ANNEXURE 12 B

SEW RHO POWER CORPORATION LTD.

Rho Hydroelectric Project (93 MW)

DETAILED PROJECT REPORT

EXECUTIVE SUMMARY

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Business Associate

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Date............

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SNC·LAVALIN
Engineering India

Power Division

169114-40ER-0003-00

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EXECUTIVE SUMMARY

VOLUME I	:	MAIN REPORT
VOLUME II	:	BILL OF QUANTITIES AND COST ESTIMATION
VOLUME III	:	GEOLOGICAL AND GEOTECHNICAL STUDIES
VOLUME IV	:	DRAWINGS (CIVIL STRUCTURE, HM & EM EQUIPMENTS)
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1 INTRODUCTION

Rho hydroelectric project is proposed for development on Tawang Chu, near Rho village in Tawang district of Arunachal Pradesh. The project is envisaged as a run-of-the-river scheme. The scheme proposes to harness the available head between elevations 2240m and 2129m. The project site is accessible through NH-52 and NH 229.

As per Memorandum of Agreement (MoA) between M/s SEW Energy Ltd. and the Government of Arunachal Pradesh, concession for development of the project has been awarded to M/s SEW who intend to develop the project on Build, Own, and Operate and Transfer (BOOT) basis. M/s SEW have formed an SPV named SEW Rho Power Corporation Limited for execution of this project. SEW has entrusted the work of preparation of a detailed project report to M/s SNC-Lavalin Engineering India Pvt. Ltd. (SLEI).

2 PROJECT AREA

Tawang basin is situated in the North-Eastern river basin of India. The basin is bounded by Tibet in its north, Kameng basin on east & Brahmaputra river on its south. The Tibetan plateau is the source of some of the major rivers in the Himalayas. The river system for Nyukcharong Chu originates from Tibet in the eastern Himalayan ranges and flow towards southern direction before entering India near Shyamdling. Mago Chu originates in India and travels in a southwesterly direction before joining with Nyukcharong Chu. These two rivers combine to form the Tawang Chu, one of the major rivers in Tawang district and a right bank tributary of Brahmaputra river. Rho Hydroelectric Project is located about 1.5 km downstream of the confluence of Mago Chu and Nyukcharong Chu.

Location map of Rho hydroelectric project is shown in **Plate-1.**

2.1 Access to the project

The project is located near Jung town, in Tawang district in the state of Arunachal Pradesh, India. Project site is about 515 km from Guwahati, the commercial capital of Assam. The breakup of important locations enroute Tawang is as follows:

Guwahati - Tezpur	170 km
Tezpur - Bhalukpong	60 km
Bhalukpong - Bomdila	100 km

Bomdila - Jang	140 km
Jang - Tawang	40 km

Helicopter services from Guwahati to Tawang are presently not in operation. The nearest airport is at Guwahati and nearest railhead is at Bhalukpong (metre gauge) but is not being in operation. The nearest broad gauge rail head is at Guwahati. There is also a small airport at Tezpur. Guwahati/Nagaon are the broad gauge rail heads from where heavy equipment or construction materials are to be transported by road up to project site.

A new road is being developed from Jang along Tawang Chu and Mago Chu banks which will provide vehicular access to the project site in the near future.

2.2 General Climatic Conditions

The climate of the state is dominated by the Himalayan system characterized by wide altitudinal range.

The year can be divided into four seasons. The winter season starts from December to February, pre-monsoon season from March to May, the South-West monsoon season from June to September and post-monsoon or transition period during October and November. The state also falls in one of the heaviest rainfall zones of the country. The annual rainfall is spread over 8–9 months and varies from 1,000 mm in the higher reaches to 3,500 mm in the foothills.

2.3 Inter State / International Aspects

Tawang Chu is formed by the confluence of two rivers – Mago Chu and Nyukcharong Chu. While the full catchment of Mago Chu lies in India, the origin of Nyukcharong Chu is in the region of Tibet. These two rivers combine to form the Tawang Chu, one of the major rivers in Tawang district and a right bank tributary of Brahmaputra river. After a traverse of about 45 km in the Indian region, the river enters Bhutan and joins River Manas.

The project headwater and tail water areas both lay well within the state of Arunachal Pradesh. The project is envisaged as run-of-river scheme. As such, the project does not entail any inter-state or international aspects.

3 NEED FOR THE PROJECT

Hydro power is renewable and environmentally benign source of energy. Hydro power stations have the inherent ability for instantaneous starting, stopping and managing load variations which helps in improving reliability of the power supply system. Hydro stations are a natural choice for meeting the peak demand. The generation cost is inflation free and, in fact, reduces over time. A hydroelectric project has a long useful life extending to well over 50 years and helps in conserving scarce fossil fuels. Development of hydro power projects also provides the added advantage of opening up avenues for development of remote and backward regions of the country.

India is endowed with an enormous hydro power potential, last assessed to be about 84000 MW at 60% load factor, which translates to 148700 MW in terms of installed capacity. In addition to the above, 6782 MW of installed capacity has been assessed from small, mini and micro hydel schemes (i.e. schemes of capacity up to 25 MW).

Despite being recognized as a relatively benign and renewable source of energy, the share of hydro power in the overall generating capacity in the country has been steadily declining. The Hydro share has declined from 44% in 1970 to about 19.13% today.

Comparing the projected growth of peak power demand, energy requirement anticipated and increase in the generating capacity on the basis of new projects proposed and/or under construction/consideration during 11th Five Year Plan, it is evident that there is a dire need to provide additional power to the National Grid to meet the objective of power on demand immediately. New schemes have to be taken up immediately and implemented to derive timely benefits. The most important source of power development in the North-Eastern region is hydroelectric power located in Arunachal Pradesh and other sister states.

The power from hydro projects in the northeastern region would be in excess of the demand in the region and would have to be exported for utilization in other regions of the country through the Siliguri corridor. Presently there is no problem in the availability of transmission systems beyond the Northeastern power region for dispersal of power as the five power regions of the country are in the process of greater integration within a national grid.

Thus, implementing Rho Hydroelectric Project will not only meet the power requirement of North-East but excess power can be exported to other parts of the country where the demand is more.

4 SURVEY AND INVESTIGATIONS

As part of preparation of the DPR, detailed Topographical survey of the project area has been carried out with the objective of preparing grid maps, establishing ground control points, fixing waterway alignments and obtaining the L-section and cross sections of the river. The topographical survey was carried out by experienced personnel using Total Station instruments

A number of benchmarks in barrage area, Reservoir area, HRT area, Adit locations and powerhouse area have been put up in the project area. Detailed topographical survey covered the reservoir area, the entire head works covering the barrage, the intake and temporary diversion works, the entire water conductor system and the powerhouse areas.

Longitudinal section and several cross sections of the river were also observed in the project component areas as required for design.

In addition to the project component areas, several other areas, as identified for locating the project infrastructure and work facilities, were surveyed and topographic contour plans prepared.

4.1 Route Survey from Rail Head to Project Site

The nearest broad gauge rail head is at Guwahati in Assam. Bulk consignments would be received at Guwahati station and after unloading the rail wagons, they would be temporarily stocked in a warehouse/store shed which would be constructed near the station. From Guwahati warehouse, the consignments would be transported to the project site in trucks/trailers as required.

In order to confirm the heavy-traffic-worthiness of the road and to identify area that would require strengthening/widening, the entire route from Guwahati to Rho project site has been surveyed. The road passes via Tezpur, Balipara, Bhalukpong, Sessa, Nechiphu, Tenga, Bomdila, Dirang, Sapper, Senge, Sela Pass, Jaswantgarh and Jang. Jang is the nearest township to the project and located 505 km from Guwahati. The diversion site of the project is about 9.4km from Jang and is approachable through a new road being developed by RWD.

The adequacy of the roads to transport heavy, over-dimensioned equipment and machines has been assessed and generally found to be capable of handling the project traffic requirements. For the few places that require improvement, cost provisions have been made.

4.2 Other Investigations

In addition to the above, extensive in-situ and laboratory investigations have been carried out during the DPR preparation phase. The field investigation pertaining to geological aspects comprised comprehensive surface geological mapping and geotechnical investigations involving drilling at different project component locations. Drilling has been done in the river bed, abutments, HRT alignment and surge shaft and powerhouse area.

5 SELECTION OF ALTERNATIVES

5.1 General

To identify alternative project schemes through a combination of desk studies and detailed reconnaissance of the project area has been carried out for the most suitable option for the development of the project. Several alternatives were studied to finalize the most suitable scheme for the project included the study of left bank vs. right bank development, identification and assessment of several diversion axes, identification and assessment of different locations of the powerhouse.

5.2 Revision of Tailwater Level

Initially, the project was envisaged between El 2240m to El 2100m as per the Memorandum of Agreement between the Owner & Govt. of Arunachal Pradesh and alternative layouts were prepared for studies and optimization of the project layout. Subsequently, the Terms of Reference (ToR) accorded by Ministry of Environment and Forests (MoEF) stipulated that a 1km free stretch be available between Rho tail race and downstream project (Tawang-I HEP) reservoir tip. Tawang-I FRL being 2090m, it was observed that the free stretch available between Tawang-I reservoir and River bed level 2100m was only about 250m. Hence it was decided to shift Rho Tailrace further upstream to allow the free stretch required between the two projects. At present, Rho Tailrace is located at EL. 2129m, allowing about 965m free stretch between the tailrace and the downstream Tawang-I reservoir.

5.3 Alternative Schemes

Before the initial site reconnaissance, it was learnt that Central Water Commission (CWC) had studied the project previously and the axis identified by CWC for the diversion structure could also be located at site. However, other component locations or details envisaged by CWC for development of the project were not available. Hence it could not be studied in detail. An independent assessment of the site was carried out and alternative layouts were developed for comparison and optimization of the final project layout.

5.3.1 Alternative Diversion Site-A

This alternative was studied before the tailwater level was revised to EL. 2129m. The slope of Tawang Chu is very steep of the order of 1:25 to 1:35. Also, the river is of limited width, generally of the order of 30-40m. Hence, to have sufficient storage capacity in the reservoir for peaking purposes, a high dam would be required. From the topographic survey available, it was estimated that sufficient storage would be available if the dam was located sufficiently downstream of Murga bridge.

A suitable diversion site was identified near river bed elevation ±2135m, about 1.2 km downstream of Murga bridge. The width of the river at this location is about 30-35m. With the proposed FRL at 2240m, the height of the dam would be about 105-110m above the river bed and the powerhouse would be located near the toe of the dam. This alternative would eliminate HRT and the design discharge would be led directly to powerhouse.

This alternative became irrelevant once the tailrace was shifted from RBL 2100m to RBL 2129m due to insufficient distance from the FRL of Tawang Stage-I reservoir.

5.3.2 Alternative Diversion Site-B

In order to reduce the height of the diversion structure identified in Alternative Site-A, another site with reduced height of diversion structure was proposed to be studied. Murga bridge is located about 1.2 km upstream of identified Alternative Axis-A. No diversion site could be identified in the stretch between Axis-A and Murga bridge because of nalas joining the main river on the right bank and slide zones/ wide terraces on the left bank. Alternative Diversion Site-B was identified about 475m upstream of Murga bridge, where river bed elevation is ±2210m. This axis is about 160m downstream of the diversion axis proposed by Central Water Commission (CWC) in their earlier studies.

