obtained from the offices of the Geological Survey of India.

The rocks of the area comprise a variety of metamorphic gneiss, schists and other intrusives described in previous chapters. Of consequence to the project is that the rocks of different epochs form sheets of rocks which are separated by thrust and faulted contacts susceptible to relative displacements due to tectonic forces from within.

Three major dislocations have been identified in the project area and are shown in Figure 7.1. They include:

(1) Jhakri thrust, south-west of the project area.
(2) Kaurik fault zone, south-east of Karcham dam site which offsets the main central thrust.
(3) the main central thrust, dipping towards north.

There are three hot springs in the project area, the spring at Karcham being the hottest. These hot springs suggest high geothermal gradients. They emerge at the zone of intersection of faults forming conduits for circulation of water through considerable depths.

Table 7.1

IMPORTANT EARTHQUAKES WITHIN 200 km FROM KARCHAM-WANGTOO HYDRO-ELECTRIC SITE

Date	Epicentre		Magnitude
	Latitude (N)	Longitude (E)	
05.03.1842	30.00	78.00	6.5
16.06.1902	31.00	79.00	6.0
04.04.1905	32.25	76.25	8.0
13.06.1906	31.00	79.00	6.0
28.02.1908	32.00	77.00	7.0
20.10.1937	31.10	78.00	6.0
12.05.1939	32.50	78.00	6.3
22.06.1945	32.80	76.90	6.5
10.06.1947	32.60	75.90	6.0
27.06.1955	32.50	78.50	6.0
12.04.1963	32.00	78.79	6.0
19.01.1975	32.35	78.76	6.8
20.10.1991	30.75	78.86	6.6 (m_b), 7.1 (m_s)

7.3 ICOLD Guidelines for Selecting Seismic Parameters for Design of Dams

- ICOLD guidelines recommend evaluation of seismic hazard rating of the dam site regardless of the type of dam, based on the peak ground acceleration (PGA) that would be expected from the Maximum Credible Earthquake (MCE) and nearby presence of fault from low to extreme seismic hazard, which provide a preliminary indication of the seismic evaluation requirements. Dam sites in Himalayan belt, as per these guidelines, could thus be considered to be in seismic hazard class II (moderate 0.10 g < PGA < 0.25 g), III (high: PGA ≥ 0.25 g but no active fault within 10 km of site) and IV (extreme: PGA ≥ 0.25 g with active fault closer than 10 km from site) to have a quick way of rating the seismic hazard. Other factors must be considered before making the final decision regarding seismic design or evaluation parameters in terms of PGA values, response spectra or acceleration time histories depending on the type of dam, its risk rating and its possible modes of failure. The potential risk associated with dams consists of structural components (which depends mostly on storage capacity and on the height of the dam) and socio-economic components (which can be expressed by the number of person who need to be evacuated in case of danger and by potential downstream damage). The total risk factor further guides the selection of seismic evaluation parameters. Keeping in view the live storage, height and evacuation requirements and potential damage downstream of the dam site, it is noted that the Karcham dam will have moderate risk rating.

- ICOLD guidelines recommend evaluation of design earthquake in terms of maximum design earthquake (MDE), operating basis earthquake (OBE) and reservoir induced earthquake (RIE). MDE represents the maximum level of ground motion for which the dam should be designed or analyzed. For dams whose failure would present a great social hazard (extreme seismic risk), the MDE will normally be characterised by a level of motion equal to MCE expected at the dam site. Should failure of the dam present no hazard to life, a level of motion less than MCE may be adopted to represent the design earthquake based on alternative consideration, such as the cost of designed dam resulting from a specified level of motion and cost of failure of the completed structure.

- OBE represents the level of ground motion (significantly lower than MDE) at the dam site at which only minor damage is acceptable. The dam, appurtenant structures and equipment should remain functional and damage easily repairable, from the occurrence of earthquake shaking not exceeding the OBE.

- RIE represents the maximum level of ground motion capable of being triggered at the dam site by the filling, draw down or presence of reservoir. Isolated incidents of earthquake occurrence after impoundment of water behind dams have led to the postulation of concept of reservoir induced seismicity. However, changes in stress regime induced by a large artificial reservoir can only act as a trigger to initiate a natural earthquake that would have occurred otherwise. Therefore, presence of a reservoir does not increase the seismic potential at the site higher than the seismic evaluation parameters corresponding to MCE/MDE level of ground motion.

7.4 Seismotectonic Framework

Figure 7.1 shows the seismotectonic domains of North-western Himalayas. The five seismic zones developed, include:

(1) Foot Hill seismic zone
(2) Main Himalayan seismic zone
(3) High Himalayan seismic zone
(4) High Plateau seismic zone
(5) Kashmir Syntaxial zone.

The Main Himalayan zone is bounded by the main boundary faults to the south and the main central thrust to the north.

7.5 Seismic Hazards at Karcham Site

The project is situated in Shimla Block, shown in Figure 7.2. The block is bounded to the west by Sundernagar fault and to the east by the Kaurik fault. The most important earthquake event affecting the project area was the 1975 Kinnaur earthquake with a magnitude of 6.8. The concentration of seismic events in this block is much less than those in the adjacent Kangra block in the west and the Garhwal block in the east. However, concentration of events in the north-south direction is very much pronounced (Figure 7.2).

Table 7.2 gives peak ground acceleration values at the dam and power house sites.

7.6 Parameters for Earthquake Resistant Design

- For the purpose of arriving at the seismic acceleration at the dam site, two levels of earthquake are recommended, viz. Maximum Credible Earthquake (MCE), and Design Basis Earthquake (DBE), corresponding to MDE and DBE as per ICOLD guidelines described in Section 7.3. Whereas the DBE is recommended for design purposes in replacement of the coefficient recommended in IS:1893 for which the structure should be safe without any structural or non-structural damage, the MCE is recommended only for checking the state of the structure under ultimate loading conditions. It is considered permissible that under MCE, the structure may sustain some yielding or permanent displacement of minor structural damage but should not have partial or complete collapse. This checking for MCE is carried out only in case of very important structures involving high seismic risk.

- **Maximum Credible Earthquake (MCE)**

The Maximum Credible Earthquake is defined as the earthquake that can cause the most a severe ground motion capable of being produced at the site under the currently known seismotectonic framework. It is a rational and believable event which can be supported by all known geological and seismological data. MCE is determined by the judgement based on the maximum earthquake that a tectonic region can produce considering the geological evidence on past movement and the recorded seismic history of the area.

- **Design Basis Earthquake (DBE)**

The Design Basis Earthquake is defined as that earthquake which can reasonably be expected to occur during the economic life of the structure (say 100 or 50 years) and in the event of the exposure to earthquake hazard, there will be no loss of life and the structure will undergo permissible deformations and repairable damage such that the structures, equipments, facilities and services will remain functional after the earthquake. As a design criteria, the resulting ground accelerations at the site under the DBE may be taken as 100 years acceleration with exceedence probability 0.5 or as a fraction of MCE based on engineering judgement for the adopted design methodology.

7.7 Maximum Credible Earthquake for the Karcham Dam Site

- **Earthquake Parameters**

Based on the seismotectonic set up of the area and the seismic history of the region as described in Sections 7.2, 7.4 and 7.5, the parameters of MCE are taken with horizontal and vertical PGA values as 0.23 g and 0.14 g, respectively, as indicated in Section 7.5. The accelerations have been computed using magnitude distance-acceleration relationship proposed by Abrahamson and Litehiser (1989).

Table 7.2

PGA VALUES IN FRACTION OF 'g' AT THE KARCHAM-WANGTOO SITE ESTIMATED FROM REGRESSION RELATION OF ABRAHAMSON AND LITEHISER (1989)

Source	Magnitude	Fault Mechanism	Karcham Dam Site			Wangtoo Power House		
			r(km)	a_h(g)	a_v(g)	r(km)	a_h(g)	a_v(g)
Jhakri Thrust (length 30 km)	6.5	Normal Strike Slip	32	0.09	0.05	28	0.10	0.05
		Thrust/Reverse	32	0.12	0.06	28	0.14	0.06
Kaurik Fault (length 100-200 km)	7.2	Normal Strike Slip	22	0.15	0.10	28	0.13	0.08

Source	Magnitude	Fault Mechanism	Karcham Dam Site			Wangtoo Power House		
Main Central Thrust (length 125 km bounded by Sundernagar and Kaurik Faults)	7.2	Thrust/Reverse	22	0.21	0.12	22	0.21	0.12
MCT Belt in Shimla Block	7.2	Thrust/Reverse	20	0.23	0.14	20	0.23	0.14

r = Distance from zone of maximum energy release
a_h = Horizontal PGA
a_v = Vertical PGA

- **Ground Motion Characteristics**

Time history of ground motion has been worked out from the shape of targeted acceleration response spectra of structure, which in turn depends on parameters of the earthquake, the predominant period of ground motion and the amplified (spectral) acceleration with respect to the ground acceleration to which the structures of different periods and damping will be subjected. For the present situation predominant period has been assumed as 0.10 to 0.25 sec. and the maximum amplification is taken as 2.5 corresponding to 5% damping. The history of ground motion (accelerogram) has been generated for these response spectra parameters. Figure 7.3 shows the accelerogram with normalised peak ground acceleration time history. The complete listing of acceleration ordinates at intervals of 0.01 sec. corresponding to MCE is given in Appendix 2, Volume IV.

- **Acceleration Response Spectra**

The smoothened acceleration spectra corresponding to MCE are given in Figure 5. These spectra already include the seismic environment of the site as well as the importance and risk factor related to the structure. Hence these spectra do not require any further consideration of the seismic zone factor (F_o), and importance factor (I), as used in IS:1893-1984 (Indian Standard Criteria for Earthquake Resistant Design of Structures). Soil foundation factor (*β*) as required may be taken as per IS:1893-1984, and for the proposed Karcham dam *β* will be 1.

- **Vertical Acceleration**

Vertical spectral acceleration values may be taken as two thirds of the corresponding horizontal values. Similarly, acceleration ordinates for the time history of vertical ground motion may be assumed as two thirds of the corresponding horizontal value.

- **Safety Criteria for Dams**

(1) Factor of safety against sliding for MCE condition should not be less than 1.0.

(2) For concrete dams the maximum tension under MCE should be allowed to exceed to 50% more than that specified for DBE but not exceeding 20 kg/cm^2.

7.8 Design Basis Earthquake for Karcham Dam Site

- **Earthquake Parameters**

As per Section 7.6, Design Basis Earthquake, the seismic risk at the Karcham-Wangtoo site was evaluated following the probabilistic approach, taking into consideration the data on earthquake occurrence from 1917 onwards in the whole of the Indian subcontinent. The 100 year peak ground acceleration for exceedence probability of 0.5 is estimated as 0.07 g. Considering this value with the value of effective peak horizontal ground acceleration of 0.23 g for MCE, the value of effective peak ground horizontal acceleration, corresponding to DBE for elastic design of the dam, is recommended to be taken as 0.115 g.

- **Ground Motion Characteristics**

The horizontal acceleration values for this condition shall be derived by multiplying the acceleration at intervals of 0.01s corresponding to MCE (given in Appendix 2 Vol. IV - Table 4) by a factor 0.5 for dynamic analysis of the dam under DBE conditions.

- **Acceleration Response Spectra**

The normalised smoothened acceleration spectra are given in Figure 7.4 with suitable multiplying factors for MCE and DBE. These spectra already include the seismic environment of the site as well as the importance and risk factors related to the structure. Hence these spectra do not require any further consideration of the seismic zone factor (F_o), and importance factor (I) as used in IS:1893-1984 (Indian Standard Criteria for Earthquake Resistant Design of Structures). Soil Foundation Factor (**β**), as required, may be taken as per IS:1893-1984 and for the proposed Karcham dam **β** will be 1.

- **Vertical Acceleration**

Vertical spectral acceleration values may be taken as two thirds of the corresponding horizontal values. Similarly, acceleration ordinates for the time history of vertical ground motion may be assumed as two thirds of the corresponding horizontal values.

- **Safety Criteria for Dams**

(1) Factor of safety against sliding for DBE condition should not be less than 1.2.

(2) For concrete dams, the maximum tension under DBE may be allowed to exceed up to 12.5% of the ultimate compressive strength.

7.9 Ground Motion

Tunnels and other underground structures and foundations could be damaged by strong ground motion or direct shear zone/fault movement across the structure. Suitable measures are, therefore, undertaken where an active fault cuts across the underground structures and foundations, which could cause damage. No evidences of any active fault cutting across the tunnel, power house and other underground structures have been reported to occur at Karcham-Wangtoo project site.

The intensity of strong ground motion reduce with depth. Indian Standard Code (IS:1893-1984, Fourth Revision) specifies that for underground structures and foundations at 30 m depth or below, the basic seismic coefficients may be taken as half of the basic seismic coefficients on the ground and for structures placed between ground level and 30 m the basic seismic coefficients may be linearly interpolated between the value at ground level and 30 m. As underground structures and foundations on exposure to ground motion corresponding to MCE at the Karcham-Wangtoo project site will not pose any socio-economic aspect in terms of floods in the downstream region, seismic evaluation parameters for their design are recommended to be evaluated for adoption from the acceleration time history of ground motion under MCE and DBE conditions for the dam after using a multiplication factor 0.5 for structures below 30 m depth and linearly interpolated between the value at ground level and 30 m. Longitudinal, shear and Rayliegh wave velocities will be required to be evaluated at various locations for evaluation of axial strain, curvature and displacements in tunnels and dynamic analysis of various underground structures.

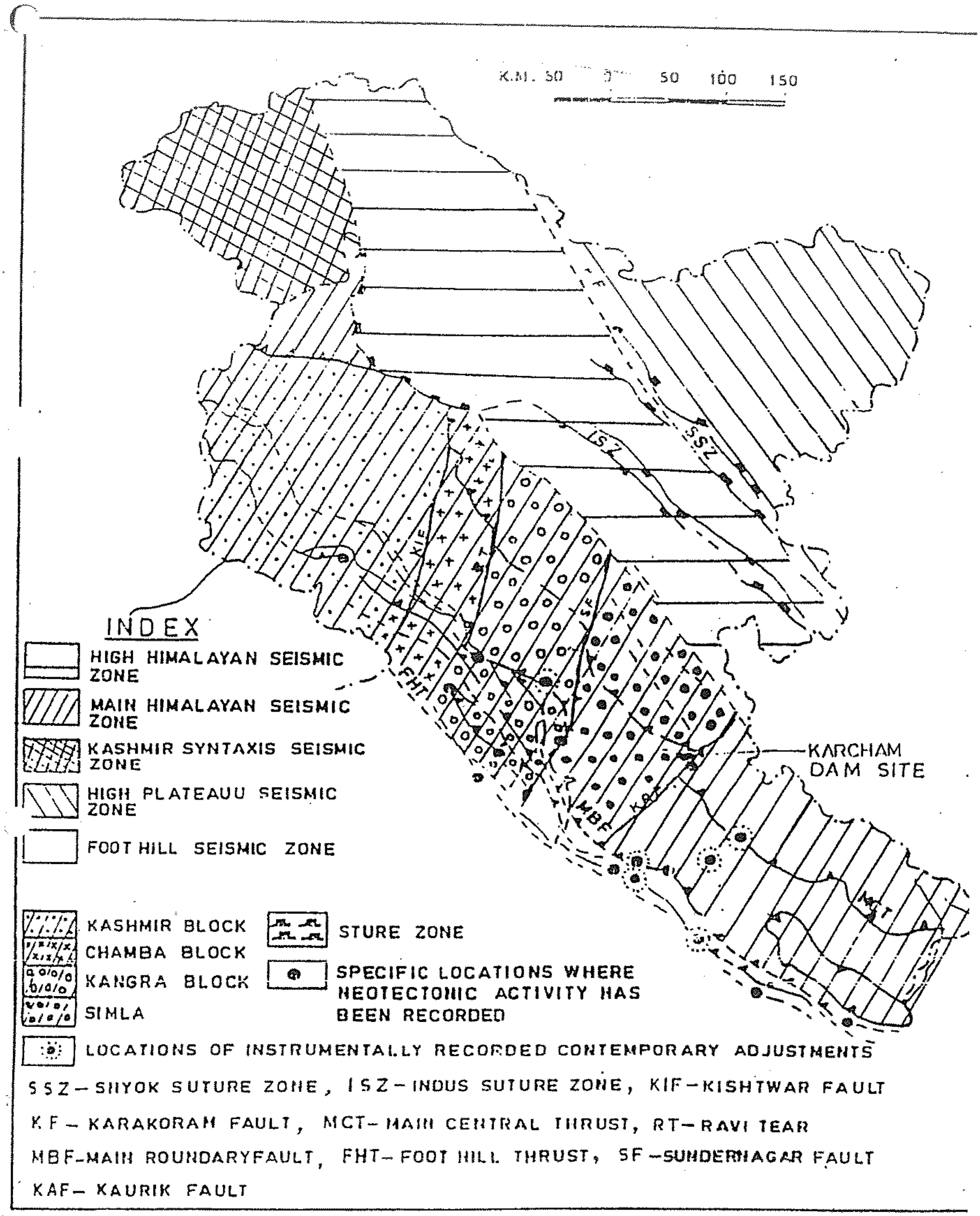
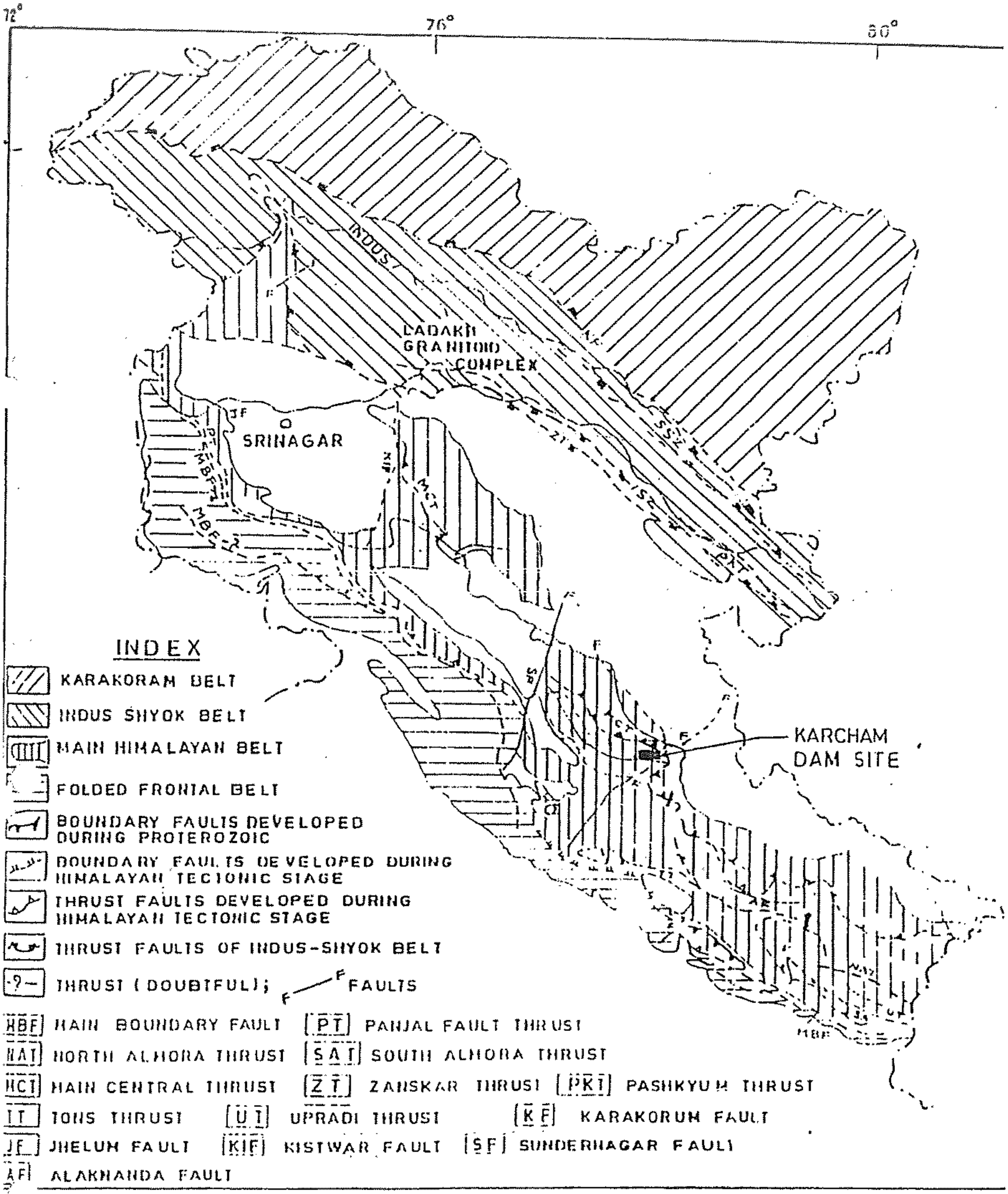


FIG.7.1 SEISMOTECTONIC DOMAINS OF NW HIMALAYA (AFTER NARULA, 1991)



G.7.2 TECTONIC BELTS OF NORTHWEST HIMALAYA (AFTER KUMAR et al., 1989)

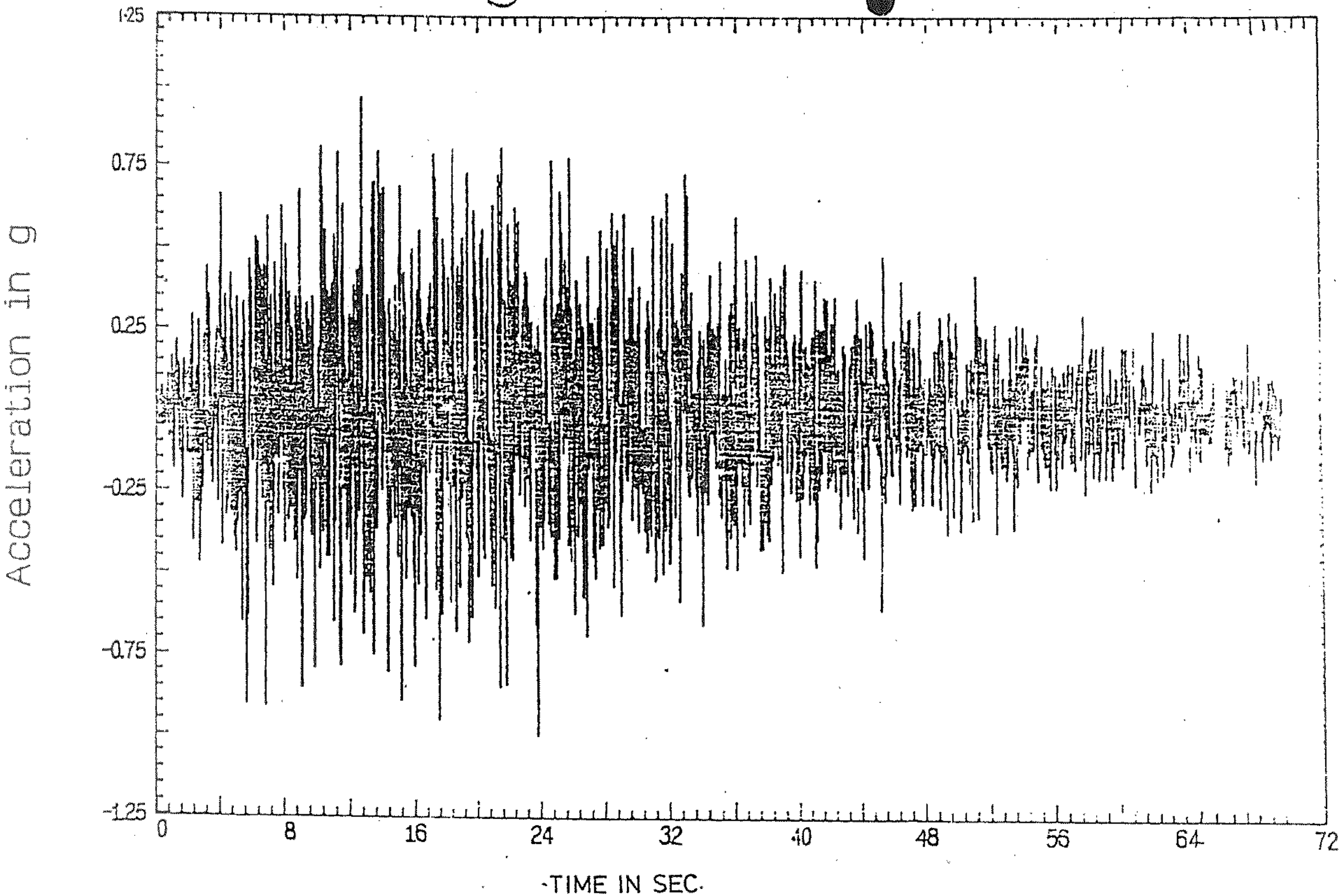


FIG.7.3 ACCELERATION TIME HISTORY OF GROUND MOTION NORMALISED TO 1g FOR KARCHAM WANGTOO H.E.P. SITE.

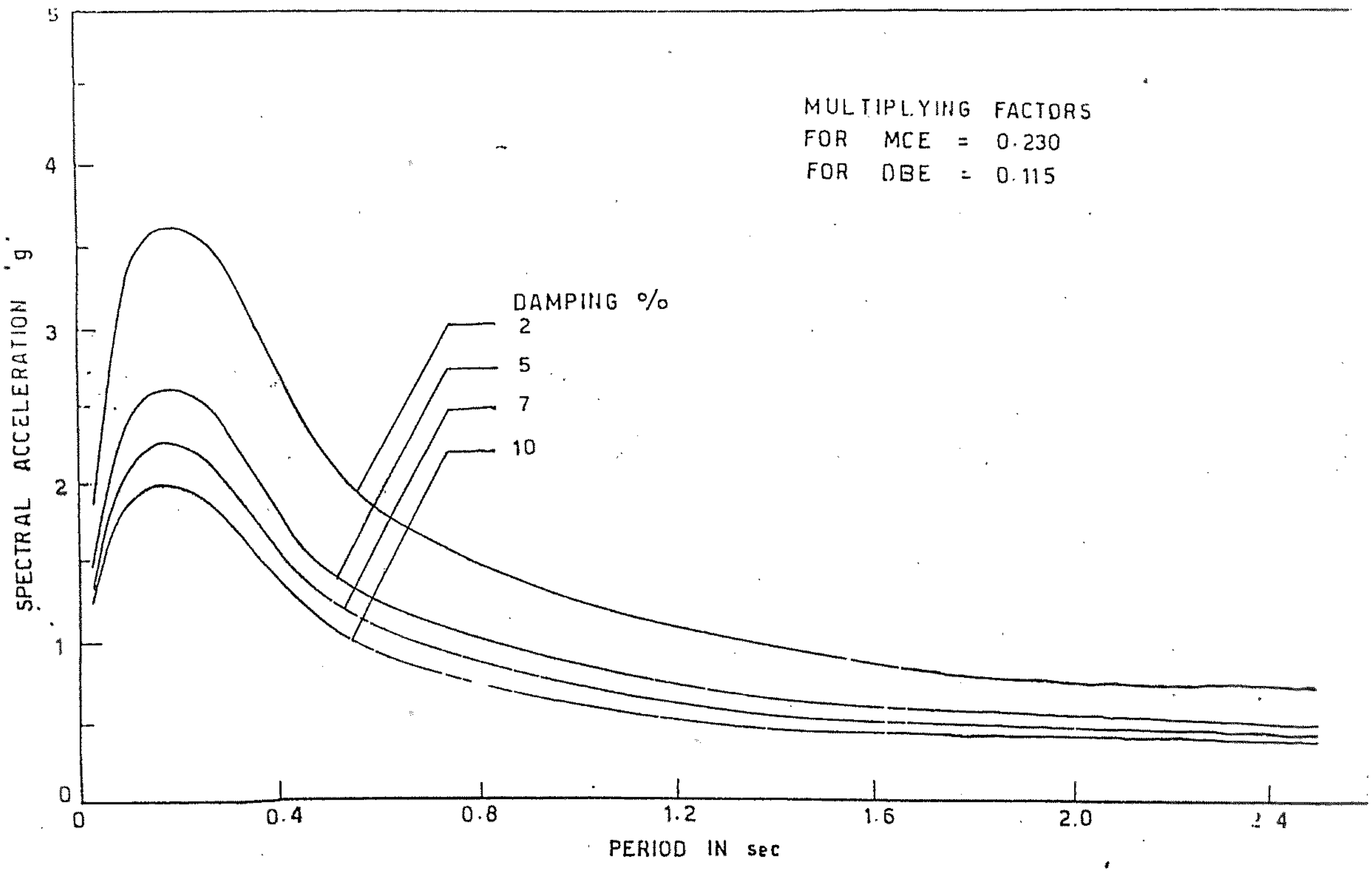


FIG. 7.4 SMOOTHENED ACCELERATION RESPONSE SPECTRA FOR KARCHAM DAM SITE.

Chapter - 8

RIVER DIVERSION WORKS

8.1 Method of Diversion

To construct the diversion dam, it will be necessary to divert the river from its natural bed to give access to the river bottom in a dewatered condition during the non-monsoon period.

The site of the dam is a narrow valley with exposed rocks on both the banks. In the river bed portion, the overburden is about 50 m. Thus, the deepest foundation level will be about 50 m below the river bed. Keeping in view these constraints, it will be necessary to construct a diversion tunnel of sufficient capacity to permit uninterrupted construction of the dam in its entire length during non-monsoon period. Since the intake works (intake structure, intake tunnels and sedimentation chamber are located on the right bank, it is proposed to provide the diversion tunnel on the left bank so that the two works do not interfere with each other.

8.2 Layout and Optimisation

The diversion works will consist of 10.5 m circular tunnel excavated on the left bank, a 20.5 m high upstream cofferdam, and a 8.5 m high downstream cofferdam. These structures will be maintained for 3 non-monsoon seasons to allow completion of the dam sub-structure and the sluice spillway openings.

The diversion tunnel and cofferdams will provide full protection to construction works in the river bed only during the non-monsoon seasons, i.e. the period between mid September to mid May (8 months). For this period, the 1/25 return flood has been estimated at 1188 m^3/s. This flow is significantly smaller than the maximum flows during the monsoon season, which typically reach the 2000 m^3/s mark every year in July or August.

It follows then that a diversion scheme providing year-round protection for two to three continuous years would have been very expensive. For this reason, it is proposed to allow both cofferdams to be overtopped during the monsoon period, as it will be more economical to reconstruct them as required for the next work season. The time needed to repair the cofferdams and to clean up the construction area in the river bed is included in the three seasons the diversion works are expected to be in operation.

Layout of the diversion scheme has been influenced by the location of other project structures and the requirements for space upstream and downstream from the proposed dam axis. First, the location of the intake structure and tunnels, the sedimentation chambers, and the headrace tunnel, all on the right bank, suggested that the diversion tunnel be rather located on the left bank to avoid problems of clearance between conduits, and concentration of construction activities around a relatively small area. Second, the surface area required to develop the excavation slopes around the dam foundation area, determined the location of the cofferdams and in turn the location of the tunnel portals.

Given the depth of excavation required in the river bed to reach the rock foundation (36 m) and the apparent perviousness of the soils, it was decided to provide both cofferdams with cut-off walls of the concrete panel type, extending fully to the bed rock.

Diversion schemes with more than one tunnel were analyzed for the design flood of 1312 m^3/s and the assumed tailwater level of 1777.3 m at the tunnel outlet. The results of the analysis indicated that the most economical scheme was one based on a 10.5 m diameter, 456 m long concrete lined tunnel, associated with 20.5 m high upstream rockfill coffer dam and a 8.5 m high downstream rockfill cofferdam.

8.3 Diversion Tunnel

Sizing of the diversion tunnel was based on the 25-year return flow for the non-monsoon period. The statistical analysis for the 34-year reconstituted hydrology at Karcham returned a value of 1312 m^3/s, which will ensure timely completion of the dam excavation and concreting of the substructure to elevation 1777 m, in about 28 months.

Bed rock at the diversion tunnel site consists of granite gneiss. Outcrops are observed at both portal sites, at elevation 1800 m. Except for the first 50 m at the upstream end, located in quartzitic rocks and the shear zone exposed on the right bank immediately upstream from the proposed dam site, the quality of rock along the diversion route is expected to be good for tunnelling, which should only require the normal supports. The thickness of overburden at the upstream portal is in the order of 30 m, and about 20 m at the downstream portal.

The maximum flow velocity in the tunnel is expected to be 13 m/s and, therefore, the tunnel will be concrete lined to avoid erosion of the rock surface. The 90° arch of the invert will be steel lined with proper anchorage. The inlet invert will be set at elevation 1772 m at the river bed to permit an easier river closure. Tunnel and portals are in general set at a level such that they do not create hydraulic problems.

Access to the tunnel portal sites will be via the road from Karcham to Kilba on the left bank of the river. This road branches off the road to Sangla (upon the Baspa valley at the Baspa Bridge, 200 m upstream from the village of Karcham.

