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Clean Energy for Sustainability

NEW & RENEWABLE ENERGY DEVELOPMENT CORPORATION OF ANDHRA PRADESH LTD

SOMASILA PUMPED STORAGE PROJECT

(4 X 225 MW)

KADAPA, ANDHRA PRADESH - INDIA

FEASIBILITY STUDY REPORT

VOLUME – I

FEASIBILITY STUDY REPORT

JUNE 2021

SOMASILA PUMPED STORAGE PROJECT
(4 x 225 MW)

FEASIBILTY STUDY REPORT

VOLUME I	**:**	**FEASIBILTY STUDY REPORT**
VOLUME II	:	DESIGN ANNEXURES
VOLUME III	:	DRAWINGS

SOMASILA PUMPED STORAGE PROJECT
(4 x 225 MW)

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FEASIBILTY STUDY REPORT

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0 EXECUTIVE SUMMARY

0.1 INTRODUCTION

The Govt. of Andhra Pradesh through its nodal agency, New & Renewable Energy Development Corporation of Andhra Pradesh (NREDCAP) appointed SMEC India Pvt. Ltd. as their consultant and awarded the work for the Preparation of Feasibility Study Report and the Detailed Project Report (DPR) of Somasila Pumped storage Project at Somasila vide order No NREDCAP/WE/PSP/SOMASILA/2020 dated 02.11.2020.

Somasila Pumped Storage Project is envisaged with a proposed installed capacity of 900 MW (4 x 225 MW) located in the Kadapa district of Andhra Pradesh. It is a standalone scheme with two new greenfield reservoirs and utilizes storage of existing Somasila reservoir for initial filling of lower reservoir. The scheme is envisaged to meet the peak demand of about 6 hours with an estimated annual energy generation of 1971.0 GWh. Off-peak pumping hours are estimated as 7.33 hours with annual pumping energy of 2409.0 GWh. The cycle efficiency of the project is 80.73%.

0.2 SCOPE OF THE WORK

The proposed Somasila PSP (4 x 225 MW) envisages construction of following civil structures:

I. **Upper Reservoir & Dam (Concrete Gravity Dam):** The Upper reservoir is located in the natural depression area having potential to create sufficient pondage by minor excavation and providing concrete gravity dam on both sides of depression area for creating the reservoir.

   a) **North Facing (Upper Intake side):** Total length of dam is 272.70m. The maximum height of the dam is around 41.50m from the deepest foundation level.

   b) **South Facing:** Total length of dam is 347.0m. The maximum height of the dam is around 33.0m from the deepest foundation level.

II. **Upper Intake:** Two intake structure consists of four bays each of 3.75m width to accommodate 17 numbers of trash rack panel of size 3.75m x 2.5m, at the mouth of the intake.

III. **Pressure Shaft: 2 Nos.** 5.30m diameter 903.2m long steel lined pressure shaft is proposed, each of which bifurcates into 2 nos. branch penstock of 3.75m diameter 78.70m length leading to powerhouse.

IV. **Underground Powerhouse & Transformer Cavern:** The overall dimension of the Powerhouse is 147m (L) x 23m (W)x 52m (H). Transformer Cavern size is 160.0m (L) x 21.5m (W) x 29.50m (H).

V. **Tailrace Tunnel:** Four nos. unit tail race tunnel of 4.50m diameter takes off from the downstream wall of machine hall and run parallel till they merge with the twin main tailrace tunnel of 6.30m diameter.

VI. **Lower Reservoir & Dam (Concrete Gravity Dam):** The lower reservoir is located at the foot of the hill in an identified natural depression having suitable potential to create an artificial reservoir by minor excavation and providing a concrete gravity dam only on one side of the depression area. The maximum height of Concrete Gravity Dam is around 33.50m.

VII. **Intake cum Jack well pump house and D.I pipe line:** 1.2m diameter, 14.70km long ductile iron pipe line is proposed from the jack well pump house (located near the existing Somasila reservoir) to the lower reservoir for initial filling.

VIII. **Pothead Yard:** Considering four numbers outgoing feeders, 420kV pothead with tentative area of 140m x 60m has been proposed.

The salient features of the Project are given at the end of this chapter.

0.3 RESULTS OF STUDIES AND INVESTIGATION

0.3.1 GEOLOGY

The Somasila PSP lies over the rock sequences of the Cumbum Formation belonging to the Nallamalai Group of the Mesoproterozoic Cuddapah Supergroup.

Both the rock outcrops and overburden covered areas are fairly well distributed. The overburden is represented by topsoil distributed all through the area, the lacustrine deposit in reservoir area, colluvium mainly along and at the base of ridge slopes, and alluvium along the nala courses. While terrace deposits are expectedly absent, the landslide debris is also not found. The rock assemblage in the area is represented by an interbedded sequence of quartzite and phyllite where quartzite is found to be the predominant partner. Intercalations of phyllite in quartzite, and vice-versa, are expected.

0.3.1.1 UPPER RESERVOIR

The Upper Reservoir is proposed along a NS trending depression i.e. along the bedding strike, with prominent breaks-in-slope on either end. The site lies over a thick bed of quartzite that spans the reservoir area and the hills on the flanks. A bed of phyllite is interpreted at considerable depth. The overburden of topsoil at the bottom of the depression and colluvium on the flanks are expected to be shallow. The physiography of the site demands two dams at the north and south ends of the depression and a low height dam in the southern part of the linear hill on the western side. Rock foundations are likely to be available at shallow depths for the proposed dams.

0.3.1.2 LOWER RESERVOIR

The Lower Reservoir area is densely vegetated. Signs of any dormant or active landslide are conspicuous by their absence. The reservoir rim runs along vegetated and stable slopes. Any major concern with respect to the reservoir rim stability, therefore, is not apprehended. The proposed dam is located over a bed of quartzite and the foundation for the dam in rock is expected to be available at a reasonable depth.

0.3.2 HYDROLOGY

The project proposes to utilize water from existing Somasila reservoir for filling of lower reservoir at the time of commissioning during the surplus period of monsoon season. The requirement of water for filling the lower reservoir is only 0.4% of the capacity of existing Somasila Reservoir. The present scheme aims to work as an independent unit after having initial pumping from existing Somasila reservoir. The evaporation losses are proposed to be compensated by refilling from existing Somasila reservoir which would be required about two times in a year. A simulation study is carried out to find out the refilling requirement of the above scheme based on daily evaporation losses. No leakage of water is considered at this stage. This will be further investigated during the DPR Stage.

0.3.3 POWER POTENTIAL STUDY

The operation simulation between the Upper and Lower Reservoir for pumped storage operation has been carried out considering the storage characteristics. The simulation has been carried out considering a shorter time interval of 10 minutes to take into account the level variations in the two reservoirs. The studies have been carried out at the beginning of generating cycle, the upper reservoir is at FRL (El. 566.0m) and Lower reservoir at MDDL (El. 170.0m) and for pumping cycle, lower reservoir is at FRL (EL 182m) and upper reservoir is at MDDL (EL 536m). The results of the simulation studies for generating mode & pumping mode are summarized below:

Summary Result of Reservoir Simulation				
	Daily Energy	Running Time	Annual Energy	Working Days/year
	GWh	hr	GWh	
Pumping Mode	6.60	7.33	2409.00	365.00
Generation Mode	5.40	6.00	1971.00	365.00
Cycle Efficiency	80.73%			

The daily energy generation is 5.4 GWh with annual generation of 1971.0 GWh. The daily pumping energy requirement would be 6.60 GWh and annual pumping energy will be 2409.0 GWh which gives a cycle efficiency of 80.73%.

0.3.4 POWER EVACUATION ASPECT

The power generated at Somasila pumped storage plant will be evacuated to nearest pooling point by 400 kV four nos. outgoing lines. Two nos. of 220/ 400 kV substations operated by APTRANSCO located at Podili & Manubolu, in the Nellore District, have been identified for the probable venture for power evacuation. The project site is around 150 km far from both locations.

0.3.5 ENVIRONMENTAL ASPECT

The project is located close to villages Racheyapeta and Ramapuram in the Gopavaram Mandal of Kadapa district in Andhra Pradesh. Diversion of forest land for non-forest purpose will be involved for construction of Somasila project components. Therefore, Forest Clearance needs to be obtained under Forest Conservation Act.

Although the project components are proposed outside the Eco-Sensitive Zone (ESZ) of Sri Penusila Narasimha Wildlife Sanctuary (PNWLS), the pipeline for the initial filling of reservoir will be laid through the PNWLS. Thus, Wildlife Protection Act is applicable for this project and clearance / NOC needs to be obtained for this project from National Board of Wild Life (NBWL).

The total land requirement for the construction of all project components is 183 ha.

0.3.6 ESTIMATES OF THE COST

The estimated total cost of the project is Rs.3498.08 Crores, including IDC at June 2020-21 price level of SOR of Andhra Pradesh. The preliminary cost estimate of the project has been prepared as per the guidelines of CEA / CWC. The breakdown of the cost estimate is given below:

Item	Estimated Cost (in Crores)
Civil Works	**1685.06**
Electro-Mechanical Works	**1320.30**
Total Capital Cost	**3005.36**
IDC	**492.72**
Total Cost	**3498.08**

0.3.7 FINANCIAL ASPECT

The estimated cost of the Project is Rs. 3498.08 Crores (including IDC of Rs. 492.72 Crores). The annual energy generation is 1971.0 GWh and the annual pumping energy requirement is 2409.0 GWh. Further, Pumping Energy of about 3.563 GWh will be required to fill the lower Reservoir initially . The levelized tariff worked out based on the above considerations are shown in the table below:

CONVERSION COST (Excluding pumping cost)	
First Year Tariff	Rs. 3.96 /kWh
Levelized Tariff	Rs. 3.52 /kWh
CONVERSION COST (Including pumping cost @ Rs. 3.0/kWh)	
First Year Tariff	Rs. 7.72 /kWh
Levelized Tariff	Rs. 7.28 /kWh

0.3.8 CONCLUSIONS

The main construction activities for the Somasila pumped storage are planned to complete within the time duration of 60 calendar months after the award of works excluding 9 months of pre-construction activities. The project is techno-economically beneficial and viable and has the following benefits:

- Somasila PSP has been designed to meet the peaking requirement in the southern region grid and in particular the state of Andhra Pradesh.
- The energy output of the project with an installed capacity of 900 MW has been estimated as 1971 GWh annually.
- The levelized cost of generation of the project has been estimated as Rs 7.28/kWh considering cost of pumping @ Rs 3.00/kWh.
- Somasila Pumped Storage Project will be beneficial in meeting the peaking requirement of energy in the beneficiary state i.e. Andhra Pradesh.

Therefore, the Feasibility Study report indicates that the scheme merits consideration for taking up the preparation of Detailed Project Report (DPR).

Salient Features

SOMASILA PUMPED STORAGE PROJECT (4 x 225 MW = 900 MW)		
1	**Location**	
	Country	India
	State	Andhra Pradesh
	District	Kadapa
	River	Pennar River
	Upper Reservoir	Lat N 14°38'4.12" and Long. E 79°10'41.98"
	Lower Reservoir	Lat N 14°39'14.09" and Long. E 79°10'34.25"
	Existing Somasila Reservoir	Lat. N 14° 28’ 32.40” and Long. E 79° 15’ 10.81”
2	**Access to the Project**	
	Road	10 km from NH 67 which connects Krishnapatnam Port, Andhra Pradesh in the east to Panjim, Goa in the west
	Nearest Airport	Renigunta, Tirupati which is 180 km from project site
	Railhead (with unloading facilities)	Kadapa – 75 km
	Nearest Port	Krishnapatnam: 140 km
3	**PROJECT**	
	Type	Pumped Storage Project
	Installed Capacity	900 MW (4x225 MW)
	Peak Generation duration	6 Hours
	Pumping Operation duration	7.33 Hours
4	**RESERVOIR LEVELS & STORAGE DETAILS**	
4.1	**Upper Reservoir**	
	FRL	566.0 m
	MDDL	536.0 m
	Total Storage	6.17 MCM
	Live Storage	5.96 MCM
4.2	**Lower Reservoir**	
	FRL	182.0 m
	MDDL	170.0 m
	Total Storage	8.33 MCM
	Live Storage	6.38 MCM

SOMASILA PUMPED STORAGE PROJECT (4 x 225 MW = 900 MW)		
4.3	**Existing Somasila Reservoir**	
	FRL	100.56.0 m
	MDDL	82.53 m
	Total Storage	2207.6 MCM
	Live Storage	1994.10 MCM
5	**CIVIL STRUCTURE**	
5.1	**Upper Dam**	
	Type	Concrete Gravity Dam
	Top of Dam	568.0m
	Maximum Height and Length	
	North Facing dam	41.50 m, 272.70m long
	South Facing dam	33.0 m, 347.0m long
5.2	**Lower Dam**	
	Type	Concrete Gravity Dam
	Top of Dam	184.0m
	Maximum Height	33.50 m
	Length	465.0m
5.3	**Upper Intake**	
	Type	Diffuser Type
	Number of Intake Structure	2 Nos.
	Nos of Trash rack bay	4 Nos.
	Size of Trash rack bay	17 Nos. trash rack panel of size 3.75m x 2.5m
	Crest of Intake	525.30 m
	Invert level of Intake Conduit	520.0 m
	Nos. and size of Service Gate	1 Nos.- 5.3 m (W) x 5.3 m (H)
	Nos. and size of Emergency Gate	1 Nos.- 5.3 m (W) x 5.3 m (H)
	Design Discharge (each intake)	136.5 Cumec
5.4	**Lower Intake**	
	Type	Diffuser Type
	Number of Intake Structure	2 Nos.
	Nos of Trash rack bay	4 Nos.

SOMASILA PUMPED STORAGE PROJECT (4 x 225 MW = 900 MW)		
	Size of Trash rack bay	10 Nos. Trash rack panel of size 3.75m x 2.5m
	Crest of Intake	159.30 m
	Invert level of Intake Conduit	155.0 m
	Nos and size of Service Gate	1 Nos.- 6.3 m (W) x 6.3 m (H)
	Nos and size of Emergency Gate	1 Nos.- 6.3 m (W) x 6.3 m (H)
	Design Discharge (each intake)	136.5 Cumec
5.5	**Pressure Shaft**	
	Pressure Shaft	2 Nos.
	Size and Type	5.30m dia, Circular shape, steel lined
	Design Discharge (each shaft)	136.5 Cumec
	Length	903.20m
5.6	**Branch Pressure Shaft**	
	Branch Pressure Shaft	4 Nos.
	Size and Type	3.75m dia, Circular shape, steel lined
	Design Discharge	68.25 Cumec
	Length	78.7 m
5.7	**POWERHOUSE CAVERN**	
	Type	Underground
	Installed capacity	900 MW
	Number of units	4 nos.
	Type of turbine	Francis, Vertical Shaft
	Centre line of generating unit	118.5m
	Powerhouse size	147m (L) x 23m (W) x 52 m (H)
	Design head (Rated net head)	371.0 m
	Service bay level	134.0m
5.8	**MAIN ACCESS TUNNEL**	
	Size	8.0m x 8.0m
	Length	1059.0 m
5.9	**TRANSFORMER CAVERN**	
	Type	Underground
	Transformer Cavern Size	160.0 m (L) x 21.5 m (W) x 29.5 m (H)
5.10	**Unit TRT**	

SOMASILA PUMPED STORAGE PROJECT (4 x 225 MW = 900 MW)		
	Unit TRT	4 Nos
	Size and Type	4.50 m dia, Circular shape, Concrete Lined
	Design Discharge	68.25 Cumec
	Length	114.63 m
5.11	**Main TRT**	
	Main TRT	2 Nos
	Size and Type	6.30 m dia, Circular shape, Concrete Lined
	Design Discharge	136.5 Cumec
	Length	575.65 m
5.12	**POTHEAD YARD**	
	Type	Surface
	Size	140.0 m (L) x 60.0 (W)
6.	**CONSTRUCTION PERIOD**	
	Construction Perion	5 years excluding 9 months of pre-construction activities
7.	**ELECTRO-MECHANICAL EQUIPMENT**	
7.1	**Generating Mode**	
	Turbine Type	Francis, Vertical Shaft
	Max Net Head	389.0m
	Min Net Head	347.0 m
	Rated Net Head	371.0 m
	Design Head	375.0 m
7.2	**Pumping Mode**	
	Max Net Head	403.0 m
	Min Net Head	361.0 m
	Rated Net Head	385.0 m
	Design Head	389.0 m
	Total Design Discharge	For 4 Units
	Generating Mode	273.0 m^3/s
	Pumping Mode	218.30 m^3/s
7.3	**Generator Motor**	
	Generator Type	Vertical shaft, Synchronous generator, Suspended type

SOMASILA PUMPED STORAGE PROJECT (4 x 225 MW = 900 MW)		
	Turbine Efficiency (Generation)	0.92
	Turbine Efficiency (Pumping)	0.93
	Generator Efficiency	98.5%
	Synchronous Speed	375 rpm
	Generator Voltage	24 kV
	Transmission Voltage	400 kV
	Generator Step up Transformer	98 MVA, 1 Phase, 24 kV/400 kV
8	**ANNUAL ENERGY**	
	Annual Energy for Generation	1971 GWh
	Generation Duration (Peaking)	6 Hours
	Annual Energy for Pumping	2409 GWh
	Pumping Duration	7.33 Hours
9.	**PROJECT COST**	
	Civil Works	Rs. 1685.06 Cr.
	Electro-mechanical Works	Rs. 1320.30 Cr.
	IDC	Rs. 492.72 Cr.
	Total	Rs. 3498.08 Cr.
10.	**CONVERSION COST (Excluding pumping cost)**	
	First Year Tariff	Rs. 3.96 /kWh
	Levelized Tariff	Rs. 3.52 /kWh
11.	**CONVERSION COST (Including pumping cost @ Rs. 3.0/kWh)**	
	First Year Tariff	Rs. 7.72 /kWh
	Levelized Tariff	Rs. 7.28 /kWh

INTRODUCTION

1 CHAPTER 1 - INTRODUCTION

1.1 OVERVIEW

The Govt. of Andhra Pradesh through its nodal agency, New & Renewable Energy Development Corporation of Andhra Pradesh (NREDCAP) identified 23 project locations in the state for preliminary examination and development of renewable power through pumped storage projects. Being the nodal agency, NREDCAP got the Techno Commercial Feasibility reports prepared for these identified projects and based on the Preliminary reports prepared therein, seven projects locations in the state were proposed for further detailed studies and preparation of Feasibility Study Reports and Detailed Project Reports.

Somasila Pumped Storage Project was earlier conceived on existing Somasila Reservoir as per the Techno Commercial Feasibility Report prepared by M/s WAPCOS Ltd in May 2020. NREDCAP appointed SMEC India Pvt. Ltd. as their consultant and awarded the work for the Preparation of Feasibility Report and the DPR of Somasila Pumped storage Hydroelectric Project at Somasila vide order No. NREDCAP/WE/PSP/SOMASILA/2020 dated 02.11.2020.

The Project as envisaged in this report is proposed in the Kadapa district of Andhra Pradesh and is a standalone scheme with two new greenfield reservoirs and initial filling from existing Somasila reservoir through a pipeline and generates energy with the available head between the proposed upper and lower reservoirs.

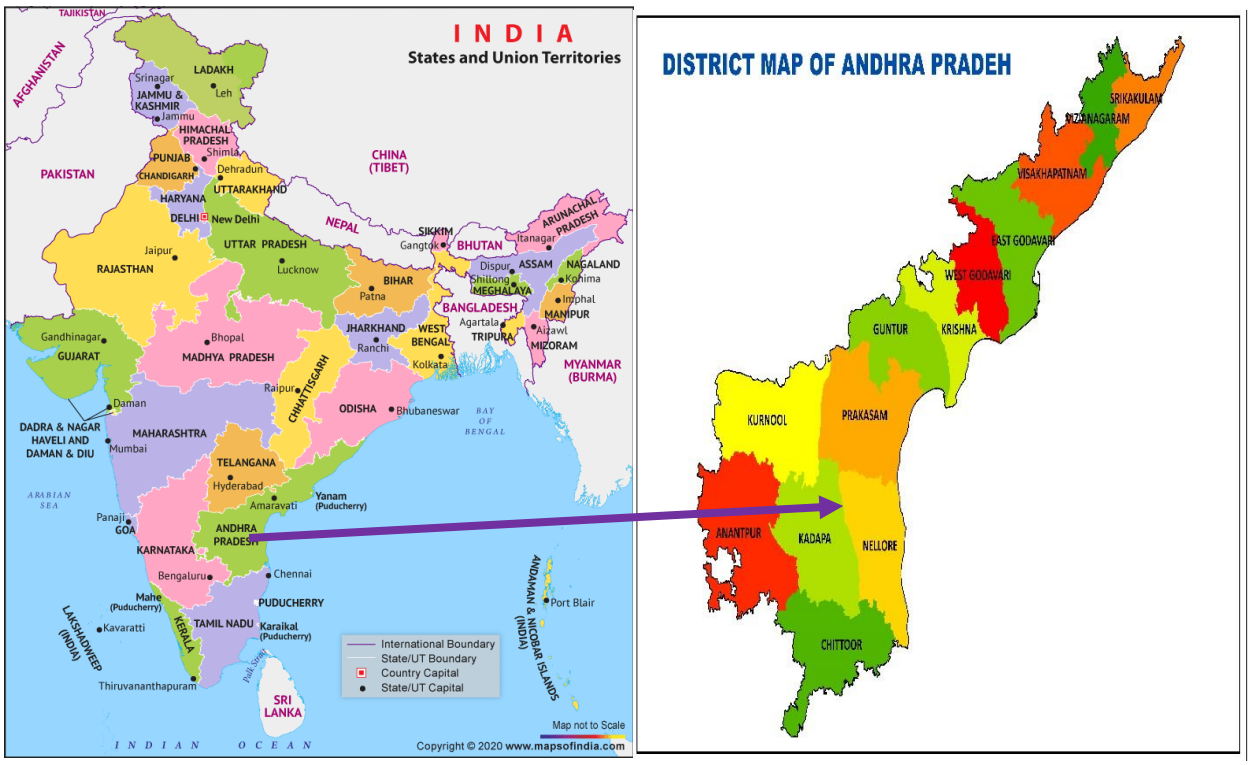


Figure 1-1: Andhra Pradesh District Map

1.2 TYPE OF THE PROJECT

The project is a pumped storage scheme to meet the power requirements during the peaking time and to maintain grid stability. The scheme is proposed with one upper and one lower reservoir. The scheme envisages drawl of water from existing Somasila reservoir for initial filling into the proposed lower reservoir through a pipeline arrangement. Both the reservoirs are planned to be interconnected through water conductor system and the reversible generator pump turbine would be installed in the underground powerhouse.

The proposed project is intended to meet the power demands during peaking time and the reversible turbines would function as pumps during non-peaking time. The power demand for pumping would be met from the grid during non-peaking hours when power demand is low. Surplus power available in the region in non-peaking hours would be utilized for strengthening the power position and flexibility, control of the frequency of the power grid and to meet the power requirements of the State.

1.3 LOCATION OF THE PROJECT

The project is located close to villages Racheyapeta and Ramapuram in the Gopavaram Mandal of Kadapa district in Andhra Pradesh. The project location falls on the left bank of existing Somasila Reservoir in NE direction with upper reservoir at geographical co-ordinate 14°38'4.12"N and 79°10'41.98"E and lower reservoir at geographical co-ordinate 14°39'14.09"N and 79°10'34.25"E.

1.4 ACCESS OF THE PROJECT

The nearest rail head is Kadapa which is about 75 km from Project site and with loading and unloading facility. The Mumbai–Chennai line, one of the busiest lines in the south coast region, passes through Kadapa railway station. It is one of the “A” category railway stations in South Coast Railway zone under Guntakal railway division. The nearest airport is Renigunta, Tirupati which is 180 km (approx.) from project site. Another Airport is Chennai which is about 325 km from the project site. The nearest sea port is Krishnapatnam Port and is about 140 km from the project site. The project site lies in Gopavaram Mandal, located in the Rajampet Revenue division of the Kadapa District of Andhra Pradesh. It is well connected with the NH 67 which connects Krishnapatnam Port, Andhra Pradesh in the east to Panjim, Goa in the west.

1.5 GENERAL CLIMATIC CONDITIONS IN THE PROJECT AREA.

The area of Kadapa is viewed as an upsettingly hot place, presumably because of the early setting in of high temperatures. Kadapa has a tropical wet and dry climate characterized by year round high temperatures. Summers are especially uncomfortable with hot and humid climate. During this time temperatures range from a minimum of 34^{o}C and can rise up to a maximum of 40^{o}C. Humidity remains around 75% during the summer months. Monsoon season brings substantial rain to the area. Kadapa gets rainfall from both the South West monsoon as well as the North East Monsoon. June to October is usually the monsoon period. Winters are comparatively

milder and the temperatures are lower after the onset of the monsoons. During this time, the temperatures range from a minimum of 25ºC and can rise up to a maximum of 35ºC. Humidity is much lower during the winter season. Winter season is the best time to visit the place. The location of automatic weather stations in Kadapa district are shown in Figure 1-2 below.

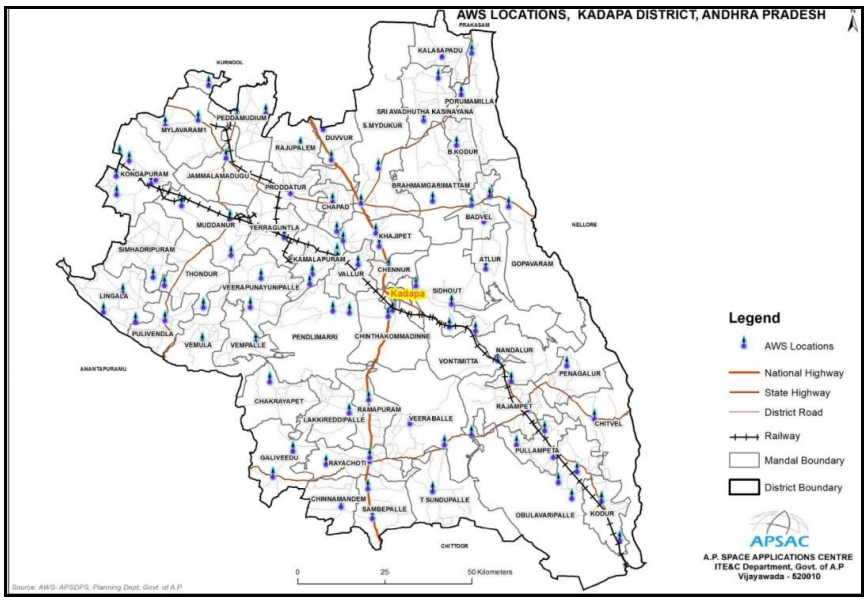


Figure 1-2: Automatic Weather Station locations in Kadapa District

1.6 NATURAL RESOURCES OF THE STATE/REGION

Andhra Pradesh has bountiful natural resources (coal, limestone, bauxite and a number of minor minerals), fertile land, water, fertile river basins (Godavari, Krishna & Pennar), extensive canal system and conducive agro-climatic conditions. The state is agriculturally prosperous. It is known as the “Rice Bowl of India”. The state also has the second longest coastline (974 kms) among all the states in India and it is also the largest producer of marine products with 40% share in country’s exports.

Andhra Pradesh is one of the store houses of mineral resources with large deposits of Chrysotile, mica Asbestos, barytes and limestone in India. It accounts for about 93% of total production of Barytes in India. Andhra Pradesh has varied geological formations with a rich variety of industrial minerals and building stones. Other important minerals in the state are copper ore, manganese, mica, coal and limestone. Minerals like coal, oil and Natural gas, barytes, Limestone, diamond, gold beach sand bauxite, ball clay fire clay, dolomite, dimensional stones etc. are still under tapped or untapped. The wide variety of minerals from the State is being traded or consumed in Power, Metals, Alloys, Cement, Chemicals, Paint, Cosmetic, Glass, Ceramics, Refractory, Refinery and manufacture of various downstream industries.

Minerals found in the state include limestone, reserves of Oil and Natural Gas, Manganese, Asbestos, Iron Ore, Ball Clay, Fire Clay, Gold Diamonds, Graphite, Dolomite, Quartz, Tungsten, Steatitic, Feldspar, Silica Sand etc. It has about one third of India's limestone reserves and is known for large exclusive deposits of Barytes and Galaxy granite in the international market.

Mining is identified as one of the growth engines for the overall development of industry and infrastructure. The Tummalapalle Uranium mine in Andhra has confirmed 49,000 tonnes of ore and there are indications that it could hold reserves totaling three times its current size. 700 million tonnes of metal grade Bauxite deposits in close proximity to Visakhapatnam Port. The Government of Andhra Pradesh is keen to utilize large deposits of KG Basin (Krishna Godavari Basin) gas for power production to overcome the energy shortage, create employment opportunities and contribute to economic value and exports.

The state is a pioneer nationwide in hydro electricity generation, encouraging privates sector in power generation and efficient use of its coal based thermal power stations. The state has become power surplus with excess power generation being exported to other states.

1.7 SOCIO-ECONOMIC ASPECTS INCLUDING TRIBAL, BACKWARD AND DROUGHT AREAS

As per Socio Economic Survey(2019 – 2020), issued by Planning Department – Government of Andhra Pradesh; the GSDP of Andhra Pradesh at Current Prices for the year 2019-20 was estimated at Rs.9,72,782 crores as against Rs.8,62,957 crores for 2018- 19. As per the report, the GSDP at constant (2011-12) prices for the year 2019-20 was estimated at Rs.6,72,018 crores as against Rs.6,21,301 crores for 2018- 19 (FRE) indicating a growth of 8.16% in comparison with the All India GDP growth rate of 5.0% for 2019-20 as per Advance estimates cited in the Socio Economic Survey Report.

Due to favourable seasonal conditions, the agriculture sector GVA grew by 18.96 per cent followed by horticulture sector with 11.67 per cent and livestock by 4.53 per cent. While the industrial sector at constant (2011-12) prices is expected to register a growth rate of 5.67 per cent in 2019-20, the services sector is indicating a growth rate of 9.11 per cent.

The per capita income of Andhra Pradesh at current prices increased to ₹1,69,519 from ₹1,51,173 in 2018-19 (FRE), a growth of 12.14 per cent. All-India per capita income for 2019-20 stands at ₹1,34,432.

1.7.1 HEALTH AND FAMILY WELFARE

Ensuring access to health facilities is one of the top agenda item for the State. Government provides key health services such as maternal health care, child health care and family welfare services through the Family Welfare department. These services are provided by 7458 Sub-centers, 1145 Primary Health Centers, 196 Community Health Centers, 28 Area Hospitals, 14 District Hospitals, 10 Other Health facilities (3 MCHs, 4 MPLs, 2 FRUs and 1 ESI) and 12 Teaching hospitals. Apart

from these, 59 Urban Family Welfare Centers, 44 Post-Partum Units, 243 e-UPHCs and 8 UHCs are facilitating health access to the people of the state. Over the years, there has been a significant improvement in various health parameters. The estimated Crude Birth rate, Crude Death rate and Infant Mortality Rates in the state stand at 16.2, 6.7 and 29 respectively as compared to 20.0, 6.2 and 32 for All India (as per Sample Registration System, bulletin - May, 2019). Maternal Mortality Ratio (MMR), defined as the proportion of maternal deaths per 1 lakh live births reported, stands at 74 for Andhra Pradesh welcomingly much lower than All-India's 122, as per the latest Sample Registration System (2015-17). During 2019-20, 94.08 % of Children below 1 Year are covered under full Immunization and 93.45 % of children of 1 to 5Yrs are covered under Complete Immunization.

1.7.2 SOCIAL WELFARE

As per the 2011 Census, Scheduled Castes population forms 17.08 percent of the total population of Andhra Pradesh and 79.98% of the Scheduled Caste People live in rural areas. Government provides reimbursement of full fee to all eligible students studying ITI, Polytechnic, Degree & above level courses, as fixed by the competent authorities under Jagananna Vidya Deevena (RTF). The amount will be adjusted into the bank account of the College. Government provides Rs. 20,000/- per student to all eligible students studying Degree and above level courses; Rs. 10,000/- per student per year for ITI students and Rs. 15,000/- per student per year for polytechnic students. The amount will be credited into the bank account of Mother of the respective student in two instalments under JaganannaVasathi Deevena(MTF). An amount of Rs.743.35 crores is released benefitting 4.68 lakh students during 2019-20 (upto April 2020) including arrears for students of 2018-19 under Jagananna Vidya Deevena (RTF) and an amount of Rs.265.50 crores is provided for benefiting 3.36 lakh SC students in the year 2019-20 under Jagananna Vasathi Deevena (MTF .) 759 Pre-matric hostels are functioning in the state with an admitted strength of 79,055 in 2019-20 and recently 3 more hostels are re-established which were closed earlier. 38 integrated hostel welfare complexes are functioning in the State with an admitted strength of 8751.

1.7.3 MINORITY WELFARE

There are 6 Pre-matric Minorities Hostels and 10 Post-matric Hostels functioning in the state aiming educational and social development of the poorest of the poor minority students. During the financial year 2019-20, an amount of Rs.1.92 crores have been released to the 7 Districts for maintenance of Minorities Welfare Hostels.

1.7.4 TRIBAL WELFARE

The tribal population of Andhra Pradesh according to 2011 Census is 27.39 lakhs which constitutes 5.53% of the total population of the State. Government accorded high priority for development of Tribals. Major focus is on Education, Health, Skill Development and creation of social infrastructure including road connectivity and supply of drinking water in tribal areas. Under “JAGJEEVAN JYOTHI SCHEME”, Government extended free power from 125 units to 200 units per month to SC/ ST colonies/Thandas consumers who consume 0-200 units from August, 2019. 4,76,206

ST Households benefitted during 2019-20 under this scheme The financial assistance under YSR Pelli Kanuka enhanced from Rs. 50,000/- to Rs. 1,00,000/- (One Lakh) w.e.f. 02.04.2020 and from Rs.75,000/- to Rs.1.20 lakh for ST Inter-caste Marriages from 02.04.2020 .

1.7.5 DROUGHT AREAS

Andhra Pradesh endeavors to provide agricultural extension services to farmers and to transfer the latest technical knowledge to the farming community under the Agriculture Sector, the government is determined to focus on Productivity enhancement, mitigating the impact of droughts through water conservation and micro-irrigation; Post-harvest management to reduce wastage and to strengthen the processing, value addition capacity and supply chain.

Andhra Pradesh Drought Mitigation Project (APDMP): The main objective of APDMP is to improve the income and strengthen the drought resilience of 165,000 farm households in 315 Grama Panchayats of 105 clusters in 105 mandals. The Programme Development Objective (PDO) is to strengthen the adaptive capacity and productivity of Agriculture in the rainfed areas of five districts in southern AP i.e. Ananthapuramu, Chittoor, Kurnool, Kadapa & Prakasam districts. The three major components of the project are:1) Climate resilient production systems, 2) Drought proofing through NRM & governance and 3) Management and lesson learning. The Climate resilient production systems aims to increase the resilience of crop and livestock production systems to climate change (drought). Under the Drought proofing through NRM & governance, issues relating to ground water management in the project area are addressed and under the 3rd component ' framework of best Management and Lesson', the practice would be introduced in all districts and the adoption would take place based on local demographics and priority. The following are the important activities under APDMP project.

1.8 GENERAL DESCRIPTION OF TOPOGRAPHY, PHYSIOGRAPHY AND GEOLOGY OF THE PROJECT AREA

The State of Andhra Pradesh is strategically located in the Indian sub-continent. Andhra Pradesh is increasingly being recognized, as the hub of industrial activity in South India. It has a geographical area of 1,62,970 Sq km and ranks as the 8th largest State in the country. Situated in a tropical region, the state has the 2nd longest coastline in the country with a length of 974 km. Kadapa is located at 14°28′N 78°49′E / 14.47°N 78.82°E / 14.47; 78.82 in the Rayalaseema region of Andhra Pradesh. The city is situated in the Bugga Vanka or Ralla Vanka rivers bordered by the Palakondas to the south and to the east by a patch of hills casting north for the Lankamalas on Penna's other side. It has an average elevation of 138 metres (452 ft). Veligonda hills is a low mountain range, forming a part of the Eastern Ghats mountain range system in Eastern India. It separates the districts of Nellore and Kadapa.

Geologically, the Kadapa district is home to the Neo to Meso Proterozoic Cuddapah Supergroup of rock and forms a part of south-western and southern part of Cuddapah Basin. The Cuddapah Basin is a crescent shaped basin with its convex

side towards west. With a 450 km long concave eastern margin, besides Kadapa District the basin occupies an area of around 44,500 sq km covering parts of Chittoor, Kurnool, Anantapur, Nellore, Prakasam, Mahbubnagar, Nalgonda, Guntur and Krishna districts. The basin attains the maximum width of 145 km in its central part. The cumulative thickness of the sedimentary pile is estimated to be of the order of 12 km. The District is endowed with natural resources like Barytes, Limestone, Asbestos, Ochere, Granite, etc.

The Somasila project area lies in Cumbum Formation of Nallamalai Group belonging to the Cuddapah Supergroup. The sedimentary fill of the Cuddapah Basin is largely arenaceous and argillaceous with subordinate calcareous and dolomitic components. Petrologically diverse assemblage of igneous rocks are associated with these sedimentary rocks. In the project area, however, the rock sequence is represented by interbedded quartzite and phyllite. North-south aligned strike ridges with easterly dipping rock formations is a conspicuous geomorphic feature in the area.

1.9 HISTORICAL BACKGROUND OF THE PROJECT

The existing Somasila dam was constructed during the period of 1976 to 1989 and is located on Pennar river (Uttara Pinakini) which rises in the Nandi Hills in Chikkaballapur District of Karnataka state, running north and east through the states of Karnataka and Andhra Pradesh before meeting the Bay of Bengal near Nellore.

Initially the project report, linking Tungabhadra River and Pennar River, was planned in 1904 by Mackonzio. At that time the proposal included construction of a reservoir to a capacity of 0.739 TMC to cater to the irrigation requirements in Nellore District. Subsequently, the planning and demands had undergone several changes and at present, Somasila Reservoir project is meeting the water requirements of its existing command area and area under Telugu Ganga canal, drinking water supply to Chennai, Nellore Corporation, Udayagiri area (through lift canal) and industrial water supply to IFFCO besides hydro-power generation.

NREDCAP identified the potential for development of pumped storage hydroelectric scheme around the Somasila Reservoir. Thereafter, WAPCOS Ltd. prepared a techno commercial feasibility report recommending the Project to be taken up for feasibility studies. Following table shows some of the key features of the identified and recommend option by WAPCOS Ltd. during the Techno Commercial Feasibility Report.

Table 1-1: Key features of Somasila PSP as per TCF Report

KEY FEATURES OF SOMASILA PUMPED STORAGE HEP AS PER RECOMMENDATIONS OF TECHNO COMMERCIAL FEASIBILITY REPORT BY WAPCOS	
Type	Pumped Storage Project
Installed Capacity	1200 MW
Peak Operating duration	5 Hours 16 min

KEY FEATURES OF SOMASILA PUMPED STORAGE HEP AS PER RECOMMENDATIONS OF TECHNO COMMERCIAL FEASIBILITY REPORT BY WAPCOS	
Average Annual Rainfall	984 mm
UPPER RESERVOIR (New) (Bund Type)	
Height of Bund	23 m
Length of Bund	3828 m
FRL	EL. 624 m
MDDL	EL. 600 m
Available Live storage	0.18 TMC (5.02 MCM)
LOWER RESERVOIR (Existing Somasila Reservoir)	
FRL	EL. 100.58 m
MDDL	EL. 82.30 m
Live storage	70.42 TMC (1993.17 MCM)
Dead Storage	7.56 TMC (214.23 MCM)

Based on the studies done during the preparation of techno commercial feasibility report, the first year and levelized tariff calculated are indicated in Table 1-2 below. The off-peak energy rate was considered as (₹3/kWh)

Table 1-2: Levelized tariff as per the TCF report

Off Peak Energy Rate (₹/kWh)	First Tariff (₹/kWh)	Levelized Tariff (₹/kWh)	Conversion cost of the project (excluding pumping cost) (₹/kWh)
3	8.36	7.83	3.81

1.10 ALTERNATIVE STUDIES AND SELECTION OF FINAL LAYOUT

Based on the topography of the area and various other factors like location, length of Water Conductor System etc, eight options have been explored and evaluated. These options are depicted in Figure 1-3 and were identified during the desk study on the toposheets.

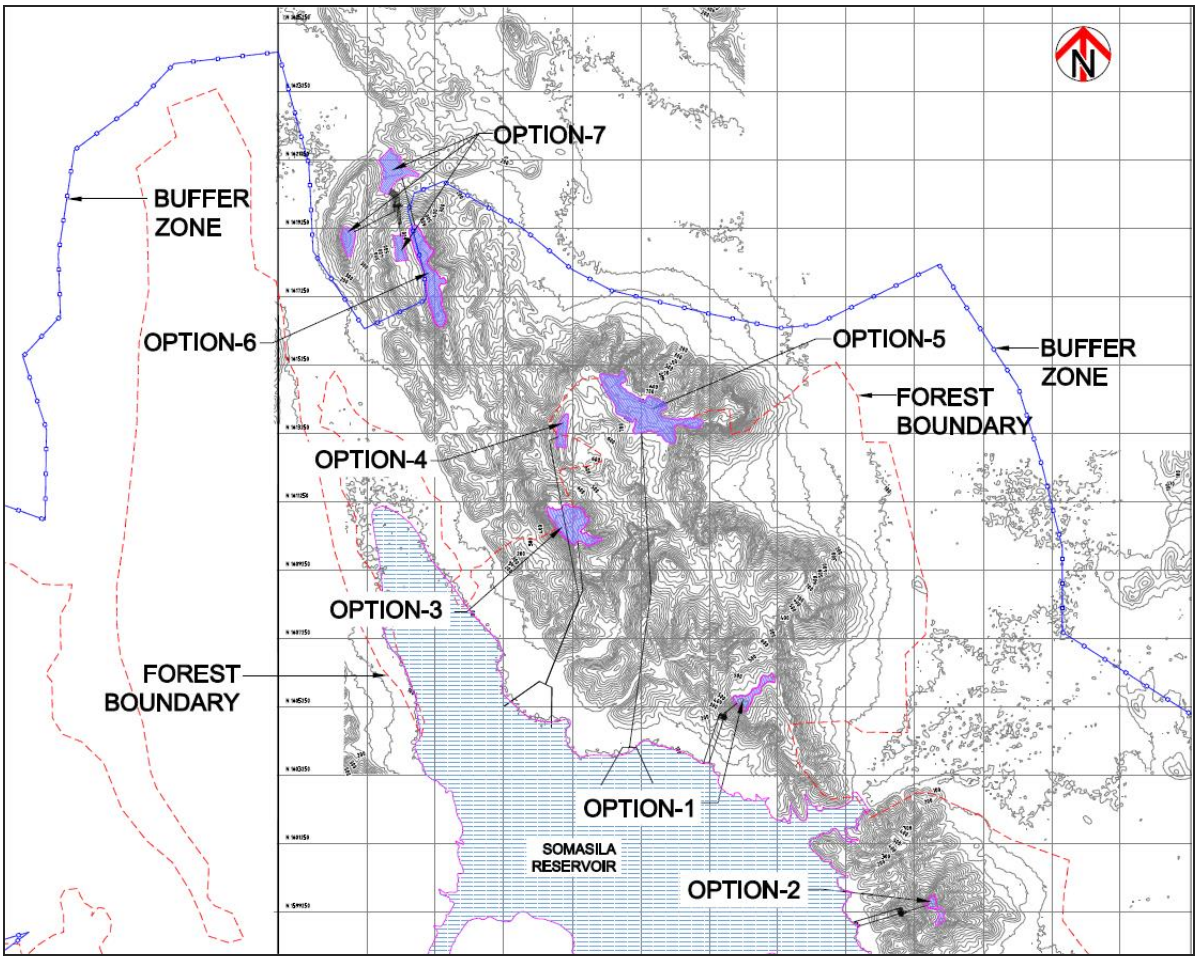


Figure 1-3: The Evaluated Options

During field visit to evaluate these options at site, it was revealed that the **Options 1 to 5** fall within the boundaries of Sri Penusila Narasimha Wildlife Sanctuary and could not be taken forward due to restricted guidelines of Wildlife Act.

Option 6 falls beyond the boundary of Sri Penusila Narasimha Wildlife Sanctuary but falls within the area of its eco-sensitive zone and hence, it was also dropped for further studies. **Option-7 and 8** were not having any interference with the wildlife zone. **Option 7** is proposed with a twin upper reservoir and single lower reservoir at the foot of hill, requiring initial water pumping from the existing Somasila Reservoir. The identified location for Option 7 falls beyond the boundary of Somasila Reservoir and its eco sensitive zone, on the left bank of existing Somasila Reservoir at geographical co-ordinate 14°38'4.12"N and 79°10'41.98"E in NE direction. Of the two identified locations for upper reservoirs, upper reservoir 1, is located in the natural depression area having potential to create sufficient pondage by minor excavation & concrete gravity dam on two sides of the depression area for creating the reservoir. The second one, upper reservoir 2 is located on the hill top area and considered for creating adequate pondage through excavated pit surrounded by concrete gravity Dam. The lower reservoir for the scheme is proposed at the foot of the hill in an identified natural depression having suitable potential to create an artificial reservoir to be filled by withdrawing water through pumping arrangement from the existing Somasila reservoir. A schematic layout of Option-7 is shown in ***Figure – 1.4*** and

detailed layout of this alternative is given in ***Drawing Volume III, drawing number 7061601-FSR-1100.***

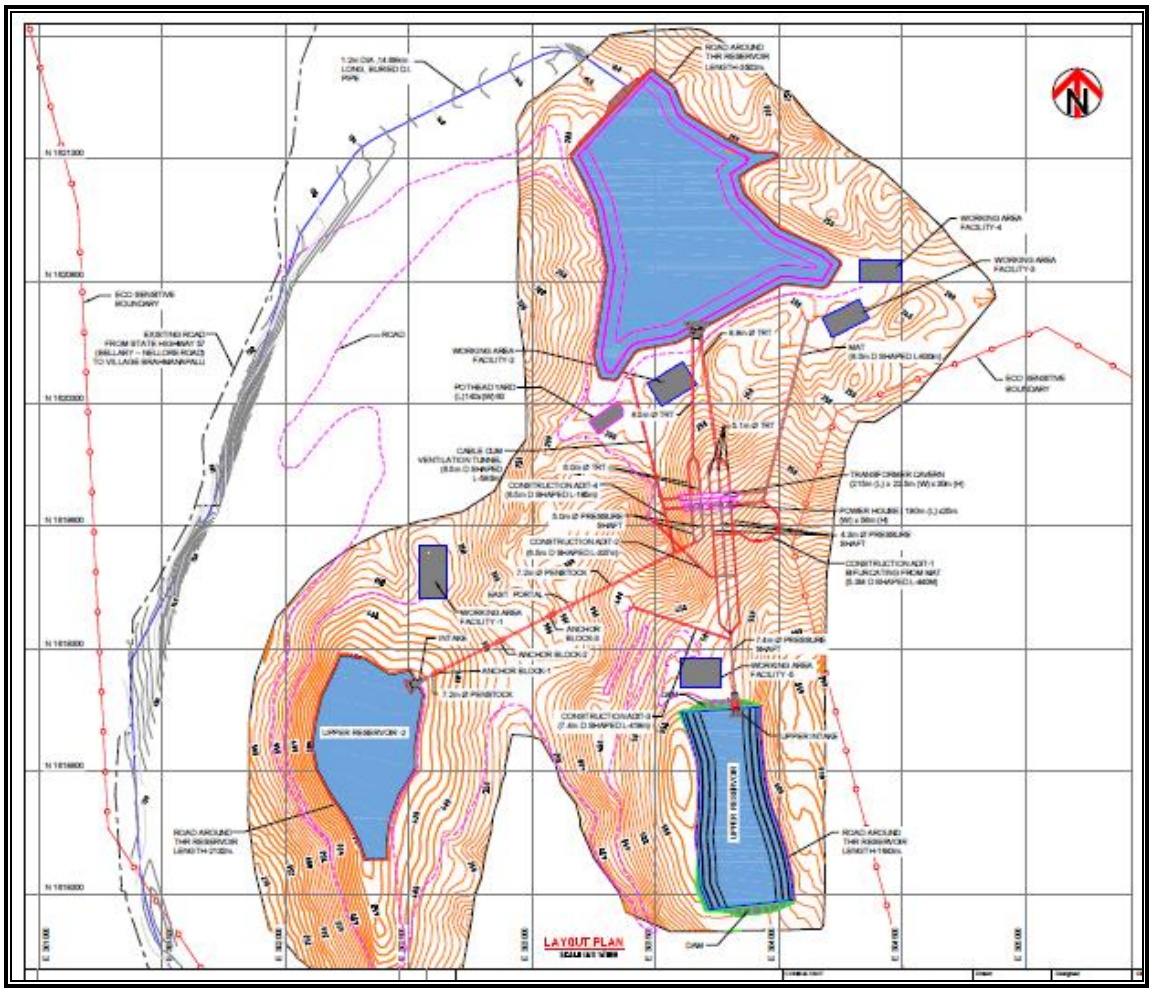


Figure 1-4: General Layout Plan of Option -7

In Option-7, the total storage capacity of upper reservoir-1 & upper reservoir-2 are 6.167 MCM & 4.839 MCM respectively where in live storage capacities are 5.96 MCM & 4.597 MCM respectively. Similarly total & live storage capacity of lower reservoir are 12.198 MCM & 10.912 MCM. Proposed Installed capacity for Option-7 is 1500 MW which is a combination of 900 MW (3 x 300 MW) installed capacity between the upper reservoir-1 to lower reservoir and 600 MW (2 x 300 MW) installed capacity between the upper reservoir-2 to lower reservoir.

The water conductor system between the upper reservoir-1 to lower reservoir is elaborated below:

1. Upper Reservoir-1 Levels
    - FRL : 566.0m
    - MDDL : 536.0 m
2. Upper Intake -1 :
    - Nos : 1 Nos
    - Design discharge : 271.0 Cumec

- Intake Conduit Invert : 515.0 m

3. Pressure Shaft : 1 nos., 7.40m diameter circular, 341.40 m long
4. Branch Penstock : 3 nos., 4.30m diameter circular, 642.70 m long
5. Power House : 190 m long x 25 m wide x 60 m high
6. Centre line of Turbine Unit : 107.0 m
7. Installed Capacity : 900 MW (3x300 MW)
8. Rated Net Head : 373.67 m
9. Unit TRT : 3 nos., 5.1m diameter circular, 191.0 m long
10. Main TRT : 1 nos., 8.90m diameter circular, 492.0 m long
11. Lower Intake
    - Intake Conduit Invert : 152.50 m
12. Lower Reservoir Levels
    - FRL : 182.0m
    - MDDL : 162.0 m

The water conductor system between the **upper reservoir-2 to lower reservoir** is elaborated below:

1. Upper Reservoir-2 Levels
    - FRL : 460.0m
    - MDDL : 441.0 m
2. Upper Intake -2 :
    - Design discharge : 248.50 Cumec
    - Intake Conduit Invert : 421.0 m
3. Pressure Shaft : 1 nos., 7.20m diameter circular, 1288.35 m long
4. Branch Penstock : 2 nos., 5.0m diameter circular, 177.30 m long
5. Power House : 190 m long x 25 m wide x 60 m high
6. Centre line of Turbine Unit : 116.0 m
7. Installed Capacity : 600 MW (2x300 MW)
8. Rated Net Head : 271.68 m
9. Unit TRT : 2 nos., 6.0m diameter circular, 199.0 m long
10. Main TRT : 1 nos., 8.50m diameter circular, 491.0 m long
11. Lower Intake
    - Intake Conduit Invert : 152.50 m
12. Lower Reservoir Levels
    - FRL : 182.0m
    - MDDL : 162.0 m

The proposed **option 8** is similar to option 7, with a single upper reservoir instead of twin upper reservoirs as proposed in option 7. The location of lower reservoir is same as proposed in the option 7 envisaging pumping for filling of proposed lower reservoir from existing Somasila reservoir. Schematic layout of Option-8 is shown in ***Figure – 1-5*** and detailed layout of project is given in ***Drawing Volume III, drawing number 7061601-FSR-1001.***

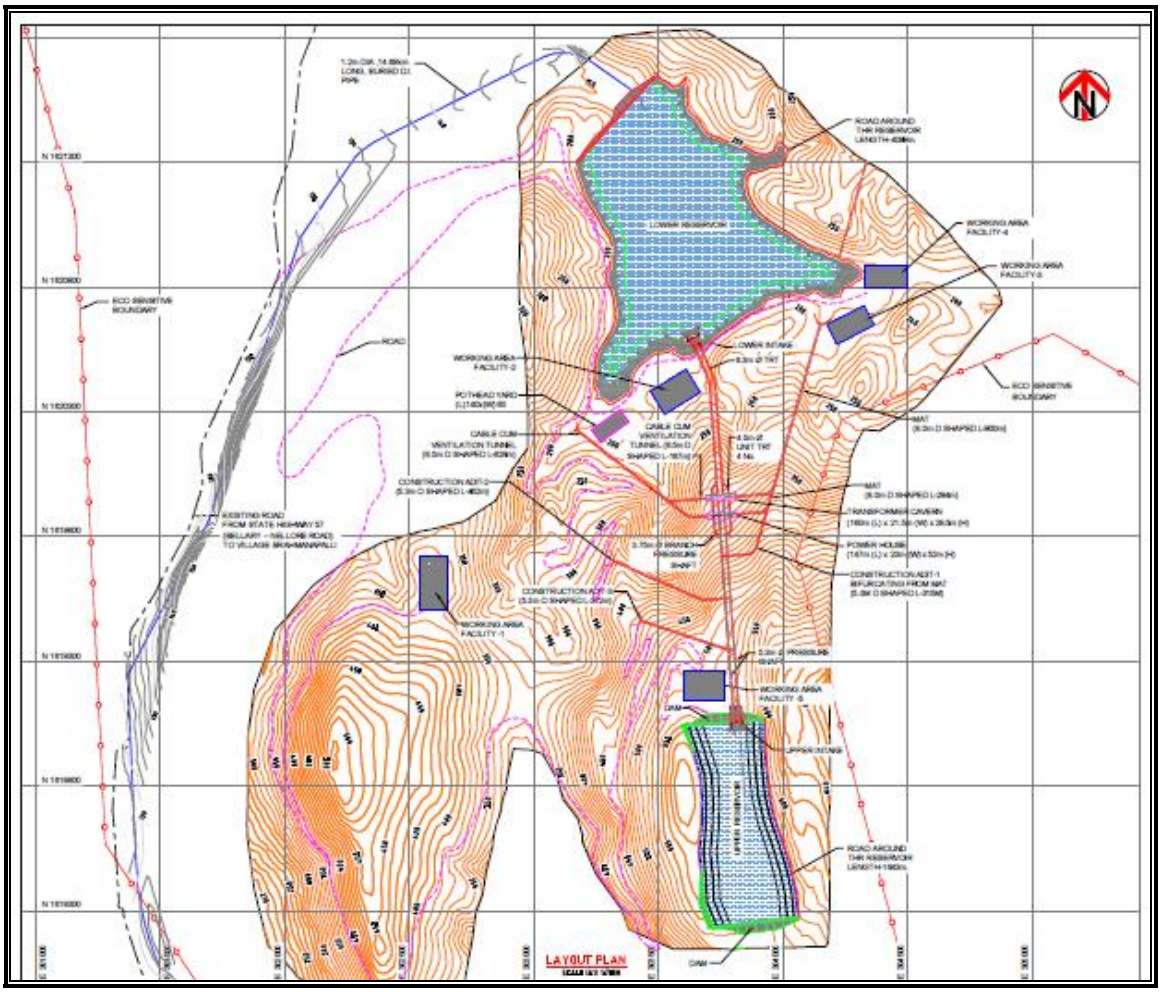


Figure 1-5: General Layout Plan of Option -8

Here in Option-8, the total & live storage capacity of upper reservoir are 6.167 MCM & 5.96 MCM respectively. Similarly, total & live storage capacity of lower reservoir are 8.329 MCM & 6.382 MCM. The proposed installed capacity of Option-8 is 900 MW (4 x 225 MW).

The water conductor system between the **upper reservoir to lower reservoir** is elaborated below:

1. Upper Reservoir
   - FRL : 566.0m
   - MDDL : 536.0 m
2. Upper Intake:
   - Nos : 2 Nos
   - Design discharge : 136.50 Cumec
   - Intake Conduit Invert : 520.0 m
3. Pressure Shaft : 2 nos., 5.30m diameter circular, 903.20 m long
4. Branch Penstock : 4 nos., 3.75m diameter circular, 78.70 m long
5. Power House : 147m (L) x 23m (W) x 52 m (H)
6. Centre line of Turbine Unit : 118.50 m
7. Installed Capacity : 900 MW (4x225 MW)

8. Rated Net Head : 371.0 m
9. Unit TRT : 4 nos., 4.5m diameter circular, 114.63 m long
10. Main TRT : 2 nos., 6.3m diameter circular, 575.65 m long
11. Lower Intake
    - Nos : 2 Nos
    - Intake Conduit Invert : 155.0 m
12. Lower Reservoir Levels
    - FRL : 182.0m
    - MDDL : 170.0 m

The options 7 & 8 were considered as the most suited options for techno-economic evaluation study after rejection of the rest of the options. During the techno economic evaluation of these options, it was observed that option 8 had major technical advantages over the option 7 and the same are listed as below:

1. The excavation volume for the upper reservoir 2 in the Option 7 is huge i.e approx. 8,000,000 cum as it envisages to excavate a peak hill top to create a reservoir ring fenced by a dam structure.
2. The excavation of the upper reservoir 2 is predicted as the most critical activity and is extending the overall construction duration of the project by 12 months as compared to option 8.
3. With a big gap in the cut fill balance, it would be a challenge to arrange space for dumping of the excavated muck from the upper reservoir 2.
4. For Option -7, turbine centre line elevation of 3 units are kept El. 107.0m (between upper reservoir-1 to PH) whereas for other 2 units (between upper reservoir-2 to PH), it is at El.116.0m. Because of the difference in turbine centre line elevations, height of power house cavern will increase significantly for smoother EOT crane operation and movement. This will also increase the column height & size of the Powerhouse and hence the project cost.

The cost estimates for both project layout options 7 & 8, including direct and indirect charges for the Civil & Electro-mechanical works have been worked out as given below in Table 1-3:

Table 1-3: Estimated Project Cost

Item	Estimated Cost (in Crores)	
	Option 7 (1500 MW)	Option 8 (900 MW)
Civil Works	3291.93	1685.06
Electro-Mechanical Works	2181.00	1320.30
Total Capital Cost	5472.93	3005.36
IDC	**1029.04**	**492.72**
Total Cost	**6501.97**	**3498.08**

As indicated above, the estimated project costs for Options 7 & 8 including IDC are about Rs. 6501.97 Crores and Rs. 3498.08 Crores respectively.

The annual energy generation for Options 7 & 8 are 3066.0 GWh and 1971.0 GWh respectively and the annual pumping energy for filling the upper reservoir for options 7 & 8 are 3850.75 GWh and 2409.00 GWh respectively.

Initial pumping Energy required for both options is in the range of about 6.776 GWh and 3.563 GWh respectively to fill the lower reservoir. Project levelized tariff is shown in the below table:

Table 1-4: Levelized Tariff Assessment

Options	Off Peak Energy Rate (Rs/ kWh)	First Year Tariff (Rs/ kWh)	Levelized Tariff (Rs/ kWh)
Option 7	**3**	**8.57**	**8.04**
Option 8	**3**	**7.72**	**7.28**

The first year tariff for Option 7 is Rs. 8.57 / kWh while that for Option 8 is Rs.7.72 / kWh and the levelized tariff for Option-7 is Rs. 8.04 / kWh and for Option-8 is Rs. 7.28 / kWh. **Considering the various technical demerits of option 7 as listed earlier and the cost benefit advantages of Option 8 as cited above, Option 8 layout has been selected for carrying out further studies and to prepare Feasibility Study Report**.

1.11 LAND REQUIRED FOR THE SELECTED OPTION FOR PROJECT CONSTRUCTION

1.11.1 FOREST LAND

Entire Project area falls under forest land. In reference to below detailed assessment, 183 ha of land is required for Project Construction

Table 1-5: Required land

Component	ha
Lower Reservoir	76.14
Upper Reservoir	29.09
Power house	7.50
Tunnel	5.08
Road	20.00
Muck disposal	36.31
Contractor facility	8.09

Total	182.21

1.11.2 TOTAL AREA OF THE LAND BEING SUBMERGED

The area under full reservoir level has been considered as submerged area. The submerged area for Lower reservoir is 76.14 ha and that for upper reservoir is 29.09 ha. The total area of the land being submerged is 105.23 ha.

1.12 ENVIRONMENTAL ASPECTS

As per Ministry of Environment, Forests and Climate Change (MoEF&CC) EIA Notification 2006 and amendments thereafter, any river valley project with over 50 MW hydroelectric power generation capacity will fall under Category A and Environmental Clearance (EC) to be obtained from Expert Appraisal Committee (EAC) of MoEF&CC. The capacity of Somasila pumped storage project is 900 MW (>50 MW), thus attracts the condition of obtaining prior environmental clearance from MoEF&CC. Detailed Environmental Impact Assessment (EIA) Study will be carried out as per the approved TOR during preparation of DPR. This report contains environmental Screening of the project and details are provided in Chapter 15.

Diversion of forest land for non-forest purpose will be involved for construction of Somasila project components. Therefore, Forest Clearance to be obtained under Forest Conservation Act.

Although the project components are proposed outside the Eco-Sensitive Zone (ESZ) of Sri Penusila Narasimha Wildlife Sanctuary (PNWLS), the pipeline for the initial filling of reservoir will be laid through the PNWLS. Thus, Wildlife Protection Act is applicable for this project and clearance / NOC to be obtained for this project from National Board of Wild Life (NBWL).

1.13 INTER STATE / INTER-NATIONAL ASPECTS

There are no specific issues envisaged in the inter-state or inter-national aspects of the project. As the project shall draw from the Somasila reservoir for filling initially during commissioning stage and at a later stage may need occasional pumping for compensation of evaporation losses etc, the project does not foresee any regular demand of water to be pumped for operational purpose.

1.14 COST AND BENEFITS OF THE SELECTED OPTION

The estimated total cost of the selected project alternative Option-8 is Rs.3498.08 Crores, including IDC at June 2020-21 price level of SOR of Andhra Pradesh. The project would provide peaking benefits of 900 MW.

Table 1-6: Capital Cost of the Selection Option

Works	Cost (in Crores)
Civil Works	1685.06
Electro-Mechanical Works	1320.30
Total Capital Cost	3005.36
IDC	492.72
Total Cost	3498.08

Table 1-7: Levelized Tariff of the Selected Option

CONVERSION COST (Excluding pumping cost)	
First Tariff	Rs. 3.96 /kWh
Levelized Tariff	Rs. 3.52 /kWh
CONVERSION COST (Including pumping cost @ Rs. 3.0/kWh)	
First Tariff	Rs. 7.72 /kWh
Levelized Tariff	Rs. 7.28 /kWh

1.15 CONSTRUCTION PROGRAMME

The construction methodology proposed for the Somasila Pumped Storage Project is based on the desk study, site visit, geological features revealed after surface mapping, topography of the area, project features and the various activities involved. The construction will involve concurrent working on all the Civil, HM & EM works for various components. Construction of Reservoirs and Power house are the most critical activities of the project. Overall Construction duration have been workout under two major heads i.e. Pre-Construction stage and Main Construction stage activities. Activities pertain to Hydro mechanical works and electromechanical works are covered in the schedule under relevant heading of civil component.

The Powerhouse has been proposed as underground structure considering the deep setting level of turbines and the slope of the TRT. However the options for considering partial underground and partial surface or fully surface power house shall explored based on additional geotechnical investigations proposed during DPR stage.

The proposed project is planned to be completed within the time duration of 60 Calendar months after award of works. The work of tendering, evaluation & award will be carried out expeditiously so that the contractor mobilizes by the start of working period.

JUSTIFICATION OF THE PROJECT

2 CHAPTER 2 JUSTIFICATION OF THE PROJECT FROM POWER SUPPLY ANGLE

Andhra Pradesh is one of the states in the country selected for implementation of 'Power for All'- flagship program of Govt. of India.

The objective of the above program is to supply 24x7 quality, reliable and affordable power supply to all domestic, commercial and industrial consumers within a fixed timeframe. This program covers the entire gamut of power sector, including generation, transmission, distribution, consumer initiatives, renewable energy, energy efficiency measures, financial health of the utilities and support required from Govt. of India to achieve the objectives of the program.

The Andhra Pradesh Electricity Regulatory Commission (APERC), Regulation 5 of 2005 directs APTRANSCO to collect and consolidate sales forecast and power procurement from distribution licensees.

The chapter has been formulated based on following reference documents:

1. Resource Plan APERC - "Approval of Load Forecasts and Resource Plans (Distribution Plans, Power Procurement Plans & Transmission Plans), comments on the State Electricity Plan for the 4th Control Period (FY2019-20 to FY2023-24) and Indicative Forecasts & Plans for the 5th Control Period (FY2024-25 to FY2028-29)" dated 2019.
2. APTRANSCO - State Electricity Plan for 4th Control Period (FY 2019-20 to FY 2023-24) and 5th Control Period (FY 2024-25 to FY 2028-29), July 2018
3. Data pertaining to power supply status in Andhra Pradesh vide letter no. NREDCAP//WE/PSP/Corrs/2021/580 dated19-Mar-21 (4435333/2021/CE-01-KRS-VJWD)

The total installed capacity of Andhra Pradesh is 17,905 MW as per power allocation after State bifurcation as on 31-03-2018.

The total number of consumers in the State is 178.11 lakhs which includes:

- 143.38 lakhs of domestic,
- 13.49 lakhs of commercial,
- 1.55 lakhs of industrial,
- 17.20 lakhs of agricultural categories as on 31.3.2018.

The per capita consumption of Andhra Pradesh as on 31st March 2017 was 1085 units. The total energy consumption (at utility periphery) in Andhra Pradesh during FY2017-18 was 58,793 MU. The peak demand reached 8,983 MW.

2.1 PRESENT INSTALLED CAPACITY OF ANDHRA PRADESH

The installed capacity of 17,905 MW comprises 5,010 MW of AP Genco thermal, 1,798 MW of AP Genco hydel, 251 MW of APGPCL & AP Discom Gas, 2,330 MW of CGS Share, 1905 MW of IPP's & others and 6522 MW of NCE's.

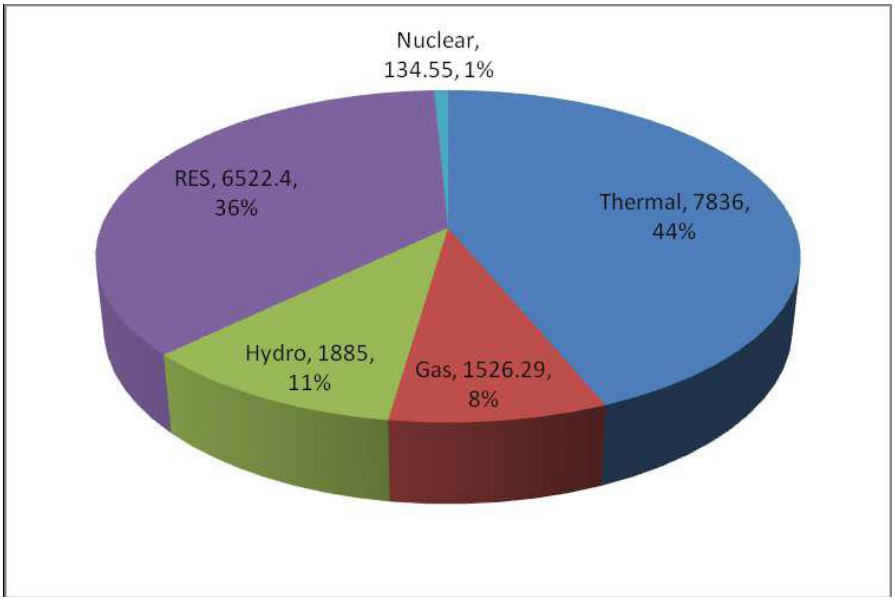


Figure 2-1: Present Installed Capacity of Andhra Pradesh (Sources – APTRANSCO)

2.2 POSITION OF TRANSMISSION AND DISTRIBUTION

The transmission infrastructure consists of 11 Nos. of 400 kV substations, 91 Nos. of 220 kV substations, 206 Nos. of 132 kV substations and 26,314 Circuit Kilometers (Ckm) of EHT lines as on 31.03.2018. The transmission loss during FY2017-18 was 3.17%. There are 2898 Nos. of 33/11 kV substations and 25,827 Ckm of 33 kV lines as on 31.03.2018.