Considering the height of diversion structure to be about 30-35m above the river bed, this site may not be suitable for barrage as diversion structure and same will have to be designed as a dam of about 35m height above the river bed. Construction of a concrete gravity dam at this site will only be techno-economically attractive if the bedrock is encountered at a reasonable depth, the possibility of which appears to be low. Accordingly, an alternative axis further upstream, with barrage as a diversion structure was considered desirable to be explored.

5.3.3 Alternative Diversion Site-C

Keeping in view the constraints observed at the Alternative Diversion Site-B, another diversion axis was appraised. The Alternative diversion site-C identified is same as axis proposed by Central water Commission (CWC) earlier. This axis is about 160m upstream of the Alternative diversion Site-B. The width of riverbed at the site is about 60m and river bed elevation about 2216m. Since the full reservoir level for the scheme has been proposed at El 2240m, the height of diversion structure at the site would be about 24m plus freeboard above the river bed. The reservoir capacity in this alternative would not be adequate to meet the peaking requirement, but the structure could be designed as a barrage compared to a dam at Alternative axis-B.

5.3.4 Powerhouse Location - Left bank Alternative

Since the access road to the project is on the left bank, the first choice was to place the powerhouse on the left bank. The river flows in a narrow valley in the vicinity of the site proposed for powerhouse and the left bank of the river is characterized by a moderately steep slope and covered with thick slopewash deposits. Near the location where RBL is about 2114m, there is a flat terrace (about 100-150m long along the river) comprising boulders of schist, gneiss, and quartzite of variable sizes embedded in sandy silt. Rock outcrops have been observed above the road level (about EL 2190m). Rockmass at the surface is slightly weathered in nature. Landslides are present on both the upstream and downstream ends of this terrace. The site could be considered to locate an underground powerhouse considering the rock exposures above the road level. However locating the portals of the Main Access Tunnel (MAT) and construction adits near the river elevation and their subsequent protection from landslides from above could pose serious problems.

5.3.5 Powerhouse Location - Right Bank Alternative

The powerhouse on the right bank has been envisaged on the right bank about 1.2km downstream of the Murga Bridge. The right bank of the river is characterized by steep slopes and bedrock is extensively exposed from river bed to a height of over 300m at many locations. The topography is characterized by alternating ridges and nalas. One dry gully meets the river at El 2130m and a nala further upstream joins the river at El 2170m. The ridge between these nallahs and a shallow gorge seems ideal to place an underground powerhouse. Rho village is situated on the right bank of river Tawang Chu at higher elevation and upstream of the proposed powerhouse. There exists a road at higher elevation connecting Rho and Jangda villages tó Tawang. Rockmass in this area comprises quartzitic gneiss, granitic gneiss, with occasionally thin band of schist, which is traversed by three joint sets. This site appears to be suitable to locate an underground powerhouse. Since the right bank of the river rises steeply above the riverbed, it may not be possible to locate open to sky surge shaft if adequate lateral and top cover has to be provided around the proposed powerhouse cavern hence same may have to be located underground.

5.3.6 Headrace Tunnel

The river Tawang Chu in general flows in southwest direction in the vicinity of the project with a slight convex turn on the right bank. Hence a right bank scheme would have a slightly longer headrace tunnel compared to a left bank alternative. However, the difference in length would be negligible. There are various nalas joining the river from both banks. However the right bank nalas are very steep and would not pose much problem in the Headrace tunnel passing underneath. It is also evident from the traverses that the right bank is much more competent with exposed rock throughout the length of the water conductor system.

5.4 Selection of Layout

The access road to the project site is located on the left bank of the river giving an infrastructural advantage for conceiving the scheme on the left bank. However, considering the geology at the diversion as well as the powerhouse sites, a right bank scheme appears more attractive. It is observed that both the river banks are dissected by various tributary nallahs but the right bank nallahs are very steep and would not pose much problem in the Headrace tunnel passing underneath. On the other hand, many slide zones have been identified on the left bank at the powerhouse area. It is clearly evinced that the right bank is much more competent with exposed rock throughout the length of the water conductor system. It may also be added that locating the intake structure on the right bank would not pose any problems whereas an intake structure on the left bank may not be founded on good rock.

The reservoir capacity at both the alternative diversion sites B & C would not be adequate to meet the peaking requirements. Barrage Axis at Alternative site-C being located 160m upstream of Dam Axis Alternative Site-B, its reservoir would be slightly smaller as compared to Site-B; however the diversion structure at Site-C could be designed as a barrage which will be significantly less costly compared to a dam at Site-B founded about 45m± below the river bed. Hence, it is proposed that the Alternative diversion site-C be considered in planning the layout of the project. The headrace tunnel in this case would be about 1552m long and located on the right bank of the river. Thus the finally selected layout envisages a diversion barrage at Site C, intake structure on the right bank immediately upstream of proposed barrage axis followed by water conductor system on the right bank and an underground powerhouse downstream of Rho village on the right bank.

6 ENVIRONMENT AND ECOLOGY

The details on forest types and forest cover in the catchment area were based on field surveys in the area supplemented with the Forest Working Plans falling in the study area. Pines represent the tree layer. Shrub layer is poorly developed. No other tree species occur in the top canopy.

The study area is quite rich in wild life point of view. About six wild animals recorded during the primary survey by their direct sighting as well as presence of their evidence in the area. A large portion of avifauna species is comprised of resident birds in the project study area. During the survey, 19 species were directly sighted in their natural habitat composed by small bushy vegetation, bare stone grounds and nearby the human habitation.

The acquisition of land for various project activities would also lead to removal of vegetation on these lands. Most of the environmental impacts of construction works are temporary in nature, rarely lasting beyond the construction period. Prima facie no site of archaeological and religious importance is getting affected due to the project.

The project would also envisage construction of temporary and permanent residential areas to accommodate labour and staff engaged. This may result in the production of domestic waste, human excreta, which if discharged into the river directly could affect the quality of river water. Proper waste management plan (solid and liquid) may therefore require implementing to mitigate effect of waste on aquatic environment.

With the construction of the barrage, powerhouse, colonies and other infrastructural facilities in the area, the air quality will be affected to some extent, at least during the period of construction. The movement of equipment and load carriers may also add to the obnoxious gases into the atmosphere. However, it will be temporary in nature.

Based on the environmental baseline conditions, planned project activities and impacts assessed earlier, Environmental Management Plan (EMP) has been formulated enumerating the set of measures to be adopted to minimize the adverse impacts. The most reliable way to ensure the implementation of EMP is to integrate the management measures in the overall project planning, designing, construction and operation phases.

7 PROJECT HYDROLOGY

Detailed assessment of project hydrology has been carried out to

- Assess the availability of water for power generation by establishing a series of average 10-daily discharges at the project site;
- Establish design flood;
- Establish the diversion flood

7.1 Catchment Characteristics

The Tibetan plateau is the source of some of the major rivers in the Himalayas. The river system for Nyukcharong Chu originates from Tibet in the eastern Himalayan ranges and flow towards southern direction before entering India near Shyamdling. Mago Chu originates in India and travels in a southwesterly direction before joining with Nyukcharong Chu. These two rivers combine to form the Tawang Chu, one of the major rivers in Tawang district and a right bank tributary of Brahmaputra river. The length of Nyukcharong Chu upto its confluence with Mago Chu is 93km and that of Mago Chu upto its confluence with Nyukcharong Chu is 48km. Both limbs of the river originate at about EL.6500 m. The average slope of the river in the vicinity of the diversion site is about 1:23. The catchment area upto the proposed diversion site is 2893 km^2.

7.2 Water Availability Study

The various G&D stations in and around Rho Project and period of data availability is shown in the following **Table-1**.

Table-1: Discharge Data Availability

G & D Site	River	Type	Catchment Area	Data Availability	Remarks
800m D/s of China Bridge	Nyukcharong Chu	10-daily	2040 km^2	Jan 1999-July 2008	With some gaps
Mago Chu	Mago Chu	10-daily	845 km^2	Apr 2002-March 2008	
Murga Bridge	Tawang Chu	10-daily	2910 km^2	Nov 1998-May 2008	
Yusum	Tawang Chu	10-daily	3397km^2	June 2001-Mar 2008	With some gaps
Uzorong	Gongri Chu	10-daily	9164 km^2,	Mar 1992-Dec 2007	

It may be noted that the G&D sites on Mago Chu and Nyukcharong Chu are located upstream of Rho diversion site. Also Murga bridge G&D site is located just about 1.2 km downstream of Rho diversion site and Yusum G&D site is located about 18 km further downstream. Thus reasonable networks of G&D sites are available to assess the inflow at Rho diversion site.

Murga bridge is just downstream of the Rho diversion site. Therefore the catchment characteristics at these two sites would be similar to each other and again there is practically no difference in the catchment area between these two sides (only 0.6%). Hence it is proposed to transpose the flow series from Murga Bridge to Rho diversion site in Catchment area proportion basis (1999-2008) and extended (1992-1999) using observed data at Uzorong based on correlation of concurrent flows of Murga bridge and Uzorong.

The reconstructed flow series stands approved by CEA vide their letter no **CWC U.O.No. 4/365/2011-Hyd (NE)/393 dated 23/09/11.**

7.3 Design Floods

Design flood computations are done using hydro-meteorological approach. Relevant Indian Standards have been used to arrive at design flood values for the spillways as well as temporary river diversion works. Design storm depth for the project has been assessed and supplied by Indian Meteorological Department (IMD), New Delhi.

The spillway design flood for barrage is established to be the SPF with glof which is computed by convoluting the SPS on the unit hydrograph. The SPF for the project is estimated to 3904 cumec & glof value is 1406 cumec. Combined flow for SPF with glof is about 5310cumecs & same is adopted for spillway water way design.

The diversion flood for the project has been estimated using observed daily peak data at Yusum and Uzorong G&D site.

7.4 Sedimentation

The sedimentation studies for run-of-the-river scheme is neither warranted technically nor required by virtue of having nil deposition of sediment at diversion site due to occasional flushing because of having rational mechanism for this activity. As such no storage is planned behind the diversion structure at Rho project i.e., the ratio of storage vs. mean annual inflow at the barrage site is negligible. Therefore, reservoir sedimentation studies have not been carried out in Rho HEP.

8 POWER POTENTIAL & INSTALLED CAPACITY

Project's hydrological assessment has been completed and the water availability series at the intake site has been developed. The present study entails assessment of the power potential of the project through detailed calculation of energy for various possible installed capacities. Optimization of the installed capacity is done based on analysis of incremental energy with increase in unit installed capacity. The energy calculations and optimization studies are carried out to arrive at the most suitable installed capacity.

As a first step, the 90% and 50% dependable years are determined from the derived flow series. Method recommended by CEA in their Manual on Best Practices in Hydro Power Engineering has been used to this effect. As per this manual, the 90% dependable year is defined as the year in which the annual generation has the probability of being equal to or higher than 90% during the expected period of operation of the scheme.

Based on the above, year 2001-02 and year 1997-98 have been, respectively, determined as the 90% and 50% dependable years.

Conforming to the environmental requirements, a nominal riparian or ecological flow is considered for release into the river at all times. In view of the EAC recommendations in other projects, 20% of the average flows during June - September of 90% dependable year has been considered as environmental flow during monsoon season and 20% of average flow from December - March of 90% dependable year has been considered for the remaining period.

