PRE-FEASIBILITY STUDY REPORT FOR 1000 MW UPPER BHAVANI PUMPED STORAGE PROJECT, TAMIL NADU

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NTPC TAMILNADU ENERGY COMPANY LIMITED

NTECL

ENERGY INFRATECH PVT. LTD.
Redefining Project Management -from Concept to Commissioning

Table of Contents

List of Tables

List of Figures

CHAPTER 1. EXECUTIVE SUMMARY

1.1 Introduction

The Upper Bhavani PSP is in the Nilgiris district, the North-western part of Tamil Nadu State. The project is proposed to be developed as Pumped Storage Plant by **M/s NTPC Tamilnadu Energy Company Limited (NTECL),** a joint venture company of **NTPC Ltd**. and Tamilnadu Generation And Distribution Corporation Limited (**TANGEDCO**) to store the surplus energy from solar and wind power sources of Tamil Nadu or elsewhere in India. The Nilgiris district is bordered on the West by the Malabar regions of Kerala, on the North by Karnataka, and on the East and South by the Coimbatore district of Tamil Nadu. The district is spread out between Latitude 11° and 11° 55’ North and Longitude 76° 13’ and 77° 02’ East.

Upper Bhavani Pumped Storage Project envisages generation of power by utilizing waters of the existing reservoirs of the Upper Bhavani dam and Avalanche-Emerald reservoir system (as the lower reservoir) operating under a head of approx. 291.81 m to generate 1000MW power. Both the reservoirs shall be connected through an underground water conductor system comprising of Head Race Tunnel, Surge-shaft, steel-lined Pressure-Shafts, an Underground Powerhouse with Transformer Cavern and Tail Race Tunnel. The Underground Powerhouse House contains four fixed speed reversible Pump-Turbines along with the Generator-Motor assembly, unit step up transformers, and other appurtenant equipment. The scheme of operation considered for the project envisages daily generation of 6 hours to meet the grid demand.

The Upper Bhavani PSP area is located between latitude 11°15’00” to 11°20’00” and Longitude 76°32’30” to 76° 37’30”. The project location falls in **Kundah Reserved Forest** of the Nilgiris District.

1.2 Project Background

The Pre-Feasibility Report (PFR) for the Upper Bhavani Pumped Storage Project (PSP) was initially prepared by the Consultancy Division of NTPC Ltd., in June 2022. Subsequently, NTECL has engaged Energy Infratech Pvt Ltd. (EIPL) to prepare the Detailed Project Report (DPR) for the development of this project. As part of this process, EIPL reviewed the original PFR, incorporating updated site data, which led to this revised Pre-Feasibility Report (PFR) that includes new layout alternatives and updated cost estimates that reflect current market conditions.

1.3 Alternative Layout Study

Three layout options have been studied as detailed in Chapter no. 3 and evaluated on techno-economical as well as environmental considerations. Subsequently, Alternative -2 as detailed below is found suitable and selected for further studies**. A broad feature of the selected layout is described below.**

The general layout of the project is shown below:

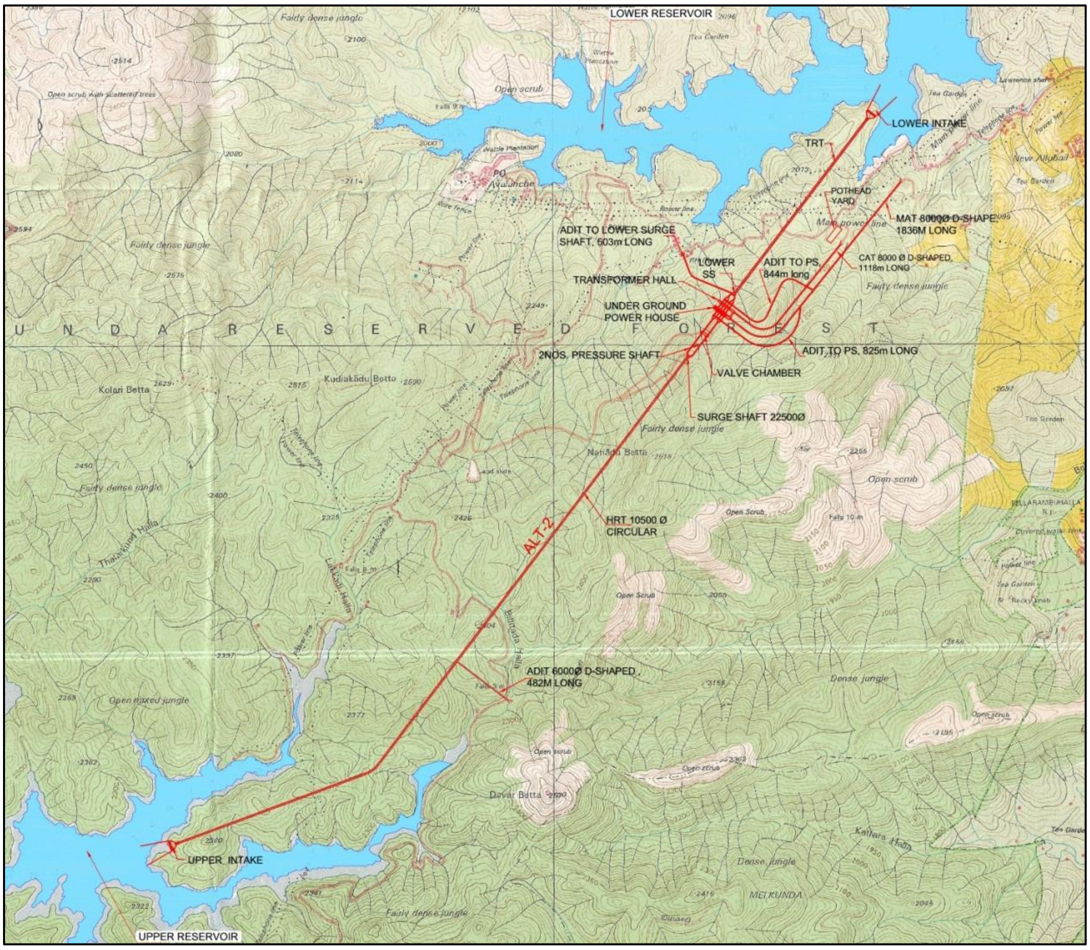


Figure 1:1 General layout plan of the Upper Bhavani PSP (1000 MW)

1.4 Broad project features

The proposed Upper Bhavani Pumped Storage Project (PSP) (4 x 250 MW) envisages following civil structures:

1. **Upper Dam (Existing)**: The Existing Upper Bhavani Dam (commissioned in 1965) serves as the Upper Reservoir, featuring a dam height of 80 m and a gross storage capacity of 97.04 MCM (as per the current data). The Full-reservoir-level is at EL 2276.88 m, while the Minimum-Drawdown-level is at EL 2249.42 m, with a catchment area of 33.61 Sq. km and the live storage capacity is 79.07 MCM.
2. **Lower Dam (Existing)**: The Existing Avalanche and Emerald Dam (commissioned in 1961) serves as the lower reservoir for the project, the dam top elevation are EL 1987.32 m and height of about 57 m. The Full-reservoir-level (FRL) of EL 1985.8 m and a Minimum- drawdown level (MDDL) of EL 1956 m with a gross storage capacity of 149.57 million cubic meters (MCM) and a live storage capacity of 134.72 MCM, it manages a catchment area of 57.53 square kilometres.

3. **Upper Intake/Outlet**: The intake structure is sloping type with a bell-mouth opening. The structure comprises 1 intake, measuring 79 m (W) x 23.5 m (H). The sill level of the intake is kept at EL 2227.50 m and the intake is designed for a discharge of 404.64 cumec. The structure includes 10 trash racks, each measuring 5.5 m (W) x 23.8m (H). Additionally, there are 1 service gates and 1 maintenance gate, each 9 m (W) x 10 m (H).
4. **Headrace Tunnel (HRT)**: The headrace tunnel is circular in shape, approximately 5.38 km long, with a finished diameter of 10.5 m. It is concrete-lined for the entire length. The tunnel alignment passes through good to fair rock mass. Detail analysis will be carried out at DPR stage for realistic assessment of rockmass condition and to decipher actual support system.
5. **Surge Shaft**: A restricted orifice surge shaft is proposed with a diameter of 22.5 m and a height of 95 m. It is concrete-lined for its entire height. The shaft is expected to pass through very good to good rockmass. Detail analysis will be carried out at DPR stage for realistic assessment of rockmass condition and to decipher actual support system.
6. **Valve House**: A surface valve house is proposed to house 2 butterfly valves, of adequate size which shall match the inlet diameter of pressure shaft. The valve house measures 45 m (L) x 15 m (W) x 26 m (H) and will accommodate oil pressure units, valve control panels, electrical panels, and a 220V DC battery with a charger.
7. **Pressure Shaft**: The water conductor system includes 2 main pressure shafts, each having diameter of 6.6 m and a length of about 623 m. The shaft comprises 320 m vertical and 303 m horizontal sections. It is steel-lined to withstand high internal water pressure and backfilled with concrete. The proposed two pressure shafts will be bifurcated into 4 no's unit pressure shafts each having 4.6 m diameter to reach the powerhouse. Detail analysis will be carried out at DPR stage for realistic assessment of rockmass condition and to decipher actual support system.
8. **Powerhouse Complex**: The underground powerhouse cavern is 144 m (L) x 24 m (B) x 47.2 m (H). The transformer cavern measures 124 m (L) x 18.5 m (B) x 30 m (H). The complex is connected to the service bay through 8 m diameter D-shaped tunnels. The powerhouse cavern is situated at a minimum rock cover of 262. m. The complex is expected to pass through very good to good rock mass. Detail analysis will be carried out at DPR stage for realistic assessment of rockmass condition and to decipher actual support system.
9. **Down Surge Shaft**: One underground down surge shaft having 22.5 m dia with top EL.2015.80m has been proposed at the downstream of powerhouse in the tail race tunnel. It is concrete-lined for its entire height. The shaft is expected to pass through very good to good rockmass. The cover above the surge shaft is 122.0m with adequate lateral rock participation. Detail analysis will be carried out at DPR stage for realistic assessment of rockmass condition and to decipher actual support system.

10. **Tailrace Tunnel**: The tailrace tunnel is circular in shape, approximately 1590 m long, with a finished diameter of 10.5 m. It is concrete-lined for the entire length and expected to pass through good to fair rock mass. Detail analysis will be carried out at DPR stage for realistic assessment of rockmass condition and to decipher actual support system.
11. **Lower Intake**: The intake structure is sloping type with a bell-mouth opening. The structure comprises 1 intake, measuring 79 m (W) x 21.6.0 m (H), including piers. The intake centreline elevation is EL 1940.50 m, with a bottom elevation of EL 1936.0 m, designed to accommodate a discharge of 404.64 Cumec for intake in turbine mode. The structure includes 10 trash racks, each measuring 5.5 m (W) x 21.93 m (H). Additionally, there are 1 service gates and 1 maintenance gate, each 9 m (W) x 10 m (H). Detail analysis will be carried out at DPR stage for realistic assessment of rockmass condition and to decipher actual support system.
12. **Pothead Yard:** A Surface Pothead Yard of size 72m (L) x 35m (W) has been envisaged at the EL of 2045 m which connected with already existing road going to upper reservoir. Connection between pothead yard to cavern has been envisaged vide 6m diameter D-shaped inclined cable shaft. The length of the same is approx. 1118m.

The salient features of the Project are given at **para 3.2, of Chapter 3.**

1.5 Geology

Geologically, the Nilgiris belong to the Archaean continental land mass of the Indian peninsula, composed of Precambrian, mainly metamorphic rocks (gneisses, charnockite, crystalline schists). Due to continental drift of the 'Indian shield' - which until late Jurassic times was a part of the ancient Gondwana land and coincident with the Himalayan Orogenesis during the cretaceous and tertiary periods, geo-tectonic movements in the southern Deccan resulted in its fragmentation and in vertical dislocations along faults that are oriented in three main directions viz. NNW-SSE, NE-SW and W-E and that recur in the morphological boundaries as well as in the courses of many streams and rivers of the Nilgiris. The Nilgiris hills consist of a great mass of foliated gneissose rocks of the charnockite series, originally described as Nilgiris gneiss or mountain gneiss, with a few later dykes. In the Nilgiris-Wynand the rocks are of typical Archaean biotite and hornblendic gneiss, with intrusive bands of charnockite and much younger biotite-granite, pegmatite and basic dolerite dykes.

As per the preliminary assessment geologically the area in general is having very strong to strong and very good to good quality of charnockite rock mass. However, the assessed conditions shall be corroborated with detail geological and geotechnical investigations during DPR stage.

1.6 Hydrology

The total catchment area of the existing Upper Bhavani Reservoir is 33.57 Sq.km. The gross storage capacity of the upper reservoir is 97.04 MCM, and the live storage is 79.07 MCM. Operational pattern has been kept in such a way that 9 MCM of water will be utilized for the proposed Upper Bhavani PSP. The project is a pumped storage scheme and hence, no consumptive utilization of water is required for its operation. This will be further investigated during the DPR Stage. Details of project hydrology are provided in **chapter 3.0**.

1.7 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+2276.88.0m) and Lower Reservoir at MDDL (El+1956.0m), and Conversely, during the pumping cycle, the Lower Reservoir level was adjusted post-generation, and the Upper Reservoir was at an MDDL of 2249.42 m. Details of the power potential study is provided in **chapter 3.0**.The results of the simulation studies for generating mode & pumping mode are summarized below

Summary Result of Reservoir Simulation			
	Running Time (in hrs)	**Annual Energy (in MU)**	**Working Days/ year**
Pumping Mode	**6.58**	**2507.87**	**365.00**
Generation Mode	**6.00**	**2080.50**	**365.00**
Cycle Efficiency	**82.96%**		

1.8 Electro-mechanical & Hydro-mechanical Works:

The plant is proposed with Constant Speed Reversible Pump Turbines with configuration of 4x250 MW for flexibility of operations in an Electric Grid dominant with Variable Renewable Energy (VRE) Sources and consistent with variable Demand. The terminal voltage of units would be in the range of 15 kV to 18 kV which will be further stepped up to proposed transmission voltage level of 400kV by Unit Step Up Transformers and connected to 400 kV Indoor Gas Insulated Switchgear(GIS) with Double bus arrangement to include 4 (Four) Incomer, 1 Bus Coupler & 2 Outgoing Cable Feeder Bays.

The power plant shall be complete with all auxiliaries and ancillary items proposed to be controlled and monitored through a dedicated Supervisory Control & Data Acquisition System (SCADA).

For isolation, Control and Safety of operation of the project Hydraulic Gates /Valves are proposed at various inlet/outlet points of the Water Conductor System.

1.9 Power Evacuation Aspect

Power from the Generating units will be stepped up from 18 KV to 400 kV through the unit step up Transformers and connect to 400 kV GIS. Power from the GIS will be transmitted through 400 kV XLPE cables to the Pothead yard and then shall be transmitted to the nearest pooling substation through 400KV D/C Transmission line. The projects envisages 1 (one) number of 400 kV double circuit transmission line with quad moose ACSR Conductor from the pothead yard of the proposed Project is to be connected to proposed 400 kV Parali pooling substation (near Pillur reservoir). Presently there are no 400 kV systems available in Nilgiris District. A 400 kV Pooling station is proposed to be developed by TANGEDCO and all the upcoming hydro projects in the said district shall be connected to it. Power from this Pooling Station will be evacuated to Karamadai 400 kV substation or any other nearby substation which shall be explored and finalized after joint load flow study with CTU &CEA/ New Delhi. The transmission line alternatives are discussed in chapter 2 under Power Evacuation clause no: 2.7. The final transmission line route shall be validated and confirmed after the transmission route survey, which will be conducted in the course of DPR, and in consultation with the regulators and stakeholders, once the land for the Parali pooling substation is finalized by the stakeholders.

1.10 Project Schedule

As a preliminary estimate, a construction period of 5 years (60 months including 12 months pre-construction period) from the date of award of civil works package has been envisaged for this project.

Approach roads are to be taken up in advance for early start of actual excavation of underground structures. This will enable the construction agency under civil works package to take up the construction of individual project components with approach roads already available before mobilization at site.

1.11 Environmental aspect

Upper Bhavani PSP comprises an existing upper Bhavani reservoir (As upper reservoir) and the existing Avalanche reservoir (As lower reservoir). There will be no additional submergence of land in the proposed Pumped Storage Project as both the reservoirs already exist. Land shall be required for the construction of powerhouse complex and other appurtenant structures. Total land requirement for construction of various components and other infra item like road, job facilities, muck disposal area Transmission line etc. is estimated to be approx. 473.24 ha. The same shall be analysed in detail during finalization of layout in DPR stage. Based on assessment of environmental impacts, management plans shall be formulated for Catchment Area Treatment, compensatory afforestation and other environmental issues like rehabilitation & resettlement shall be addressed in detail during the investigations for DPR.

1.12 Estimates of the cost

The preliminary cost estimate of the project has been prepared as per guidelines of CEA/CWC. The total project cost has been estimated at **5005.52 Crore** for year 2023-24 price level as given below:

The breakdown of the cost estimate is as mentioned hereunder:

Item	Estimated Cost (in Crores)
Civil & HM Works	2401.0
Electro-Mechanical Works	1909.0
Total Capital Cost	4310.0
IDC	683.25
FC	12.26
Total Cost	**5005.52**

1.13 Financial aspect

The economic & financial evaluation is carried out for the proposed Upper Bhavani Hydro Electric Pumped Storage Project. The Design Energy generation has been worked out as 2080.50MU against pumping energy requirement of 2507.87 MU. Accordingly, the cycle efficiency is estimated as 82.96%. The tariff has been worked out considering a debt-equity ratio of 70:30, ROE of 17 % and Rate of Interest for the loan amount is 10%. The breakdown of tariff is given below:

Conversion Cost (Excluding pumping Cost)	
A. Levelized	RS 4.16 /- per unit
B. First year	RS 4.71 /- per unit
Conversion Cost (Including pumping Cost of Rs.2.50 per unit)	
A. Levelized	RS 7.21 /- per unit
B. First year	RS 7.76 /- per unit

1.14 Conclusions & Recommendation

The Upper Bhavani PSP is proposed across the two existing reservoirs namely, Upper Bhavani and Avalanche Reservoirs. The civil structures have been selected after due diligence and based on available data. The required quantity of water is estimated to be around 9 MCM which is a small quantity in comparison to the water available in the reservoirs. Hence from hydrology point of view, there will be no problem in getting the water for generation for the proposed PSP. Upper Bhavani Pumped Storage Project involves minimum and simple civil works and could be completed in 5 years including 1 year for pre-construction activities. This study indicates that Upper Bhavani PSP has merits from technical as well as financial aspects.

In view of the above, Upper Bhavani Pumped Storage Project is recommended for taking up for DPR.

CHAPTER 2. INTRODUCTION OF THE PROJECT

2.1 General

The commitment of India to ramp up renewable energy capacity to 500 GW by 2030 is ambitious and commendable. The challenges associated with integrating such massive renewable capacities into the grid while maintaining stability are indeed significant. The intermittent nature of wind and solar power does present hurdles for ensuring a consistent energy supply.

Pumped storage projects, particularly Off-stream or On-stream schemes, offer a promising solution to address these challenges. These projects can play a crucial role in providing energy storage, grid management, and frequency regulation, thereby aiding in the integration of renewable energy into the grid.

During the COP26 summit, the Government of India reiterated its dedication to effectively harnessing renewable energy capacities. Long-duration energy storage, like that provided by Pumped Storage Projects, becomes increasingly essential as renewable energy penetration grows. These projects can store excess energy during periods of high renewable generation and release it during peak demand times or when renewable sources are not producing electricity.

By utilizing Pumped Storage Projects, India can potentially optimize the utilization of existing base-load assets, manage dynamic demand curves, and reduce the pass-through of high fixed costs to consumers. Additionally, these projects can contribute to grid stability and reliability, crucial elements in ensuring a smooth transition to a renewable-centric energy landscape.

However, the implementation of such projects requires significant investment, technological advancements, and comprehensive planning to ensure their efficiency and environmental sustainability. Collaborative efforts between the government, energy sector stakeholders, and technological innovators will be pivotal in realizing the full potential of pumped storage as a solution to India's energy transition challenges.

NTPC Tamilnadu Electric Company (NTECL), a joint venture between the NTPC Ltd., Tamil Nadu Generation and Distribution Corporation (TANGEDCO), and EIPL as a consultant, is developing the Upper Bhavani Pumped Storage Project (1000 MW) in the Kundah basin of the Nilgiris District, Tamil Nadu. Following comprehensive site evaluations, NTECL plans to secure the necessary permissions and approvals for the project, which will consist of four 250 MW units.

2.2 Historical background, Nature & scope of the project

The Pre-Feasibility Report (PFR) outlines a Standalone Pumped Storage Project (PSP) proposed by NTECL, with an installed capacity of 1000 MW and energy storage of 6580 MWh. This project is strategically located near Kundah taluka, at the foothills of the Nilgiri Hills, in Tamil Nadu. The project aims for a peak operating duration of 6 hours, making it a significant addition to energy storage capabilities in the region.

The geographical coordinates for the project site are between Latitude 11°15'00" N and 11°12'00" N, and Longitude 12°32'30" E to 12°32'00" E, indicating a carefully selected area conducive to the requirements of a pumped storage system.

Details of present proposal

The main features of the Upper & lower reservoir for the Pumped storage scheme are presented in the table below:

Table 1 Features of the Upper and Lower reservoir.

S.No.	Parameters	Upper Reservoir	Lower Reservoir
1.	FRL (m)	2276.8	1985.80
2.	MDDL (m)	2249.42	1956.0
3.	Dam Heights (m)	80.0	57.0
4.	Gross Storage (MCM)	97.04	149.57
5.	Live Storage (MCM)	79.07	134.72

The water from the upper reservoir will be diverted through Powerhouse and TRT to the proposed lower reservoir with water conductor systems. The water will be pumped back from the lower reservoir to the upper reservoir through reversible pump-turbines housed in the underground powerhouse.

The present proposal consists of the following components:

- Existing Upper Reservoir and dam
- Upper Intake
- HRT and Pressure shaft (steel lined)
- Underground Powerhouse ,Transformer Cavern/GIS and Pothead yard
- Downstream Surge Shaft
- Tailrace Tunnel
- TRT Intake/Lower Intake
- Adits
- Existing Lower Reservoir & Dam

2.3 Need for the project and its importance to the country and or region

Generation from renewable sources (like solar, wind and NCE's) will be available partially (i.e., Seasonal or intermittently in a day). To manage large swings in net power demand during the day, optimal solution would be flattening the RE generation instead of backing down and ramping up thermal generation. Flexible Energy Generation Assets that have a capability to supply both Base Load & Peaking Power efficiently and economically are the need of the future and the necessary solution to address the dynamic evolving energy needs of India.

Energy reliability on solar & wind power over the entire year may create the demand to supply issues as well as grid instability issues. Large scale energy storage systems are not available in the state. Ultra-mega solar projects connected to the grid may have variations in the grid frequency due to sudden changes in the generation by way of cloud cover, rains etc. Hence a quick response system. This large-scale injection of solar / wind power into the grid necessitates the proposals for storage of energy systems.

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.

2.4 Power Demand-Supply gap

Demand for the utilization of power has been on steady rise with an average annual rate of about 8-9% in the country. As per CEA report, the total installed capacity at the end of March 2024 stood at 4,41,969.55 MW with thermal power accounting for 55.03% (2,43,216.87 MW), hydro power for 10.61% (46,928.17 MW) and Renewables including nuclear power accounting for 34.35% (1,51,824.51MW). The energy generation is divided into six regions as shown in Table below.

Table 2: Total Amount of Installed Capacity in the Country

All India Installed Capacity (MW) Region-wise as on 31.03.2024						
Sl. No	**Region**	**Thermal (MW)**	**Hydro (MW)**	**Renewables* (MW)**	**Nuclear (MW)**	**Total (MW)**
1	Northern Region	64,525.91	20,829.76	38,492.92	1,620.00	1,25,468.59
2	Western Region	86,869.08	7,562.50	49,708.54	3,240.00	1,46,380.12
3	**Southern Region**	**60,459.86**	**11,827.48**	**53,818.82**	**3,320.00**	**1,29,426.16**
4	Eastern Region	28,592.50	4,764.42	2,009.26	0.00	35,366.18
5	North Eastern Region	2,649.98	1,944.01	574.21	0.00	5168.82
6	Islands	119.54	0.00	40.13	0.00	159.67
	ALL - INDIA	**2,43,216.87**	**46,928.17**	**1,43,644.51**	**8,180.00**	**4,41,969.55**

SOURCE: CEA REPORT ON EXECUTIVE SUMMARY ON POWER SECTOR, MARCH 2024

* Including Small Hydro Power

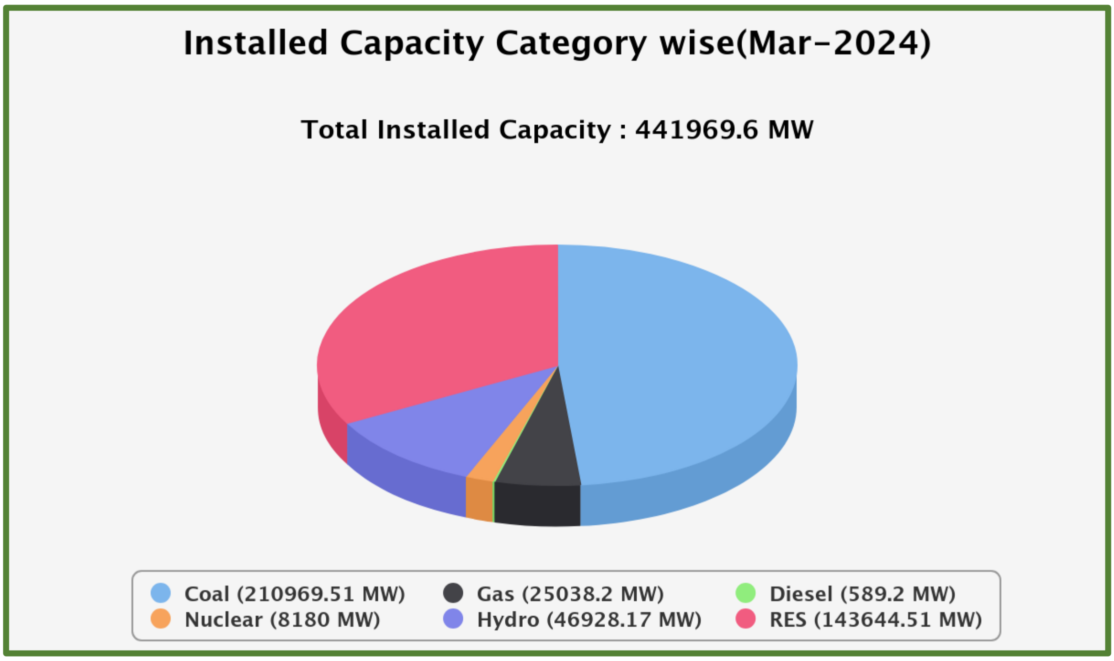


Figure 2:1 All India Installed Capacity (MW) of Power Sector

India desires to reduce the carbon emissions and achieve its set targets as a carbon free country by 2050 and reducing the oil dependency by utilizing the clean energy resources such as wind, solar & hydro. To achieve the ambitious target of 450GW clean energy by 2030 with quantum jump in the generation, nuclear and hydro are the major sources with more viability, while nuclear power has its own disadvantages whereas the hydropower depends on the water as major source which is abundantly available in the country.

As per **TABLE 2**, the Southern region has been maintaining **46.71:41.58** ratio of thermal generation to renewable energy generation compared to other regions. There is a vast scope to reduce the dependency on thermal generation and to increase the Renewables by solar, wind & hydro generations to meet the GOI mission to reduce dependency on fossils and increase the consumption of renewables. However, dependency on the renewables will be only to certain time which may create the demand to supply issues as well as grid instability issues. Suitable infrastructure is required to store or utilize the surplus energy generated during the peak generation and less demand. To avoid such circumstances a balancing source has to be developed along with the renewables in a large scale, which can be achieved with development of pumped storage hydro power generation projects.

Central Electricity Authority (CEA) in its power sector report has assessed the country's demand and anticipated power supply up to March 2024 as shown in **Table 3**. CEA has forecast an all-India peak power demand of 256.53 GW in the FY 2023-2025, rising sharply over the current FY 2023-2024.

Table 3: Peak Power & Energy demand in various regions of the country

S.No	Region	Power (MW)				Energy (MU)			
		Peak Demand	Peak Availability	Surplus(+) / Deficit (-)		Requirement	Availability	Surplus(+) / Deficit (-)	
		(MW)	(MW)	(MW)	(%)	(MU)	(MU)	(MU)	(%)
1	Northern	80,500	77,260	(-) 3,240	-4.0	4,90,767	4,82,130	-8,637	-1.8
2	Western	77,275	73,776	(-) 3,499	-4.5	4,89,791	5,23,904	34,113	7.0
3	Southern	65,188	60,360	(-) 4,828	-7.4	3,96,820	4,23,806	26,985	6.8
4	Eastern	31,056	27,559	(-) 3,497	-11.3	1,91,985	1,95,605	3,620	1.9
5	North-Eastern	3,910	3,702	(-) 209	-5.3	20,510	21,225	714	3.5
	ALL INDIA	**2,57,929**	**2,42,656**	**1,717**	**-5.9**	**15,89,873**	**16,46,670**	**56,796**	**3.6**

As per **Table 3**, **there is a mild deficit of power in the southern region**. This would invariably widen due to the increase in energy demands with the rapid growth and industrialization. Thus, an alternate balancing source of energy generation is required to meet the deficits in the region in the years ahead.

Southern region comprises States of Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, Telangana, NLC and Puducherry. Out of 129.42 GW installed in the Southern region, the State of Tamil Nadu has a total installed capacity of 38.95 GW in February 2024. To overcome the retiring plants and due to rapid industrialization in the State and to achieve Government of India's target of 450GW of energy by more reliable and balancing source is to be developed in the State.

Table 4: Installed capacity (Southern region)

(As on 29.02.2024)

State	Thermal	Nuclear	Renewable			Grand Total
			Hydro	RES*(MNRE)	Total	
Andhra Pradesh	16323.69	127.27	1673.60	9393.20	11066.80	27517.76
Telangana	11691.92	148.73	2479.93	5152.32	7632.25	19472.90
Karnataka	10761.78	698.0	3631.60	18605.45	22237.05	33696.83
Kerala	3077.67	362.0	1864.15	1202.62	3066.77	6506.44
Tamil Nadu	**16147.04**	**1448.0**	**2178.20**	**19182.14**	**21360.34**	**38955.38**
NLC	66.0	0	0	0	0	66.0

Puducherry	291.65	86.0	0	43.34	43.34	420.99
Central-Unallocated	2100.10	450	0	0	0	2550
Total (Southern Region)	**60459.86**	**3320.0**	**11827.48**	**53579.07**	**65406.55**	**129186.41**

Source: - CEA report on Executive Summary on Power Sector, March 2024

2.5 Installed Capacity

The factors influencing the installed capacity of pumped storage scheme at a site are the daily requirement of peaking hours of operation, operating head, live pondage in the reservoirs and their Elevation-Area-Capacity characteristics. Based on these factors the Installed capacity has been optimised, and the final adopted features are as Follows:

Installed Capacity (MW)	1000MW
No. of units	4
Gross maximum Head	306.44 m
Gross Minimum Head	263.62 m
Rated Head	291.81 m
Hours of Daily Peaking operation	6 hrs
Hours of Pumping operation	6.58 hrs
Energy generation (MWh)	2080.50 MU
Pumping Energy (MWh)	2507.87MU
Cycle Efficiency	82.96%

2.6 Water Requirements

Water required for operation of PSP is 9 MCM. Since the water requirement for PSP is not consumptive in nature, there would be no issue of water availability for operation of the plant.

2.7 Power Evacuation

Power from the Generating units will be stepped up from 18 KV to 400 kV through the unit step up Transformers and connect to 400 kV GIS. Power from the GIS will transmit through 400 kV XLPE cables to the Pothead yard and then to the proposed 400KV Parali pooling substation through one (1) number D/C Transmission line. Presently there is no 400KV system available in Nilgiris District. A 400kV Pooling station is proposed to be developed by TANGEDCO and all the new Pumped Storage Hydro Electric projects will relate to it. Power from this Pooling station will be evacuated to Karamadai 400kV Substation.

The proposed evacuation system for Upper Bhavani PSP is proposed as follows:

I. One Double Circuit Quad Moose Transmission line from Upper Bhavani PSHEP to the Parali Pooling Station (Near Pillur Reservoir). The distance of this line is approximately 50 KM.

II. Power from the 400kV Parali pooling station will further be transmitted to Karamadai 400 KV substation nearby substations to be explored and finalised after joint load flow study with CTU & CEA/New Delhi.

2.8 Environmental Aspects (EIA/EMP)

Upper Bhavani PSP is envisaged to comprise of existing upper Bhavani reservoir (As upper reservoir) and the existing Avalanche reservoir (As lower reservoir). There will be no additional submergence of land in the proposed Pumped Storage Project as both the reservoirs already exist. Land shall be required for the construction of the powerhouse complex and other appurtenant structures. Total land requirement for construction of various components and other infra items like road, job facilities, muck disposal area and green belt development area etc. is estimated to be approx. 473.24 ha. The same shall be analysed in detail during finalization of layout in DPR stage. Based on assessment of environmental impacts, management plans shall be formulated for Catchment Area Treatment, compensatory afforestation and other environmental issues like rehabilitation & resettlement shall be addressed in detail during the investigations for DPR.

2.9 Inter-State/International aspects

All components of the Upper Bhavani PSP are located within the administrative region of the State. The proposed project is an open loop project where water will be cycled between two reservoirs and no Inter-State or International aspects are envisaged in the project.

The location of the project is approximately 200 km radial distance from the Chennai Sea coastline. Therefore, the project area is also not close to any international waters or boundaries and no international aspect is involved.

2.10 Pumped storage benefits and ancillary services

Pumped storage offers multiple benefits to a power system. In addition to providing energy storage, pumped storage can provide power immediately and can be rapidly adjusted to respond to changes in energy demands. These benefits are part of a large group of benefits, known as ancillary services, which include the following.

Spinning Reserves – Online reserve capacity that is synchronized to the grid and ready to meet electric demand within 10 minutes of a request. Spinning Reserve is needed to maintain system frequency stability during emergency operating conditions and unforeseen load swings.

Non-Spinning Reserves – Offline generation capacity that can be ramped to capacity and synchronized to the grid within 10 minutes of a request, and that is capable of maintaining that output for at least two hours. Non-Spinning Reserve is needed to maintain system frequency stability during emergency conditions.

Frequency Regulation – Online generation equipped with automated generation control that can respond rapidly, on a second to minute basis, to fluctuations in load. Regulation up is an increase in output and regulation down is a decrease in energy output in response to an automated signal.

2.11 Project Cost Estimate

The total estimated cost of the project including direct and indirect charges including Interest during construction is **Rs.5005.52** Crores for year 2023-24 price level. For the installed capacity of 1000 MW, the cost per MW of installed capacity works out to be Rs 5 Crores the project would generate designed energy of 2080.50 MU. Other benefits of this storage project can be in the form of spinning reserve with almost instantaneous start-up from zero to full power supply, supply of reactive energy, primary frequency regulation, and voltage regulation apart from mass employment and job opportunities from the project etc.

2.12 Employment generation due to the project during Construction & Operational Phase

The project area is located in Nilgiris District of the Tamil Nadu State. Socio-economic profile of the study area covering aspects like demography, occupational pattern, literacy rate, and other important socio-economic indicators of the villages shall be studied in detail during the DPR stage.

The proposed project is envisaged to provide huge employment opportunities for the common work-force, who will be able to benefit from this project, both during the construction stage and during its operational period.

CHAPTER 3. PROJECT DESCRIPTION

3.1 Type and Location of the Project

The proposed Upper Bhavani Pumped Storage Project is located in Nilgiri hills in Kundah Taluk of Nilgiris district in the state of Tamil Nadu in India. The Nilgiris district is in the southern Indian state of Tamil Nadu. The Nilgiri hills are part of a larger mountain chain known as the Western Ghats. The proposed location map of the project is indicated as **Fig-3.1.**

The proposed Pumped Storage Scheme involves harnessing of head between two existing dams i.e. Upper Bhavani reservoir as Upper reservoir and Avalanche reservoir as lower reservoir. In this scheme, water from Upper reservoir is proposed to be diverted to lower reservoir through water conductor system to an underground powerhouse to generate 1000 MW of power by utilizing gross head of about 291.81 m. Both the dams have access through state highway whereas access road is proposed to be constructed to reach up to the location of Intakes and other civil appurtenant structures.

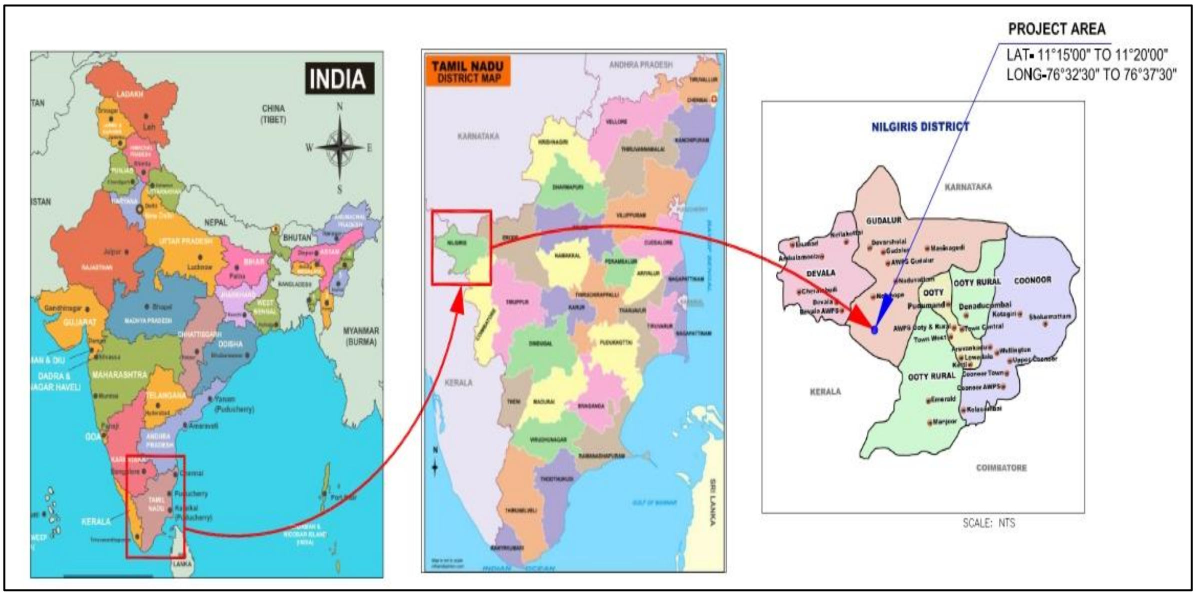


Figure 3:1 Project Location Map

3.2 Salient Features of the Project

SALIENT FEATURES			
NAME OF THE PROJECT			UPPER BHAVANI PUMPED STORAGE PROJECT (1000 MW)
1		**Project Location**	
	a	State	Tamil Nadu
	b	District	Nilgiris
	c	Taluka / Village	Kundah
	d	Latitude	$11^0$15'00" to $11^0$20'00"

	e	Longitude	76^0 32’30” to $76^0$37’30”	
	f	River	Bhavani River	
	g	Nearest rail head	Mysore-127km and Coimbatore 110 km	
	h	Nearest airport	Mysore-127km and Coimbatore 110 km	
2		**Hydrology**		
		Quantity of water required daily for 6 hours power generation	9.0 MCM	
3		**Dams / Reservoirs**	Upper (Existing)	Lower (Existing)
	a	MDDL	2249.42 m	1956.0 m
	b	FRL	2276.88 m	1985.80 m
	c	Top of Dam	2278.71m	1987.32m
	d	Live Storage / Effective Storage	79.07 MCM	134.72 MCM
4		**Intake**	**Upper**	**Lower**
	a	Type	Sloping type Bellmouth entry	Sloping type Bellmouth entry
	b	Size	79.0 W x 23.50 H	79.0 W x 21.60 H
	c	Trash rack bays	10 bays of 5.5 m each	
5		**Headrace Tunnel**		
	a	Number	1	
	b	Length	5382 m	
	c	Shape	Circular	
	d	Diameter	10.50 m	
	e	Lining	Concrete Lined	
	f	Upper Intake Sill level	EL 2227.50 m	
	g.	Velocity in tunnel	4.52 m/s	
6		**Surge Shaft**		
	a	Type	Open to air with restricted orifice	
	b	Height	95 m	
	c	Shape	Circular	
	d	Diameter	22.5m	
	e	Lining	Concrete Lined	
7		**Pressure Shaft**		
	a	Number	2	
	b	Length	623 m	
	c	Shape	Circular	
	d	Diameter	6.6 m	
	e	Lining	Steel Lined	
	f	Velocity in pressure shaft	5.71 m/s	
8		**Penstocks**		
	a	Number	4	
	b	Length	60 m each	

	c	Shape	Circular
	d	Diameter	4.6 m
	e	Material	Steel Lined
	f	Velocity in Penstock	5.88 m/s
9		**Powerhouse**	
	a	Type	Underground
	b	Installed Capacity	1000MW
	c	Size	144m(L)x24m (W)x 47.2m (H)
	d	C/L of Unit	1906.60 m
	e	Service Bay level	1921.20m
	f	Length of MAT	1836m
10		**MIV**	
	a	Type	Spherical Valve
	b	Diameter	2.6 m (Tentative)
11		**Pot-Head Yard**	
	a	Type	Surface
	b	Size	72m (L) x 35m(w)
	c	Elevation	2040.0 m
12		**Valve House**	
	a	Type	Surface
	b	Size	45 m (L) x 15m (W) x 26 m (H)
13		**Transformer Cavern**	
	a	Type	Underground
	b	Size	132m (L) x 18.5m(w) x 31.0 m
	c	Bottom Elevation	1921.20 m
14		**Tailrace Tunnel**	
	a	Number	1
	b	Length	1590 m
	c	Shape	Circular
	d	Diameter	10.5 m
	e	Lining	Concrete lined
	f	Lower Intake Sill level	EL 1936m
	g	Velocity in Tunnel	4.52 m/s
15		**Downstream Surge Shaft**	
	a	Type	Underground
	b	Height	105 m
	c	Shape	Circular
	d	Diameter	22.5m
	e	Lining	Concrete Lined
16		**Electro-Mechanical equipment**	
16.1		**Pump Turbine**	

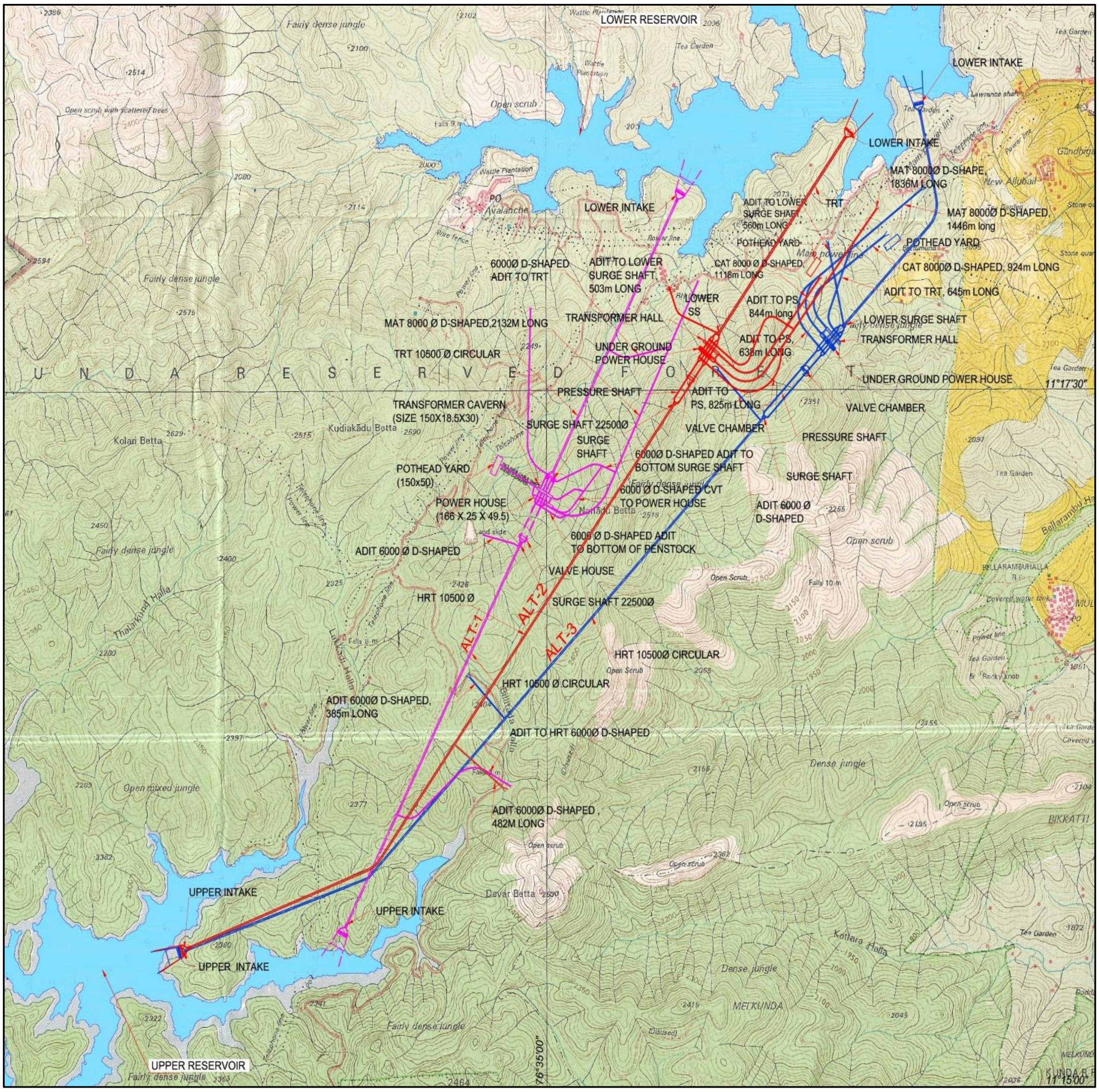
	a	Type	Single Stage Vertical Reversible Francis
	b	Number	4
	c	Rated Head	301.79 m
	d	Rated Head(Generation)	286.40 m
	e	Rated Head(Pumping)	314.59 m
	f	Rated Discharge	97.76 Cumecs (Generation) 82.15 Cumecs (Pumping)
	e	Daily Hours of Generation	6 Hrs
	f	Daily hours of Pumping	6.58 Hrs
	g	Ratio of length of water conductor system to design head (L/H)	7655m/301.79m = 25.36
	h	Head loss in generation mode	15.39 m
	i	Head loss in pumping mode	12.8 m
16.2		**Generator-Motor**	
	a	Type	Vertical Shaft, Francis pump turbine driven Synchronous motor-generator
	b	Number of units	4
	c	Rated Capacity	Generator 277.78 MVA, Pump 275 MW
	d	Rated Voltage	18 kV
	e	Rated Frequency	50 Hz
	f	Speed	300 rpm
16.3		**Main Transformer** (Generator Transformer)	
	a	Type	Single Phase
	b	Numbers	12+ 1 spare
	c	Rated Capacity	110 MVA
	d	Rated Voltage	18kV/ 420/sqrt.3
	e	Connection	Delta/Star EarthdyN11
	f	Neutral Grounding System for Secondary Winding	Solid Earthing
16.4		**Generator-Motor Circuit Breaker**	
	a	Number of Unit	4
	b	Rated Voltage (V)	24 kV
	c	Rated Normal Current	12000 A
16.5		**400 kV GIS**	
	a	Number of Bays	7
	b	Rated Voltage	400 kV
	c	Rated Normal Current	2000 A

16.6		**400 kV Transmission Line**	
	a	Type	One(1) no. of Double Circuit Quad Moose.
	b	Rated Voltage	400 kV
	c	Number of Circuits	2
16.7		**Starting Method of Pumps**	
	a	Type	SFC/ Back-to-Back
16.8		**EOT Crane**	
	a	Number of Cranes in Power house and GIS hall	2 Nos. in Power House & 1 No. in GIS hall
	b	Rated Capacity	390/50/10 MT for Power House and 10 MT for GIS Hall
	c	Valve house	One (1) No.
17		**Annual Power**	
	a	Annual generation	2080.50 MU
	b	Annual pumping	2507.87 MU
	c	Cycle Efficiency	82.96%
18		**Project Cost**	
	a	Civil & HM works	2401.0 Cr
	b	Electromechanical works	1909.0 Cr
	c	Other Costs	Nil
	d	Total cost (including IDC)	5005.52 Cr
	e	IDC	683.25 Cr
	f	FC	12.26 Cr
	g	Total Cost	5005.52 Cr
19		**Conversion Cost (excluding pumping Cost**	
	a	Levelized	RS 4.16 /- per unit
	b	First Year	RS 4.71 /- per unit
20		**Conversion Cost (including pumping Cost of Rs 2.50 per unit)**	
	a	Levelized	RS 7.21/- per unit
	b	First Year	RS 7.76/- per unit

3.3 Alternative Layout Studies

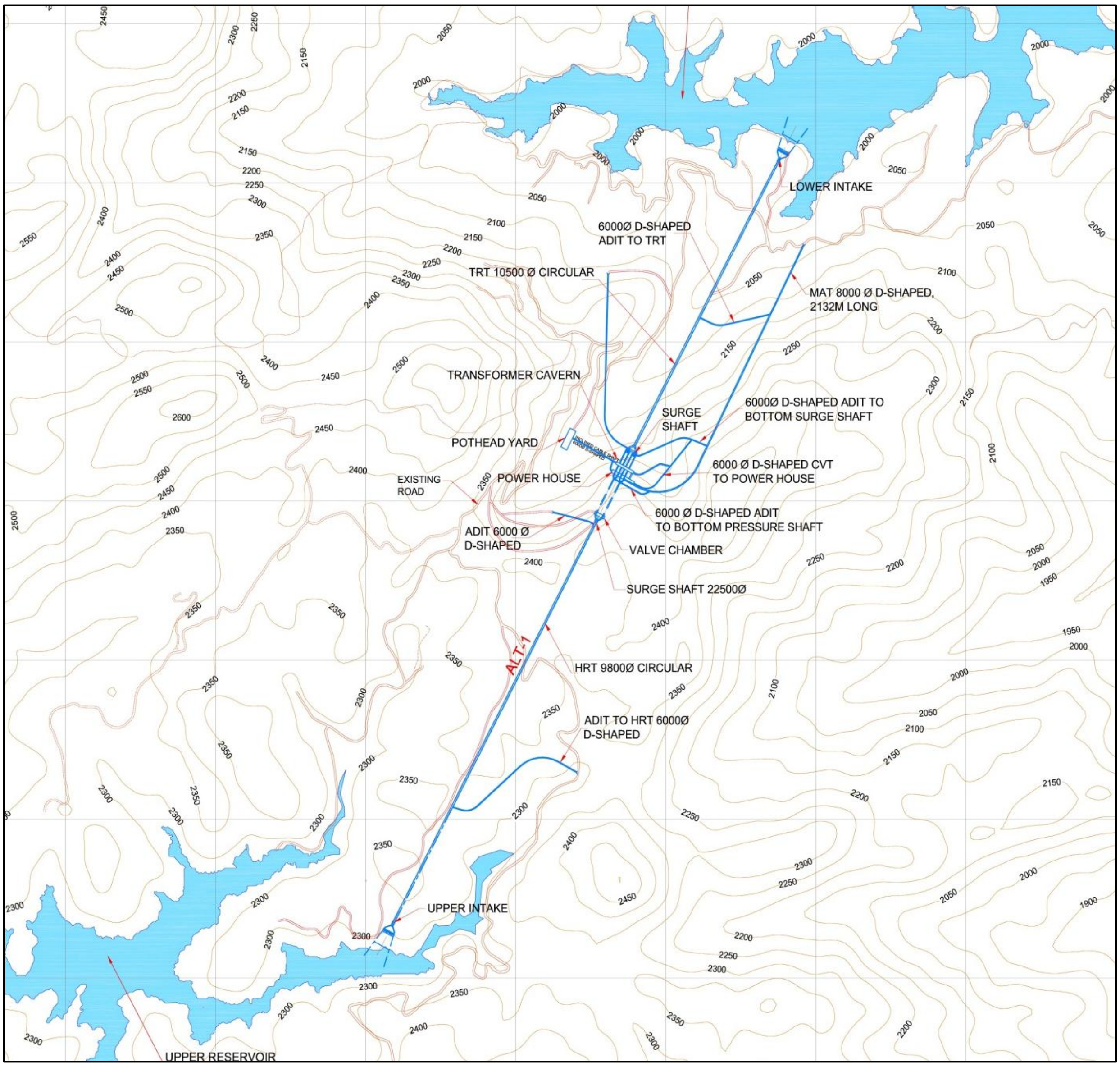
The Upper Bhavani project is identified by TANGEDCO. The proposed project area lies between lat. 11°15'00" to 11° 20' 00" N and long. 76° 32' 30" to 76° 37' 30" E with an approximate head of 301.79

m. In this scheme both Upper and Lower reservoirs are available. Alternative study is limited to finalization of layout of water conductor system and underground powerhouse structure only, as both the upper and lower reservoirs already exist. Various layout options were studied in the proposed area considering the topography, geological features and environment aspects, which led to the following three alternatives and are further discussed as shown in figure below:



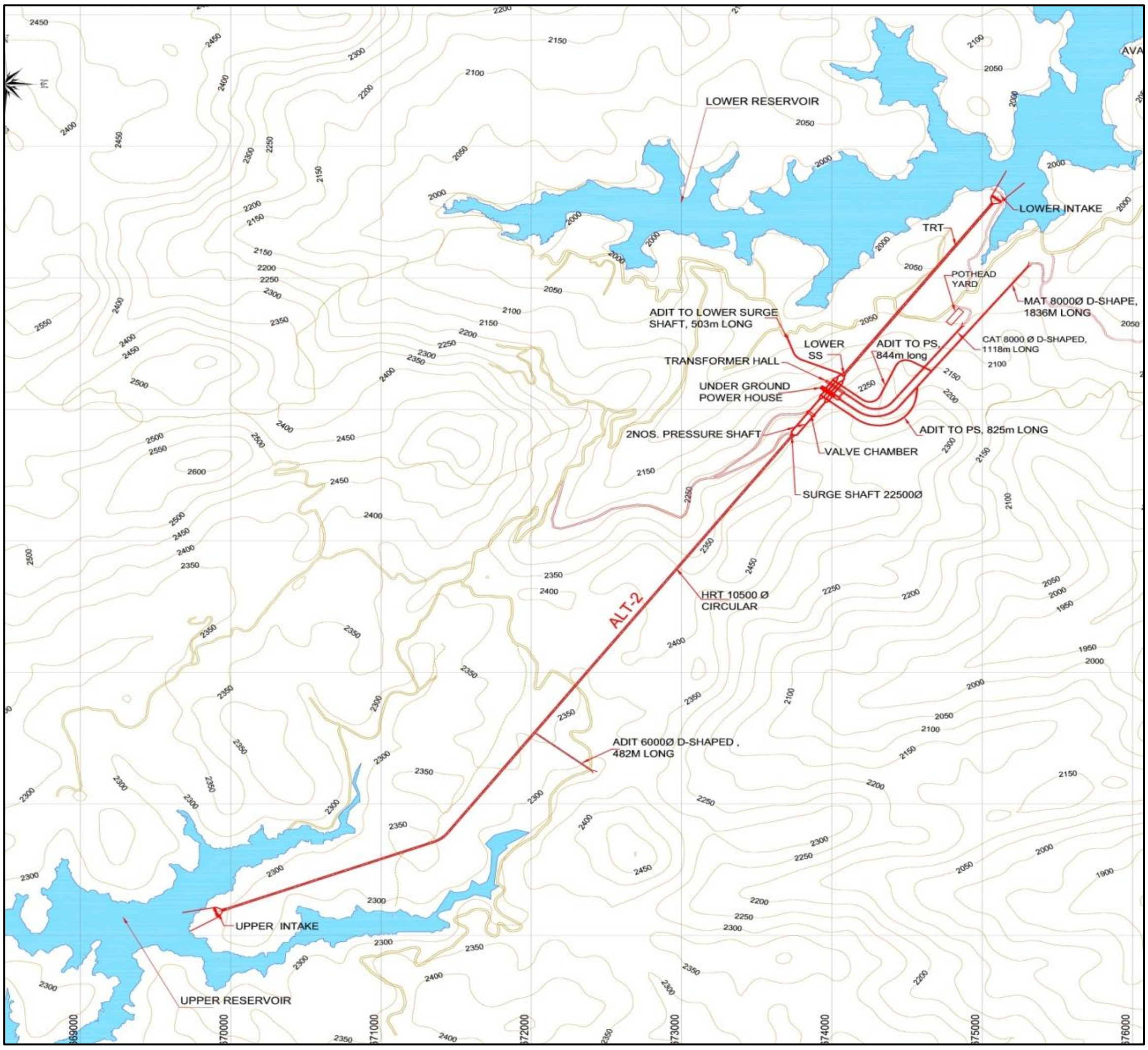
Alternative-1

In this layout, the water conductor system is aligned straight (taking the shortest route) from Upper Bhavani to Avalanche reservoir without considering existing reservoir bed levels, water levels etc. The length of the water conductor system works out to be about 5.3 km. The layout is shown in figure below:-



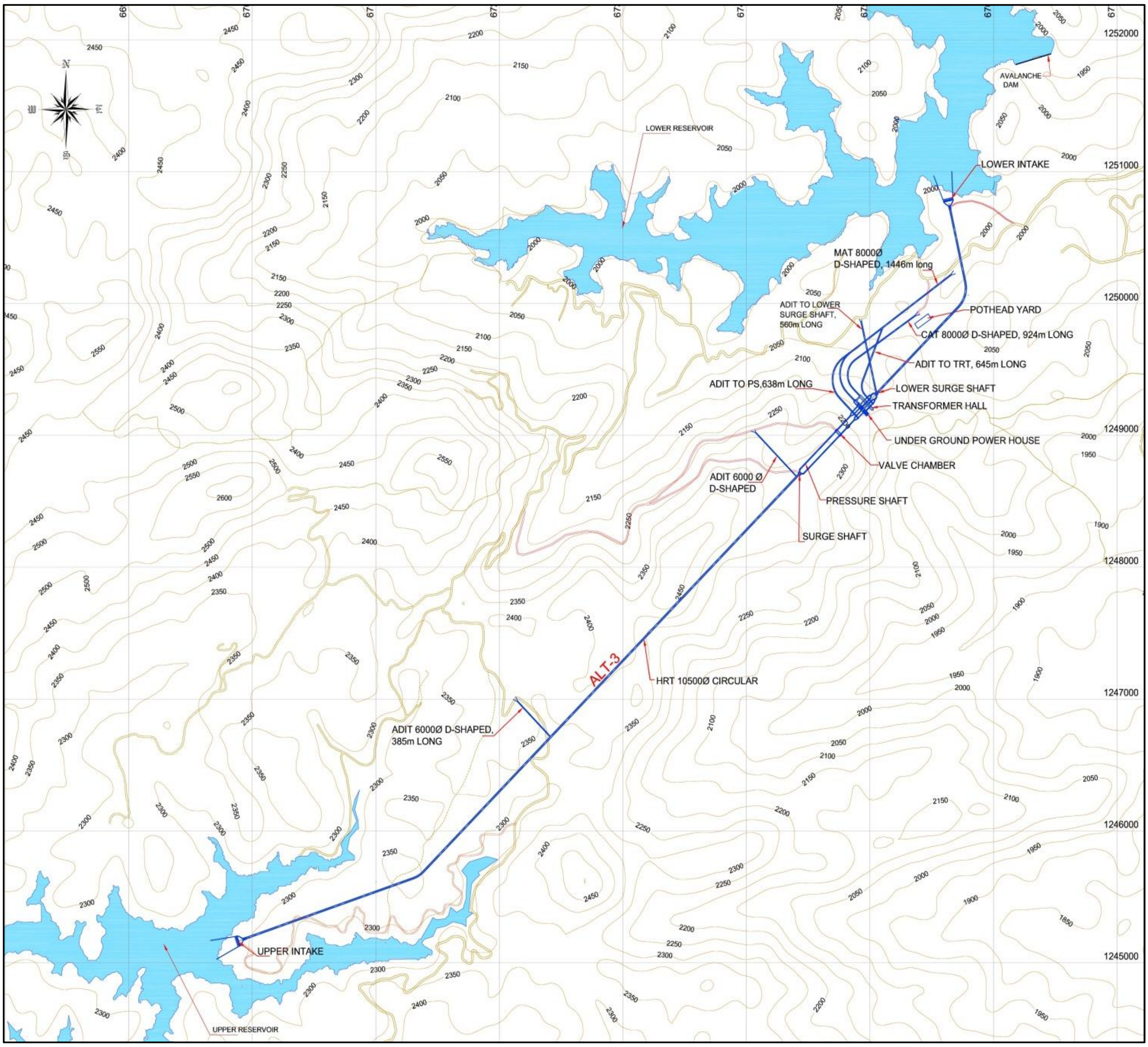
Alternative-2

Alternative 2 (Alt-2) has been proposed, positioning the upper and lower intakes to ensure year-round water availability. This option locates the lower intakes closer to the lower dam and features a water conveyance system (WCS) that spans 7.68 km, along with similar underground structures. The proposed alignment is situated approximately 400 to 1,800 meters laterally from the existing Alt-1 project alignment, traversing a hillside with elevations ranging from 2,300 to 2,350 meters, where sufficient rock cover is anticipated above the water conductor system. The tunnel alignment runs along the eastern hillside adjacent to the Alt-1 alignment, with the upper intake for Alt-1 positioned similarly. Additionally, Alt-2 incorporates a kink in its layout and includes an open to sky surge shaft for head race tunnel & an underground surge shaft for tail race tunnel which are located on a hillside with adequate lateral cover (greater than 3D). The proposed layout is as in figure below:-



Alternative-3

In this alternative, the upper intake is positioned similarly to that in Alternative 2, while the lower intake is located closer to the dam, ensuring adequate rock cover. The length of the water conductor system is 8.8 km; however, this increased length results in greater head loss. Additionally, this alignment incorporates two kinks in its layout. In addition, the pressure shaft length is also increasing 1.12 Km. The tunnel layout as well as main access tunnel & construction adits of Alt-3 is also crossing near the tribal village which also is not desirable on EIA ground. The layout is shown in figure below:-



3.4 Selection of Layout

The selection of the suitable layout is evaluated based on the following parameters:

- Technical feasibility
- Project Economics
- Environmental, R&R impacts

Since the upper and lower reservoirs are existing, the selection of layout options is primarily influenced by the location of the intakes and length of the water conveyance system (WCS), which includes both the head race tunnel (HRT) and the tailrace tunnel (TRT), given that the upper and lower reservoirs are already established. Other factors which influence the selection of the layout are also the geological conditions, topography, reservoir bed levels, environmental, R&R aspects etc. While the technical features of major structures, such as surge shafts, powerhouses, and transformer caverns, will remain largely consistent across all alternatives; their overall effectiveness can vary significantly.

To evaluate the layouts from economic considerations, the parameters of project cost, levelized tariff and cycle efficiency are considered.

Proximity of any existing village, religious monuments, forest area, wild life etc, is considered under the environment and R&R impacts.

Alternative 1 has been ruled out due to the lack of year-round water availability due to its location of upper and lower intakes, despite having the shortest water conductor system. Both the upper intake and the lower intakes for this alternative are located in the reservoir, where the bed levels are higher compared to the proposed MDDL. The sill level of the intakes is much below the prevailing bed levels in the reservoir, requiring long approach channel / tunnel (nearly 3.0km in both the reservoirs). Also, the length of the MAT is more than 2.0 km in length. Most of the underground structures are located below existing natural streams, which can pose seepage during construction and operation of power plant. Therefore, the Alternative-1 layout is ruled out on technical grounds.

Alternative 2 features a WCS length of 7.68 km. Consequently, Alternative 2 experiences less head loss compared to Alternative 3. Additionally, the longer construction time associated with Alternative 3 further diminishes its feasibility.

Alternative 3 features a WCS length of 8.8 km. The water conductor comes in the proximity of an existing village and temple monument, which will have environmental impact. Further the “Shola forests”, a grassland ecosystem will also get impacted by the alignment. Therefore, Alternative 3 gets eliminated from environmental, R&R aspects in addition to the longer water conductor system.