2.3 ENERGY AVAILABILITY

The summary of year-wise available plant capacities in MW has been shown below:

Table 2-1: Year wise available plant capacities (MW) for 4th Control Period

Plants	FY18	FY19	FY20	FY21	FY22	FY23	FY24
APGENCO Thermal	4410	4614	4614	5412	4957	4574	4574
APGENCO Hydel	1798	1780	1780	1780	1898	2413	2723
CGS	2795	2674	2686	2686	2686	2686	2686
APGPCL/DISCOM Gas	818	792	792	792	792	792	792
IPPS – Others	285	233	233	233	222	217	217
NCE – Solar	1927	2592	4431	5596	5596	5596	5596
NCE – Wind Power	3685	4326	4729	4742	4740	4679	4615
NCE – Mini Hydel	45	46	51	48	51	46	43
NCE – Others	201	175	212	220	189	165	131
Total	15963	17231	19526	21509	21131	21167	21377

Table 2-2: Year wise available plant capacities (MW) for 5th Control Period

Plants	FY 18 (Actual)	FY25	FY26	FY27	FY28	FY29
APGENCO Thermal	4.410	4.574	4.574	4.574	4.574	4.574
APGENCO Hydel	1,798	2,730	2,730	2,730	2,730	2,730
CGS	2,795	2,686	2,686	2,686	2,686	2,686
APGPCL / DISCOM Gasd	818	792	792	792	792	792
IPPs - Others	285	217	217	217	217	217
NCE - Solar	1,927	5,596	5,596	5,596	5,596	5,596
NCE – Wind Power	3,685	4,615	4,611	4,601	4,599	4,599
NCE – Mini Hydel	45	40	37	30	30	28
NCE - Others	201	113	100	79	78	78
Total	15,963	21,362	21,341	21,303	21,301	21,299

From the above table, it has been observed that Non-Conventional Energy Sources (NCE) has 36% contribution to the available plant capacities during the FY 2017-18 and it is projected to be increased to 48% of total plant capacity during the FY 2028-29. It is noteworthy that the large scale solar parks and non-conventional energy sources like Wind are being implemented in the State of Andhra Pradesh and Southern Region. However, the generation from renewable sources (like solar, wind and NCE's) will be available partially (i.e, seasonal or intermittently in a day) and cannot be relied entirely to meet the energy/power requirements throughout the day/year. Also, this will result in grid stability issues. Hence, large-scale addition of renewables necessitates implementation of a suitable system for storing surplus energy generated during peak generation period and utilizing the same during off-season as per the demand scenario. Pumped Storage hydro-electric projects are the most reliable option available in the current scenario for large-scale energy/power storage systems required for maintaining grid stability.

According to the Resource Plan of APERC, below tables are showing the energy availability in MUs based on existing and future planned installed capacities:

Table 2-3: Projected Energy Generation at State for 4th and 5th Control Period

Projected energy generation for 4th Control Period (MU)							
Sources	**FY18 (Actual)**	**FY19**	**FY20**	**FY21**	**FY22**	**FY23**	**FY24**
APGENCO Thermal	26646	30312	30312	35544	32568	30050	30050
APGENCO Hydel	2392	2477	2477	2477	2591	3370	4051
CGS	19480	19754	19845	19845	19845	19845	19845
APGPCL / DISCOM Gas	5195	5195	5195	5195	5195	5195	5195
IPPs - Others	315	1816	1816	1816	1745	1709	1709
NCE - Solar	2998	5095	8186	10130	10130	10130	10130

NCE – Wind Power	7282	8429	9223	9245	9237	9115	8987
NCE – Mini Hydel	97	103	120	127	158	147	139
NCE – Others	458	683	822	823	732	642	552
Energy Availability	64863	73864	77996	85202	82201	80203	80658

Energy Availability at State for 5th Control Period (MU)					
Sources	**FY 25**	**FY 26**	**FY 27**	**FY 28**	**FY 29**
APGENCO Coal	30050	30050	30050	30050	30050
APGENCO Hydel	4066	4066	4066	4066	4066
CGS	19845	19845	19845	19845	19845
APGPCL / DISCOM Gas	5195	5195	5195	5195	5195
IPPs – Others	1709	1709	1709	1709	1709
NCE – Solar	10130	10130	10130	10130	10130
NCE – Wind Power	8987	8976	8958	8954	8954
NCE – Mini Hydel	133	124	96	96	93
NCE – Others	455	427	398	394	394
Energy Availability	80570	80522	80447	80439	80436

2.4 ENERGY INPUT PROJECTION

The projected energy inputs at the state level in MUs for 4th and 5th Control Periods listed in Table 2-4 & 2-5:

Table 2-4: Energy Input Projection at State Level for 4th Control Period

Energy Input (Mus)	FY 18 (Actual)	FY19	FY20	FY21	FY22	FY23	FY24
Energy input @ EPDCL	19,678	21,976	24,508	26,443	28,576	30,968	33,565
Energy Input @ SPDCL	34,328	39,593	42,473	45,711	49,343	53,401	57,956
Transmission Losses	1,768	2,001	2,131	2,261	2,430	2,609	2,788
PGCIL Losses	436	460	460	460	460	460	460
Less: Procurement at 33 kV	0	0	966	1,663	1,663	1,663	1,663
Total Energy Input at State Level	56,209	64,030	68,606	73,212	79,146	85,776	93,106

Table 2-5: Energy Input Projection at State Level for 5th Control Period

Energy Input (Mus)	FY 25	FY26	FY27	FY28	FY29
Energy input @ EPDCL	36,440	39,558	43,212	47,339	51,950
Energy Input @ SPDCL	63,085	69,001	75,835	83,715	92,788
Transmission Losses	2,984	3,205	3,458	3,744	4,064
PGCIL Losses	460	460	460	460	460
Less: Procurement at 33 kV	1,663	1,663	1,663	1,663	1,663
Total Energy Input at State Level	101,306	110,561	121,302	133,594	147,599

2.5 ENERGY BALANCE

The peak demand forecasted at the State level is shown below:

Table 2-6: Andhra Pradesh State Peak Demand for 4th and 5th Control Period

Parameters	FY18 (Actuals)	FY19	FY20	FY2 1	FY22	FY23	FY24	CAGR
Energy Requirement at State level (MUs)	56,209	64,030	68,606	73,212	79,146	85,776	93, 106	8.8%
State Peak Demand (MW)	8,983	10,532	11,450	12,219	13,209	14,315	15,539	9.6%
Parameters	FY 18 (Actuals)	FY25	FY26	FY27	FY28	FY29	CAGR	
Energy Requirement at State level (MUs)	56,209	1,01,306	1,10,561	12 1,302	1,33,594	1,47,599	9.2%	
State Demand (MW)	8,983	16,907	18,452	20,245	22,296	24,633	9.6%	

Below tables summarizes Energy (MU) balance in Andhra Pradesh:

Table 2-7: Energy Surplus / Deficit summary for 4th and 5th Control Period

4 Control period	FY 19	FY20	FY2 1	FY22	FY23	FY24
State Energy Availability	73,865	77,998	85,203	82,200	80,204	80,658
State Energy input*	60,971	66,313	71,355	76,951	83, 152	90,033
State Energy Surplus/ (Deficit)	12,894	11,685	13,847	5,248	(2,949)	(9,375)
5 Control period	FY25	FY26	FY27	FY28	FY29	CAGR
State Energy Availability	80,570	80,52 1	80,446	80,439	80,436	0.9%
State Energy input*	97,707	1,06,247	1,16,046	127,14 1	1,39,665	8.6%
State Energy Surplus/ (Deficit)	(17, 138)	(25,726)	(35,6001)	(46,702)	(59,229)	
This energy input doesn't include energy contribution from Open Access Sales						

From the above tables, it has been observed that at present Andhra Pradesh is handling 56209 MU (FY2017-18) of energy and maximum demand reached is 8983 MW. This is likely to increase to MU of energy147599 & 24633 MW of peak demand by FY 2028-29. According to the Table -2, available plant capacities by FY2028-29 is 21299 MW. Thus, the energy deficit for the FY 2028-29 is 3334 MW or 59229 MU as per below table 10. Also it is prudent to mention here that the entire projected installed capacity may not be available all time for meeting the peak demand owing to the following reasons:

- Reduced power output from hydel stations due to non-availability/reduced water availability during summer season or due to occurrence of droughts.
- Seasonal, daily and hourly fluctuations in power output from renewable energy sources like Solar and Wind power stations.

- Non-availability of power from a few thermal power stations due to scheduled and unscheduled outages and maintenance activities or due to non-availability of coal

Thus, development of suitable energy storage system for power and energy like pumped storage project is become a necessity to supply the power during the peak demand period.

2.6 LOAD CURVE ON PEAK AND OFF-PEAK PERIODS

Figures 2-2 to 2-5 present the hourly variation of load curve (*Sources- NREDCAP//WE/PSP/Corrs/2021/580 dated19-Mar-21 (4435333/2021/CE-01-KRS-VJWD*)

Table 2-8: Hourly demand

Source: NREDCAP//WE/PSP/Corrs/2021/580 dated19-Mar-21 (4435333/2021/CE-01-KRS-VJWD)											
Hour/ Month	Hourly Power Demand										
	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW
	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21
1.00	5846.33	6808.00	6496.43	6000.55	6049.52	6379.77	6083.06	5963.57	5448.39	5804.06	6380.75
2.00	5832.67	6704.26	6365.97	5857.52	5948.65	6274.80	5981.42	5899.40	5407.52	5790.32	6340.56
3.00	5745.73	6596.35	6239.83	5764.19	5958.13	6194.63	5905.81	5852.87	5369.81	5798.50	6361.71
4.00	5776.20	6577.65	6226.63	5710.03	5900.94	6137.43	5899.71	5864.67	5427.81	5861.71	6466.39
5.00	5903.23	6744.32	6305.10	5798.06	6046.48	6275.10	6083.03	6125.23	5723.94	6155.87	6890.39
6.00	5941.27	6628.48	6322.83	5859.84	6288.94	6363.63	6180.39	6454.03	6223.84	6821.90	7645.29
7.00	5673.87	6601.35	6384.23	5974.65	6552.65	6442.57	6362.77	6668.00	6747.16	7487.42	8458.39
8.00	6086.63	7018.13	6667.53	6185.61	6753.97	6787.80	6616.71	6952.77	7187.48	8142.29	9042.89
9.00	7238.90	7955.23	7505.57	6760.26	7417.00	7314.83	7021.74	7535.20	7654.52	8840.80	9725.43
10.00	7410.17	8180.68	7626.47	6822.68	7418.26	7368.33	7062.55	7504.07	7569.37	8864.19	9638.26
11.00	7414.77	8340.68	7674.40	6801.48	7326.35	7323.77	7079.00	7392.47	7521.77	8724.74	9572.18
12.00	7723.53	8608.84	7856.97	6905.35	7440.58	7543.43	7193.19	7541.60	7586.52	8825.19	9704.32

Source: NREDCAP//WE/PSP/Corrs/2021/580 dated19-Mar-21 (4435333/2021/CE-01-KRS-VJWD)											
Hour/ Month	Hourly Power Demand										
	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW
	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21
13.00	7617.48	8636.29	7906.57	6927.97	7546.61	7544.57	7215.29	7547.13	7439.71	8527.55	9470.18
14.00	7611.03	8893.06	7938.30	6754.16	7250.87	7314.57	6937.48	7134.00	7082.13	8236.68	9216.00
15.00	7743.97	9007.63	8107.63	6794.10	7159.60	7355.33	7012.45	7134.10	7082.39	8111.65	9158.14
16.00	7258.30	8452.43	7637.67	6586.97	6918.61	7001.07	6762.32	6901.20	6820.39	7845.03	8773.71
17.00	6248.83	7200.58	6771.40	6010.61	6449.48	6491.03	6500.77	6536.77	6458.16	7125.13	7921.04
18.00	5169.47	5924.10	5920.73	5701.84	6094.13	6590.40	7078.97	7204.30	7169.90	7031.10	7286.96
19.00	5769.80	6409.94	6369.97	6520.10	6885.03	7295.60	7369.65	7176.50	7135.45	7396.06	7793.29
20.00	5926.73	6724.13	6697.33	6903.94	6940.84	7190.00	7189.03	6948.13	6798.58	7020.84	7427.46
21.00	6469.63	7370.00	7164.77	6930.84	6965.16	7217.17	7071.45	6782.00	6445.84	6810.52	7295.54
22.00	6672.60	7711.03	7356.77	6836.29	6795.97	7060.43	6817.68	6447.67	6089.35	6438.03	6983.07
23.00	6427.33	7492.48	7114.80	6522.10	6459.06	6798.83	6537.32	6187.53	5696.58	6037.71	6633.07
24.00	6092.00	7127.23	6767.70	6232.06	6214.10	6527.13	6354.13	6046.87	5526.13	5903.13	6417.75

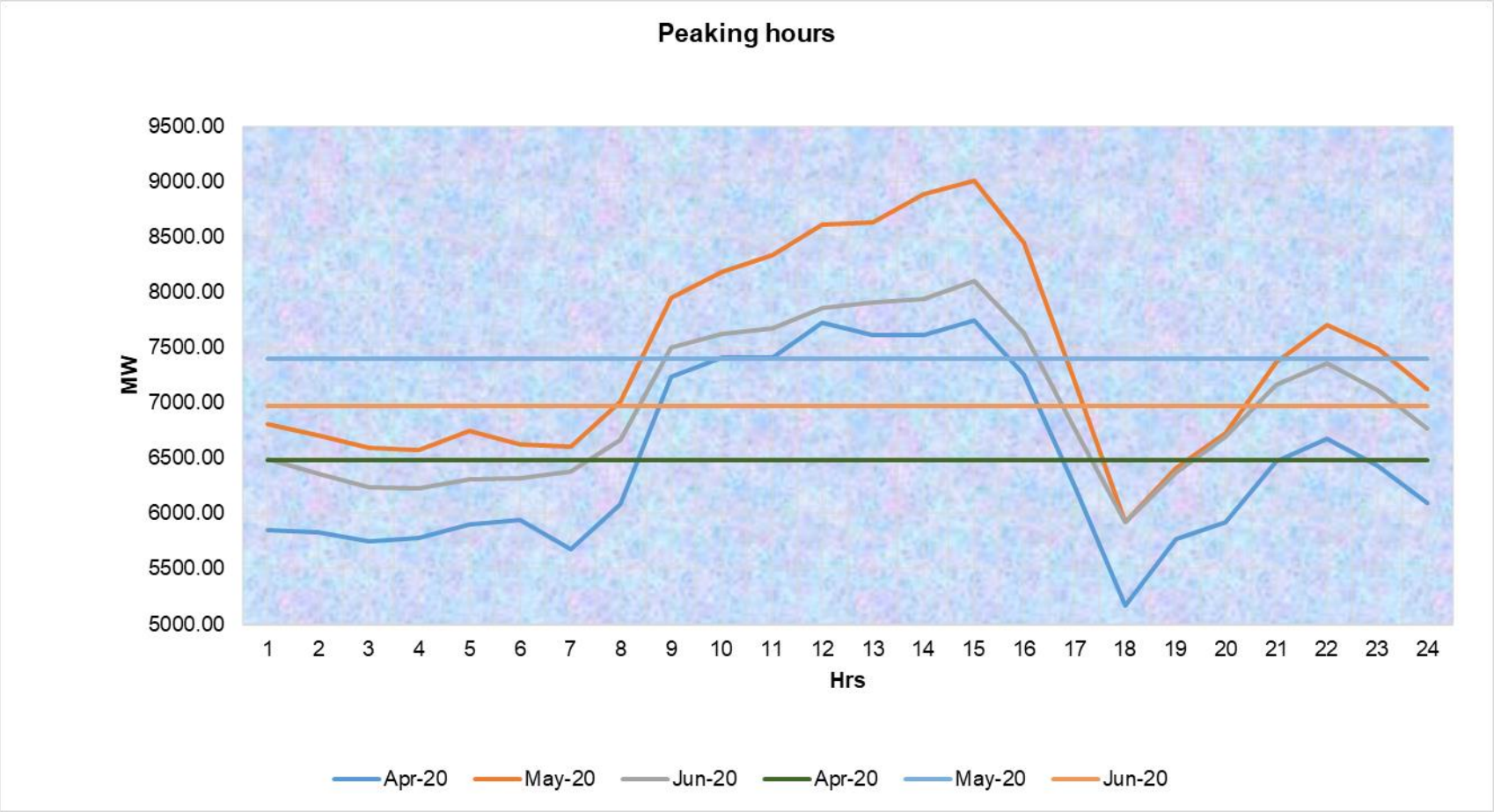


Figure 2-2: Peaking hours for Apr-20 to Jun-20

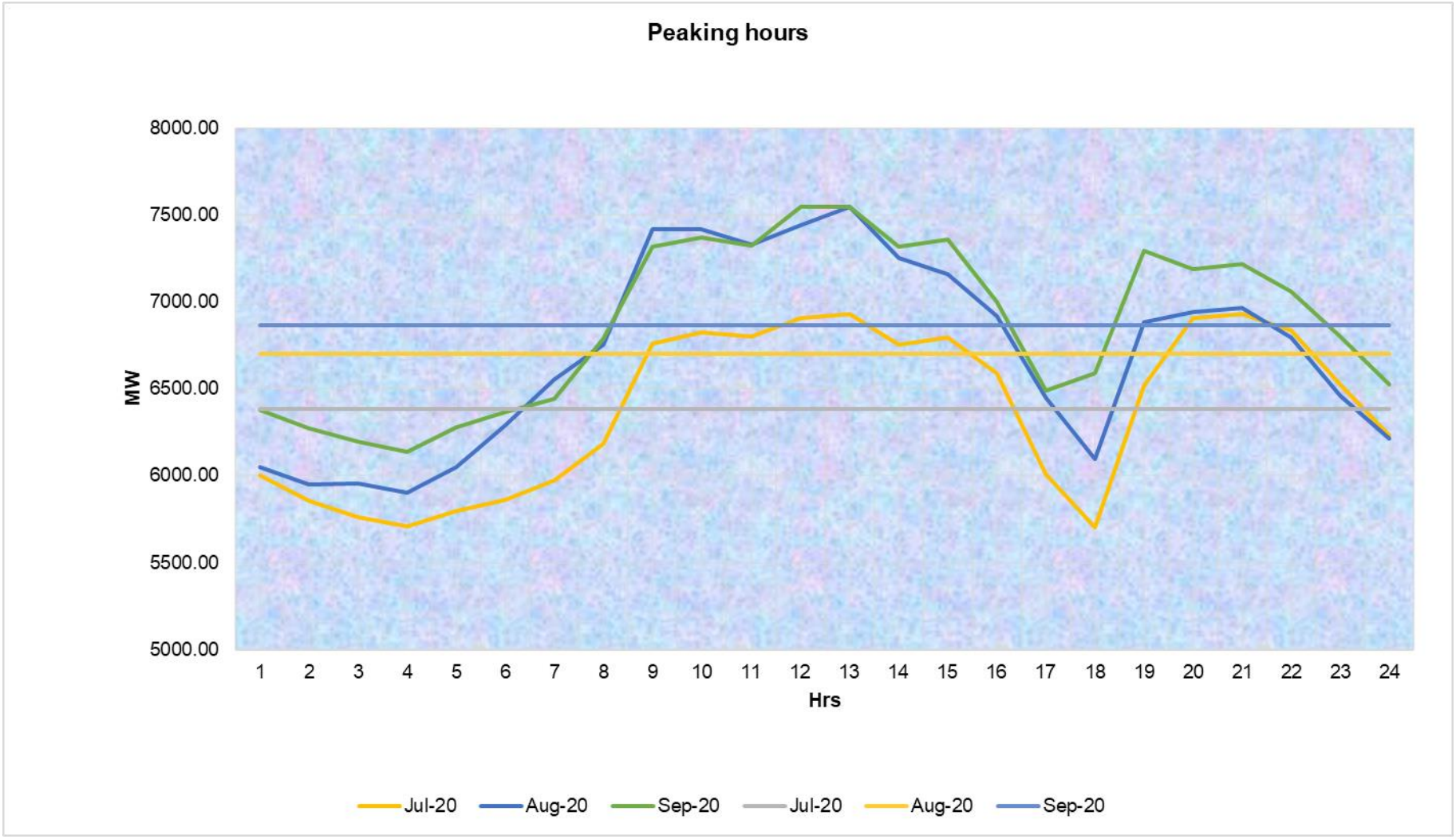


Figure 2-3: Peaking hours for Jul-20 to Sep-20

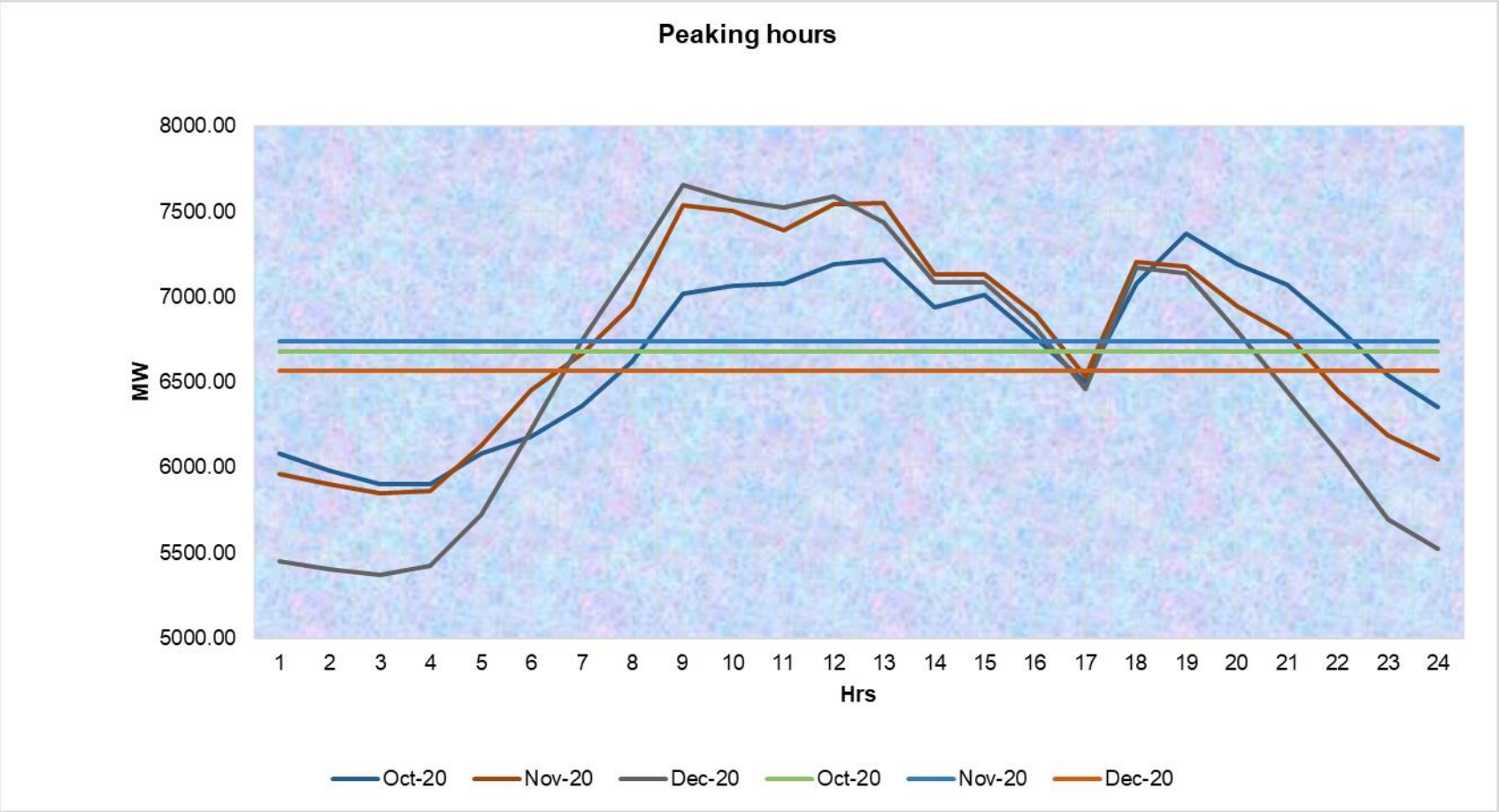


Figure 2-4: Peaking hours for Oct-20 to Dec-20

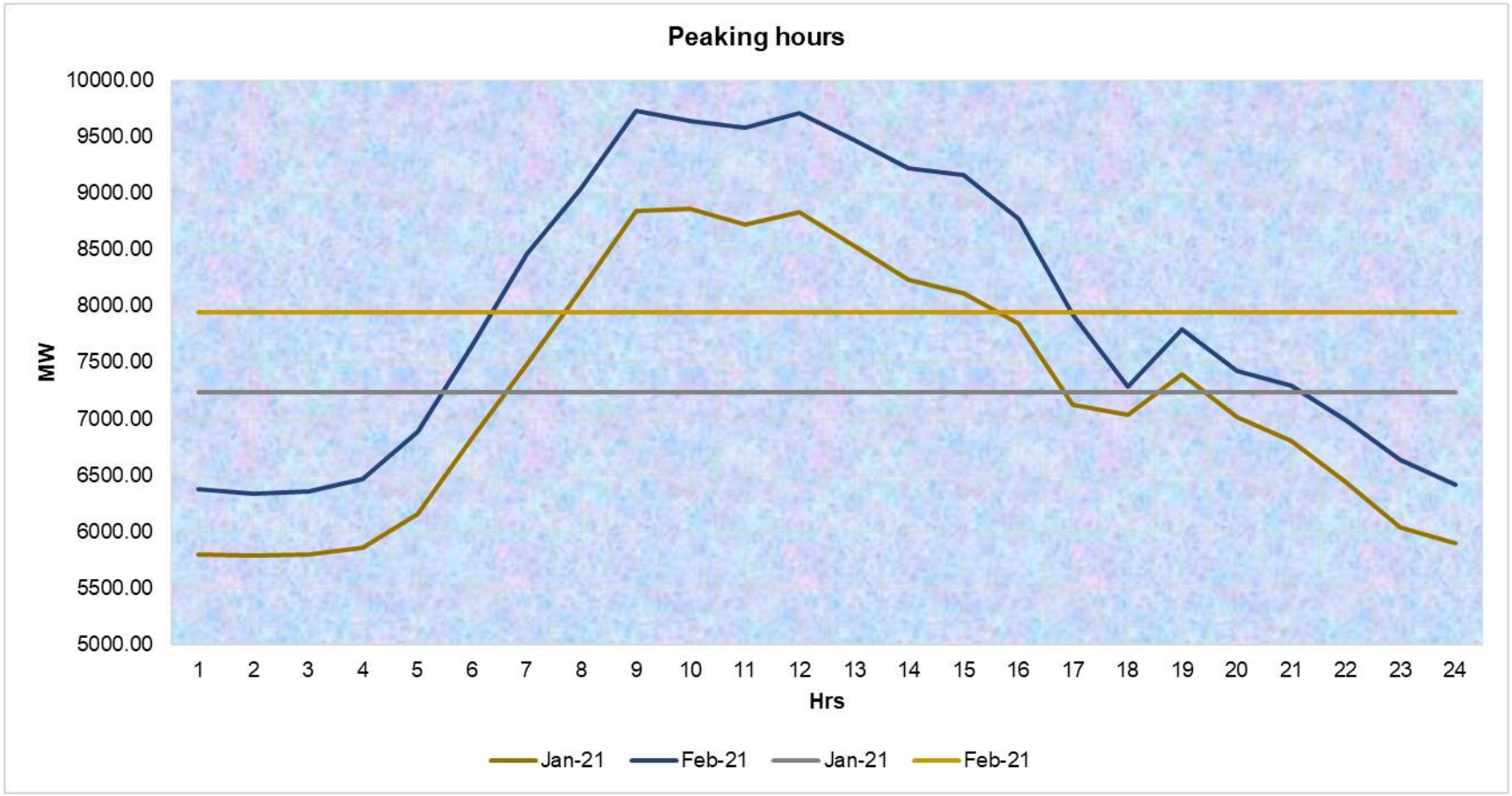


Figure 2-5: Peaking hours for Jan-21 to Feb-21

From the above figure 3 to 6 of month wise 24 hour duration load curve, the following peaking demand for the FY 2020 – 21 has been established for the day & night period.

Table 2-9: Peaking hours

Hour/Month	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21
Peaking Morning-Evening Hrs (12:00 am to 4:00 pm)	7	7	7	7	8	7	7	8	9	9	9
Peaking Evening - Night Hrs (4:00 pm to 12:00 am)	2	3	4	6	5	5	6	5	4	2	1

Thus, as summarized in above table, peak demand occurs typically for a duration of seven hours during day time and in night 5 to 6 hours. As the available hydroelectric potential in Andhra Pradesh has already been harnessed, the pumped storage schemes need to be pursued for meeting the system peak. These schemes are amenable for quick start, reliable and render operation flexibility in the system besides providing economic source for meeting peaking capacity requirement. In this connection, this Somasila PSP has potential to develop pumped storage project to cater the peak demand of 6 hours during the day time. Surplus wind / solar power will be used for pumping of water during off-peak time.

2.7 ADVANTAGES OF PUMPED STORAGE PROJECT

Thermal plants are less able to respond to sudden changes in demand and may result in frequency and voltage instability. The coal or nuclear based thermal power generation cannot steeply rise or fall matching the load demand. The thermal power generators cannot normally be shut off in the night and brought on line in the morning to match system loads. If the thermal power stations are to share base and peak loads, then the power system will be subjected to frequency excursions. Moreover the thermal plants in such conditions have to run at low loads for prolonged periods needing fuel oil support thereby increasing the cost of generation, which is not desirable and not recommended. In case of renewable energy sources like Wind and Solar power stations, it is essential to note that generation from Wind power varies from hour to hour and from season to season, often increasing after evening hours, particularly during monsoon season. Similarly, generation from Solar power is available only during day time, but also varies hourly and by season. The power generated from these sources at a certain hour on a future date of a year are uncertain.

The most reliable option for energy storage is development of pumped storage scheme, which utilizes the surplus power available during Off-peak period to pump up the water for storage and meets the On-peak demand by utilizing the stored water during peak demand. Along with balancing On-peak and Off-peak demands, a pumped storage scheme also helps in controlling electrical network frequency and stabilizing the operation of grid.

The benefits to the state by setting up of Somasila PSP is summarized below:

a. Peak Power Shortage: The development of Somasila Pumped Storage Project would address peak power shortage to the extent of 5.4 GWh per day and help in giving an impetus to Andhra Pradesh with 24x7 power supply.

b. Stabilizing the Grid: The National Solar Mission would induct large quantum of renewable energy to the grid in the years to come and the Solar power would go off the grid by the end of the day. The pumped storage project (PSP) will be required for stabilizing the grid and in turn supporting the National Solar Mission and facilitate induction of renewable energy in to the grid.

c. Long Term Asset to the State: The state will own a state of the art Pump storage facility after the end of concession period of 40 years. The state will benefit from investment of the money and save its precious resources.

d. Time of Day Tariff and Smart Metering: The Time of Day Tariff with smart metering would be a reality in the next few years. The Pump Storage Scheme would give the option of maximizing revenue to the state, since it can bring in additional power online at very short notice anywhere in the grid.

e. Employment and Local Area Development: The setting up of a 900 MW PSP project would provide employment to hundred plus technical staff and provide job opportunity to thousands during the construction phase.

f. The flexibility of Southern Regional grid would also be enhanced by the addition of 900 MW Somasila PSP and the power system efficiency of the state as well as Southern Region would increase. Surplus wind/solar power will be used for pumping of water. The water thus stored in the upper reservoir during power surplus periods will be used for meeting peak demand. Hence, Somasila Pumped Storage Project of 900 MW capacity in the Kadapa district of Andhra Pradesh is justified.

BASIN DEVELOPMENT

3 CHAPTER 3 - BASIN DEVELOPMENT

3.1 THE COURSE OF THE RIVER

Andhra Pradesh is a land of many rivers and lakes and it is popularly referred as the "Riverine State". There are 40 major, medium and minor rivers in the state, of which Godavari, Krishna and Pennar are prominent rivers in peninsular India. All these rivers carry 2765 TMC of water annually at 75% dependable yield. Out of 40 rivers, 15 rivers are interstate rivers. The Krishna and Godavari river waters are covered by the Tribunal Awards. The Bahudha, Vamsadhara, Nagavali, Palar, Ponniar river waters are covered by the Agreements among basin states.

The Ministry of Water Resources formulated a National Perspective for Water Development in August 1980. The National perspective Plan comprises of two components, namely

1. Himalayan Rivers Development; and
2. Peninsular Rivers Development.

The broad approach adopted in the National Perspective is given below.

1. Existing uses have been kept undisturbed.
2. The development envisaged is within the framework of all the existing agreements between the States.
3. While planning inter basin and inter-state transfer of water, reasonable needs of the basin states for the foreseeable future have been kept in view and provided for.
4. Most efficient use of land and water in the existing irrigation and hydro-power stations has been kept as the principal objective to be achieved.

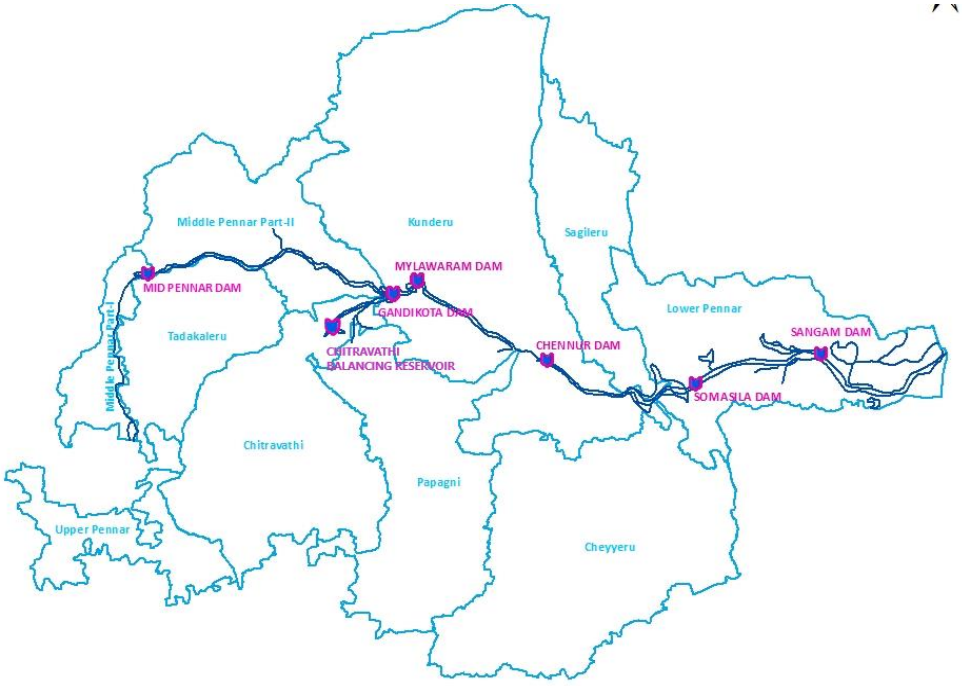


Figure 3-1: Pennar Basin Map

Figure 3-2: Pennar Basin Index Map

The National Water Development Agency (NWDA) was set up in July 1982 as registered Society to carry out the water balance and other studies on scientific and realistic basis

for optimum utilization of water resources of the Peninsular Rivers system for preparation of feasibility reports and thus to give concrete shape initially to the Peninsular Rivers Development component of the National Perspective Plan and the Himalayan Rivers Development Component was added later.

The Mahanadi - Godavari link system comprises of nine canal systems identified in Peninsular component to divert the surplus water available in Mahanadi and Godavari to water short basins of Krishna, Pennar, Cauvery and Vaigai. Eight out of Nine link Projects benefits the Andhra Pradesh state.

Link proposals of Peninsular Rivers: - (Connected to Andhra Pradesh).

1. The Mahanadhi – Godavari Link
2. Godavari (Inchampalli) – Krishna (Nagarjunasagar) Link.
3. Godavari (Inchampalli_ - Krishna (Pulichintala) Link.
4. Godavari (Polavaram) – Krishna (Vijayawada) Link.
5. Krishna (Almatti) – Pennar Link.
6. Krishna (Srisailam) – Pennar (Proddutur) Link.
7. Krishna (Nagarjunasagar) – Pennar (Somasila) Link.
8. Somasila – Grand Anicut Link

3.2 POWER POTENTIAL OF THE RIVER BASIN AND STAGES OF DEVELOPMENT

The Somasila Project was constructed across river Pennar near Somasila Village of Anantha Sagaram Mandal in S.P.S.R. Nellore District with a Gross storage capacity of 78.00 TMC at FRL +100.58 Mts (+330 Ft). River Pennar originates on the slope of Nandi hills in Karnataka State, and the basin of Pennar River is fed by a number of tributaries viz Cheyyeru, Papagni, Chitravathy, Kundu and Sagileru.

- State : Andhra Pradesh
- District : Sri Potti SriRamulu Nellore
- Village : Somasila.
- Basin : Pennar Basin
- Longitude : 79o-18’- 25” E.
- Latitude : 14o-29’-15” N.
- Total Ayacut : 5, 84, 500 Acres
- Stabilization of wet Ayacut : 4, 05, 500 Acres
- New Ayacut : 1, 79,000 Acres
- Catchment area at Dam Site : 48,645 Sq. KM. (18,790 Sq. Miles)
- Free Catchment : 20,900 Sq. KM. (8,073 Sq. Miles)

- Intercepted Catchment : 27,745 Sq. kms. (10,717 Sq. Miles)

3.3 PENNAR BASIN

The Penneru (Penneru, Penner, Pennar or Uttara Pinakini) rises in an upland region on the Deccan plateau, 7 miles (11 km) west-southwest of Chik Ballapur in southeastern Karnataka. It flows north into Andhra Pradesh state and turns east and then southeast. After passage through a gap in the Eastern Ghats range, it again bends east toward the Coromandel Coast, emptying into the Bay of Bengal near Nellore. The river is seasonal, becoming torrent after the rains and a thin stream during dry periods.

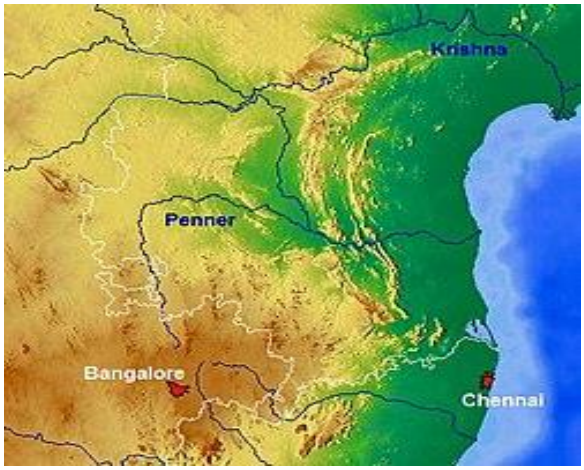


Figure 3-3: Pennar river

- The Pennar basin extends over an area of 55,213 km^2 which is nearly 1.7% of the total geographical area of the country.
- Out of the total area of the basin, 6,937 km^2 lies in Karnataka and 48,276 km^2 in Andhra Pradesh.
- The basin lies between east longitudes of 77º04' and 80º10' and north latitudes of 13º16' and 15º52'.
- It is bounded on the north by the Erramala range, on the east by the Nallamala and Velikonda ranges of the Eastern Ghats, on the south by the Nandidurg hills and on the west by the narrow ridge separating it from the Vedavati valley of the Krishna basin.
- The basin lies in the States of Andhra Pradesh and Karnataka.

3.4 LAND

The geology of the drainage basin is predominantly formed from Archean rocks, principally granitic intrustives into metamorphic schists. The Archeans in this region comprise biotite and hornblende granite-gneisses, granodiorite, diorite, and pegmatite. Of secondary importance are the Dhawar metamorphics comprising of phyllites, slates, schists with chlorite, biotite, garnet, staurolite, kyanite, silllimanite and hornblende. In the central part of the basin, the dominant rocks belong to the Cuddapah and Kurnool groups consisting of conglomerates, sandstones, shales, dolomites, limestones and cherts.

These are intruded by doloritic and basaltic igneous materials in many places. In the coastal regions major sediments are laterites and recent alluvium.

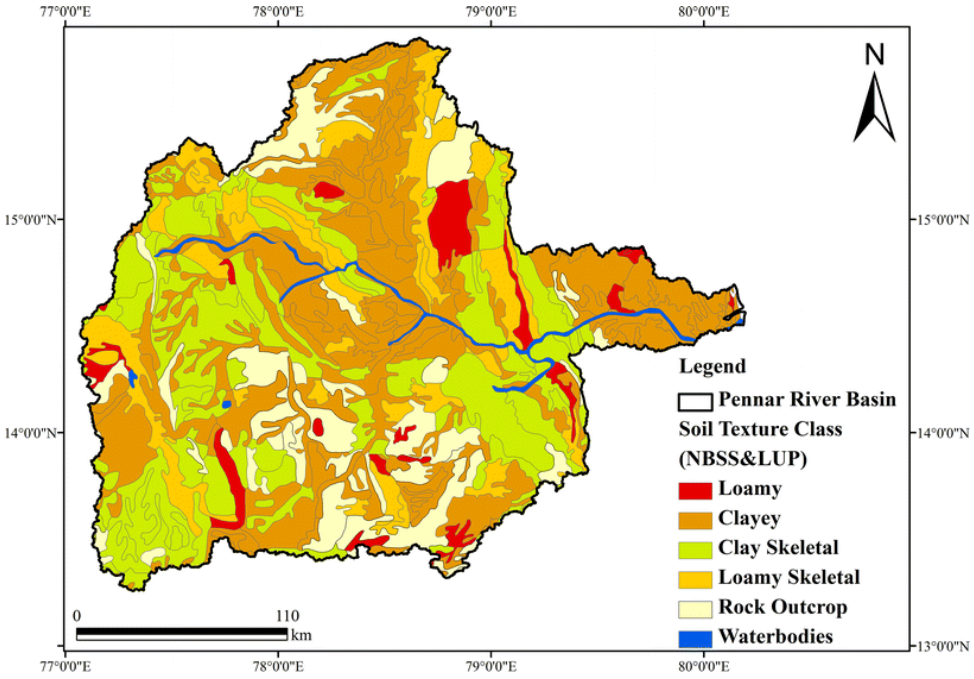


Figure 3-4: Soil texture map of Pennar Basin

Under major land uses in the Pennar basin, forests account for 21% of the area whereas nearly 12% area falls under barren land. Net sown area is 36% of the total basin area while total culturable area is about 55%. In the basin, double crops are taken over very small, about 1.66 % area.

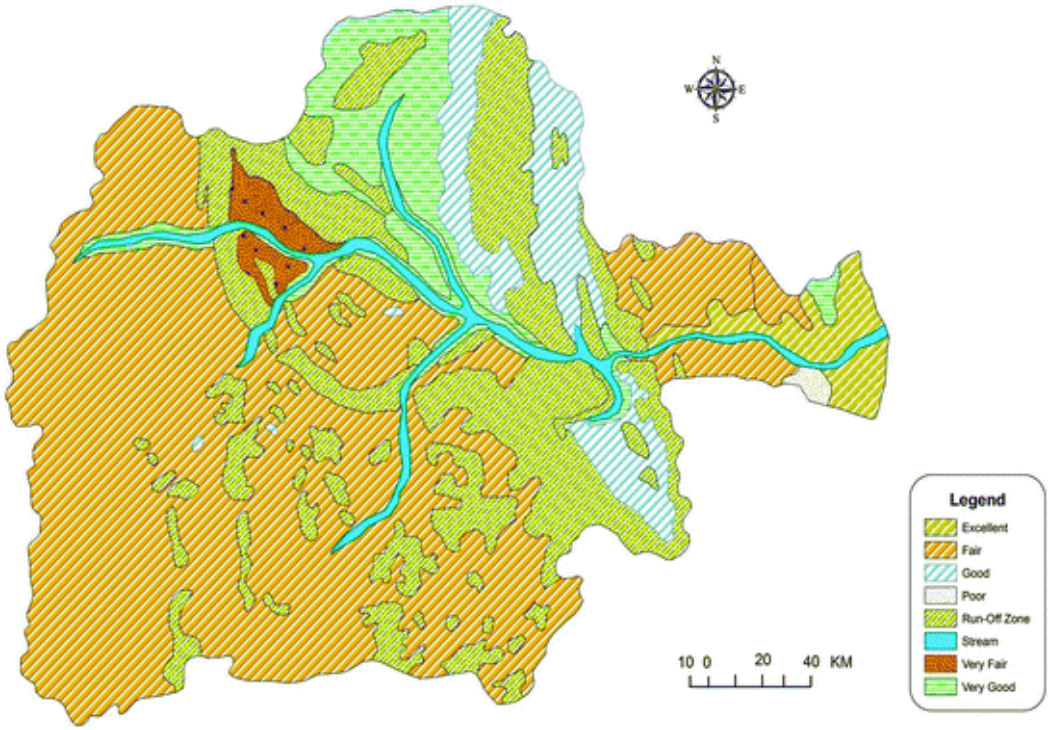


Figure 3-5: Pennar Basin – Hydrogeomorphology

3.5 DRAINAGE AREA

The principal tributaries of the Pennar River are the Jayamangali, the Kunderu, the Sagileru, from the left and the Chitravati, the Papagni and the Cheyyeru from the right.

The drainage area is listed as below:-

Table 3-1: Statewise Drainage Area (Km^2)

Name of State	Drainage area
Andhra Pradesh	48,276
Karnataka	6,937
Total Drainage Area (Km^2)	55,213

Table 3-2: Water Potential of the Basin

Surface Water potential	6.32 km^3
Ground Water potential	4.93 km^3

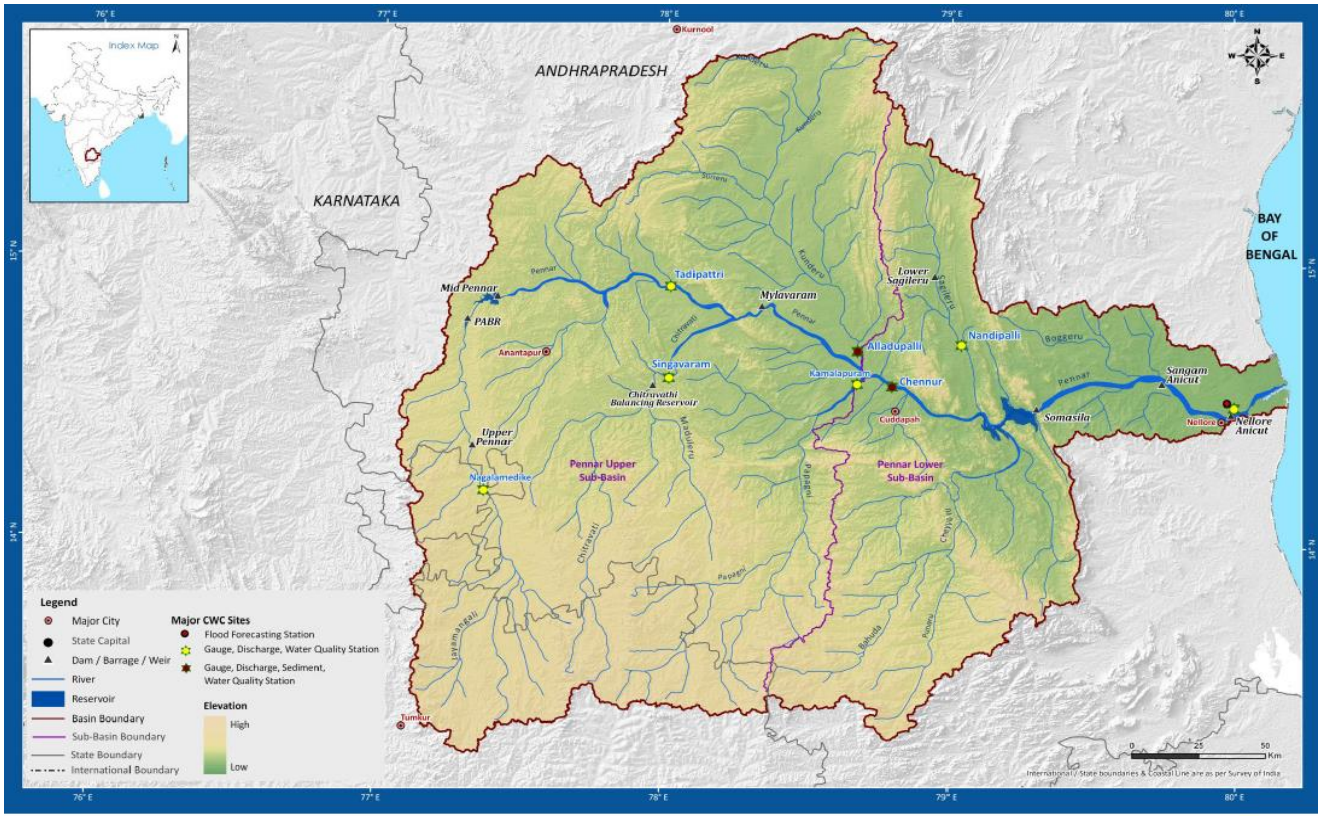


Figure 3-6: Drainage & Sub-basin

3.6 WATER QUALITY

Rivers in semi-arid areas are characterized by wide variations in the annual flows and poor quality of water. Pennar River also has a semi-arid catchment. Water of the Pennar River up to Anantpur and Cuddapah is not of good quality for irrigation and drinking due to large quantities of carbonates and bicarbonates. The fluoride concentration is also high due to the presence of soluble salts and fluorides from the rocks and soils in the catchment. Due to poor quality of water, yield from irrigated crops is very poor. In case of paddy, only special saline resistant varieties could be grown with low yields. While the soils nearer the ridges are generally good, nearer the valleys the soils are saline or alkaline due to water logging and deposition of salts. However, the quality of water of the tributaries of Pennar is good and hence there is good irrigation development in the lower reaches. Kundu River, a major tributary of the Pennar carries water of K.C. Canal which draws good quality water from Tungabhadra. Even though the catchments of Tungabadra and Pennar are close by (the basin of Vedavati lies in between), there is large difference in the quality of water of these rivers.

3.7 CLIMATE OF BASIN

The catchment receives rainfall both during the south-west and north-east monsoons. The rainfall during the non-monsoon period is not significant. The north-east monsoon (October through January) provides a little precipitation but the predominant rain falls when the southwest monsoon (June through September) occurs. Post monsoon cyclonic activity in the Bay of Bengal during September and October produces an increased rainfall in the coastal region. The mean annual rainfall within the drainage basin varies from about 550 mm around Anantapur area to 900 mm around Nellore.

From the temperature records, it is seen that the mean maximum daily temperature varies from 40.3ºC observed at Cuddapah to 34.7°C observed at Arogyavaram and the mean minimum daily temperature varies from 20°C observed at Nellore to 15.3°C observed at Arogyavaram. In general, humidity is high during the monsoon period and moderate during non-monsoon period. The relative humidity in the catchment of Pennar ranges from 21 to 84 percent.

Figure 3-7: Pennar Basin - East Flowing Peninsular Rivers

3.8 PROBLEMS IN THE BASIN

The Pennar water possess high silt load during monsoon period resulting acute drinking water problems for people in rural areas who directly depend on it. In Andhra Pradesh, ground water occurs under unconfined and semi confined conditions. Rainfall is the principal source of recharge; the others being percolation of river water during high flow periods and seepage of irrigation water. During summer (low flow) period, ground water contributes to baseflow. Among the cations and anions present in the ground water, sodium and chloride are predominant in Andhra Pradesh region. Concentration of cations and anions are in the order: Na > K > Ca > Mg; Cl > SO4 > F. Non-carbonate hardness is present in the region.

The indices of salt-water contamination like Mg/Ca, Na/Ca indicate that the ground water in the entire area is slightly contaminated with sea water. Based on this fact, some people have hypothesized that this area was probably inundated by seawater in the past. Seawater from the Bay of Bengal is the main contributor to salinity in the coastal areas and this is caused by the reduction in the Pennar water flow. The problem of saline water intrusion in the fresh water zone gets severe during the dry period when the Pennar and its tributaries face a drastic fall in river flow. This situation is worsening and might lead to a terrible environmental hazard in the future unless a suitable remedial action is initiated.

3.9 SALIENT FEATURES

Salient features for the basin are as listed below:

Table 3-3: Salient Features of the Basin

Summary		
1	Basin Extent	77° 1' to 80° 10' E
		13° 18' to 15° 49' N
2	Area (Sq.km)	55,213 (as reported by CWC)
		54243.42 (GIS based)
3	States in the basin	Andhra Pradesh (87.48 %), and Karnataka (12.52%)
4	Districts	10
5	Parliamentary Constituencies (2009)	14
6	Mean Annual Rainfall (mm)	770.18 (0.5° Grid 1971-2005)
		746.90 (1° Grid 1969-2004)
7	Mean Maximum Temperature (o C)	32.71
8	Mean Minimum Temperature (o C)	21.63
9	Total Population (As per Census 2001)	1,02,43,715
10	Number of villages (As per Census 2001)	5,099
11	Highest Elevation (m)	1439
12	Live Storage Capacity (BCM)	48.2
13	Avg. Annual Water Potential (BCM)	6.32
14	Utilizable Surface Water (BCM)	6.9
15	Number of Sub Basins	2

Summary		
16	Number of Watersheds	90
17	Number of water resources structures	Dams-58
		Barrages-0
		Weirs-1
		Anicuts-2
		Lifts-0
		Power Houses-1
18	Highest Dam	Gorakallu Dam - 48.5 m
19	Longest Dam	Kanigiri Dam - 10 km
20	Longest Barrage/ Weir/ Anicut	Sangam Anicut- 1.242 km
21	Number of Irrigation projects	Major-7
		Medium-14
22	Number of HE projects	2
23	Number of Ground water observation wells	426
24	Number of Hydro-Observation Sites	8
25	Number of Flood Forecasting Sites	1
26	Water tourism sites	5

3.10 PROJECTS

As on today, there are total 21 water resources projects in the basin which includes reservoir schemes, hydroelectric and multipurpose projects. Pennar basin has 6.32 BCM average water resource potential and Live Storage Capacity (LSC) of 4.82 BCM.

There are 7 major and 14 medium irrigation projects in the basin. There is no Lift irrigation schemes and ERM project in the basin.

3.10.1 IRRIGATION PROJECTS

Details of some of the major irrigation projects in the basin are given below:

1. **Somasila Major Irrigation Project:** This is an operational major project on Pennar River in Andhra Pradesh for stabilizing irrigation in Pennar delta. The dam is located near Somasila Village, Atmakur taluk of Nellore district. Culturable Command Area (CCA) of project is 38.48 Th. Ha. Catchment area at dam site is 48645 Sq.km. It is an earth and rockfill + masonry and concrete dam whose maximum height above deepest foundation level is 39 m. Somasila has also been integrated as a component of the Telugu Ganga canal project which is proposed to carry water from Srisailam to Chennai city and provide irrigation benefits to the en-route areas. The gross storage capacity at FRL 100.58 m and live storage capacity of the reservoir are 2091 MCM and 1,994 MCM respectively. At the maximum water level of 101.80 m the storage capacity is 2,483 MCM and at dead storage level of 82.30 m, it is 214 MCM.

2. **Pulivendula Branch Canal Major Irrigation Project:** This is an ongoing major project on Chitravathi River which is joining from the right to Pennar. The dam is located near Pulivendula city of Anantapur District. It is an earthen dam whose catchment area is 5431 Sq.km. Mainly Anantapur, Cuddapah districts benefited from the project. The

culturable command area, ultimate irrigation potential and live storage capacity of the project are 24.70 Th ha, 24.28 Th ha and 283.1 MCM, respectively.

3. **Tungabhadra RB High Level Canal Stage–I & II:** This is a major project of Pennar basin. Four Associated Structures are in this project PABR Dam, Pennar Dam, Mylavaram Dam, Chitravati Balancing Reservoir located in. Status of Stage-I is completed but stage II is ongoing. Mainly Anantapur, Cuddapah districts benefited from the project. The culturable command area and Installed capacity of the project are 133.36 Th ha and 20 MW, respectively.
4. **Pennar Delta Project:** This is also a major project of Pennar basin. Two associated structures are present in this project Sangam Anicut and Nellore Anicut. Mainly Nellore district benefited from the project. The culturable command area and gross command area of the project are 67.72 Th ha and 156.75 Th ha, respectively.
5. **Handri Neeva Sujala Sravanti (HNSS) Major Irrigation Project:** This is also a major project of Pennar basin. Four associated structures are present in this project PABR Dam, Pennar Dam, Mylavaram Dam, Chitravati Balancing Reservoir. Status of Stage-I is completed and stage II is ongoing. Mainly Anantapur, Cuddapah districts benefited from the project. The culturable command area and Installed capacity of the project are 133.36 Th ha and 20 MW, respectively.

Table 3-4: Projects in Basin

Sl. No.	Type of Projects	Number of Projects
1	Major Irrigation Projects	7
2	Medium Irrigation Projects	14
3	ERM Projects	0
4	Hydro-Electric Projects	2
5	Lift Irrigation Projects	0

3.10.2 HYDRO-ELECTRIC SCHEME

The hydro-electric scheme presently in operation in the basin is:

1. Penna Ahobilam Hydroelectric Project on the river kakatiya/ Pennar in Anantapur district. The power house has an installed capacity of 20 MW. PABR dam on Pennar river located near Rayadurg district Anantapur, Andhra Pradesh. Penna Ahobilam power house situated in dam toe position has 2 units of 10 MW each and its annual design energy is likely to be 54 MU. For power generation, the surface power house has Vertical Francis Turbines, which work at net rated head of 42.7 m. Penna Ahobilam Hydroelectric Project is under control of APGENCO.
2. 2 x 5 M.W. Mini Hydel Scheme for Power Generation is executed at Somasila Dam, Nellore District. With incorporation of a Mini Hydel Project, the power is enhanced to 2 X 6 MW i.e. 12 MW, which is now operational. The approval for the enhancement was also accorded.

3.10.3 DAMS

Water resources structures are manmade structures to store the water for hydropower, irrigation, drinking water supply etc.

There is a total of 62 water resource assets in Pennar basin. The biggest dam in the basin is Somasila dam located in Nellore district of Andhra Pradesh with a total gross storage capacity 2091 MCM and 1994 MCM live storage capacity. There are 2 anicuts and 1 weir in the basin. The longest anicut in the basin is Sangam anicut located in Nellore district of Andhra Pradesh with a Length of 1242.4 m. There are no barrage structures or lift irrigation schemes in the basin.

Table 3-5: Sub-basin wise number and type of water resources structures

Sl. No.	Sub Basin	Dams	Barrages	Weirs	Anicuts
1	Pennar Lower Sub Basin	19	0	0	2
2	Pennar Upper Sub Basin	39	0	1	0

3.10.4 MULTIPURPOSE PROJECT

There are only two multipurpose project in Pennar basin *viz.* Tungabhadra Multipurpose Project and Srisailam Multipurpose Project.

1. **Tungabhadra Multipurpose Project**: Part of Tungabhadra Multipurpose Project a) Pulivendula Branch Canal Major Irrigation Project b) Tungabhadra High Level Canal Stage I & II Irrigation Project envisages the creation of CCA of 24.70 Th ha 133.36 Th ha, respectively. c) Penna Ahobilam Hydroelectric Project on the river kakatiya or Penna in Anantapur district is also a part of the Tungabhadra Multipurpose Project.

2. **Srisailam Multipurpose Project**: This multipurpose poject a) Handri Neeva Sujala Sravanti (HNSS) Major Irrigation Project b) Telugu Ganga Major Irrigation Project envisages the creation of CCA of 243.83 Th ha 233 Th ha respectively.

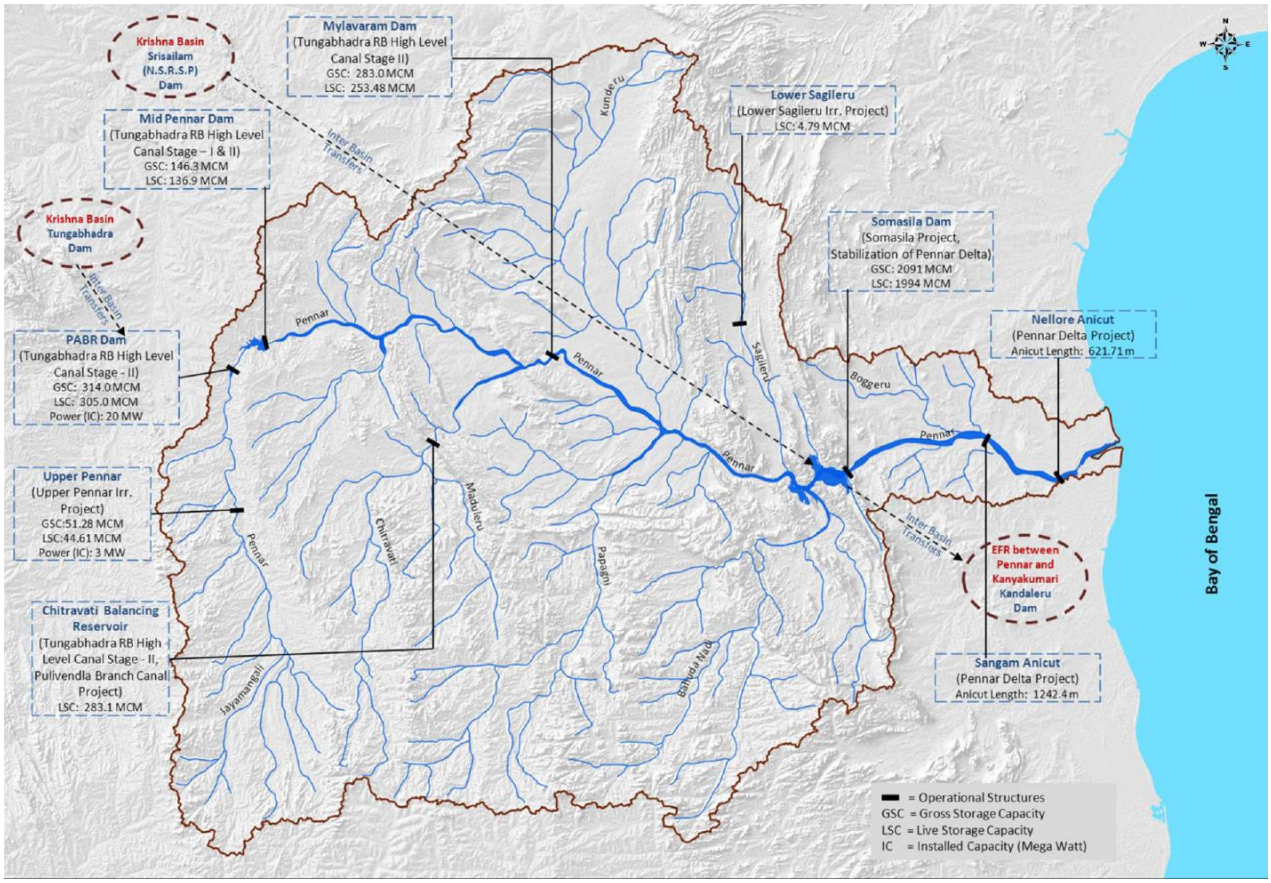


Figure 3-8: Major water resources structures and projects

INTER-STATE/ INTERNATIONAL ASPECTS

4 CHAPTER 4 - INTER-STATE / INTER-NATIONAL ASPECTS

4.1 STATES/COUNTRIES TRAVERSED BY THE RIVER

Pennar (also known as Penna, Penner, Penneru, and Uttara Pinakini) is a river of southern India. The Pennar rises in the Nandi Hills in Chikkaballapur District of Karnataka state, and runs north and east through the states of Karnataka and Andhra Pradesh to empty into the Bay of Bengal.

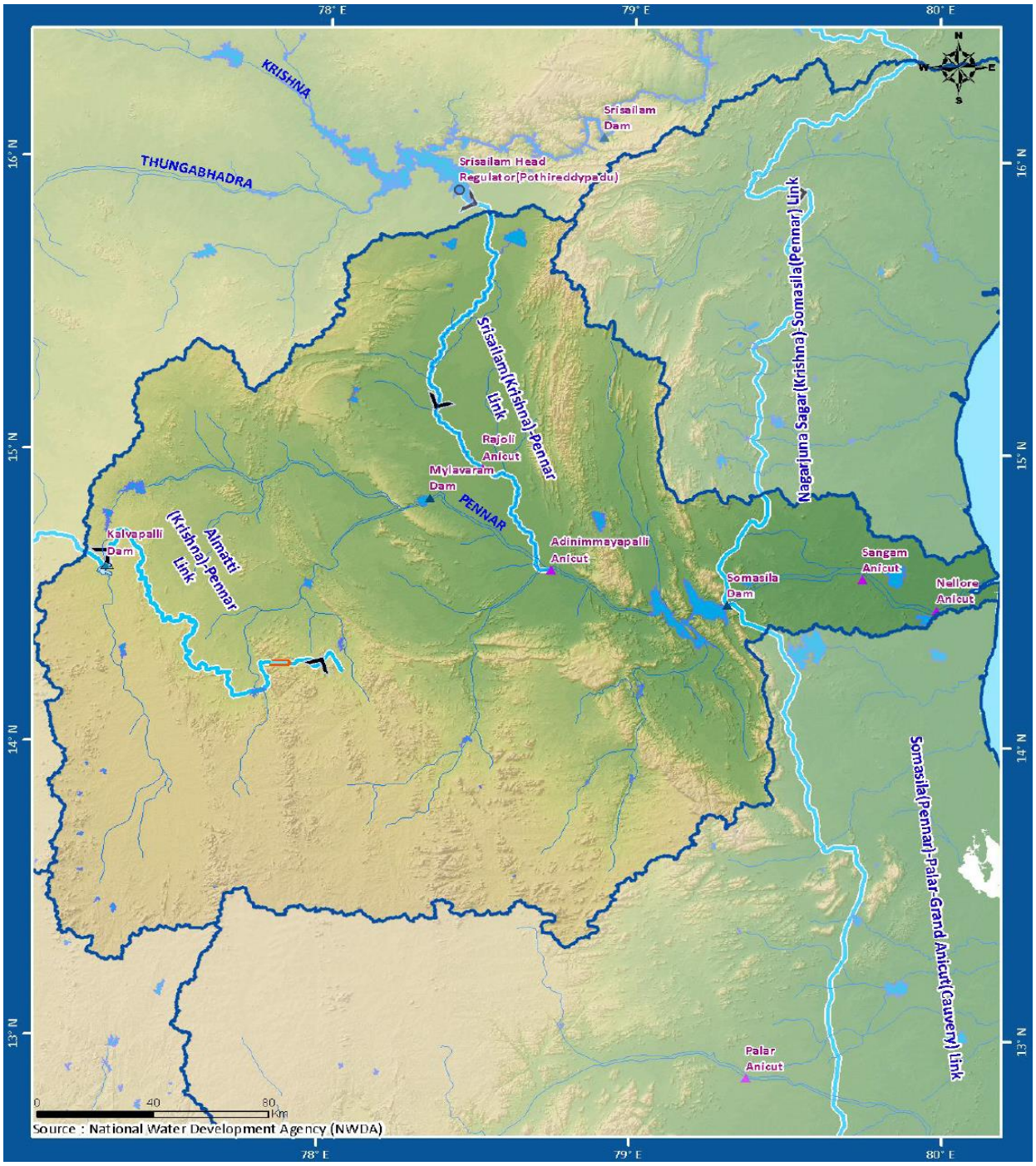


Figure 4-1: Pennar Basin and Somasila River

It is 597 kilometres (371 mile) long, with a drainage basin covering 55,213 km^2: 6,937 km^2 in Karnataka and 48,276 km^2 in Andhra Pradesh. The river basin lies in the rain shadow region of Eastern Ghats and receives 500 mm average rainfall annually.

4.2 DISTRIBUTION OF CATCHMENT AND YIELDS FROM THE CATCHMENT OF STATE

Pennar basin extends over an area of 55,213 sq. km. which is nearly 1.7% of the total geographical area of the country. It is bounded on the north by the Erramala range, on the east by the Nallamala and Velikonda ranges of the Eastern Ghats, on the south by the Nandidurg hills and on the west by the narrow ridges separating it from the Vedavati valley of the Krishna basin. The basin lies in the States of Andhra Pradesh and Karnataka. The State-wise distribution of drainage area is given below:

Table 4-1:Drainage area

State	Drainage area (sq. km.)
Andhra Pradesh	48276
Karnataka	6937
Total	55213

4.3 INTER STATE ASPECTS

4.3.1 INTER-STATE AGREEMENT ON SHARING OF WATERS

Both the reservoirs of the project (Upper and Lower Reservoir) lie in the State of Andhra Pradesh. As such there is no Inter-state aspects involved in the development of the Project.

As filling from the existing Somasila reservoir will be taken up during monsoon season when there is surplus water available; no impact on any international or national aspects is envisaged. There will be minor replenishment to compensate for the evaporation losses which will be taken up twice a year.

4.3.2 INTER-STATE ADJUDICATION

There is no Inter-state adjudication involved in this project.

The Pennar basin water apportionment is governed by colonial time water sharing agreement in the year 1892 and the Interstate River Water Disputes Act 1956. However the future development of Pennar basin depends on Interstate water sharing agreements of Krishna River. Tungabhadra Dam which is located in Karnataka and a joint project of Andhra Pradesh and Karnataka, is the only gate way to transfer water from Krishna River to the uplands of Pennar basin up to 600 m MSL. Inter-State agreements between the erstwhile Govts. of Madras and Mysore were made on 18.02.1892 for "Irrigation works Mysore State restoration and construction of certain rules and schedules" and later on for "Sharing of waters of inter-State rivers – Pennar waters" on 5.09.1933. The agreements are mainly for certain streams and are project specific. No new inter-State agreements exist between Karnataka and Andhra Pradesh States on sharing of Pennar river waters.