The gross head was computed based on the following reservoir levels

Full reservoir level	=	2240m
Minimum drawdown level	=	2232 m
Normal tail water level (all units running)	=	2134.70 m (at Collection Gallery)
Min tail water level (one unit at 10% load)	=	2129.50 m (at Collection Gallery)

It is proposed to maintain the reservoir at FRL during monsoon and regulate between FRL and MDDL during non-monsoon periods. With these parameters, the gross head during monsoon comes to about 105.30m and during non-monsoon; the gross head comes to about 102.63m.

Considering the head available for power generation, Francis turbines are the most suitable choice at the project. The following efficiencies applicable for Francis turbine driven generating units have been considered:

Efficiency of turbine	:	94.5%
Efficiency of generator	:	98.5%
Overall efficiency of turbine and generator	:	93.08%

Maximum head losses in the water conductor system have been calculated to be 6.30 m. Thus with above the head loss and different operating conditions, net heads have been calculated to 99.0m and 96.33m during monsoon and non-monsoon period respectively, for arriving at the installed capacity.

8.1 Optimization of Installed Capacity on the Basis of Ratio of Incremental Energy to Incremental Installed Capacity (δkWh/δkW)

In this optimization study, energy generation with different installed capacities ranging from 80 MW to 108 MW is analyzed. The energy computations are done for the 90% dependable year and the installed capacities are increased in steps of 2 MW. The ratio of incremental energy to incremental installed capacity (δkWh/δkW) as well as the incremental energy for each 2 MW change in the installed capacity are plotted.

Results indicated that δkWh/δkW starts becoming quite low as the installed capacity is increased beyond 96 MW. The incremental energy per kW increase in the installed capacity is about 1488 kWh if the installed capacity is increased from 94 MW to 96 MW but reduces to about 604 kWh above 96 MW installed capacity.

Thus, 96 MW appears to be the possible threshold beneficial values for the installed capacity for Rho H. E. P. from incremental energy consideration.

The incremental energy benefits were also studied for average flows for the discharge data available. In the case of average flows, the incremental energy per kW increase in the installed capacity is about 1968 kWh at 96 MW.

8.2 Choice of Installed Capacity

Accordingly Power potential report for 96MW installed capacity was submitted in CEA for approval. After thorough review, CEA recommended keeping dkwh/dkw about 2000 and vide their letter dated **2/ARP/38/CEA/2011-PAC/5858-59 dated 17th Sep 2012** have recommended the installed capacity of project as **93 MW** for framing the DPR. It is proposed to install 3 generating units of 31 MW each.

8.3 Determination of Installed Capacity for operating the Power Plant as a Peaking Station

As per CEA guidelines, it is recommended that a project be designed with a minimum of 3 hours peaking capability in a 24 hour period. With a design discharge of about 105.83 cumecs and minimum net river inflows after allowing the environmental flow being about 25.55 cumec in the 90% dependable year, the required storage volume would be about 435,000 cum for peaking of 1.5 hrs in a 12 hour period. Gross storage at FRL (EL. 2240) is about 411,270 cum. and at MDDL (EL. 2232m) are 160,474 cum. Thus the live storage available at Rho HEP between FRL and MDDL works out to about 250,796 cum, clearly short of the required storage. However with available live storage of Rho HEP & supplemented live storage of Nyukcharong Chu HEP & Mago Chu HEP this plant would become a peaking station. Detailed would be worked out once the upstream projects are implemented.

8.4 Design Energy

As per CERC, design energy is the energy generated in a 90% dependable year at 95% plant availability. The energy generated in the 90% and 50% dependable years with an installed capacity of 93 MW is given below.

90% Dependable year	493.97MU
50% Dependable year	476.21MU

It may be noted that the annual generation in the 50% year is marginally lesser than in the 90% dependable year. This is due to the seasonal variation in the inflows with the 50% year having high inflows in the monsoon season and relatively lesser inflows in the non-monsoon season as compared to the 90% year.

9 GEOLOGY

9.1 Regional Geology

The Rho Hydroelectric Project being conceived on Tawang Chu, a major tributary of river Manas is located within Higher Himalaya in Tawang district of Arunachal Pradesh. Arunachal Pradesh can be divided into four physiographic segments having distinct stratigraphy and structures viz. Himalayan Ranges, Mishmi Hills, Naga-Patkoi ranges, Brahmaputra plains. Out of them Himalayan Ranges in Arunachal Pradesh can again be subdivided into Tethys / Tibetan Himalaya in the north, Higher Himalaya, Lesser / Lower Himalaya and Sub Himalaya in the south. The project area is characterized by fluvio-glacial features such as terminal or lateral moraine deposits indicating that the area was snow bound in geological past. Besides, fluvial valley filled deposits formed by scree, talus, fan deposits have also been observed in the area. The landscape of Tawang valley is dotted with many landslides of which many are active. Lithostratigraphically, the rocks exposed in the area belong to Sela Group and Lumla Formation.

Geotectonically, the Project area falls in Higher Himalayas of Western Arunachal Pradesh and has rugged topography characterized by high hills and deep valleys with steep slopes. Geological mapping for the project indicates that rocks belonging to Sela Group and Lumla Formation intruded by tourmaline granite and pegmatite of Tertiary age are exposed in the area around the proposed Rho Hydroelectric Project in Tawang valley.

Figure-1: Map showing physiographic division of Arunachal Pradesh

9.2 Geology of the Project Area

Different alternative schemes were studied with diversion sites located between the river stretch just downstream of the confluence of Mago Chu and Nyukcharong Chu and about 2km downstream of Murga Bridge with FRL 2240m and TWL 2100m.

At the proposed barrage site (Alternative-C), bedrock comprising quartzitic gneiss and granitic gneiss is exposed on both abutments. However, the bedrock on the surface is slightly weathered and it requires stripping in the tune of 1-2m along the abutments beyond overburden. The rock mass is traversed by four intersecting joint sets including foliation joints, disposition of these joints need to be considered while excavating foundation and due care is necessary. The results of sub-surface investigation reveal that bedrock in the river bed in the deepest portion has been encountered at 66m depth (El 2151m) and bedrock profile is steeper on the right flank as compared to that on the left abutment. Keeping in view the morphology, results of surface geology and subsurface explorations, it has been planned to design the diversion structure on permeable strata as a 26m high and 205m long gated barrage with top at El 2242m and by providing free board of about 2m above FRL at El 2240m.

The reservoiris expected to spread over an area of 4.74ha spreading about 700m upstream of diversion barrage along river Tawang Chu. The area between FRL and MDDL (El 2232m) is occupied by slope wash deposits in most of the reaches. Further, no evidences of significant distress were observed on the valley slopes on both banks, even on overburden-covered slopes in the area around reservoir.

A 39.0m x 20.5m size intake structure with crest at El 2224.50m is proposed to be located on the right bank of the river Tawang Chu aligned nearly parallel to the flow suitable for hydraulics. The slope on the right abutment is steep and bedrock comprising quartzitic gneiss is extensively exposed on this abutment between Els 2240m and 2650m. Drill hole data at intake area shows availability of bedrock at El 2215.0m. So, the portal can be safely located by developing proper slope and supporting the cut slopes by rock bolts.

Two modified D-shaped feeder tunnels of size 5.0m x 5.0m are proposed to emerge from intake to convey 127 cumec water to desanding chambers are likely to encounter Quartzitic gneiss and granitic gneiss belonging to Sela Group of Higher Himalayan Crystallines along their lengths. The assessment of RMR from the surface geology corroborated with sub-surface data indicates that rocks belonging to Class II (good quality) are expected to be encountered in most of the length along the feeder tunnels and occasionally Class III (Fair quality) rock may be encountered in short reaches. Rocks belonging to Class IV may also be encounter at places.

Two numbers of underground desanding chambers of size 176.0m (L) x 18.8m (H) x 14.0m (W) are envisaged in removing sediments coarser than 0.25mm with the objective of conveying sediment free water to powerhouse, which is aligned in 100°-280° direction based on discontinuity data. The rock mass in the area comprises quartzitic gneiss/ granitic gneiss belonging to Sela Group of Higher Himalayan sequence. It is expected that desanding chamber will tentatively encounter rock mass belonging to Class II for about 48% of length, and Class III along 47% of its length and rock mass belonging to Classes IV for 05% of its length. A construction adits have been envisaged to access bottom of desanding chambers to facilitate construction. Tentatively it appears that this adits are likely to encounter the rock mass belonging to Class II along most of its length, and belonging to Class III for small portion of length and Class IV may encounter occasionally during excavation. Two 2.5m x 2.5m diameter, D-shaped silt flushing ducts of approximate lengths 167.7m and 113.4m have been envisaged to flush silts from desanding chambers to river. The geotechnical conditions along these tunnels are expected to be similar to those of desanding chambers.

A 6.0m diameter and about 1552m long modified horseshoe shape head race tunnel (HRT) has been envisaged on the right bank that starts from the end of link tunnel with its invert at El 2219.35m and joins surge shaft at El 2203.95m with a general gradient of 1 in 94.7.

HRT is optimised keeping in view the topography and requirement of adequate rock cover over the structure. The ground cover over HRT generally varies between 118 and 311m, which is considered adequate. The HRT route in general exposes quartzitic gneiss and granitic gneiss rockmass, which is expected to be good. From surface and subsurface geology, it is expected that HRT will pass through rock mass belonging to Class II for about 55% of length, and Class III along 40% of its length and the remaining portion i.e. 5% of its length may encounter class IV rock. As HRT could not be probed every where, therefore provision of advance probing during construction has been included in construction schedule to determine the strata condition beforehand and design support accordingly.

The proposed powerhouse complex is located on the right bank of the River Tawang Chu. It includes a 16m diameter and 54.44m high (Up to Crown) restricted orifice type underground surge shaft; 5.1m diameter and about 135.41m long pressure shaft. In addition, a transformer / GIS cavern of size 64.9m long, 12.0m wide and 22.0m high, an underground powerhouse of 95m long, 21m wide and 38.15m high with installed capacity of 93 MW and a Tail Race Tunnel (TRT) of 6.0m diameter and 248.74m long.

The surge shaft drill hole encounters bedrock of quartzitic gneiss at a depth of 7.0m corresponding to EL 2338m. The drilling data indicates that although rock mass of fair to good quality is expected all along surge shaft except between depth range of 46 and 51m i.e. elevation varying between 2299m and 2293m, where poor rock mass is expected.

The main pressure shaft would be of 5.1m diameter which at lower level will be converted to an intermediate pressure shaft of diameter 4.1m and then it will trifurcate into three unit penstocks of 2.9m diameter each to feed three units in the powerhouse. The entire pressure shaft will be steel lined. The rock mass through which pressure shaft will pass belong to classes II and III along major portion. The rock mass belonging to Class IV could be encountered in small portions.

The bedrock exposed in powerhouse complex area comprises quartzitic gneiss and granitic gneiss. Based on attitude of rock mass on surface i.e. joint orientation of the outcrops the powerhouse cavern has been oriented in 117°-297° trend, which is considered ideal.