Therefore, **Alternative 2 is selected as the ideal option**.

Geologically, the project area is favourable along the entire length of the proposed water conductor system, with adequate rock cover for underground works such as the headrace tunnel, underground structures and pressure shaft. A detailed evaluation of the project will be conducted during the Detailed Project Report (DPR) stage, following geological and geotechnical investigations.

Summary of the features of the three alternatives are tabulated below:-

S. No	Description	Alternative 1	Alternative 2	Alternative 3
1	**Installed Capacity**	1000 MW (4 X 250 MW)	1000 MW (4 X 250 MW)	1000 MW (4 X 250 MW)
2	**Water Conductor System**	Head Race Tunnels, Pressure Shafts & TRT	Head Race Tunnels, Pressure Shafts & TRT	Head Race Tunnels, Pressure Shafts & TRT
3	**Upper Intake Structure**			
3.1	Dimensions			
3.2	Number & Size of Gates	1 Nos. 11.6 m (W) x 15.5 m (H)	1 Nos. 10.0 m (W) x 9.0 m (H)	1 Nos. 10.0 m (W) x 9.0 m (H)
3.3	Invert Level of Structure	EL 2225 m	EL 2227.50 m	EL 2227.50 m
4	**Head Race Tunnel**			
4.1	Numbers & Size	1 Nos. of 9.8 m dia. (Circular Tunnel)	1 Nos. of 10.5 m dia. (Circular Tunnel)	1 Nos. of 10.5 m dia. (Circular Tunnel)
4.2	Length	2841 m	5382 m	5792 m
5	**U/S Surge Shaft**			
5.1	Dia	22.5 m	22.5 m	22.5 m
5.2	Height of surge shaft	106 m	95 m	110 m
6	**Main Pressure Shaft**			
6.1	Numbers & Size	2 Nos. of 6.6 m dia. (Circular Tunnel)	2 Nos. of 6.6 m dia. (Circular Tunnel)	2 Nos. of 6.6 m dia. (Circular Tunnel)
6.2	Length	397 m	623 m	885 m
7	**Branch Pressure Shaft**			
7.1	Numbers & Size	4 Nos. of 4.6 m dia. (Circular Tunnel)	4 Nos. of 4.6 m dia. (Circular Tunnel)	4 Nos. of 4.6 m dia. (Circular Tunnel)
7.2	Length	50 m	60 m	90 m
8	**POWER HOUSE**			
8.1	Size (Machine Hall +Service Bay+ Control Block)	166m(L) x 25m (w) x 49.50 m (H)	144m(L) x 24m (w) x 47.2 m (H)	144m(L) x 24m (w) x 47.2 m (H)
8.2	Powerhouse Centreline	1908.90 m	1906.60 m	1906.60 m
8.3	Service Bay Level	1923.40 m	1921.20 m	1921.20 m
9	**D/S SURGE SHAFT**			
9.1	Dia	22.5 m	22.5 m	22.5 m
9.2	Height of surge shaft	106 m	105 m	115 m
10	**Tail Race Tunnel**			
10.1	Shape, Nos. & Size	1 Nos. of 10.5 m dia. (Circular Tunnel)	1 Nos. of 10.5 m dia. (Circular Tunnel)	1 Nos. of 10.5 m dia. (Circular Tunnel)
10.2	Length of TRT	2013 m	1590 m	1682

11	**Lower Intake Structure**			
11.1	Number & Size of Gates	1 Nos. 11.6 m (W) x 15.5 m (H)	1 Nos. 10.0 m (W) x 9.0 m (H)	1 Nos. 10.0 m (W) x 9.0 m (H)
11.2	Invert Level of Structure	EL 1919 m	EL 1936.0 m	EL 1936.0 m
12	**ADIT to HRT**			
12.1	Numbers & Size	1 Nos 6m Dia D-Shape	1 Nos 6m Dia D-Shape	1 Nos 6m Dia D-Shape
12.2	Length	1028 m	482 m	385 m
13	**ADIT to Pressure shaft**			
13.1	Numbers & Size	1 Nos 6m Dia D-Shape	1 Nos 6m Dia D-Shape	1 Nos 6m Dia D-Shape
13.2	Length	286 m	825 m	582 m
14	**Adit to TRT**			
14.1	Numbers & Size	1 Nos 6m Dia D-Shape	1 Nos 6m Dia D-Shape	1 Nos 6m Dia D-Shape
14.2	Length	491.51	847	645
15	**Adit to Bottom of Penstock and U/S Surge Shaft**			
15.1	Numbers & Size	1 Nos 6m Dia D-Shape	-	1 Nos 6m Dia D-Shape
15.2	Length	269.2	-	475
16	**Cable Ventilation Tunnel to Power House**			
16.1	Numbers & Size	1 Nos 6m Dia D-Shape	-	-
16.2	Length	531.39	-	-
17	**Adit to D/S Surge shaft**			
17.1	Numbers & Size	1 Nos 6m Dia D-Shape	1 Nos 6m Dia D-Shape	1 Nos 6m Dia D-Shape
17.2	Length	520	503	560
18	**Adit to Top of Surge Shaft**			
18.1	Numbers & Size	1 Nos 6m Dia D-Shape	-	-
18.2	Length	1168.81	-	-
19	**Adit to Transformer Cavern**			
19.1	Numbers & Size	1 Nos 6m Dia D-Shape	-	-
19.2	Length	265	-	-
20	**CAT**			
20.1	Numbers & Size	1 Nos 8m Dia D-Shape	1 Nos 8m Dia D-Shape	1 Nos 6m Dia D-Shape
20.2	Length	398.48 (Inclined)	1118 m	926 m
21	**MAT**			
21.1	Numbers & Size	1 Nos 8m Dia D-Shape	1 Nos 8m Dia D-Shape	1 Nos 6m Dia D-Shape
21.2	Length	2131 m	1836 m	1446 m

22	**Total Length of Underground Tunnel Components**			
22.1	**Length (Meters)**	**12937.39**	**14069**	**14623**
23	**Others**			
	L/H Ratio	19.49	26.23	28.86
	ANNUAL ENERGY Generation (MU)	1567.5	2080.50	2080.50
	ANNUAL ENERGY Consumption (MU)	1853.37	2507.87	2520.58
	Cycle Efficiency	84.57%	82.96%	82.54%
	Total Present Day Cost including IDC (Rs. in Crore.)	4648	5005.52	5087.97
	Total Cost per MW (Rs. in Crore.)	4.65	5.0	5.09
	Construction Period (Months)	60	60	60
	Levelized Tariff	5.13	4.16	4.23
24	**Approach Road**			
	Approach Road to MAT	0.4 Km	-	-
	Approach Road to Pothead Yard	0.2 Km	-	-
	Approach to Upper Intake Area	1.5 Km	-	-
	Approach to Surge Shaft Area	0.5 Km	-	-
	Approach to Lower Dam Location	0.8 Km	-	-
	Lower Stockyard Area	-	0.6 Km	-
	Contractor Facilities	-	2.5 Km	-
	Lower Intake Area	-	0.95 km	0.54 km
	Upper Intake Area	-	4.1 km	4.1 km
	Road to Surge Shaft	-	2.9 km	3.07 km
	Road to Valve Houses	-	0.85 km	1.8 km
	Road to CAT	-	0.2 Km	-
	Total Length: Approximately	**3.0 km**	**12.2 km**	**9.5 km**
25	**Land Details (ROW) (Other than facility)**	**15.23 Ha.**	**19.28 Ha.**	**19.15 Ha.**
26	**Geology**	The powerhouse is located on the valley slope where numerous nalas are coming which poses a risk of seepage into the underground structures.	Good to Very Good Rock mass	Good to Very Good Rock mass

27	**Environment, R&R impacts** **(The** environmental sensitive areas within the site or in the close vicinity of the project site is given in the table below)	-	-	Shola forest, Existing Tribal Village & temple
28	**Technical Feasibility**	**Not feasible.** Reservoir bed levels are higher than envisaged earlier, resulting in plant operation for only 8-9 months in a year**.**	**Feasible**	**Feasible**

Comparative analysis of alternate layouts from environment and eco-sensitive perspective:-

S. No.	Parameters consider for comparison	Alternate - 1	Alternate – 2	Alternate - 3
1.	Approximate Length of Tunnel including spurs (in m)	12937.39	14069	14623
2.	Forest land Involvement (30 meters ROW) in ha.	76	76.75	79
3.	Nearest distance from Protected area (National Park, Wildlife Sanctuary, Tiger Reserve, Elephant Corridor etc.) if any?	• Eco-sensitive zone boundary of Silent Valley WLS is at a distance of 8.8 km • Approx. aerial distance of the project site from Mukurthi National Park is 1.7 km	• Eco-sensitive zone boundary of Silent Valley WLS is at a distance of 8.0 km • Approx. aerial distance of the project site from Mukurthi National Park is 1.4 km	• Eco-sensitive zone boundary of Silent Valley WLS is at a distance of 8.0 km • Approx. aerial distance of the project site from Mukurthi National Park is 1.4 km
4.	Numbers of Structure/settlement falling within ROW (30 metres)	4	0	1 Village of "Toda" Tribal community may get affected due to the project
5.	Crossing of Water Bodies (Pond, Nallah, Streams, Lakes etc.)	Multiple 1st order streams are passing through the Project site	0	0

S. No.	Parameters consider for comparison	Alternate - 1	Alternate – 2	Alternate - 3
6.	Crossing of River/Canal (Number of Crossing)	Thalaikund Halla (1)	0	0
7.	Crossing of NH/SH/MDR/Other Roads (Number of Crossing)	Other Roads (0)	Other Roads (0)	Other Roads (0)
8.	Crossing of Railway Line, if any	No	No	No
9.	Agricultural Area within ROW (30 meters)	No	No	No
10.	Archaeological Monuments if any within 300 meter from central line of Tunnel	No	No	No
11.	Minimum and Maximum Elevation along the Tunnel Route	Max - 2526 m Min - 1982 m	Max - 2454 m Min - 1982 m	Max - 2419 m Min - 1982 m
12.	Crossing of Transmission Line (Yes/No)	Yes	Yes	Yes
13.	Shola Forest	No	No	Yes
14.	Annual energy, Generation	1567.5 MU	2080.50 MU	2080.50 MU
15.	Total Present-Day Cost incl. IDC	4646.65 CR	5005.52 CR	5087.97 CR
16.	Tarif (@ Rs 2.5/ KW input power), Levelized/1st year	Rs 8.11/ 8.79 per unit	Rs 7.21/ 7.76 per unit	Rs 7.29/ 7.85 per unit

3.5 Size or Magnitude of Operation

The Upper Bhavani pumped storage project shall have a plant capacity of 1000MW (4 x 250MW). The plant shall use the water between the Existing upper reservoir and lower reservoir under a design head of 291.81 m for 250 MW units utilizing a design discharge of 101.16 Cumec. An annual energy generation of 2080.50 MU is envisaged through the plant in a time period of 6.00 hours in a day. Water from the lower reservoir utilizing the off-peak energy, shall be pumped back to the upper reservoir in a time span of 6.58 Hours. The pumping operation shall require 2507.87MU.

3.6 Project description with process details

Pumped storage Projects are broadly categorized in three types as under:-

- **On-Stream pumped storage scheme**-Both reservoirs are located on any river/stream/nallah.

- **Off-Stream Open loop pumped storage scheme**-One reservoir is located on river/stream/nallah. Another reservoir (off-Stream reservoir) is not located on any river/perennial stream/non-perennial stream/nallah.
- **Off-Stream Closed loop pumped Storage scheme**-None of the reservoirs is located on any river/perennial stream/perennial nallah.

The proposed Upper Bhavani PSP is an on-stream Open loop scheme.

3.7 Hydrology

Upper Bhavani pumped storage project is proposed to be located in Nilgiris district of Tamil Nadu State. Hydrological Studies have been carried out in order to:

- Assess water availability for running the proposed PSP scheme throughout the year.
- Estimate the design flood for PSP Upper & Lower Reservoir.
- Assess sediment inflow to estimate storage loss of the reservoir after 70 years of operation.
- Assess evaporation losses based on climatic characteristics of the region.

The Upper Bhavani Pumped Storage project (UBPSP) has been planned in the Nilgiris district of Tamil Nadu, India, utilizing Upper Bhavani Dam as upper reservoir and Avalanche-Emerald complex reservoir system as the lower reservoir. Upper Bhavani reservoir and the Avalanche-Emerald complex reservoirs are the already existing reservoirs. Both the Emerald River and the Avalanche River are the part of the Kundah Catchment which is subsequently the part of Bhavani River catchment.

Finally, the Bhavani River catchment merges with the Cauvery Basin, Thus the entire River system of the Project lies in the Cauvery basin.

As the UBPSP is a Pump storage project hence no consumptive use of water has been envisaged for power generation. The Proposed Upper Bhavani PSP envisages recycling of stored water between upper and lower reservoir which are already in operation.

Kundah conventional hydroelectric scheme phase-V is situated on Bhavani River with an installed capacity of 40 MW. The scheme is receiving inflows from the Upper Bhavani reservoir itself and after generation the water is discharged to the Avalanche-Emerald reservoir complex via Tail race Tunnel. Upper Bhavani dam was constructed in 1965 on Bhavani River with a gross storage capacity of 97.04 MCM. It is also supported by Banghihallah earthen bund as a saddle dam of height 22.56 m and length of about 280.42 m. Apart from receiving inflow from the Bhavani River, the reservoir is also receiving the quantum of water from the upper Bhavani Diversion weir via pump mode. Upper Bhavani Diversion weir is constructed downstream to the Upper Bhavani dam at an approximate distance of 2 km downstream of it. Upper Bhavani dam is also receiving inflow from the Western Catchment No 1 diversion weir via Tunnel mode under gravity head.

Kundah conventional Hydroelectric scheme phase- I is situated on the Avalanche river with an installed capacity of 60 MW. The scheme is receiving inflows from the Avalanche Dam and after generation the water is sent to the Kundah Forebay Dam.

The Avalanche-Emerald complex reservoir system has been constructed in 1961 with the combined gross storage capacity of 149.57 MCM. The Avalanche dam is situated on Avalanche River and the Emerald Dam is situated on the Emerald River. Apart from receiving inflows from the Avalanche River and the Emerald River, the reservoir system is receiving inflows from the East Varahapallam Diversion weir also.

There is another proposed Kundah Pumped storage HEP with installed capacity of 500 MW to be operated in between Porthimund reservoir as upper reservoir and Emerald reservoir as lower reservoir. In addition to it, it is also receiving quantum of water through TRT of Kundah conventional hydroelectric scheme phase- VI with installed capacity of 30 MW. Kundah conventional HEP is being operated considering the inflows from the Parson Valley reservoir. The Emerald dam does not have any spillway arrangement. The surplus water is diverted to the Avalanche reservoir via interconnecting tunnel of length 722m to discharge the surplus flow if any via spillway arrangement in the Avalanche dam.

3.8 Bhavani River system and basin characteristics

The proposed Upper Bhavani PSP is an on-stream open loop scheme. Upper Bhavani PSP is in the Nilgiris district of Tamil Nadu, India. The upper dam and lower dam of the proposed PSP are located on the Bhavani River and the Avalanche River respectively. Both the rivers are the part of Bhavani River Catchment. Bhavani River merges with Cauvery River at Bhavani. Hence the entire catchment of the proposed PSP comes under Cauvery Basin.

The Cauvery River is one of the major rivers in peninsular India. It rises at an elevation of 1341 m at Talakaveri on the Brahmagiri Range near Cherangala village of Kodagu district of Karnataka and drains into Bay of Bengal. The total length of the river from the origin to the outfall point is around 800 KM. It drains an area of around 85,626 sq.km. Out of the total catchment area, 42% lies in Karnataka region, 54 % lies in the Tamil Nadu region and the rest 4 % lies in the Kerala region.

The catchment maps have been prepared taking into account the Advanced Space-borne Thermal Emission and Reflection Radiometer Digital Elevation Model (ASTER DEM). The DEM tiles have been selected considering the available Coordinates of the project location. The ASTER DEM data has been downloaded from the USGS (United States Geological Survey) Earth explorer portal which is a geo-database platform of National Aeronautics and Space Administration (NASA).

Different DEM tiles of adjacent region have been processed in GIS based software for the catchment delineation.

The location of the Bhavani River catchment inside the Cauvery basin shows that the proposed location of the PSP falls inside the Cauvery-Middle sub-basin. The Cauvery-Middle sub-basin constitutes an area of 57280.98 sq.km, the largest among the Upper, Middle, and Lower sub-basin. It consists of 86 watersheds. The three different sub-basins of the Cauvery basin have been shown in the figure below**.** The Cauvery basin is bounded on the west by the Western Ghats, on the east and south by the Eastern Ghats and on the north by the ridges separating it from the Tungabhadra and Pennar basin. From the available slope map of Cauvery basin given in the Cauvery basin report published by CWC, it is envisaged that the maximum elevation of about 2000-3000m is observed in 1% of the total geographical area of the basin. Around 32% of the basin area falls under the 750- 1000 m elevation zone.

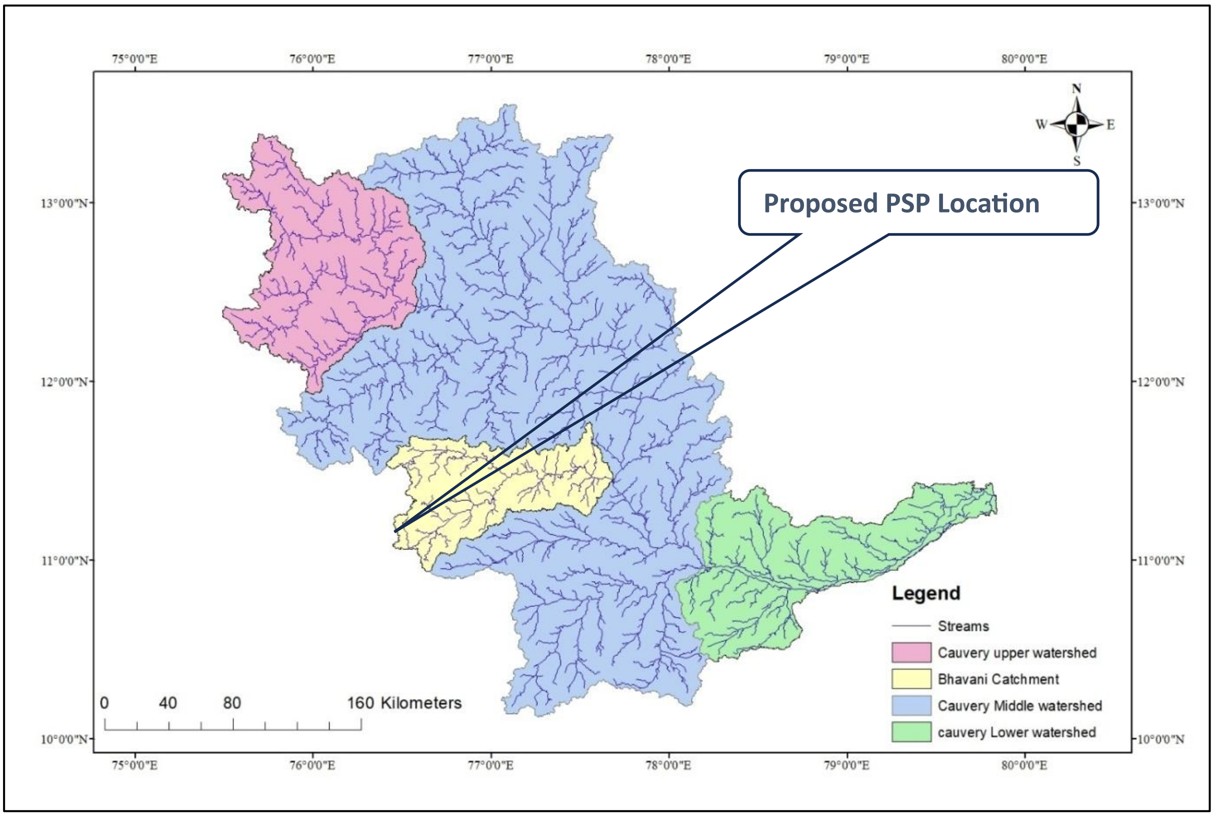


Figure 3:2 Three Sub-basins of Cauvery Basin along with the project location

The catchment area of Bhavani River at its outfall in Cauvery River is computed as 6462.95 sq.km. The catchment area map exhibiting the Upper Bhavani catchment, Avalanche catchment and Emerald Catchment has been shown in **Figure 3.3 and Figure 3.4** below. Avalanche River and Emerald River, being the streams of the Kundah catchment merges with the Bhavani River near Athikadavu village, Tamil Nadu. The catchment area of Kundah River before it merges with River

Bhavani is computed as 296.8sqkm.The catchment area of Upper Bhavani reservoir, Avalanche reservoir and Emerald reservoir is computed as 33.62 sq.km, 30.61sq.km and 29.92 sq.km respectively.

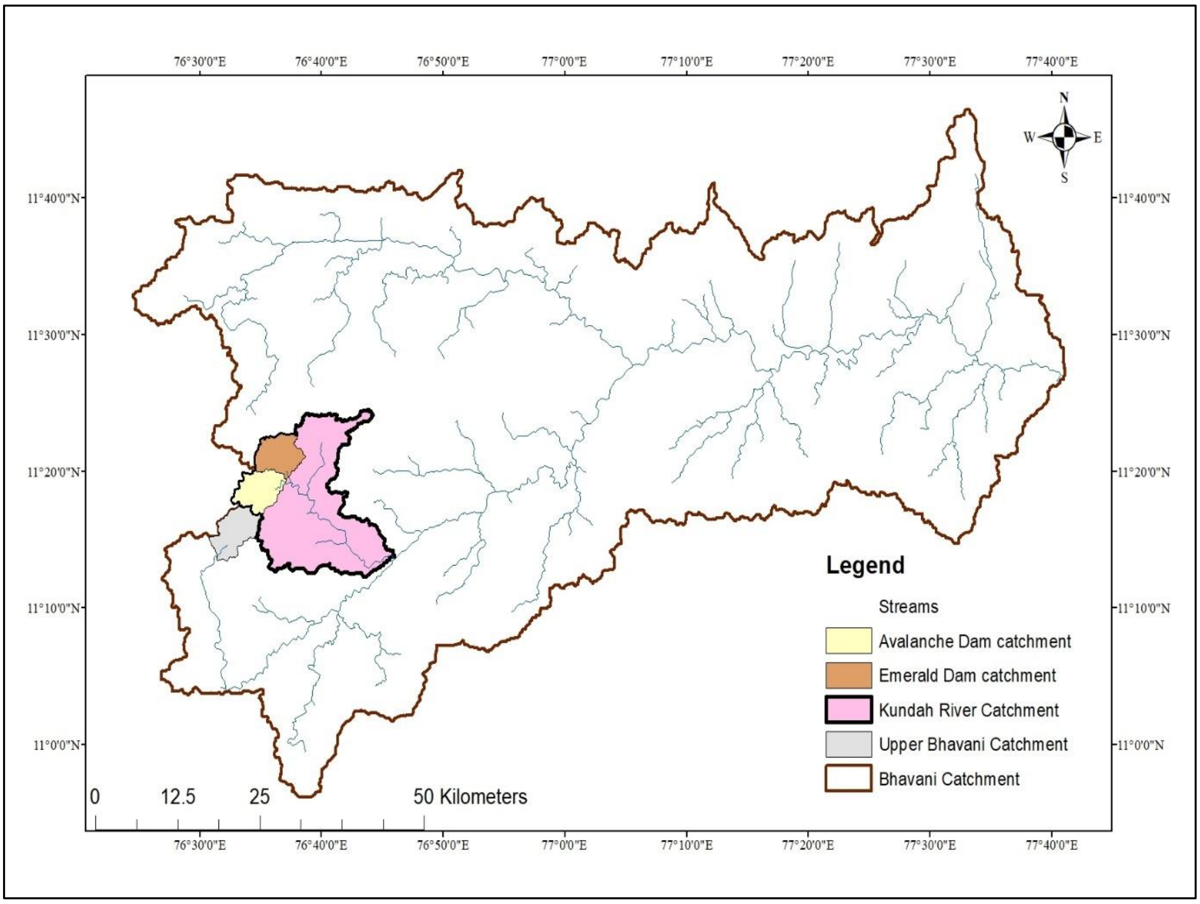


Figure 3:3 Proposed Reservoir catchments inside the Bhavani catchment

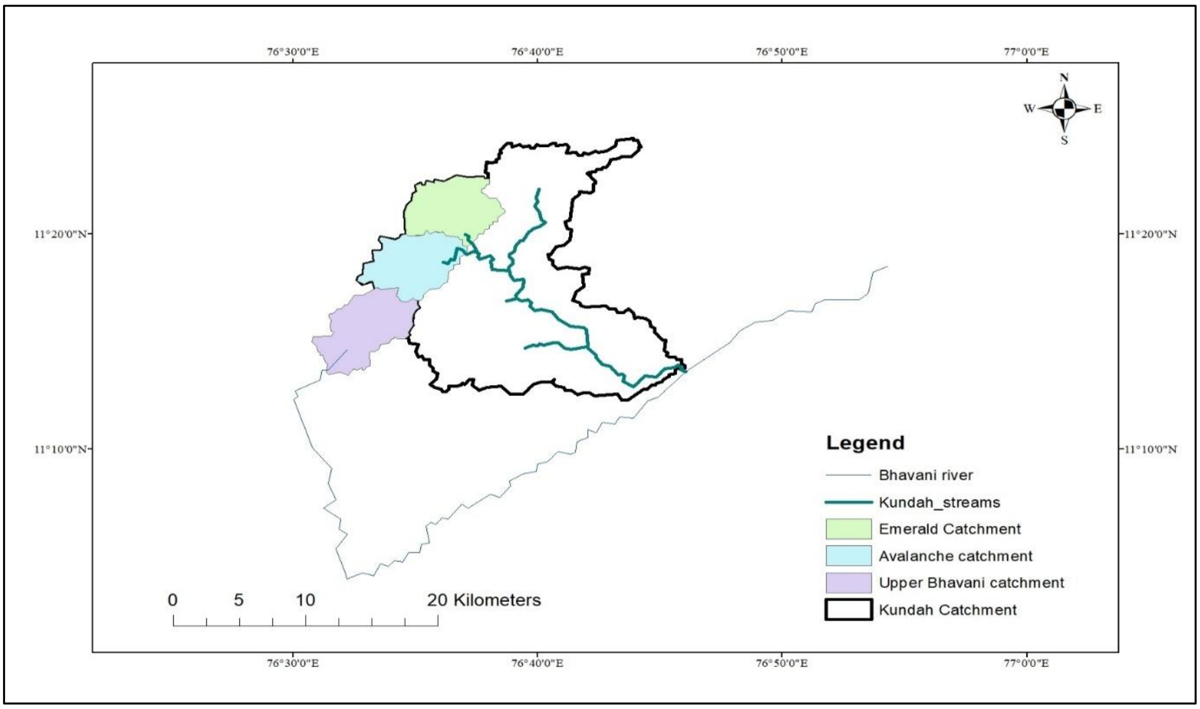


Figure 3:4 Proposed Reservoir catchments with the Kundah Catchment

3.9 Hydrological Inputs for the Project Planning

The following hydrological inputs have been considered for the planning of the proposed PSP.

a. Meteorological data
b. Rainfall data
c. Water availability study
d. Lake evaporation
e. Sediment inflows
f. Flood inputs

a. Meteorological Data

The Monthly temperature data from 1990 to 2022 for the project location has been downloaded from IMD website and the analysis has been presented in the form of a graph appended at **Figure 3.5**. As per the analysis the temperature in the region is envisaged to vary from the minimum of around 10^0 C (in 1994) to the maximum of around 40^0 C (in 2016). The temperature during winter months varies in between 5^0 C to 10^0 C and during summer it varies in between 25^0 C to 37^0 C. The summer begins early in the March and till it reaches May, the region experiences high temperature values. The temperature begins to drop down from the middle of July and till it reaches January, February, the temperature drops down to its minimum value of the year. Thus, the annual average temperature of the region is around 20^0 C. Overall; the climate of the region is temperate and salubrious throughout the year.

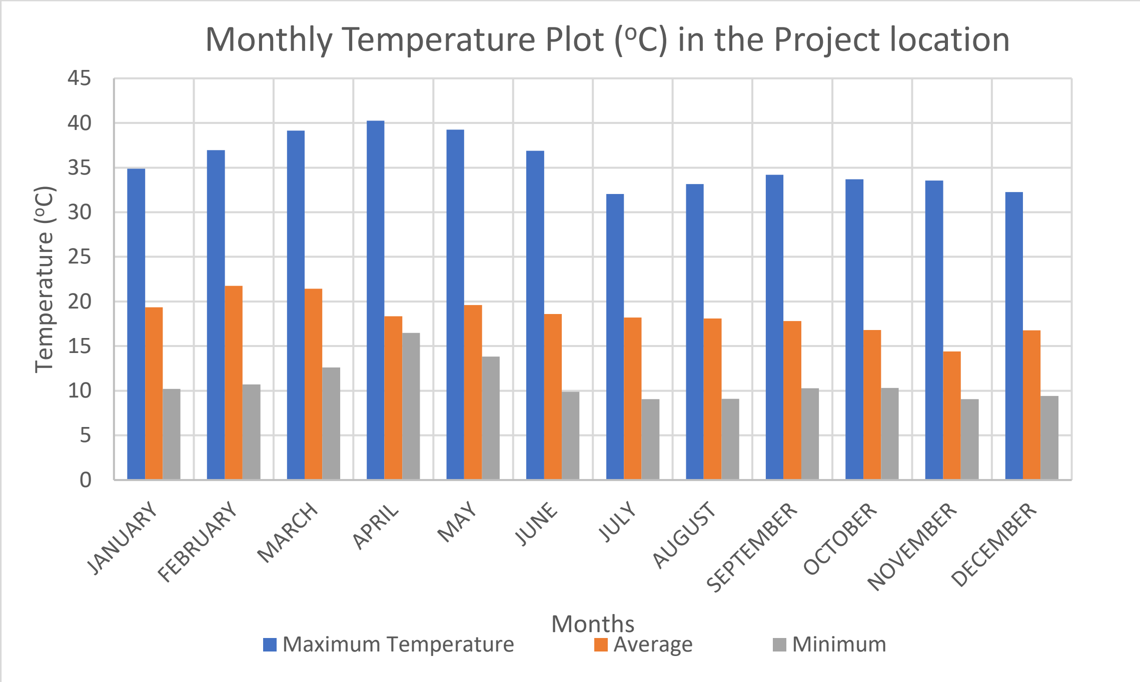


Figure 3:5 Monthly Temperature variation plot of the project region

b. Rainfall Data

The region is characterized by heavy to very heavy rainfall during monsoon and accompanied by appreciable downpour during North-east monsoon also.

The daily data series of the rainfall has been provided by the NTECL office from 2011(January) to 2021(May), the monthly and annual abstract is given in the Table below.

Table 5 Monthly Rainfall depth value for both the catchments

	Avalanche-Emerald	**Upper Bhavani**
Month	Rainfall depth (mm)	Rainfall depth (mm)
January	17.1	7.3
February	10.1	3.7
March	19.8	10.9
April	69.5	47.7
May	136.4	127.7
June	783.2	728.6
July	772.0	563.7
August	1025.6	662.5

	Avalanche-Emerald	Upper Bhavani
September	419.6	295.1
October	203.7	170.6
November	122.2	101.1
December	44.9	22.5
Average	302.0	228.5

Table 6 Monsoon Rainfall depth value for both catchments

YEAR	Avalanche	Upper Bhavani
	Monsoon Rainfall depth (mm)	Monsoon Rainfall depth (mm)
2011	2542.00	2577.00
2012	1701.00	1513.31
2013	3816.00	
2014	2993.00	3528.00
2015	2278.00	2220.50
2016	1536.00	1222.00
2017	2193.00	2765.00
2018	4113.00	3760.00
2019	5283.00	2783.00
2020	3549.00	2645.00
Average	3000.40	2301.38

Table 7 Annual Rainfall depth (considered hydrologic year) for both catchments

HYDROLOGIC YEAR- (JUNE TO MAY)				
Catchment Area Upper		33.62	sq.km	
Catchment Area Lower		30.61	sq.km	
	Lower Catchment	**Lower Catchment**	**Upper Catchment**	**Upper Catchment**
	Rainfall Values (mm)	Rainfall Volume (MCM)	Rainfall Values (MM)	Rainfall Volumes (MCM)

2011	3158	96.67	3077.00	103.45
2012	2340	71.63	1957.31	65.80
2013	4385	134.22		
2014	3857	118.06	4131.36	138.90
2015	2905	88.92	2697.50	90.69
2016	1879	57.52	1550.00	52.11
2017	2753	84.27	3138.00	105.50
2018	4595	140.65	4048.00	136.09
2019	6003	183.75	3364.00	113.10
2020	4339	132.82	3316.20	111.49
Average	3621.40	110.85	2761.64	92.85
Max	6003.00	183.75	4131.36	138.90
Min	1879.00	63	1550	52.11

It is observed that the annual average rainfall value for the upper Bhavani catchment is **2762mm** and for Avalanche Catchment, it is computed as **3622** mm. It is pertinent to mention that besides being both the reservoir to proximity, there is a significant difference in the variation of rainfall depth in both the reservoirs because of the ridge dividing both the catchments. The ridge as presented in the figure below separates both the catchments with an elevation difference of about 280 m to 300 m. The upper Bhavani catchment with latitude extent of approximately 11.20 ° N to 11.33° N and longitude extent of 76.42 ° E to 76.66° E is situated at an average elevation of about 2200 m to 2400 m whereas The Avalanche-Emerald complex catchment with latitude extent of approximately 11.34 ° N to 11.67° N and longitude extent of 76.43° E to 76.68° E is situated at an average elevation of about 1965 m to 2000 m. This might be the possible reason due to which the significant difference in the rainfall has been observed in the data series.

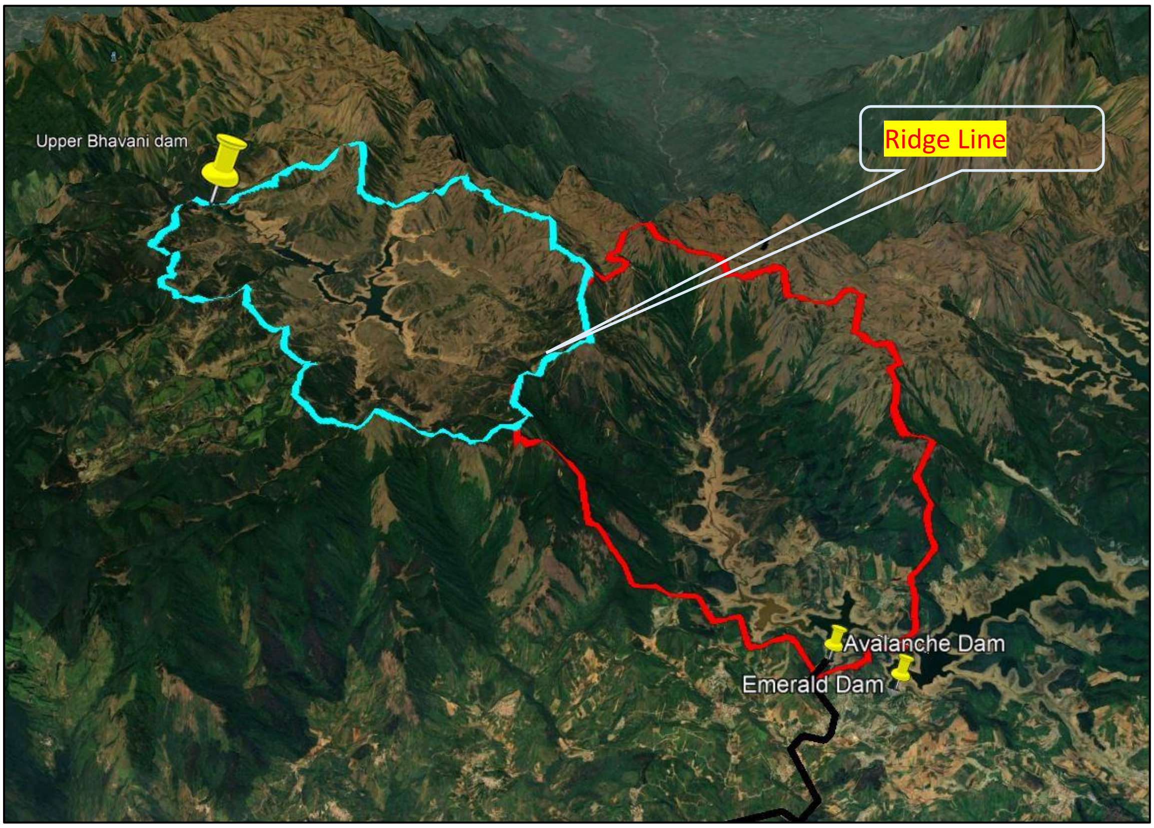


Figure 3:6 Catchments with ridge line

The annual rainfall variation plot for both the catchments has been represented in the form of a graph below. In a data series of 11 years, the average rainfall depth for Upper Bhavani reservoir as discussed has been computed as 3622 mm with a maximum depth of 4131 mm in the year 2014 and a minimum of 1550 mm in the year 2016 whereas the average rainfall depth for Avalanche-Emerald reservoir complex as discussed has been computed as 2761 mm with a maximum depth of 6003 mm in the year 2019 and a minimum of 1879 mm in the year 2016.

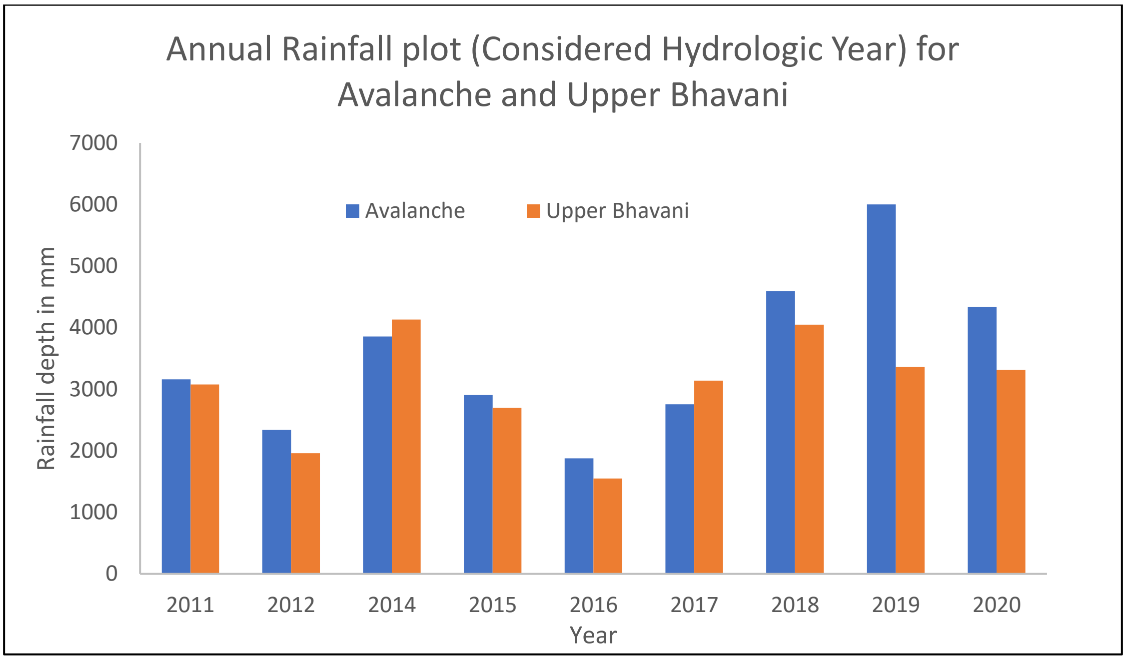


Figure 3:7 Annual Rainfall Plot (hydrologic year) for both the catchments

It is pertinent to mention from the figure provided below (**monthly rainfall plot**) that the ordinates corresponding to abscissa from July to November attains greater value in comparison to abscissa during rest of the months. The graph thus shows that the region receives most of its annual rainfall during the months of July to September i.e., during monsoon season. It also receives appreciable amount of rain pour during retreating monsoon season i.e., North east monsoon during the months of October to Mid-December. The average depth of rainfall during monsoon season (June-September) for the Upper Bhavani catchment has been computed as **2302** mm whereas for Avalanche-Emerald complex it has been computed as **3000** mm. Percentage wise it can be said that around 81% of the annual rainfall is received during South-west monsoon (June-September), around 15% of the rainfall is received during North-east monsoon (October-December) and rest 4 % is received during the month of January to June. The monthly average rainfall depth for both the catchment has been represented in the table below. The monthly average rainfall depth for Avalanche-Emerald complex and Upper Bhavani catchment has been computed as 302 mm and 229 mm respectively.

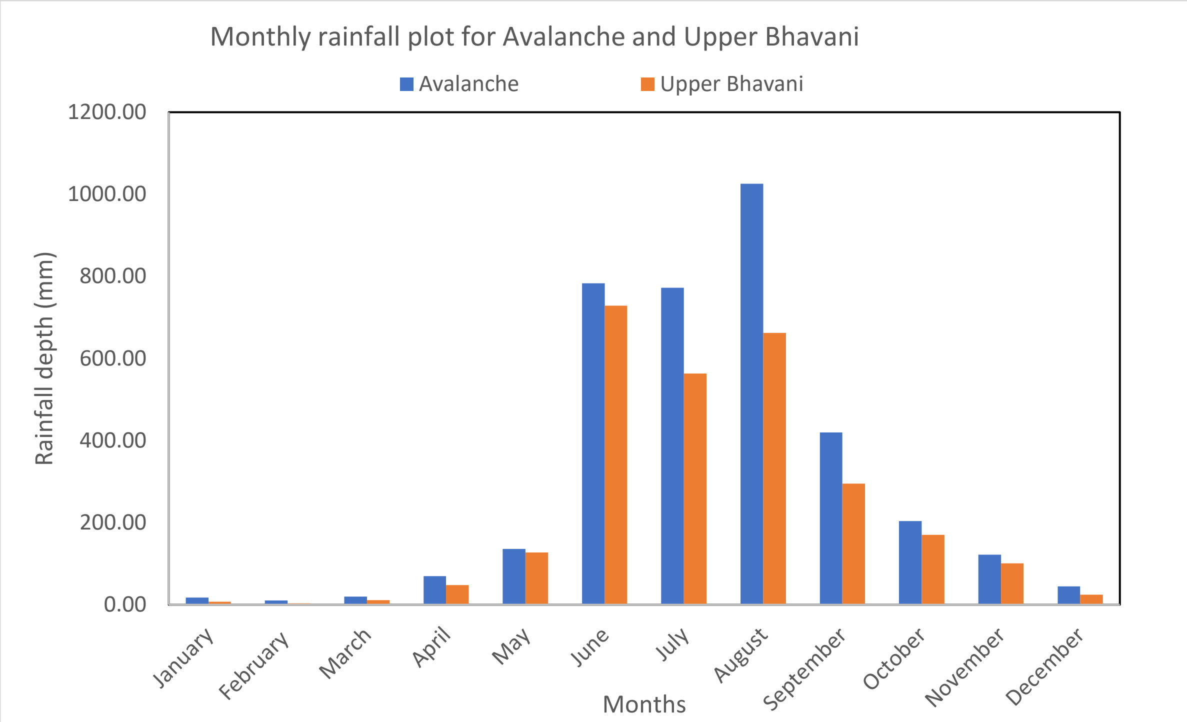


Figure 3:8 Monthly Rainfall plot for both catchments

The rainfall data as provided by the NTECL is believed to be taken from the Rain gauges installed in the catchment. As such the Rainfall data may be required as an input for the Hydrological modelling to derive long term water availability series (at the later stage, possible at DPR stage), thus the datasets are required to undergo the consistency test to adhere reliable level of certainty in it. In context of the previous statement, the consistency checks for the catchment rainfall of Upper Bhavani and Catchment rainfall of Avalanche -Emerald have been done. A time series is said to be consistent if all its values belong to the same statistical distribution. Inconsistent data should not be used to predict the design parameters, since such data may indicate change in regime of the concerned parameters, which needs to be accounted for while estimating them for design purposes.

The internal consistency of a rainfall record is tested with single mass curve analysis, cumulative value of the datasets is plotted with respect to time and the plot is checked for the change in slope. Major change in slope indicates change in the regime of the variable under concern and so its consistency.

The external consistency of a rainfall record is tested with double mass curve analysis. The cumulative pairs (double mass values) are plotted in a XY arithmetic coordinate system, and the plot is examined for trend changes. If the plot is essentially linear, the record at a station X is said to be consistent. If the plot shows a break in slope, the record at station X is inconsistent and should be corrected. The correction is performed prior to reflect the new state (after the break). To accomplish this, the annual rainfall data prior to the break are multiplied by the ratio of slopes after and before the break.

In context of the above lines, the single mass curve has been plotted based on the annual rainfall series (considered hydrologic year) for the Upper Bhavani catchment and Avalanche catchment. Furthermore, the double mass curve has also been plotted between the two. The single mass curve for both the catchment has been shown in the figure below.

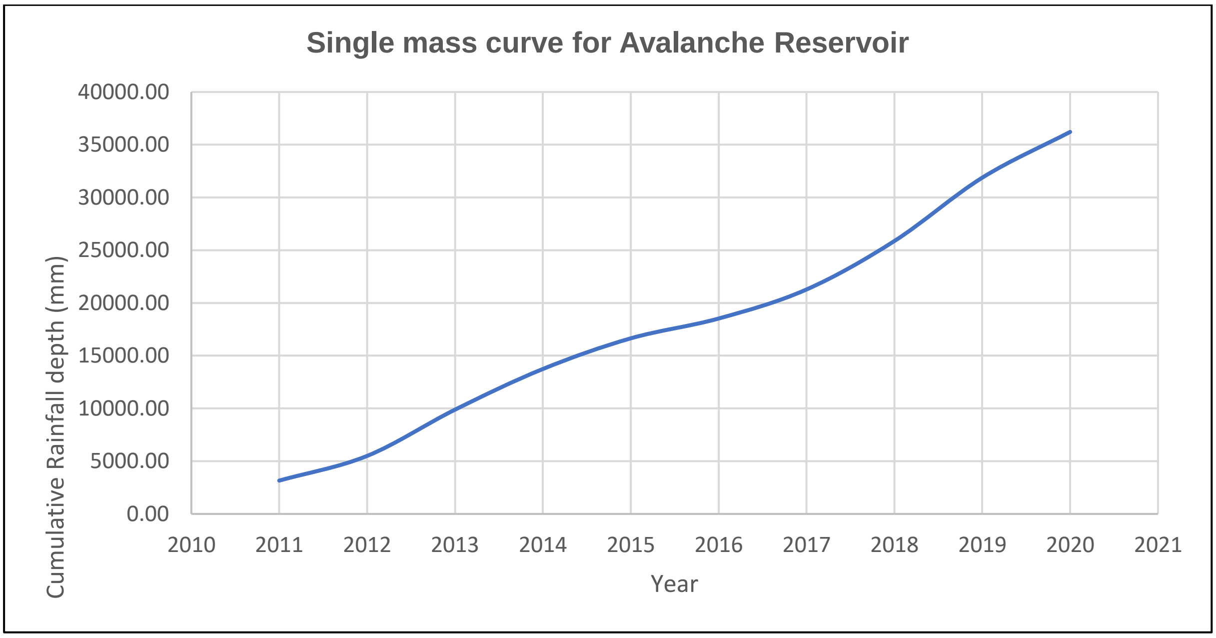


Figure 3:9 Single Mass Curve for avalanche-emerald complex catchment

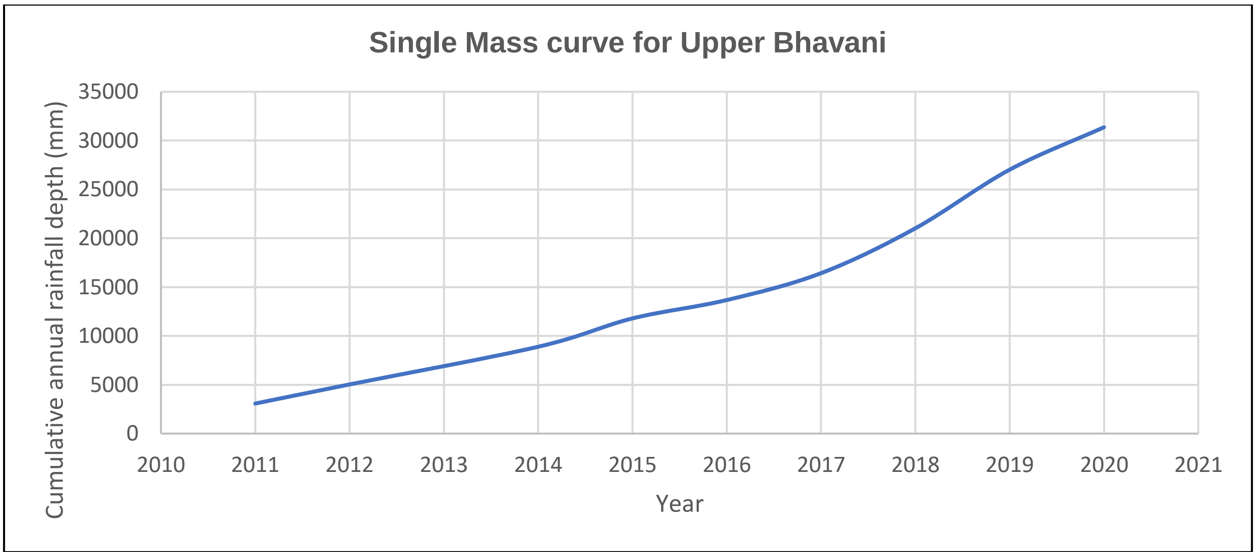


Figure 3:10 Single Mass curve for Upper Bhavani catchment

Both the single mass curve seems to be consistent. The double mass curve between rainfall of Upper Bhawani and Avalanche -Emerald Complex is shown in Figure below.

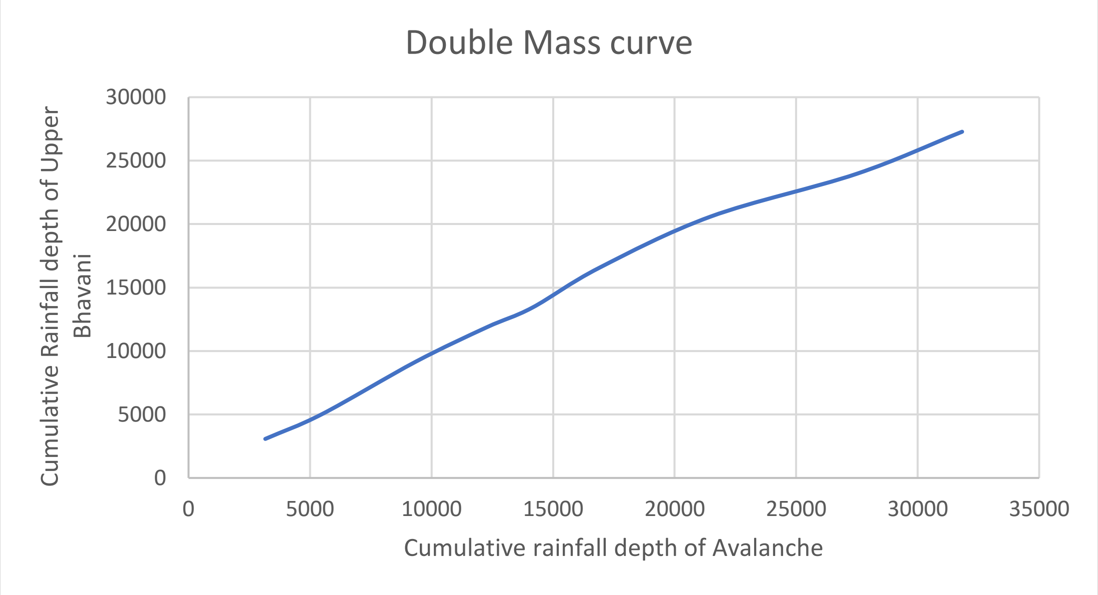


Figure 3:11 Double Mass curve plot

The daily inflow data in Upper Bhawani Reservoir (January 2011 to May 2021period) and Avalanche-Emerald complex reservoir (January 2011 to November 2021) have been supplied by NTECL. The monthly and yearly series have been derived from it is and the details are available in the water availability section.

Now the Rainfall dataset has been tested for external consistency with Rainfall-Runoff correlation. The length of the data provided by the client is of 10 years (Rainfall, Observed Runoff etc.). As for the current study (PFR level) the provided set of data has been examined but at the later stage (DPR stage) long term runoff series needs to be derived.

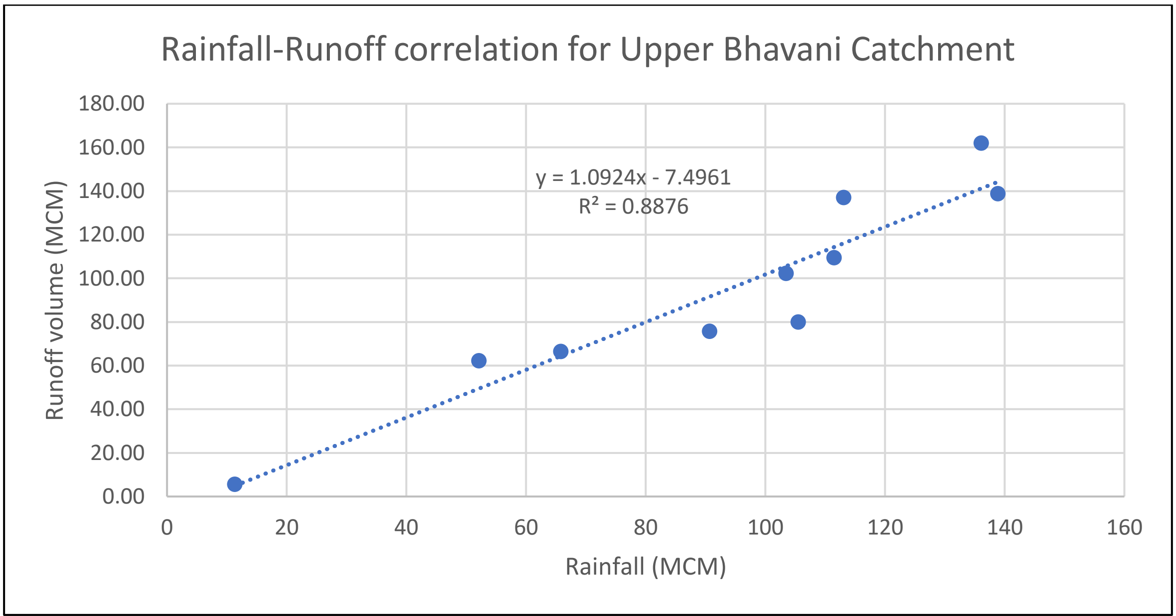


Figure 3:12 Rainfall-Runoff correlation for Upper Bhavani catchment

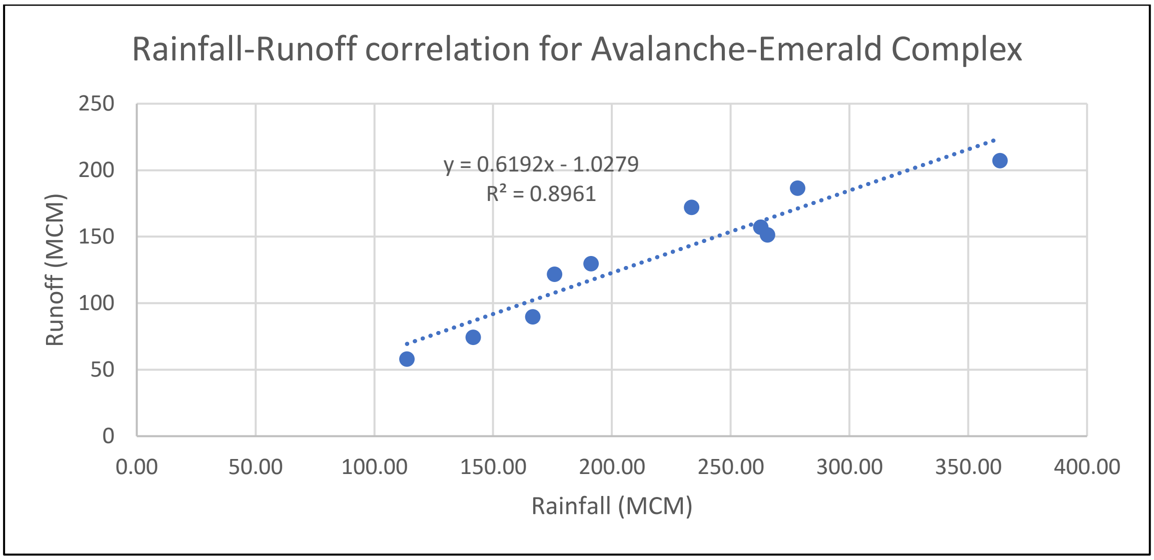


Figure 3:13 Rainfall- Runoff correlation for Avalanche-Emerald Complex

It is evident from the figure presented above that the rainfall series is consistent and is showing strong coefficient of correlation against runoff.

For getting long rainfall series, it is thought prudent to rely on Daily grid rainfall data provided by IMD (Indian Meteorological Department). To account the same, daily grid IMD rainfall data has been downloaded and analysed in the study. The Daily grid (0.25° x 0.25°) rainfall data of the project area (**Considered Lat-Long–11.25 ° N- 76.5 ° E)** has been obtained from Indian Meteorological Department for the recent 43 years period during January 1980 to December 2022 as Binary Grid files. The binary grid flies are then converted into excel/tabular format using Grid extractor code (obtained through C programming).

On analysis it is observed that the areal influence of the above-mentioned rain grid point is 100% for upper reservoir and lower reservoir respectively. Hence the data series of the above rain grid point has been taken as the rainfall dataset of the project location. On analysing the series based on Hydrological year the mean annual rainfall in the region is computed as **1302 mm** with the maximum annual value of 2244 mm in 1998 and minimum annual value of 106.3 mm in 2002 in a rainfall data series of 44 years (1980 to 2023). However, it can be noted that only one grid point is found in proximity to both the reservoir and therefore the spatial variability has not been captured particularly in a highly orographic area affected by ridges between the two project catchments as also the grid points. Further, the annual rainfall depth of 1302 mm (Based on IMD dataset) is much lesser compared to that of observed data series (Provided by NTECL). Annual rainfall plot and the Monthly rainfall plot based on IMD data set are presented in the figure below.

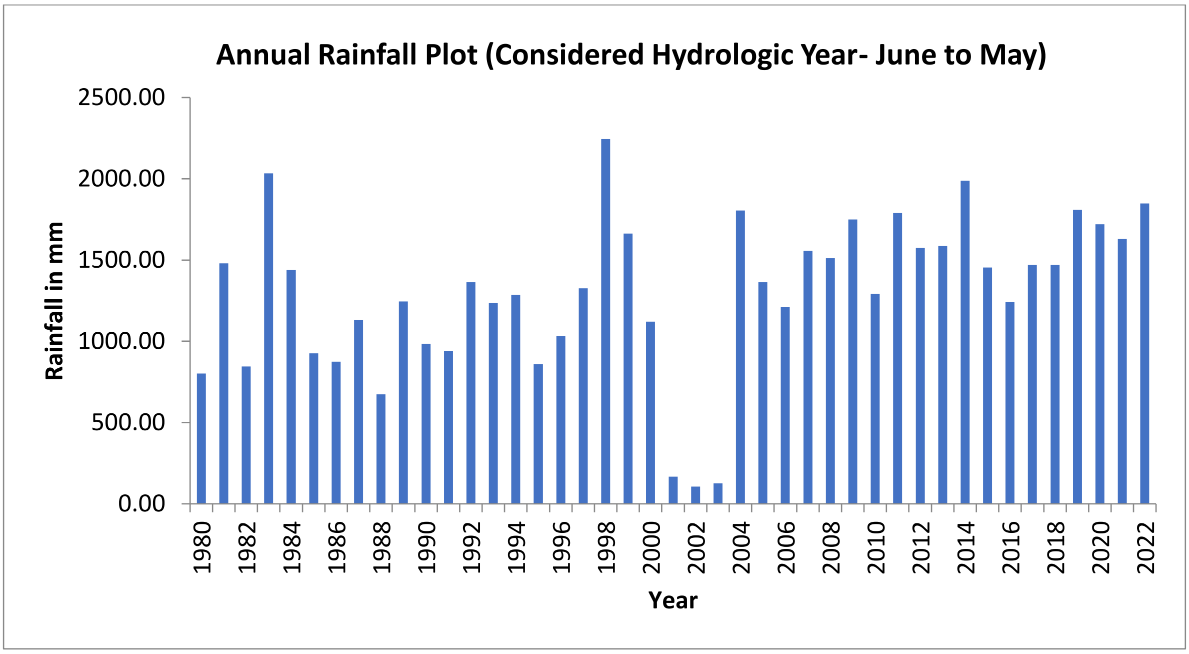


Figure 3:14 Annual Rainfall plot of the project region considering hydrologic year (June-May)

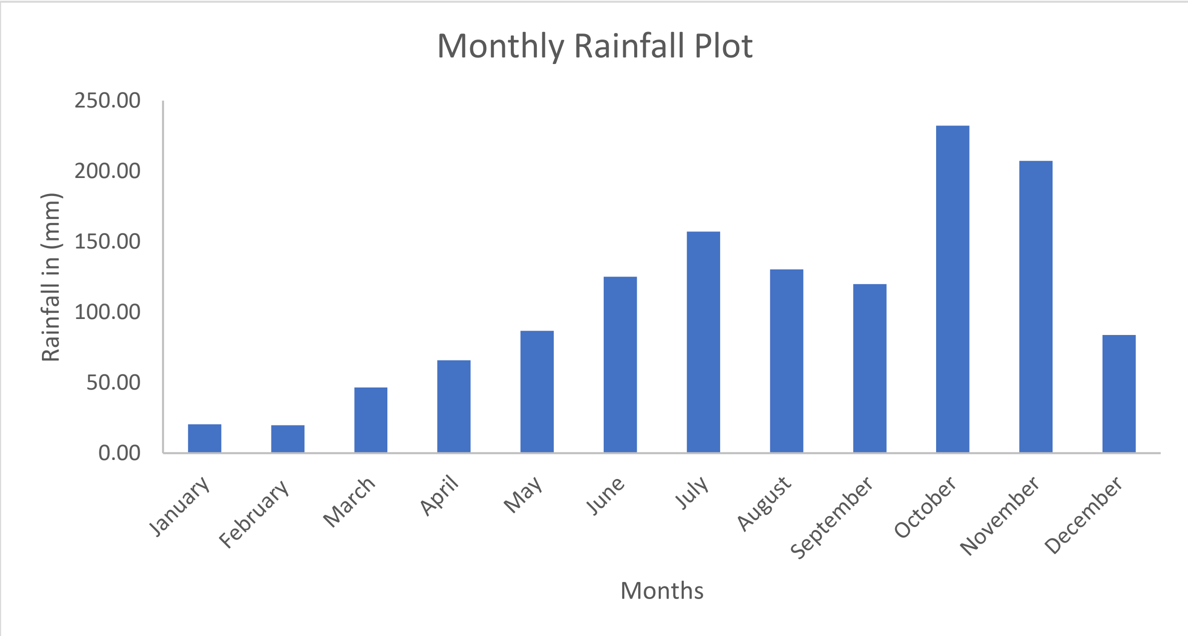


Figure 3:15 Monthly Rainfall plot of the project location

c. Water availability study

i. Upper Reservoir

Both Upper and lower reservoir falls in the Bhavani River catchment. Upper reservoir is on Bhavani River and the lower reservoir is on Avalanche River. Both the dams have been constructed very close to the originating points of the respective river itself. TANGEDCO has provided data series of inflow volume to the reservoirs based on the water level differences envisaged in the reservoir from 2011 to 2021.

As discussed above in Paragraph related to external consistency, the regression coefficient (R^2) between rainfall and runoff has come out to be 0.88 which shows a better consistency between the catchment rainfall and runoff. Once it is ensured, 90% dependable year calculation has been done based on the annual inflow volume series. The table appended below shows the annual inflow volume series. The 90 % dependable year is calculated as 2016. The detailed calculation for assessing the 90% dependable year has been listed in the subsequent chapter detailed at next chapter. On analysing the runoff series of the upper Bhavani catchment (Data available from 2011-2021) provided by TANGEDCO, the annual runoff volume has been computed as **103.7 MCM.**

Table 8 Annual Inflow Volume for Upper Bhavani Reservoir System

Hydrological Year (June-May)	ANNUAL RUNOFF VALUE(MCM)
2011	102.29
2012	66.39
2014	138.82
2015	75.70
2016	62.16
2017	79.98
2018	161.89
2019	137.07
2020	109.42
Maximum	161.89
Minimum	62.16
Average	103.75

For 90% dependable year 2016, the fluctuation of water level round the year has been represented in the figure below. On analysing the figure, the minimum water level comes out to be around 2252.7 m. However, there are some down spikes being shown in the water level variation graph which on practical basis is not commendable or possible. The computation of inflows done needs to be verified with actual elevation capacity relations and spikes in water level need to be closely examined.