4.3.3 INTER-STATE ASPECTS OF TERRITORY

There are no Inter-state aspects of territory, property etc. coming under submergence, rehabilitation & compensation involved in this project.

4.3.4 INTER-NATIONAL ASPECTS

The entire catchment of River Pennar lies in India only. Hence, there is no International aspect involved in the project.

4.4 UTILIZATION OF WATER

The Pennar basin lies largely in a semi-arid region with low rainfall. The mean annual rainfall within the drainage basin varies from about 400 mm around Anantapur area to 1200 mm around Nellore. 44.90%, of the basin is covered with crop land. Deciduous forest area is about 13.04 % and water bodies occupy 3.55% of the total basin area. Red, black, sand and mixed soils are predominant in the basin. Around 26.70% of total basin area lies in the elevation zone of 500-750 m. Pennar basin consists of surface water bodies in the form of lakes, ponds, reservoirs, tanks etc. Tanks are the most predominant in the basin and forms about 93.04% of the total water bodies of the basin. 58 Dams and 3 Barrage/Weirs are constructed in the basin. Around 94.04% dams are used for the purpose of irrigation. Somasila Project, Tungabhadra RB High Level Canal Stage – I (AP), Pulivendla Branch Canal Project (AP), Pennar Delta Project (AP) are some of the major projects being executed in the basin. At present there are 21 major and medium irrigation/multi-purpose projects in the basin out of which 14 are completed and 7 are ongoing. Apart from this, CWC maintains 1 flood forecasting station and 8 hydrological observation stations also in the basin. The basin also houses 8 hydro-meteorology stations by Central Water Commission (CWC), 40 stations by Indian Meteorological Department (IMD) and 45 Automated Weather Stations (AWS) by Indian Space Research Organisation (ISRO) for the observation of various meteorological parameters.

Inland Waterways Authority of India (IWAI)'s National Waterway No. 4 falls in the Pennar basin. Four important inter basin transfer links *viz.*, the Krishna Almatti Pennar link, the Krishna (Srisailam) Pennar link, the Krishna (Nagarjunasagar) – Pennar (Somasila) link and the Pennar (Somasila) – EFR between Pennar and Kanyakumari (Grand Anicut link) are also present in the basin. Nine major tourist spots including a wildlife sanctuary are also present the Pennar basin.

The economy of the basin at present largely depends on agriculture, which, in view of the uneven incidence of the rainfall, provides a low level of subsistence except in parts of the basin where irrigation has been provided and where major industries have developed.

4.5 SOMASILA RESERVOIR

Somasila Reservoir is constructed across River Pennar near Somasila, village of Ananthasagaram Mandal in Nellore District of Andhra Pradesh.

The Project envisages **storage of 78.00TMC** of water at F.R.L. +100.58M. The contemplated ayacut under the project is 5, 84,500 acres in SPSR Nellore and Prakasam Districts. Out of which stabilization of wet ayacut under Pennar Delta Kanupur canal system and existing tanks in up lands is 4,05,500acres and new I.D.is1, 79,000 acres.

Out of the above ayacut an extent of 82,500 acres stabilization and 1,35,000 new I.D is under Somasila Project canals viz., GKNC Canal (North Feeder Channel), south feeder channel and Kavali canal.The allocation of water for the above ayacut is **60.892 TMC**. It also envisages to transmit **30.00 TMC of water to Kandaleru Reservoir** under Telugu Ganga Project for irrigating 3, 00,000 Acres of I.D. ayacut in Nellore and Chittoor Districts besides **15.00 TMC of Krishna water** to Chennai city for drinking water purposes. In addition to the above **2.40 TMC** of water was allocated to Nellore, Kavali, Gudur and Tirupathi towns for drinking water needs.

The current 900MW pumped storage project envisages to cater to **total storage of 8.33 MCM** in the lower reservoir vide pumping arrangement from the existing Somasila Reservoir. After considering evaporation losses, intermitted water refilling will be required when:-

'Total Storage falls below the sum of dead storage of lower reservoir and live storage of upper reservoir storage i.e. 7.91 MCM.'

Considering the same, the simulation results indicate as under:-

- No. of days simulation carried out = 730 Days (2 water year)
- No of refills required = 4
- No of days after that refill is required = 100 days (first fill), 176 days (second fill), 195 days (third fill) & 176 days (fourth fill)

Thus the proposed Pumped Storage Project will require refilling in 100 days to compensate the water lost in evaporation for first refill.

SURVEY & INVESTIGATION

5 CHAPTER 5 - SURVEY & INVESTIGATION

Topographical surveys of river, reservoir, head works, colony layout, pressure shaft, power house, switchyard, tail race tunnel, adits etc. have been carried out.

5.1 INTRODUCTION – TOPOGRAPHICAL SURVEY

The basic objective of the topographic survey is to capture the essential ground features and creating the Digital Terrain Model (DTM) and do the slope study for the planning of Pumped Storage Hydro Electric project. The Project area lies in the reserved forests area in the northwest direction to the existing Somasila Dam. To initiate the survey works, SOI toposheets (D44H3, D44H4, D44H7 and D44H8) were used to mark out the Project layout and the reference benchmark for the control point was collected from Somasila Dam, Somasila Project Circle Irrigation Department, GoAP.

Preliminary Survey using Cartosat Imagery

In order to proceed with the preliminary studies and planning of the key components of the Project, a high resolution digital elevation model (DEM) and overlay of topographical contours were produced to portrait the topographical maps of the Project area. The Digital Elevation Model was generated using 2.5 resolution cartosat imagery and ground control points established using DGPS. 139 Sq km area was covered under this DEM which covered the various alternatives of Project.

5.2 DETAILED TOPOGRAPHIC SURVEY

5.2.1 DGPS SURVEY FOR CONTROL NETWORK

As the site lies in the reserved forest area, no established bench marks with X, Y and Z Co-ordinates were available. GPS surveying was carried out using differential GPS for establishing GCPSs (Ground Control Points) at various project components location to form the baselines and establishing a control network. In order to ensure the control network is consistent with the adjoining existing Somasila Reservoir Project, the GCPs of the established control network were linked with the Permanent benchmark, details listed in the table below, at the existing Somasila Reservoir Project.

Table 5-1 : Details of Permanent Benchmark

S No	Easting	Northing	Elevation	Description
1	318432.776	1603534.104	59.649 m	GTS2A Plate top

Following is the list of Ground Control Points established at various components of the proposed project using DGPS for the Survey Control Network.

Table 5-2: List of Ground Control Points

S No	Easting	Northing	Elevation	Description
1	302283.400	1619669.000	322.223	DGPS-1
2	302596.700	1619504.000	376.244	DGPS-2
3	302716.700	1619386.000	370.176	DGPS-3
4	302444.200	1618982.000	466.088	DGPS-4

5	303057.600	1621274.000	199.460	DGPS-6
6	303315.800	1620791.000	185.612	DGPS-7
7	303312.200	1620749.000	190.456	DGPS-8
8	303119.700	1621239.000	196.740	DGPS-9
9	303309.500	1621697.000	164.378	DGPS-10
10	303633.012	1620796.540	179.070	DGPS-11(T-9)
11	304210.073	1621084.260	268.241	DGPS-12(T-24)
12	302970.631	1619173.710	331.596	DGPS-13(T-13)
13	304301.473	1620389.829	271.290	DGPS-14(T-28)
14	302228.466	1618782.658	507.609	DGPS-15(T-48)
15	303260.283	1619175.308	399.965	DGPS-16(T-52)
16	303402.558	1618974.817	488.560	DGPS-17(-T-54)
17	303140.270	1620182.376	199.066	DGPS-18(T-33A)
18	303739.769	1619746.993	403.749	DGPS-19(T-67)
19	304298.628	1619487.181	629.851	DGPS-20(T-69)

GPS observations from satellites covering all the above Ground Control Points were carried out using 4 Nos. of GPS sets viz. Trimble R8S. The observed data were downloaded to a computer using the Trimble Business Centre downloading software. The entire processing was done using Trimble Business Centre. The co-ordinates of these control points were taken as the basis for computing the co-ordinates of all points further surveyed. The co-ordinates were first derived in WGS84 system and then were transformed to Plane Co-ordinates.

Photo 5-1: Establishment of GCP using DGPS

5.2.2 TOPOGRAPHIC SURVEY

The Ground Control Points were further used to conduct the topographical survey using the total station equipment & DGPS.

The Total station instrument has capability to calculated reduced levels and coordinates with reference to benchmark/ GCPs. The details of the points recorded during the topographical survey of the various components are listed in **Annexure – 5.1.**

Photo 5-2: Topographical Survey using DGPS

5.2.3 FIXING UP THE PROJECT COMPONENTS

The project components initially based on the GPS survey drawings were fixed using the topographic survey drawings generated from the outputs of topographic survey done using total station. Following project components were fixed using the said outputs.

a. Lower Reservoir
b. Upper Reservoir
c. Power House
d. MAT Portal
e. TRT Portal
f. CCVT Portal
g. Intake Location

5.2.4 SURVEY DRAWINGS

Longitudinal Section and plan for the above components were prepared based on the detailed surveys carried out and are furnished in **Volume III (Drg. No. 7061601-FSR-1001)**.

5.2.5 COMMUNICATION SURVEY

Surveys for the formation of new roads and widening of the existing roads to have access to the project components during construction and operation phase of the project have

been carried out. A layout showing all the new roads is shown in **Volume III (Drg. No. 7061601-FSR-1001)**

5.3 GEOLOGY, SEISMICITY & CONSTRUCTION MATERIAL

5.3.1 INTRODUCTION

The surface geological studies have been carried out for feasibility stage assessment of the proposed components of the project. The main objective of the studies has been to define the geological model of the project area, identify geological and engineering concerns, assess feasibility of each component, and finally, to list out the engineering geological issues demanding attention during the next phase of investigations through survey, surface & subsurface exploration, field & laboratory tests, etc.

The objective of the feasibility stage studies has been achieved through geological mapping of the project area on 1:5,000 scale, accompanied by detailed discontinuity survey. The project with a 8.33 MCM capacity Lower Reservoir, 6.17 MCM Upper Reservoir, 147m (L) x 23m (W) x 52m (H) powerhouse cavern with appurtenant structures, and 1672 m long subsurface water conductor system (including pressure shaft & TRT), is rather compact yet spans an area of about 7.9 sq km – a sizeable area in terms of detailed geological mapping (Figure 5.1). The 1.2m dia and 14.7 km long D.I piped surface water conductor for initial pumping of water during commissioning from Somasila Reservoir to the Lower Reservoir comprises another major component of the project and has been traversed for geological studies leading to the assessment of its feasibility. While 12 sq km area has been geologically mapped and around 15km length geologically traversed, a dataset of as many as 518 discontinuities has been generated for rock mass dissection analysis.

The project area lies adjoining to a reserved forest and wildlife sanctuary and is thickly vegetated. The consequent poor visibility and inaccessibility constitute major impediments in carrying out surface geological studies. The mapping has been facilitated by the presence of Gopavaram-Ramapuram tar road by the side of the project area and difficult-to-find foot tracks in the thickly vegetated terrain. The work wouldn't have been possible without the constant help of the forest officials and local guides who not only helped the geologists and engineers of the survey team to find their way in the jungle, they also provided the confidence in dealing with any untoward eventuality in the wake of the wildlife.

5.3.2 REGIONAL GEOLOGY

5.3.2.1 GEOLOGY OF ANDHRA PRADESH

Home to the proposed Somasila PSP, Andhra Pradesh is drained by three major rivers, viz. Godavari, Krishna and Pennar. Originating in the neighbouring states, these rivers enter AP from the west as they drain the Deccan Plateau and cut across the Eastern Ghats to debouch into the Bay of Bengal to the east. The deltas of these rivers constitute the dominant component of the 1000 km long and 40 km wide coastal plains along the Bay of Bengal.

The project lies in the Pennar basin, east of the township of Cuddapah – the type area for the Mesoproterozoic Cuddapah Supergroup of rocks.

The Eastern Ghats run parallel to the coast with the northern segment comprising a series of parallel hill ranges trending NE-SW to NNE-SSW. The southern segment encompasses Nallamala Hills and the associated Lankamala and Velikonda Hills with a general N-S trend and attaining an altitude of about 1040 m towards south. The Deccan Plateau occupies the rest of the area in Andhra Pradesh west of the Eastern Ghats.

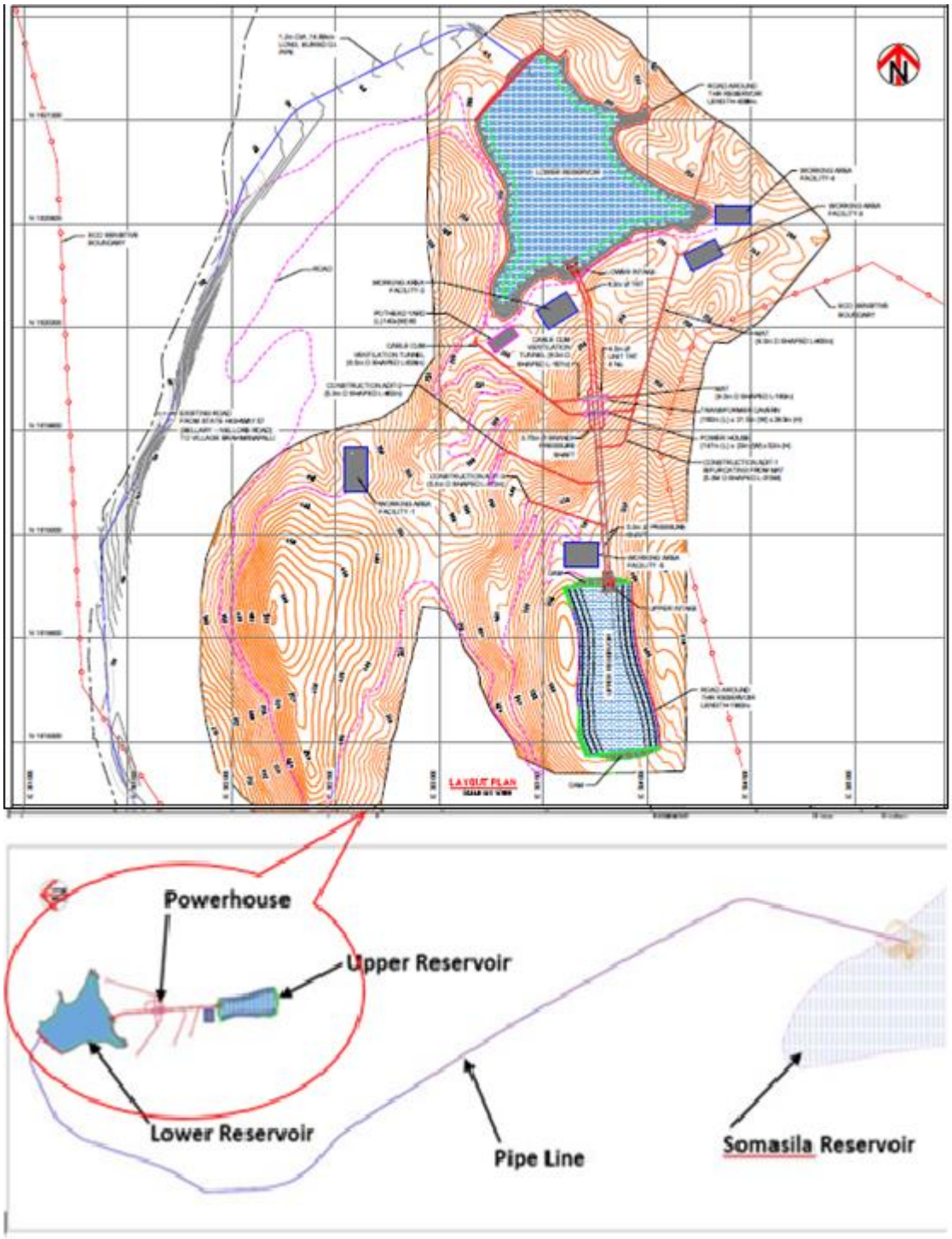


Figure 5-1: Proposed layout of the project

Situated in the Precambrian Shield of India, the Precambrian terrain in the state is divisible in to two distinct litho-tectonic entities, viz. Dharwar Craton and the Eastern Ghats Mobile Belt (EGMB) (GSI Misc Pub 30 Pt-8, 2006; Geol & Min Map AP, GSI 2006). Granites and gneisses with a few narrow, linear and widely separated greenstone belts constituting the eastern part of the craton occupy a major part of the area. The craton is bounded in the northeast by the EGMB, which consists mainly of granulites. In the northern part, the craton is partly covered by Phanerozoic Gondwana sediments along the NW -SE trending Godavari Rift Graben, which is flanked on either side by Proterozoic sedimentary sequences of Pakhal, Penganga and Sullavai basins. Proterozoic sediments, constituting the well-known Cuddapah Basin, occupy large tracts in the south-central part. The late Mesozoic Deccan Trap cover of central and western India has its extension marginally into the northwestern part of the state.

Extensive and thick pile of Meso- to Neoproterozoic sedimentary rocks and associated volcanics unconformably overly the Archaean – Palaeoproterozoic cratonic gneisses, granitoids, schists and mafic dykes. They are distributed in well-defined sedimentary basins such as Cuddapah, Pakhal and Bhima. Among these basins, the Cuddapah Basin is the most significant by virtue of its vast mineral potential and areal extent.

The Somasila PSP is located in the rock sequences of the Cuddapah Basin (**Figure- 5.2**).

The Cuddapah Basin is a crescent shaped basin with its convex side towards west. With a 450 km long concave eastern margin, the basin occupies an area of around 44,500 sq km covering parts of Chittoor, Cuddapah, Kurnool, Anantapur, Nellore, Prakasam, Mahbubnagar, Nalgonda, Guntur and Krishna districts. The basin attains the maximum width of 145 km in its central part. The cumulative thickness of the sedimentary pile is estimated to be of the order of 12 km. The sedimentary fill is largely arenaceous and argillaceous with subordinate calcareous and dolomitic components. Petrologically diverse assemblage of igneous rocks are associated with these sedimentary rocks. The sequence of rocks in the Cuddapah Basin have been grouped under Cuddapah Supergroup which are overlain by rocks of Kurnool Group.

5.4 CUDDAPAH SUPERGROUP

5.4.1 LITHO-STRATIGRAPHY

The Cuddapah Supergroup of rocks is sub divided into the following three groups and one formation.

i) Papaghni Group

ii) Chitravati Group

iii) Nallamalni Group

iv) Srisailam Quartzite

The lithostratigraphy of the Cuddapah Supergroup is given in **Table-5.3.**

Table 5-3: Geological Succession of Meso to Neoproterozoic Rocks of Andhra Pradesh

Era	Supergroup	Group	Formation	Supergroup	Group	Formation	Group	Intrusives
		CUDDAPAH BASIN		Pakhal Basin			Bhima Basin	
NEOPROTEROZOIC		KURNOOL GROOP	Nandyal Shale KolKuntia- Limestone Paniam Quartzite Owk Shale Narji Limestone Banganapalle Quartzite		SULLAVAI SANDSTONE		BHIMA GROUP	
					--------Unconformity--------			
					PENGANGA GROUP	Putnur Limestone Takkallapalli Arkose		
----------Unconformity----------								
MESOPROTEROZOIC	CUDDAPAH SUPERGROUP	NALLAMALAI GROUP	SRISAILAM QUARTZITE --------Unconformity-------- Cumbum (Pullampet) Formation Bairenkonda (Nagari) Quartzite	PAKHAL SUPER GROUP	MULUG GROUP	ALBAKA SANDSTONE ----Disconformity---- Laknavaram Shale Pattipalli Quartzite Enchecheruvu Formation Polaram Formation Jakkaram Arkose		Kimberlites and lamproites; granite, alkali feldspar granite; nepheline syenite, syenite, quartz syenite and other alkaline rocks; gabbro, gabbroic-anorthosite, pyroxenitte, dunite and serpentinite (Koodapali Complex); gabbro-norite, anorthosite and pyroxenite (Chimakurti Complex)
		CHITRAVATI GROUP	--------Disconformity-------- Gandikota Quartzite Tadpatri Formation Pulivendla Quartzite			----Disconformity----		
		PAPAGHNI GROUP	--------Disconformity-------- Vempalle Formation Gulcheru Quartzite		MALLAMPALLI GROUP	Pandikunta (Karlai Shale Gunjeda Dolomite (Bayyaram Quartzite) Bolapalli Formation		
----------Unconformity----------								
Gneisses, granitoids, schists and mafic dykes								

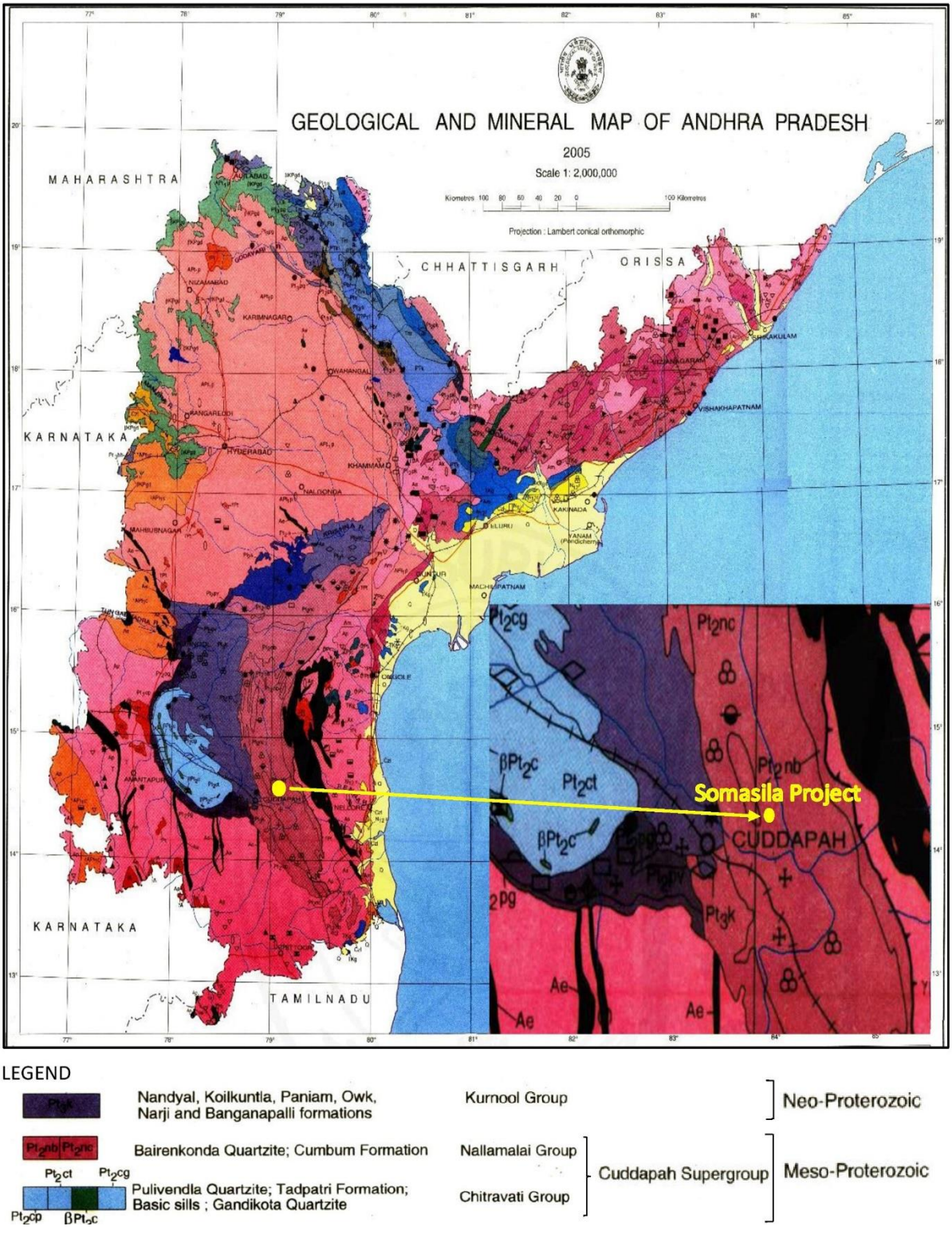


Figure 5-2: Regional geological map of the project area (after Geol & Min Map AP, GSI 2006)

5.4.2 PAPAGHNI GROUP

The Papaghni Group, named after the Papaghni River, a tributary to the Pennar, is exposed only along the western margin of the basin and is divided into the following two formations.

(i) Gulcheru Quartzite

(ii) Vempalle Formation

The Gulcheru Quartzite is exposed in the southern parts of the basin along its convex margin. It is composed of quartzite, conglomerate and grit with shale intercalations. The basal part of the formation is dominated by conglomerate in the north and quartzite in the south. The quartzite attains a thickness of about 300 m near Idupulapayavally ESE of Vempalle, but the thickness gradually diminishes to 60 m northward.

The Vempalle Formation overlies the Gulcheru Quartzite with a graded contact and attains a thickness of about 1500 m at Vempalle. It comprises grey, fine grained and flaggy dolomite, dolomitic limestone, purple shale, chert and quartzite, in that order of abundance. Along the southwestern margin of the basin, the dolomite is intruded by basic sills, which range in thickness from a few metres to more than 100m. Also, contemporaneous igneous flows/sills and tuffs of dolcritic or basaltic composition and showing chilled margins have been found within the dolomite. Serpentinised dolomite developed at the dolerite sill-dolomite contact hosts the well-known chrysotile asbestos deposits of the basin. At places, dolomite also contains high-grade limestone and veins of barite.

5.4.3 CHITRAVATI GROUP

The Chitravati Group, named after the Chitravati River, is estimated to be 4975m thick and is subdivided into three formations, namely:

I) Pulivendla Quartzite

II) Tadpatri Formation

III) Gandikota Quartzite

The Pulivendla Quartzite is about 55 m thick 13 and is separated from the underlying Vempalle Formation by a 1.25 m thick amygdaloidal lava flow with ash bed and agglomerate, traceable over 30 km along strike. The quartzite which is well exposed along the Pennar and Cheyyeru river sections, consists of thin and impersistent basal oligomictic conglomerate followed upward by grit and quartzite. The quartzite units show ripple marks and sun cracks.

The Tadpatri Formation attains a maximum thickness of about 4600 m and is well exposed along the Pennar Valley. It consists mostly of variegated shales with interbeds of dolomite and flaggy quartzite. A number of basaltic sills and a few basic dykes are present at different horizons of the Tadpatri Formation.

The Gandikota Quartzite (300 m thick) occurs over the Tadpatri Formation, which is exposed mainly in the Gandikota hill range and, as inliers, in the Nossam area. It is dominantly an arenaceous unit with numerous shale intercalations.

5.4.4 NALLAMALAI GROUP

With an estimated thickness of 3500 m, the Nallamalai Group derives its name from the hill range of the same name which occurs longitudinally in the middle of the Cuddapah Basin. The group is subdivided into two formations, namely

I) Bairenkonda Quartzite

II) Cumbum Formation

The Bairenkonda Quartzite attains a maximum thickness of about 1500 m. It constitutes the Nallamalai, Lankamalai and Velikonda hill ranges, the Ishwarakuppam Dome and the Tirumala Hills. In the Nallamalai and Lankamalai Hill ranges, the formation is predominantly arenaceous with minor intercalations of shale. The arenaceous units are thin bedded, fine to medium grained and cherty. Nagari Quartzite exposed in Tirumala area, is considered to be the southern extension of the Bairenkonda Quartzite.

The Cumbum Formation has a maximum thickness of about 2000 m. It conformably overlies the Bairenkonda Quartzite and includes the erstwhile Pultampet Shale, Irlakonda Quartzite and Kolamnala Shale. The Cumbum Formation is mainly argillaceous consisting of shale, slate and phyllite of varying shades intercalated with thin bands of quartzite, limestone and dolomite. The dolomite shows frequent intercalations of chert and chert breccia layers containing galena, sphalerite and chalcopyrite at places. The world famous volcanogenic bedded baryte deposit of Mangampeta is confined to the upper part of Puliampet Shale.

5.4.5 SRILSAILAM QUARTZITE

Srisailam Quartzite derives its name from the famous Srisailam Temple, located atop an imposing plateau, which is constituted exclusively of the quartzite. The formation, which is about 300 m thick, is exposed along the Krishna River upstream of Srisailam in the southwest to Jaggayyapeta in the northeast as an ENE-WSW trending plateau rising to a height of 700 m. It is given the group status in the stratigraphic sequence. The quartzite is interbedded with thin siltstone units and is usually thick bedded, dense and fine to medium grained. The siltstone is flaggy and contains several intercalations of shale.

5.4.6 TECTONICS

The Cuddapah Basin is a crescent shaped basin, the western half being undeformed and the eastern half, known as the Nallamalai Fold Belt, intensely deformed. The deformation is reflected by open low amplitude folds in the western part which gradually change over towards east into tight isoclinal folds. The folds plunge either towards north or south, giving rise to a number of E-W trending culminations and depressions. The most notable domal structures in the basin include the Ishwarakuppam dome in the north-central part of the Nallamalai, the Lankamalla dome south of Zangamrajupalle, and the domal features north of Vinukonda and west-northwest of Venkatagiri along the eastern margin of the basin. The eastern margin of the basin is a major thrust along which the older granitic basement had ridden over the Nallamalai strata. The concavity of this margin is apparently due the differential impact of the forces of thrusting from the east, the

maximum impact being along 15° parallel. The basin experienced at least six periods of igneous activity manifested in the form of acid, basic and barium-rich phases.

Among the major faults traversing the Cuddapah Basin are the ENE-WSW trending Veldurti-Gani-Kalva fault in the central part and the Karkambadi fault at the southern end of the basin. The WNW-ESE trending Dindi River fault in Srisailam Sub-basin is another major fault. The EW trending Atmakur fault delimits the northern margin of the Kurnool Sub-basin.

5.5 SEISMICITY

The project area lies in Zone-II – the lowest in the four-fold zonation from Zone-II to Zone-V - of the Seismic Zoning Map of India (**Figure-5.3**) and, hence, may be considered a favourable situation in this respect particularly when the project envisages creating reservoirs on ridge tops.

Regionally, the area has witnessed large magnitude earthquakes like the M7.6 Kutch (Bhuj) Earthquake of 2001, the M6.2 Latur Earthquake of 1993, and the M6.0 Koimbatore Earthquake of 1900. However, the project area falls in low intensity zones of these earthquakes and is considered a low seismicity area.

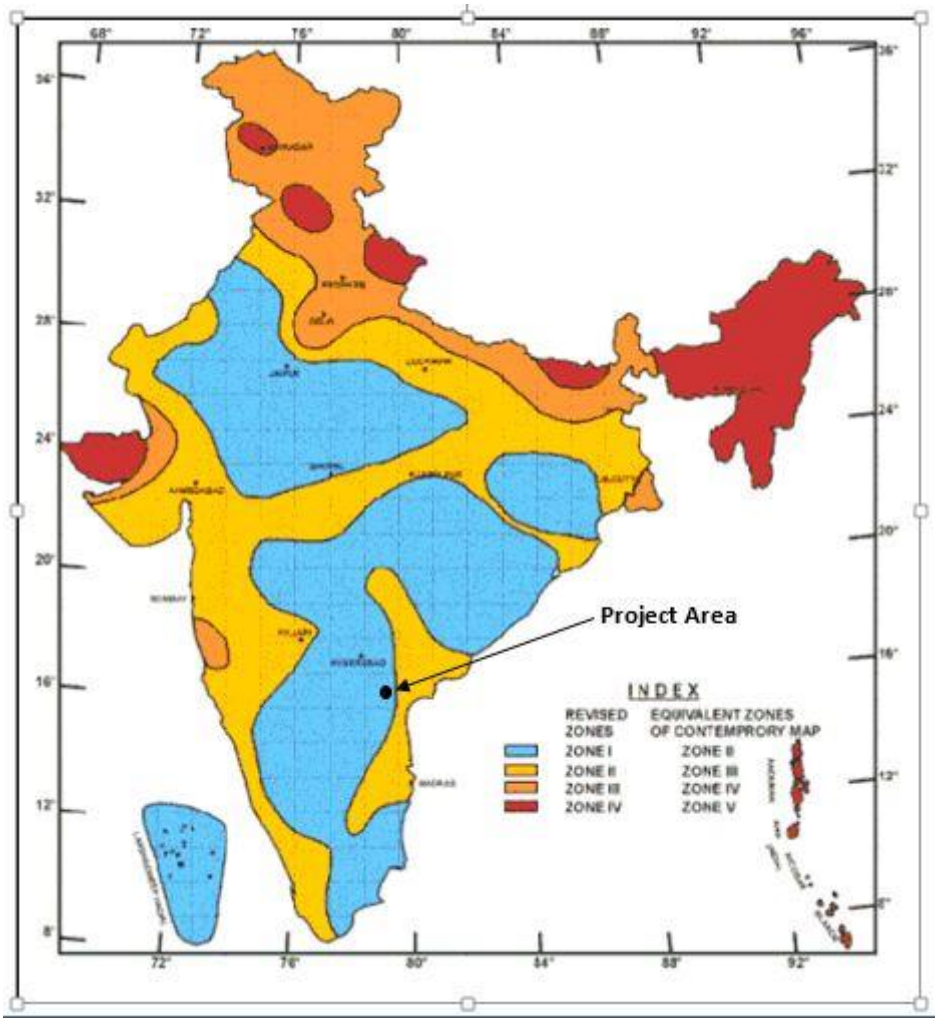


Figure-5-3: Position of the project area in the Seismic Zoning Map of India

The statutory site-specific seismic design parameter study of the project area, necessary for the clearance of NCSDP, would be carried out at an appropriate stage of the investigations and shall provide the required design parameters.

5.6 GEOLOGY OF THE PROJECT AREA

5.6.1 GEOMORPHOLOGY

The project area is located in the Pennar River basin and lies on its left flank, close to the northern tip of the Somasila Reservoir across the Pennar. The project site lies in a ridges & furrows like terrain where NS aligned ridges rise conspicuously in an otherwise gently rolling terrain (Figure 5.4). Not far from the project area, such standalone ridges in a gentle terrain, provide promising avenues for wind farming and the presence of linearly placed wind turbines is a common site along the NH-67 between Badvel and Proddatur (Photo 5.3). The ridges are strike ridges, i.e., they overwhelmingly follow the strike of the rock sequences. The furrows, occupying the inter-ridge areas, represent the drainage system, viz. the nallas and their flood plains.

A rather interesting shape of the Somasila Reservoir, where two conspicuous NS aligned arms of the reservoir across the E-W flowing River provide the bulk storage (Figure 5.5), presents an example of the ridge & furrow feature. It also represents the regional tectonic fabric constituted by NS striking beds on one hand, and the EW striking sub-vertical transverse joints, believed to be the control for the other predominant drainage system, on the other.

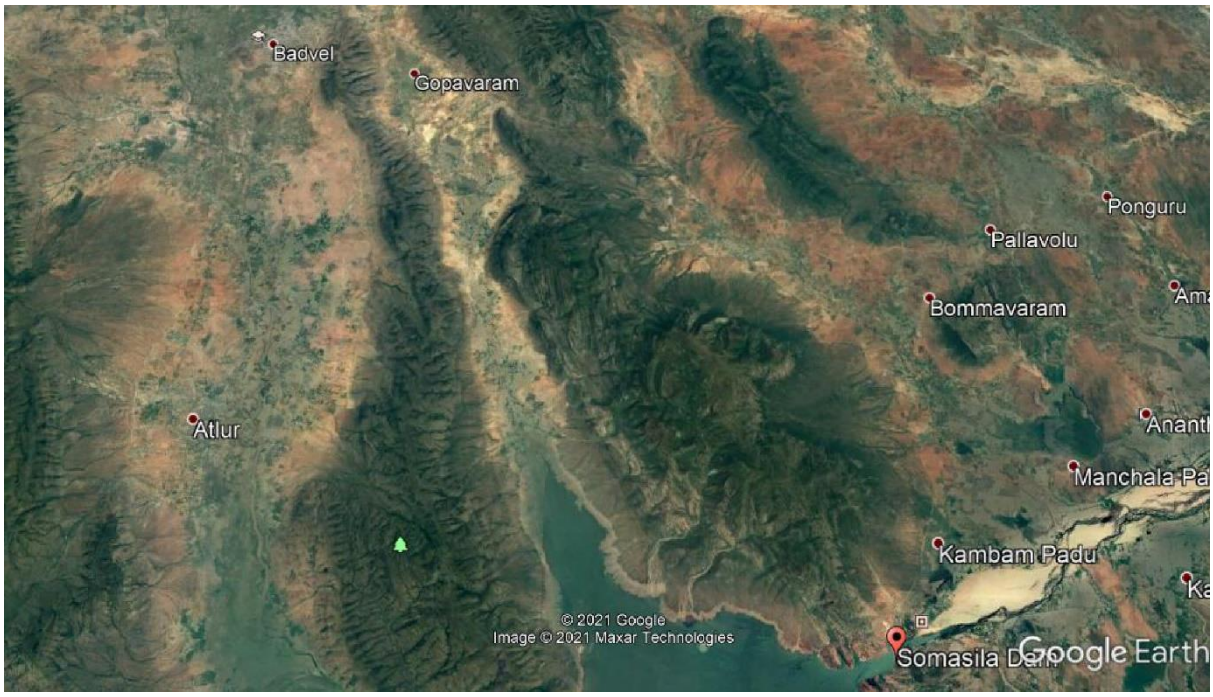


Figure 5-4: Ridge & furrow terrain in and around the project area

Photo 5-3: Wind farming along standalone ridges on NH-67 (Badvel-Proddatur)

The 925m long, 620m wide and minimum 16m deep (maximum 33m near Dam axis) Lower Reservoir is proposed in a seasonal nala. The Upper Reservoir is proposed over a prominently running ridge and is separated from another N-S running prominent ridge by a saddle on western side (Photo.5.4). While the access road in the area runs along the base of this ridge, the ridge also provides the abutments of the dam for the Lower Reservoir.

Photo 5-4: The ridge with shallow overburden towards the West of Upper Reservoir

The ground elevations range between 170 m and 600 m. The consequent relief of 430m is considered moderate relief. The slopes along the ridges are mostly steep to very steep on the updip side and low to moderate on the downdip side.

Figure 5-5: The Somasila Reservoir with predominant NS aligned arms across the River Pennar

5.6.2 LITHOLOGY

5.6.2.1 GENERAL

The Somasila PSP lies over the rock sequences of the Cumbum Formation belonging to the Nallamalai Group of the Mesoproterozoic Cuddapah Supergroup.

Both the rock outcrops and overburden covered areas are fairly well distributed **(Refer Drawing no. 7061601-FSR-1003 to 1005 of Volume - III).** The overburden is represented by topsoil distributed all through the area, the lacustrine deposit in reservoir area, colluvium mainly along and at the base of ridge slopes, and alluvium along the nala courses. While terrace deposits are expectedly absent, the landslide debris is also not found.

The rock assemblage in the area is represented by an interbedded sequence of quartzite and phyllite where quartzite is found to be the predominant partner. Intercalations of phyllite in quartzite, and vice-versa, are expected. The contrasting physical features of the two - quartzite being the hard, strong, and weathering-resistant unit, and phyllite comparatively weaker but moderately strong and easy-to-weather unit - have left a conspicuous geo-botanical signature in the terrain where the phyllites stand out as well-vegetated green streaks in an otherwise sparsely vegetated and light-coloured beds of quartzite (Photo.5.5). Such geo-botanical signatures of phyllite beds are also seen

conspicuously on the western face of the prominent N-S aligned ridge west of the Upper Reservoir ridge (Photo-5.6).

In general, a total seven beds of phyllite and eight of quartzite have been differentiated in the project area (**Refer Drawing no. 7061601-FSR-1003 to 1005 of Volume - III**). The thickness of quartzite and phyllite beds is estimated to range between 30m & 1200m and 17m & 100m, respectively. Proposed detailed surface and sub-surface studies during next stage of survey & investigations are expected to confirm this.

Photo 5-5: Geo -botanical signature with phyllite standing out as green streaks

Photo 5-6: Western slope of the NS aligned ridge. Note geo-botanical signature of phyllite beds

5.6.2.2 ROCK TYPES

The main rock types found are quartzite and phyllites. Quartzite constitutes the predominant rock type and phyllites the subordinate.

Quartzite is generally off-white to white in colour, bedded, massive to jointed, fine-grained, strong, hard and compact rock (Photo - 5.7). On the surface, the rock tends to be pale to rust coloured due to the effects of weathering. The rock is found well exposed in the upper reaches of the ridges and is also found exposed intermittently along the nalla courses (Photo 5.8). Most of the project components are located in quartzite.

Photo 5-7: Jointed quartzite

Photo 5-8: Quartzite outcrop at the dam site of the Lower Reservoir

A local quartz reef has been found on the western slope of the ridge between the dam site for the Lower Reservoir and Upper Reservoir (Photo – 5.9). It lies close to the Ramapuram village.

Photo 5-9**:** Quartz reef

Phyllites are greyish green in colour in colour, fine grained, well foliated and moderately strong (Photo 5.10) The predominant argillaceous content of the beds of phyllite supports vegetation for which good outcrops are difficult to find. The rock occurs on the ridge slopes and in saddles. Phyllite is expected to be encountered across the subsurface water conductor systems.

Photo 5-10**:** Exposed phyllite on updip side of the ridge, north of Upper Reservoir site.

5.6.3 RECENT DEPOSITS (OVERBURDEN)

The recent deposits, or overburden, has been broadly classified into lacustrine deposit, alluvium, colluvium, and topsoil.

The lacustrine deposit is represented by the fine grained, semi-consolidated silt deposited in the still waters of the Somasila reservoir. This is expected at the intake site of the

surface water conductor for pumping water from the Somasila Reservoir to the Lower Reservoir.

Colluvium consists of rock pieces set in silty matrix. It occupies lower parts of the ridges, generally about the lower 2/3rd. A considerable length of the surface water conductor from the Somasila Reservoir to the Lower Reservoir is expected to rest on this unit.

The alluvium is found deposited all along the nalla courses. In particular, these are thicker and wider where the nalla courses have gentle gradients (Photo - 5.11). The material consists of semi-rounded gravel and boulders. The matrix of finer material like sand or silt is in minute proportions mainly due to the nalla catchments restricted to intra-ridge area and, consequently, small. The alluvium is found well exposed at the site of the dam of the Lower Reservoir.

Photo 5-11**:** Nalla bed alluvium at the dam site for Lower Reservoir

Topsoil occupies the gently rolling inter-ridge areas and intermittently on gently sloping ridge sections. Strewn over angular fragments of quartzite are a common sight. These deposits would occupy large parts at the bottom of the Lower Reservoir.

5.7 STRUCTURE

The strata, in general, have a fairly uniform orientation and dip moderately in easterly direction. This is true not only for the project area but is also noted for long distances along the NH-67. The rock deformation by folding, therefore, is not expected and the exposed rock beds can be projected with confidence in the subsurface.

In an attempt to define the rock mass dissection by discontinuities, special attention has been paid to the collection of joint data in the initial stages of the surface geological mapping itself. In all, a dataset of 518 joint orientations has been generated and analysed using the software DIPS (rocscience). The data processing has led to identification of three sets of joints, viz. J1: N104/40 (Bedding/ Foliation), J2: N245/79, and J3:N345/73 (Figure 5.6).

The ruling joint set J1 with easterly dips (N104/40) represents bedding and foliation. This is in good agreement with the N-S aligned strike ridges. The other two sets represent the steep and sub-vertical discontinuities. The joint set J3 is represented by the cross drainages in ridges.

Although shear zones have not been found, closely spaced jointing has been seen. One such conspicuous occurrence is in the vicinity of the proposed dam site for the Lower Reservoir (Photo - 5.12). While occurrence of shear zones can still not be ruled out, closely jointed and fracture zones may be expected, in particular, along the bedding/ foliation.

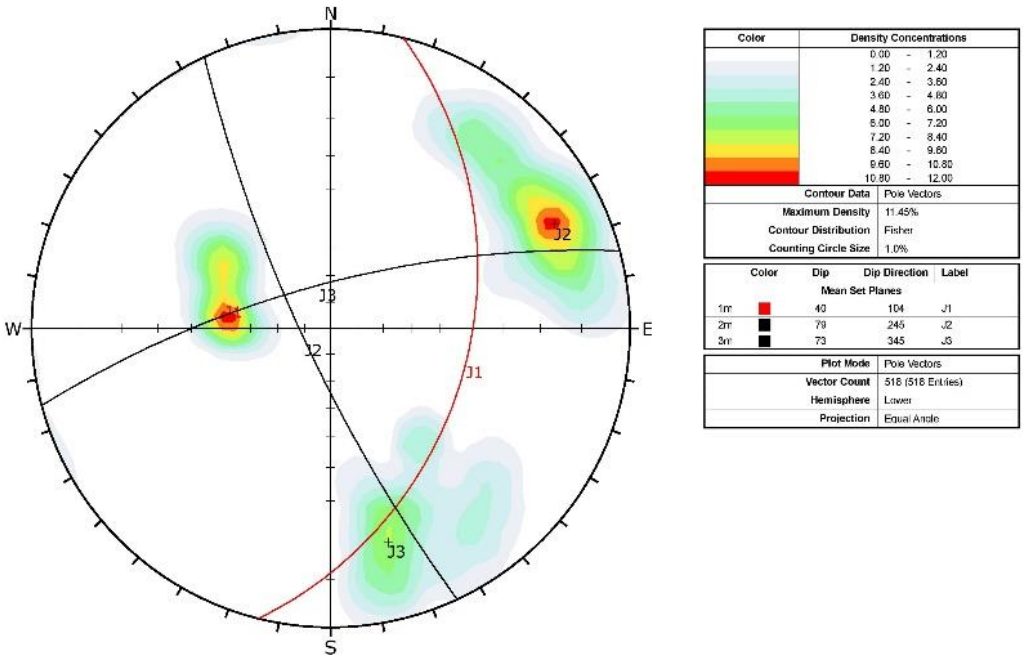


Figure 5-6: Stereoplot of discontinuities in the project area.

Photo 5-12**:** Zone of very closely spaced joints (vicinity of the Lower Reservoir dam site)

5.8 GEOTECHNICAL ASSESSMENT

5.8.1 GENERAL

The site-specific geological model is represented by uniformly dipping interbedded rock sequence of quartzite and phyllite with quartzite being the predominant partner **(Refer Drawing no. 7061601-FSR-1003 to 1005 of Volume – III).** The strata dip N104/40 and, besides the bedding being the ruling set of joints J1, are dissected by two other joint sets J2: N245/79 and J3: N345/73. Barring the colluvium deposits, that could be considerably thick at the base of the ridges, the other overburden deposits are considered to be of low to moderate thickness.

The project area is generally dry, but a mild spring discharge is found at the northern edge of the proposed site for Upper Reservoir. This confirms the presence of subsurface water that otherwise also is expected and assessment of the depth of water table would be one of the objectives of the subsurface exploration by drilling. In particular, the interbedded sequence of quartzite and phyllite presents a situation where phyllites serve as impervious barrier and significantly higher subsurface water content is sometimes encountered in jointed quartzites immediately underlying the phyllite beds.

5.9 SURFACE WATER CONDUCTOR

The 14.7 km long D.I piped surface water conductor for initial pumping of water from Somasila Reservoir to Lower Reservoir would rest mostly on colluvium deposits at the base of the ridges. Any significant geotechnical problem along the alignment is not expected. The intake structure (pumphouse) would lie over the lacustrine deposits of the Somasila Reservoir (Photo – 5.13) and may have to be founded on the underlying strata that could be topsoil. Bedrock may not be expected at reasonable depth.

Photo 5-13: Intake and adjoining piped WCS alignment area

5.10 LOWER RESERVOIR

The proposed reservoir (Photo 5.14) lies in a small intra-ridge basin formed by two nallas with confluence just a little upstream of the proposed 33.5m high dam. These two nallas are reflected well as the two broad arms of the reservoir-to-be. The area is densely vegetated. Signs of any dormant or active landslide are conspicuous by their absence. The reservoir rim runs along vegetated and stable slopes. Any major concern with respect to the reservoir rim stability, therefore, is not apprehended.

Photo 5-14: General view of the Lower Reservoir area (looking downstream)

The proposed dam is located over a bed of quartzite that is fairly well exposed intermittently all along the nalla. While the nalla bed is covered with sub-rounded alluvium comprising gravel and pebbles, the abutments are covered with topsoil and colluvium. The foundation for the dam in rock is expected to be available at a reasonable depth. The axis of the dam makes a large angle with the upstream dipping beds and, hence, is considered favourably disposed. However, the dam axis would be kept appropriately away from the closely jointed quartzites that are found exposed at this site.

5.11 UPPER RESERVOIR

The 820m long, 378m wide and 33m deep (max) reservoir is proposed along a NS trending depression (Photo 5.15), i.e. along the bedding strike, with prominent breaks-in-slope on either end. Prominent seasonal gullies drain the slope on either side. While the long side of the depression is unconfined on the western side where the hill slope descends down to a prominent saddle below, it stands against a rising hill slope on the eastern long side. The site lies over a thick bed of quartzite that spans the reservoir area and the hills on the flanks. A bed of phyllite is interpreted at considerable depth. The overburden of topsoil at the bottom of the depression and colluvium on the flanks are expected to be shallow.

Photo 5-15: Natural depression being exploited for Upper Reservoir

The physiography of the site demands two dams at the north and south ends of the depression and a low height dam in the southern part of the linear hill on the western side. Reservoir capacity is to be increased by excavation along the depression leading to long excavated slopes demanding appropriate stabilisation measures.

Rock foundations are likely to be available at shallow depths for the proposed dams. These, however, are disposed across the rock beds and, hence, oriented unfavourably. The consequent concerns of seepage avenues along bedding, therefore, need to be addressed in design suitably.

The main geotechnical concern relates to the jointed nature of the brittle quartzite. It would require considerable investigations for establishing the permeability of the rock mass and leakage potential of the reservoir, both from the unconfined flanks as also from the bottom. This aspect is considered to be the main focus area for surface and sub-surface investigations, especially as the proposed reservoir would sit atop the ridge and seepage avenues could be unlimited. Appropriate design measures based on adequately planned investigations – mainly drilling with Water Pressure Tests, however, are expected to result in the construction of a competent and leak-proof reservoir.

5.12 RESERVOIR POWERHOUSE CAVERN

The 147m (L) x 23m (W) x 52m (H) powerhouse cavern is proposed on the eastern periphery of the Lower Reservoir. The hill slope is well vegetated and superficially covered by colluvium (Photo 5.16). Rock is expected at shallow depths of <5m.

The EW aligned cavern is located in interbedded quartzite and phyllite. With its longer axis making a negligible angle of <10 with the easterly bedding dips of the strata, the cavern is considered aligned very favourably with respect to the rock structure. It would, however, be prudent to house the cavern in a single lithological unit that would be possible on the basis of subsurface investigations, especially the exploratory drift along MAT or CVVT that would reveal the complete rock sequence in the powerhouse complex.

Photo 5-16: Colluvium covered hill face above the powerhouse cavern

However the options for considering partial underground and partial surface or fully surface power house shall be explored based on geotechnical investigations proposed during DPR stage.

5.13 SUBSURFACE WATER CONDUCTOR SYSTEM

5.13.1 WCS FOR UPPER RESERVOIR

The 1672m long including head and tail race water conductor system comprises gently sloping tunnels and inclined shafts, and rises from the base of the eastern valley face of the Lower Reservoir to the top of the ridge at Upper Reservoir. The hill slope is well vegetated and is covered with colluvium that is expected to be shallow (<5m) in the upper reaches but may be much thicker at the base.

The WCS is aligned sub-parallel to the bedding strike and, hence, unfavourably disposed in this respect. Although an alternative alignment may not be workable but the one proposed would be easily manageable with prudent layout optimisation, design, and construction management. The mandatory exploratory drift along MAT/ CVVT revealing litho-structural and engineering details of the rock mass would be greatly helpful in optimising the layout.

The locations of portals of MAT, CVVT, construction adits, and WCS would require careful selection in areas where the colluvium is at its minimum thickness. In this reference, exploration by drilling may be required.

5.14 CONSTRUCTION MATERIAL

With the abundance of quartzite all through the project area and its neighbourhood, there is no dearth of coarse aggregate for concrete as also for rock fill dams or embankments, should these be considered. The fine aggregate of good quality sand may be available along the banks of the Pennar River that is not too far from the project area. Alternatively, crushed quartzite could also meet the requirement if it is found more economical compared to the cost of longer haulage of sand from the River.

Considerably large quantities of quartzite would be generated by excavation of surface and subsurface components of the project and, hence, may fulfil good portions of the overall requirement. The balance requirement would be met from identified quarries close to the project components.

The availability of impervious material for rock fill dams and embankments may be a cause of concern as the area around the project is quartzite dominated and the soil is expected to be sandy. This may be the focus of attention during the investigations for the construction material.

5.15 ENGINEERING GEOLOGICAL CONCERNS FOR INVESTIGATIONS

In the 'Survey and Investigations' phase for Detailed Project Report (DPR), where standard investigations, explorations and field & laboratory tests would be conducted according to the guidelines of the competent authority (CWC, CEA, GSI, CSMRS), it is planned to pay special attention to the following engineering geological aspects.

a) Regional traverses are envisaged for better appreciation of litho-tectonic model of the project area.

b) Higher subsurface water content is suspected in quartzites underlying phyllite for which special attention would be paid to the permeability in the region of the contacts of these two rock types while conducting field permeability tests in the drill holes in the powerhouse – subsurface water conductor complex.

c) The subsurface exploration by drilling at the dam site for Lower Reservoir would be an appropriate combination of vertical and inclined holes (across the bedding) for assessing the depth to bedrock and the structural condition of the rock mass, particularly the closely jointed, fractured or sheared zones. This would help in optimising the dam axis by avoiding weak zones in the seat of the dam.

d) The site for the dam at the ends of the depression hosting the Upper Reservoir have axes aligned across the bedding for which this site would be explored through inclined holes (across the bedding) for intercepting maximum number of weak zones along bedding. These are the ones most susceptible to seepage across the proposed dams.

e) Permeability of the dam foundations, and of the overall area of the upper reservoirs, is of utmost concern as any high permeability zone anywhere may lead to leakage through the unconfined hill slopes around the reservoir that is perched high on the ridge top. A carefully formulated exploration program would address this issue, both for the assessment of leakage potential and for formulation of remedial measures towards making the reservoir a water-proof entity.

f) The geological model based on subsurface exploration by drifts in the powerhouse area would help locate the powerhouse cavern in a single lithological unit and free from any major weakness zone. For the reason that the phyllite beds are of limited thickness, the cavern is expected to be located fully in quartzite.

g) The subsurface water conductor system makes a small angle of about 20^{o} with the strike of the strata and a major weakness zone may persist for longer lengths along it, should one be encountered. The results of exploratory drifts in the powerhouse complex would be used in keeping the subsurface water conductor free from any major weakness zone.

HYDROLOGY

6 CHAPTER 6 - HYDROLOGY

6.1 INTRODUCTION

The project lies in the Pennar basin, in the Kadapa district on the left bank of existing Somasila Reservoir at geographical co-ordinate 14°38'4.12"N and 79°10'41.98"E in NE direction. The project is proposed with two reservoirs i.e. upper and lower reservoir. The proposed lower reservoir is located in the foothills near the North Ramapauram village of the Kadapa District, where as the upper reservoir is proposed in the depression zone to the south west of proposed lower reservoir. The project layout is shown in the figure 5-1.

It is planned to initially fill the proposed lower reservoir by drawing water from the existing Somasila Reservoir through a 14.7 km long D.I piped surface water conductor during the commissioning stage. The proposed lower reservoir has a gross storage capacity of 8.33 MCM. Following the initially filling of proposed lower reservoir, the project operations viz. pumping and power generation operation etc. will be carried out among upper reservoir and lower reservoir.

Since initial filling of water is required from existing Somasila reservoir, therefore, no specific hydrological studies are required to be carried out. No sedimentation studies are required as there will be no sediment load entry in the reservoir water system

6.2 KEY PARAMETERS

The table 6-1 shows the key water levels of the proposed upper and lower reservoir of the Project.

	Unit	*FRL*	*MDDL*
Upper Reservoir	m	566	536
Lower Reservoir	m	182	170

Table 6-1: Key Parameters of Reservoirs

The elevation capacity table and the elevation capacity curve for the proposed lower reservoir is given in the Table 6-2 and Figure 6-1.

ELEVATION CAPACITY TABLE FOR LOWER RESERVOIR				
Elevation (m)	**Capacity (MCM)**		**Elevation (m)**	**Capacity (MCM)**
156.00	0.00		173.00	3.41
158.00	0.04		174.00	3.91
160.00	0.13		175.00	4.43
162.00	0.29		176.00	4.95
164.00	0.53		177.00	5.49
166.00	0.86		178.00	6.04
168.00	1.30		179.00	6.59
169.00	1.57		180.00	7.16

170.00	1.95		181.00	7.74
171.00	2.42		182.00	8.33
172.00	2.91			

Table 6-2: Elevation Capacity Table for Proposed Lower Reservoir

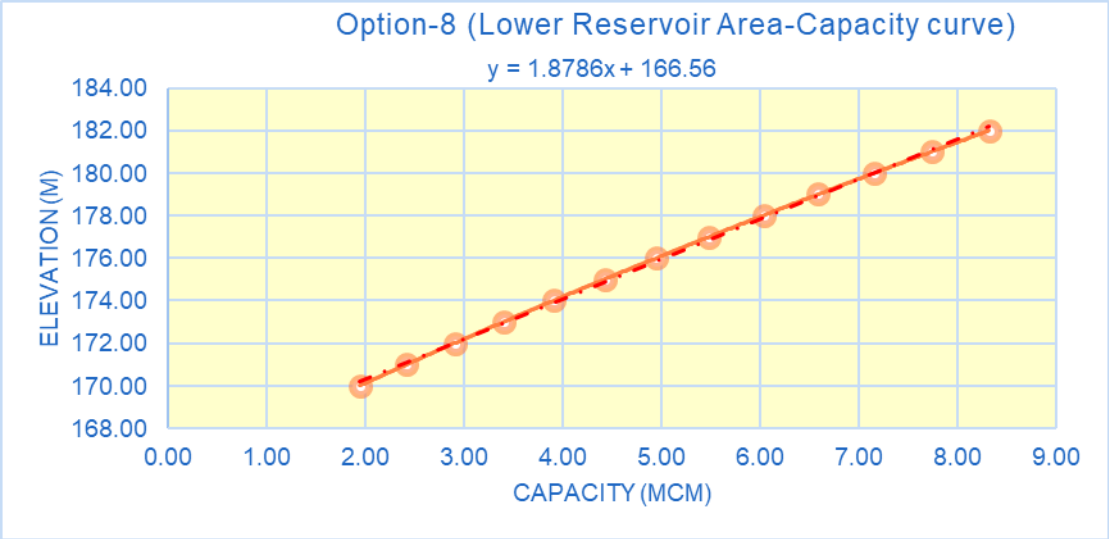


Figure 6-1: Elevation Capacity Curve for Proposed Lower Reservoir

The elevation capacity table and the elevation capacity curve for the proposed Upper reservoir is given in the Table 6-3 and Figure 6-3.

ELEVATION CAPACITY TABLE FOR UPPER RESERVOIR				
Elevation (m)	**Capacity (MCM)**		**Elevation (m)**	**Capacity (MCM)**
535.00	0.000		552.00	2.963
536.00	0.207		554.00	3.373
538.00	0.502		556.00	3.795
540.00	0.811		558.00	4.231
542.00	1.132		560.00	4.686
544.00	1.465		562.00	5.156
546.00	1.815		564.00	5.639
548.00	2.182		566.00	6.167
550.00	2.566			

Table 6-3: Elevation Capacity Table for Proposed Upper Reservoir

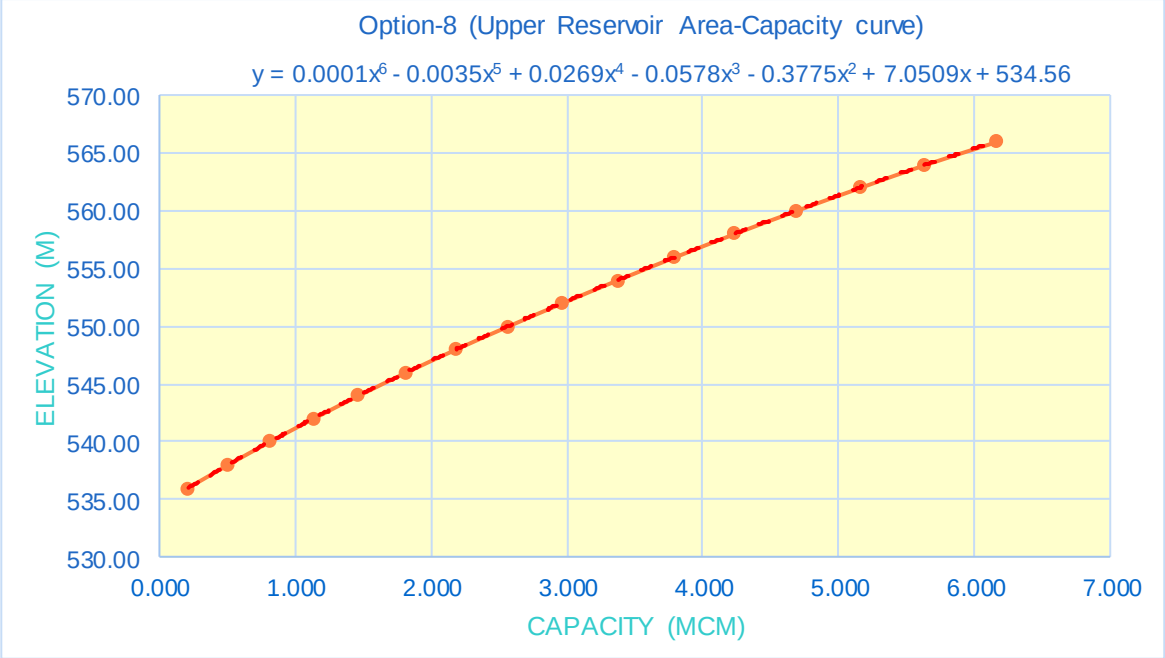


Figure 6-2: Elevation Capacity Curve for Proposed Lower Reservoir

6.3 DATA AVAILABILITY

A multi-disciplinary team visited the Somasila dam and proposed location of reservoirs and the team members had detailed interaction with project officials including Irrigation department officials on data availability, Somasila reservoir operations etc. The data listed in table 6-4 was collected for existing Somasila reservoir during the site visit from Irrigation Dept. (Govt. of AP) for assessing the efficacy of the proposed Pumped Storage Project (PSP) scheme.

Sl. No	Data Type	Frequency	Data Supplied	
			From	To
1	Inflow	Daily	June 1998	Sept 2018
2	Outflow	Daily	June 1998	Sept 2018
3	Evaporation losses	Daily	May 2000	Sept 2018
4	Gauge Discharge Data of Chennur (CWC, G & D Site)	Daily	June 1998	Sept 2018 *(Source: Indiawris.gov.in)*
5	ORIGINAL ELEVATION –AREA –CAPACITY of Somasila reservoir			

Table 6-4: Data Collected from various sources

Since the existing Somasila scheme is operational from 1989, the actual inflows and outflows into the existing reservoir (site specific) together with evaporation losses measured at dam site and as available with Irrigation department have been considered instead of transposition of runoff from nearby G & D site.

6.4 HYDROLOGICAL STUDIES

The project commissioning with initial utilization of water from existing Somasila reservoir does not need to be relooked afresh for the proposed Pumped Storage Project recycling operation as the water requirement is 8.33 MCM, i.e. only 0.4 % the capacity of existing Somasila Reservoir and it is feasible to fill the lower reservoir of the project from the surplus water available in existing Somasila reservoir during the monsoon season.

Storage for the proposed reservoirs is given below:-

	Unit	Live Storage	Dead Storage	Gross Storage
Upper Reservoir	MCM	5.96	0.21	6.17
Lower Reservoir	MCM	6.382	1.95	8.33

Table 6-5: Storage Capacity of Proposed Reservoirs

The storage capacity of the existing Somasila reservoir is as follows:-

	Unit	Quantity
Gross Storage	MCM	2207.6
Live Storage	MCM	1994.10
Dead Storage	MCM	214.22

Table 6-6: Storage Capacity of Existing Somasila Reservoir

The present scheme aims to work as independent unit after having initial pumping from existing Somasila Reservoir. The evaporation losses are proposed to be compensated by refilling from existing Somasila Reservoir. A simulation study is carried out to find out the refilling requirement of the above scheme based on daily evaporation losses. No leakage of water is considered at this stage. This will be further investigated during the DPR Stage. The calculations for Lower Reservoir and Upper Reservoir are attached as **Annexure–6.1 and Annexure 6.2 (Vol. II)** and same is summarised as below.

The total storage of the lower reservoir is 8.33 MCM including dead and live storages. After suffering evaporation losses, water refilling will be required when:-

'Total storage falls below the sum of dead storage of lower reservoir and live storage of upper reservoir storage i.e. 7.91 MCM.'

Considering the same, the simulation results indicate as under:-

- No. of days simulation carried out = 730 Days (2 water year)
- No of refills required = 4
- No of days after that refill is required = 100 days (first fill), 176 days (second fill), 195 days (third fill) & 176 days (fourth fill)

Thus the proposed Pumped Storage Project will require refilling in 100 days to compensate the water lost in evaporation for first refill.

RESERVOIR

7 CHAPTER 7 - RESERVOIR

The project is proposed as a Pumped Storage Project which envisages generation of 900 MW of power during peak hours. It has two reservoirs i.e., Upper and Lower (both new construction) at project site utilizing maximum & minimum gross head of about 398.0 m and 366.0 m respectively. The existing Somasila reservoir would not be used for daily operations. Surplus water from existing Somasila reservoir will be pumped in monsoon season during the commissioning stage of the project through a proposed pipeline to fill up the proposed lower reservoir which is located at foothills of Nellore town with gross storage of 8.33 MCM. The project operations viz pumping and power generation operation etc. will be carried out among upper reservoir and lower reservoir.

7.1 GEOLOGY OF RESERVOIR AREA

7.1.1 UPPER RESERVOIR

The upper reservoir is proposed along a NS trending depression, i.e. along the bedding strike, with prominent breaks-in-slope on either end. The site lies over a thick bed of quartzite that spans the reservoir area and the hills on the flanks. A bed of phyllite is interpreted at considerable depth. The overburden of topsoil at the bottom of the depression and colluvium on the flanks are expected to be shallow. The physiography of the site demands two dams at the north and south ends of the depression and a low height dam in the southern part of the linear hill on the western side. Rock foundations are likely to be available at shallow depths for the proposed dams.

7.1.2 LOWER RESERVOIR

The lower reservoir area is densely vegetated. Signs of any dormant or active landslide are conspicuous by their absence. The reservoir rim runs along vegetated and stable slopes. Any major concern with respect to the reservoir rim stability, therefore, is not apprehended. The proposed dam is located over a bed of quartzite and the foundation for the dam in rock is expected to be available at a reasonable depth.

7.2 SEDIMENTATION DATA AND STUDIES

Since it is closed loop circulation of water between the upper and lower reservoirs, therefore, no specific sedimentation studies are required as there will be no sediment load entry in the reservoir water system.

7.3 FIXATION OF STORAGE AND RESERVOIR LEVELS

The storage planning for daily cycle of operation for proposed Somasila pumped storage project envisages:

- Generation - 6 hours daily
- Pumping – 7.33 hours daily

7.3.1 LOWER RESERVOIR

The storage capacity with respect to reservoir levels for lower reservoir is shown below:

Particulars	Elevation (m)	Storage (MCM)
FRL	182	8.33
MDDL	170	1.95
Total Storage		**8.33**
Live Storage		**6.38**

Table 7-1 : Lower Reservoir details

7.3.2 UPPER RESERVOIR

The storage capacity with respect to reservoir levels for upper reservoir is shown below:

Particulars	Elevation (m)	Storage (MCM)
FRL	566	6.17
MDDL	536	0.21
Total Storage		**6.17**
Live Storage		**5.960**

Table 7-2 : Upper Reservoir details

7.4 ANNUAL LOSSES

The evaporation losses are proposed to be compensated by refilling from existing Somasila Reservoir. A simulation study is carried out to find out the refilling requirement of the above scheme based on daily evaporation losses. Considering evaporation losses, water refill will be required when 'Total storage falls below sum of dead storage of lower reservoir and live storage of upper reservoir storage i.e. 7.91 MCM'.

Considering the same, the simulation results indicate as under:

- No. of days simulation carried out = 730 Days (2 water year)
- No of refills required = 4
- No of days after that refill is required = 100 days (first fill), 176 days (second fill), 195 days (third fill) & 176 days (fourth fill)

Thus the proposed Pumped Storage Project will require refilling in 100 days to compensate the water lost in evaporation for first refill.