For construction of underground powerhouse, two adits were envisaged namely one 183.64m long accessing top of powerhouse and 613.23m long MAT. From the rock outcrop, li is apprehended that the top adit will encounter good to fair rock quality (52% good and 43% fair) rock mainly and poor (Class IV) rock quality may be expected in 5% of length along the tunnel. The tentative assessment along MAT reveals that rock types of fair to good quality (Good 48%, Fair 42%) in most cases and about 10% poor rock are expected along the tunnel.

Tail Race Tunnel (TRT) of 248.7m long is aligned on the right bank of the Tawang Chu River. The portal and initial part of TRT area is covered by slope wash deposits. Based on surface and sub-surface data, it is observed that rock is not available at portal location and up to 45m length along the tunnel. A false portal will have to be developed in the overburden followed by over burden tunneling for the length till bedrock encountered. Thereafter, for about 20m length, the tunnel shall have to be designed as structural tunnel till adequate rock cover over it is available. TRT will encounter about 60% good (Class II), 25% fair (Class III) and about 15% poor to very poor (Class IV & V) quality rocks.

The project site lies in seismic zone V as per the seismic zoning map of India as incorporated in Indian Standard Criteria for Earthquake Resistant Design of Structures IS : 1893 - (Part I) 2002. Being located in high seismic area, the site-specific design parameters i.e. Peak Ground Acceleration (PGA) values have been estimated by IITR, which works out as 0.38g and 0.19g respectively for Maximum Credible Earthquake (MCE) and Design Base Earthquake (DBE) conditions and has been recommended for designing.

Appraisal of geothermal condition reveals that eight springs i.e. Schumaling, Tsona Chu, Mago Chu, Dungma, Thingbu and Tawang are located within 8.5-23.5 km from the project site. Therefore, the possibility of encountering the warm water cannot be ruled out. It is therefore recommended that measures required for countering the effects of warm water must be included in the construction plans.

10 CIVIL ENGINEERING STRUCTURES

10.1 General

Rho HEP is located on Tawang Chu, at upstream of Tawang Stage-I HEP. The project is planned as a run-of-the-river scheme. The barrage axis is located about 450m upstream of Murga bridge and the Powerhouse is located about 1.9 Km downstream of proposed barrage axis.

General layout of the project is shown in **Plate-2.**

Based on detailed topographical & geological considerations, the project headworks are proposed to be located in a narrow valley at downstream of the confluence of Mago Chu & Nyukcharong Chu. The area is readily accessible from Tawang – Jung road on left bank side. Based on topographical and geological conditions, the water conductor system is proposed on right bank of Tawang Chu.

Detailed geological mapping of the area have been carried out and extensive subsurface geological investigations have also been undertaken at head works area as well as power house complex area

10.2 Project Design Data

The following data is pertinent for layout and design of project components:

Full reservoir level (FRL)	=	2240.0m
Maximum Water Level (MWL)	=	2241.0m
Minimum draw down level (MDDL)	=	2232.0m
1 in 100 year flood	=	990.0 m^3/sec
Standard Project Flood (SPF)	=	3904.0 m^3/sec
Glof discharge	=	1406 m^3/sec
River diversion flood (1 in 25 year non-monsoon flood)	=	415 m^3/sec

10.3 Head works - Barrage and Intake

In addition to topographical and geological considerations, the following general principles are used while deciding the layout of the barrage, power intake, feeder tunnels, desanding chambers area.

- Valley is narrow at proposed diversion structure but bed rock is not available at reasonable depth for a dam-like structure. The site is suitable for barrage-like structure.
- Since Tawang river is expected to carry significant sediment during monsoons, effective management of sediment removal is necessary to protect the runner. Two

nos. underground desanding chambers are proposed for the effective removal of sediment from water.

- At the location of proposed barrage axis river has a relatively short length of straight reach (about 300m only). Just downstream of the apron, the river shows a slight curvature towards the right side. To make the flow path straight after stilling basin, some extra excavation work may be required.
- The intake should be so located that significant sediment deposit does not remain in front of the intake. However suspended sediment will pass through trash rack structure. To avoid the larger size sediment, intake structure is raised by provision of intake wall.
- The intake sill should be kept sufficiently high so that only the top, relatively sediment free, layer of water is drawn into the water conductor system. Position of the intake sill, the MDDL and the spillway crest is thus to be carefully decided. As the sediment laden water will enter through intake structure, the velocity in feeder tunnel should be sufficient to avoid the deposition of sediment in feeder tunnel itself.

General Layout of the Barrage

River bed material at the site proposed for the barrage consists of boulders, gravels/pebbles in a sandy matrix. Exploratory holes drilled at the site show bedrock at about 60 m below the river bed level. For dam-like structure, rock should be available at reasonable depth. A concrete barrage founded on RBM is, therefore, considered a natural choice for the diversion structure.

The barrage axis is placed perpendicular to the direction of flow. Lateral positioning of the barrage is done in such a manner that the construction of the intake & cut-and-cover duct on the right bank would require minimum excavation. Natural rock profile available on the right bank at the selected barrage axis provides for the right abutment. Sufficient width is available at the selected location do not require any extensive cutting of the rock either at the barrage site or downstream.

Given the importance of barrage at Rho HEP it is considered prudent to use 1 in 100 year flood as the design flood for the project & SPF with combination of glof, for the free board computation.

At Rho HEP diversion site, the 1 in 100 year flood is 990 cumecs and the SPF with glof is 5310 cumecs.

To avoid any deposition of sediment in the upstream of the barrage axis, the crest of all the barrage bays is proposed at the river bed level i.e. at EL 2216.0 m. The sill level of the intake crest is kept about 8.5 m above the floor of the barrage so that entry of bed load into the intake is precluded. FRL and MDDL of the barrage have been fixed at El. 2240.0m and El. 2232.0m, respectively. Keeping a free board of 1.0m (above MWL), top of the barrage is provided at El. 2242.0m. Five barrage bays are proposed, each equipped with a radial gate, 7.5m (W) x 9.5m (H). It is checked that the proposed water passage will be capable of passing 5310 cumec with all gates open condition & maximum water level of El. 2241.0m. In order to reduce the height of gates, as well as from structural consideration, breast walls have been proposed connecting the adjacent piers. Breast walls, in conjunction with downstream trunnion walls also provide additional stiffness to the structure, which ensures better performance during seismic conditions.

The reservoir level is 2240.0m & water level in downstream reach is about 2217.0 for 1 in 100 year flood of 990 m^3/sec & hence large magnitude of energy is to be dissipated after the flow passing through the gates. Downstream cistern level is sufficiently depressed to meet the requirement of sequent depth after the formation of hydraulic jump. Downstream cistern level is adjusted to form the hydraulic jump at the sloping apron with the floor level kept at El. 2209m. In order to dissipate the energy, 45m long stilling basin is provided.

River Diversion

Temporary diversion of the river would be required during construction of the barrage & intake structure. Based on project's construction planning, the construction of the barrage will be undertaken during non-monsoon periods. Since the river in the area of head works is quite wide, two phases of temporary diversion are proposed; i.e. during construction of each portion of the barrage the river will be diverted through the remaining available width.

Intake structure is located on right bank of the river. It is proposed that the two right side bays of the barrage, the intake structure, and the training walls will be constructed in the first phase. During this period, the river will keep flowing in its natural creek towards left bank and the construction area will be encircled by building a coffer dam of random rubble masonry, on the right bank. The height of coffer dam will be about 5m. In the second phase, when construction of the two right side barrage bays and the intake structure is completed, the river will be diverted along the right bank over the newly constructed bays. About 5m high coffer dam of random rubble masonry will be constructed surrounding the construction area on the left bank.

10.4 Intake Works

The intake structures are located on right bank of the river, at just upstream of the barrage at right angle to river flow direction. The intake structure sill is provided at El. 2224.5m i.e. about 8.5m above the barrage floor. The raised sill will obstruct the entry of heavy sediment particles in to intake structure. Each intake structure comprises of 4 numbers, 3.0m wide trash rack structure with 1.5m wide piers. The water is fed to two modified D-shaped feeder tunnels of size 5.0m (W) x 5.0m (H). Two gates of size 4.6m (W) x 5.0m (H) are provided at the entrance of the feeder tunnels to isolate the desanding chambers for repair & maintenance.

10.5 Feeder Tunnels

Two 5.0m (W) x 5.0m (H), modified D-shaped feeder tunnels connect the intake structure to the underground desanding chambers. The length of the two tunnels is 165.57m & 141.88m. The flow through velocity in feeder tunnels is kept about 2.75m/sec. 300mm thick concrete lining is provided.

10.6 Desanding Chambers

For effective removal of sediment, two Dufour type underground desanding chambers are provided. Considering the moderate net head of 96m, Desanding chambers are designed for the removal of particles of 0.25mm & above. To provide the flexibility & to keep the structural dimensions in reasonable limits, 14.0m wide, 176.0m long & 18.8m deep desanding chambers are proposed. A 2.5m (W) x 2.5m (H) modified D-shaped, free flow flushing tunnel is provided to carry the flushed water. At the end of the flushing duct, a separate gate operation chamber is proposed for the flushing operation.

Downstream of the desanding chambers, two link tunnels (5.0m (W) x 5.0m (H), modified D-shaped) are provided to convey water to the Headrace Tunnel.

10.7 Headrace Tunnel

The two link tunnels join to form a single Headrace Tunnel (HRT) of 1552.06m long, 6.0m diameter, modified horse shoe shaped. The size of the HRT has been finalized through an optimization study. Modified horse shoe sections are strong in their resistance to external pressure while also offering the advantage of flat base for constructional ease. The velocity in the tunnel comes out about 3.61 m/sec which is within permissible limits for a concrete lined tunnel. Concrete lining of 350mm thickness is provided to resist the external pressure.

10.8 Surge Shaft

A restricted-orifice type, underground surge tank of dia 16.0m is proposed. Required area of the tank is estimated using the Thoma criterion and the tank design is finalized through detailed transient analysis of the water conductor system. Based on the results of the transient analyses, top of surge shaft is proposed to be kept at El. 2266.39 m (Crown elevation); the top of orifice slab has been kept at El. 2211.95 m.

10.9 Pressure Shafts

For hydro projects in Himalayas, it is usually desirable that the pressure shaft(s) be steel lined. From the criteria of economic diameter calculation, a diameter of 5.1 m is proposed for the main pressure shaft. The shaft emanates from the circumference of the surge shaft with invert at El. 2203.95 m. At upstream end, as they emanate from the surge tank, the shaft is rectangular in shape and transitioned to a circular shape in a length of 5m. The pressure shaft is horizontal for a distance of about 31.0m before bending downwards. At this bend, a pressure shaft erection chamber of size 10m(W)x10m(H)x15m(L) is provided to facilitate the erection.). A straight reach of about 8.0 provided after the bend. After this point main pressure shaft bifurcates in two branches. One branch is 2.9m diameter & feeds unit-3 & other branch is 4.1m diameter which is further bifurcated in two branches of 2.9m diameter to feed Unit-1 & Unit-2. A reducer of 2.3m dia is provided just before the Main Inlet Valves.

The pressure shafts will be steel lined in the whole length. The shaft liners have been designed to withstand internal as well as external pressures. The internal pressure including water hammer has been considered at different sections. External pressure has been taken equal to the difference between water level equal to FRL and the level of the shaft sections being designed.