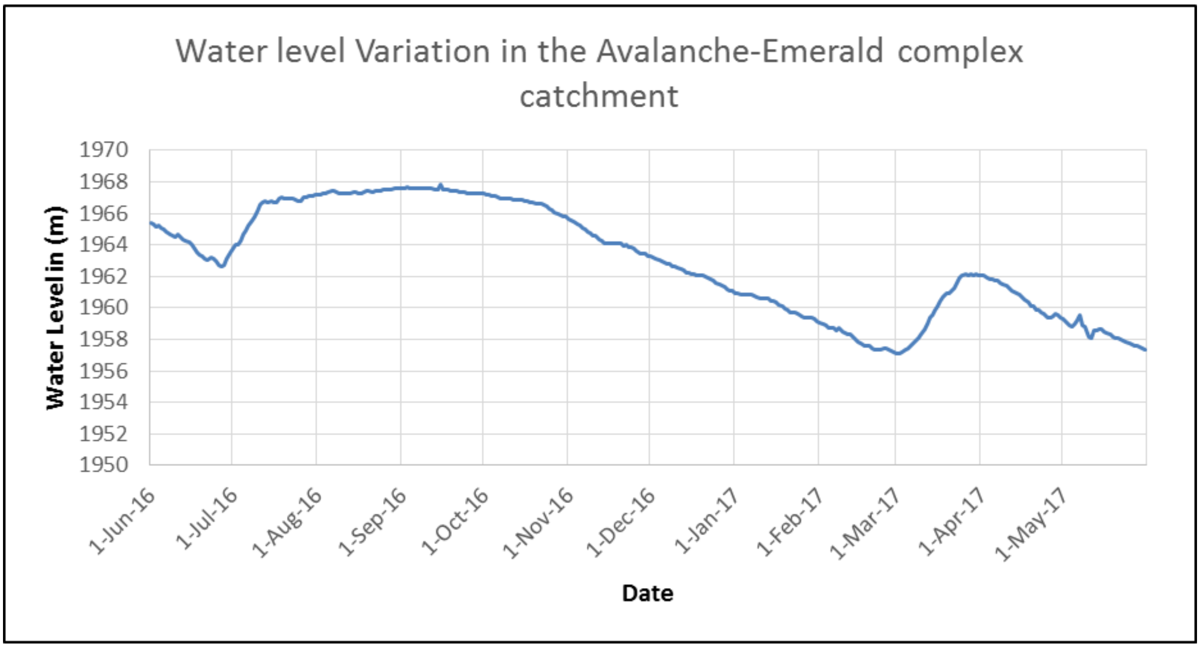


Figure 3:16 Water level Variation in Upper Bhavani Reservoir

ii. Lower Reservoir

Similarly, for the Avalanche-Emerald complex reservoir system, Rainfall -runoff consistency checks have been applied to ensure proper corroboration of Runoff volume with the Rainfall as discussed above in Para related to external consistency.

It can be seen that that the regression coefficient (R^2) has come out to be near 0.9 which shows a better consistency between the catchment rainfall and runoff. Once it is ensured, 90% dependable year calculation has been done based on the annual inflow volume series. The table appended below shows the annual inflow volume series for the lower reservoir. The 90 % dependable year is calculated as 2016. The detailed calculation for assessing the 90% dependable year has been listed in the subsequent chapter detailed at next chapter. The annual average inflow volume for combined emerald-avalanche complex system is 134.7 MCM.

Table 9 Annual Inflow volume series for Avalanche-Emerald complex Reservoir System

Hydrological Year (June-May)	ANNUAL RUNOFF VALUE (MCM)
2011.00	129.55
2012.00	74.37
2013.00	151.22
2014.00	171.99

Hydrological Year (June-May)	ANNUAL RUNOFF VALUE (MCM)
2015.00	121.61
2016.00	57.93
2017.00	89.65
2018.00	186.39
2019.00	207.08
2020.00	157.18
Maximum	207.08
Minimum	57.93
Average	134.70

For 90% dependable year 2016, the fluctuation of water level round the year has been represented in the figure below. On analysing the figure, it can be seen that the minimum water level comes out to be around 1957 m. The down spikes in the graph as discussed above will be smoothened applying the same curve fitting techniques.

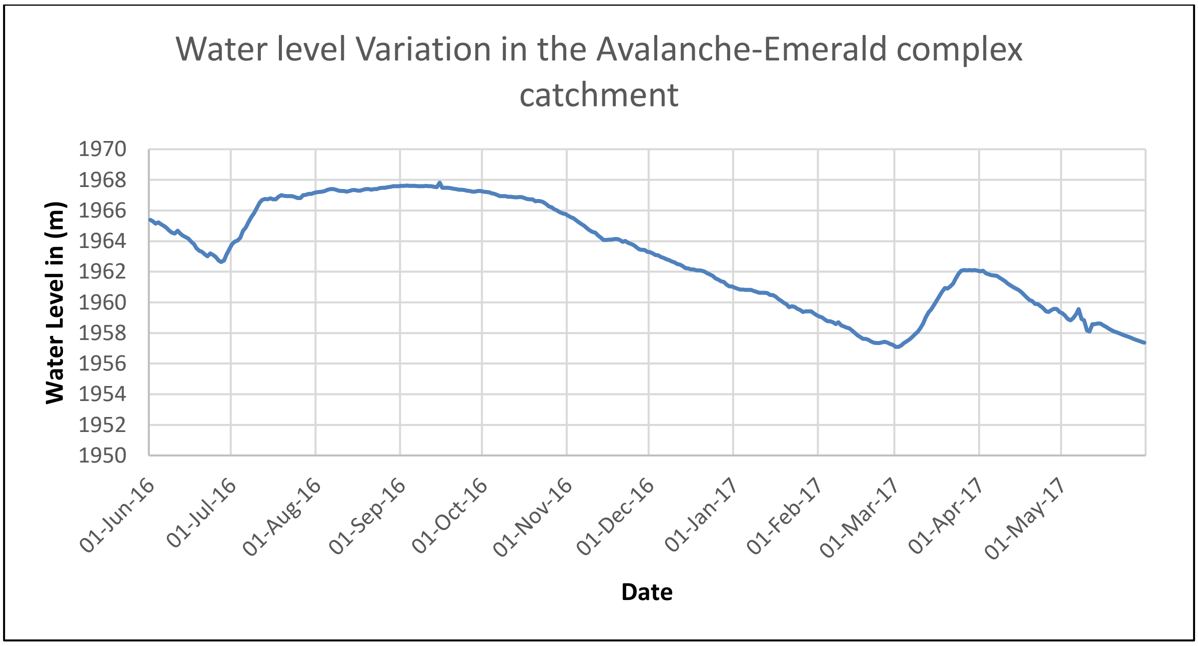


Figure 3:17 Water level in the avalanche-emerald complex catchment in the year 2016

It is observed from the set of figures presented above that the reservoir attains the FRL (or near FRL) in most of the years during the monsoon period. However, it attains its lowest level of around 2249.5 m during the months of April, May and June. On observing the combined data series of the integrated operation of the upper reservoir which considers the inflow from Kundah Power house 5 and Kundah power house 6 along with the natural rain fed inflow and the outflow for the Kundah power house 1, it can be said that the utilization of storage has been optimally planned in such a way that the reservoir water is drawn down up to its MDDL (for power house 1) immediately before the onset of the monsoon. Thus, the annual water balance of upper reservoir is optimally planned and therefore it is important to pump back the quantum of water used for daily peaking operation of the present proposed project regularly on daily basis. This daily pumping ensures that the withdrawal of water from upper Bhavani is temporary, and the annual water budgeting is unaffected by the PSP operation.

d. Lake Evaporation

No evaporation data is available in the vicinity of the projects. The location of projects is in a typical site condition and therefore, it is suggested that data from AWS on project sites for the period during which it was operational may be retrieved to include in the project report.

e. Sediment inflows

An observed sedimentation rate of 0.5541 ha-m/sq.km/Year has been given for upper reservoir (Upper Bhavani). The above sedimentation rate has been taken referring to compendium on sedimentation of reservoirs in India, 2020 detailed at page no 362.

Based on the latest survey of 2000 as reported in the compendium of sedimentation of reservoirs in India, 2020 detailed at page no 317, an observed rate of 0.314 ha-m/sq.km/year has been given to be used for the lower reservoir (Avalanche-Emerald complex).

Based on the above sedimentation rate, Trap efficiency method and Empirical Area reduction method has been applied to calculate the Life of the reservoir and the New zero Elevation after a span of 70 years for both the reservoir. The details are appended in the Sedimentation studies chapter.

f. Flood inputs

The design flood for a hydraulic structure is the maximum flood that can be safely discharged through the structure without causing any damage to it. As per the guidelines of CWC, the design flood for a hydraulic structure may be one of the following.

- Probable Maximum flood
- Standard project flood
- Flood of specified frequency (T-Year flood)

As per BIS 11223 **Guidelines for fixing the Spillway capacity**, para no- 3.1.2 and 3.1.3, the criteria for adopting the design flood depends upon the classification of the dam based on storage capacity and Hydraulic head as shown in table below.

Classification	Gross Storage (S) (Mm^3)	Hydraulic Head (H) (m)
Small	Between 0.5 to 10	Between 7.5 and 12
Intermediate	Between 10 and 60	Between 12 and 30
Large	Greater than 60	Greater than 30

The classification adopted would be greater of that indicated by the above two parameters.

Dam Type	Design flood calculation approach
Small Dam	100-year flood
Intermediate Dam	SPF
Large Dam	PMF

In the present project, for the existing reservoirs, as the static head of the dam is more than 30 m with gross capacity much more than 60 MCM, the design flood against which the spillway were designed must be based on the PMF Value (Probable Maximum Flood). The PMF has been reviewed in the present study based on the PMP (Probable Maximum Precipitation) value.

3.10 Existing spilling arrangements

- Upper Bhavani reservoir- The present spillway capacity of the Upper Bhavani reservoir is 467 cumec.
- Lower reservoir- The present spillway capacity of the Avalanche-Emerald complex reservoir is 705 cumec.

3.11 Probable Maximum Precipitation (PMP)

The PMP has been estimated based on the physical approach in the present set of study. Both lower and upper reservoir catchments are covered in the PMP Atlas: Cauvery and other East Flowing River Basins volume -I& II with Catchment Number 302 L.

The Cauvery and other east flowing river basins are divided into five catchments and IMD has assigned their numbers from 301 to 305. Based on the significant topographical differences, catchment number 302 has been further delineated into 302 L, 302 M and 302 U. Both the reservoirs as discussed falls under catchment number- **302 L– River Cauvery downstream of Mettur Dam.**

For both the reservoir location, the nearest grid point is CAU-302-03 (11° N, 77° E, EL approx.- 440 m). The catchment is slightly north and slightly west of this grid point. It is ensured that the grid point is on the same side of the ridges. The maximum one-day depth observed is 460 mm on 15 November 1992 for area smaller than equal to 100 Km as mentioned in Page no 174, volume 1 of the atlas. The catchment area of both upper and lower reservoir (Coordinate of the centroid of the upper reservoir- 11.26° N, 76.55° E approx. elevation 2240 m, coordinate of the centroid of the lower reservoir 11.3° N, 76.58° E, elevation- 1980 m approx.) is greater than 25 sq.km and smaller than 100 sq.km, Hence Transposition Adjustment Factor (TAF) value has been taken as 0.99 which has been taken from Page no 174, volume 1 of the Atlas. As discussed earlier the catchment area of upper reservoir is 33.61 sq.km and the catchment area of lower reservoir (combined emerald and avalanche) is 57.53 sq.km. Hence the magnitude of the Standard Project Storm (SPS) comes out to be 455.4 mm (460 x 0.99). The Moisture maximization factor (MMF) for the grid point corresponding to this storm is 1.20 (Given at Page no 174), thus the **magnitude of the PMP for both the reservoir is estimated as 546.5 mm**. The 100-year return period depth is 240 mm taken from page no 282, volume 2 of the atlas.

For short interval distribution, ratio of 12 hr./24 hr. is taken from Table 3.42 given at page no 197, volume 1 of the atlas. The Value of the coefficient is 74.5 for sub duration of 12 hours. Furthermore, the ratio of 1 hr./12 hr. is taken from Table 3.40 given at page no 193, volume-1 of the atlas. The Value of the coefficient is 19.4 for sub duration of 1 hour. Thus, the rainfall intensity based on PMP is computed as 79 mm/hr, rainfall intensity based on SPS is computed as 65.81 mm/hr and the rainfall intensity based on the 100-year return period rainfall depth is computed as 34.7 mm/hr.

3.12 Probable Maximum Flood (PMF)

a. Lower Reservoir

Once the PMP has been estimated, rational formula is then applied to arrive at the PMF value. The value of coefficient C is chosen based on different land use land cover pattern of the catchment. The catchment area being very small, most part of it is covered with the green patches and reservoir itself, thus average r value of 0.55 has been adopted. The above value has been taken from K. Subramanya Engineering Hydrology Book considering considerable percentage of area in forest and soil type being of clay nature. It can be seen form the table provided below that the PMF value for the lower reservoir has been assessed as 695 **m^3/sec.** Thus, it can be said that that the spillway has the adequate capacity to pass the PMF as the present existing spilling capacity is 705 cumec.

It is prudent to note that the catchment area of both the Avalanche and Emerald dam has been added to arrive at the total catchment area of 57.53 sq.km, the catchments are however not naturally connected, they are connected through an interconnecting tunnel which brings the surplus water from Emerald to Avalanche for the extra water to spill out through the spillway. There is no provision of spillway arrangement in the Emerald dam.

Table 10 Calculation of peak flood for lower reservoir

Coefficient C	0.55		LR
Catchment Area(Sq.KM)			57.53
	DEPTH (mm)	1hr max as obtained from short hour time distribution (Critical rainfall intensity) (mm/hr.)	Peak Flow (M3/sec)
PMP	546.5	79	695
SPS	455.4	65.81	579
100-Year	240	34.7	305

b. Upper Reservoir

The PMF value as shown in the table below has been assessed as 406 cumec. Thus, it can be said that that the spillway has the adequate capacity to pass the PMF. The same rational formula is applied to arrive at the PMF value. The higher value of order 0.55 for the coefficient C has been chosen because of the same reason of catchment being very small and most part of it is lying in the forest cover zone and reservoir only.

Table 11 Calculation of Peak flood for Upper reservoir

Coefficient C	0.55		UR
Catchment Area(Sq.KM)			33.61
	DEPTH (mm)	1hr max as obtained from short hour time distribution (Critical rainfall intensity) (mm/hr.)	Peak Flow (M3/sec)
PMP	546.5	79	406
SPS	455.4	65.81	338
100-Year	240	34.7	179

3.13 Reservoir Characteristics

a. Catchment Area

The catchment area of upper reservoir catchment is computed as 33.61 sq.km and the combined catchment area of Avalanche-Emerald complex is computed as 57.53 sq.km. The catchment area map of both the catchments has been presented in the figure below.

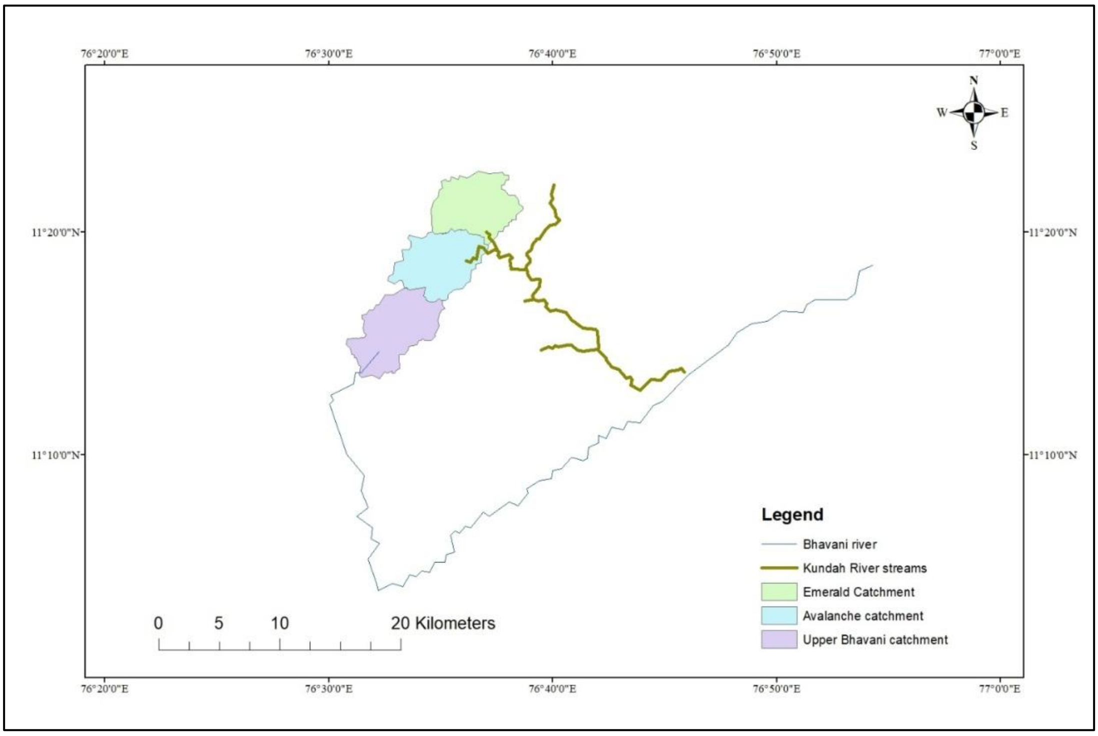


Figure 3:18 Catchment Map of upper and lower reservoir

b. Annual runoff/Reservoir Yield

As discussed in the water availability section, the annual average inflow volume for the upper catchment and the lower catchment has been computed as 103.7 MCM and 134.7 MCM considering the data length from 2011 to 2021.

c. Dependability studies

The dependability analysis has been carried out by performing ranking studies on the estimated annual yield. The details of calculation made for estimation of dependable yield at upper and lower dam sites is furnished in the table below. For both the catchment, as can be seen from the table below that the 90 % dependable year comes out to be 2016.

Table 12 Ranking Studies for upper reservoir

Year	Annual series (MCM)	Sorted Series (MCM)	Sorted Year	Rank	% exceedance
2011	102.29	161.89	2018	1	10
2012	66.38	138.81	2014	2	20

Year	Annual series (MCM)	Sorted Series (MCM)	Sorted Year	Rank	% exceedance
2014	138.81	137.06	2019	3	30
2015	75.70	109.42	2020	4	40
2016	62.15	102.29	2011	5	50
2017	79.97	79.97	2017	6	60
2018	161.89	75.70	2015	7	70
2019	137.06	66.38	2012	8	80
2020	109.42	62.15	2016	9	90

Table 13 Ranking Study for lower reservoir

YEAR	Runoff Volume (MCM)	sorted year	sorted runoff volume (MCM)	Rank	% exceedance
2011	129.55	2019	207.08	1	9.1
2012	74.37	2018	186.39	2	18.2
2013	151.22	2014	171.99	3	27.3
2014	171.99	2020	157.18	4	36.4
2015	121.61	2013	151.22	5	45.5
2016	57.93	2011	129.55	6	54.5
2017	89.65	2015	121.61	7	63.6
2018	186.39	2017	89.65	8	72.7
2019	207.08	2012	74.37	9	81.8
2020	157.18	2016	57.93	10	90.9

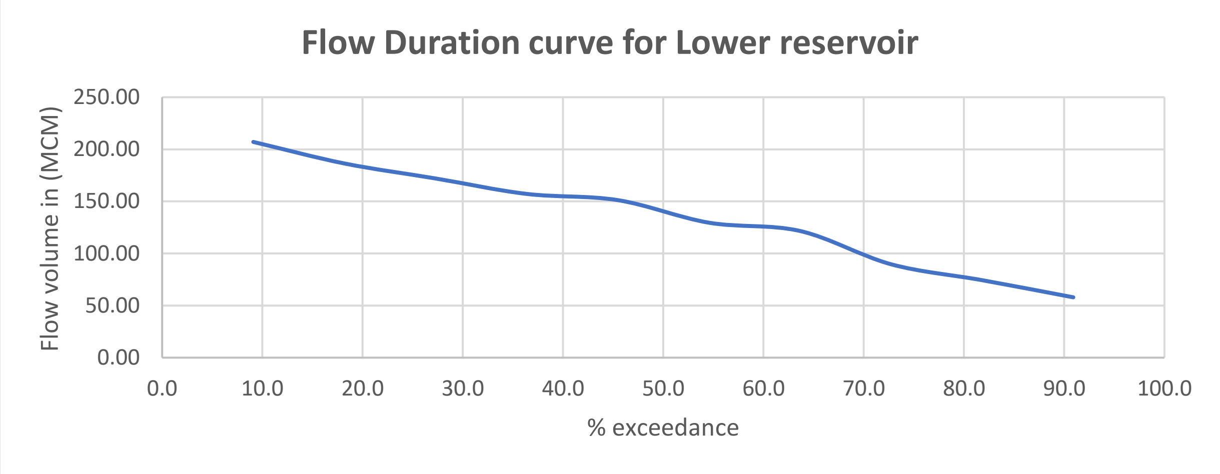


Figure 3:19 flow duration curve for lower reservoir

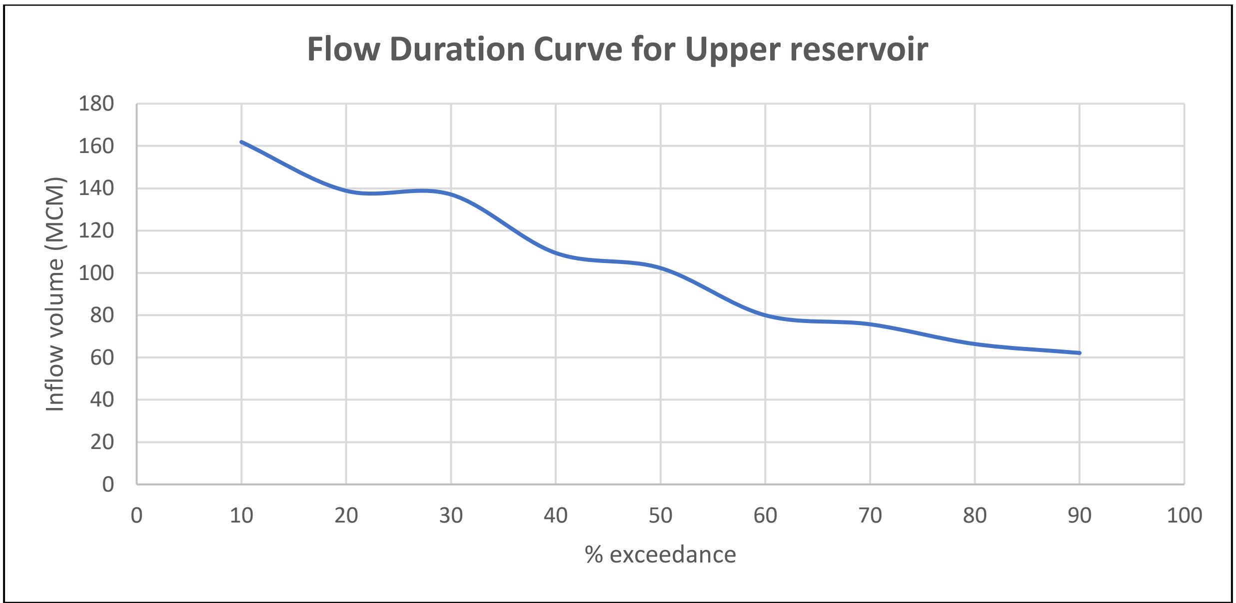


Figure 3:20 flow duration curve for upper reservoir

Table 14 Dependable yields at dam site.

Dependability	Upper Reservoir (MCM)	Lower Reservoir (MCM)
90%	62.15	57.93
75%	66.38	74.37
50%	102.29	129.55

d. Elevation-Area-Capacity Data of the reservoirs

The elevation-area-capacity data of upper reservoir have been presented in the table below. The data has been obtained from the report on Sedimentation studies in Upper Bhavani Reservoir prepared by Institute of Hydraulics and Hydrology Poondi. The dataset based on latest capacity survey (Second capacity survey in 2021) have been taken for the sedimentation study from the report. From the table presented below, at the proposed FRL level of 2276.86 M, the cumulative volume comes out to be 97.06 MCM.

Table 15 Elevation – Area – Capacity data for upper reservoir

Upper Reservoir				
EAC as per II capacity survey of 2021				
Elevation (m)	**Area (Ha)**	**Capacity (Ha-m)**	**Depth (m)**	**MCM**
2276.86	461.500	9705.800	76.2	97.06
2272.00	375.300	7741.600	71.3	77.42
2266.00	321.000	5650.800	65.3	56.51
2260.00	257.700	3894.100	59.3	38.94
2254.00	192.100	2554.100	53.3	25.54
2248.00	138.400	1562.300	47.3	15.62
2242.00	86.800	889.100	41.3	8.89
2236.00	53.300	489.200	35.3	4.89
2230.00	35.500	223.700	29.3	2.24
2224.00	15.500	70.200	23.3	0.70
2218.00	3.600	19.800	17.3	0.20
2212.00	1.700	6.100	11.3	0.06
2200.66	0.000	0.000	0.0	0.00

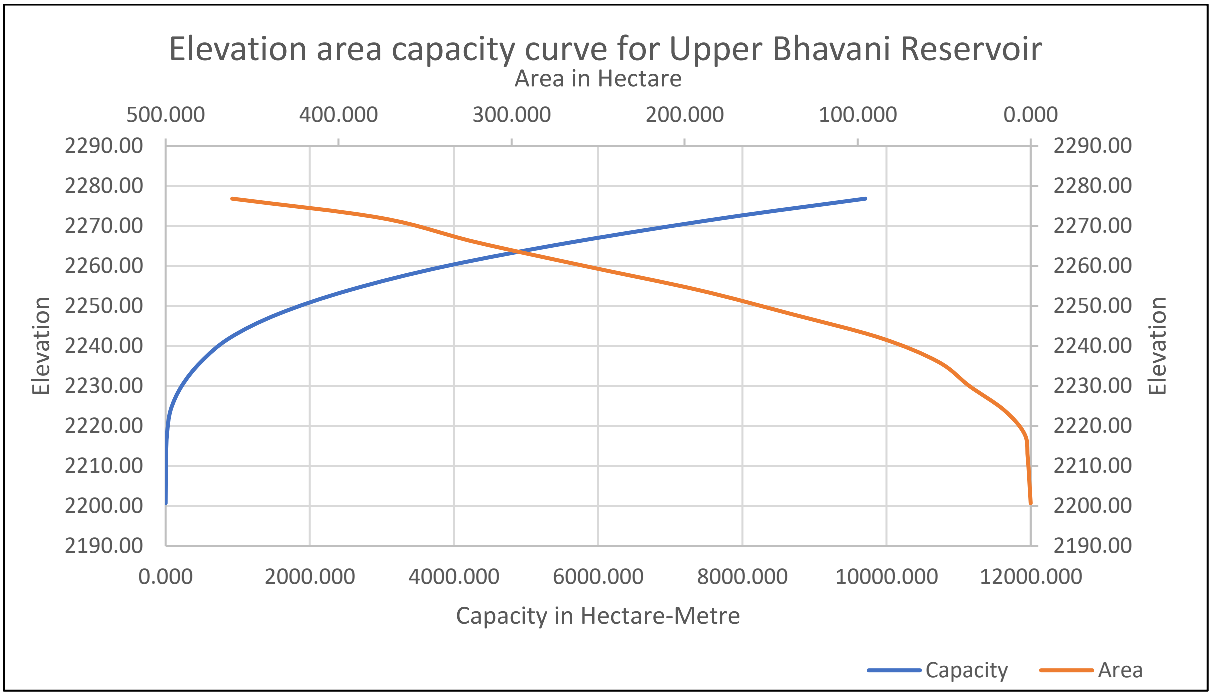


Figure 3:21 Elevation -Area-Capacity curve for upper Bhavani

The elevation-area-capacity data of Lower reservoir have been presented in the table below. The combined elevation-capacity-area dataset of the Emerald-Avalanche complex reservoir system has been taken from Kundah PSP DPR. From the table presented below, at the proposed FRL level of 1985.8 M, the cumulative volume comes out to be 149.57 MCM.

Table 16 Elevation-Area-Capacity data for lower reservoir

Lower Reservoir				
Elevation (m)	**Area (Ha)**	**Capacity (Ha-m)**	**Depth (m)**	**MCM**
1985.80	804.40	14957.00	56.2	149.57
1984.00	751.00	13712.00	54.4	137.12
1981.00	679.20	11584.00	51.4	115.84
1978.00	610.00	9660.00	48.4	96.60
1975.00	533.70	7825.00	45.4	78.25
1972.00	468.20	6340.00	42.4	63.40
1969.00	406.10	5143.00	39.4	51.43
1966.00	347.50	4043.00	36.4	40.43
1963.00	290.80	3098.00	33.4	30.98
1960.00	283.90	2298.00	30.4	22.98

1957.00	191.00	1660.00	27.4	16.60
1954.00	148.30	1135.00	24.4	11.35
1951.00	110.80	722.00	21.4	7.22
1948.00	74.30	409.00	18.4	4.09
1945.00	43.90	207.00	15.4	2.07
1942.00	19.90	105.00	12.4	1.05
1939.00	9.10	26.00	9.4	0.26
1936.00	1.70	2.00	6.4	0.02
1933.00	0.00	0.00	3.4	0
1932.40	0.00	0.00	2.8	0
1929.60	0.00	0.00	0.0	0

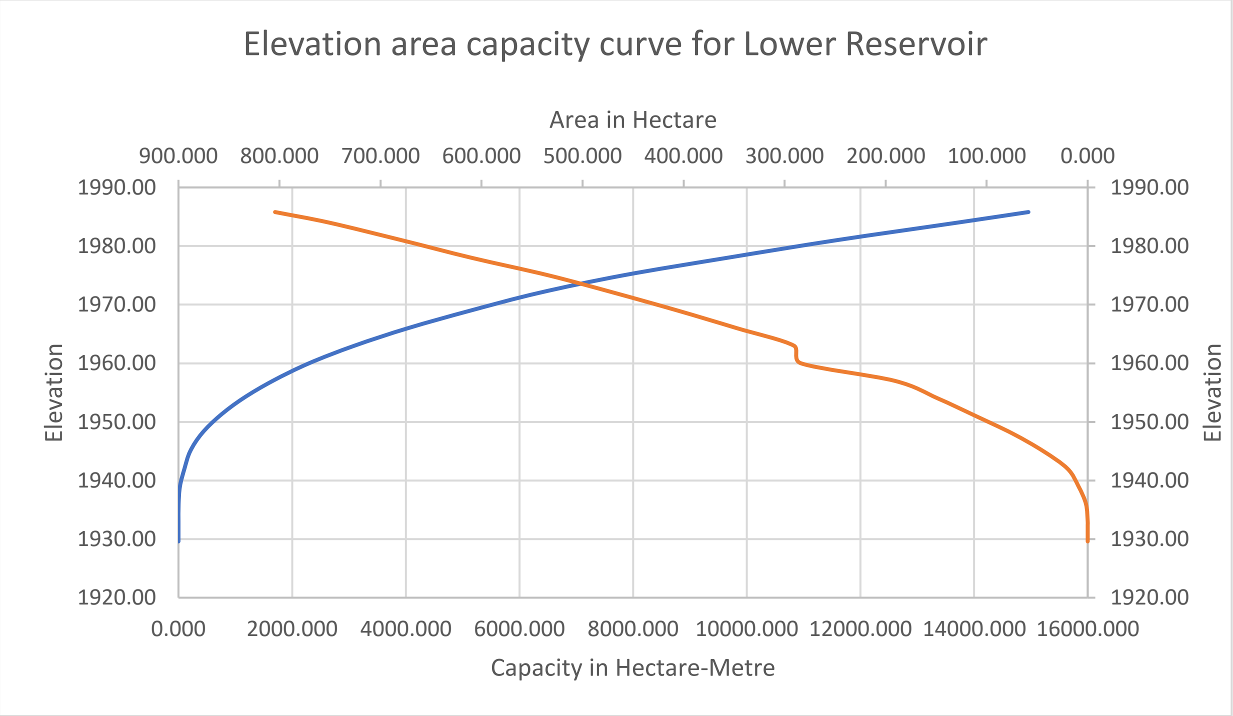


Figure 3:22 Elevation area capacity curve for lower reservoir

3.14 Sedimentation studies

3.14.1 Design requirements

As per IS: 12182, Guidelines for Determination of Effects of sedimentation in planning and performance of Reservoirs, the revised reservoirs capacity after a period of 25 years needs to be estimated. Similarly, at the design stage, it is essential to predict the extent of sediment deposition at or near the hydraulic structure to fix the outlet/sill levels after a time horizon of 25 & 70 years.

3.14.2 Sediment Data

An observed sedimentation rate of 0.5541 ha-m/sq.km/Year has been given for upper reservoir (Upper Bhavani). The above sedimentation rate has been taken referring to compendium on sedimentation of reservoirs in India, 2020 detailed at page no 362.

Based on the latest survey of 2000 as reported in the compendium of sedimentation of reservoirs in India, 2020 detailed at page no 317, an observed sedimentation rate of 0.314 ha-m/sq.km/year has been recommended to be used for the lower reservoir (Avalanche reservoir).

A. Upper Reservoir

The Upper Bhavani reservoir had been commissioned in the year 1965. The first sedimentation survey or the first capacity survey had been carried out during the year 1985 after 20 years of operation by Watershed Management Board Division under the control of Institute of Hydraulics and Hydrology, Poondi. The second capacity survey had been conducted in the year 2021 after 56 years of operation by Watershed Management Board under Dam Rehabilitation Improvement Project (DRIP). The sedimentation details observed during the years 1985 and 2021 are detailed at the Table appended below.

Table 17 Sedimentation details for Upper Bhavani reservoir based on capacity surveys data.

S.No	Description	Original (1965)	Year 1985	Year 2021
1	Capacity (MCM)	101.1476	97.48	97.058
2	Annual average inflow volume (MCM)	101.419		
3	Watershed (Sq.km)	33.59		
4	Capacity /Watershed ratio (MCM/sq.km)	3.01	2.90	2.89
5	Silt deposition (MCM)		3.6676	4.0896
6	Average annual silt Load (MCM/Year)		0.183	0.073
7	% of silt deposition		3.626	4.043
8	Average annual silting rate in %		0.181	0.072
9	Average annual silting rate/sq.km (MCM/Year/sq.km)		0.005	0.002
10	capacity inflow ratio	0.997	0.961	0.957

B. Lower Reservoir

The Avalanche reservoir had been commissioned in the year 1961. The first sedimentation survey or the first capacity survey had been carried out during the year 1981 after 20 years of operation by Watershed Management Board Division under the control of Institute of Hydraulics and Hydrology, Poondi. The second capacity survey had been conducted in the year 2018 after 57 years of operation by Watershed Management Board under Dam Rehabilitation Improvement Project (DRIP). The sedimentation details observed during the years 1981 and 2018 are detailed at the Table appended below.

Table 18 Sedimentation details for Avalanche reservoir based on capacity surveys data.

S.No	Description	Original (1961)	Year 1981	Year 2018
1	Capacity (MCM)	61.475	63.824	58.282
2	Annual average inflow volume (MCM)	59.784		
3	Watershed (Sq.km)	30.5		
4	Capacity /Watershed ratio (MCM/sq.km)		2.09	1.91
5	Silt deposition (MCM)		-	3.193
6	Average annual silt Load (MCM/Year)		-	0.056
7	% of silt deposition		-	5.19%
8	Average annual silting rate in %		-	0.09%
9	Average annual silting rate/sq.km (MCM/Year/sq.km)		-	0.002
10	Capacity Inflow ratio		1.068	0.975

3.14.3 Prediction of sediment distribution

The sediment entering storage reservoirs get deposited progressively with the passage of time and thereby reduce the dead as well as live storage capacity of the reservoir. This causes the bed level near the dam to rise, and the raised bed level is termed as new Zero elevation. The detailed sedimentation analysis calculations and determination of New Zero elevation after 70 years of sedimentation has been discussed in this section.

I. Upper Reservoir

A. Classification of reservoir

Boreland and Miller evolved a method to classify the reservoir type based on the analysis of data of different reservoirs. In this method depth vs capacity curve is plotted on log-log sheet keeping reservoir depth as ordinate and the classification is made as follows

Value of M	Reservoir Type	Standard classification
1 to 1.5	Gorge	IV
1.5 to 2.5	Hill	III
2.5 to 3.5	Flood plain foot hill	II
3.5 to 4.5	Lake	I

For upper Bhavani reservoir the Value of M (x/y) is computed as 3.9, Hence it can be classified as Lake pertaining to the current standard classification. Log capacity vs Log depth curve for the upper Bhavani reservoir has been appended in the figure below.

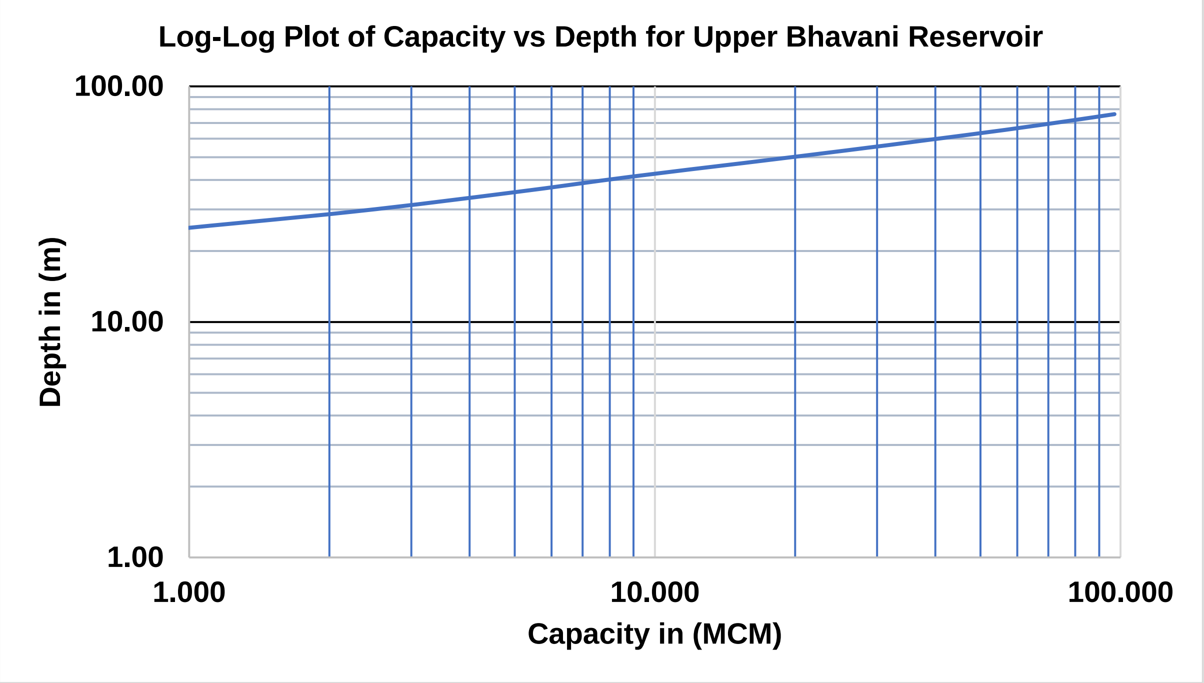


Figure 3:23 Log Capacity–log depth curve for Upper Bhavani Reservoir

B. Trap efficiency

After the reservoir classification, Trap efficiency has been assessed. Trap efficiency of a reservoir is defined as the ratio of deposited sediment to the total sediment inflow. In the present set of study, Trap efficiency has been computed based on Brune's curve. Based on the capacity inflow ratio of 0.957, the Trap efficiency has been computed as 98%.

C. Life of the reservoir

Life of the reservoir is the period of its usefulness to the designed purpose. The useful life depends upon the operation level between MDDL and FRL.

Gunner Brune has developed envelope curves keeping the capacity inflow ratio as abscissa and trap efficiency as ordinate on a semi log paper. Using the median curve of the graph and capacity inflow ratio for different capacities, average trap efficiency is found out. Sediment load trapped is calculated from the above value and dividing the volume interval by the sediment load yields the number of years to fill the volume. Thus, the years required to fill up the volume interval up to 30% of its original capacity is worked out and added to get the useful life of the reservoir. In other word it can be understood as "the year required to fill up the 70 % of the storage with sediment. The detailed arithmetic calculation is appended in the table below. It is inferred from the table that the life of reservoir based on trap efficiency method is computed as 992 years.

Table 19 Life of Reservoir Based on trap efficiency method

Capacity in MCM	Capacity inflow ratio	Trap efficiency	Average Trap efficiency	Annual sediment trapped (MCM)	Reduction in volume (MCM)	Years to fill
101.148	0.997	97.50%	-	-		
97.058	0.957	96.50%	97.00%	0.073035714	4.09	56
90	0.887	96.00%	96.25%	0.072471005	7.058	97
80	0.789	95.50%	95.75%	0.072094532	10	139
70	0.690	95.00%	95.25%	0.07171806	10	139
60	0.592	94.50%	94.75%	0.071341587	10	140
50	0.493	94.00%	94.25%	0.070965144	10	141
40	0.394	93.50%	93.75%	0.070588641	10	142
30.34	0.299	93.00%	93.25%	0.070212169	9.6556	138
					Life of Reservoir	992

In addition to the above, Institute of Hydraulics and Hydrology Poondi have also studied the Life of reservoir based on **Hachiro Kira Method**. This method uses an empirical relationship between the rate of annual sediment and the capacity inflow ratio and the number of years when the reservoir will be fully silted up.

$V_s = 0.214\left(\frac{C}{I}\right)^{0.473}$ where Vs= Annual mean silt deposition rate in percentage

C = Original capacity of the reservoir (101.1476 MCM)

I = Annual mean inflow volume (101.419 MCM)

Based on the above formula the value of Vs comes out to be 0.214% per year.

Now $Y_s = 467\left(\frac{C}{I}\right)^{0.473}$ where Ys represents number of years during which the silt will fill up the reservoir completely. Thus, the life of the reservoir is computed as 466 years.

Comparing both the method, the life of the reservoir (Upper Bhavani reservoir) is taken as 466 years by Hachira Karo Method.

D. Computation of New Zero elevation level

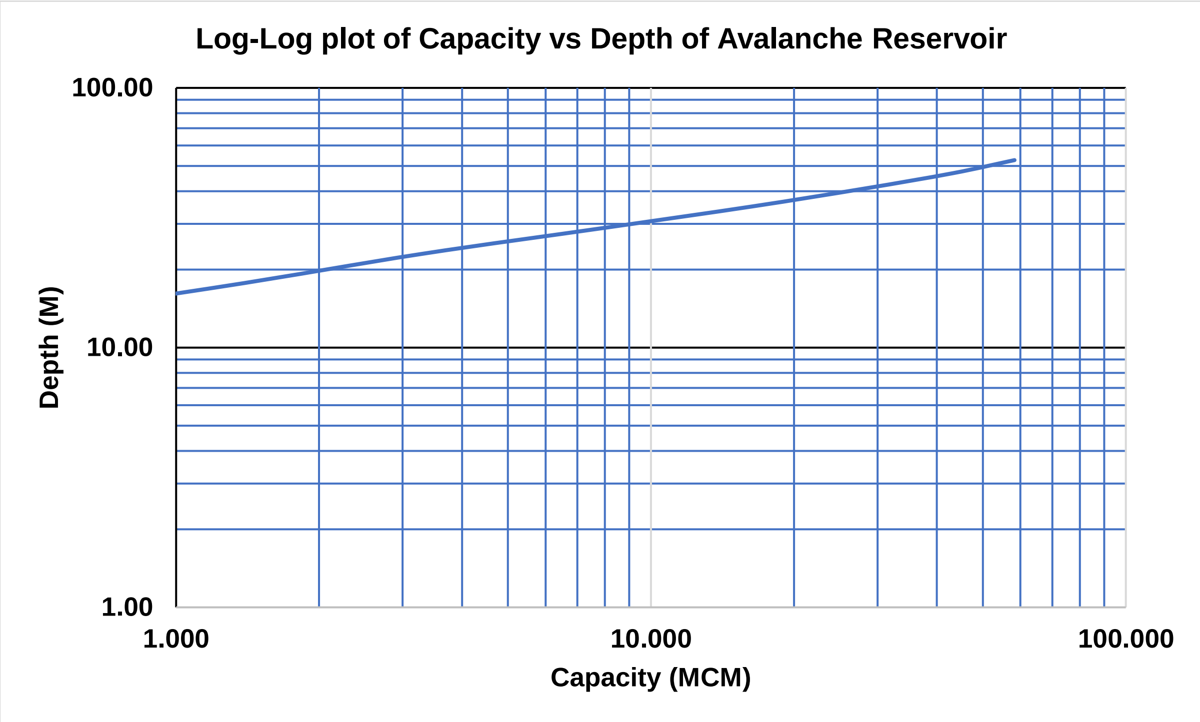
Computation of New Zero elevation level has been done using Empirical Area Reduction Method (EARM). It is the most used method for predicting the impact of sediment deposition in a reservoir. The method was proposed by Borland and Miller (1958) based on an analysis of sedimentation data for 30 reservoirs in the USA. This method uses the EAC (Elevation Area Capacity) curve of the reservoir and standard reservoir classification based on which the relationships between volume, surface area and depth are calculated. The new zero elevation considering a span of 70 years based on the EARM method for the upper reservoir is computed as 2230 M. This value has been considered taking into account the EAC data of latest capacity survey of the year 2021. This aspect will once again be reviewed based on the latest EAC data which will be obtained once the Bathymetric survey, which is currently in progress, is completed. The computation sheet has been provided in **Table 3.17**.

II. Lower Reservoir

A. Classification of Reservoir

For Avalanche reservoir the Value of M (x/y) is computed as 3.51, hence it can be classified as Lake pertaining to the current standard classification. Log capacity vs Log depth curve for the Avalanche reservoir has been appended in the figure below.

Figure 3:24 Log Capacity – Log Depth curve for the Avalanche reservoir



B. Trap efficiency

In the present set of study, Trap efficiency has been computed based on Brune's curve. Based on the capacity inflow ratio of 0.975, the Trap efficiency has been computed as 98%.

C. Life of the reservoir

The life of the Avalanche reservoir based on the trap efficiency method is computed as 781 Years. The detailed arithmetic calculation table is appended below.

Table 20 life of reservoir based on trap efficiency method for lower reservoir

Capacity in MCM	Capacity inflow ratio	Trap efficiency	Average Trap efficiency	Annual sediment trapped (MCM)	Reduction in volume (MCM)	Years to fill
61.475	1.028	98.00%	-	-		
58.282	0.975	97.50%	97.75%	0.05602	3.193	57
55	0.920	97.00%	97.25%	0.05573	3.282	59
50	0.836	97.00%	97.00%	0.05559	5	90
45	0.753	96.50%	96.75%	0.05544	5	90
40	0.669	96.50%	96.50%	0.05530	5	90

35	0.585	96.00%	96.25%	0.05516	5	91
30	0.502	95.50%	95.75%	0.05487	5	91
25	0.418	95.00%	95.25%	0.05458	5	92
20	0.335	94.50%	94.75%	0.05430	5	92
18.4425	0.308	94.00%	94.25%	0.05401	1.5575	29
					Life of reservoir (Years)	781

In addition to the above, Institute of Hydraulics and Hydrology Poondi have also studied the Life of reservoir based on Hachiro Kira Method. This method uses an empirical relationship between the rate of annual sediment and the capacity inflow ratio and the number of years when the reservoir will be fully silted up.

$V_s = 0.214\left(\frac{C}{I}\right)^{0.473}$ Where Vs= Annual mean silt deposition rate in percentage

C = Original capacity of the reservoir (61.475 MCM)

I = Annual mean inflow volume (59.784 MCM)

Based on the above formula the value of Vs comes out to be 0.217% per year.

Now, $Y_s = 467\left(\frac{C}{I}\right)^{0.473}$ where Ys represents number of years during which the silt will fill up the reservoir completely. Thus, the life of the reservoir is computed as 473 years.

Comparing both the method, the life of the reservoir (Avalanche reservoir) is taken as 473 years by Hachira Karo Method.

E. Computation of New Zero elevation level

The new zero elevation considering a span of 70 years based on the EARM method for the lower reservoir is computed as 1950 m. This value has been considered taking into account the EAC data of latest capacity survey of the year 2018. This aspect will once again be reviewed based on the latest EAC data which will be obtained once the Bathymetric survey, which is currently in progress, is completed. The computation sheet has been provided in **Table 3.18**.

Table 21 Computation of New zero Elevation Level for Upper Bhavani Reservoir.

COMPUTATION OF SEDIMENT DEPOSITION BY EMPIRICAL AREA REDUCTION METHOD - 70 Yrs										
Assumed Zero elevation=			2230.0	m	Capacity	223.7	ha-m	Area	35.5	ha
Silt Volume at NZE=			2223.7	ha-m		Ap=	1.21	K=Original area/Ap=		29.4
70-Year Silt Load =			1302.8	ha-m						
Reservoir Level (m)	Area (ha)	Capacity	Reservoir depth	Relative depth	Relative sediment area (Ap)	Sediment Area K*Ap	Sediment Volume	Accumulated sediment volume	Revised area after 70 years	Revised capacity after 70 years
		ha-m			Type -I	ha	ha-m	ha-m	ha	ha-m
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
2276.86	461.50	9705.80	76.20	1.00	0.00	0.00	0.00	2223.70	461.50	7482.10
2272.00	375.30	7741.60	71.34	0.94	1.67	49.06	119.09	2104.60	326.24	5637.00
2266.00	321.00	5650.80	65.34	0.86	1.89	55.71	314.32	1790.28	265.29	3860.52
2260.00	257.70	3894.10	59.34	0.78	1.86	54.62	331.00	1459.28	203.08	2434.82
2254.00	192.10	2554.10	53.34	0.70	1.70	50.04	313.99	1445.29	142.06	1408.81
2248.00	138.40	1562.30	47.34	0.62	1.48	43.64	281.06	864.23	94.76	698.07
2242.00	86.80	889.10	41.34	0.54	1.24	36.36	240.00	624.23	50.44	264.87
2236.00	53.30	489.20	35.34	0.46	0.98	28.80	195.48	428.75	24.50	60.45
2230.00	35.50	223.70	29.34	0.39	0.00	35.50	192.91	235.84	0.00	0.00
2224.00	15.50	70.20	23.34	0.31	0.00	15.50	153.00	82.84	0.00	0.00
2218.00	3.60	19.80	17.34	0.23	0.00	3.60	57.30	25.54	0.00	0.00
2212.00	1.70	6.10	11.34	0.15	0.00	1.70	15.90	9.64	0.00	0.00
2200.66	0.00	0.00	0.00	0.00	0.00	0.00	9.64	0.00	0.00	0.00

Table 22 Computation of New zero Elevation Level for Avalanche Reservoir.

Lower Reservoir										
COMPUTATION OF SEDIMENT DEPOSITION BY EMPIRICAL AREA REDUCTION METHOD - 70 Yrs										
Assumed Zero elevation=			1950.00	m	Capacity	118.4	ha-m	Area	22.3	ha
Silt Volume at NZE=			690.2	ha-m		Ap=	1.20	K=Original area/Ap=		18.7
70-Year Silt Load =			656.98	ha-m						
Reservoir Level(m)	Area (ha)	Capacity	Reservoir depth	Relative depth	Relative sediment area (Ap)	Sediment Area K*Ap	Sediment Volume	Accumulated sediment volume	Revised area after 70 years	Revised capacity after 70 years
		ha-m			Type-I	ha	ha-m	ha-m	ha	ha-m
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1985.79	312.10	5828.20	1985.79	1.00	0.00	0.00	0.00	690.21	312.10	5137.99
1980.00	284.00	4318.50	1980.00	1.00	0.62	11.51	33.33	656.89	272.49	3661.61
1974.00	224.80	2806.40	1974.00	0.99	0.79	14.79	78.89	577.99	210.01	2228.41
1968.00	166.90	1628.00	1968.00	0.99	0.91	17.05	95.51	482.48	149.85	1445.52
1962.00	110.60	799.70	1962.00	0.99	1.01	18.82	107.63	374.86	91.78	424.84
1956.00	51.60	327.80	1956.00	0.98	1.09	20.30	117.37	257.49	31.30	70.31
1950.00	22.30	118.40	1950.00	0.98	0.00	22.30	127.79	129.70	0.00	0.00
1944.00	10.40	23.20	1944.00	0.98	0.00	10.40	98.10	31.60	0.00	0.00
1938.00	0.10	0.00	1938.00	0.98	0.00	0.10	31.50	0.10	0.00	0.00
1936.00	0.00	0.00	1936.00	0.97	0.00	0.00	0.10	0.00	0.00	0.00
1933.07	0.00	0.00	1933.07	0.97	0.00	0.00	0.00	0.00	0.00	0.00

Power Potential & Installed Capacity

A. Type of Scheme

The Upper Bhavani Pumped Storage Project is envisaged as an On-stream Open loop type of scheme plant with a proposed generation plant capacity of 1000 MW. The project is planned for daily regulated operation considering every-day generation and pumping utilizing the water to meet the peak demand. The daily regulated operation from the upper to lower reservoir shall have a power generation time of 6.0 hours and 6.58 hours to pump back the water from the lower reservoir into the upper reservoir. The broad parameters of the Upper and Lower Reservoir are as follows

Reservoirs Parameters	Unit	Upper Reservoir	Lower Reservoir
Full Reservoir Level (FRL)	m	2276.88	1985.80
Minimum Draw Down Level (MDDL)	m	2249.42	1956.00
Gross Storage	MCM	97.04	149.57
Live Storage	MCM	79.07	134.72

The storage capacity ensures that the plant can effectively balance power generation and pumping activities throughout each day, optimizing its overall performance and contribution to the electricity grid.

B. Optimization of Installed Capacity

The installed capacity of a pumped storage project is mainly dependent on:

- The demand for peak power
- Availability of pumping energy and
- Reservoir storage and head available at the site

The State of Tamil Nadu has already commissioned several renewable projects to about 19,182.14 MW as in Sep. 2023 under the Renewable Energy Export policy. This large-scale injection of renewable energy into the grid necessitates the need and new proposals for storage of energy systems. The pumped storage projects are planned to effectively utilize the surplus energy during the daytime for meeting the energy requirement during peak time and also to balance the grid. More so, with the highly seasonal nature of solar and wind energy, storage systems to supply firm dispatch able power to the Discoms become demanding.

As the PSPs are very site specific, the optimization of the installed capacity is based on the reservoir storage and head available at the site. These plants are thus required to be operated on a daily cycle basis. For daily regulation, the requirement of live storage must remain consistent for both upper and lower reservoir, as water is recycled regularly.

The installed capacity of the Upper Bhavani project has been arrived at considering minimum 6 hours of possible generation in a day. Accordingly, a reservoir simulation study has been carried out taking into account the reservoir parameters and required operating regime to achieve a conversion efficiency higher than 75 % and the installed capacity has been fixed at 1000 MW, The total generation time shall be 6.00 hours in a day and the pumping time required to pump the water into the upper reservoirs from the lower reservoirs would be 6.58 hours. The PSP will have a cycle efficiency of 82.96%.

Daily Regulation and Required Storage

With a proposed installed capacity of 1000 MW, the Upper Bhavani Pumped Storage Project (PSP) relies on live storage volumes in both the upper and lower reservoirs to meet daily power generation regulations. These volumes are determined using the Elevation Area Capacity (EAC) curves detailed in the sedimentation report prepared by the Institute of Hydrology and Hydraulics Poondi.

Based on hydrology data from 2011 to 2021, the 90% dependable year is identified as 2016-2017. During this period, integrated reservoir operations project the water level to reach 1957.09 meters in the lower Avalanche reservoir **Annexure 1**. To ensure safety, the Minimum Drawdown Level (MDDL) for the lower reservoir is set at 1956 meters. Observations on March 1st indicate that the upper reservoir's level aligns with this lowest level in the lower reservoir.

We conducted simulations for the lean months of March, April, and May. Below are the details of our analysis:

	Case 1 : Simulated Results in the month of March			
	Hydraulic Levels	**Units**	**Upper Bhavani**	**Avalanche**
a	Full Reservoir Level (FRL)	M	2262.44	1985.80
b	Minimum Draw Down Level (MDDL)	M	2249.42	1956.00
	Parameters			
1	Generation Hours	Hrs	6.00	
2	Pumping Hours	Hrs	6.97	
3	Annual Energy in Generation	MU	2080.50	
4	Annual Energy in Pumping	MU	2657.26	
5	Cycle efficiency		78.29%	
6	Volume of Water required for 6 hours generation	MCM	8.45	
	Case 2 : Simulated Results in the month of April			

	Hydraulic Levels	Units	Upper Bhavani	Avalanche
a	Full Reservoir Level (FRL)	M	2258.081	1985.80
b	Minimum Draw Down Level (MDDL)	M	2249.420	1956.00
	Parameters			
1	Generation Hours	Hrs	6.00	
2	Pumping Hours	Hrs	7.11	
3	Annual Energy in Generation	MU	2080.50	
4	Annual Energy in Pumping	MU	2711.30	
5	Cycle efficiency		76.73%	
6	Volume of Water required for 6 hours generation	MCM	8.62	
	Case 3 : Simulated Results in the month of May			
	Hydraulic Levels	**Units**	**Upper Bhavani**	**Avalanche**
a	Full Reservoir Level (FRL)	M	2254.54	1985.80
b	Minimum Draw Down Level (MDDL)	M	2249.42	1956
	Parameters			
1	Generation Hours	Hrs	6.00	
2	Pumping Hours	Hrs	7.23	
3	Annual Energy in Generation	MU	2080.50	
4	Annual Energy in Pumping	MU	2755.80	
5	Cycle efficiency		75.80%	
6	Volume of Water required for 6 hours generation	MCM	8.77	
	Case 4 : Simulated Results Normal Scenario			
	Hydraulic Levels	**Units**	**Upper Bhavani**	**Avalanche**
a	Full Reservoir Level (FRL)	M	2276.88	1985.80
b	Minimum Draw Down Level (MDDL)	M	2249.42	1956
	Parameters			
1	Generation Hours	Hrs	6.00	
2	Pumping Hours	Hrs	6.58	
3	Annual Energy in Generation	MU	2080.50	
4	Annual Energy in Pumping	MU	2507.87	
5	Cycle efficiency		82.96%	
6	Volume of Water required for 6 hours generation	MCM	7.98	

From the above table, it may be seen that the plant is able to generate 1000MW in the normal months of water availability (i.e., 8 MCM). However, it is observed due to lowering of reservoir levels in the lean months of March to May, the head variation do not permit a full 6-hour generation with 8 MCM of water. In order for the plant to generate 1000 MW, due to varying heads in lean season, there is a need for increased water allocation of about 8.77 MCM (say 9.0 MCM) needed to meet the generation requirement.

This analysis of daily regulation and required storage for the Upper Bhavani PSP demonstrates its capacity to meet peak energy demands effectively. By assessing reservoir levels and operational metrics during critical dry months, the project is positioned to enhance grid stability and optimize water resource management in alignment with Tamil Nadu's renewable energy initiatives.

C. Installed Capacity

As described above, an installed capacity of 1000 MW is proposed for the Upper Bhavani project.

D. Number of Units

Four Units of 250 MW are proposed to be installed in an underground Power House connected to lower reservoir and an upper reservoir. The detail of selection of number of units is covered in Chapter on Electro-Mechanical works.

E. Operating Criteria of the PSP

Upper Bhavani PSP plant is not envisaged to operate round-the-clock operation, and the proposed scheme is only aimed at meeting the peak demand and to provide Grid stabilization.

The upper reservoir has a live storage of 79.07 MCM, lower reservoir has 134.72 MCM. In the generation mode during daily regulation, the plant turbine can generate 1000 MW power in 6.0 operational hours. During the pumping mode, the turbine is planned to operate in the reversible pump mode to pump back the water from the lower to the upper reservoir in 6.58 hours. The daily operation table of upper and lower reservoir for case 1 is shown in Table below.