River diversion will be through a 10.5 m circular tunnel. In the section within the shear zone, the tunnel will be supported adequately with shotcrete, steel ribs and rock bolts, and also lined with concrete 0.50 m thick. Elsewhere, the concrete lining will be limited to 0.40 m.

The concrete inlet structure at the upstream tunnel portal will be about 23.5 m high (top elevation 1795.5 m) and will be provided with groove and guides. The tunnel has a uniform slope of 1/225, and falls from elevation 1772 m to 1770 m. Past the concrete lined tunnel upto the downstream portal, the diversion flows are to be returned to the river through an open channel.

8.4 Cofferdams

Both cofferdams will be of the rockfill type with impervious core. Full concrete cut-off extending to the bedrock level is proposed, for both the coffer dams in view of the high permeability of the overburden material. The cut-off will be provided with a concrete capping of suitable size for protection during monsoon floods.

The upstream cofferdam is located 140 m from the proposed dam axis which allows for an excavation slope of 1:1.5 at the dam foundation plus some reasonable working space around it. The isolated area also includes the intake area on the right bank.

Based on the assumed river bed elevation 1772 m at the upstream cofferdam location, the overall height of the structure will be approximately 20.5 m thus setting the crest elevation at 1792.5 m. This elevation includes a freeboard of 0.8 m under design flood conditions. The 6 m wide crest spans 140 m across the river; longitudinally, the cofferdam has slopes of 1:1.5 upstream and 1:2 downstream. These dimensions define the fill volume as 61000 m^3. The upper part of the upstream face, the crest, and the entire downstream face of the cofferdam will be protected with gabions to allow overtopping during the monsoon season without major damage to the structure.

The downstream cofferdam has been located 160 m from the dam, and will be similar in construction to the upstream cofferdam, except that at a volume of 9000 m^3, it will be much smaller. Unlike the upstream cofferdam, both side slopes will be 1:2 and unprotected from overtopping. The crest elevation will be at elevation 1778.5 m, based on the downstream water level of 1777.3 m at design flood conditions.

8.5 Plugging of Diversion Tunnel

The diversion tunnel will be plugged after the completion of dam and erection of the spillway gates. The diversion conduit will be closed during Nov./Dec. when river flows are minimum.

A concrete plug will be placed just downstream of the gates at the inlet end. Before placing the plug, any leakage from the gate will be channelised through a steel pipe with valves at the outlet end.

Provision for contact grouting will be made for grouting the space between the plug concrete and the concrete lining of the diversion tunnel. The contact grouting will be carried out after 28 days of placement of the concrete plug.

The hoists for the diversion tunnel gates will be reclaimed after final closure of the gates.

8.6 Drawings

The details of the diversion tunnel are shown in the following drawings in Volume V of the Project Report:

Sl. No.	Drawing No.	Title
1.	1200-03-01	Layout of Diversion Tunnel and Coffer Dams
2.	1200-03-02	Details of Upstream and Downstream Coffer Dams
3.	1200-03-03	Details of Inlet Structure of Diversion Tunnel
4.	1200-03-04	Details of Outfall Structure of Diversion Tunnel
5.	1200-03-05	Details of Concrete Plug for the Diversion Tunnel

Chapter - 9

DIVERSION DAM

9.1 Selection of Dam site

The Karcham-Wangtoo Project is located between two important hydroelectric projects, namely the Baspa-II and the Nathpa-Jhakri, immediately upstream and downstream of the project. Because of this constraint, site choices for project structures were somehow restricted, especially if the maximum valley potential were to be used.

In this reach of the river, high dams are not appropriate since they could flood large populated areas. Nevertheless, an acceptable reservoir must have sufficient pondage capacity to produce peaking power for at least four hours per day.

In this undeveloped stretch of the Satluj river between the Baspa-II and Nathpa-Jhakri projects, four possible dam sites were identified. They are described below, starting with the most upstream dam site emplacement.

a) **SITE 1**

Situated immediately upstream of the Baspa river confluence and downstream of the Baspa-II tailrace, near the Karcham bridge, this site features a narrow gorge in hard and competent granitic rock. From geological and morphological considerations this site is the most suitable location for a concrete dam and intake structures. However, the reservoir storage capacity is insufficient for peaking purposes as the stretch of Baspa river will not be available for reservoir. Moreover the water of Baspa river can not be utilised in this alternative.

b) **SITE 2**

Situated on the Satluj river, some 300m downstream of the Baspa confluence. This site allows for a medium height dam with reservoir of sufficient storage capacity. Inundation of populated areas will be relatively very small and submergence of NH-22 will be minimum.

c) **SITE 3**

Immediately upstream of the Urnidhang landslide, this narrow stretch of the Satluj can support a suitably high dam. However, this dam would flood a large populated area including Army and para-military establishments on the right bank of river. About 20km length of NH 22 will also be submerged.

d) **SITE 4**

Near the proposed powerhouse site and upstream of the Bhaba Khad, the Satluj river narrows appreciably and the steep abutments form a canyon, suitable for a high dam. This site will have the same disadvantages as site 3.

Of the four sites, Site 2 has been adopted as the most favourable site for diversion dam for the Karcham-Wangtoo Hydroelectric Project.

The diversion dam will be located about 300m downstream of the confluence of river Satluj with river Baspa. The main considerations for selecting this location are

a) The geological set up is acceptable for constructing a 40m high (above river bed) at this location.

b) With the maximum pond level fixed at El 1810m based on the tailwater level of Baspa Hydroelectric Project Stage-II sufficient diurnal storage is available for peaking purposes.

c) The waters of Baspa river are also utilised for this project.

d) Good site is available for locating intake and sedimentation chambers on the right bank on which H.R.T. is located.

e) Submergence of the populated area and of highway is the minimum.

9.2 Geology of the Dam Site

The rock types encountered in the area are Rampur quartzites which is ± 60m thick and augen gneisses and its variants.

The geological mapping around the dam site indicates presence of schistose gneiss and Rampur quartzite along and upstream of dam axis. On the downstream side the rock is exposed along the road level (± 1793m) for about 20m downstream of dam axis, beyond which moderately to steep slopes are covered with talus/slope wash and glacial deposits. On the upstream side of the dam axis the rock is found to occur along the road for about 100m along the road with a small 35m talus core in between. Below the road level, the slopes are covered with talus/slope wash and river borne material. Along the dam axis the gneisses and quartzite are exposed upto an El of 1824m (i.e. about 10m above the top of dam) and the upper slopes are covered with talus/slope wash material. The contact of gneiss and quartzite is a sheared contact with about 5m thick shear zone developed along it. This sheared contact trending N-S and dipping 45° in east is encountered along the dam axis at El ± 1809m. Upstream of this sheared contact, moderately jointed quartzite extends for about 60m followed by biotite schist and biotite. The contact of quartzite and biotite schist is comfortable and does not show significant shearing.

9.3 Type of Dam

Due to the shape of valley and non-availability of a suitable site for a spillway rockfill dam or a concrete faced rock fill dam have been ruled out.

Therefore, it is proposed to provide a concrete gravity dam. Use of roller compacted concrete for the dam was also studied but since almost entire length of the dam consists of spillway and spillway crest is located only 12m above the river bed, this alternative was also not found feasible. Thus the diversion dam will be a conventional concrete gravity dam. It will combine in one single structure, the diversion dam, spillway facilities for excess flows and spillway clean up.

9.4 Foundation Levels

At the proposed dam site bed rock has been found at El 1715m on the middle of river bed and 1751m on the left bank through exploratory drilling.

In addition to exploratory drilling, seismic, electrical and geological field investigations were carried out. Based on these investigations a geological cross section along the proposed dam site has been prepared. This geological section collaborates very well with the bore hole data. This confirms the validity of the interpretation and confidence in the results.

The general trend of the basement rock is that, it dips from upstream to downstream side and from right bank to left bank side. The basement depth is also not uniform and this is explained in terms of valley formation due to erosion.

The extent of excavation required for the dam foundations have been determined on the basis of these studies. It is seen that founding the dam on granitic gneiss will also require about 3 to 5m of excavation of weathered rocks. In addition foundation treatment in the form of consolidation grouting would be required through drill holes, 15m deep spaced 3m centres over the dam foundation area.

9.5 Pond Levels

For fixing the pond levels, a capacity curve at the proposed dam site has been prepared (Fig.9.1)

As stated earlier the maximum pond level at the dam is fixed at El 1810m which is based on the tailwater levels fixed for Baspa Hydroelectric Project Stage-II which is under construction.

The tunnel discharge required for 1000 MW installed capacity is 417 cumec. Based on the minimum river discharge of 87.03 cumec on 90% availability basis, a live storage of 475.15 Ham is required for providing 4 hour peaking through out the non-monsoon period. The gross storage available at El 1810m is 858.29 Ham (695.66 Ham along Satluj river and 162.63 Ham along Baspa river). It is proposed to keep the minimum pond level at El 1799m. The gross capacity of reservoir at this elevation is 313.32 Ham (266.14 Ham along river Satluj and 47.18 Ham along river Baspa). Thus the total storage available between maximum and minimum pond levels is 544.97 Ham.

After the construction of dam it is assumed that the reservoir will be silted upto crest level (El 1782m) in the first 2-3 years and thereafter the river upstream of the dam will attain a new slope. Thus a part of the capacity will be lost due to silting. As shown in figs. 9.2 and 9.3 the loss of capacity due to silting will be 51.53 Ham along river Satluj and 2.31 Ham along river Baspa, the total loss of capacity being 53.84 Ham. Thus the net capacity available between the maximum and minimum pond levels will be 491.13 Ham, which is sufficient to provide 4 hour peaking through out the year on 90% availability basis.

Since the reservoir capacity is small the sediment load deposited in the reservoir will be flushed out frequently during monsoon period (when additional discharge is available) by undershot operation of the sluice spillway gates. Flushing is an effective method to contain siltation of the reservoir and to inhibit fore-shore of the delta from advancing into the reservoir.

9.6 **Layout of Dam**

The dam will consist of 6 sluice blocks of 16m width, 1 auxiliary spillway block of 22.0m width. In addition there will be two non overflow blocks of 20.0m and 17.64m, width on the left bank and two non-overflow blocks of 11.08m width on the right bank. Thus the total length of the dam at the top will be 177.8m.

The top of the dam has been kept at El 1813m which provides a free board of 3m over the maximum pond level and free board of 5m above maximum flood level. A road way of 6m width with 1m walk way on both sides will be provided on the top of the dam. The cables for the lighting and electric supply for the equipment will be provided in the ducts below the walk way. Suitable railings and lamp posts will also be provided on the top of the dam.

The dam cross-section will have a constant 0.8:1(H:V) slope on the downstream face. On the upstream face below El 1770m slope is 1:2.43 (H:V). Above elevation 1770m the upstream face will be vertical. These dimensions have been chosen on the basis of stability analysis.

The deepest foundation level for the dam is expected at El 1715m. Thus the height of dam will be 98m above the deepest foundation level.

A foundation grouting and drainage gallery of size 2m (width) x 2.5m (height) will run across the dam. In addition, a foundation gallery is also provided on downstream side 30m parallel to this gallery. Both these galleries are connected by cross galleries. On the left bank an elevator cum staircase shaft has been provided for approach to the foundation. In addition and emergency exit staircase has also been provided on the right bank. The gallery will be extended in the left and right abutments as required to provide suitable drainage arrangement for the abutments. A dewatering sump will be provided at the deepest point in block no. 6. To relieve seepage pressure a single curtain of drainage holes spaced 3m centres will be driven at an angle of 80° with the horizontal, from the dam drainage and grouting gallery at elevation 1715m. The curtain will extend across the river in depths varying from a minimum of 15m at elevation 1810m on the abutments to a maximum of two-third the hydrostatic pressure. Similarly, a single vertical grout curtain will be constructed with drill holes spaced 3m centres and driven vertically to depths ranging from 15m at elevation 1810m on the abutments to a maximum equivalent to one-half the hydrostatic head on the dam base, approximately 20m.

9.7 Layout of Spillway

The spillway design flood has been taken as 8260 cumec (ref Chapter-3 `Hydrology').

As given in previous para the minimum pond level has been fixed at El 1799m.

Based on this level the crest of intake is to be kept at El 1786m. It is desirable that the intake is at least 4-5m above the spillway crest so that the entry of silt into the intake is minimised and the silt deposited near the intake can be flushed out by opening the spillway gates. The spillway crest is therefore proposed to be kept at El 1782m.

Since the maximum pond level is 28m above the spillway crest, it is proposed that main spillway will consist of sluices which will cater the design flood with pond level at El 1808m and radial gates fully open. It is proposed to provide 6 sluices of size 9m (width) x 9m (height). This size has been selected so that the size of the spillway sluice gates is fully manageable. This also gives the spillway blocks of 16m width, which is considered acceptable. For the design of sluices the tailwater level has been taken as 1783.8m based on the water level at Karcham Gauging Station adjusted to +1.3m to reflect the level at dam site.

In addition to the sluices an auxiliary surface spillway is also proposed to be provided. The purpose of this auxiliary spillway is to pass the floating debris as also surplus water during small floods or sudden closure of power station. The auxiliary spillway will consist of one bay of 8m width with crest at El 1803m. The discharge capacity of auxiliary spillway is 275 cumec corresponding to pond level at El 1808m.

The sluice spillway will be provided with top sealing type radial gates for opening size of 9m (width) x 9.25m (height), the crest level of the gates being at El 1781.75m. The gates will be operated by hydraulic hoists from top of dam. Arrangement of stoplogs has been provided at the entrance to isolate the radial gates (one at a time) for inspection and maintenance. One set of stoplogs will consist of seven units of size 14.62m (width) x 2.50m (height).

The auxiliary spillway will be provided with radial gates of size 8m (width) x 7.35m (height). A set of stoplogs will also be provided to isolate the radial gates for maintenance and repairs.

The stoplogs both for the sluices and the auxiliary spillway will be operated by a gantry crane moving on the road way on the top of the dam.

9.8 Energy Dissipation System

The energy dissipation arrangement for the sluices will be of ski jump bucket type. The bucket invert level has been kept at El 1774.65m while lip level has been kept at El 1778.0m. The exit angle of the bucket will be 30° with the vertical.

The energy dissipation arrangement for the auxiliary spillway will also be of ski jump bucket type with bucket invert level at El 1777.326m and lip elevation at 1778.8m.

Steel lining consisting of 25mm thick plates with lugs has been provided in the sluices portion. In the bucket portion the lining will consist of ISHB 150 @ 300mm c/c with 12m thick M.S. plates on the top. The space between the plates will be filled with suitable adhesive concrete with silica fumes.

An apron 22m in length has been provided downstream of bucket so that trajectory falls over the apron only and does not erode the river bed downstream of the bucket. Beyond the apron three rows of blocks of size 2m x 2m x 2m will be provided as flexible protection to river bed material.

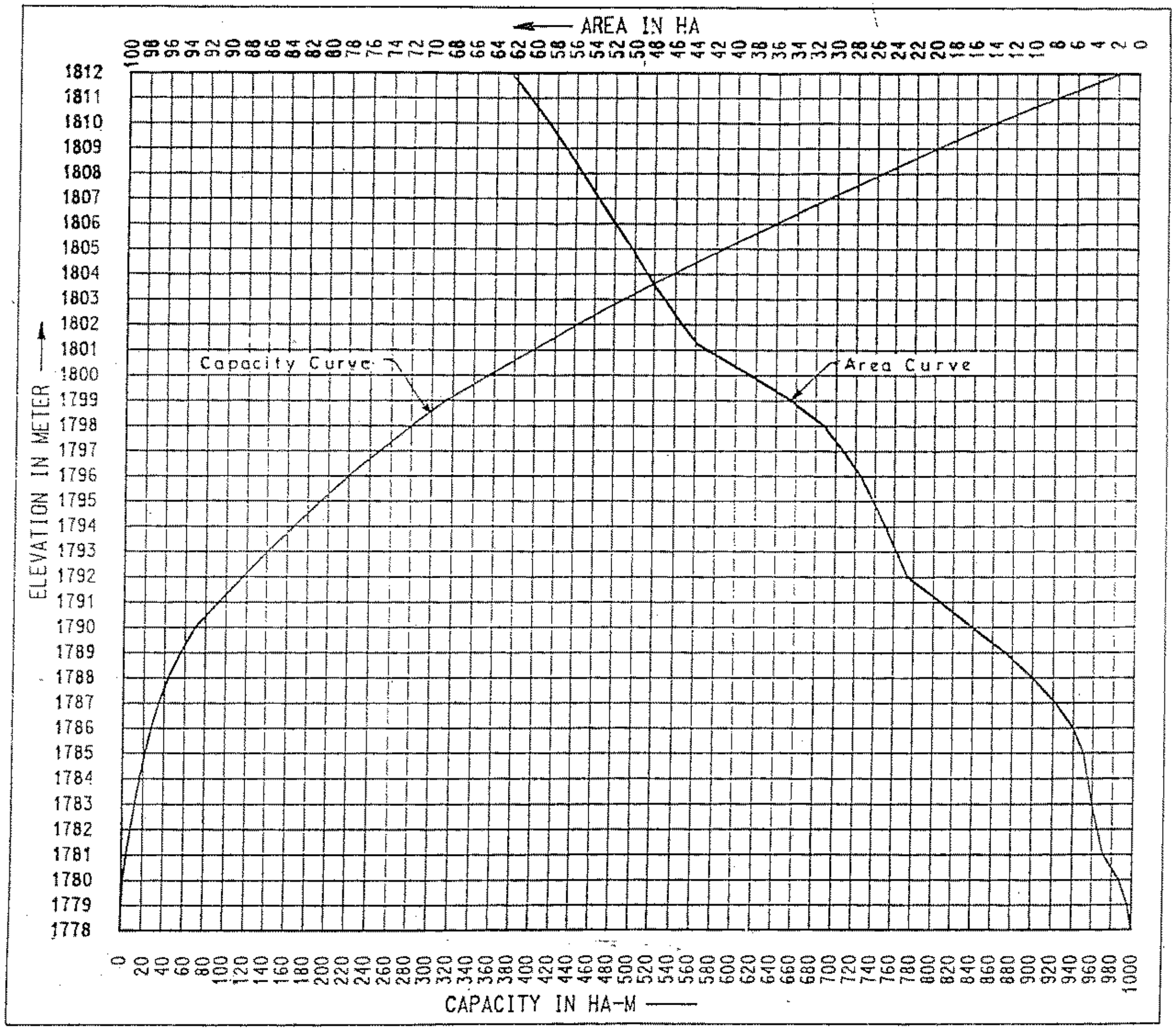
9.9 Drawings

The details of the diversion dam and spillway are shown in the following drawings in Volume V of the report.

Sl. No.	Drawing No.	Title	
1.	1200-04-01 (Rev.2)	Karcham Diversion Dam -	Plan
2.	1200-04-02 (Rev.2)	Karcham Diversion Dam -	Upstream Elevation
3.	1200-04-03 (Rev.2)	Karcham Diversion Dam -	Downstream Elevation
4.	1200-04-04 (Rev.1)	Karcham Diversion Dam -	Auxiliary Spillway, Sluices and Non-overflow Sections

Sl. No.	Drawing No.	Title	
5.	1200-04-05 (Rev.1)	Karcham Diversion Dam -	Sluice Spillway - Section and Profile
6.	1200-04-06 (Rev.1)	Karcham Diversion Dam -	Sluice Lining Details
7.	1200-04-07	Karcham Diversion Dam -	Water Stop Details
8.	1200-04-08 (Rev.1)	Karcham Diversion Dam -	Zoning of Materials
9.	1200-04-09 (Rev.1)	Karcham Diversion Dam -	Undersluice - GA of Radial Gates and Stoplogs
10.	1200-04-10 (Rev.1)	Karcham Diversion Dam -	Undersluice radial gates - Top, Side and Bottom Seals and Seal Seat Details
11.	1200-04-11	Karcham Diversion Dam -	Undersluice Spillway Stoplogs - Details of Bottom Seals, Side Seals and Top Seals
12.	1200-04-12	Karcham Diversion Dam -	Auxiliary Spillway - GA of Radial Gates and Stoplogs

FIGURE 9.1



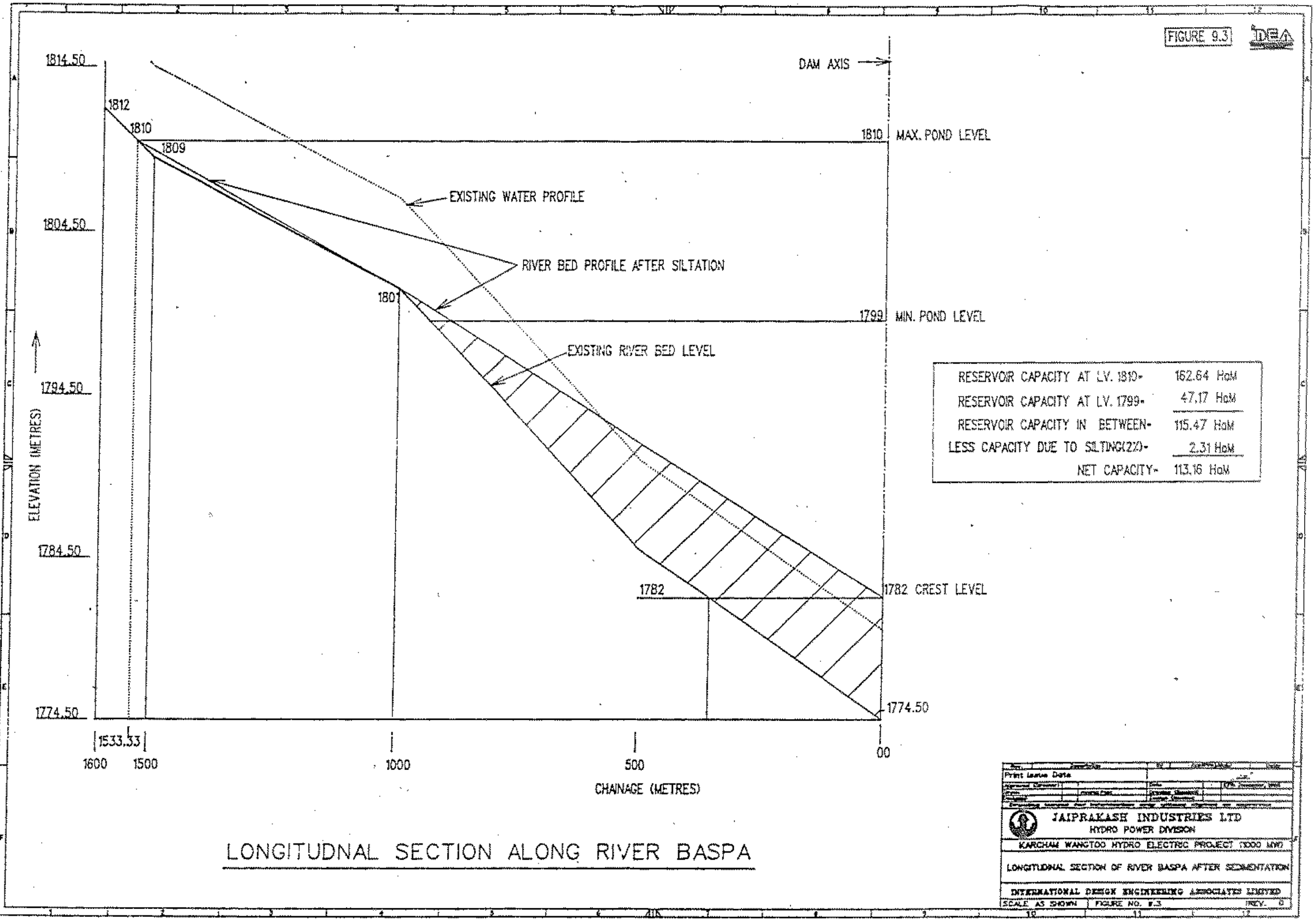
ELEVATION (M)	AREA (HA)	CAPACITY (HA-M)
1778	0.0	0.0
1779	0.44	0.28
1780	1.26	1.31
1781	2.84	4.47
1782	3.44	8.06
1783	4.01	12.08
1784	4.49	16.54
1785	4.98	21.42
1786	6.03	27.16
1787	7.78	34.45
1788	9.99	43.70
1789	12.72	55.32
1790	16.06	69.72
1791	19.29	92.64
1792	22.63	116.39
1793	23.77	140.98
1794	24.95	166.38
1795	26.19	192.60
1796	27.49	220.04
1797	29.28	249.10
1798	31.19	280.10
1799	34.51	313.32
1800	38.60	354.31
1801	45.11	397.93
1802	45.35	443.01
1803	47.05	489.57
1804	48.70	537.59
1805	50.31	587.08
1806	51.97	638.12
1807	53.65	690.74
1808	55.38	744.96
1809	57.09	800.80
1810	58.84	858.29
1811	60.70	919.16
1812	62.61	981.74

JAIPRAKASH INDUSTRIES LTD
HYDRO POWER DIVISION
KARCHAM WANGTOO HYDRO ELECTRIC PROJECT (1000 MW)

AREA CAPACITY CURVE AT DAM SITE

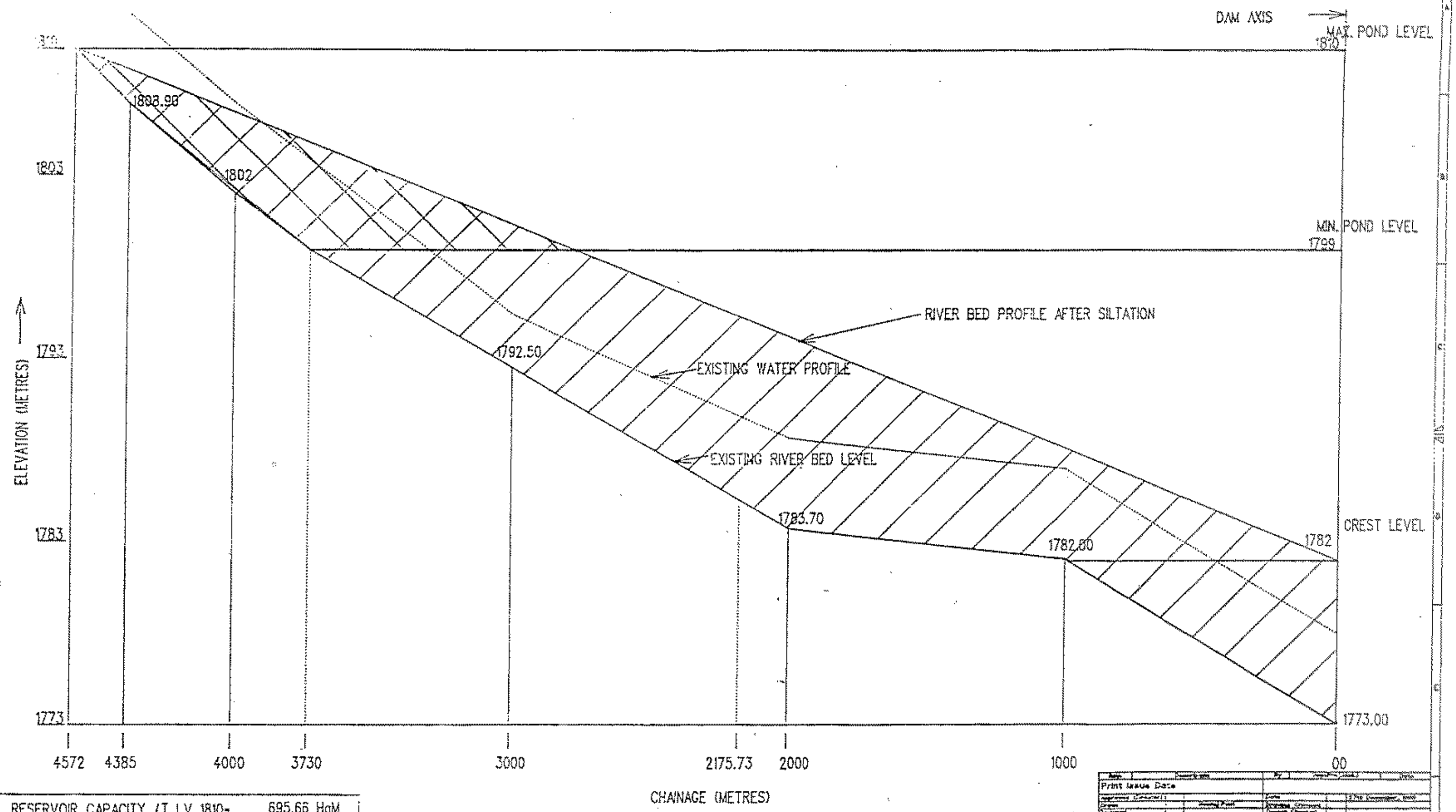
INTERNATIONAL DESIGN ENGINEERING ASSOCIATES LIMITED

SCALE AS SHOWN | FIGURE NO. 9.1 | REV. 0



LONGITUDNAL SECTION ALONG RIVER BASPA

FIGURE 9.2



RESERVOIR CAPACITY AT LV. 1810-	695.66 HaM
RESERVOIR CAPACITY AT LV. 1799-	266.13 HaM
RESERVOIR CAPACITY IN BETWEEN-	429.53 HaM
LESS CAPACITY DUE TO SILTING (12%)-	51.53 HaM
NET CAPACITY-	378.00 HaM

LONGITUDNAL SECTION ALONG RIVER SATLUJ

JAIPRAKASH INDUSTRIES LTD
HYDRO POWER DIVISION
KARCHAM WANGTOO HYDRO ELECTRIC PROJECT (1000 MW)
LONGITUDNAL SECTION OF RIVER SUTLEJ AFTER SEDIMENTATION
INTERNATIONAL DESIGN ENGINEERING ASSOCIATES LIMITED
SCALE AS SHOWN | FIGURE NO. 9.2 | REV. 0

Chapter - 10

INTAKE AND SEDIMENTATION CHAMBER

10.1 Intake

10.1.1 General

On the basis of hydrological studies, it is estimated that in non-monsoon period all the discharge of river Satluj at the diversion dam will be diverted to the headrace tunnel. However during monsoon period surplus discharge will be released through the spillway.

The intake is to be designed for 521.25 cumec discharge, 417 cumec for power generation and 104.25 cumec for arresting and flushing the sediment from water entering the Head Race Tunnel. In non-monsoon period the river flow will be comparatively clear and flushing of the sediment through sedimentation chambers will not normally be required. In monsoons, the river carries large quantity of sediment as bed-load and suspended load. Since the incoming velocities will be greatly reduced in the pond, the reservoir upto the intake will also function as a sedimentation tank. The much of the coarser sediment will settle in the reservoir and most of the bed load will be eliminated from the flow entering the reservoir and be flushed out through the spillway.

10.1.2 Siting of the intake

Since the headrace tunnel and powerhouse will be constructed on the right bank, the intake will also be located on the right bank. The exposed rocks on the right bank upstream of the diversion dam indicate that construction of intake structures and intake tunnels will not be problematic. The geology of the area on the right bank also indicates that construction of underground sedimentation chambers will be feasible without undue problems.

Since 4 underground sedimentation chambers are required to be provided so that size of cavity is manageable, separate intakes are proposed to be provided for each chamber. The first intake has been located at 5m upstream of the dam axis. This distance is considered necessary to accommodate the operating equipment on the intake. The distance between centre line of intakes has been kept 18m.

10.1.3 Intake levels

The maximum and minimum pond levels at the diversion dam have been fixed at El 1810m and El 1799m respectively (as already explained earlier). The intake will have its invert at El 1786m which is 4m above the main spillway crest. Each intake will be of size 6m (W) x 5m (H). The top of the bell mouth entry will be at El 1793.345. Thus sufficient water cushion is available below the minimum pond level so that there is no vortex formation.

10.1.4 Inlet

At the entry to intakes, trashracks inclined at 70° with horizontal will be provided for restricting the entry of large size pebbles, floating debris and ice etc. Each intake has been divided into 4 compartments for reducing the size of racks and supporting girders.

A breast wall with bell mouth entry will be provided at the inlet for smooth entry of flow. At the trashracks the size of each intake bay is 16m (W) x 7.82m (H) which gives velocity of 1.11 m/sec through the trashracks which is within the recommended velocity of 0.6m to 1.5 m/sec. Beyond the bell mouth entry, the size of each intake duct is 6m (W) x 5m (H). Fixed wheel type intake gates with hydraulic hoist mounted on the top of intake structure will be provided on the top of intake structure. Grooves for stoplogs have also been provided so that any intake bay can be isolated for inspection of corresponding gate and hoist. A trash cleaning machine will be provided on the top of intake structure. This machine will also have a hoist mounted on it, for operation of intake stoplogs.

10.2 Intake Tunnels

At the downstream of gate, transition from 6m (W) x 5m (H) rectangular section to 6m circular section has been provided in a length of 5.5m. This section has been chosen for maintaining little higher velocity than that at the entry. Circular curve of 60m dia has been provided in the intake tunnel for smooth conveyance of flow into the sedimentation chamber. Straight length of tunnel before the sedimentation chamber is 50m to 75m. This will ensure uniform velocity at the entry of sedimentation chambers. At the end of intake tunnel diverging transitions have been provided in a length of 20m increasing the width from 6m to 16m. If hydraulic model experiments so indicate, the length of this transition will be increased without altering the overall length upto exit point.