10.10 Powerhouse Complex

10.10.1 Powerhouse Cavern

The general arrangement the powerhouse has been developed for the installation of three vertical axis Francis turbines of 31.0 MW each. The powerhouse cavern is 95m (L) x 21.0m (W) x 38.15m (H) in size. Units are spaced at 16m c/c. The 20m long erection bay is located at the right end, while the 20m long control block is located at the left end of the machine hall cavern. The centerline of machines is set at EL 2124.10m.

The structural framework inside the machine hall and the Control block is proposed as reinforced concrete frame.

The approach to the main powerhouse cavern will be through a 613.23m long; 7mx8m modified D-shaped Main Access Tunnel. The invert elevation of MAT portal is at EL.2140.0m and it meets the erection bay at EL 2134.90m. Other construction and approach adits are provided as required.

10.10.2 Transformer Hall Cavern

The transformer hall cavern is located 30 m upstream of the machine hall and is 12 m wide. Its length is 64.9 m and height is 22 m. The structural framework inside the transformer hall is proposed as reinforced concrete frame.

Three bus duct galleries are provided between the machine hall cavern and the transformer hall cavern. The bus duct galleries connect the machine hall to the main floor of the transformer hall cavern.

10.10.3 Draft Tube Tunnels

Three unit tailrace tunnels of size 6m (W) x 3.5m (H) off take from the downstream wall of the machine hall and run parallel until they fall into the collection gallery, 30m downstream of the Powerhouse cavern.

10.10.4 Collection Gallery and Tail Race Tunnel

The collection gallery is a 50m long and 10.0m wide from EL. 2122.0 to El. 2143m & 11.8m wide from EL. 2143 to EL. 2153.95 and collects water from all the three units of the power plant. A gate control deck is provided at El. 2143m and is above HFL in the river, which is computed to be at El. 2141.8m (for SPF with glof).

The tail race tunnel is a modified horse shoe tunnel of 6.0m diameter, about 248.74 m, connecting the collection gallery to the river.

10.10.5 Cable Tunnel

The cable shaft is provided near from adit to transformer cavern to bring the cables to the pothead yard.

10.10.6 Pothead Yard

A 56m x 28m, 132 kV surface pothead yard area is proposed at EL. 2310m, just near the portal face of the cable tunnel.

11 HYDRO-MECHANICAL EQUIPMENT

Hydro-mechanical equipment at the project comprises the spillway radial gates, the intake, intake tunnel gates, silt flushing gate, desanding chamber gates, surge shaft gate, draft tube gates and the tail race outfall gates. Trash racks and trash rack cleaning machine comprise the other hydro-mechanical equipment.

Five (5) nos. of barrage radial gates of size 7500 mm wide x 9500 mm high are provided to control the discharge through the barrage. Each gate will be operated by means of twin hydraulic hoist. The sill of the gate will be located at EL 2216.0m. The Radial gate shall be designed for the head corresponding to FRL i.e. EL 2240.0 m. The design of the gates shall be checked for MWL of 2241.00m with allowable higher stresses and would operate under any water head between sill level of EL 2216.0m and MWL of EL 2241.0m.

One (1) set of sliding type stoplog is proposed to cater to the maintenance requirement of five radial gates. The stoplogs will be required to be raised and lowered under balanced head condition. The balanced head condition will be achieved with the provision of bye-pass piping & manually operated valve arrangement

The trash racks are proposed to be provided on the upstream face of the intake to prevent entry of extraneous material into the water conductor system. Trash collected on the trash rack panels during operation shall be removed by a trash rack cleaning machine.

Two (2) no. vertical lift slide type bulkhead gates and two (2) No. vertical lift wheel type intake gate of size 4.6m(W x 5.0m(H) are proposed to be provided at intake structure. The sill of the gates is located at EL 2221.50m. The gates are designed for head corresponding to FRL 2240.00m. The design of the gates will be checked for maximum water level of 2241.00m with allowable higher stresses

Two (2) nos. fixed wheel type vertical lift gates for opening size of 4600 mm x 5000 mm will be provided at desanding chamber outlet. The sill of the gates is located at EL 2220.00 m. The gates will be designed for head corresponding to FRL 2240.00 m. The design of the gates will be checked for maximum water level of 2241.00m with allowable higher stresses

Two (2) silt flushing tunnels of size 1.60 m x 2.20 m have been provided for flushing of silt in the river. It is proposed to provide one service gate and one emergency gate in each silt flushing tunnel. The gates will be of vertical lift slide type and the sill of the gates is located at EL 2203.80m.

One (1) fixed wheel type vertical lift gate for an opening size of 4000 mm x 5100 mm will be provided at the out let of surge shaft. The sill of the gate is located at El 2203.95 m. The gate is to be designed for head corresponding to FRL 2240.00 m and for self lowering against flowing water with upstream water level corresponding to FRL. The design of the gates will be checked for maximum water level of 2241.00m with allowable higher stresses

Three (3) nos. of fixed wheel vertical lift gates are proposed to cater for the maintenance and inspection requirement of turbines and their underwater components; and to prevent flooding of powerhouse from river side. The gates for opening size of 6000 mm (W) x 3500 mm (H) shall be provided.

Draft tube gates are provided with skin plate and sealing towards powerhouse side and designed for head corresponding to normal tail water level in collection gallery i.e. EL 2134.70 m.

One (1) fixed wheel type vertical lift gate for an opening size of 6.00m x 4.80m is proposed to be provided at the outfall of tailrace out to prevent flow and silt from river side during high flood.

12 ELECTROMECHANICAL EQUIPMENT

Principal electromechanical equipments of the project are located in an underground powerhouse complex situated on the right bank of the river. As mentioned earlier, project's installed capacity has been fixed at 93 MW and, correspondingly, Three (3) generating units of 31 MW each are proposed.

Francis type turbines are provided in a vertical axis configuration. The turbines are directly coupled to the generators. Butterfly type inlet valves are provided for each turbine for isolation during shutdown and maintenance.

The generators are directly connected to the step-up transformer through segregated phase bus duct. The step-up transformers are located in a separate transformer cavern adjacent to the main powerhouse cavity. GIS is located above the transformer hall. Total generated power will be routed to pothead yard through 132 kV Gas Insulated Switchgear and GIB. The power evacuation will be through 3 nos. outgoing lines to the nearest pooling station.

Principal electromechanical equipment of the project include

The following equipment shall be covered under electromechanical package:

- Main Inlet valve;
- Turbine;
- Governing system;
- Oil pressure system for governing system and main inlet valve;
- Generator;
- Excitation system;
- Segregated phase bus duct;
- Generator Step up Transformer;
- 132 kV GIB
- SF6 Gas insulated switchgear
- Outdoor pot head yard equipment;
- DC supply system;
- Digital control system and SCADA
- Protection system;
- Cabling system;
- Auxiliary AC supply system;
- Communication system;

- Illumination system;
- Electrical workshop;
- Electrical Overhead Traveling Cranes ;
- Cooling water system;
- Drainage and Dewatering system;
- HVAC system;
- Grounding system;
- Compressed air system;
- Fire Fighting system;
- Mechanical workshop;
- Oil handling System;
- DG sets;
- Elevator

Three vertical shafts Francis turbines each of rated capacity corresponding to generator output of 31 MW are provided in the powerhouse. Each turbine shall comprise of runner, shaft, spiral case, stay ring, head cover, bottom ring, a set of guide vanes & operating mechanism, guide bearing, shaft seal and draft tube etc.

Turbine shall be designed to have minimum cavitation damage. To facilitate repair and maintenance of runner, a provision shall be made to remove it from the bottom without disturbing the generator components.

Each turbine will be equipped with a main inlet valve (MIV) of butterfly valve type. The valves shall be located inside the powerhouse cavern.

Each turbine will be equipped with electro hydraulic governor of digital type and compatible with station SCADA system. The governor shall be provided with necessary controls to enable accurate speed / power regulation. The governor shall be suitable for peaking as well as base load operation.

The generators shall be vertical shaft, salient pole and semi umbrella type. The generator shall be directly coupled to the turbine shaft and rated for 34.44 MVA with 0.9 PF lag, 300 rpm, 50 Hz with an output voltage of 11.0 kV.

The static excitation system shall be matched to the field requirements of the 34.44 MVA hydro generators with 10% continuous overload capability. Excitation system shall be equipped with regulation panel, excitation transformer, field breaker, AC and DC field flashing equipment, Thyristor bridges, associated instrumentation, protection and Thyristor cooling system.

Each generating unit at the powerhouse will be directly connected to a 40MVA, 11KV/132KV OFWF generator step-up (GSU) transformer. The low voltage bushings will be directly connected to the corresponding generator through 11 kV Segregated phase bus duct system. The H.V. terminations will be connected to the SF_6 Gas Insulated Switchgear (GIS) through GIB (gas insulated bus). The GIS shall be housed above the Transformer gallery/floor.

The GIS will be double bus arrangement comprising of 3 incoming GT bays, three outgoing line bays, one SAT bay and 1 bus coupler bay. GIS outgoing bays will be connected to outdoor pothead yard equipments through gas insulated bus.

Each Generating unit shall be provided with an independent cooling water system. Cooling water requirement for each unit shall be tapped from the respective penstock upstream of the MIV.

The powerhouse will have one dewatering sump (common for all the units) and one drainage sump for the entire power house. The drainage sump and dewatering sump will be interconnected through non return valve and isolating valve with extended spindle for operation at a convenient location. The drainage and dewatering sumps will be located near the control block.

The HVAC systems maintain a healthy atmosphere and acceptable temperature levels in various areas of the powerhouse. In case of fire, these systems shall be used for both smoke exhaust and pressurization of staircases and other escape passages to permit evacuation of the operating personnel.

Air circulation shall be automatically controlled and shall not be influenced by natural air movements. Areas exposed to harmful gases or odors shall be maintained at a negative pressure. Re-circulation of the room air is not to be allowed but rather totally exhausted outside.

Water supply for fire fighting requirement will be met from an overhead water tank. The tank shall supply fire fighting water to entire areas of the powerhouse complex by gravity. The capacity of water tank will be adequate to supply water requirement for two hours.

A hydrant system shall be provided in the pothead yard, powerhouse, transformer hall, GIS gallery and other areas of the complex. The piping network shall be mainly above the ground and provided with isolating valves at strategic locations for isolation and directing water at desired locations. Layout shall be designed such that water can flow to each hydrant through at least two independent paths from the main water source (i.e. fire water tank), so that supply can be ensured even if one pipe section is cut off for maintenance purposes.

One 132T EOT crane is provided in powerhouse for handling Turbine, MIV & Generator components and transformers during erection and maintenance. One 10 MT pendant operated EOT crane shall be provided in GIS hall for handling GIS equipment.

Power Evacuation System

The transmission and power evacuation system of Rho HE Project will be designed to cater to the combined generation of all the three machines for an installed capacity of 93 MW with 10% continuous overload. For the evacuation of this power, there will be three (3) outgoing overhead transmission lines. One 132kV double circuit line to PGCIL Tawang PP- II and one 132kV single circuit line to STU

The interconnection between GIS and Pothead yard shall be through 132kV Gas Insulated Bus. SF_6 to air termination will be provided for transmission line connection. Outgoing lines shall be provided with Lightning arresters, CVTs and Wave traps.