Figure 3:25 Daily Operation Table for Upper and Lower Reservoirs

Generation – Operation Simulation (When The Lower Reservoir is near to FRL)																		
Upper Reservoir				Lower Reservoir														
	EL	Mcum	TMC			EL	Mcum	TMC										
FRL	2276.85	97.04	3.43		FRL	1985.80	149.57	5.28										
MDDL	2249.42	17.97	0.63		MDDL	1956.00	14.85	0.52										
Storage for PSP		79.07	2.79		Storage for PSP		134.72	4.76										
				Upper Reservoir						Lower Reservoir						MW Generation		
Sl.No	Time (Min)	Generation (MW)	Design Discharge (Cumecs)	Initial Level (m)	Initial Storage (Mcum)	Power Draft (Mcum)	Final Storage (Mcum)	Final Level(m)	Average Level (m)	Initial Level (m)	Initial Storage (Mcum)	Power Draft (Mcum)	Final Storage (Mcum)	Final Level(m)	Average Level (m)	Head Loss (m)	Net Head (m)	Energy Generation (Mwh)
1	10	1000	365.61	2276.85	97.04	0.22	96.82	2276.80	2276.82	1956.00	14.85	0.22	15.07	1956.13	1956.06	14.75	306.01	166.7
2	10	1000	365.85	2276.80	96.82	0.22	96.60	2276.74	2276.77	1956.13	15.07	0.22	15.29	1956.25	1956.19	14.77	305.81	166.7
3	10	1000	366.09	2276.74	96.60	0.22	96.38	2276.69	2276.71	1956.25	15.29	0.22	15.51	1956.38	1956.31	14.79	305.61	166.7
4	10	1000	366.33	2276.69	96.38	0.22	96.16	2276.63	2276.66	1956.38	15.51	0.22	15.73	1956.50	1956.44	14.81	305.41	166.7
5	10	1000	366.57	2276.63	96.16	0.22	95.94	2276.58	2276.61	1956.50	15.73	0.22	15.95	1956.63	1956.56	14.83	305.21	166.7
6	10	1000	366.81	2276.58	95.94	0.22	95.72	2276.52	2276.55	1956.63	15.95	0.22	16.17	1956.75	1956.69	14.85	305.01	166.7
7	10	1000	367.05	2276.52	95.72	0.22	95.50	2276.47	2276.50	1956.75	16.17	0.22	16.39	1956.88	1956.82	14.87	304.81	166.7
8	10	1000	367.29	2276.47	95.50	0.22	95.28	2276.42	2276.44	1956.88	16.39	0.22	16.61	1957.00	1956.94	14.89	304.61	166.7
9	10	1000	367.51	2276.42	95.28	0.22	95.06	2276.36	2276.39	1957.00	16.61	0.22	16.83	1957.11	1957.06	14.91	304.43	166.7
10	10	1000	367.72	2276.36	95.06	0.22	94.84	2276.31	2276.33	1957.11	16.83	0.22	17.05	1957.21	1957.16	14.92	304.25	166.7
11	10	1000	367.94	2276.31	94.84	0.22	94.62	2276.25	2276.28	1957.21	17.05	0.22	17.27	1957.32	1957.26	14.94	304.07	166.7
12	10	1000	368.15	2276.25	94.62	0.22	94.40	2276.20	2276.22	1957.32	17.27	0.22	17.49	1957.42	1957.37	14.96	303.90	166.7
13	10	1000	368.36	2276.20	94.40	0.22	94.18	2276.14	2276.17	1957.42	17.49	0.22	17.71	1957.52	1957.47	14.98	303.72	166.7
14	10	1000	368.58	2276.14	94.18	0.22	93.95	2276.09	2276.12	1957.52	17.71	0.22	17.93	1957.63	1957.58	14.99	303.55	166.7
15	10	1000	368.79	2276.09	93.95	0.22	93.73	2276.03	2276.06	1957.63	17.93	0.22	18.16	1957.73	1957.68	15.01	303.37	166.7
16	10	1000	369.00	2276.03	93.73	0.22	93.51	2275.98	2276.01	1957.73	18.16	0.22	18.38	1957.84	1957.78	15.03	303.19	166.7
17	10	1000	369.22	2275.98	93.51	0.22	93.29	2275.92	2275.95	1957.84	18.38	0.22	18.60	1957.94	1957.89	15.05	303.02	166.7
18	10	1000	369.43	2275.92	93.29	0.22	93.07	2275.87	2275.90	1957.94	18.60	0.22	18.82	1958.04	1957.99	15.06	302.84	166.7
19	10	1000	369.65	2275.87	93.07	0.22	92.85	2275.81	2275.84	1958.04	18.82	0.22	19.04	1958.15	1958.10	15.08	302.66	166.7
20	10	1000	369.87	2275.81	92.85	0.22	92.62	2275.76	2275.79	1958.15	19.04	0.22	19.26	1958.25	1958.20	15.10	302.49	166.7
21	10	1000	370.08	2275.76	92.62	0.22	92.40	2275.70	2275.73	1958.25	19.26	0.22	19.49	1958.36	1958.30	15.12	302.31	166.7
22	10	1000	370.30	2275.70	92.40	0.22	92.18	2275.65	2275.68	1958.36	19.49	0.22	19.71	1958.46	1958.41	15.13	302.13	166.7
23	10	1000	370.52	2275.65	92.18	0.22	91.96	2275.59	2275.62	1958.46	19.71	0.22	19.93	1958.57	1958.51	15.15	301.96	166.7
24	10	1000	370.73	2275.59	91.96	0.22	91.74	2275.54	2275.57	1958.57	19.93	0.22	20.15	1958.67	1958.62	15.17	301.78	166.7
25	10	1000	370.95	2275.54	91.74	0.22	91.51	2275.48	2275.51	1958.67	20.15	0.22	20.38	1958.78	1958.72	15.19	301.60	166.7
26	10	1000	371.17	2275.48	91.51	0.22	91.29	2275.43	2275.46	1958.78	20.38	0.22	20.60	1958.88	1958.83	15.21	301.42	166.7
27	10	1000	371.39	2275.43	91.29	0.22	91.07	2275.37	2275.40	1958.88	20.60	0.22	20.82	1958.98	1958.93	15.22	301.25	166.7
28	10	1000	371.61	2275.37	91.07	0.22	90.84	2275.32	2275.35	1958.98	20.82	0.22	21.04	1959.09	1959.04	15.24	301.07	166.7
29	10	1000	371.83	2275.32	90.84	0.22	90.62	2275.26	2275.29	1959.09	21.04	0.22	21.27	1959.19	1959.14	15.26	300.89	166.7
30	10	1000	372.05	2275.26	90.62	0.22	90.40	2275.21	2275.24	1959.19	21.27	0.22	21.49	1959.30	1959.25	15.28	300.71	166.7
31	10	1000	372.27	2275.21	90.40	0.22	90.17	2275.15	2275.18	1959.30	21.49	0.22	21.71	1959.40	1959.35	15.30	300.53	166.7
32	10	1000	372.49	2275.15	90.17	0.22	89.95	2275.10	2275.13	1959.40	21.71	0.22	21.94	1959.51	1959.46	15.31	300.36	166.7
33	10	1000	372.71	2275.10	89.95	0.22	89.73	2275.04	2275.07	1959.51	21.94	0.22	22.16	1959.61	1959.56	15.33	300.18	166.7
34	10	1000	372.94	2275.04	89.73	0.22	89.50	2274.99	2275.02	1959.61	22.16	0.22	22.38	1959.72	1959.67	15.35	300.00	166.7
35	10	1000	373.16	2274.99	89.50	0.22	89.28	2274.93	2274.96	1959.72	22.38	0.22	22.61	1959.83	1959.77	15.37	299.82	166.7
36	10	1000	373.38	2274.93	89.28	0.22	89.06	2274.88	2274.90	1959.83	22.61	0.22	22.83	1959.93	1959.88	15.39	299.64	166.7
						7.98												
	360																	6000.00
	6.00																	
	Annual Energy Generation =				6000.00	X 365 X 0.95 /1000 =			2080.50	MU				Cycle Efficiency			82.96%	
		Total Annual Energy Generation (A)						=	2080.50	MU								

Pumping – Operation Simulation (When the lower reservoir is Near MDDL)

Upper Reservoir	EL	Mcum	TMC	Lower Reservoir	EL	Mcum	TMC
FRL	2276.85	97.04	3.43	FRL	1985.80	149.57	5.28
MDDL	2249.42	17.97	0.63	MDDL	1956.00	14.85	0.52
Storage for PSP		79.07	2.79	Storage for PSP		134.72	4.76

				Lower Reservoir						Upper Reservoir						Pump input		
Sl.No	Time (Min)	Pump Capacity (MW)	Design Discharge For Pump (Cumecs)	Initial Level (m)	Initial Storage (Mcum)	Power Draft (Mcum)	Final Storage (Mcum)	Final Level(m)	Average Level (m)	Initial Level (m)	Initial Storage (Mcum)	Power Draft (Mcum)	Final Storage (Mcum)	Final Level(m)	Average Level (m)	Head Loss (m)	Net Head (m)	Energy Generation (Mwh)
1	10	1100	341.40	1959.93	22.83	0.20	22.63	1959.83	1959.88	2249.42	17.97	0.20	18.18	2249.54	2249.48	12.864	302.46	183.3
2	10	1100	341.17	1959.83	22.63	0.20	22.42	1959.74	1959.79	2249.54	18.18	0.20	18.38	2249.67	2249.61	12.846	302.67	183.3
3	10	1100	340.94	1959.74	22.42	0.20	22.22	1959.64	1959.69	2249.67	18.38	0.20	18.58	2249.79	2249.73	12.829	302.87	183.3
4	10	1100	340.71	1959.64	22.22	0.20	22.01	1959.55	1959.59	2249.79	18.58	0.20	18.79	2249.92	2249.85	12.812	303.07	183.3
5	10	1100	340.49	1959.55	22.01	0.20	21.81	1959.45	1959.50	2249.92	18.79	0.20	18.99	2250.04	2249.98	12.795	303.27	183.3
6	10	1100	340.26	1959.45	21.81	0.20	21.61	1959.35	1959.40	2250.04	18.99	0.20	19.20	2250.16	2250.10	12.778	303.48	183.3
7	10	1100	340.03	1959.35	21.61	0.20	21.40	1959.26	1959.31	2250.16	19.20	0.20	19.40	2250.29	2250.22	12.761	303.68	183.3
8	10	1100	339.81	1959.26	21.40	0.20	21.20	1959.16	1959.21	2250.29	19.40	0.20	19.61	2250.41	2250.35	12.744	303.88	183.3
9	10	1100	339.58	1959.16	21.20	0.20	20.99	1959.07	1959.11	2250.41	19.61	0.20	19.81	2250.53	2250.47	12.727	304.08	183.3
10	10	1100	339.35	1959.07	20.99	0.20	20.79	1958.97	1959.02	2250.53	19.81	0.20	20.01	2250.66	2250.59	12.710	304.29	183.3
11	10	1100	339.13	1958.97	20.79	0.20	20.59	1958.87	1958.92	2250.66	20.01	0.20	20.22	2250.78	2250.72	12.693	304.49	183.3
12	10	1100	338.91	1958.87	20.59	0.20	20.38	1958.78	1958.83	2250.78	20.22	0.20	20.42	2250.90	2250.84	12.676	304.69	183.3
13	10	1100	338.68	1958.78	20.38	0.20	20.18	1958.68	1958.73	2250.90	20.42	0.20	20.62	2251.02	2250.96	12.660	304.89	183.3
14	10	1100	338.46	1958.68	20.18	0.20	19.98	1958.59	1958.64	2251.02	20.62	0.20	20.83	2251.15	2251.09	12.643	305.09	183.3
15	10	1100	338.23	1958.59	19.98	0.20	19.77	1958.49	1958.54	2251.15	20.83	0.20	21.03	2251.27	2251.21	12.626	305.29	183.3
16	10	1100	338.01	1958.49	19.77	0.20	19.57	1958.40	1958.44	2251.27	21.03	0.20	21.23	2251.39	2251.33	12.610	305.50	183.3
17	10	1100	337.79	1958.40	19.57	0.20	19.37	1958.30	1958.35	2251.39	21.23	0.20	21.43	2251.52	2251.45	12.593	305.70	183.3
18	10	1100	337.57	1958.30	19.37	0.20	19.17	1958.21	1958.25	2251.52	21.43	0.20	21.64	2251.64	2251.58	12.576	305.90	183.3
19	10	1100	337.34	1958.21	19.17	0.20	18.96	1958.11	1958.16	2251.64	21.64	0.20	21.84	2251.76	2251.70	12.560	306.10	183.3
20	10	1100	337.12	1958.11	18.96	0.20	18.76	1958.02	1958.06	2251.76	21.84	0.20	22.04	2251.88	2251.82	12.543	306.30	183.3
21	10	1100	336.90	1958.02	18.76	0.20	18.56	1957.92	1957.97	2251.88	22.04	0.20	22.24	2252.01	2251.94	12.527	306.50	183.3
22	10	1100	336.68	1957.92	18.56	0.20	18.36	1957.83	1957.87	2252.01	22.24	0.20	22.45	2252.13	2252.07	12.511	306.70	183.3
23	10	1100	336.46	1957.83	18.36	0.20	18.16	1957.73	1957.78	2252.13	22.45	0.20	22.65	2252.25	2252.19	12.494	306.90	183.3
24	10	1100	336.24	1957.73	18.16	0.20	17.95	1957.64	1957.68	2252.25	22.65	0.20	22.85	2252.37	2252.31	12.478	307.10	183.3
25	10	1100	336.02	1957.64	17.95	0.20	17.75	1957.54	1957.59	2252.37	22.85	0.20	23.05	2252.49	2252.43	12.462	307.31	183.3
26	10	1100	335.80	1957.54	17.75	0.20	17.55	1957.45	1957.49	2252.49	23.05	0.20	23.25	2252.62	2252.55	12.445	307.51	183.3
27	10	1100	335.58	1957.45	17.55	0.20	17.35	1957.35	1957.40	2252.62	23.25	0.20	23.45	2252.74	2252.68	12.429	307.71	183.3
28	10	1100	335.37	1957.35	17.35	0.20	17.15	1957.26	1957.30	2252.74	23.45	0.20	23.65	2252.86	2252.80	12.413	307.91	183.3
29	10	1100	335.15	1957.26	17.15	0.20	16.95	1957.16	1957.21	2252.86	23.65	0.20	23.86	2252.98	2252.92	12.397	308.11	183.3
30	10	1100	334.93	1957.16	16.95	0.20	16.75	1957.07	1957.12	2252.98	23.86	0.20	24.06	2253.10	2253.04	12.381	308.31	183.3
31	10	1100	334.71	1957.07	16.75	0.20	16.54	1956.97	1957.02	2253.10	24.06	0.20	24.26	2253.22	2253.16	12.365	308.51	183.3
32	10	1100	334.48	1956.97	16.54	0.20	16.34	1956.85	1956.91	2253.22	24.26	0.20	24.46	2253.34	2253.28	12.348	308.72	183.3
33	10	1100	334.24	1956.85	16.34	0.20	16.14	1956.74	1956.80	2253.34	24.46	0.20	24.66	2253.47	2253.41	12.330	308.94	183.3
34	10	1100	334.01	1956.74	16.14	0.20	15.94	1956.62	1956.68	2253.47	24.66	0.20	24.86	2253.59	2253.53	12.313	309.16	183.3
35	10	1100	333.77	1956.62	15.94	0.20	15.74	1956.51	1956.57	2253.59	24.86	0.20	25.06	2253.71	2253.65	12.295	309.38	183.3
36	10	1100	333.54	1956.51	15.74	0.20	15.54	1956.40	1956.45	2253.71	25.06	0.20	25.26	2253.83	2253.77	12.278	309.59	183.3
37	10	1100	333.30	1956.40	15.54	0.20	15.34	1956.28	1956.34	2253.83	25.26	0.20	25.46	2253.95	2253.89	12.261	309.81	183.3
38	10	1100	333.08	1956.28	15.34	0.20	15.14	1956.17	1956.22	2253.95	25.46	0.20	25.66	2254.05	2254.00	12.244	310.02	183.3
39	10	1100	332.87	1956.17	15.14	0.20	14.94	1956.05	1956.11	2254.05	25.66	0.20	25.86	2254.14	2254.10	12.229	310.22	183.3
40	4.5	1100	332.72	1956.05	14.94	0.09	14.85	1956.00	1956.03	2254.14	25.86	0.09	25.95	2254.18	2254.16	12.218	310.35	82.5
						7.98												
	394.5 Min																	7232.5
	6.58 Hrs																	

Annual Energy Generation = 7232.5 X 365 X 0.95 /1000 = 2507.87 MU

Total Annual Energy Generation (A) = 2507.87 MU

As can be seen from the above analysis, it is observed that the reservoir volumes proposed are adequate for daily regulated generation and pumping operations.

F. Cycle Efficiency of the Scheme

The plant cycle efficiency is defined as the ratio of the annual energy generated to the annual energy required for pumping following parameters of the pump-turbine have been considered for power studies based on general experience prevailing in various PSP projects in India.

- Efficiency of Turbine = 92%
- Efficiency of Generator = 98.5%
- Efficiency of Pump = 93.5%

From the **figure 3.25**, the cycle efficiency is calculated as 2080.50 / 2507.87 * 100 = 82.96%.

G. Annual Generation and Availability of Pumping Energy

From the **figure 3.25**, it can be seen that the plant is capable of generating 2080.50 MU annually for the installed capacity in 95% of machine availability (as per CERC norms). When the energy demand is low, the plant will thus require consuming energy to pump back the waters from the lower to the upper reservoir. The annual pumping energy required is estimated to be 2507.87 MU in about 6.58 hours daily of off-peak time. This energy required for the pumping mode shall be taken from the southern grid.

3.15 Design Features of Major Components

The Upper Bhavani Pumped Storage Project aims to connect the Upper Bhavani reservoir with the Avalanche reservoir, utilizing an available head of around 291.81 m. Both reservoirs have ample live storage capacity, but the project plans to use 9 MCM of water specifically for energy generation. It will produce 1000 MW of power by drawing water from the upper reservoir during peak demand periods, while off-peak surplus energy will be used to pump water back from the lower reservoir. The project’s layout and structural designs comply with the standards of the Central Electricity Authority (CEA) and the Central Water Commission (CWC)**.**

3.16 Various Components of the Project

The proposed Upper Bhavani PSP (4x250 MW) envisages the following major civil structures:

Upper Dam (Existing):

The Existing Upper Bhavani Dam serves as the upper reservoir, featuring a dam height of 80 m and a gross storage capacity of 97.04 MCM. The full reservoir level is at EL 2276.88 m, while the minimum drawdown level stands at EL 2249.42 m. With a catchment area of 33.61 Sq. km, the net storage capacity is 79.07 MCM.

Lower dam (Existing)

The Existing Avalanche and Emerald Dam serves as the lower reservoir for the project, featuring a dam top elevation of EL 1987.32 m and a height of 57 m. It has a full reservoir level (FRL) of EL 1985.8 m and a minimum drawdown level (MDDL) of EL 1956 m. With a gross storage capacity of 149.57 million cubic meters (MCM) and a net storage capacity of 134.72 MCM, it manages a catchment area of 57.53 square kilometres.

Upper Intake/Outlet:

The intake structure, designed with a sloping bell-mouth opening, plays a crucial role in efficiently diverting water from the reservoir to the headrace tunnel for power generation. With a width of 79 meters and a height of 23.5 meters, it is built to accommodate a substantial discharge of 404.64 cubic meters per second in turbine mode. The intake's centreline is positioned at an elevation of 2232.0 meters, with the bottom set at 2227.50 meters, ensuring proper submergence for optimal water entry. To protect the intake from debris, ten trash racks, each measuring 5.5 meters in width and 23.8 meters in height, are installed to prevent obstruction of the flow. Additionally, two large gates—one service gate and one maintenance gate, each 9 meters wide and 10 meters high—provide necessary control for flow isolation and maintenance access. The hydraulic design calculation of upper intake is shown below.

Upper bhavani Upper Intake Design

1.0	**Design Inputs:**			
	Normal Operation (100%)	=	391.04	m^3/s
	Overloading Operation	=	391.04	m^3/s
	Full Reservoir Level (FRL)	=	2276.88	m
	Min. Drawdown Level (MDDL)	=	2249.42	m
	Penstock Diameter, D	=	10.50	m
	No of HRT/Penstock	=	1.00	nos
2.0	**Design Calculations:**			
2.1	**Flow Characteristics**			
	Normal Operation (100%)			
	Total design discharge	=	391.04	m^3/s
	Discharge through each Intake	=	391.04 /1	
		=	391.04	m^3/s
	Flow velocity in Intake tunnel/HRT	=	4.52	m/s
	Overloading Operation (100%)			
	Total design discharge	=	391.04	m^3/s
	Discharge through each Intake	=	391.04 /1	
		=	391.04	m^3/s
	Flow velocity in Intake tunnel/HRT	=	4.52	m/s
2.2	**Required Bellmouth Opening**			
	Cross sectional area of tunnel, A	=	0.7854 x 10.5^2	
		=	86.59	m^2
	Coefficient of contraction, C_c *(as per IS 9761:1995)*	=	0.60	
	Inclination of intake (with horizontal), Ø	=	0.00	
	Required Opening Area, A_o	=	$A/(C_c \cdot \text{Cos}\Phi)$	
		=	86.59 / (0.6 x Cos 0)	
		=	**144.32**	m^2
2.3	**Bell Mouth Shape Calculations**			
	Gate Size:			
	Deeply seated intake structure which subjected to water head of;		49.4	m
	Provided Gate Size:			
	Gate Width, w	=	10.0	m
	Gate Height, h	=	9.0	m
	Number of bays, n	=	1.0	nos
	Area provided at gate section,	=	90.0	m^2
	Bellmouth Shapes:			
a)	**Elevation (roof/bottom)**	=	$\left(\frac{x}{a_1}\right)^2 + \left(\frac{y}{b_1}\right)^2 = 1$	
	a_1 — 1.1 *h	=	1.1*9	m
		=	9.90	m
	b_1 — 0.291 *h	=	0.291 x 9	m
			2.6	m
	Height of opening, h_e	=	$2^*b_1 + h$	
		=	2.619*2 + 9	
		=	**14.24**	m
	Hence, required width of opening,	=	A_o / he	
		=	144.317 / 14.238	
		=	**10.14**	**m**

b) Plan

Sides profile = $\left(\frac{x}{a_2}\right)^2 + \left(\frac{y}{b_2}\right)^2 = 1$

a_2 0.6 *be = 0.55 x 10.137

= 5.58 m

b_2 0.2143 *be = 0.2143 x 10.137

= 2.20 m

Width of opening, = $(2*b_2 + w)$

= 14.537

= **14.5** m

width is more than require hence ok

Hence area provided = **206.977806**

hence ok

Note: The side profiles for intake have been proposed in reference to IS 9761:1995

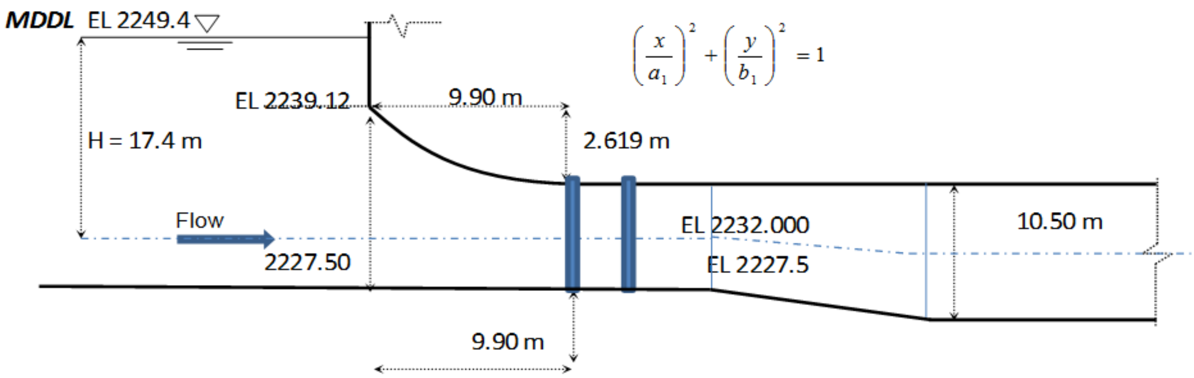
2.4 Intake Submergence:

Proposed Intake Sill level = 2227.50 m

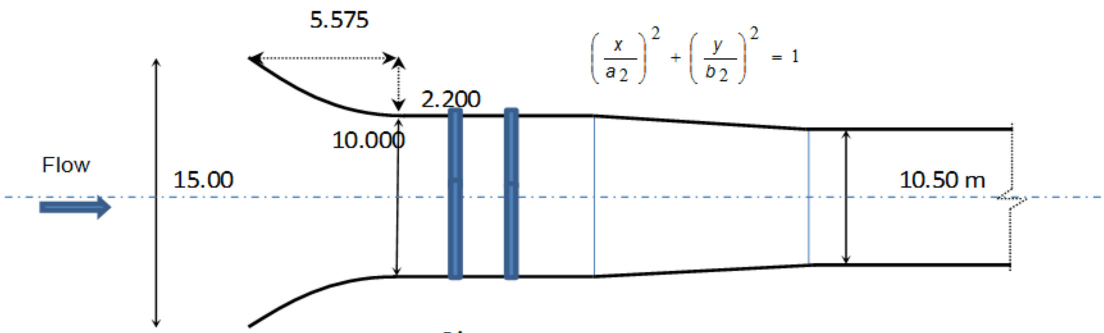
Intake approach invert level = 2227.50 m

Center Line Elevation = 2227.5 + 9/2

= 2232.000 m



Elevation



Plan

INTAKE STRUCTURE - GENERAL ARRANGEMENT **[NOT TO SCALE]**

i) As per IS 9761:1995

Submergence depth, *S*	=	2249.42 - 2232
Hence, S	=	17.42 m
Determination of Froude Number, Fr	=	$V/\sqrt{gD}$
a) Flow Area at Intake Gate	=	(10 x 9)
	=	90.00 m^2
b) Flow Area at HRT	=	86.60 m^2
Minimum area of above shall governs the submergence.		
Normal Operation (100%)		
Velocity of flow	=	391.04 / 86.6
	=	4.52 m/s
Froude No, Fr	=	4.52 / Sqrt (9.81 x 10.5)
	=	0.445
Overloading Operation (100%)		
Velocity of flow	=	391.04 / 86.6
	=	4.52 m/s
Froude No, Fr	=	4.52 / Sqrt (9.81 x 10.5)
	=	0.445
Since Froud Number 'Fr' is more than 1/3, considered as medium/small size installation		
H/D	=	0.5 + 2Fr
Normal Operation (100%)	=	0.5 + 2 x 0.445
	=	1.39
Overloading Operation (100%)	=	0.5 + 2 x 0.445
	=	1.39
Minimum invert required		
Normal Operation (100%)	=	2249.42 - 1.39 x 10.5 - 10.5/2
Required Invert level	=	2229.58 m
Overloading Operation (100%)	=	2249.42 - 1.39 x 10.5 - 10.5/2
Required Invert level	=	2229.58 m
Invert level at entrance	=	**2229.58** m

ii) As per Gordon Formula

Min. submergence over tunnel crown,	=	$S = C*V*[D/g]^{0.5}$
where,		
Gordon's Coefficient, c		1.7 ; for symmetrical approach
		2.3 ; for asymmetrical approach
Normal Operation (100%)		
considering asymmetric approach, s	=	2.3 x 4.52 x (10.5 / 9.81)^0.5
	=	10.76 m
Minimum invert required	=	2249.42 - 10.76 - 10.5
	=	2228.16 m
Overloading Operation (100%)		
considering asymmetric approach, s	=	2.3 x 4.52 x (10.5 / 9.81)^0.5
	=	10.76 m
Minimum invert required	=	2249.42 - 10.76 - 10.5
	=	2228.16 m
Invert level at entrance	=	2228.16
Additional Margin	=	0.50 m
Hence, sill level is adequately provided at elevation;	=	2227.50 m

2.5 Trash Rack Layout Arrangement

Intake approach floor level	=	2227.5 m	
Permissible velocity - Mannual Cleaning	=	0.75 m/s	
Net Trash rack area	=	65%	
Clogging % (for design)	=	30%	
Flow depth at MDDL	=	2249.42 - 2227.5	
	=	21.92 m	
Provide 10 bays of 5.5 m width			
Width provided	=	55.00 m	
Gross area of flow	=	00000000001 x 55	
	=	1205.60 m^2	
Net area of flow	=	783.64 m^2	
Net area in clogged condition	=	783.640000000003 x (1 - 0.3)	
	=	548.55 m^2	
Check for velocity			
Flow velocity	=	Discharge / Area of flow	
Velocity on gross area	=	391.04 / 1205.6	
	=	0.32 m/s	
Velocity on net area	=	0.50 m/s	
Velocity on net area in clogged condition	=	0.71 m/s	
	<	0.75 m/s	***OK***
Trash rack Dimensions			
No of bays	=	10.00	
No of intermediate piers	=	9.00	
Width of Intermediate piers	=	2.00 m	
No. of side pier	=	2.00 m	
Width of side pier	=	3.00 m	
Clear width	=	55.00 m	
Total width provided	=	**79.00** m	

3.0 Reference:

1. IS 9761:1995 (Reaffirmed 2000), "Hydropower Intakes – Criteria for hydraulic design".
2. IS 11388:1995 (Reaffirmed 2000), "Recommendation for design of Trash Racks for Intakes".
3. IS 11570:1985, "Criteria for Hydraulic Design of Irrigation Intake Structures".

Headrace Tunnel:

The headrace tunnel will be of circular shaped and approx. 5.38 km long. It is proposed to have a concrete lined section of HRT. The finished diameter of HRT has been worked out based on velocity criteria initially. Subsequently, economic dia studies have been carried out considering various diameters to determine the most optimum diameter for the headrace tunnel. Based on preliminary optimization studies carried out, a finished diameter of 10.5 m has been adopted for the HRT.

Longitudinal section along the HRT indicating the ground profile and suggested tunnel grade is shown in and typical cross section details are shown in Drawings Volume. The tunnel alignment has been fixed considering a minimum cover of 3 times dia of tunnel i.e. about 30 m both in lateral as well as vertical direction.

Keeping in view the preliminary geological data, majority of the tunnel alignment will pass through very good to good rock mass, as per the preliminary assessment. Considering the type of rock mass, preliminary supports in the form of shotcrete and rock bolts are envisaged during construction. However, the entire tunnel design including supports will be further reviewed during DPR stage based on detailed investigations and lab test results.

Economical Diameter of HRT

Design Input:

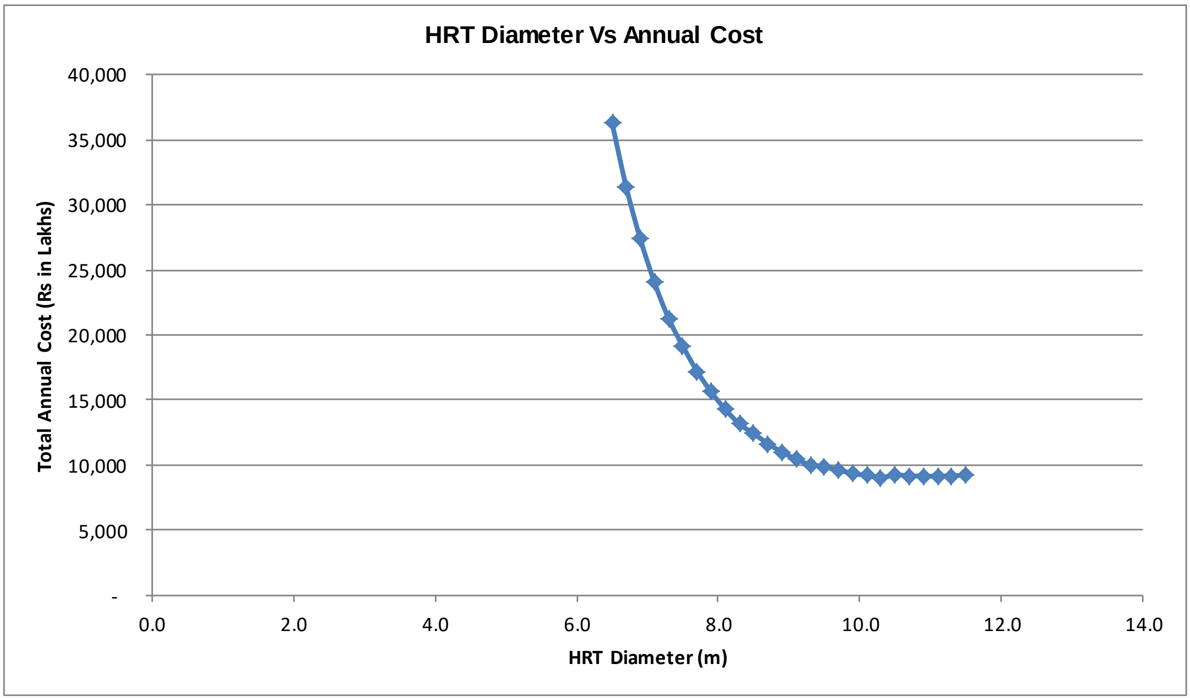
Design Discharge =	404.64	m^3/s
Overall Efficiency =	0.911	
Plant load Factor =	0.25	
Levellised Tariff =	4.57	Rs
Interest and Maintenance =	0.125	

Economical Diameter:

Diameter (m)	Total Cost (Rs)	Annual Charges (Rs)	Head Loss (m)	Net Annual Energy Loss @ Specified PLF (MU)	Annual Cost of Energy Loss (Rs)	Total Cost Annual (Rs)-Lacs
9.0	4320347001	540,043,375	15.66	124.04	566,856,882	11,069.00
9.1	4397560558	549,695,070	14.77	116.96	534,520,353	10,842.15
9.2	4475527623	559,440,953	13.93	110.36	504,353,555	10,637.95
9.3	4554214883	569,276,860	13.16	104.20	476,189,585	10,454.66
9.4	4633655652	579,206,956	12.43	98.44	449,875,982	10,290.83
9.5	4713833272	589,229,159	11.75	93.06	425,273,343	10,145.03
9.6	4794731088	599,341,386	11.11	88.02	402,254,084	10,015.95
9.7	4921277118	615,159,640	10.52	83.30	380,701,323	9,958.61
9.8	5003648637	625,456,080	9.96	78.89	360,507,893	9,859.64
9.9	5086773664	635,846,708	9.44	74.74	341,575,438	9,774.22
10.0	5170618886	646,327,361	8.95	70.86	323,813,615	9,701.41
10.1	5255217617	656,902,202	8.49	67.21	307,139,368	9,640.42
10.2	5340536543	667,567,068	8.05	63.78	291,476,275	9,590.43
10.3	5426608977	678,326,122	7.65	60.56	276,753,961	9,550.80
10.4	5513418262	689,177,283	7.26	57.53	262,907,567	9,520.85
10.5	5600947744	700,118,468	6.90	54.68	249,877,269	9,499.96
10.6	5704860061	713,107,508	6.56	51.99	237,607,847	9,507.15
10.7	5793863245	724,232,906	6.24	49.46	226,048,289	9,502.81
10.8	5883619938	735,452,492	5.94	47.08	215,151,435	9,506.04
10.9	5974096826	746,762,103	5.66	44.83	204,873,655	9,516.36
11.0	6065327222	758,165,903	5.39	42.71	195,174,557	9,533.40
11.1	6157277813	769,659,727	5.14	40.70	186,016,717	9,556.76
11.2	6249981913	781,247,739	4.90	38.81	177,365,440	9,586.13
11.3	6343406208	792,925,776	4.67	37.02	169,188,537	9,621.14
11.4	6437584010	804,698,001	4.46	35.33	161,456,123	9,661.54
11.5	6577393371	822,174,171	4.26	33.73	154,140,437	9,763.15
					Minimum	9,499.96

Economical Diameter, D_{eco} = **10.50** **m**

Velocity corresponding to economical diameter, V = **4.43** **m/s**



Surge Shaft:

The surge shaft is of restricted orifice type and circular in shape with 22.5 m finished diameter & 95 m high and will be concrete lined for its entire height. Hydraulic design of surge shaft has been carried out as per IS 7396 (Part 1): Criteria for Hydraulic Design of Surge Tanks - Simple Restricted Orifice and Differential Surge Tanks. Based on preliminary analysis, an orifice diameter of 5.1 m has been adopted for the project and water levels in the surge shaft during maximum upsurge and down surge conditions have been estimated based on transient analysis in WHAMO.

Thomas' criteria has been considered for calculating the size of the Surge shaft, for orifice, Calame and Gordon's criteria is satisfied for the size of the orifice.

Based on the preliminary geological data, majority of the shaft alignment will pass through very good to good rockmass, as per the preliminary assessment. Considering the type of rock mass, preliminary supports in the form of shotcrete and rock bolts are envisaged during DPR stage. However, the entire tunnel design including support will be further reviewed during DPR stage based on detailed investigations and lab test results.

Size of Surge Shaft as per Thoma Criteria

IS 7396 Part 1 (1985):

-

Design Discharge with overload =	391.04	m^3/s
Length of HRT =	5382.00	m
Equivalent Diameter of Tunnel =	10.50	m
Cross Sectional Area of Tunnel, A_t =	86.55	sq.m.

(From Equivalent diameter)		
Velocity in the Tunnel =	4.52	m/s
Total head loss, h_L =	6.83	m
Net Head	284.25	m
Coefficient of Hydraulic Losses, β =	0.33	
Thoma area of Surge Tank A_{th} =	249.75	m^2
Type of Surge Shaft =	Restricted	
Factor of Safety =	1.60	
A_{smin} =	399.60	m^2
Φmin =	22.56	m

Surge Tank Dia Provided	**22.50**	**m**
Surge Tank Area Provided	**397.61**	**m^2**

Dimensions of Orifice:

Diameter of Orifice	5.100	m
Orifice Area Ao	20.43	m^2
(H.R.T to SS) C_d =	0.70	
(SS to H.R.T.) C_d =	0.80	
Loss Coefficient (H.R.T to SS) =	2.04	
Loss Coefficient (SS to H.R.T.) =	1.56	
h_{or}	38.11	m
Z*	49.37	m
$Z^*/\sqrt{2} + h_f/4$	36.62	m
$Z^*/\sqrt{2} + 3\,h_f/4$	40.03	m
	38.33	
OK		

Pressure Shaft:

The pressure shaft will be of circular shape and a total length of about 623 m (which comprises 320m long vertical shaft and 303m long horizontal shaft). Considering the high head of the scheme, long-term stability and O & M aspects, pressure shaft will be provided with steel liner to withstand the internal water pressure and suitably backfilled with concrete. Economic studies have been carried out considering various diameters to determine the most optimum diameter for the pressure shaft. Based on preliminary analysis, a finished diameter of 6.6 m is adopted.

Based on the preliminary geological data, majority of the shaft alignment will pass through very good to good rock mass, Considering the type of rock mass, preliminary supports in the form of shotcrete and rock bolts are envisaged during DPR stage. However, the entire design including supports will be further reviewed during DPR stage based on detailed investigations and lab test results.

Powerhouse Complex:

Powerhouse Complex comprises of one underground cavern for Powerhouse and another underground cavern for Transformers & GIS.

The size of Powerhouse Cavern is 144m (L) x 24m (B) x 47.20m (H) and of Transformer Cavern is 144m (L) x18.5m (B) x30m (H). The clear distance between caverns is 50m. The minimum rock cover above the cavern is of the order of 250m.

Main approach to Powerhouse cavern & to transformer cavern is through 1836 M long, 8m diameter D-shaped main access tunnel-MAT. Powerhouse excavation shall be done in phased manner and to facilitate the excavation of the powerhouse complex, an adit of size 6m D-shaped, to crown of caverns and adits to bottom of penstock and bottom of surge shaft been planned, the same have been shown on the layout drawing.

For supporting EOT crane in Powerhouse & Transformer Cavern, RCC columns have been envisaged. A clearance of 500mm has been provided between the column edge and excavated rock surface to take care of convergence of the walls.

Auxiliary Rooms shall be located on different floors provided on the service bay side of machine hall cavern.

As per the preliminary geological data, Powerhouse complex is situated in very good to good kind of rock mass, and prima facie, it seems that there will not be any major geological problem. Considering the very good to good rook mass conditions, preliminary supports in the form of shotcrete (75mm in cavern & 50mm in tunnels), rock-bolts of suitable length & ribs are envisaged.

However, the entire design including primary & final support system will be further reviewed during DPR stage based on detailed geological and geotechnical investigations.

The plan and typical cross section of powerhouse are indicated in drawings.

Valve House

A Surface Valve House is envisaged to house 2 Butterfly Valves of adequate size which shall match with the inlet diameter of pressure shaft. The size of the Valve House is 45m (L) x15m (W) x26m (H). Oil Pressure Units and valve control panel, Electrical panels, 220V DC Battery with Charger will be accommodated in the valve house.

Down Surge Shaft:

One underground down surge shaft having 22.5 m dia with top EL. 2015.80m has been proposed at the downstream of powerhouse in the tail race tunnel. It is concrete-lined for its entire height. The shaft is expected to pass through very good to good rockmass. The cover above the surge shaft is 122.0m with adequate lateral rock participation. Detail analysis will be carried out at DPR stage for realistic assessment of rockmass condition and to decipher actual support system.

Tailrace Tunnel

Water after power generation is discharged into the lower reservoir through a tailrace tunnel of about 1590 m long. It will be of circular shaped and proposed to provide concrete lining for the entire length of tunnel. A finished diameter of 10.50 m is adopted for the tailrace tunnel, similar to HRT.

The longitudinal section of along the tailrace tunnel indicating the ground profile and Suggested tunnel grade is shown in and cross section details are shown in Drawing Volume.

Based on the preliminary geological data, majority of the tunnel alignment will pass through very good to good rockmass with occasional patches of fair category rockmass as per the preliminary assessment the tunnel. Considering the type of rock mass, preliminary supports in the form of shotcrete and rock bolts are envisaged. However, the entire tunnel design including support will be further reviewed during DPR stage based on detailed investigations and lab test results.

Lower Intake

The lower intake is proposed to draw water during pumping mode to pump water from lower reservoir to upper reservoir. The intake structure is of a sloping type with a bell-mouth opening. The structure comprises 1 intake, measuring 79 m (W) x 21.6.0 m (H), including piers. The intake centreline elevation is EL 1940.50 m, with a bottom elevation of EL 1936 m, designed to accommodate a discharge of 404.64 Cumec for intake in turbine mode. The structure includes 10 trash racks, each measuring 5.5 m (W) x 21.93 m (H). Additionally, there are 1 service gates and 1 maintenance gate, each 9 m (W) x 10 m (H). However, the entire tunnel design including support will be further reviewed during DPR stage based on detailed investigations and lab test results.

Upper bhavani Lower Intake Design

1.0 Design Inputs:

Normal Operation (100%)	=	328.60 m^3/s
Overloading Operation (110%)	=	328.60 m^3/s
Full Reservoir Level (FRL)	=	1985.80 m
Min. Drawdown Level (MDDL)	=	1956.00 m
Penstock Diameter, D	=	10.50 m
No of HRT/Penstock	=	1.00 nos

2.0 Design Calculations:

2.1 Flow Characteristics

Normal Operation (100%)

Total design discharge	=	328.60 m^3/s
Discharge through each Intake	=	328.6 /1
	=	328.60 m^3/s
Flow velocity in Intake tunnel/HRT	=	3.79 m/s

Overloading Operation (110%)

Total design discharge	=	328.60 m^3/s
Discharge through each Intake	=	328.6 /1
	=	328.60 m^3/s
Flow velocity in Intake tunnel/HRT	=	3.79 m/s

2.2 Required Bellmouth Opening

Cross sectional area of tunnel, A	=	0.7854 x 10.5^2
	=	86.59 m^2
Coefficient of contraction, C_c *(as per IS 9761:1995)*	=	0.60
Inclination of intake (with horizontal), Ø	=	0.00
Required Opening Area, A_o	=	$A/(C_c \cdot \cos\Phi)$
	=	86.59 / (0.6 x Cos 0)
	=	**144.32** m^2

2.3 Bell Mouth Shape Calculations

Gate Size:

Deeply seated intake structure which subjected to water head of; 49.8 m

Provided Gate Size:

Gate Width, w	=	10.0 m
Gate Height, h	=	9.0 m
Number of bays, n	=	1.0 nos
Area provided at gate section,	=	90.0 m^2

Bellmouth Shapes:

a) Elevation (roof/bottom) = $\left(\frac{x}{a_1}\right)^2 + \left(\frac{y}{b_1}\right)^2 = 1$

a_1	1.1 *h	=	1.1*9 m
		=	9.90 m
b_1	0.291 *h	=	0.291 x 9 m
			2.6 m

Height of opening, h_e	=	$2*b_1 + h$
	=	2.619*2 + 9
	=	**14.24** m
Hence, required width of opening,	=	A_o / he
	=	144.317 / 14.238
	=	**10.14 m**

b) Plan

Sides profile = $\left(\frac{x}{a_2}\right)^2 + \left(\frac{y}{b_2}\right)^2 = 1$

a_2 0.6 *be = 0.55 x 10.137
= 5.58 m

b_2 0.2143 *be = 0.2143 x 10.137
= 2.20 m

Width of opening, = $(2{*}b_2 + w)$
= 14.537

= **14.5** m

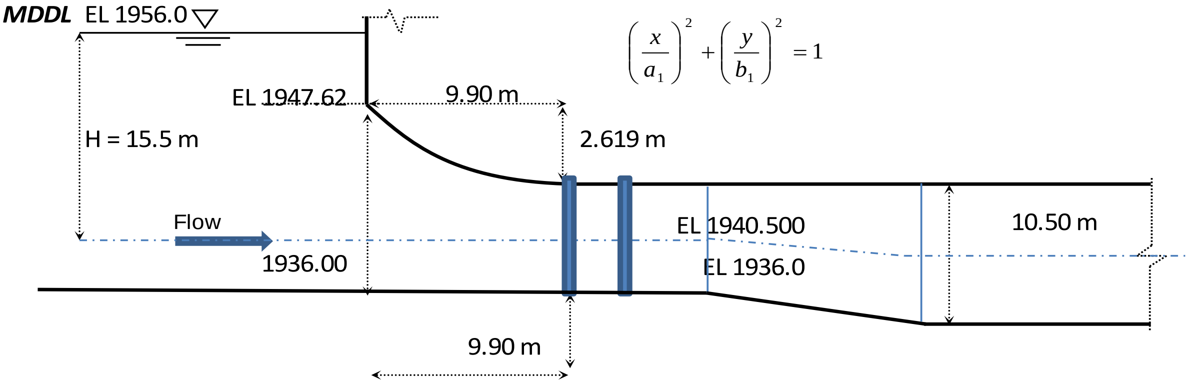
width is more than require hence ok

Hence area provided = **206.977806**
hence ok

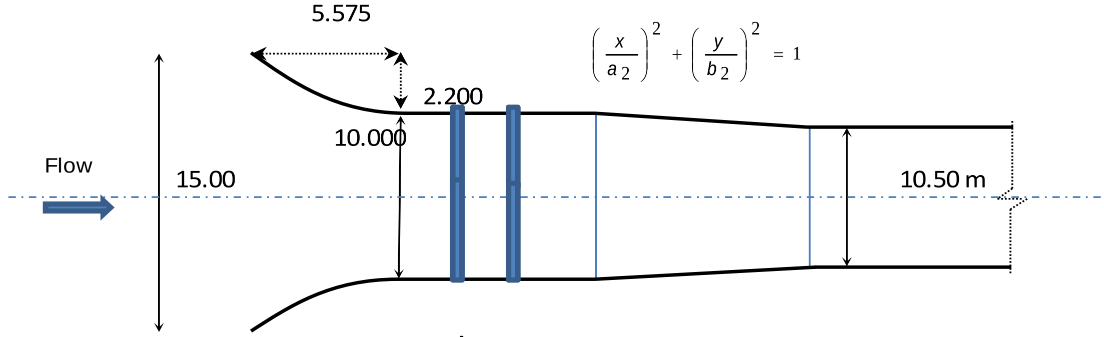
Note: The side profiles for intake have been proposed in reference to IS 9761:1995

2.4 Intake Submergence:

Proposed Intake Sill level	=	1936.00 m
Intake approach invert level	=	1936.00 m
Center Line Elevation	=	1936 + 9/2
	=	1940.500 m



Elevation



Plan

INTAKE STRUCTURE - GENERAL ARRANGEMENT **[NOT TO SCALE]**

i) As per IS 9761:1995

Submergence depth, *S*	=	1956 - 1940.5
Hence, S	=	15.50 m
Determination of Froude Number, Fr	=	$V/\sqrt{gD}$
a) Flow Area at Intake Gate	=	(10 x 9)
	=	90.00 m^2
b) Flow Area at HRT	=	86.60 m^2
Minimum area of above shall governs the submergence.		
Normal Operation (100%)		
Velocity of flow	=	328.6 / 86.6
	=	3.79 m/s
Froude No, Fr	=	3.79 / Sqrt (9.81 x 10.5)
	=	0.373
Overloading Operation (110%)		
Velocity of flow	=	328.6 / 86.6
	=	3.79 m/s
Froude No, Fr	=	3.79 / Sqrt (9.81 x 10.5)
	=	0.373
Since Froud Number 'Fr' is more than 1/3, considered as medium/small size installation		
H/D	=	0.5 + 2Fr
Normal Operation (100%)	=	0.5 + 2 x 0.373
	=	1.25
Overloading Operation (110%)	=	0.5 + 2 x 0.373
	=	1.25
Minimum invert required		
Normal Operation (100%)	=	1956 - 1.25 x 10.5 - 10.5/2
Required Invert level	=	1937.63 m
Overloading Operation (110%)	=	1956 - 1.25 x 10.5 - 10.5/2
Required Invert level	=	1937.63 m
Invert level at entrance	=	**1937.63** m

ii) As per Gordon Formula

Min. submergence over tunnel crown,	=	$S = C*V*[D/g]^{0.5}$
where,		
Gordon's Coefficient, c		1.7 ; for symmetrical approach
		2.3 ; for asymmetrical approach
Normal Operation (100%)		
considering asymmetric approach, s	=	2.3 x 3.79 x (10.5 / 9.81)^0.5
	=	9.02 m
Minimum invert required	=	1956 - 9.02 - 10.5
	=	1936.48 m
Overloading Operation (110%)		
considering asymmetric approach, s	=	2.3 x 3.79 x (10.5 / 9.81)^0.5
	=	9.02 m
Minimum invert required	=	1956 - 9.02 - 10.5
	=	1936.48 m
Invert level at entrance	=	1936.48
Additional Margin	=	0.50 m
Hence, sill level is adequately provided at elevation;	=	1936.00 m

2.5 Trash Rack Layout Arrangement

Intake approach floor level	=	1936.0 m
Permissible velocity - Mannual Cleaning	=	0.75 m/s
Net Trash rack area	=	65%
Clogging % (for design)	=	30%
Flow depth at MDDL	=	1956 - 1936
	=	20.00 m
Provide 10 bays of 5.5 m width		
Width provided	=	55.00 m
Gross area of flow	=	20 x 55
	=	1100.00 m^2
Net area of flow	=	715.00 m^2
Net area in clogged condition	=	715 x (1 - 0.3)
	=	500.50 m^2
Check for velocity		
Flow velocity	=	Discharge / Area of flow
Velocity on gross area	=	328.6 / 1100
	=	0.30 m/s
Velocity on net area	=	0.46 m/s
Velocity on net area in clogged condition	=	0.66 m/s
	<	0.75 m/s ***OK***
Trash rack Dimensions		
No of bays	=	10.00
No of intermediate piers	=	9.00
Width of Intermediate piers	=	2.00 m
No. of side pier	=	2.00 m
Width of side pier	=	3.00 m
Clear width	=	55.00 m
Total width provided	=	**79.00** m

3.0 Reference:

1. IS 9761:1995 (Reaffirmed 2000), "Hydropower Intakes – Criteria for hydraulic design".
2. IS 11388:1995 (Reaffirmed 2000), "Recommendation for design of Trash Racks for Intakes".
3. IS 11570:1985, "Criteria for Hydraulic Design of Irrigation Intake Structures".

Pothead Yard:

A Surface Pothead Yard of size 72m (L) x 35m (W) has been envisaged at the EL of 2045 m which connected with already existing road going to upper reservoir. Connection between pothead yard to cavern has been envisaged vide 6m diameter D-shaped inclined cable shaft. The length of the same is approx. 1118m.

Approach Roads:

The following new roads have been proposed to approach various components of the project:

Approach to Lower Stockyard area:

Approach Road to Stockyard (Near Main Access Tunnel), a new road of about 0.6 km m length would be required to be constructed.

Approach to Contractor facilities:

In order to access MAT, Fabrication yard, B&M , Crusher, Muck disposal and Contractor facility, a new road of about 2.5 km length would be required to be constructed.

Approach to Lower Intake area:

In order to access lower intake area location, a new road of about 0.95 km length would be required to be constructed.

Approach to Upper Intake area:

A new road of about 4.1 km length would be required to be constructed to reach the lower Intake site. Thus, a total of about 8.1 km long road would need to be constructed to approach all locations of the project.

Proposed Road R-5 to Surge Shaft

A new road of approximately 2.9 km will be constructed to access the surge shaft.

Proposed Road R-6 to Valve Houses

A road of about 0.85 km will be built to provide access to the valve houses.

Proposed Road R-7 to CAT

A road of about 0.2 km will be built to provide access to the valve houses.

3.17 Hydro-Mechanical Equipment's

Gate components

A gate consists basically of three elements: leaf, embedded parts and operating device. The leaf is movable element that serves as bulkhead to the water passage and consists of skin plate and girders. The shield plate directly responsible for the water thrust is called the skin plate. The seals, components responsible for the water tightness, consist generally of rubber seals screwed on the skin plate. On the gate leaf are also attached the support elements (wheels/bearing plates, guide rollers, lifting brackets and so on).

The embedded parts are the components embedded onto the concrete, which serve to guide and house the leaf, to redistribute to the concrete the forces acting on the gate, acting also as protection to the concrete edges and support element for seal. The basic components of the embedded parts are sill beam, wheel or slide tracks, side guides, counter guides, lintel, seal seats and eventually, slot lining. The operating device is directly responsible for opening and closing of the gate. The main requirement of a gate operating device is to develop a large operating force with low power supply.

Trash Rack, Gates & its Components

The Gates are provided to regulate or restrict the flow of water through the conductor system. The Gates can be further divided into three basic components:

a) ***Gate leaf:*** The gate leaf is movable element that serves as bulkhead to the water passage and consists of skin plate, horizontal & vertical girders. The shield plate directly responsible for the water thrust is called the skin plate. The seals, components responsible for the water tightness, consist generally of rubber seals screwed on the skin plate. The gate leaf is also provided with the support elements (wheels/bearing plates, guide rollers/shoes, lifting brackets and so on).

b) ***Embedded parts:*** The embedded parts are the components embedded onto the concrete, which serve to guide and house the leaf, to redistribute the gate load to the concrete. Embedded parts also act as protection to the concrete edges and support element for seal. The basic components of the embedded parts are sill beam, wheel girder or slide tracks, side guides, counter guides, lintel, seal seats and eventually, slot lining.

c) ***Operating system:*** The operating device is directly responsible for opening and closing of the gate. The main requirement of a gate operating device is to develop a large operating force with low power input.

Upper Intake - Trash Rack

The 10 no. bays are provided with trash racks in an inclined groove on the upstream of the intake to prevent the entry of extraneous material into the powerhouse. These will be of fabricated steel construction consisting of trash bars, having clear opening between the trash bars, the opening will be confirmed by the turbine supplier. The trash bars are supported on horizontal girders. These horizontal girders, in turn, will be supported on end girders to bear against the vertical girders embedded in the concrete. Trash racks will be split into panels for easy handling. Each panel will have two lifting points. The trash rack panels shall be designed as per the provisions of IS: 11388 – 2012.

The salient features of the trash racks are given in **Table below:**

Parameter	Unit	Particulars
Trash Rack Bay Size	M	5.5 (w) x 23.8 (h)
Number of bays	No.	10
Size of one individual panel	M	5.5 (w) x 2.0 (h)

Parameter	Unit	Particulars
No. of individual Panel per bay	No.	12
Total Number of panels	No.	120 Nos.
Sill elevation	M	2227.50 m
FRL	M	2276.88 m
Cleaning of Trash racks		Manual

Upper Intake – Service Gate

A single vertical fixed wheel service gate is provided to restrict the flow of water into the HRT. The gate is provided with skin plate & sealing arrangement at the downstream side with respect to the gate groove. The clear opening size of the Intake service gates is 10.0 m (W) x 9.0 m (H). The gate will be operated by means of rope drum hoist. The tentative gate hoist capacity will be of 225 mt. The sill beam top of the gates is located at EL 2227.50 m. The gates shall be designed for the head corresponding to FRL of EL 2276.88 m. To prevent leakage, a Hollow music note type side rubber seal shall be attached with the skin plate and flat wedge type rubber seal at the bottom. The double stem rubber seal shall be attached at the top of the skin plate to prevent the leakage. The structural design of the gate & its embedded parts including selection of material for various components of the gate shall be in accordance with provision of IS 4622:2003.

The salient features of the Upper Intake are given in **Table below:**

Parameter	Unit	Particulars
Clear opening size	m	10.0 (w) x 9.0 (h)
Type of gate		Fixed wheel gate
Number of bays	no	1
Number of gates	no	1
Sill elevation	m	2227.50
FRL	m	2276.88
Design head	m	49.38
Type of hoist		Rope Drum Hoist
Operating condition		Unbalance Head

Upper Intake –Stoplog Gate

One number stoplog gate is proposed to cater for the maintenance, inspection and report of Upper reservoir Intake service gates. The size of clear opening of the gate is 10.0 m (W) x 9.0 m (H). Gate will have downstream skin plate and downstream sealing. The entire height of the Gate is divided into 09 numbers of interchangeable individual elements of identical size. Gate will be designed for head corresponding to FRL of EL 2276.88 m. The gate is designed lowering in flowing water and lifting under balanced head condition. Gate will be operated with the help of a Gantry Crane of adequate capacity (tentative capacity–30 t). When not in use, the gate will be in open position and stacked at the deck level.

The salient features of the Spillway Stoplog are given in **Table below:**

Parameter	Unit	Particulars
Clear opening size	m	10.0 (w) x 9.0 (h)
Type of gate		Slide Gate
Number of vent & gate	No.	1
Number of Segments	No.	9
Sill elevation	m	2227.50
FRL	m	2276.88
Design head	m	49.38
Type of hoist		Gantry Crane
Operating condition		Balance Head

Lower Intake - Trash Rack

The 10 no. bays are provided with trash racks in an inclined groove on the upstream of the intake to prevent the entry of extraneous material into the powerhouse. These will be of fabricated steel construction consisting of trash bars, having clear opening between the trash bars, the opening will be confirmed by the turbine supplier. The trash bars are supported on horizontal girders. These horizontal girders, in turn, will be supported on end girders to bear against the vertical girders embedded in the concrete. Trash racks will be split into panels for easy handling. Each panel will have two lifting points. The trash rack panels shall be designed as per the provisions of IS: 11388 – 2012.

The salient features of the trash racks are given in **Table below.**

Parameter	Unit	Particulars
Trash Rack Panel Size	m	5.5 (w) x 21.93 (h)
Number of bays	no	10
Size of one individual panel	m	5.5 (w) x 2.0 (h)
Total Number of panels	no	110 Nos.
Sill elevation	m	1936.00 m
FRL	m	1985.80 m
Cleaning of Trash racks		Manual

Lower Intake – Service Gate

A single vertical fixed wheel service gate is provided to restrict the flow of water into the HRT. The gate is provided with skin plate & sealing arrangement at the downstream side with respect to the gate groove. The clear opening size of the Intake service gates is 10.0 m (W) x 9.0 m (H). The gate will be operated by means of rope drum hoist. The tentative gate hoist capacity will be of 225 mt. The sill beam top of the gates is located at EL 1936.0 m. The gates shall be designed for the head corresponding to FRL of EL 1985.80 m. To prevent leakage, a Hollow music note type side rubber seal shall be attached with the skin plate and flat wedge type rubber seal at the bottom. The double stem rubber seal shall be attached at the top of the skin plate to prevent the leakage. The structural design of the gate & its embedded parts including selection of material for various components of the gate shall be in accordance with provision of IS 4622:2003.

The salient features of the Upper Intake are given in **Table below:**

Parameter	Unit	Particulars
Clear opening size	m	10.0 (w) x 9.0 (h)
Type of gate		Fixed wheel gate
Number of vent	no	1
Number of gate	no	1
Sill elevation	m	1936.0
FRL	m	1985.80
Design head	m	49.80
Type of hoist		Rope Drum Hoist
Operating condition		Unbalance Head

Lower Intake – Stoplog Gate

One number stoplog gate is proposed to cater for the maintenance, inspection and report of Upper reservoir Intake service gates. The size of clear opening of the gate is 10.0 m (W) x 9.0 m (H).

Gate will have downstream skin plate and downstream sealing. The entire height of the Gate is divided into 09 numbers of interchangeable individual elements of identical size. Gate will be designed for head corresponding to FRL of EL 1985.8 m. The gate is designed lowering in flowing water and lifting under balanced head condition. Gate will be operated with the help of a Gantry Crane of adequate capacity (tentative capacity – 30 t). When not in use, the gate will be in open position and stacked at the deck level.

The salient features of the Spillway Stoplog are given in **Table below:**

Parameter	Unit	Particulars
Clear opening size	m	10.0 (w) x 9.0 (h)
Type of gate		Fixed wheel gate
Number of vent & gate	No.	1
Number of Segments	No.	9
Sill elevation	m	1936.0
FRL	m	1985.80
Design head	m	49.80
Type of hoist		Gantry Crane

Parameter	Unit	Particulars
Operating condition		Balance Head

Draft Tube Gate

Proposed four number of bonnet type draft tubes gate are proposed for each turbine. The clear opening for draft tube gate shall be of size 7.2 (W) x 4.7 (H) m. The gates shall be used for the maintenance of the turbine units by isolating the powerhouse from the individual tailrace or to restrict the water from Lower reservoir. The gate will travel in gate groove of enclosed bonnet type which will be embedded in concrete piers to facilitate the repair and maintenance of the individual draft tubes and to isolate the unit for repair and maintenance. The gate will be operated with the help of 02 no. inverted telescopic hydraulic jacks which will be provided with mechanical dog latch to prevent error closure of gate in event of hydraulic failure.

The sill of the gates is located at EL 1897.56 m and will be designed for a head of 38.44 m corresponding to FRL of Lower Intake. Gate shall be capable of self-closing, i.e. closed by gravity under its own weight. The structural design of the gate & its embedded parts including selection of material for various components of the gate shall be in accordance with provision of IS 4622:2003

The salient features of the Draft Tube gate are given in **Table below:**

Parameter	Unit	Particulars
Clear opening size	m	7.2 (w) x 4.7 (h)
Type of gate		Fixed wheel Type
Number of Gate	no	4
Sill elevation	m	1897.56
FRL	m	1936.0
Design head (max)	m	38.44 m
Type of hoist		Hydraulic Hoist
Operating condition		Unbalanced head

Penstock

The steel liner take-off from the downstream side of the upper Surge shaft, having following lengths

a. ***Upper Horizontal*** - 02 nos. parallel upper horizontal of individual length of 229.45 m each & Diameter 6.6 m.

b. ***Vertical Pressure Shaft*** - 02 Nos. Vertical Pressure shaft of depth 282.5 m each & diameter 6.6m with vertical bends of bend radius 20 m at each end of pressure shaft.

c. ***Lower Horizontal*** - 02 Nos. lower Horizontal of lengths of 65.15 m & diameter 6.6 m are provided upstream of bifurcation.

d. ***Bifurcation*** – 02 Nos. bifurcations reducing the diameter from 6.6 to 4.4 m are provided. An internal sickle & ring girder type of reinforcement has been provided for even distribution of stresses in the three conduits at the trifurcation point.

e. ***Unit Penstock -*** 04 Nos. parallel unit penstocks of 4.4 m diameter & individual length of 63.74 m shall be provided to convey flow to the individual spiral-casings.

Depending upon the head to be resisted, thickness of the plates comes range 22 - 32 mm (tentative). Carbon steel conforming to ASTM 517 Gr F steel plates has been selected for the steel liner & penstock. As per the requirement of the grade of the steel pre & post heating up to the required temperature for welding joints will be required for all thickens of steel liner.

Length of each ferrule has been restricted to 2.5mtr for ease in handling.

QAP plan – Followings will be recommended NDT testing required for the steel liner and penstock.

a. Radiography –

- 100 % length of all shop joints that is longitudinal joint.
- 10% of Field Joint with compulsion at 'Tee' spots

b. Ultrasonic - 100 % of the field joints that is Circumferential joint.

c. Hydrostatic testing - All individual ferrules must successfully pass the hydrostatic pressure testing at min. twice the required pressure.

Each ferrule would be provided with a min. of 08 nos. equally spaced grout holes of min. diameter 50mm to facilitate the grouting of steel liner. Each Grout holes should be provided with suitable reinforcement pad.

The penstock shall be designed for FRL + dynamic head. In machine hall at penstock centre line the static head is 320.8 m, and dynamic head is considered as 35% of static head. The penstock is also checked for external pressure and suitable size of stiffeners is provided at the outer surface of penstock as the critical pressure is less than the external pressure.

Main Technical Parameters

i	No. of generating Units	4
ii	No. of Unit Penstock	4
iii	No. of Bifurcation	2
iv	Discharge through Penstock - Normal	97.76 m^3/sec

	working	
v	Discharge through Penstock – Pumping	82.15 m^3/sec
vi	Velocity in penstock	5.88 m/sec
vii	Thickness of penstock plate	25 mm to 56 mm
viii	FRL	2276.88 m
ix	Centre line Penstock at top	2220.00 m
x	Centre line Penstock at machine Hall	1907.90 m
xv	Design head	320.8 m+ 35% pressure rise at turbine CL
xvi	Reference codes	IS 11639

Material of Penstock

i	Penstock Plate Material	Carbon steel conforming to ASTM 517 Gr F or equivalent

3.18 Electrical & Mechanical Systems

Introduction

The Upper Bhavani PSP powerhouse will be of underground type with total installed generation capacity of 1000 MW (4 X 250 MW). The project envisages on- stream pumped storage scheme with installation of four (4) reversible pump turbine driven motor generators sets each of 250 MW capacity. The design head during operation in turbine and pump mode are calculated as 286.40 m & 314.59 m respectively. The terminal voltage of the motor generator is presently proposed 18 kV. This voltage will be stepped up to 400kV voltage level by single phase unit step up transformers. The single-phase unit step up transformers placed in the transformer cavern shall be connected to the motor-generators by means of isolated phase bus ducts. The HV bushing of step-up transformers will be further connected to the 400 kV GIS through 400 kV XLPE cable/400 kV gas insulated bus duct (GIB).

All the electromechanical equipment shall be designed as per the technical standards of CEA and other relevant Indian/IEC Standards.

Sizing and technical specification of main plant

Estimation of Design and Rated Head for Turbine & Pump Operation:

Parameter	Value (m)
Full Reservoir Level of Upper Reservoir (FRL(U))	2276.88
Minimum Draw Down Level of Upper Reservoir (MDDL(U))	2249.42
Full Reservoir Level of Lower Reservoir (FRL(L))	1985.8
Minimum Draw Down Level of Lower Reservoir (MDDL(L))	1956.00
Gross Maximum Head (Hgmax)	320.88
Average Head Losses (Turbine Mode) (HLt)	15.39
Average Head Losses (Pump Mode) (HLp)	12.8
Gross Minimum Head (Hgmin)	263.62
Maximum Net Head for Turbine Mode (Hnmax (Tur))	305.49
Minimum Net Head for Turbine Mode (Hnmin (Tur))	248.23
Maximum Net Head for Pump Mode (Hnmax (Pump))	333.68
Minimum Net Head for Pump Mode (Hnmin (Pump))	276.42
Net Design Head (Turbine Mode) (Hn (Tur))	286.40
Net Design Head (Pump Mode) (Hn (Pump))	314.59

For Pump Turbine Sizing and Dimension Refer **Annexure 2.**

For Head loss Calculations Refer **Figure 3:25**:

	Turbines		
a	Turbine Capacity	250	MW
b	Total No of units	4	Units
c	Turbine Unit Discharge	97.76	cumecs
d	Rated Head in Turbine Mode	286.40	m
e	Pump Capacity	275	MW
f	Rated Head in Pump Mode	314.59	m
g	Synchronous speed	300	rpm
Assumed Weighted Average Efficiency of Turbine, η_t		92.5	%
Assumed Weighted Average Efficiency of Generator, η_g		98.5	%
Assumed Weighted Average Efficiency of Pump, η_p		93.5	%
Assumed Weighted Average Efficiency of Motor, η_m		98.5	%
Acceleration due to gravity, g		9.81	m/s^2

Based on the gross head range of 263.62 m to 320.88 m as well as the unit capacity of 250 MW, the single stage Francis Type Pump Turbine has been chosen as the most suitable option.