The layout of intake tunnels has also been governed by the existence of 5m thick shear zone at the contact of gneisses and quartzite. This shear zone will be crossed in the intake tunnels and the sedimentation chambers and the transitions at the entry will be sufficiently clear from this zone.

10.3 Sedimentation Chamber

10.3.1 Since the silt carried by Satluj river contains quartz particles also, sediment coarser than 0.2mm is proposed to be eliminated from the flow of HRT for durability of the turbines in the Power Station against damage by silt. This is proposed to be achieved by providing well designed sedimentation exclusion device consisting of sedimentation hoppers and flushing ducts. The flow through velocity in the chamber is reduced to such an extent that desired particles settle down in the chamber within a reasonable length. At the bottom of the chamber, hoppers are provided for the collection of settled sediment which is flushed back to the river through a flushing duct.

10.3.2 The dimensions of the chamber are fixed on the basis of the total area required for passing the intake discharge at the desired flow through velocity. Since in underground construction, the size of the chambers will have to be kept within practicable limits. The size of units of desilting arrangement are fixed accordingly. If a single unit of sedimentation chamber is selected, its size will be too large to pose construction problems. On the other hand with large number of units, flushing discharge in each unit may be reduced to such an extent that size of the flushing duct will be too small to construct and maintain.

10.3.3 As already stated, four sedimentation chambers i.e. one for each intake will be provided.

A flow through velocity varying from 0.2 to 0.6m per sec is recommended in the sedimentation chambers. It is proposed to provide velocity of 0.3 m/sec on economic grounds and also considering that the river carries heavy suspended silt load. For this velocity the area of each chamber required is 434 m^2. The length of each sedimentation chamber provided is 505 m which is based on fall velocity of 0.02 m/s for 0.2mm size particles and 95% efficiency of the chamber.

Different alternative arrangements of sedimentation chamber with different width and depth were analyzed. The chamber having a width of 16m and depth of 29.65m has been found to be optimum. The section of chambers will be pot shaped having an arch of 8m radius at top. At the bottom the sides converge to terminate into a 3m wide strip which is required for locating the hoppers.

The distance between centre line of chambers has been kept 46m with a view to provide a rock ledge of 30m between them.

The chambers have been aligned in the direction of N 36°48'34" W to suit the geological conditions at site.

10.3.4 The location and size of the openings to be provided at the bottom of the chamber have been determined on a mathematical model and best suitable arrangement has been evolved keeping the following points in view:-

a) Head loss in system should be minimum

b) The size of narrowest opening i.e. diameter of the last opening must be at least twice the maximum particle size expected to enter through the intake.

c) The dimension of flushing duct should be such that enough working space is available from point of view of its construction and maintenance.

Based on this criteria 64 hoppers with opening size varying from 1.0m x 1.0m (for first opening) to 0.15m dia (for the last opening) have been provided. The centre of openings has been kept 6m at the beginning and 10.25m at the end.

10.4 Flushing ducts/conduits

10.4.1 In the sedimentation chamber type desilting arrangement, the functioning of flushing system should be perfect. Its design involves computations of number and sizes of opening and flushing duct. For computation of size of opening, the principle of equal head loss through different paths (i.e. one along the length of flushing duct and other through the opening) at a particular location under consideration, has been adopted. Different parameters such as total number of openings, size of each opening, spacing between the openings, dimensions of the flushing duct below each opening have been varied on a mathematical model for optimisation.

It has been found that for total number of 64 openings of size varying for 1.0m x 1.0m to 0.15m dia, the loss of head is 11.16m at the design discharge. A duct of 2m width has been provided below the openings all along the length of chamber.

depth varies uniformly from 0.37m below the first opening to 3.0m below the last opening. Since relationship between velocity and maximum concentration of sediment which can be transported does not exist, the velocities in the duct are kept varying from 3.0 m/sec to 4.3 m/sec.

10.4.2 At the downstream of the last opening the duct has been kept of circular section of 2.75m diameter.

The out fall of flushing ducts has been kept about 900m downstream of dam axis. The invert of the duct of the outfall has been kept above the maximum flood levels. The reverse slope in the ducts has been limited to 1:9:5 to facilitate excavation. The total length and sill levels of different ducts are as below :

Duct No.	Length (m)	Total Head Loss (m)	Sill Level (m)
1.	300	12.99	1785.80
2.	330	13.17	1785.80
3.	370	13.42	1785.50
4.	405	13.63	1785.50

10.5 Link Tunnels

At the end of sedimentation chambers converging transitions have been provided in a length of 15 m. The size of opening at the end of transitions has been kept 6m x 6m rectangular upto the location of the gates, which are proposed to be provided to isolate any chamber for inspection and maintenance. At the downstream of the gate, the transition from square section to circular section has been provided in a length of 5m. The two outer link tunnels of 6m dia join the main H.R.T. at a distance of 98.5 m. The two central link tunnels join to form a single link tunnel of 8m dia at a distance of 35.5m, which joins the H.R.T. about 46m downstream. The centre line of H.R.T. at the starting point has been kept at El. 1785.85m.

10.6 Construction and Approach Adits

An approach adit (Adit No. 1) of 7.5m D-shaped has been provided about 20m downstream of the junction of link tunnels. The excavation of sedimentation chamber will be carried out through this adit as well as the intake tunnels on the upstream side.

A construction adit of 7.5m D-shaped has been provided cutting across all the four sedimentation chambers. The invert of this adit at the junction with sedimentation chamber matches with the bottom elevation of chambers i.e. El. 1761.35. This adit will be used for the excavation of the chambers below the springing level.

A gate operating gallery of size 7.5m(W) x 10.0m(H) D-shaped has been provided above the link tunnels with invert at El. 1810.50 with individual gate shafts for each link tunnel.

10.7 Gates

Fixed wheel type gates have been provided in the link tunnels at the end of each chamber.

As stated earlier the approach to the gate chamber above the link tunnels will be through approach adit of 7.5m(W) x 10.0m(H) D-shaped.

The approach adit will have a length of 140m and will have access portal upstream of flushing ducts with its invert at El. 1800m, which is above the maximum flood level.

The gates in the link tunnel will be operated by a gantry crane moving in the gate chamber.

With the provision of these gates and separate flushing conduits for each chamber, it will be possible to feed H.R.T., through any intake and its corresponding sedimentation chamber, with the other intakes and chamber closed for inspection and maintenance.

The gates at the end of flushing conduits will also be of fixed wheel type and will be operated by independent hoists mounted at the portal at each outfall structure.

10.8 Drawings

The details of intakes, sedimentation chambers and flushing conduits are shown in the following drawings included in Volume V of the project report.

Sl. No.	Drawing No.	Title		
1.	1200-05-01	Intake and Sedimentation Chamber - Layout Plan		
2.	1200-05-02	Water Conductor System upto start of HRT - Plan and L-Section		
3.	1200-05-03	Intake Structure	-	Plan
4.	1200-05-04	Intake Structure	-	Longitudinal Section
5.	1200-05-05	Intake Structure	-	Front Elevation
6.	1200-06-01	Sedimentation Chambers	-	Plan & Longitudinal Section
7.	1200-06-02	Sedimentation Chambers	-	Cross-Sections
8.	1200-06-03	Sedimentation Chambers	-	Hopper Details
9.	1200-06-04	Flushing Conduits	-	Longitudinal Sections
10.	1200-06-05	Flushing Conduits	-	General Arrangement of Gates & Hoist at outfall structure
11.	1200-06-06 (Rev. 1)	Link Tunnels	-	General Arrangement of Gates

Chapter - 11

HEADRACE TUNNEL

11.1 General

The total length of the headrace tunnel from the exit end of sedimentation chamber upto the junction with surge shaft is 17198 metres. The alignment of the tunnel is based on the surface and sub-surface explorations carried out along the tunnel alignment.

11.2 Geology along the Tunnel Alignment

The rocks along the tunnel alignment are gneissic rocks of Pre-Cambrian age which form the northern limb of an anticlinical fold. The angle between the tunnel alignment and the strike of foliation varies from 10°-25° in about 40 percent and 30°-70° in about 60 percent length.

The rock types have been classified into three broad lithological zones as below:-

Zone I (0-7.75 km)

The zone contains mainly alternate bands of porphyroblastic gneiss, augen gneiss, medium grained gneiss and quartz mica schist, amphibolite schist and intrusion of pegmatites.

Zone II (7.75 to 9.45 km)

The rock in this zone is fine grained quartzitic gneiss with bands of biotite schist and muscovite schist.

Zone III (9.45 to 17.198 km)

In this zone the rock is mainly massive Wangtoo gneiss which is classified as ortho gneiss. The upper contact of this zone with overlaying Zone II rocks is not sharp but gradational.

Rock mass classification according to 'Q' system carried out along the tunnel alignment has given the following values :

Sl No	Length along HRT (m)	Q Value and Rock Class	Structural and Lithological Description	
1.	1150	0.01-0.1 Extremely poor	1) Shear zones 3-5m thick with ground water flow, oriented N-S, N20°W-S20°E, and N20°E-S20°W i.e. running across the tunnel alignment occurring at 75-100m interval; assumed aggregate length	1133m
			2) Choling khad fault with ground water	17m
			Total	1150m
2.	850	0.1-1 Very poor	1) Foliation shear zones, mica schist, biotite schist zones etc.	600m
			2) Very poor rock reaches in Zone II	250m
			Total	850m
3.	13198	1-4 Poor rock	3 to 3+ random joint sets, close spaced, average RQD ranging from 50-80% forming wedges in the crown having gravity fall conditions as well as sliding conditions in gneissic rock	
4.	2000	4-10 Fair to good rock	Massive Wangtoo gneiss, normally two to 2+ random sets of joints and widely spaced, RQD - 70-100%	

The geological section along the headrace tunnel alignment is given in Drawing No. 1200-01-02.

11.3 Optimisation Studies

The tunnel is required to pass a maximum discharge of 417 cumec. The optimum size works out to 10.48m dia circular. A modified horse shoe shaped tunnel will be excavated as it will provide a wider base for use of rubber tyred equipment.

The maximum velocity in the tunnel will be 4.83 m/sec which is within permissible limit for concrete lined tunnel.

11.4 Layout and alignment

The invert level of headrace tunnel at the exit end of sedimentation chamber is at El 1780.7m. The minimum down surge level in the surge shaft is at El 1718.87m. Keeping a water seal of about 45m (1.5 times the head loss in orifice) over orifice, the invert level of headrace tunnel at the junction of surge shaft could be at about El 1673m. It is proposed to provide a uniform grade of 1 in 150 in the entire length of headrace tunnel with this grade the invert level of HRT of junction with surge shaft will be El 1600.04. This grade is considered suitable for use of rubber tyred haulage equipment and also to provide proper drainage during excavation.

The main consideration for fixing the tunnel alignment is that suitable locations for required number of intermediate adits are obtained. As the H.R.T. is the most critical structure for the completion of the project it is proposed that intermediate adits are located such that the maximum length of the tunnel to be excavated from each face is not more than 2 km or so. The other consideration for the location of intermediate adits is that good exposed rock is available for establishing the portal and the requirement of construction of approach road to the adit site is minimum. Based on these considerations it is proposed to have 5 intermediate adits in addition to the adit at the inlet end and adit at the surge shaft end. In order to keep the length of adits minimum and also to ensure required adequate vertical and horizontal cover in the entire reach, six horizontal curves have been introduced along the tunnel alignment. The maximum radius of the curves have been kept 300m so that excavation and concreting equipment can negotiate these curves without any difficulty.

The location and other details of various adits are as below :

Adit	Length m	Invert level at portal	Invert level at junction with HRT	Remarks
Inlet Adit	225	1803.000	1780.567	Portal on NH22
Intermediate Adit 1	470	1786.000	1765.256	Portal on NH22
Intermediate Adit 2	450	1759.250	1744.739	Portal on NH22
Intermediate Adit 3	250	1704.000	1729.200	Portal on NH22
Intermediate Adit 4	100	1704.000	1707.080	Road to adit 650m long off-taking from NH22
Intermediate Adit 5	600	1645.000	1690.828	Portal on NH22
Surge Shaft adit	140	1665.000	1666.585	Road to adit above 3350m long off-taking from NH22

All the adits will be 7.5m D-shaped so that required construction equipment can be carried through them leaving space for ventilation pipes and other services. All the adits will be provided with a concrete plugs after completion of all the works of HRT.

The inlet adit, adit 3 and surge shaft adit will also be provided with a vehicle access gate of size 2.925m x 3.225m to provide access for inspection and maintenance.

11.5 Method of driving tunnel

The excavated diameter of the tunnel is about 11m. The excavation of this size of tunnel by using a tunnel boring machine (TBM) will not be economical. The rock of the tunnel alignment has a crushing strength varying from 600 kg/cm^2 to 1200 kg/cm^2. For this formation TBM can be used as a reamer with a pilot hole of 4.5m dia or so. Moreover to complete the excavation in a period of 24 months for completion of project in a period of 5 years, two TBM will be required. Thus the use of TBM is not considered a viable and economical solution. It is therefore proposed to use conventional method of drilling and blasting for excavation of HRT. For fast excavation, it is proposed to use 3 boom computerised hydraulic drill Jumbos for drilling, 3.5 cum loaders for loading and 20T Dumper for haulage of muck.

For providing support system automatic rock bolters will be used for rock bolting along with wet shotcrete machines. Fibre reinforced shotcrete will also be used in weak zones where thick shotcrete (100mm and above) is required.

For continuous concrete lining of HRT it is proposed to use collapsible shutters with traveller.

11.6 Support System

It is expected that in most of the length of the tunnel the support system will consist of rock bolts with or without shotcrete. However in shear zones and very bad patches steel sets may be required.

Based on rock quality index `Q', the support requirements will generally be as given below. However, the exact support requirements will depend on actual site conditions.

SUPPORT SYSTEM GUIDE

Tunnelling Quality Index `Q'	Rock Quality	Nature of Support
Above 40	Very Good	50mm in crown portion, if required.

40-10	Good	Tensioned and grouted expansion shell type spot rockbolts - 25 dia, 3500 long and 50mm shotcrete in arch portion only as required.
10-4	Fair	Tensioned and grouted expansion shell type rockbolts - 25 dia, 3500 long @ 1500 C/C staggered both ways and 50 to 75 mm shotcrete in arch portion only.
4-1	Poor	Tensioned and grouted expansion shell type rockbolts - 25 dia, 3500 long @ 1250 C/C staggered both ways and 100mm fibre reinforced shotcrete in arch portion and extended to sides, if required.
1-0.4	Very poor	Tensioned and grouted expansion shell type spot rockbolts - 25 dia, 3500 long @ 1250 C/C staggered both ways and 150mm fibre reinforced shotcrete in arch portion and extended to sides, if required.
0.4-0.1	Very poor	ISHB 150 @ 34.6 kg/m @ 750 C/C and 150mm fibre reinforced shotcrete between the ribs.
0.1-0.01	Extremely poor	ISHB 150 @ 34.6 kg/m @ 500 C/C and 150mm fibre reinforced shotcrete between the ribs.

11.7 Lining, Grouting and Drainage

The HRT will be lined by plain cement concrete of M20 A40 grade. The concrete lining is not required to take any rock loads and is designed for cracking due to interval pressure. These cracks will be very fine and are likely to be self-healing or get filled with silt during course of time. Thus the purpose of concrete lining is to provide a smooth hydraulic surface and to protect the rock surface from weathering and prevent rock falls due to loosening of joints due to water pressure, after the tunnel has been commissioned. As all the rock types along the tunnel alignment are traversed by closely spaced rock joints, excavated tunnel surface is not expected to be smooth, concrete lining is considered unavoidable for the safety of the tunnel as well as the turbines and stream line flow of water. The thickness of the lining has been kept as 400mm except in poor rock zones where thickness will be increased to 500mm. If any major shear zones are met during excavation, RCC lining, to withstand the full interval pressure, will be provided in such reaches.

Provision of consolidation grouting has been made to seal the cavities and cracks in rock, developed due to blasting. However, exact requirement of consolidation grouting will be decided after the excavation of the tunnel and its geological logging.

The work of concrete lining will be started after completion of excavation between the two adits that would also provide adequate time lag between excavation of tunnel and lining for dilation of rock. Collapsible form work with traveller and concrete pumps with distributor will be used for placing the concrete. Transit mixers will be used for transport of concrete from batching and mixing plant to the concrete pumps.

11.8 Adit Plugs

After completion of all the works in the HRT adit plugs will be provided in the various adits near their junctions with HRT. The first stage concrete in the plug length of about 20-25 metres will be placed in advance and the cavity grouting will be carried out for filling space between rock and concrete. Consolidation and contact grouting will be carried out after placing the plug concrete for which necessary provisions will be made.

Opening of size 2.925m (width) x 3.225m (height) with gates will be provided plugs at inlet adit, intermediate adit no. 3, and surge shaft adit to provide access to the tunnel for inspection and maintenance when it is dewatered. The gates will be water tight hinged type which can be opened only when the tunnel is fully dewatered.

11.9 Dewatering Facility

The HRT can be dewatered through the power house but an additional dewatering facility is proposed to be provided in the adit plug of surge shaft adit by embedding a 300mm dia steel pipe in the plug. A manually operated guard valve and a manually operated fixed cone valve for regulating the discharge will be provided at the outer end of the pipe. The water will be discharged through the approach adit by an open dewatering channel which will ultimately take it to an existing natural drain.

11.10 Drawings

The layout and details of the headrace tunnel and adits are shown in the following drawings in Volume V of the report :

Sl. No.	Drawing No.	Title
1.	1200-07-01	Project layout and headrace tunnel profile
2.	1200-01-02	Geological Map along Karcham-Wangtoo tunnel alignment
3.	1200-07-02	Headrace Tunnel - L-section of water conducting system
4.	1200-07-03	Headrace Tunnel - Typical details of adit portals

Sl. No.	Drawing No.	Title	
5.	1200-07-04	Headrace Tunnel -	Plan and L-section of inlet adit, intermediate adit 1 and surge shaft adit
6.	1200-07-05	Headrace Tunnel -	Plan and L-section of intermediate adits 2 and 3
7.	1200-07-06	Headrace Tunnel -	Plan and L-sections of intermediate adits 4 and 5
8.	1200-07-07 (Rev. 1)	Headrace Tunnel -	Typical excavation sections and rock supports
9.	1200-07-08 (Rev. 1)	Headrace Tunnel -	Typical concrete lining and grouting details
10.	1200-07-09 (Rev. 1)	Headrace Tunnel -	Typical details of plug with access gate
11.	1200-07-10	Headrace Tunnel -	Adit plug vehicle access door
12.	1200-07-11	Headrace Tunnel -	Adit plug vehicle access door - Downstream face and seal arrangement

Chapter - 12

SURGE SHAFT

12.1 Type of Surge Shaft

It is proposed to provide surge shaft at the end of 10.48m dia finished circular and 17198m long headrace tunnel. A restricted orifice type surge shaft is proposed as it will be most economical and efficient for this installation. The centre line of the headrace tunnel at inlet i.e. downstream end of sedimentation chambers and at the surge shaft junction will be El 1788.0 and El 1673.1 respectively. These levels have been so fixed that satisfactory flow conditions at the inlet end and at surge shaft end are ensured even under the worst condition.

12.2 Area of Surge Shaft

While deciding the area of surge shaft, power house has been taken to be operating in isolation. The area of surge shaft as per Thomas criteria works out to be 386.08 sqm. Taking a factor of safety of 1.6 as suggested by Charles Jaeger, the area work out to 617.7 sqm. The diameter of surge shaft adopted is 27m. The power station will always operate in the grid and stabilizing effect of grid can be taken into account and area of surge tank can be reduced. However, area corresponding to 27m dia has been taken to keep the surge elevations within practical limits based on the topography of the area.

12.3 Area of Orifice

Area of orifice has been adopted as 19 sqm. which satisfies the Calme and Goden criteria. This area will be provided by four gate grooves of size 4.3m x 0.75m in the orifice slab and an opening at the centre of 2.80m dia.

12.4 Surge Studies

Surge analysis has been carried out for the following conditions using a computer programme :

1. Maximum upsurge for total load rejection (100% - 0%).

2. Maximum upsurge for 50% load acceptance followed by full load rejection (50% - 100% - 0%)

3. Minimum downsurge for 50% load rejection followed by 50% load acceptance (100% - 50% - 100%).

4. Minimum downsurge for 50% load rejection followed by instantaneous 50% load acceptance (50% - 0% - 50%).

5. Minimum downsurge for full load rejection followed by 50% load acceptance (100% - 0% - 50%).

For upsurge calculations friction factor has been taken as minimum i.e. 0.012 and reservoir level has been taken at maximum i.e. at El 1810 while for downsurge calculations friction factor has been taken as maximum i.e. 0.014 and reservoir level at El 1799.0 (minimum reservoir level) as per IS:1736 (Part I) 1985. For the transients of combination of load change, the second change was effected at the maximum/minimum velocity on the tunnel. The Governor closing time has been taken as 15 sec.

The result of these studies are tabulated below :

Sl No	Load change in MW	Reservoir level (m)	Losses max/min	Steady state head in surge shaft	Maximum/Minimum surge level
1.	1000-0	1810	min	1810	1848.680
2.	500-1000-0	1810	min	1810	1848.484
3.	1000-500-1000	1799	max	1810	1717.103
4.	500-0-500	1799	max	1810	1739.209
5.	1000-0-500	1799	max	1810	1735.168

Since the load acceptance can be controlled with the help of load limiters the condition of 50% load switch on has been taken the governing condition for fixing the centre line of tunnel below the surge shaft.

12.5 Size and Levels of the Surge Shaft

The maximum surge will go upto El 1848.680 keeping a free board of about 3.3 metres the top of 27m dia surge shaft has been kept at El 1852.0. The diameter of riser has been kept as 16m so that the gate grooves for the four pressure shaft can be accommodated. The top of riser has been kept at El 1755m.

The minimum downsurge elevation will be 1717.103. This gives a cover of 44.003m over the centre line of H.R.T. This is about 1.5 times the velocity head in orifice, which is considered adequate for avoiding vortex formation and jetting action in the surge shaft.

12.6 Geological Features

The surge shaft will be located in massive and hard gneitic gneiss. Surface geological indication are that the rock enclosing the surge shaft and pressure shafts is massive not abnormally fractured, and of excellent quality relative to the rocks in Himalayas.

12.7 Excavation and Support System

The surge shaft is open to sky at the top of surge shaft a terrace will be developed at El 1852 by excavating the exposed rock.

The excavated diameter of surge shaft will vary from 28m at the top to 30m at the junction with the riser. The excavated diameter of riser will vary from 18.5m to 19.5m.

The excavation of surge shaft will be carried out by first making a pilot shaft of about 3m dia by using a raise climber and then widening to the required diameter from top to bottom.

During the excavation the support system will consist of rock bolts and shotcreting. Rock bolts will be 25mm dia 6-7m deep @ 1.5m c/c in either direction and shotcrete will be 100mm thick with welded wire mesh 100x100x4.2 mm in between. Steel sets with lagging may also be required in certain bad reaches.

12.8 Concrete Lining

The surge shaft will be lined with reinforced concrete lining. The lining will prevent leakage through shaft and will protect turbines by preventing any loose rock pieces falling into the water passing into the machines. The lining will resist internal pressure with or without rock support as the case may be. The lining will resist external pressure as well. The lining will also be required to withstand high velocities of water during upsurge and downsurge. M25 A40 concrete is proposed to be used for the lining.

The lining has been designed for an internal pressure corresponding to the maximum surge level. Rock sharing has been considered as the rock is very competent and adequate rock cover is available. In the reach above El 1830.0 rock sharing has not been considered as the rock cover is not adequate. For working out the load to be shared by the rock modulus of deformation of surrounding rock has been taken as 75000 kg/cm^2.

The concrete lining has been checked for external loads due to water pressure corresponding to top of surge shaft (El 1852.0) and also for grouting pressure. External rock loads have not been considered for the design of the lining as the surrounding rock deformations would have stabilised during the time which would elapse between excavation and lining of the surge shaft.

Hoop reinforcement consisting of deformed bars and a sandwitched steel plate has been provided. The sandwitched steel plate of 16mm and 12mm (as shown in the Drawing - Surge shaft excavation and concrete lining details) thereon will extend upto El 1849.0 only. The provision of sandwitched steel plate will eliminate the possibility of saturation of the surrounding rock due to leakage from the surge shaft through the concrete lining.

12.9 Grouting

Gap between the rock and concrete lining will be pack grouted. For this purpose Nx holes will be drilled 300mm inside the rock at 3000 c/c circumferentially. Consolidation grouting shall also be carried out from the same holes by re-drilling upto a depth of 6000mm inside the rock. 50mm dia pipes shall be left for grouting holes in the lining.

12.10 Air Vents

Air vent of 500mm dia will be provided to meet the air requirement just at the downstream of the surge shaft gates. As these gates will always be closed or opened under balanced pressure conditions, smaller air vents would have sufficed, but 500mm dia air vent have been provided so that their cleaning is not difficult. The air vent will consist of welded steel pipes. The air vent pipes will be placed in niches to be cut in the rock and surrounded by concrete of the same grade as that of the lining.

12.11 Surge Shaft Gates

Gates will be provided at the junction of surge shaft with the junction with pressure shafts. These gates will be of stoplog type (i.e. opening and closing in balanced pressure) and will be used for isolating any pressure shaft for inspection and maintenance of the corresponding butterfly valve. Only two gates will be provided for the four pressure shafts. The gates which will normally be stored below the top of surge shaft will be handled by a radially travelling hoist provided at the top of the surge shaft.

The size of the gate grooves in the orifice slab will be 4.3m x 0.75m. The gate guides will be provided in the surge shaft from bottom to top by providing concrete piers inside the shaft. The gate grooves and transition in HRT including bottom of the orifice slab will be lined with a steel liner of 20mm thickness so as to avoid damage to concrete by high velocity water flow in these areas.

12.12 Drawings

The following drawing giving details of the surge shaft are included in Volume V of the project report.

Sl. No.	Drawing No.	Title		
1.	1200-08-01 (Rev. 1)	Surge Shaft and Pressure Shaft	-	Plan and L-Section
2.	1200-08-02 (Rev. 1)	Surge Shaft	-	Excavation and Concrete Lining Details

Chapter - 13

PRESSURE SHAFTS AND PENSTOCKS

13.1 General

The power house will be fed through 4 pressure shafts of 4.75m dia each one of which will start from bottom of the surge shaft. The pressure shafts will negotiate a head of 171.6m between the centre line of HRT at junction with surge shaft at El 1673.1m and centre line of machine at El 1501.5m.

The pressure shafts will have provision of stoplog gates at the junction with the surge shaft. The size of the gate will be 3.10m (W) x 4.75m (H). The transition from rectangular size of 3.10m x 4.75m (W) to circular diameter of 4.75m will be provided in a length of 8m.

For isolating any pressure shaft in emergency and for normal inspection and maintenance of pressure shafts, butterfly valves will be provided in a valve chamber located at downstream of the surge shaft. The size of the valve chamber will be 10m (w) x 95m (L) x 22m (H). The valve chamber will be approached through an approach adit of size 7.5m D-shaped.

The distance between centre to centre of pressure shaft beyond the valve chamber will be 22m.

13.2 Economic Diameter

The conventional arrangement would have been to provide two pressure shafts with Wye-piece bifurcations upstream of the power station. However, this require pressure shafts of 6.5m dia. As it will not be possible to transport penstock ferrules of 6.5m dia through the project roads and their handling and installation in underground shafts will be difficult and clumsy, this alternative has not been considered.

It is, therefore, proposed to provide individual pressure shaft taking off from the surge shaft for each machine, with its attendant advantages for a long and large diameter Head Race Tunnel.

The economic diameter of each pressure shaft worked out on the basis of various empirical formulae ranges from 4.04m to 5.12m. The economical diameter on the basis of rational method of monitoring the actual expenses on the total cost and revenue loss per year works out to 4.7m. The diameter of each penstock has therefore been adopted as 4.75m.

13.3 Layout

To save the quantity of steel, the bottom horizontal lengths of the pressure shafts has been kept minimum. The length of each pressure shaft will be 290.50m. A drop of 171.60m to the power house at the turbine level will be covered by vertical shafts. The radius of bend in the pressure shaft have been kept 23.75m i.e. 5 times the diameter of pressure shaft.

The centre to centre distance of pressure shafts will be 22m. The penstocks will be provided with taper pieces at their downstream ends. The diameter of pressure shafts at the end of taper piece will be 3.8m.

13.4 Penstock Liners

The pressure shafts will be steel lined along their whole length. The penstock liners have been designed to withstand internal as well as external water pressure. The internal water pressures including water hammer have been considered at different sections. External water pressure has been taken equal to the level difference between the ground level and the penstock level. The liners have also been checked for external pressures due to contact/consolidation grouting. The liners have been provided with stiffeners to resist buckling due to external water pressure and handling stresses.

Rock participation has been taken into consideration as the rock is competent and adequate rock cover is available. For computing the rock participation modulus of deformation of the rock has been taken as 75000 kg/cm^2, which is quite on the conservative side.

13.5 Liner Details

The penstock liners will be made of Pressure vessel plates (heat treated carbon manganese-silicon steel) conforming the ASTM A-537 Class 1. The thickness of penstock liners will vary from 14mm to 25mm. As the maximum thickness required is less than 36mm, stress relieving of the ferrules will not be required.

The maximum length of each ferrule will be 2.5m. However before erection two ferrules of 2.5m will be jointed together and each ferrule of 5m will be transported through the adits for erection. The transition portion and the horizontal and vertical bends in the liners will be all welded joints. The development and assembly of the bends will be carried out as per standard practice.

All the shop welding of the longitudinal joints will be double V-butt welds. The field welds on the circumferential joints will be single V-butt welds with backing strip. All the shop joints will be checked by radiographic examination while all the field welds will be tested by ultrasonic examination.

The hydraulic testing of the completed penstocks will not be carried out as the entire length is embedded in concrete. However, all the steel flats will be tested by ultrasonic examination so that they are free of manufacturing and other defects.

The ferrules will be painted from inside using epoxy based coaltar paint. Before painting the steel surfaces will be cleaned by sand blasting. 2 coats of epoxy premier paint will be applied.

13.6 Concreting and Grouting

The annular space between the steel liners and the rock will be filled with M20 concrete in a maximum thickness of 500mm. Grout holes will be provided in underground ferrules for carrying out pack grouting and contact grouting. After the excavation of pressure shafts, bad patches of the rock will be identified and consolidation grouting shall be done where required, using the above mentioned holes. For contact grouting holes will be drilled in the rock upto 0.3m depth. The same holes will be drilled for a minimum depth of 6m for consolidation grouting.

13.7 Drawings

The details of pressure shafts and penstock liners are given in the following drawings in the Volume V of the project report.

Sl. No.	Drawing No.	Title	
1.	1200-09-01	Pressure Shafts -	L-Section
2.	1200-09-02	Penstock Liners -	Liner Detail (Sheet 1 of 5)
3.	1200-09-03	Penstock Liners -	Liner Detail (Sheet 2 of 5)
4.	1200-09-04	Penstock Liners -	Liner Detail (Sheet 3 of 5)
5.	1200-09-05	Penstock Liners -	Liner Detail (Sheet 4 of 5)
6.	1200-09-06	Penstock Liners -	Liner Detail (Sheet 5 of 5)
7.	1200-09-07	Penstock Liners -	Grouting Details
8.	1200-09-08	Penstock Liners -	Welding Details.

Chapter - 14

CIVIL WORKS OF POWERHOUSE

14.1 Location

The powerhouse and transformer hall cavities are located on the right bank of Satluj river near the junction with Bhaba river, in a massive granitic gneiss knob with a cover of over 200m. Surface and sub-surface geological indications indicate that the knob is massive, not abnormally fractured and of excellent quality relative to the rocks in Himalayas. The excavation of the exploratory drift along the alignment of main access adit has also indicated absence of any glide cracks in the rock mass.

14.2 Access Adit

The approach to the main powerhouse cavity and transformer hall cavity will be through a 8.5m D-shaped adit to the service bay at El 1515.00m on the north end of the cavity. This adit which will be 883m long will take off from NH 22 at El 1591.50. Another adit of 6.5m D-shaped will provide approach to the control room at El 1530.50. This adit will take off from the main access adit. Another adit will branch off from this adit to the transformer hall cavity with junction at El 1531.40. These adits will initially be used for construction of roof arch of the main Power House Cavity and transformer hall cavity respectively and will later on provide additional access to the control room and the G.I.S. chamber.

A 7.5m D-shaped adit will take off from the main access adit and will provide access to bottom of pressure shafts and bottom of downstream surge chamber so that the work of excavation of pressure shafts from bottom and excavation of d/s surge chamber as also erection of penstock liners from the bottom can be carried out independently without disturbing the activities in the powerhouse.

14.3 Power House Cavity

The power house will be 21m wide, 45m high and 143m long and will house four vertical 250 MW Francis turbine-driven generating sets. The electro-mechanical equipment service bay (30m long) will be located on the north end of this cavity at El 1515.00. The control building block (25m long) will be located on the south end of this cavity.