No leakage of water has been considered at this stage. This will be further investigated during the DPR Stage.

7.5 SUBMERGENCE AREA

Based on available topographical data, the water spread area is about 29.09 hectare and 76.14 hectare at dam top with El.568.0 m and El. 184.0 m of upper reservoir and lower reservoir respectively.

7.6 LAND ACQUISITION

The construction of upper and lower reservoir will result in submergence of land which has to be acquired from concerned agencies like forest department. The area of land to be acquired for upper and lower reservoirs is tabulated below.

Sl. No	Reservoir	Total Land (Ha)	Forest Land (Ha)	Govt. / Private Land (Ha)
1	Upper	29.09	29.09	-
2	Lower	76.14	76.14	-

Table 7-3: Land to be acquired

POWER POTENTIAL & INSTALLED CAPACITY

8 CHAPTER 8 - POWER POTENTIAL AND INSTALLED CAPACITY

The type of power plant envisaged is a Pumped Storage Project with an installed generating capacity of 900 MW. The scheme of operation considered is daily regulation to meet the daily peak demand of about 6 hours of peak power. Daily off-peak pumping hours are considered as 7.33 hours. The net storage required in the reservoirs for the envisaged daily operation is estimated to be 5.96 MCM.

8.1 OPTIMIZATION OF STORAGE CAPACITIES OF RESERVOIRS & RELATED PARAMETERS

8.1.1 UPPER RESERVOIR

The Upper reservoir is located on the natural depression area having potential to create sufficient pondage by minor excavation & providing gravity dam on the two sides of the depression area for locking the land. The location of upper reservoir is on the left bank at geographical co-ordinates 14°38'4.12"N and 79°10'41.98"E in NE direction of existing lower Reservoir. The upper reservoir has a live storage capacity of 5.96 MCM as under:

Table 8-1: Upper Reservoir details

Particulars	Elevation (m)	Storage (MCM)
FRL	566	6.17
MDDL	536	0.21
Live Storage		**5.960**

8.1.2 LOWER RESERVOIR

The lower reservoir for the scheme is proposed at the foot of the hill in an identified natural depression having suitable potential to create an artificial reservoir by minor excavation & providing a concrete gravity dam only on one side of the depression area for locking the land. The maximum height of concrete gravity dam is around 35.0 m. This lower reservoir is to be filled initially at the time of commissioning by pumping surplus water during monsoon from the existing Somasila reservoir by means of an intake well and jack well cum pump house structure via D.I (ductile iron) pipeline. The location of lower reservoir is on the left bank at geographical co-ordinates 14°39'14.09"N and 79°10'34.25"E in NE direction of existing Somasila reservoir. The following parameters have been considered for Lower reservoir:

Table 8-2: Lower Reservoir details

Particulars	Elevation (m)	Storage (MCM)
FRL	182	8.33
MDDL	170	1.95
Live Storage		**6.38**

8.1.3 OPTIMIZATION OF INSTALLED CAPACITY

The installed capacity of a typical PSP is dependent on the following condition:

i. Reservoir storages and head available at the site

ii. Demand for peak power and

iii. Availability of pumping energy

8.1.3.1 OPTIMIZATION OF UPPER RESERVOIR STORAGE CAPACITY

The Upper reservoir is located in the natural depression area like a deep channel having potential to create sufficient pondage by minor excavation & providing concrete gravity dam on the two sides of the depression area for locking the land.

Deepest bad level towards the North face dam is at El. 530m wherein for South face is at EL. 540m. The maximum peak of west facing hill is at EL. 582m which is almost varying to the downward lowest peak at El. 540m on both side along its length near both Dam (North & South face). Other side i.e. on the east side face, hill slope is quite high all through the reservoir length.

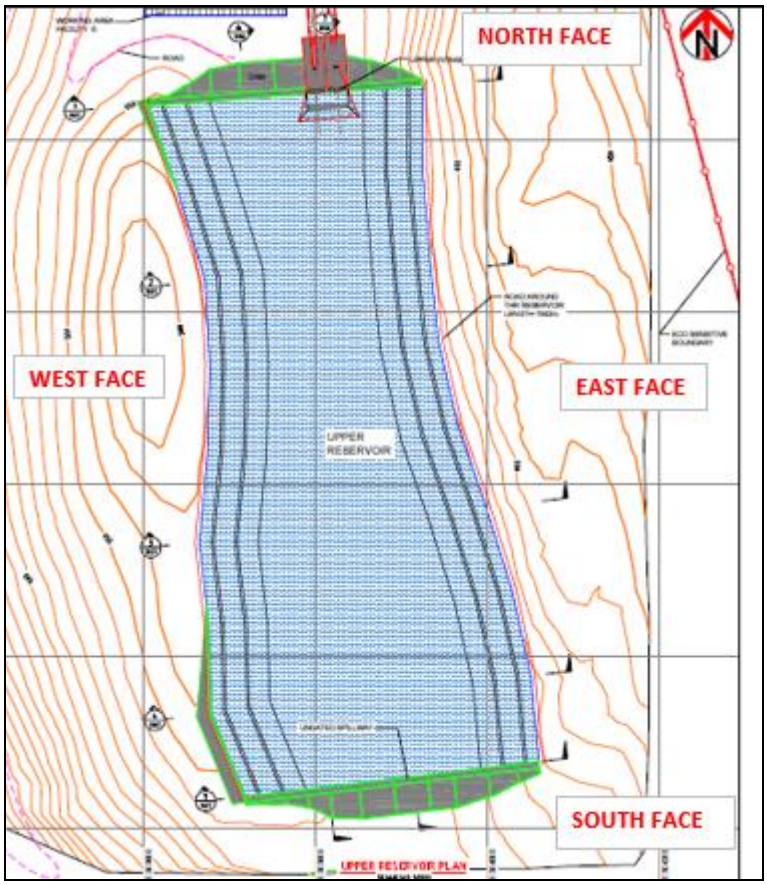


Figure 8-1: Layout of Upper Reservoir

For optimizing the upper reservoir capacity, seven cases have been studied and are elaborated as below:

Case-1: Considering the FRL and MDDL of upper reservoir are El. 562 & EL. 536m. Top of Dam is on both north & south face is 564.0m. Calculated total & live storage are 5.19 MCM & 4.98 MCM.

Case-2: Considering the FRL and MDDL of upper reservoir are El. 564 & EL. 536m. Top of Dam is on both north & south face is 566.0m. Calculated total & live storage are 5.68 MCM & 5.47 MCM.

Case-3: Considering the FRL and MDDL of upper reservoir are El. 566 & EL. 536m. Top of Dam is on both north & south face is 568.0m. Calculated total & live storage are 6.17 MCM & 5.96 MCM.

Case-4: Considering the FRL and MDDL of upper reservoir are El. 569 & EL. 536m. Top of Dam is on both north & south face is 571.0m. Calculated total & live storage are 6.82 MCM & 6.61 MCM.

Case-5: Keeping the FRL and MDDL of upper reservoir same as Case-3 i.e. El. 566 & EL. 536m. Top of Dam is on both north & south face is 568.0m. To increase the storage capacity, excavation of about 26m length is increase towards the east side hill slope. Calculated total & live storage are 6.82 MCM & 6.61 MCM.

Case-6: Considering the FRL and MDDL of upper reservoir are El. 569 & EL. 536m. Top of Dam is on both north & south face is 571.0m. To increase the storage capacity, excavation of about 20m length is increase towards the east side hill slope. Calculated total & live storage are 7.44 MCM & 7.23 MCM.

Case-7: Considering the FRL and MDDL of upper reservoir are El. 569 & EL. 536m. Top of Dam is on both north & south face is 571.0m. To increase the storage capacity, excavation of about 43m length is increase towards the east side hill slope. Calculated total & live storage are 8.03 MCM & 7.82 MCM.

Detail storage capacity, excavation & concrete quantity, construction cost for each cases are tabulated in the **Table 8-3**

Item case & Description		Total Storage Capacity of Upper Reservoir (MCM)	Live Storage Capacity of Upper Reservoir (MCM)	Increment Increase in Capacity (MCM)	Excavation Qty (Lakh Cum)	Concrete Qty (Lakh Cum)	Total Cost (Cr.)	Cost / Storage Capacity (Cr./MCM)	% Increase in Excavation Qty wrt. Case-3	% Increase in Concrete Qty wrt. Case-3
Case - 1	FRL - 562 & MDDL 536	5.19	4.98	-	18.01	1.99	221.74	42.72	-1.52	-26.42
Case - 2	FRL - 564 & MDDL 536	5.68	5.47	0.49	18.26	2.35	238.30	41.95	-0.18	-13.19
Case - 3	FRL - 566 & MDDL 536	6.17	5.96	0.49	18.29	2.71	253.97	41.16	-	-
Case - 4	FRL - 569 & MDDL 536 Increased the Dam height by 5m	6.82	6.61	0.65	19.01	3.68	305.05	44.73	3.92	35.88
Case - 5	FRL - 566 & MDDL 536 Increased excavation about 26m towards the East Side	6.82	6.61	0.00	28.36	2.99	316.36	46.39	55.02	10.33
Case - 6	FRL - 569 & MDDL 536 Increased the Dam height by 5m & excavation about 20m towards the East Side	7.44	7.23	0.62	27.29	3.96	358.54	48.19	49.16	46.35
Case - 7	FRL - 569 & MDDL 536 Increased the Dam height by 5m & excavation about 43m towards the East Side	8.03	7.82	0.59	39.10	4.29	429.94	53.54	113.77	58.39

Table 8-3 : Storage and cost estimation details of Upper Reservoir for different cases

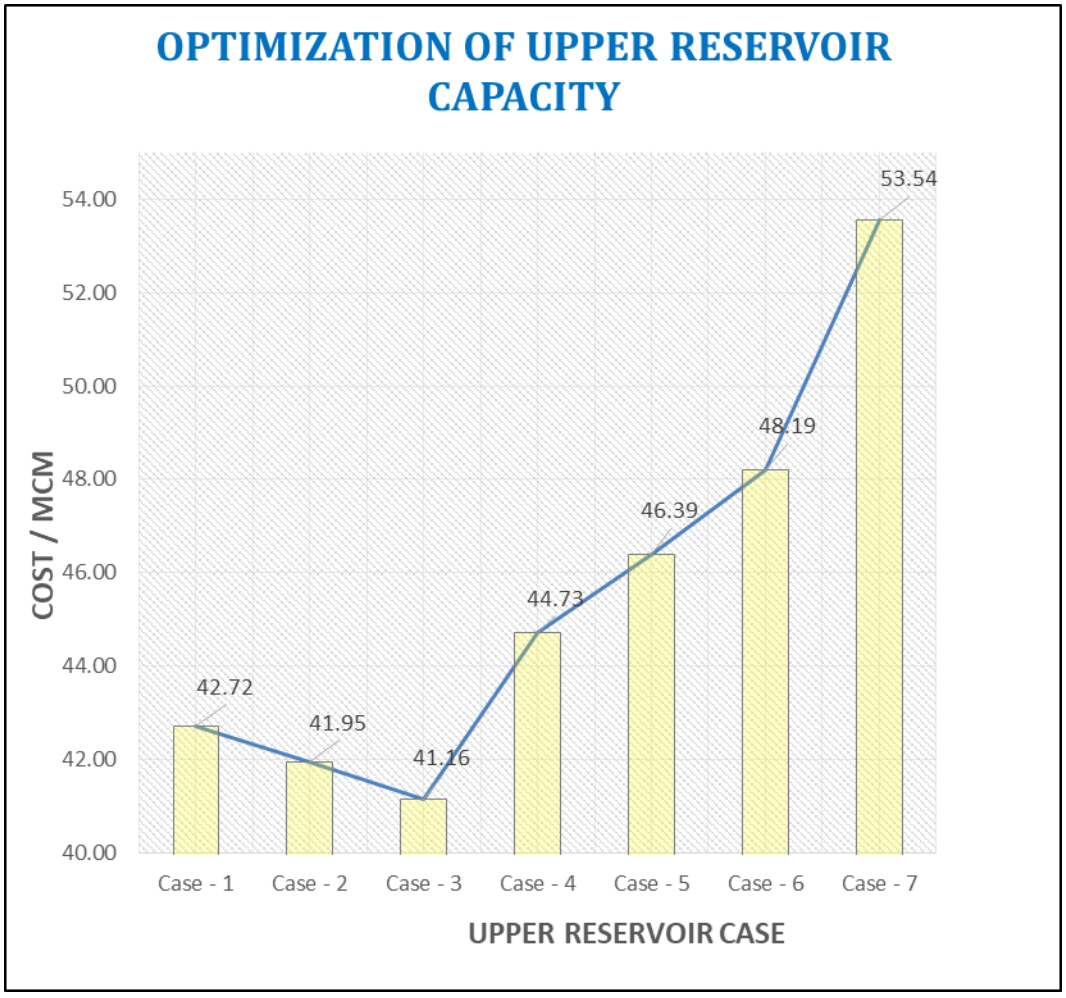


Figure 8-2: Graph for Cost per MCM wrt. Different cases

From the figure 8-2, it has been observed that Case -3 is the most optimized case among the studied seven cases. Thus, the total storage capacity of Upper reservoir has been finalized as per findings of Case-3.
Selected parameters of Optimized Upper Reservoir given below:

- FRL 566 m
- MDDL 536 m
- Total Storage Capacity 6.17 MCM
- Live Storage Capacity 5.96 MCM

8.1.3.2 SELECTION OF INSTALLED CAPACITY WRT. 6 HOUR PEAKING TIME

Based on the selected parameters of Upper & Lower Reservoirs and considering 6 hour peaking time (please refer paragraph 8.2 for peaking hour assessment), installed capacity of 900 MW has been finalized. Details are given in **Table 8-4:**

Table 8-4 : Fixation of Installed Capacity

Fixation of Installed Capacity					
Installed Capacity	**800**	**900**	**1000**	**1100**	**1200**
Live Storage Capacity	5.96	5.96	5.96	5.96	5.96
UR - FRL	566	566	566	566	566
UR - MDDL	536	536	536	536	536
LR - FRL	182	182	182	182	182
LR - MDDL	170	170	170	170	170
Head Loss	7	7	7	7	7
Net Head	371	371	371	371	371
Turbine Efficiency	0.9062	0.9062	0.9062	0.9062	0.9062
Design Discharge	242.562	272.882	303.203	333.523	363.843
Peaking Duration	6.83	**6.07**	5.46	4.96	4.55

8.1.3.3 AVAILABITY OF PUMPING ENERGY

Large scale solar parks and non-conventional energy sources like Wind are being implemented in the State of Andhra Pradesh and Southern Region. Owing to highly seasonal/intermittent nature of above sources, development of suitable energy storage system like Pumped Storage Projects for power and energy shifting has become a necessity to meet the peak demand in future. Adequate surplus power required for pumping would be available during off-peak time from non-conventional source of energy.

8.2 PEAKING HOURS ASSESSMENT

Studies were carried out for peaking hour assessment based on hourly demand in the State of Andhra Pradesh.

Table 8-5: Hourly demand

Source: NREDCAP//WE/PSP/Corrs/2021/580 dated19-Mar-21 (4435333/2021/CE-01-KRS-VJWD)											
Hour/ Month	Hourly Power Demand										
	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW
	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21
1.00	5846.33	6808.00	6496.43	6000.55	6049.52	6379.77	6083.06	5963.57	5448.39	5804.06	6380.75
2.00	5832.67	6704.26	6365.97	5857.52	5948.65	6274.80	5981.42	5899.40	5407.52	5790.32	6340.56
3.00	5745.73	6596.35	6239.83	5764.19	5958.13	6194.63	5905.81	5852.87	5369.81	5798.50	6361.71
4.00	5776.20	6577.65	6226.63	5710.03	5900.94	6137.43	5899.71	5864.67	5427.81	5861.71	6466.39
5.00	5903.23	6744.32	6305.10	5798.06	6046.48	6275.10	6083.03	6125.23	5723.94	6155.87	6890.39
6.00	5941.27	6628.48	6322.83	5859.84	6288.94	6363.63	6180.39	6454.03	6223.84	6821.90	7645.29
7.00	5673.87	6601.35	6384.23	5974.65	6552.65	6442.57	6362.77	6668.00	6747.16	7487.42	8458.39
8.00	6086.63	7018.13	6667.53	6185.61	6753.97	6787.80	6616.71	6952.77	7187.48	8142.29	9042.89
9.00	7238.90	7955.23	7505.57	6760.26	7417.00	7314.83	7021.74	7535.20	7654.52	8840.80	9725.43
10.00	7410.17	8180.68	7626.47	6822.68	7418.26	7368.33	7062.55	7504.07	7569.37	8864.19	9638.26
11.00	7414.77	8340.68	7674.40	6801.48	7326.35	7323.77	7079.00	7392.47	7521.77	8724.74	9572.18
12.00	7723.53	8608.84	7856.97	6905.35	7440.58	7543.43	7193.19	7541.60	7586.52	8825.19	9704.32
13.00	7617.48	8636.29	7906.57	6927.97	7546.61	7544.57	7215.29	7547.13	7439.71	8527.55	9470.18
14.00	7611.03	8893.06	7938.30	6754.16	7250.87	7314.57	6937.48	7134.00	7082.13	8236.68	9216.00
15.00	7743.97	9007.63	8107.63	6794.10	7159.60	7355.33	7012.45	7134.10	7082.39	8111.65	9158.14
16.00	7258.30	8452.43	7637.67	6586.97	6918.61	7001.07	6762.32	6901.20	6820.39	7845.03	8773.71
17.00	6248.83	7200.58	6771.40	6010.61	6449.48	6491.03	6500.77	6536.77	6458.16	7125.13	7921.04
18.00	5169.47	5924.10	5920.73	5701.84	6094.13	6590.40	7078.97	7204.30	7169.90	7031.10	7286.96
19.00	5769.80	6409.94	6369.97	6520.10	6885.03	7295.60	7369.65	7176.50	7135.45	7396.06	7793.29
20.00	5926.73	6724.13	6697.33	6903.94	6940.84	7190.00	7189.03	6948.13	6798.58	7020.84	7427.46
21.00	6469.63	7370.00	7164.77	6930.84	6965.16	7217.17	7071.45	6782.00	6445.84	6810.52	7295.54
22.00	6672.60	7711.03	7356.77	6836.29	6795.97	7060.43	6817.68	6447.67	6089.35	6438.03	6983.07
23.00	6427.33	7492.48	7114.80	6522.10	6459.06	6798.83	6537.32	6187.53	5696.58	6037.71	6633.07
24.00	6092.00	7127.23	6767.70	6232.06	6214.10	6527.13	6354.13	6046.87	5526.13	5903.13	6417.75

Table 8-6: Peaking hours

Hour/Month	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21
Peaking Morning-Evening Hrs (12:00 am to 4:00 pm)	**7**	**7**	**7**	**7**	**8**	**7**	**7**	**8**	**9**	**9**	**9**
Peaking Evening - Night Hrs (4:00 pm to 12:00 am)	**2**	**3**	**4**	**6**	**5**	**5**	**6**	**5**	**4**	**2**	**1**

The project can contribute to the day/night peaking hours when there is a substantial increase in the power demand of the State. As the available hydroelectric potential in the State has already been harnessed, the pumped storage schemes need to be pursued for meeting the system peak. After daily generation, the water can be recycled back by pumping during the off peak hours when there is surplus power available from the non conventional sources like Wind and Solar parks These schemes are amenable for quick start, reliable and render operation flexibility in the system besides providing economic source for meeting peaking capacity requirement. In this connection, this Somasila PSP has potential to develop pumped storage project to cater the peak demand of 6 hours during the day time.

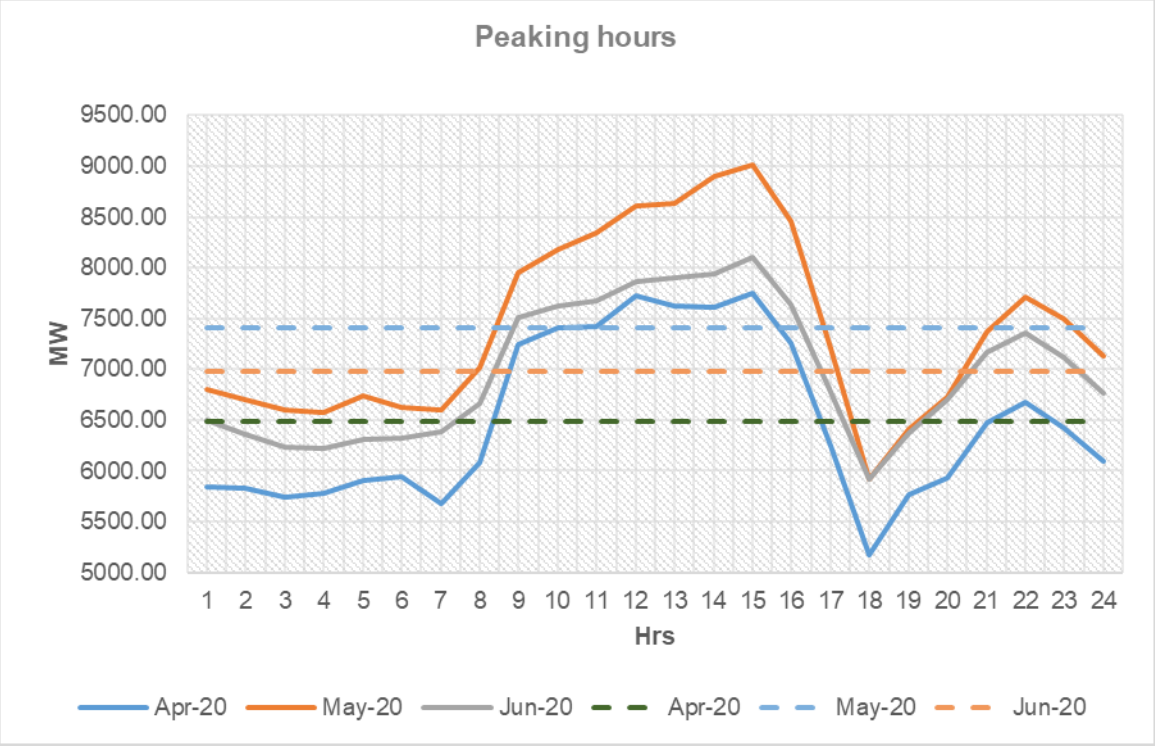


Figure 8-3: Peaking hours for Apr-21 to Jun-21

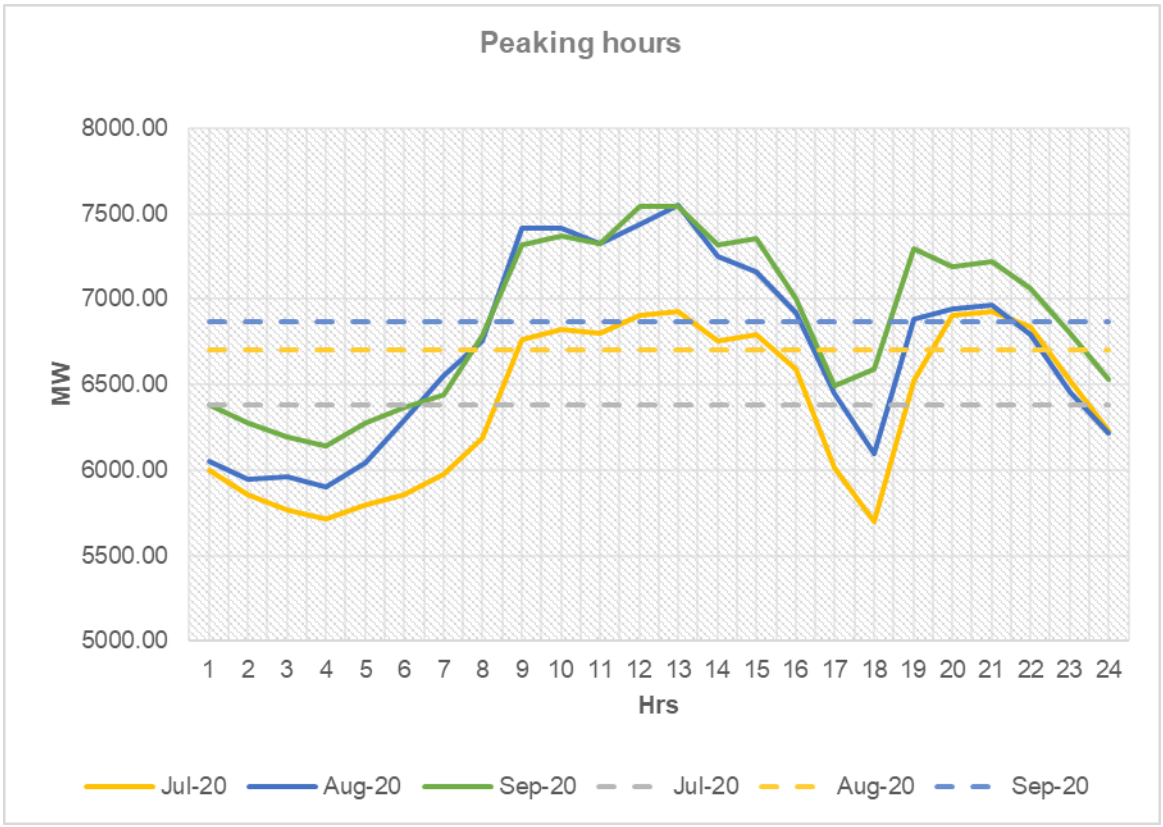


Figure 8-4: Peaking hours for Jul-21 to Sep-21

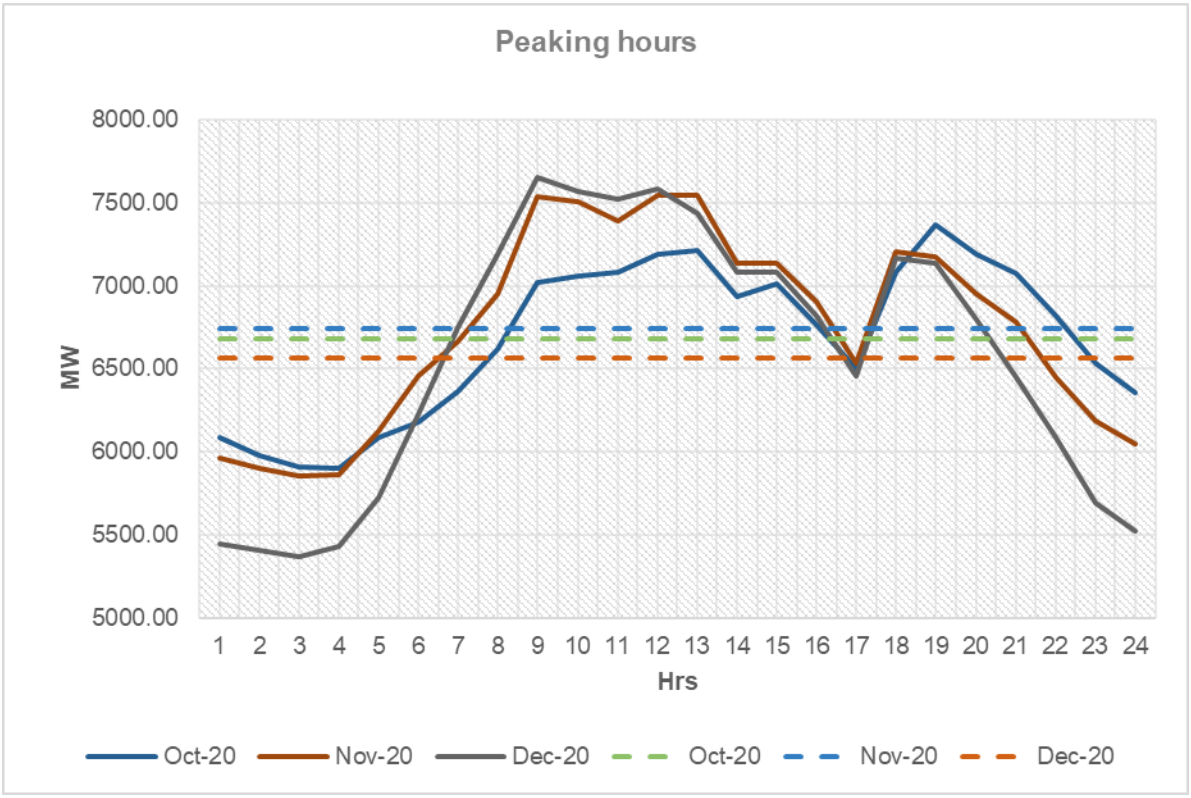


Figure 8-5: Peaking hours for Oct-21 to Dec-21

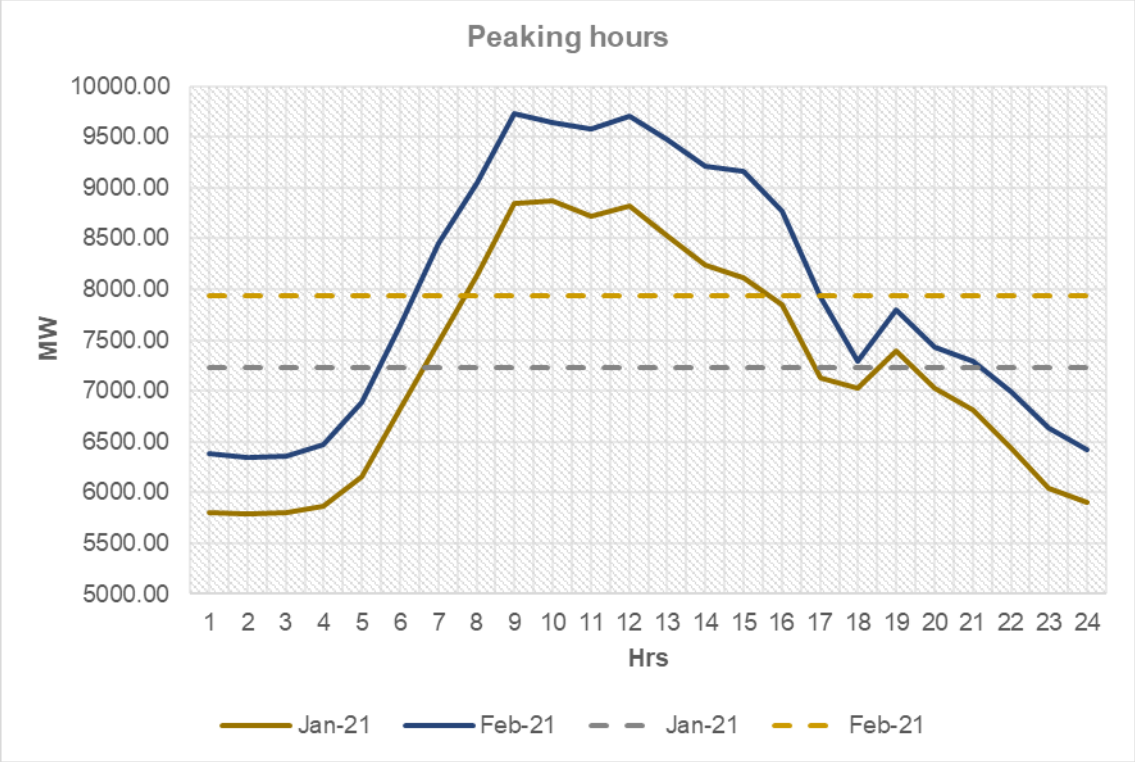


Figure 8-6: Peaking hours for Jan-21 to Feb-21

8.2.1 INSTALLED CAPACITY

An installed capacity of 900 MW has been proposed. The project would provide peaking capacity for 6 hour block.

8.2.2 NUMBER OF UNITS

For the selected installed capacity of 900 MW and head available at project site, four pump-turbine-generator (PTG) units are recommended – 225MW X 4. The details of selection of number of units is covered in Chapter on Electro-Mechanical works.

8.2.3 OPERATING GROSS HEAD & NET HEAD DURING GENERATION

The maximum and minimum gross operating head on pumped storage units would vary from 396.0 m to 354.0m. The minimum gross head is 89.39% of the maximum gross head. The head loss in the water conductor system also varies from 6.37m to 8.02m during generation and accordingly, the net design head on the machine would vary from 347.43 m to 388.86 m.

8.2.4 GENERATOR TURBINE EFFICIENCY

The efficiency of the pump-turbine unit during generating mode is adopted as 90.62% and during the pumping mode is adopted as 91.6%.

8.2.5 OPERATION SIMULATION STUDIES

The operation simulation of the two reservoirs for pumped storage operation has been carried out considering the storage characteristics. The simulation has been carried out considering a shorter time interval of 10 minutes to take into account the

level variations in the two reservoirs. The studies have been carried out at the beginning of generating cycle, the upper reservoir is at FRL (El. 566.0m) and Lower reservoir at MDDL (El. 170.0m) and for pumping cycle, lower reservoir is at FRL (EL 182m) and upper reservoir is at MDDL (EL 536m) . The results of the simulation studies for generating mode & pumping mode are given in **Annexure-8.1** and summarized below:

Table 8-7: Summary of Results

Summary Result of Reservoir Simulation				
	Daily Energy	Running Time	Annual Energy	Working Days/year
	GWH	hr	GWH	
Pumping Mode	6.60	7.33	2409.00	365.00
Generation Mode	5.40	6.00	1971.00	365.00
Cycle Efficiency	80.73%			

The energy generation during the period is 5.4 GWh and annually generation of 1971.0 GWh of energy. The pumping energy requirement would be 6.60 GWh and annually pumping energy of 2409.0 GWh which gives a cycle efficiency of 80.73%.

8.2.6 RATED DESIGN DISCHARGE FOR TURBINE MODE & PUMPING MODE

Upper & Lower reservoir parameters are given below:

Table 8-8: Upper and Lower Reservoir Levels

Level				UR	LR
Full Reservoir Level	FRL	m	=	566.00	182.00
Minimum Draw Down Level	MDDL	m	=	536.00	170.00

Average water level of Upper Reservoir	Average water level of Lower Reservoir	Head loss in WCS	Net head	Acc due to gravity	Pump Efficiency	Installed Capacity	**Rated Design discharge**	**Adopted Rated Design discharge**
m	**m**	**m**	**m**	**m/s²**		**MW**	**cumec**	**cumec**
556.00	178.00	7.00	385.00	9.81	0.916	900.00	218.28	218.30

Table 8-9: Design discharge for Pumping mode

Table 8-10: Design discharge for Turbine mode

Average water level of Upper Reservoir	Average water level of Lower Reservoir	Head loss in WCS	Net head	Acc due to gravity	Turbine Efficiency	Installed Capacity	Rated Design discharge	Adopted Rated Design discharge
m	**m**	**m**	**m**	**m/s²**		**MW**	**cumec**	**cumec**
556.00	178.00	7.00	371.00	9.81	0.9062	900.00	272.88	273.00

8.2.7 SUMMARY OF POWER POTENTIAL STUDY

Table 8-11: Input parameters

S.No.	Input Parameter		Unit		UR	LR
1	Full Reservoir Level	FRL	m	=	566.00	182.00
2	Minimum Draw Down Level	MDDL	m	=	536.00	170.00
3	Total Storage	TS	MCM	=	6.17	8.33
4	Dead Storage	DS	MCM	=	0.21	1.95
5	Live Storage	LS	MCM	=	5.96	6.38

Table 8-12: Summary of Annual Energy & Cycle Efficiency

Simulation Results	Daily Energy	Running Time	Annual Energy	Power	Working Days/year
	GWH	hr	GWH	MW	
Pumping	6.60	7.33	2409.00	900.00	365.00
Generation	5.40	6.00	1971.00	900.00	365.00
Cycle Efficiency	80.73%				

DESIGN OF CIVIL STRUCTURES

9 CHAPTER 9 - DESIGN OF CIVIL STRUCTURES

Somasila project is a Pumped Storage Project envisaging generation of 900 MW of power during peak hours. It envisages two reservoirs i.e., Upper and Lower at project site utilizing maximum & minimum gross head of about 396.0 m and 354.0 m respectively. The water from upper reservoir will be utilized for generating power during peaking hours and during off-peak periods, water from lower reservoir shall be pumped back to upper reservoir using surplus off-peak power available from solar and wind projects. A schematic layout of project is shown in ***Figure – 9.1*** and detailed layout of project is given in ***Drawing Volume III, drawing number 7061601-FSR-1001.***

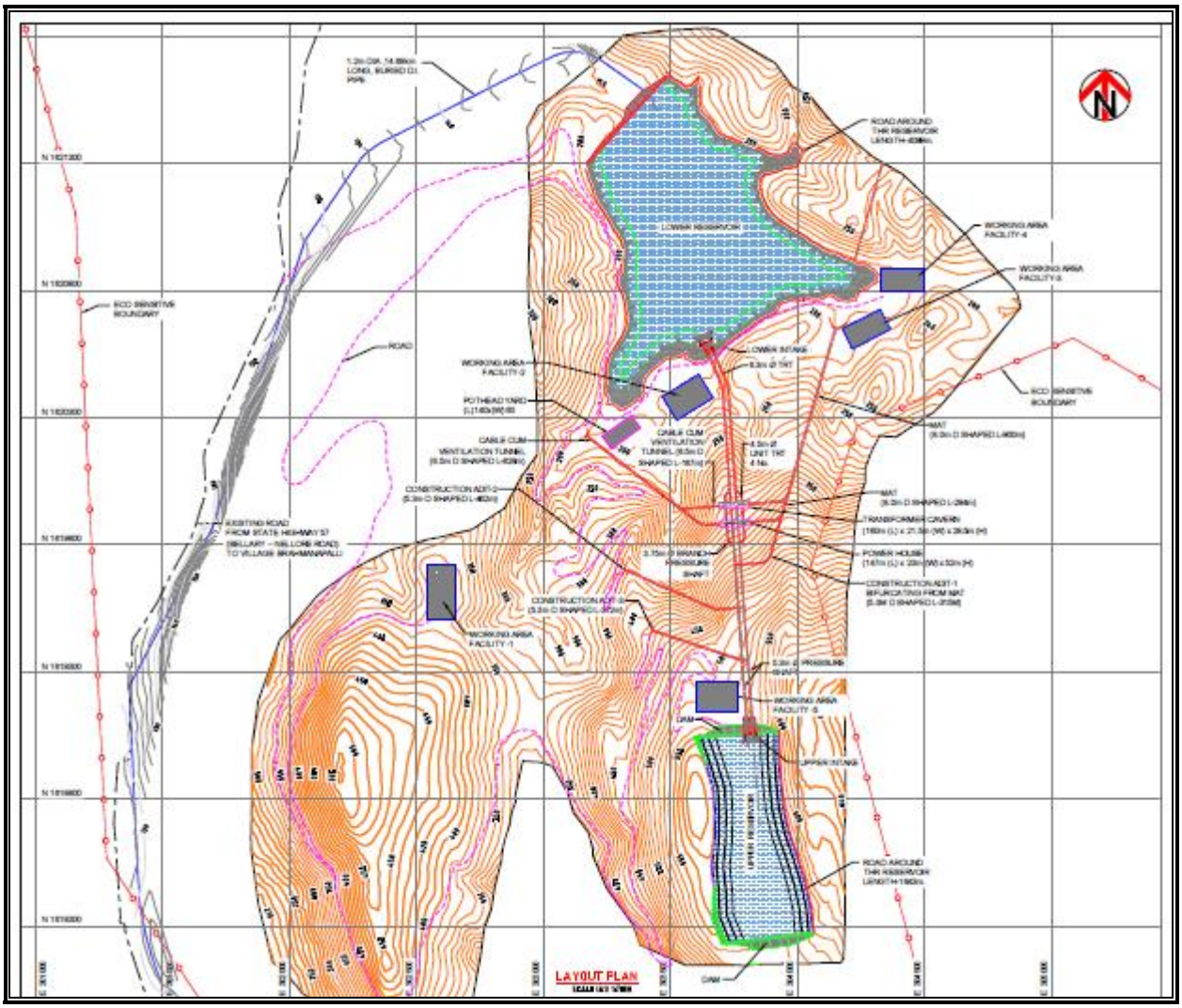


Figure 9-1: General Layout Plan

During turbine mode, upper intake draws water from upper reservoir into twin pressure shaft of 5.30m circular finished diameter which further bifurcates into two branch penstock of 3.75 m diameter leading to Power House unit bay.

During pumping mode, water is drawn from lower reservoir through lower intake at tailrace tunnel and led back into the upper reservoir through the same water conductor system as briefed above.

The proposed Somasila PSP (4 x 225 MW) envisages following major civil structures:

I. **Upper Reservoir & Dam (Concrete Gravity Dam):** The Upper reservoir is located on the natural depression area having potential to create sufficient pondage by minor excavation & providing concrete gravity dam on the two sides of the depression area for creating the reservoir.
   c) **North Facing (Upper Intake side):** Total length of dam is 272.70m. The maximum height of the dam is around 41.50m from the deepest foundation level.
   d) **South Facing:** Total length of dam is 347.0m. The maximum height of the dam is around 33.0m from the deepest foundation level.

II. **Upper Intake:** Two intake structure consists of four bays each of 3.75m width to accommodate 17 numbers of trash rack panel of size 3.75m x 2.5m, at the mouth of the intake.

III. **Pressure Shaft:** 903.2m long 5.30 m finished diameter twin steel lined pressure shaft is proposed, each of which bifurcates further into 2 nos. branch penstock of 78.70m long, 3.75m diameter leading to powerhouse.

IV. **Underground Power House & Transformer Cavern:** The overall dimensions of the powerhouse are 147 m long x 23 m wide x 52 m high. Transformer Cavern size is 160.0 m x 21.5 m x 29.50 m

V. **Tailrace Tunnel:** Four numbers unit tail race tunnel of 4.50m diameter off takes from the downstream wall of machine hall and run parallel till they merge with the twin main tailrace tunnel of 6.30m diameter.

VI. **Lower Reservoir & Dam (Concrete Gravity Dam):** The lower reservoir is located at the foot of the hill in an identified natural depression having suitable potential to create an artificial reservoir by minor excavation & providing a concrete gravity dam only on one side of the depression area for creating the lower reservoir. The maximum height of concrete gravity Dam is around 33.50m.

VII. **Intake cum Jack well pump house and D.I pipe line:** 1.2m diameter, 14.70 km long ductile iron pipe line is proposed from the jack well pump house (located near the existing Somasila reservoir) to the lower reservoir for initial filling of lower reservoir.

VIII. **Pothead Yard:** Considering four numbers outgoing feeders, 420kV pothead with tentative area of 140mx60m has been proposed.

9.1 PROJECT DESIGN DATA

- The following data is pertinent for layout and design of project components:
- Full Reservoir Level (FRL – Upper reservoir) : 566.0 m
- Minimum Drawdown Level (MDDL – Upper Reservoir) : 536.0 m
- Live storage capacity of Upper reservoir : 5.96 MCM
- Full Reservoir Level (FRL – Lower reservoir) : 182.0 m

- Minimum Drawdown Level (MDDL – Lower Reservoir) : 170.0 m
- Live storage capacity of Lower reservoir : 6.38 MCM
- Head Loss in the Water Conductor System : 7.0 m
- Combine efficiency of Turbine during generating mode : 0.906
- Combine efficiency of Turbine during pumping mode : 0.916
- Maximum net head on turbine : 389.0m
- Minimum net head on turbine : 347.0m
- Rated net head on Turbine during generating mode : 371.0m
- Rated net head on Turbine during pumping mode : 385.0m
- Rated design discharge during generating mode :273.0 Cumec
- Rated design discharge during pumping mode :218.30 Cumec

9.2 UPPER RESERVOIR

The Upper reservoir is located in the natural depression area having potential to create sufficient pondage by minor excavation & providing gravity dam on the two sides of the depression area for locking the land. The location of upper reservoir is on the left bank at geographical co-ordinates 14°38'4.12"N and 79°10'41.98"E in NE direction of existing Somasila Reservoir.

The upper reservoir area is located along a NS trending depression, i.e. along the bedding strike, with prominent breaks-in-slope on either end. The site lies over a thick bed of quartzite that spans the reservoir area and the hills on the flanks. A bed of phyllite is interpreted at considerable depth. The overburden of topsoil at the bottom of the depression and colluvium on the flanks are expected to be shallow. Rock foundations are likely to be available at shallow depths for the proposed dams. For ensuring water tightness of the reservoir along bedding, grouting and asphaltic membrane lining may be proposed where necessary. Detailed surface and sub-surface investigations will be carried out at DPR stage and appropriate design measures will be taken based on investigations.

The total storage capacity of upper reservoir is 6.167 MCM whereas the live storage capacity is 5.96 MCM. FRL & MDDL of the upper reservoir are 566.0m and 536.0m respectively whereas top & bottom of upper reservoir fixed as 568.0m & 535.0m respectively. The maximum height of concrete gravity dam on north facing i.e. on the upper intake face is around 41.5m. Similarly, on the south facing, maximum height of concrete gravity dam is 33.0m. Stability analysis of gravity dam has been carried out for the following load combinations:

1. **Load Condition A** - (construction condition) - Dam Completed but no water in reservoir
2. **Load Condition B** - (Normal Operating condition) -Full reservoir elevation, normal uplift (drains inoperative)
3. **Load Condition C** - Load Combination A with Earthquake
4. **Load Condition D** - Load Combination B with Earthquake

Table 9-1: Summary of Stability Analysis of 41.5m high Concrete Gravity Dam, North Facing

Description	F.O.S against Sliding	F.O.S against Overturning	Base Pressure (kN/m^2)	
			Toe	Heel
Load Condition A - (construction condition) - Dam Completed but no water in reservoir	N/A	N/A	177.68	763.45
Load Condition B - (Normal Operating condition) -Full reservoir elevation, normal uplift (drains inoperative)	3.98	1.72	499.52	105.93
Load Condition C - Load Combination A with Earthquake	13.43	13.25	231.08	672.40
Load Condition D - Load Combination B with Earthquake	3.24	1.46	600.20	-32.40

Table 9-2 : Summary of Stability Analysis of 33m high Concrete Gravity Dam, South Facing

Description	F.O.S against Sliding	F.O.S against Overturning	Base Pressure (kN/m^2)	
			Toe	Heel
Load Condition A - (construction condition) - Dam Completed but no water in reservoir	N/A	N/A	114.86	642.03
Load Condition B - (Normal Operating condition) -Full reservoir elevation, normal uplift (drains inoperative)	5.67	1.69	397.24	86.58
Load Condition C - Load Combination A with Earthquake	13.43	12.99	162.02	564.61
Load Condition D - Load Combination B with Earthquake	4.55	1.40	510.54	-57.00

For detail stability calculation of Gravity Dam, please refer **Annexure 9.1 and 9.2 of Volume - II**.

9.3 UPPER INTAKE

Upper intake envisages the construction of a twin bell-mouth shaped, breast walled power intake structure with accelerating velocities from the trash rack location to the mouth of the inlet pressure conduit. Each intake structure consists of four bays each of 3.75m width to accommodate 17 numbers of trash rack panel of size 3.75m x 2.5m, at the mouth of the intake. A platform has been provided at El 568.0m to facilitate gate and trash rack cleaning machine. The length of the exposed structure housing trash rack and gate slots along the longitudinal section is around 31.0m. At the inlet of intake conduit, one no. fixed wheel type service gate and one number emergency gate is proposed. The emergency gate would be at upstream of the service gate after the bell mouth entry of tunnel. The size of the opening, at gate location is 5.3 m x 5.3 m. Two 5.30 m diameter circular-shaped pressure shaft has been proposed for connecting the twin intake conduit to power house. For details of upper Intake, please refer ***Drawing Volume III, drawing number 7061601-FSR-1009 and 1010***.

9.3.1 HYDRAULIC DESIGN

Assumption and configuration as considered are:

- Maximum velocity through trash racks 1.5m/s when operating at MDDL. This satisfies the requirement of para 6.1 and para 6.2 of BIS 11388-1995 “Recommendations for Design of Trash Racks for Intakes”.
- The inlet tunnel has been proposed with a flat bottom, elliptical inlet top curve and curved section for the side inlet walls.
- Crest level of the intake has been proposed at El 525.30 m which satisfies the limiting velocity through trash-rack corresponding to discharge of 134.50 cumec passing at MDDL 536.0m.
- The center line of intake has been decided based on the submergence criteria. The minimum submergence requirements are as per Cl. 5.2.2 of IS 9761: 1995 and design guidance provided by Gordon has been followed.
- According to the Cl. 2.3.2 of IS 9761: 1995, upper intake structure falls in the category of high head type intake (above 30m). Since the upper intake structure is situated within the man-made artificial reservoir which is not directly connected with the main river stream, therefore, chances of clogging of the trashrack structure are unlikely to happen. Furthermore, as per the Cl.6.2 of IS 11388 (1995), velocity up to 3 m/sec on the gross area of racks may be permitted where serious clogging of trash racks is not expected for high pressure intakes. Hence, being conservative, width of trashrack bay has been fixed considering 20% of the trashrack area being clogged.

Table 9-3: Hydraulic Design of Upper Intake Structure

Submergence Design check: Assessment of intake invert			
			UR
Full reservoir Level	F.R.L.	=	566.00m
Minimum draw down Level	M.D.D.L.	=	536.00m

Submergence Design check: Assessment of intake invert			
			UR
Invert of Intake at invert		=	520.00m
C/L of Intake		=	522.65m
Design Discharge	Q	=	273.00 m^3/sec
No of Intake Tunnel		=	2.00 nos
Discharge through Intake		=	136.50 m^3/sec
Shape of Opening		=	Square
Diameter of opening leading to connected tunnel	D	=	5.30 m
Area of Opening	A	=	28.09 m^2
Velocity	v	=	4.86 m/sec
Provisions: IS 9761:1995			
Required Depth of Submergence			
Froude No, $F = V/(gD)^{0.5}$	F	=	0.67
Applicable formula for submergence based on "F"		=	D*(0.5+2*F)
Min distance between C/L and MDDL		=	9.79m
Provided Depth of Submergence			
Actual distance between C/L and MDDL		=	13.35m
Check for submergence			
Depth of submergence		=	ok
Recommended invert of the Intake			
Invert of Intake		=	no change
Provisions: Gordon's Formula			
Required Gordon Depth of Submergence			
Submergence over Intake overt		=	8.17m
Required Gordon Depth of Submergence		=	10.82m
Provided Depth of Submergence			
Actual distance between C/L and MDDL		=	13.35m
Check for submergence			
Depth of submergence		=	ok
Recommended invert of the Intake			
Intake invert		=	no change
Intake invert to be considered		=	**520.00 m**
Trash-rack Design			
			UR
Invert of trash rack			525.30m
Discharge			136.50 m^3/sec
MDDL			
Height of the trash rack w.r.t. MDDL & invert	H_M	=	10.70m
Angle of inclination with the vertical		=	10.00 degree
Effective height of trash rack		=	10.87m
% of open area in trash rack		=	70.00%

Submergence Design check: Assessment of intake invert			
			UR
% without Clogging		=	80.00%
Effective open height of trash rack		=	6.08m
Flushing discharge		=	0%
Net discharge		=	136.50 m^3/sec
Desired velocity		=	1.50 m/sec
Minimum Width of the trashrack		=	14.96 m
Net area		=	91.02 m^2
Velocity		=	1.50 m/sec
FRL			
Height of the trash rack w.r.t. FRL & invert	H_F	=	40.70m
Angle of inclination with the vertical		=	10.00 degree
Effective height of trash rack		=	41.33m
% of open area in trash rack		=	70.00%
% without Clogging		=	80.00%
Effective open height of trash rack		=	23.14m
Flushing discharge		=	0%
Net discharge		=	136.50 m^3/sec
Desired velocity		=	1.50 m/sec
Minimum Width of the trashrack		=	3.94 m
Net area		=	91.19 m^2
Velocity		=	1.50 m/sec
Width to be considered for trash rack		=	**14.96 m**
Clear Width provided for trashrack			**15.00 m**

9.4 PRESSURE SHAFT

5.30 m diameter, 903.20m long twin pressure shaft emanates from upper intake at El 522.15.0m which bifurcates at El. 118.50m into four branch penstock of 3.75m diameter (78.70m long) leading to unit bay. The shaft is proposed to be steel lined all along its length. The space between the liner and the excavated surface of the shaft will be backfilled with concrete. Actual support system will be decided after geological investigations and analysis at DPR stage.

9.4.1 ECONOMIC DIAMETER OF THE PRESSURE SHAFT

The economic diameter of pressure shaft is calculated based on empirical formulae as described in Para 6 of BIS code 11625:1986. The economic diameter of pressure shaft worked out as 5.30 m.

Table 9-4: Economic diameter of Pressure Shaft

Economical Diameter of Pressure Shaft

1. Economical diameter of the pressure shaft is calculated to ensure that the annual cost, which includes the cost of power lost due to friction, the annual depreciation and the annual cost of maintenance, is minimum. Mathematically, the economical diamet

$$D^{22/3} = \frac{2.36 * 10^6 * Q^3 * n^2 * e * p_f * C_p}{\left[1.39 * C_s + 0.6 * C_c + \frac{121 * H * C_s * (1+i)}{\sigma * e_j}\right] * p}$$

Q	Equivalent Discharge Q (m^3/sec)	136.50
	Net Head h (m)	371.00
	water hammer	35.00
H	Design Head H (m) including water hammer effect	500.85
L	Length of Pressure shaft (m)	1000.00
e	Overall Efficiency of Plant	0.906
n	Rugosity coefficient in Manning's formula	0.010
σ	Allowable Stress in Steel (kg/cm^2)	**1866.00**
σ	Allowable Stress in Steel (Mpa)	**183.00**
	Duration of Operation in a Year (hrs)	2190.00
p_f	Annual Load Factor p_f	0.90
C_p	Cost of 1 kWh of energy in Rupees	4.50
C_s	Cost of Steel (Rs/kg)	135.00
p	Ratio of Annual Charge to Construction Cost p	0.170
e_j	Joints Efficiency of Penstock	0.90
i	Percentage by which steel in penstock is overweight due to provision of stiffeners, corrosion allowance etc.	0.10
C_e	Unit cost of excavation in Rupees/m^3	2900.00
C_c	Unit cost of concrete lining in Rupees/m^3	6600.00
	Economical Dia.D (m) IS Code's Formula (IS:11625-1986)	**5.307**
	Say	**5.30**

Longitudinal section through water conductor system between upper reservoir to lower reservoir has been shown in ***Drawing Volume III, drawing number 7061601-FSR-1002.***

9.4.2 WATER HAMMER

The magnitude of the water hammer pressure depends upon the material and elastic properties of the penstock and time for closure of emergency valve or gate. According to Cl.5.6 of IS 12837 (1989), maximum limited pressure rise for Francis turbine is in within the range of 30 – 35%. In the present study, pressure rise due to water hammer is considered as 35 %. Preliminary transient analysis has been carried out to estimate the actual pressure rise due to water hammer condition and to assess the requirement of a surge tank in the water conductor system.

9.5 CHECK FOR REQUIREMENT OF U/S & D/S SURGE SHAFT

A surge tank is provided at the water conductor system (WCS) to reduce the pressure surges created due to water hammer and to limit their further transmission to WCS. The surge tank would also assist in improving the regulation and to provide water supply to turbines in case of sudden startup of a machine.

Upstream Surge Shaft

The following criteria are usually adopted to determine whether a surge tank is required in a given hydraulic system:

(a) According to a rule of thumb, a surge tank is usually necessary if L/H is equal to or more than 5; 'L' being length of HRT and 'H' the net head.

In the case of Somasila PSP,

Table 9-5: L/H Ratio

Length of WCS (pressure shaft), L	982	m	
Net Head, H	371	m	
Ratio of L/H	2.65	<	5

As seen from the above, u/s surge shaft clearly not required.

(b) Another criterion pertains to the acceleration time of the hydraulic system. The acceleration time of a hydraulic system is given by the equation:

$$Ta = \frac{L\,x\,V}{g\,x\,H}$$

Where, L = Length of water conductor

V = velocity of flow in water conductor

H = Net head

g = Acceleration due to gravity

If the acceleration time of a hydraulic system is less than 2 seconds, no surge tank is required in the hydraulic system. For acceleration time between 2 and 5 seconds, surge tank may be provided for a stable operation of the system. For acceleration time greater than 5 sec, a surge tank is almost always required.

Table 9-6: Calculation for Ta

Length of WCS (pressure shaft), L	982	m	
Diameter of Pressure Shaft	5.3	m	
Design Discharge	136.50	Cumec	
Velocity	6.19	m/sec	
Net Head, H	371	m	
Ta	1.67	<	5

As seen from the above, u/s surge shaft not required.

Downstream / Tailrace Surge Shaft

According to the Journal ***"A new setting criterion of tailrace surge chambers for pumped-storage power plants"*** published in Renewable Energy, requirement of tailrace surge shaft has been checked and shown below:

Table 9-7: Calculation for Tail race Surge Shaft

CALCULATIONS FOR TAILRACE SURGE SHAFT		
Diameter of Head Race Tunnel, D	5.30	m
Length of Head Race Tunnel, L	982	m
Maximum Discharge through HRT, Qo	136.50	m^3/s
Minimum net Head on Turbines, Ho	371.00	m
X-Area of Head Race Tunnel, A_t	22.05	m^2
Velocity in Head Race Tunnel, V_1	6.19	m/s
Total Head Loss	7.000	m

Penstock	22.05	982	6.19	6078.87
Unit TRT	15.90	114.63	4.29	491.91
TRT	31.17	575.65	4.38	2520.69
Σ			**14.86**	**9091.47**
Hnet =	371.00			

Ts 10 sec

Critical length of Tailrace system (CLTS) [Lw]= $(2-\sigma)K(8-\frac{\nabla}{900}-Hs)(\frac{g*Ts}{(2+Ks)Vwo})$ = 831.7 m

σ= ∑LV/(gHoTs) = 0.249799

K (0.6-0.7)= 0.6

∇= 118.5

Ks= Hloss/Ho = 0.018868

Hs= Draft Head= -63.5 51.5
FRL MDDL

Lw= 690.28 m

Lw>[Lw] Tailrace Surge tank required
Lw<[Lw] Tailrace Surge tank not required

In this case, 690.28 < 831.70

Hence, Tailrace Surge Shaft Not required.

9.5.1 NUMERICAL TRANSIENT ANALYSIS IN HAMMER SOFTWARE

Transient analysis has been carried out to check the requirement of U/S & D/S surge shaft for both generation mode & pumping mode condition. According to the analysis result, it has been observed that the HGL profile is above the water conductor system which indicates that there are no negative pressures in the pressure shaft & TRT and therefore U/S and D/S Surge shaft is not required.

9.5.2 GENERATION MODE

9.5.2.1 HGL FOR LOAD ACCEPTANCE

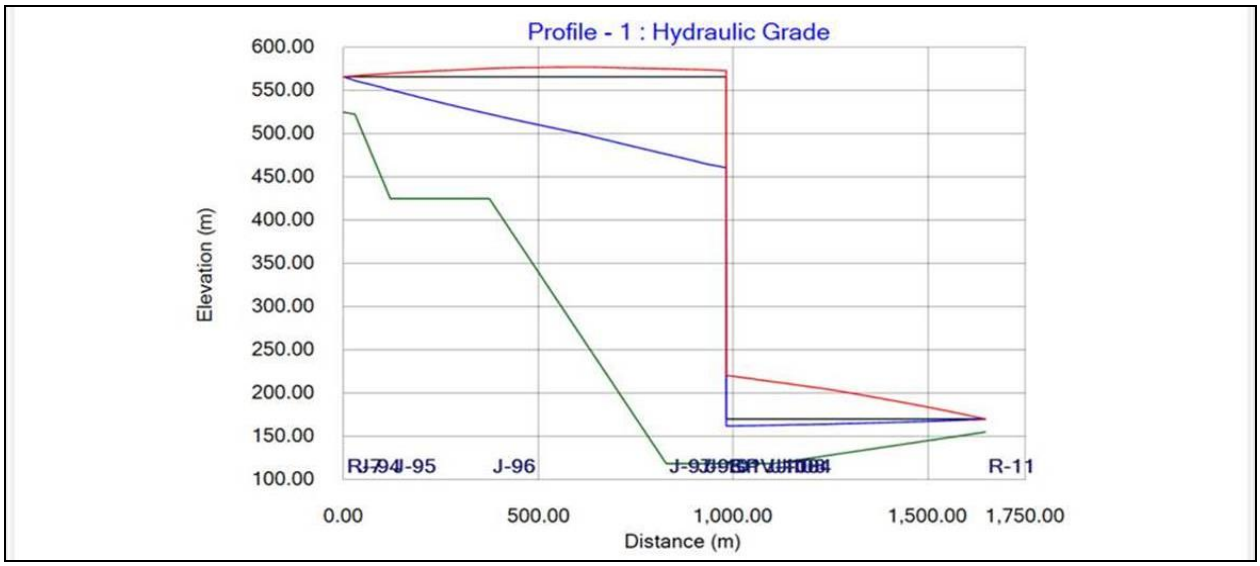


Figure 9-2: HGL for Load Acceptance

9.5.2.2 HGL FOR LOAD REJECTION

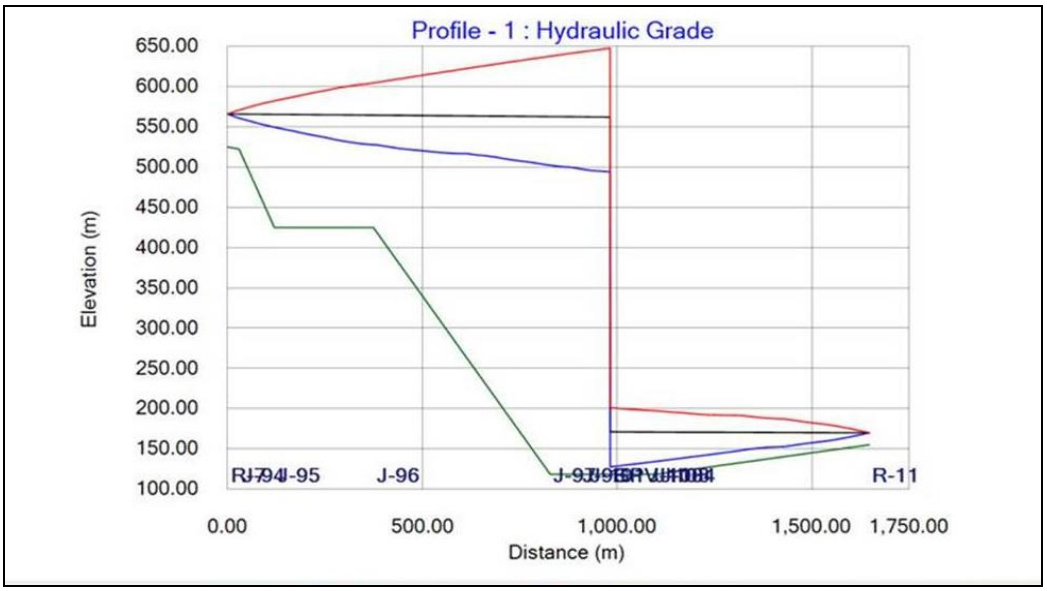


Figure 9-3: HGL for Load Rejection

9.5.3 PUMPING MODE

9.5.3.1 HGL FOR PUMP START-UP

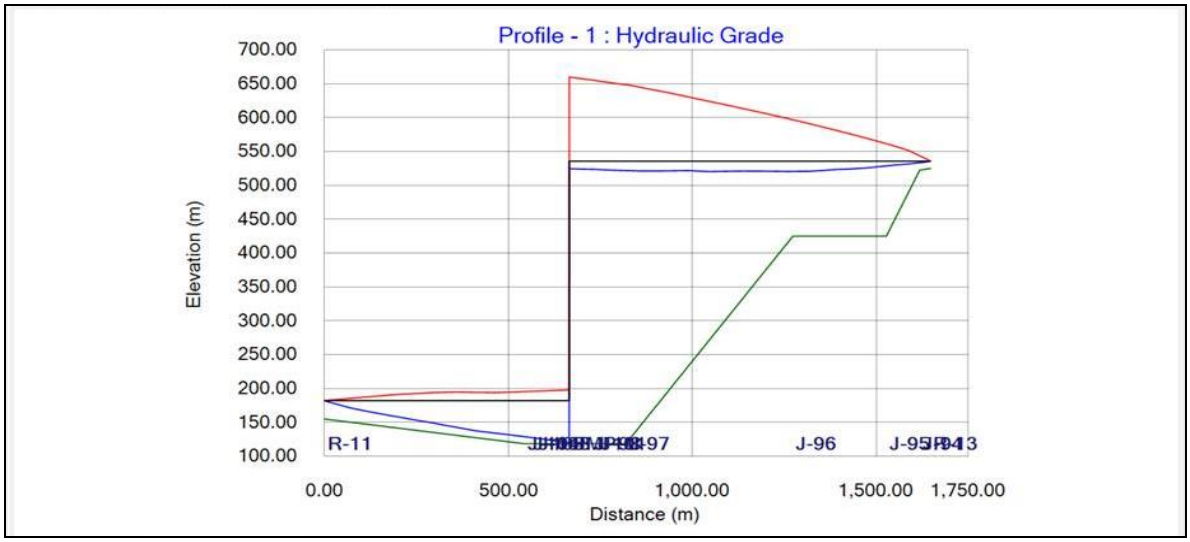


Figure 9-4: HGL for Pump Start Up

9.6 DESIGN OF STEEL LINER THICKNESS CALCULATION

9.6.1 DESIGN LOADS

The following loads are considered in the design.

9.6.1.1 INTERNAL WATER PRESSURE

Under working condition, the steel liner is subjected to internal water pressure corresponding to pressure rise due to water hammer measured above static water level in reservoir and it varies uniformly along penstock from maximum at turbine end to zero at reservoir level as elaborated under clause 5.1.4 of IS: 11639(Part-2):1995.

9.6.1.2 EXTERNAL WATER PRESSURE

The steel liner of the pressure shaft will be subjected to external water pressure by the surrounding ground water when pressure shaft is dewatered. As per IS 11639 (Part 2), external pressure due to ground water may be taken as the pressure exerted by a water column having a height equal to the vertical rock cover above the liner. In other words, the code postulates that the ground water surface follows the natural surface profile. For the design of the liner, stability against buckling due to external pressure is verified for the height of the water column which is assumed to be equal to the height of rock above the liner.

9.6.2 MATERIAL AND DESIGN STRESSES

9.6.2.1 MATERIAL

The pressure shaft and four unit penstocks are proposed to be fabricated using pressure vessel (boiler) quality steel plates. The following factors influence the selection of a particular grade of steel for pressure shaft lining:

- Cost of material
- Mechanical properties of steel plates for various thickness

- Ease of fabrication, erection and its related costs
- Ductility, notch roughness, welding compatibility with other steel grades etc.

For pressure shafts, high strength quenched and tempered alloy steel plates are commonly used. Among the various types of such steels, plates conforming to ASTM A537, Class II and ASTM A517, Grade F, fall in this category and are proposed to be used at Somasila PSP.

Table 9-8: Yield Strength and Ultimate Tensile Strength of Various Steels Grade

Material	Yield Strength, f_y (MPa)	Ultimate Tensile Strength, f_u (MPa)
ASTM A 517, Grade F	690	795
ASTM A537, Class-2	415	550

9.6.2.2 DESIGN STRESSES

As per IS: 11639 (Part 2), allowable stresses for embedded shafts/penstocks shall be taken as:

- In normal operating condition, the design stresses should not exceed 1/3 of the minimum ultimate tensile strength or 60% of minimum yield strength, whichever is less.
- In intermittent condition, the design stresses should not exceed 40% of the minimum ultimate tensile strength or 2/3 of minimum yield strength, whichever is less.
- In emergency condition, the design stresses should not exceed 2/3 of the minimum ultimate tensile strength or 90% of minimum yield strength, whichever is less.
- In exceptional condition, the design stresses should not exceed the minimum yield strength.

9.6.3 DESIGN OF STEEL LINER

9.6.3.1 MINIMUM THICKNESS

The minimum plate thickness is the minimum thickness required to provide rigidity for handling during fabrication and transportation. The minimum thickness "t_0"is given by

$$t_0 = \frac{R + 0.25}{200}$$

Where, R is the radius of pressure shaft in meters.

In the present case, the minimum thickness comes out to be about 14.50mm for shaft radius of 2.65m.

9.6.3.2 CORROSION ALLOWANCE

As per IS: 11639 (Part 2), a corrosion allowance of 1.5 mm should be added to the plate thickness computed on the basis of strength requirement.

9.6.3.3 DESIGN FOR INTERNAL PRESSURE

In a circular pressure shaft, minimum plate thickness required to resist the design internal pressure is calculated using the principle for hoop stress. Using this principle, the plate thickness t (mm), required to resist internal pressure p (MPa), acting inside a circular steel shaft of diameter D (mm), is given by

$$t = \frac{pD}{2\sigma}$$

Where,

σ = Allowable stress (MPa) in steel.

Alternatively, for a given plate thickness, t (mm), the permissible internal pressure in meters of water head, H, would be

H = 2000 σ t/ (9.81D)

Where t and D are expressed in mm and σ is in MPa.

The permissible internal pressure head in the normal load condition for various plate thicknesses were worked out.

9.6.3.4 DESIGN FOR EXTERNAL PRESSURE

Failure of steel liner due to external water pressure occurs by buckling which forms mostly a single lobe parallel to the axis of the shaft. Analytical methods have been developed by Jacobson, Amstutz and Vaughan for determination of critical buckling pressures for cylindrical steel liners without stiffeners. Amstutz method gives the minimum critical buckling pressure among all three methods. IS 11639 (Part 2) also recommends Amstutz and Vaughan methods; hence the buckling resistance of the pressure shaft liner has been calculated by Amstutz's method.