The high voltage equipment to be placed in the outdoor switchyard will have their nominal characteristics de-rated due to the altitude exceeding 1000 m above sea level. They will be designed for a minimum 40 kA rms rated short circuit current.

The switchyard and its surrounding area will have their respective grounding system. The earthing grid will be designed and constructed for operating voltages and short-circuit capacities corresponding to short-circuit and earth-fault current levels.

The pothead yard area will also accommodate one 11 kV substation and one building to house Dg sets and pothead yard control room along with the 132 kV substation.

13 INFRASTRUCTURAL PLAN

Elaborate infrastructures works are have been planned for the construction of Rho Project. Large component sizes require extensive quantities of construction material as well as large areas for dumping of the generated muck. Sizeable dimensions of equipment, such as transformers and penstock liners, necessitate wide carriageways, which are usually difficult to lay in a hilly terrain such as in the Rho project area. Taking the above factors into consideration a comprehensive infrastructure plan has been developed.

Given their large size, both the barrage and powerhouse areas would be major hubs of construction activities throughout the implementation period of the project. However, they are located relatively close to each other (about 1.5km only). Hence a combined workshop for maintenance works of construction equipments and plants like earth moving equipment, concreting equipment, drilling equipment and transport vehicles etc. has been proposed.

Since all the work would be highly mechanized, and noting that there are no services or facilities of mechanical nature available near the project area, adequate and self sufficient repair and service facilities would be set up at the project site.

The penstock fabrication yard would be equipped with plate bending rolls, a battery of welding and gas cutting sets, hydro-testing and radiography facility, sand-blasting and painting equipment and sufficient space to stock the raw plates as well as the finished ferrules awaiting dispatch.

13.1 Aggregate and Batching Plants

A total requirement of about 2.44 lakh cum of concrete is estimated for civil works of the entire project.

The following table shows the proposed aggregate and batching plants for production of concrete to cater for the project:

S. No.	Component	Capacity	Remarks
1	APP	220 TPH	For entire project
2	BMP-1	55 m^3/hr	For Head works area
3	BMP-2	30 m^3/hr	For Powerhouse area

13.2 Project Roads and Bridges

To execute the various civil works, roads would be made for linking the work site to other sites and to job facility areas. They would be constructed at a workable gradient so that loaded construction equipment does not have to toil hard to go up slope. An average gradient of 1:15 has been contemplated. These roads would be connected to the existing roads in the area or to other project roads.

The width of the roads would be such as would be suitable for free flow of two way traffic mostly comprising of dumpers, tipper trucks, transit mixers and occasionally for loading equipment like loaders, shovels, backhoes, etc. Allowing clearances on the sides, drains and parapets, the formation width of the road works out to 7.5 m. A total of 6.25 km of road need to be constructed during construction and operation stage of the project.

Two permanent bridges are proposed to be constructed to cross the waterways falling in the alignments of the roads, one downstream of the barrage and another downstream of the powerhouse. Both these bridges shall be designed for 70R loading.

13.3 Owner's and Contractors' Colonies

The colonies of the owner as well as the contractors who would be engaged for construction of the project have been located in a manner as would suit their requirements.

13.4 Muck Disposal areas

The spoil from the various construction sites would be disposed off at designated sites in a controlled and orderly manner. All measures would be adopted to ensure that the dumping of muck does not cause injury or inconvenience to the people or the property around the area. The spillage of muck into the river at any site would be prevented by making concrete toe walls with wire gabions over them to retain the muck pile.

The total quantity of spoil (including the swell factor) which would be generated has been assessed to be about 6.93 lakh cum.

13.5 Quarry Areas

After testing of the aggregates and keeping into consideration the lead factor, 02 Nos insitu rock quarries have been identified and selected for extraction of construction material. Based on the concrete & shotcrete quantities, total coarse and fine aggregate requirement is estimated to be 4.74 Lakh cum. About 3.12 Lakh cum of aggregates shall be from excavated muck and the balance 1.61 Lakh cum from in-situ rock quarries. Assuming the total losses of 38% to be accounted for in the quantity estimation of raw material from quarry site to batching plant for producing aggregates, the total quantity of raw material for production of coarse and fine aggregates works out to be 2.22 Lakh cum.

13.6 Requirement of Land

Land would be required for locating the permanent works as well as for setting up the infrastructural facilities necessary for constructing the project in an expeditious and optimal manner.

About 39.71 Ha of land shall be required for development of the Rho H. E Project including notional area for underground works.

13.7 Construction Adits

Construction adits, 12 in number, to approach various underground work sites are proposed. Main Access Tunnel to powerhouse and adits planned for handling the pressure shaft shall be of size 7m (W) x 8m (H), while all other adits shall be of size 5m (W) x 6m (H).

13.8 Explosive Magazines

Permanent explosive magazine of adequate capacity would be constructed to store the explosives and detonators required for the construction of the project components. It has been assessed that one magazines of 30 MT capacity would be sufficient to meet the requirement of the project.

14 CONSTRUCTION METHODOLOGY AND PLANT PLANNING

The construction of some of the major components will be taken up even when partial infrastructural activities are completed. However, basic minimum facilities to sustain the job requirements would be made available before those works start.

The construction methodology for each type of structure has been framed. The type and size of equipment to be used has also been indicated while describing the construction methodology. The number of machines required for construction of the project and total requirement for each type and size of the major equipment has been worked out. Although a project of such a magnitude does require several different types of equipment to cater to the progress rates as required by the construction schedule, the proposed methodology has been developed keeping in view the objective that variety of equipment is minimized.

It is to be appreciated that the contractors, in all probability, would suggest their own construction techniques and equipment for execution of the job based on equipment actually available with them. However, the present exercise will help in evaluating the reasonableness of the bids, the proposed construction methods and cost estimate.

14.1 Project Implementation Philosophy

The construction methodology has been formulated based on the general construction practices and machinery generally proposed to be deployed for the respective works. The guidelines of the Working Group Report of the Central Water Commission (CWC), Govt. of India have been used in framing the write-up. Certain factors/parameters for relevant machinery have been adopted from the above guidelines for assessing the cycle time of operation of equipment and work.

14.2 Working Season

Equipment planning for calculating requirement of equipment is carried out based on the number of working days available, which depend upon climatic conditions in the project area. For open works a working season of 8 months is considered after allowing for monsoon season of 4 months. The working hours for open works have been considered 15 hours with 3 shifts and 25 working days per month.

For underground works execution will be carried out almost throughout the year though the progress may be less during rainy days due to constraints associated with the monsoon season. Working hours for underground works have been considered 22 hours with 3 shifts.

14.3 Project Implementation Schedule

Construction Programme and selection of Methodology with the planning for equipment has, as such, been worked out keeping above site constraints in view. The project has been planned to be commissioned in a period of 45 months from the start of the project. Another 18 months has been provided for completion of all pre-construction activities. Pre-construction activities involve development of infrastructure facilities in the project, obtaining requisite clearances, financial approvals, land acquisition, tendering and award of work, design and engineering. Detailed construction schedule is enclosed at **Plate-3**.

15 COST ESTIMATES

15.1 General

The estimate of cost has been prepared in detail to arrive at the total capital cost of the project. The estimate is based on the prices prevailing in June 2013, for material, labour etc. Interest charges during construction period have been worked out separately.

15.2 Principles Adopted for Estimation of the Project Cost

The basis of working out the hard cost of the project is given below:

i) Hourly use rate of construction machinery & working rates for various items of civil works has been prepared on the basis of CWC guide lines.

ii) The quantities of various items have been worked out from the drawings prepared on the basis of preliminary planning and design of various components.

iii) A provision of 3% of the cost has been made to cover contingencies in the estimate of different components of civil works. The contingencies have not been taken on items for which lump sum amount has been provided.

iv) A provision of 2 % for work charged establishment is kept.

v) A provision of 4.944% for Service Tax and 1% for building construction workers welfare cess is kept.

vi) Contractor overhead and profit @20% has been considered.

vii) The hard cost of the project has been estimated at June 2013 Price Level.

15.3 Project Cost

The present day cost in the form of major heads of expenditure is provided in the abstract of cost and are enclosed as Annexures-1 & 2 covering civil works as well as HM and E&M works. The total cost of the project at June, 2013 price level works out as under:

Hard Cost	Rs. Crores
Civil Works incl. HM Works	611.69
E&M Works	171.72
Total	**783.41**

16 Financial Analysis

For determination of phasing, escalation & interest during construction the implementation schedule of project is arrived as follows:

- Base date of Estimate – June 2013
- Pre-Construction period - 18 months from October 2014 to March 2016.
- Start date of main construction – April 2016.
- Total construction period including commissioning – 45 months from April 2016 to December 2019.

Commission period of 3 units – 1.5 months (November 2019 to December 2019)

16.1 Escalation

An escalation of 6.20% p.a. in Civil works and 4.39% p.a. for Electromechanical works over the estimated cost at June 2013 price level has been considered.

16.2 Interest during Construction (IDC)

Disbursement of capital expenditure has been considered in six monthly periods. The interest rate is taken as 12% per annum. The interest during construction has been calculated starting from April 2016 (start of first disbursement) till mean COD of the 3 units.

16.3 Financing

The project will be financed at a Debt: Equity ratio of 70:30.

16.4 Energy Benefits

The Design Energy of the project is **493.97 MU.** Auxiliary consumption of 0.7%, transformation losses of 0.5% and 13% as free power to state have been considered in the preliminary financial evaluation of the project in line with CERC Regulations. The net saleable energy is 424.6 Million Units

16.5 Tariff Calculation

The tariff has been calculated in line with the Central Electricity Regulatory Commission (Terms and Conditions of Tariff) Regulations, 2009. The main parameters are:

- Return on Equity: 16.5% on pre-tax basis, grossed up by relevant tax rate
- O&M Charges: 2% of Project Cost except the cost of R&R Works
- O&M Escalation: 5.72% p.a.
- Maintenance Spares : 15% of O&M Charges for the year
- Loan Repayment: Depreciation allowed for the year taken as repayment
- Depreciation: As per rates provided. Depreciation rates considered as 5.06% for the first 12 years calculation is attached as Annexure in Chapter-19
- Plant Life: Taken as 35 years
- Residual Plant Value: 10%
- Discount Rate: Taken as 12.23% based on CERC notification for Escalation Rates and Discount Rates dated 2nd April, 2012.
- Free Power: Taken as 13%, (12% + 1% for Local area development)
- Interest on Loan: 12.0%
- Interest on working capital: 12.75%
- Financing Charges: 0.5%

16.6 Financial Results

The financial results of the project are shown in **Table-2.**

Table-2: Financial Parameters

Description		
Basic Cost at June-2013 price level	Rs. Crore	783.41
Escalation	Rs. Crore	203.03
Interest During Construction and Financing Charges	Rs. Crore	174.31
Total Project Cost	Rs. Crore	**1160.75**
Cost per MW	Rs. Crore/ MW	12.48
Levellised Tariff (with free power to state)	Rs. / kWh	**5.19**
Tariff in the First Year	Rs. / kWh	5.99