The draft tubes will be about 10m long. At the north outlet the draft tubes change cross-section through a transition and continue as 7.5m D-shaped tunnels for about 58m, before discharging into the downstream surge chamber. Each draft tube will be provided with a gate at the downstream end of the tunnel, which will be operated from a gate operating gallery located at El 1525.00. The draft tube gallery will be approached from 8m D-shaped adit taking off from NH 22.

14.4 Layout of Powerhouse Cavity

The centre line of the turbines have been kept at El 1501.50 which is 4.5m below the minimum tailwater level. The machine hall will have four floors viz. valve gallery floor at El 1479.00, turbine floor at El 1505.50 generator floor at El 1510.00 and machine hall floor at El 1515.00. Arrangement for runner removal gallery is proposed to be provided at the basement floor to facilitate removal of runner for repair/replacement without dismantling the whole machine. Although silt particles larger than 0.2mm will be almost completely removed from water entering the headrace tunnel, high percentage of quartz in the silt can be a cause of erosion of runners or damage to seals. These can be easily and expeditiously attended with the proposed bottom removal of runners.

The control block located on the south end of the machine hall cavity and is proposed with 6 floors as below.

- El 1510.00 m
- El 1515.00 m
- El 1519.00 m
- El 1522.50 m
- El 1526.50 m
- El 1530.50 m

The control block floors will be used for auxiliary equipment like LT switchgear, station transformers, workshop, model room, stores, canteen, offices, visitor's room, battery chargers d.c., distribution boards, ventilation and air-conditioning etc. The main control room for the powerhouse and switchyard will be at El 1526.50.

The erection bay located on the north end of the power house cavity has only one floor at El 1515.00.

Two 275/40/10 T electric overhead travelling cranes will run on rails at El 1525.00 in the erection bay and machine hall.

14.5 Transformer Hall

The step-up power transformers will be housed in a separate cavity 15.5m wide, 25m high, and 143m long, parallel to powerhouse cavity and 21m downstream. The transformer hall has two distinct levels the floor at elevation 1515.00m, will house the 13 single phase power transformers (4x3 and one spare), and floor at level 1526.00m will house 400kV G.I.S. equipment.

Access to the transformer hall during construction and operation will be through a short extension to 8.5m D-shaped access tunnel to the powerhouse service bay, which will connect both the cavities at El 1515.00m. Similarly, the 6.5m D-shaped construction adit to the cavity at El 1522.00m will, after construction, remain as permanent access to the switchgear equipment floor.

The cables from the switchgear room will be taken to the pothead yard at El 1845.00 through a cable tunnel of size 5m dia circular and 528.71m long.

14.6 Design of Cavities

Finite element analysis has been carried for determination of the state of stress around the machine hall, transformer hall, downstream surge chamber cavities with the following objectives:-

a) To determine the distribution and magnitude of critical stresses around the cavities.

b) To locate the tension zones for design of roof arch and wall supports.

c) To plot major and minor principal stresses around the cavities.

d) To check the deformation pattern around the cavities.

e) To check the safety factor around the cavities (safety sector is calculated by dividing the rock strength by the induced strength).

The details of FEM analysis are given in Volume III of the report.

14.7 Support System for the Cavities

Based on the rock mass quality `Q' of the rock as determined during the excavation of the exploratory drift upto the junction of Power House Cavity the support pressure as below have been adopted for design of support system.

Roof 0.66 kg/cm^2

Walls 0.50 kg/cm^2

The support system as below has therefore been proposed :

Power House Cavity

Roof		Fibre reinforced shotcrete	10 cm
		Rock bolts (36mm dia) Grid spacing	1.5m c/c
		Length	6/7m
Side Walls	U/S	Fibre reinforced shotcrete	12.5 cm
		Rock bolts (36mm dia) Grid spacing	1.5m
		Length	9/11m
	D/S	Fibre reinforced shotcrete	12.5 cm
		Rock anchors 50T Capacity	21m
		Grid spacing	2.75m
		Rock bolts (36mm dia) Grid spacing	1.5m
		Length	9/11m

Transformer Hall Cavity

Roof		Fibre reinforced shotcrete	10 cm
		Rock bolts (25mm dia) Grid spacing	1.5m c/c
		Length	5/6m
Side Walls	D/S	Fibre reinforced shotcrete	12.5 cm
		Rock bolts (25mm dia) Grid spacing	1.5m
		Length	6/7m

	U/S	Fibre reinforced shotcrete	12.5 cm
		Rock anchors 50T Capacity	21m
		Grid spacing	2.75m

D/S Surge Chamber Cavity

Roof	Fibre reinforced shotcrete	10 cm
	Rock bolts (25mm dia) Grid spacing	1.5m c/c
	Length	4/5m
Side Walls	Fibre reinforced shotcrete	10 cm
	Rock bolts (25mm dia) Grid spacing	1.5m
	Length	6/7m

The support system will be increased in the reaches where shear zones are met, and in the reaches where structural discontinuities require longer rock bolts or rock anchors.

14.8 Drawings

The details of powerhouse and appurtenant works are shown in the following drawings in Volume V of the report :-

Sl. No.	Drawing No.	Title
1.	1200-10-01 (Rev. 2)	General Plan showing Layout of Works at Power House Site.
2.	1200-10-02(Rev. 2))	Cross-section of Power House Cavity, Transformer Hall Cavity and Downstream Surge Chamber.
3.	1200-10-03 (Rev 2)	Supporting Details of Power House Cavity, Transformer Hall Cavity and Downstream Surge Chamber.

Chapter - 15

TAILRACE WORKS

15.1 Downstream Surge Chamber

A surge chamber is provided downstream of the powerhouse to help stabilize the pressure level downstream caused by load fluctuations. This chamber also acts as collection chamber for the discharge from draft tube tunnels. The chamber is 220m long, 16m wide and 42.5m high. The elevations of the invert and the roof are 1492.00m and 1534.50m respectively.

The elevation of the draft tube gate operating gallery and the surge chamber is dictated by the maximum surge level expected. The table 15.1 below presents the maximum and minimum water levels in the downstream surge chamber for different loading conditions. It can be seen that the maximum expected water level is 1523.065m.

Table 15.1

MASS OSCILLATIONS IN DOWNSTREAM SURGE CHAMBER

Sl. No.	Operating Conditions (0% of the total load)	Tailrace Level (m)	Losses (max/min)	Maximum/Minimum Surge Level (m)
1.	100-0	1505.80	Max	1498.605
2.	50-100-0	1505.80	Max	1497.812
3.	100-50-100	1516.25	Min	1521.223
4.	50-0-50	1516.25	Min	1520.052
5.	100-0-50	1516.25	Min	1523.065

15.2 Draft Tube Gate Operating Gallery

The draft tube operating gallery has been provided at El 1525.0m. The gallery will be connected to the 6.5m D-shaped adit to control room. Concrete piers will be provided in the surge chamber to accommodate track and guides for the draft tube gates. The draft tube gates when not in use will be stored in the gate grooves below elevation 1525.0m. A gantry crane will be provided in the gallery for handling the draft tube gates.

15.3 Tailrace Tunnel

A 909m long tailrace tunnel will carry the turbine discharge to the river Satluj. As the other underground structures in the powerhouse area this tunnel will also be located in massive granitic gneiss. The tailrace tunnel will have the same cross-section as the headrace tunnel and will rise from elevation 1492.0m at the surge/collection chamber to El 1505.00 at the outlet structure at a constant slope of 1.43%.

15.4 Outlet Structure

At the outlet end of the tailrace tunnel an outlet structure will be provided to house two wheeled stoplog gates of size 6.3m (width) which will be used for isolating the tunnel for inspection and maintenance and when the river is carrying heavy silt loads during high floods and power stations is shut down.

The top of outlet structure will be at El 1516.50 which is above the maximum flood level. The excavated rock above the outlet portal will be protected by shotcreting and rock bolting.

Construction of outlet structure will require provision of a steel bulkhead near the outlet end of the tailrace tunnel. This bulkhead will be removed when the stoplog gates are in place.

15.5 Drawings

The details of the outlet works are shown in the following drawings in Volume V of the report :-

Sl. No.	Drawing No.	Title
1.	1200-11-01(Rev. 1)	Tail Race Tunnel and Outlet Structure - General Arrangement

Chapter - 16

HYDRAULIC GATES AND VALVES

16.1 Diversion Tunnel Gates

Two gates will be provided at the inlet structure of the tunnel. These gates will be required to shut off the flow through diversion tunnel to effect closure of river after completion of dam. These gates can also be used to isolate the diversion tunnel when it is in operation, if any urgent inspection or repairs are required.

The gates will be of fixed wheel type for opening size 5.25m (W) x 10.5m (H). Each gate will be in 3 parts which will be joined at site.

The gates will be operated by electrically operated rope drum hoists mounted on the top of inlet structure at El 1795.5. These hoists will be reclaimed after final closure of diversion tunnel on completion of dam.

16.2 Sluice Spillway Gates

The sluice spillway will have six bays of 9m (W) x 9m (H) with crest at elevation El 1782.

It is proposed to provided top sealing type of radial gates for the sluice spillway.

The radial gates have been favoured as compared to the vertical lift gates as the gates will be required to operate in undershot condition during the monsoons to flush out the sediment deposit in the reservoir and particularly near the intake. This operation is necessary as the Satluj river carries lot of bed load during the rainy season. To meet this requirement vertical lift gates are not considered suitable as these gates can not be run undershot for extended periods. The requirement of deep grooves for vertical lift gates is also not a desirable feature. Though not a ruling consideration, economy also favours radial gates.

The sill of the radial gate has been kept at El 1781.75 so that there are no negative pressures on the crest during partial opening of the gates.

The radial gates will be operated by hydraulic hoists as they are more efficient and compact and will also be economical as compared to mechanical hoists for the required capacity.

The operation of the gates will be carried out from a control room located on the right bank of the spillway. Remote indication (digital) of the gate position will also be provided in the control room. For inspection and maintenance purposes or in case of any fault in the control panels, the gates can also be operated from local control panels mounted on the piers and abutments.

16.3 Auxiliary Spillway Gate

The purpose of the auxiliary spillway is to pass floating debris as also to pass low floods and excess water due to sudden closure or rating down of any machine when the reservoir is full.

The auxiliary spillway will have one bay of 8m width with crest at El 1803.0. It is proposed to provide radial gate of size 8m (W) x 7.35m (H) for the auxiliary spillway.

The radial gate for the auxiliary spillway will also be operated by hydraulic hoists mounted on the piers.

16.4 Spillway Stoplogs

Provision of stoplogs has been made for both the sluice spillway and the auxiliary spillway.

For the sluice spillway grooves for stoplogs will be provided in all the six bays while one set of stoplogs consisting of 7 units will be provided to enable to isolate one sluice at a time for inspection and maintenance of the radial gates. The stoplogs will consist of one bottom unit, 5 interchangeable intermediate units, and one top unit. The top unit will have provision of top seal which will sit on the top seal seat mounted on the breast wall.

The stoplogs for the auxiliary spillway will consist of 5 units (one bottom unit and four interchangeable other units)
The stoplogs for both the sluice spillway and auxiliary spillway will have the following special features.

1. Slot fillers for masking the stoplog grooves will be provided. This will eliminate the possibility of damage to the grooves and spillway profile due to hydraulic turbulence. The possibility on any deposit of sediment or debris in the stoplog grooves will also be eliminated.

2. The stoplog units will be provided with double bulb seals to provide better sealing capability.

The stoplogs both for the sluice spillway and auxiliary spillway will be operated by using a gantry crane moving on the roadway on top of dam. The same crane will also be used for removing the slot fillers before placing the stoplog units and putting the slot fillers in position after the stoplog units have been removed. The stoplogs for sluice spillway when not in use will be stored in the top portion of the grooves below the road level. The stoplogs for auxiliary spillway will be stored in a storage shaft on the left bank of the dam.

16.5 Trashracks and Trash Cleaning Machine

At the entrance of intake, trashracks will be provided. The trashrack units will be of size 4.5m (W) x 4m (H) with 75mm C/C spacing of the trashracks. 8 such units will be required for each intake bay. This spacing has been provided to avoid frequent choking of trashracks particularly during monsoons.

A heavy duty trash cleaning machine is proposed to be provided for carrying out regular cleaning of trashracks. A hydraulic grab winch will also be mounted on the trash cleaning machine for picking and removal of heavy trash and floating logs etc.

The trash cleaning machine will travel on the rail track provided on top of intake structure. The hoist for handling trashracks will also be mounted on the trash cleaning machine.

16.6 Intake Gates

Intake is free flow type and therefore, gates are not required for controlling the flow through the intake. The intake gates are required for inspection and maintenance of intake tunnels and sedimentation chambers.

The gates will also be required when anyone or more sedimentation chambers have been closed for inspection and maintenance and the water is being fed into headrace tunnel through other sedimentation chambers.

For the intake gates of size 6m (W) x 5m (H) will be provided. The gates will be of fixed wheel type with skin plate and seals on the upstream side. The gates will be operated by individual hydraulic hoists. A control room housing the gate control equipment and hydraulic power pack will be provided adjacent to the intake structure.

Grooves for the stoplog gate have also been provided on the upstream of the intake gates so that if required any intake bay can be isolated by putting the stoplog gate. Although the intake gates will most of the time remain in open position and they can be maintained without use of stoplog gate, but the provision of stoplog gate will provide flexibility in operation in case any gate is stuck due to malfunctioning or otherwise.

The embedded parts for the stoplog gate will be provided in all of the intake bays, but only one stoplog gate will be provided for all the 4 intake bays. The stoplog gate will also be operated by electric hoist mounted on the trash cleaning machine.

16.7 Sedimentation Chamber Gates

The gates of size 6m (W) x 6m (H) will be provided in the link tunnels at the end of each sedimentation chamber. The purpose of these gates is to stop backflow of water in any sedimentation chamber which has been isolated for maintenance and repairs and the other chambers are being used for feeding water to H.R.T.

These gates will be of fixed wheel type. The skin plate and seals will be provided on the upstream side to provide positive sealing from the back water.

The gates will be operated by a gantry moving in the gate chamber which are connected by the approach adit.

16.8 Flushing Conduit Gates

At the end of each flushing conduit a fixed wheel gate will be provided to regulate the flow from the flushing conduit and also to isolate the flushing conduit from the river side for inspection and maintenance. The opening size of these gates is 2.75m (W) x 2.75m (H).

The flushing conduit gates will be operated by independent hydraulic hoists mounted on the top of the gate structure. Operation of these gates can be carried out from the local control panel as well as from the remote control panels provided in the control room at the dam.

16.9 Surge Shaft Gates

For isolating the pressure shafts for inspection and maintenance of the butterfly valves stoplog gates will be provided at the junction of the surge shaft and pressure shafts. The opening size for the stoplog gate will be 3.1m (W) x 4.75m (H).

The stoplog gate will be fixed wheel type suitable for use in balanced condition only i.e. when there is no flow through the pressure shaft.

The gate guides for the surge shaft stoplog gate will be mounted on the extended piers inside the surge shaft. The stoplog gate will be operated by a radially travelling hoist mounted on the top of the surge shaft. When not in use the gate will be stored at the top of the surge shaft with the help of dogging beam.

For filling the pressure shaft for balancing the pressure, a filling valve will be mounted on the gate which will be initiated by operating the hoist. An electrical interlock will be provided so that the gate can be raised only by operation of the hoist when the pressure is balanced on both sides of the gate.

An airvent pipe of 500mm dia will also be provided in each pressure shaft just downstream of the gate.

16.10 Emergency Valves

A valve chamber of size 10m (W) x 95m (L) x 22m (H) will be provided downstream of the surge shaft to accommodate an emergency valve for each pressure shaft.

The emergency valves will be butterfly type and will be operated by hydraulic servomotors. In emergency these valves can be closed under unbalanced condition but the opening will only be possible in balanced condition. The water pressure can be balanced by using the bypass pipe provided in the valve chamber.

In emergency, this valve can be operated from the power station control rooms. Necessary interlocks will be provided so that power station cannot be started unless this valve is in fully open position.

16.11 Main Inlet Valves

The main inlet valves to be located in the machine hall on each unit penstock will be of spherical type operated by hydraulic servomotor. The diameter of these valves will be 3.2m. Taper pieces will be provided in the unit penstocks upstream of the valves to reduce the diameter from 4.75m to 3.2m.

The operation of these valves will be carried out from the power station control room.

16.12 Draft Tube Gates

Draft tube gates will be provided near the junction of the draft tubes with the collection gallery so that any draft tube can be isolated for maintenance of the corresponding turbine. The size of each draft tube gate will be 7m (W) x 5.5m (H).

The draft tube gates will be operated by using a gantry crane provided in the draft tube gate operating gallery at El 1536.00m.

16.13 Outlet Gates

Fixed wheel type gates will be provided at the outfall structure at the end of tailrace tunnel. The purpose of these gates will be to isolate the tailrace works from the river for inspection and maintenance when power station is closed. Outfall structure will have two bays of 5.25m width with an intermediate pier of 1.5m width. Thus two gates will be required at the outlet structure. These gates will be operated by fixed hoists on the top of outfall structure. Normally the gates will be in open position and will rest on the dogging beams mounted at the top of gate grooves.

16.14 Access Doors

Vehicle access doors will be provided in concrete plugs in the inlet adit, intermediate adit no. 3 and surge shaft adit to provide access for vehicles and for transport of equipment etc. when the headrace tunnel is dewatered for inspection and maintenance.

The door will be hinged type rotating on two hinges. For sealing the gate on the seal seats single stem music note neoprene seals will be provided on the door. The opening for the door in the concrete plug will be 2.2m (W) x 2.35m (H) while the overall size of the door will be 2.9m (W) x 3m (H).

16.15 **Salient Features of various Gates and Hoists**

The salient features of various gates and hoists are given in Annexure 16.1.

16.16 **Drawings**

The details of various hydraulic gates and operating equipment are shown in the following drawings in Volume V the project report :

Sl. No.	Drawing No.			Title
1.	1200-03-03	Diversion Tunnel	-	Details of Inlet Structure of Diversion Tunnel
2.	1200-04-09 (Rev.1)	Diversion Dam	-	Undersluice - GA of Radial Gates and stoplogs
3.	1200-04-10	Diversion Dam	-	Undersluice radial gates - Top, Side and Bottom Seals and Seal Seat Details
4.	1200-04-11	Diversion Dam	-	Undersluice Spillway Stoplogs - Details of Bottom Seals, Side Seals and Top Seals
5.	1200-04-12	Diversion Dam	-	Auxiliary Spillway - GA of Radial Gates and Stoplogs
6.	1200-05-04 (Rev. 1)	Intake structure	-	Longitudinal Section
7.	1200-06-05 (Rev. 1)	Flushing Conduits	-	General Arrangement of Gates and Hoist at outfall structure
8.	1200-06-06	Link tunnels	-	General Arrangement of Gates
9.	1200-07-09	HRT	-	Typical details of plug with access gate
10.	1200-07-10	HRT	-	Adit plug vehicle access door
11.	1200-07-11	HRT	-	Adit plug vehicle access door - Downstream face and sealing arrangement
12.	1200-11-01 (Rev. 1)	Tail Race Tunnel and Outlet Structure	-	General Arrangement

SALIENT FEATURES OF VARIOUS HYDRAULIC GATES AND VALVES

A) DIVERSION TUNNEL GATES

1.	Type of gates	Fixed wheel
2.	Size of gates	5.25m (W) x 10.5m (H)
3.	Sill elevation	El 1772.0 m
4.	Top of inlet structure	El 1795.5 m
5.	Type of hoists	Individually electrically operated rope drum hoists

B) SLUICE SPILLWAY GATES

1.	Type of gates	Radial gates with top sealing
2.	Number of gates	6
3.	Opening size	9 m (W) x 9 m (H)
4.	Size of gates	9 m (W) x 9.25 m (H)
5.	Sill elevation	El 1781.662 m
6.	Centre line of trunnion	El 1792.00 m
7.	Radius to inside of skin plate	12.5 m
8.	Hoists	2 hydraulic hoists of 250 T capacity mounted on each gate.
9.	Operation	From control room located on the right abutment of the Dam in addition to local control panels.
10.	Gate position indicators	Digital gate position indicators in the control room and disc type mechanical gate position indicators mounted on the hoists.
11.	Standby power	D.G. sets in case of electric power failure from the grid.

C) AUXILIARY SPILLWAY GATES

1.	Type of gates	Radial
2.	Number of gates	1
3.	Size of gates	8 m (W) x 7.35 m (H)

4.	Sill elevation	El 1802.90 m
5.	Centre line of trunnion	El 1806.30 m
6.	Radius to inside of skin plate	9.6 m
7.	Hoists	2 hydraulic hoists of 50 T capacity mounted on gate.
8.	Operation	From control room located on the right abutment of the Dam in addition to local control panels.
9.	Gate position indicators	Digital gate position indicators in the control room and disc type mechanical gate position indicators mounted on the hoists.
10.	Standby power	D.G. sets in case of electric power failure from the grid.

D) **SPILLWAY STOP LOGS**

1.	Type	Sliding type with double bulb seals on the sides, bottom and top.
2.	No. of units	
	Sluice spillway	7 units (1 bottom, 5 interchangeable intermediate units and 1 top unit)
	Auxiliary spillway	5 units (1 bottom and 4 interchangeable other units)
3.	Size of each unit	
	Sluice spillway	9 m (W) x 2.7 m (H)
	Auxiliary spillway	8 m (W) x 1.9 m (H)
4.	Size of groove	875 m (W) x 400 m (D)
5.	Slot fillers	Grooves will be masked with slot fillers when stop logs are not in the grooves.
6.	Operation	By using a gantry crane moving on top of dam and semi-automatic lifting beams. The slot fillers will also be removed or replaced in the grooves by using the same gantry crane.
7.	Operating condition	Balanced condition i.e. when the corresponding radial gate is in closed position.

8.	Storage	
	Sluice spillway stop log units	In top position of grooves.
	Auxiliary spillway stop log units	In storage shaft on left bank.
9.	Capacity of gantry crane	35 T
10.	Centre to centre of rails	3750 mm

E) **INTAKE TRASH RACKS**

1.	Size of each unit	4.5 m (W) x 4 m (H)
2.	Number of units for each intake	8
3.	Total number of units	32
4.	Centre to centre of trashrack bars	75 mm
5.	Operation	By using hoist mounted on the trash cleaning machine.

F) **TRASH CLEANING MACHINE**

1.	Type	Heavy duty with separate hydraulic grab winch to handle big pieces of floating debris.
2.	Cleaning rope	Jaw type 2.25m width
3.	Capacity	Rake 20 KW winch Grab crane 3.5 T (approx.)
4.	Centre to centre vertical posts	3300 mm
5.	Disposal of trash	By motorised trolleys moving on rails on the top of intake structure.

G) **INTAKE GATES**

1.	Type of gates	Fixed wheel type
2.	Number of gates	4 (One for each intake)
3.	Opening size	6 m (W) x 5 m (H)
4.	Sill elevation	El 1786.0 m

5.	Sealing	Upstream sealing
6.	Operation of gates	By individual hydraulic hoists
7.	Operating conditions	The reservoir level will be kept at min. pond level (El 1799.0m) while operating the gates
8.	Capacity of hoists	75 T

H) **INTAKE STOPLOG GATE**

1.	Location	Upstream of intake gates
2.	Number of bays	4
3.	Size of stoplog gate	6 m (W) x 5 m (H)
4.	Number of stoplog gate	1
5.	Operating conditions	By using the electric hoists mounted on the trash cleaning machine.

I) **SEDIMENTATION CHAMBER GATES**

1.	Location	In link tunnels d/s of exit of sedimentation chambers.
2.	Type of gates	Fixed wheel type
3.	Number of gates	4 (One for each sedimentation chamber)
4.	Opening size	6 m (W) x 5 m (H)
5.	Sill elevation	El 1785.0 m
6.	Operating conditions	Balanced condition
7.	Operation of gates	By a gantry crane running in the gate operating gallery.
8.	Capacity of crane	45 T

J) **FLUSHING CONDUIT GATES**

1.	Location	At the end of each flushing conduit.
2.	Type of gates	Fixed wheel type
3.	Number of gates	4 (1 for each flushing conduit)
4.	Opening size	2.75 m (W) x 2.75 m (H)
5.	Sill elevation	El 1785.80m for two gates and 1785.50 for two gates
6.	Hoists	50 T capacity hydraulic hoists.
7.	Operation	From the control room located on the right abutment of the Dam and also from local control panels.

8.	Operating conditions	The gates can be operated or closed under unbalanced condition.

K) **SURGE SHAFT GATES**

1.	Location	At the entrance to the pressure shafts
2.	Type of gates	Fixed wheel type
3.	Number of gates	2 (for 4 pressure shafts)
4.	Size of gates	3.1 m (W) x 4.75 m (H)
5.	Sill elevation	El 1670.725 m
6.	Operating condition	Balanced condition
7.	Arrangement for balancing pressure	Filling valve mounted on each gate.
8.	Operations	Radially travelling hoist mounted on top of surge shaft.
9.	Capacity of hoist	40 T.

L) **EMERGENCY VALVES**

1.	Location	In valve chamber on the downstream of surge shaft.
2.	Number of valves	4 (one for each pressure shaft)
3.	Type of valves	Butterfly type
4.	Diameter of valves	4000 mm
5.	Dimensions of valve chamber	95 m (W) x 10 m (L) x 22 m (H)
6.	Operation	Hydraulic servomotor
7.	Operating conditions:	(a) Closing - Emergency closing under unbalanced condition from Power House control room. (b) Opening - In balanced condition i.e. when the corresponding machine at the power station is not running and pressure shaft is full
8.	Arrangement for balancing pressure	Bypass pipe with valves on each pressure shaft.

M) **MAIN INLET VALVES**

1.	Location	In main Power House cavity.
2.	Number of valves	4 (one for each turbine)

3.	Type of valves	Spherical type
4.	Diameter of valves	3200 mm
5.	Operation	By hydraulic servomotor
6.	Operating conditions:	(a) Closing - Emergency closing under unbalanced condition from Power House control room. (b) Opening - In balanced condition.

N) **DRAFT TUBE GATES**

1.	Location	Near junction of draft tubes with collection gallery cum downstream surge chamber.
2.	Type of gates	Sliding type
3.	Number of gates	2 (for 4 draft tubes)
4.	Size of gates	7.0 m (W) x 5.5 m (H)
5.	Sill elevation	El 1500.0 m
6.	Operation	By gantry crane provided in draft tube gate operating gallery at El 1536.0 m.
7.	Capacity of crane	35 T

O) **OUTLET GATES**

1.	Location	At the outfall structure at the end of tailrace tunnels
2.	Type of gates	Fixed wheel type
3.	Number of gates	2
4.	Size of each gate	5.25m (W) x 10.3m (H)
5.	Sill elevation	El 1505.00 m
6.	Operation	By individual electrically operated rope drum hoists.
7.	Capacity of hoists	40 T.

P) **VEHICLE ACCESS DOORS**

1.	Location	At the plugs at inlet adit, intermediate adit 3 and surge shaft adit.
2.	Type of doors	Hinged type rotating on two hinges.
3.	Number of doors	3
4.	Opening size of door	2.2 m (W) x 2.25 m (H)
5.	Overall size of door	2.9 m (W) x 3.0 m (H)

CHAPTER - 17

POWER PLANT

17.1 Powerhouse Equipment

17.1.1 Turbine and Generators

Turbines

Four vertical axis Francis turbines have been chosen for the Karcham-Wangtoo project on the basis of the following hydraulic conditions:

Maximum reservoir operating level	1810.0 m
Maximum reservoir drawndown level	1799.0 m
Normal tailwater level (4 unit discharge)	1509.5 m
Minimum tailwater level (½ unit discharge)	1506.5 m

Each of the four turbines will have a rated output of 255,000 kW under a rated net head of 273.5 m at 214.3 RPM synchronous speed. The design flow through each unit will be 104.25 m^3/s.

The distributor axis will be at El. 1501.50 m to provide the runners adequate protection against cavitation.

An inlet valve of the spherical type will be provided to each turbine at the inlet to the turbine spiral casing. The spherical valve will be connected to the pressure shaft steel liner on the upstream side with a flanged section.

Generators

The generators will be synchronous and of the vertical shaft type. Each of the four generators will have the following characteristics:

Rated power	250 MW

Power factor	0.9	
Frequency	50	Hertz
Phases	3	
Speed	214.3	RPM
Voltage	≥ 13.8	kV

The generator will be provided with static excitation and the units will be controlled through Computerised Data Acquisition and Control System. Protection, metering panels and mosaic mimic board shall be provided for generator, transformer, bus coupler and feeders.

The major electrical equipment of the powerhouse is indicated on the single-line diagram 1200-2132-001 & 002 appended with Vol. II - Electro-Mechanical Works.

17.1.2 Auxiliary Equipment and Services

Electrical Auxiliaries

- A.C. Supply for the auxiliary equipment in the powerhouse will be supplied by unit and station service transformers of the Epoxy Cast Resin Dry type, rated 1000 kVA, 3-phase, 13.8/0.415 kV (UAT) or 22/0.415 kV (SST). For emergency start provision for 2x1000 kVA diesel sets has been made. The system also includes L.T. Switchgear panel (Unit Auxiliary Board and Station Service Board) for the Powerhouse.

- The D.C. power required for control and protection equipment will be provided by two sets of 220 V D.C. batteries. This equipment will include 2 battery charges, D.C. distribution board, etc.

- Illumination of the powerhouse, transformer cavern, access tunnels, switchyard, dam, valve/gate operating galleries, surge shaft area, etc.

- Communication equipment for transmission of data and speech including inter communication.

- Grounding system for the powerhouse and switchyard electrical equipment.

- An electrical test laboratory shall be provided for routine tests and maintenance.

Mechanical Auxiliaries

Two electrically powered overhead travelling cranes, each with 275 tonnes main hoist, 40 tonnes auxiliary hoist and a 10 tonne mono-rail hoist will be provided for the installation and maintenance of heavy equipment such as the generator stators, rotors, turbine runners and spherical valves.

Mechanical auxiliaries services will be provided, in the powerhouse as under:

- Passenger lift serving various floors of Power House and Control block

- Cooling water system for generator, air coolers, thrust and guide bearing coolers, transformer coolers, shaft seal etc.

- Drainage and dewatering system

- Ventilation system for the Underground Power House, transformer hall, access tunnels, BF Valve Chamber etc.

- Air-conditioning System for control room and offices.

- Compressed air system for governing system, inlet valves, generator brakes and other station services

- Fire protection, detection and alarm system for generators, transformers, cables in the Power House and Switchyard areas. Portable fire extinguishers shall also be provided.

- Oil handling system for transformer insulating oil and lubricating oil for governor / bearings etc.

- A mechanical workshop for routine repairs/maintenance

17.2 Power Transformers and GIS Equipment

Power produced by the powerhouse generators will be at 13.8 kV or above. This voltage will be stepped up to 400 kV by single-phase transformers 93 MVA, $13.8/400/\sqrt{3}$ kV, OFWF type installed in the transformer hall.

The transformers will be connected to the 400 kV Indoor-GIS (gas-insulated switchgear) installed in the same cavern and comprising 4 generator bays and a bus-coupler bay. Outdoor type 400 GIS has been provided for 6 feeder bays. Indoor-GIS will be connected to the outdoor GIS through 400 kV, SF_6 gas insulated phase buses. The CVTs, line end surge-arresters, wave trap etc. will be outdoor conventional type installed in outdoor potyard.

17.3 Other Details

For other details of electro-mechanical equipment, reference may please be made to chapters contained in Vol. II 'Electro-mechanical Works' of the project report.

Chapter - 18

TRANSMISSION SYSTEM

18.1 Existing 400 kV Transmission Network

Existing 400 kV transmission network in the vicinity of Wangtoo Power Station for evacuation of power from Baspa II P.S. (3x100 MW) and Nathpa-Jhakri P.S. [6x250 MW] is shown in drg no. 1200-2132-014. Two 400 kV feeders are to be constructed from Baspa II to Jhakri by Jaiprakash Hydro Power Ltd. From Jhakri, Two 400 kV feeders to Kol Dam and two 400 kV feeders to Abdullapur are under construction. From Kol Dam two 400 kV feeders to Hissar are being provided for evacuation of power. From Abdullapur, 2 feeders for Bawana in Delhi, two feeders for Yamuna Nagar in Haryana and one feeder for Pipli have been proposed. This transmission system is being executed by POWERGRID CORPORATION LTD.

18.2 Proposed Power Evacuation Plan

It is proposed to have provision for six out going feeders at Wangtoo P.H. 400 kV yard at El.1845.0m. Existing transmission system will be required to be supplemented and new feeders will be required to be planned for evacuation of power from Wangtoo. At Wangtoo Pot yard provision of all equipment upto take-off gantry has been made in the cost estimate. This project report does not include cost of transmission system.

18.3 Equipment for Protection and Monitoring

It is proposed to provide phase comparison and/or impedance protection as Main I and Main II Protection for fast clearances of faults in co-ordination with grid substation protection. It is also proposed to provide fault locators which will help in fault location as well as analysis. Sequence event recorders and disturbance recorders are also proposed for monitoring, recording and diagnosis of line faults on the circuits connecting power station to the grid.