9.6.4 WEIGHT OF STEEL LINER

Based on above design philosophy the weights of steel liner have been worked out. Details of steel liner thickness calculation are given in **Annexure 9.3 of Volume - II**.

9.7 POWER HOUSE AND TRANSFORMER CAVERN

The overall dimensions of the underground powerhouse are 147 m long x 23 m wide x 52 m high. This includes a 32 m long service bay and 25 m long control block both located longitudinally at the opposite ends of the Powerhouse.

Isolated phase bus ducts will emanate from the generator terminals and will provide connection between each generator and its corresponding 3 nos., single phase, transformers.

Underground Transformer Cavern size: 160.0 m x 21.5 m x 29.5 m The Transformer cavern will also house the following:-

i. Bank of 3 No. Single phase generator Transformer of capacity each of 98 MVA, 24kV/400 kV for each unit is proposed and totally 13(12+1 number spare) transformer is to be installed in transformer cavern.

ii. Draft tube gates of all units

iii. Cable ducts and 4 Nos. interconnected bus duct tunnels between power house and transformer cavern.

A 400 kV GIS building will be constructed above transformer hall cavern at a suitable location accommodating the 400 kV Gas Insulated Switchgear.

Table 9-9: Features

S. No.	Description	Value
i.	Installed Capacity of Plant	900 MW
ii.	Number of Units	4 Units
iii.	Capacity of each unit	225 MW
iv.	Continuous Overload	10%
v.	Type of Power House	Pump storage Hydro Plant Underground
vi.	Gross Head	
	Max. Gross Head	396.0 m
	Min. Gross Head	354.0 m
	Rated gross head	378.0 m
vii.	Head Loss	7.0 m
viii.	Generating Mode	
	Max Net Head	389.0m
	Min Net Head	347.0 m
	Rated Net Head	371.0 m
ix.	Design Head	375.0 m
	Pumping Mode	
	Max Net Head	403.0 m
	Min Net Head	361.0 m
x.	Rated Net Head	385.0 m
	Design Head	389.0 m
	Total Design Discharge	For 4 Units
xi.	Generating Mode	273.0 m^3/s
xii.	Pumping Mode	218.3 m^3/s
xiii.	Centre line of generating	EL 118.5 m

S. No.	Description	Value
	unit	
xiv.	Turbine Type	Francis, Vertical Shaft
xv.	Generator Type	Vertical shaft, Synchronous generator, Suspended type
xvi.	Turbine Efficiency (Generation)	92%
xvii.	Turbine Efficiency (Pumping)	93%
xviii.	Generator Efficiency	98.5%
xix.	Synchronous Speed	375rpm
xx.	Generator Voltage	24 kV
xxi.	Transmission Voltage	400 kV
xxii.	Generator Step up Transformer	98 MVA, 1 Phase, 24 kV/400 kV
xxiii.	Switchyard	400kV GIS + 400kV Pothead Yard
xxiv.	Service Bay Level	EL 134.00 m

9.8 TAIL RACE TUNNEL

Four numbers horizontal unit tail race tunnel of 4.50m diameter, 114.63 m long off takes from the downstream wall of machine hall and run parallel till they merged with the twin main tailrace tunnel of 6.30m diameter & 575.65m long. TRT will be provided with suitable rock support system depending upon the geological strata. Actual support system will be decided after geological investigations and analysis at DPR stage.

9.9 LOWER INTAKE

The tail water from the machines, is led back to the lower reservoir through a tailrace tunnel during Turbine mode and divert the discharge to main Tailrace tunnel during Pumping mode. Crest of Lower intake placed at elevation of EL 159.30m. The invert of main tailrace tunnel is kept at EL. 155.0m considering sufficient submergence depth with respect to MDDL of lower reservoir. Similar hydraulic design criteria has been followed as described in the paragraph 9.3. For details of lower Intake, please refer ***Drawing Volume III, drawing number 7061601-FSR-1015***.

Table 9-10: Hydraulic Design of Lower Intake

Submergence Design check: Assessment of intake invert			
			LR
Full reservoir Level	F.RL.	=	182.00m

Submergence Design check: Assessment of intake invert			
			LR
Minimum draw down Level	M.D.D.L.	=	170.00m
Invert of Intake at invert		=	155.00m
C/L of Intake		=	158.15m
Design Discharge	Q	=	273.00m^3/sec
No of Intake Tunnel		=	2.00 nos
Discharge through Intake		=	136.50m^3/sec
Shape of Opening		=	Square
Diameter of opening leading to connected tunnel	D	=	6.30m
Area of Opening	A	=	39.69m^2
Velocity	v	=	3.44m/sec
Provisions: IS 9761:1995			
Required Depth of Submergence			
Froude No, F = $V/(gD)^{0.5}$	F	=	0.44
Applicable formula for submergence based on "F"		=	D*(0.5+2*F)
Min distance between C/L and MDDL		=	8.66m
Provided Depth of Submergence			
Actual distance between C/L and MDDL		=	11.85m
Check for submergence			
Depth of submergence		=	ok
Recommended invert of the Intake			
Invert of Intake		=	no change
Provisions: Gordon's Formula			
Required Gordon Depth of Submergence			
Submergence over Intake overt		=	6.30m
Required Gordon Depth of Submergence		=	9.45m
Provided Depth of Submergence			
Actual distance between C/L and MDDL		=	11.85m
Check for submergence			
Depth of submergence		=	ok
Recommended invert of the Intake			
Intake invert		=	no change
Intake invert to be considered		=	**155.00 m**

Trash-rack Design			
			LR
Invert of trash rack			159.30m
Discharge			136.50m^3/sec
MDDL			
Height of the trash rack w.r.t. MDDL & invert	H_M	=	10.70m
Angle of inclination with the vertical		=	10.00 degree
Effective height of trash rack		=	10.87m
% of open area in trash rack		=	70.00%
% without Clogging		=	80.00%
Effective open height of trash rack		=	6.08 m

Submergence Design check: Assessment of intake invert			
			LR
Flushing discharge		=	0%
Net discharge		=	136.50m^3/sec
Desired velocity		=	1.50 m/sec
Minimum Width of the trashrack		=	14.96 m
Net area		=	91.02 m^2
Velocity		=	1.50 m/sec
FRL			
Height of the trash rack w.r.t. FRL & invert	H_F	=	22.70m
Angle of inclination with the vertical		=	10.00 degree
Effective height of trash rack		=	23.05m
% of open area in trash rack		=	70.00%
% without Clogging		=	80.00%
Effective open height of trash rack		=	12.91m
Flushing discharge		=	0%
Net discharge		=	136.50m^3/sec
Desired velocity		=	1.50 m/sec
Minimum Width of the trashrack		=	7.05 m
Net area		=	91.00 m^2
Velocity		=	1.50 m/sec
Width to be considered for trash rack		=	**15.00 m**
Clear Width provided for trashrack			**15.00 m**

9.10 LOWER RESERVOIR

The lower reservoir for the scheme is proposed at the foot of the hill in an identified natural depression having suitable potential to create an artificial reservoir by minor excavation & providing a concrete gravity dam only one side of the depression area for creating the reservoir.

The lower reservoir area is densely vegetated. Signs of any dormant or active landslide are conspicuous by their absence. The reservoir rim runs along vegetated and stable slopes. Any major concern with respect to the reservoir rim stability, therefore, is not apprehended. The proposed dam is located over a bed of quartzite and the foundation for the dam in rock is expected to be available at a reasonable depth. For ensuring water tightness of the reservoir along bedding, grouting may be proposed where necessary. Detailed surface and sub-surface investigations will be carried out at DPR stage and appropriate design measures will be taken based on investigations.

The maximum height of concrete gravity Dam is around 33.50m. The location of lower reservoir is on the left bank at geographical co-ordinates 14°39'14.09"N and 79°10'34.25"E in NE direction of existing Somasila Reservoir. The total storage capacity of lower reservoir is 8.329 MCM whereas the live storage capacity is 6.382 MCM. FRL & MDDL of the lower reservoir are 182.0m and 170.0m respectively whereas top & bottom of upper reservoir fixed as 184.0m & 168.0m respectively.

Stability analysis of gravity dam at lower reservoir area has been carried out for the following load combinations:

1. **Load Condition A** - (construction condition) - Dam Completed but no water in reservoir
2. **Load Condition B** - (Normal Operating condition) -Full reservoir elevation, normal uplift (drains inoperative)
3. **Load Condition C** - Load Combination A with Earthquake
4. **Load Condition D** - Load Combination B with Earthquake

Table 9-11: Summary of Stability Analysis of Concrete Gravity Dam (33.5m high)

Description	F.O.S against Sliding	F.O.S against Overturning	Base Pressure (kN/m^2)	
			Toe	Heel
Load Condition A - (construction condition) - Dam Completed but no water in reservoir	N/A	N/A	118.87	648.54
Load Condition B - (Normal Operating condition) -Full reservoir elevation, normal uplift (drains inoperative)	5.53	1.69	403.47	87.19
Load Condition C - Load Combination A with Earthquake	13.43	13.01	166.34	570.37
Load Condition D - Load Combination B with Earthquake	4.44	1.40	515.73	-55.76

For detail stability calculation of Gravity Dam, please refer **Annexure 9.4 of Volume - II**.

9.11 INITIAL PUMPING ARRANGEMENT FROM EXISTING SOMASILA RESERVOIR

The lower reservoir is proposed to be filled by initial pumping arrangement from the existing Somasila reservoir by means of a jack well cum pump house structure via D.I (ductile iron) pipeline from pump house to lower reservoir. The FRL & MDDL of existing Somasila reservoir are 100.56m and 82.3m respectively. The gross & live storage capacity of existing Somasila reservoir are 2208.374 MCM & 1994 MCM whereas the total capacity of lower reservoir is around 8.329 MCM. Therefore, proposed utilization of water corresponding to the required storage of lower reservoir to the live storage of existing Somasila reservoir is only 0.42% which is on very lower side and does not have any significant impact on existing Somasila reservoir. Furthermore, this initial pumping operation will be carried out during monsoon season

when the existing Somasila reservoir will be at FRL and have enough surplus water to supply to the lower reservoir.

The pump operating floor level of Jack well pump house is proposed at EL. 102.56m. The length of ductile iron pipe line from jack well pump house to lower reservoir is around 14.7kM whereas the diameter of D.I pipe has been kept as 1.2m from economic analysis consideration. It is estimated that pump will be operated for 16 hours in a day and total design head required to be generated by pump is about 125.56m including head losses in the pipe line. As per the initial assessment, to fill the lower reservoir completely (total capacity 8.329 MCM), it will take about 2 month time. Details calculation are given in **Annexure 9.5 of Volume - II**.

9.12 HYDRO-MECHANICAL DESIGN

9.12.1 TRASHRACKS, GATE AND HOISTS

9.12.1.1 SCOPE

For satisfactory performance of the project as per stipulated requirements, a well-planned, reliable and efficient arrangement of hydro-mechanical equipment is essential. The outline of the various hydro-mechanical controls has been worked out at FSR stage within the selected parameters of the project. Following hydro-mechanical equipment consisting of various types of gate, hoists, etc. have been envisaged for Somasila Pumped Storage Hydroelectric Power Project which utilizes the available head between the proposed upper reservoir and Lower Reservoir.

9.12.1.2 INTAKE TRASH RACKS - UPPER RESERVOIR (3.75M X 2.5M – 8 SETS /17 PANNELS)

The trash racks shall be required to be installed in the trash rack grooves of Intake structure U/S of Emergency gate groove to prevent entry of extraneous material into the water conductor system. These shall be of fabricated steel construction consisting of trash flats supported on horizontal girders, which in turn shall be supported on end channels/members to bear against the downstream face of slots. Trash racks for two Intake tunnels shall be split into eight openings and each opening consists of 17 panels of 3.75 m width and 2.5 m height. The trash rack sill is kept at El. 525.3 m and shall be provided up to the top of intake for cleaning with trash cleaning machine. For easy handling trash rack shall be divided into number of panels of equal height. The size of panel shall be 3.75 m x 2.5 m (W x H) and as such there shall be 136 panels in total for the intake openings. The panels shall be interchangeable and each unit shall have two lifting points. The trash racks panels shall be handled by any winch/ crane available at the project using an automatic lifting beam capable of grappling/un-grappling automatically under water. The lifting beam shall also travel in the same groove as the trash racks. The trash rack shall be designed for differential head of 6.0 to 7.0m in accordance with the provision made in IS: 11388:1995. The velocity through the racks shall be restricted to1.5 m/second.

Cleaning of trash racks shall be done by trash rack cleaning machine. Each trash rack panels shall be inclined at 10 degrees with the vertical to facilitate cleaning of

the Trashracks mechanically. The alignment of all trash racks will be kept in an arc line and one single unit of trash rack cleaning machine shall be used for all the units.

Table 9-12:Technical data as per IS: 11388:1995

No. of Intake Tunnels/Bays	2 Nos.
No of Opening in each bay	4 Nos.
No of Trash Rack panels per Opening	17 Nos.
Total no. of Trash rack panels	136 Nos.
Trash Rack Panel Size	3.75 m x 2.5 m
FRL	El. 566.00m
Sill Level	El. 525.30 m
Design Head	6.0m and 7.0m Differential Head for bars and supporting members respectively.
Lifting Height	42.7 m (Deck level – Sill Level)

Trash racks panel shall be cleaned with the help of a trash cleaning machine (TRCM) which shall also have log grappling attachment for removing the trees. The machine shall be hydraulically operated.

9.12.1.3 TRASH RACK CLEANING MACHINE (TRCM)

This Automatic Trash Rack Cleaning Machine shall be provided at the top of intake structure at EL 568.00m. This machine shall be provided with wheel type bucket for proper travelling on the Trash Rack support channel. Side Guide rollers shall be provided on this bucket for its proper alignment on the Trash Rack support channels. The bucket shall be raised/ lowered by an electric hoist. This machine shall also be provided with the hydraulic system for the purpose of tilting during it's unloading. The TRCM shall be provided with wheel and rail for its movement on the intake structure so as to cover all the Trash rack bays for cleaning of the trash accumulated in front of Trash Racks and for removing debris/logs along the intake structure. Longitudinal motion shall be performed with the help of an electric motor provided on this machine. The TRCM shall be out door travelling type machine. The hoist and longitudinal motors shall be of suitable capacity totally enclosed fan cooled, squirrel cage type design to suit 3 phases 415/440V AC, 50 Hz conforming to IS-325:1996. The TRCM shall also be provided with a 5 T capacity log grappling mounted on a hydraulic log boom.

9.12.1.4 INTAKE EMERGENCY (MAINTENANCE) GATE: (5.3 M X 5.3 M – 2 NOS.) UPPER RESERVOIR

At the inlet of water conductor system, one no. fixed wheel type service gate and one number emergency gate is proposed. The emergency gate would be at upstream of

the service gate after the Bell mouth entry of tunnel. The size of the opening, where gate is to be installed shall be 5.3 m x 5.3 m.

The gate shall be lifted in balanced head conditions. This gate is provided with individual rope drum hoist and designed as fixed wheel type gate having upstream skin plate and upstream sealing. The sill level of gate is kept at EL. 520.00m and the gate is to be designed for a head of 46 m corresponding to FRL El. 566.0m

The gate shall be operating with the help of electrically operated rope drum hoist of adequate capacity. The Gate shall be designed as per IS: 4622:2003.

Table 9-13:Technical data as per IS: 4622:2003

No of Intake Tunnel	2 No.
No of Emergency gate	2 No.
Clear Width of Opening	5.3 m
Clear Height Of Opening	5.3 m
F.R.L	El. 566 m
Sill Level	El. 520 m
Design Head	46.0m
Type of Sealing arrangement and seals.	Upstream Sealing: Music Note Type Teflon Cladded Rubber Seal IS: 11855
Operating Condition	Under balanced head condition.
Lifting Speed	0.5 m/min
Lowering Speed	0.5 m/min
Type of Hoist	Fixed Rope Drum provided on regulating platform and Trestles.
Lifting Height	48 m (Deck level – Sill Level)

9.12.1.5 INTAKE SERVICE GATE: (5.3 M X 5.3 M – 1NO.) UPPER RESERVOIR

For the inspection and maintenance of water conductor system, one number fixed wheel type service gate of size 5.3 m x 5.3 m with downstream skin plate and sealing, shall be provided at the downstream of the emergency gate. This gate shall be designed to withstand full static head corresponding to FRL El. 566.00m water level. The lifting of gate shall be under unbalanced head conditions with the help of individual Electrically Operated Rope Drum Hoists of adequate capacity. The gate shall be self closing under its own weight under water flowing conditions.

This gate is provided with individual rope drum hoist and designed as fixed wheel type gate. The sill level of gate is kept at EL. 520.00 m and the gate is to be designed for a head of 46.0 m corresponding to FRL El. 566.0m

Table 9-14:Technical data as per IS: 4622:2003

No of Intake Tunnel	2 No.
No of Service gate	2 No.
Clear Width of Opening	5.3 m
Clear Height Of Opening	5.3 m
F.R.L	El. 566 m
Sill Level	El. 520 m
Design Head	46.0m
Type of Sealing arrangement and seals.	Downstream Sealing: Music Note Type Teflon Cladded Rubber Seal IS: 11855
Operating Condition	Lifting: Unbalanced head condition. Lowering: Flowing water condition
Lifting Speed	0.5 m/min
Lowering Speed	0.5 m/min
Type of Hoist	Fixed Rope Drum provided on regulating platform and Trestles.
Lifting Height	48 m (Deck level – Sill Level)

9.12.1.6 INTAKE TRASH RACKS – LOWER RESERVOIR (3.75 M X 2.5 M – 8 SETS /10 PANNELS)

The trash racks shall be required to be installed in the trash rack grooves of Intake structure U/S of Emergency gate groove to prevent entry of extraneous material into the water conductor system. These shall be of fabricated steel construction consisting of trash flats supported on horizontal girders, which in turn shall be supported on end channels/members to bear against the downstream face of slots. Trash racks for two Intake tunnels shall be split into eight openings and each opening consists of 10 panels of 3.75 m width and 2.5 m height. The trash rack sill is kept at El. 159.3.00 m and shall be provided up to the top of intake for cleaning with trash cleaning machine. For easy handling trash rack shall be divided into number of panels of equal height. The size of panel shall be 3.75 m x 2.5 m (W x H) and as such there shall be 80 panels in total for the intake openings. The panels shall be interchangeable and each unit shall have two lifting points. The trash racks panels shall be handled by any winch/ crane available at the project using an automatic lifting beam capable of grappling/un-grappling automatically under water. The lifting beam shall also travel in the same groove as the trash racks. The trash rack shall be designed for differential head of 6.0 to 7.0m in accordance with the provision made in IS: 11388:1995. The velocity through the racks shall be restricted1.5 m/second.

Cleaning of trash racks shall be done by trash rack cleaning machine. Each trash rack panels shall be inclined at 10 degrees with the vertical to facilitate cleaning of

the Trashracks mechanically. The alignment of all trash racks will be kept in an arc line and one single unit of trash rack cleaning machine shall be used for all the units.

Table 9-15:Technical data as per IS: 11388:1995

No. of Intake Tunnels/Bays	2 Nos.
No of Opening in each bay	4 Nos.
No of Trash Rack panels per Opening	10 Nos.
Total no. of Trash rack panels	80 Nos.
Trash Rack Panel Size	3.75 m x 2.5 m
FRL	El. 182.00m
Sill Level	El. 159.30m
Design Head	6.0m and 7.0m Differential Head for bars and supporting members respectively.
Lifting Height	24.7 m (Deck level – Sill Level)

Trash racks panel shall be cleaned with the help of a trash cleaning machine (TRCM) which shall also have log grappling attachment for removing the trees. The machine shall be hydraulically operated.

9.12.1.7 TRASH RACK CLEANING MACHINE (TRCM)

This Automatic Trash Rack Cleaning Machine shall be provided at the top of intake structure at EL 184.00m. This machine shall be provided with wheel type bucket for proper travelling on the Trash Rack support channel. Side Guide rollers shall be provided on this bucket for its proper alignment on the Trash Rack support channels. The bucket shall be raised/ lowered by an electric hoist. This machine shall also be provided with the hydraulic system for the purpose of tilting during it's unloading. The TRCM shall be provided with wheel and rail for its movement on the intake structure so as to cover all the Trash rack bays for cleaning of the trash accumulated in front of Trash Racks and for removing debris/logs along the intake structure. Longitudinal motion shall be performed with the help of an electric motor provided on this machine. The TRCM shall be out door travelling type machine. The hoist and longitudinal motors shall be of suitable capacity totally enclosed fan cooled, squirrel cage type design to suit 3 phases 415/440V AC, 50 Hz conforming to IS-325:1996. The TRCM shall also be provided with a 5 T capacity log grappling mounted on a hydraulic log boom.

9.12.1.8 INTAKE EMERGENCY (MAINTENANCE) GATE : (6.3 M X 6.3 M – 2 NOS.) LOWER RESERVOIR

At the inlet of water conductor systems, one no. fixed wheel type service gate and one number emergency gate is proposed. The emergency gate would be at upstream of the service gate after the Bell mouth entry of tunnel. The size of the opening, where gate is to be installed shall be 6.3 m x 6.3 m.

The gate shall be lifted in balanced head conditions. This gate is provided with individual rope drum hoist and designed as fixed wheel type gate having upstream skin plate and upstream sealing. The sill level of gate is kept at EL. 155 m and the gate is to be designed for a head of 27 m corresponding to FRL El. 182.0m

The gate shall be operating with the help of electrically operated rope drum hoist of adequate capacity. The Gate shall be designed as per IS: 4622:2003.

Table 9-16:Technical data as per IS: 4622:2003

No of Intake Tunnel	2 No. (6.3 m diameter)
No of Emergency gate	2 No.
Clear Width of Opening	6.3 m
Clear Height Of Opening	6.3 m
F.R.L	El. 182 m
Sill Level	El. 155 m
Design Head	27 m
Type of Sealing arrangement and seals.	Upstream Sealing: Music Note Type Teflon Cladded Rubber Seal IS: 11855
Operating Condition	Under balanced head condition.
Lifting Speed	0.5 m/min
Lowering Speed	0.5 m/min
Type of Hoist	Fixed Rope Drum provided on regulating platform and Trestles.
Lifting Height	29 m (Deck level – Sill Level)

9.12.1.9 INTAKE SERVICE GATE : (6.3 M X 6.3 M – 2 NOS.) LOWER RESERVOIR

For the inspection and maintenance of water conductor system, one number fixed wheel type service gate of size 6.3 m x 6.3 m with downstream skin plate and sealing, shall be provided at the downstream of the emergency gate. This gate shall be designed to withstand full static head corresponding to FRL El. 182.00m water level. The lifting of gate shall be under unbalanced head conditions with the help of individual Electrically Operated Rope Drum Hoists of adequate capacity. The gate shall be self closing under its own weight under water flowing conditions.

This gate is provided with individual rope drum hoist and designed as fixed wheel type gate. The sill level of gate is kept at EL. 155 m and the gate is to be designed for a head of 27 m corresponding to FRL El. 182.0m

Table 9-17:Technical data as per IS: 4622:2003

No of Intake Tunnel	2 No. (6.3 m diameter)

No of Service gate	2 No.
Clear Width of Opening	6.3 m
Clear Height Of Opening	6.3 m
F.R.L	El. 182 m
Sill Level	El. 155 m
Design Head	27 m
Type of Sealing arrangement and seals.	Downstream Sealing: Music Note Type Teflon Cladded Rubber Seal IS: 11855
Operating Condition	Lifting: Unbalanced head condition. Lowering: Flowing water condition
Lifting Speed	0.5 m/min
Lowering Speed	0.5 m/min
Type of Hoist	Fixed Rope Drum provided on regulating platform and Trestles.
Lifting Height	29 m (Deck level – Sill Level)

9.12.1.10 DRAFT TUBE GATE :(4.5 M X 4.5 M – 4 NOS. FOR UNIT 1, 2, 3 & 4)

In order to carried out the maintenance of power house, 4 nos. of draft tube gate of size 4.5 m x 4.5 m are provided for Unit 1, 2, 3 & 4. These gates shall be provided with downstream skin plate and downstream sealing in accordance with IS: 11855 & 15466 considering flow from the TRT side/Lower Reservoir side.

The sill level of gate is kept at EL. 111.75 m and the gate is to be designed for a head of 70.25 m corresponding to Maximum tail water level El. 182.00m (Lower Reservoir FRL).

The gate shall be operated by means of bonnet type double acting hydraulic hoist of adequate capacity, located on the hoist platform at EL. 134 m.

Table 9-18:Technical data as per IS: 4622:2003

Number of Draft Tubes	4 Nos.
Number of gate	4 Nos.
Clear width of opening	4.5 m
Clear height of opening	4.5 m
Sill level of gate	El. 111.75 m
Maximum Tail Water level/Lower	El. 182.00 m

Reservoir FRL	
Deck Level	El. 134 m
Design Head	70.25 m
Type of Gate	Fixed Wheel Gate
Type of Sealing arrangement and seals.	Downstream Sealing: Music Note Type Teflon Cladded Rubber Seal IS: 11855
Operating Condition	Under Unbalanced head condition.
Lifting Speed	0. 5m/min
Lowering Speed	0.5m/min
Type of Hoist	Bonnet Type double acting Hydraulic Hoist
Lifting height	22.25 m (Deck Level – Sill Level)

ELECTRICAL & MECHANICAL DESIGNS

10 CHAPTER 10 - ELECTRO-MECHANICAL WORKS

10.1 GENERAL

The Somasila Pumped Storage scheme consists of upper and lower reservoirs connected with a water conductor system through an underground power house complex equipped with desired numbers of Generator-Motor and Pump-Turbine units. The Underground power house will have Four (04) nos. Pump-Turbine units of 225 MW each along with all the auxiliary system such as cooling water system, compressed air system, potable water supply system, fire protection system, ventilation and air conditioning system, illumination system, HT & LT AC and DC systems etc.

10.2 REFERENCE DRAWINGS

The following Drawings may be referred to as:

S.No	Title of Drawing
1	General Layout (Drawing no. 7061601-FSR-1001 of Volume – III)
2	Power House Longitudinal Section Through C – Line (Drawing no. 7061601-FSR-1020 of Volume – III)
3	Power House Cross Section along C/L of Turbine (Drawing no. 7061601-FSR-1021 of Volume – III)
4	PH Plan at Service Bay level (Drawing no. 7061601-FSR-1019 of Volume – III)
5	Main single Line Diagram (Drawing no. 7061601-FSR-1022 of Volume – III)

10.3 SALIENT FEATURES

The salient features of the Project are as shown in below table.

S.N.	Description	Value
i.	Full Reservoir Level (FRL) of Upper Reservoir	EL 566.0 m
ii.	Minimum Drawdown Level (MDDL) of Upper Reservoir	EL 536.0 m
iii.	Full Reservoir Level (FRL) of Lower Reservoir	EL 182.0 m
iv.	Minimum Drawdown Level	EL 170.0 m

S.N.	Description	Value
	(MDDL) of Lower Reservoir	
v.	Installed Capacity of Plant	900 MW
vi.	Number of Units	4 Units
vii.	Capacity of each unit	225 MW
viii.	Continuous Overload	10%
ix.	Type of Power House	Pump storage Hydro Plant Underground
x.	Gross Head	
	Max. Gross Head	396.0 m
	Min. Gross Head	354.0 m
	Rated gross head	378.0 m
xi.	Head Loss	7.0 m
xii.	Generating Mode	
	Max Net Head	389.0m
	Min Net Head	347.0 m
	Rated Net Head	371.0 m
	Design Head	375.0 m
xiii.	Pumping Mode	
	Max Net Head	403.0 m
	Min Net Head	361.0 m
	Rated Net Head	385.0 m
	Design Head	389.0 m
xiv.	Total Design Discharge	For 4 Units
	Generating Mode	273.0 m^3/s
	Pumping Mode	218.3 m^3/s

S.N.	Description	Value
xv.	Centre line of generating unit	EL 118.5 m
xvi.	Turbine Type	Francis, Vertical Shaft
xvii.	Generator Type	Vertical shaft, Synchronous generator, Suspended type
xviii.	Turbine Efficiency (Generation)	92%
xix.	Turbine Efficiency (Pumping)	93%
xx.	Generator Efficiency	98.5%
xxi.	Synchronous Speed	375 rpm
xxii.	Generator Voltage	24 kV
xxiii.	Transmission Voltage	400 kV
xxiv.	Generator Step up Transformer	98 MVA, 1 Phase, 24 kV/400 kV
xxv.	Switchyard	400kV GIS + 400kV Pothead Yard
xxvi.	Service Bay Level	EL 134.00 m
xxvii.	Elevation of Transformer Cavern	El 134.00 m
xxviii.	Elevation of GIS Hall	EL 146.50 m

10.4 LAYOUT

Power House and Transformer Cavern

The overall dimensions of the powerhouse are 147 m long x 23 m wide x 52 m high. This includes a 32 m long service bay and 25 m long control block both located longitudinally at the opposite ends of the Powerhouse.

Isolated phase bus ducts will emanate from the generator terminals and will provide connection between each generator and its corresponding 3 nos., single phase, transformers.

Transformer Cavern size: 160.0 m x 21.5 m x 29.5 m The Transformer cavern will also house the following:-

(i) Bank of 3 No. Single phase generator Transformer of capacity each of 98 MVA, 24KV/400 kV for each unit is proposed and totally 13(12+1 number spare) transformer is to be installed in transformer cavern.

(ii) Draft tube gates of all units

(iii) Cable ducts and 4 Nos. interconnected bus duct tunnels between power house and transformer cavern.

A 400 kV GIS building will be constructed above transformer hall cavern at a suitable location accommodating the 400 kV Gas Insulated Switchgear.

Dewatering Sump – Draft tubes will be connected with this sump through a network of valves & pipes.

Drainage Sump – Seepage and drainage from various floors of power house will be collected to this sump.

24 kV Isolated Phase Bus Ducts (IPBD) interconnecting machine hall Floor with the Transformer cavern will be laid in individual bus duct tunnel of respective units. LAVT cubicles, Station Service (Auxiliary) connections with IPB shall also be installed in these tunnels. Beside these Four Bus Duct Tunnels, two (02) tunnels (One at Service bay side and other on opposite side) will be provided for inter-connecting Machine Hall cavern with Transformer Hall. Please refer power house layouts.

One cable tunnel of adequate size will be provided to accommodate 400 kV XLPE cables for transmitting power between Pothead Yard and 400 kV GIS / 400 kV Switchyard.

The access to turbine pit will be from pump-turbine Floor. Necessary hatches for erection and removal of MIV will be provided at various floors in the machine hall cavern.

10.5 BALANCE OF PLANT

This section covers the mechanical /electrical balance of plant and control & monitoring system of the plant.

This section deals with the basic design aspects for the electrical and mechanical equipment. The criteria for dimensioning and the layout of the equipment are governed by the need for compatibility with modern practice and development in the field of underground pump storage power projects. Particular attention has to be paid the climatic conditions encountered at site, to the difficult accessibility of the site and to the transport weight limitation imposed by the road conditions and the capacity of the bridges.

Mechanical balance of Plant

Sl. No.	Item
1	Main Inlet Valve
2	Compressed air system
3	Cooling water system
4	Drainage and Dewatering system
5	EOT crane for power house
6	Air conditioning and ventilation system
7	Oil Handling and purification system
8	Mechanical workshop
9	Lift / Elevator System
10	Fire Protection System

Electrical Balance of Plant

Sl. No.	Item
1	Auxiliary Transformers
2	Emergency DG Set
3	SFC and LV and MV Switchgear
4	UPS / Inverter System
5	Protection System
6	DC System
7	Communication System,
8	Public Address System & Security & Surveillance System
9	Illumination System
10	Grounding System
11	Cables and accessories
12	Electrical Workshop Equipment
13	Control and Monitoring System

10.6 TURBINE

The Pump-turbine shall be of vertical shaft reversible Francis type coupled to Generator-Motor. 4 nos. of the Francis pump-turbine set each of 225 MW output rating while operating under rated head shall be installed.

The Pump-Turbine shall be designed to have output of 0 to 100% rated output at the head ranges and a stable pumping mode shall be obtainable within the design pump head specified above without pressure fluctuation and/or other faults. A design of highest efficiency for both turbine and pump shall be made.

The unit shall also be capable of operating in Synchronous Condenser mode. To facilitate the same, necessary water supply system for runner gaps shall be provided. The machine shall be capable of Line Charging operation including charging of one Transmission line during total grid failure, towards restoration of grid power.

10.7 GOVERNOR

It is proposed to provide digital PID type Electro-Hydraulic Governor for each unit to operate the units in pump and turbine modes. The governing system shall mainly consist of speed transducers, position transducers, microprocessor based governor unit, oil pumping unit etc as per system requirement.

10.8 INLET VALVES

Spherical valves of 2500mm each with each unit , operated by hydraulic pressure are proposed to be provided upstream of each turbine inlet for normal operations and also for isolating each unit in case of emergency / maintenance thus affording flexibility of operation of the power plant. The Valve shall be of double seal, self closing type complete with downstream cum expansion joint. The Valves shall be operated through pressure oil operated servomotor with provision of closing by means of counter weight through gravity in case of emergency.

10.9 DRAFT TUBE GATES

Individual hoisting mechanism shall be provided for draft tube gate of each unit for quick closing, under the unbalanced condition of water pressure.

10.10 GENERATOR & EXCITATION SYSTEM

Generator-Motor

The Generator-Motor will be three phase alternating current synchronous generator motor of rotating field, vertical shaft type. Each of the Generator-Motors shall have the following characteristics:

10.10.1 GENERATING MODE

Rated capacity	225.00 MW
Rated terminal voltage between phases	24 kV ± 10%

Frequency	50 Hz
Phase	3
Synchronous Speed	375 rpm
Range of frequency	50 Hz ± 3%
Over load capacity	247.5 MW (with 10%)
Power factor	0.85 lagging

10.10.2 PUMPING MODE

Motor capacity	247.50 MW
Power factor	0.95 leading
Rated terminal voltage between phases	24 kV ± 10%
Frequency	50 Hz
Phase	3
Synchronous Speed	375 rpm
Range of frequency	50 Hz ± 3%

10.11 EXCITATION SYSTEM

The excitation equipment shall be static type potential-source, rectifier-type excitation system completes with digital type Automatic Voltage Regulator (AVR). Static excitation system shall be used for generating, motoring and synchronous condenser operation in the generating and motoring direction, back-to-back synchronous starting operation and static frequency converter (SFC) starting for pumping.

The AVR will be capable of covering 80% to 110% of the rated voltage of the generator at no-load operation. It will also be suitable for synchronous condenser operation.

10.12 PHASE REVERSAL DISCONNECTING SWITCH

Rotational directions of pumping mode and generating mode of the unit are opposite. Therefore, a 24 kV Phase Reverse Disconnecting Switch Set of required current rating will be installed to change any 2 phases of 3 phases of main circuit in order to change the phase rotational direction at the generator-motor terminal to assure the desired direction of rotation for both generation mode and pumping mode.

10.13 GENERATOR CIRCUIT BREAKER

24 kV, Indoor type, metal-enclosed, SF6 circuit breaker will be installed between each Generator and respective Main Step-up Transformer for protection and

synchronization (for remote closing and remote tripping or automatic tripping due to fault)

10.14 PUMP STARTING DISCONNECTING SWITCH

For each unit, 24 kV Disconnecting Switch for pump-starting by SFC will be provided between the generator-motor circuit breaker and the generator-motor

10.15 NEUTRAL GROUNDING DEVICE FOR GENERATOR-MOTOR

Neutral Grounding Resistor (NGR) system and Neutral Grounding Transformer (NGT) system are available for the neutral point grounding of the generator- motor.

10.16 LAVT SYSTEM

LAVT Cubicles shall include Surge Capacitors, Lightning Arrestors, Voltage Transformers and associated accessories.

10.17 ISOLATED PHASE BUS DUCT (IPBD)

24kV Metal Enclosed Isolated Phase Bus duct (IPBD) will be provided between the terminals of generator-motor and the primary terminals of main step-up transformer.

10.18 MOTOR STARTING METHOD

A. Static Frequency Converter (SFC)

One (01) set of Static Frequency Converter (SFC) with digital control type shall be used in common for all units of the generator / motor simultaneously and shall be connected to each generator / motor through the selective Disconnecting Switch, Circuit Breakers etc. to accelerate the machine in reverse direction for “pumping operation” up to rated speed by grid power. After synchronizing the machine with the grid SFC gets cut off.

B. Back to Back Starting Method

Beside SFC as main starting method of the motor (pumping mode), back-to-back (BTB) starting method as back-up option is recommended for the project.

In this case one unit will be started as generator and other will be in motor mode (by phase reversal switch operation) and ultimately synchronize with the grid to run the motor for pumping operation and generator will return to shut down. In this method, the generating unit and the pumping unit shall be selected in such a combination / manner that the units are connected to different penstocks / HRTs / TRTs.

10.19 STEP-UP TRANSFORMER

The generated voltage of 24kV shall be stepped up to 400kV by Generator Step-up Transformers which are located underground in Transformer-cum-GIS Cavern. It is proposed to use single-phase step-up transformers each rated 98 MVA, 1Ø, 24 kV/400/√3 kV. Thirteen (12+1 spare) single phase transformers will be provided, 3 nos. for each generating unit + 1 no. spare. The Transformer would be OFWF type with OCTC (Off load tapping) in accordance with BIS/IEC standards.

10.20 POWER PLANT CONTROL & MONITORING SYSTEM

Power Plant control and monitoring system shall be based on Programmable Logic controller for unit and auxiliary control, monitoring and interlocking. The system shall also include provision for uninterrupted power supply through DC batteries.

A supervisory control and data acquisition (SCADA) system will be provided for an efficient and economic plant operation. The power house will be designed to be operated with three levels of control:

(i) From the control room

(ii) From the Unit control board located on the machine hall floor.

(iii) From local control cubicles of each element located adjacent to the unit.

A main supervisory computer system supporting necessary man-machine interface will be located at the Main Control Room and separate local plant controllers will be provided for each main unit, station service circuit and 420 kV switchyard. The computer system and controllers will be linked by high-speed data transmission system.

10.21 POWER PLANT PROTECTION

The protection scheme adopted shall provide protection for generator, generator transformers & plant auxiliaries. The scheme shall incorporate necessary provision for alarm, annunciation, signaling and tripping of breakers for the protection of power plant equipment.

10.22 AUXILARY POWER SUPPLY/SYSTEM

10.23 AUXLIARY TRANSFORMERS

650 kVA, 24 kV / 415 V Unit auxiliary Transformer shall be provided for each unit for catering to the requirement of the unit and plant load auxiliaries such as governor, dewatering & drainage pumps, crane, ventilation and other misc. loads. The sharing of loads between the transformers shall be optimal. The above system shall be further studied and optimized during DPR stage.

Two nos 20MVA Stepdown transformers 400kV/24kV and Two number 2500kVA, 24 kV / 415 V Station auxiliary Transformers shall be provided to cater to the requirement of the SFC load and other station load auxiliaries. The above system shall be further studied and optimized during DPR stage.

10.24 DC SUPPLY SYSTEM

220V and 48 V battery system of suitable rating with charger and DCDB shall be provided to meet complete DC load requirement in the power House.

10.25 EMERGENCY DIESEL GENERATOR SYSTEM

For emergency supply Two no. DG set of 800 KVA, 415 V, 50 Hz, 3 phase 4 wire with electric start and AMF panel shall be provided. The DG set will start automatically when supply on the 415V panel fails.

10.26 415 V STATION AUXILIARY BOARD/ PANEL

A Switchboard for operation at 415 V, 3 ph, 4 wire, 50 Hz supply shall be provided. The panel shall comprise of incomer MCCBs, CTs, PTs, voltmeters, Kwh meters, fuses etc, outgoing feeders with MCBs mainly for loads like drainage& dewatering pump sets, lighting, exhaust fans, Governor OPU, CW pumps etc.

10.27 EOT CRANE

The heaviest assembly required to be lifted by the EOT crane would be the assembled rotor. Two nos EOT crane with a main hook of 350 T capacity and an auxiliary hook of 50 T and 10T mono rail hoist is envisaged in power house. The crane capacity shall review during DPR stage. One no 10 T EOT crane shall be installed in GIS hall for handling the GIS equipment

10.28 ILLUMINATION OF PLANT

Illumination at all important locations such as Power House, Switchyard, Access Roads etc including emergency lighting shall be carried as per relevant IS specifications. All fittings, luminaries, conduits, wire fixtures etc shall be of standard make and of good quality.

10.29 CABLE & CABLE TRAYS

Single core 400 kV high voltage XLPE cables will be installed and connected from the underground secondary GIS to the outside switchyard through the cable tunnel for power evacuation between the main step-up transformers and the GIS / outdoor switchyard.

11 kV XLPE cables shall be used for connection from and to the 11 kV switchboards to be installed at different load centers in power house and switchyard.

1.1 kV Grade PVC insulated Copper / Aluminium power cables shall be used in the power house, transformer cavern, switchyard, Lower Dam, Upper Dam areas for supplying power to various auxiliaries, while for control cables 1.1 kV Grade PVC insulated copper cables will be employed.

The instrumentation cables used including Optical Fiber Cables (OFC) will be immune to electromagnetic interference. The number of pairs / cores required will be as per the requirement of the system.

10.30 COMPRESSED AIR SYSTEM

High pressure compressed air plant (main & standby) system will be installed to meet the water depression system, governor OPU and MIV OPU and bonnet type DT gate OPU.

Low pressure compressed (main & standby) air plant would be installed to meet the requirements for brake of generator and for shaft sealing system of turbine. A low pressure compressed air plant would also be installed to meet the requirement of the station pneumatic tools and other general purpose in the power house.

10.31 VENTILATION

All areas of the power house shall be provided with suitable ventilation system.

10.32 COOLING WATER SYSTEM

It is proposed to provide individual cooling water system for each unit to remove heat from generators and bearing oils through heat exchangers.

The water supply system shall be provided for replenishing the leakage water from the spiral case at depressing water level in draft tube at pump starting.

The cooling water for each main unit is supplied from the corresponding draft tube by an individual motor driven pump set. There is one regular use pump set for each main unit and one stand-by use pump set is provided for two main units. The stand-by use pump and regular use pumps are isolated by automatic operated valves.

The cooling water for each main unit is supplied from the corresponding draft tube by an individual motor driven pump set. There is one regular use pump set for each main unit and one stand-by use pump set is provided for two main units. The stand-by use pump and regular use pumps are isolated by automatic operated valves.

10.33 FIRE PROTECTION SYSTEM

The Fire Protection System in the underground power house, main access tunnel, isolated phase bus duct tunnels, GIS / switchyard etc. shall be designed to timely detect the occurrence & quick extinguishing of fire break outs and prevention of spread of fire so as to minimize the extent of damage.

Water spray type Fire Extinguishing System shall be provided for all the generator-motor sets, main transformer, Station service system & SFC transformer. The fire extinguisher system shall detect fire inside the generator-motor barrel and transformer rooms instantaneously and accurately, and shall discharge water automatically by actuation both of the fire detector and protection relay, and also, by manual operation at the extinguisher panel.

Fire protection system comprising of pump systems, piping with hydrant valves and hose cabinets at strategic places shall be provided. Portable fire extinguishers shall also be provided at strategic points for protection in case of small fires/ emergencies.

10.34 LUBRICATION OIL PURIFICATION SYSTEM

A portable oil purifier could be provided for the purification of lubricating oil.

10.35 DRAINAGE DEWATERING SYSTEM

A common drainage and dewatering and flooding system with submersible pumps has been proposed to enable dewatering of unit penstock, spiral casing as well as draft tube pit.

10.36 400 KV GAS INSULATED SWITCHGEAR

Due to space and reliability constraints, 400 kV Gas Insulated Switchgear has been proposed and shall be housed on a floor located just above the transformers in the transformer cavern. Double bus bar arrangement is proposed for this project after giving due consideration to its reliability, stability, easy maintenance and accessibility.

The 400 kV SF_6 gas insulated switchgear will be provided for switching operation from generating unit to grid transmission lines. The Switchgear rated for 400 kV, 3 phase, 50 Hz will be indoor metal-enclosed type and will be housed in the upper part of Transformer-cum-GIS Cavern above the step-up transformers housed in the lower part of the cavern. Refer Main Single Diagram for details.

10.37 POTHEAD

Considering Four nos outgoing feeders, 400kV pothead with tentative area of 140mx60m is proposed at suitable elevation. Each bay width is considered 27m. DG room/station transformer area is planned at pothead area

10.38 COMMUNICATION SYSTEM & SURVEILLANCE SYSTEM

A suitable communication and surveillance system shall be installed in the power house complex to facilitate the communication and desired security in the power house area. Communication system comprises of the public address system and EPBAX equipment. The surveillance system would comprise of access control system and CCTV system equipment including all spaces of power house.

10.39 ELECTRICAL EQUIPMENT TESTING LABORATORY

Portable Electrical Testing Equipment will be provided to carry out normal testing of power house equipment. Separate room is proposed in the power house for Electrical Testing Laboratory for storage of portable equipment and to serve as a base for testing personnel. All the testing equipment should be PC compatible and of latest design.

10.40 MECHANICAL WORKSHOP

A Mechanical Workshop will be provided in control block in machine hall cavern for routine maintenance as required for all works & will be equipped with drilling, welding, milling & lathe machines & other required machine tools.

10.41 LIFT

Two numbers electrically operated lifts shall be in the power house for easy movement. The lift shall be designed for approximately a load of 10 persons.

10.42 SELECTION OF TURBINE (FIXED SPEED VS. VARIABLE SPEED COMPARISON)

10.42.1 PROJECT KEY PARAMETERS

The base case for the proposed Somasila Pumped Storage Project is the traditional fixed speed synchronous motor/generator design. The main unit characteristics of the proposed single-stage reversible Francis pump-turbines based on a fixed speed synchronous design are given in Table 10-1:

Table 10-1: Generator/Pump Motor Characteristics

Description	Unit	Rating
Number of Units		4
Synchronous Speed	rpm	375
Generator/Pump Motor Unit rated Capacity	MVA	264.7 with 10% col
Power Factor		0.85
Pump Electrical Power (Min Net Head)	MW	204.6
Pump Electrical Power (Max Net Head)	MW	228.4

10.42.2 VARIABLE SPEED MOTOR-GENERATOR UNITS OPERATING CHARACTERISTICS

A conventional synchronous motor-generator, when in either generating mode or in pumping mode, operates at a constant speed. By adjusting the wicket gates position, the power output in the generating mode can be controlled. There is no adjustment possible in the pumping mode, and hence the power demand by the motor cannot be adjusted.

For a variable speed asynchronous motor-generator of greater capacity than 100 MW, the motor- generator design is normally a “Doubly Fed induction machine (DFIM) when the wound rotor current is controlled by a separate variable frequency convertor. Whether in generating mode or in pumping mode, the DFIM motor-generator speed can be continuously adjusted between 7 and up to 10 percent less than the normal synchronous speed depending on the design of the DFIM and the type of frequency converter controlling the wound rotor current.

By adjusting the frequency convertor output and hence the motor-generator speed, this allows for the power generated in the generator mode or the power demand in pumping mode to be quickly adjusted by up to 30% of rated power output of the motor-generator over a short period of time. Adjusting the speed and power requirements of the motor-generator allows for many important benefits which are outlined in the following Sections.

However, these variable speed asynchronous motor-generators are more complex, require additional control equipment requirements, and are therefore more expensive

than a conventional synchronous motor-generator. The additional complexity, equipment and power losses are outlined in this chapter.

10.42.3 VARIABLE SPEED UNITS VERSUS FIXED SPEED SYNCHRONOUS UNITS

In comparison with a conventional synchronous motor-generator operating at a constant speed, a variable speed hydro pumped storage system has not only the advantage of an increased overall efficiency over a wide operating range in turbine generator mode, it also offers the following benefits for the power system network:

- Possibility of active power control in the pumping mode;
- Possibility of reactive power control
- Possibility of instantaneous active power injection into the transmission system by reduction of the speed set value and using the kinetic energy stored in the rotating mass.
- These possibilities lead to an appreciable improvement of the transmission system quality in terms of performance and stability which results in the following-
- Increased turbine efficiency
- Active power control in the pumping mode
- Reactive power control at the national grid interconnection point
- Instantaneous active power injection into the national grid

10.42.4 ADDITIONAL EQUIPMENT COMPLEXITY WITH VARIABLE SPEED UNITS

Compared with a traditional fixed synchronous PSP machine, a variable speed PSP machine is more complex in the design of the motor-generator and its associated control equipment. The key differences between the two types of motor-generators are as follows-

- Doubly fed wound rotor asynchronous motor-generator
- Frequency converter
- Other electrical control equipment

In addition to the wound rotor asynchronous motor-generator, frequency converter, and rotor control transformer, other major equipment required for variable speed unit includes:

Machine Starting Circuitry for the wound rotor asynchronous machine that feeds directly the rotor up to near the synchronous speed, prior to the VSP frequency converter taking over controlling the wound rotor;

- Additional medium voltage circuit breakers;
- Harmonic filters;
- Short circuit current-limiting reactors in the - circuit;
- Rotor over-current and over-voltage protection cubicle;
- Non-conventional current transformers and voltage transformers for rotor current and voltage measurement at very low frequency;
- Supply Transformer to the Frequency Converter. In order to reduce space requirements and costs in underground caverns, some vendors may give an option of incorporating the output winding of the control transformer as a

tertiary winding within the main step-up transformer design. However, this will be reviewed further in design.

10.42.5 ADDITIONAL LOSSES ASSOCIATED WITH VARIABLE SPEED UNITS

Variable speed hydro pumped storage motor-generators, the total additional power losses compared with the same sized fixed speed synchronous motor-generator is higher per machine, and the actual power loss depends on how far the variable machine speed is operating from its machine's synchronous speed.

Increase in the turbine shaft power efficiency when the generator is operating at below 75% turbine output power. This efficiency increase begins to tail away as the turbine output power increases to towards 100% turbine power output. At a 100% turbine output power, the generator speed is getting near the machine's natural synchronous speed. If the electrical losses of the combined variable speed asynchronous motor-generator and its associated control system are superimposed on this turbine output efficiency curve, it would show that electrical power losses at near synchronous speed would cancel out all of the slight increased turbine power output at 100% turbine output power.

When the turbine is operating at a partial load; say 75% turbine output power, the turbine efficiency output power gain is higher than the additional electrical losses due having a wound rotor asynchronous generator, and there is likely to be approximately 1.0% increase in net output at high voltage terminals of the step-up power transformer.

10.42.6 ADDITIONAL CAPITAL COSTS ASSOCIATED WITH VARIABLE SPEED UNITS

Compared with a traditional fixed synchronous PSP machine, a variable speed PSP machine is more expensive to manufacture due to the complexity of each wound rotor asynchronous motor- generator and its associated control circuitry to fed power to the rotor circuit.

Wound rotor asynchronous machine compared with the rated salient pole synchronous machine: Plus approximately ~20% capital cost for each motor-generator unit (rough budget estimate). If the motor-generators are to be sized to operate at 5% over speed for periods of time, then the wound rotor asynchronous machines would need to be rated for enhanced capacity and accordingly the cost increase.

Power Converter, its supply transformer and other associated electrical control equipment(cost varies based on type of power converter selection)

The underground cavern space would need to increase by approximately 5 %.

10.42.7 VARIABLE SPEED UNITS FOR SOMASILA PSP

The proposed plan at this feasibility study stage is for the Somasila PSP Scheme to have 4 fixed speed synchronous motor-generators as the base case scenario. This document is to consider the advantage of having variable speed asynchronous motor-generators verses fixed speed synchronous motor-generators. Apart from the higher capital cost of having variable speed motor-generators which can be

considered as a negative effect in any business case, most other the features of having a variable speed asynchronous motor-generator have a highly positive effect to any business case.

However, if the additional higher capital cost of having 4 separate variable speed 265 MVA asynchronous motor-generators is too high for any sound business case, Authority can also consider two variable speed asynchronous motor-generator units and two fixed speed synchronous motor- generators for the Somasila PSP Project. In this scenario, the two fixed speed synchronous PSP machine units could be used as block loaded operation machine units during the pumping mode and run at a relative high power outputs in their generating mode. The other two variable speed units would be variable speed asynchronous machine units, which are able to act as the national power grid system balancers.

It would be normal that these two units would operate at only part loads both in the pumping mode and in their generating mode. During periods of low demand for either for pumping or for generating services from the Somasila PSP Scheme, it will be the two variable speed asynchronous units doing all of the operation. This will mean that the two variable speed asynchronous motor-generator units would have a far higher utilization factor when the other two fixed speed synchronous motor-generator units over the course of a normal year.

Advantages of having two variable speed asynchronous motor-generators units and two fixed speed synchronous motor-generator units within the Somasila PSP Scheme:

- The additional capital cost is likely to be only about 50 % of the total capital cost difference between the Base Case of the 4 fixed speed synchronous motor-generator units and the likely capital cost for the 4 variable speed asynchronous motor-generators units.
- Most of the time, the two variable speed asynchronous motor-generator units when in-service are likely to be able to manage the full range of varying national power grid issues as to why the variable speed motor-generator units are being considered.

Disadvantages of having two variable speed asynchronous motor-generators units and two fixed speed synchronous motor-generator units within the Somasila PSP Scheme:

- Two different types of motor-generators and associated electrical equipment within the same powerhouse that will both require appropriate levels of maintenance spares to be held.
- The maintenance and operating personnel who need to trained on both types of motor- generator systems.
- With power system dispatch management for this PSP scheme, there will be times when the operating PSP machines will need to started and other PSP machines stopped, because the two fixed speed synchronous PSP machines are not as flexible as the two variable speed asynchronous PSP machines.

10.42.8 RECOMMENDATION

Based on the recent increase in the solar, wind generation capacity and increased use of renewables, the grid demand for PSP batteries are increasing. The conceptual comparison of fixed speed vs variable speed machines have been compared in this chapter.

The detailed study and control scheme for both shall be performed during DPR stage based on the studies for grid requirement for condenser mode operation and pumping mode operation requirements. Accordingly the cooling water requirements, shaft seal operational requirements, control system equipment requirements, medium voltage equipment, frequency converter requirement during starting and regenerative braking requirement shall also be studied in detail.

Based on above the techno commercial optimisation for Somasila PSP Scheme shall be studied along with the reference projects (executed and ongoing).

TRANSMISSION OF POWER AND COMMUNICATION FACILITIES

11 CHAPTER 11 – TRANSMISSION OF POWER AND COMMUNICATION FACILITIES

11.1 POWER EVACUATION

The power generated at Pumped Storage plant will be evacuated to nearest pooling point by 400 kV four nos. outgoing lines. Two nos. of 220/ 400 kV substations operated by APTRANSCO located at Podili & Manubolu, in the Nellore District, have been identified for the probable venture for power evacuation. The project site is around 150 Km far from both locations as shown in Figure 11-1.

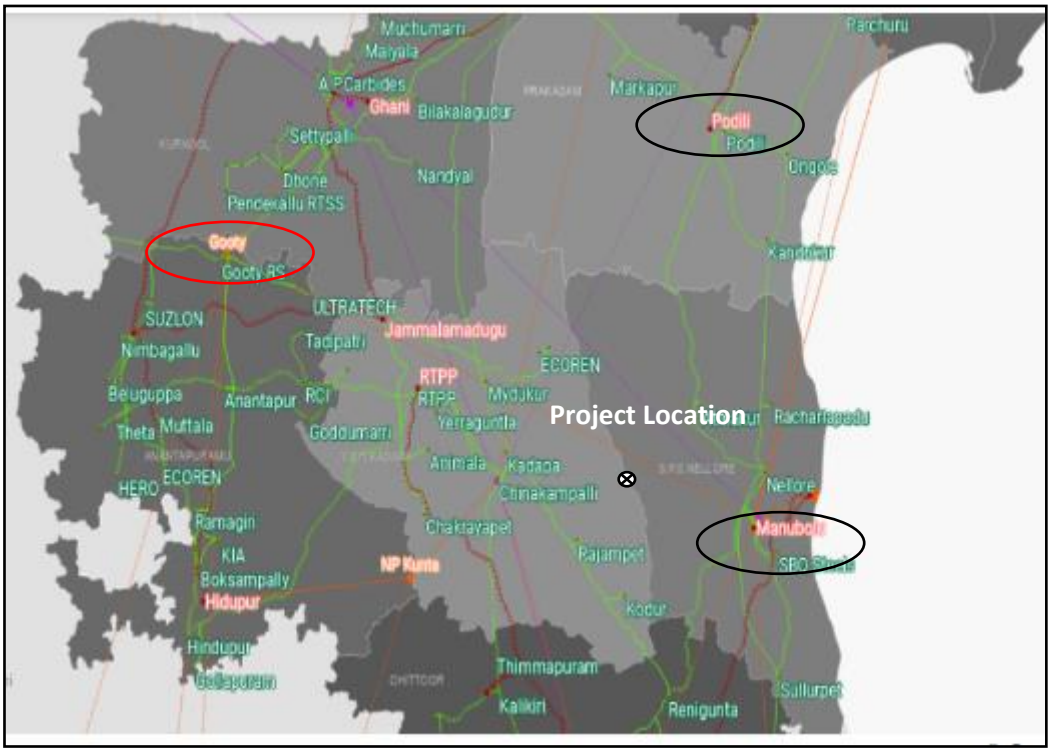


Figure 11-1: Probable stations for Power Evacuation

11.2 COMMUNICATION EQUIPMENT (FOTE)

For the purpose of data transmission, and voice communication, transmission line protection, remote control, the 400 kV transmission system will be provided with Fiber Optic Communication Network (FOTE).

11.3 REFERENCE DRAWINGS

The following Drawing may be referred to as:

S.No	Title of Drawing
1	Main single Line Diagram (Drawing No. 7061601-FSR-1022)

CONSTRUCTION PROGRAMME & PLANT PLANNING

12 CHAPTER 12 - CONSTRUCTION PROGRAMME & PLANT PLANNING

12.1 CONSTRUCTION PROGRAMME FOR MAJOR COMPONENTS

The proposed Somasila Pumped Storage Project (900 MW) is mainly an underground Project and the construction program would eventually be dependent on various factors like topography and geological conditions of the project area. The same have been considered for assessment during this feasibility study.

Apart from the technological complexities, several site specific characteristics like natural, social and other locational conditions such as weather, labor supply, local building codes, etc., are unique to the planning of the construction of the Project. These complexities and characteristics act as constraints and further dictate the construction method to be adopted for carrying out various activities required for project completion.

The construction methodology proposed for the Somasila Pump Storage Project is based on the desk study, site visit, geological features revealed after surface mapping, topography of the area, preliminary design of the project components and the various activities involved.

At this stage, the construction program has been scheduled based on current industrial practices considering excavation & concreting of open and underground works involved. Special attention has been given in working out the time duration for the underground works as the restricted workspace and geological conditions make the activities critical. The construction will involve concurrent working on all the Civil, HM & EM works for various components. Construction of Reservoirs and powerhouse are the most critical activities of the project.

Overall Construction duration has been worked out under two major heads i.e. Pre-Construction stage & Main Construction stage activities as shown in the list of WBS Activities in Table 12-1.

List of WBS Activities considered are as follows:

WBS	Task Name
1	**Implementation Schedule**
1.1	Start of Work activities up on Approval of DPR
1.2	**Preconstruction Activities**
1.2.1	Financial Closure
1.2.2	Tender & award of work
1.2.3	Land acquisition
1.2.4	Access Roads and Bridges

WBS	Task Name
1.2.5	Construction Camps and Colonies
1.2.6	Mobilization
1.3	**Construction Activities**
1.3.1	Construction Adits
1.3.2	Construction of Intake Well, Jack Well & Buried Pipeline
1.3.3	Upper Reservoir & Dams
1.3.3.1	Upper Reservoir
1.3.3.1.1	Dam -1 (UR)
1.3.3.1.2	Dam -2 (UR)
1.3.3.1.3	Power Intakes (UR)
1.3.4	Pressure Shafts
1.3.5	Power House (Underground)
1.3.6	Tail Race Tunnels
1.3.7	Power Intakes (LR)
1.3.8	Lower Reservoir (LR)
1.3.9	Pothead Yard
1.3.10	Reservoir Filling
1.3.11	Testing and Commissioning

Table 12-1: WBS Activities

12.2 KEY MATERIALS PLANNING

The project site is accessible from the nearest rail head at Kadapa which is about 75 km from Project site and has loading & unloading facility. It is one of the “A” category railway stations in South Coast Railway zone under Guntakal railway division. The nearest airport is Renigunta, Tirupati which is 180 km (approx.) from project site. Another Airport is Chennai which is about 325 km from the project site. The nearest sea port is Krishnapatnam Port and is about 140 km from the project site.

Various construction materials required during the construction stage including aggregates, cement, and admixtures for concrete/ shotcrete, reinforcement steel, structural steel, HSD, Explosives and other miscellaneous consumables will be transported to site after procurement through road. It is presumed that the majority of the construction materials for the construction of Project will be procured from within the State of Andhra Pradesh. Penstock/pressure shaft steel liner plates, steel,

explosives and admixtures being industrial products are planned to be procured from external agencies identified for bulk supplies.

For movement of heavy equipment, construction material and manpower within the Project area, internal communication roads have been planned up to project components. The requisite area for setting up the basic infrastructure facilities for the staff, site offices, stores etc. during the construction stage has been identified and considered in the total Project area.

12.3 EXECUTING AGENCIES FOR MAJOR WORKS – DEPARTMENTAL/CONTRACTOR

The Pumped storage projects are strategically planned to be executed through either turnkey/ EPC mode or through award of various package contracts taking into consideration the capabilities of eligible contractors mainly relying on their past satisfactory performance in execution, completion and commissioning of hydro projects and pumped storage projects.

In case of turnkey/ EPC contracts, the entire project including civil, hydro- mechanical & electro-mechanical works are awarded to a single company / consortium / joint venture based on the criterion established by the implementing agency not limiting to the past performance of the bidders with limited owner responsibility. In case of package wise contract system, all civil works can be suitably divided into optimum number of contract packages. The hydro-mechanical works can be executed through a separate package and preferably could be part of civil works package. For electro-mechanical works, a separate package can be awarded. The strategy behind deciding on the optimum number of civil works packages is usually governed by minimum interference between different work areas and availability of sufficient space for different contractor's camps and construction facilities.

The development of basic infrastructure shall be taken up in advance so that basic facilities are available for start of the work at the time of mobilization.

The proposed project involves construction of upper & lower reservoirs, intake, HRT, pressure shaft and powerhouse involving open and underground excavation, concreting etc. along with supply, fabrication, and erection of Hydro-mechanical and Electro-mechanical equipment. The decision on the mode of execution shall be adopted in view of the magnitude of works and construction schedule.

12.4 CONSTRUCTION PLANNING

Following assumptions have been considered while estimating the duration required for construction of project:

i. 25 working days per month are considered.
ii. 15 hours per day have been considered as working hours.
iii. Lead of 2 kms is assumed for mucking.
iv. Duration for mobilization of contractor is assumed as 30 days.
v. Construction of access roads and other basic infrastructure works will be done by Project Developer before mobilization of contractor

vi. Work hindrance due to monsoon on surface works are not considered

vii. Swell factor of 0.83 & 0.63 has been considered for common excavation & well blasted rock respectively.

Based on the assumption mentioned in the above, time duration required for construction have been estimated.

Implementation schedule is prepared covering major heads as shown here below:

S. No.	Task Name
1.	**Implementation Schedule**
2.	Start of Work activities up on Approval of DPR
3.	**Preconstruction Activities**
4.	**Construction Activities**
5.	Reservoirs Filling
6.	Testing and Commissioning

It is proposed to start of Pre-construction activities immediately after award of works and approval of DPR.

12.5 PRE-CONSTRUCTION ACTIVITIES

The activities to be undertaken during preconstruction work includes

1. Detailed topographic survey, marking the layout at site, pre-construction geotechnical investigations and clearance from Govt. agencies for TEC, FC, etc.
2. Acquisition of land required for construction of structures, access roads, colonies, stores, workshops muck disposed area, quarry area etc.
3. Achieving financial closure based on the approved DPR, preparation of bid documents, award of main construction works, setting up site office, construction of residential, non-residential buildings, stores etc.
4. Arrangement of construction power before start of construction activities, upgradation of existing roads & construction of additional access roads etc.

These pre-construction activities are planned for infrastructure works starting 9 months before zero date so as to ensure that all such works are completed before the schedule date of start of main works. Some of the pre-construction activities may continue for some time during 1st year of construction also. Special attention shall be paid to the early completion of main access roads & bridges. All administrative, financial & legal formalities shall be completed during pre-construction stage. The bidding procedures and the award of works shall be completed during this phase including mobilisation of the contractor at site.

12.6 CONSTRUCTION ACTIVITIES

The construction activities for various components along with their duration & dependencies on other activities and resources are elaborated below:

a) Construction Adits:

The construction of various underground components is planned to be facilitated by construction of adits. The main activities considered during construction of adits are tunnel excavation and rock support, invert laying in permanent tunnels and concrete plugs (wherever required).

For the planning purpose and ease of construction, the pressure shaft is divided into 3 parts viz. upper vertical & horizontal pressure shaft, inclined pressure shaft and lower horizontal pressure shaft. 3 nos. adits of 5.3 m dia D-shaped have been planned for construction of the pressure shaft.

315 m long Adit-1 is proposed at about EL. 118.5m for construction of lower horizontal pressure shaft & 4 nos. of branch lower horizontal pressure shaft.

Adit-2 having a length of 462m is proposed at El. 271.75 for construction of inclined pressure shaft.

372m long Adit -3 is provided at El. 425m to facilitate construction of upper vertical & horizontal pressure shaft.

The total duration envisaged for completion of these activities is about 12 months which includes Excavation & support along with the invert (temporary/permanent). However, plugging of the adits is planned after completion of construction of dependent components in 1.5 months.

b) Construction of Jack Well Pump House & Buried Pipeline:

The project envisages initial & intermittent water filling from the existing Somasila Reservoir. For pumping of water from the existing Somasila Reservoir, a dedicated Intake near existing Somasila Reservoir is proposed to be constructed along with the feeder D.I pipeline of about 14.7 kms.

The construction of dedicated Intake & feeder pipeline is planned with an estimated duration of about 8.5 months.

c) Upper Reservoir:

The upper reservoir is planned with twin Intake structure for feeding & withdrawal of discharges during operations.

The upper reservoir (UR) is located on the natural depression which is utilized to create sufficient pondage with required excavation & gravity dam at the two ends of the depression for locking the reservoir.

The excavation of the dam abutments will be carried out simultaneously on both the right and left abutments. During excavation, stripping will be carried out to the depth limit of the de-stressed rock zone. The overburden material will be removed with excavators and material hauled out to the dumping areas deploying loaders & dumpers. Thereafter, rock stripping will start by deploying crawler mounted drilling equipment along with portable compressors. The

stripping will be done in stages of about 2 - 2.5 m metres benches so that slope protection measures are carried out simultaneously with the excavation of slopes. Muck will be hauled to the dumping areas using loader/backhoes and dumpers.

Apart from the above excavation for dam, excavation of reservoir will be carried out concurrently with the removal of overburden in the reservoir area followed by the excavation in hard rock.

The excavation activities will be carried out with the help of various equipment's such as Wagon drill, Hydraulic excavator (0.9cum to 3cum), Dozer of 180 HP, Jack Hammer 120 cfm capacity, Dumpers 20 MT capacity, Shotcrete Machine, Vibratory Roller for compaction of muck at dumping area.

Concreting of Dam is proposed to be done using tower crane using buckets with a capacity of 2-3 cum. It is also proposed to use concrete pumps of suitable capacity along with concrete transit millers wherever feasible depending upon the ease of pouring & placement of concrete.

To improve upon rock deformability, close up seams, joints, cracks in the dam foundation, abutment and reservoir area, consolidation grouting will be carried out. The consolidation grouting holes will be drilled in a 3m x 3m grid pattern to a required depth into rock. Grouting will be carried out using cement water mix at a pressure of 5 Kg/cm^2. Hydraulic track drills and diamond core rock drills will be used for drilling and grout pumps for grouting.

Grouting gallery has been provided in the dam body at different elevations. The primary grout holes depth will vary with the height of the dam and properties of the foundation rock. Depending upon the efficacy of grouting through primary grout holes, requirement of secondary holes will be assessed during construction stage. To ensure watertightness of reservoir, wherever required Asphaltic membrane is proposed to be used. Based on preliminary assessment, Asphaltic membrane lining will be required for about 50% area of the upper reservoir.

The construction of upper reservoir is planned in duration of about 32 months. Construction of twin Power Intake is planned in 9.5 months including 4 months for Hydromechanical works.

d) Lower Reservoir:

Lower reservoir is proposed at the foot of the hill in an identified natural depression having suitable potential to create an artificial reservoir. Construction activities such as excavation & support, concreting, grouting, etc of lower reservoir will be taken up with similar method of construction using similar set of equipment's as mentioned in the Upper reservoir area.