Mechanical equipment

Pump -Turbines

The reversible pump turbine speed is a function of specific speed, head and discharge. The upper and lower limits of specific speeds are determined from experience data of existing machines and empirical relations of head and specific speed as provided in standards/ guidelines such as IS: 12800-Part II, USBR Monograph EM 39 and JICA's Guidelines. For economic considerations, the trend is towards selecting turbines with higher specific speeds.

The calculated speed is not synchronous speed. Therefore, the nearest synchronous speed is selected to match the turbine speed with the generator speed, which is a function of frequency and pole pairs.

As per IS:12800, corresponding to Pump rated head of 314.59m, the trial-specific speed of the unit is 36.40 metric. The trial synchronous speed (Ns') thus works out to be = nst' X Hn^0.75/Qp^0.5= 313.70 rpm. The nearest value of synchronous speed adopted for unit is 300 rpm for a conventional design of the Synchronous Motor Generator with the nearest even number of pairs of poles.

It is imperative to mention that with increased Speed, the cost of the Synchronous Motor Generator is reduced. At the same time, a variable speed option is also available, which has the following advantages in the case of a pumped storage scheme:

- Higher and flatter generating efficiency curve: The unit is operated at a slower speed at part load to improve part load and peak efficiency. Over the typical normal operating range of the unit, this could be about 0.5% to 2.0% improvement in generating efficiency. This also depends on the energy recovery from the wound rotor excitation system; nevertheless, there is some degree of efficiency improvement.
- Pump regulation: Variable-speed operation would permit regulation in the pumping mode. For example, a unit capable of being operated as a pump with a variable speed of +/- 7% from normal speed could potentially regulate power at +/- 20%. This is the primary advantage of variable speed; however, at the extremes of pond elevation, it may not be possible to fully utilize this entire range because of generator-motor or pump-turbine limitations.
- Wider generating operating range: A typical generating mode operating range is from about 60% of full load to 100% of full load because of concerns for rough operation and cavitation. Operation at a lower speed raises part load efficiency and should allow the unit to operate over a wider range.
- Wider operating head range: The typical head range of a single-speed pump turbine used for preliminary studies is a minimum operating head of no less than 80% of the maximum

operating head. Operation at wider head ranges will result in high cavitation levels or excessive unit submergence. The variable-speed operation allows a wider operating head range without cavitation and/or a higher unit setting than a single-speed machine with a wide head range.

- Easier start-up process: For larger single-speed pump turbines, it can be problematic to obtain the large block of power necessary for pump starting. A variable-speed pump turbine can be started at a lower speed, reducing the power that is required to bring the pump online. This advantage is normally only applicable to very large pumps where the input power can affect the grid performance.
- The main disadvantage associated with variable-speed technology is the higher equipment costs and the cost of additional civil work to accommodate the physically larger variable-speed units in the powerhouse. The best information at present indicates that the incorporation of variable-speed units roughly doubles the cost of a typical generator-motor and excitation system. Powerhouse size and civil costs will also increase when additions to the powerhouse are required for the electronic equipment and additional transformers.

A detailed evaluation of various aspects of fixed speed and variable speed units has been made and a comparative statement is furnished in table below:

Characteristic	Single-speed	Variable-speed
Equipment Costs		Approximately 30% to 50% Greater
Powerhouse Size		Approximately 25% to 30% Greater
Powerhouse Civil Costs		Approximately 20% Greater
Project Schedule		Longer-Site Specific
O&M Costs		Greater
Operating Head Range	80% to 100% of Max. Head	70% to 100% of Max. Head
Generating Efficiency		Approximately 0.5% to 2% Greater
Power Adjustment Generation Mode	Approximately 60% to 100%	Approximately 50% to 100%
Power Adjustment Pump Mode	None	+/-20%
Operating Characteristics		
Idle to Full Generation	Generally, Less than 3 Minutes	Generally, Less than 3 Minutes
100 Percent Pumping to 100 Percent Generation	Generally, Less than 6 to 10 Minutes	Generally, Less than 6 to 10
100 Percent Generation to 100 Percent Pumping	Generally, Less than 6 to 10 Minutes	Minutes Generally Less than 6 to 10 Minutes
Load Following	Seconds (i.e., 10 MW per Second)	Seconds (i.e., 10 MW per Second)
Reactive Power Changes	Instantaneously	Instantaneously
Automatic Frequency Control	No	Yes

The source of off-peak power required for pumping is envisaged from the renewable energy projects like Solar & Wind power plants. The total share of non-fossil fuel sources in national power grid is targeted to be greater than 50% of overall capacity by 2030 and 500 GW of total installed capacity shall be from renewables by 2030.

Due to the varying nature of renewable energy sources, fluctuations in availability of off-peak power can be expected.

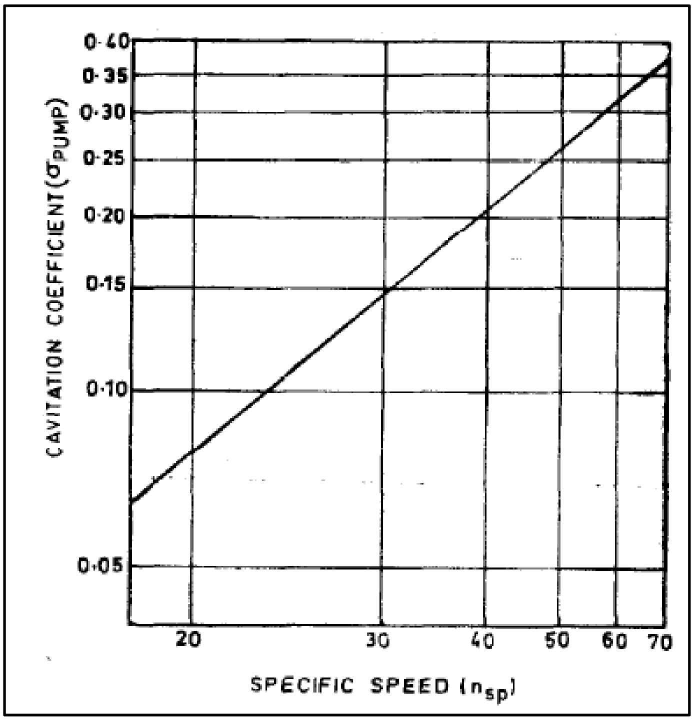
Constant / fixed speed units are cost efficient and the variable speed units offer better utility of the power but at a higher cost.

As per CEA committee report on requirement of variable speed machines vis-à-vis fixed speed machine in PSP, "fixed speed machine may be considered as an optimal solution at present for machine selection for sites having head ratio below 1.35 and if the head ratio of gross maximum head to gross minimum head is more than 1.35 then the variable speed machine could be adopted.

Taking into account all the aspects as stated above and also the ratio of maximum Gross head to Minimum gross head works out to be 1.21, the constant speed machine is envisaged for the proposed PSP. Henceforth, the speed of the Pump Turbine is adopted as 300 rpm for all the units under constant speed option. However, this aspect will be further validated in consultation with the manufacturers during the course of DPR.

Cavitation and Turbine Setting

Cavitation is the formation of water vapour bubbles in areas of the water passage through the Pump Turbine where localized pressure levels fall to or below that of the vapour pressure of water. When these bubbles travel into higher-pressure areas, they collapse back into liquid. If this occurs adjacent to a pump turbine surface, it results in pitting.



To avoid cavitation, the unit elevation must be sufficiently low relative to the Minimum Drawdown Level of the Lower Reservoir to ensure proper absolute pressures. This difference between the Minimum Draw Down Level of the Lower Reservoir elevation and the runner blade centreline elevation is the 'setting' of the unit, which has been calculated based on IS 12800 part 2, at 49.40 m below the MDDL of the Lower reservoir for all the units.

Main Inlet valve (spherical valve)

Each Pump-Turbine is provided with a spherical valve to act as a main inlet valve in order to achieve quick closing to cut off the water supply for the Pump Turbine in the event of any machine tripping on a lock out fault. The spherical valve shall be designed for operation against the maximum static head plus water hammer pressure. The opening operation of the MIV will be carried out by pressure oil operated servomotors. The oil pressure operated spherical valve shall have capacity to allow maximum flow of pump-Turbine discharges. The Spherical valve shall be normally opened and closed by hydraulic system and have backup closing system with dead weight for closing during emergency. Hydraulic operated Bypass valve along with isolating valve is provided across the Spherical valve for smooth operation of the valve with pressure balance condition using differential pressure switch and auto operation scheme. The size of spherical valve shall be in line with the inlet diameter of spiral casing.

Butterfly Valves

Two (2) no's of Butterfly Valves of adequate size which shall match with the inlet diameter of Pressure shaft have been envisaged for two (2) number of pressure shafts. A Valve house of size

45m(L) x 15m(W) x 26m(H) will be constructed to accommodate the valves and auxiliaries and electrical equipment.

Overall dimensions of the powerhouse

The overall dimension of the Powerhouse is calculated as per IS 12800 Part 2. The Length, Width and Height of the Power Station are calculated as 144m(L) x 24m(W) x 47.2m(H) , including the service bay. The dimensions of the Powerhouse and tentative layout of the Powerhouse have been estimated as per the IS: 12800-Part II and attached as **Annexure- 2.**

Specific Design & Quality Requirements

Design Stress Limits

The pump-turbine shall be designed to withstand forces arising under the worst conditions of operation taking also into account superimposed seismic forces.

Under the most severe conditions of loading expected in normal operation, stresses in the materials shall not exceed the values listed below:

Direct or combined steady stresses:

- ❖ For materials used in the construction of the equipment, the maximum stress due to maximum normal rated load operating conditions shall not exceed one-third of the minimum yield point or one-fifth of the minimum ultimate strength of the material, whichever is lower. The minimum factor of safety under the worst conditions shall not be less than 1.5 on yield point (YP) or 3 (three) on ultimate tensile strength (UTS).
- ❖ Parts subject to water pressure shall be designed to the applicable provisions of the ASME Code and welding shall be as specified herein and in accordance with ASME Boiler and Pressure Vessel code Section 8, Division 2.

Operating Temperature Limits

The guide bearing metal temperature of the pump turbine shall not exceed 70°C.

The guide bearing shall be designed for the following conditions:

- ❖ That the normal working metal pad temperature shall not exceed 70°C for turbine operating at all loads up to permitted overloads.
- ❖ Continuous operation at any speed from 90% to 110% of rated speed.
- ❖ Capability of operating safely at maximum allowed load for a period of fifteen (15) minutes without cooling water supply.
- ❖ Safely withstand turbine going to run away speed due to any fault for a period of fifteen (15) minutes with cooling water supply intact and subsequent closing down period without any damage to the guide bearing.

- ❖ Withstand safely and without damage the natural retardation from maximum over speed without application of generator brakes.
- ❖ Withstand operation at low speed (4-5% of rated speed) for a period of at least Thirty (30) minutes.

The pump turbines shall be of the plate steel spiral type.

Various components shall be strong and rigid to withstand forces acting upon them under any conditions of operation with safety and without undue deformations. The stay vanes, top cover, bottom ring, discharge ring, draft tube cone & liner, turbine pit-liner etc. shall be amply robust and substantially ribbed. The maximum static pressure acting on the turbine (inlet, scroll casing, guide vanes etc.) will be 1.5 times the maximum static head. The spiral casing and other parts subjected to penstock pressure shall be designed for the maximum pressure, to which it will be subjected under most severe conditions of operation. The forces acting under maximum tail water condition load rejection shall be particularly taken care of in designing top cover.

The head cover shall provide rigid support to the guide bearing housing, shaft seal housing, guide vane upper stems and guide operating ring. The stay ring shall be designed to withstand safely the loads and forces acting upon it. The upper un-embedded portion of the draft tube cone and liner shall be especially strengthened with ribs and other means to avoid undesirably vibrations and limit the same within permissible limits. The guide operating ring and its supporting structures shall be of adequate strength and stiffness to prevent deflection of the ring, guide bearing or the main shaft in the event of the guide operating ring getting subjected to the thrust of only one servomotor with the other servomotor blocked or without oil pressure.

The gate operating mechanism (levers, links etc.) shall be of ample strength to withstand most severe operating conditions. The servomotors and oil piping between servomotors and the governor hydraulic actuator shall be designed and selected respectively to suit this working pressure. All parts that would be embedded in concrete shall be designed assuming no contribution in load sharing by the surrounding concrete. Adequate corrosion and erosion allowance in the wall thickness of embedded parts shall be allowed in the design. This allowance shall be deemed to be not contributing to the strength of the embedded parts.

Governor

The governor of each unit would be state of the art, digital-hydraulic type, microprocessor type PID governor. Speed, gate opening, gate limit positioning etc will be indicated both on the governor cubicle and on the unit control board, to facilitate supervision of operation of the unit. The governor shall be designed to control the wicket gates both in turbine as well as pump mode of operation.

Power House EOT Crane

The heaviest equipment required to be handled during erection and subsequently during maintenance is the motor - generator rotor. Considering the weight of motor - generator rotor, equalizing / lifting beam and the crane margin, two (2) nos. of EOT cranes of 390/50/10 ton (tentative capacity) each, designed to travel the full length of the powerhouse have been envisaged. A 10-ton crane for GIS hall is also envisaged for handling equipment. An EOT crane of adequate capacity shall also be installed in butterfly valve house.

Auxiliary Systems for the Power Station

i) Cooling Water System

This system will be designed to meet the cooling water requirements of the following equipment in the power house

- Motor-Generator Bearings,
- Motor-Generator Air Coolers,
- Pump-Turbine Bearings,
- Unit Step Up Transformers,
- OPU for pump-turbine/ MIV (if applicable)
- Shaft seal.

The cooling water system will be provided with necessary pumps (main and stand by), pipes & fittings, valves, strainers, heat exchangers and instrumentation such as flow switches, differential pressure switches across the strainers, and pressure switches etc., for safe and reliable operation of the units.

ii) Fire Protection system

A complete fire protection system shall be provided in the powerhouse, Transformer cavern, GIS hall and pothead yard. The fire protection system shall comprise of Fire detection system and Fire suppression system. The following system will be considered for the purpose:

- Hydrant system
- High velocity water (HVWS) spray system
- Medium velocity water (MVWS) spray system
- Portable Fire extinguishers

Portable fire extinguishers of different types shall be provided at strategic points at all the floors of powerhouse, transformer cavern and GIS hall for protection in case of small fire emergencies.

iii) Drainage and Dewatering System (including flood dewatering system)

A dewatering system would be provided in the station with a suitable number of pump motor sets arranged to dewater passages of the turbine and draft tube. A separate station drainage system, with a suitable number of pump sets, would also be provided to drain and pump off miscellaneous inflows, and ground water seepage in the power house. Starting and stopping of the pumps would be automatic, controlled by level switches in the dewatering/ drainage sumps. Provision of flood dewatering system is also envisaged.

iv) Air Conditioning and Ventilation System

The powerhouse shall be provided with adequate ventilating and centralized air conditioning system as required to maintain the control room, work areas and power house at the selected temperature & humidity levels. The temperature and humidity levels would be selected to suit the requirement of equipment and plant staff.

v) Oil Handling System

Oil handling system for transformer oil and lubricating oil will be provided with suitable piping, valves, tanks, purifiers etc. In addition, portable type oil purifiers will also be provided.

vi) Station Compressed Air System

A low-pressure compressed air system would also be installed to meet the requirements of the motor-generator brakes and station service air.

vii) Mechanical Workshop

A workshop with Lathe machine, Milling machine, drilling, welding and other required machine tools has been envisaged to carry out normal repairs of the equipment in the powerhouse.

viii) Elevator

One (1) no. of elevator will be provided in the power house building. The elevator will be designed, for approximately a load of 10 passengers each and landings at all the floors of the powerhouse.

3.18.1 Electrical equipment

Motor- Generators

Four (4) nos. of 277.78 MVA vertical synchronous motor- generators are proposed to be installed in the powerhouse. The Motor-Generators are to be directly coupled to the hydraulic pump turbines to match their speed. The output capacity of the Synchronous Motor-Generator is adopted matching with the maximum possible output of the Turbine and standard Power Factor of 0.9 has been adapted in line with generating units of comparable capacity.

The feasibility of installation of Doubly Fed Induction Motor Generator (DFIMG) shall also be studied as an option during the DPR stage. However, the present study is limited to Synchronous Type Motor- Generator.

The voltage rating shall be in the range of 15 -18 kV. If required, the same shall be optimized during the preparation of the detailed project report in consultation with the manufacturers. Class F insulation will be provided for the armature winding and the field winding of the generator-motor.

The motor-generator will be complete with excitation system, neutral grounding arrangement, phase and neutral side C.T.s, RTDs, bearings with bearing oil level and temperature monitoring/protection system, brake and jack assembly etc.

Starting System of the Pump

At the start of pumping operation, a generator motor is started as an Induction motor. After having been synchronized with the power system, pumping is started by synchronous motor operation of a generator motor. To reduce the energy on start-up, the draft water level is depressed by pressurized air to run the runner in the air, and the generator motor is started as a motor using any of the following methods:

Table 23 : Starting Methods of Pump System

Name	Methods	Features
(a) Half voltage start up (Full voltage start up)	The damper coil of the generator rotor is utilized to start the generator motor as an induction machine.	This method is not suitable for starting a large capacity motor because it imposes great shock on the power system when connected to it as an induction machine.
(b) Synchronous start up (Back-to-Back start up : BTB start up)	Two sets of generators and motors are directly connected in the stationary state, with one set started as a turbine and the other as a generator to drive the generator motor using synchronized force.	The last unit requires a separate device for self-starting.
(c) Direct coupling motor start up (Pony motor start up)	Directly connected starting induction motor is mounted coaxially with the generator motor to start the generator motor.	This method requires auxiliary devices, such as a starting motor, a starting transformer, and a liquid resistor for speed control.
(d) Thyristor starters start up	A thyristor starter (frequency converter) is equipped to start the generator motor by applying a low frequency up to the rated frequency.	Two or more pump turbines and generator motors can be effectively utilized on sequential start up. The fewer the units, the higher the cost.

It is considered that based on the size of the Motor Generator units, Thyristor based Static Frequency Converter common for both the Units would be the most suitable option.

Static Frequency Converter (SFC) system

One (1) set of Static Frequency Converter (SFC) system is considered for starting equipment and this starting equipment is common for all four (4) Units in the power station. Starting equipment shall be suitable to start the units as pump-motors smoothly with impeller in dewatered condition and without inrush current. The Pump-motor shall be soft started and reach its rated speed within 5 minutes. It shall include the necessary transformers, H.T switchgear and all the control equipment required. The isolator cubicles shall be provided with circuit breakers for incoming feeders and 4 Nos. outgoing feeders one for each unit. The system shall be suitable to start one pump at a time.

The power circuit's panels of starting system shall be designed such that it can withstand system fault currents during starting of pumps.

Back-to-back Starting panels

Each fixed speed type unit shall be provided with back-to-back starting panel. Mainly to the extent possible the units will be started in back-to-back starting mode.

Generator Circuit Breaker

Generator Circuit Breaker of 24kV capacity will be provided for each fixed speed type unit along with all required accessories. The circuit breaker shall be three-phase, Single pole indoor, metal enclosed, SF6 gas self-extinguishing type suitable for Indoor installation with all necessary accessories for trouble free operation is to be considered.

Phase Reversal Isolators

Each unit shall be provided with phase reversing switch disconnectors. These are used whenever the system is operated in pumping mode for the motor operation. The equipment consists of two isolators kept in parallel with each other and one isolator with reverse phase sequence.

The main differences between the generating and pumping operating modes are changes in direction of the machine rotation and change of direction (i.e. sign) of the active power flow. This change in direction of rotation is achieved by phase reversal disconnect switches. These disconnect switches simply swap two phases in pumping mode in order to reverse the phase sequence of the machine.

Excitation System

The excitation system will be of the fully static type including digital type programmable automatic voltage regulator, Thyristor rectifiers and field suppression equipment. The Excitation System shall conform to IEEE 421 & IEC 60034.The design shall be based on (N-1) principle; if one essential function fails, another shall automatically take over and a watch dog function shall be activated.

The ceiling voltage shall not be less than 2 p.u. of the rated excitation voltage. The response of the system shall be very quick and shall be such that when operating at rated MVA output, Terminal Voltage, Power Factor and Speed, the system shall be capable of changing from rated voltage to 90% of Ceiling Voltage within not less than 25 milli seconds for a sustained drop in Generator Terminal Voltage of 5%.

The System shall be complete with all the essential features like protection, Monitoring and Limiters and Power System Stabilizers and comprise of Voltage Regulator Panel, Field Breaker Cubicle with Field Suppression, Thyristor Rectifiers and Excitation Transformers.

Isolated Phase Bus Duct

Each generator-motor unit would be connected to its step-up transformer by means of air insulated isolated phase bus ducts. The isolated phase bus duct system would incorporate the required current and voltage transformers for protection and metering on the line and neutral side of the motor-generator. Each Motor- generator will be provided with 24 kV rated isolated phase and tap off Bus Ducts, along with associated equipment like phase reversal isolators, neutral grounding transformer, neutral grounding resistor, PT & SP cubicles, GCB, dynamic braking cubicle, CLR etc.

The continuous type of isolated phase bus duct system will connect the Motor-generator to generator transformer, with tap off connection to Dynamic breaking Cubicle, Excitation transformer, PT and SP cubicles, GCB. Also, an extension of tap off connection to Starting Equipment (SFC) isolator panel shall be provided in all units.

Unit Step Up Transformers

Twelve (12) numbers of single-phase unit step up transformers of around 110 MVA, 18/420/√3 kV, 50 Hz capacity shall be provided for Four (4) units and one (1) spare. The transformers shall have OFWF Cooling. The transformers shall be equipped with necessary protection equipment. However, depending upon the transportation survey during the DPR stage the single-phase transformer configuration may change to three-phase.

Control, Metering and Relaying System

Supervisory Control Monitoring and Data Acquisition System (SCADA) has been envisaged the project. The system shall be applied for automatic control such as start, stop and protection of the pump- turbine combined with the control and protection system during all modes of operation such as turbine and pumping. All necessary components required for performing the automatic sequential control of the pump-turbine, and their main parts shall be accommodated inside the pump-turbine control boards. At unit level, Unit Control Boards will be provided and at Plant level, control will be provided at Central Control Room.

Station Service & Unit Auxiliaries Supply

Four nos. of 1250 kVA, 3-phase, 18kV/0.433kV, dry type unit Auxiliary Transformers shall be tapped down from 24 kV bus ducts of four numbers of units and feed power to 415V unit auxiliaries as shown in the Single Line Diagram. The station service power supply is proposed to be taken from 11 kV switchgear through two nos. of 11/0.433 kV, 2.5 MVA, 3-phase, ONAN/ONAF cooled Station Service Transformers suitable to meet the load requirement.

D.C. Supply System

A 220-volt DC System, with two sets of battery bank of not less than 2000 AH each, would provide power for the control of switchgear, for the protection and control equipment, and for emergency lighting of the power house & transformer cavern. The batteries would be provided with two battery chargers, each equipped with float and boost charging facility with all protective devices necessary to protect the system. Distribution boards would be provided for feeding various DC loads of the units. A 48 V DC system along with battery charger would be installed for signalling control system and the OPGW/PLCC system.

400 kV GIS and Pothead Yard

The GIS shall be located inside in the vicinity of powerhouse taking into consideration the power evacuation arrangement. Double bus scheme of 400 kV has been envisaged to ensure reliability and flexibility in switching without interruption. The GIS shall consist of 7 nos. of bays- 4 no. of unit bays, 2 nos. of outgoing line bays, 1 no. of bus coupler bay. Also, provision of space shall be kept for one bay in future.

400 kV Pothead Yard will be provided with AIS Current Transformers, CVT, Wave Trap, Lightning Arresters and facilitate termination of the Transmission lines.

Cabling System

All cables will be selected to carry the full load current under site conditions, with permissible voltage drop. In addition, these cables will be rated for short circuit capacity wherever required.400kV XLPE, 11kV power cables, 1100V grade PVC, control cables and instrumentation cables will be provided.

11 kV & 415 V Switchgear

Two nos. of 6.3MVA, 3-phase, 18kV/11kV ONAN/ONAF Station auxiliary transformer is tapped down from unit 1 and unit 4 from 24kV bus ducts to station auxiliary board. Two nos. of Diesel Generating sets of 1250 kVA, will also be provided for 11kV station auxiliary board. The Indoor 11 kV Switchgear would comprise of 4 incoming feeders (two nos. of 11 kV supply feeders from & two feeders from DG sets), 10 No. outgoing feeders and one bus coupler. The outgoing feeders would include 2 No. feeders to Station Service Transformers, 2 nos. feeders to BFV house, 2 nos. feeder for Upper reservoir, 2 nos. for Lower reservoir and 2 nos. for Surge Shaft area. The Switchgear would include all necessary protection equipment and relays. 415V switchgear shall also be provided with sufficient number of feeders. Equipment ratings are tentative and will be further validated during preparation of draft DPR

PLCC Equipment

OPGW/ PLCC system shall be used for line protection, communication, tele-metering and remote control between powerhouse, receiving end substation and load dispatch centre.

Public Address System

A suitable public address and surveillance system like CCTV camera, personal identification system, EPABX etc., will be installed in the powerhouse complex to facilitate the communication and desired security in the powerhouse area.

Equipment Grounding

The Powerhouse complex as well as the pothead yard would be provided with separate main grounding grids. All non-current carrying equipment in the powerhouse, transformer cavern, GIS hall and pothead yard would be grounded separately and connected to the main grounding grid. The grounding system would be designed to minimize the touch & step potential within acceptable safe limits.

Illumination System

The Power plant lighting mainly LED based would comprise interior and exterior lights as appropriate for the entire power house, Transformer cavern and GIS hall. A separate emergency lightning system fed from the station battery system would be provided for essential locations e.g. control room, machine hall, exits etc. Also, the luminaries for battery room shall be acid fume proof.

Electrical Equipment Testing Laboratory

A laboratory for electrical testing equipment will be available to do routine testing of Powerhouse equipment's. In order to store portable equipment and provide a basis for testing workers, a separate room is suggested for the Electrical Testing Laboratory in the Powerhouse. Every testing apparatus will be modernly designed and compatible with PCs.

3.18.2 Power Evacuation System

1 (one) number of 400 kV double circuit transmission line with quad moose ACSR Conductor from the pothead yard of the proposed Project is to be connected to proposed 400 kV Parali pooling

substation (near Pillur reservoir). This double circuit transmission line will be used for both evacuation of generated power and input of power during pumping mode.

A sketch indicating the transmission scheme is attached as **Annexure No 3.**

Presently there are no 400 kV systems available in Nilgiris District. A 400 kV Pooling station proposed to be developed by TANGEDCO and all the upcoming hydro projects in the said district shall be connected to it. Power from this Pooling Station will be evacuated to Karamadai 400 kV substation or any other nearby substation which shall be explored and finalized after joint load flow study with CTU &CEA/ New Delhi. The TANGEDCO Letter No: CE/Plg&RC/SE/SS/EE1/AEE3/F.PSP/D 88/22 dated 25.03.2022 and is attached as **Annexure No 4.**

The estimated length of the transmission line is about 50 km from the Switchyard of the proposed PSP to 400kV proposed Parali pooling substation (near Pillur reservoir).

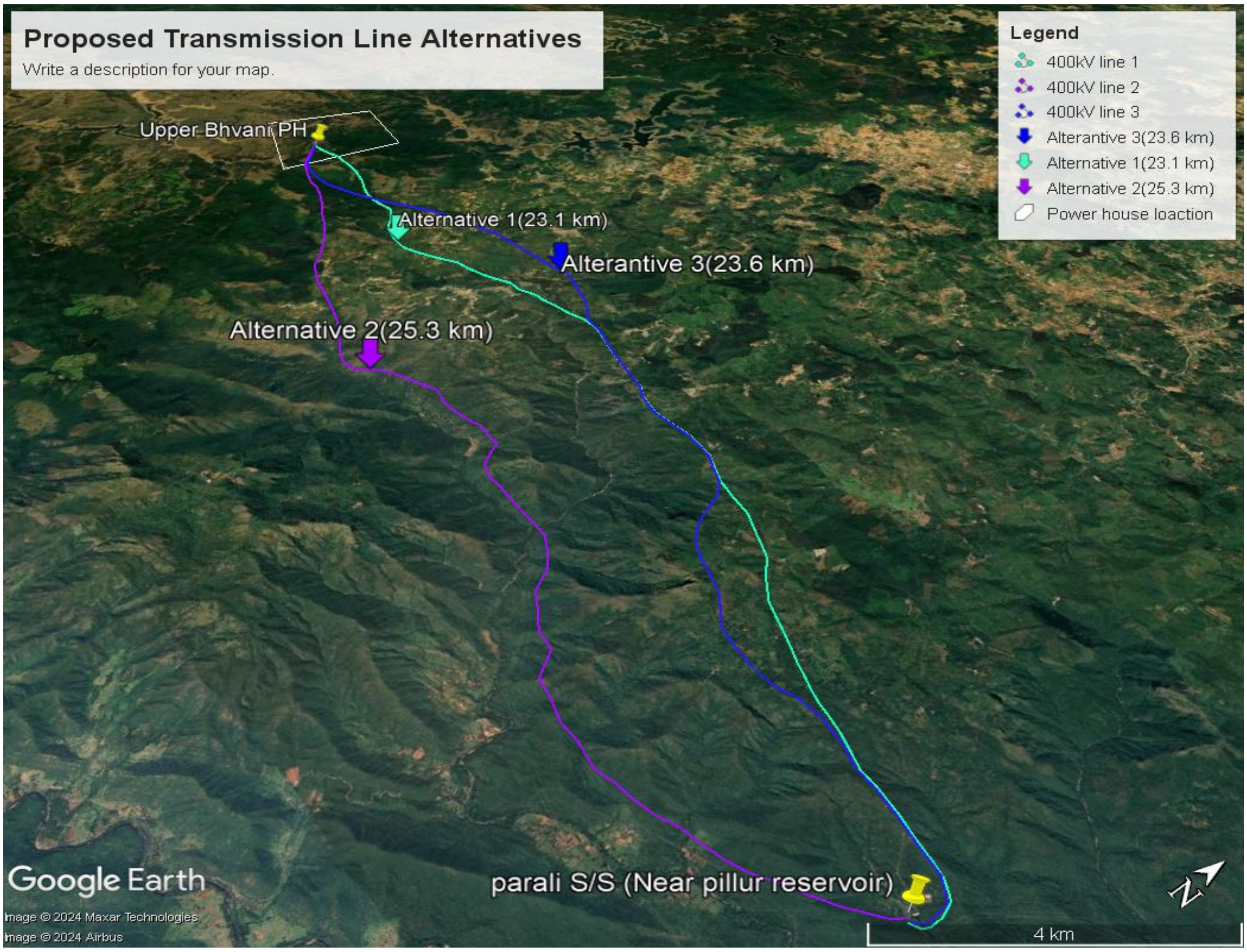
Also, the following three alternative routes for transmission line were studied as shown in the sketch on the next page. Note that the distances shown in the sketch are aerial distances and actual distances shall vary and are estimated as below:

I. Alternative 1: The estimated distance is 45 kms.

II. Alternative 2: The estimated Line length is 40 Kms.

III. Alternative 3: The estimated Line length is 40 Kms.

The final transmission line route shall be validated and confirmed after the transmission route survey, which will be conducted in the course of DPR, and in consultation with the regulators and stakeholders, once the land for the Parali pooling substation is finalized by the stakeholders.



3.19 Source and Requirement of Water & Power, water diagram and wastewater generation and utilization

The Upper Bhavani Pumped Storage Project (PSP) requires approximately 9 million cubic meters (MCM) of water for its cyclic operation of power generation and pumping. Water will be sourced from the Upper Bhavani and Avalanche-Emerald reservoirs, which will serve as the upper and lower reservoirs, respectively. During generation mode, water flows from the upper reservoir to the lower reservoir, passing through turbines to generate electricity, while in pumping mode, water is lifted back to the upper reservoir from the lower one using surplus energy during off-peak hours. This cyclical process is critical for energy storage and retrieval. The wastewater generated during the construction and operational phases will be carefully managed, treated, and reused for non-potable purposes such as irrigating greenbelts or dust suppression. Any excess treated water will be safely discharged into nearby water bodies, ensuring compliance with environmental standards. The project will thus ensure efficient water use and wastewater management while minimizing its environmental impact.

3.20 Quantity of wastes to be generated and its management

The Upper Bhavani Pumped Storage Project (PSP) does not generate significant waste during its core operations, as it mainly involves the cyclical movement of water between the upper and lower reservoirs for energy generation and pumping. However, during the construction and operation phases, some waste may be produced, such as construction debris, packaging materials, and vegetation clearance. These will be managed through proper waste segregation, recycling, and disposal practices. Additionally, wastewater from construction and operational activities will be treated and reused for non-potable purposes like irrigation and dust suppression. Any hazardous materials, such as oils or chemicals, will be handled in compliance with environmental regulations. Overall, the project will implement an effective waste management strategy to ensure minimal environmental impact and adherence to sustainability practices.

3.21 Layout plan representations of feasibility drawing (for EIA)

The general layout of the Upper Bhavani PSP project is shown in the Figure below.

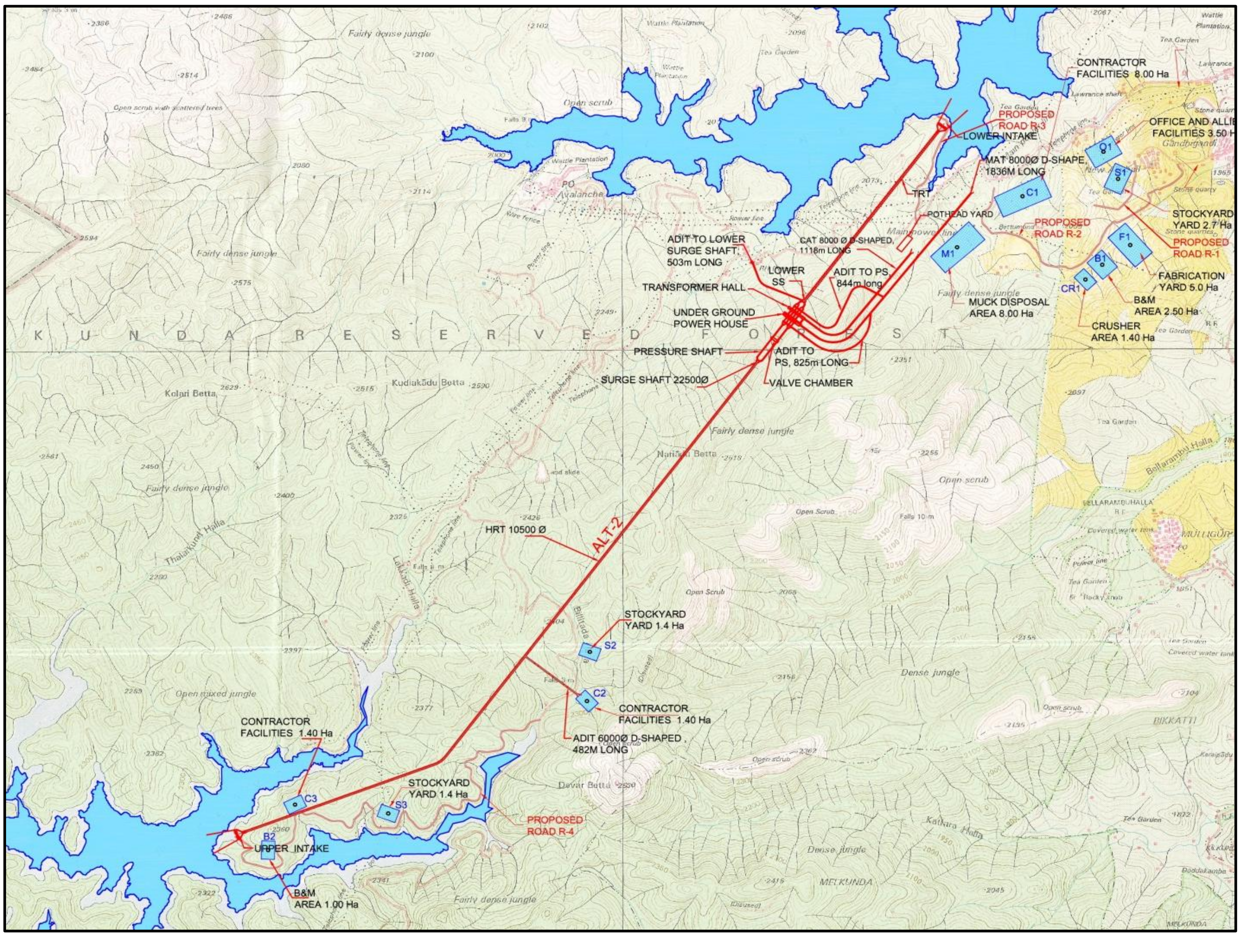


Figure 3:26 General layout of the Upper Bhavani PSP (1000 MW)

3.22 Greenbelt details/development plan

The greenbelt development plan for the Upper Bhavani Pumped Storage Project (PSP) aims to mitigate environmental impacts and promote sustainability by establishing ecological buffers around the project area. Located in the Nilgiris district of Tamil Nadu, the project will involve compensatory afforestation to offset the loss of forest land due to infrastructure development. According to the Indian Forest (Conservation) Act, 1980, compensatory plantations will be carried out on degraded forest land or non-forest areas, with a focus on creating a greenbelt around key project infrastructure, such as the powerhouse, roads, and colony areas. Native plant species will be used to enhance local biodiversity, support wildlife, and improve soil stability. Additionally, the greenbelt will serve as a barrier against soil erosion, noise, and air pollution, while promoting carbon sequestration and preserving the region's ecological balance. The greenbelt's long-term success will be ensured through regular monitoring and maintenance, in collaboration with the Tamil Nadu Forest Department. This comprehensive plan underscores the project's commitment to minimizing its environmental footprint while contributing to the region's ecological restoration and sustainability.

CHAPTER 4.SITE ANALYSIS

4.1 Connectivity

The proposed location falls in the Nilgiris District of Tamil Nadu and its city administration. The Nilgiris district is known as the Queen of the Hills. The Nilgiris district in Sanskrit is termed as the Blue Mountains with a total geographical area of 2545 sq.km. It is surrounded by the Coimbatore district, Kerala state and Karnataka state on the eastern, western and the northern side respectively. Udhagamandalam is the capital town of the Nilgiris district which has also been one of the constituencies of Tamil Nadu Legislative Assembly. There are 4 panchayat Unions and four Municipalities viz. Udhagamandalam, Coonoor, Gudalur and Kotagiri located in the district. Apart from 11 special village panchayats, Wellington is the only cantonment of this district. The Nilgiris Biosphere Reserves one of the critical catchment areas of peninsular India. Many of the major tributaries of the river Cauvery like the Bhavani, Moyar, Kabini, Chaliyar and Punampuzha have their source and catchment areas within the reserve boundary.

The project site is connected to the Ooty (Udhagamandalam) city by about 45 km distance. The Nagapattinam–Gudalur National Highway passes through this district. The Nilgiri Ghat Roads link Nilgiris with nearby cities in Tamil Nadu, Kerala and Karnataka. All the taluks are connected with major roads. Ooty bus stand serves as the central bus stand for the district. Mettupalayam railway station is the nearest Broad Gauge tracked Railway station from the project location at about 60 KM. The nearest airport from the project location is Coimbatore International Airport at about 140 KM.

4.2 Land use and Land Ownership Pattern

The present land use pattern of the Nilgiris District as per the survey report of National Agriculture Development Programme (NADP) in 2014-2015 is shown in the table 4.1. Below:

Table 24 Land use pattern of The Nilgiris district

Sl. No.	Classification	Udhagai	Coonoor	Kotagiri	Gudalur	Total (ha)
1	Forest	80634	4107.08	20203.62	37631.99	142576.69
2	Barren and Uncultivable land	1761	562	694.72	357	3374.72
3	Land put in Non-agricultural use	3640	2764.15	1169.01	2403	9976.16
4	Cultivable Waste	973.14	28.13	501.03	216.68	1718.98
5	Permanent pastures and other Grazing Lands	2132	923.02	1660.96	362	5077.98
6	Miscellaneous trees crop and grows not included in the net area sown	2253	600.37	414.08	553	3820.45
7	Current fallow lands	5627.31	1014.12	1704.72	792.59	9138.74
8	Other fallow lands	1467.23	38	0	1555.08	3060.31
9	Net - Cultivated Area	21276.32	12846.56	13317.06	28300.97	75740.91
10	Total Geographical area	119764	22883.43	39665.2	72172.31	254484.94

Source: commodity potential report (2013), Directorate of CARDS, TNAU, Coimbatore, Tamil Nadu

From the above table, it is envisaged that the Nilgiris District has mostly the Forest cover followed by Net cultivated area. The other minor percentage of land use is categorized under Barren land, current fallow land, cultivable waste etc. Almost 85 percent of the area is under the forest zone and thereafter agricultural activities are predominant in this district. Plantation crops like tea and coffee are the major crops which covered most of the agricultural area. Among the four blocks Coonoor has the highest agricultural activities with 56.14 percent and followed by Gudalur with 39.21 percent, Kotagiri with 33.57 percent and Udhagamandalam with 17.76 percent of net cultivable area, corresponding to its block total geographical area. Udhagamandalam has the least agricultural activities than other blocks. It is noticed that most of the tourist and other commercial activities are in the district headquarters. The share of district area under cultivable waste, current fallow and other fallow accounted for about 5.47 per cent of the total area and this would reveal that implementation of land reclamation, strengthening of irrigation facilities and so on through schemes by various departments increases the net sown area or area under forest.

There are five categories of land holdings. They are marginal (below 1 ha), small (1-2 ha), semi-medium (2-4 ha), medium (4-10 ha), large (10ha and above). The number and extent of operational land holdings are given in Table below. As can be seen from the table that the distribution of land holdings in Nilgiris district is high among the marginal and small farmers category. Big farmers, scheduled castes and scheduled tribes are in small contribution.

Table 25 Land Holding Pattern of the farmers

	Udhagai		Coonoor		Kotagiri		Gudalur	
Particulars	No.	%	No.	%	No.	%	No.	%
Marginal Farmers	11377	63.26	5294	72.88	8910	80.3	4564	32.43
Small Farmers	5884	38.72	1411	19.42	1775	16	8476	60.22
Big Farmers	723	4.03	559	7.69	410	3.7	1035	7.35
Total Farmers	17984	100	7264	100	11095	100	14075	100

Table 26 Caste wise land holding in (ha)

	Udhagai		Coonoor		Kotagiri		Gudalur	
Particulars	No.	%	No.	%	No.	%	No.	%
SC.Farmers	3187	17.72	847	11.66	1042	9.39	4588	32.6
ST Farmers	783	4.35	178	2.45	608	5.48	1999	14.2
Other Farmers	14014	77.93	6239	85.89	9445	85.13	7488	53.2
Total Farmers	17984	100	7264	100	11095	100	14075	100

As from the table it can be seen that In SC community people holds is 17 to 20 %, ST community people hold is 5 to 6% and others community people hold 70-77% of land area from the total.

4.3 Natural resources of the region

Nilgiri district is a mountainous district of Tamil Nadu with many hill ranges and broad valleys with slopping towards plain. The prominent geomorphic units identified in the district through interpretation of Satellite imagery are 1) Structural hills, 2) Ridges, 3) Valley fills, 4) Pediments, 5) Shallow Pediments, 6) Deep Pediments and 7) Hill top valley 8) Erosional plains. The Nilgiris hills rise abruptly from the plains (300 m. above MSL) to an average elevation of 1370 m. above MSL. Some of the prominent peaks are the Dodda Betta (2632 m), the highest peak in Tamil Nadu, Kolari (2625 m), Mukurthi (2554 m), Kudikadu (2590.m), and Deva Betta (2552 m), the conical grass covered Der Betta and Bear hill (2531 m) and Nilgiris peak.

Nilgiris is one of the oldest mountain ranges, located at the tri-junction of Tamil Nadu, Kerala and Karnataka and it is a part of Western Ghats. Nilgiris is India's first biosphere, and it has been declared as one of the 14 hotspots of the world because of its unique bio-diversity. Nilgiris is situated at an elevation of 900 to 2636m above Mean Sea level. The district has maximum percentage of its area as its forest region. Forests have economical, ecological, and recreational values, known collectively as environment services and benefits derived from forests include grazing, hunting, shade, forest foods in the form of tree leaves, wild fruits, nuts, tubers and herbs, tree bark form medicinal purposes, and non-wood products such as honey.

The district is falling in part of east flowing Cauvery River basin as per the Irrigation Atlas of India. Moyar, Bhavani, Kethar halla are the important sub basins. The district is further sub divided into number of minor basins. The Nilgiris district is drained by a number of streams originating from the number of peaks available in the district. Among the major rivers Moyar river flows in an easterly direction and is bordering the northern boundary of the district. Sigur and Pykara are the major streams of Moyar river. Number of minor streams joins this river from north – northwest and south directions. The Bhavani River originates in Bhavaniar Betta and flows southwest ward and swings southwards. The Khuda River drains southern part of the district which, joins Bhavani River in the south. The Katteri is another minor river, which flows eastwards and joins the Bhavani River. The river Kethar halla is flowing in the northern direction. Most of the rivers in Nilgiris plateau have been harnessed by drawing them at several points under the Kundah, Mukurthi, Pykara, Chalatti, Puzhe and Moyar Hydro- electric schemes.

4.4 Topography

The proposed Upper Bhavani Pumped Storage Project is located in south-western part of Nilgiri hills, Kundah Taluk, Nilgiri District, Tamil Nadu, India. The project site falls in SOI toposheet no. 58A/11/SW on 1:25000 scale, and is bounded by Lat. N 11°21'to 11°13'and Long. E 76°29' to 76°37'

(Figure- 4.1). The proposed project envisages construction of one water conductor system in between two existing reservoirs, to divert the water from upper reservoir to lower reservoir through an Intake-HRT-Surge Shaft-Pressure shaft to an underground powerhouse to generate 1000MW of peaking power and the tail water will be stored at lower reservoir through a TRT for pumping to upper reservoir in off-peak hours. EIPL on behalf of NTPC is preparing the DPR and undertaken surface geological mapping, exploratory drilling, lab & field-based tests, EIA study as DPR stage investigation works.

Nilgiris district is a mountainous district of Tamil Nadu with many hill ranges and broad valleys sloping towards plain. The prominent geomorphology in the area includes Structural hills, Ridges, Valley fills, Pediments and Erosional plains.

The Nilgiri hills rise abruptly from the plains (300 m. above MSL) to an average elevation of 1370 m. above MSL. Some of the prominent peaks are the Dodda Betta (2632 m), the highest peak in Tamil Nadu, Kolari (2625 m), Mukurthi (2554 m), Kudikadu (2590.m), and Deva Betta (2552 m), the conical grass covered Dedh Betta and Bear betta (2531 m) and the Nilgiri peak.

The district is falling in part of east flowing Cauvery River basin as discussed in the Hydrology chapter of this report.

The maximum elevation about 2000-3000m is observed in 1% of the total geographical area of the basin. Around 32% of the basin area falls under the 750- 1000 m elevation zone (Source: SRTM 90m). The elevation zones are shown in **Map below**.

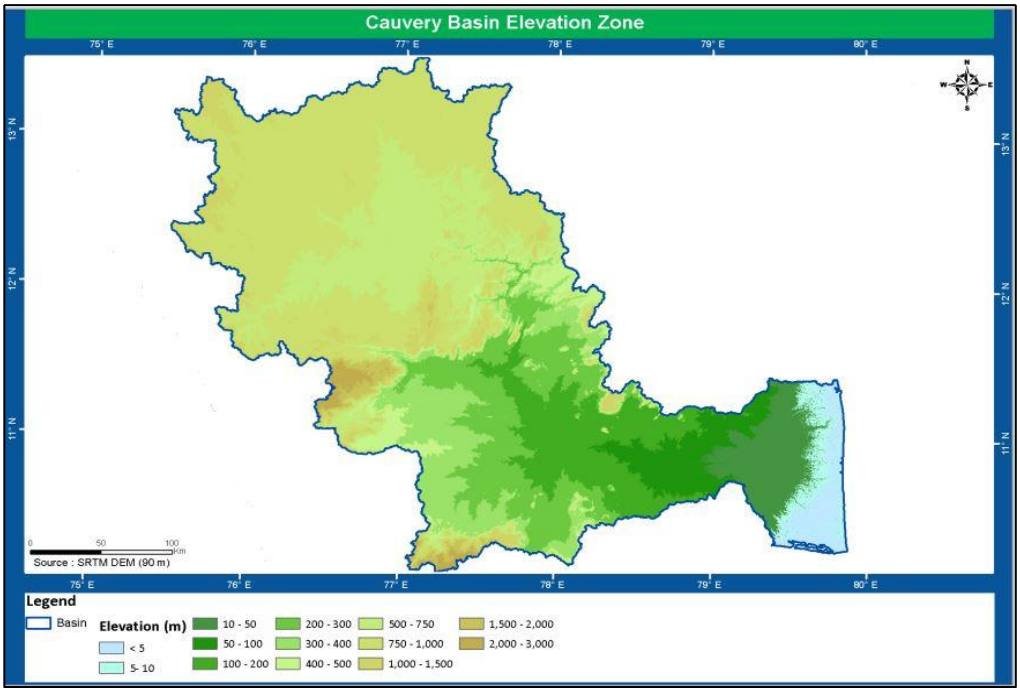


Figure 4:1 Slope Map of Cauvery Basin
(Source- Cauvery Basin report CWC)

4.5 Archaeological survey

As per available information no site in the project area was notified having national importance by Archaeological survey of India.

4.6 Communication survey

The proposed pumped storage scheme is proposed near to the existing Stage-v Hep and near to the Kundah Pumped Storage Project (500MW) which is under construction and have all the infrastructural development (road heads, major railheads and airports) at various project component sites are available to **enable convenient execution & smooth operations and maintenance later on.**

4.7 Geomorphology and Geohydrology

The project is located in the south-western part of Nilgiri Hills. Nilgiri Hills represent a plateau which is steeply sloping into Mysore Plateau in the north and gradually merges with the Western Ghat hill ranges in the north-western and south western parts (Fig-2). The Nilgiri Hills rise abruptly from the surrounding plains to an elevation of 1370m above MSL. They are surrounded by the Coimbatore plains (EL.411.0m) in the southeast. Bhavani plains (EL.173.0m) in the northeast, Moyar valley (EL.431.0-585.0m) in the north and Gudalur plateau (EL.1072.0m) in the northwest. The prominent hills are Ooty, Dodabetta, Kodaibetta, Bhavni Betta and Devabetta. Dodabetta is the highest peak (EL.2637.0m) in Tamilnadu. The other high peaks are Mukurthi, Vellari Mala and Mukkali Mudi further west of the Project area.

The principal rivers that drain the area are Bhavani, Kundah in the south, Pykara towards north and Coonoor to further east of the project area. One of the major tributaries of Kundah River is Sillahalla stream – a perennial stream across which construction of the upper dam is contemplated, whereas the lower dam is proposed across Kundah River.

Moyar is a prominent river in the district and flows in an easterly direction, along the northern boundary of the district. The drainage is dendritic to radial at places with prominent rapids, cascades and water falls.

The erosional surfaces such as Dodabetta, Ootacamund, Coonoor and Moyar are recorded in the district. All these erosional surfaces are capped by residual laterite. The Dodabetta Surface includes landform as high peaks, structural hills, rocky escarpment with or without soil cover around which prominent drainage is developed (**Fig.4.2**). A number of active and old landslide scars are observed in the project area. The Oatacamund and Coonoor surfaces include gentle mounds with soil cover, stream meanderings and gentle smoothening of the hills. The latter abuts against the former at many places, with break in the slope.

Geo-hydrologically the area forms a part of the Cauvery River Basin, having two sub-basins i.e. Moyar sub-basin in the north and Bhavani sub basin in the south. Ground water occurs under discontinuous, unconfined to semi confined aquifers, down to 200m b.g.l. in the charnockitic terrain and 150m b.g.l. in the gneissic country and is restricted to weathered mantle and fractures. The specific yield from charnockitic terrain is <1ltr/second and in the gneissic country the yield varies from <1ltr/second to 1-5ltrs/second. The quality of ground water is generally good for both irrigation and domestic purposes.

The Nilgiri district exposes charnockite group of rocks with associated migmatites and Bhavani Group along with the enclaves of Satyamangalam Schist Complex.

The Regional Stratigraphic Succession is given in Table below-

Table : Stratigraphy of the Project Area

Lithology	Group	Age
Laterite	-	Cainozoic
Felsite	Younger intrusive	Proterozoic
Dolerite/Gabbro	Basic intrusives	
Fissile hornblende biotite gneiss	Bhavani Group (Peninsular Gneissic Complex)	
Ultramafic complex	Satyamangalam Schist Complex	Archaean
Quartz-sericite or mica schist Banded magnetite quartzite		
Hornblende biotite gneiss	Migmatite complex	
Pyroxene granulite	Charnockite Group	
Charnockite/Magnetite quartzite		

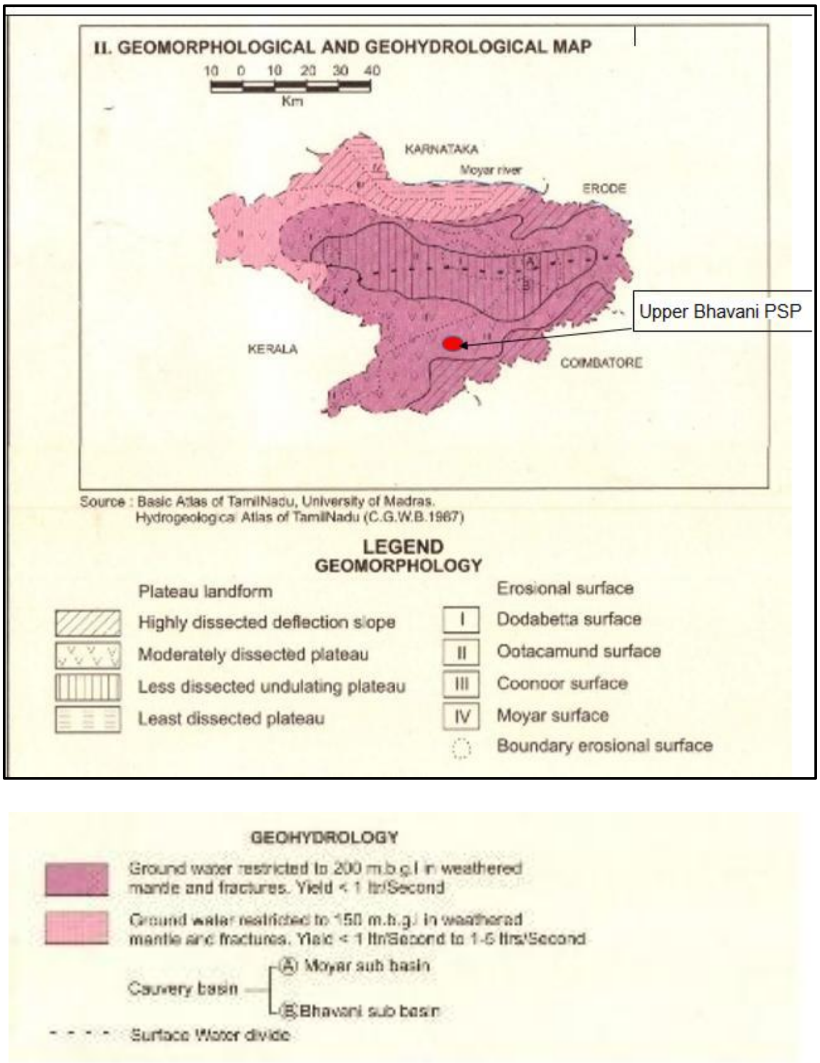


Figure 4:2 Geomorphology-Nilgiris

4.8 Regional Geology

Geologically the Nilgiris belong to the Archean complex of the Peninsular India, composed of pre-Cambrian, mainly metamorphic rocks (gneisses, charnockite, and crystalline schist). Due to continental drift of the “Indian shield” which until late Jurassic times was a part of the ancient Gondwanaland - and coincident with the Himalayan orogenesis during the Cretaceous and Tertiary periods, geo-tectonic movements in the southern Deccan resulted in its fragmentation and in vertical dislocations along fault lines that are oriented in three main directions, viz. NNW-SSE, NE-SW and E-W, and that recur in the morphological boundaries as well as in the courses of many streams and rivers of the Nilgiris (**Fig.4.3**).

The triangular-shaped mountain block of the Nilgiris was formed by the phase-wise uplifting of a portion of the Deccan. This horst is almost entirely made up of garnetiferous, acid hypersthene charnockite (Holland 1900) traversed by dolerite and quartzite dykes at places. It is slightly tilted towards the east - like the entire Deccan Plateau - and has a base size of roughly 2400 square kilometres, of which 40 % rises above 1800 meters in the central Nilgiris Plateau (which falls off steeply on all sides). It culminates in Doda Betta, or “big mountain” with 2636 m elevation above mean sea level.

The rock formations are broadly classified as follows:

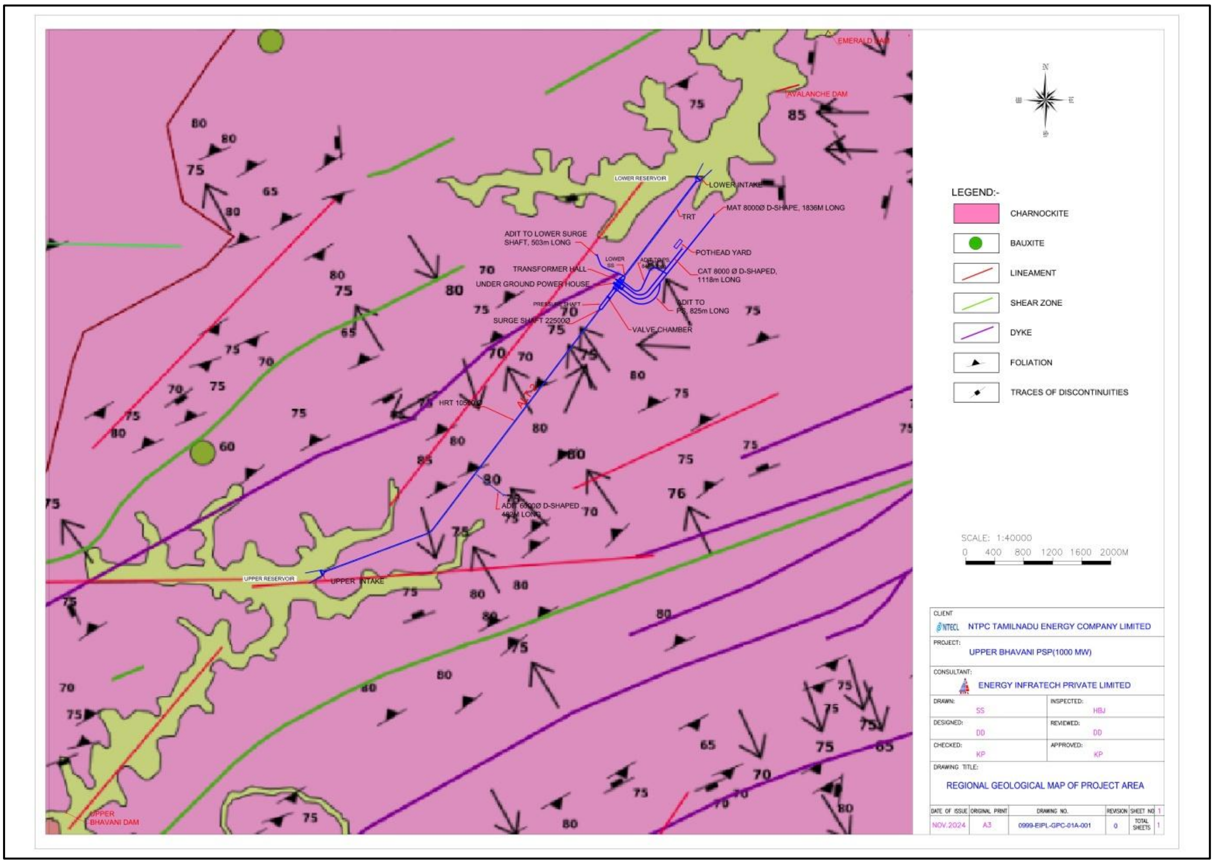


Figure 4:3 Regional Geological Map (Source: NGDR, GSI)

4.9 Various rock types encountered in The Nilgiris area

4.9.1 Charnockite

These rocks constitute the bulk of the Nilgiris massif. Acid and basic varieties are recognized, with acid varieties comprising garnetiferous and non-garnetiferous types. The garnetiferous acid charnockite occupies a major part of the south-central portion of the Nilgiri hills and includes lenses and bands of basic and non – garnetiferous acid charnockite. The strike of the banding foliation of the garnetiferous acid charnockite is in NE – S W direction (65° and above) northerly or southerly dips in the southern part. The rock is light bluish grey in colour, medium to coarse grained and consists of blush- grey coloured quartz, feldspar, garnet and pyroxene as the essential minerals. The non-garnetiferous acid charnockite occurs on the southern portions of the Nilgiri massif. The Strike of foliation in these areas is ENE – WSW with steep (65° and above) northerly or southerly dips.

Basic charnockite occurs as large, roughly lenticular outcrops, enclosed within the garnetiferous acid charnockite and weathers into large spheroidal boulders. It is a dark grey, medium to coarse grained rock consisting of pyroxene and plagioclase feldspar as the main constituents (**Fig.4.4**).

4.9.2 Pyroxene-granulite:

Pyroxene-granulite, generally showing spheroidal weathering, occurs as narrow concordant bands within the charnockite on the south-eastern slopes of the Hill. The rock is light to dark grey in colour, medium to coarse grained with granulitic texture and consists of pyroxene and feldspar as the main constituents.

The concordant relationship of the pyroxene-granulite with the charnockite is suggestive, that it may be older to the latter, and represents the metamorphosed equivalent of the older basic intrusive in the area.

4.9.3 Biotite Gneiss

The rocks are confined only to the low-lying country north of Mudumalai and Mettupalayam, on the foothills of Nilgiris. The rocks are well-foliated, and the strike of foliation varies from ENE. - WSW to ESE. - WNW. with steep dips in a southerly direction.

4.9.4 Hornblende granulite

This is invariably associated with Magnetite quartzite in the Wayanad part of the Nilgiris ranges. Fibrous Amphibole, Hornblende, Garnet, Quartz and Magnetite are the minerals making up the rocks.

4.9.5 Pegmatite Vein Quartz:

Pegmatite occurs as small bodies with sharp contacts, conformable to the attitude of acid charnockite. The pegmatites are pink to white in colour, coarse grained and granitic, consisting essentially of quartz and pinkish feldspar. Vein quartz occurs parallel to and across the trend of the acid charnockite. The vein quartz is white in colour.

4.9.6 Dolerite Dykes:

The Dolerite dykes traversing charnockite are roughly parallel or oblique to the foliation. The dykes are dark in colour, medium to fine grained.