For communication with grid sub-stations, Area load Despatch Centre and Central Load Despatch Centre power line carrier communication channels will be provided. Further provision for data acquisition (i.e. MW, MVAR, Voltage, Current etc.) and its transmission to Area/Central Load Despatch Centre, through superimposed telemetry channels, has been made. This will facilitate better co-ordination between various agencies.

Chapter - 19

INFRASTRUCTURAL WORKS

19.1 Rail Head Facilities

Karcham-Wangtoo Project is located about 210 km from Shimla. Kalka is the nearest broad gauge railway station on the Northern Railway and is about 300 km from the Project site. The heavy machinery and equipment is, therefore, proposed to be transported up to Kalka by rail. A store yard with crane facilities for unloading the railway wagons will be provided at Kalka. Two Nisson sheds will also be provided in the store yard to store electrical and other equipment till it is transported to site of works. Space for storage of about 1000 tonnes of cement will also be provided in this store yard.

19.2 Road Transport Facilities

Kalka is connected to the Project site by National Highway - 22 (Hindustan - Tibet Road). All culverts and bridges on this road are being constructed conforming to Class AA. The road upto Jhakri is being improved to transport heavy equipment for Jhakri power house of Nathpa-Jhakri Project. It will be necessary to modify the road and bridge between Jhakri and Wangtoo for transport of heavy equipment weighing 120 tonnes excluding weight of the trailer and tractor unit for this project. The provision has, therefore, been made in the project estimate for improvement of this road. Both the power station and the dam are located on National Highway - 22.

19.3 Project Roads

The main project roads to be constructed are road to surge shaft and roads to inlet adit and intermediate adits 3 and 4. These roads will take off from National Highway - 22. The length of road to surge shaft will be 4.0 km, while the total length of road to inlet adit and intermediate adits will be 1.25 km. These roads will have formation width of 9m and metalled width of 6 m.

In addition, haulage roads (6.1 m wide) will be required to be constructed for plant areas, quarry sites, disposal sites and explosive magazines, etc. The total length of these roads will be about 3 km.

Internal roads will also have to be constructed in the Colony and Stores areas etc. The total length of such internal roads will be about 2 km. Cost of these roads has also been provided in the estimate of cost.

In addition to these roads, it will also be necessary to realign part of National Highway-22 which will be submerged in the reservoir. At present, National Highway-22 crosses from right bank to left bank at Karcham upstream of the proposed dam and upstream of confluence of Baspa with Satluj river. This bridge will be submerged after construction of dam. It will, therefore, be necessary to construct a new bridge downstream of the dam to take the National Highway - 22 on the left bank, then after crossing Baspa river, National Highway - 22 will join the road to Baspa Stage II - Underground Power Station. Beyond this road, a high level road will be constructed on the left bank which will meet existing NH-22 on left bank at 358 km.

19.4 Bridges

The following bridges will be required to be constructed:-

(i) 105 m span permanent bridge over river Satluj downstream of the dam site for taking the National Highway - 22 on the left bank.

(ii) 69.2 m span permanent bridge over river Baspa u/s of Karcham dam on realigned Karcham-Sangla road.

(iii) 69.2 m span temporary bridge over river Satluj at 337.5 km on National Highway - 22 to provide access to the dumping areas on the left bank.

(iv) 105m Span permanent bridge on river Satluj upstream of Karcham Dam on NH 22 at 356.46 km.

(v) 40m Span permanent bridge over Bhabha Khud near Wangtoo Power House.

(vi) 40m Span permanent bridge over Bhabha Khud on Surge Shaft road.

(vii) 50m Span permanent bridge over Punang Nallah.

(viii) 53m Span permanent bridge over Satluj at Wangtoo.

19.5 Construction Camp Sites and Permanent Colony

The main construction camp and stores etc. for all the works of the project are proposed to be established at Sholtu on the left bank of river Satluj. This site is about 8 km from Karcham. The main advantage of this site is that sufficient land which will require minimum of terracing work is available at this place. Moreover, the Tapri town which has got a good market and also schooling facilities is nearby. The National Highway - 22 upto Tapri is open most of the time during winter months also. Therefore, the construction staff and workers will not feel isolated. Moreover, the camp site for Baspa Hydro-Electric Project Stage II is also located at this place.

The permanent colony for the operation and maintenance staff for the power station is also proposed to be constructed at this site. However, temporary camps will also be established near the dam site, power house site and intermediate adit sites to house the staff during construction period.

19.6 Construction Plant Areas

Construction Plant areas for locating the batching and mixing plant, compressor house and field workshops will be provided at different work sites as indicated below:-

(i)	Dam site	Near dam site on left bank
(ii)	Works of power house complex including tail race tunnel	Near power house site.
(iii)	Surge shaft and H.R.T. from downstream end	Near H.R.T. portal.
(iv)	Intermediate adits 3, 4 & 5	

Suitable dumping areas for excavated material have also been ear-marked at the above sites.

The main workshop for earthmoving equipment is proposed to be located at dam on left bank. A workshop will also be provided at the power house site and repairs of tunnelling equipment will be provided at the H.R.T. adit sites.

Aggregate manufacturing equipment including sand processing plant will be located at quarry site near village Jhangi.

19.7 Construction Power

The total requirement of construction power is estimated as about 12 MVA at different sites as below :-

Dam Site	2 MVA
Adits (1 to 5)	5 MVA
Surge Shaft Site	1 MVA
Powerhouse Site	2 MVA
Colony and Stores etc. and Workshops	2 MVA
	12 MVA

It is proposed to provide two 22 kV feeders from 60/22 kV Nathpa Sub-station o. HPSEB. Standby diesel sets of 3 MVA capacity each will also be provided at dam site and P.H. Site to provide power for essential works in case of grid failure.

19.8 Telephones

The nearest Telephone Exchange is at Reckongpeo, which is about 18 km from Karcham. This Telephone Exchange has been commissioned as satellite station having STD Code No. 017852.

It is proposed to take 2-3 lines from Reckongpeo Exchange by lying cables from this Exchange to Karcham.

It is also proposed to have an independent 100 line automatic Exchange for the Project works. This Exchange will be located at Sholtu and lines will be extended upto all camp sites and work sites. It is also proposed to have satellite station at Sholtu. This will provide telephone link to Delhi and other places. This facility will also be used to transfer computer data through E-Mail.

19.9 Wireless System

It is also proposed to provide VHF wireless link between Project sites (Sholtu and Karcham and Wangtoo) and Shimla. Wireless link between the Project and the Head Office of JIL at Delhi will also be provided, so as to have a continuous communication link.

19.10 Drawings

The details of various Infrastructure Drawings are shown in the following drawings in Volume V of the Project Report.

Sl. No.	Drawing No.	Title
1.	1200-02-01	Access road to surge shaft - Contour Plan.
2.	1200-02-02	Access road to Intermediate Adit no. 4 - Contour Plan.
3.	1200-02-03	105m span IRC Class 70R Through type Truss bridge across river Satluj on NH 22 - General Arrangement.
4.	1200-02-04	L-Section of 105m span IRC Class 70R bridge across river Satluj on NH-22
5.	1200-02-05	105m span IRC Class 70R bridge across river Satluj on NH-22 - Abutment and bed block details
6.	1200-02-06	69.2m span IRC Class 70R Through type Truss bridge across river Baspa on NH-22 - General Arrangement.
7.	1200-02-07	L-Section of 69.2m span IRC Class 70R bridge across river Baspa on NH-22
8.	1200-02-08	69.2m span IRC Class 70R bridge across river Baspa on NH-22 Abutment and bed block details
9.	1200-02-09	69.2m span IRC Class 50R Through type Truss bridge across river Satluj (for Dumping Area) - General Arrangement.
10.	1200-02-10	L-Section of 69.2m span IRC Class 50R bridge across river Satluj (for Dumping Area) at road R.D. 337.50 km of NH-22.
11.	1200-02-11	69.2m span IRC Class 50R bridge across river Satluj (for Dumping Area) - Abutment and bed block details
12.	1200-02-12	Plan showing Dumping Areas along the Head Race Tunnel.
13.	1200-02-13	Plan showing quarry site at Jhangi
14.	1200-02-14	Realignment of NH-22 and other existing roads in reservoir area (Sheet 1 of 2).
15.	1200-02-15	Realignment of NH-22 and other existing roads in reservoir area (Sheet 2 of 2).

Chapter - 20

ADDITIONAL STUDIES

20.1 Need for Additional Studies

In any Water Resources project, usually it so happens that after the preparation of a Project Report on the basis of which Techno-economic viability of the project is established and an investment decision is taken, additional studies and investigations are required for preparation of detailed designs and construction drawings. The broad nature and scope of such additional studies, surveys and investigations as may be required are outlined in this Chapter.

20.2 Topographical Surveys

The topographical survey of Dam site including reservoir area and Power house site have been carried out on 1:1000 scale. The topographical surveys at the intermediate adit sites has also been carried out on 1:1000 scale.

It will be necessary to carry out detailed surveys, as below, for the preparation of detailed designs.

1. Triangulation survey of the complete project area from Dam site to Powerhouse site.

2. River survey upto 2 km u/s and 1 km d/s from the Dam axis along with river cross sections at every 50m. This survey will be required for carrying out hydraulic model studies for the Dam and intake.

3. Topographical survey along the tunnel alignment.

4. Topographical survey on 1:500 scale at all the intermediate adit sites.

5. Topographical survey on a scale of 1:500 for the dam site.

6. Topographical survey on a scale of 1:500 of the surge shaft and P.H. area.

7. Surveys for access roads, areas for borrow pits, and disposal areas, and for layout of construction plant and machinery.

20.3 Hydrological Observations

Continuous long-term data on various hydrological parameters is necessary for not only the detailed designs but also the operation of the project. Long-term data on rainfall, river water temperature, river gauge and discharge and the sediment load at the Dam site will be required for the detailed design of various works. It is, therefore, planned that a self recording raingauge station as well as a snow measurement station is installed immediately near the Dam site. The river water temperatures shall also be recorded daily.

For up-dating the hydrology (both the water availability as well as the design flood) it is necessary that automatic gauge recorders are established immediately at the Dam and Tailrace outlet site. Gauges and discharges will be observed daily. However, during floods, gauge observations will be taken every hour. The velocity will be measured either by current meter or by float method.

It may also being considered that once during high floods and once during the lean flows, discharges are also measured by radio-active tracer technique so that accuracy of the discharge measurements by the float method on current meter are verified.

20.4 Suspended Silt Observations

The quantity and type of silt which will pass with the water into the head race tunnel will have a great bearing on the design and the life of the turbines. It has been observed that Himalayan rivers carry a considerable load of silt particularly during the period from May to September. It has also been the experience on similar projects in this region that in spite of provision of silt exclusion devices, there has been damage to turbines due to abrasion and erosion caused by the silt carried with the water. This type of damage is more in the case of projects on the rivers where the percentage of quartz content is high in the silt. Thus, not only the quantity of silt but also the mechanical and petrographic analysis of the particles are very important.

In this project it is proposed to provide well-planned and designed sedimentation chambers with flushing conduits so that comparatively silt-free water with silt particles of not more than 0.20 mm size enter the head race tunnel. The design of the sedimentation chamber will have an efficiency of about 90%. Thus, only about 10% of the suspended silt load is likely to pass through the head race tunnel into the turbines.

For proper design of turbines as well as the sedimentation chamber, a long-term reliable silt data is thus absolutely necessary. During the last few years, silt sampling has been done at the Dam site by HPSEB. To supplement this data, it will be necessary, the silt sampling is done daily, particularly during the period when the river is in flood. The silt sampling will be done using silt samplers and as per the procedure prescribed in IS-4890.

For every water sample taken for silt analysis, the time, the river gauge and the discharge should also be noted. This data will be of help to fix a safe limit beyond which the power house may have to be closed for short periods to ensure that the excessive silt does not enter the tunnel.

The mechanical analysis and petrographic examination of the silt will also be carried out when the silt content is more than 5000 ppm.

In addition to the observations of sediment flows, water samples of the river will also be analyzed to find out the quality of the water (alkaline or acidic) and also the quantum of dissolved salts in the flowing water.

20.5 Geological Investigations

20.5.1 Dam and Intake

A geological plan of the Dam site is available. However, it will be necessary to carry out the detailed geological mapping up to the upstream end of the reservoir/pondage area and also to cover both the river banks up to EL 1850.

Five holes have been drilled at the proposed Dam site. It may now be necessary to carry out further drilling at the Dam site as well as the location of the intakes and the sedimentation chambers. It is proposed to have twelve additional drill holes. The locations and the depths of these holes would approximately will be as below:

Number of Holes	Location	Total Depth m
4	Upstream and downstream of coffer dam	200
2	Axis of dam in river channel	160
2	Toe of dam in river channel	120
2	Apron area	120
2	Intake	120
	TOTAL	720 m

Permeability tests at every 1m of the depth will also be carried out while drilling these holes.

20.5.2 Sedimentation Chambers

It will be necessary to carry out tests for determining modulus of deformation and insitu stresses of the rock in the sedimentation chamber area. These tests are proposed to be carried out at three locations in the exploratory drift to be constructed along the alignment of the intake tunnel and sedimentation chamber.

20.5.3 Headrace Tunnel

Exploratory holes are proposed to be made where the tunnel alignment crosses the deeply incised streams. Three such holes of about 100m depth are proposed.

20.5.4 Surge Shaft and Power House Site

Detailed geological mapping for the location of the surge shaft and power house complex works are also to be carried out.

The drift constructed at the P.H. site will be extended in the full length of P.H. Cavity. In addition 4 cross cuts would be made to explore the entire width of P.H. Cavity area.

Further rock tests for determination of modulus of deformation and in situ stresses will be carried out in this extended drift. The data will be required for the detailed designs of the underground works of the power house complex.

For determination of the modulus of deformation, plate jacking tests will be carried out at 5 locations in both the directions (horizontal and vertical). For determination of in situ stresses, hydraulic fracturing tests or flat jack tests will be carried out at three locations in the drift.

20.5.5 Pothead Yard

Two drill holes are proposed at the expected position of the top of cut slopes rock to explore the thickness of over burden.

20.6 Construction Material Surveys

It is estimated that the total quantity of concrete for all the works of the project will be about 12,73,854 cum. For this quantity of concrete, the requirement of coarse aggregate will be 12,73,854 cum, while the requirement of fine aggregate will be about 6,36,927 cum.

The quarry for the requirement of aggregate will be established at Jhangi near the bank of river Satluj about 30km u/s of Dam site. It is expected that entire need of the coarse aggregate and boulders required for the works of the project will be met from the river bed. Fine aggregate, in the required quantity, is not available in the river in natural form within reasonable distance. Therefore sand will be prepared by crushing suitable stones.

Tests have been carried out on the river bed material at the proposed quarry sites as per requirements of IS codes.

20.7 Concrete Mix Design

The total requirement of cement for various works of the project is estimated to be about 3,51,000 tonnes. It will be necessary to identify the nearest Cement factory and to carry out standard tests to determine the quality and standard of the cement. Alternately, the use of Jaypee cement from their factory at Rewa will also be examined along with the costs involved in additional transport from Rewa to the project site.

After finalising the sources of coarse and fine aggregate as indicated above, proper mix designs will be carried out through an established concrete laboratory in respect of the following mixes which will be mainly used in the works.

i) M 15 A 150 for mass concrete
ii) M 15 A 75 for mass concrete
iii) M 20 A 40 for concrete lining
iv) M 25 A 40 for RCC work and concrete on wearing surfaces
v) M 25 A 20 for RCC work
vi) M 30 A 20 for blockouts and prestressed concrete works
vii) Silica fume concrete for spillway and other wearing surfaces.

The use of Pozzuolana for mass concrete is not considered feasible, as the quantity of mass concrete is limited and making separate arrangements for handling and dispensing pozzuolana at site will not be economical.

For the concrete in tunnel lining, intake works, and sedimentation chamber, super plasticizers are proposed to be used which will help in reducing the quantity of cement and will also produce a more workable and dense concrete. This is a desirable requirement for concrete in the water conductor system and also for using concrete pumps for placing the concrete. Investigations on identifying the most suitable super plasticizers available in India and tests thereon will therefore be carried out.

20.8 Hydraulic Model Studies

It is standard practice to carry out hydraulic model studies for the Dam, intake, the sedimentation chamber and the head race tunnel for firming up the detailed layout and designs. Such model studies will also help in deciding the best orientation of the Dam axis. The requirement and adequacy of upstream and downstream protection works will also be finalised on the basis of these model studies. The most suitable siting of intake so that it carries least amount of silt will also be firmed up by model studies.

The layout and hydraulic profile of the intake and sedimentation chambers, including the size and spacing of the hoppers in the sedimentation chambers, and layout of flushing conduits will also be finalised on the basis of model studies.

The model studies which are proposed to be conducted are given below : The scale of models on which these studies will be carried out are also given within brackets.

1) Stage Discharge Curve (1:40)

2) Siting of Diversion Dam and Intake (1:40)

3) Profile and energy dissipation arrangement for the Dam (1:40)

4) Profile of Sedimentation chambers and flushing conduits (1:20 & part model 1:10)

5) Surge shaft and orifice (Hor. = 1:20, Vert = 1:40, Time = 1:15)

Since model studies for similar works on a number of Himalayan rivers have already been carried out at the Irrigation Research Institute, Roorkee, it is proposed to carry out such studies there.

20.9 Instrumentation for Underground Works

In all modern projects, adequate instrumentation is always provided in the underground works to verify the design assumptions, to check the validity of the designs adopted and also to monitor the behaviour of the structures during operation. In line with this modern trend, the following instrumentation programme is proposed.

1) **Diversion Dam**

a) Strain meters
b) Stress meters
c) Piezometers
d) Inclinometers
e) Temperature gauges
f) Joint meter
g) Reinforcement load gauges

2) **Head Race Tunnel**

Test section will be made in the head race tunnel and the following instruments will be installed.

a) Convergence measurement by tape extensometer
b) Rock bolt load cells
c) Multiple point bore hole extensometers

3) **Surge Shaft and Pressure Shaft**

Rock bolt load cells and bore hole extensometers will be installed at one or two suitable locations. In addition, strain meters and pore pressure cells will also be installed in the pressure shafts/penstocks at four locations.

4) **Power House Cavity**

The following instruments are proposed to be installed at two locations in the roof and side walls of the machine hall cavity.

a) Multiple point bore hole extensometers;

b) Rock bolt load cells, and

c) Tape extensometer for convergency measurement.

Chapter - 21

CONSTRUCTION PLANNING AND MANAGEMENT

21.1 Construction Schedule

It is proposed to complete the project and commission all the four units in a period of 6 years from date of start of the project. The headrace tunnel which is 10.48m finished dia and 17.2 km long is the critical structure for completion of the project. The layout of HRT has therefore been kept such that intermediate adits are provided in such a way that the maximum excavation from any face is not more than about 2 km. The selection of the construction equipment has also been made to achieve the objective of completion of HRT in least possible time. The method of construction based on the proposed equipment ensures that all the works are completed in a period of 68 months allowing a period of 4 months for filling and testing the water conductor system and commissioning tests on all the units to commission the same at interval of 3 weeks.

The proposed construction schedule has been shown in Master Control Network Diagram (Annexure 21.1).

21.2 Infrastructure Works

The infrastructure works required for execution of the main civil works are as below:

1. Setting up of camp sites, workshops and stores
2. Construction of roads to surge shaft adit and intermediate adit 4
3. Setting up of aggregate plant at quarry and installation of construction equipment at various work sites
4. Arrangements for construction power

These works are required to be completed in a period of 12 month.

For taking the work on intake structure it will also be necessary to temporarily divert the NH 22 by construction of a high level road. This work is also proposed to be completed by end of 12th month.

The permanent diversion of NH 22 is proposed to be carried out by construction of bridges over river Satluj (d/s of the dam) and over river Baspa (u/s of the dam) and realignment of road in a length of 5.5 km. These works are required to be completed before commissioning of the project. However, the work on the bridge over river Satluj will be started early so that it is available to provide approach to construction facilities for the dam which will be installed on the left bank.

The bridge over river Satluj at Km 337.5 of NH22 to provide approach to dumping areas will also be completed by 18th month.

The Govt. and private land at Karcham will also have to be acquired with in six months so that this area is available for setting up of construction facilities for the diversion tunnel and dam. Some Govt. houses in this area will have to be dismantled to provide area for the construction facilities. Rest of the houses will be used for housing the staff during construction. All the houses in this area will have to be removed before commissioning of the Project.

21.3 Construction Equipment Planning

The requirement of construction equipment has been worked out on the basis that construction work will be carried out at the following sites :

1) Dam site (works of Diversion Tunnel and Coffer Dams, Diversion Dam, Intakes, Sedimentation Chambers and Flushing Conduits and HRT from inlet end).

2) Intermediate adit sites - adits 1 to 5 (work of HRT)

3) HRT adit to surge shaft (work of HRT, Surge Shaft, Valve Chamber and Pressure Shafts)

4) Surge top site - (works of Surge Shaft and Pothead Yard)

5) Powerhouse site (works of Powerhouse Complex, Pressure Shafts, d/s Surge Chamber, Outlet Tunnel and Outfall Works)

21.4 Details of Construction Equipment

The quantities of major item of works at different sites and time available for the construction are given in Annexure 21.2.

Based on the time available for construction and the quantity of work requirement of construction equipment at different sites has been worked out. The details of this equipment are given in Annexure 21.3.

21.5 Construction Methodology

The construction methodology for various works as proposed is given in paras 21.5.1 to 21.5.11 hereinafter.

21.5.1 Diversion Tunnel

The diversion tunnel is 458m long and of 10.5m finished dia. The area of excavated section upto the pay line will be 109.36 sqm.

The diversion tunnel will be excavated from upstream and downstream faces. The open excavation at either end will be done by use of compressed air driven machines for drilling. Mucking will be done by 0.9 m^3 /2 m^3 hydraulic excavators and 10/20 T dumpers will be used for transportation of muck.

The time schedule for execution of these work is given below :

1)	Open excavation	2 months
2)	Construction of portals	2 months
3)	Excavation (229m from each face)	5 months
4)	Concrete Lining (229m from each face)	3 months
5)	Inlet and outlet structures	3 months
6)	Erection of gates at inlet structure	3 months
	TOTAL	18 months

The equipment proposed to be deployed for this work is given below :

i)	3 Boom Jumbos	2
ii)	3.5 m^3 Loaders	2
iii)	20T dumpers	6
iv)	Concrete pumps	2

v) Transit mixers 3

vi) Shotcrete machines 2

vii) Tyre mounted backhoe 2

viii) Compressors 2

ix) Rock drills 8

x) Batching and mixing plant (for dam works) 1

21.5.2 Coffer Dams

The work on coffer dams will be taken up in lean season after diverting the wate. into diversion tunnel. It is proposed to provide a positive concrete cut off by using a trench cutter suitable for use in boulder strata. A period of 9 months has been provided for construction of concrete cut off and the coffer dams.

21.5.3 Diversion Dam

The excavation for the dam upto the bed rock is proposed to be carried out in a period of 4 months after the monsoons and most of the concrete upto the river bed level will be carried out in a period of 4-5 months thereafter.

Two seasons have been provided for concreting of the dam upto the top level and a period of 12 months has been provided for erection of gates and hoists

21.5.4 Intake Structure and Intake Tunnels

The work on open excavation for intake structures will be taken up after diverting NH 22 at higher elevation. A period of 6 months have been provided for open excavation and establishing portals for all the intake tunnels. The excavation of 4 no. intake tunnels (varying in length from 120m to 237m) will be carried in a period of six months.

The concreting of intake structures will be taken up after completion of excavation of sedimentation chambers from the intake end. A period of 15 months has been provided for construction of intake structure while a further period of 12 months will be required for erection of gates and hoists etc.

21.5.5 Sedimentation Chambers

The size of each of the four sedimentation chambers is 16m (W) x 28m (H) x 505m (L). The excavation of roof arch of these chambers will be carried out through intake tunnels and also through the gate operating gallery at the end of the chambers. An intermediate adit has also been provided to open extra faces for excavation of these chambers. The excavation of these adits will be completed simultaneously with the construction of intake tunnels.

A period of 15 months has been provided for excavation of roof arch of all the chambers. The benching down of the chambers will be carried out after completion of roof arch and period of 15 months has been provided for this work. The mucking for this excavation will be carried out through the intermediate adit.

Concreting of the hoppers and walls of the chambers will be carried out in a period of 12 months while another four months will be required for erection of the gates at the end of the chambers.

21.5.6 Flushing Conduits

The length of the four flushing conduits varies from 300m to 405m and excavated dia is 4.5m. The excavation of these tunnels will be carried out from the outlet end. The time provided for various activities is as below :

Excavation	12 months
Erection of steel liners and concreting	18 months
Outlet structures	6 months
Erection of gates and hoists	3 months

21.5.7 Headrace Tunnel

21.5.7.1 Construction of Adits

As the construction of HRT is critical, five intermediate adits in addition to the adits at the inlet end and surge shaft end have been provided.

The details of these adits are as below :

Adit	Length (m)	Chainage from intake end (m)	Length of HRT to be excavated from each face (m)
Inlet Adit	225	900	d/s 1102
Intermediate adit 1	470	3104	u/s 1102 d/s 994
Intermediate adit 2	450	5092	u/s 994 d/s 1146
Intermediate adit 3	250	7385	u/s 1146 d/s 2237
Intermediate adit 4	100	11860	u/s 2237 d/s 1225
Intermediate adit 5	600	14310	u/s 1225 d/s 1720
Surge shaft adit	140	17750	u/s 1720

The maximum length of HRT to be excavated from any face will be 2237m.

All the adits will be 7.5m dia D-shaped. The time provided for excavation of these adits is as below :

Adit	Length (m)	Portal (months)	Excavation (months)	Total period	Progress of excavation per month (m)
Inlet Adit	225	3	4	7	56
Intermediate adit 1	470	3	8	11	59
Intermediate adit 2	450	3	8	11	56
Intermediate adit 3	250	3	4	7	62
Intermediate adit 4	100	3	2	5	50
Intermediate adit 5	600	3	10	13	60
Surge shaft adit	140	3	6	6	50

Basic equipment for excavation of adits will be Boomers for drilling and CAT 966 E loaders with side dumping bucket for mucking.

21.5.7.2 Excavation of HRT

The cycle time calculations for construction of HRT will be as below :

Data

1.	Excavated area upto minimum excavation line	103.5/107.2 sqm
2.	Blast hole dia	45 mm
3.	Empty hole dia	102 mm
4.	Advance per round	3 m
5.	Drill rig designation	Rocket boomer 353E - 1938
6.	Hydraulic boom	BUT-35
7.	Rock drill	COP-1838
8.	Rig mounting	Three
9.	Predicted penetration	3m/min
10.	Scheduled work time	12 hrs
11.	Shifts per day	2
12.	Drill steel type	R 38
13.	Working face per rig	one
14.	Estimated loose muck per round	560 cum
15.	No. of holes	170
16.	Drilling (metres)	170x3.5 = 595m
17.	Specific drilling	1.8 m/m^3
18.	Powder factor	1.2 kg/m^3
19.	Practical drill rate / boom / minute	1.8m
20.	Drilling time	110 minute
21.	Charging time (Charges to be made in pipes and loaded by use of basket boom and scaffold on loader bucket)	60 minute

Based on the above data the cycle time for rockbolt supported and rib supported reaches will be as below :-

Cycle time (rock bolt supported reaches)

		Time
1.	Survey	0.30
2.	Setting of machine	1.00
3.	Drilling	2.00
4.	Charging	1.30
5.	Defuming	0.30
6.	Scaling	0.30
7.	Mucking	6.00
8.	Initial shotcreting	1.00
9.	Rock bolts (12 nos.) in arch portion	2.00
	TOTAL	15.00 hours

Cycle time (steel rib supported reaches)

		Time
1.	Survey	0.30
2.	Setting of machine	0.30
3.	Drilling	2.00
4.	Charging	1.30
5.	Defuming	0.30
6.	Scaling	0.30
7.	Mucking	6.00
8.	Cleaning	0.30
9.	Shotcreting	1.00
10.	Erection of ribs	5.00
11.	Blocking concrete	6.00
	TOTAL	24.00 hours

The calculations for mucking time are as below :

1.	Loose muck for 3m pull	560 cum
2.	Capacity of loader (CAT 966E with side dump bucket)	2.8 cum loose muck

3.	No. of sweeps per hour (Normally 80, assumed 50 on the safer side)	50
4.	Quantity loaded per hour	140 m^3
5.	Time for mucking	4 hour

Assuming 2 hours for cleaning the bottom using JCB/Escorts backhoe, the total time for mucking will be 6 hours.

The requirement of 20T dumpers for mucking has been worked out as below :-

1.	Quantity per trip		$10m^3$
2.	No. of trips/hour		14 (140/10)
3.	No. of trips per vehicle taking average lead of 2km		
	Spotting and loading	3.50 minute	
	Travel 2x2/15	16.00 minute	
	Unloading	0.50 minute	
	Total	**20.00 minute**	
4.	Quantity carried/vehicle/hour	= 10x3	= 30 cum
5.	No. of vehicles required	= 140/30	= 4.7 vehicles say 5 vehicles

As worked out above the cycle time will be 15 hours for shotcrete supported reaches and 24 hours for rib supported reaches. Assuming one sixth length as rib supported the average cycle time will be 17 hours or say 18 hours.

For calculating the time required for excavation cycle time of 24 hours has been assumed, which gives a float of 33 percent.

Thus maximum progress per month will be 25x3 = 75 metres. However a sustained progress of 60 metres per month has been taken allowing for unforeseen reasons and bad ground conditions.

The equipment proposed for each face of HRT will be as below :

1.	Three boom Jumbo with basket boom	1
2.	3.5 m^3 loader	1

3.	20T dumpers	5
4.	Wet shotcrete machine	1
5.	Rock bolter	1
6.	JCB/Escort backhoe	1
7.	Compressed air	at each adit
8.	Dewatering arrangement	at each adit
9.	Water supply arrangement	at each adit
10.	Concrete/shotcrete supply Batching and Mixing plant (40 m^3/hr capacity)	at each adit
11.	Transit mixers	3
12.	Rubber tyred crane	at each adit
13.	Dozer (D-65) for muck disposal	at each disposal site

21.5.7.3 **Concrete Lining of HRT**

It is proposed to use collapsible shutter with traveller and concrete pump with concrete distribution system for continuous lining of tunnel. With this equipment a progress of 30-40 metres per day can be achieved.

The time period as below for concrete lining has been provided :

1.	Maximum length (between faces 4 and 5)	4475m
2.	Time required based on progress of 600m per month	8 months
3.	Extra time for remaining length of invert	1 month

In addition a period of 3 months has been provided for grouting and 3 months for construction of concrete plug and installation of access door etc.

21.5.8 **Surge Shaft**

It is proposed to construct road upto the top of surge shaft. The open excavation for the platform at the top will be carried out by use of hydraulic excavator, dozer and adequate number of dumpers.

The pilot shaft of surge shaft (187m in height) will be excavated by using raise climber equipment after the adit to surge shaft is completed and access to bottom to surge shaft is available.

After completion of pilot shaft the widening will be done from top to bottom in a period of 15 months. The widening will be done by use of a platform lowered from top for purposes of scaling, drilling and blasting.

The concrete lining will be carried out in a period of 12 months. It is proposed to place a lift of 1.5m in 4/5 days.

A time of 3 months has been allowed for construction of orifice slab, and 9 months for erection of gates and embedded parts.

21.5.9 Valve Chamber

An independent adit (64m long) and taking off from road to surge shaft has been provided for access to valve chamber. This work can therefore be carried out independently of the work of surge shaft.

21.5.10 Pressure Shafts

The excavation of the top horizontal portion of pressure shafts will be carried out through the adit to the valve chamber.

The excavation of vertical portion of the pressure shafts (each about 175m in height) will be carried out from the bottom using raise climber equipment. A construction adit branching off from the adit to powerhouse erection bay has been provided for approach to the bottom of pressure shafts. Two raise climbers have been provided and it will therefore be possible to take up excavation of two pressure shafts at a time. Widening of pressure shafts to the required size will be carried out from top downwards. The excavation of top horizontal length and top level will be carried out through valve chamber adit.

The erection of penstock liners (ferrules) in the top horizontal portion will be carried out through the valve chamber adit while the erection of ferrules in the bottom horizontal portion will be carried out through the construction adit at the bottom.

21.5.11 **Power House Complex**

21.5.11.1 **Approach Adits**

The approach adits as below have been provided :

Sl No		Size	Length (m)
1.	Adit to erection bay	8.5m D-shaped	305
2.	Adit to control room	6.5m D-shaped	156
3.	Adit to transformer hall roof (GIS Chamber)	6.5m D-shaped	112
4.	Adit to draft tube gate operating gallery	8m D-shaped	80
5.	Adit to pressure shaft bottom	7.5m D-shaped	387
6.	Adit to D/S surge chamber	6.5m D-shaped	176
7.	Cable tunnel	5m D-shaped / 5m circular	511

The adits to erection bay, adit to control room and adit to D.T. gate operating gallery take off from NH-22. The construction adit to pressure shafts takes off from the adit to erection bay while the construction adit to d/s surge chamber takes off from the adit to pressure shafts.