ANNEXURE -1
Abstract of Cost Estimates of Civil and Hydro Mechanical Works

ABSTRACT OF COST ESTIMATES FOR CIVIL AND HYDROMECHANICAL WORKS

DIRECT CHARGES

S. No.	Description	Amount (Rs. in Lacs)	Service Tax 4.944%	Construction Workers Welfare Cess 1%	Total (Amount in lacs)
I	**171.72**				
1	A-Preliminary	3218.00			3218.0
2	B-Land	1034.02			1034.0
3	C-Works				
	C-1 River Diversion Works	480.52	23.76	4.81	509.1
	C-2 Barrage and Intake	13526.58	668.85	135.29	14332.7
	C-3 Hydromechanical Works	1105.93		11.06	1117.0
	Sub-total C-Works	**15115.04**			**15958.80**
4	J-Works				
	J-1 Feeder Tunnels	535.62	26.48	5.36	567.5
	J-2 Link Tunnels	458.38	22.66	4.58	485.6
	J-3 Desilting Chambers Works	5081.43	251.23	50.81	5383.5
	J-4 Headrace Tunnel	3622.25	179.08	36.22	3837.6
	J-5 Surge Shaft	899.55	44.47	9.00	953.0
	J-6 Pressure Shaft	2923.48	144.54	29.23	3097.3
	J-7 Powerhouse	3652.19	180.56	36.52	3869.3
	J-8 Transformer Hall	933.00	46.13	9.33	988.5
	J-9 Collection Gallery and Unit TRT	1137.84	56.25	11.38	1205.5
	J-10 Tail Race Tunnel	1358.83	67.18	13.59	1439.6
	J-11 Adits - 5m x 6m	2003.04	99.03	20.03	2122.1
	J-12 Adits - 7m x 8m	1702.71	84.18	17.03	1803.9
	J-13 Switch yard	330.88	16.36	3.31	350.5
	J-14 Hydro-mechanical Works	1165.86		11.66	1177.5
	Sub-total J-Works	**25805.07**			**27281.28**
5	K-Buildings	2435.76	120.42	24.36	2460.1
6	M-Plantation	11.00			11.0
7	O-Miscellaneous	689.97			690.0
8	P-Maintenance	433.56			433.6
9	Q-Special T & P	82.00			82.0
10	R-Communication	2500.00	123.60	25.00	2525.0
11	X-Environment, Ecology & Afforestaton	4350.00			4350.0
12	Y-Losses on Stock	108.39			108.4
	TOTAL I-WORKS	**55782.81**			**58152.14**
II	Establishment	2627.94			2627.9
III	T &P @ 1% of I- Works	100.00			100.0
IV	Receipts and Recoveries (-)	(-) 41.75			41.8
	TOTAL DIRECT CHARGES	**58469.00**			**60836.33**
INDIRECT CHARGES					
V	Audit & Accounts @ 0.5% of I-Works	278.91			278.9
VI	Capitalisation of abatement of Land revenue	51.70			51.7
	TOTAL INDIRECT CHARGES	**330.62**			**330.62**
	TOTAL OF DIRECT & INDIRECT CHARGES	**58799.61**			**61168.95**
	TOTAL CIVIL WORKS COST	**588.00 Cr**			**611.69 Cr**

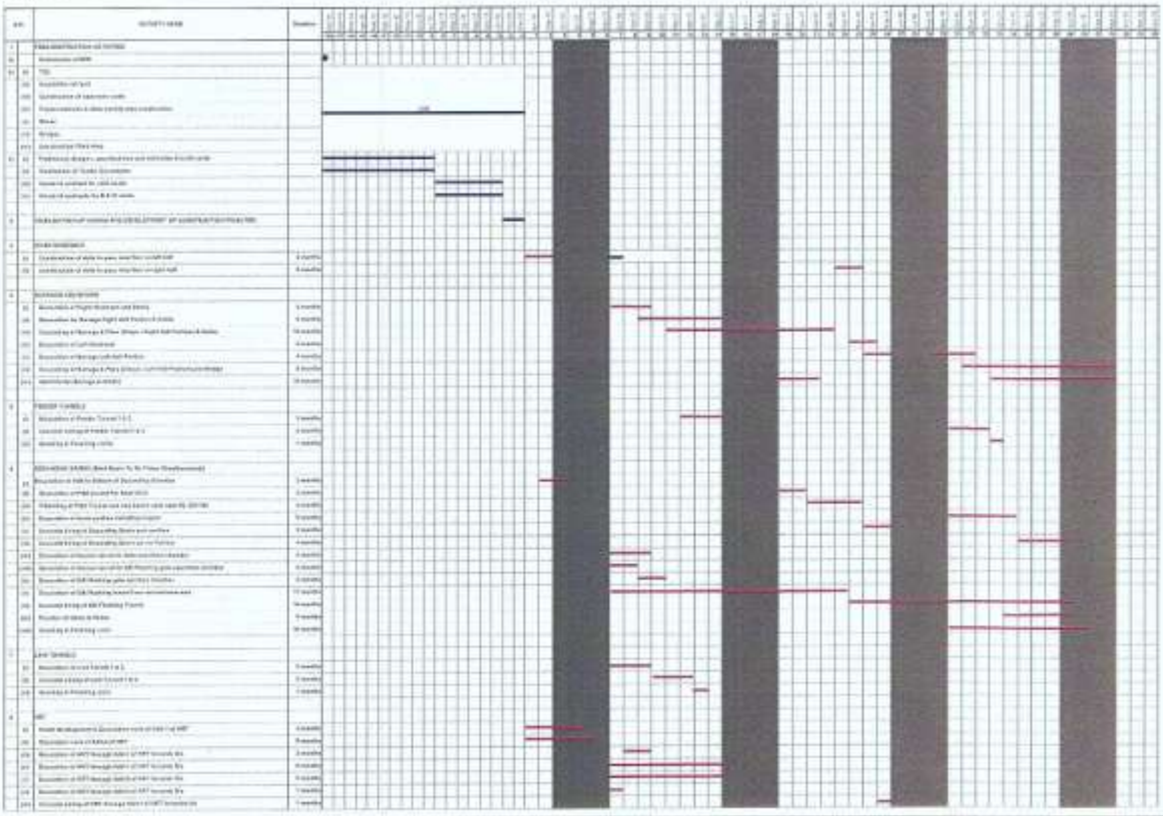
ANNEXURE-2
Abstract of Cost Estimates of Electro Mechanical Works

(Abstract of Cost Estimates of Electro Mechanical Works)

Price Level: June-13
FE Rate: 1US$ = 58.40 INR

Item No.	ITEM	TOTAL AMOUNT (Rs. In Lakhs)	FOREIGN COMPONENT (US$ in Millions)
1	Preliminary Model Test cost	158	
2	**Generating Plant and Equipment**		
a)	Generator, turbine and accessories - **Annex - B(1)** *(accessories include cooling water system, Drainage and Dewatering system, Compressed Air system, Bus Ducts, SCADA, Protection system & Butterfly Valves)*	8,237.00	
b)	Auxiliary electrical equipment for power station - **Annex - B(2)** *(includes AC & DC supply system, DG set, Control and Power Cables, Grounding, Illumination & Electrical lab)*	1,801.95	
c)	Auxiliary mechanical equipment and services for power station - **Annex - B(3)** *(includes EOT cranes, Elevator, Fire Fighting Equipment, HVAC, Filtered Water supply, Oil Handling & Mechanical Workshop)*	668.01	
d)	Central Sales Tax (2%) on 2 a), b) and c)	214.14	
e)	Transportation handling and Insurance charges @ 6% of 2 a), b) & c)	642.42	
f)	Entry tax (4%) on landed cost of equipment (i.e. 2 a) to e))	402.54	
g)	Erection and commissioning charges @ 8% of 2 a), b) & c) excluding spares (i.e. Rs. 10276.45 Lakhs)	822.12	
	Sub-Total (Generating Plant and Equipment)	12,844.18	
3	**132 kV Pothead yard equipment, Auxiliary equipment and services of pothead yard**		
a)	132 kV pothead yard equipment, Auxiliary equipment ans services of pothead yard - **Annex - B(4)**	157.16	
b)	Central Sales Tax (2%) on 3 a)	3.14	
c)	Transportation, handling and Insurance charges @ 6% of 3 a)	9.43	
d)	Entry tax (4%) on landed cost of equipment (i.e. 3 a) to c))	6.79	
e)	Erection and commissioning charges @ 8% of 3 a) excluding spares (i.e. Rs 152.58 Lakhs)	12.21	
	Sub-Total (132 kV Pothead yard equipment, Auxiliary equipment and services of pothead yard)	188.73	
4	**GIS and GIB with accessories**		
a) i	GIS - **Annex - B(5)**	990.65	
a) ii	GIB - **Annex - B(5)**		1.632
b)	Custom Duty	218.58	
c)	Central Sales Tax (2%) on 4 a) on indigenous component	19.81	
d)	Freight & Insurance @3% (Marine) of item 4 a)ii only on foreign component	28.59	
e)	Freight & Insurance @6% (Inland) of item 4 a),b) & d) (i.e Rs. 2190.63 Lakhs)	131.44	
f)	Entry tax (4%) on landed cost of equipment (i.e. 4 a) to e)) (i.e. Rs. 2322.07 Lakhs)	93.66	
g)	Erection and commissioning charges @ 8% of 4 a) & b) excluding spares (i.e. Rs. 2099.07 in Lakhs)	167.93	
	Sub-Total (GIS and GIB with accessories)	1,650.67	1.632
5	Contingencies @ 1% on items 2,3 & 4 (i.e Rs. 15640.30 Lakhs)	156.40	
6	Tools & Plant @ 0.5% of items 2,3 & 4 excluding insurance, transport, entry tax, erection and commissioning charges(i.e. Rs. 15640.39 Lakhs)	78.20	
7	**Sub total (Item 1 to 6)**	15,072.19	1.632
8	Establishment based on manpower to be deployed limited to 6% on E & M equipment cost not exceeding 750 crore i.e. of item 2, 3, 4 & 6. (E & M Equipment cost including taxes & Duties plus transport, handling & insurance and erection & commissioning i.e. Rs. 15718.59 Lakhs)	943.12	
9	**Sub total (Item 7 to 8)**	16,015.31	1.632
10	Audit and account @ 0.5% of Item 9	80.08	
11	Service Tax @ 12.36% on erection and commissioning (i.e. Rs. 1002.25 Lakhs)	123.88	
12	**GRAND TOTAL FOR ELECTRO-MECHANICAL WORKS**	16,219.25	1.632
13	**Equivalent INR (in Lakhs)**		952.81
14	**GRAND TOTAL COST INR**	17,172.06	
	Say	171.72 [illegible]	