These activities are planned to complete in duration of about 26 months. Excavation of the twin Power Intake will be taken up synchronously with excavation of lower reservoir. Concreting & Hydromechanical works will be taken up after completion of Reservoir concreting activities.

Construction of the twin Power Intake for lower reservoir require about 9 months including 4 months for Hydromechanical works.

e) Pressure Shaft

The scheme is proposed with 903.20 m long 5.3 m dia, twin Pressure shafts originating from upper twin intake at El 520.0m bifurcating at El. 118.5m into four 78.70 m long, 3.75m dia, branch pressure shafts leading to powerhouse unit bays.

For the planning purpose and ease of construction, the pressure shaft is divided into 3 parts viz. upper vertical & horizontal pressure shaft, inclined pressure shaft and lower horizontal pressure shaft. The underground excavation of the pressure shafts shall be carried out through 3 nos. D-shaped, 5.3 m diameter, adits planned for construction of the pressure shaft.

The horizontal pressure shaft excavation will be carried out using conventional drilling & blasting techniques deploying hydraulic drilling jumbos. Blasting pattern requiring minimum charge and yielding maximum pull will be designed based on the nature and quality of rock mass and size of excavation. The sequence of tunnelling excavation is given below:

- Surveying and Marking
- Drilling of holes as per blast pattern design
- Loading of explosives
- Blasting
- Defuming
- Scaling
- Shotcreting/Rock bolting
- Drilling drainage holes wherever water seepage encountered
- Concreting and grouting

Muck handling will be carried out by combination of loaders, dumpers and dozers working independently for each portal. Rock support will be provided by steel ribs (near the portals) and rock bolts and shotcrete.

For excavation loaders, dumpers, dozers, drilling jumbos, shotcrete machines, etc. Will be required. Portal & tunnel lining concrete will be carried out by using 30 cum/hr capacity pumps, 6 cum transit mixers etc.

The inclined and vertical pressure shaft will be executed by using raise climber, having a platform size of 2.5m upward holes will be drilled with approximate advance of 2 / 3 meters. The operation will consist of drilling, charging, blasting, scaling and extending of rail on which the raise climber operates. The muck will automatically fall down at the bottom of the pressure shaft and will be removed with the help of loader and dumper combination.

Enlargement of the shaft will be carried out after the completion of excavation of shaft from top to bottom with the help of Jack hammers. Primary rock support using rock bolts/ anchors and shotcreting will be done simultaneously to support the surface. During drilling operations, the pilot hole will be covered by grizzly platform, to provide space for drilling & will also act as a safety measure against free falls. The enlargement will be done by conventional method of drilling and blasting and mucking from under the shaft by deploying dumpers and loaders.

The activities of Pressure Shaft includes excavation, primary support works, erection of steel liner & backfill concrete, grouting and adit plugging. These activities are planned to be completed within a duration of about 49 months.

f) Powerhouse (Underground)

Underground Powerhouse of size 147m (L) x 23m (W) x 52m (H) is proposed to house turbines for both the water conductor systems coming from Upper Reservoir and transformer cavern hall of 160m (L) x 21.5m (W) x 29.5m (H) has been proposed. The powerhouse will have four Francis type vertical shaft reversible units of 225 MW each.

The underground Powerhouse will be accessible through 900m long, D-Shaped, Main Access Tunnel (MAT) having a size of 8m x 8m. Apart from MAT, a 6.5m dia D-shaped, 628m long Ventilation Cum Cable Tunnel is also provided for ventilation & routing the cable from Transformer hall to Pothead Yard.

Excavation of Powerhouse is proposed to be taken up in stages. The excavation of the cavern would be done in five stages as below:

a. Stage I: Pilot tunnel 6.5 m dia at the top
b. Stage II: Widening/slashing of sides up to invert of pilot tunnel
c. Stage III: Benching up to top level of MAT
d. Stage IV: Benching from MAT top level to service bay
e. Stage V: Below service bay level

The excavation of Powerhouse would commence from two locations, one from the Ventilation Cum Cable Tunnel to reach the top of Powerhouse and the other from Main Access Tunnel (MAT) to reach the service bay level of the Powerhouse.

After completing the ventilation tunnel, the excavation work of Powerhouse shall be taken up. A pilot tunnel of 6.5m would be constructed throughout the length of the cavern. Since the crown of the cavern would get exposed during this cut, the rock reinforcement required for the crown as per design would be installed along with the excavation. Thereafter, the widening of the section shall be carried out to achieve the final profile of the Powerhouse.

Following the excavation of the crown, Stage III to stage V benching activities would then be taken up in stages of 3.0 m each along with rock support activity concurrently.

Same methodology will be adopted for excavation of Transformer cavern. The time considered for excavation of these two caverns is about 21 months. After completing the excavation up to required level concreting will be carried out upward from the foundation. Concreting will be done with the help of concrete pump and transportation of concrete by transit mixers. Concreting is planned to be completed in next 14 months. Overall works of Powerhouse is planned to complete within 54 months including E&M and HM works.

g) Tail Race Tunnel

Four numbers horizontal unit tail race tunnel of 4.5m diameter off takes from the downstream wall of machine hall and merges in to two numbers of main tail race tunnel of 6.3 m dia which further discharges flow in the lower reservoir.

The excavation of the tail race tunnel will be done using loaders, dumpers, dozers, drilling jumbos, shotcrete machines, etc. Portal and tunnel lining concreting activities will be carried out by using 30 cum/hr capacity concrete pumps, 6 cum transit mixers etc. The tunnel concrete lining activities will be followed by contact grouting.

The estimated time required to complete all activities of TRT is about 41.5 months.

h) Pothead Yard

Work activities of Pothead yard are planned to complete within 15 months.

i) Reservoir Filling

Initial filling of the lower reservoir from the existing Somasila reservoir is planned for 2 months by installing required capacity of pumps.

j) Testing and Commissioning

Dry and wet testing and commissioning of the turbines is planned to complete within duration of 6 months.

k) Electro-Mechanical Equipment

The duration for the design, manufacture, delivery have not been shown in the schedule. However, time required for installation of the electromechanical is considered as 20 months. It is envisaged that the actual duration for this activity will be closely coordinated with the manufacturers during actual construction.

12.7 GANTT CHART SHOWING THE CONSTRUCTION PROGRAMME

The main construction activities for the project are planned to complete within the time duration of 60 Calendar months after the award of works excluding 9 months of pre-construction activities. The bidding procedures including award of works will be

carried out expeditiously so that mobilization of equipment, manpower and other resources is completed before the start of working period.

Sr. No.	Task Name	Estimated Construction Duration (in months)
1.	**Implementation Schedule**	**69**
2.	Start of Work activities up on Approval of DPR	0
3.	**Preconstruction Activities**	**9**
4.	**Construction Activities**	**60**
5.	Reservoirs Filling	3
6.	Testing and Commissioning	6

[#] *Construction Duration may change during Detailed Project Report stage*

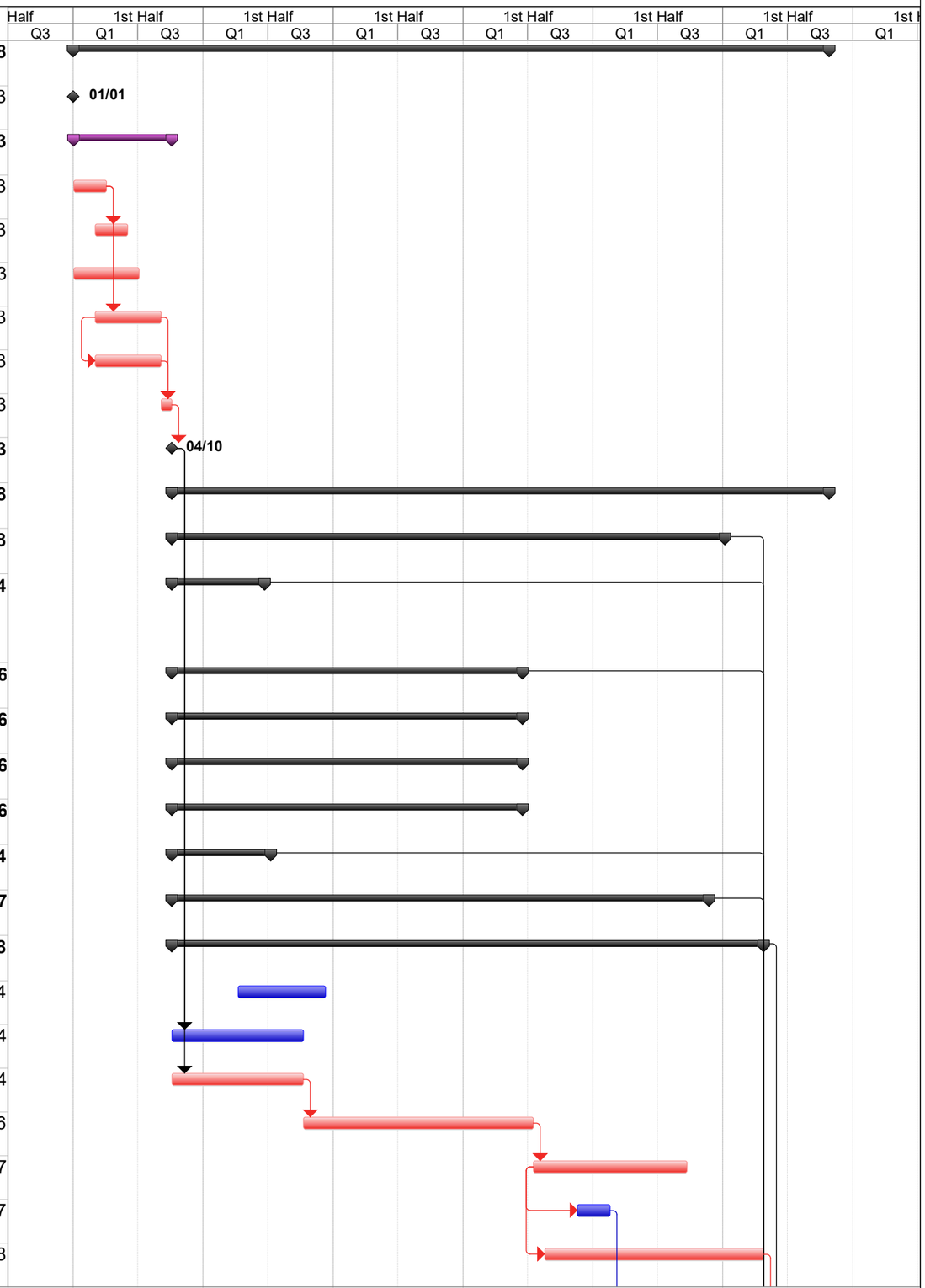
Table 12-2: L1 Schedule

The construction schedule is attached as **Annexure**.

CONSTRUCTION SCHEDULE OF SOMASILA PUMPED STORAGE PROJECT

ANNEXURE -A

ID	Task Mode	WBS	Task Name	Duration	Start	Finish
1		**1**	**Implementation Schedule**	**69 mons**	**Sun 01/01/23**	**Wed 25/10/28**
2		1.1	Start of Work activities up on Approval of DPR	0 mons	Sun 01/01/23	Sun 01/01/23
3		**1.2**	**Preconstruction Activities**	**9 mons**	**Mon 02/01/23**	**Wed 04/10/23**
4		1.2.1	Financial Closure	3 mons	Mon 02/01/23	Mon 03/04/23
5		1.2.2	Tender & award of work	3 mons	Fri 03/03/23	Fri 02/06/23
6		1.2.3	Land acquisition	6 mons	Mon 02/01/23	Tue 04/07/23
7		1.2.4	Access Roads and Bridges	6 mons	Fri 03/03/23	Mon 04/09/23
8		1.2.5	Construction Camps and Colonies	6 mons	Fri 03/03/23	Mon 04/09/23
9		1.2.6	Mobilization	1 mon	Tue 05/09/23	Wed 04/10/23
10		**1.2.7**	**Zero Date**	**0 mons**	**Wed 04/10/23**	**Wed 04/10/23**
11		**1.3**	**Construction Activities**	**60 mons**	**Thu 05/10/23**	**Wed 25/10/28**
12		**1.3.1**	**Construction Adits**	**50.5 mons**	**Thu 05/10/23**	**Thu 06/01/28**
16		**1.3.2**	**Construction of Intake Well, Jack Well & Buried Pipeline**	**8.5 mons**	**Thu 05/10/23**	**Fri 21/06/24**
20		**1.3.3**	**Upper Reservoir & Dams**	**32 mons**	**Thu 05/10/23**	**Tue 16/06/26**
21		**1.3.3.1**	**Upper Reservoir (UR)**	**32 mons**	**Thu 05/10/23**	**Tue 16/06/26**
22		**1.3.3.1.1**	**Dam -1 (UR)**	**32 mons**	**Thu 05/10/23**	**Tue 16/06/26**
26		**1.3.3.1.2**	**Dam -2 (UR)**	**32 mons**	**Thu 05/10/23**	**Tue 16/06/26**
30		**1.3.3.1.3**	**Power Intake (UR)**	**9 mons**	**Thu 05/10/23**	**Mon 08/07/24**
34		**1.3.4**	**Pressure Shaft**	**49 mons**	**Thu 05/10/23**	**Mon 22/11/27**
41		**1.3.5**	**Power House (Underground)**	**54 mons**	**Thu 05/10/23**	**Mon 24/04/28**
42		1.3.5.1	Access Adit to PH bottom	8 mons	Mon 08/04/24	Mon 09/12/24
43		1.3.5.2	Ventilation\Cable Tunnel	12 mons	Thu 05/10/23	Tue 08/10/24
44		1.3.5.3	Main Access Tunnel	12 mons	Thu 05/10/23	Tue 08/10/24
45		1.3.5.4	Excavation-PH & Transformer Hall	21 mons	Wed 09/10/24	Thu 16/07/26
46		1.3.5.5	Concreting	14 mons	Fri 17/07/26	Tue 21/09/27
47		1.3.5.6	E O T Crane	3 mons	Wed 18/11/26	Wed 17/02/27
48		1.3.5.7	Electro-Mech Equipment's	20 mons	Tue 18/08/26	Mon 24/04/28

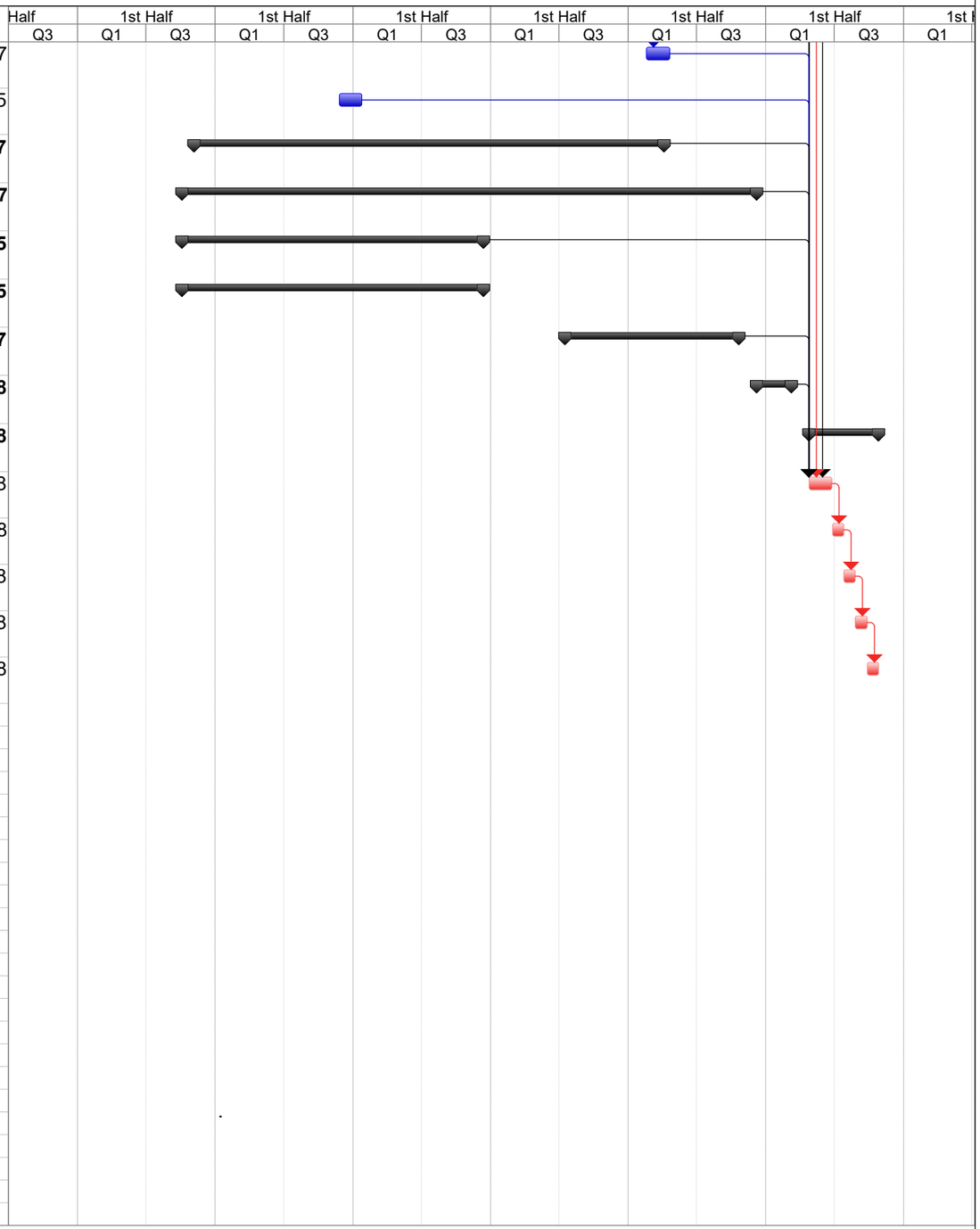


Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Critical
Critical Split
Progress
Deadline

CONSTRUCTION SCHEDULE OF SOMASILA PUMPED STORAGE PROJECT

ANNEXURE -A

ID	Task Mode	WBS	Task Name	Duration	Start	Finish
49		1.3.5.8	Transformers	2 mons	Thu 18/02/27	Tue 20/04/27
50		1.3.5.9	Draft Tube Gates and Hoist	2 mons	Mon 25/11/24	Thu 23/01/25
51		**1.3.6**	**Tail Race Tunnel**	**40.5 mons**	**Mon 06/11/23**	**Mon 05/04/27**
56		**1.3.7**	**Power Intakes (LR)**	**49.5 mons**	**Thu 05/10/23**	**Tue 07/12/27**
60		**1.3.8**	**Lower Reservoir (LR)**	**26 mons**	**Thu 05/10/23**	**Fri 12/12/25**
61		**1.3.8.1**	**Dam (LR)**	**26 mons**	**Thu 05/10/23**	**Fri 12/12/25**
65		**1.3.9**	**Pothead Yard**	**15 mons**	**Fri 17/07/26**	**Thu 21/10/27**
69		**1.3.10**	**Reservoir Filling**	**3 mons**	**Wed 08/12/27**	**Wed 08/03/28**
71		**1.3.11**	**Testing and Commissioning**	**6 mons**	**Tue 25/04/28**	**Wed 25/10/28**
72		1.3.11.1	Water conductor filling	2 mons	Tue 25/04/28	Fri 23/06/28
73		1.3.11.2	Unit 1	1 mon	Mon 26/06/28	Tue 25/07/28
74		1.3.11.3	Unit 2	1 mon	Wed 26/07/28	Thu 24/08/28
75		1.3.11.4	Unit 3	1 mon	Fri 25/08/28	Mon 25/09/28
76		1.3.11.5	Unit 4	1 mon	Tue 26/09/28	Wed 25/10/28



Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Critical
Split		External Tasks		Inactive Summary		Manual Summary		Critical Split
Milestone		External Milestone		Manual Task		Start-only		Progress
Summary		Inactive Task		Duration-only		Finish-only		Deadline

PROJECT ORGANISATION

13 CHAPTER 13 - PROJECT ORGANISATION

13.1 PROPOSED SET UP FOR THE PROJECT

Human resources planning determines project roles, responsibilities, timing of inputs and reporting relationships. For successful projects, it requires that the PM consider the organizational structure, staffing schedule and the roles and responsibilities of all staff.

Human resources management requires the monitoring and modification (if necessary) of these plans during project execution for:

(i) Civil works

(ii) Electrical and mechanical works

(iii) Administrative & financial set up

(iv) Others

As this project involves complex technical design assessments and calculations, the project shall engage design engineers supervised by Discipline Managers at the Design office and Field Engineers, Geologist along-with other required personnel headed by the Team Leader in the field during the construction phase.

13.2 PROPOSED ORGANIZATION FOR CONSTRUCTION PERIOD, NUMBER OF STAFF AND EXPENDITURE

The allocation and understanding of job responsibilities in pivotal for successful execution of the project. The construction period shall involve the setting up of a Head office that shall be supported by the field office at the project location.

Table 13-1: Key Project Personnel

Position	Nature of position	Responsibilities and Comments
Chief Engineer (Projects)	Project Director	Oversight of the project
Superintending Engineer	Project Manager	Implementation of the project
Superintending Engineer	Team Leader	Management of design activities on the project. Several may be appointed to mirror any subdivision of the project.
Executive Engineer	Discipline Manager	Coordination of design and site activities of discipline elements. Appointment for each discipline involved.
Assistant Executive Engineer	Designer	Design of discipline elements. Appointment for each discipline

Position	Nature of position	Responsibilities and Comments
		involved.

13.2.1 HEAD OFFICE UNIT

An outline of the potential organization structure is shown below for the key personnel at the office unit

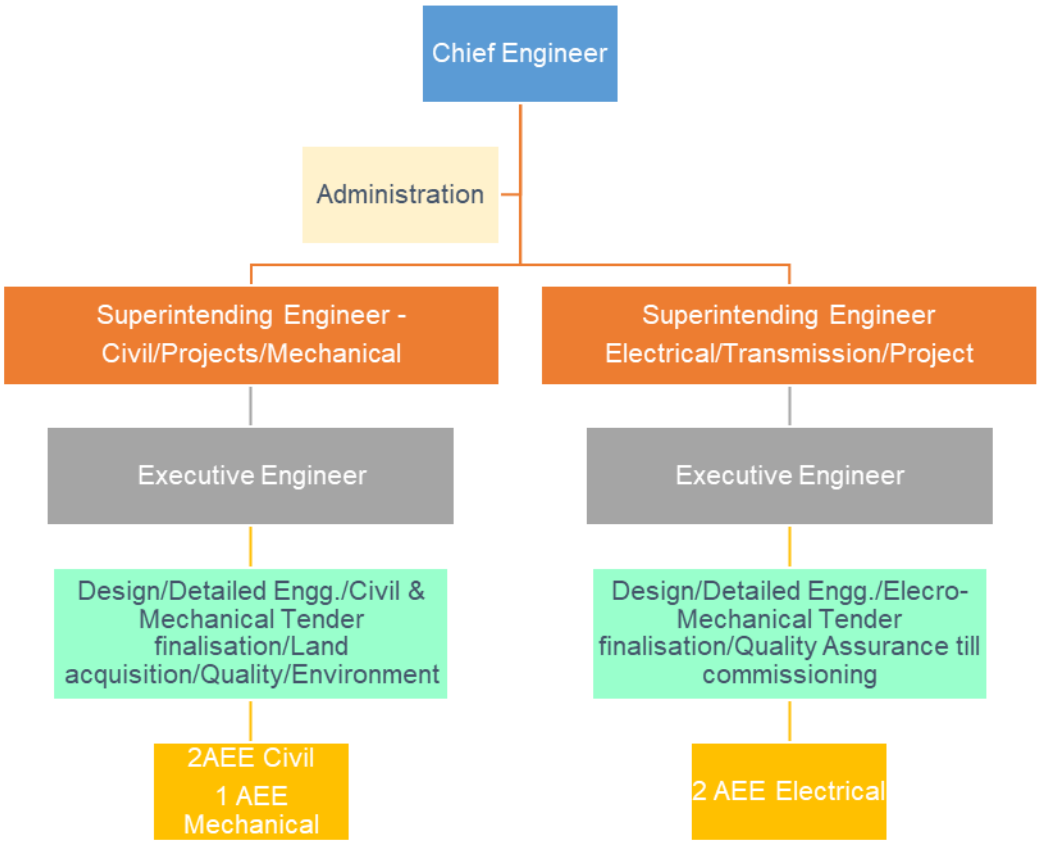


Figure 13-1: Key Personnel - Project Organization chart for Head Office Unit

13.2.2 CHIEF ENGINEER

- Time Management, Cost Management & Over-all project management.

i. Civil & Hydro-Mechanical

- Verification of the design, detailed drawings and methodologies of all the civil works & hydro -mechanical works of the Project.
- Tender finalization for the engaged civil works and hydro-mechanical works leading to award of the work.
- Finalizing all the Technical studies
- Resolution of the Technical issues as emerge during the execution of the Project work till the commissioning of the project.
- Monitoring of the project

- Quality assurance.

ii. Electro-Mechanical

- Verification of the design, drawings and methodologies of E & M works of the Project.
- Tender finalization for the engaged E & M works leading to award of the required project work.
- Assessment and closing of engaged technical issues.

1. Superintending Engineer

i. Civil & Hydro-Mechanical

- Finalization of the Design and detailed drawings and methodologies of all the civil & hydro-mechanical works – Pressure shaft System, Power House & appurtenances and Tail Race System.
- Tender scrutiny for the civil works & hydro-mechanical works and award of work.
- Assessment of the Technical studies & Technical issues that emerge during the execution of the Project work till the commissioning of the project.
- Monitoring of the project & Quality assurance of the engaged works

2. Executive Engineer With supplementary Assistant Executive Engineers

I. Civil & Hydro-Mechanical

- Assessment of the Design, detailed drawings and methodologies of all the civil & hydro-mechanical works – Pressure shaft System, Power House appurtenances and Tail Race System.
- Examination and assessment of the Tender for the civil works & hydro-mechanical works and corresponding award of work.
- Examination and assessment of the Technical studies & Technical issues till the commissioning of the project.
- Monitoring of the project & Quality assurance
- Land acquisition, Forest area assessment and other information exchange

3. Superintending Engineer

i. Electro-Mechanical

- Examination and assessment of the design, drawings of electrical & mechanical works
- Tender closure for the electrical & Mechanical works and corresponding award of the work.
- Engagement and assessment of the technical issues

4. Executive Engineer With supplementary Assistant Executive Engineers

i. Electro-Mechanical

- Examination and assessment of the design, drawings and methodologies of electrical & mechanical works

- Evaluation of tender for the electrical & Mechanical works and corresponding award of the work.
- Engagement and assessment of the technical issues

13.2.3 FIELD UNIT

An outline of the potential organization structure is shown below for the key personnel at the field unit.

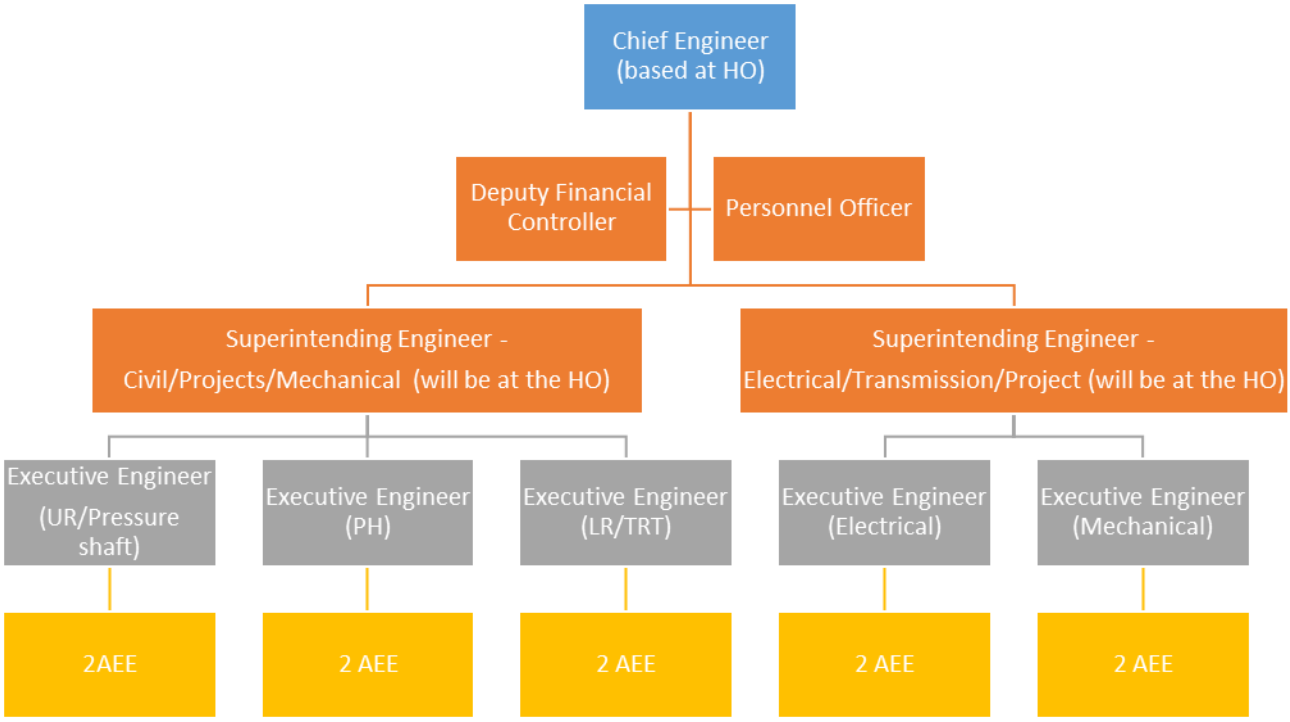


Figure 13-2: Key Personnel - Project Organization chart for Field Unit

1. Superintending Engineer

i. Civil & Hydro-Mechanical

- Management of execution and advisory control of implementation as per the drawings and quality assurance for all the civil & hydro – mechanical works in along-with administration works.
- He will be assisted by three Executive Engineers /Civil, One Deputy Financial Controller and One Personnel Officer with supporting staff.

2. **Executive Engineer**

i. Civil & Hydro-Mechanical

- Implementation of the civil works of Pressure shaft System
- EE will be assisted by two Assistant Executive Engineers and supporting staff

3. Executive Engineer

i. Civil & Hydro-Mechanical

- Implementation of all the civil works of Power House and appurtenant works.

- EE will be assisted by two Assistant Executive Engineers and supporting staff

4. Executive Engineer

i. Civil & Hydro-Mechanical

- Implementation of all the civil works of Tail Race System
- EE will be assisted by two Assistant Executive Engineers and supporting staff

5. Deputy Financial Controller

- Accountable for all the financial matters pertaining to this Scheme.
- Personnel will be assisted by one Accounts Officer & one Assistant Accounts Officer and supporting staff.

6. Personnel Officer

- Accountable of all the administration works.
- He will be assisted by Assistant Personal Officer with supporting staff.

7. Superintending Engineer

i. Electro-Mechanical

- The inception of the position shall be conceptualized after the receipt of Turbo-generator & accessories and other equipment, erection of Turbo-generator control equipment and machineries, .Switchyard equipment and also transport of machineries and equipment.

8. Executive Engineer

i. Electro-Mechanical

- Personnel shall be engaged in and shall be responsible for erection of generating control equipment and machineries. Switchyard equipment and transport of machineries and equipment.
- The Executive engineers/ Electrical & Mechanical will be assisted by two Assistant Executive Engineers/ Electrical and Two Assistant Executive Engineers/ Mechanical and supporting staff.

13.3 PROPOSED ORGANIZATION FOR PRE-CONSTRUCTION PERIOD

The Pre-construction period shall engage only the Head office/Office personnel for evaluation and assessment of the studies under scrutiny for potential construction options keeping in view the techno-commercial viability of the project/scheme.

13.4 PROPOSED ORGANISATION FOR OPERATION PERIOD

The key personnel anticipated to be engaged during the operation period are as listed below and costing has been depicted correspondingly.

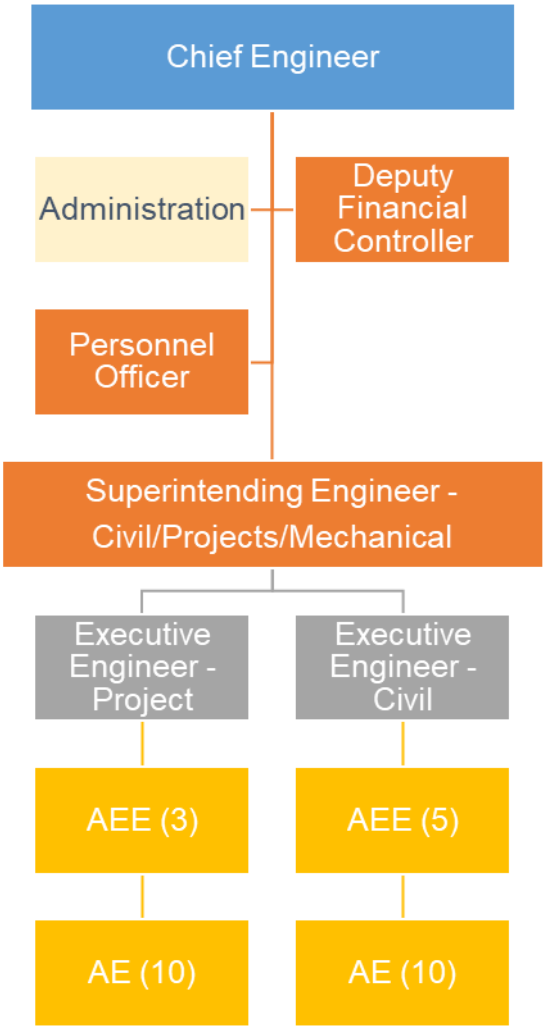


Figure 13-3: Key Personnel - Project Organization chart during Operation

13.5 CONSULTANTS

Consultants shall be on - boarded as deemed essential on the culmination of the project scheme. Below category of consultants may be considered as per the requirement:

1. Project Management Consultant
2. Owner Engineer
3. Detailed Engineering Design Consultant

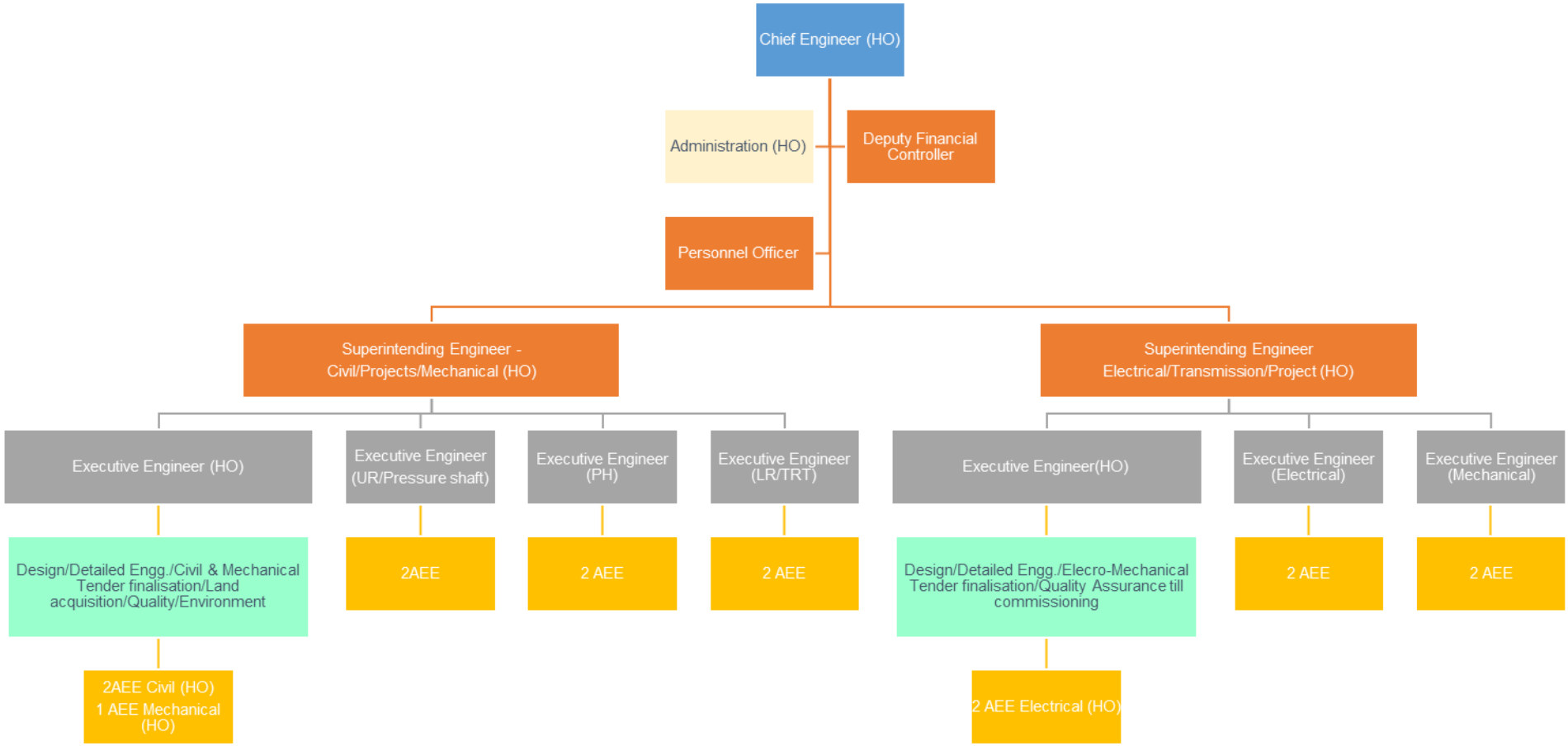


Figure 13-4: Key Personnel - Project Organization chart for Construction

(HO) means stationed at head office

INFRASTRUCTURAL FACILITIES

14 CHAPTER 14 - INFRASTRUCTURAL FACILITIES

14.1 ACCESS ROADS

(i) Roads to the project

The proposed Somasila Pumped Storage Project is located in the Gopavaram Mandal, of the Kadapa District of Andhra Pradesh. The project area is very well connected with the existing network of road as the project area is located 75 km from District headquarters Kadapa.

There is a good network of roads connecting all the Mandals in the District Headquarters. The major roads meeting at Kadapa (District Headquarters) are

1. Kurnool-Kadapa-Chittoor State Highway
2. Kadapa-Madras State Highway
3. Kadapa-Vempalle
4. Kadapa-Sidhout

Project area is well connected with National Highway no. 67 which is bifurcating from NH 565 near Nellore city.

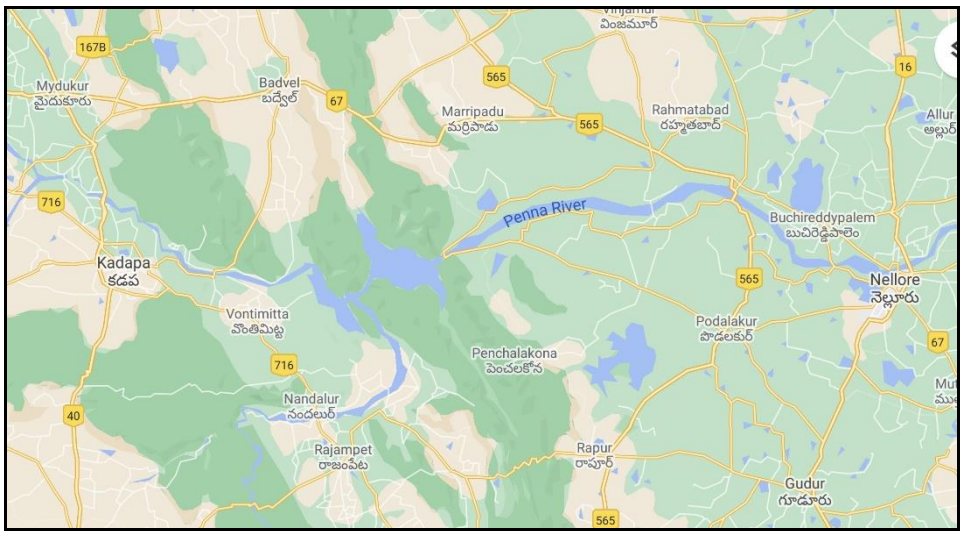


Photo 14-1: Road network near Project Site

The existing highway may require upgrading/improvement for the E&M equipment's considering its transportation and other heavy items of machinery and construction materials.

(ii) Roads in the project area

From the existing network of road, a village road is bifurcating towards the project area from National Highway 67 (Bellary – Nellore road), which is all weather road up to village Brahmanapalli.

Project roads have been planned from the existing village road and internal project road network is planned to connect various project component, work shop area, facility area, etc.

Sr. No.	Description		Length (m)	Remarks
	From	**To**		
1	Existing Village Road	Pothead Yard & Cvt Portal	2608	
2	Pothead Yard & CVT Portal	Working Area Facility-4	1183	Via Working Area Facility-4
3	Lower Reservoir	Construction Adit-2 Portal	2431	
4	Lower Reservoir	Upper Reservoir	9725	
5	Branch LR To UR	Working Area Facility-1	1578	
6	Branch LR To UR	Construction Adit-3 Portal	780	
7	Upper Reservoir		1643	Around Upper Reservoir
8	Lower Reservoir		4499	Around Lower Reservoir
		Total	**24447**	

Table 14-1: Details of Internal Roads

For construction and inspection during operations of reservoir area, it is proposed that the roads along the reservoir periphery will also be developed. The proposed road will be helpful during operational stage to take up any repair and maintenance works pertaining to Dam and Intake structure.

Apart from the above, five nos. of working facility areas have also been identified based on the desk study of topographical map. The validation of these facility areas is proposed to be taken up during the DPR stage.

These roads and facility areas have been marked and are furnished in the **Volume – III** in **Drg. No. 7061601-FSR-1001.** Identification of suitable location for Batching plants, crushing plants, dumping area, Labour colonies, office buildings and colonies will be taken up during DPR stage.

14.2 RAIL HEAD

The nearest rail head is Kadapa which is about 75 km from Project site and with loading and unloading facility. The Mumbai–Chennai line, one of the busiest lines in the south coast region, passes through Kadapa railway station. It is one of the A category railway stations in South Coast Railway zone under Guntakal railway division. Heavy machinery and equipment may be planned for transportation up to

these rail heads. Sheds will also be required to store electrical equipment and other equipment until it is transported to the site of works. Space for storage of cement may also be required.

14.3 PORT FACILITIES, (AS APPLICABLE)

The nearest sea port is Krishnapatnam Port and is about 140 km from the project site. Steel liner plates, heavy machinery and equipment may also be planned for transportation up to this port. Store yards/sheds will also be required to store transported items/equipment until it is transported to the site of works.

14.4 CONSTRUCTION POWER REQUIREMENT

During construction of project, various equipment's and machineries will be electrically driven and power will also be required for project illumination, for batching and crushing plants, tunnel ventilation, office buildings, Project colonies, labour camp, fabrication yards, store yards, etc. Generally, assessment of power requirement for the above is calculated during DPR stage. However, based on experience of other similar project it is expected that the demand of Construction power will be around 3-4 MW. It is proposed that the construction power will be taken from the nearby sub-station and depending up on the power availability use of Diesel generators will be decided.

14.5 POWER SUPPLY FACILITIES

An 11 kV line from 132/33 kV substation at Chilakalamarri has been considered to meet the construction power requirement for the execution of the project. A 15-20 km long transmission line will be constructed from the Chilakalamarri sub-station to the site of the Somasila Pump Storage Project.

14.6 TELECOMMUNICATION FACILITIES REQUIRED DURING CONSTRUCTION AND AFTER COMPLETION OF THE PROJECT

The different work sites of the Project, offices, stores, laboratories, workshops and residence etc. will be connected through a telecommunication network. The telecommunication facilities will also be provided between the project area and the outside. An internal automatic telephone exchange (EPABX) with 100 lines capacity will be provided for the communication within and outside the project. All-important sites of work, offices and residences of senior officers will be connected by telephone.

The powerhouse and permanent colonies will also be provided with a CHF wireless link to keep contact with other power stations and sub-stations in the grid. Presently, the cellular network with 4G connectivity are available in the project area.

14.7 PROJECT COLONIES / BUILDINGS

There are small villages around project area with basic facilities of health care, schooling, market, postal and telephone communication.

These facilities cater to the needs of a very small population and would be inadequate for the project personnel. It is therefore necessary to plan additional housing, offices, recreation and store facilities etc. for meeting the increased requirements of the project.

Residential quarters are required to be constructed for the staff deployed on the execution of the project. Sufficient space for the accommodation of contractor staff would be required as also for their workshop and plant areas.

14.8 OTHERS

For the storage and handling of explosives required for the drilling and blasting operations, permanent magazines and site magazines will be made by the project Contractors for which necessary approvals will be taken by the Project Developer from the concerned authorities. Explosive vans will be used for the transport of explosives from the magazine to the work sites. All safety codes and regulations prescribed by the central and state government in this respect will be followed and magazines will be suitably guarded around the clock.

With safety being an essential job requirement, adequate arrangements for lighting, security will be made in the project area. Adequate preventive measures against accidents will be taken as prescribed in various IS codes. The project work sites will have restricted entry and visitors will only be allowed on permits issued by the relevant authority. All work force and other personnel will carry identity cards and passes which will be checked at the entry check posts provided at suitable places.

ENVIRONMENTAL & ECOLOGICAL ASPECTS

15 CHAPTER 15 - ENVIRONMENTAL AND ECOLOGICAL ASPECTS

15.1 INTRODUCTION

River valley projects are among the most sensitive of all development projects in terms of pervasively of their influence in altering environmental resources, since these create a major alteration in the hydrologic regime of the watershed involved. The purpose of environmental impact assessment of the proposed Somasila pumped storage project is to identify and evaluate the nature, magnitude and significance of the potential adverse environmental impacts arising during construction and operation of the project. In order to identify and evaluate the anticipated environmental impacts during construction and operation phase of the proposed Irrigation Project, detailed Environmental Impact Assessment (EIA) study will be carried out as per EIA Notification 2006 and amendments thereafter. This chapter contains an initial screening of the project.

15.2 METHODOLOGY FOLLOWED FOR SCREENING

Environmental assessment is a detailed process, which starts from the conception of the project and continues till the operation phases. The steps for environmental assessment are, therefore, different in different phases. The first step for environmental assessment is known as screening and scoping. The present study Environmental Screening and Scoping is a preliminary study of Environmental Impact Assessment and is being conducted to identify hotspots, categorization of the project, preliminary identification of potential environmental impacts and for providing recommendations for integrating environmental measures into design. This study is a part of feasibility of the project in accordance with the Terms of Reference.

The screening process mainly consists of following activities:

1) Study of background information on project
2) Study of Applicable Policies, Legal and Institutional Setup
3) Identification of data gap
4) Reconnaissance survey of the project impact zone
5) Collection of Secondary data on baseline environment – physical, biological and socio-cultural
6) Identification of Critical Parameters
7) Preliminary identification of environmental impacts
8) Provision of Environmental Management Plan as a future course of action

15.2.1 STUDY OF BACKGROUND INFORMATION ON PROJECT

First task is to study the project documents to have the understanding of the project objectives, its main components, its boundary etc. Unless the project is well understood, its different impacts on environment and social issues cannot be properly identified. For detailed scope of work, contract document has been studied.

15.2.2 POLICY, LEGAL, ADMINISTRATIVE AND STATUTORY FRAMEWORK

The environmental consideration in any development process has become a necessity for achieving sustainable development. To achieve these goals, the Ministry of Environment & Forests, Govt. of India, has enacted various acts, legislations, guidelines and standards from time to time. The principal environmental regulatory agency in India is the Ministry of Environment, Forests and Climate Change (MoEFCC), New Delhi. MoEFCC formulates environmental policies and accords environmental clearances (EC) for different projects. EC requirement for this project is described as follows:

- **EIA Notification, 2006 and amendments**

The Environment Impact Assessment (EIA) Notification 2006, Ministry of Environment and Forests, Government of India, came into effect from 14th September 2006. The EIA Notification, 2006 specifies the requirement of prior clearance from MoEF&CC for certain development projects specified under the schedule of the Notification. The projects and activities under the Notification have been classified into two categories- Category A and Category B, based on the spatial extent of potential impacts on human health, natural and man-made resources. As per Schedule of the Notification, the River valley project has been classified under Physical Infrastructure including Environmental Services and is listed under item no. 1(c). Project categorization for River Valley project is as follows:

Project or Activity		Category with threshold limit	
		A	B
1(c)	River Valley projects	(i) ≥ 50 MW hydroelectric power generation; (ii) ≥ 10,000 ha. of culturable command area	(i) < 50 MW ≥ 25 MW hydroelectric power generation; (ii) < 10,000 ha. of culturable command area

Moreover, any project or activity specified in Category B will be treated as Category A if located in whole or in part with in 5 km from the boundary of:

i) Protected areas notified under the Wild Life (Protection) Act, 1972,
ii) Critically Polluted areas as notified by Central Pollution Control Board from time to time,
iii) Eco sensitive areas as notified under section 3 of Environment Protection Act, 1986 such as Mahabaleshwar, Panchangi, Matheran, Pachmarhi, Dahanu, Doon Valley
iv) Inter State boundaries and international boundaries.

Scope of EIA: If any project falls under Category 'A', Comprehensive EIA study need to be carried out and environmental clearance need to be obtained from Expert Appraisal Committee (EAC), MoEF&CC before start of any construction activity. Project falling under Category 'B', Rapid EIA study need to be carried out and environmental clearance need to be obtained from respective State Environmental Impact Assessment Authority (SEIAA) before start of any construction activity.

Categorization of Present Project: The capacity of Somasila pumped storage project is 900 MW (>50 MW), thus falls under 'Category A'. The project attracts the condition of obtaining prior environmental clearance from MoEF&CC.

The other important environmental legislations in India and their applicability in this project are given in **Table 15.1**.

Table 15-1: Key Environmental Legislations

Name	Scope and Objective	Key Areas	Applicability	Operational Agencies/ Key player
Environment (Protection) Act, 1986	To provide for the protection and improvement of environment	An umbrella legislation, supplements pollution laws	This act being an umbrella act is applicable for this project.	Central Govt. nodal agency, MoEFCC can delegate to state departments of environment
Forest (Conservation) Act, 1980, 1988	To consolidate acquisition of common property such as forest, halt India's rapid deforestation and resulting environmental degradation	Regulates access to natural resources, state has a monopoly right over land, categories forests, restriction on de- reservation and using forest for non-forest purpose	The Act is applicable for this project as the diversion of forest land for non-forest purpose will be involved for construction of project components.	State Government and Central Government
Wildlife (Protection) Act, 1972, 1993	To protect wildlife	Creates protected areas (national parks / sanctuaries) categories of wildlife which are protected	This act is applicable for this project. Although the project components are proposed outside the ESZ zone of Sri Penusila Narasimha Wildlife Sanctuary (PNWLS), but the pipeline for the first filling of reservoir will be laid through the PNWLS.	Wildlife Advisory Boards, Central Zoo Authorities
Water (Prevention and Control of Pollution) Act, 1974, 1988	To provide for the prevention and control of water pollution and enhancing the quality of water	Control sewage and industrial effluent discharges	The project requires Consent to Establish from the State Pollution Control Board under Water (Prevention and Control of Pollution) Act of 1974.	Central and State Pollution Control Boards

Name	Scope and Objective	Key Areas	Applicability	Operational Agencies/ Key player
Air (Prevention and Control of Pollution) Act, 1981, 1987	To provide for the prevention and control of air pollution	Controls emission of air pollutants	The above act is applicable for this project as emission of pollutants in ambient air will be involved during construction phase.	Central and State Pollution Control Board
The Noise Pollution (Regulation and Control) Rules, 2000	To regulate and control noise levels to prevent their adverse effects on human health and psychological wellbeing of the people.	Controls noise levels at industrial, commercial and residential or silence areas	The act will be applicable for this project as generation of noise will be there during construction phase.	Central and State Pollution Control Board
National Water Policy, 2012	Legislation needed in view of inequalities in distribution and lack of unified perspective in planning, management and use of water resources with due consideration to environmental sustainability and holistic benefit to the people.	To recognize and consider while planning the environmental needs of aquatic eco-system, wetlands and embanked flood plains besides adaptation to strategies to provide a mechanism for dealing with increased variability due to climate change.	This policy will be applicable for this project.	State and Central Government
The Ancient Monuments and Archaeological Sites and Remains Act 1958	Area within the radii of 100 m and 300 m from the “protected property” are designated as “protected area” and “controlled area” respectively.	No development activity (including building, mining, excavating, blasting) is permitted in the “protected area” and development activities likely to damage the protected property are not	There is no archaeologically notified area in and around the project site. Therefore, no such clearance is required for his project.	Archaeological Survey of India (ASI) / State Directorate of Archaeology

Name	Scope and Objective	Key Areas	Applicability	Operational Agencies/ Key player
		permitted in the "controlled area" without prior permission of the ASI.		
Construction & Demolition Rule, 2016	The rules shall apply to every waste resulting from construction, re-modelling, repair and demolition of any civil structure of individual or organisation or authority who generates construction and demolition waste such as building materials, debris, rubble	Collection, segregation of concrete, soil and others and storage of construction and demolition waste generated	The project will be covered under service providers, thus this act will be applicable for this project.	Concerned local authority
Hazardous and Other Wastes (Management and Trans-boundary Movement) Rules, 2016	These rules shall apply to the management of hazardous and other wastes as specified in the Schedules to these rules with some exclusions.	Storage and handling of hazardous and other wastes	The project will be covered under this act for use of used oil, bitumen and maintenance of the machines.	Concerned local authority
Solid Waste Management Rules, 2016	These rules shall apply to every urban local body, State and Central government organisations to every domestic, institutional, commercial and any other	Proper handling and dispose of solid wastes.	The project will be covered under this rule for management of waste generated from the labour camps.	Respective State government

Name	Scope and Objective	Key Areas	Applicability	Operational Agencies/ Key player
	non-residential solid waste generator.			
EIA Notification 14th Sep 2006 and amendment thereof	Environment Impact Assessment	Environmental Protection	Environmental Clearance is required to be obtained from MoEF&CC for this project	MoEF&CC / SEIAA
Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013	To address concerns of farmers and those whose livelihoods is dependent on land being acquired and at the same time facilitating land acquisition in a timely and transparent manner and for ensuring comprehensive package for the land owners for calculation of market value of the land besides comprehensive rehabilitation and resettlement package for land owners.	The Act aims to minimize displacement and other negative impacts originating due to any kind of projects.	The land requirement and identification of ownership of land is still under process. Thus, applicability of RTFCTLARR Act will be assessed at a later state during preparation of detailed EIA study.	Central and State Government

Clearances and permissions required to be obtained for this project are summarised in **Table 15.2**.

Table 15-2: Clearances and Permissions Required for the Project

Sl. No.	Type of Clearance / Permission	Statutory Authority	Applicability	Project stage	Responsibility
1.	Environmental Clearance	MoEF&CC, GoI	The project is falling under Category A as per EIA Notification 2006 and amendments	Prior to start of construction	Project Proponent
2.	Forest Clearance	MoEF&CC, GoI	The project requires diversion of forest areas for non-forest purposes under Forest (Conservation) Act,1980	Prior to start of construction	Project Proponent
3.	Wildlife Clearance	National Board of Wild Life	Laying of pipeline is required for filling of reservoir within the Penusila Narasimha Wild Life Sanctuary	Prior to start of construction	Project Proponent
4.	Consent to establish and consent to operate under Water Act, Air Act and Authorization under Hazardous Wastes Rules	Andhra Pradesh Pollution Control Board (APPCB)	For establishment and operation of construction camp, construction plant, crusher, batching plant etc.	Pre-construction and Construction stage (Prior to initiation of any work)	Contractor
5.	Permission to withdraw water for construction from surface water sources	Water Resource Department, Govt. of Andhra Pradesh	Use of surface water for construction	Construction stage (Prior to initiation of any work)	Contractor

Sl. No.	Type of Clearance / Permission	Statutory Authority	Applicability	Project stage	Responsibility
6.	Permission to withdraw ground water for construction	Central Ground Water Board	Extraction of ground water	Construction stage (Prior to initiation of any work)	Contractor
7.	Permission for storage, handling and transport of hazardous materials	Andhra Pradesh Pollution Control Board (APPCB)	Manufacture, storage and import of Hazardous Chemical	Construction stage (Prior to initiation of any work	Contractor
8.	Explosive License	Chief Controller of Explosives	For storing fuel oil, lubricants, diesel etc. at construction camp	Construction stage (Prior to initiation of any work)	Contractor
9.	Pollution Under Control (PUC) Certificate for vehicles for construction under Central Motor and Vehicle Act 1988	Ministry of Road Transport and Highways, Govt. Of India	For all construction vehicles	Construction stage (Prior to initiation of any work)	Contractor
10.	Labour license Licenses and permissions under Factories Act and Labour Law	Labour commissioner office, Govt. of Andhra Pradesh	Engagement of Labour	Construction stage (Prior to initiation of any work)	Contractor

15.2.3 IDENTIFICATION OF DATA GAP

After desktop study of all available documents, identification of data gaps is an important step before going to field visit. Once data gap is identified, the same can be collected during the reconnaissance survey.

15.2.4 RECONNAISSANCE SURVEY OF THE PROJECT IMPACT ZONE

A reconnaissance site visit has been conducted by SMEC along with the representative of NREDCAP for visualization of Somasila project site and collection of secondary data and screening between 8th to 13th March 2021 to identify the hot spot and sensitive receptors in and around the project site.

15.2.5 COLLECTION OF DATA ON BASELINE ENVIRONMENT

After having the background information about the project and its environmental aspects from legal and policy points along with a list of identified data gaps, the next step involves site visit and collection of data from secondary sources. The relevant topographic sheets (D44H3, D44H4, D44H7 and D44H8) for the project were also collected from Survey of India.

Primary data shall also be collected from the study area for analysis of ambient air quality, ambient noise, surface and ground water quality and soil quality at a later stage as per the approved ToR by the MoEF&CC.

The secondary data has been collected under 3 sections – Physical environment, Biological environment and Socio-cultural environment. Details of collected secondary data are provided in the following paragraphs:

A. PHYSICAL ENVIRONMENT

Topography, Geography, Physiography and Geology of the project District have been provided in Chapter 1 of this report.

15.2.5.1 CLIMATE

The climatological data of Kadapa district is detailed in **Table 15.3.**

Table 15-3: Climatological Details of the Study Area (Kadapa District)

Based on observations from 1981 - 2007

Month	Monthly Max Temp (°C)	Monthly Min Temp (°C)	Relative Humidity (%)	Monthly Total Rainfall (mm)	Wind Speed (km/h)
Jan	34.6	16.1	61.5	2.6	6.5
Feb	37.9	17.9	52.5	0.8	6.4
Mar	41.6	21.2	44	6.6	6.6
Apr	43.1	23.6	42	16.5	6.8
May	43.3	23.8	44.5	51.6	6.8
June	40.8	23.5	54	76.9	6.8
July	38	23.5	59.5	122.7	7
Aug	36.5	23.1	62.5	119	6.8
Sep	36.9	22.5	65	156.2	6.6
Oct	35.8	21	68.5	139.5	6.2
Nov	33.8	17.5	72	60	6
Dec	32.5	16	69	18.1	6.3
Annual Total or Mean	**43.7**	**14.9**	**58**	**770.4**	**6.6**

Source: *IMD Climatological Table (1981-2010)*

15.2.5.2 DRAINAGE

The important river that drains through the district is Pennar which is perennial and flows in NW-SE direction. Its tributaries Chitravathi, Cheyyair, Papagni, Kundair and Sagileru

are imtermittant in nature. The drainage pattern in general is dendraitic to sub-dendritic and parallel. The drainage is often parallel to sub parallel indicating structural control.

15.2.5.3 GEOMORPHOLOGY

Geomorphologically, YSR District (Kadapa) has been classified into three units based on relief, slope factor and soil. The three groups are (i) Structural land forms (ii) Denudational land forms and (iii) fluvial land forms.

15.2.5.4 SOIL TYPE OF THE DISTRICT

Kadapa district is endowed with Red loamy, Red sandy, Red earths and Black cotton soils. Red and black soils ranging from poor to fertile soils. Red soils occupy 53% of the cultivated area and are mostly situated in L.R.Palli, Rayachoty, Rajampet, Pulivendla and Kodur Mandals. These soils have a low nutrient status. Black soils covered nearly 47% of the cultivated area and are generally associated with clay content located in Muddanur, Jammalamadugu, Proddatur, Mydukur, Pulivendla and Kamalapuram Mandals.

15.2.5.5 LAND USE OF THE DISTRICT

As per CWGB report of the district (2012), Forest land is 5,00,961 ha, Barren and uncultivated area is 2,22,099 ha Cultivable waste land is 46,013 ha, Current fallow land is 1,35,935 ha and Net area sown is 3,52,762 ha.

Land use and land cover of the project study area will be assessed from satellite image and during detailed study, map will be prepared and the same will be provided in the EIA report along with the percentage of different land uses.

15.2.5.6 SEISMIC HAZARD

According to GSHAP data, the state of Andhra Pradesh falls in a region with low to moderate seismic hazard. Historically, parts of this state have experienced seismic activity in the M5.0-6.0 range. The seismic hazard map of India was updated in 2000 (6) by the Bureau of Indian Standards (BIS). According to this map, the state of Andhra Pradesh lies in Zones II and III. The south-eastern districts of Chitoor, Cudappah and Nellore have been placed in Zone II.

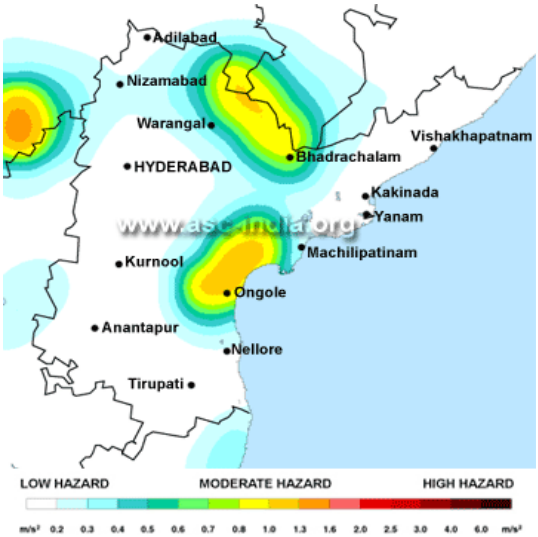


Figure 15-1: Seismic Hazard Map of India

15.2.5.7 HYDROGEOLOGY

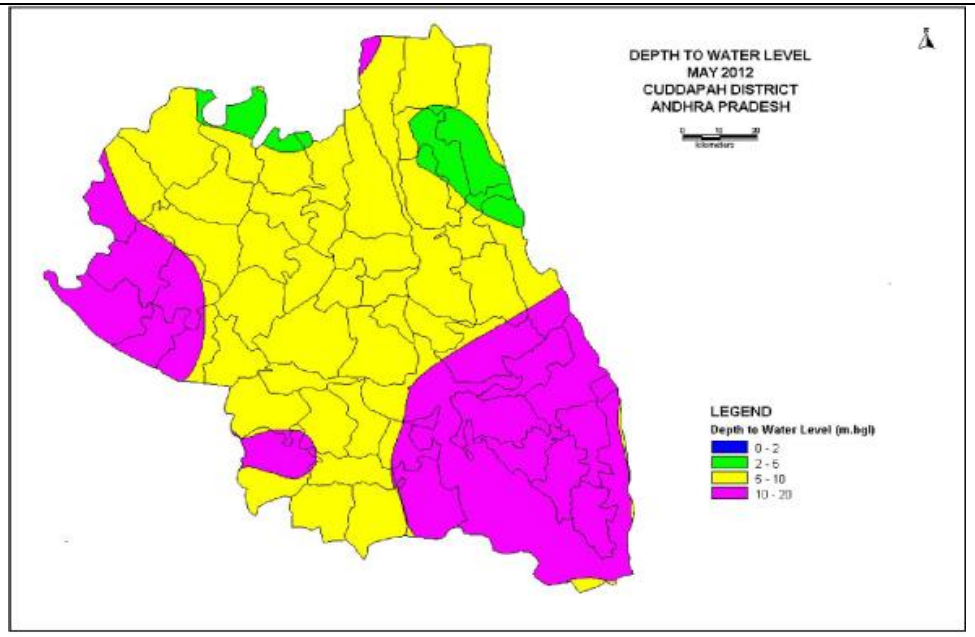
The YSR District (Kadapa) is underlain by various rock types of different age groups ranging from Archaean to Recent. Ground water in Archaean Crystalline rocks: These rocks consists mostly granite gneisses, migmatites and generally lack primary porosity. However, development of secondary porosity through weathering and fracturing gives scope for occurrence of ground water. Ground water occurs under unconfined conditions in weathered portion and under semi-confined conditions in joints and fractures. The ground water in weathered zone is developed by large diameter (6 m) dug wells and dug-cum-bore wells. The thickness of the weathered zone is generally upto 10 m in most of the area. The ground water in fractured portion is developed through construction of shallow/ deep bore wells.

15.2.5.8 DEPTH TO WATER LEVEL

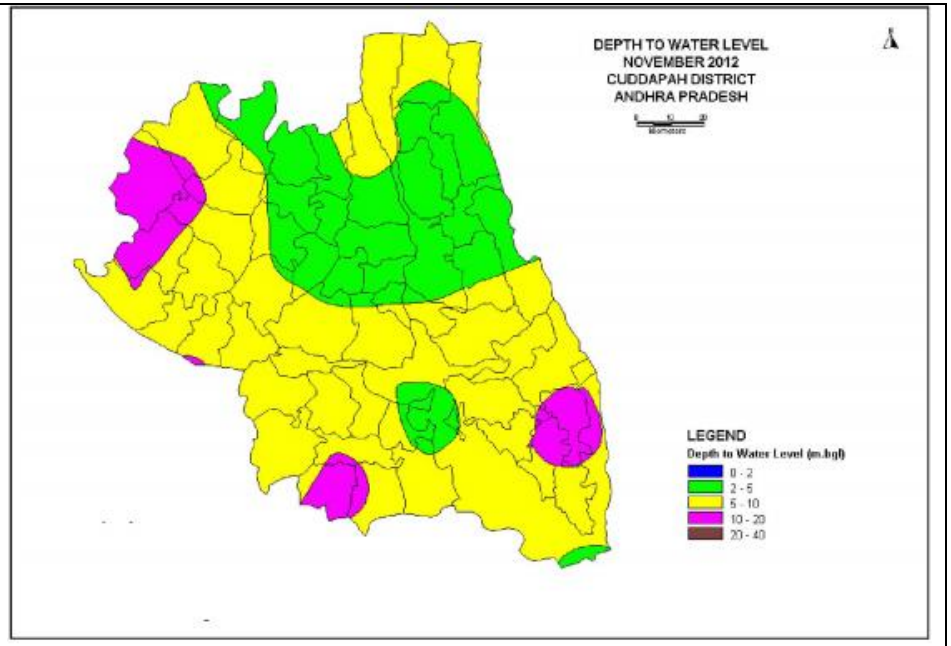
Ground water levels are monitored from a network of 29 hydrograph stations in the district which are being monitored four times in a year i.e. in the months of January, May, August and November. The depth to water level distribution maps prepared for May 2012 (Pre-monsoon) and Nov 2012 (Post-monsoon) are shown in **Figure 15.2**.

Pre-monsoon water levels: The depth to water level during pre-monsoon (2012) range from 3.13 m to 17.35 m bgl. The shallow water levels of 2 to 5 m are observed in north east and north western part of the district. The depth to water levels between 5-10 m are observed in majority of the area. Deeper water levels of more than 10 m bgl are observed in the northwestern and south eastern parts of the district.

Post-monsoon water levels: The depth to Water level range from 0.85 to 12.27 m bgl during the post monsoon period (2012). The shallow water levels of less than 5 m are observed in northern and southern part of the district. The depth to water levels between 5-10 m are observed in major part of the area. The depth to water levels 10 -20 m are observed in north western and south eastern part of the district.



Depth to Water Level Map of YSR District (Kadapa), A.P (May 2012)



Depth to Water Level Map of YSR District (Kadapa), A.P (Nov-2012)

Source: Ground Water Brochure, YSR District (Kadapa), Andhra Pradesh, September 2013

Figure 15-2: Depth to Water Level Map of YSR District (Kadapa)

15.2.5.9 WATER ENVIRONMENT

Surface and ground water quality analysis will be done covering the project study area after the approval of ToR during detailed EIA study.

15.2.5.10 AIR ENVIRONMENT

Baseline monitoring of ambient air quality will be conducted covering the project study area after the approval of ToR during detailed EIA study.