These adits will provide independent simultaneous working on P.H. cavity, transformer hall cavity, pressure shafts and d/s surge chamber.

21.5.11.2 **P.H. Cavity**

The construction of P.H. cavity is the most critical item in the power house complex. The work on the approach adit to erection bay and adit to control room will, therefore, be started simultaneously. The approach adit to control room will be used for excavation of roof arch of P.H. cavity. Similarly the adit to transformer hall roof (G.I.S. chamber) will be used for excavation of roof arch of transformer hall.

The time schedule for construction of P.H. cavity will be as below:

Excavation of adit to control room	4 months
Excavation of adit to erection bay	8 months
Excavation of central adit along roof arch (143m long)	3 months

Excavation of roof arch (143m long)	10 months
Benching down of cavity	12 months

The excavation sequence for P.H. cavity is given in Fig. 21.1.

21.5.11.3 Transformer Hall Cavity

The excavation of roof arch (143 m long) will be carried out through the adit at top of transformer hall. The benching down will be carried out thereafter and mucking will be done through the adit to erection bay.

21.5.11.4 Downstream Surge Chamber

The excavation of roof arch will be carried out through the adit taking off from the adit to pressure shafts.

The benching down of this cavity as also excavation of draft tubes will be carried out through tail race tunnel.

21.5.11.5 Diversion Tunnel Gate Operating Gallery

The excavation of gate operating gallery and gate shafts will be carried out through the approach adit to gate operating gallery.

21.5.11.6 Cable Tunnel

This work will be carried out after construction of transformer hall cavern upto El 1532m. The excavation of the vertical portion of the cable tunnel will be carried out by using raise climber equipment.

21.5.11.7 Tail Race Tunnel and Outfall Structure

The excavation of tail race tunnel will be carried out from the river end. A coffer dam will be constructed to isolate the portal from the river. A steel bulkhead will also be provided at the portal which will be closed during monsoon period so as to safeguard the works during floods. This bulkhead will be in operation till the gates at the outlet structure are installed.

The outlet structure will be constructed during non-monsoon period after all the excavation to be carried out from tail race tunnel is completed.

21.6 Construction Organisation

To achieve the objective of commissioning the project in a period of 6 years and also to ensure quality of all the works to the recognised Indian and international standards an efficient and result oriented construction organisation will be set up.

The proposed organisation structure will have a built-in mechanism for constant progress review, and monitoring the works by using management information systems.

The computer software for PERT and CPM will be extensively used for overall planning of the project as well as for day to day planning of individual components of the project.

The construction organisation will be headed by a resident Director with four General Managers in-charge of (a) Construction of civil works (b) Construction of electrical works (c) Planning and quality control including procurement and (d) Administration including infra-structure facilities.

Different categories of technical and non-technical staff in suitable strength will be positioned for various activities depending upon the actual requirement.

The design and engineering aspects of the project will be carried out at the head office. Assistance of Indian and international consulting organisations of repute and who have wide experience in design and construction of similar projects will be taken as required.

A core group of engineers having long experience of investigation, design, construction and O&M of hydroelectric projects particularly in Himalayan rivers will be established at the head office. The broad functions of this core group will be as below:

1) Provide technical support in investigation, analysis of data, and supply of relevant data to the consulting organisations.

2) Technical interaction with the concerned Central and State Govt. agencies like Central Water Commission, Central Electricity Authority, Geological

Survey of India, India Meteorological Department, State Electricity Board etc.

3) Preparation of overall conceptual and General Arrangement drawings for the different components of the project to arrive at the most economical and safe designs.

4) Liaison with retained consulting organisations and broad checking of their design and construction drawings.

5) Liaison with construction organisation

6) Modify/revise construction drawings to meet the field conditions

7) Carry out plant design and other field designs and to provide full technical support to the construction organisation

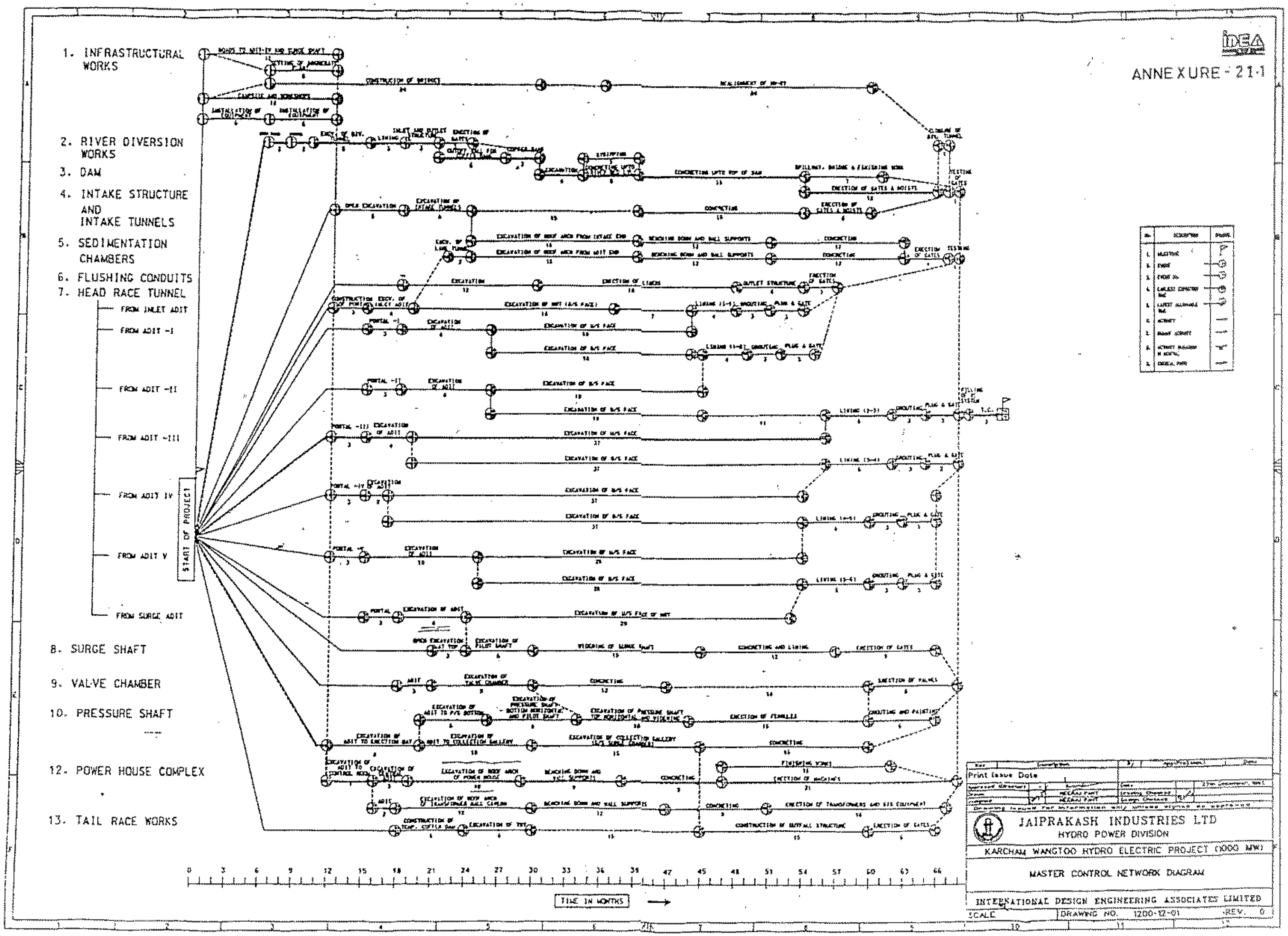
8) Prepare schemes for quality control and inspection and to oversee that the same are executed satisfactorily

9) Prepare testing and commissioning schedules and O & M manuals in collaboration with the manufacturers of mechanical and electrical equipment

Besides the core group, a Panel of Experts (POE) with eminent Indian and foreign engineers as members will be constituted. The POE will meet at regular intervals for obtaining the recommendations on general layout of works, design considerations for major works, and specific design and construction problems.

A chart showing the organisation setup for the field organisation is given as Annexure 21.4.

ANNEXURE - 21.1



Annexure 21.2

QUANTITIES OF MAJOR ITEMS OF WORKS AND TIME AVAILABLE FOR COMPLETION

Sl No	Item of Work	River Diversion Works		Diversion Dam		Intake Sedimentation Chamber and Flushing Conduits		Headrace Tunnel		Surge Shaft and Pressure Shafts		Powerhouse Complex		Tailrace Works		Pothead Yard		Total Qty
		Qty	Time In Months	Qty	Time In Months	Qty	Time In Months	Qty	Time In Months	Qty	Time In Months	Qty	Time In Months	Qty	Time In Months	Qty	Time In Months	
1.	Excavation in overburden (cum)	103500	2	144000	4	500	6	2500	3	2100	3	7000	6	1200	2	1000	6	261800
2.	Excavation in rock (cum)	3600	2	36000	5	30000	6	14500	3	-	3	14000	6	3500	2	8500	6	110100
3.	Concrete cut off (sqm)	10200	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10200
4.	Rock fill (including clay core filter) cum	75340	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	75340
5.	Underground excavation (cum)	51000	5	875	15	1200000	33	2018324	37	147000	21	297280	31	57500	18	-	-	3771979
6.	Rock bolts (m)	5505	5	45000	15	110000	33	365270	37	104400	21	120350	31	21890	18	-	-	772415
7.	Shotcreting (cum)	970	5	6000	15	1900	33	57299	37	2690	21	10400	31	1450	18	-	-	80709
8.	Concreting (cum)	21855	3+3	594000	20	168000	12	415057	6+3	26650	16	40557	18	6200	15	1635	12	1273954
9.	Reinforcement (tonne)	500	3	4505	15	6660	12	1000	6+3	4505	12	2440	18	560	15	150	12	20320
10.	Drilling (m)	6850	3	18600	15	67000	12	216720	9	16000	16	1575	6	3400	6	-	-	330145
11.	Grouting (tonne)	605	3	1900	15	6700	12	21672	9	1255	16	160	6	340	6	-	-	32632
12.	Stone masonry (cum)	6200	3	-	-	6500	6	3500	3	2700	12	-	-	210	6	510	12	19620
13.	Steel liners (tonne)	475	3	930	15	2000	18	-	-	3859	16	-	-	-	-	-	-	7264
14.	Steel ribs (tonne)	150	2	-	-	1340	2	4907	4	700	3	216	10	150	2	-	-	7463
15.	Weld mesh (kg)	2950	2	110000	4	30360	6	14510	4	43250	3	10120	10	1300	2	-	-	212490
16.	Dewatering (kWh)	64500	6	1000000	9	300000	6	1891000	37	-	-	418000	19	150000	6	-	-	3823500
17.	Concrete cut-off	10200	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10200

Annexure 21.3

DEPLOYMENT OF CONSTRUCTION EQUIPMENT AT DIFFERENT SITES

Sl.No.	Description of Equipment	Dam, Intake, Sedimentation Chambers and Flushing Conduits	Head Race Tunnel / Inlet Adit Intermediate Adits 1 to 5 & Surge Shaft Adit	Surge Shaft, Valve Chamber and Pressure Shafts	Underground Power House Complex including Outlet Works	Supporting Equipment	Total
1.	Compressors Diesel - 600 cfm	2	7	2	2	-	13
2.	Compressors Electrical - 838 cfm	8	14	5	4	-	31
3.	Rock Drills	40	70	20	20	-	150
4.	Feeder Legs	40	70	20	20	-	150
5.	Truck Jumbos / Hydraulic Platforms	4	7	2	4	-	17
6.	Blasting Equipment	4	7	2	3	-	16
7.	Drilling Accessories (Lot)	4	7	2	2	-	15
8.	Three Boom Hydraulic Jumbo with Basket boom	-	12	-	-	-	12
9.	Two Boom Hydraulic Jumbo with basket boom	4	-	1	3	-	8
10.	Rockbolters	4	12	-	3	-	19
11.	Air Track	2	-	-	-	-	2
12.	Wheel Loader 3.5 m^3	4	12	-	3	-	19
13.	20 T Dumpers	30	60	8	15	-	113
14.	Scoop Trams 2m^3	-	-	-	2	-	2
15.	Transit Mixers - 6 cum	16	24	6	6	-	52
16.	Concrete Pumps with Booms	4	-	-	3	-	7
17.	Concrete Pumps without Booms	-	6	-	-	-	6
18.	Concrete distribution system hydraulically operated	-	6	-	-	-	6
19.	Shutters (10x6 m) for continuous lining along with traveller	-	6	-	-	-	6

Sl.No.	Description of Equipment	Dam, Intake, Sedimentation Chambers and Flushing Conduits	Head Race Tunnel / Inlet Adit Intermediate Adits 1 to 5 & Surge Shaft Adit	Surge Shaft, Valve Chamber and Pressure Shafts	Underground Power House Complex including Outlet Works	Supporting Equipment	Total
20.	Wet shotcrete machine with Boom	4	12	2	3	-	21
21.	Wagon Drills (IRCM 341)	4	-	-	-	-	4
22.	Hydraulic Excavator 2.0m^3	2	-	-	-	-	2
23.	Hydraulic Excavator 0.9m^3	2	-	-	3	-	5
24.	Tyre Loaders (1.5 cum)	4	-	-	-	3	7
25.	10T Tippers	20	14	8	-	15	57
26.	Aggregate Processing Plant 500 T/hr	-	-	-	-	1	1
27.	Batch and Mixing Plants 60 m^3	-	-	-	1	-	1
28.	Batch and Mixing Plants 40 m^3	-	5	-	-	-	5
29.	Concrete Placers	-	12	2	2	-	16
30.	Concrete Buckets 3 cum (truck mounted)	10	-	3	-	-	13
31.	Tower Crane 10 T @ 40m radius	2	-	-	-	-	2
32.	Tower Crane 10 T @ 30m radius	2	-	-	-	1	3
33.	Rubber Tyred Crane 15T	4	-	-	-	-	4
34.	Rubber Tyred Crane 100T	-	-	-	-	1	1
35.	Rubber Tyred Crane 8/10T	-	5	-	-	-	5
36.	Dozers D-80	3		-	-	-	3
37.	Trucks 10 T	20	21	3	-	-	44
38.	Trailer 70 T	-	-	-	-	1	1
39.	Transformers (Total 10 MVA)	-	-	-	-	-	0
40.	Diesel Generator Sets 1000 kVA	-	-	-	-	6	6
41.	Dozers D-65	3	7	2	-	-	12

Sl.No.	Description of Equipment	Dam, Intake, Sedimentation Chambers and Flushing Conduits	Head Race Tunnel / Inlet Adit Intermediate Adits 1 to 5 & Surge Shaft Adit	Surge Shaft, Valve Chamber and Pressure Shafts	Underground Power House Complex including Outlet Works	Supporting Equipment	Total
42.	Vent. Fans (Large)	8	27	2	8	-	45
43.	Vent. Fans (Small)	2	-	3	-	-	5
44.	Vent. Duct (1.5m dia.) in metres	3000	22000	1500	4500	-	31,000
45.	Dewatering pumps						0
	(a) 2 cusec 20m Head	20	21	2	-	-	43
	(b) 1 cusec 20 m Head	-	-	2	-	-	2
	(c) 2 cusec 40m Head	16	21	2	-	-	39
	(d) 2 cusec 70m Head	4	21	2	-	-	27
	(e) 7 cusec 20m Head	10	-	-	-	-	10
46.	Portal Crane 20T	-	-	2	-	-	2
47.	Crab winches 10T	6	7	8	-	-	21
48.	Electrical Winches 20T	-	-	4	-	-	4
49.	Light Vehicles	-	-	-	-	60	60
50.	Buses	-	-	-	-	20	20
51.	Trailers 20T	-	-	-	-	4	4
52.	Survey Instruments (Lot)	1	7	1	1	-	10
53.	JCB Loader/Backhoe	2	-	-	-	-	2
54.	Workshop equipment (Lot)	1	7	1	1	1	11
55.	Garage equipment (Lot)	-	-	1	1	1	3
56.	Fabrication Shop equipment (Lot)	1	-	-	-	-	1
57.	Vibrators for Concrete						0
	1) 150 mm	16	-	-	-	-	16
	2) Flexible Shaft	20	-	-	-	-	20
	3) External (electric)	20	60	20	20	-	120
58.	Electrical winches 10T	-	-	-	-	2	2

Sl.No.	Description of Equipment	Dam, Intake, Sedimentation Chambers and Flushing Conduits	Head Race Tunnel / Inlet Adit Intermediate Adits 1 to 5 & Surge Shaft Adit	Surge Shaft, Valve Chamber and Pressure Shafts	Underground Power House Complex including Outlet Works	Supporting Equipment	Total
59.	Hydraulic excavator 3.0 m^3	2	-	-	-	-	2
60.	Portal Crane 20T	-	-	2	-	-	2
61.	Tyre mounted Backhoe	2	5	2	2	-	11
62.	Batching and mixing plant 120 m^3/hr	1	-	-	-	-	1
63.	Raise Climber	-	-	2	-	-	2
64.	Dry Shotcrete Machines	4	14	2	2	-	22
65.	Core Drilling Machine	2	3	-	-	1	6
66.	Road Rollers	-	-	-	-	2	2
67.	Motor Grader	-	-	-	-	2	2
68.	Grouting Equipment	6	12	4	3	-	25
69.	Crawler Crane 100T	1	-	-	-	-	1
70.	Trailer 100T	-	-	-	-	1	1
71.	Unlisted Equipment (Lot)	-	-	-	-	1	1
72.	Communication System	-	-	-	-	1	1
73.	Computer System (Hardware and Software)	-	-	-	-	1	1

Annexure 21.4

KARCHAM WANGTOO HYDROELECTRIC PROJECT
(FIELD ORGANISATION)

RESIDENT DIRECTOR

GENERAL MANAGER (Civil Works)	**GENERAL MANAGER (Electrical Works)**	**GENERAL MANAGER (Planning & Quality Control)**	**GENERAL MANAGER (Admn. & Infrastructural Facility)**
1. Project Manager (Barrage)	1. Project Manager (Construction Power)	1. Project Manager (Construction Planning)	1. Project Manager (Personnel)
2. Project Manager (Intake & Sedimentation Chamber)	2. Project Manager (Mechanical)	2. Project Manager (Plant Design)	2. Project Manager (Finance)
3. Project Manager (H.R.T.)	3. Project Manager (Electrical)	3. Project Manager (Field Laboratories)	3. Project Manager (Camps)
4. Project Manager (Surge & Penstocks)	4. Project Manager (Ancillaries)	4. Project Manager (Quality Control)	4. Project Manager (Communication)
5. Project Manager (Power House)	5. Project Manager (Transmission)		5. Project Manager (Stores & Workshops)
6. Project Manager (Hydraulic Gates, etc.)			6. Project Manager (Plant Stores)
			7. Chief Medical Officer

CHAPTER - 22

ENVIRONMENTAL EVALUATION

22.1 General

As brought out in earlier chapters, the proposed Karcham-Wangtoo Hydroelectric Project is essentially a run-of-the-river project without a storage dam. It will have a diversion dam to divert waters into the power conductor system and also to provide diurnal storage for peaking purposes. All the main components of the project like intake tunnels, sedimentation chambers, headrace tunnel, surge shaft, pressure shafts, powerhouse and downstream works are underground. The only components which are on surface are the diversion dam, intake structure and outfall structure. As a result of these basic features there will be nominal disturbance to the existing environment and ecology either during construction or during the operation of the project.

22.2 Environmental Impact Studies

Environmental impact studies for the project have been carried out by a team comprised of Indian and Canadian biophysical and socio-cultural specialists. The detailed report of these studies is contained in Appendix 3, in Volume IV of the project report.

These studies have been carried out keeping in view the five principle objectives as below:

i) Collect existing environmental data for the project area.

ii) Carry out site reconnaissance

iii) Identify the potential environmental effects of the proposed project.

iv) Assess the significance of the resultant impacts

v) Recommend the appropriate measures to minimise the environmental impact of the project and provide enhancement where possible.

22.3 Identification and Assessment of Impact

The Asian Development Bank (ADB) Impact Assessment matrix for Dams and Reservoirs/Hydropower Projects was employed to assist in identifying potential environmental effects. These potential effects were assessed as to their probability, magnitude, importance, duration, and reversibility in order to evaluate the likely significance of resulting impacts.

Biophysical Impacts

With appropriate mitigation and management, the direct and cumulative biophysical impacts of the reservoir and power generation components of Karcham-Wangtoo Project are acceptable. Many of the biophysical impact of development in Satluj Valley have already been felt.

Socio-economic Impacts

The most significant potential social impact would be resettlement of about 150 people presently in the reservoir area. Considering that most of these people are Government employees living in Government residences and by carrying out an acceptable resettlement programme this should not pose any problem. The basic principle of resettlement programme will be that the displaced people must be as well or better off after the project than before.

22.4 Requirement of Land

The requirement of land for permanent works including land coming in the reservoir submergence is as below :

Forest Land Govt. Land	95.22	Ha
Private Land	3.79	Ha
TOTAL	99.01	Ha

In addition the land as below will be required for the construction period :

Forest Land Govt. Land	64.41	Ha

This land will be returned after the completion of the project in better condition as it will be made levelled by filling the muck or otherwise.

The forest land involved in this project does not have extensive forest or trees.

22.5 Proposed Safeguards

The following safeguards will be implemented for maintaining the environmental and ecological balance in the Project area. Additional safeguards, if any, advised by the Department of Environment will also be implemented.

Adequate fuel for domestic use will be made available through Depots for persons working on Project implementation and they would not be allowed to cut trees for this purpose.

The State Government will be requested to prohibit grazing on the periphery of the reservoir to prevent soil erosion and deforestation.

The State Government will be requested to enforce anti-poaching laws on the periphery of the reservoir to encourage and attract wild life.

Wherever open slope cutting is required, the same shall be stabilised by proper benching, drainage and afforestation.

The excavated material from the underground works will be properly dumped into specified dumping areas so as not to increase the silt load in the existing nalas and rivers.

Adequate action for afforestation, plantation, soil conservation, etc. in the Project areas will be undertaken and suitable provisions have been made in the project estimates.

22.6 Basic Information

The environmental and ecological information on the performa prescribed by Ministry of Environment and Forests, Government of India is given in Annexure 22.1.

ENVIRONMENT AND ECOLOGICAL INFORMATION

1.0 BASIC INFORMATION

1.1 Existing land-use in the catchment upto the source of river or 100 km upstream of the structure whichever is less. Total land is 39089 Ha (Kalpa).

a) Agriculture land	1355 Ha
b) Grazing land	7110 Ha
c) Forests:	
i) Reserved	3866 Ha
ii) Un-reserved	-
d) Barren land etc.	25477 Ha
e) Other	1281 Ha

1.2 Submerged area

a) Cultivated land	0.57 Ha
b) Forest and Barren land	57.08 Ha (barren land)
c) Shrubs and fallow	-
d) Wet lands	-
e) Area under ponds and tanks, etc.	-
f) Other uses	-
g) Total	57.65 Ha

1.3

i) Forest types in the catchment and submerged area (type of trees, sparse or thickly Wooded and other details).	Himalayan Sub-tropical pine. No forest under submergence.
ii) Extent and nature of forest in the area proposed to be cleared for construction of roads, colonies and other use of the project.	Only to a small extent shrubs and other trees are required to be cleared.

1.4 Proposed period of construction — 6 years

1.5 Labour

a) Estimated strength (Peak)

i) Total	6000

	ii) Skilled and semi-skilled (separate)	300 - Skilled 1200 - Semi-skilled
	iii) Unskilled	4500
	b) Availability of labour from the affected area	Labour from surrounding areas will be employed
	i) Total	200
	ii) Skilled	Nil
	iii) Unskilled	200

1.6 Population density (per sq.km.)

a)	Catchment	8 persons/sq.km.
b)	Submerged area	Nil
c)	Command	Nil

1.7 Villages affected and population displaced.

a) Number of villages — Nil

b) Population

i)	Scheduled Caste	Nil
ii)	Schedule Tribe	Nil
iii)	Others	Nil

c) Occupation of the affected people

i) Agriculturists
ii) Agricultural labour
iii) Industrial labour
iv) Forest labour
v) Artisans
vi) Any other

Does not arise

d) Land ownership

i) Marginal farmers (0-1.0 Hect.)
ii) Small farmers (1.0-2.5 Hect.)
iii) Medium farmers (2.5-5.0 Hect.)
iv) Big farmers (over 5.0 Hect.)

Does not arise

1.8 Resettlement	
a) Details of rehabilitation committee, if any.	The settlement of the displaced Govt. employees and other people in the submergence area of the dam will be carried out in consultation with the concerned agencies of the State Government.
b) Existing guidelines for resettlement and compensation in cash and/or kind, if any,	
c) Compensation proposed to be paid.	
d) Resettlement plans for oustees (number of persons and families):	
i) In existing villages ii) At new village sites iii) Plan of the new village iv) Facilities being provided (School, Post Office, Bank, Panchayat Ghar, Police Station, Roads Drainage, Water supply, Vocational training etc.)	Does not arise in view of (a) above.
e) Proposals to provide vocational training and employment to oustees	Does not arise
1.9 Details of development activity in the affected area.	
a) Drought-prone Area programme.	-
b) Small Farmer Development Agency.	-
c) Rural Development	-
d) Tribal Development	Tribal area development programme is being implemented in this Project area by H.P. Government.
e) Other programmes	-

1.10 Sedimentation of the reservoir	
a) Expected rate of siltation	Diversion structure being a diversion dam, no siltation is expected. However, a provision of 313 ha m has been kept in the pondage for deposition of sediment.
b) Proposed/existing soil conservation programme/measures in the catchment	No specific soil conservation programme is necessary. However, afforestation in the catchment area will be undertaken by H.P. Government as part of their general programme.
c) Problems of slips and slides on the periphery of the reservoir and proposed remedial measures	Problem of slips and slides is not anticipated. Afforestation, however, will be done on the periphery to check the sliding of hill slopes, if any.
1.11 Present flood situation in the command area	Not applicable
1.12 Wind rise diagram, wind speed (maximum average) direction (Seasonal) etc. at the head works site.	Not applicable
1.13 Frequency of occurrence of tornadoes, cyclones, hurricanes (maximum and minimum wind velocity)	Not applicable
1.14 Ground water (command)	
a) Depth and Seasonal variations (pre and post monsoons)	Not applicable
b) Quality-potable fit for irrigation/industry	
c) Present use	
i) Area under irrigation	
ii) Extent of industrial use	
d) Interaction between the altered surface water patterns and underground water recharge) etc. (based on the experience of similar projects)	

2.0 ENVIRONMENTAL STATUS

2.1	Known sources of pollution in the region a) Industrial units b) Thermal power house c) Mining operations etc.	Nil
2.2	Industrial development in project area	
	a) Present status	Nil
	b) Future plans (10 years)	-
2.3	Broad details of the aquatic life (fish, crocodiles etc.) supported by the area. If economically viable, indicate the breeding grounds in the river/tributary(s)/area(s) coming under submergence.	The river Satluj do not harbour much fisheries in the effected reach. No organised fishing is done in the area.
2.4	Wild animals and birds	
	a) Existence in the area	Monal, Chokas, Gordel, Snow leopard, black bear, etc. in the catchment area.
	b) Rare/dying species (number if any)	Nil
	c) Breeding/feeding area(s)	On periphery of river
	d) Migration routes	Nil
	e) Is the area a potential wild life sanctuary?	No
2.5	Flora, fauna in the submerged area	
	a) Broad details of the rare/dying species	Nil
	b) Number of affected valuable wild life	Nil
	c) Measure proposed to salvage/rehabilitate	Does not arise
2.6	Tourism	
	a) Is the area a tourist resort?	No, although a panoramic valley.
	b) Broad details of religious, archaeological and recreational centre, wild life sanctuaries, national parks likely to be affected by the project etc.	Nil

2.7	Broad details of epidemic health due to soil and water borne diseases	Round worm infestation, Hook worm infestation and Gastroenteritis Bacillary dysentery are already prevailing.
3.0	**ENVIRONMENTAL IMPACTS**	
3.1	Proposals to develop the site to attract tourism (recreation, water sport, picnic sites, etc.)	No proposal at present.
3.2	Effect of the storage in flood mitigation	Except for diurnal storage for peaking there is no storage envisaged in the Project.
3.3	Changes in salinity of underground water expected and remedies, if required.	Not applicable.
3.4	Expected water-logging problems and remedies.	Not applicable, as no irrigation is proposed.
3.5	Aquatic life	
	a) Existence of migratory fish life and proposals for fish ladder, if any.	Fish only in small quantity available in the river.
	b) Proposals for fisheries development and crocodile farming, if any.	Pisciculture will be undertaken in the reservoir.
	c) Loss in aquatic production up or downstream, if any.	Nil
3.6	Broad details of mines, minerals, commercial timber and other natural resources coming under submergence with estimated loss.	Nil
3.7	Broad details of injurious mineral coming under submergence.	Nil
3.8	Effect of water body in enhancement of water borne diseases.	Nil

3.9	Broad details of likely growth of weeds (salvinia, water hyacinth etc.) intermittent host (vectors like snails, mosquitoes) and proposed remedial measures.	Nil
3.10	Effect of project on climatological changes (temperature, humidity, wind and precipitation including modification to micro and macro climate).	Nil
3.11	Measures to prevent animal over grazing and cultivation of foreshore of reservoir to prevent premature silting.	Cultivation and grazing will be prohibited around the reservoir periphery by H.P. Government.
3.12	Likely impact of reservoir loading of seismicity	Nil. However, dam and other structures have been designed to withstand seismic forces by natural earthquakes.
3.13	Likely impact of population pressure on (during construction)	
	a) Felling the trees for fire wood	Strict enforcement of laws for preventing tree felling in Project area will be implemented.
	b) Forest fires	Not anticipated.
	c) Overgrazing leading to depletion of pasture land.	Grazing will be prohibited by H.P. Government.
	d) Visual pollution and damage to scenery	Nil
3.14	Arrangement made for	
	a) Fuel requirement of the labour force during construction period to prevent indiscriminate felling of trees for fire wood (fuel depots)	Fuel will be supplied through Depots.
	b) Compensatory afforestation	Will be undertaken with the help of State Forest Deptt.
	c) Enforcing of anti-poaching laws	Anti-poaching laws will be enforced by H.P. State Wild Life Department.
	d) Control of sediments and pollution	No problem of sedimentation and pollution anticipated.

4.0	Proposals for observance and monitoring of suggested safeguards and mitigative measure etc. during and after construction of the project.	Adequate safeguards for maintaining environmental and ecological balance will be taken on the advice of Department of Environment and Forests, Govt. of India, both during construction and operation of the project.

Chapter - 23

ESTIMATES OF COSTS

23.1 General

The estimates of cost have been prepared in detail to arrive at the total capital cost of the project. The estimates are based on the prices prevailing in Dec'99, for materials, equipments, labour, etc. Interest during construction period and financing charges have been worked out separately.

The estimates of cost have been prepared in two parts - Part - I covers the Civil works of the project, while Part - II covers Electrical works. The cost of transmission has not been taken into account, as this component does not form part of this Project.

23.2 Cost of Civil works

The detailed estimates of cost of civil works are based on the planning and preliminary design of different components of works after review of site conditions, carrying out detailed field investigations and analysis and studies etc. General arrangement and layout details of various structures as well as their salient features are shown in drawings in Volume - V of this report.

Detailed analysis of rates have been prepared for major items of works which are given in Volume - III (Section - D) of the report. Rates for minor item of works and lumpsum provisions for some works have been made on the basis of experience of similar works on other projects which have been recently completed or are under construction.

The rates for hydraulic gates, hoists, and cranes etc. are based on the prevalent market rates for such works.

A provision of 5% of the cost has been made to cover contingencies and work charged staff in the estimates of different components of civil works. The contingencies have not been taken on items for which L.S. amount has been provided.

23.3 Broad sub-head-wise provisions for civil works

The provisions under various sub-heads are based as per guide lines for preparation of detailed project reports of Irrigation and Multipurpose Projects issued by Ministry of Water Resources, Government of India. Broad provisions made under various sub-heads of civil works are briefly described below :

A - Preliminary

Under this head provision has been made for topographical surveys, geological and geophysical investigations including drilling and drifting, field and laboratory tests on rocks, construction material investigations and testing, collection of hydrological and meteorological data, hydraulic model studies for dam and intake etc., environmental and ecological studies. Provision has been made for consultant's fees for preparation of the project report and other reports. The total provision under this sub-head is Rs. 1539 lacs which is within 1% of the I-Works as per guidelines.

B - Land

This sub-head covers the provision for acquisition/purchase of land for permanent works, approach roads, camp sites, workshops, stores, offices and permanent colony for the maintenance staff etc. The provision has also been made for compensation of houses and trees etc. coming in the reservoir submergence.

The total provision under this sub-head is Rs. 1483.51 lacs.

C - Works

This covers the cost of river diversion works and diversion dam including cost of hydraulic gates and hoists and upstream and downstream protection works.