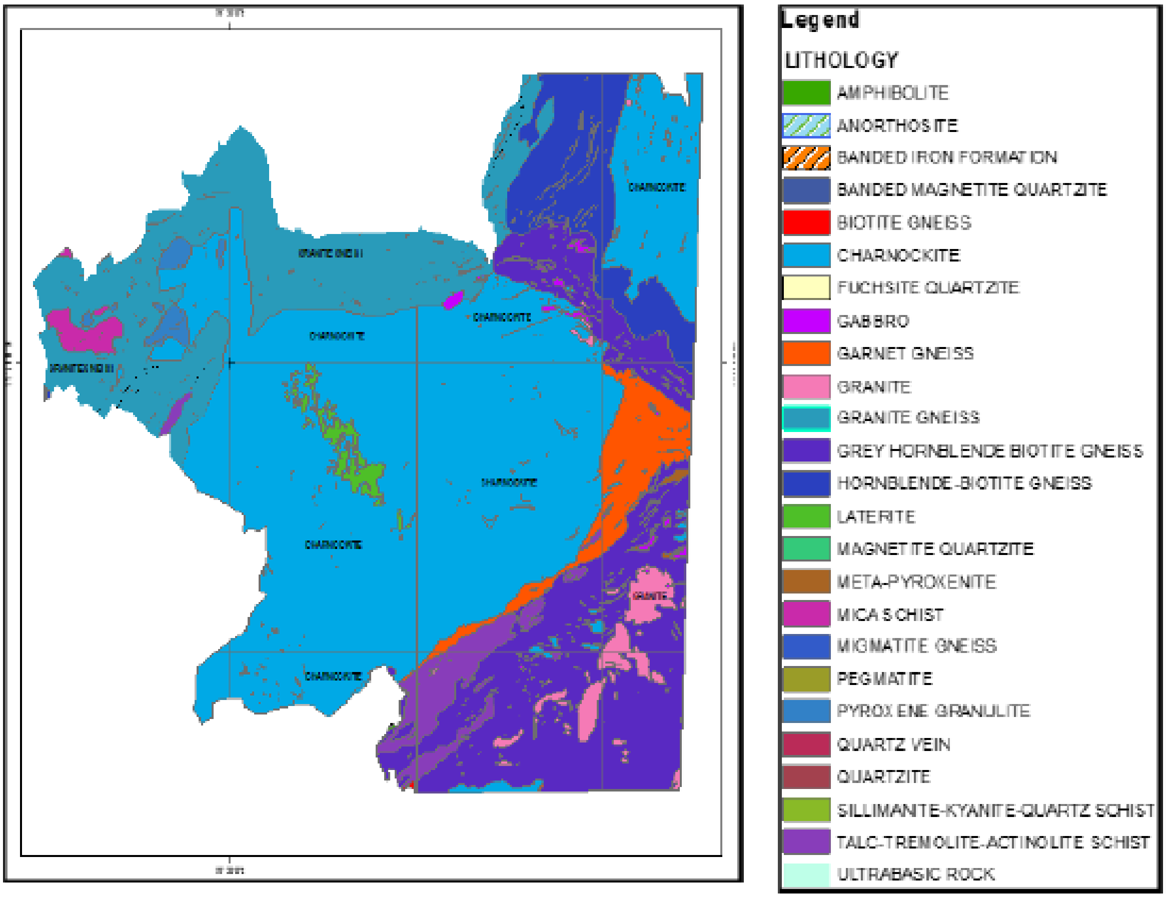


Figure 4:4 Lithology-The Nilgiris

4.9.7 Laterite and Soils:

Laterite is found as capping the summits of charnockite hills of the Nilgiri plateau, at different elevations ranging from 2133 to 2412m above the msl. They occur principally on flat surfaces or gentle slopes in a well-drained area. It is confined to the top portions of the hills, whereas on slopes, detrital laterite is encountered in boulder mass. The laterite is both aluminous and ferruginous.

Aluminous laterite caps occupy the well-drained, topographically higher elevations. It is moderately hard; light rose to red in colour.

Ferruginous Laterite is seen in poorly drained areas. It is moderately hard, rusty to dark brown in colour, heavier and lamellar.

4.10 Geotechnical Characteristics -The Nilgiris

As per GSI Geotechnical map the area has been divided into three engineering geological provinces based on the bearing capacity/compressive strength, and foundation characteristics of the rocks. The bearing capacity/compressive strength of rocks vary from medium (500 kg/cm^2) to high (1000 - 2000 kg/cm^2) and foundation characteristics vary from good to very good. The charnockite terrain in the south with intrusive has high bearing capacity/compressive strength and very good foundation characteristics. The gneissic terrain in the north has medium bearing capacity/compressive strength and good foundation characteristics. The metasedimentary/ metavolcanic terrain has moderately high bearing capacity/compressive strength and good foundation characteristic. Thirteen major river valley dam/ barrage projects are shown in the map. The waters of the minor streams as well as major rivers of the Nilgiris plateau are used for hydroelectric schemes such as Kundah, Mukurthi, Pykara, and Moyar at several places.

4.11 Project Geology:

Light yellow to reddish-brown coloured laterite soils mixed with angular rock fragments occurs as colluvium in the project area. These are derived in situ from the weathering of the underlying rocks i.e. charnockite. The charnockite show extensive in-situ weathering ranging from brownish to buff coloured clay in the road sections and at times along the hill slopes mixed with debris material. Small pockets of siliceous white clays are also noticed. Three set of joints (foliation +2 set) are observed in the massive charnockite. The strike of foliation for charnockite is N065°-075°E-S065°-075°W with steep dips (70° and above) in a south-easterly or north-westerly direction. The either side dipping of foliation indicates presence of regional folding. The geomorphic features in the project area are crest lines, escarpments, conical hills, landslide scars, slopes with natural vegetation, plantations, settlements and barren rocks, barren valleys, filled valleys etc.

The brief component wise geology shall be as follows.

4.11.1 Intake:

The proposed project envisages construction of one intake each at upper & lower reservoir area. The proposed intake size considered to be 23.8m height & 79.0m width with trashracks. Mainly colluvium material composed of lateritic soil mixed with boulders of different sizes is observed during traverses in the lower intake area. Weathered rock mass is observed along the reservoir periphery in the upper intake area. However, medium strong to strong charnockite rock belonging to Class-II/III category is observed during field traverses which is anticipated to provide acceptable foundation grade rock for intake structure. In the lower reservoir area, scanty outcrops are observed during field traverse and strong to medium strong charnockite rock is expected to be present at depths (**Fig.4.5**). Mainly charockite with its variants are expected to be present in the proposed tunnel grade. It is estimated that at about 60.0m high excavation is required to place the upper intake and at about 95.0m high excavation is required for the lower intake. The depth of overburden and nature of rock mass condition will be further explored through sub-surface investigations during DPR stage and intake portal location will be placed accordingly. Necessary slope protection studies will be carried out during DPR stage investigations.

Figure 4:5 Charnockite rock outcrop near the lower intake area

4.11.2 Head Race Tunnel (HRT):

The head race tunnel is 5.38km long and 10.5m finished dia is proposed to carry the water from upper existing reservoir to the pressure shafts. The cover above the head race tunnel varied from 59.0m to 215.0m. A no of nalas is cross cutting the tunnel where seepage may occur during excavation. However, considering the medium strong to strong charnockite rock mass with sufficient cover such chances are remote. The rock mass in the area varies from Class-I/II/III category. Deterioration of the rock mass is expected below nala bed/weak bands where Class-IV rock types may be encountered. The proposed tunnel is aligned along N037°E-S037°W. The average strike of foliation in the area is N 065°- 075°E – S 065°-075°W with steep dips (75° and above) towards N155°-N165° along with J1: N340°-010° dipping sub vertical towards N070°-100°, J2: N130°-N310° dipping 82° towards southerly and J3:N070°E-S070° dipping 12°-15° towards N160° & N340° as observed during preliminary geological mapping. The proposed tunnel is making angles of 18°-28° with foliation, 37° with J1, 97° with J2 & 33° with J3 which seems favourable. However, detailed study through sub-surface explorations will be carried out during DPR stage investigations. Detail investigations along with wedge analysis will be carried out at DPR stage for realistic assessment of rock mass condition and to decipher actual support system.

4.11.3 Surge Shaft:

One open to sky circular 22.5m dia and 90.0m high surge shaft has been proposed for the project. At about 15.0m high excavation is required for the proposed surge shaft. The depth of overburden will be confirmed through sub-surface explorations through drill holes during DPR stage. Mainly strong to medium strong Charnockite is either exposed or present below thin (5-8m) colluvium. The overall rock mass belonging to Class-I/II/III category. However, deterioration of the rock mass may be encountered at places in weak bands. Detail investigations along with wedge analysis will be carried out at DPR stage for realistic assessment of rock mass condition and to decipher actual support system.

4.11.4 Pressure Shafts:

Two Nos of circular Pressure shafts of 623m length and each 6.6M dia along with bifurcation into four no's of unit pressure shafts (each 4.6m dia) at about 60m long is envisaged to be constructed. Mainly strong to medium strong Charnockite is either exposed or present below thin (5-8m) colluvium. The overall rock mass belonging to Class-I/II/III category. The proposed tunnel is aligned along N037°E-S037°W. The average strike of foliation in the area is N 065°- 075°E – S 065°-075°W with steep dips (75° and above) towards N155°-N165° along with J1: N340°-010° dipping sub vertical towards N070°-100°, J2: N130°-N310° dipping 82° towards southerly and J3:N070°E-S070° dipping 12°-15° towards N160° & N340° as observed during preliminary geological mapping. The proposed tunnel is making angles of 18°-28° with foliation, 37° with J1, 97° with J2 & 33° with J3 which seems favourable. Detail investigations along with wedge analysis will be carried out at DPR stage for realistic assessment of rock mass condition and to decipher actual support system.

4.11.5 Powerhouse (Underground):

An underground Powerhouse of size 144m (L)x24m(W)x47.2m (H) with transformer cavern (124.0m (L)X 18.5m (W) X 30.0m(H) have been contemplated. Mainly very strong to strong Charnockite rock belonging to Class I/II category is expected to be present in a major part of the cavern barring few weak zones caused due to selective weathering (**Fig.4.6**). In addition, presence of dolerite dyke cannot be ruled out in some stretches. The average strike of foliation in the area is N 065°- 075°E – S065°-075°W with steep dips (75° and above) towards N155°-N165° along with J1 :N340°-010° dipping sub vertical towards N070°-S100°, J2: N090°E-S090°W dipping 82° towards north and J3:N070°E-S070°W dipping 12°-15° towards N160° & N340° as observed during preliminary geological mapping. The alignment of the powerhouse is N127°E-S127°W. Therefore, the L-axis of the foliation is making an angle of 52° with the strike of the foliation which is favourable considering the stress field. It is also to mention that the discontinuities are also favourable as they intersect the L-axis of underground powerhouse at 53°, 37° and 57°respectively. The powerhouse appears to be favourable considering the very strong to strong rock and high rock cover i.e. 262.0m. Detailed geological investigations through sub-surface geological exploration along with wedge analysis will be carried out at DPR stage for realistic assessment of rock mass condition. Further optimization of the orientation of the powerhouse will be carried out during DPR stage through in-situ test if required.

Figure 4:6 Charnockite rock outcrop near the proposed powerhouse area

4.11.6 Down Surge Shaft:

One underground surge shaft has been proposed at the tail race tunnel for the project. The cover above the surge shaft is 122.0m with adequate lateral rock participation. Mainly strong to medium strong Charnockite is either exposed or present below thin (5-8m) colluvium. The depth of overburden will be confirmed through sub-surface explorations through drill holes during DPR stage. The overall rockfaces belong to Class-I/II/III category. However, deterioration of the rock mass may be encountered at places in weak bands. Detail investigations along with wedge analysis will be carried out at DPR stage for realistic assessment of rock mass condition and to decipher actual support system.

4.11.7 Tail race Tunnel:

The proposed project envisages construction of one 1.8km long 10.5m dia tail race tunnel to discharge the water to the lower reservoir. Mainly colluvium material composed of lateritic soil mixed with boulders of different sizes is observed during traverses in the lower intake area. Medium strong to strong charnockite rock belonging to Class-II/III category is observed during field traverses which form the tunnelling media. In the lower reservoir area, scanty outcrops are observed during field traverses and strong to medium strong charnockite rock is expected to be present at depths. Prima facie, very strong to strong Charockite with its variants are expected to be present in the proposed tunnel grade. The cover along the tunnel varies from 95.0m to 247.0m The proposed tunnel is aligned along N037°E-S037°W. The average strike of foliation in the area is N 065°- 075°E – S 065°-075°W with steep dips (75° and above) towards N155°-N165° along with J1: N340°-010° dipping sub vertical towards N070°-100°, J2: N130°-N310° dipping 82° towards southerly and J3:N070°E-S070° dipping 12°-15° towards N160° & N340° as observed during preliminary geological mapping. The proposed tunnel is making angles of 18°-28° with foliation, 37° with J1, 97° with J2 & 33° with J3 which seems favourable. The depth of overburden and nature of rock mass condition will be further explored through sub-surface investigations during DPR stage and intake portal location will be placed accordingly. Necessary slope protection studies will be carried out during DPR stage investigations.

4.11.8 Main Access Tunnel & Construction adits:

The requirement of construction of main Access Tunnel & constructions adits has been explored and finalization of the tunnel portal will be fixed based on detail geological mapping & sub-surface exploration during DPR stage. Prima facie very strong to strong charnockite rock belonging to class I/II category will form the tunnelling media. However, patches of weak zones caused by selective weathering may be encountered at places which will be explored through sub-surface investigations during DPR stage.

4.12 Seismicity:

The Project is located within the Archean age Group of rocks in Nilgiri Plateau. The area falls under seismic zone -II/III as per Seismic Zonation Map of India and further seismic Damage risk zones map of Tamilnadu Several escarpments (lineaments) are represented by master joints trending NNE-SSW, NNW-SSE and E-W. Zones of brecciations along ENE-WSW direction are reported in the charnockite terrain on either side of the Bhavani Reservoir area (**Fig.4.7 & 4.8**).

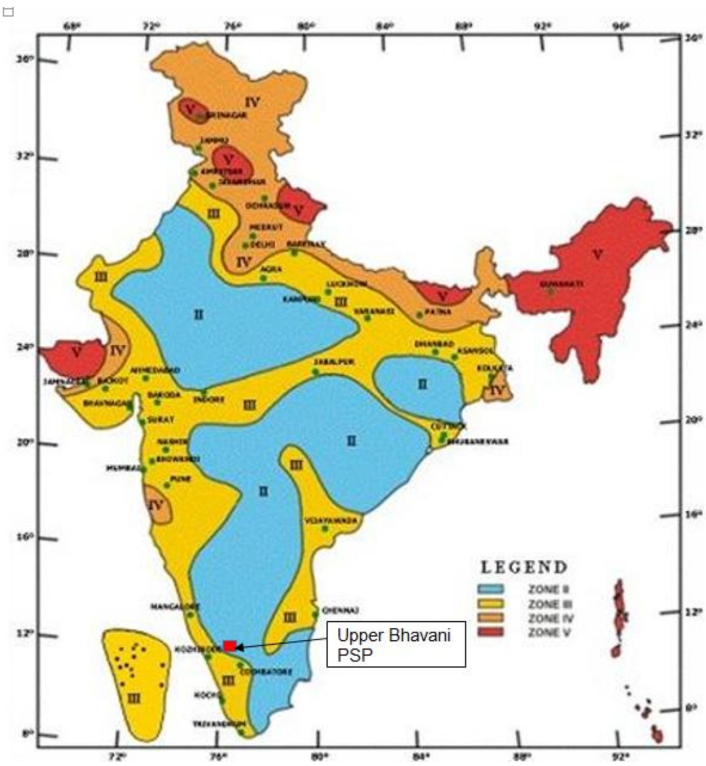


Figure 4:7 Seismic Zonation Map of India

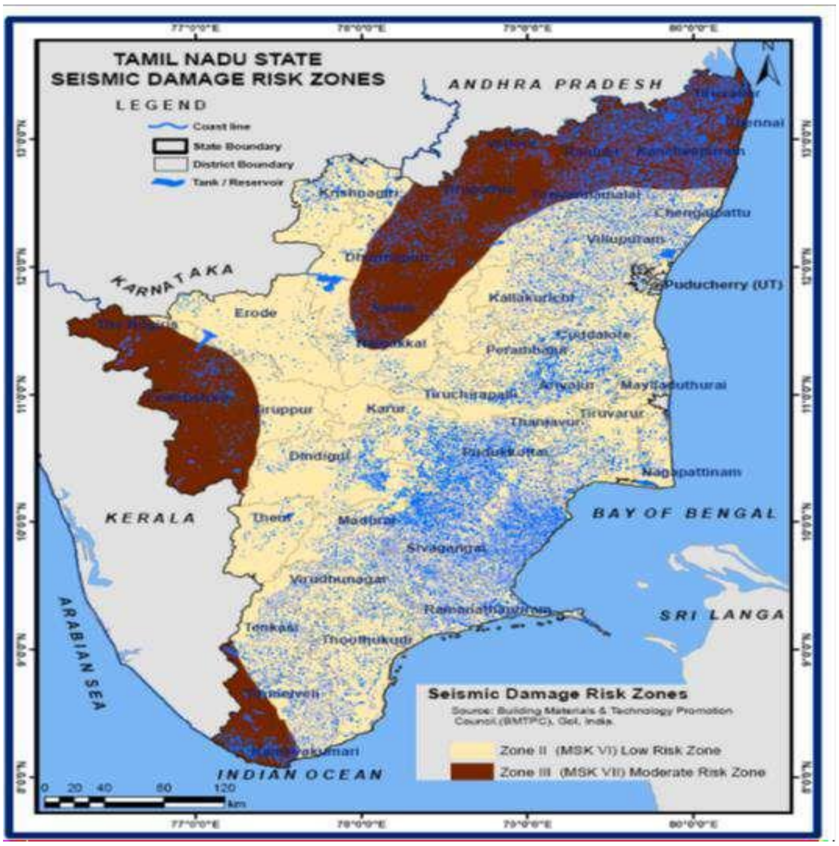


Figure 4:8 Seismic Damage Risk Zones of Tamilnadu

Historical record says that no high magnitude earthquake greater than 5 MS have been reported in the area except a historical magnitude of 6.0 have been reported in Coimbatore area, Tamil Nadu in the year 1900. Both deterministic and probabilistic approaches for evaluation of design ground motion for a project site require a comprehensive database on past earthquakes in the region of the project which will be carried out during DPR stage

The seismic status of the region has been provided in the Seism tectonic Atlas of India and its environs in SEISAT-38 **(Fig 4.9)**

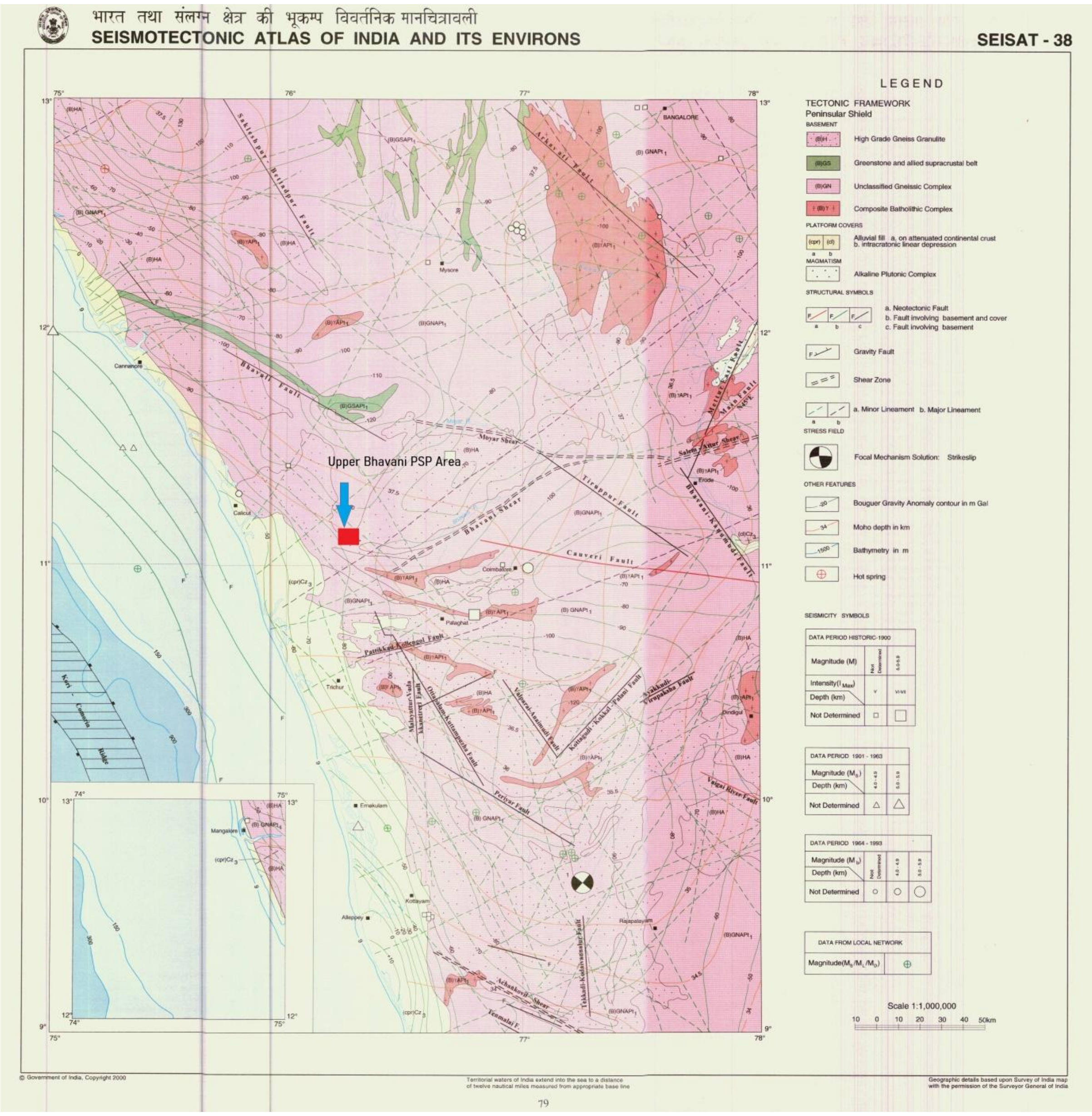


Figure 4:9 Seismo-tectonic map showing project location- SEISAT-38

4.13 Construction Material

A number of dolerite dykes are present in and around the project area. Fresh dolerite dyke can be utilized as coarse aggregate of concrete. Again, fresh charnockite can be used as coarse aggregate if found suitable. The excavated material from the tunnels, underground structures to be sorted, crushed, tested, and utilized for the construction activities.

4.13.1 Coarse Aggregate

It is being considered in PFR stage that 50% of the excavated muck shall be utilized for construction, if found suitable after requisite testing during DPR stage for establishing materials suitability and its viable quantities for wearing and non-wearing surfaces.

4.13.2 Fine Aggregate

The sand deposit of Rivers is present in the vicinity of the project to be tested for being utilized as fine aggregates. However suitable quarry sites shall be finalized during DPR stage after carrying out required testing for their suitability. The suitability of crushed material from rock shall also be checked as fine aggregate by requisite testing during DPR stage.

Notwithstanding the availability of suitable rock mass (charnockite) in the project feature, Nilgiris district being a special respect with no mining activity where either special permission shall be required within boundaries of the project for quarrying, or the material must be procured from the nearby area. During the site visit a pair of large quarry has been identified near Karamadai area at about 82km from the project area, where mining is going on and material can be acquired if found suitable (**Fig.4.10**). The rock type in the area is charnockite in nature. The adequacy and suitability of the construction material will be carried out during DPR Stage.

Figure 4:10 Quarry Area Near Kadamalai Area

4.14 Existing Land Use Pattern

The Land Use Land Cover Map of the Nilgiris district is appended in the figure below. The percentage of land lying under different land use land cover zones are tabulated below. It can be seen from the table that most % of land classification is categorized under the forest zone followed by Range land.

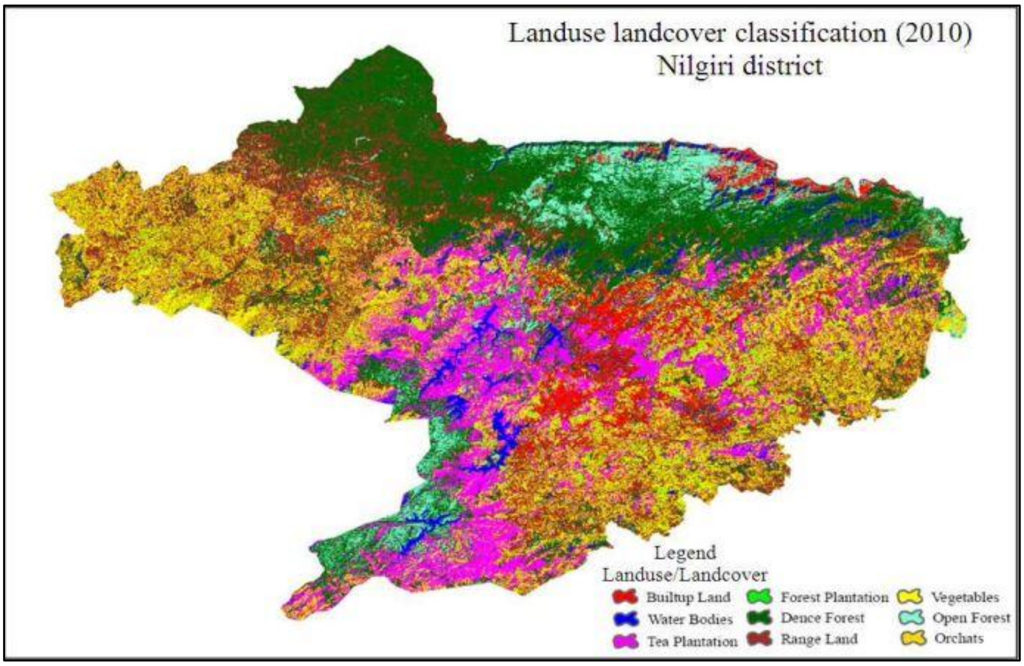


Figure 4:11 LULC Map of the Nilgiris district.

4.15 Soil Classification

The soils of Nilgiris district can be broadly classified into 5 major soil types viz., Lateritic soil, Red sandy soil, red loam, black soil, alluvial and colluvial soil. Major part of the district covered by lateritic soil. The red sandy soil and red loams are occurring as small patches. Black soil is developed in the valleys, where the water logging is also common during the monsoon period. The alluvial and colluvial soils are seen along the Valleys and major river courses respectively.

4.16 Climatic Data from secondary sources

For the Rainfall series analysis, the base rainfall data series has been obtained through IMD data base at 0.25^0 x 0.25^0 grid and finally Voronoi Polygon analysis has been done to obtain the rainfall series for the catchment. The base temperature data for the catchment belonging to a particular region has been downloaded IMD Website. The base file for the catchment analysis i.e. DEM (Digital elevation Model) file has been obtained through CartoSat DEM provided by BHUVAN, NRSC which is powered by ISRO. Additionally, the Dem has also been downloaded from USGS Earth Explorer Website, Powered by NASA.

4.17 Existing Infrastructure

The Nilgiris district is one of the 38 districts in the southern Indian state of Tamil Nadu. Nilgiris (English: Blue Mountains) is the name given to a range of mountains spread across the borders among the states of Tamil Nadu, Karnataka and Kerala. The Nilgiris Hills are part of a larger mountain chain known as the Western Ghats. Their highest point is the mountain of Dodda Betta, height 2,637 m. The district is contained mainly within the Nilgiris Mountains range. The administrative headquarters is located at Ooty (Ootacamund or Udhagamandalam). The district is bounded by Coimbatore to the south, Erode to the east, and Chamarajanagar district of Karnataka and Wayanad district of Kerala to the north. As it is located at the junction of three states, namely, Tamil Nadu, Kerala, and Karnataka, significant Malayali and Kannadiga populations reside in the district. Nilgiris district is known for natural mines of Gold, which is also seen in the other parts of Nilgiris Biosphere Reserve extended in the neighbouring states of Karnataka and Kerala too.

Economy

The Nilgiris district is noted for the natural beauty is a heaven on earth remains to be the main tourist attraction in all times. The inflow of tourists is high enough to get an annual bid amount of around Rs.5 crores from tollgates entry points in Nilgiris. The proportionate sales generated in the sector of petrol, diesel and engagements in hotel and restaurants run into multiplies of crores. The sales of TANTEA products like Eucaliptus oil, Geranium Oil and other traditional and artistic items certainly have boosted the economic prosperity of Nilgiris. The government is getting a respectable amount of tax collection through the tourism in Nilgiris. All the aforesaid sources of income have a vibrant effect and impact on the economic development of the Nilgiris.

Rural Electrification

Overall, 100 per cent of the hamlets are covered under rural electrification through the various schemes implemented by the state and central government.

4.18 Social Infrastructure

Before there are 2 revenue divisions and 4 blocks in the district. There are 55 revenue villages in the district. Nilgiris district is classified into West Coast Plains and Hilly Zones (under Zone XII) among the 13 agro-climatic zones in the country. Normally, cold climate prevails over the district. The district is one of the famous tourist destinations in the country mainly for its weather, greenery, enchanting beauty of the hills and tea gardens. It is also one of the industrially backward districts. Agriculture continues to be the prime activity of the rural population of the district with around 25% of the workforce directly dependent on it. The gross cropped area and the net sown area were 74928 ha during 2013-14. The net sown area constituted 29.5% of the total geographical area of 2.54 lakh ha. It is pertinent to mention here that around 56% of the geographical area is occupied by forests. Out of the net sown area, 99.6% is rainfed and a meagre 0.5% is irrigated. The major perennial crops raised in the district are Tea, Coffee and Pepper. Annual Crops such as Carrot, Potato, Banana, Cardamom and Ginger are also raised in this hilly district. The entire economy of the district revolves around Tea, Coffee and hilly vegetables. Around 93% of the land holdings are small and marginal covering approximately over 36% of the cultivated area.

Health

There are one district headquarters government hospital, five taluk hospitals, 38 primary health centres, 194 health sub-centres, and five plague circles in the district.

Banking

The district has 138 branches (all under semi-urban / rural category) of Scheduled Commercial Banks including Public Sector Banks, Private Sector Bank and New-Generation banks. 2 branches of Pallavan Grama Bank 22 branches of Nilgiris DCCB, TNSCARDB and TAICO. 74 PACS are also operating in the district. Repco Bank also has its presence in the district.

Literacy and Education

The district has literacy rate of 85% higher than the state and the country average of 80% and 74% respectively. The Nilgiris district has one of the highest sex ratios in the state as per 2011 census which is around 1042. The sex ratio from 1991 to 2011 follows an increasing trend as per the report of District Diagnostics Study, Tamil Nadu.

Tourism

The Nilgiris, the paradise of holiday makers, nestles among hills at a point where the Eastern Ghats meet the Western Ghats and Sprawls among a beautiful plateau. One can see many profiles of natures each with distinct grandeur. This hill station attracts visitors from all over the country in all seasons. Ooty has been receiving on an average about 2.5 Million tourists annually. An average 20,000 to 25,000 visitors to Ooty every day. There are more than 3111643 tourist arrivals in the district. The Nilgiris district receives about 6.4 % of the total domestic tourist arrivals in Tamil Nadu. Arrival of foreign tourists is high compared to the other districts. There is a tremendous growth in tourist arrivals in Nilgiris district. Nilgiris district shows the average annual growth rate of about 4 %.

CHAPTER 5. PLANNING BRIEF

5.1 Planning Brief

The project planning phase of the pumped storage project facilities aims to establish a comprehensive roadmap for the successful execution of the project. This chapter outlines the key objectives, strategies and methodologies adopted to ensure efficient planning and execution. It provides a comprehensive overview of the strategies and methodologies adopted to plan and execute the Pumped Storage project. By integrating land use planning, construction material planning, infrastructure assessment, and amenity provision, the project aims to achieve its objectives while minimizing environmental impact and maximizing stakeholder value.

5.2 Project Planning

The proper selection of construction methodology and project scheduling followed by strict monitoring during construction are the major tools available in the hands of developers for ensuring completion of projects within scheduled time and cost. The project implementation schedule of the scheme is divided into five stages as follows:

1. Preparation of DPR
2. Clearances and Permits
3. Pre-Construction Activities
4. Construction Activities
5. Testing and Commissioning

Project Development (viz., preparation of DPR, clearances, EIA study etc.) and pre-construction activities (detailed egg. model studies, access road construction, construction of colonies, water/power lines etc.,) are considered in a total time span of 18 months. The total construction of the project including testing and commissioning is proposed to be completed within 60 months (including 18 months of pre-construction/ pre-development).

5.3 Land Use Planning

Based on topographical, hydrological, and environmental criteria, land identification has been done considering the land availability, topography, its nature, etc. Details of the proposed project facilities and approach roads are planned, and the land requirement is shown in **Figure below-**

Figure 5:1 Project Facilities and Approach Roads.

The Land required for construction of project components has been estimated to be about 91.75 ha. In addition to above, the extent of land involved for Right of Way (RoW) for Transmission Lines has been estimated to be about 250 ha. The forest land involved in the project shall be applied for diversion as per the guidelines issued under the Forest (Conservation) Act, 1980, Non-Forest (Government) land shall be applied from competent authority of the State Govt as per the laid-out process, whereas the private land involved in the project will be purchased directly from respective land owners through private negotiations on land price and completed on a mutual agreement.

The details of the land requirement for various project facilities and approach roads are given in Table 5-2 below. Layout and locations of various project facilities and approach roads is presented drawing volume.

Figure 5:2 Details of Land Requirements.

S. No.	Component	Forest Land (ha)			Non-Forest/ Private Land (ha)	Total Land (ha)
		Surface	Underground	Total		
1	**Upper Intake**	3.00	0.00	3.00	0.00	3.00
2	**Head Race Tunnel**	0.00	6.19	6.19	0.00	6.19
3	**HRT Adit**	0.30	0.69	0.99	0.00	0.99
4	**Surge Shaft**	0.1	0.00	0.10	0.00	0.10
5	**Pressure Shaft**	0.00	1.23	1.23	0.00	1.23
6	**Branch PS**	0.00	1.04	1.04	0.00	1.04
7	**Adit to PS**	0.00	0.58	0.58	0.00	0.58
8	**Valve House**	0.80	0.00	0.80	0.00	0.80
9	**Pothead Yard**	0.03	0.00	0.03	0.00	0.03
10	**Powerhouse Complex including transformer cavern**	0.00	1.45	1.45	0.00	1.45
11	**MAT & Other Adits**					
	MAT	0.20	1.34	1.54	0.00	1.54
	Adit to Upstream PS	0.00	0.22	0.22	0.00	0.22
	Adit to Downstream PS	0.00	0.39	0.39	0.00	0.39
	Adit to TRT	0.00	0.17	0.17	0.00	0.17
	Adit - MAT to Transformer Cavern	0.00	0.09	0.09	0.00	0.09
	Ventilation tunnel	0.00	0.32	0.32	0.00	0.32
11	**CAT**	0.30	0.47	0.77	0.00	0.77
12	**Adit to Upper SS**	0.00	0.11	0.11	0.00	0.11
13	**Adit to Lower SS Top**	0.06	0.41	0.47	0.00	0.47
14	**Lower SS**	0.00	0.051	0.05	0.00	0.05
15	**Tailrace tunnel**	0.00	1.91	1.91	0.00	1.91
16	**Lower intake**	3.00	0.00	3.00	0.00	3.00
17	**Proposed Approach Road**					
	Lower Intake (R1)	2.40	0.00	2.40	0.00	2.40
	Upper Intake (R2)	12.00	0.00	12.00	0.00	12.00
	U/S Surge Shaft (R3)	9.00	0.00	9.00	0.00	9.00
	Valve House (R4)	3.00	0.00	3.00	0.00	3.00
	HRT Adit Portal (R5)	1.50	0.00	1.50	0.00	1.50
	Inter connecting roads in facility area	4.00	0.00	4.00	4.00	8.00
18	**Infrastructure Facility Area**					
	Contractor Facility	0.00	0.00	0.00	12.00	12.00
	Muck Disposal Area	0.00	0.00	0.00	42.00	42.00
	Fabrication Yard	0.00	0.00	0.00	5.00	5.00
	Crusher and storage Area	0.00	0.00	0.00	20.00	20.00

	B &M Plan Area	0.00	0.00	0.00	15.00	15.00
	Stockyard	0.00	0.00	0.00	10.00	10.00
	Office and Allied Facilities	0.00	0.00	0.00	3.50	3.50
19	**Right of Way (ROW) for Transmission Line**	250.00	0.00	250.00	0.00	250.00
20	**Green Belt Development**	0.00	0.00	0.00	15.00	15.00
	Total	**289.69**	**16.66**	**306.35**	**126.50**	**432.85**

5.4 Construction Material Planning with quantities

The Upper Bhavani PSP envisages the following construction material requirements:

S.No.	Details	Unit	
1.	Excavation quantity	m^3	3799853
2.	Concreting quantity	m^3	226026
3.	Steel Reinforcements	MT	9702
4.	Penstock Steel Liner Requirements	MT	9554

The total excavation quantity is assessed at a 3799853 cum. The works for these quantities shall be carried out through appropriate machinery viz., wagon drills, drill jumbos, excavators, loaders and dump trucks of adequate capacity, etc. These shall be further assessed in detail during the DPR stage.

The excavated quantities shall be partially utilized in the construction works for the underground concrete works, depending upon the reusability of the material in construction after thorough testing of the excavated muck. This shall be established during the DPR stage through appropriate geotechnical investigations and testing. The remaining muck material shall be disposed-off to their identified muck disposal sites.

Material for the concrete works shall comprise of cement and aggregates (both coarse and fine). The aggregates for the concrete, as stated above, shall be partially derived from the excavated material from both surface and underground works. The remaining material for aggregates shall be obtained from nearby quarry area (Karamadai Quarry area) located at about 82km from the project site.

Penstock Steel liner material shall be considered as ASTM 517 Gr F grade material or its equivalent. About 9554 MT material of steel liner is required as the diameter of the penstock is quite large with 6.6 m for the main shaft liners and 4.6m diameter for the branch manifolds. The plate materials shall vary in thicknesses from 12mm thick to 20mm thick for the straight ferrule. Each ferrule shall be 2.5m in length. Appropriate plate bending machines of adequate capacity, welding machines, NDT test equipment etc., shall be made available for this job along with the skilled manpower.

5.5 Assessment of Infrastructure Demand (Physical & Social)

Pumped storage projects should be sited away from high seismic zones and flood-prone areas due to the potential risks to the safety and stability of the associated infrastructure. These risks include ground shaking, displacement, and liquefaction, which can lead to infrastructure failure and negative environmental impacts, endangering human settlements and causing property damage. To ensure safety, selecting suitable sites for pumped storage projects requires thorough consideration of seismic and flood hazards, including geotechnical and seismic hazard assessments, flood hazard assessments, and consultation with local communities and stakeholders.

The project primarily falls within the Kundah Reserved Forest area, meaning that predominantly forest land is involved in the construction. However, a detailed demarcation of the land will be assessed during the Detailed Project Report (DPR) stage.

Construction facilities, such as the batching and mixing (B&M) plant area, crusher area, and penstock fabrication area, are proposed to be located away from existing villages. All approach and access roads to these site locations will be constructed.

5.6 Amenities/Facilities

Developmental (Pre-construction) works and main Construction activities require arrangements for basic amenities (viz., potable water, drinking water, toilets / bathrooms, reliable power source, connectivity etc.), to be provided in the project areas for the workforce, colony set-up both temporary and permanent. These are discussed in Chapter VI of this PFR. However, these shall be further studied in detail during the DPR stage and addressed appropriately.

CHAPTER 6. PROPOSED INFRASTRUCTURE

6.1 Industrial Area & Non-Industrial Area

Project site office(s) shall be constructed in the vicinity of the Project Area. The project site office(s) shall house the office of Construction managers and their support staff. Suitable plan shall be prepared for this office considering the number of the personnel required for the efficient and effective support, monitoring, and control of the construction activities. Based on manpower requirement, accommodation and its area have been assessed for Owners and Contractors. Since the Project is of long duration, appropriate, though limited, family accommodation is also proposed for those who would like to keep their families at Project site. Field hostels/ Bachelor's accommodation is proposed for remaining executives, non-executives, and workers. Following provision is being kept for construction of offices and residential building at various sites:

- Permanent office building
- Temporary office building.
- Temporary site office
- Permanent residential building
- Temporary residential building

6.2 Green Belt

The forest loss and the loss of vegetal cover due to various project appurtenances has been compensated as a part of compensatory afforestation. However, in addition to compensatory afforestation, it is proposed to develop greenbelt around the perimeter of various project appurtenances, selected stretches along the periphery of water spread area, roads, etc. The Indian Forest Conservation Act (1980) stipulates: if non-forest land is not available, compensatory forest plantations are to be established on degraded forest lands, which must be twice the forest area affected or lost, and if non-forest land is available, compensatory forest are to be raised over an area equivalent to the forest area affected or lost. As per the applicable forest laws in vogue, the cost of compensatory afforestation, the NPV for environment loss as well as cost of trees are also payable as per the applicable norms.

6.3 Social Infrastructure

Social infrastructure includes the construction and maintenance of facilities that support social services. These can include healthcare (medical facilities and ancillary infrastructure), education (schools, universities, and student accommodation), and housing.

Medical Facilities- During the construction phase migratory population will be present and spread along construction sites in labour colonies. One part of the impact is on local population due to migrant population and second part is medical needs of migrant population putting stress on existing limited medical resources in the area. Another dimension which needs to be kept in mind while planning medical services from the project side is the risk of accidents during project construction and emergency medical services to respond to such incidents. Working at heights, underground operations, blasting using explosives, use of heavy machinery and equipment with moving parts, movement of large number of vehicles carrying men and material, etc. increase the risk of accidents at workplace. Despite training and use of safety gears, possibilities of accidents at workplace cannot be ruled out and require preparedness. It is recommended that the developer provide the following medical facility, directly or through contractor, to ensure safe and healthy operations during the entire construction phase. This also helps in minimizing the dependence of labour population on the existing medical facility. Fully equipped ambulances need to be procured to provide pre-hospital care to accident victims. The ambulances should always be stationed near major construction sites or the sites where risky operations are taking place. Typically, the ambulance should have equipment such as Fornoflex Chair/COT, Ventilator, Vacuum Splint Kit (Adult), Scoops Stretcher, Oxygen Cylinder with accessories, Resuscitation Bag (Adult), Suction Pump, Spine Board, siren/beacon, Emergency Light with public address system, Wireless equipment, additional battery, First Aid bag, BP instrument, stethoscope, etc. and with trained manpower. First-aid posts need to be established near proposed construction sites and colony areas to take care of basic medical needs of the workers at major construction sites. The first aid post will have essential medicines including dressing materials, stretcher, wheelchair, ORS packets, etc. The first aid post can be housed in the temporarily erected structure and should be managed by one Health Assistant and assisted by one dresser/first aid attendant. Visiting doctors can attend First Aid post regularly every day at a fixed time.

6.4 Connectivity

The following new roads have been proposed to approach various components of the project:

Approach to Lower Stockyard area:

Approach Road to Stockyard (Near Main Access Tunnel), a new road of about 0.6 km m length would be required to be constructed.

Approach to Contractor facilities:

In order to access MAT, Fabrication yard, B&M , Crusher, Muck disposal and Contractor facility, a new road of about 2.5 km length would be required to be constructed.

Approach to Lower Intake area:

In order to access lower intake area location, a new road of about 0.95 km length would be required to be constructed.

Approach to Upper Intake area:

A new road of about 4.1 km length would be required to be constructed to reach the lower Intake site.

Approach Road to Surge Shaft

A new road of approximately 2.9 km will be constructed to access the surge shaft.

Approach Road to Valve Houses

A road of about 0.85 km will be built to provide access to the valve houses.

Approach Road to CAT

A road of about 0.2 km will be built to provide access to the valve houses.

Thus, a total of about 12.2 km long road would need to be constructed to approach all locations of the project.

6.5 Drinking water management and water requirement

Water for construction and for drinking will be drawn from the existing reservoir. Water tanks of adequate capacity will be constructed at each work location and water will be pumped from river to water tanks. Water tanks of adequate capacity shall be provided/constructed for batching plant, curing of concrete and various construction activities. Water for project colony and camps shall be drawn from existing reservoir. Water shall be treated for portable use for supply to the colony and camps. Water tank will also be provided at camps & colony considering the total manpower and average daily consumption. Suitable distribution network shall be developed in the camps and colony for supply of water.

6.6 Wastewater Generation, Treatment and Management details along with Water Balance Diagram

During construction phase the wastewater (sewage) coming from temporary arrangements like offices, labour camp sheds, canteens etc., and impact due to soil erosion during monsoon period may cause surface water pollution. Some of the control measures adopted for controlling water pollution are establishing septic tanks followed by soak pits to treat the domestic waste water generated from the offices, canteens, labour camp sheds etc.

A. Sewage from Construction sites due to worker's camps.

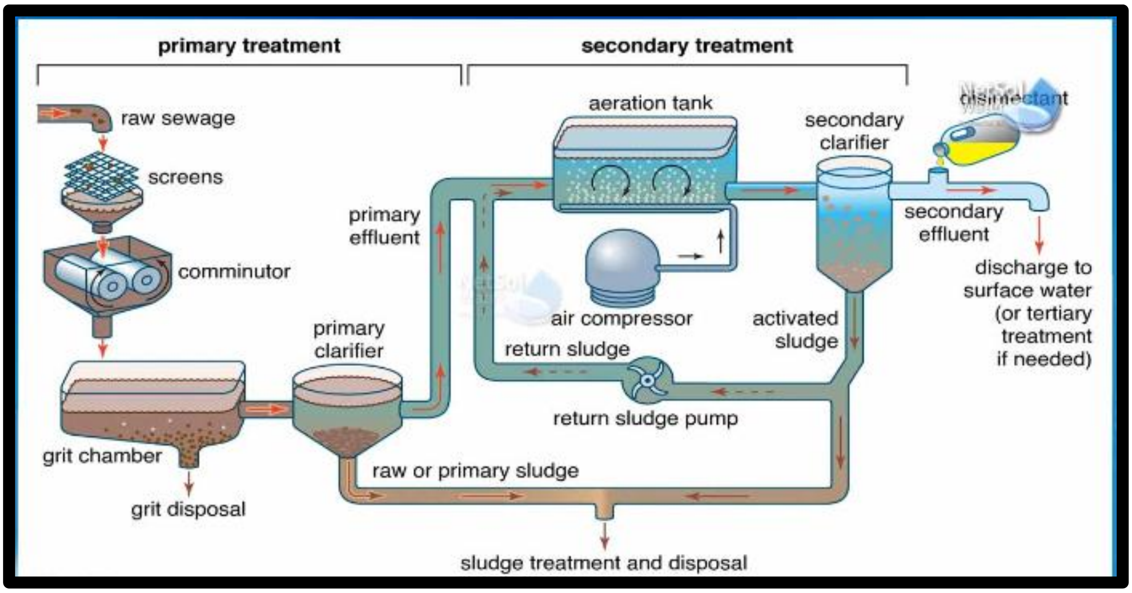
The disposal of untreated sewage can lead to water pollution, resulting in increase in coliforms and other various pathogens, which can lead to incidence of water borne diseases. Therefore, appropriate measures must be taken to check such disposal into the natural water bodies. To avoid any deterioration in water quality due to disposal of untreated sewage from labour camps, appropriate sewage treatment facilities shall be constructed in the labour camps.

B. Effluent from construction plants and workshops

Discharge of untreated wastewater will adversely affect the water quality of receiving water body. Turbidity and oil & grease levels will increase substantially in small tributaries, especially, in lean season. To minimize the impact, such effluent needs to be treated in situ before discharge to any water body or for land application.

C. Disposal of Muck

The major impact on the water quality arises when the muck is disposed along the river bank. The project authorities have identified suitable muck disposal sites which are not located near the river banks. The provision of adequate water supplies for both the construction purposes and the use of personnel shall be done. To avoid any deterioration in water quality and subsequent changes in the aquatic biota, a proper sewage disposal system in and around various labour colonies and industrial belts shall be planned to check the discharge of untreated waste. The stages of primary and secondary treatment applicable for domestic and Industrial sewage are depicted through the diagrammatic representation below.



6.7 Waste Management

The territorial area of the project complex/ colony shall be responsible for the implementation of the provision of Solid Wastes Management. Facilities for collection, conveyance and disposal of solid waste shall be developed. Any solid waste generated in the project complex/ project colony/ labour colony, shall be managed, and handled appropriately. Various aspects of solid waste management include:

- **Reuse/Recycling -** Project proponent/contractor will explore opportunity to recycle the waste generated at the project site, in this context project will identify authorized vendors for recycling or disposal of used batteries, used oil and used oil filters (as these are hazardous waste). Biodegradable waste will be treated in Organic Waste Composter (OWC) and the manure generated will be distributed to local villagers.

● **Storage/Segregation** - In the labour colony, provisions shall be made to separately store the degradable and non-degradable solid waste. Two different coloured bins will be supplied to each labour family, who will segregate the waste generated in their household. Green and Biodegradable waste is to be deposited in one container and non-biodegradable waste in another container. In case of canteens and community kitchens also, two different coloured dust bins will be used for separately storing the biodegradable and non-biodegradable waste generated. A sustained awareness programme will be conducted to educate workers about the segregation of degradable and biodegradable wastes.

● **Collection and Transportation -** The project authorities shall prohibit littering of solid wastes in the area under their control by resorting to following collection practices:

- **i.** Organizing house-to-house collection of solid waste on regular pre-informed timing by using mini trucks.
- **ii.** Collected waste from residential areas shall be transferred to community bin by suitable vehicle
- **iii.** Collection of wastes from office complexes and commercial areas
- **iv.** Construction / demolition wastes or debris shall be separately collected and disposed of.

Solid waste collected shall be disposed-off at a common storage point. Trucks will be commissioned to collect the solid waste and dispose the same at sites designated for disposal of solid waste.

● **Disposal-** The solid waste will be transported for disposal at the designated landfill sites. The landfill shall have impervious clay at the bottom most layers. The second layer shall be impervious liner (Geo membrane), third layer will be of sand, after that well compacted solid waste is to be put over the sand, then again, a layer of clay, finally a layer of soil. Vegetation shall be grown on the topmost layers. It will give a good aesthetic view of landfill.

Since a lot of material comes in plastic wrapping, specific attention ought to be given to the plastic waste as this could have long term impacts on the environment and on the project itself.

6.8 Power Requirement and Source during Construction & Operation Phase, D.G. set details

To meet the construction power requirement, it is proposed to draw power from already existing 11kV lines of TANGEDCO in the vicinity of the project area. A new 2-3 MVA, 11 kV Substation and Distribution network shall be developed to feed various Construction machinery to be deployed during the construction phase of the project and also to meet the illumination requirement during the night-time in the project temporary/permanent colonies. As an emergency backup, a Sikent type

Diesel Power Station is proposed to be installed with an aggregate capacity of 2500 kVA to cater to the construction power requirement of the project with due consideration of prevailing environmental norms.

A network of 11kV and 415 V Lines shall be developed to feed the power requirements at various work sites such as Upper Reservoir &Intake, Pressure Shaft, Powerhouse, Lower Reservoir &Intake, etc.

Considering the preferred EPC mode of contracting for the works, it is also. envisaged that the Contractor shall be solely responsible for arranging the Construction Power for various construction machinery based on their Construction planning and schedule.

CHAPTER 7. REHABILITATION AND RESETTLEMENT (R&R) PLAN

7.1 Introduction

Resettlement and Rehabilitation Plan (R&R) is an important aspect to be considered for project implementation. The project components are envisaged to be located in forest land and are required to be acquired for development of upper, lower reservoir and ancillary infrastructure facilities. It is important to provide fair and just compensation to the affected families whose land may be acquired and to make adequate provisions for such affected persons for their rehabilitation and resettlement in accordance with the latest Resettlement Act including its amendments.

The Land requirement for the Project may be categorized as Forest, Non-Forest and Private Land.

7.2 Land Requirement

The land required for the construction of project components has been estimated to be about 223.24 ha. In addition to this, the extent of land involved for the Right of Way (RoW) for transmission lines has been estimated to be about 250 ha. Therefore, the total land required for the project is approximately 432.85 ha. The forest land involved in the project will be applied for diversion in accordance with the guidelines issued under the Forest (Conservation) Act, 1980. Non-forest (government) land will be obtained from the competent authority of the State Government as per the established process, while private land involved in the project will be purchased directly from the respective landowners through private negotiations on the land price, finalized through mutual agreement. The details of the various project facilities and approach roads are presented in Table 7-1 below.

Table 7-1 Details of various project facilities

S. No.	Component	Forest Land (ha)			Non-Forest/ Private Land (ha)	Total Land (ha)
		Surface	Underground	Total		
1	**Upper Intake**	3.00	0.00	3.00	0.00	3.00
2	**Head Race Tunnel**	0.00	6.19	6.19	0.00	6.19
3	**HRT Adit**	0.30	0.69	0.99	0.00	0.99
4	**Surge Shaft**	0.1	0.00	0.10	0.00	0.10
5	**Pressure Shaft**	0.00	1.23	1.23	0.00	1.23
6	**Branch PS**	0.00	1.04	1.04	0.00	1.04
7	**Adit to PS**	0.00	0.58	0.58	0.00	0.58
8	**Valve House**	0.80	0.00	0.80	0.00	0.80
9	**Pothead Yard**	0.03	0.00	0.03	0.00	0.03
10	**Powerhouse Complex including transformer cavern**	0.00	1.45	1.45	0.00	1.45
11	**MAT & Other Adits**					
	MAT	0.20	1.34	1.54	0.00	1.54
	Adit to Upstream PS	0.00	0.22	0.22	0.00	0.22

	Adit to Downstream PS	0.00	0.39	0.39	0.00	0.39
	Adit to TRT	0.00	0.17	0.17	0.00	0.17
	Adit - MAT to Transformer Cavern	0.00	0.09	0.09	0.00	0.09
	Ventilation tunnel	0.00	0.32	0.32	0.00	0.32
11	**CAT**	0.30	0.47	0.77	0.00	0.77
12	**Adit to Upper SS**	0.00	0.11	0.11	0.00	0.11
13	**Adit to Lower SS Top**	0.06	0.41	0.47	0.00	0.47
14	**Lower SS**	0.00	0.051	0.05	0.00	0.05
15	**Tailrace tunnel**	0.00	1.91	1.91	0.00	1.91
16	**Lower intake**	3.00	0.00	3.00	0.00	3.00
17	**Proposed Approach Road**					
	Lower Intake (R1)	2.40	0.00	2.40	0.00	2.40
	Upper Intake (R2)	12.00	0.00	12.00	0.00	12.00
	U/S Surge Shaft (R3)	9.00	0.00	9.00	0.00	9.00
	Valve House (R4)	3.00	0.00	3.00	0.00	3.00
	HRT Adit Portal (R5)	1.50	0.00	1.50	0.00	1.50
	Inter connecting roads in facility area	4.00	0.00	4.00	4.00	8.00
18	**Infrastructure Facility Area**					
	Contractor Facility	0.00	0.00	0.00	12.00	12.00
	Muck Disposal Area	0.00	0.00	0.00	42.00	42.00
	Fabrication Yard	0.00	0.00	0.00	5.00	5.00
	Crusher and storage Area	0.00	0.00	0.00	20.00	20.00
	B &M Plan Area	0.00	0.00	0.00	15.00	15.00
	Stockyard	0.00	0.00	0.00	10.00	10.00
	Office and Allied Facilities	0.00	0.00	0.00	3.50	3.50
19	**Right of Way (ROW) for Transmission Line**	250.00	0.00	250.00	0.00	250.00
20	**Green Belt Development**	0.00	0.00	0.00	15.00	15.00
	Total	**289.69**	**16.66**	**306.35**	**126.50**	**473.24**

7.3 Purchase of Private Land

The private land required for the project, if any is proposed to be purchased through a voluntary sale with a willing buyer and seller process. The process is undertaken through direct negotiations between landowners and Project Proponent with no obligation to the seller. The landowners are informed in advance, and each landowner negotiates the price of land as part of land take.

The some of the steps in the land procurement process shall include the following:

- Identification of land required for the project and due diligence of land through verification of Revenue Records.
- Undertake consultation and negotiations with the land-owners about the project and private land requirement.
- After negotiations on all aspects of purchase the voluntary sale of land is completed through a registered sale agreement.

7.4 R&R Plan - Policy to be adopted (Central/ State)

During the EIA/EMP Studies, Socio-economic survey for the Project Affected Families (PAFs) shall be carried out. Based on the findings of the socio-economic studies and survey, an appropriate R&R compensation package as per the provisions of Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement, 2013 (RFCTLARR, 2013) and respective State R&R Policy in vogue would be required to be formulated. If the total private land purchased exceeds the specified limits notified by the relevant rules of concerned State Government policy, the provisions of RFCTLARR, 2013 shall be applicable to the proposed Project.

The project primarily falls in Kundah Reserved Forest area so mainly forest land is involved in the construction of project. However, the detailed demarcation of land shall be assessed during DPR stage. Necessary clearances will be obtained during DPR stage for construction & operation of project. However, there are no major R&R issues likely to occur in the project.

CHAPTER 8. PROJECT SCHEDULE

8.1 General

The project components of the 1000 MW Upper Bhavani pumped storage project comprise the following,

- Existing Upper Reservoir and dam
- Upper Intake
- HRT & Pressure shaft (steel lined)
- Upstream Surge Shaft
- Underground Powerhouse and Transformer Cavern/GIS
- Downstream Surge Shaft
- Tailrace Tunnel
- TRT Intake/Lower Intake
- Adits
- Existing Lower Reservoir & Dam

8.2 Schedule

The project implementation schedule of the scheme is divided in to five stages as follows:

1. Preparation of DPR

2. Clearances and Permits

3. Pre-Construction Activities

4. Construction Activities

5. Testing and Commissioning

The preparation of Detailed Project Report includes Topographic Survey and Geotechnical Investigation, the Clearances and Permits includes Forest Land clearance, Environmental clearances, DPR approval and other permits and licenses activities. These activities are planned to be completed within 18 months of the development phase.

Pre-Construction activity involves construction infrastructure works like access road to project site and construction of building for accommodating men and materials which shall part of the development phase. Award of tender for detailed engineering works, model studies, preparation of tender documents for Civil, H&M and E&M works, floating of tenders, bid evaluation, award of work and mobilization to site. All these activities are planned to be completed in a time-period 12 months.

The main Construction activities will be taken up once Pre-Construction activities are completed. The Construction work for Civil, H&M and E&M will be carried out either by EPC contract or based on item rate contract. Quality control of civil, H&M and E&M works will be taken care through internal / external agencies. Based on the specific work of the project, equipment planning will be taken up and state-of-the-art equipment will be deployed at site during execution. It is proposed to get the Civil, Hydro-Mechanical and Electro-mechanical works done through reputed contractors who have been doing similar kinds of works. The Testing and Commissioning including water filling in the system will be taken up once the construction works are completed. The total construction of the project including testing and commissioning is proposed to be completed within **48 months**.

The total project shall be completed by **60 months**. Broad details of the project construction schedule are presented in Drawings volume.

CHAPTER 9. PROJECT COST ESTIMATES

9.1 General

The Upper Bhavani Pumped Storage Project is proposed with an installed capacity of 1000 MW (4 x 250 MW) and is located in the Nilgiris district of Tamil Nadu. It is designed as an open-loop scheme that utilizes storage between existing reservoirs, facilitating energy generation through the storage capacity between the proposed reservoirs. The scheme aims to meet peak demand for approximately 6.0 hours, with an estimated annual energy generation of 2080.50 MU. Off-peak pumping hours are estimated at 6.58 hours, with an annual pumping energy of 2507.87 MU. The cycle efficiency of the project is projected to be 82.96%.

9.2 Basis of project cost

The cost of the project has been worked out based on preliminary designs and drawings as annexed to the present report.

The Civil Cost Estimates of the project has been prepared as per "Guidelines for preparation of estimates for the river valley projects" issued by CWC and Indian Standard IS: 4877 "Guide for Preparation of Estimate for River Valley Projects".

Rates of major items and GST of works have been prepared based on SOR of Tamil Nadu and local pre-vailing rates are adopted for the items not covered by the SOR wherever quantification has not been possible at the present stage of design, lump sum provisions have been made based on judgement/ experience of other projects.

The estimates of the Hydro Power Scheme have been divided under the following account heads:

I. Direct Cost

II. Works

A – Preliminary

B – Land

C – Works

J - Power Plant Civil Works

K – Buildings

M - Plantation

O - Miscellaneous

P - Maintenance during construction

Q - Special T&P R

R - Communication

X - Environment and Ecology

Y - Losses on stock

S – Power Plant Electrical Works

Total I-Works

Establishment

Tools and Plants

Suspense

Receipt and Recoveries

Total (A) - Direct Cost

Indirect Cost

Capitalization of Abatement of Land Revenue Audit and Account Charges

Total (B) - Indirect Cost

Total Cost (A+B)

9.3 Project cost of civil and HM

The project cost estimate is done based on the preliminary design and drawings, "Guidelines for Preparation of Project Estimates for River Valley Projects.

The project cost is likely to undergo changes like additional cost to be incurred due to changes at the detailed design stage especially as a result of hydraulic model studies, variation in the geo-technical parameters which cannot be adjudged precisely at this stage. The cost to completion is also liable to change depending upon the final construction drawings, prevailing rates of materials, equipment & manpower during execution, terms of loan, phasing of expenditure. The detailed Hard Cost for Civil, Hydro mechanical and Electromechanical Works is given below.

Table-27: Abstract of Project Cost

ABSTRACT OF COST			
S. No.	**Item Code**	**ITEM**	**Cost (INR) In Crore**
A		**CIVIL AND HM WORKS:**	
1		**DIRECT CHARGES**	
i		**I-WORKS**	
	A	**Preliminary & Pre-Operative Expenses**	26.55
	B	**Cost of Land**	24.82
	C	**Civil Works**	
		Reservoir Excavation and Embankment Filling	15.00
		C Works (Sub Total)	**15.00**
	J	**Power Plant Civil Works**	
	J1	Upper Power Intake	199.23
	J2	Lower Intake	223.44
	J3	Pressure Shafts including Steel Liner	327.31

	J4	Adits	82.73
	J5	Surge Shaft (Upper and Lower)	166.65
	J6	Main Access Tunnel (MAT)	103.34
	J7	Cable Access Tunnel (CAT)	41.63
	J8	Power House	415.31
	J9	HRT and TRT	551.29
		J Works (Sub Total)	**2110.94**
	K	Buildings	29.83
	M	Land Development and Plantation	0.50
	O	Miscellaneous	22.45
	P	Maintenance during Construction @ 1% of C, J, K	22.00
	Q	Special Tools & Plants	2.01
	R	Communication	72.00
	X	Environment and Ecology	5.00
	Y	Losses on stock @ 0.25% of C, J, K	5.39
		TOTAL I-WORKS	**2336.48**
ii		Establishment Charges, 6% of (I-B) Work	1.49
iii		Tools & Plants	2.00
iv		Receipts and Recoveries (-)	-1.82
		TOTAL DIRECT CHARGES	**2338.15**
2		**INDIRECT CHARGES**	
i		Capitalisation of Abatement of Land revenue (5% of cost of culturable Land)	0.62
ii		Audit & Accounts etc. (0.5% of I-Works)	11.68
		TOTAL INDIRECT CHARGES	**13.00**
B		**HM COST**	**49.77**
		TOTAL CIVIL AND HM WORKS	**2401.00**
C		**ELECTRICAL WORKS:**	**1750.00**
		TRANSMISSION LINE	**159.00**
		TOTAL COST (CIVIL & HM + ELECTRICAL)- INR (Crore)	**4310.00**

DIRECT CHARGES:

I – Works: INR (233648 Lakhs)

Under this heading, provision has been made for various components of the Project.

A-Preliminary: INR (2655 Lakhs)

This head covers the provision for the Surveys and investigations like topographical survey, geological/geotechnical investigations. Construction material availability, route survey, Construction of accessroads/paths for investigations, model studies, Consultancy fees for development of project already executed or to be executed in the post DPR phase. This section also covers the consultation fee towards the preparation of bid documents, detailed design & engineering etc. The provision is about 2% of I- works.

B-Land: INR (2482 Lakhs)

The provision under this head covers Acquisition of Land; Rehabilitation & Resettlement including compensation for property, Interest charges, Solatium charges, demarcation & measurement charges, etc. have been made as per actuals. A provision of 2482 Lakhs has been made under this head.

C– Works: INR (1500Lakhs)

This head has provisions for various components of Head works, viz, River diversion works, Diversion tunnel, Coffer Dams, Upper and Lower Dam.

J – Power Plant Civil Works: INR (211094 Lakhs)

This head has provisions for various project components viz., Intake Structure, Headrace Tunnel, Tail Race Tunnel, Pressure Shaft, Upstream and Downstream surge shaft, Powerhouse and Transformer Cavern, Civil works of switchyard.

K – Buildings: INR (2983 Lakhs)

Buildings, both residential and non-residential have been provided under this head. Under the permanent category only those structures have been included, which will be subsequently utilized for the running and maintenance of the project utilities. The costs are worked out on the plinth area basis for the type of construction involved as per prevailing rates in project area.

M – Plantation: INR (50 Lakhs)

The provision under this head covers the plantation programme including Gardens etc. required for beautification as considered necessary downstream of Dam and appurtenances around Power House and other important structures. The provision is made on a lump sum basis.

O– Miscellaneous: INR (2245 Lakhs)

The provision under this head covers the capital cost & maintenance of Electrification, Water supply, Sewage disposal and drainage works, Recreation, Medical, Firefighting equipment's, Inspection vehicles, School bus, Pay van, visit of dignitaries, welfare works etc. A provision of around 2% C-Works, J- Power plant civil works and K-Buildings is made under this head.