ANNEXURE-3
Construction Schedule

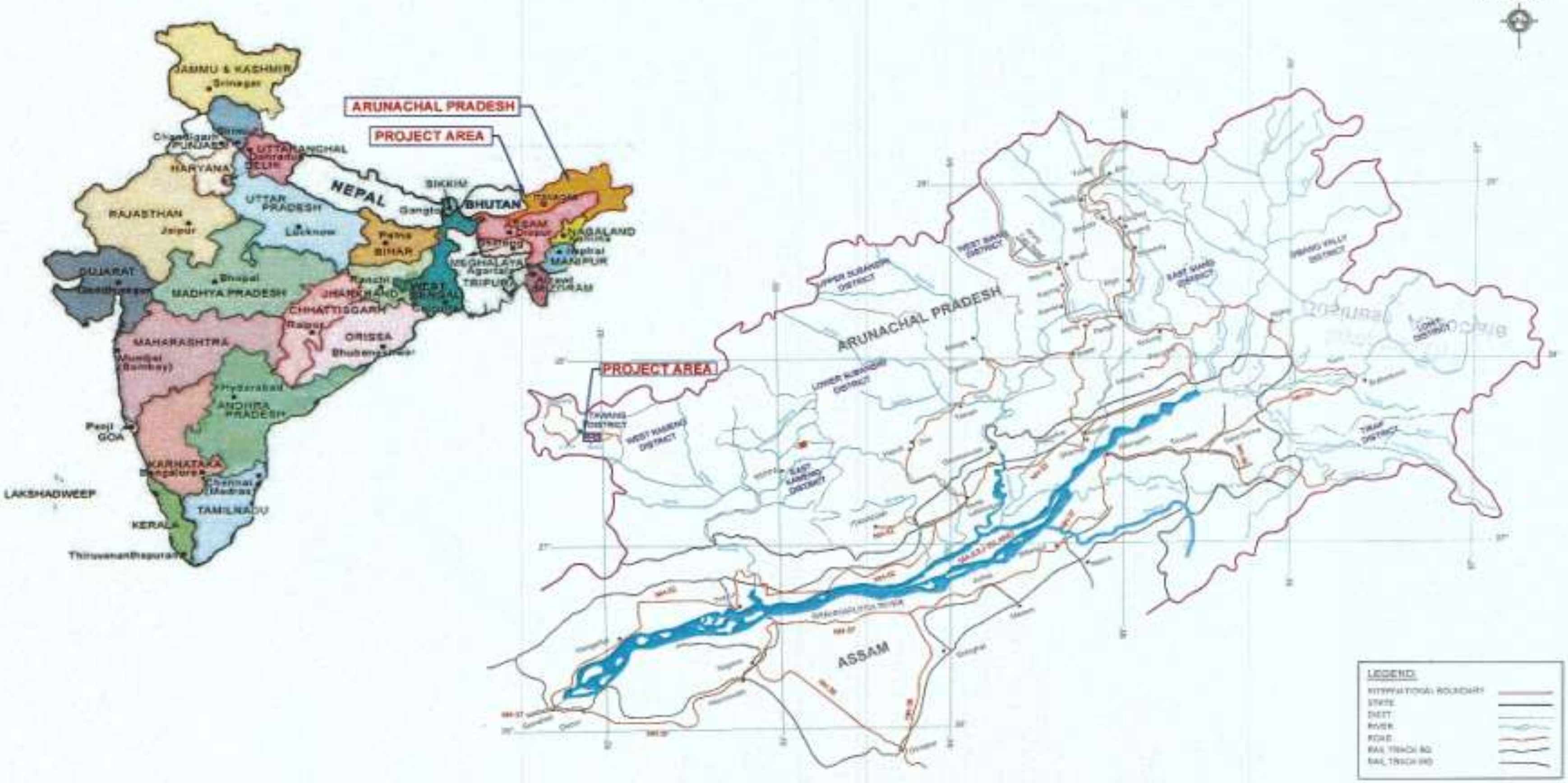


S.N.		ACTIVITY NAME	Duration
	(viii)	Concrete Lining of HRT through Adit-1 of HRT towards [illegible]	8 months
	(ix)	Concrete Lining of HRT through Adit-2 of HRT towards [illegible]	8 months
	(x)	Concrete Lining of HRT through Adit-3 of HRT towards [illegible]	1 months
	(xi)	Grouting & Finishing work	4 months
	(xii)	Plugging of Adits and installation of access doors	3 months
9		SURGE SHAFT	
	(i)	Portal Development & Excavation of Adit to top of Surge Shaft	5 months
	(ii)	Excavation of pilot Shaft	3 months
	(iii)	Widening of Surge Shaft	4 months
	(iv)	Concrete Lining	4 months
	(v)	Grouting & Finishing work	2 months
	(vi)	Gate installation	3 months
10		PRESSURE SHAFT	
	(i)	Adit to Pressure Shaft [illegible] (PSST)	1 months
	(ii)	Excavation of top Horiz. section of [illegible] pressure shaft	1 months
	(iii)	Adit to bottom of pressure shaft (Adit-[illegible])	2 months
	(iv)	Excavation of bottom Horiz. section of [illegible] pressure shaft and [illegible]	4 months
	(v)	Excavation of vertical section of [illegible] pressure shaft (Pilot Shaft & its widening)	8 months
	(vi)	Installation of top horiz. & vertical pressure shaft liner, testing & backfilling	7 months
	(vii)	Installation of bottom horiz. & unit penstock pressure shaft liner, testing & backfilling	12 months
	(viii)	Grouting & Finishing work	4 months
11		POWERHOUSE COMPLEX	
	(i)	Excavation of Adit to top of Power House Cavern (Adit-[illegible])	3 months
	(ii)	Excavation of Main Access Tunnel (MAT)	9 months
	(iii)	Excavation of Power House Cavern (Heading & Benching)	18 months
	(iv)	Concreting of Power House Cavern	17 months
	(v)	Installation of E&M equipments by E&M contractor	14 months
	(vi)	Finishing works	3 months
12		TRANSFORMER CAVERN	
	(i)	Adit to top of Transformer Cavern (Adit-[illegible])	1 months
	(ii)	Excavation of Transformer Cavern (Heading & Benching)	8 months
	(iii)	Concrete work of Transformer Cavern	8 months
	(iv)	Transformer Installation Work	8 months
	(v)	Finishing works	3 months
13		Collection Gallery and Unit TRT	
	(i)	Excavation of Adit to top of Collection Gallery (Adit-[illegible])	2 months
	(ii)	Excavation of Collection Gallery (Heading & Benching)	6 months
	(iii)	Excavation of Unit TRT	3 months
	(iv)	Concrete work of unit TRT & Collection gallery	10 months
	(v)	Installation of Hydro Mechanical works (Draft tube gates & Crane)	6 months
	(vi)	Grouting & Finishing works	3 months
14		Tail Race Tunnel (TRT)	
	(i)	Excavation of Tail Race Tunnel	3 months
	(ii)	Concreting of Tail Race Tunnel	2 months
	(iii)	Installation of outfall Gate and Hoist	3 months
	(iv)	Grouting & Finishing work	2 months

S.N.		ACTIVITY NAME	Duration
15		Pothead Yard	
	i)	Pothead assemblies	6 months
	ii)	Concreting & installation of equipments	10 months
16		FILLING AND TESTING OF WATER CONDUCTOR SYSTEM	30 Days
17		COMMISSIONING OF UNITS	
	i)	UNIT-1	15 Days
	ii)	UNIT-2	30 Days
	iii)	UNIT-3	15 Days

PLATES

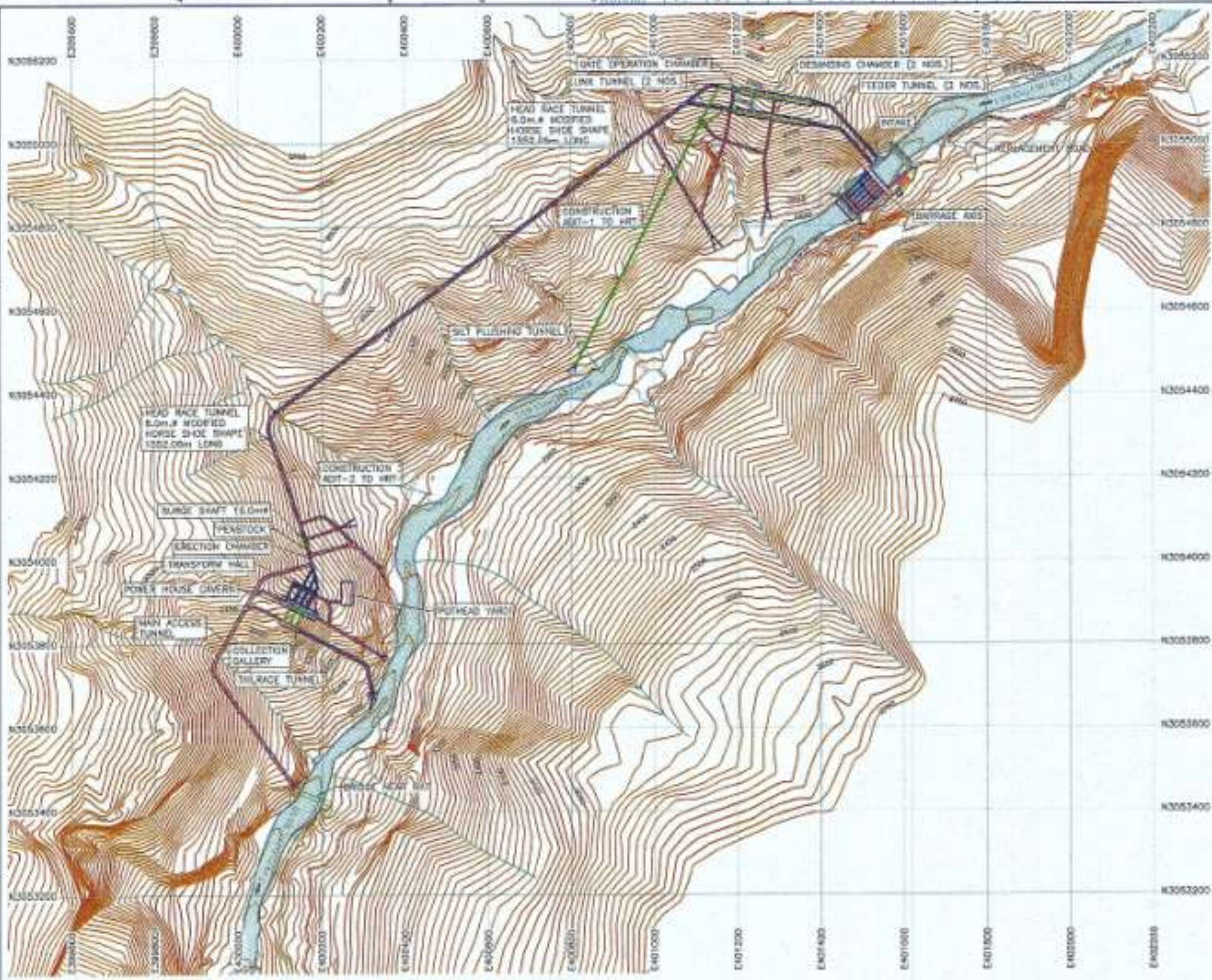
PLATE-1



SNC-LAVALIN Engineering India

Client	SEW RHO POWER CORPORATION LTD.
Project	RHO HYDROELECTRIC PROJECT Arunachal Pradesh, India.
Title	GENERAL LOCATION OF PROJECT

PLATE-2



Jayaprakash N.,
Business Associate

SEW RHO POWER CORPORATION LTD.

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS AND LEVELS ARE IN METERS UNLESS OTHERWISE SPECIFIED.
2. NO DIMENSION SHOULD BE MEASURED FROM THE DRAWING.

SCALE 1 : 10000

Client	SEW RHO POWER CORPORATION LTD.
Project	RHO HYDROELECTRIC PROJECT Arunachal Pradesh, India.
Title	GENERAL LAYOUT PLAN

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