The total provision under this sub-head is as below:

i)	River Diversion Works			
	- Diversion Tunnel	Rs.	3,575.34	Lacs
	- Coffer Dams	Rs.	2,805.67	Lacs
ii)	Diversion Dam	Rs.	31,935.53	Lacs
	Total	**Rs.**	**38,316.54**	**Lacs**

J - Power plant civil works

Under this sub-head provision has been made for the following works:

i)	Intake, sedimentation chambers and flushing conduits	Rs.	38,696.22	Lacs
ii)	Head race tunnel	Rs.	82,975.51	Lacs
iii)	Surge shaft	Rs.	7,085.13	Lacs
iv)	Pressure shafts and penstocks	Rs.	6,088.41	Lacs
v)	Power house complex	Rs.	15,325.41	Lacs
vi)	Downstream surge chamber, tail race tunnel and outfall works	Rs.	9,531.16	Lacs
vii)	Pothead Yard	Rs.	170.02	Lacs
	Total	**Rs.**	159,871.86	Lacs

K - Buildings

Provision has been made under this sub-head for permanent and temporary residential buildings for various categories of staff, non-residential buildings for offices, workshops, stores, rest houses and field hostels and other service buildings such as hospital, school, police station and utility services etc. Provisions for land development, lawns and gardens, fencing, internal water supply, sanitation and electrical fittings have been made as per norms for various type of buildings as per norms.

The total provision under this sub-head is Rs. 5,309.75 lacs, which is 1.5% of the I-Works (Civil and Electrical works). This is well within permissible limit.

M - Plantation

A lump sum provision of Rs. 198 lacs has been made under this sub-head for plantation near the Dam and reservoir area and camp sites etc.

O - Miscellaneous

Under this sub-head provision has been made for the following items :

i) Capital cost of electrification, water supply, sewage disposal and drainage.

ii) Fire fighting equipment, telephone, telegraph, wireless and other communication facilities.
iii) Recreation facilities and beautification of project area.
iv) Maintenance services for electrification, water supply etc. and other services including security arrangement and fire fighting arrangement.
v) Running of inspection vehicles, transport of staff, school buses and ambulances.
vi) Other items such as visit of dignitaries, technical record of works, power supply, compensation to workmen, writing of completion report and history of project etc.
vii) Construction power arrangements for construction of civil works and for camp sites and workshop etc. during the construction period.

The total provision under this sub-head is Rs. 7,379.20 lacs which is within 4% of the I-Works (Civil and Electrical works) as per guide lines.

P - Maintenance

The provision has been made under this sub-head for maintenance of buildings and roads, and main civil works during the construction period. The total provision is Rs. 2,143.60 lacs which is about 1% of I-Works less A-Preliminary, B-Land, O-Misc, M-Plantation, Q-Spl T&P, X-Environment and Ecology and Y-Losses on Stock.

Q - Special Tools and Plant

Provision has been made under this sub-head for vehicles such as cars, jeeps, buses, ambulances etc. Provision for construction equipment for civil works has not been made under this head, as the construction of civil works will be carried out by a separate construction agency. This is as per recent guidelines of CWC in respect of private sector power projects.

The total provision under this subhead is Rs. 521.00 Lacs.

R - Communications

Provision has been made under this sub-head for construction of roads and bridges including approach roads. Provision has also been made for remodelling and strengthening of main highway and bridges to make them suitable for transport of heavy equipment for power station. The provision of realignment of 5.5 km length of NH-22 and small portion road to Sangla which will come under reservoir submergence has also been made under this sub-head. The total provision under this subhead is Rs. 8718.72 Lacs.

X - Environment and Ecology

Provision under this sub-head has been made for compensatory afforestation, measures for maintaining environment and ecological balance of the area, public health measures, establishment of fuel depots etc. Provision has also been made for treatment of catchment area for prevention of soil erosion etc.

The total provision under this sub-head is Rs. 3,438.83 lacs.

Losses on Stock

Provision under this sub-head has been made at 0.25% of I-work less A - preliminary, B - land, O-Misc, M-Plantation, Q-Spl T&P, X-Environment and Ecology and P-Maintenance. The total provision under this sub-head is Rs. 531.90 Lacs.

Establishment

Provision has been made @ 11% of I-Works less B-land. This provision also includes establishment for carrying out detailed designs, site supervision, coordination between different agencies, quality control and cost control cell. The total provision under this sub-head is Rs. 25,076.52 Lacs.

Tools and Plants

Provision @ 1% of I-Works has been made to cover survey instruments, camp equipment, office furniture, office equipment etc. The total provision under this sub-head is Rs. 2,294.52 Lacs.

Receipts and recoveries on capital account

Under this head estimated recoveries by way of transfer of temporary buildings (@ 15%), resale of special T & P (@ 20%) and other miscellaneous recoveries have been provided. The total provision under this sub-head is Rs. 686.64 Lacs.

Audit and Accounts

It has been taken as 1% of the cost of I-Works, and amounts to Rs. 2,294.52 Lacs.

23.4 Cost of Electromechanical Works (Part II)

Cost of generating plant and equipment is based on current budgetary prices of plant from M/s SIEMENS AG, Germany for 4x250 MW units.

A provision of 5% for initial spares has been made along with the cost of equipment. Prices of major auxiliary equipment and services are based on current budgetary prices while that of some minor items are based on prices for similar equipment procured in the past for similar projects.

Provisions for duty, insurance and transport to site are based on prevailing rates. Erection and commissioning charges have been taken as 10% of the cost of equipment based on the experience gained on similar installations in the country.

Provisions of other items like Establishment, Audit and Account charges, etc. have been made as per prevailing norms of Central Electricity Authority (CEA).

23.5 Estimated Cost of the Project

Total cost of the Project at December 1999 price level works out as under :

			INR (Rs. Crores)		**F.C. (million US$)**	
1.	Civil Works	Rs.	2584.00		-	
2.	E-M Works (Generating plant and equipment)	Rs.	525.50	US$	155.00	
	Total	**Rs.**	**3109.50**	**+ US$**	**155.00**	**million**
		=	Rs. 3784 Crores (1 US$ = Rs. 43.50)			

The abstract of cost of Civil Works is given in Annex. 23.1, while details of costs under various sub-heads of Civil Works are given in Volume - III (Section- C-2) of the report.

The abstract of cost for Electrical Works - (generating plant and equipment) are given in Annexure - 23.2. The details thereof are given in Volume - III (Section -C-3) of the report.

Annexure 23.1

ABSTRACT OF COSTS
PART I - CIVIL WORKS

Sl. No.	Description	Amount (in Lacs) (At Dec. 99 Price level)	Annexure No.
I	DIRECT CHARGES: I-Works		
1.	A - Preliminary	1,539.00	C-2.1 (R)
2.	B - Land	1,483.51	C-2.2 (R)
3.	C - Works		
3.1	River Diversion Works		C-2.3 (R)
	- Diversion Tunnel	3,575.34	
	- Coffer Dams	2,805.67	
3.2	Diversion Dam	31,935.53	C-2.4 (R)
4.	J - Power plant civil works		
4.1	Intake, Sedimentation Chambers and Flushing Conduits	38,696.22	C-2.5 (R)
4.2	Head Race Tunnel and Construction Adits	82,975.51	C-2.6 (R)
4.3	Surge Shaft	7,085.13	C-2.7 (R)
4.4	Pressure Shafts and Penstocks	6,088.41	C-2.8 (R)
4.5	Power House Complex	15,325.41	C-2.9 (R)
4.6	Downstream Surge Chamber, Tail Race and Outfall Works	9,531.16	C-2.10 (R)
4.7	Pothead Yard	170.02	C-2.11 (R)
5.	K - Buildings	5,309.75	C-2.12 (R)
6.	M - Plantation	198.00	C-2.13
7.	O - Miscellaneous	7,379.20	C-2.14 (R)
8.	P - Maintenance	2,143.60	C-2.15 (R)
9.	Q - Spl. T & P (vehicles)	521.00	C-2.16
10.	R - Communications	8,718.72	C-2.17 (R)
11.	X - Environment & Ecology	3,438.83	C-2.18 (R)
12.	Losses on Stock @ 0.25% [(I Works) - (A Preliminary + B Land + O Misc. M plantation + Q Spl T& P + X Environment & & Ecology + P-Maintenance)]	531.90	C-2.19 (R)
	Total of I-Works	**229,451.92**	

contd..

Sl. No.	Description	Amount (Rs. Lacs)	Annexure No.
13.	Establishment including design wing and cost control cell @ 11% of I-Works less B-Land	25,076.52	
14.	T&P (@ 1% of I-Works)	2,294.52	
15.	Receipts and recoveries on capital account	(686.64)	C-2.20 (R)
	Total of Direct Charges	**256,136.33**	
II	INDIRECT CHARGES		
16.	Capitalised value of abatement of land revenue (@ 5% of cost of culturable land)	1.14	
17.	Audit and accounts (@ 1% of I-Works)	2,294.52	
	Total of Indirect Charges	**2,295.66**	
	Total of Direct and Indirect Charges	**258,431.99**	
	Say Rs.	**2,584.00**	**Crores**

Annexure 23.2

ABSTRACT OF COSTS

PART II - Generating Plant and Equipment

(P - PRODUCTION)

Sl. No.	DESCRIPTION	Amount (Rs.in.Lacs)	Annexure No.
1.	**Design, Consultancy Charges**	1,000.00	
2.	**Generating Plant Equipment (Imported):**		
	(a) Generating plant and accessories	50,895.00	C-3.-R1
	(i) Custom Duty @22.38%	11,390.30	
	(ii) Clearing and forwarding charges @ 1%	508.95	
	Sub total [A] item 2	**62,794.25**	
3	(a)Electrical Auxiliary Equipment for Power Station	2,054.00	C-3.2-R1
	(b)Mechanical Auxiliary Equipment for Power Station	1,818.00	C-3.3-R1
	(c) Excise Duty @16% on3(a) & 3(b)	619.52	
	(d) Central S.T. @ 4% on 3(a), (b) & ©	179.66	
	Sub total [B] item3	**4,671.18**	
4	(a) Inland Transportation @ 5% on 2(a) , 3(a) + 3(b)	2,738.35	
	(b) Insurance charges @ 1% on 2(a) , 3(a) + 3(b)	547.67	
	(c) Erection & Commissioning charges @ 10% on 2(a) , 3(a) + 3(b)	5,476.70	
	Sub - Total [C] Item 4	**8,762.72**	
	Sub - Total [D] Item 2,3 &4	**76,228.15**	
5	**Sub-station Equipment:**		
	A - Indigeneous		
	(i) Gen-Transformers, LAs, PLCC & Allied Eqpt.	2,829.00	C-3.4-R1
	(ii) Excise duty @16% on 5(A)(i)	452.64	
	(iii) CST @ 4% on item 5A(i) & (ii)	131.27	
	(iv) Inland Transportation @ 5% on 5A (i)	141.45	
	(v) Insurance @ 1% on 5A (i)	28.29	
	(iv) Erection & Commissioning charges @ 10% on 5A (i)	282.90	
	Sub - Total [E] Item 5 A	**3,865.55**	
	B - Imported		
	(i) 400 kV SF6 Switchgear, SF6 Busducts & Accessories	16,530.00	C-3.4-R1
	(ii) Custom Duty @22.38%	3,699.41	
	(iii)Clearing forwarding charges @ 1%	165.30	
	(iv) Inland Transportation @ 2% on 5B (i)	330.60	
	(v) Insurance charges @ 1% on 5B(i)	165.30	
	(vi) Erection & Commissioning @ 5% on 5B (i)	826.50	
	Sub - Total [F] Item 5 B	**21,717.11**	
	Sub-Total [G] item5A & 5B	**25,582.66**	

Annexure 23.2
Contd...

Sl. No.	DESCRIPTION	Amount (Rs.in.Lacs)	Annexure No.
6	**Plant Handling Equipment**		
	(i) Plant handling equipment	665.00	C-3.5-R1
	(ii) Excise duty @16% on 6(i)	106.40	
	(iii) CST @ 4% on item 6(I) & (ii)	30.86	
	(iv) Insurance @ 1% on 6 (i)	6.65	
	Sub - Total [H] Item 6	**808.91**	
	Sub - Total [I] Item [D]+[G] +[H]	**102,619.72**	
7	**Other Items**		
	(i) Losses on stock @ 0.25% of Sub Total [I]	256.55	
	(ii) Maintenance during construction @ 1% of Sub Total [I]	1,026.20	
	(iii) Third party inspection of equipment charges @ 1% of Sub-Total [I] excluding erection & commissioning (i.e. 102619.72-5476.7-282.9-826.5= 96033.62)	960.34	
	(iv) Contingencies for unforseen items @ 3% of Sub Total [I]	3,078.59	
	(v) T & P charges @ 1% of Sub Total [I]	1,026.20	
	Sub-Total Item 7	**6,347.87**	
	Sub- Total [J] of Items 1,2,3,4, 5,6 & 7	**109,967.59**	
	(vi) Establishment @ 8.0% of [J]	8,797.41	
	Total Direct Charges [J] + (vi)	118,765.00	
6.	Audit & Accounts charges @ 1% of Total Direct Charges	1,187.65	
	GRAND TOTAL	**119,952.65**	

Foreign Component:	**155. MUSD**	**6,742.50**
		(@ 1 USD = 43.50 Rs.)
Rupee Component:	**5253 MINR**	**5,252.76**
TOTAL COST in MILLION INR		**11,995.26**

TOTAL COST OF E&M WORKS **155. MUSD + 5253 MINR** **I.e. Rs. Crores** **1,200.00**

Elec & C ... Excel\Karcham-IABST CEA elec summ-2-pankaj.xls (A (2))

Chapter – 24

ECONOMIC APPRAISAL

24.1 Policy Guidelines of the Government of India

In order to encourage greater participation by private sector in the electricity generation, supply, and distribution field, the Government of India have made some major changes in its Policy.

After amendments to Indian Electricity Act, 1910 and Electricity (Supply) Act, 1948, the Ministry of Power and Non-Conventional Energy Sources (Department of Power), Government of India, in a Resolution dated 22.10.1999, framed the policy guidelines to encourage private enterprises' participation in power generation, supply and distribution. Subsequently, in a Notification No. 7/A-6/91-IPC dated 31.01.1992 and as revised vide notification dated 29.03.1994, the Ministry of Power specified the guidelines for calculation of depreciation on a straight-line formula for various components of Civil and Electrical works forming part of a Hydro-Electric Project. The Department of Power, Ministry of Power and Non-Conventional Energy Sources, vide their Notification dated 31.03.1992 as revised, from time to time vide several notifications, published the guidelines for fixation of tariff for the sale of electricity by generating companies. As per these notifications, two part tariff consisting of capacity charges and energy charges has been specified. Economic criteria for the purposes of fixation of tariff, based on Return on Equity and other considerations have been laid down by the Government of India. The economic appraisal and the evaluation of Karcham Wangtoo Hydro-Electric Project has accordingly been made in this Chapter, in accordance with the Notifications of the Department of Power, Government of India, as mentioned above.

The details of computation of the capital cost on completion and fixation of tariff for sale, etc. are discussed below.

24.2 Basic Capital Cost of the Project

In Chapter 23, an estimate of cost of the Project comprising both Civil and Electrical Works on the basis of the prices as prevalent in December, 1999 has been presented. The total cost of the Project at December, 1999 prices works out as under:-

	Rupee Cost	F. C. Cost
Civil Works (INR Component)	Rs. 2584.00 Crores	-
E&M Works Works (INR Component)	Rs. 525.50 Crores	-
E&M Works (FC Component)		US$ 155.00 Million
Total	**Rs. 3109.50 Crores**	**US$ 155.00 Million**

The details are as per Annexure-24.

24.3 Completion Cost of the Project

The total completion cost of project including escalation, IDC and financing costs will be as below:-

		Rupee Cost	F.C. Cost
i)	*Basic Cost of Project (Dec'99 Price Level)*		
	a) Civil Work (INR Component)	Rs 2584.00 cr	
	b) E&M Works (INR Component)	Rs. 525.50 cr	
	c) E&M Works (FC Component)		US$ 155.00 Million
ii)	*Escalation:*		
	Upto date of commencement:		
	a) Civil Work (INR Component)	Rs 563.73 cr	
	b) E&M Works (INR Component)	Rs.114.63 cr	
	c) E&M Works (FC Component)		US$ 9.20 Million
	During construction period:		
	a) Civil Work (INR Component)	Rs. 631.28 cr	
	b) E&M Works (INR Component)	Rs. 149.31 cr	
	c) E&M Works (FC Component)		US$ 10.16 Million
iii)	*IDC and Financing Costs*		
	a) On INR Component	Rs.2268.91 cr	
	b) On FC Component		US$ 64.41 Million
	Total Cost on Completion	**Rs 6837.36 cr+**	**US$ 238.77 Million**
		= Rs.7876.01 crores (@ 1 US$ = Rs.43.50)	
		(Say) Rs 7877 crores	

The details of this cost is given in Annexures 24.1 to 24.4 (Sheet 1 & Sheet 2).

The summary of completion cost of Project and its means of financing are given in Annexure 24.4 (Sheet 3).

The completion cost is based on the tentative financing assessment and it may vary based on the firm financial package.

24.4 Annual Escalation

As per Implementation Agreement entered into with Govt. of Himachal Pradesh, a period of thirty six months from the Effective Date i.e. date of signing the agreement has been provided for obtaining necessary clearances, tying up the transmission systems for evacuation of power from the Project and for achieving the Financial Closure. The commercial operation of the Project is required to be achieved within one hundred twenty (120) months from the Effective Date. However, it is proposed to obtain the necessary clearances and to achieve the Financial Closure in two years and eleven months and to complete the Project within a period of 6 years from the date of Financial Closure. The escalation up to date of commencement of construction and during construction period has, therefore, been taken accordingly. The rate of escalation on the civil works (all rupee component) and rupee component of electro-mechanical works has been taken as 7% based on the price indices in India for the previous years and the rate of escalation on the foreign exchange component of electro-mechanical works has been taken at an estimated rate of 2% per annum. The calculations for escalation during construction are given in Annexures 24.1, 24.2 and 24.3.

24.5 Loan Component

In para 2.1 of the Resolution dated 22.10.1991 of the Ministry of Power & Non-Conventional Energy Sources (Department of Power), it has been specified that the debt equity ratio upto 4:1 is permissible for all prospective private enterprise entrants to the power sector, i.e. a minimum of 20% of the total capital outlay should be the equity component. It will thus be permissible to raise loans equivalent to 80% of the total Project cost. The loans have to be raised from Indian Financial Institutions, foreign lenders including any other sources such as suppliers' credit, etc.

The Indian Financial Institutions, however, require that a minimum of 30% of total outlay should be equity. In view of this requirement, the loan component and equity component of the Project has been taken as 70% and 30% respectively.

The loan component will include term loans from Indian Financial Institutions, suppliers' credit, ECB or such other instruments which will be finalised at the time of Financial Closure of the Project.

24.6 **Equity in the Project**

As per the implementation agreement for the Project executed between Govt. of Himachal Pradesh (GoHP) and Jaiprakash Industries Ltd. (JIL) on 18th November, 1999, JIL shall incorporate a new company for the implementation of the project with its registered office situated in the State of Himachal Pradesh. The Equity structure in such new company for the Project shall be as follows:

a)	Promoters	- Not less than 17.5% of total Project cost which will represent approximately 58% of the total equity.
b)	Others	- Balance 12.5% of the total Project cost which will represent approximately 42% of the total equity.

24.7 **Interest on Loans**

The rate of interest for rupee term loans being charged by the Indian Financial Institutions is approximately 3.50% over the Prime Lending Rate (PLR) prevailing at the time of execution of the loan documents. The current PLR is about 13%, therefore the total interest of 16.50% per annum has been considered for calculation purposes. Interest tax of 2% has been withdrawn in the Finance Bill 2000-2001, therefore, has not been considered. The interest on foreign currency loans has been estimated at 8% per annum. The interest on loans is likely to change based on the actual applicable rates as may be charged by the Lenders. Such actual interest cost will need to be considered in the final Cost of the Project.

24.8 **Front-end Fees, Management Fees, Exposure Fees and Commitment Charges :**

a) The Indian Financial Institutions charge a Front-end fees on loan amount. These are made to cover the financial commitment/ servicing charges. Since this is an established practice, the same has been taken into account in calculation of the capital cost. These charges have been taken as 1.05% of the rupee term loans.

b) The management fee / arrangement fee on the foreign currency loans have been taken at an estimated rate of 1% of the foreign currency loans.

c) The exposure fee is charged by the Export Credit Agencies to cover the country risks of the foreign lenders who provide the suppliers' credit which vary from country to country.

This has been estimated at 8% of the foreign currency loans.

d) The foreign currency loans shall be provided by the foreign lenders against the guarantee (DPG) by Indian Financial Institutions. As per the present practice of the Indian Institutions, the charges of providing DPG include the management fee / arrangement fee of 1.05% of DPG amount and the Guarantee Commission of 3.5% p.a. on the outstanding amount of principal guaranteed. These charges have been accordingly considered for the DPG facility to be provided for foreign currency loans.

e) Commitment charges / fee have been taken at the rate of 0.5% on the undrawn amount of foreign currency loans as per the prevailing norms of foreign lenders.

f) Other financing cost has been taken as 0.35% of the loan amount which will include the fee / charges of lenders' counsels, lenders' engineers, lenders' insurance consultants and any other fees / charges in compliance with the stipulations of the lenders.

24.9 Repayment Period

A repayment period of 12 years has been taken into account in respect of rupee loans and foreign currency loans.

24.10 Interest During Construction (IDC)

The details of cash flow during the construction period and the calculations of interest during construction including interest on IDC are shown in Annexures 24.4 (sheet 1 & sheet 2) It will be seen that interest during construction & financing costs (front-end fees, arrangement fees, exposure fees, etc.) and interest on such IDC and financing cost during construction period will be Rs. 2549.10 Crores.

24.11 Fixation of Tariff

As already stated earlier, the tariff has been worked out on the basis of the norms/ guidelines prescribed by the Department of Power in their Notification dated 31.03.1992 as amended from time to time through various Notifications.

.1 **Units available for Sale**

As brought out in Chapter 5 – Power Studies, total generation of units in 90% dependable year is 4228.5 million units. Out of this, as per guidelines, 0.5% of the units generated are accounted for auxiliary consumption, and 0.5% of the units generated have been taken as the loss in the transmission upto bus bars, which works out to 42.28 million units. Thus the units available at bus bar will be 4186.22 millions.

As per the implementation agreement, 12% of the annual generation of power is to be given free to the State Government for the first 12 years and 18% of the annual generation is to be given as free power for the next 28 years. This works out to 502.34 million units for the first 12 years and 753.52 million units for the next 28 years. Thus, the net energy available for sale will be 3683.88 million units for the first 12 years and 3432.70 million units for the next 28 years. The tariff for primary energy has, therefore, been worked out on this basis.

.2 **Capacity Charges**

Capacity charges have been worked out taking the following components:

.2.1 **Interest on Loans and Financing Cost**

As already explained earlier, the interest on rupee term loans has been taken at 16.50% per annum and the interest on foreign currency loans has been taken at an average rate of 8% per annum both during construction period as well as during repayment period. The guarantee commission @3.50% p.a. on the outstanding amount of principal guaranteed has been taken as per the prevailing stipulations of the Institutions. The total repayment period for both the rupee loans and the foreign currency loans has been considered as 12 years for calculation of tariff. The tariff as calculated is only indicative and is subject to change on account of changes in IDC and financing cost etc. as explained hereinbefore.

.2.2 **Depreciation/ Advance against Depreciation**

As per para 2.6(b) of Notification dated 13.01.1995, "Advance against depreciation" shall be applicable at an annual amount not exceeding one-twelfth of the loan amount and limited to the actual loan liability of the year.

The advance against depreciation as per this Notification has, therefore, been taken accordingly for calculation of the capacity charges.

As per the guidelines of Government of India (GoI) the depreciation up to 90% of the capital cost is allowed during the operating period. After the repayment of loans, the balance capital cost (up to a limit of 90% of total capital cost) has been depreciated taken an assumed rate of annual depreciation of 4% as per guidelines of CEA / Ministry of Power.

.3 Energy Charges

.3.1 Operation and Maintenance (O&M) Expenses

As prescribed in para 2.8 of the Notification of Department of Power dated 13.01.1995, the operation and maintenance expenses inclusive of insurance for the first full year have been taken as 1.5% of the capital cost. Escalation in O&M expenses during the operating period has not been considered.

.3.2 Taxes on Income

As per para 2.8(b) of Notification dated 13.01.1995, taxes on income, if any, shall be computed as expenses on actuals. Therefore, income tax has been considered on the taxable profits of the Project as per Income Tax Law.

.3.3 Return on Equity

The return on equity has been computed at 16% of the equity capital.

.4 Incentives

.4.1 Energy charges for secondary energy have been considered as per GOI notification equal to per unit cost of primary energy.

.4.2 Incentive for availability of installed capacity has been considered at 3.5% return on equity at the rate of 0.7 per cent return on equity for each percentage point increase in availability beyond 90% as per GOI notification.

.5 **Calculation of Tariff**

Calculation of tariff for energy during forty years of operation are presented in Annexure – 24.5

The effective tariff for the total energy (primary/ design energy plus secondary energy) will be Rs.4.78 per unit during first year of operation and Rs.3.65 during tenth year of operation. The average rates for the first ten years and forty years will be Rs.4.22 per unit and Rs.2.84 per unit respectively.

These rates are considered very attractive as the project will provide peaking power to the extent of 1000 MW for at least 4 hours daily on 90% availability basis.

KARCHAM WANGTOO HYDRO-ELECTRIC PROJECT (1000 MW)

Annexure-24

Estimated Completion Cost of the Project

(A) Assumptions:

1	Date of Commencement	01-Nov-2002
2	Project Colmpletion Period	6 Years
3	Scheduled Project Completion Date	31-Oct-2008
4	Escalation	7% p.a. (compounded annually) on Civil Works Component (all INR) and E & M Works and 2% (compounded annually) on FC component of E & M works up to Date of Commencement
5	Rate of Interest:	
a)	Rupee Term Loans	16.50% p.a
b)	On FC Loan (US$)	8.00 p.a.
6	Financing Cost	
a)	Front-end fee on Rupee Term Loans	1.05% on loan amount
b)	Management fee and commitment charges on FC Loan	1% on loan amount
c)	Exposure fee on FC Loan	8% on loan amount
7	Equity Participation	30% of Project Completion Cost
8	Term Loans	70% of Project Completion Cost

		US $ Mill	Rs/Crores	
(B)	**Basic Cost of Project on Base Date of Dec-99**			
i)	Civil Works (INR Component)		2,584.00	*Annexure 24.1*
ii)	E & M Works (INR Component)		525.50	*Annexure 24.2*
iii)	E & M Works (FC Component)	155.00		*Annexure 24.3*
	Sub-Total (B)	**155.00**	**3,109.50**	
(C)	**Escalation since Base Date (Dec-99) till assumed Date of Commencement (Nov-2002)**			
i)	Civil Works (INR Component)		563.73	*Annexure 24.1*
ii)	E & M Works (INR Component)		114.63	*Annexure 24.2*
iii)	E & M Works (FC Component)	9.20		*Annexure 24.3*
	Sub-Total (C)	**9.20**	**678.36**	
(D)	**Basic Cost of Project as on the Date of Commencement- November 2002 (B + C)**	**164.20**	**3,787.86**	
(E)	**Escalation during Construction Period of 6 Years (from Nov-2002 to Oct-2008)**			
i)	*Civil Works (INR Component)*		631.28	*Annexure 24.1*
ii)	E & M Works (INR Component)		149.31	*Annexure 24.2*
iii)	E & M Works (FC Component)	10.16		*Annexure 24.3*
	Sub-Total (E)	**10.16**	**780.59**	
(F)	**Total Escalation [(C) + (E)]**	**19.36**	**1,458.95**	
(G)	**Total Cost on completion including escalation (Hard Cost) (D + E)**	**174.36**	**4,568.45**	
(H)	**Total IDC & Financing Charges**			
a)	IDC on INR Component		**2268.91**	***Annexure 24.4 (Sheet 1)***
b)	IDC on FC Component	**64.41**		***Annexure 24.4 (Sheet 2)***
	Sub-Total (H)	**64.41**	**2268.91**	
(I)	**Total Cost of Project on Completion including IDC & FC [G + H]**	**238.77**	**6,837.36**	
	Total Cost of Project on Completion in equivalent Rs.crores	**7,876.01**		
	Say Rs.	***7,877.00***		
(J)	**Average Tariff**			***Annexure 24.5***
i)	*for 1st Year of Operation*		4.78	
ii)	*for 1st Five Years of Operation*		4.41	
iii)	*for 1st Thirty Years of Operation*		3.04	
iv)	*for 1st Forty Years of Operation*		2.84	

c:\rcs\excel\karcham_financial_analysis9 (escal.compound)\Summary

Annexure 24.1

KARCHAM WANGTOO HYDRO-ELECTRIC PROJECT (1000 MW)

COST OF CIVIL WORKS INCLUDING ESCALATION (INR COMPONENT)

Rs.in Crores

S. No.	Particulars	YEAR-0	YEAR-1 Nov. 2002 - Oct.2003	YEAR-2 Nov. 2003 - Oct.2004	YEAR-3 Nov. 2004 - Oct.2005	YEAR-4 Nov. 2005 - Oct.2006	YEAR-5 Nov. 2006 - Oct.2007	YEAR-6 Nov. 2007 - Oct.2008	TOTAL
1	2	3	4	5	6	7	8	9	10
1)	Basic Cost of Civil Works INR Component (at Dec-1999 price level)								
a)	Percentage of work assumed.		30.00%	10.00%	15.00%	20.00%	15.00%	10.00%	100.00%
b)	**BASIC COST OF CIVIL WORKS**		**775.20**	**258.40**	**387.60**	**516.80**	**387.60**	**258.40**	**2584.00**
2)	**Escalation since Base Date (Dec- 1999) to assumed date of commencement (Nov- 2002) [@ 7% p.a. compounded annually for 2 years & 11 month on1(b) above]**		169.12	56.37	84.56	112.75	84.56	56.37	563.73
3)	**Basic cost including escalation as on the Date of Commencement (Nov- 2002) [1(b) + 2]**		944.32	314.77	472.16	629.55	472.16	314.77	3147.73
4)	**Escalation during Construction Period (from Nov-2002 to Oct-2008 i.e. 6 yrs) [@ 7% p.a. compounded annually on (3) above]**		32.49	33.62	87.02	168.21	168.04	141.90	631.28
5)	**TOTAL ESCALATION [2+4]**		**201.61**	**89.99**	**171.58**	**280.96**	**252.60**	**198.27**	**1195.01**
	TOTAL COST INCLUDING ESCALATION (1(b) + 5)		**976.81**	**348.39**	**559.18**	**797.76**	**640.20**	**456.67**	**3779.01**

NOTE: The escalation has been considered on the basis of annual compounding rate of 7% per annum from the base date to the date of commencement of construction.The said escalated cost has been taken as the base for calculation of further escalation during the construction period.

KARCHAM WANGTOO HYDRO-ELECTRIC PROJECT (1000 MW)

COST OF E&M WORKS INCLUDING ESCALATION (INR COMPONENT)

Rs.in Crores

S. No.	Particulars	YEAR-0	YEAR-1 Nov. 2002 - Oct.2003	YEAR-2 Nov. 2003 - Oct.2004	YEAR-3 Nov. 2004 - Oct.2005	YEAR-4 Nov. 2005 - Oct.2006	YEAR-5 Nov. 2006 - Oct.2007	YEAR-6 Nov. 2007 - Oct.2008	TOTAL
1	2	3	4	5	6	7	8	9	10
1)	Basic Cost of E&M works INR component (as on Dec-1999 price level)								
a)	Percentage of work assumed.		25.00%	5.00%	10.00%	25.00%	25.00%	10.00%	100.00%
b)	**BASIC COST OF E&M WORKS**		131.38	26.26	52.55	131.38	131.38	52.55	525.50
2)	Escalation since Base Date (Dec- 1999) to assumed date of commencement (Nov- 2002) [@ 7% p.a. compounded annually for 2 years & 11 month on 1(b) above]		28.66	5.73	11.46	28.66	28.66	11.46	114.63
3)	Basic cost including escalation as on the Date of Commencement (Nov- 2002) [1(b) + 2]		160.04	31.99	64.01	160.04	160.04	64.01	640.13
4)	Escalation during Construction Period (from Nov-2002 to Oct-2008 i.e. 6 yrs) @ 7% p.a. compounded annually on (3) above .		5.51	3.42	11.80	42.76	56.96	28.86	149.31
5)	**TOTAL ESCALATION [2+4]**		34.17	9.15	23.26	71.42	85.62	40.32	263.94
	TOTAL COST INCLUDING ESCALATION (1(b)+5)		165.55	35.41	75.81	202.80	217.00	92.87	789.44

NOTE: The escalation has been considered on the basis of annual compounding rate of 7% per annum from the base date to the date of commencement of construction. The said escalated cost has been taken as the base for calculation of further escalation during the construction period.