P– Maintenance during Construction: INR (2200 Lakhs)

The provision under this head covers the cost of maintenance of all works during the construction period. A provision of 1% of the total cost under the heads of C-Works, J-Power House Civil Works and R-Communication is considered.

Q– Special Tools and Plant: INR (201 Lakhs)

It is assumed that the work will be carried through Contracts and accordingly provision for general purpose equipment and inspection vehicle only has been made as per CEA/CWC guidelines.

R– Communication: INR (7200 Lakhs)

The cost is based on the construction cost of road and bridges in similar areas as of the Project. The road length / location of bridges proposed in this head are tentative and may change during actual construction. Provision under this head covers the cost of construction of main approach roads to all project components, easing of bends/filling deeps/ strengthening of bridges and roads within project area, widening, strengthening of existing road.

X– Environment and Ecology: INR (500 Lakhs)

Provision under this head covers the cost of the Bio-diversity Conservation, Creation of Green Belt, and Restoration of Construction Area, Catchment Area Treatment and Compensatory Afforestation and the Rehabilitation & Resettlement plan. A lump sum provision has been kept.

Y- Losses on stock: INR (539 Lakhs)

The provision is made at 0.25% of the total cost of C-Works, J-Power Plant Civil Works and K-Buildings only as per the CEA Guidelines.

II– Establishment: INR (149 Lakhs)

Provision for establishment has been made by evaluating 6% of I works less land figures.

III– Tools and Plants: INR (200 Lakhs)

This provision is distinct from that under Q-Special T&P and is meant to cover cost of survey instruments, camp equipment and other small tools and plants. A provision of 2 cr. has been kept as per CWC guideline.

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.

V– Receipts and Recoveries: INR (-182 Lakhs)

Under this head, provision has been made for estimated recoveries by way of resale or transfer temporary buildings and special tools & plants.

Indirect charges: INR (1300 lakhs)

As per the guideline, a provision of 0.5% of the cost of I-Works has been made towards capitalized values of abatement of land revenue (@ 5% of cost of cultivable land and audit & accounts charges).

Hydro mechanical works: INR (4977 lakhs)

This includes cost of all Gates and Valves.

Electrical works and generating plant including transmission line

S-INR (175000 Lakhs)

The cost of generating plant and equipment is based on sources from India. The prices of auxiliary equipment and services are based on prevailing market prices/costs at other ongoing or commissioned projects in India.

Transmission line

S-INR (15900 Lakhs)

One Double Circuit Quad Moose Transmission line from Upper Bhavani PSP to the 400 KV Parali Pooling Station (Near Pillur Reservoir). Distance of this line is approximately 50 KM.

9.4 Project cost

The total project cost has been estimated at **5005.52 Crore** for year 2023-24 price level as given below:

S.No.	Component	Cost In Crores.
1	Civil and HM Works	2401.0
2	E&M Works and Transmission Line	1909.0
3	**Total Hard Cost**	**4310.0**
4	**IDC**	**683.25**
5	**FC**	**12.26**
	Total Project Cost (INR Cr.)	**5005.52**

9.5 Economic viability of the project

Introduction

The economic viability of a project is determined by comparison with the alternative sources at the same place considering therein all elements such as cost of transmission/distribution etc., In isolated areas, it is often compared with diesel or other sources available for affording the same energy bene - fits. The economics of the project, where existing facilities are required to meet the demand could be computed considering system requirements and the ability of the scheme for meeting the demand. When a Pumped Storage Project is to be developed by an independent producer, he would have to consider returns to him considering all factors such as rate offered to him by third party sale or captive consumption or sale to state electricity boards, any subsidies, and concessions available for funding or otherwise.

The economic and financial evaluation of the Upper Bhavani Pumped Storage Project has been considered as per the standard guidelines issued by Central Electricity Authority and the norms laid down by the Central Electricity Regulatory Commission (CERC) for Hydro and pumped storage projects have been kept in view in this regard.

Generation benefits from the project

In a year, the planned power generation will be 2080.50 MU considering the rate of 6.0 hours per day for 365 days operation @ 95% machine availability.

Annual requirement of pumping energy

The input energy required for pumping works out to 2507.87 MU for 365 days operation @ 95% machine availability

Means of finance

The project is proposed to be financed through term loans from financial institutions and balance through equity participation or as in practice of Organisation.

Equity: The developer will provide Equity to the extent of 30% of the project cost based on the estimates by adopting a debt equity ratio of 70:30 is borrowed.

Debt: The term loan to the extent of 70% of the project cost (including IDC) based on the estimates will be obtained from the financial institutions.

The analysis has been carried out, considering the rate of interest equal to 10.0% on term loan. As per CERC Terms & Conditions of Tariff Regulations, 2019 (in short, "**CERC Tariff Regulations 2019**"), re- payment of loan has been considered equal to the depreciation allowed under these regulations, until the loan is fully paid off. Interest charges have been computed based on average of opening and closing amount of outstanding loan.

9.6 Phasing of expenditure

The project is scheduled to be completed in **60 months** in all respects including preconstruction period of 12 months. The phasing of the expenditure worked out on the basis of proposed construction programme is summarized in Table Below.

Table 28: Abstract of phasing

Yearly Phasing	Capital Expenditure (Crores)
Pre-Construction	
12	175.19
24	525.58
36	875.97
48	1051.16
60	875.97

9.7 Interest during construction

Interest charges during construction would depend on phasing of expenditure. IDC has been considered for scheduled completion period of 60 months excluding preconstruction period. The Interest during Construction period is expected to be Rs. 683.25 Crore.

9.8 Depreciation provision

As per CERC Tariff Regulations 2019, Depreciation is considered @ 5.28% p.a. for the initial period of 14 years and the remaining depreciation to cover 90% depreciable value shall be spread over balance useful life of 40 years of the project.

Land is not a depreciable asset; hence depreciation is to be provided on total cost of the project other than Land.

9.9 Viable tariff

Following assumptions are made to arrive at the viable tariff, as per CERC Tariff Regulations 2019.

- Operation and maintenance (O & M) Expenses @ 3.5% of the project cost, escalated @ 4.77% per annum.
- Interest on working capital has been arrived as follows: The total working capital is arrived at by considering sum of 15.00% on maintenance of spares, 1-month O&M cost, and 45 days Receivables.
- Discount Factor for the purpose of calculating levelized tariff has been considered at 10%
- Interest on loan is taken as 10%
- Return on equity – 17%
- Auxiliary consumption – 1.20%
- Charges for pumping energy –Rs 2.5 per unit; and Free power

Table -29: Levelized tariff

Conversion Cost (Excluding pumping Cost)	
Levelized	RS 4.16 /- per unit
First year	RS 4.71 /- per unit
Conversion Cost (Including pumping Cost of Rs.2.50 per unit)	
Levelized	RS 7.21 /- per unit
First year	RS 7.76 /- per unit

CHAPTER 10. ANALYSIS OF PROPOSAL

10.1 Financial and social benefits with emphasis on benefit to local people including tribal population, if any, in the area

The project area is located in Nilgiris district, Tamilnadu. The development of this pumped storage project will benefit the local population in the vicinity of the project area by way of large-scale employment and infrastructure development in the locality. The benefits in terms of financial and from social perspective, if any, shall be studied during the preparation of DPR and addressed accordingly. The collection of data on the socio-economic status should be delineated within the approximate radius of the main project components such as upper reservoir, lower reservoir, Underground Water conductor system, Adits muck disposal area etc.

Details regarding the socio-economic aspects should include:

- Collection of baseline data on human settlements, health status of the community and existing infrastructure, educational facilities, source of livelihood, job opportunities and surrounding population.
- Information on Agricultural practices, cultural and aesthetical sites.
- Demographic profile, Ethnographic Profile, Economic structure and
- Development profile.
- Impact on socio-cultural and ethnographic aspects due to proposed project.
- List of the entire project affected persons with their names, education, land holdings, other properties, occupation, and source of income, land etc.

Socio-economic profile of the study area covering aspects like demography, occupational pattern, literacy rate, and other important socio-economic indicators of the villages shall also be studied in detail during the DPR stage.

10.2 Conclusion and recommendation

In this proposed 1000 MW Upper Bhavani Pumped Storage project, both the Upper and Lower reservoirs are existing and therefore envisages the construction of underground water conductor system connecting the two existing reservoirs.

Preliminary pre-feasibility study is based on the SRTM data. The inflow data as received from TANGEDCO, and bathymetry maps received from PWD have been utilised. Review of the original PFR carried out by NTPC has also been done and accordingly the various alternative layouts were developed. Out of three alternative layouts studied, Alt-2 was found to be more feasible from technical, geological, economic and environmental considerations.

The original PFR had conceived a water allocation of 8 MCM for the generation of 1000MW plant capacity. However, it is observed that during the lean month of May, with lowering of reservoir being done for supplying water to the lower catchments, there is a need for higher water allocation of about 9 MCM to run the PSP from the original 8 MCM. The higher water allocation is required on account of reduced head for power generation.

Summary of the feasibility study for the selected layout is presented in the following table:

Sl.	Parameter	Results	Remarks
I Technical			
1	Accessibility	Good	Well connected to the railway network & road.
2	Inter-state/ International Issues	Good	No such issue is envisaged
3	Geology	Good	Geology is favourable
4	Water Availability (Initial Filling)	Good	The average annual yield at existing Upper Reservoir (Upper Bhavani) & Lower reservoir (Emerald and Avalanche reservoir) has been estimated to be about 103.7 MCM & 134.70 MCM. Total water required for PSP Operation is 9 MCM.
5	Water Availability (Operation)	Good	Water required for operation of PSP is 9 MCM. Since the water requirement for PSP is not consumptive in nature, there Would be no issue of water availability for operation of the plant.
6	Capacity	1000 MW	Installed capacity has been firmed up based on water availability.
7	Cycle Efficiency	82.96%	Greater than the present benchmark value of 75% for PSP's.
8	L/H Ratio	26.23	Average. It is to be noted that project is envisaged utilizing two existing reservoirs. Hence there is least possibility of reduction of the L/H ratio. Moreover, length of the Water conductor system from Upper Intake to Turbine C/L is 6067.3m and static head between MDDL & Turbine C/L is 320.8m.
9	Dam	Good	Upper & Lower dams are existing. No change is envisaged.
10	Construction Period	Good	5 years (60 Months)
II Commercial			
11	Capital Cost	Good	Rs. 5005.52 Cr including IDC & FC.
12	Levelized Tariff	Good	1.Rs 4.16/kWhr (without pumping cost)

			2. Rs 7.21/kWhr (including pumping cost of Rs 2.5/kWhr) is reasonable as against BESS option.
III Environmental			
13	Land Issues	432.85 ha	Land requirement is reasonable for a Project of such magnitude which includes the land for right of way for the transmission lines also. However, most of the land required for the project comes from the Reserved Forest area and involves land acquisition. Hence, obtaining clearances from MoEF&CC will be involved.
14	R & R Issues	Good	Prima-facie, there are no habitations within the project area and hence no R&R issue Is envisaged.

Based on the above, the following broad conclusions are drawn and recommended:

10.3 Technical Merits of The Project:

- The Upper Bhavani PSP is proposed across the two existing reservoirs namely, Upper Bhavani and Avalanche Reservoirs. The civil structures have been selected after due diligence and based on available data.
- Upper and Lower reservoirs are already existing, and the required quantity of water is estimated to be around 9MCM which is a small quantity in comparison to the water available in the reservoirs. Hence from hydrology point of view, there will be no problem in getting the water for generation for the proposed PSP.
- Based on the preliminary geological studies, it can be concluded that no geological surprise is envisaged in the project. Geological setup is favourable for underground works.
- The land requirement is on the lower side considering the size of the project i.e., 1000 MW.
- Based on preliminary stage studies, it is envisaged that most of the land is Forest land.
- As per preliminary study and discussion, no R&R issue is envisaged.
- The cost is approx. 5.0 Crores/MW, which is very attractive.

In view of the above Upper Bhavani Pumped Storage Project is found techno-economically feasible and recommended for taking up the preparation of DPR.

ANNEXURES

ANNEXURE 1

WATER BUDGET FOR UPPER BHAVANI												WATER BUDGET FOR EMERALD-AVALANCHE COMPLEX RESERVOIR SYSTEM											
Date	Initial Level	Initial Storage	Natural Inflow at Dam site	pumping water from Diversion weir	Total inflow (3+4+5)	Outflow for Kundah PH5	water consumption	Outflow of NTECL PSP of 1000 MW	total outflow (7+8+9+10)	Net balance (inflow-outflow)	final Level at the end	Initial Level	Initial Storage	Natural Inflow at Dam site	Inflow of Proposed Kundah PSP (500 MW)	Inflow of Kundah PH 5	Inflow of NTECL PSP of 1000 MW	Inflow of Kundah PH 6	Total inflow (14+15+16+17+18+19)	Outflow for Kundah PH1	total outflow (19)	Net balance (inflow-outflow)	final Level at the end
	masl	MCM	MCM	MCM	MCM	MCM	MCM	MCM	MCM	MCM	M	MASL	MCM	MCM	MCM	MCM	MCM	MCM	cumec	MCM	MCM	MCM	MCM
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	18	19	20	21	22
Wednesday, June 01, 2016	2254.42	26.49	0.16	0.01	26.65	0.00	0.00	9.00	9.00	17.65	2249.23	1965.38	38.48	0.11	5.18	0.00	9.00	0.00	52.77	0.606	0.61	52.17	1969.18
Thursday, June 02, 2016	2254.39	26.42	0.01	0.00	26.42	0.07	0.06	9.00	9.14	17.29	2249.01	1965.29	38.19	0.07	5.18	0.07	9.00	0.00	52.52	0.443	0.44	52.08	1969.16
Friday, June 03, 2016	2254.27	26.14	-0.02	0.00	26.12	0.23	0.19	9.00	9.43	16.69	2248.65	1965.14	37.71	0.11	5.18	0.23	9.00	0.00	52.24	0.840	0.84	51.40	1968.99
Saturday, June 04, 2016	2254.27	26.14	0.07	0.01	26.22	0.09	0.08	9.00	9.17	17.05	2248.87	1965.23	38.00	0.68	5.18	0.09	9.00	0.00	52.95	0.474	0.47	52.48	1969.26
Sunday, June 05, 2016	2254.27	26.14	0.00	0.00	26.14	0.00	0.00	9.00	9.00	17.14	2248.92	1965.11	37.62	-0.02	5.18	0.00	9.00	0.00	51.77	0.372	0.37	51.40	1968.99
Monday, June 06, 2016	2254.27	26.14	0.00	0.00	26.14	0.00	0.00	9.00	9.00	17.14	2248.92	1964.98	37.23	-0.01	5.18	0.00	9.00	0.00	51.41	0.390	0.39	51.02	1968.89
Tuesday, June 07, 2016	2254.18	25.94	0.00	0.00	25.94	0.20	0.16	9.00	9.36	16.58	2248.58	1964.86	36.85	0.03	5.18	0.20	9.00	0.00	51.26	0.627	0.63	50.63	1968.78
Wednesday, June 08, 2016	2254.09	25.74	-0.02	0.00	25.72	0.17	0.15	9.00	9.32	16.40	2248.47	1964.68	36.27	0.07	5.18	0.17	9.00	0.00	50.70	0.841	0.84	49.86	1968.57
Thursday, June 09, 2016	2254.21	26.01	0.19	0.03	26.23	0.00	0.00	9.00	9.00	17.23	2248.97	1964.56	35.89	0.16	5.18	0.00	9.00	0.00	50.23	0.560	0.56	49.67	1968.52
Friday, June 10, 2016	2254.12	25.80	0.08	0.01	25.90	0.30	0.26	9.00	9.56	16.34	2248.43	1964.50	35.70	0.20	5.18	0.30	9.00	0.00	50.38	0.700	0.70	49.68	1968.52
Saturday, June 11, 2016	2254.00	25.53	0.17	0.02	25.72	0.48	0.40	9.00	9.88	15.84	2248.13	1964.68	36.27	0.87	5.18	0.48	9.00	0.00	51.80	0.754	0.75	51.05	1968.90
Sunday, June 12, 2016	2254.09	25.74	0.15	0.02	25.90	0.00	0.00	9.00	9.00	16.90	2248.77	1964.50	35.70	0.03	5.18	0.00	9.00	0.00	49.91	0.724	0.72	49.18	1968.39
Monday, June 13, 2016	2254.12	25.80	0.04	0.01	25.86	0.00	0.00	9.00	9.00	16.86	2248.75	1964.34	35.22	0.12	5.18	0.00	9.00	0.00	49.52	0.518	0.52	49.00	1968.34
Tuesday, June 14, 2016	2254.18	25.94	0.10	0.01	26.05	0.00	0.00	9.00	9.00	17.05	2248.86	1964.25	34.93	0.07	5.18	0.00	9.00	0.00	49.18	0.364	0.36	48.81	1968.29
Wednesday, June 15, 2016	2254.15	25.87	0.05	0.00	25.93	0.13	0.11	9.00	9.24	16.69	2248.64	1964.16	34.64	0.05	5.18	0.13	9.00	0.00	49.00	0.476	0.48	48.52	1968.21
Thursday, June 16, 2016	2254.21	26.01	0.10	0.01	26.12	0.00	0.00	9.00	9.00	17.12	2248.90	1963.98	34.06	0.04	5.18	0.00	9.00	0.00	48.28	0.648	0.65	47.64	1967.97
Friday, June 17, 2016	2254.27	26.14	0.11	0.00	26.25	0.00	0.00	9.00	9.00	17.25	2248.99	1963.80	33.49	0.03	5.18	0.00	9.00	0.01	47.71	0.648	0.65	47.06	1967.81
Saturday, June 18, 2016	2254.33	26.28	0.09	0.02	26.39	0.00	0.00	9.00	9.00	17.39	2249.07	1963.52	32.62	0.03	5.18	0.00	9.00	0.00	46.84	0.950	0.95	45.89	1967.49
Sunday, June 19, 2016	2254.36	26.35	0.14	0.00	26.49	0.11	0.00	9.00	9.11	17.39	2249.07	1963.37	32.14	0.04	5.18	0.11	9.00	0.00	46.47	0.656	0.66	45.82	1967.47
Monday, June 20, 2016	2254.42	26.49	0.10	0.01	26.59	0.00	0.09	9.00	9.09	17.50	2249.14	1963.31	31.95	-0.01	5.18	0.00	9.00	0.00	46.12	0.193	0.19	45.93	1967.50
Tuesday, June 21, 2016	2254.51	26.69	0.18	0.00	26.87	0.02	0.00	9.00	9.02	17.85	2249.35	1963.13	31.37	-0.01	5.18	0.02	9.00	0.00	45.57	0.628	0.63	44.95	1967.23
Wednesday, June 22, 2016	2254.70	27.10	0.32	0.01	27.43	0.00	0.02	9.00	9.02	18.41	2249.68	1963.00	30.99	0.02	5.18	0.00	9.00	0.00	45.19	0.425	0.43	44.76	1967.18
Thursday, June 23, 2016	2255.03	27.85	0.66	0.02	28.53	0.09	0.00	9.00	9.09	19.43	2250.31	1963.19	31.57	0.80	5.18	0.09	9.00	0.00	46.64	0.276	0.28	46.36	1967.62
Friday, June 24, 2016	2255.12	28.05	0.13	0.03	28.21	0.00	0.08	9.00	9.08	19.14	2250.13	1963.09	31.28	0.08	5.18	0.00	9.00	0.00	45.54	0.390	0.39	45.15	1967.29
Saturday, June 25, 2016	2255.22	28.25	0.16	0.00	28.42	0.00	0.00	9.00	9.00	19.42	2250.30	1962.97	30.91	0.11	5.18	0.00	9.00	0.00	45.20	0.514	0.51	44.68	1967.16
Sunday, June 26, 2016	2255.28	28.39	0.11	0.00	28.50	0.00	0.00	9.00	9.00	19.50	2250.35	1962.73	30.26	0.06	5.18	0.00	9.00	0.00	44.50	0.814	0.81	43.69	1966.89
Monday, June 27, 2016	2255.43	28.73	0.27	0.00	29.00	0.00	0.00	9.00	9.00	20.00	2250.65	1962.64	30.01	0.08	5.18	0.00	9.00	0.00	44.27	0.352	0.35	43.92	1966.95
Tuesday, June 28, 2016	2256.28	30.64	1.53	0.00	32.17	0.00	0.00	9.00	9.00	23.17	2252.56	1962.73	30.26	0.61	5.18	0.00	9.00	0.00	45.05	0.334	0.33	44.71	1967.17
Wednesday, June 29, 2016	2257.87	34.18	2.80	0.04	37.02	0.00	0.00	9.00	9.00	28.02	2255.11	1963.13	31.37	1.47	5.18	0.00	9.00	0.00	47.03	0.215	0.21	46.82	1967.74
Thursday, June 30, 2016	2258.72	36.08	1.49	0.12	37.69	0.00	0.00	9.00	9.00	28.69	2255.41	1963.49	32.53	1.39	5.18	0.00	9.00	0.00	48.10	0.169	0.17	47.93	1968.05
Friday, July 01, 2016	2259.76	38.40	2.37	0.03	40.80	0.00	0.00	9.00	9.00	31.80	2256.80	1963.80	33.49	1.13	5.18	0.00	9.00	0.00	48.80	0.114	0.11	48.69	1968.25
Saturday, July 02, 2016	2260.03	39.03	0.61	0.03	39.67	0.00	0.00	9.00	9.00	30.67	2256.30	1963.98	34.06	0.82	5.18	0.00	9.00	0.00	49.07	0.209	0.21	48.86	1968.30
Sunday, July 03, 2016	2260.21	39.57	0.32	0.10	39.99	0.00	0.00	9.00	9.00	30.99	2256.44	1964.04	34.26	0.64	5.18	0.00	9.00	0.00	49.07	0.432	0.43	48.64	1968.24
Monday, July 04, 2016	2260.40	40.10	0.33	0.10	40.53	0.00	0.00	9.00	9.00	31.53	2256.68	1964.22	34.83	1.17	5.18	0.00	9.00	0.00	50.18	0.564	0.56	49.62	1968.51
Tuesday, July 05, 2016	2260.61	40.73	0.38	0.04	41.15	0.00	0.00	9.00	9.00	32.15	2256.96	1964.65	36.18	2.06	5.18	0.00	9.00	0.00	52.42	0.674	0.67	51.74	1969.08
Wednesday, July 06, 2016	2260.64	40.82	0.27	0.12	41.20	0.38	0.32	9.00	9.69	31.51	2256.67	1964.89	36.94	1.01	5.18	0.38	9.00	0.24	52.75	0.835	0.83	51.92	1969.12
Thursday, July 07, 2016	2260.79	41.26	0.29	0.12	41.67	0.07	0.06	9.00	9.12	32.55	2257.14	1965.23	38.00	1.32	5.18	0.07	9.00	0.03	53.61	0.334	0.33	53.27	1969.46
Friday, July 08, 2016	2260.88	41.53	0.10	0.11	41.74	0.00	0.05	9.00	9.05	32.69	2257.20	1965.56	39.06	1.48	5.18	0.00	9.00	0.00	54.72	0.387	0.39	54.33	1969.73
Saturday, July 09, 2016	2261.10	42.16	0.48	0.02	42.65	0.00	0.00	9.00	9.00	33.65	2257.63	1965.84	39.92	1.04	5.18	0.00	9.00	0.00	55.14	0.111	0.11	55.03	1969.90
Sunday, July 10, 2016	2262.35	45.81	2.83	0.07	48.71	0.00	0.00	9.00	9.00	39.71	2260.26	1966.14	40.95	1.53	5.18	0.00	9.00	0.00	56.66	0.514	0.51	56.15	1970.18
Monday, July 11, 2016	2263.44	49.03	2.53	0.02	51.57	0.00	0.00	9.00	9.00	42.57	2261.24	1966.51	42.30	1.27	5.18	0.00	9.00	0.00	57.75	0.080	0.08	57.67	1970.56
Tuesday, July 12, 2016	2263.84	50.19	0.92	0.00	51.11	0.00	0.00	9.00	9.00	42.11	2261.08	1966.69	42.97	0.90	5.18	0.00	9.00	0.00	58.04	0.198	0.20	57.84	1970.61
Wednesday, July 13, 2016	2264.21	51.26	0.85	0.00	52.11	0.00	0.00	9.00	9.00	43.11	2261.42	1966.75	43.19	0.59	5.18	0.00	9.00	0.00	57.96	0.344	0.34	57.62	1970.55
Thursday, July 14, 2016	2264.51	52.15	0.65	0.06	52.86	0.00	0.00	9.00	9.00	43.86	2261.68	1966.72	43.08	0.42	5.18	0.00	9.00	0.00	57.68	0.541	0.54	57.14	1970.43
Friday, July 15, 2016	2264.72	52.77	0.47	0.12	53.36	0.06	0.05	9.00	9.12	44.24	2261.81	1966.78	43.30	0.46	5.18	0.06	9.00	0.09	58.09	0.363	0.36	57.73	1970.58
Saturday, July 16, 2016	2264.91	53.31	0.45	0.12	53.88	0.05	0.04	9.00	9.08	44.80	2262.00	1966.72	43.08	0.40	5.18	0.05	9.00	0.00	57.71	0.696	0.70	57.01	1970.40
Sunday, July 17, 2016	2265.03	53.67	0.23	0.12	54.02	0.00	0.00	9.00	9.00	45.02	2262.08	1966.72	43.08	0.56	5.18	0.00	9.00	0.00	57.82	0.559	0.56	57.26	1970.46
Monday, July 18, 2016	2265.18	54.11	0.33	0.12	54.56	0.00	0.00	9.00	9.00	45.56	2262.26	1966.90	43.75	0.90	5.18	0.00	9.00	0.00	58.83	0.148	0.15	58.68	1970.82
Tuesday, July 19, 2016	2265.33	54.56	0.42	0.03	55.00	0.00	0.00	9.00	9.00	46.00	2262.41	1967.00	44.08	0.55	5.18	0.00	9.00	0.00	58.82	0.177	0.18	58.64	1970.81
Wednesday, July 20, 2016	2265.43	54.83	0.24	0.03	55.09	0.00	0.00	9.00	9.00	46.09	2262.44	1966.97	43.97	0.30	5.18	0.00	9.00	0.00	58.46	0.428	0.43	58.03	1970.65
Thursday, July 21, 2016	2265.49	55.01	0.19	0.02	55.22	0.04	0.00	9.00	9.04	46.18	2262.47	1966.94	43.86	0.28	5.18	0.04	9.00	0.00	58.36	0.444	0.44	57.92	1970.63
Friday, July 22, 2016	2265.58	55.27	0.24	0.03	55.54	0.00	0.00	9.00	9.00	46.54	2262.60	1966.94	43.86	0.25	5.18	0.00	9.00	0.00	58.29	0.249	0.25	58.04	1970.66
Saturday, July 23, 2016	2265.70	55.63	0.36	0.00	55.99	0.00	0.00	9.00	9.00	46.99	2262.75	1966.94	43.86	0.27	5.18	0.00	9.00	0.00	58.31	0.266	0.27	58.04	1970.66
Sunday, July 24, 2016	2265.79	55.90	0.23	0.04	56.17	0.00	0.00	9.00	9.00	47.17	2262.81	1966.87	43.64	0.22	5.18	0.00	9.00	0.00	58.03	0.466	0.47	57.57	1970.54
Monday, July 25, 2016	2265.88	56.17	0.23	0.04	56.43	0.00	0.00	9.00	9.00	47.43	2262.90	1966.81	43.41	0.07	5.18	0.00	9.00	0.00	57.66	0.319	0.32	57.35	1970.48
Tuesday, July 26, 2016	2265.94	56.34	0.22	0.00	56.57	0.05	0.04	9.00	9.10	47.47	2262.91	1966.81	43.41	0.25	5.18	0.05	9.00	0.06	57.95	0.356	0.36	57.59	1970.54
Wednesday, July 27, 2016	2266.10	56.84	0.41	0.03	57.29	0.00	0.00	9.00	9.00	48.29	2263.19	1967.00	44.08	1.07	5.18	0.00	9.00	0.00	59.33	0.331	0.33	59.00	1970.90
Thursday, July 28, 2016	2266.22	57.27	0.31	0.05	57.63	0.00	0.00	9.00	9.00	48.63	2263.31	1967.03	44.19	0.47	5.18	0.00	9.00	0.00	58.84	0.217	0.22	58.63	1970.80
Friday, July 29, 2016	2266.31	57.59	0.27	0.00	57.85	0.00	0.00	9.00	9.00	48.85	2263.39	1967.09	44.42	0.51	5.18	0.00	9.00	0.00	59.11	0.387	0.39	58.72	1970.83
Saturday, July 30, 2016	2266.40	57.91	0.24	0.03	58.17	0.00	0.00	9.00	9.00	49.17	2263.49	1967.09	44.42	0.22	5.18	0.00	9.00	0.00	58.82	0.219	0.22	58.60	1970.80
Sunday, July 31, 2016	2266.49	58.23	0.23	0.04	58.49	0.00	0.00	9.00	9.00	49.49	2263.60	1967.15	44.64	0.31	5.18	0.00	9.00	0.00	59.14	0.063	0.06	59.07	1970.92
Monday, August 01, 2016	2266.58	58.54	0.27	0.00	58.81	0.00	0.00	9.00	9.00	49.81	2263.71	1967.18	44.75	0.22	5.18	0.00	9.00	0.00	59.15	0.091	0.09	59.06	1970.91
Tuesday, August 02, 2016	2266.65	58.76	-0.23	0.02	58.54	0.00	0.00	9.00	9.00	49.54	2263.62	1967.21	44.87	0.21	5.18	0.00	9.00	0.00	59.26	0.109	0.11	59.15	1970.93
Wednesday, August 03, 2016	2266.71	58.97	0.39	0.04	59.39	0.00	0.00	9.00	9.00	50.39	2263.91	1967.24	44.98	0.14	5.18	0.00	9.00	0.00	59.30	0.038	0.04	59.26	1970.96
Thursday, August 04, 2016	2266.80	59.29	0.41	0.02	59.71	0.00	0.00	9.00	9.00	50.71	2264.02	1967.27	45.09	0.30	5.18	0.00	9.00	0.00	59.57	0.197	0.20	59.37	1970.99
Friday, August 05, 2016	2266.89	59.61	0.53	0.03	60.17	0.00	0.14	9.00	9.14	51.03	2264.13	1967.36	45.42	0.49	5.18	0.00	9.00	0.00	60.10	0.186	0.19	59.91	1971.13
Saturday, August 06, 2016	2267.04	60.14	0.03	0.04	60.21	0.00	0.00	9.00	9.00	51.21	2264.19	1967.39	45.54	0.35	5.18	0.00	9.00	0.00	60.07	0.251	0.25	59.82	1971.10
Sunday, August 07, 2016	2267.19	60.67	0.15	0.06	60.88	0.00	0.00	9.00	9.00	51.88	2264.42	1967.39	45.54	0.34	5.18	0.00	9.00	0.00	60.06	0.338	0.34	59.72	1971.08
Monday, August 08, 2016	2267.32	61.09	0.35	0.04	61.48	0.00	0.03	9.00	9.03	52.45	2264.61	1967.36	45.42	0.22	5.18	0.00	9.00	0.00	59.83	0.326	0.33	59.50	1971.02
Tuesday, August 09, 2016	2267.41	61.41	0.39	0.04	61.84	0.00	0.21	9.00	9.21	52.62	2264.67	1967.30	45.20	-0.01	5.18	0.00	9.00	0.00	59.37	0.190	0.19	59.18	1970.94
Wednesday, August 10, 2016	2267.47	61.62	0.26	0.00	61.88	0.00	0.12	9.00	9.12	52.77	2264.72	1967.27	45.09	0.19	5.18	0.00	9.00	0.00	59.46	0.281	0.28	59.17	1970.94
Thursday, August 11, 2016	2267.56	61.94	0.24	0.03	62.21	0.00	0.19	9.00	9.19	53.01	2264.81	1967.27	45.09	0.20	5.18	0.00	9.00	0.00	59.47	0.207	0.21	59.27	1970.96
Friday, August 12, 2016	2267.62	62.16	0.19	0.03	62.37	0.00	0.00	9.00	9.00	53.37	2264.93	1967.24	44.98	0.28	5.18	0.00	9.00	0.00	59.44	0.381	0.38	59.06	1970.91
Saturday, August 13, 2016	2267.68	62.37	0.22	0.03	62.61	0.06	0.09	9.00	9.15	53.46	2264.96	1967.27	45.09	0.00	5.18	0.06	9.00	0.07	59.40	0.027	0.03	59.37	1970.99
Sunday, August 14, 2016	2267.71	62.47	0.26	0.02	62.75	0.00	0.19	9.00	9.19	53.56	2264.99	1967.33	45.31	0.40	5.18	0.00	9.00	0.00	59.90	0.198	0.20	59.70	1971.07
Monday, August 15, 2016	2267.74	62.58	0.18	0.02	62.78	0.00	0.11	9.00	9.11	53.67	2265.03	1967.33	45.31	0.13	5.18	0.00	9.00	0.00	59.63	0.132	0.13	59.49	1971.02
Tuesday, August 16, 2016	2267.77	62.69	0.16	0.02	62.86	0.00	0.00	9.00	9.00	53.86	2265.10	1967.30	45.20	0.06	5.18	0.00	9.00	0.00	59.44	0.159	0.16	59.28	1970.97
Wednesday, August 17, 2016	2267.86	63.00	0.16	0.02	63.18	0.00	0.00	9.00	9.00	54.18	2265.21	1967.30	45.20	0.16	5.18	0.00	9.00	0.00	59.54	0.162	0.16	59.38	1970.99
Thursday, August 18, 2016	2268.02	63.54	0.16	0.02	63.71	0.00	0.00	9.00	9.00	54.71	2265.39	1967.36	45.42	0.25	5.18	0.00	9.00	0.00	59.86	0.046	0.05	59.81	1971.10
Friday, August 19, 2016	2268.14	63.96	0.38	0.02	64.36	0.00	0.04	9.00	9.04	55.32	2265.59	1967.39	45.54	0.29	5.18	0.00	9.00	0.00	60.00	0.183	0.18	59.82	1971.10
Saturday, August 20, 2016	2268.23	64.28	0.43	0.03	64.74	0.00	0.02	9.00	9.02	55.72	2265.73	1967.39	45.54	0.41	5.18	0.00	9.00	0.00	60.12	0.405	0.41	59.72	1971.08
Sunday, August 21, 2016	2268.29	64.49	0.84	0.05	65.38	0.00	0.00	9.00	9.00	56.38	2265.96	1967.36	45.42	0.32	5.18	0.00	9.00	0.00	59.93	0.445	0.44	59.49	1971.02

	Monday, August 22, 2016	**2268.35**	64.70	0.86	0.03	65.59	0.00	0.00	9.00	9.00	56.59	2266.02	**1967.39**	45.54	0.06	5.18	0.00	9.00	0.00	59.77	0.124	0.12	59.65	1971.06
	Tuesday, August 23, 2016	**2268.44**	65.02	0.64	0.11	65.78	0.00	0.04	9.00	9.04	56.73	2266.07	**1967.39**	45.54	0.30	5.18	0.00	9.00	0.00	60.02	0.302	0.30	59.72	1971.08
	Wednesday, August 24, 2016	**2268.50**	65.24	0.70	0.04	65.97	0.00	0.20	9.00	9.20	56.77	2266.07	**1967.45**	45.76	0.38	5.18	0.00	9.00	0.00	60.32	0.175	0.18	60.15	1971.18
	Thursday, August 25, 2016	**2268.53**	65.34	0.60	0.02	65.97	0.00	0.18	9.00	9.18	56.79	2266.08	**1967.48**	45.87	0.30	5.18	0.00	9.00	0.00	60.36	0.201	0.20	60.16	1971.19
	Friday, August 26, 2016	**2268.60**	65.55	0.04	0.06	65.65	0.00	0.00	9.00	9.00	56.65	2266.04	**1967.48**	45.87	0.29	5.18	0.00	9.00	0.00	60.34	0.287	0.29	60.05	1971.16
	Saturday, August 27, 2016	**2268.69**	65.87	0.26	0.01	66.14	0.00	0.00	9.00	9.00	57.14	2266.18	**1967.51**	45.98	0.21	5.18	0.00	9.00	0.00	60.38	0.110	0.11	60.27	1971.21
	Sunday, August 28, 2016	**2268.75**	66.08	0.50	0.04	66.62	0.00	0.00	9.00	9.00	57.62	2266.32	**1967.54**	46.09	0.22	5.18	0.00	9.00	0.00	60.50	0.128	0.13	60.37	1971.24
	Monday, August 29, 2016	**2268.81**	66.30	1.91	0.05	68.26	0.00	0.00	9.00	9.00	59.26	2266.79	**1967.58**	46.21	0.15	5.18	0.00	9.00	0.00	60.53	0.060	0.06	60.47	1971.27
	Tuesday, August 30, 2016	**2268.87**	66.51	2.46	0.12	69.09	0.00	0.00	9.00	9.00	60.09	2267.03	**1967.58**	46.21	0.26	5.18	0.00	9.00	0.00	60.65	0.060	0.06	60.59	1971.29
	Wednesday, August 31, 2016	**2268.96**	66.83	0.43	0.12	67.38	0.00	0.11	9.00	9.11	58.27	2266.51	**1967.58**	46.21	0.12	5.18	0.00	9.00	0.00	60.51	0.117	0.12	60.39	1971.25
	Thursday, September 01, 2016	**2269.05**	67.15	0.25	0.02	67.41	0.00	0.00	9.00	9.00	58.41	2266.55	**1967.61**	46.32	0.23	5.18	0.00	9.00	0.00	60.73	0.111	0.11	60.62	1971.30
	Friday, September 02, 2016	**2269.11**	67.36	0.16	0.18	67.70	0.00	0.00	9.00	9.00	58.70	2266.63	**1967.61**	46.32	0.10	5.18	0.00	9.00	0.00	60.60	0.095	0.10	60.50	1971.27
	Saturday, September 03, 2016	**2269.21**	67.68	0.25	0.02	67.95	0.00	0.00	9.00	9.00	58.95	2266.70	**1967.64**	46.43	0.17	5.18	0.00	9.00	0.00	60.78	0.068	0.07	60.71	1971.33
	Sunday, September 04, 2016	**2269.27**	67.89	0.16	0.02	68.07	0.00	0.00	9.00	9.00	59.07	2266.73	**1967.61**	46.32	0.13	5.18	0.00	9.00	0.00	60.63	0.231	0.23	60.40	1971.25
	Monday, September 05, 2016	**2269.36**	68.21	0.25	0.01	68.48	0.00	0.00	9.00	9.00	59.48	2266.85	**1967.61**	46.32	0.13	5.18	0.00	9.00	0.00	60.63	0.069	0.07	60.56	1971.29
	Tuesday, September 06, 2016	**2269.39**	68.32	0.07	0.25	68.64	0.00	0.00	9.00	9.00	59.64	2266.90	**1967.61**	46.32	0.13	5.18	0.00	9.00	0.00	60.63	0.130	0.13	60.50	1971.27
	Wednesday, September 07, 2016	**2269.42**	68.42	0.09	0.00	68.51	0.00	0.00	9.00	9.00	59.51	2266.86	**1967.58**	46.21	0.16	5.18	0.00	9.00	0.00	60.55	0.283	0.28	60.27	1971.22
	Thursday, September 08, 2016	**2269.48**	68.63	0.15	0.03	68.81	0.00	0.00	9.00	9.00	59.81	2266.95	**1967.58**	46.21	0.15	5.18	0.00	9.00	0.00	60.54	0.148	0.15	60.39	1971.25
	Friday, September 09, 2016	**2269.54**	68.85	0.18	0.00	69.02	0.00	0.00	9.00	9.00	60.02	2267.01	**1967.58**	46.21	0.11	5.18	0.00	9.00	0.00	60.50	0.110	0.11	60.39	1971.25
	Saturday, September 10, 2016	**2269.60**	69.06	0.14	0.03	69.24	0.00	0.00	9.00	9.00	60.24	2267.07	**1967.61**	46.32	0.43	5.18	0.00	9.00	0.00	60.93	0.309	0.31	60.62	1971.30
	Sunday, September 11, 2016	**2269.63**	69.17	0.09	0.00	69.25	0.00	0.00	9.00	9.00	60.25	2267.08	**1967.58**	46.21	0.09	5.18	0.00	9.00	0.00	60.48	0.212	0.21	60.27	1971.22
	Monday, September 12, 2016	**2269.66**	69.27	0.06	0.03	69.36	0.00	0.00	9.00	9.00	60.36	2267.11	**1967.58**	46.21	0.13	5.18	0.00	9.00	0.00	60.52	0.079	0.08	60.44	1971.26
	Tuesday, September 13, 2016	**2269.69**	69.38	0.09	0.00	69.47	0.00	0.00	9.00	9.00	60.47	2267.14	**1967.54**	46.09	0.06	5.18	0.00	9.00	0.00	60.33	0.143	0.14	60.19	1971.20
	Wednesday, September 14, 2016	**2269.75**	69.59	0.18	0.00	69.77	0.00	0.00	9.00	9.00	60.77	2267.22	**1967.51**	45.98	0.08	5.18	0.00	9.00	0.00	60.24	0.178	0.18	60.06	1971.16
	Thursday, September 15, 2016	**2269.82**	69.80	0.18	0.00	69.98	0.00	0.00	9.00	9.00	60.98	2267.28	**1967.82**	47.10	0.24	5.18	0.00	9.00	0.00	61.52	0.235	0.24	61.28	1971.47
	Friday, September 16, 2016	**2269.85**	69.91	0.09	0.00	70.00	0.00	0.00	9.00	9.00	61.00	2267.29	**1967.48**	45.87	0.07	5.18	0.00	9.00	0.00	60.13	0.175	0.18	59.95	1971.14
	Saturday, September 17, 2016	**2269.91**	70.12	0.12	0.05	70.30	0.00	0.00	9.00	9.00	61.30	2267.37	**1967.48**	45.87	0.08	5.18	0.00	9.00	0.00	60.14	0.084	0.08	60.05	1971.16
	Sunday, September 18, 2016	**2270.00**	70.44	0.25	0.02	70.71	0.00	0.00	9.00	9.00	61.71	2267.49	**1967.48**	45.87	0.10	5.18	0.00	9.00	0.00	60.15	0.098	0.10	60.05	1971.16
	Monday, September 19, 2016	**2270.06**	70.65	0.18	0.00	70.83	0.00	0.00	9.00	9.00	61.83	2267.53	**1967.45**	45.76	0.15	5.18	0.00	9.00	0.00	60.09	0.250	0.25	59.84	1971.11
	Tuesday, September 20, 2016	**2270.09**	70.76	0.08	0.01	70.85	0.00	0.00	9.00	9.00	61.85	2267.53	**1967.42**	45.65	0.08	5.18	0.00	9.00	0.00	59.91	0.158	0.16	59.75	1971.08
	Wednesday, September 21, 2016	**2270.15**	70.97	0.16	0.02	71.15	0.00	0.00	9.00	9.00	62.15	2267.62	**1967.39**	45.54	0.05	5.18	0.00	9.00	0.00	59.77	0.174	0.17	59.60	1971.05
	Thursday, September 22, 2016	**2270.18**	71.08	0.07	0.02	71.17	0.00	0.00	9.00	9.00	62.17	2267.62	**1967.36**	45.42	0.13	5.18	0.00	9.00	0.00	59.74	0.234	0.23	59.50	1971.02
	Friday, September 23, 2016	**2270.24**	71.29	0.16	0.02	71.47	0.00	0.00	9.00	9.00	62.47	2267.71	**1967.36**	45.42	0.09	5.18	0.00	9.00	0.00	59.70	0.095	0.10	59.60	1971.05
	Saturday, September 24, 2016	**2270.30**	71.50	0.16	0.02	71.68	0.00	0.00	9.00	9.00	62.68	2267.77	**1967.33**	45.31	0.03	5.18	0.00	9.00	0.00	59.52	0.130	0.13	59.39	1971.00
	Sunday, September 25, 2016	**2270.36**	71.71	0.18	0.02	71.91	0.00	0.00	9.00	9.00	62.91	2267.84	**1967.30**	45.20	0.08	5.18	0.00	9.00	0.00	59.46	0.183	0.18	59.28	1970.97
	Monday, September 26, 2016	**2270.42**	71.93	0.06	0.00	71.99	0.00	0.00	9.00	9.00	62.99	2267.86	**1967.27**	45.09	0.10	5.18	0.00	9.00	0.00	59.37	0.197	0.20	59.17	1970.94
	Tuesday, September 27, 2016	**2270.46**	72.03	0.09	0.03	72.15	0.00	0.00	9.00	9.00	63.15	2267.91	**1967.24**	44.98	0.15	5.18	0.00	9.00	0.00	59.31	0.251	0.25	59.06	1970.91
	Wednesday, September 28, 2016	**2270.49**	72.14	0.16	0.00	72.30	0.00	0.00	9.00	9.00	63.30	2267.95	**1967.24**	44.98	0.16	5.18	0.00	9.00	0.00	59.32	0.276	0.28	59.05	1970.91
	Thursday, September 29, 2016	**2270.55**	72.35	0.07	0.02	72.45	0.00	0.00	9.00	9.00	63.45	2267.99	**1967.27**	45.09	0.32	5.18	0.00	9.00	0.00	59.59	0.217	0.22	59.37	1970.99
	Friday, September 30, 2016	**2270.58**	72.46	0.09	0.02	72.56	0.00	0.00	9.00	9.00	63.56	2268.02	**1967.27**	45.09	0.12	5.18	0.00	9.00	0.00	59.39	0.116	0.12	59.27	1970.97
	Saturday, October 01, 2016	**2270.61**	72.56	0.26	0.00	72.82	0.00	0.00	9.00	9.00	63.82	2268.10	**1967.24**	44.98	0.08	5.18	0.00	9.00	0.00	59.24	0.181	0.18	59.06	1970.91
	Sunday, October 02, 2016	**2270.67**	72.78	0.15	0.03	72.95	0.00	0.00	9.00	9.00	63.95	2268.14	**1967.21**	44.87	0.17	5.18	0.00	9.00	0.00	59.22	0.270	0.27	58.95	1970.88
	Monday, October 03, 2016	**2270.67**	72.78	0.14	0.00	72.92	0.00	0.00	9.00	9.00	63.92	2268.13	**1967.18**	44.75	0.10	5.18	0.00	9.00	0.00	59.04	0.204	0.20	58.83	1970.86
	Tuesday, October 04, 2016	**2270.70**	72.88	0.07	0.02	72.97	0.00	0.00	9.00	9.00	63.97	2268.14	**1967.12**	44.53	0.17	5.18	0.00	9.00	0.00	58.88	0.419	0.42	58.46	1970.76
	Wednesday, October 05, 2016	**2269.51**	68.74	0.07	0.02	68.83	0.00	0.00	9.00	9.00	59.83	2266.95	**1967.09**	44.42	0.14	5.18	0.00	9.00	0.00	58.74	0.260	0.26	58.48	1970.77
	Thursday, October 06, 2016	**2269.51**	68.74	0.00	0.00	68.74	0.00	0.00	9.00	9.00	59.74	2266.93	**1967.03**	44.19	0.04	5.18	0.00	9.00	0.00	58.42	0.294	0.29	58.13	1970.68
	Friday, October 07, 2016	**2270.52**	72.25	0.05	0.00	72.30	0.80	0.67	9.00	10.48	61.82	2267.52	**1966.94**	43.86	0.25	5.18	0.80	9.00	0.00	59.09	1.427	1.43	57.67	1970.56
	Saturday, October 08, 2016	**2270.42**	71.93	0.17	0.03	72.12	0.55	0.46	9.00	10.02	62.11	2267.61	**1966.94**	43.86	0.10	5.18	0.55	9.00	0.36	59.06	1.017	1.02	58.04	1970.66
	Sunday, October 09, 2016	**2270.27**	71.40	0.01	0.00	71.40	0.54	0.45	9.00	9.99	61.41	2267.41	**1966.94**	43.86	0.07	5.18	0.54	9.00	0.00	58.65	0.610	0.61	58.04	1970.66
	Monday, October 10, 2016	**2270.24**	71.29	0.09	0.00	71.38	0.22	0.18	9.00	9.40	61.98	2267.57	**1966.90**	43.75	-0.09	5.18	0.22	9.00	0.00	58.06	0.254	0.25	57.81	1970.60
	Tuesday, October 11, 2016	**2270.09**	70.76	0.12	0.01	70.89	0.68	0.57	9.00	10.25	60.63	2267.18	**1966.90**	43.75	0.00	5.18	0.68	9.00	0.78	59.38	1.453	1.45	57.93	1970.63
	Wednesday, October 12, 2016	**2269.78**	69.70	0.00	0.02	69.72	1.08	0.91	9.00	10.99	58.72	2266.64	**1966.87**	43.64	-0.17	5.18	1.08	9.00	0.53	59.27	1.574	1.57	57.69	1970.57
	Thursday, October 13, 2016	**2269.57**	68.95	0.11	0.00	69.06	0.87	0.73	9.00	10.60	58.46	2266.56	**1966.84**	43.52	0.21	5.18	0.87	9.00	0.39	59.17	1.592	1.59	57.58	1970.54
	Friday, October 14, 2016	**2269.39**	68.32	0.14	0.02	68.47	0.82	0.69	9.00	10.51	57.96	2266.42	**1966.87**	43.64	0.26	5.18	0.82	9.00	0.44	59.33	1.389	1.39	57.94	1970.63
	Saturday, October 15, 2016	**2269.24**	67.78	0.17	0.00	67.95	0.73	0.61	9.00	10.34	57.61	2266.32	**1966.87**	43.64	0.36	5.18	0.73	9.00	0.00	58.91	1.093	1.09	57.82	1970.60
	Sunday, October 16, 2016	**2269.02**	67.04	0.03	0.02	67.10	0.81	0.68	9.00	10.48	56.61	2266.03	**1966.81**	43.41	0.04	5.18	0.81	9.00	0.43	58.87	1.522	1.52	57.35	1970.48
	Monday, October 17, 2016	**2268.78**	66.19	0.00	0.01	66.21	0.86	0.73	9.00	10.59	55.62	2265.70	**1966.75**	43.19	0.19	5.18	0.86	9.00	0.31	58.73	1.611	1.61	57.12	1970.43
	Tuesday, October 18, 2016	**2268.53**	65.34	0.03	0.00	65.37	0.88	0.74	9.00	10.62	54.75	2265.40	**1966.72**	43.08	0.08	5.18	0.88	9.00	0.40	58.62	1.490	1.49	57.13	1970.43
	Wednesday, October 19, 2016	**2268.23**	64.28	-0.10	0.03	64.20	0.97	0.81	9.00	10.78	53.42	2264.95	**1966.72**	43.08	0.01	5.18	0.97	9.00	0.49	58.73	1.468	1.47	57.26	1970.46
	Thursday, October 20, 2016	**2268.02**	63.54	0.11	0.00	63.65	0.87	0.73	9.00	10.60	53.04	2264.82	**1966.60**	42.63	-0.02	5.18	0.87	9.00	0.14	57.80	1.483	1.48	56.31	1970.22
	Friday, October 21, 2016	**2268.02**	63.54	0.02	0.01	63.56	1.09	0.92	9.00	11.01	52.56	2264.65	**1966.63**	42.74	0.10	5.18	1.09	9.00	0.41	58.52	1.475	1.47	57.05	1970.41
	Saturday, October 22, 2016	**2267.56**	61.94	0.17	0.02	62.13	0.75	0.63	9.00	10.38	51.75	2264.38	**1966.60**	42.63	-0.21	5.18	0.75	9.00	0.54	57.89	1.199	1.20	56.69	1970.32
	Sunday, October 23, 2016	**2267.38**	61.31	0.09	0.00	61.40	0.75	0.63	9.00	10.37	51.03	2264.13	**1966.54**	42.41	0.06	5.18	0.75	9.00	0.23	57.62	1.358	1.36	56.27	1970.21
	Monday, October 24, 2016	**2267.16**	60.56	0.00	0.00	60.57	0.75	0.63	9.00	10.37	50.19	2263.84	**1966.42**	41.96	-0.04	5.18	0.75	9.00	0.00	56.85	1.004	1.00	55.84	1970.11
	Tuesday, October 25, 2016	**2267.10**	60.35	0.03	0.02	60.40	0.28	0.23	9.00	9.51	50.89	2264.08	**1966.26**	41.40	0.13	5.18	0.28	9.00	0.17	56.16	1.074	1.07	55.09	1969.92
	Wednesday, October 26, 2016	**2267.04**	60.14	-0.03	0.00	60.10	0.17	0.15	9.00	9.32	50.79	2264.05	**1966.20**	41.18	0.30	5.18	0.17	9.00	0.18	56.01	0.854	0.85	55.16	1969.94
	Thursday, October 27, 2016	**2267.04**	60.14	0.10	0.01	60.25	0.13	0.11	9.00	9.25	51.00	2264.12	**1966.08**	40.73	0.13	5.18	0.13	9.00	0.13	55.31	0.794	0.79	54.52	1969.77
	Friday, October 28, 2016	**2267.01**	60.03	-0.01	0.00	60.02	0.09	0.07	9.00	9.16	50.85	2264.07	**1965.99**	40.40	0.09	5.18	0.09	9.00	0.11	54.87	0.586	0.59	54.28	1969.72
	Saturday, October 29, 2016	**2267.01**	60.03	-0.02	0.02	60.03	0.00	0.00	9.00	9.00	51.03	2264.13	**1965.90**	40.11	0.15	5.18	0.00	9.00	0.00	54.44	0.454	0.45	53.99	1969.64
	Sunday, October 30, 2016	**2267.01**	60.03	0.00	0.00	60.03	0.00	0.00	9.00	9.00	51.03	2264.13	**1965.81**	39.82	0.15	5.18	0.00	9.00	0.00	54.15	0.462	0.46	53.69	1969.57
	Monday, October 31, 2016	**2267.07**	60.24	0.18	0.00	60.42	0.00	0.00	9.00	9.00	51.42	2264.26	**1965.78**	39.73	0.36	5.18	0.00	9.00	0.00	54.27	0.462	0.46	53.81	1969.60
	Tuesday, November 01, 2016	**2267.13**	60.46	0.14	0.03	60.63	0.00	0.00	9.00	9.00	51.63	2264.34	**1965.66**	39.34	0.07	5.18	0.00	9.00	0.00	53.59	0.487	0.49	53.11	1969.42
	Wednesday, November 02, 2016	**2267.10**	60.35	-0.06	0.00	60.29	0.03	0.03	9.00	9.06	51.23	2264.20	**1965.56**	39.06	0.04	5.18	0.03	9.00	0.00	53.31	0.368	0.37	52.94	1969.38
	Thursday, November 03, 2016	**2267.10**	60.35	0.00	0.00	60.35	0.00	0.00	9.00	9.00	51.35	2264.24	**1965.50**	38.86	0.12	5.18	0.00	9.00	0.00	53.17	0.318	0.32	52.85	1969.36
	Friday, November 04, 2016	**2267.16**	60.56	0.18	0.00	60.74	0.00	0.00	9.00	9.00	51.74	2264.37	**1965.35**	38.38	0.07	5.18	0.00	9.00	0.00	52.63	0.561	0.56	52.07	1969.16
	Saturday, November 05, 2016	**2267.22**	60.77	0.15	0.03	60.95	0.00	0.00	9.00	9.00	51.95	2264.44	**1965.23**	38.00	0.04	5.18	0.00	9.00	0.00	52.22	0.435	0.43	51.79	1969.09
	Sunday, November 06, 2016	**2267.22**	60.77	0.00	0.00	60.77	0.00	0.00	9.00	9.00	51.77	2264.38	**1965.11**	37.62	0.09	5.18	0.00	9.00	0.00	51.88	0.484	0.48	51.40	1968.99
	Monday, November 07, 2016	**2267.22**	60.77	0.00	0.00	60.77	0.00	0.00	9.00	9.00	51.77	2264.38	**1964.98**	37.23	-0.21	5.18	0.00	9.00	0.00	51.21	0.189	0.19	51.02	1968.89
	Tuesday, November 08, 2016	**2267.22**	60.77	-0.02	0.02	60.77	0.00	0.00	9.00	9.00	51.77	2264.38	**1964.83**	36.75	0.10	5.18	0.00	9.00	0.00	51.03	0.595	0.60	50.44	1968.73
	Wednesday, November 09, 2016	**2267.25**	60.88	0.09	0.00	60.97	0.00	0.00	9.00	9.00	51.97	2264.45	**1964.71**	36.37	0.14	5.18	0.00	9.00	0.00	50.69	0.537	0.54	50.15	1968.65
	Thursday, November 10, 2016	**2267.25**	60.88	0.11	0.00	60.99	0.13	0.11	9.00	9.23	51.75	2264.38	**1964.59**	35.98	-0.01	5.18	0.13	9.00	0.15	50.43	0.663	0.66	49.77	1968.55
	Friday, November 11, 2016	**2267.16**	60.56	-0.08	0.02	60.49	0.24	0.20	9.00	9.44	51.06	2264.14	**1964.56**	35.89	0.02	5.18	0.24	9.00	0.26	50.59	0.643	0.64	49.95	1968.60
	Saturday, November 12, 2016	**2267.07**	60.24	0.00	0.00	60.25	0.32	0.27	9.00	9.59	50.65	2264.00	**1964.38**	35.31	0.05	5.18	0.32	9.00	0.06	49.93	1.032	1.03	48.90	1968.31
	Sunday, November 13, 2016	**2267.01**	60.03	0.05	0.02	60.10	0.29	0.24	9.00	9.53	50.56	2263.97	**1964.22**	34.83	0.10	5.18	0.29	9.00	0.11	49.51	0.995	0.99	48.52	1968.21
	Monday, November 14, 2016	**2266.95**	59.82	-0.06	0.00	59.76	0.14	0.12	9.00	9.26	50.50	2263.95	**1964.07**	34.35	0.09	5.18	0.14	9.00	0.14	48.90	0.875	0.88	48.03	1968.07
	Tuesday, November 15, 2016	**2266.83**	59.39	0.23	0.00	59.62	0.69	0.58	9.00	10.27	49.35	2263.55	**1964.07**	34.35	0.08	5.18	0.69	9.00	0.24	49.54	1.006	1.01	48.54	1968.21
	Wednesday, November 16, 2016	**2266.71**	58.97	0.02	0.02	59.01	0.47	0.40	9.00	9.87	49.14	2263.48	**1964.10**	34.45	0.48	5.18	0.47	9.00	0.19	49.77	1.034	1.03	48.73	1968.26
	Thursday, November 17, 2016	**2266.61**	58.65	0.01	0.00	58.66	0.33	0.28	9.00	9.60	49.05	2263.45	**1964.10**	34.45	0.11	5.18	0.33	9.00	0.29	49.35	0.731	0.73	48.62	1968.23
	Friday, November 18, 2016	**2266.43**	58.01	-0.20	0.00	57.81	0.40	0.34	9.00	9.74	48.08	2263.12	**1964.13**	34.54	0.13	5.18	0.40	9.00	0.03	49.28	0.450	0.45	48.83	1968.29
	Saturday, November 19, 2016	**2266.28**	57.48	-0.09	0.00	57.39	0.42	0.35	9.00	9.77	47.62	2262.96	**1964.13**	34.54	-0.02	5.18	0.42	9.00	0.34	49.47	0.772	0.77	48.69	1968.25
	Sunday, November 20, 2016	**2266.19**	57.16	-0.16	0.02	57.02	0.15	0.12	9.00	9.27	47.75	2263.01	**1964.07**	34.35	0.08	5.18	0.15	9.00	0.24	49.00	0.674	0.67	48.33	1968.15
	Monday, November 21, 2016	**2266.22**	57.27	0.09	0.00	57.36	0.00	0.00	9.00	9.00	48.36	2263.22	**1963.95**	33.97	0.03	5.18	0.00	9.00	0.00	48.18	0.442	0.44	47.74	1967.99
	Tuesday, November 22, 2016	**2266.13**	56.95	0.18	0.00	57.13	0.53	0.44	9.00	9.97	47.16	2262.81	**1964.01**	34.16	0.00	5.18	0.53	9.00	0.26	49.13	0.582	0.58	48.54	1968.21
	Wednesday, November 23, 2016	**2266.10**	56.84	0.04	0.00	56.89	0.16	0.13	9.00	9.29	47.60	2262.96	**1963.89**	33.78	0.02	5.18	0.16	9.00	0.10	48.23	0.678	0.68	47.55	1967.94
	Thursday, November 24, 2016	**2266.04**	56.63	-0.09	0.00	56.54	0.13	0.11	9.00	9.24	47.30	2262.86	**1963.83**	33.58	0.25	5.18	0.13	9.00	0.14	48.28	0.722	0.72	47.56	1967.94
	Friday, November 25, 2016	**2266.01**	56.53	0.00	0.00	56.52	0.10	0.09	9.00	9.19	47.33	2262.87	**1963.73**	33.30	0.14	5.18	0.10	9.00	0.05	47.77	0.594	0.59	47.17	1967.84
	Saturday, November 26, 2016	**2265.94**	56.34	-0.08	0.00	56.26	0.11	0.09	9.00	9.21	47.05	2262.77	**1963.61**	32.91	0.06	5.18	0.11	9.00	0.00	47.27	0.583	0.58	46.69	1967.71
	Sunday, November 27, 2016	**2265.85**	56.08	0.00	0.01	56.09	0.33	0.28	9.00	9.62	46.48	2262.57	**1963.46**	32.43	0.07	5.18	0.33	9.00	0.00	47.02	0.919	0.92	46.10	1967.55
	Monday, November 28, 2016	**2265.82**	55.99	-0.02	0.00	55.97	0.08	0.07	9.00	9.15	46.82	2262.69	**1963.43**	32.34	0.10	5.18	0.08	9.00	0.13	46.83	0.354	0.35	46.47	1967.65
	Tuesday, November 29, 2016	**2265.70**	55.63	0.05	0.00	55.68	0.48	0.40	9.00	9.88	45.80	2262.34	**1963.43**	32.34	0.04	5.18	0.48	9.00	0.11	47.14	0.621	0.62	46.52	1967.66