15.2.5.11 NOISE ENVIRONMENT

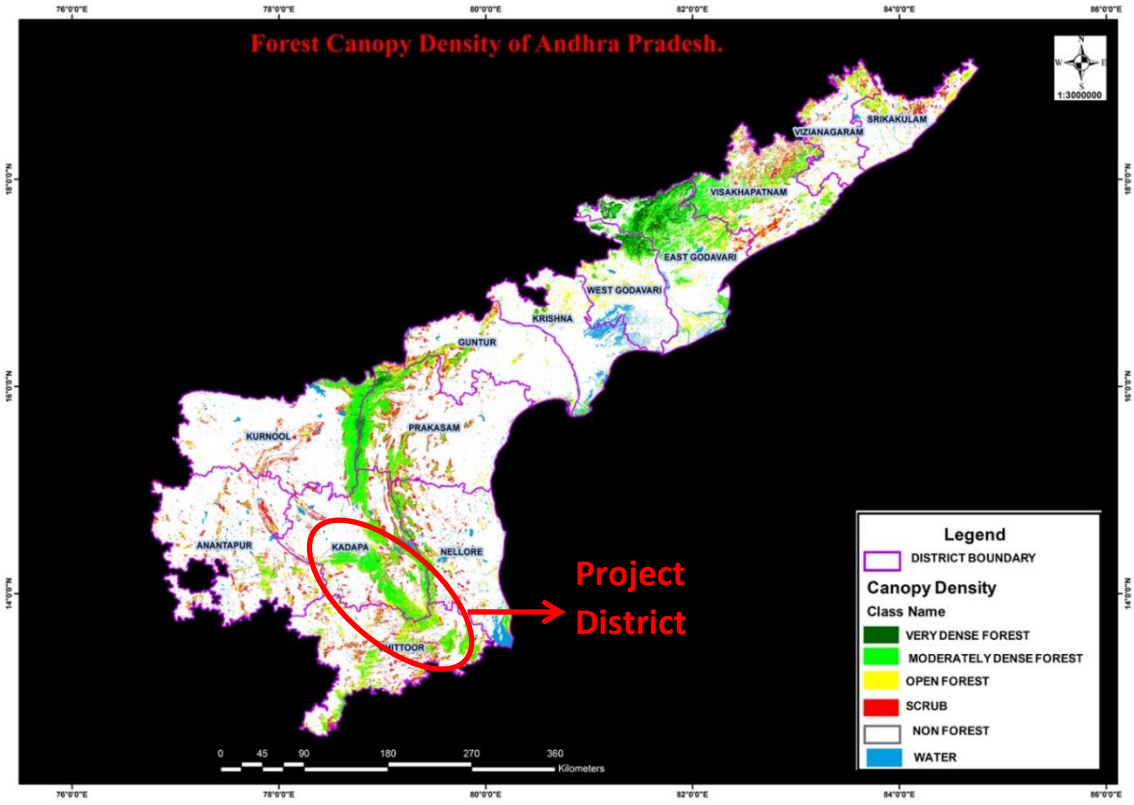
Baseline monitoring of ambient noise level will be conducted covering the project study area after the approval of ToR during detailed EIA study.

B. Biological Environment

Andhra Pradesh has reported extent of recorded forest area (RFA) 37,258 sq km which is 22.86 % of its geographical area. The reserved, protected and unclassed forests are 85.78 % and 13.60 % and 0.62 % of the recorded forest area in the State respectively.

15.2.5.12 FOREST COVER

Forest Cover in the State is 29,137.40 sq km which is 17.88 % of the State's geographical area. In terms of forest canopy density classes, the State has 1,994.22 sq km under Very Dense Forest (VDF), 13,938.36 sq km under Moderately Dense Forest (MDF) and 13,204.82 sq km under Open Forest (OF). Forest density of the state showing project district is presented in **Figure 15.4**.



Source: http://forests.ap.gov.in/

Figure 15-3: Forest density of the state

15.2.5.13 BIODIVERSITY

Andhra Pradesh forests are endowed with varied forest types, unique eco-systems, diverse habitats and biodiversity rich areas. It's store house of several unique and endemic flora and fauna which includes Pterocarpus santalinus (Red Sanders), Cycas beddomi, Shorea tambaggia, Syzizium alternifolium, Terminalia pallida etc. It has fauna like Tiger, Gaur (Indian Bison), Great Indian Bustard, Lesser Florican, Jerdon's Courser, Golden Gecko, other avifauna like Flamingo, Pelican etc. It has the largest Tiger reserve in the country i.e Srisailam Tiger reserve, and the second largest Mangrove eco-system in the country (Godavari and Krishna Estuaries.)

15.2.5.14 WILDLIFE

Andhra Pradesh has 3 National Parks and 13 Wildlife Sanctuaries covering an area of 7,311.08 sq km which is about 4.49% of the geographical area of the State. It has fauna like Tiger, Gaur (Indian Bison), Great Indian Bustard, Lesser Florican, Jerdon's Courser, Golden Gecko, other avifauna like Flamingo, Pelican etc. It has the largest Tiger reserve in the country i.e. Srisailam Tiger reserve and the second largest Mangrove eco-system in the country (Godavari and Krishna Estuaries.) Wildlife & Eco-tourism.

C. SOCIO-CULTURAL ENVIRONMENT

15.2.5.15 DEMOGRAPHY

According to the 2011 census of India, Kadapa has a population of 28,84,524 (Male: 14,54,136 and Female: 14,30,388). Kadapa district has a sex ratio of 984 females for every 1000 males, and a literacy rate of 67.88%. The urban population is 9,83,736 whereas rural population is 19,00,788. The decadal growth rate of 1991-2001 is 10.87%. The population density is 188 (persons/sq.km). Its population growth rate over the decade 2001–2011 was 10.87%.

15.2.5.16 LANGUAGES

Telugu and Urdu are the official languages in Kadapa. Hindi is also spoken in many areas of the city among North Indian traders. English is gaining popularity day by day in the city due to the development. Urdu is also spoken throughout the district especially by its large Muslim population live in a large number.

15.2.5.17 CULTURAL SIGNIFICANCE

The district in its long history acquired composite culture. The people are hard-working and very hospitable. The population of the District consists of all important religious groups but the Hindus are in predominant number. In addition to Islam, the district came under the influence of Jainism and Buddhism also during different periods as Danavulapadu and Nandalur ancient sites suggest. Christianity was introduced into the district in the first half of eighteenth century by the Jesuit mission. Due to influence of different religions and beliefs, the people of the district acquired composite culture and secular attitude.

15.2.5.18 ROAD CONNECTIVITY

There is a good network of roads connecting all the Mandals in the District Headquarters. The major roads meeting at Kadapa (District Headquarters) are

5. Kurnool-Kadapa-Chittoor State Highway
6. Kadapa-Madras State Highway
7. Kadapa-Vempalle
8. Kadapa-Sidhout

15.2.5.19 CROPS

A major irrigation sources in the district are K-C canal, the Mydukur and the Chapadu Project, the upper Sagileru and lower Sagileru and the Pincha Projects. Paddy, Groundnut, Red gram, Cotton, Bengal gram are the major Agricultural crops. Mango, Citrus, Banana, Melons and Papaya are the fruit crops. Turmeric, Onion, Chillies, Coriander, Vegetables and Chrysanthemum are other commercial crops grown in the district.

15.2.5.20 ECONOMY

The economy of city is largely based on Agriculture crops like ground nut, cotton, red gram, Bengal gram are grown here and Mining. Being a district headquarters all types of Government departments are situated within the city. For most of the families the source of income is through the Government jobs and Private sector jobs in various departments including Business Shops, Hospitality industry, Marketing. Apart from these, Tourism also forms a part of economy to the city.

15.2.5.21 SETTLEMENT / BUILT-UP AREAS

The project area is devoid of any settlement. Nearest settlement is village Rachayapeta, around 2 kms away from the project area.

15.2.5.22 COMMON PROPERTY RESOURCES

No religious / cultural resources are available in the project area.

15.2.5.23 HISTORICAL/ ARCHAEOLOGICAL SITES

No archeological site listed under Archeological Survey of India, has been identified in close vicinity of the project site.

15.2.6 IDENTIFICATION OF CRITICAL PARAMETERS

Based on the collected site data and initial field investigations, the critical parameters have been recognized for further detailed Environmental Impact Assessment study. As the number of environmental features in the study area increases, the project becomes more sensitive. Special care will be needed for the sensitive zones during designing and construction phase as well and specific mitigation measures will be formulated for adverse impacts during the detailed environmental assessment study.

The identified critical parameters for this project in terms on environment are as follows:

- Forest - submergence, tree cutting

- Wildlife Sanctuary
- Muck dumping

15.2.7 PRELIMINARY IDENTIFICATION OF ENVIRONMENTAL IMPACTS

Attempt has been made to identify and assess the probable impacts on different environmental parameters due to planning, construction and the operation of the proposed development. After studying the existing baseline environmental scenario, initial field surveys, reviewing the process and related statutory norms, the major impacts can be identified and assessed during design, construction and operation phases.

The major impact during Planning and designing phase is related with the private land acquisition (if any), impact on forest/ tree cutting. The impacts during construction phase, in general, have adverse influence on all the environmental attributes. Most of these impacts are short lived and reversible in nature. A proper care is must to minimize the negative impacts, which can facilitate the restoration. Operation phase impacts are continuous in nature. To identify these impacts broadly on physical, ecological and social environment Impact Identification Matrix of potential environmental impacts due to the project and preliminary mitigation measures has been developed and is presented in **Table 15.3**.

Table 15-4: Environmental Impacts Matrix - During Construction Phase

Activities during Construction	Nature of Likely Impacts										
	Local	Regional	Short Term	Long Term	Reversible	Irreversible	Adverse	Beneficial	No Impact	Significant	Insignificant
1. Change in Land Use											
Site Clearing (cutting of trees, shrubs, etc.)	*			*		*	*			*	
Muck Disposal	*			*		*	*			*	
Creation of Submergence area	*			*		*	*			*	
2. Air Quality											
Excavation	*		*		*		*				*
Blasting	*		*		*		*			*	
Operation of DG Sets	*		*		*		*				*
Vehicle Movement	*		*		*		*				*
3. Water Quality											
Sewage from labour camp	*		*		*		*				*
Waste Generation	*		*		*		*				*
Turbid Water from Muck disposal	*		*		*		*				*
4. Water Resources											
Water for Construction									*		
Diversion of water though tunnel	*		*			*	*			*	
5. Noise and Vibration											
Drilling	*		*		*		*				*
Blasting	*		*		*		*			*	
Operation of Construction Equipment	*		*		*		*				*
Vehicular Movement	*		*		*		*				*
6. Land Environment											
Acquisition of Land	*			*		*	*			*	
Muck Disposal	*			*		*	*			*	
Construction of	*			*		*	*			*	

Activities during Construction	Nature of Likely Impacts										
	Local	Regional	Short Term	Long Term	Reversible	Irreversible	Adverse	Beneficial	No Impact	Significant	Insignificant
Approach Road											
Land Contamination by waste and sewage	*		*		*		*				*
7. Terrestrial Flora											
Site Clearing (Cutting of trees and shrubs)	*			*		*	*			*	
Creation of Submergence Area	*			*		*	*			*	
Increased Human Interferences	*		*		*		*				*
Dust Emission	*		*		*		*				*
Muck Disposal	*			*		*	*			*	
8. Terrestrial Fauna / Wildlife											
Site Clearing (Cutting of trees and shrubs)- Habitat destruction	*		*			*	*			*	
Blasting	*		*		*		*			*	
Regular Construction Activities	*		*		*		*			*	
Anthropogenic Pressure in the area	*		*			*	*			*	
9. Aquatic Ecology											
Diversion of Water through diversion tunnel	*			*		*	*			*	
Turbid Water from Muck Disposal Area	*			*		*	*			*	
Sewage from Labour Camp	*		*			*	*				*
Influx of people	*		*		*		*			*	

Activities during Construction	Nature of Likely Impacts										
	Local	Regional	Short Term	Long Term	Reversible	Irreversible	Adverse	Beneficial	No Impact	Significant	Insignificant
10. Socio – economic											
Employment		✱	✱					✱		✱	
Economic Impact		✱		✱				✱		✱	
Cultural Impact		✱		✱				✱			✱
Conflict with local Community	✱		✱		✱		✱				✱

Table 15-5: Environmental Impacts Matrix - During Operation Phase

Activities during operation	Nature of Likely Impacts										
	Local	Regional	Short Term	Long Term	Reversible	Irreversible	Adverse	Beneficial	No Impact	Significant	Insignificant
1. Change in Land Use											
Compensatory Afforestation & Plantation around the Reservoir				✱				✱			
2.Water Quality											
Sewage from Power House & Staff Colony	✱			✱	✱		✱				✱
Waste Generation from Power House & Staff Colony	✱			✱	✱		✱				✱
3.Water Resources											
Changes in Hydraulic Regime	✱			✱		✱	✱			✱	
Erosion and Sedimentation	✱			✱		✱	✱			✱	

Activities during operation	Nature of Likely Impacts										
	Local	Regional	Short Term	Long Term	Reversible	Irreversible	Adverse	Beneficial	No Impact	Significant	Insignificant
4. Noise and Vibration											
Water discharge from tail race tunnel	*			*		*	*				*
Vehicular movement	*		*		*		*				*
5. Land Environment											
Land Contamination by waste and sewage	*			*		*	*			*	
6. Terrestrial Ecology & Wildlife											
Anthropogenic Pressure	*			*		*	*			*	
7. Socio – economic											
Employment		*		*		*		*		*	
Economic Impact		*		*		*		*		*	
Cultural Impact									*		
Health Risk									*		

15.2.8 PROVISION OF ENVIRONMENTAL MANAGEMENT PLAN

A project specific Environmental Management Plan (EMP) will be prepared for avoiding/ reducing/ mitigating/ checking the adverse impacts envisaged during EIA studies on various environmental components during construction and operational phase of the project including cost of implanting the EMP.

15.3 STRUCTURE OF THE EIA & EMP REPORT

The EIA & EMP report will be prepared as per the approved ToR based on MoEF&CC EIA Notification 2006 and amendments thereafter and chapters will also be structured accordingly. Tentative Structure of EIA & EMP report is provided as follows:

Environmental Impact Assessment (EIA) Report

Chapter No.	Chapter Heading
1	Introduction
2	Project Description
2	Analysis of Alternatives
4	Description of the Baseline Environmental Components
5	Socio-economic and cultural Aspects
6	Anticipated Environmental Impacts & Mitigation Measures
7	Additional Studies
8	Project Benefits
9	Conclusion
10	Disclosure of Consultant Engaged

Environment Management Plan (EMP) Report

Chapter No.	Chapter Heading
1	Catchment Area Treatment Plan
2	Green Belt Development Plan
3	Biodiversity Conservation and Management Plan
4	Fisheries Conservation and Management Plan
5	Resettlement and Rehabilitation (R&R) Plan
6	Muck Disposal Plan
7	Fuel Distribution Scheme
8	Dam Break Analysis & Disaster Management Plan
9	Restoration and Landscaping of Working Area
10	Public Health Delivery System
11	Sanitation and Solid Waste Management Plan
12	Water, Air and Noise Quality Management

Chapter No.	Chapter Heading
13	Forest Protection Plan
14	Compensatory Afforestation
15	Environmental Monitoring Programme
16	EMP Budget

COST ESTIMATES

16 CHAPTER 16 – COST ESTIMATE

16.1 INTRODUCTION

Quantity estimates have been worked out based on the drawings developed for various components. This chapter includes the costs of Civil Works, Hydromechanical works, Electrical works and other allied works required for commissioning the project. The estimates cover the direct charges and indirect charges heads. The direct and indirect charges cover the following minor heads:

A) Direct Charges

a. I Works

b. II Establishment

c. III Tools& Plants

d. IV Suspense

e. V Receipt & Recoveries

B) Indirect Charges

a. I Audit and Account charges

b. II Capitalized abatement on land revenue

The cost estimates are based on the feasibility stage design and drawings of the various structures. It is proposed to take up the detailed analysis of rates for principal items of works, rates of construction materials, construction equipment and basic materials etc. during Detailed Project report (DPR) stage. The rates of various items for civil works such as different grades of concrete, steel, excavation, etc have been adopted in the estimate based on Schedule of Rates (SOR:2020-21) Andhra Pradesh. Some rates for minor items and lump sum provisions have been made based on the experience gained on other similar projects. The cost estimate of the Project has been worked out at 2020-21 Price Level.

The project estimate has been framed on the basis of “Guidelines for Formulation of Detailed Project Reports for Hydro Electric Schemes, their Acceptance and Examination for Concurrence”, published by Central Electricity Authority (CEA), New Delhi in March, 2015 and “Guidelines for preparation of Project Estimates for River Valley Projects”, published by Central Water Commission(CWC), New Delhi in March, 1997.

16.2 SUMMARY OF COST UNDER VARIOUS HEADS

The brief summary of allocation of cost under various sub-heads is given in the Table 16.1.

Table 16-1: Cost estimate for the project

Sl.No.	DESCRIPTION	AMOUNT (in Crore)		
		Civil & H-M Works	E & M Works	Total
	DIRECT COST			
I	**WORKS**			
1	A. Preliminary	31.50		31.50
2	B. Land (Cost of land, plantation & NPV)	32.98		32.98
3	C. Works	593.13		593.13
4	J. Power Plant Civil works	543.74		543.74
5	Hydromechanical works	139.12		139.12
6	K. Buildings	24.72		24.72
7	M. Plantation	1.00		1.00
8	O. Miscellaneous	31.50		31.50
9	P. Maintenance during construction	12.61		12.61
10	Q. Special T&P	1.00		1.00
11	R. Communication	16.00		16.00
12	S. E & M works		1260.00	1260.00
13	X. Environment & Ecology	45.00		45.00
14	Y. Losses on stock	3.58		3.58
15	Intake Well cum Pump House & DI Pipeline	99.22		99.22
	Total of I - Works	**1575.10**	**1260.00**	**2835.10**
II	**ESTABLISHMENT COST**	91.26	60.30	151.56
III	**TOOLS & PLANTS**	15.00		15.00
IV	**SUSPENSE**	-	-	
V	**RECEIPTS & RECOVERIES**	-0.25		-0.25
	TOTAL DIRECT COST	**1681.12**	**1320.30**	**3001.42**
	INDIRECT CHARGES	**3.94**		**3.94**
	TOTAL	**1685.06**	**1320.30**	**3005.36**

The above project cost includes 12% GST. The estimated total cost of the project is Rs.3498.08 Crores, including IDC at June 2020-21 price level of SOR of Andhra Pradesh.

16.3 COST ESTIMATION

The estimate covers the cost of A-Preliminary, B-Land, C-Civil Works, J-Power Plant, Civil Works, K-Buildings, M-Plantation, O-Miscellaneous, P-Maintenance, Q-Special T&P, R-Communication, X-Environment & Ecology and Y-Losses on Stock during construction. The cost of electro-mechanical works is considered based on similar project experience. The costs of establishment and general Tools & Plant have also been provided in this estimation. The receipts and recoveries on capital account have been deducted from the total cost of the project. The indirect charges like audit and account charges and capitalized value of abatement of land revenue have also been included in the total estimated cost.

16.3.1 ASSUMPTIONS

The quantities of various items of works under the heads C'-Works' and J-Power Plant and Appurtenances' have been worked out on the basis of Feasibility level drawings. However, there are a few items like curtain grouting, consolidation grouting etc. which are site specific and require further detailed assessment during DPR stage. Certain assumptions in this regard have been made so that quantities of such items of works could be calculated on reasonable basis.

The estimate comprises different schedules covering cost of various components of the project. The schedules have been coded and sequenced in accordance with the guidelines referred earlier. The estimated costs, minor head wise, are summarized below.

16.3.2 I-WORKS

16.3.2.1 A – PRELIMINARY

Provision under this head has been made to cover the expenditure incurred on survey and investigations carried out for the preparation of various project reports. This also includes expenditure likely to be incurred for detailed survey, geological investigation, hydrological and meteorological observations, construction material survey, model tests etc. to be carried out at pre-construction stage and also includes the cost of camp equipment, inspection vehicles, preparation of project report, consultant's fee, design charges etc.

16.3.2.2 B – LAND

Provision under this head has been made to cover the expenditure for acquiring of forest, private and agricultural land, degraded forest / waste-lands etc. required for the construction of infrastructure works, permanent works, rehabilitation cost and compensation for Government / private property and standing crops, solatium charges for compulsory acquisition and establishment charges etc.

16.3.2.3 C – WORKS

Under this head, cost of estimated quantities for reservoirs and diversion structures has been worked out. Lump sum provision has also been made for jungle clearance, hill

slope protection work, instrumentation, construction, joints and seals, dewatering during excavation etc.

Cost towards filling of lower reservoir from existing Somasila reservoir using dedicated pumping arrangement is covered under I works.

16.3.2.4 J-POWER PLANT & APPURTENANT

Under this head the cost of civil works for the components of power plant like Intake structure, Pressure shafts, Power house complex, TRT and Pothead yard is covered. The estimation of construction adits have been taken separately. The respective quantities of underground excavation, open excavation, rock bolting, shotcrete etc have been worked out. Provision of concrete lining and sub structure concrete in Power house has been made.

16.3.2.5 BUILDINGS

Under this head, lump sum cost provision @2% of total cost of C works and J works has been made to cover the expenditure to be incurred both on residential and non-residential buildings.

16.3.2.6 M – PLANTATION

Under this head, lump sum cost of INR 1 crore is considered towards landscaping and plantation required for beautification as necessary on Reservoir, Dam and appurtenances around power house and other important structures.

16.3.2.7 O – MISCELLANEOUS

Under this head, lump sum provision of @2% of total cost of C works and J works has been made to cover the cost of following miscellaneous works:

(a) Capital cost of electrification, Repair and maintenance of electric lines etc.

(b) Water supply, sewage disposal, recreation, medical assistance, communication system, security arrangements, firefighting equipment, inspection vehicles, transport for labour and staff etc.

(c) Other services such as power supply, railway siding, R&M of guest houses and transit camps, photographic instruments, inauguration and foundation stone laying ceremony.

16.3.2.8 P – MAINTENANCE

Under this head, provision has been made to cover the cost of maintenance of all works during the construction. Cost provision of @1% of total cost of C works, J works and K-buildings have been made.

16.3.2.9 Q – SPECIAL T&P

The provision under this head has been made to cover the residual value of the inspection vehicles i.e. capital cost of the equipment less the credit due to resale or transfer of equipment and value recovered during the life of machineries used in the works.

16.3.2.10 R – COMMUNICATIONS

Necessary provision has been made under this head to cover the cost of approach roads, quarry roads, temporary roads in the work area, and bridges, etc.

16.3.2.11 X – ENVIRONMENT & ECOLOGY

The provision under this head has been made on lump sum basis to cover the expenditure for compensatory afforestation, catchment area treatment, maintenance of fuel depots for labour, control of water borne diseases and aquatic growth, etc.

16.3.2.12 Y – LOSSES ON STOCK

Provision has been made under this head on lump sum basis @ 0.25% of the total cost of C-Works, J-Works and K-Buildings only.

16.3.2.13 ELECTRO-MECHANICAL SYSTEM

The provision under this head has been made based on the estimate framed by Central Electricity Authority, which includes cost of generating plant and equipment, Electrical & Mechanical Auxiliary Systems, Generator Transformers, Switchyard Equipment & Structures, other ancillary electrical and mechanical equipment and services.

16.3.2.14 II – ESTABLISHMENT

The provision for establishment has been made under this sub-head @ Rs. 90.00 Crores plus 3.00% of cost exceeding Rs. 1500 Crores, less cost of B-land. For E & M works Rs. 67.50 Crores plus 2.25% of cost exceeding Rs. 1500 Crores of cost has been considered.

16.3.2.15 III – TOOLS & PLANTS

The provision under this head for Civil works has been made on lump sum basis and 0.5% of the Cost of E&M works to cover the expenditure on survey instruments, camp equipments, office furniture and other small tools etc.

16.3.2.16 IV – SUSPENSE

No provision has been made under this head as all the outstanding suspense are expected to be cleared by adjustment to appropriate heads at completion of the project.

16.3.2.17 V – RECEIPT & RECOVERIES

Under this head, estimated recoveries by way of resale of temporary buildings, inspection vehicles, special T&P and electrical installations in power line and Electrical Sub-Stations, have been considered.

16.4 ANNEXURES FOR COST ESTIMATES

The details of the cost estimates are shown in following pages:

ABSTRACT OF COST ESTIMATE

Sl.No.	DESCRIPTION	AMOUNT (in Crore)		
		Civil & H-M Works including GST 12%	E & M Works	Total
	DIRECT COST			
I	**WORKS**			
1	A. Preliminary	31.50		31.50
2	B. Land (Cost of land, plantation & NPV)	32.98		32.98
3	C. Works	593.13		593.13
4	J. Power Plant Civil works	543.74		543.74
5	Hydromechanical works	139.12		139.12
6	K. Buildings	24.72		24.72
7	M. Plantation	1.00		1.00
8	O. Miscellaneous	31.50		31.50
9	P. Maintenance during construction	12.61		12.61
10	Q. Special T&P	1.00		1.00
11	R. Communication	16.00		16.00
12	S. E & M works		1260.00	1260.00
13	X. Environment & Ecology	45.00		45.00
14	Y. Losses on stock	3.58		3.58
15	Intake well cum Pump House & DI Pipe Line	99.22		99.22
	Total of I - Works	**1575.10**	**1260.00**	**2835.10**
II	**ESTABLISHMENT COST**	91.26	60.30	151.56
III	**TOOLS & PLANTS**	15.00		15.00
IV	**SUSPENSE**	-	-	
V	**RECEIPTS & RECOVERIES**	-0.25		-0.25
	TOTAL DIRECT COST	**1681.12**	**1320.30**	**3001.42**
	INDIRECT CHARGES	**3.94**		**3.94**
	TOTAL	**1685.06**	**1320.30**	**3005.36**

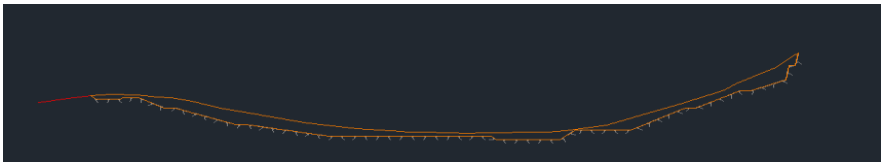
Contigencies to be considered	Range	Considered
Dewatering	2%-3%	2%
Instrumentation	1%-2%	1%
Physical Contigencies	15%-25%	20%
Price Contigencies	5%-10%	0%
	Total Contigencies	**23%**

		COST (in Cr.)		
S.No.	**Component**	***Without Contingencies***	***with contingencies***	***with tax @ 12%***
	I - Works			
1	Intake well cum Pump House & DI Pipe Line	*72.02*	88.59	99.22
	C Works			
2	UPPER RESERVOIR	*253.97*	312.38	349.86
3	LOWER RESERVOIR	***176.59***	217.20	243.27
	Total Civil Cost - C- Works	***430.55***	***529.58***	***593.13***
	J Works			
4	UPPER & LOWER INTAKE	*56.16*	69.08	77.36
5	PRESSURE SHAFT	*49.21*	60.52	67.79
6	Portals	*1.51*	1.86	2.08
7	POWER HOUSE (PART I - IV)	*155.12*	190.80	213.69
8	Adits	21.99	27.05	30.29
9	MAT	*26.61*	32.73	36.66
10	TRT	*64.10*	78.85	88.31
11	Switch Yard	**20.00**	24.60	27.55
	Total Civil Cost - J- Works	***394.70***	***485.48***	***543.74***
	Cost of Hydromechanical works			
12	HM COST (2.5% of Civil)		*58.26*	65.25
13	Pressure Shaft Steel Liner		*65.96*	73.87
			124.22	139.12
	Total Civil Cost - I Works		**1227.87**	**1375.21**

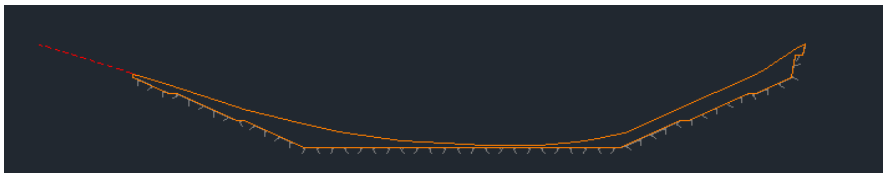
Upper Reservoir

Rock Excavation

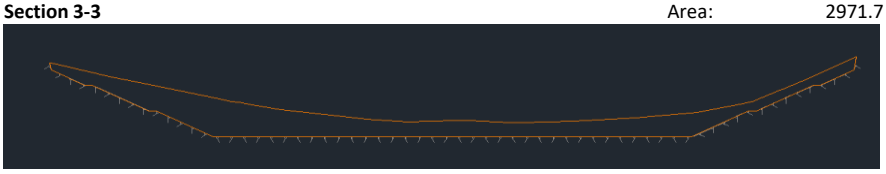
Section 1-1 Area: 1899.8



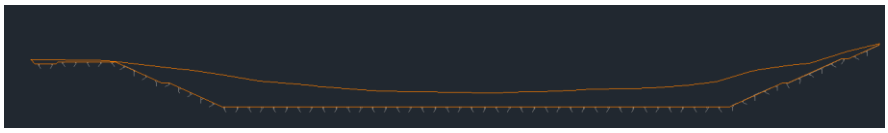
Section 2-2 Area: 1316.57



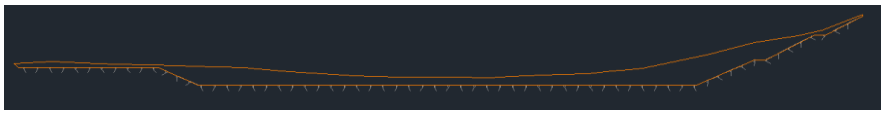
Section 3-3 Area: 2971.7



Section 4-4 Area: 3121.65



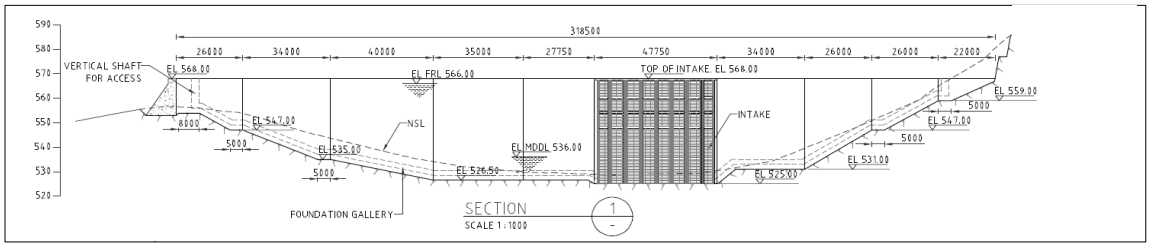
section 5-5 Area: 1979.76



					Area (Sqm)	Avg. Area	Length (m)	Excavation Volume (cum)
Average Excavation Area	=	Ref Table	Sqm	**Area1**	1899.8			
Length	=	800	m	**Area2**	1316.57	1608.185	200	321637
Rock Excavation Volume	=	**1829283**	Cum	**Area3**	2971.7	2144.135	300	643240.5
				Area4	3121.65	3046.675	200	609335
				Area5	1979.76	2550.705	100	255070.5
						Total	**800**	**1829283**

Dam Concrete

Intake Side (D/S)



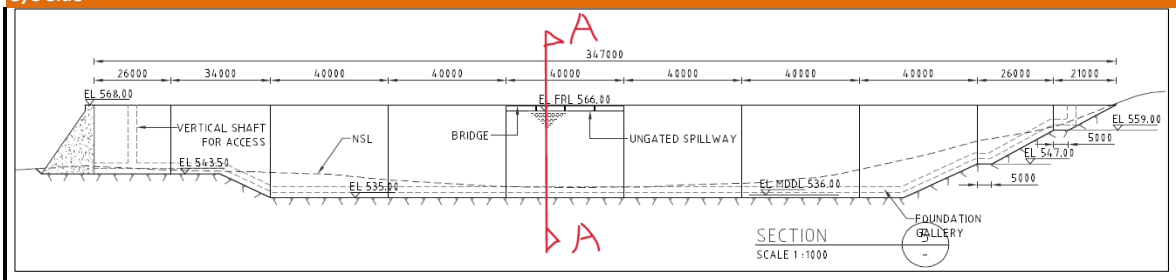
Concrete Qty

Dam Block	Total Area (Sqm)	M15 Concrete Area (Sqm)	M25 Concrete Area (Sqm)	Length (m)	M15 Concrete Volume (Cum)	M25 Concrete Volume (Cum)
Block-1	193.37	83.33	110.03	26	2166.68	2860.81
Block-2	331.97	191.86	140.11	34	6523.21	4763.60
Block-3	662.45	463.70	198.75	40	18547.97	7950.12
Block-4	777.95	562.39	215.56	62.75	35290.10	13526.41
Block-5	777.95	562.39	215.56	34	19121.33	7329.05
Block-6	706.82	501.34	205.48	26	17045.51	6986.29
Block-7	394.97	244.77	150.20	26	6364.14	3905.08
Block-8	121.37	43.63	77.73	22	1134.46	2021.10
	24.68	1.97	22.72	22	43.25	499.76
					106236.645	**49842.22**

Concrete Qty

Dam Block	Total Area (Sqm)	M15 Concrete Area (Sqm)	Key	Gallery	Gallery M25	M25 Concrete Area (Sqm)	M15 Concrete Area (Sqm)	Length (m)	M15 Concrete Volume (Cum)	M25 Concrete Volume (Cum)
Block-1A	90.50	26.50	9.00	9.20	5.20	78.20	17.30	9	155.70	703.80
Block-1B	134.50	54.40	9.00	9.20	5.20	94.30	45.20	12	542.40	1131.60
Block-1C	188.50	92.00	9.00	9.20	5.20	110.70	82.80	5	414.00	553.50
Block-2A	308.10	181.90	9.00	9.20	5.20	140.40	172.70	29	5008.30	4071.60
Block-2B	465.60	309.10	9.00	9.20	5.20	170.70	299.90	5	1499.50	853.50
Block-3	600.00	422.20	9.00	9.20	5.20	192.00	413.00	40	16520.00	7680.00
Block-4	753.50	554.10	9.00	9.20	5.20	213.60	544.90	35	19071.50	7476.00
Block-5	753.50	554.10	9.00	9.20	5.20	213.60	544.90	28.7	15638.63	6130.32
Block-6	600.00	422.20	9.00	9.20	5.20	192.00	413.00	35	14455.00	6720.00
Block-7	356.50	220.10	9.00	9.20	5.20	150.60	210.90	26	5483.40	3915.60
Block-8A	188.50	92.00	9.00	9.20	5.20	110.70	82.80	5	414.00	553.50
Block-8B	102.00	33.40	9.00	9.20	5.20	82.80	24.20	21	508.20	1738.80
Block-9A	44.50	3.53	9.00			49.97	3.53	5	17.65	249.85
Block-9B	22.00	0.00	9.00			31.00	0.00	17	0.00	527.00
									79728	**42305**

U/S Side



Concrete Qty

Dam Block	Total Area (Sqm)	M15 Concrete Area (Sqm)	M25 Concrete Area (Sqm)	Length (m)	M15 Concrete Volume (Cum)	M25 Concrete Volume (Cum)
Block-1	470.57	300.38	170.19	26	7809.98	4424.84
Block-2	470.57	300.38	170.18	34	10213.06	5786.24
Block-3	470.57	300.38	170.18	40	12015.36	6807.24
Block-4	470.57	300.38	170.18	40	12015.36	6807.24
Block-5	470.57	300.38	170.18	40	12015.36	6807.24
Block-6	470.57	300.38	170.18	40	12015.36	6807.24
Block-7	470.57	300.38	170.18	40	12015.36	6807.24
Block -8	331.97	182.40	149.56	40	7296.02	5982.58
Block-9	121.37	34.17	87.19	26	888.54	2266.95
Block-10	27.36	2.17	25.19	21	45.49	529.02
				TOTAL	**86329.883**	**53025.83**

Concrete Qty

Dam Block	Total Area (Sqm)	M15 Concrete Area (Sqm)	Key	Gallery	Gallery M25	M25 Concrete Area (Sqm)	M15 Concrete Area (Sqm)	Length (m)	M15 Concrete Volume (Cum)	M25 Concrete Volume (Cum)
Block-1A	253.70	140.00	9.00	9.20	5.20	127.90	130.80	26	3400.80	3325.40
Block-2A	253.70	140.00	9.00	9.20	5.20	127.90	130.80	16.7	2184.36	2135.93
Block-2B	350.20	215.10	9.00	9.20	5.20	149.30	205.90	17.3	3562.07	2582.89
Block-3	465.60	309.10	9.00	9.20	5.20	170.70	299.90	40	11996.00	6828.00
Block-4	465.60	309.10	9.00	9.20	5.20	170.70	299.90	40	11996.00	6828.00
Block-5	465.60	309.10	9.00	9.20	5.20	170.70	299.90	40	11996.00	6828.00
Block-6	465.60	309.10	9.00	9.20	5.20	170.70	299.90	40	11996.00	6828.00
Block-7	465.60	309.10	9.00	9.20	5.20	170.70	299.90	40	11996.00	6828.00
Block-8A	465.60	309.10	9.00	9.20	5.20	170.70	299.90	15	4498.50	2560.50
Block-8B	308.10	181.90	9.00	9.20	5.20	140.40	172.70	25	4317.50	3510.00
Block-9A	188.50	92.00	9.00	9.20	5.20	110.70	82.80	5	414.00	553.50
Block-9B	22.00	0.00	9.00	9.20	5.20	36.20	-9.20	17	-156.40	615.40
Block-9B	102.00	33.40	9.00	9.20	5.20	82.80	24.20	21	508.20	1738.80
Block-10A	44.50	3.53	9.00			49.97	3.53	5	17.65	249.85
Block-10B	20.00	0.00	9.00			29.00	0.00	16	0.00	464.00
								TOTAL	**78727**	**51876**

Upper Reservoir Side

Concrete Qty						
Dam Block	**Total Area (Sqm)**	**M15 Concrete Area (Sqm)**	**M25 Concrete Area (Sqm)**	**Length (m)**	**M15 Concrete Volume (Cum)**	**M25 Concrete Area (Sqm)**
Block-1	68.88	3.24	65.63	229.515	744.317145	15063.76
					744.317145	**15063.76**

Upper Reservoir Side

Dam Block	Total Area (Sqm)	M15 Concrete Area (Sqm)	Key	Gallery	Gallery M25	M25 Concrete Area (Sqm)	M15 Concrete Area (Sqm)	Length (m)	M15 Concrete Volume (Cum)	M25 Concrete Volume (Cum)
intake side	44.50	3.50				41.00	3.50	73	255.50	2993.00
South side	65.00	12.50				52.50	12.50	230	2875.00	12075.00
									3130.5	**15068**

Asphaltic Lining — Note: assumed 50% of the floor area of upper reservoir

Floor surface area	Assumed coverage	Asphaltic lining (sqm.)
140345	0.5	70172.5
		70172.5

Asphaltic Lining = **70172.5** sqm.

Reservoir Area Grouting

Area	assumed coverage	depth (m)	Grout per meter of drill hole (in bags)	Grout (MT)
161396.75	1	4	2	7173.189
				7173.189 MT

assumed 3 m c/c drill hole
increased by 15% for sides.

Curtain Grouting

@ Section 1 — **2 m** — **Depth of Concrete from Bed rock to Gallery Found**

Block	Length	average H	Drilling Depth	spacing	Nos. of Grout
1	26	19	14.67	**3**	9
2	34	25	18.67	**3**	11
3	40	36.7	26.44	**3**	13
5	62.75	41	29.33	**3**	21
6	34	38	27.33	**3**	11
7	26	27	20.00	**3**	9

8	26	13	10.67	**3**	9
9	22	2.5	3.67	**3**	7

@ Section 5					
Block	**Length**	**average H**	**Drilling Depth**	**spacing**	**Nos. of Grout**
Block-1	26	31	22.67	**3**	9
Block-2	34	31	22.67	**3**	11
Block-3	40	31	22.67	**3**	13
Block-4	40	31	22.67	**3**	13
Block-5	40	31	22.67	**3**	13
Block-6	40	31	22.67	**3**	13
Block-7	40	31	22.67	**3**	13
Block -8	40	25	18.67	**3**	13
Block-9	26	13	10.67	**3**	9
Block-10	21	2.5	3.67	**3**	7

@ Side					
Block	**Length**	**average H**	**Drilling Depth**	**spacing**	**Nos. of Grout**
1	229.515	9.392	8.26	**3**	77

Total Drilling Length	**350.71**	**m**
Bags of cement per m length	**2.5**	
Total Cement required	**43.84**	**MT**

	area	**length**	**volume**	**steel**
Gallery	5.2	593.70	3087.24	
Canopy	5	939.7	4698.5	
			7785.74	389.287

Summary of Quantity							
						Rate / Rs.	**Cost (Cr.)**
Overburden Excavation		548784.90	Cum			208.60	11.45
Rock Excavation		1280498.10	Cum			524.10	67.11
Dam - Plum Concrete (M15)		161585.46	Cum			3671.00	59.32
Dam - M25 Concrete		109249.34	Cum			7177.90	78.42
Steel Quantity		389.29	MT			59285.31	2.31
Grouting in reservoir		7173.19	m			12601.00	9.04
Drilling for Grouting incl. 10% redrilling		72117.67	RM			653.60	4.71
Cement for Grout		43.84	MT			12601.00	0.06
Drainage Hole		61396.46	RM			653.60	4.01
Asphaltic Lining		70172.50	sqm			2500.00	17.54
						TOTAL	**253.97**

Lower Reservoir

Rock Excavation

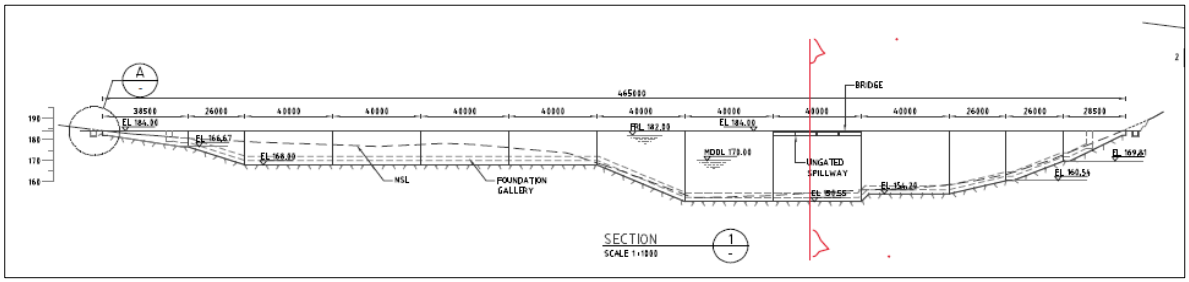
Open Drain

Excavated area	11.88	sq.m.
Length	4099	m
Excavated Volume	48696.12	cum

Section	Excavation Area (sqm)	average area	Length (m)	Excavation Volume (cum)
Section 1-1	2450		0	0
Section 2-2	274.5	1362.3	100	27450
Section 3-3	352	313.3	100	35200
Section 4	605.9	479.0	200.0	121180
Section 5	2746	1676.0	200	549200
Section 6	2707	2726.5	200.0	541400
Section 7	1222	1964.5	200	244400
				1518830

Rock Excavation Volume = **1567526** Cum

Dam Concrete



Concrete Qty

Dam Block	Total Area (Sqm)	M15 Concrete Area (Sqm)	M25 Concrete Area (Sqm)	Length (m)	M15 Concrete Volume (Cum)	M25 Concrete Volume (Cum)
Block-1	119.75	32.44	87.31	38.5	1248.90	3361.47
Block-2	128.42	38.23	90.19	26	994.01	2345.01
Block-3	137.10	44.02	93.08	160	7043.68	14892.08
Block-4	310.50	177.74	132.76	40	7109.48	5310.54
Block-5	483.90	311.45	172.45	80	24916.08	13795.96
Block-6	432.88	269.63	163.25	40	10785.30	6529.92
Block-7	309.87	171.80	138.06	26	4466.85	3589.65
Block-8	167.69	67.37	100.32	26	1751.56	2608.35
Block-9	73.44	11.44	62.00	28.5	326.00	1766.93
				TOTAL	**58641.85**	**54199.90**

Concrete Qty

Dam Block	Total Area (Sqm)	M15 Concrete Area (Sqm)	Key	Gallery	Gallery M25	M25 Concrete Area (Sqm)	M15 Concrete Area (Sqm)	Length (m)	M15 Concrete Volume (Cum)	M25 Concrete Volume (Cum)
Block-1	20.40		9.00			29.40	0.00	38.5	0.00	1131.90
Block-2	66.80	13.40	9.00			62.40	13.40	26	348.40	1622.40
Block-3	114.40	41.20	9.00	9.20	5.20	87.40	32.00	40	1280.00	3496.00
Block-4	114.40	41.20	9.00	9.20	5.20	87.40	32.00	40	1280.00	3496.00
Block-5	114.40	41.20	9.00	9.20	5.20	87.40	32.00	40	1280.00	3496.00
Block-6	114.40	41.20	9.00	9.20	5.20	87.40	32.00	40	1280.00	3496.00
Block-7	259.90	144.70	9.00	9.20	5.20	129.40	135.50	40	5420.00	5176.00
Block-8	480.50	321.50	9.00	9.20	5.20	173.20	312.30	40	12492.00	6928.00
Block-9	480.50	321.50	9.00	9.20	5.20	173.20	312.30	40	12492.00	6928.00
Block-10	382.10	240.80	9.00	9.20	5.20	155.50	231.60	40	9264.00	6220.00
Block-11	308.00	181.80	9.00	9.20	5.20	140.40	172.60	26	4487.60	3650.40
Block-12	154.90	68.30	9.00	9.20	5.20	100.80	59.10	26	1536.60	2620.80
Block-13	38.25	1.50	9.00			45.75	1.50	28.5	42.75	1303.88
								TOTAL	**51203**	**49565**

Concrete Lining in Drain

Plan Area	Lining Area (Sqm)	Length (m)	Lining Volume (cum)
Plan area	1.46	3362	4908.52

Concrete Lining Volume (M20) = **4908.52** Cum

Reservoir Area Grouting

Area	assumed coverage	depth (m)	Grout per meter of drill hole (in bags)	Grout (MT)	
471889	1	4	2	20972.8444	assumed 3 m c/c drill hole
				20973 MT	inceased by 15% for sides

Curtain Grouting

@ Section 1					4 m	Depth of Concrete from Bed rock to Gallery Foundation
Block	**Length**	**average H**	**Drilling Depth**	**spacing**	**Nos. of Grout**	
Block-1	38.5	14.00	11.33	**3**	13	
Block-2	26	14.67	11.78	**3**	9	
Block-3	160	15.33	12.22	**3**	53	
Block-4	40	31.45	22.97	**3**	13	
Block-5	80	31.45	22.97	**3**	27	
Block-6	40	29.63	21.75	**3**	13	
Block-7	26	24.63	18.42	**3**	9	
Block-8	26	16.83	13.22	**3**	9	
Block-9	28.5	5.10	5.40	**3**	10	

Total Drilling Length		**140.05**	**m**
Bags of cement per m length		2.5	
Total Cement required		**17.51**	**MT** considering per bag of 50 kg

	area	length	volume	steel
Gallery	5.2	372.00	1934.4	
Canopy	5	465	2325	
			4259.4	212.97

Summary of Quantity

						Rate / Rs.	
Overburden Excavation		313505.22	Cum			166.00	5.20
Rock Excavation		1254020.90	Cum			481.50	60.38
Dam - Plum Concrete (M15)		51203.35	Cum			3628.40	18.58
Dam - M25 Concrete		49565.38	Cum			7135.30	35.37
Concrete Lining - M20 Concrete		4908.52	Cum			6300.00	3.09
Steel Qty		360.23	MT			59259.61	2.13
Rock Anchor		0.00	MT			1608.90	0.00
Drilling for Grouting incl. 10% redrilling		209882.50	RM			653.60	13.72
Cement for Grout		20990.35	MT			12601.00	26.45
Drainage Hole		178438.63	RM			653.60	11.66
Asphaltic Lininig		0.00					
						TOTAL	**176.59**

UPPER AND LOWER INTAKE

Rock Excavation

Intake	Excavation Area (Sqm)	Length (m)	Plum Concrete Volume (Cum)
upper	1221.105	47.750	58307.76
Lower	923.63	45.714	42222.82
			100530.6

		Length for Shotcrete	width	Quantity	
Shotcrete for UI+LI		51.48	46.732	120.28	cum
Rock Bolts		51.48	46.732	2405.58	m

Note: considering 3 m lengthof rock anchor

Intake Concrete

Lower Intake	Concrete Area (Sqm)	Length (m)	Nos	Concrete Volume (Cum)	Steel (MT)
Bottom slab-1	67.35	16.15	2	2175.41	174.03
Bottom slab-2	5.00	45.50	1	227.50	13.65
Trashrack Pier	50.16	1.50	6	451.46	36.12
Breast Wall	93.46	7.52	2	1405.64	112.45
End wall, side wall	118.89	26.85	2	6384.12	510.73
Back Wall	45.40	6.30	2	572.04	45.76
Top Slab	336.52	0.50	2	336.52	26.92
Backfill Comapcted	148.47	24.30	1	7362.22	

Upper Intake	Concrete Area (Sqm)	Length/thickness/height	Nos	Concrete Volume (Cum)	Steel (MT)
Bottom slab-1	69.00	16.15	2	2228.70	178.30
Bottom slab-2	9.50	45.50	1	432.25	25.94
Trashrack Pier	86.72	1.50	6	780.46	62.44
Breast Wall	173.32	6.40	2	2218.55	177.48
End wall, side wall	119.29	45.50	2	10855.30	868.42
Back Wall	42.70	5.30	2	452.66	36.21
Top Slab	256.66	0.50	2	256.66	20.53
Anchor Block	771.97	45.87	1	44713.04	
Backfill Compacted	111.74	45.87	1	5125.96	

Summary of Quantity

							Rate	Cost
Overburden Excavation			30159.18	Cum			208.60	0.63
Rock Excavation			70371.41	Cum			524.10	3.69
M25 Concrete			28777.26	Cum			7177.90	20.66
M15 Backfill Concrete			44713.04	Cum			3671.00	16.41
Reinforcement Steel			2288.99	MT			59285.31	13.57
Rock bolt			2405.58	m			1608.90	0.39
Shotcrete			120.28	cum			13296.09	0.16
Compacted Backfill			12488.18	cum			524.10	0.65
								56.16
							Total Cost	**56.16**

Intake well cum PH & Pipe Line

Pipe Line Excavation Qty

Area	3.14	sqm
Length	14690	m
Volume	46126.60	Cum

Excavation at Intake Well

Excavation area	339.12	sqm
Length	10	m
Excavation Volume	3391.2	cum

Total Excavation Volume **49517.80** Cum

Coffer Dam area (12 m height)			108	sqm		
length			1132.60	m	**Concrete**	**Rockfill**
Qty			122320.80	Cum	30580.20	91740.60

Intake Well

Top of Intake Well	106.56	m
Bottom of Intake Well	86	m

Intake Shaft			**Area (sqm)**	**Net Area (sqm)**	**Height (m)**	**Concrete Qty**
Inner Dia	5	m	19.63	8.64	20.56	**177.63**
Outer Dia	6	m	28.27			

		Inner Dia	**Area (sqm)**	**Thickness**	**Concrete Qty**
Raft qty		6	28.27	2	56.55
Slab at Pump operation leve		6	28.27	1	28.27
Slab at intake top		5	19.63	1	19.63
					104.46

Total Concrete Qty **17224.6** cum

Reinforcement steel 1550.2 MT

D.I Pipe Quantity

Length of D.I Pipe	14690	m
Thickness of D.I Pipe	0.01	m
Dia of D.I Pipe	1.2	m
Area of Steel /m	0.03801327	Sqm
Total Steel Qty	4383.56	MT

Summary of Qty

						Rate	Cost
Overburden Excavation			14855.34	Cum		208.60	0.31
Rock Excavation			34662.46	Cum		524.10	1.82
Coffer Dam Plum Concrete			30580.20	Cum		3671.00	11.23
Coffer Dam Rockfill			91740.60	Cum		624.50	5.73
M25 Concrete			17224.58	Cum		7177.90	12.36
Reinforcement Steel			1550.21	MT		59285.31	9.19
D.I Pipe			4383.56	MT		47025.70	21.64
Pump Cost			3711.00	kW		25000.00	9.74
						TOTAL	**72.0**

QUANTITY FOR MAIN PRESSURE SHAFT

	Class III		Class IV	Class V
	5.3	**M DIAMETER**	**5.3**	**5.3**
	75%		15%	10.0%
Payline offset	0.1	m	0.1	0.1
Shotcrete Thickness	0.05	m	0.1	0.15
Thickness of Backfill Concrete	0.5	m	0.5	0.5
Length of Tunnel	597.22	m		
Steel Ribs, ISHB 150mm 27.1 kg/m				0.15
EXCAVATION (Payline Offset = 100 mm)				
Excavated Diameter	6.6		6.7	7.1
Area of D-shape portion from AutoCAD	38.886	sq.m.	40.073	45.001
Length of D-shape	447.915	m	89.583	59.722
Excavation Volume in the D-Portion of Pressure Shaft	17417.43	cu.m.	3589.85	2687.52
Extra Excavation for Curved portion expressed as Percentage	0%		0%	0%
Therefore Total Excavation Volume in Horizontal Reach	**17417.43**	cu.m	**3589.85**	**2687.52**
OVERBREAK				
Include 5% for Overbreak	0	cu.m	0	0
Total EXCAVATION including overbreak	**17417.43**	cu.m.	**3589.85**	**2687.52**
SHOTCRETE				
Perimeter of Shotcrete Application from AutoCAD	16.5	m	16.7	17.0
Length of Area to be Shotcreted (from Above)	447.915	m	89.583	59.722
Thickness of Shotcrete	0.05	m	0.1	0.15
Volume of Shotcrete	**368.51**	cu.m	**149.71**	**152.01**
VOLUME OCCUPIED BY PRESSURE SHAFT				
Diameter of Pressure Shaft including liner thickness 40 mm	5.38	m	5.38	5.38
Area of Cross section of Pressure Shaft Liner	22.733	sq.m.	22.733	22.733
Volume of Pressure Shaft Liner	10182.397	cu.m	2036.479	1357.653
CONCRETE VOLUME				
Therefore Volume of Concrete excluding Shotcrete	**6866.53**	cu.m	**1403.66**	**1177.86**
ROCK SUPPORT DETAILS				
Rock support will be provided in the Arch Portion only				
Height of vertical legs	3.30	m	3.35	3.55
Perimeter of Arch Portion	10.37	m	10.52	11.15
Spacing of Rock Bolts	2.00	m	1.50	1.00
Number of Bolts per section	8.00		11.00	18.00
Number of section in the longitudinal direction	223.96		59.72	59.72
Total Number of Bolts	1791.66		656.94	1075.00
Length of Each Bolt	3.50	m	3.50	3.50
Total Length of Rock Support	6270.81	m	2299.30	3762.49
Steel Ribs				48.82 MT
CONTACT GROUTING				
Perimeter of Arch Portion	10.37	m	10.52	11.15
Spacing of Contact Grouting holes	3.00	m	3.00	3.00
Number of Grout holes per section	3.50		3.60	3.80
Number of section in the longitudinal direction	149.31		29.86	19.91
Total number of Grout Section	522.57		107.50	75.65
Length of Grout Holes (0.5 m into Rock)	1.00	m	1.00	1.00
Drilling for Contact Grouting	522.57	m	107.50	75.65
Cement Consumption @1 bags per running meter	26.13	MT	5.37	3.78
Admixture Consumption @ 2%	523	Kg	107	76

QUANTITY FOR PRESSURE SHAFT IN VERTICAL REACH & INCLIEND REACH

	Class III		Class IV	Class V
EXCAVATION (Payline Offset = 100 mm)	75%		15%	10.0%
Excavated Diameter	6.60		6.70	6.80
Area of D-shape portion from AutoCAD	34.21	sq.m.	35.26	36.32
Length of circular -shape	861.90	m	172.38	114.92
Excavation Volume in the D-Portion of Pressure Shaft	29487.27	cu.m.	6077.52	4173.53
Extra Excavation for Curved portion expressed as Percentage	0%		0%	0%
Therefore Total Excavation Volume in Horizontal Reach	**29487.27**	cu.m	**6077.52**	**4173.53**

OVERBREAK					
Include 5% for Overbreak	0	cu.m	0	0	
Total EXCAVATION including overbreak	**29487.27**	cu.m.	**6077.52**	**4173.53**	
SHOTCRETE					
Perimeter of Shotcrete Application from AutoCAD	20.11	m	20.42	21.68	
Length of Area to be Shotcreted (from Above)	861.90	m	172.38	114.92	
Thickness of Shotcrete	0.05	m	0.1	0.15	
Volume of Shotcrete	**866.48**	cu.m	**352.01**	**373.67**	
VOLUME OCCUPIED BY PRESSURE SHAFT					
Diameter of Pressure Shaft including liner thickness 40 mm	5.38	m	5.38	5.38	
Area of Cross section of Pressure Shaft Liner	22.73	sq.m.	22.73	22.73	
Volume of Pressure Shaft Liner	19593.47	cu.m	3918.69	2612.46	
CONCRETE VOLUME					
Therefore Volume of Concrete excluding Shotcrete	**9027.33**	cu.m	**1806.82**	**1187.40**	
ROCK SUPPORT DETAILS					
Rock support will be provided in the Arch Portion only					
Height of vertical legs	0	m	0	0	
Perimeter of Circular Portion	20.11	m	20.42	21.68	
Spacing of Rock Bolts	2	m	1.5	1	
Number of Bolts per section	11		14	22	
Number of section in the longitudinal direction	430.95		114.92	114.92	
Total Number of Bolts	4740.45		1608.88	2528.24	
Length of Each Bolt	3.5	m	3.5	3.5	
Total Length of Rock Support	16591.58	m	5631.08	8848.84	
CONTACT GROUTING					
Perimeter of Arch Portion	20.11	m	20.42	21.68	
Spacing of Contact Grouting holes	3.00	m	3.00	3.00	
Number of Grout holes per section	6.80		6.90	7.30	
Number of section in the longitudinal direction	287.30		57.46	38.31	
Total number of Grout Section	1953.64		396.47	279.64	
Length of Grout Holes (0.5 m into Rock)	1.00	m	1.00	1.00	
Drilling for Contact Grouting	1953.64	m	396.47	279.64	
Cement Consumption @1 bags per running meter	97.68	MT	19.82	13.98	
Admixture Consumption @ 2%	1954	Kg	396	280	
Steel Ribs				22.64	MT

SUMMARY

Excavation Volume	63433.12	cu.m
Overbreak	0.00	cu.m
Shotcrete	2262.38	cu.m
Concrete	21469.59	cu.m
25mm dia Rock Bolts 4.5 m long	43404.09	m
Drilling for Contact Grouting	3335.47	m
Grouting Operations	3335.47	Nos
Cement Consumption for Contact Grouting	166.77	MT
Admixture Consumption for Contact Grouting	3335.47	Kg
Steel Liner	0.00	MT
Consolidation grouting	53.29	MT
Steel Rib	71.46	MT

QUANTITY FOR BRANCH PRESSURE SHAFT	Class III		Class IV	Class V
	3.75	**M DIAMETER**	**3.75**	**3.75**
	75%		15%	10.0%
Payline offset	0.1	m	0.1	0.1
Shotcrete Thickness	0.05	m	0.1	0.15
Thickness of Backfill Concrete	0.5	m	0.5	0.5
Length of Tunnel	78.72	m		
Steel Ribs, ISHB 150mm 27.1 kg/m	230			0.15
EXCAVATION (Payline Offset = 100 mm)				
Excavated Diameter	5.05		5.15	5.55
Area of D-shape portion from AutoCAD	22.766	sq.m.	23.676	27.497
Length of D-shape	59.04	m	11.808	7.872
Excavation Volume in the D-Portion of Pressure Shaft	1344.09	cu.m.	279.57	216.46
Extra Excavation for Curved portion expressed as Percentage	0%		0%	0%
Therefore Total Excavation Volume in Horizontal Reach	**1344.09**	cu.m	**279.57**	**216.46**
OVERBREAK				
Include 5% for Overbreak	0	cu.m	0	0
Total EXCAVATION including overbreak	**1344.09**	cu.m.	**279.57**	**216.46**
SHOTCRETE				
Perimeter of Shotcrete Application from AutoCAD	12.5	m	12.7	13.0
Length of Area to be Shotcreted (from Above)	59.04	m	11.808	7.872
Thickness of Shotcrete	0.05	m	0.1	0.15
Volume of Shotcrete	**36.81**	cu.m	**15.03**	**15.33**
VOLUME OCCUPIED BY PRESSURE SHAFT				
Diameter of Pressure Shaft including liner thickness 40 mm	3.83	m	3.83	3.83
Area of Cross section of Pressure Shaft Liner	11.521	sq.m.	11.521	11.521
Volume of Pressure Shaft Liner	680.196	cu.m	136.039	90.693
CONCRETE VOLUME				
Therefore Volume of Concrete excluding Shotcrete	**627.09**	cu.m	**128.50**	**110.43**
ROCK SUPPORT DETAILS				
Rock support will be provided in the Arch Portion only				
Height of vertical legs	2.525	m	2.575	2.775
Perimeter of Arch Portion	7.93	m	8.09	8.72
Spacing of Rock Bolts	2	m	1.5	1
Number of Bolts per section	6		9	14
Number of section in the longitudinal direction	29.52		7.87	7.87
Total Number of Bolts	177.12		70.85	110.21
Length of Each Bolt	2.5	m	2.5	2.5
Total Length of Rock Support	442.8	m	177.12	275.52
Steel Ribs				4.92 MT
CONTACT GROUTING				
Perimeter of Arch Portion	7.933	m	8.090	8.718
Spacing of Contact Grouting holes	3	m	3	3
Number of Grout holes per section	2.7		2.7	3
Number of section in the longitudinal direction	19.68		3.936	2.624
Total number of Grout Section	53.136		10.6272	7.872
Length of Grout Holes (0.5 m into Rock)	1	m	1	1
Drilling for Contact Grouting	53.136	m	10.6272	7.872
Cement Consumption @1 bags per running meter	2.6568	MT	0.53136	0.3936
Admixture Consumption @ 2%	53	Kg	11	8

QUANTITY FOR PRESSURE SHAFT IN INCLINED REACH REACH

		Class III		Class IV	Class V
EXCAVATION	(Payline Offset = 100 mm)	75%		15%	10.0%
Excavated Diameter		5.05		5.15	5.25
Area of D-shape portion from AutoCAD		20.03	sq.m.	20.83	21.65
Length of circular -shape		0	m	0	0
Excavation Volume in the D-Portion of Pressure Shaft		0.00	cu.m.	0.00	0.00
Extra Excavation for Curved portion expressed as Percentage		0%		0%	0%
Therefore Total Excavation Volume in Horizontal Reach		**0.00**	cu.m	**0.00**	**0.00**
OVERBREAK					
Include 5% for Overbreak		0	cu.m	0	0
Total EXCAVATION including overbreak		**0.00**	cu.m.	**0.00**	**0.00**
SHOTCRETE					
Perimeter of Shotcrete Application from AutoCAD		15.24	m	15.55	16.81
Length of Area to be Shotcreted (from Above)		0	m	0	0
Thickness of Shotcrete		0.05	m	0.1	0.15
Volume of Shotcrete		**0.00**	cu.m	**0.00**	**0.00**
VOLUME OCCUPIED BY PRESSURE SHAFT					
Diameter of Pressure Shaft including liner thickness 40 mm		3.83	m	3.83	3.83
Area of Cross section of Pressure Shaft Liner		11.521	sq.m.	11.521	11.521
Volume of Pressure Shaft Liner		0.00	cu.m	0.00	0.00
CONCRETE VOLUME					
Therefore Volume of Concrete excluding Shotcrete		**0.00**	cu.m	**0.00**	**0.00**
ROCK SUPPORT DETAILS					
Rock support will be provided in the Arch Portion only					
Height of vertical legs		0	m	0	0
Perimeter of Circular Portion		15.24	m	15.55	16.81
Spacing of Rock Bolts		2	m	1.5	1
Number of Bolts per section		8		11	17
Number of section in the longitudinal direction		0		0	0
Total Number of Bolts		0		0	0
Length of Each Bolt		2.5	m	3	3
Total Length of Rock Support		0	m	0	0
CONTACT GROUTING					
Perimeter of Arch Portion		15.24	m	15.55	16.81
Spacing of Contact Grouting holes		2.5	m	2	1.5
Number of Grout holes per section		4		4	4
Number of section in the longitudinal direction		0		0	0
Total number of Grout Section		0		0	0
Length of Grout Holes (0.5 m into Rock)		1	m	1	1
Drilling for Contact Grouting		0	m	0	0
Cement Consumption @1 bags per running meter		0	MT	0	0
Admixture Consumption @ 2%		0	Kg	0	0

SUMMARY

			Nos of Branch Penstock	
Excavation Volume	1840.12	cu.m		7360.49
Overbreak	0.00	cu.m	4	0.00
Shotcrete	67.17	Cum		268.67
Concrete	866.03	cu.m		3464.11
Rock Bolts 2.5 m long	895.44	m		3581.76
Drilling for Contact Grouting	71.64	m		286.54
Grouting Operations	71.64	Nos		286.54
Cement Consumption for Contact Grouting	3.58	MT		14.33
Admixture Consumption for Contact Grouting	53.14	Kg		212.54
Steel Liner	0.00	MT		0.00
Consolidation grouting	0.98	MT		3.94
Steel Rib	4.92	MT		19.70

TOTAL SUMMARY OF PRESSURE SHAFT (MAIN AND BRANCH)

			Rate	Cost
Excavation Volume	70793.6	cu.m	2895.2	20.50
Overbreak	0.0	cu.m	0	0.00
Shotcrete	2531.0	Cum	13296.09	3.37
Concrete	24933.7	cu.m	6578.5	16.40
Rock Bolts 2.5 m long	46985.8	m	1608.9	7.56
Drilling for Contact Grouting	3622.0	m	653.6	0.24
Grouting Operations	3622.0	Nos	0	0.00
Cement Consumption for Contact Grouting	181.1	MT	12601	0.23
Admixture Consumption for Contact Grouting	3548.0	Kg	200	0.07
Steel Rib	91.16	MT	85003.7	0.77
Consolidation Grout	57.23	MT	12601	0.07
			TOTAL	**49.21**
Steel Liner	5184.8	MT	127212	**65.96**

		Class III		Class IV	Class V	
QUANTITY FOR MAIN TRT		**6.3**	**M DIAMETER**	**6.3**	**6.3**	
		75%		15%	10.0%	
Payline offset		0.1	m	0.1	0.1	
Shotcrete Thickness		0.05	m	0.15	0.2	
Thickness of Backfill Concrete		0.5	m	0.5	0.5	
Length of Tunnel		1151.3	m			
Steel Ribs, ISHB 150mm	27.1 kg/m	520			0.15	
EXCAVATION	(Payline Offset = 100 mm)					
Excavated Diameter		7.6		7.8	8.2	
Area of D-shape portion from AutoCAD		47.900	sq.m.	50.455	55.762	
Length of D-shape		863.475	m	172.695	115.13	
Excavation Volume in the D-Portion of Pressure Shaft		41360.77	cu.m.	8713.26	6419.89	
Extra Excavation for Curved portion expressed as Percentage		0%		0%	0%	
Therefore Total Excavation Volume in Horizontal Reach		**41360.77**	cu.m	**8713.26**	**6419.89**	
OVERBREAK						
Include 5% for Overbreak		0	cu.m	0	0	
Total EXCAVATION including overbreak		**41360.77**	cu.m.	**8713.26**	**6419.89**	
SHOTCRETE						
Perimeter of Shotcrete Application from AutoCAD		16.8	m	17.2	17.5	
Length of Area to be Shotcreted (from Above)		863.475	m	172.695	115.13	
Thickness of Shotcrete		0.05	m	0.15	0.2	
Volume of Shotcrete		**724.27**	cu.m	**446.31**	**401.94**	
VOLUME OCCUPIED BY PRESSURE SHAFT						
Diameter of Pressure Shaft including liner thickness 40 mm		6.3	m	6.3	6.3	
Area of Cross section of Pressure Shaft Liner		31.17	sq.m.	31.17	31.17	
Volume of Pressure Shaft Liner		26916.63	cu.m	5383.33	3588.88	
CONCRETE VOLUME						
Therefore Volume of Concrete excluding Shotcrete		**13719.86**	cu.m	**2883.62**	**2429.07**	
ROCK SUPPORT DETAILS						
Rock support will be provided in the Arch Portion only						
Height of vertical legs		3.8	m	3.9	4.1	
Perimeter of Arch Portion		11.94	m	12.25	12.88	
Spacing of Rock Bolts		2	m	1.5	1	
Number of Bolts per section		10		13	21	
Number of section in the longitudinal direction		431.74		115.13	115.13	
Total Number of Bolts		4317.38		1496.69	2417.73	
Length of Each Bolt		4.5	m	4.5	4.5	
Total Length of Rock Support		19428.19	m	6735.11	10879.79	
Steel Ribs					96.82	MT
CONTACT GROUTING						
Perimeter of Arch Portion		11.938	m	12.252	12.881	
Spacing of Contact Grouting holes		3	m	3	3	
Number of Grout holes per section		4		4.1	4.3	
Number of section in the longitudinal direction		287.825		57.565	38.38	
Total number of Grout Section		1151.3		236.0165	165.02	
Length of Grout Holes (0.5 m into Rock)		1	m	1	1	
Drilling for Contact Grouting		1151.3	m	236.0165	165.02	
Cement Consumption @1 bags per running meter		57.565	MT	11.800825	8.25	
Admixture Consumption @ 2%		1151	Kg	236	165	

MAIN TRT SUMMARY

Excavation Volume	56493.9	cu.m
Overbreak	0.0	cu.m
Shotcrete	1572.5	Cum
Concrete	19032.6	cu.m
Rock Bolts 4.5 m long	37043.1	m
Drilling for Contact Grouting	1552.3	m
Grouting Operations	1552.3	Nos
Cement Consumption for Contact Grouting	77.6	MT
Admixture Consumption for Contact Grouting	1151.3	Kg
Consolidation grouting	24.8	MT
Steel Rib	96.8	MT

QUANTITY FOR BRANCH TRT

		Class III		Class IV	Class V
		4.5	**M DIAMETER**	**4.5**	**4.5**
		75%		15%	10.0%
Payline offset		0.1	m	0.1	0.1
Shotcrete Thickness		0.05	m	0.1	0.15
Thickness of Backfill Concrete		0.5	m	0.5	0.5
Length of Tunnel		114.63	m		
Steel Ribs, ISHB 150mm	27.1 kg/m				0.15
EXCAVATION	(Payline Offset = 100 mm)				
Excavated Diameter		5.8		5.9	6.3
Area of D-shape portion from AutoCAD		27.898	sq.m.	28.868	32.915
Length of D-shape		85.97	m	17.19	11.46
Excavation Volume in the D-Portion of Pressure Shaft		2398.43	cu.m.	496.37	377.30
Extra Excavation for Curved portion expressed as Percentage		0%		0%	0%
Therefore Total Excavation Volume in Horizontal Reach		**2398.43**	cu.m	**496.37**	**377.30**
OVERBREAK					
Include 5% for Overbreak		0	cu.m	0	0
Total EXCAVATION including overbreak		**2398.43**	cu.m.	**496.37**	**377.30**
SHOTCRETE					
Perimeter of Shotcrete Application from AutoCAD		12.7	m	12.9	13.1
Length of Area to be Shotcreted (from Above)		85.9725	m	17.1945	11.463
Thickness of Shotcrete		0.05	m	0.15	0.2
Volume of Shotcrete		**54.57**	cu.m	**33.33**	**30.14**
VOLUME OCCUPIED BY PRESSURE SHAFT					
Diameter of Pressure Shaft including liner thickness 40 mm		4.5	m	4.5	4.5
Area of Cross section of Pressure Shaft Liner		15.90	sq.m.	15.90	15.90
Volume of Pressure Shaft Liner		1367.33	cu.m	273.47	182.31
CONCRETE VOLUME					
Therefore Volume of Concrete excluding Shotcrete		**976.53**	cu.m	**189.58**	**164.85**
ROCK SUPPORT DETAILS					
Rock support will be provided in the Arch Portion only					
Height of vertical legs		2.9	m	2.95	3.15
Perimeter of Arch Portion		9.11	m	9.27	9.90
Spacing of Rock Bolts		2	m	1.5	1
Number of Bolts per section		7		10	16
Number of section in the longitudinal direction		42.99		11.46	11.46
Total Number of Bolts		300.90		114.63	183.41
Length of Each Bolt		3	m	3	3
Total Length of Rock Support		902.71125	m	343.89	550.224
Steel Ribs					7.26 MT
CONTACT GROUTING					
Perimeter of Arch Portion		9.111	m	9.268	9.896
Spacing of Contact Grouting holes		3	m	3	3
Number of Grout holes per section		3.1		3.1	3.3
Number of section in the longitudinal direction		28.66		5.73	3.82
Total number of Grout Section		88.84		17.77	12.61
Length of Grout Holes (0.5 m into Rock)		1	m	1	1
Drilling for Contact Grouting		88.84	m	17.77	12.61
Cement Consumption @1 bags per running meter		4.442	MT	0.888	0.630
Admixture Consumption @ 2%		89	Kg	18	13

BRANCH TRT SUMMARY

			Nos of Branch TRT	
Excavation Volume	3272.10	cu.m		13088.42
Overbreak	0.00	cu.m	4	0.00
Shotcrete	118.04	Cum		472.18
Concrete	1330.95	cu.m		5323.79
25 mm dia Rock Bolts 3 m long	1796.83	m		7187.30
Drilling for Contact Grouting	119.22	m		476.86
Grouting Operations	119.22	Nos		476.86
Cement Consumption for Contact Grouting	5.96	MT		23.84
Admixture Consumption for Contact Grouting	88.84	Kg		355.35
Consolidation grouting	1.89	MT		7.57
Steel Rib	7.26	MT		29.05

TRT SUMMARY (MAIN AND BRANCH)

			Rate	Cost
Excavation Volume	69582.3	cu.m	2895.2	**20.15**
Overbreak	0.0	cu.m	0	**0.00**
Shotcrete	2044.7	Cum	13296.09	**2.72**
Concrete	24356.3	cu.m	8347.2	**20.33**
Reinforcement Steel	1461.381	MT	85003.7	**12.42**
Rock Bolts 4 m long	44230.4	m	1608.9	**7.12**
Drilling for Contact Grouting	2029.2	m	653.6	**0.13**
Grouting Operations	2029.2	Nos	0	**0.00**
Cement Consumption for Contact Grouting	101.5	MT	12601	**0.13**
Admixture Consumption for Contact Grouting	1506.7	Kg	0	**0.00**
Consolidation Grouting	32.3	MT	12601	**0.04**
Steel Rib	125.9	MT	85003.7	**1.07**
			TOTAL	**64.10**

QUANTITY FOR UNIT MAT (8 X8 M DIA)

EXCAVATION (Payline Offset = 100 mm)

Area of D-shape portion from AutoCAD	62.241	sq.m.
Length of D-shape	1059	m
Excavation Volume in the D-Portion of Pressure Shaft	65912.77	cu.m.
Extra Excavation for Curved portion expressed as Percentage	0%	
Therefore Total Excavation Volume	**65912.77**	cu.m

OVERBREAK

Include 5% for Overbreak	0	cu.m
Total EXCAVATION including overbreak	**65912.77**	cu.m.