Annexure 24.3

KARCHAM WANGTOO HYDRO-ELECTRIC PROJECT (1000 MW)

COST OF E&M WORKS INCLUDING ESCALATION (FC COMPONENT)

US$ Millions

S. No.	Particulars	YEAR-0	YEAR-1 Nov. 2002 - Oct.2003	YEAR-2 Nov. 2003 - Oct.2004	YEAR-3 Nov. 2004 - Oct.2005	YEAR-4 Nov. 2005 - Oct.2006	YEAR-5 Nov. 2006 - Oct.2007	YEAR-6 Nov. 2007 - Oct.2008	TOTAL
1	2	3	4	5	6	7	8	9	10
1)	Basic Cost of E&M Works-FC Component)								
a)	Percentage of work assumed		25.00%	5.00%	10.00%	25.00%	25.00%	10.00%	100.00%
b)	**BASIC COST OF E&M WORKS**		38.75	7.75	15.50	38.75	38.75	15.50	155.00
2)	**Escalation since Base Date (Dec- 1999) to assumed date of commencement (Nov- 2002) [@ 2% p.a. compounded annually for 2 years & 11 month on 1(b) above]**		2.30	0.46	0.92	2.30	2.30	0.92	9.20
3)	**Basic cost including escalation as on the Date of Commencement (Nov- 2002) [1(b) + 2]**		41.05	8.21	16.42	41.05	41.05	16.42	164.20
4)	**Escalation during Construction Period (from Nov-2002 to Oct-2008 i.e. 6 yrs) @ 2% p.a. compounded annually on (3) above.**		0.41	0.25	0.83	2.95	3.83	1.89	10.16
5)	**TOTAL ESCALATION [2+4]**		2.71	0.71	1.75	5.25	6.13	2.81	19.36
	TOTAL COST INCLUDING ESCALATION (1(b)+ 5)		41.46	8.46	17.25	44.00	44.88	18.31	174.36

NOTE: The escalation has been considered on the basis of annual compounding rate of 2% per annum from the base date to the date of commencement of construction. The said escalated cost has been taken as the base for calculation of further escalation during the construction period.

Annexure 24.4
Sheet 1

KARCHAM WANGTOO HYDRO-ELECTRIC PROJECT (1000 MW)

FINANCIAL PACKAGE, IDC AND FINANCING CHARGES (CIVIL WORKS AND E&M WORKS- INR COMPONENT)

Rs. in Crores

S. No.	Particulars of Inflow/Half Yearly	YEAR-0	YEAR-1 Nov. 2002 - Oct.2003	YEAR-2 Nov. 2003 - Oct.2004	YEAR-3 Nov. 2004 - Oct.2005	YEAR-4 Nov. 2005 -	YEAR-5 Nov. 2006 - Oct.2007	YEAR-6 Nov. 2007 - Oct.2008	TOTAL
1	2	3	4	5	6	7	8	9	10
1	**Basic cost at DEC-1999 price level in INR.**								
a)	Cost of Civil Works excluding escalation	0.00	775.20	258.40	387.60	516.80	387.60	258.40	2584.00
b)	Cost of electro-mech. Equipment excluding escalation	0.00	131.38	26.26	52.55	131.38	131.38	52.55	525.50
	Sub-total (Basic cost excluding escalation)	0.00	906.58	284.66	440.15	648.18	518.98	310.95	3109.50
2	**Escalation upto date of commencement and during construction period(from Dec-1999 to Oct 2002)**								
a)	Escalation on Civil Works	0.00	201.61	89.99	171.58	280.96	252.60	198.27	1195.01
b)	Escalation on EM Works		34.17	9.15	23.26	71.42	85.62	40.32	263.94
	Sub-total (Total escalation)		235.78	99.14	194.84	352.38	338.22	238.59	1458.95
3	**Total cost including escalation without IDC & FC**		1142.36	383.80	634.99	1000.56	857.20	549.54	4568.45
4	**Interest during construction and financing charges (IDC&FC) as per 7 below.**	0.00	123.43	205.78	268.10	402.14	566.65	702.81	2268.91
5	**TOTAL COST INCLUDING IDC & FC**	**0.00**	**1265.79**	**589.58**	**903.09**	**1402.70**	**1423.85**	**1252.35**	**6837.36**
6	MEANS OF FINANCING								
a)	EQUITY [As per Annexure 24.4(Sheet 3)]	0.00	444.26	195.17	303.28	494.23	507.05	418.82	2362.81
b)	LOAN AMOUNT [As per Annexure 24.4(Sheet 3)]	0.00	853.81	403.55	615.99	945.18	956.73	855.11	4630.37
	Cumulative loan amount	*0.00*	853.81	1257.36	1873.35	2818.53	3775.26	4630.37	
7	**Details of (IDC & FC)**								
a)	Interest during construction -IDC@16.5% p.a.	0.00	70.44	174.17	258.28	387.08	543.99	674.05	2108.01
b)	Financing charges.								
	Upfront fee @ 1.05% flat on total loan amount		24.31	24.31					48.62
c)	Other financing charges @ 0.35% flat on total loan amount		16.21						16.21
d)	Management fee @ 1.05% of DPG amount		9.27						9.27
e)	Guarantee commission payable for DPG @ 3.50% p.a. on outstanding principal amount		3.20	7.30	9.82	15.06	22.66	28.76	86.80
	(Total of IDC and Financing Charges)	0.00	123.43	205.78	268.10	402.14	566.65	702.81	2268.91
8	TOTAL LOAN COMPONENT INCLUDING IDC & FINANCING CHARGES	**0.00**	**853.81**	**403.55**	**615.99**	**945.18**	**956.73**	**855.11**	**4630.37**

Annexure 24.4
Sheet 2

KARCHAM WANGTOO HYDRO-ELECTRIC PROJECT (1000 MW)

FINANCIAL PACKAGE, IDC AND FINANCING CHARGES (E&M -FC COMPONENT)

US$ In Million

S. No.	Particulars of Inflow/Half Yearly	YEAR-0	YEAR-1 Nov. 2002 Oct.2003	YEAR-2 Nov. 2003 - Oct.2004	YEAR-3 Nov. 2004 - Oct.2005	YEAR-4 Nov. 2005 -	YEAR-5 Nov. 2006 - Oct.2007	YEAR-6 Nov. 2007 Oct.2008	TOTAL
1	2	3	4	5	6	7	8	9	10
1	**Basic cost E&M works (FC Comp).**								
	Cost of E&M works equipment excluding escalation(FC Comp)	0.00	38.75	7.75	15.50	38.75	38.75	15.50	155.00
	Sub-total (Basic cost excluding escalation)	0.00	38.75	7.75	15.50	38.75	38.75	15.50	155.00
2	**Escalation**								
	Escalation on E&M Works	0.00	2.71	0.71	1.75	5.25	6.13	2.81	19.36
	Sub-total (Total escalation)	0.00	2.71	0.71	1.75	5.25	6.13	2.81	19.36
3	**Total cost including escalation without IDC & FC**		41.46	8.46	17.25	44.00	44.88	18.31	174.36
4	**Interest during construction IDC & FC**	0.00	7.98	5.56	7.54	12.26	16.34	14.73	64.41
5	**TOTAL COST INCLUDING IDC & FC**	**0.00**	**49.44**	**14.02**	**24.79**	**56.26**	**61.22**	**33.04**	**238.77**
6	MEANS OF FINANCING								
a)	EQUITY (As per Annexure 24.4,Sheet 3)	0.00	7.42	2.10	3.72	8.44	9.18	4.96	35.82
b)	LOAN AMOUNT (As per Annexure 24.4,Sheet 3)	0.00	42.02	11.92	21.07	47.82	52.04	28.08	202.95
	Cumulative loan amount	*0.00*	42.02	53.94	75.01	122.83	174.87	202.95	
7	**Details of IDC & FC**								
a)	Interest during construction-IDC @ 8%p.a.	0.00	1.68	3.84	5.16	7.91	11.91	12.41	42.91
b)	Financing Charges								
i)	Management fee @ 1.00% flat on total loan amount		2.03						2.03
ii)	Exposure fees payable to ECAs @ 8%		3.36	0.95	1.69	3.83	4.16	2.25	16.24
iii)	Management fee @ 1.05% of DPG amount		0.00						0.00
iv)	Commitment fee @ 0.50% of the undrawn amount of loan		0.91	0.77	0.69	0.52	0.27	0.07	3.23
v)	Guarantee commission payable for DPG @ 3.50% p.a. on outstanding principal amount		0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sub-total (Total of IDC and Financing Charges)	0.00	7.98	5.56	7.54	12.26	16.34	14.73	64.41
8	TOTAL LOAN COMPONENT INCLUDING IDC & FINANCING CHARGES	**0.00**	**42.02**	**11.92**	**21.07**	**47.82**	**52.04**	**28.08**	**202.95**

Annexure 24.4
(Sheet 3)

KARCHAM WANGTOO HYDRO-ELECTRIC PROJECT (1000 MW)

SUMMARY OF COMPLETION COST OF PROJECT AND MEANS OF FINANCING

Rs. in Crores

S. No.	Particulars	YEAR-0	YEAR-1 Nov. 2002 Oct.2003	YEAR-2 Nov. 2003 - Oct.2004	YEAR-3 Nov. 2004 - Oct.2005	YEAR-4 Nov. 2005 -	YEAR-5 Nov. 2006 - Oct.2007	YEAR-6 Nov. 2007 Oct.2008	TOTAL
1	2	3	4	5	6	7	8	9	10
1	***Completion Cost of Project***								
a)	Cost of Civil Works & E&M Works (INR Component) including IDC & FC [As per S.No. 5 of Annexure 24.4 (Sheet 1)]	0.00	1265.79	589.58	903.09	1402.70	1423.85	1252.35	6837.36
b)	Cost of E&M Works (FC Component) including IDC & FC. (Equivalent Rs in crores @43.5=1US$)	0.00	215.06	60.99	107.84	244.73	266.31	143.72	1038.65
	Cost of E&M Works in US $ Million	0.00	49.44	14.02	24.79	56.26	61.22	33.04	238.77
	[As per S.No. 5 of Annexure 24.4 (sheet 2)]								
	Total Cost Completion (a+b)	**0.00**	**1480.85**	**650.57**	**1010.93**	**1647.43**	**1690.16**	**1396.07**	**7876.01**
2	***Means of Financing***								
a)	Equity @30% of the total completion cost of project as per (1) ab	0.00	444.26	195.17	303.28	494.23	507.05	418.82	2362.81
b)	Loans:								
i)	Rupee Loans	0.00	853.81	403.55	615.99	945.18	956.73	855.11	4630.37
ii)	FC Loans@ 85% of total cost of E&M works (FC Component) as per 1(b) above. In equiv.Rs.Crores	0.00	182.79	51.85	91.65	208.02	226.37	122.15	882.83
	FC Loans in US $ Millions	0.00	42.02	11.92	21.07	47.82	52.04	28.08	202.95
	Total loans @ 70% of total completion cost of project as per (1) above	0.00	1036.60	455.40	707.64	1153.20	1183.10	977.26	5513.20
	Total Funding (a+b)	**0.00**	**1480.86**	**650.57**	**1010.92**	**1647.43**	**1690.15**	**1396.08**	**7876.01**

c:\rcs\excel\karcham_financial_analysis9 (escal.compound)\IDC

KARCHAM WANGTOO HYDRO-ELECTRIC PROJECT (1000 MW)

COMPUTATION OF TARIFF PER UNIT

A	Project Cost Incl. IDC&FC	Rs. 7,876.01 Cr.	D	Primary/Design Energy:	4,228.50 MU
B	Equity Component	Rs. 2,362.81 Cr.	D1	Net Primary Energy for first 12 years.(after 12% free supply)	3,684.00 MU
C	LOAN Component:		D2	Net Primary Energy for next 28 years.(after 18% free supply)	3,433.00 MU
C1	Rupee Loans	Rs. 4,630.37 Cr.	E	Secondry Energy:	422.00 MU
C2	Foreign Currency Loans	Rs. 882.83 Cr.	E1	Net Secondry Energy for first 12 years (after 12% free supply)	367.00 MU
	TOTAL LOANS (Equivelent Rupees)	RS. 5,513.20 Cr.	E2	Net Secondry Energy for next 28 years (after 18% free supply)	342.00 MU

Rs.in Crores

S.No.	Particulars	1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year	7th Year	8th Year	9th Year	10th Year	11th Year	12th Year	13th Year	14th Year	15th Year
1	*Loans:*															
a)	Outstanding Rupee Loan Amount at the beginning of the year	4,630.37	4,244.51	3,858.64	3,472.78	3,086.91	2,701.05	2,315.19	1,929.32	1,543.46	1,157.59	771.73	385.86	0.00	0.00	0.00
b)	Outstanding Foreign Currency Loan at the beginning of the year	882.83	809.26	735.69	662.12	588.55	514.98	441.42	367.85	294.28	220.71	147.14	73.57	0.00	0.00	0.00
2.	***Interest on Loan Component during the year***															
a)	Interest on Rupee Loans *16.50%*	764.01	700.34	636.68	573.01	509.34	445.67	382.01	318.34	254.67	191.00	127.34	63.67	0.00	0.00	0.00
b)	Interest on Foreign Currency Loans *8%*	70.63	64.74	58.86	52.97	47.08	41.20	35.31	29.43	23.54	17.66	11.77	5.89	0.00	0.00	0.00
c)	Guarantee Commission on DPG *3.50%*	30.90	28.32	25.75	23.17	20.60	18.02	15.45	12.87	10.30	7.72	5.15	2.57	0.00	0.00	0.00
3.	***Advance against Depreciation/Depreciation*** (1/12 of Loan amt. or 4% of 'A')	459.43	459.43	459.43	459.43	459.43	459.43	459.43	459.43	459.43	459.43	459.43	459.43	315.04	315.04	315.04
4.	**Total Capacity Charges ('2'+'3')**	**1,324.97**	**1,252.83**	**1,180.72**	**1,108.58**	**1,036.45**	**964.32**	**892.20**	**820.07**	**747.94**	**675.81**	**603.69**	**531.56**	**315.04**	**315.04**	**315.04**
5.	O & M expenses @1.5% of 'A'. *1.50%*	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14
6.	Return on Equity @ 16% of 'B'	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05
7.	Interest on working capital 0.175 x [('4+9+11+15)/6 +5/12]	60.64	58.47	56.29	54.12	51.95	56.09	53.89	51.68	49.47	47.27	49.36	47.13	37.56	37.56	37.56
8	Provision For Income Tax (Appendix 'A')	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*190.67*	*189.72*	*188.77*	*187.82*	*186.87*	*315.48*	*313.87*	*221.87*	*221.87*	*221.87*
9	**Total Energy Charges ('5'+'6'+'7'+'8')**	***556.83***	***554.66***	***552.48***	***550.31***	***548.14***	***742.95***	***739.80***	***736.64***	***733.48***	***730.33***	***861.03***	***857.19***	***755.62***	***755.62***	***755.62***
10	**Energy charges per unit of Primary Energy: (9/D1 x 10) for first 12 years and (9 / D20 x 10) for next 28 years.**	*1.51*	*1.51*	*1.50*	*1.49*	*1.49*	*2.02*	*2.01*	*2.00*	*1.99*	*1.98*	*2.34*	*2.33*	*2.20*	*2.20*	*2.20*
11	**Incentive for Secondary Energy: (10 x E1 / 10) for first 12Years and (10 x E2 / 10) for next 28 Years.**	*55.42*	*55.42*	*55.05*	*54.68*	*54.68*	*74.13*	*73.77*	*73.40*	*73.03*	*72.67*	*85.88*	*85.51*	*75.24*	*75.24*	*75.24*
12	Effective Tariff for Total Energy (in Rs./kwh){(4+9+11) / D1+E1)x10 for first 12 years and (4+9+11) / D2 + E2 x 10 for next 28 years	4.78	4.60	4.41	4.23	4.05	4.40	4.21	4.02	3.84	3.65	3.83	3.64	3.04	3.04	3.04
13	**Average Effective Tariff for Total Energy**		Average Tariff for 1st FIVE Years =			Rs.4.41		Average Tariff for 1st TEN Years =			Rs.4.22		Average Tariff for FIFTEEN Years =			Rs.3.92
14	**Levelised Tariff at 12% rate of discounting**	4.27	4.06	3.83	3.62	3.41	3.63	3.40	3.18	2.96	2.74	2.79	2.57	2.07	2.00	1.92
15	**Incentive for higher plant Availability @ 3.5% of Return on Equity.**	82.70	82.70	82.70	82.70	82.70	82.70	82.70	82.70	82.70	82.70	82.70	82.70	82.70	82.70	82.70

Notes:

1) *NET Energy is after deduction of: (a) Unit auxiliary consumption @ 0.5%, (b) Transformation Losses @ 0.5%; and (c) Free Power @ 12% for first 12 years and @ 18% for remainder 28 years*

2) *Generation of electricity shall start from 2008. It is difficult to estimate escalation rate from 2008 onwards at this stage and, therefore, no escalation has been considered on O&M expenses for tariff calculations at present*

3) *Incentives for availabilty/secondary energy have not been.considerred in the above calculations.*

KARCHAM WANGTOO HYDRO-ELECTRIC PROJECT (1000 MW)

COMPUTATION OF TARIFF PER UNIT

A	Project Cost Incl. IDC&FC	Rs.	7,876.01	Cr.
B	Equity Component	Rs.	2,362.81	Cr.
C	LOAN Component:			
C1	Rupee Loans	Rs.	4,630.37	Cr.
C2	Foreign Currency Loans	Rs.	882.83	Cr.
	TOTAL LOANS (Equivelent Rupees)	RS.	5,513.20	Cr.

D	Primary/Design Energy:	4,228.50	MU
D1	Net Primary Energy for first 12 years.(after 12% free supply)	3,684.00	MU
D2	Net Primary Energy for next 28 years.(after 18% free supply)	3,433.00	MU
E	Secondry Energy:	422.00	MU
E1	Net Secondry Energy for first 12 years (after 12% free supply)	367.00	MU
E2	Net Secondry Energy for next 28 years (after 18% free supply)	342.00	MU

Rs.in Crores

S.No.	Particulars		16th Year	17th Year	18th Year	19th Year	20th Year	21st Year	22nd Year	23rd Year	24th Year	25th Year	26th Year	27th Year	28th Year	29th Year	30th Year
1	*Loans:*																
a)	Outstanding Rupee Loan Amount at the beginning of the year		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
b)	Outstanding Foreign Currency Loan at the beginning of the year		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.	*Interest on Loan Component during the year*																
a)	Interest on Rupee Loans	*16.50%*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
b)	Interest on Foreign Currency Loans	*8%*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
c)	Guarantee Commission on DPG	*3.50%*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.	***Advance against Depreciation/Depreciation*** (1/12 of Loan amt. or 4% of 'A')		315.04	315.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.	**Total Capacity Charges ('2'+'3')**		**315.04**	**315.09**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
5.	O & M expenses @1.5% of 'A'	*1.50%*	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14
6.	Return on Equity @ 16% of 'B'		378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05
7.	Interest on working capital 0.175 x [('4+9+11+15)/6 +5/12]		37.56	37.56	21.53	21.53	21.53	22.02	28.56	28.56	28.56	28.56	28.56	28.56	28.56	28.56	28.56
8	Provision For Income Tax (Appendix 'A')		*221.87*	*221.91*	*24.65*	*24.65*	*24.65*	*39.47*	*236.66*	*236.66*	*236.66*	*236.66*	*236.66*	*236.66*	*236.66*	*236.66*	*236.66*
9.	**Total Energy Charges ('5'+'6'+'7'+'8')**		***755.62***	***755.66***	***542.37***	***542.37***	***542.37***	***557.68***	***761.41***	***761.41***	***761.41***	***761.41***	***761.41***	***761.41***	***761.41***	***761.41***	***761.41***
10	**Energy charges per unit of Primary Energy: (9/D1 x 10) for first 12 years and (9 / D20 x 10) for next 28 years.**		*2.20*	*2.20*	*1.58*	*1.58*	*1.58*	*1.62*	*2.22*	*2.22*	*2.22*	*2.22*	*2.22*	*2.22*	*2.22*	*2.22*	*2.22*
11	**Incentive for Secondary Energy: (10 x E1 / 10) for first 12Years and (10 x E2 / 10) for next 28 Years.**		*75.24*	*75.24*	*54.04*	*54.04*	*54.04*	*55.40*	*75.92*	*75.92*	*75.92*	*75.92*	*75.92*	*75.92*	*75.92*	*75.92*	*75.92*
12	Effective Tariff for Total Energy (in Rs./kwh)(('4+9+11) / D1+E1)x10 for first 12 years and (4+9+11) / D2 + E2 x 10 for next 28 years.		3.04	3.04	1.58	1.58	1.58	1.62	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22
13	**Average Effective Tariff for Total Energy**		Average Tariff for 1st TWENTY Years =				Rs.3.48	Average Tariff for 1st Twenty-Five Years =				Rs.3.20	Average Tariff for THIRTY Years =				Rs.3.04
14	**Levelised Tariff at 12% rate of discounting**		1.83	1.76	0.87	0.82	0.78	0.71	0.91	0.85	0.79	0.73	0.68	0.62	0.57	0.53	0.48
15	**Incentive for higher plant Availability @ 3.5% of Return on Equity.**		82.70	82.70	82.70	82.70	82.70	82.70	82.70	82.70	82.70	82.70	82.70	82.70	82.70	82.70	82.70

Notes:

1) *NET Energy is after deduction of: (a) Unit auxiliary consumption @ 0.5%, (b) Transformation Losses @ 0.5%; and (c) Free Power @ 12% for first 12 years and @ 18% for remainder 28 years*

2) *Generation of electricity shall start from 2008. It is difficult to estimate escalation rate from 2008 onwards at this stage and, therefore, no escalation has been considered on O&M expenses for tariff calculations at present*

3) *Incentives for availablity/secondary energy have not been considerred in the above calculations.*

Annexure 24.5

KARCHAM WANGTOO HYDRO-ELECTRIC PROJECT (1000 MW)

COMPUTATION OF TARIFF PER UNIT

A	Project Cost Incl. IDC&FC	Rs.	7,876.01 Cr.
B	Equity Component	Rs.	2,362.81 Cr.
C	LOAN Component:		
C1	Rupee Loans	Rs.	4,630.37 Cr.
C2	Foreign Currency Loans	Rs.	882.83 Cr.
	TOTAL LOANS (Equivelent Rupees)	RS.	5,513.20 Cr.

D	Primary/Design Energy:	4,228.50 MU
D1	Net Primary Energy for first 12 years.(after 12% free supply)	3,684.00 MU
D2	Net Primary Energy for next 28 years.(after 18% free supply)	3,433.00 MU
E	Secondry Energy:	422.00 MU
E1	Net Secondry Energy for first 12 years (after 12% free supply)	367.00 MU
E2	Net Secondry Energy for next 28 years (after 18% free supply)	342.00 MU

Rs.in Crores

S.No.	Particulars	31st Year	32nd Year	33rd Year	34th Year	35th Year	36th Year	37th Year	38th Year	39th Year	40th Year
1	***Loans:***										
a)	Outstanding Rupee Loan Amount at the beginning of the year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
b)	Outstanding Foreign Currency Loan at the beginning of the year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.	***Interest on Loan Component during the year***										
a)	Interest on Rupee Loans *16.50%*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
b)	Interest on Foreign Currency Loans *8%*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
c)	Guarantee Commission on DPG *3.50%*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.	***Advance against Depreciation/Depreciation*** (1/12 of Loan amt. or 4% of 'A')	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.	**Total Capacity Charges ('2'+'3')**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
5.	O & M expenses @1.5% of 'A'. *1.50%*	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14
6.	Return on Equity @ 16% of 'B'	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05	378.05
7.	Interest on working capital 0.175 x [('4+9+11+15)/6 +5/12]	28.56	28.56	28.56	28.56	28.56	28.56	28.56	28.56	28.56	28.56
8	Provision For Income Tax (Appendix 'A')	*236.66*	*236.66*	*236.66*	*236.66*	*236.66*	*236.66*	*236.66*	*236.66*	*236.66*	*236.66*
9	**Total Energy Charges ('5'+'6'+'7'+'8')**	***761.41***	***761.41***	***761.41***	***761.41***	***761.41***	***761.41***	***761.41***	***761.41***	***761.41***	***761.41***
10	**Energy charges per unit of Primary Energy: (9/D1 x 10) for first 12 years and (9 / D20 x 10) for next 28 years.**	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22
11	**Incentive for Secondary Energy: (10 x E1 / 10) for first 12Years and (10 x E2 / 10) for next 28 Years.**	*75.92*	*75.92*	*75.92*	*75.92*	*75.92*	*75.92*	*75.92*	*75.92*	*75.92*	*75.92*
12	Effective Tariff for Total Energy (in Rs./kwh){(4+9+11) / D1+E1)x10 for first 12 years and (4+9+11) / D2 + E2 x 10 for next 28 years.	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22
13	**Average Effective Tariff for Total Energy**		**Average Tariff for 1st Thirty-Five Years =**			**Rs.2.92**		**Average Tariff for FORTY Years =**			**Rs.2.84**
14	**Levelised Tariff at 12% rate of discounting**	**0.44**	**0.40**	**0.37**	**0.33**	**0.30**	**0.27**	**0.25**	**0.22**	**0.20**	**0.18**
15	**Incentive for higher plant Availability @ 3.5% of Return on Equity.**	**82.70**	**82.70**	**82.70**	**82.70**	**82.70**	**82.70**	**82.70**	**82.70**	**82.70**	**82.70**

Notes:

1) *NET Energy is after deduction of: (a) Unit auxiliary consumption @ 0.5%, (b) Transformation Losses @ 0.5%; and (c) Free Power @ 12% for first 12 years and @ 18% for remainder 28 years*

2) *Generation of electricity shell start from 2008. It is difficult to estimate escalation rate from 2008 onwerds at this stage end, therefore, no escalation has been considered on O&M expenses for tariff calculations at present*

3) *Incentives for availabilty/secondary energy have not been considerred in the above calculations.*

c:\rns\excel\karcham_financial_analysis9 (excel.compound)\Tariff

KARCHAM WANGTOO HYDRO-ELECTRIC PROJECT (1000 MW)

CALCULATION OF INCOME TAX

S.No.		Particulars	1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year	7th Year	8th Year	9th Year	10th Year	11th Year	12th Year	13th Year	14th Year	15th Year
1		Revenue															
	a.	Total Capacity Charges	1,324.97	1,252.83	1,180.72	1,108.58	1,036.45	964.32	892.20	820.07	747.94	675.81	603.69	531.56	315.04	315.04	315.04
	b.	Total Energy Charges	556.83	554.66	552.48	550.31	548.14	742.95	739.80	738.64	733.48	730.33	861.03	857.19	755.62	755.62	755.62
		Total Revenue	**1,881.80**	**1,807.49**	**1,733.20**	**1,658.89**	**1,584.59**	**1,707.27**	**1,632.00**	**1,558.71**	**1,481.42**	**1,406.14**	**1,464.72**	**1,388.75**	**1,070.66**	**1,070.66**	**1,070.66**
2		Expenditure															
	a.	O & M Expenses	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14
	b.	Interest on Term Loans	834.64	765.08	695.54	625.98	556.42	486.87	417.32	347.77	278.21	208.66	139.11	69.56	0.00	0.00	0.00
	c.	Interest on Working Capital	60.64	58.47	56.29	54.12	51.95	56.09	53.69	51.68	49.47	47.27	49.36	47.13	37.56	37.56	37.56
	d.	Depreciation @ 4.30 % on SLM	338.67	338.67	338.67	338.67	338.67	338.67	338.67	338.67	338.67	338.67	338.67	338.67	338.67	338.67	338.67
		Total Expenditure	**1,352.09**	**1,280.36**	**1,208.64**	**1,136.91**	**1,065.18**	**999.77**	**928.02**	**856.26**	**784.49**	**712.74**	**645.28**	**573.50**	**494.37**	**494.37**	**494.37**
3		Profit before tax (1-2)	529.71	527.13	524.56	521.98	519.41	707.50	703.98	700.45	696.93	693.40	819.44	815.25	576.29	576.29	576.29
4		Benefits u/s 80 IA															
		Exemption	1.00	1.00	1.00	1.00	1.00	0.30	0.30	0.30	0.30	0.30	0.00	0.00	0.00	0.00	0.00
		Exempted Profits	529.71	527.13	524.56	521.98	519.41	212.25	211.19	210.14	209.08	208.02	0.00	0.00	0.00	0.00	0.00
5		Taxable Income (3-4)	0.00	0.00	0.00	0.00	0.00	495.25	492.79	490.31	487.85	485.38	819.44	815.25	576.29	576.29	576.29
6		TAX @ 35%+Surcharge @ 10% = 38.50%	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**190.67**	**189.72**	**188.77**	**187.82**	**186.87**	**315.48**	**313.87**	**221.87**	**221.87**	**221.87**

c:\rca\exca\karcham_financial_analysis9 (local compound)\Tax

Appendix A

KARCHAM WANGTOO HYDRO-ELECTRIC PROJECT (1000 MW)

CALCULATION OF INCOME TAX

S.No.		Particulars	16th Year	17th Year	18th Year	19th Year	20th Year	21st Year	22nd Year	23rd Year	24th Year	25th Year	26th Year	27th Year	28th Year	29th Year	30th Year
1		Revenue															
	a.	Total Capacity Charges	315.04	315.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	b.	Total Energy Charges	755.62	755.66	542.37	542.37	542.37	557.68	761.41	761.41	761.41	761.41	761.41	761.41	761.41	761.41	761.41
		Total Revenue	**1,070.66**	**1,070.75**	**542.37**	**542.37**	**542.37**	**557.66**	**761.41**	**761.41**	**761.41**	**761.41**	**761.41**	**761.41**	**761.41**	**761.41**	**761.41**
2		Expenditure															
	a.	O & M Expenses	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14
	b.	Interest on Term Loans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	c.	Interest on Working Capital	37.56	37.56	21.53	21.53	21.53	22.02	28.56	28.56	28.56	28.56	28.56	28.56	28.56	28.56	28.56
	d.	Depreciation @ 4.30 % on SLM	338.67	338.67	338.67	338.67	338.67	315.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Total Expenditure	**494.37**	**494.37**	**478.34**	**478.34**	**478.34**	**455.17**	**146.70**	**146.70**	**146.70**	**146.70**	**146.70**	**146.70**	**146.70**	**146.70**	**146.70**
3		Profit before tax (1-2)	576.29	576.38	64.03	64.03	64.03	102.51	614.71	614.71	614.71	614.71	614.71	614.71	614.71	614.71	614.71
4		**Benefits u/s 80 IA**															
		Exemption	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Exempted Profits	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5		Taxable Income (3-4)	576.29	576.38	64.03	64.03	64.03	102.51	614.71	614.71	614.71	614.71	614.71	614.71	614.71	614.71	614.71
6		**TAX @ 35%+Surcharge @ 10% = 38.50%**	**221.87**	**221.91**	**24.65**	**24.65**	**24.65**	**39.47**	**236.66**	**236.66**	**236.66**	**236.66**	**236.66**	**236.66**	**236.66**	**236.66**	**236.66**

c:\vcs\excel\karcham_financial_analysis9 (excel compound)\Tax

Appendix A

KARCHAM WANGTOO HYDRO-ELECTRIC PROJECT (1000 MW)

CALCULATION OF INCOME TAX

S.No.		Particulars	31st Year	32nd Year	33rd Year	34th Year	35th Year	36th Year	37th Year	38th Year	39th Year	40th Year
1		Revenue										
	a.	Total Capacity Charges	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	b.	Total Energy Charges	761.41	761.41	761.41	761.41	761.41	761.41	761.41	761.41	761.41	761.41
		Total Revenue	**761.41**	**761.41**	**761.41**	**761.41**	**761.41**	**761.41**	**761.41**	**761.41**	**761.41**	**761.41**
2		Expenditure										
	a.	O & M Expenses	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14	118.14
	b.	Interest on Term Loans	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
	c.	Interest on Working Capital	*28.56*	*28.56*	*28.56*	*28.56*	*28.56*	*28.56*	*28.56*	*28.56*	*28.56*	*28.56*
	d.	Depreciation @ 4.30 % on SLM	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
		Total Expenditure	**146.70**	**146.70**	**146.70**	**146.70**	**146.70**	**146.70**	**146.70**	**146.70**	**146.70**	**146.70**
3		Profit before tax (1-2)	*614.71*	*614.71*	*614.71*	*614.71*	*614.71*	*614.71*	*614.71*	*614.71*	*614.71*	*614.71*
4		**Benefits u/s 80 IA**										
		Exemption	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Exempted Profits	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5		Taxable Income (3-4)	614.71	614.71	614.71	614.71	614.71	614.71	614.71	614.71	614.71	614.71
6		**TAX @ 35%+Surcharge @ 10% = 38.50%**	**236.66**	**236.66**	**236.66**	**236.66**	**236.66**	**236.66**	**236.66**	**236.66**	**236.66**	**236.66**

c:\...\karcham_financial_analysis9 (excel compound)\Tax