	Wednesday, November 30, 2016	**2265.70**	55.63	0.04	0.02	55.69	0.07	0.06	9.00	9.14	46.56	2262.60	**1963.31**	31.95	0.11	5.18	0.07	9.00	0.00	46.32	0.594	0.59	45.73	1967.44
	Thursday, December 01, 2016	**2265.61**	55.36	0.03	0.00	55.40	0.36	0.30	9.00	9.66	45.74	2262.32	**1963.28**	31.85	0.09	5.18	0.36	9.00	0.00	46.48	0.549	0.55	45.93	1967.50
	Friday, December 02, 2016	**2265.58**	55.27	-0.06	0.00	55.22	0.04	0.03	9.00	9.07	46.14	2262.46	**1963.19**	31.57	0.04	5.18	0.04	9.00	0.00	45.83	0.385	0.38	45.44	1967.37
	Saturday, December 03, 2016	**2265.61**	55.36	0.08	0.01	55.45	0.00	0.00	9.00	9.00	46.45	2262.57	**1963.09**	31.28	0.06	5.18	0.00	9.00	0.00	45.52	0.362	0.36	45.15	1967.29
	Sunday, December 04, 2016	**2265.61**	55.36	0.03	0.00	55.39	0.14	0.12	9.00	9.25	46.14	2262.46	**1963.06**	31.18	0.02	5.18	0.14	9.00	0.27	45.80	0.534	0.53	45.26	1967.32
	Monday, December 05, 2016	**2265.61**	55.36	0.07	0.02	55.45	0.00	0.00	9.00	9.00	46.45	2262.57	**1962.97**	30.91	0.12	5.18	0.00	9.00	0.00	45.21	0.425	0.43	44.78	1967.19
	Tuesday, December 06, 2016	**2265.64**	55.45	0.11	0.00	55.56	0.03	0.02	9.00	9.05	46.51	2262.59	**1962.91**	30.75	0.04	5.18	0.03	9.00	0.07	45.06	0.338	0.34	44.72	1967.17
	Wednesday, December 07, 2016	**2265.64**	55.45	0.00	0.00	55.45	0.00	0.00	9.00	9.00	46.45	2262.57	**1962.82**	30.50	0.08	5.18	0.00	9.00	0.00	44.76	0.359	0.36	44.41	1967.08
	Thursday, December 08, 2016	**2265.61**	55.36	0.00	0.02	55.38	0.12	0.10	9.00	9.22	46.15	2262.46	**1962.76**	30.34	0.12	5.18	0.12	9.00	0.27	45.03	0.690	0.69	44.34	1967.07
	Friday, December 09, 2016	**2265.52**	55.10	0.01	0.00	55.11	0.33	0.28	9.00	9.61	45.50	2262.24	**1962.67**	30.10	0.06	5.18	0.33	9.00	0.10	44.78	0.773	0.77	44.00	1966.97
	Saturday, December 10, 2016	**2265.43**	54.83	-0.05	0.00	54.77	0.25	0.21	9.00	9.47	45.31	2262.17	**1962.61**	29.93	-0.01	5.18	0.25	9.00	0.11	44.47	0.541	0.54	43.93	1966.96
	Sunday, December 11, 2016	**2265.40**	54.74	0.05	0.02	54.81	0.19	0.16	9.00	9.34	45.46	2262.23	**1962.52**	29.69	-0.06	5.18	0.19	9.00	0.23	44.23	0.632	0.63	43.59	1966.86
	Monday, December 12, 2016	**2265.40**	54.74	0.00	0.00	54.74	0.00	0.00	9.00	9.00	45.74	2262.32	**1962.45**	29.53	0.04	5.18	0.00	9.00	0.00	43.75	0.231	0.23	43.52	1966.84
	Tuesday, December 13, 2016	**2265.40**	54.74	0.00	0.00	54.74	0.00	0.00	9.00	9.00	45.74	2262.32	**1962.36**	29.28	0.03	5.18	0.00	9.00	0.00	43.50	0.311	0.31	43.19	1966.75
	Wednesday, December 14, 2016	**2265.46**	54.92	0.20	0.01	55.13	0.04	0.03	9.00	9.08	46.05	2262.43	**1962.24**	28.96	0.07	5.18	0.04	9.00	0.10	43.34	0.572	0.57	42.77	1966.64
	Thursday, December 15, 2016	**2265.33**	54.56	-0.05	0.02	54.53	0.39	0.33	9.00	9.72	44.81	2262.01	**1962.21**	28.88	0.04	5.18	0.39	9.00	0.12	43.62	0.592	0.59	43.02	1966.71
	Friday, December 16, 2016	**2265.18**	54.11	-0.04	0.00	54.07	0.48	0.40	9.00	9.88	44.19	2261.79	**1962.15**	28.71	0.07	5.18	0.48	9.00	0.00	43.44	0.730	0.73	42.71	1966.62
	Saturday, December 17, 2016	**2265.09**	53.85	-0.07	0.00	53.77	0.23	0.20	9.00	9.43	44.35	2261.85	**1962.15**	28.71	0.09	5.18	0.23	9.00	0.13	43.35	0.450	0.45	42.90	1966.67
	Sunday, December 18, 2016	**2265.06**	53.76	0.01	0.00	53.77	0.12	0.10	9.00	9.22	44.55	2261.91	**1962.09**	28.55	0.08	5.18	0.12	9.00	0.14	43.08	0.533	0.53	42.54	1966.58
	Monday, December 19, 2016	**2265.03**	53.67	-0.01	0.02	53.68	0.12	0.10	9.00	9.22	44.46	2261.88	**1962.09**	28.55	0.04	5.18	0.12	9.00	0.14	43.03	0.339	0.34	42.69	1966.62
	Tuesday, December 20, 2016	**2264.97**	53.49	0.04	0.00	53.53	0.26	0.22	9.00	9.48	44.05	2261.74	**1962.06**	28.47	0.05	5.18	0.26	9.00	0.26	43.22	0.650	0.65	42.57	1966.58
	Wednesday, December 21, 2016	**2264.88**	53.22	-0.03	0.00	53.20	0.29	0.24	9.00	9.53	43.67	2261.61	**1962.00**	28.31	0.05	5.18	0.29	9.00	0.10	42.93	0.625	0.63	42.31	1966.51
	Thursday, December 22, 2016	**2264.85**	53.13	-0.03	0.00	53.10	0.07	0.06	9.00	9.13	43.97	2261.72	**1961.91**	28.06	0.09	5.18	0.07	9.00	0.01	42.42	0.427	0.43	41.99	1966.43
	Friday, December 23, 2016	**2264.82**	53.04	-0.01	0.01	53.04	0.10	0.09	9.00	9.19	43.85	2261.68	**1961.81**	27.82	0.09	5.18	0.10	9.00	0.15	42.34	0.595	0.60	41.75	1966.36
	Saturday, December 24, 2016	**2264.82**	53.04	0.03	0.00	53.07	0.03	0.03	9.00	9.06	44.01	2261.73	**1961.72**	27.58	0.04	5.18	0.03	9.00	0.07	41.90	0.413	0.41	41.49	1966.29
	Sunday, December 25, 2016	**2264.82**	53.04	0.00	0.00	53.04	0.00	0.00	9.00	9.00	44.04	2261.74	**1961.57**	27.17	0.00	5.18	0.00	9.00	0.00	41.35	0.420	0.42	40.93	1966.14
	Monday, December 26, 2016	**2264.82**	53.04	0.00	0.00	53.04	0.00	0.00	9.00	9.00	44.04	2261.74	**1961.48**	26.93	0.10	5.18	0.00	9.00	0.00	41.21	0.359	0.36	40.85	1966.11
	Tuesday, December 27, 2016	**2264.82**	53.04	0.08	0.02	53.14	0.11	0.09	9.00	9.21	43.93	2261.70	**1961.39**	26.68	0.05	5.18	0.11	9.00	0.14	41.17	0.563	0.56	40.61	1966.05
	Wednesday, December 28, 2016	**2264.79**	52.95	-0.03	0.00	52.92	0.07	0.06	9.00	9.13	43.79	2261.66	**1961.33**	26.52	0.08	5.18	0.07	9.00	0.15	41.00	0.468	0.47	40.54	1966.03
	Thursday, December 29, 2016	**2264.79**	52.95	0.03	0.00	52.98	0.04	0.03	9.00	9.07	43.92	2261.70	**1961.17**	26.11	0.00	5.18	0.04	9.00	0.00	40.33	0.450	0.45	39.88	1965.83
	Friday, December 30, 2016	**2264.79**	52.95	0.00	0.00	52.95	0.00	0.00	9.00	9.00	43.95	2261.71	**1961.05**	25.79	0.11	5.18	0.00	9.00	0.00	40.08	0.435	0.43	39.64	1965.75
	Saturday, December 31, 2016	**2264.76**	52.86	0.02	0.03	52.91	0.16	0.13	9.00	9.29	43.62	2261.60	**1961.05**	25.79	0.03	5.18	0.16	9.00	0.32	40.47	0.499	0.50	39.97	1965.85
	Sunday, January 01, 2017	**2264.72**	52.77	-0.01	0.00	52.76	0.09	0.08	9.00	9.17	43.60	2261.59	**1960.96**	25.54	0.07	5.18	0.09	9.00	0.20	40.08	0.602	0.60	39.48	1965.70
	Monday, January 02, 2017	**2264.72**	52.77	0.00	0.00	52.77	0.00	0.00	9.00	9.00	43.77	2261.65	**1960.90**	25.38	0.10	5.18	0.00	9.00	0.00	39.67	0.268	0.27	39.40	1965.67
	Tuesday, January 03, 2017	**2264.69**	52.69	0.00	0.00	52.68	0.10	0.09	9.00	9.19	43.49	2261.55	**1960.84**	25.22	0.11	5.18	0.10	9.00	0.16	39.77	0.536	0.54	39.24	1965.62
	Wednesday, January 04, 2017	**2264.66**	52.60	0.02	0.00	52.61	0.13	0.11	9.00	9.23	43.38	2261.52	**1960.84**	25.22	-0.02	5.18	0.13	9.00	0.24	39.75	0.350	0.35	39.40	1965.67
	Thursday, January 05, 2017	**2264.63**	52.51	0.04	0.00	52.55	0.14	0.11	9.00	9.25	43.30	2261.49	**1960.81**	25.14	0.03	5.18	0.14	9.00	0.19	39.67	0.437	0.44	39.24	1965.62
	Friday, January 06, 2017	**2264.60**	52.42	0.00	0.02	52.44	0.11	0.09	9.00	9.20	43.24	2261.47	**1960.81**	25.14	0.11	5.18	0.11	9.00	0.17	39.70	0.386	0.39	39.32	1965.65
	Saturday, January 07, 2017	**2264.54**	52.24	0.07	0.00	52.31	0.26	0.21	9.00	9.47	42.84	2261.33	**1960.81**	25.14	0.00	5.18	0.26	9.00	0.34	39.91	0.588	0.59	39.32	1965.65
	Sunday, January 08, 2017	**2264.48**	52.06	-0.05	0.00	52.01	0.11	0.09	9.00	9.21	42.81	2261.32	**1960.75**	24.97	0.08	5.18	0.11	9.00	0.08	39.43	0.441	0.44	38.99	1965.54
	Monday, January 09, 2017	**2264.45**	51.97	0.05	0.00	52.03	0.15	0.13	9.00	9.27	42.75	2261.30	**1960.69**	24.81	0.06	5.18	0.15	9.00	0.10	39.31	0.476	0.48	38.83	1965.49
	Tuesday, January 10, 2017	**2264.39**	51.79	-0.01	0.00	51.79	0.16	0.13	9.00	9.29	42.49	2261.21	**1960.63**	24.65	0.03	5.18	0.16	9.00	0.12	39.14	0.470	0.47	38.67	1965.44
	Wednesday, January 11, 2017	**2264.30**	51.53	0.07	0.00	51.60	0.34	0.29	9.00	9.63	41.97	2261.04	**1960.63**	24.65	0.03	5.18	0.34	9.00	0.24	39.44	0.609	0.61	38.83	1965.49
	Thursday, January 12, 2017	**2264.18**	51.17	-0.03	0.00	51.14	0.31	0.26	9.00	9.56	41.58	2260.90	**1960.63**	24.65	-0.05	5.18	0.31	9.00	0.33	39.41	0.581	0.58	38.83	1965.49
	Friday, January 13, 2017	**2264.05**	50.81	-0.04	0.00	50.77	0.29	0.24	9.00	9.53	41.24	2260.79	**1960.60**	24.57	0.02	5.18	0.29	9.00	0.22	39.28	0.615	0.61	38.67	1965.44
	Saturday, January 14, 2017	**2263.96**	50.54	-0.03	0.00	50.52	0.22	0.19	9.00	9.41	41.11	2260.74	**1960.47**	24.24	0.00	5.18	0.22	9.00	0.00	38.64	0.548	0.55	38.10	1965.26
	Sunday, January 15, 2017	**2263.96**	50.54	0.00	0.00	50.54	0.00	0.00	9.00	9.00	41.54	2260.89	**1960.47**	24.24	0.25	5.18	0.00	9.00	0.00	38.67	0.250	0.25	38.42	1965.36
	Monday, January 16, 2017	**2263.96**	50.54	0.00	0.00	50.54	0.00	0.00	9.00	9.00	41.54	2260.89	**1960.38**	24.00	0.10	5.18	0.00	9.00	0.00	38.28	0.336	0.34	37.95	1965.21
	Tuesday, January 17, 2017	**2263.96**	50.54	0.00	0.00	50.54	0.00	0.00	9.00	9.00	41.54	2260.89	**1960.23**	23.59	0.03	5.18	0.00	9.00	0.00	37.81	0.411	0.41	37.40	1965.04
	Wednesday, January 18, 2017	**2263.96**	50.54	0.00	0.00	50.54	0.00	0.00	9.00	9.00	41.54	2260.89	**1960.11**	23.27	0.10	5.18	0.00	9.00	0.00	37.55	0.405	0.41	37.14	1964.96
	Thursday, January 19, 2017	**2263.96**	50.54	0.00	0.00	50.54	0.00	0.00	9.00	9.00	41.54	2260.89	**1959.99**	22.95	0.03	5.18	0.00	9.00	0.00	37.16	0.331	0.33	36.83	1964.86
	Friday, January 20, 2017	**2263.96**	50.54	0.00	0.00	50.54	0.00	0.00	9.00	9.00	41.54	2260.89	**1959.86**	22.69	0.08	5.18	0.00	9.00	0.00	36.96	0.388	0.39	36.57	1964.77
	Saturday, January 21, 2017	**2263.96**	50.54	0.00	0.00	50.54	0.00	0.00	9.00	9.00	41.54	2260.89	**1959.68**	22.30	0.12	5.18	0.00	9.00	0.00	36.60	0.558	0.56	36.04	1964.61
	Sunday, January 22, 2017	**2263.96**	50.54	0.00	0.00	50.54	0.00	0.00	9.00	9.00	41.54	2260.89	**1959.74**	22.43	0.18	5.18	0.00	9.00	0.00	36.80	0.036	0.04	36.76	1964.84
	Monday, January 23, 2017	**2263.96**	50.54	0.02	0.00	50.56	0.02	0.02	9.00	9.04	41.52	2260.88	**1959.71**	22.37	-0.03	5.18	0.02	9.00	0.04	36.58	0.093	0.09	36.49	1964.75
	Tuesday, January 24, 2017	**2263.96**	50.54	0.00	0.00	50.54	0.00	0.00	9.00	9.00	41.54	2260.89	**1959.59**	22.11	0.02	5.18	0.00	9.00	0.00	36.31	0.333	0.33	35.98	1964.59
	Wednesday, January 25, 2017	**2263.96**	50.54	0.04	0.00	50.59	0.05	0.04	9.00	9.09	41.49	2260.87	**1959.50**	21.91	-0.01	5.18	0.05	9.00	0.12	36.26	0.380	0.38	35.88	1964.56
	Thursday, January 26, 2017	**2263.96**	50.54	0.13	0.00	50.68	0.15	0.13	9.00	9.28	41.40	2260.84	**1959.38**	21.65	0.03	5.18	0.15	9.00	0.00	36.02	0.462	0.46	35.56	1964.45
	Friday, January 27, 2017	**2263.93**	50.45	0.05	0.00	50.51	0.15	0.12	9.00	9.27	41.24	2260.78	**1959.41**	21.72	0.08	5.18	0.15	9.00	0.31	36.44	0.468	0.47	35.97	1964.58
	Saturday, January 28, 2017	**2263.90**	50.37	0.01	0.00	50.37	0.09	0.08	9.00	9.17	41.20	2260.77	**1959.41**	21.72	0.00	5.18	0.09	9.00	0.36	36.36	0.461	0.46	35.90	1964.56
	Sunday, January 29, 2017	**2263.87**	50.28	0.00	0.01	50.29	0.10	0.08	9.00	9.18	41.11	2260.74	**1959.41**	21.72	-0.06	5.18	0.10	9.00	0.23	36.17	0.269	0.27	35.90	1964.56
	Monday, January 30, 2017	**2263.87**	50.28	-0.02	0.02	50.28	0.00	0.00	9.00	9.00	41.28	2260.80	**1959.28**	21.46	0.08	5.18	0.00	9.00	0.00	35.72	0.361	0.36	35.36	1964.39
	Tuesday, January 31, 2017	**2263.81**	50.10	-0.02	0.00	50.08	0.14	0.12	9.00	9.26	40.82	2260.64	**1959.16**	21.20	0.00	5.18	0.14	9.00	0.00	35.53	0.423	0.42	35.10	1964.31
	Wednesday, February 01, 2017	**2263.75**	49.92	-0.03	0.00	49.88	0.13	0.11	9.00	9.23	40.65	2260.58	**1959.07**	21.01	0.05	5.18	0.13	9.00	0.05	35.41	0.434	0.43	34.98	1964.27
	Thursday, February 02, 2017	**2263.72**	49.83	0.04	0.00	49.87	0.13	0.11	9.00	9.23	40.63	2260.58	**1959.01**	20.88	0.02	5.18	0.13	9.00	0.12	35.33	0.411	0.41	34.92	1964.25
	Friday, February 03, 2017	**2263.69**	49.74	-0.01	0.00	49.73	0.07	0.06	9.00	9.13	40.60	2260.57	**1958.89**	20.62	-0.13	5.18	0.07	9.00	0.21	34.94	0.420	0.42	34.52	1964.12
	Saturday, February 04, 2017	**2263.66**	49.65	0.05	0.00	49.70	0.14	0.12	9.00	9.26	40.44	2260.51	**1958.77**	20.36	0.09	5.18	0.14	9.00	0.00	34.77	0.508	0.51	34.26	1964.04
	Sunday, February 05, 2017	**2263.63**	49.56	0.04	0.00	49.60	0.13	0.11	9.00	9.23	40.36	2260.49	**1958.77**	20.36	0.14	5.18	0.13	9.00	0.29	35.10	0.556	0.56	34.54	1964.13
	Monday, February 06, 2017	**2263.57**	49.38	-0.09	0.00	49.30	0.07	0.05	9.00	9.12	40.18	2260.42	**1958.71**	20.23	0.11	5.18	0.07	9.00	0.13	34.71	0.441	0.44	34.27	1964.04
	Tuesday, February 07, 2017	**2263.51**	49.21	0.08	0.00	49.29	0.27	0.23	9.00	9.49	39.80	2260.29	**1958.58**	19.97	-0.06	5.18	0.27	9.00	0.13	34.48	0.611	0.61	33.87	1963.92
	Wednesday, February 08, 2017	**2263.44**	49.03	0.04	0.04	49.10	0.07	0.18	9.00	9.25	39.86	2260.31	**1958.71**	20.23	-0.08	5.18	0.07	9.00	0.13	34.53	0.499	0.50	34.03	1963.97
	Thursday, February 09, 2017	**2263.38**	48.85	-0.05	0.03	48.83	0.11	0.10	9.00	9.21	39.62	2260.23	**1958.49**	19.77	0.02	5.18	0.11	9.00	0.20	34.29	0.398	0.40	33.89	1963.92
	Friday, February 10, 2017	**2263.32**	48.67	-0.05	0.00	48.62	0.11	0.09	9.00	9.21	39.42	2260.16	**1958.43**	19.64	0.03	5.18	0.11	9.00	0.26	34.22	0.537	0.54	33.69	1963.86
	Saturday, February 11, 2017	**2263.26**	48.49	-0.02	0.00	48.47	0.14	0.12	9.00	9.26	39.21	2260.09	**1958.34**	19.45	0.06	5.18	0.14	9.00	0.13	33.96	0.531	0.53	33.42	1963.78
	Sunday, February 12, 2017	**2263.20**	48.31	-0.04	0.00	48.27	0.12	0.10	9.00	9.21	39.06	2260.04	**1958.31**	19.38	0.04	5.18	0.12	9.00	0.26	33.98	0.505	0.51	33.48	1963.79
	Monday, February 13, 2017	**2263.20**	48.31	0.00	0.00	48.31	0.00	0.00	9.00	9.00	39.31	2260.13	**1958.16**	19.06	0.06	5.18	0.00	9.00	0.00	33.31	0.402	0.40	32.90	1963.61
	Tuesday, February 14, 2017	**2263.20**	48.31	0.00	0.00	48.31	0.00	0.00	9.00	9.00	39.31	2260.13	**1958.00**	18.74	0.07	5.18	0.00	9.00	0.00	32.99	0.388	0.39	32.60	1963.52
	Wednesday, February 15, 2017	**2263.17**	48.22	0.00	0.00	48.23	0.09	0.07	9.00	9.17	39.06	2260.04	**1957.85**	18.41	0.13	5.18	0.09	9.00	0.13	32.95	0.481	0.48	32.47	1963.47
	Thursday, February 16, 2017	**2263.14**	48.13	-0.03	0.00	48.10	0.04	0.04	9.00	9.08	39.02	2260.03	**1957.73**	18.15	0.11	5.18	0.04	9.00	0.10	32.58	0.443	0.44	32.14	1963.37
	Friday, February 17, 2017	**2263.11**	48.05	-0.06	0.05	48.03	0.05	0.04	9.00	9.09	38.94	2260.00	**1957.61**	17.89	0.11	5.18	0.05	9.00	0.12	32.36	0.469	0.47	31.89	1963.29
	Saturday, February 18, 2017	**2263.08**	47.96	0.02	0.00	47.98	0.11	0.09	9.00	9.20	38.77	2259.93	**1957.61**	17.89	0.02	5.18	0.11	9.00	0.25	32.46	0.380	0.38	32.08	1963.35
	Sunday, February 19, 2017	**2263.05**	47.87	0.00	0.00	47.87	0.08	0.07	9.00	9.15	38.71	2259.90	**1957.55**	17.76	0.13	5.18	0.08	9.00	0.00	32.16	0.379	0.38	31.78	1963.25
	Monday, February 20, 2017	**2263.05**	47.87	0.03	0.00	47.90	0.04	0.03	9.00	9.08	38.83	2259.95	**1957.46**	17.57	0.05	5.18	0.04	9.00	0.00	31.85	0.399	0.40	31.45	1963.15
	Tuesday, February 21, 2017	**2263.02**	47.78	-0.03	0.00	47.75	0.05	0.04	9.00	9.08	38.66	2259.87	**1957.36**	17.38	0.01	5.18	0.05	9.00	0.13	31.74	0.357	0.36	31.38	1963.13
	Wednesday, February 22, 2017	**2262.99**	47.69	0.01	0.00	47.70	0.10	0.08	9.00	9.18	38.52	2259.81	**1957.33**	17.31	0.01	5.18	0.10	9.00	0.21	31.81	0.523	0.52	31.29	1963.10
	Thursday, February 23, 2017	**2262.90**	47.42	-0.01	0.00	47.41	0.24	0.20	9.00	9.45	37.97	2259.56	**1957.33**	17.31	-0.11	5.18	0.24	9.00	0.55	32.18	0.687	0.69	31.49	1963.16

Friday, February 24, 2017	2262.71	46.89	-0.05	0.01	46.85	0.46	0.39	9.00	9.84	37.00	2259.13	1957.40	17.44	-0.18	5.18	0.46	9.00	0.68	32.58	0.826	0.83	31.76	1963.25
Saturday, February 25, 2017	2262.59	46.53	-0.01	0.02	46.53	0.34	0.28	9.00	9.62	36.91	2259.09	1957.43	17.51	0.07	5.18	0.34	9.00	0.31	32.40	0.644	0.64	31.76	1963.25
Sunday, February 26, 2017	2262.50	46.26	0.00	0.00	46.26	0.27	0.23	9.00	9.50	36.77	2259.03	1957.36	17.38	0.04	5.18	0.27	9.00	0.16	32.02	0.612	0.61	31.41	1963.14
Monday, February 27, 2017	2262.47	46.17	-0.03	0.00	46.15	0.11	0.05	9.00	9.16	36.99	2259.13	1957.27	17.18	0.03	5.18	0.11	9.00	0.14	31.64	0.478	0.48	31.16	1963.06
Tuesday, February 28, 2017	2262.44	46.08	-0.03	0.00	46.06	0.11	0.04	9.00	9.15	36.90	2259.09	1957.21	17.05	0.06	5.18	0.11	9.00	0.13	31.53	0.376	0.38	31.15	1963.06
Wednesday, March 01, 2017	2262.44	46.08	0.03	0.00	46.11	0.06	0.03	9.00	9.09	37.02	2259.14	1957.09	16.79	0.06	5.18	0.06	9.00	0.06	31.16	0.432	0.43	30.73	1962.91
Thursday, March 02, 2017	2262.41	45.99	0.02	0.01	46.02	0.12	0.10	9.00	9.22	36.80	2259.04	1957.09	16.79	0.05	5.18	0.12	9.00	0.22	31.37	0.391	0.39	30.97	1963.00
Friday, March 03, 2017	2262.38	45.90	0.05	0.00	45.95	0.14	0.12	9.00	9.25	36.69	2258.99	1957.18	16.99	-0.03	5.18	0.14	9.00	0.30	31.58	0.205	0.21	31.37	1963.12
Saturday, March 04, 2017	2262.23	45.46	-0.04	0.00	45.42	0.37	0.31	9.00	9.69	35.73	2258.56	1957.33	17.31	-0.07	5.18	0.37	9.00	0.48	32.28	0.448	0.45	31.83	1963.27
Sunday, March 05, 2017	2262.10	45.10	0.01	0.00	45.11	0.35	0.29	9.00	9.64	35.47	2258.45	1957.46	17.57	-0.05	5.18	0.35	9.00	0.47	32.53	0.505	0.51	32.02	1963.33
Monday, March 06, 2017	2261.98	44.74	-0.01	0.01	44.74	0.34	0.28	9.00	9.62	35.12	2258.29	1957.58	17.83	-0.08	5.18	0.34	9.00	0.41	32.68	0.397	0.40	32.28	1963.41
Tuesday, March 07, 2017	2261.80	44.21	0.00	0.00	44.21	0.51	0.43	9.00	9.94	34.27	2257.91	1957.73	18.15	0.00	5.18	0.51	9.00	0.29	33.13	0.459	0.46	32.67	1963.54
Wednesday, March 08, 2017	2261.62	43.67	-0.01	0.01	43.67	0.50	0.42	9.00	9.93	33.75	2257.67	1957.91	18.54	-0.02	5.18	0.50	9.00	0.58	33.79	0.573	0.57	33.22	1963.71
Thursday, March 09, 2017	2261.46	43.23	-0.03	0.00	43.20	0.39	0.33	9.00	9.71	33.49	2257.56	1958.07	18.87	-0.04	5.18	0.39	9.00	0.44	33.84	0.512	0.51	33.33	1963.75
Friday, March 10, 2017	2261.25	42.60	-0.01	0.00	42.59	0.58	0.49	9.00	10.06	32.53	2257.13	1958.31	19.38	-0.20	5.18	0.58	9.00	0.73	34.68	0.570	0.57	34.11	1963.99
Saturday, March 11, 2017	2261.07	42.07	-0.01	0.01	42.06	0.50	0.42	9.00	9.93	32.14	2256.95	1958.61	20.03	0.04	5.18	0.50	9.00	0.62	35.38	0.476	0.48	34.91	1964.25
Sunday, March 12, 2017	2260.88	41.53	0.00	0.00	41.53	0.50	0.42	9.00	9.92	31.61	2256.72	1959.01	20.88	0.07	5.18	0.50	9.00	0.67	36.30	0.350	0.35	35.96	1964.58
Monday, March 13, 2017	2260.85	41.44	0.04	0.00	41.48	0.13	0.11	9.00	9.24	32.24	2257.00	1959.35	21.59	0.03	5.18	0.13	9.00	0.89	36.83	0.347	0.35	36.48	1964.75
Tuesday, March 14, 2017	2260.82	41.35	0.00	0.00	41.35	0.09	0.07	9.00	9.16	32.19	2256.98	1959.53	21.98	0.03	5.18	0.09	9.00	0.60	36.88	0.354	0.35	36.52	1964.76
Wednesday, March 15, 2017	2260.70	41.00	0.04	0.00	41.03	0.38	0.32	9.00	9.70	31.33	2256.59	1959.83	22.63	0.04	5.18	0.38	9.00	0.70	37.93	0.422	0.42	37.51	1965.07
Thursday, March 16, 2017	2260.61	40.73	-0.06	0.02	40.68	0.20	0.17	9.00	9.36	31.32	2256.59	1960.11	23.27	0.05	5.18	0.20	9.00	0.62	38.32	0.212	0.21	38.11	1965.26
Friday, March 17, 2017	2260.43	40.19	-0.01	0.00	40.19	0.50	0.42	9.00	9.91	30.27	2256.12	1960.41	24.08	0.05	5.18	0.50	9.00	0.68	39.50	0.527	0.53	38.97	1965.54
Saturday, March 18, 2017	2260.27	39.75	0.04	0.00	39.78	0.47	0.39	9.00	9.86	29.93	2255.96	1960.69	24.81	0.03	5.18	0.47	9.00	0.53	40.02	0.330	0.33	39.69	1965.77
Sunday, March 19, 2017	2260.18	39.48	-0.02	0.00	39.46	0.22	0.19	9.00	9.41	30.04	2256.01	1960.93	25.46	0.03	5.18	0.22	9.00	0.70	40.60	0.301	0.30	40.30	1965.96
Monday, March 20, 2017	2260.15	39.39	0.00	0.00	39.38	0.08	0.07	9.00	9.15	30.24	2256.10	1960.90	25.38	0.05	5.18	0.08	9.00	0.17	39.87	0.416	0.42	39.45	1965.69
Tuesday, March 21, 2017	2260.09	39.21	0.04	0.00	39.25	0.21	0.18	9.00	9.39	29.86	2255.93	1961.05	25.79	0.08	5.18	0.21	9.00	0.49	40.75	0.366	0.37	40.38	1965.98
Wednesday, March 22, 2017	2259.94	38.81	0.02	0.01	38.84	0.46	0.39	9.00	9.85	28.99	2255.55	1961.24	26.27	-0.14	5.18	0.46	9.00	0.93	41.70	0.753	0.75	40.95	1966.14
Thursday, March 23, 2017	2259.63	38.13	-0.16	0.00	37.97	0.65	0.55	9.00	10.20	27.77	2255.00	1961.57	27.17	0.02	5.18	0.65	9.00	0.94	42.96	0.685	0.69	42.27	1966.50
Friday, March 24, 2017	2259.33	37.44	-0.19	0.00	37.25	0.61	0.51	9.00	10.12	27.13	2254.71	1961.88	27.98	0.08	5.18	0.61	9.00	0.76	43.62	0.606	0.61	43.01	1966.70
Saturday, March 25, 2017	2259.15	37.04	-0.01	0.01	37.03	0.50	0.42	9.00	9.93	27.11	2254.70	1962.06	28.47	0.03	5.18	0.50	9.00	0.60	43.79	0.641	0.64	43.14	1966.74
Sunday, March 26, 2017	2259.03	36.76	-0.01	0.00	36.75	0.32	0.27	9.00	9.59	27.16	2254.72	1962.12	28.63	0.03	5.18	0.32	9.00	0.55	43.71	0.377	0.38	43.33	1966.79
Monday, March 27, 2017	2258.96	36.63	-0.05	0.00	36.57	0.11	0.09	9.00	9.19	27.38	2254.82	1962.09	28.55	0.02	5.18	0.11	9.00	0.29	43.15	0.519	0.52	42.63	1966.60
Tuesday, March 28, 2017	2258.78	36.22	-0.09	0.01	36.14	0.41	0.35	9.00	9.76	26.38	2254.38	1962.12	28.63	0.04	5.18	0.41	9.00	0.19	43.46	0.548	0.55	42.91	1966.68
Wednesday, March 29, 2017	2258.69	36.02	0.00	0.00	36.02	0.26	0.22	9.00	9.47	26.55	2254.45	1962.09	28.55	0.03	5.18	0.26	9.00	0.00	43.02	0.389	0.39	42.63	1966.60
Thursday, March 30, 2017	2258.39	35.33	-0.14	0.00	35.19	0.56	0.47	9.00	10.03	25.16	2253.77	1962.12	28.63	0.07	5.18	0.56	9.00	0.00	43.44	0.557	0.56	42.88	1966.67
Friday, March 31, 2017	2258.26	35.06	0.01	0.01	35.08	0.28	0.23	9.00	9.51	25.57	2254.01	1962.06	28.47	0.05	5.18	0.28	9.00	0.00	42.98	0.508	0.51	42.47	1966.56
Saturday, April 01, 2017	2258.08	34.65	0.01	0.00	34.66	0.40	0.34	9.00	9.74	24.92	2253.63	1962.03	28.39	0.04	5.18	0.40	9.00	0.00	43.01	0.529	0.53	42.48	1966.56
Sunday, April 02, 2017	2257.84	34.11	-0.01	0.00	34.10	0.51	0.43	9.00	9.93	24.16	2253.17	1962.06	28.47	0.05	5.18	0.51	9.00	0.00	43.21	0.472	0.47	42.74	1966.63
Monday, April 03, 2017	2257.81	34.04	-0.05	0.00	33.99	0.51	0.00	9.00	9.51	24.48	2253.36	1961.91	28.06	0.03	5.18	0.51	9.00	0.00	42.79	0.469	0.47	42.32	1966.51
Tuesday, April 04, 2017	2257.68	33.77	0.02	0.00	33.79	0.29	0.24	9.00	9.53	24.26	2253.23	1961.85	27.90	0.03	5.18	0.29	9.00	0.00	42.40	0.489	0.49	41.91	1966.40
Wednesday, April 05, 2017	2257.50	33.36	-0.02	0.01	33.35	0.37	0.31	9.00	9.69	23.66	2252.86	1961.78	27.74	0.04	5.18	0.37	9.00	0.00	42.33	0.583	0.58	41.75	1966.36
Thursday, April 06, 2017	2257.35	33.02	0.02	0.00	33.04	0.35	0.29	9.00	9.64	23.40	2252.70	1961.75	27.66	0.10	5.18	0.35	9.00	0.00	42.28	0.527	0.53	41.75	1966.36
Friday, April 07, 2017	2257.17	32.61	0.01	0.00	32.62	0.41	0.34	9.00	9.75	22.88	2252.39	1961.72	27.58	0.05	5.18	0.41	9.00	0.00	42.21	0.537	0.54	41.67	1966.34
Saturday, April 08, 2017	2257.07	32.41	-0.01	0.01	32.41	0.20	0.17	9.00	9.37	23.04	2252.49	1961.60	27.25	0.09	5.18	0.20	9.00	0.00	41.72	0.632	0.63	41.09	1966.18
Sunday, April 09, 2017	2256.98	32.20	0.02	0.00	32.22	0.22	0.18	9.00	9.40	22.82	2252.36	1961.51	27.01	0.01	5.18	0.22	9.00	0.00	41.42	0.483	0.48	40.93	1966.14
Monday, April 10, 2017	2256.92	32.07	-0.02	0.00	32.05	0.11	0.09	9.00	9.20	22.85	2252.37	1961.39	26.68	-0.01	5.18	0.11	9.00	0.00	40.97	0.443	0.44	40.52	1966.03
Tuesday, April 11, 2017	2256.92	32.07	0.00	0.00	32.07	0.00	0.00	9.00	9.00	23.07	2252.50	1961.24	26.27	0.05	5.18	0.00	9.00	0.00	40.51	0.465	0.46	40.05	1965.88
Wednesday, April 12, 2017	2256.92	32.07	-0.01	0.01	32.07	0.00	0.00	9.00	9.00	23.07	2252.50	1961.11	25.95	0.06	5.18	0.00	9.00	0.00	40.20	0.393	0.39	39.80	1965.80
Thursday, April 13, 2017	2256.86	31.93	0.01	0.00	31.94	0.14	0.12	9.00	9.27	22.68	2252.27	1960.99	25.62	0.11	5.18	0.14	9.00	0.00	40.06	0.562	0.56	39.50	1965.70
Friday, April 14, 2017	2256.74	31.66	0.00	0.00	31.65	0.25	0.21	9.00	9.47	22.19	2251.97	1960.90	25.38	0.06	5.18	0.25	9.00	0.00	39.88	0.561	0.56	39.32	1965.65
Saturday, April 15, 2017	2256.74	31.66	0.00	0.00	31.66	0.00	0.00	9.00	9.00	22.66	2252.26	1960.81	25.14	0.08	5.18	0.00	9.00	0.00	39.40	0.326	0.33	39.07	1965.57
Sunday, April 16, 2017	2256.74	31.66	-0.01	0.01	31.66	0.00	0.00	9.00	9.00	22.66	2252.26	1960.66	24.73	0.07	5.18	0.00	9.00	0.00	38.99	0.484	0.48	38.50	1965.39
Monday, April 17, 2017	2256.74	31.66	0.00	0.00	31.66	0.00	0.00	9.00	9.00	22.66	2252.26	1960.50	24.32	0.05	5.18	0.00	9.00	0.00	38.56	0.465	0.46	38.10	1965.26
Tuesday, April 18, 2017	2256.71	31.59	-0.04	0.00	31.55	0.02	0.02	9.00	9.03	22.52	2252.17	1960.32	23.84	0.04	5.18	0.02	9.00	0.00	38.08	0.523	0.52	37.55	1965.09
Wednesday, April 19, 2017	2256.68	31.52	-0.02	0.00	31.50	0.05	0.04	9.00	9.09	22.41	2252.10	1960.14	23.35	0.10	5.18	0.05	9.00	0.00	37.68	0.612	0.61	37.07	1964.93
Thursday, April 20, 2017	2256.59	31.32	-0.01	0.00	31.31	0.18	0.15	9.00	9.34	21.97	2251.84	1960.08	23.19	0.19	5.18	0.18	9.00	0.00	37.74	0.523	0.52	37.22	1964.98
Friday, April 21, 2017	2256.53	31.18	-0.03	0.00	31.16	0.10	0.08	9.00	9.18	21.97	2251.84	1959.89	22.76	0.03	5.18	0.10	9.00	0.00	37.07	0.590	0.59	36.48	1964.75
Saturday, April 22, 2017	2256.37	30.84	-0.02	0.00	30.83	0.31	0.26	9.00	9.56	21.26	2251.41	1959.89	22.76	0.12	5.18	0.31	9.00	0.00	37.37	0.430	0.43	36.94	1964.89
Sunday, April 23, 2017	2256.37	30.84	-0.01	0.01	30.84	0.00	0.00	9.00	9.00	21.84	2251.76	1959.74	22.43	0.22	5.18	0.00	9.00	0.00	36.83	0.587	0.59	36.25	1964.67
Monday, April 24, 2017	2256.34	30.77	0.00	0.00	30.77	0.06	0.05	9.00	9.11	21.66	2251.65	1959.62	22.17	0.10	5.18	0.06	9.00	0.00	36.51	0.380	0.38	36.13	1964.64
Tuesday, April 25, 2017	2256.28	30.64	0.01	0.00	30.65	0.14	0.12	9.00	9.26	21.39	2251.49	1959.41	21.72	0.05	5.18	0.14	9.00	0.00	36.10	0.765	0.76	35.33	1964.38
Wednesday, April 26, 2017	2256.01	30.02	0.01	0.00	30.03	0.45	0.50	9.00	9.95	20.08	2250.70	1959.38	21.65	0.14	5.18	0.45	9.00	0.00	36.43	0.830	0.83	35.60	1964.47
Thursday, April 27, 2017	2255.49	28.87	-0.02	0.00	28.85	0.97	0.91	9.00	10.88	17.97	2249.42	1959.50	21.91	0.07	5.18	0.97	9.00	0.00	37.14	0.877	0.88	36.26	1964.68
Friday, April 28, 2017	2255.06	27.91	0.01	0.00	27.92	0.86	0.77	9.00	10.63	17.29	2249.01	1959.59	22.11	0.10	5.18	0.86	9.00	0.00	37.24	0.795	0.80	36.45	1964.74
Saturday, April 29, 2017	2254.73	27.17	0.00	0.00	27.16	0.51	0.60	9.00	10.11	17.05	2248.86	1959.56	22.04	0.08	5.18	0.51	9.00	0.00	36.82	0.868	0.87	35.95	1964.58
Sunday, April 30, 2017	2254.67	27.03	-0.01	0.00	27.02	0.12	0.10	9.00	9.21	17.80	2249.32	1959.38	21.65	0.11	5.18	0.12	9.00	0.00	36.06	0.642	0.64	35.42	1964.41
Monday, May 01, 2017	2254.54	26.76	-0.03	0.00	26.73	0.23	0.19	9.00	9.42	17.31	2249.02	1959.28	21.46	0.10	5.18	0.23	9.00	0.00	35.96	0.533	0.53	35.43	1964.41
Tuesday, May 02, 2017	2254.51	26.69	-0.01	0.01	26.69	0.06	0.05	9.00	9.11	17.57	2249.18	1959.13	21.14	0.09	5.18	0.06	9.00	0.00	35.47	0.502	0.50	34.97	1964.27
Wednesday, May 03, 2017	2254.48	26.62	-0.03	0.00	26.60	0.03	0.03	9.00	9.06	17.53	2249.15	1958.92	20.68	0.09	5.18	0.03	9.00	0.00	34.99	0.616	0.62	34.38	1964.08
Thursday, May 04, 2017	2254.24	26.08	0.00	0.00	26.08	0.52	0.44	9.00	9.96	16.12	2248.30	1958.83	20.49	0.06	5.18	0.52	9.00	0.00	35.25	0.787	0.79	34.46	1964.10
Friday, May 05, 2017	2253.75	25.13	0.01	0.00	25.14	1.05	0.89	9.00	10.94	14.20	2246.73	1958.98	20.81	0.07	5.18	1.05	9.00	0.00	36.11	0.771	0.77	35.34	1964.38
Saturday, May 06, 2017	2253.45	24.63	0.01	0.00	24.64	0.67	0.56	9.00	10.23	14.41	2246.92	1959.22	21.33	0.07	5.18	0.67	9.00	0.00	36.25	0.323	0.32	35.93	1964.57
Sunday, May 07, 2017	2253.45	24.63	0.01	0.00	24.64	0.02	0.01	9.00	9.03	15.61	2247.99	1959.56	22.04	0.05	5.18	0.02	9.00	0.00	36.30	0.558	0.56	35.74	1964.51
Monday, May 08, 2017	2253.42	24.58	0.03	0.00	24.61	0.11	0.09	9.00	9.19	15.42	2247.82	1958.92	20.68	0.09	5.18	0.11	9.00	0.00	35.06	0.264	0.26	34.80	1964.21
Tuesday, May 09, 2017	2253.39	24.53	0.04	0.00	24.57	0.11	0.10	9.00	9.21	15.36	2247.76	1958.83	20.49	0.07	5.18	0.11	9.00	0.00	34.85	0.394	0.39	34.46	1964.10
Wednesday, May 10, 2017	2253.39	24.53	0.03	0.00	24.55	0.03	0.03	9.00	9.06	15.49	2247.88	1958.16	19.06	0.08	5.18	0.03	9.00	0.00	33.35	0.246	0.25	33.11	1963.68
Thursday, May 11, 2017	2253.29	24.38	0.00	0.02	24.39	0.21	0.18	9.00	9.39	15.00	2247.44	1958.10	18.93	0.05	5.18	0.21	9.00	0.00	33.38	0.407	0.41	32.97	1963.63
Friday, May 12, 2017	2253.17	24.17	-0.01	0.00	24.16	0.25	0.21	9.00	9.45	14.71	2247.19	1958.58	19.97	0.07	5.18	0.25	9.00	0.00	34.46	0.591	0.59	33.87	1963.92
Saturday, May 13, 2017	2252.96	23.82	0.00	0.00	23.82	0.46	0.38	9.00	9.84	13.98	2246.54	1958.58	19.97	0.06	5.18	0.46	9.00	0.00	34.66	0.512	0.51	34.15	1964.01
Sunday, May 14, 2017	2252.78	23.52	0.02	0.00	23.54	0.41	0.34	9.00	9.75	13.78	2246.36	1958.61	20.03	0.04	5.18	0.41	9.00	0.00	34.66	0.379	0.38	34.29	1964.05
Monday, May 15, 2017	2252.78	23.52	0.00	0.00	23.52	0.00	0.00	9.00	9.00	14.52	2247.02	1958.61	20.03	0.25	5.18	0.00	9.00	0.00	34.46	0.248	0.25	34.21	1964.03
Tuesday, May 16, 2017	2252.78	23.52	0.00	0.00	23.52	0.00	0.00	9.00	9.00	14.52	2247.02	1958.49	19.77	0.11	5.18	0.00	9.00	0.00	34.07	0.387	0.39	33.68	1963.86
Wednesday, May 17, 2017	2252.78	23.52	0.00	0.00	23.52	0.00	0.00	9.00	9.00	14.52	2247.02	1958.40	19.58	0.05	5.18	0.00	9.00	0.00	33.81	0.254	0.25	33.55	1963.82
Thursday, May 18, 2017	2252.78	23.52	0.00	0.00	23.52	0.00	0.00	9.00	9.00	14.52	2247.02	1958.28	19.32	0.06	5.18	0.00	9.00	0.00	33.56	0.333	0.33	33.23	1963.71
Friday, May 19, 2017	2252.87	23.67	0.15	0.01	23.83	0.00	0.00	9.00	9.00	14.83	2247.30	1958.19	19.13	0.12	5.18	0.00	9.00	0.00	33.43	0.326	0.33	33.10	1963.67
Saturday, May 20, 2017	2252.87	23.67	0.00	0.00	23.67	0.00	0.00	9.00	9.00	14.67	2247.15	1958.10	18.93	0.11	5.18	0.00	9.00	0.00	33.22	0.309	0.31	32.91	1963.61
Sunday, May 21, 2017	2252.93	23.77	0.11	0.00	23.88	0.00	0.00	9.00	9.00	14.88	2247.34	1958.04	18.80	0.11	5.18	0.00	9.00	0.00	33.09	0.244	0.24	32.85	1963.59
Monday, May 22, 2017	2252.93	23.77	-0.01	0.01	23.77	0.00	0.00	9.00	9.00	14.77	2247.24	1957.97	18.67	0.02	5.18	0.00	9.00	0.00	32.87	0.157	0.16	32.71	1963.55
Tuesday, May 23, 2017	2252.93	23.77	0.00	0.00	23.77	0.00	0.00	9.00	9.00	14.77	2247.24	1957.88	18.48	0.05	5.18	0.00	9.00	0.00	32.71	0.256	0.26	32.45	1963.47
Wednesday, May 24, 2017	2252.93	23.77	0.00	0.00	23.77	0.00	0.00	9.00	9.00	14.77	2247.24	1957.82	18.35	0.07	5.18	0.00	9.00	0.00	32.60	0.212	0.21	32.39	1963.45
Thursday, May 25, 2017	2252.96	23.82	0.05	0.00	23.88	0.00	0.00	9.00	9.00	14.88	2247.33	1957.76	18.22	0.13	5.18	0.00	9.00	0.00	32.53	0.269	0.27	32.26	1963.41
Friday, May 26, 2017	2253.02	23.92	0.11	0.00	24.03	0.00	0.00	9.00	9.00	15.03	2247.47	1957.70	18.09	0.04	5.18	0.00	9.00	0.00	32.31	0.178	0.18	32.13	1963.36
Saturday, May 27, 2017	2253.02	23.92	-0.02	0.02	23.92	0.00	0.00	9.00	9.00	14.92	2247.38	1957.61	17.89	0.04	5.18	0.00	9.00	0.00	32.11	0.254	0.25	31.86	1963.28
Sunday, May 28, 2017	2253.05	23.97	0.02	0.04	24.03	0.00	0.00	9.00	9.00	15.03	2247.47	1957.55	17.76	0.03	5.18	0.00	9.00	0.00	31.98	0.169	0.17	31.81	1963.26
Monday, May 29, 2017	2253.05	23.97	0.00	0.00	23.97	0.00	0.00	9.00	9.00	14.97	2247.42	1957.49	17.63	0.01	5.18	0.00	9.00	0.00	31.82	0.144	0.14	31.68	1963.22
Tuesday, May 30, 2017	2253.11	24.07	0.05	0.00	24.13	0.00	0.00	9.00	9.00	15.13	2247.56	1957.43	17.51	0.02	5.18	0.00	9.00	0.00	31.71	0.185	0.18	31.52	1963.17
Wednesday, May 31, 2017	2253.11	24.07	0.09	0.00	24.16	0.11	0.09	9.00	9.19	14.97	2247.42	1957.36	17.38	-0.01	5.18	0.11	9.00	0.00	31.65	0.195	0.20	31.46	1963.15

ANNEXURE 2

*For data entry please go to last page **Annexure B.1**

Upper Bhavani Pump Storage Project (4X 250 MW)

Preliminary Dimensions of Power House

Full reservior Level of Upper Reservoir	FRL(U)	2262.44	m
Minimum Draw Down Level of Upper Reservoir	MDDL(U)	2249.42	m
Number of Units	n_u	4	
Design Discharge (for all units)	Q	0.000	m^3/sec
Design Discharge per Unit	$q = Q/n_u$	0.00	m^3/sec
Full reservior Level of Lower Reservoir	FRL(L)	1985.80	m
Minimum Draw Down Level of Lower Reservoir	MDDL(L)	1956.00	m
Installed Capacity(Turbine Mode)	P	1,000,000	kW
Installed Capacity per Unit (Turbine Mode)	$Pg=P/n_u$	250,000.00	kW/unit
Installed Capacity(Pump Mode)	P	1,100,000	kW
Installed Capacity per Unit (Pump Mode)	$Pg=P/n_u$	275,000.00	kW/unit
Gross Maximum Head	Hg_{max}=FRL(U)-MDDL(L)	306.44	m
Average Head Losses(Turbine Mode)	HLt	15.39	m
Average Head Losses(Pump Mode)	HLp	12.8	m
Gross Minimum Head	Hg_{min}=MDDL(U)-FRL(L)	263.62	m
Maximum net head for Turbine Mode =Hgmax-HL	Hnmax(Tur)	291.05	m
Minimum net head for Turbine Mode =Hgmin-HL	Hnmin(Tur)	248.23	m
Maximum net head for Pump Mode =Hgmax+HL	Hnmax(Pump)	319.24	m
Minimum net head for Pump Mode =Hgmin+HL	Hnmin(Pump)	276.42	m
Net Design Head(Turbine)	Hn(Tur)=	276.78	m
Net Design Head (Pump)	Hn(Pump)=Hg+HL	304.97	m
Turbine Efficiency	nt	0.925	
Pump Efficiency	np	0.935	
Generator Efficiency	ng	0.985	
Motor Efficiency	nm	0.985	
Turbine output Power per unit	$P_t=P_g/ng$	253,807.11	kW
Pump Input Power per unit	Pp=Pm*nm	270,875.00	kW
Turbine Unit Discharge	Qt	101.16	Cumec
Pump Unit Discharge	Qp	84.74	Cumec

Refer IS: 12800 -(Part 2 /Sec 1)

Trial Turbine specific Speed	n_{st}'=	133.781	
Trial Pump specific Speed	nsp'=	34.74	

Other references

As per USBR Monograph EM 39	nsp loptimum value = 640/H^0.5	36.65	
	nsp as per WPDC'1980 = 1768*Hp^(-0.480)	37.84	
As per JICA's Report	nsp limit value = 12500/(Hnp+80)+ 13	45.47	
	Adopted Trial Specific Speed =	38.67	
Trial synchronous speed	$n'=n_{st}$'Ht^0.75/Qp^0.5	306.58	rpm
Trial No of Poles for n'	6000/n'	19.57	
Hence, selected no of poles		20.00	nos.
		10	nos.

	Adopted Pair of Poles		Rated Turbine Speed		
	10		300.00		
Final rated speed [for calculations]			n	300.00	rpm
Final Specific Speed (for Calcultion)			nsp	37.84	

Pump Turbine Setting

Refer [IS:12800 -2 Fig 4]

The Estimated Cavitation Co-efficient = σ= 0.18800

Refer USBR Monograph EM 39 -Fig 8

The Estimated Cavitation Co-efficient = σ= 0.17406

Average water temperature 20 °C

[IS:12800-I, Fig 2 page 2]

for an altitude about = 2262.44 m

Temp(°C)	Hb-Hv (m)
0	7.74
10	8.60
15	9.03
20	9.46
30	8.22
40	6.99
60	5.72

(Hb-Hv) = 9.46 m

Suspension Head Hs=(Hb-Hv)-σ(Hn)

-47.90 m

Giving a margin of 1.5 m

Since Hs is negative, center line should be kept atleast 49.400 m

below minimum MDDL of of Lower Reservoir

Turbine Distributer Centerline should be set at **EL=TWLmin+Hs**

1906.6000

Runner Dimensions

[IS:12800-II, Fig 6]

For Specific speed	ns	37.84	
Velocity Coefficient	Ku	1.01000	
Runner Inlet Diameter			
	D1=60*sqrt(2*g*Hn)*Ku/πn		
	D1=60*sqrt(2*g*Hn)*Ku/pn	4.975	m

Spiral Casing Dimensions

[IS:12800-II, Fig 8]

The water flow velocity at Inlet of Spiral Casing is considered as 15.6 m/s as per Fig 7 of IS:12800 -Part II

V= 15.6 | A= | 2.630 m

B=	0.97- 1.18	*D1	
		B=	5.124 m
C=	1.05 - 1.3	*D1	
		C=	5.578 m
D=	1.1 -1.42	*D1	
		D=	5.926 m
E=	0.98 - 1.1	*D1	
		E=	5.045 m

The Flow velocity at Inlet of Spiral Casing is considered as 16.5 m/s as per Fig 7 of IS:12800 -Part II

Draft Tube Dimensions

Depth of draft tube	H1+H2=1.82 to 2.4 D1	
		10.083 m
Height from Top of DT Cone to Centre Line	H1=0.22 to 0.3D1	1.236 m
Width of the draft tube (clear width)	W= 0.9 to 2.4D1	7.140 m
Length of the draft tube from turbine axis	L = 2.85 to 3.7 D1	15.687 m
Height of the draft tube at exit	H3=.8 to 1.175D1	4.645 m

Main Parameters of Hydro-Generator

Generator rated output	Pg	250,000.00 kW
Power factor	p_f	0.9
Rated MVA of Generator	$W=Pg/p_f$	277.78 MVA
Rated speed of Machine	n	300.00 rpm
No of Pairs of poles	p	10

[IS:12800-II Fig 12]

Pole pairs	Vr(m/s)	Ko
5	93.75	5.720
6	90.03	5.921
8	84.540	6.125
9	82.269	6.236
10	80.561	6.309
12	77.273	6.407
14	74.091	6.519
16	70.909	6.630
18	69.091	6.722
20	67.727	6.778
22	67.273	6.852
32	66.180	7.125

Maximum Rotor Peripherical Velocity	Vr		80.561 m/s
Air gap dia	Dg	60*Vr/(πn)	
			5.1296 m
Outer Core Diameter	Dc	Dg(1+p/2p)	
			5.94 m
Stator frame diamter	Df	(Do+1.2)	
			7.14 m
	say		7.20 m
Inner diamter of generator Barrel	Db	(Df+2.3 to 2.8)	
	say	(Df+2.55)	
			9.75 m
Core length of stator	Lc	$W*1000/(k_oD_g^2n)$	
	Ko=		6.309
	Lc=		5.5775 m
Lc/Dg ratio			1.08731

Length of stator frame	L_f	Lc + 1.5 to 1.6m	
		Lc+ 1.5m	
	say		7.08 m
Axial Hydraulic thrust	P_H	$k\ D_1^2Hnmax$	

[IS:12800-II, Fig 11]

	k	0.08830
	P_H	635.98 Tonnes

[IS:12800-II, Fig 14]

Weight of Generator Rotor for Dg= 5.13 | Wr=Lc* 136.000 | 758.544 Tonnes

[IS:12800-II, Fig 10)

Weight of Turbine Runner		Wtr	44.00 Tonnes
Weight of M/C rotating parts	W_r+Wtr+PH=		1438.53 Tonnes
Height of Load Bearing Bracket hj =			
	k*sqrt(Dg)	umbrella type construction	
	k*sqrt(Df)	suspended type construction	
No of arms of bearing bracket			8
Hence, load per arm of the bracket (Tonnes) Lt			179.816

Lt	k
<50	0.65
50-100	0.75
>100	0.85

Generally 4 to 8 arms of the bracket are taken.

		k =	0.85
1. Umbrella type construction	k*sqrt(Dg) =		1.93 m
2. Suspended type construction	k*sqrt(Df) =		2.28 m

Note: Upto speed of 300rpm, Umbrella type construction should be preferred.

selecting 1 umbrella type | say hj = | 2.00 m

Power House Dimensions

Spiral casing width	C+B+A/2	12.02 m
	D+E	10.97 m
Inner Dia of Generator Barrel	Db	9.75 m

[IS 5496:1993, Cl. 3.3]

no pier for span upto 7m
one pier for span 8-15m
two piers for span more than 16m
pier of minimum 1 m width will be provided

Number of piers according to range Db			1
Assumed width of one pier		Wpier	2 m
Total width of pier(s)		Wpiert	2 m
Width of Draft tube with pier width **B1 = B+Wpiert**			9.14 m
Outer dia of generator barrel	*Do=Db+1.20m*		10.95 m
Maximum Dimensions out of above	MaxDim		12.02 m
Unit spacing	*Us = MaxDim+Clrnc (2*1.5m)+(2*1.5)*		
			18.02 m
		say	20.00 m
Erection Bay length	L_{eb} = 1 to 1.5 Us		
	say	2 Us	40 m
		**No of units in a power house*	4
Total length of a Power House =			
		Space for units Us*Nu	80 m
		.+Leb	40.00 m
		.+Space for EOT crane to handle last unit	4 m
		.+space for control bay	20 m
			144.00 m
		say	144.00 m

Width of power house super structure

On upstream side

Do/2	5.475 m
.+approaching distance to manhole	2 m
.+MIV Spacing	3.5 m
.+column width	1.2 m
.+Space of EOT Crane movement	1.5 m
W_1=	13.675 m

On down stream side

Do/2	5.475 m
.+moving space	2 m
.+clearance for EOT crane movement	1.5 m
.+column width	1.2 m
W_2=	10.175 m

Total widht of power house	W_1+W_2=	23.85 m
	say	24.00 m

Total height of machine hall

H1	10.08 m
.+ Depth of concrete	2 m
.+Lf	7.08 m
.+hj	2.00 m
.+k	5.5 m
	26.661 m
say	26.70 m

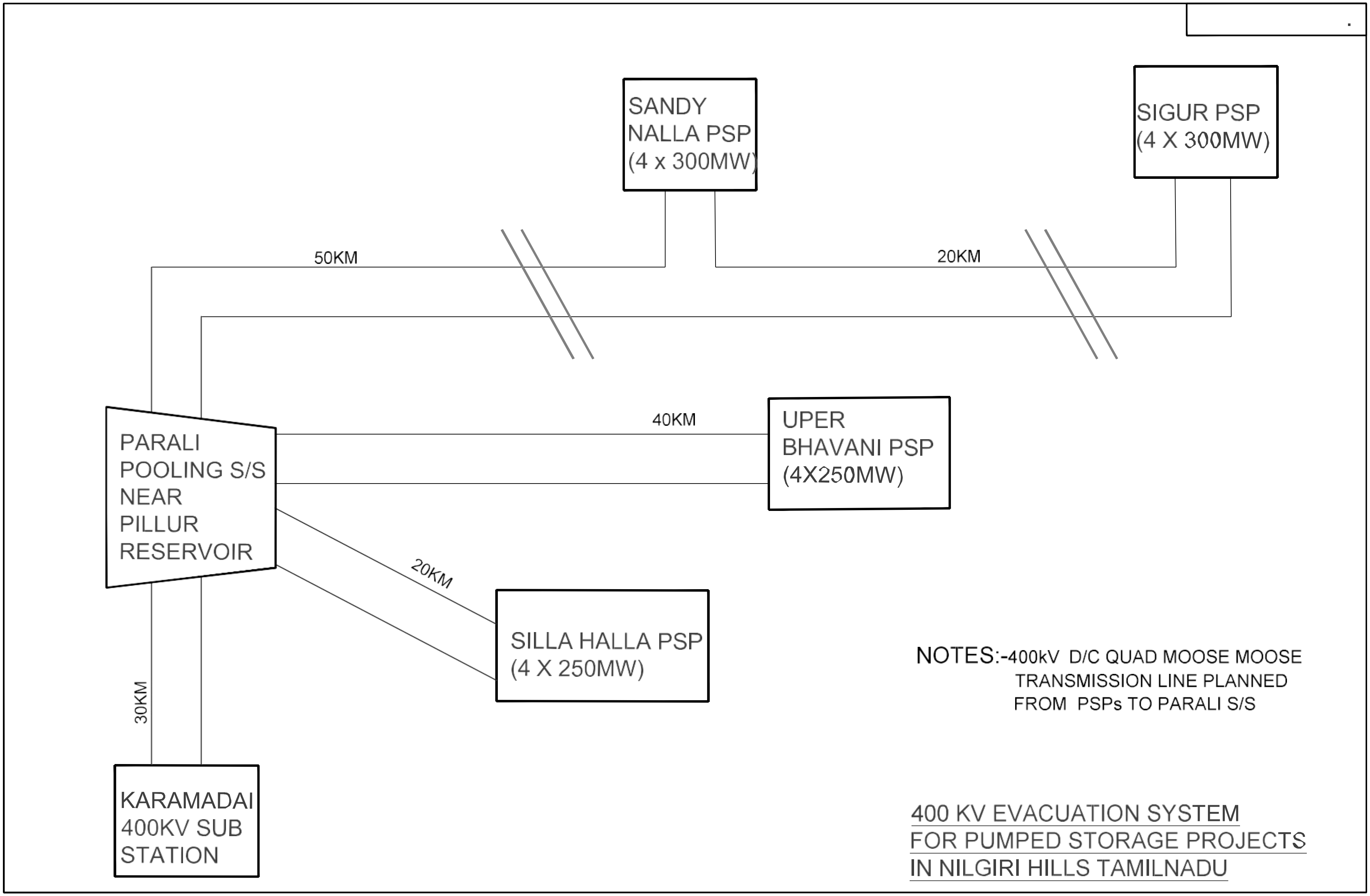
References of Input Data

Project Name	Upper Bhavani Pump Storage Project (4X 250 MW)	
Full Reservoir Level of Upper Reservoir		2262.44 m
Minimum Draw Down Level of Upper Reservoir		2249.42 m
Number of Units		4
Design Discharge		0.00 m^3/s
Full Reservoir Level of Lower Reservoir		1985.80 m
Minimum Draw Down Level of Lower Reservoir		1956.00 m
Net Head		0.00 m
Installed Capacity		1,000,000 kW
Generator efficiency		0.985
Turbine efficiency		0.925
Pump Efficiency		0.935
Average Head Loss Turbine mode		15.39 m
Average Head Loss Pump mode		12.8 m
Average water temperature		20 °C
Power factor	General	0.9
Silt concentration on specific speed		No

Note:

Only red colored data should be modified according to project data and outputs

ANNEXURE 3


SANDY
NALLA PSP
(4 x 300MW)
SIGUR PSP
(4 X 300MW)
50KM
20KM
40KM
PARALI
POOLING S/S
NEAR
PILLUR
RESERVOIR
UPER
BHAVANI PSP
(4X250MW)
20KM
SILLA HALLA PSP
(4 X 250MW)
30KM
KARAMADAI
400KV SUB
STATION
NOTES:-400kV D/C QUAD MOOSE MOOSE
TRANSMISSION LINE PLANNED
FROM PSPs TO PARALI S/S
400 KV EVACUATION SYSTEM
FOR PUMPED STORAGE PROJECTS
IN NILGIRI HILLS TAMILNADU

ANNEXURE 4

By Email

TAMILNADU TRANSMISSION CORPORATION LTD.
(Subsidiary of TNEB Ltd.)

From

Er. N.Kannan, M.E, M.B.A.,
Chief Engineer,
Planning & R.C,
TANGEDCO,
6th floor, Eastern Wing,
144,Anna Salai,
Chennai-2.

To

Shri. J.C.Kakoti
AGM & Project Manager,
HRHQ, Noida,
NTPC Ltd.

Lr.No.CE/Plg.&R.C/SE/SS/EE1/AEE3/F.PSP/D. 88 /22 dt. 25.03.2022.

Sir,

Sub: Elecy- Evacuation System for Pumped Storage Projects (PSP) in Nilgiri hill of Tamilnadu – review and confirmation requested - reply furnished – reg.

Ref: Your Email dated 04.03.2022.

****

Adverting to the reference cited above, the remarks for Evacuation system of Pumped Storage Projects (PSP) in Nilgiri hills of Tamilnadu are furnished below.

a) The Establishment of 400/230 kV substation at Parali has been approved vide (Per).FB.TANTRANSCO Proceeding No. 21, dated 05.03.2019 with 2 nos. of 400 kV feeder bays and 5 Nos. of 230 kV feeder bays for the proposed power evacuation of Kundha Pumped storage HEP - VII (4 X 125 MW) and the existing Kundha Power house -III (3 X 60 MW). In the above B.P, 2 nos. of 400 kV lines with HTLS conductor has been approved for evacuation of power from Parali 400 kV substation to Karamadai 400 kV substation.

b) It has been proposed to evacuate 4400 MW power of various PSPs through 8 nos. of 400 kV feeders from Parali 400 kV SS as shown in the SLD. The outgoing 400 kV DC lines to Karamadai 400 kV substation will not be sufficient to evacuate 4400 MW power. Hence, nearby 400 kV substations in addition to Karamadai 400 kV SS shall be explored for Power evacuation and will be finalized after conducting joint load flow study with CTU & CEA/NewDelhi.

c) The space availability in the sanctioned Parali 400/230 kV substation needs to be checked with the field personnel to accommodate all the above said 400 kV feeders.

d) The land for the establishment of Parali 400/230 kV substation is not yet finalized since there is a different thought of opinion in establishing the substation in plains or hills, due to difficulty in getting the approval from the Forest Department. If the location of Parali substation is getting changed to Plains, then the line distance from other PSP will get increased further.

e) 400kV DC Quad Moose conductor shall be proposed for 400 kV transmission lines to avoid outage under N-1 condition.

25/03/22

(M.Sudarsan)
Superintending Engineer/System Studies
For Chief Engineer/Planning & R.C