SHOTCRETE

Perimeter of Shotcrete Application from AutoCAD	29.818	m
Length of Area to be Shotcreted (from Above)	1059	m
Thickness of Shotcrete	0.05	m
Volume of Shotcrete	**1578.86**	cu.m

VOLUME OCCUPIED BY PRESSURE SHAFT

Diameter of Unit TRT	8 X 8	m
Area of Cross section of Pressure Shaft Liner	58.080	sq.m.
Volume of Pressure Shaft Liner	61506.72	cu.m

CONCRETE VOLUME

Therefore Volume of Concrete excluding Shotcrete	**2827.20**	cu.m

ROCK SUPPORT DETAILS

Rock support will be provided in the Arch Portion only

Perimeter of Arch Portion	11.16	m
Spacing of Rock Bolts	2	m
Number of Bolts per section	6	
Number of section in the longitudinal direction	529.5	
Total Number of Bolts	3177	
Length of Each Bolt	6	m
Total Length of Rock Support	19062	m

CONTACT GROUTING

Perimeter of Arch Portion	11.16	m
Spacing of Contact Grouting holes	2.5	m
Number of Grout holes per section	0	
Number of section in the longitudinal direction	423.6	
Total number of Grout Section	0	
Length of Grout Holes (0.5 m into Rock)	1	m
Drilling for Contact Grouting	0	m
Cement Consumption @1 bags per running meter	0	MT
Admixture Consumption @ 2%	0	Kg

MAT SUMMARY			Rate	Cost
Excavation Volume	65912.8	cu.m	2895.2	19.08
Overbreak	0.0	cu.m	0	0.00
Shotcrete	1578.9	Cum	13296.09	2.10
Concrete	2827.2	cu.m	8347.2	2.36
Rock Bolts 3 m long	19062	m	1608.9	3.07
Drilling for Contact Grouting	0	m	653.6	0.00
Grouting Operations	0	Nos	12601	0.00
Cement Consumption for Contact Grouting	0	MT		0.00
Admixture Consumption for Contact Grouting	0	Kg		0.00
			TOTAL	**26.61**

QUANTITY FOR UNIT ADIT (5.3 X5.3 M DIA) (including ventilation tunnel)

EXCAVATION (Payline Offset = 100 mm)

Area of D-shape portion from AutoCAD	28.497	sq.m.
Length of D-shape	834	m
Excavation Volume in the D-Portion of Pressure Shaft	23766.4117	cu.m.
Extra Excavation for Curved portion expressed as Percentage	0%	
Therefore Total Excavation Volume	**23766.4117**	cu.m

OVERBREAK

Include 5% for Overbreak	0	cu.m
Total EXCAVATION including overbreak	**23766.4117**	cu.m.

SHOTCRETE

Perimeter of Shotcrete Application from AutoCAD	17.18	m
Length of Area to be Shotcreted (from Above)	834	m
Thickness of Shotcrete	0.05	m
Volume of Shotcrete	**716.406**	cu.m

ROCK SUPPORT DETAILS

Rock support will be provided in the Arch Portion only

Perimeter of Arch Portion	10.68	m
Spacing of Rock Bolts	2	m
Number of Bolts per section	6	
Number of section in the longitudinal direction	417	
Total Number of Bolts	2502	
Length of Each Bolt	3.5	m
Total Length of Rock Support	8757	m

CONTACT GROUTING

Perimeter of Arch Portion	10.68	m
Spacing of Contact Grouting holes	3	m
Number of Grout holes per section	0	
Number of section in the longitudinal direction	278	
Total number of Grout Section	0	
Length of Grout Holes (0.5 m into Rock)	1	m
Drilling for Contact Grouting	0	m
Cement Consumption @1 bags per running meter	0	MT
Admixture Consumption @ 2%	0	Kg

QUANTITY FOR UNIT ADIT (6.5 X6.5 M DIA) (including ventilation tunnel)

EXCAVATION (Payline Offset = 100 mm)

Area of D-shape portion from AutoCAD	41.887	sq.m.
Length of D-shape	812	m
Excavation Volume in the D-Portion of Pressure Shaft	34012.44	cu.m.
Extra Excavation for Curved portion expressed as Percentage	0%	
Therefore Total Excavation Volume	**34012.44**	cu.m

OVERBREAK

Include 5% for Overbreak	0	cu.m
Total EXCAVATION including overbreak	**34012.44**	cu.m.

SHOTCRETE

Perimeter of Shotcrete Application from AutoCAD	24.461	m
Length of Area to be Shotcreted (from Above)	812	m
Thickness of Shotcrete	0.05	m
Volume of Shotcrete	**993.13**	cu.m

ROCK SUPPORT DETAILS

Rock support will be provided in the Arch Portion only

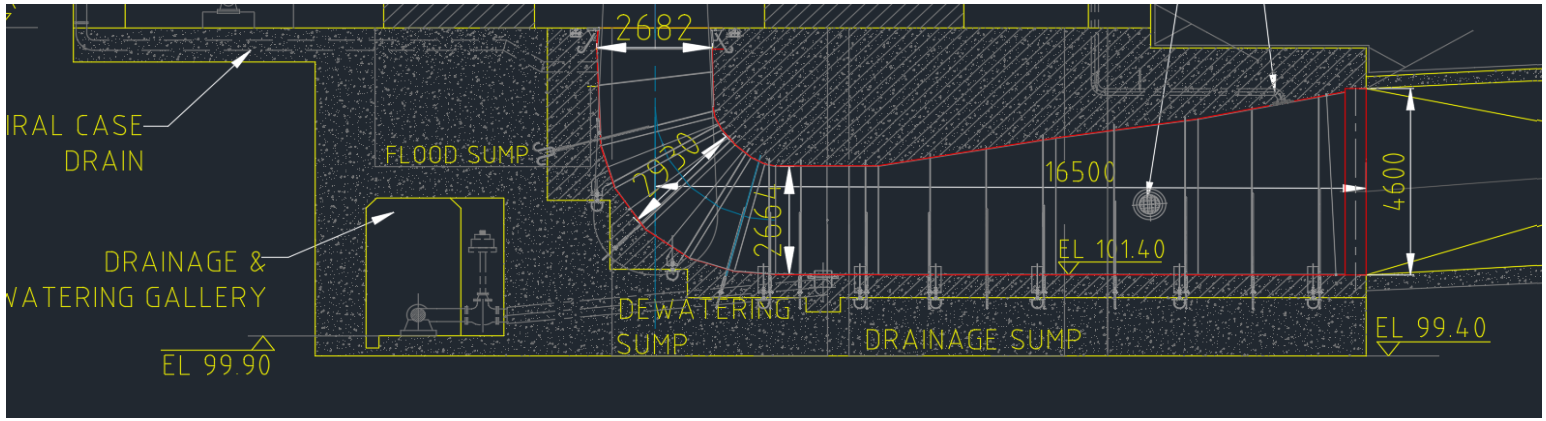
Perimeter of Arch Portion	10.68	m
Spacing of Rock Bolts	2	m
Number of Bolts per section	6	
Number of section in the longitudinal direction	406	
Total Number of Bolts	2436	
Length of Each Bolt	4	m
Total Length of Rock Support	9744	m

CONTACT GROUTING

Perimeter of Arch Portion	10.68	m
Spacing of Contact Grouting holes	2.5	m
Number of Grout holes per section	0	
Number of section in the longitudinal direction	324.8	
Total number of Grout Section	0	
Length of Grout Holes (0.5 m into Rock)	1	m
Drilling for Contact Grouting	0	m
Cement Consumption @1 bags per running meter	0	MT
Admixture Consumption @ 2%	0	Kg

SUMMARY OF ALL ADITS

	6.5 m Dia		5.3m Dia		Rate	Cost
Excavation Volume	34012.4	cu.m	23766.41	57778.86	2895.2	16.73
Overbreak	0.0	cu.m	0.00	0.00	0	0.00
Shotcrete	993.1	Cum	716.41	1709.54	13296.09	2.27
Concrete	0.0	cu.m	0.00	0.00	8347.2	0.00
Rock Bolts 3 m long	9744	m	8757.00	18501.00	1608.9	2.98
Drilling for Contact Grouting	0	m	0.00	0.00	653.6	0.00
Grouting Operations	0	Nos	0.00	0.00		0.00
Cement Consumption for Contact Grouting	0	MT	0.00	0.00		0.00
Admixture Consumption for Contact Grouting	0	Kg	0.00	0.00		0.00
Consolidation Grouting	5	MT	5.00	10.00	12601	0.01
					TOTAL	**21.99**

POWERHOUSE -(PART I)										
S. No.	Components	Elevations	Length (m)	Width/ Thickness	Radius (m)	Area (m^2)	Height (m)	Qty (Nos.)	Volume(m^3)	Reinforcement (MT)
A	**MASS CONCRETE - Unit 2 - EL. 107.00 - EL. 114.00 (depicted below)**									
										
A1	**Structural Concrete**									
	Total Structural Concrete	*EL. 107.00 - EL. 114.00*	8.00			168.48		1	1347.81	
	Total Structural Concrete / Raft between Units	*EL. 113.15 - EL. 114.00*	14.00	27.25		23.16	0.85	1	324.28	
	Drainage / Dewatering Gallery Lining (500mm)	*EL. 108.00*	14.00			6.67		1	93.35	
A2	**Deductions**									
	Drainage Dewatering Gallery	*EL. 108.00*	8.00			7.51		1	-60.06	
	Draft tube bend	*EL. 107.00 - EL. 114.00*	6.33			6.45		1	-40.86	
	Draft tube bend to Outfall	*EL. 109.00 - EL. 114.00*	13.73			14.13		1	-193.91	
							Total Structural Concrete =		**1470.6**	**58.8**
B	**Unit 2 - EL. 114.00 - EL. 121.50 - Concrete around Turbine shaft / Barrel**									
B1	**Structural Concrete**									
	Concrete Around Spiral Casing	*EL. 114.00 - EL. 121.50*	14.72			111.12		1	1635.66	
	Concrete Around Spiral Casing / Barrel	*EL. 121.50 - EL. 127.50*				287.05	6.00	1	1722.30	

	Concrete Around Spiral Casing / Barrel	*EL. 127.50 - EL. 134.00*				84.98	6.50	1	552.37	
B2	**Deductions**									
	Turbine Shaft	*EL. 114.00 - EL. 121.50*				21.24	7.50	1	-159.28	
	Penstock Straight Portion	*EL. 118.50 / EL at CL of Penstock*	6.80			4.91		1	-33.38	
	Spiral Casing	*EL. 118.50 / EL at CL of Penstock*	31.42			4.17		1	-131.15	
							Total Structural Concrete =		**3586.5**	**269.0**
C	**Unit 2 - EL. 121.50 - EL. 149.00 - MIV Floor + Generator Motor Floor + Hall Floor**									
C1	**Structural Concrete**									
	RCC Wall (500mm thick)	*EL. 114.00 - EL. 134.00 / Along Grid D & F Line*	21.50	0.50			17.00	2	365.50	27.41
	Crane Column (1.00x1.20)	*EL. 114.00 - EL. 149.00*				1.20	35.00	9	378.00	45.36
	Crane Beam (1.75x1.50)	*EL. 149.00 / Along Grid-D & F*	21.50			2.63		2	112.88	13.55
	300mm thick Slab	*EL. 121.50 / Unit 2 / Bw Grid D & F*				276.84	0.30	1	83.1	5.40
	300mm thick Slab	*EL. 127.50 / Unit 2 / Bw Grid D & F*				76.89	0.30	1	23.1	1.50
	300mm thick Slab	*EL. 134.00 / Unit 2 / Bw Grid E & D*				76.89	0.30	1	23.1	1.50
	Beam (0.50x1.00)	*All 3 Floors / Along Grid D & F / from Grid 10 to 12*	10.00			0.50		6	30.0	2.25
	Beam (0.50x1.00)	*All 3 Floors / Along Grid D, E & F / from Grid 12 to 13*	8.50			0.50		9	38.3	2.87
	Beam (0.50x1.00)	*Hall & Generator Floors / Along Grid 10, 12 & 13/ from Grid D to F*	19.40			0.50		6	58.2	4.37
	Beam (0.50x1.00)	*Turbine Floors / Along Grid 12 / from Grid D to F*	8.20			0.50		1	4.1	0.31
	Beam (0.50x1.00)	*Turbine Floors / Along Grid 13 / from Grid D to F*	19.40			0.50		1	9.7	0.73
C2	**Deductions**									
	Deduction for Runner Removal Hatch					42.88	0.30	3	-0.9	-0.06
	Deduction for MIV Hatch		6.00	6.00			0.30	3	-32.4	-2.11
							Total Structural Concrete =		**1092.5**	**103.1**
D	**Addition specific to Unit 4**									

D1	**Structural Concrete - Drainage & Dewatering Sump - EL. 107.00 & EL. 134.00**									
	RCC Wall (1m thick)	*EL. 107.00 & EL. 134.00 / Grid-16 & 17 / Grid D to F*	23.00	1.00			7.00	1	161.00	12.08
	Raft (1m thick)	*EL. 107.00 / Grid-16 to 17 / Grid D to F*	23.00	6.61			1.00	1	152.03	9.88
	RCC Wall (1m thick)	*EL. 107.00 & EL. 134.00 / Grid-D & F / Grid 16 to 17*	6.61	1.00			8.10	1	53.54	4.02
	300mm thick Slab	*EL. 114.00 / Over Sump*	23.00	6.61			0.30	1	45.6	2.96
D2	**No cutouts as in Unit 1 & 2**									
	Runner Removal Hatch					42.88	0.30	3	0.9	0.06
	MIV Hatch		6.00	6.00			0.30	3	32.4	2.11
D3	**Lift**									
	RCC Wall around lift	*EL. 114.00 - EL. 134.00*				1.88	20.00	1	37.66	2.82
D4	**Staircase**									
	Area of Concrete per m height for Staircase (R=150 T=250)		=	***0.7081***	*m3*	*per m width per m Height*		*for 250mm thick Base Slab*		
	Staircase	*EL. 114.00 - EL. 134.00*		1			20.00		14.2	
	Landing for Staircase	*EL. 114.00 - EL. 134.00*				2.00	0.25	6	3.0	
	Beam for Landing (0.30 x0.50)					0.15		6	0.9	
							Total Structural Concrete =		**18.1**	**1.4**
D5	**Deductions**									
	Deduction for Access Hatches for Dewatering & Drainage Sump	*EL. 114.00*	2.50	2.50			0.30	2	-3.8	-0.24
	Deduction for Lift shaft cutout from Slab	*EL. 114.00 - EL. 134.00*	2.50	3.00			0.25	3	-5.6	-0.37
	Deduction for Material Hatch	*All 3 Floors*	2.50	2.50			0.30	3	-5.6	-0.37
							Total Structural Concrete =		**486.2**	**34.3**

E	**Addition specific to Unit 1**									
E1	**Structural Concrete**									
	RCC Wall (500mm thick)	*Change in Length of Unit 2 - 21.5m to Unit 1 - 27.05m / Grid D & F*	5.55	0.50			17.00	2	94.35	7.08
	Additional Crane Column (1.00x1.20)	*Change in Length of Unit 2 - 21.5m to Unit 1 - 27.05m / Grid D & F*				1.20	35.00	3	126.00	15.12
	Additional length of Crane Beam (1.75x1.50)	*Change in Length of Unit 2 - 21.5m to Unit 1 - 27.05m / Grid D & F*	5.55			2.63		2	29.14	3.50
	Beam (0.50x1.00)	*Change in Length of Unit 2 - 21.5m to Unit 1 - 27.05m / Grid D & F*	5.13			0.50		3	7.7	0.58
	Beam (0.50x1.00)	*Hall & Generator Floors / Along Grid 10, 12 & 13/ from Grid D to F*	19.40			0.50		2	19.4	1.46
	300mm thick Slab	*Change in Length of Unit 2 - 21.5m to Unit 1 - 27.05m / Grid D & F*	23.00	5.55			0.30	1	38.3	2.49
							Total Structural Concrete =		**314.9**	**30.2**
F	**Control Room/Block**									
F1	**Structural Concrete - EL. 114.00 - EL. 149.00**									
	Raft (1.0m thick)	*EL. 114.00*	23.00	25.00			1.00	1	575.00	37.38
	Column (1.00X1.00)	*EL. 114.00 - EL. 149.00*				1.00	35.00	12	420.00	31.50
	250mm thick Slab	*All 6 floors upto EL. 149.00*	23.00	25.00		575.00	0.25	6	862.5	69.00
	Beam (0.50x0.70)	*Along*	25.00			0.35		4	35.0	2.63
	Beam (0.50x0.70)	*Across*	28.00			0.35		3	29.4	2.21
F2	**Deductions**									
	Deduction for Lift shaft + Staircase cutout from Slab	*EL. 114.00 - EL. 149.00*	4.10	6.75			0.25	6	-41.5	-2.70
F3	**Staircase**									
	Area of Concrete per m height for Staircase (R=150 T=250)		=	***0.7081***	*m3*	*per m width per m Height*		*for 250mm thick Base Slab*		
	Staircase	*EL. 114.00 - EL. 149.00*		1			35.00		24.8	
	Landing for Staircase	*EL. 114.00 - EL. 149.00*				2.00	0.25	19	9.5	
	Beam for Landing (0.30 x0.50)					0.15		19	2.9	
							Total Structural Concrete =		**37.1**	**2.8**

F4	**RCC Walls (on Periphery of CB)**									
	RCC Wall (0.3m thick)		20.00	0.30			30.80	1	184.80	13.86
	RCC Wall (0.3m thick)		21.00	0.30			30.80	2	388.08	29.11
							Total Structural Concrete =		**2490.4**	**185.8**
G	**Service Bay**									
	Raft (1m thick)	*EL. 134.00*	23.00	32.00			1.00	1	736.00	47.84
	Crane Column (1.00x1.00)	*EL. 149.00 - EL. 134.00*				1.00	15.00	6	90.00	10.80
	Crane Beam (1.75x1.50)	*EL. 149.00 / Along Grid-D & F*	29.00			2.63		2	152.25	18.27
	Column (1.00x1.00)	*EL. 149.00 - EL. 134.00*				1.00	15.00	2	30.00	3.60
	RCC Wall (0.3m thick)	*Along*	29.00	0.30			15.00	2	261.00	19.58
	RCC Wall (0.3m thick)	*Across*	20.00	0.30			15.00	1	90.00	6.75
							Total Structural Concrete =		**1359.3**	**106.8**
H	**Summary**									
		Unit-1	**Unit-2**	**Unit-3**	**Unit-4**	**Control Bay**	**Service Bay**			
	Total Structural Concrete	6464.5	6149.6	6149.6	6635.8	2490.4	1359.3	m3		
	Reinforcement	461.1	430.9	430.9	465.2	185.8	106.8	MT		

POWER HOUSE -(PART II)

Excavation

	Unit Bay & Control Building		Service Bay	
PH c/s area	1145.45	sqm	565.13	sqm
Length	114.95	m	32	m
	131669.5	cum	18084.16	cum
Excavation Qty	149753.6	cum		
TH c/s area	629.25	sqm		
Length	160	m		
Excavation Qty	100680	cum		
Total Excavation	**250433.6**	**Cum**		

Rock Support

PH perimeter	122.58	m	67.25	m
Length	114.95	m	32	m
Rock Bolt area	14090.57	sqm	2152	sqm
Area occupied by each rock bolt	2.25	sqm	2.25	sqm
Nos of bolts	6262.48	nos	956.44	nos
length of rock bolt	12	m	12	m
Total length rock bolt	**75149.71**	m	**11477.33**	m
PH side face area	2290.9	sqm		
Area occupied by each rock bolt	2.25	sqm		
Nos of bolts	1018.178	nos		
length of rock bolt	12	m		
Total length rock bolt	**12218.13**	m		
TH perimeter	75.42	m		
Length	215	m		
Rock Bolt area	16215.3	sqm		
Area occupied by each rock bolt	2.25	sqm		
Nos of bolts	7206.8	nos		
length of rock bolt	10	m		
Total length rock bolt	**72068**	m		
TH side face area	629.08	sqm		
Area occupied by each rock bolt	2.25	sqm		
Nos of bolts	280	nos		
length of rock bolt	10	m		
Total length rock bolt	**2796**	m		
Total length of Rock Bolt	**173709**	**m**		

Shotcrete

PH perimeter	122.58	m	67.25	m
Length	114.95	m	32	m
Shotcrete area	14090.57	sqm	2152	sqm
PH side face shotcrete area	2290.9	sqm		
TH perimeter	75.42	m		
Length	215	m		
Shotcrete area	16215.3	sqm		
TH side face shotcrete area	1258.5	sqm		
Total Shotcrete Area	**33855.27**	**sqm**		

PH Concrete volume	0	cum
Nos of Unit	3	nos
Total PH concrete volume	0	Cum
Reinforcement Steel	0	MT

TH Superstructure Concrete volume

	area	Length	Nos	Qty	Steel
Column	4	15	64	3840	384
Beam	3	215	2	1290	129
Slab	20	215	2	8600	860
				13730	**1373**

Summary Of Qty (POWERHOUSE PART I AND II)

			Rate	Itemwise unit rate for Labour Component	Lead	Lead Charges	Rate	Cost (in Cr.)
Excavation	250433.6	cum	2039.2	813.4	2	42.6	2895.2	72.51
Rock Bolts (32 mm dia)	173709.1	m	1546.22	461.45			2007.67	34.88
Rock Bolts (25 mm dia)							0	
Shotcrete (200mm thk)	6771.054	Cum	13253.49		2	42.6	13296.09	9.00
M25 Concrete	29249.22	Cum	5176.4	1958.9	2	42.6	7177.9	20.99
Reinforcement steel	2080.638	MT	54173.71	5085.9	2	25.7	59285.31	12.34
							TOTAL	**149.71**

POWER HOUSE (PART III)

QUANTITY FOR LINK TUNNEL (4X4 M DIA)

EXCAVATION (Payline Offset = 100 mm)

Area of D-shape portion from AutoCAD	16.892	sq.m.
Length of D-shape	46	m
Excavation Volume in the D-Portion of Pressure Shaft	777.03	cu.m.
Extra Excavation for Curved portion expressed as Percentage	0%	
Therefore Total Excavation Volume	**777.03**	cu.m

OVERBREAK

Include 5% for Overbreak	0	cu.m
Total EXCAVATION including overbreak	**777.03**	cu.m.

SHOTCRETE

Perimeter of Shotcrete Application from AutoCAD	15.53	m
Length of Area to be Shotcreted (from Above)	46	m
Thickness of Shotcrete	0.05	m
Volume of Shotcrete	**35.73**	cu.m

ROCK SUPPORT DETAILS

Rock support will be provided in the Arch Portion only

Perimeter of Arch Portion	10.68	m
Spacing of Rock Bolts	2	m
Number of Bolts per section	6	
Number of section in the longitudinal direction	23	
Total Number of Bolts	138	
Length of Each Bolt	4	m
Total Length of Rock Support	552	m

CONTACT GROUTING

Perimeter of Arch Portion	10.68	m
Spacing of Contact Grouting holes	2.5	m
Number of Grout holes per section	0	
Number of section in the longitudinal direction	18.4	
Total number of Grout Section	0	
Length of Grout Holes (0.5 m into Rock)	1	m
Drilling for Contact Grouting	0	m
Cement Consumption @1 bags per running meter	0	MT
Admixture Consumption @ 2%	0	Kg

SUMMARY

			Rate	Cost
Excavation Volume	777.03	cu.m	2895.20	0.22
Overbreak	0.00	cu.m	0.00	0.00
Shotcrete	35.73	Cum	13296.09	0.05
Concrete	0.00	cu.m	8347.20	0.00
Rock Bolts 3 m long	552.00	m	1608.90	0.09
Drilling for Contact Grouting	0.00	m	653.60	0.00
Grouting Operations	0.00	Nos		0.00
Cement Consumption for Contact Grouting	0.00	MT		0.00
Admixture Consumption for Contact Grouting	0.00	Kg		0.00
Consolidation Grouting	5.00	MT	12601.00	0.01
			TOTAL	**0.37**

POWER HOUSE (PART IV)

QUANTITY FOR BUS DUCT (8 X8 M DIA)

EXCAVATION (Payline Offset = 100 mm)

Area of D-shape portion from AutoCAD	62.24	sq.m.
Length of D-shape	192	m
Excavation Volume in the D-Portion of Pressure Shaft	11950.19	cu.m.
Extra Excavation for Curved portion expressed as Percentage	0%	
Therefore Total Excavation Volume	**11950.2**	cu.m

OVERBREAK

Include 5% for Overbreak	0	cu.m
Total EXCAVATION including overbreak	**11950.19**	cu.m.

SHOTCRETE

Perimeter of Shotcrete Application from AutoCAD	29.82	m
Length of Area to be Shotcreted (from Above)	192.00	m
Thickness of Shotcrete	0.05	m
Volume of Shotcrete	**286.25**	cu.m

VOLUME OCCUPIED BY TUNNEL

Diameter of Unit TRT	8 X 8	m
Area of Cross section of Pressure Shaft Liner	58.080	sq.m.
Volume of Pressure Shaft Liner	0	cu.m

CONCRETE VOLUME

Therefore Volume of Concrete excluding Shotcrete	**768.00**	cu.m

ROCK SUPPORT DETAILS

Rock support will be provided in the Arch Portion only

Perimeter of Arch Portion	11.16	m
Spacing of Rock Bolts	2	m
Number of Bolts per section	6	
Number of section in the longitudinal direction	96	
Total Number of Bolts	576	
Length of Each Bolt	6	m
Total Length of Rock Support	3456	m

CONTACT GROUTING

Perimeter of Arch Portion	11.16	m
Spacing of Contact Grouting holes	2.5	m
Number of Grout holes per section	0	
Number of section in the longitudinal direction	76.8	
Total number of Grout Section	0	
Length of Grout Holes (0.5 m into Rock)	1	m
Drilling for Contact Grouting	0	m
Cement Consumption @1 bags per running meter	0	MT
Admixture Consumption @ 2%	0	Kg

SUMMARY

			Rate	Cost
Excavation Volume	11950.2	cu.m	2895.2	3.46
Overbreak	0.0	cu.m	0	0.00
Shotcrete	286.3	Cum	13296.09	0.38
Concrete	768.0	cu.m	8347.2	0.64
Rock Bolts 3 m long	3456	m	1608.9	0.56
Drilling for Contact Grouting	0	m	653.6	0.00
Grouting Operations	0	Nos	12601	0.00
Cement Consumption for Contact Grouting	0	MT		0.00
Admixture Consumption for Contact Grouting	0	Kg		0.00
			TOTAL	**5.04**

PORTAL

Rock Excavation in Anchor Block Area

Excavation Qty (40 % of AB)	0	cum

Portal Excavation

Excavation area	2000	sqm
Length	11	m
Nos of Portal	4	nos
Portal Rock excavation qty	88000	cum
Total Rock Excavation Qty	**88000**	cum
Portal Concrete for 1 protal	12.375	cum
For 8 portals	49.5	cum

Summary of Quantity

			Rate	Itemwise unit rate for Labour Component	Lead	Lead Charges	Rate	Cost (in Cr.)
Overburden Excavation	17600	Cum	133.4	32.6	2	42.6	208.6	0.37
Rock Excavation	17600	Cum	392.9	88.6	2	42.6	524.1	0.92
Shotcrete	66.0	cum	3569.7	235.8	2	42.6	13296.09	0.09
Rock bolt	495.0	m					1608.9	0.08
M25 Concrete	49.5	Cum	5176.4	1958.9	2	42.6	7177.9	0.04
Reinforcement Steel	2.97	MT	54173.71	5085.9	2	25.7	59285.305	0.02
							TOTAL	**1.51**

HM BOQ & Cost				
S.No.	Description	Gate Size (Width X Height) in M	Number Of Sets	Amount in INR Lakhs (incl. transportation)
A	**INTAKE (Upper Reservoir)**			
1	**Intake Trash rack**			
1.1	Embedded parts for intake Trash Rack	3.75 X 43.4	8	168.5448
1.2	Trash rack (1 sets of 17 panels each) 1 panel = 2.43 T Total 8 sets required for 2 vents.	3.75 X 2.5	136	627.912
1.3	Trash rack cleaning machine (Cost of hoist supporting Structures included)		1	300
1.4	TRCM rails & Embedded Parts		1	2.55
1.5	**TOTAL**			1099.01
2	**Intake Maintenance Gate**			
2.1	Embedded parts for intake Bulkhead Gate (Maintenance gate)	5.3 X 5.3	2	51
2.2	Intake Bulkhead Gate (maintenance gate)	5.3 X 5.3	2	114
2.3	Rope Drum hoist for Bulkhead gate 60 T each		2	240
2.4	Hoist Supporting Structures (Trestles)		2	102
2.5	**TOTAL**			507
3	**Intake Service Gate**			
3.1	Embedded parts for intake Service Gate	5.3 X 5.3	2	51
3.2	Intake Service Gate	5.3 X 5.3	2	114
3.3	Rope Drum hoist for Bulkhead gate 75 T each		2	300
3.4	Hoist Supporting Structures (Trestles)		2	127.5
3.5	**TOTAL**			592.5
B	**INTAKE (Lower Reservoir)**			
1	**Intake Trash rack**			
1.1	Embedded parts for intake Trash Rack	3.75 X 25.0	8	99.144
1.2	Trash rack (1 sets of 10 panels each) 1 panel = 2.43 T	3.75 X 2.5	80	369.36
1.3	Trash rack cleaning machine		1	300
1.4	TRCM rails & Embedded Parts		1	2.55
1.5	**TOTAL**			771.054
2	**Intake Maintenance Gate Lower Reservoir**			
2.1	Embedded parts for intake Bulkhead Gate (Maintenance gate)	6.3 X 6.3	2	51
2.2	Intake Bulkhead Gate (maintenance gate)	6.3 X 6.3	2	114
2.3	Rope Drum hoist for Bulkhead gate 60T each		2	240
2.4	Hoist Supporting Structures (Trestles)		2	102
2.5	**TOTAL**			507

3	**Intake Service Gate Lower Reservoir**			
3.1	Embedded parts for intake Service Gate	6.3 X 6.3	2	51
3.2	Intake Service Gate	6.3 X 6.3	2	114
3.3	Rope Drum hoist for service gate 75T each		2	300
3.4	Hoist Supporting Structures (Trestles)		2	127.5
3.5	**TOTAL**			592.5
C	**Draft tube Gate Unit 1, 2, 3 & 4**			
1.1	Embedded parts for intake Service Gate	5.0 X 29.0	4	119
1.2	Intake Service Gate	5.0 X 5.0	4	266
1.3	Bonnet Type Hydraulic Hoist 90 T each		4	1080
1.4	Hoist Supporting/base Structures		4	122.4
1.5	**TOTAL**			1587.4
1.6	**TOTAL (A+B+C)**			5656.46
	3 % Wastage			169.69
	Sub- Total			**5826.15**
D	**Cost of Steel Liner**			**6595.70**
	Grand Total Cost in Crs.			**124.22**

COST ESTIMATE OF ELECTRO-MECHANICAL WORKS

Sl.NO.	ITEM	Qty.	Unit	Rate	Unit	Amount (In Rs. Lakhs)	GST Rate		Total Amount (In Rs. Lakhs)
							Rate	Amount (In Rs. Lakhs)	
1	2	3	4	5	6	7	8	9	10
1	Generator-Motor Unit and associated accessories each of 225.0MW., 375 RPM , Turbine Mode Head 371m, Pumping Mode Head 385.0m	4	Nos.	0.061	Lakh Rs./kW	55109	0.18	9920	65028
2	Step up transformer 24/420 kV,98MVA , Single Phase	13	Nos.	600	Rs./kVA	10140	0.18	1825	11965
3	Auxiliaries Electrical Equipment for power Stations (21% of item 1,2,)					13702	0.18	2466	16169
4	Auxiliary Mechanical Equipment and services for power stations (10% of item 1,2,)					6525	0.18	1174	7699
5	Spares(5% of 1 and 3% of 2-5)					3666			3666
6	**Sub- total(1)**					**89142**		15386	**104528**
7	Transportation & Insurance @ 6% of item 6								6272
8	Erection and Commissioning @ 8% of item 6 Except Spares								8069
9	**Sub- total(2)**								**118869**
10	Establishment, Contingency, other Charges @ 8% of item 6								7131
	GRAND TOTAL								**126000**

FINANCIAL EVALUATION

17 CHAPTER 17 - FINANCIAL EVALUATION

The financial evaluation for the project has been carried out with 900 MW capacity with 4 units of 225 MW each. The design energy is 1971 GWhr, with 95% machine availability.

The Annual Pumping Energy (GWh) for filling the upper reservoir is 2409 GWhr.

One-time Pumping Energy of 3.563 GWhr is required to fill the lower Reservoir requirement. This is only one time at the start of Project Operations on COD.

17.1 BASIC CRITERIA

The terms and conditions used for carrying out the analysis based on the CEA guidelines for formulation of DPR for Hydro Electric Schemes-January 2015 & CERC (Terms and Conditions for determination of Hydro Generation Tariff) Regulation, 2019, as amended till date. The detailed list of these terms and conditions are given in the relevant section below.

17.2 BASIC COST

The Tariff for sale of energy from the Project has been done for the following Basic cost of the project which includes the Initial Spare Cost.

Table 17-1: Cost

	Rs. Crores
Project Hard Cost (including Initial Spare Parts)	3005.36

17.3 COST OF THE PROJECT

1. The Estimated Basic Cost of the Project comprising of Civil, Hydro-Mechanical & Electro-Mechanical Works on the basis of the prices as prevalent presently and costs of equipment from indigenous sources.
2. Commissioning of the project is proposed in a period of 60 months excluding pre-construction and other activities. 9 months of pre-construction activities is required for financial closure, tendering and mobilization. Escalation is not considered during this stage.
3. **Phasing** of the Project Cost during construction phase is presented below, which is based on consultant's project experience:

Table 17-2: Phasing

Phasing of Hard Cost(in Rs. Crores)	Civil Works Phasing %	EM Phasing %

Expenditure to be incurred up to Zero Date (Pre-Construction)	0.00%	0.00%
1st Half year	5.58%	0.00%
2nd Half year	5.38%	8.45%
3rd Half year	6.22%	10.78%
4th Half year	6.84%	10.01%
5th Half year	12.93%	11.53%
6th Half year	13.62%	12.03%
7th Half year	20.25%	12.09%
8th Half year	15.00%	10.92%
9th Half year	11.24%	11.95%
10th Half year	2.94%	12.24%
Total	100.00%	100.00%

4. Total Project Cost (including Interest during Construction)

The Total Cost of the Project including IDC under each alternative is presented below:

Table 17-3: Cost by component

Cost Components	Rs. Crores
Project Hard Cost including Initial Spare Parts	3005.36
IDC and Financing Cost [1]	492.72
Total Project Cost	**3498.08**

[1]The annexure includes the detailed calculations of interest during construction and financing cost etc.

17.4 PROJECT FINANCING

The capital structure of the project is proposed to have 70% Loan Component and 30% Equity Component. It is as per the norms of CERC (Terms and Conditions for determination of Hydro Generation Tariff) Regulation, 2019 and amendments upto date.

Table 17-4: Project Financing

	Rs. Crores
Debt (of project cost and IDC, Financing Charges as above)	2,448.65
Equity (balance to be brought by promoters)	1,049.42

Details of project cost and financing it are given in Annexure at the end of this chapter, as per the CEA guidelines.

The loan component will be financed from Commercial Banks. The financing cost or rate of interest is 10% p.a compounding six months, as per CEA guidelines. Financial charges are considered at 0.5% as per the CERC Regulations.

The Interest during construction has been considered based on above financial arrangement.

The loan Re-payment tenure of 20 years is considered without any moratorium period. The 3 units are considered in each of the last three months before Commercial Operation Date (COD). The interest during construction is thus, reduced during these months, to take effect, as per standard practice.

17.5 TARIFF CALCULATION

17.5.1 ANNUAL COSTS

(a) Operation & Maintenance (O&M) Expenses

The Operation & Maintenance Expenses including spares, insurance costs are taken at 4% of the Project Cost as per substituted CERC (Terms and Conditions for determination of Hydro Generation Tariff) Regulation, 2019 amended.

As per the modified Regulations, O&M expenses shall be escalated for subsequent years to arrive at the O&M expenses for the control period at 4.77% each year.

(b) Depreciation

As per CERC Regulations 2019, Annual Depreciation is provided on Capital Cost excluding Land. The depreciable base is 90%. Land other than the land held under lease and the land for reservoir in case of hydro generating station

is not a depreciable asset and its cost is excluded from the capital cost while computing depreciable value of the asset.

The depreciation is provided on Straight Line Method @ 5.28% and 3.34% for category I and II has been adopted, as per norms provided in Appendix of CERC (Terms and Conditions for determination of Hydro Generation Tariff) Regulation, 2019 and weighted accordingly, as shown in the annexures.

(c) Interest on Working Capital

Interest at 10.5% on Working Capital (latest SBI MCLR Rate plus 350 basis points) has been considered for the calculations. The Working Capital has been calculated after incorporating O&M expenses for one month, maintenance spares at 15% of the annual O&M costs, and two months receivables, as provided in CERC (Terms and Conditions for determination of Hydro Generation Tariff) Regulation, 2019.

(d) Income tax

The current income tax rate (including surcharge) @ 25.17% has been taken into account for calculation of tax liabilities. As per Section 115BAA of Income Tax Act, Basic Corporate Tax Rate@22%, Surcharge@10%, Education Cess@4% on Income-tax inclusive of surcharge. MAT is not applicable.

(e) Return on Equity

ROE is taken at the post-tax rate @ 15.5% on the Equity Component, CERC (Terms and Conditions for determination of Hydro Generation Tariff) Regulation, 2019.

This rate is grossed to 20.71%, by consideration of the tax rate of 25.17%.

(f) Royalty Payment

No Royalty to the State for the project life on the net energy at bus bar has been considered.

17.6 COST OF GENERATION CAPACITY AT POWER HOUSE BUS BARS (WITH IDC)

The Capital Cost of generation capacity at Power Bus Bars is Rs. 3.89 Cr./MW.

17.7 LEVELLISED TARIFF INCLUDING PUMPING COST @ RS. 3.0/KWH

The project is mainly, an underground hydro generating station with static excitation system. As per CERC (Terms and Conditions for determination of Hydro Generation Tariff) Regulation, 2019, a 1.2% of gross energy generated is provided for auxiliary energy consumption (AUX).

Based on above data and methodology provided in CERC Tariff Regulations 2019-24, the levelised tariffs and 1st Year tariff for 90% dependable year are presented below. The tariff without the pumping energy cost is around the range of Rs. 3.5/kWh.

Table 17-5: Tariff at 90% Dependable Year

	First Tariff (₹/kWh)	Levellized Tariff (₹/kWh)
Tariff Rate considering Pumping Cost @ Rs. 3.0/kWh	7.72	7.28
Tariff Rate considering without considering the Pumping Cost	3.96	3.52

17.8 SENSITIVITY ANALYSIS

We have undertaken the sensitivity analysis for increase in cost due to physical and price contingencies for Civil and HM Works. The impact of this is shown below:

Table 17-6: Tariff

	Project Costs Rs. Crores (with Sensitivities)	First Tariff (₹/kWh)	Levelized Tariff (₹/kWh)
Base Case	**3005.36**	7.72	7.28
Sensitivity Case 1	**3061.17**	7.80	7.35
Sensitivity Case 2	**3116.99**	7.87	7.41

17.9 CONCLUSION & RECOMMENDATION

The Somasila PS HEP has the installed capacity of 900 MW. The design energy is 1971 GWhr, with 95% machine availability.

The Annual Pumping Energy (GWh) for filling the upper reservoir is 2409 GWhr. One-time Pumping Energy is required for 3.563 GWhr to fill the lower Reservoir requirement only one time at the start of Project Operations on COD.

The estimated hard cost of the project, including initial spare parts is Rs. 3,005.36 crores. IDC and Financing Cost is expected to be Rs. 492.72 crores. The TPC (all inclusive) is thus expected to be Rs. 3,498.08 crores.

The levelised cost over a 40-year period works out to Rs. 7.28 per kWh. The cost of generation in the first year of operation is estimated at Rs. 7.72 per kWh.

The levelised cost without the pumping cost works out to Rs. 3.52 per kWh and cost of generation in the first year of operation is estimated at Rs. 3.96 per kWh.

With ready accessibility to the project site/works and availability of infrastructure, Somasila PS H.E.P. can be taken up for active construction. The Project can be implemented in a period of 60 months.

SOMASILA PUMPED STORAGE PROJECT (225 MW*4 Units)=900 MW

Annual Energy in 90% Dependable Year on 95% machine availability

TARIFF CALCULATIONS — **Rs. Crores**

Year	ROE	O&M	Dep	Outstanding loan	Norm Loan Repayment	Intt on Loan	Actual loan Repayment	W.C				Intt on W.C	Annual Cost of Pumpin	Annual Fixed Cost	Energy		Tarrif Rs/Kwh	Discount Factor	Discounted Tariff (Rs/Kwh)
								O&M	Spares	Receivables	Total				Free	Sold			
	(Rs Crs)	(Rs Crs)	(Rs Crs)	(Rs Crs)	(Rs Crs)	(Rs Crs)	(Rs Crs)	(Rs Crs)	(Rs Crs)	(Rs Crs)	(Rs Crs)	(Rs Crs)	(Rs Crs)	(Rs. Cr.)	(%)	(Gwh)			
1	217.37	122.43	182.07	2448.65	182.07	235.76	204.05	10.20	18.36	188.02	216.59	22.74	723.77	1504.14	0	1947.3	7.72	1.00	7.72
2	217.37	128.27	182.07	2266.59	182.07	217.56	204.05	10.69	19.24	186.33	216.26	22.71	722.70	1490.67	0	1947.3	7.65	0.91	6.94
3	217.37	134.39	182.07	2084.52	182.07	199.35	204.05	11.20	20.16	184.82	216.18	22.70	722.70	1478.57	0	1947.3	7.59	0.82	6.23
4	217.37	140.80	182.07	1902.45	182.07	181.14	204.05	11.73	21.12	183.35	216.20	22.70	722.70	1466.78	0	1947.3	7.53	0.74	5.60
5	217.37	147.52	182.07	1720.38	182.07	162.94	204.05	12.29	22.13	181.91	216.33	22.72	722.70	1455.30	0	1947.3	7.47	0.67	5.04
6	217.37	154.55	182.07	1538.32	182.07	144.73	204.05	12.88	23.18	180.52	216.58	22.74	722.70	1444.16	0	1947.3	7.42	0.61	4.53
7	217.37	161.93	182.07	1356.25	182.07	126.52	204.05	13.49	24.29	179.17	216.95	22.78	722.70	1433.36	0	1947.3	7.36	0.55	4.07
8	217.37	169.65	182.07	1174.18	182.07	108.32	204.05	14.14	25.45	177.87	217.45	22.83	722.70	1422.93	0	1947.3	7.31	0.50	3.66
9	217.37	177.74	182.07	992.12	182.07	90.11	204.05	14.81	26.66	176.61	218.08	22.90	722.70	1412.88	0	1947.3	7.26	0.45	3.30
10	217.37	186.22	182.07	810.05	182.07	71.90	204.05	15.52	27.93	175.40	218.86	22.98	722.70	1403.24	0	1947.3	7.21	0.41	2.97
11	217.37	195.10	182.07	627.98	182.07	53.69	204.05	16.26	29.27	174.25	219.78	23.08	722.70	1394.01	0	1947.3	7.16	0.37	2.67
12	217.37	204.41	182.07	445.92	182.07	35.49	204.05	17.03	30.66	173.15	220.85	23.19	722.70	1385.22	0	1947.3	7.11	0.34	2.41
13	217.37	214.16	33.35	263.85	33.35	24.72	0.00	17.85	32.12	154.22	204.19	21.44	722.70	1233.74	0	1947.3	6.34	0.31	1.94
14	217.37	224.38	33.35	230.50	33.35	21.38	0.00	18.70	33.66	155.12	207.47	21.78	722.70	1240.96	0	1947.3	6.37	0.28	1.77
15	217.37	235.08	33.35	197.15	33.35	18.05	0.00	19.59	35.26	156.09	210.94	22.15	722.70	1248.69	0	1947.3	6.41	0.25	1.61
16	217.37	246.29	33.35	163.80	33.35	14.71	0.00	20.52	36.94	157.12	214.59	22.53	722.70	1256.95	0	1947.3	6.45	0.23	1.47
17	217.37	258.04	33.35	130.45	33.35	11.38	0.00	21.50	38.71	158.22	218.43	22.94	722.70	1265.77	0	1947.3	6.50	0.21	1.34
18	217.37	270.35	33.35	97.10	33.35	8.04	0.00	22.53	40.55	159.40	222.48	23.36	722.70	1275.17	0	1947.3	6.55	0.19	1.23
19	217.37	283.24	33.35	63.75	33.35	4.71	0.00	23.60	42.49	160.65	226.74	23.81	722.70	1285.18	0	1947.3	6.60	0.17	1.12
20	217.37	296.76	33.35	30.40	30.40	1.52	0.00	24.73	44.51	162.00	231.24	24.28	722.70	1295.97	0	1947.3	6.66	0.15	1.02
21	217.37	310.91	33.35	0.00	0.00	0.00	0.00	25.91	46.64	163.64	236.19	24.80	722.70	1309.13	0	1947.3	6.72	0.14	0.94
22	217.37	325.74	33.35	0.00	0.00	0.00	0.00	27.15	48.86	165.57	241.57	25.37	722.70	1324.52	0	1947.3	6.80	0.13	0.86
23	217.37	341.28	33.35	0.00	0.00	0.00	0.00	28.44	51.19	167.58	247.21	25.96	722.70	1340.65	0	1947.3	6.88	0.11	0.79
24	217.37	357.56	33.35	0.00	0.00	0.00	0.00	29.80	53.63	169.69	253.12	26.58	722.70	1357.55	0	1947.3	6.97	0.10	0.72
25	217.37	374.61	33.35	0.00	0.00	0.00	0.00	31.22	56.19	171.91	259.32	27.23	722.70	1375.26	0	1947.3	7.06	0.09	0.66
26	217.37	392.48	33.35	0.00	0.00	0.00	0.00	32.71	58.87	174.23	265.81	27.91	722.70	1393.81	0	1947.3	7.16	0.09	0.61
27	217.37	411.20	33.35	0.00	0.00	0.00	0.00	34.27	61.68	176.66	272.60	28.62	722.70	1413.24	0	1947.3	7.26	0.08	0.56
28	217.37	430.82	33.35	0.00	0.00	0.00	0.00	35.90	64.62	179.20	279.73	29.37	722.70	1433.61	0	1947.3	7.36	0.07	0.51
29	217.37	451.37	33.35	0.00	0.00	0.00	0.00	37.61	67.71	181.87	287.19	30.15	722.70	1454.94	0	1947.3	7.47	0.06	0.47
30	217.37	472.90	33.35	0.00	0.00	0.00	0.00	39.41	70.93	184.66	295.00	30.98	722.70	1477.29	0	1947.3	7.59	0.06	0.43
31	217.37	495.46	33.35	0.00	0.00	0.00	0.00	41.29	74.32	187.59	303.20	31.84	722.70	1500.71	0	1947.3	7.71	0.05	0.40
32	217.37	519.09	33.35	0.00	0.00	0.00	0.00	43.26	77.86	190.66	311.78	32.74	722.70	1525.24	0	1947.3	7.83	0.05	0.37
33	217.37	543.85	33.35	0.00	0.00	0.00	0.00	45.32	81.58	193.87	320.77	33.68	722.70	1550.95	0	1947.3	7.96	0.04	0.34
34	217.37	569.79	33.35	0.00	0.00	0.00	0.00	47.48	85.47	197.23	330.19	34.67	722.70	1577.88	0	1947.3	8.10	0.04	0.31
35	217.37	596.97	33.35	0.00	0.00	0.00	0.00	49.75	89.55	200.76	340.05	35.71	722.70	1606.09	0	1947.3	8.25	0.04	0.29
36	217.37	625.45	33.35	0.00	0.00	0.00	0.00	52.12	93.82	204.46	350.39	36.79	722.70	1635.66	0	1947.3	8.40	0.03	0.27
37	217.37	655.28	33.35	0.00	0.00	0.00	0.00	54.61	98.29	208.33	361.23	37.93	722.70	1666.63	0	1947.3	8.56	0.03	0.25
38	217.37	686.54	33.35	0.00	0.00	0.00	0.00	57.21	102.98	212.38	372.58	39.12	722.70	1699.07	0	1947.3	8.73	0.03	0.23
39	217.37	719.29	33.35	0.00	0.00	0.00	0.00	59.94	107.89	216.63	384.47	40.37	722.70	1733.07	0	1947.3	8.90	0.02	0.21
40	217.37	753.60	33.35	0.00	0.00	0.00	0.00	62.80	113.04	221.09	396.92	41.68	722.70	1768.69	0	1947.3	9.08	0.02	0.19
			3118.59		**2448.65**		**2448.65**											**10.45**	**76.06**

Levellized Tariff (Rs./Kwh)= 7.28

Initial Year Tariff(Rs/Kwh)= 7.72

SOMASILA PUMPED STORAGE PROJECT (225 MW*4 Units)=900 MW

Annual Energy in 90% Dependable Year on 95% machine availability

BASIC DATA SHEET FOR THE FINANCIAL ANALYSIS(Update: April 29, 2021)

S.No	Description	Rate	Unit	Basis
1	**Name of Project:**	Somasila Pumped Storage Project, Andhra Pradesh		
2	**Total Installed Capacity**	900	MW	
3	**Name of Promoter/s**	NREDCAP (New & Renewable Energy Development Corporation of Andhra Pradesh Ltd.)		
4	**Currency for the financial analysis, unless otherwise provided**	Indian Rupees	Rs.	
5	**Denomination of the figures, unless otherwise provided**	Crores		
6	**Regulation applicable on the Financial Analysis**	CERC Tariff Regulations 2019, with Schedules		
7	**Project cost**			
	Project Hard Cost including Capitalized Initial Spares	3005.36	Rs. Crores	CERC Regulations
	Escalation	0.00	Rs. Crores	Escalation Sheet
	IDC	480.48	Rs. Crores	IDC Calculation Sheet
	Financing Charges	12.24	Rs. Crores	1% of Debt
	Total project cost with IDC	3498.08	Rs. Crores	
8	**Time Line**			
	Expected month of DPR approval	31-Mar-2023		
	Expected month of commencement of construction	01-Dec-2024		
	Construction period (Months)	60	Months	
	Expected month of completion of construction	30-Nov-2029		
	Commercial Operation Date(COD) for the Project	01-Dec-2030		
	Financial evalution period(Years)	40 Years	From COD	As per CERC Regulations
	Commissioning schedule of each unit			
9	**Escalation** Civil Works	0.00%	per year	
	E&M Works	0.00%	per year	

9 **Phasing of Hard Cost(in Rs. Crores)**	Phasing of Civil Works and H&M Works	E&M Works	Total	Phasing of Civil & HM	Phasing of E&M Works
Expenditure to be incurred up to Zero Date (Pre-Construction)			0.00	0.00%	0.00%
1st Half year	93.24	0.00	93.24	5.58%	0.00%
2nd Half year	89.79	112.84	202.63	5.38%	8.45%
3rd Half year	103.84	143.98	247.82	6.22%	10.78%
4th Half year	114.18	133.71	247.90	6.84%	10.01%
5th Half year	215.95	154.02	369.97	12.93%	11.53%
6th Half year	227.34	160.67	388.01	13.62%	12.03%
7th Half year	338.05	161.51	499.56	20.25%	12.09%
8th Half year	250.43	145.83	396.26	15.00%	10.92%
9th Half year	187.76	159.61	347.37	11.24%	11.95%
10th Half year	49.17	163.44	212.61	2.94%	12.24%
Total	1669.76	1335.60	3005.36	100.00%	100.00%

10 **Phasing of Escalated Hard Cost (in Rs. Crores)**	Escalated Civil Works and HM Works	Escalated E & M Works	Total Cost
Expenditure to be incurred up to Zero Date (Pre-Construction)	0.00	0.00	0.00
1st Half year	93.24	0.00	93.24
2nd Half year	89.79	112.84	202.63
3rd Half year	103.84	143.98	247.82
4th Half year	114.18	133.71	247.90
5th Half year	215.95	154.02	369.97
6th Half year	227.34	160.67	388.01
7th Half year	338.05	161.51	499.56
8th Half year	250.43	145.83	396.26
9th Half year	187.76	159.61	347.37
10th Half year	49.17	163.44	212.61
Total	1669.76	1335.60	3005.36

11	**Debt Equity ratio**		70/30	CERC Regulations, 2019-2024
	Debt (of project cost and IDC as above)		2,448.65	Rs. Crores
	Equity (balance to be brought by promoters)		1,049.42	Rs. Crores
12	**Loan Amortization and Interest Payment**			
	Cost of Borrowing (100% from Commercial Banks)		10.00%	Source: Rates taken from study of WAPCOS
	Debt from Commercial Banks			
	Financing Charges on term loan		0.50%	
	Working Capital		10.50%	As per the applicable bank rate of SBI (1 yr. MCLR + 3.5%) Effective from 10th March 20121, CERC Regulations
	Working Capital Margin		25.00%	

	Interest during construction	10.00%	
	Moratorium Period	-	Year
	Repayment Period (incl. Moratorium Period) Years	12	As per standard practice for repayment
	Interest compounding	Quarterly	
	Principal and Interest repayment	Quarterly	
	Discounting factor	10.36%	Source: Rates taken from study of WAPCOS
13 Tax			
	Basic Tax rate@22%, Surcharge@10%, Education Cess@4% on Income-tax inclusive of surchage	25.168%	As per Section 115BAA of the Applicable Finance Act.
14 Depreciation			
	Depreciation (as per CERC Tariff Regulations, 2009)		
	Category 1	5.28%	Depreciation Rate under Appendix of the CERC Tariff
	Category 2	3.34%	Regulations 2019
	Category 3	0.00%	
	Weighted Average Depreciation Rate	**5.25%**	

	Depreciation allowed	3,118.59	Rs. Crores	(after adjusting Salvage Value of 10%)
15	**Operation and maintenance cost** (of the original project cost less R& R Cost)	4%	CERC Tariff Regulations 2019 and latest amendments	
	Escalation rate for Operation and maintenance cost	4.77%	CERC Tariff Regulations 2019 and latest amendments	
16	**Working Capital**			
	i) Maintenance Spares(% of O&M)	15%	CERC Tariff Regulations 2019	
	ii) O&M expenses(Months)	1.00	Month	
	iii) Receivables(Months)	1.50	Month (or 45 Days)	
17	**Total Land cost**	32.98	Rs. Crores	
	Less: Land on Lease (will be depreciated)	0.00	Rs. Crores	NA
	Less: Land for reserviour(will be depreciated)	0.00	Rs. Crores	NA
	Net Land Cost (that will not be depreciated)	32.98	Rs. Crores	
17	**Cost of Rehabilitation and Reconstruction**	0.00	Rs. Crores	NA
18	**Preliminary expences**	0.00	Rs. Crores	
19	**Energy**			
	Design Energy Generation at 90% DY with 95% Machine Availability			
	Main Units	**1,971.00**	GWHr	
			GWHr	
	Total	1,971.00	GWHr	
a	Primary energy produced	1971.00	GWHr	
	Aux and Transformer Losses%	1.20%	CERC Tariff Regulations 2019-24	
	Aux and Transformer Losses(in GWHr)	23.65	GWHr	
	Net energy produced	1,947.35	GWHr	
b	Free power for State(%)			
	First 15 Years	0%		
	After 15years	0%	As per the mail dated 09-02-2021, this is assumed as nil	
c	Free power for State(GWHr)	-	GWHr	
	First 15 Years	-	GWHr	
	Saleable energy for first 15 years	1,947.35	GWHr	
	After 15years	-	GWHr	
	Saleable energy for after 15 years	1,947.35	GWHr	
d	Net Saleable Primary energy	1,947.35	GWHr	
20	**Return on Equity (Net)**	15.50%	CERC Tariff Regulations 2019	
	Pre-Tax RoE(normal tax grossing 25.17%)	20.71%	Tax Rates As per Section 115BAA of the Applicable Finance Act.	
	Return on equity if normal tax applicable (in Rs. Cr.)	217.37	Rs. Crores	
	Tax Holiday	10.00	Years	
21	**Tariff**			
	Levellised Tariff (based on discount factor as provided by CERC)	7.28	Tariff Sheet	
22	**Operating Cost for Pumping**			
	Energy required for pumping each year	2409	GWHr Annually	
	Additonal Energy required for pumping during initial year	3.563	GWHr in the initial year (additional to above)	
	Rate for off peak energy	3.00	Rs/KWHr	

Source: Rates taken from study of WAPCOS

SOMASILA PUMPED STORAGE PROJECT (225 MW*4 Units)=900 MW

Annual Energy in 90% Dependable Year on 95% machine availability

IDC Computation:

			Interest rate	10.00%
			F.C. on	
Completed cost	3498.08	Cr.	loan	0.50%

Six-Monthly	Hard cost phasing	F.C.	Equity	Loan	IDC	IDC component in Loan	IDC component in Equity	Cumulative Loan	Cumulative Equity
Pre-cons	0.00	12.24	3.67	8.57	0.21	0.15	0.06	8.72	3.74
6	93.24		27.97	65.27	2.07	1.45	0.62	75.44	32.33
12	202.63		60.79	141.84	7.32	5.12	2.20	222.40	95.31
18	247.82		74.35	173.47	15.46	10.82	4.64	406.69	174.30
24	247.90		74.37	173.53	24.67	17.27	7.40	597.49	256.07
30	369.97		110.99	258.98	36.35	25.44	10.90	881.91	377.96
36	388.01		116.40	271.61	50.89	35.62	15.27	1189.13	509.63
42	499.56		149.87	349.69	68.20	47.74	20.46	1586.56	679.96
48	396.26		118.88	277.38	86.26	60.38	25.88	1924.33	824.71
54	347.37		104.21	243.16	102.30	71.61	30.69	2239.09	959.61
60	212.61		63.78	148.83	86.76	60.73	26.03	2448.65	1049.42
Total	**3005.36**	**12.24**	**905.28**	**2112.32**	**480.48**	**336.33**	**144.14**		

Total Cost	3498.08	Cr.
Debt	2448.65	Cr.
Equity	1049.42	Cr.
IDC	480.48	Cr.
F.C	12.24	Cr.
D/E Ratio	2.33	
Debt(%)	70%	
Equity(%)	30%	

Calculation of IDC for the last quarter(each Unit is installed at the end of last day of the month)

IDC for units			Commissioning Months		
			58th month (30-09-2029)	59th month (31-10-2029)	60th month (30-11-2029)
Unit(MW) Installation out of total 4 units(225*4)=900 MW					
	225				
	225		225		
	225		225	225	
	225		225	225	225
	900		**675**	**450**	**225**
IDC/Month			14.46	9.64	4.82
IDC before COD of Final Unit(total)				28.92	

RECOMMENDATIONS

18 CHAPTER 18 - RECOMMENDATIONS

The Somasila pumped storage project (4 x 225 MW) contributes design energy of 1971.00 GWh annually at an **economically attractive** levelized tariff of Rs. 7.28 per KWh. The Project has good economic viability. Somasila Pumped Storage Project can be taken up for active construction after accessibility to the project site/works is established. The project is proposed to be completed in 60 months (excluding 9 months for preconstruction activities).

Social benefits will include business partnerships, royalties, development funds, equity sharing, job creation, improvements of roads and other infrastructures, fisheries, granting **preferential electricity rates** and fees for other water-related services to local companies and project-affected populations.

Figure 18-1: Project benefits

The Project site lies in Gopavaram Mandal of the Kadapa District in Andhra Pradesh. It is very **well connected** with the **existing network** of roads. A 10 KM long stretch from the Project site connects to the NH 67 which connects Krishnapatnam Port, Andhra Pradesh in the east to Panjim, Goa in the west. The major roads meeting at Kadapa (District Headquarters) are

1. Kurnool-Kadapa-Chittoor State Highway
2. Kadapa-Madras State Highway
3. Kadapa-Vempalle
4. Kadapa-Sidhout

Table 18-1: Recommendations

S. N.	Parameter	Results	Remarks	Recommendations
I	**General**			
1.	Accessibility	Good	Well connected & has access to major roads & railway network within a short distance.	The existing highway may require upgrading/ improvement for the E&M equipment's considering its transportation and other heavy items of machinery and construction materials
2.	Inter-state/ International Issues	Good	None	-
3.	Geology	Good	No Adverse geology traced till now	• Tests especially in context of permeability of the reservoir area shall be critically examined during detailed investigations. However, there does not appear to be any concern on this aspect. • Availability of impervious material for rock fill dams and embankments may be a cause of concern as the area around the project is quartzite dominated and the soil is expected to be sandy. Accordingly, concrete gravity dam has been proposed for both the reservoirs at the FSR stage. However, availability of impervious material will be the focus of attention during the investigations for the construction material to finalize the type of dam. • The subsurface water conductor system makes a small angle of about 20^{o} with the strike of the strata and a major weakness zone may persist for longer lengths along it, should one be encountered. The results of exploratory drifts in the powerhouse complex would be used in keeping the subsurface water conductor free from any major weakness zone.

S. N.	Parameter	Results	Remarks	Recommendations
4.	Water Availability (Filling)	Good	Somasila reservoir has storage of 78.00TMC, thus water is available	Water planned to utilize from existing Somasila reservoir shall be informed in advance to the authorities for management with other water utilization agencies. Initial filling will be done in monsoon season when the reservoir is at FRL and surplus water is available. It will take approx. 2 months to complete initial filling of the lower reservoir.
5.	Water Availability (Operation)	Good	Proposed scheme PSP will require refill in 100 days (first fill) to compensate the water lost in evaporation for first refill.	The same shall be communicated to the concerned agencies and it will be taken care by the pumping required water through the proposed pipeline from the existing Somasila reservoir.
6.	Capacity	900 MW	Generation capacity of project is significant & worth further evaluation.	4x225MW has been proposed keeping in mind the availability of machine.
7.	Cycle Efficiency	80.73%	Considering average anticipated efficiency of 75%, this is satisfactory	Reservoir volumes shall be maintained vide appropriate sealing and head loss shall be controlled vide appropriate linings an length of the water conductor system
8.	L/H Ratio	4.5 < 10	Good	Lower L/H ratio (< 10) will result in lower capital cost, lesser head loss as well less construction time.
II	**Commercial**			

S. N.	Parameter	Results	Remarks	Recommendations
9.	Capital Cost	Good	Rs 3.88 Crores/MW	Attractive investment opportunity for such a large scale Project.
10.	Levelized Tariff	Good	Rs 3.52 /kWhr (without pumping cost) Rs 7.28/kWhr (including pumping cost of Rs 3/kWhr)	Attractive for a Pump Storage project which will also act as a surplus energy storage arrangement during off peak hours.
III	**Environmental**			
11.	Land Issues	Appox. 183 Ha.	Land requirement is reasonable for a project of such magnitude. Project mostly lies outside the eco-sensitive boundary and is in the forest area	Project specific Environmental Management Plan (EMP) will be prepared for avoiding/ reducing/ mitigating/ checking the adverse impacts envisaged during EIA studies

Considering the above aspects, the proposed Somasila Pumped Storage Project (4 x 225 MW) is an investment worthy project and hence recommended to be considered for further DPR studies and detailed evaluation.