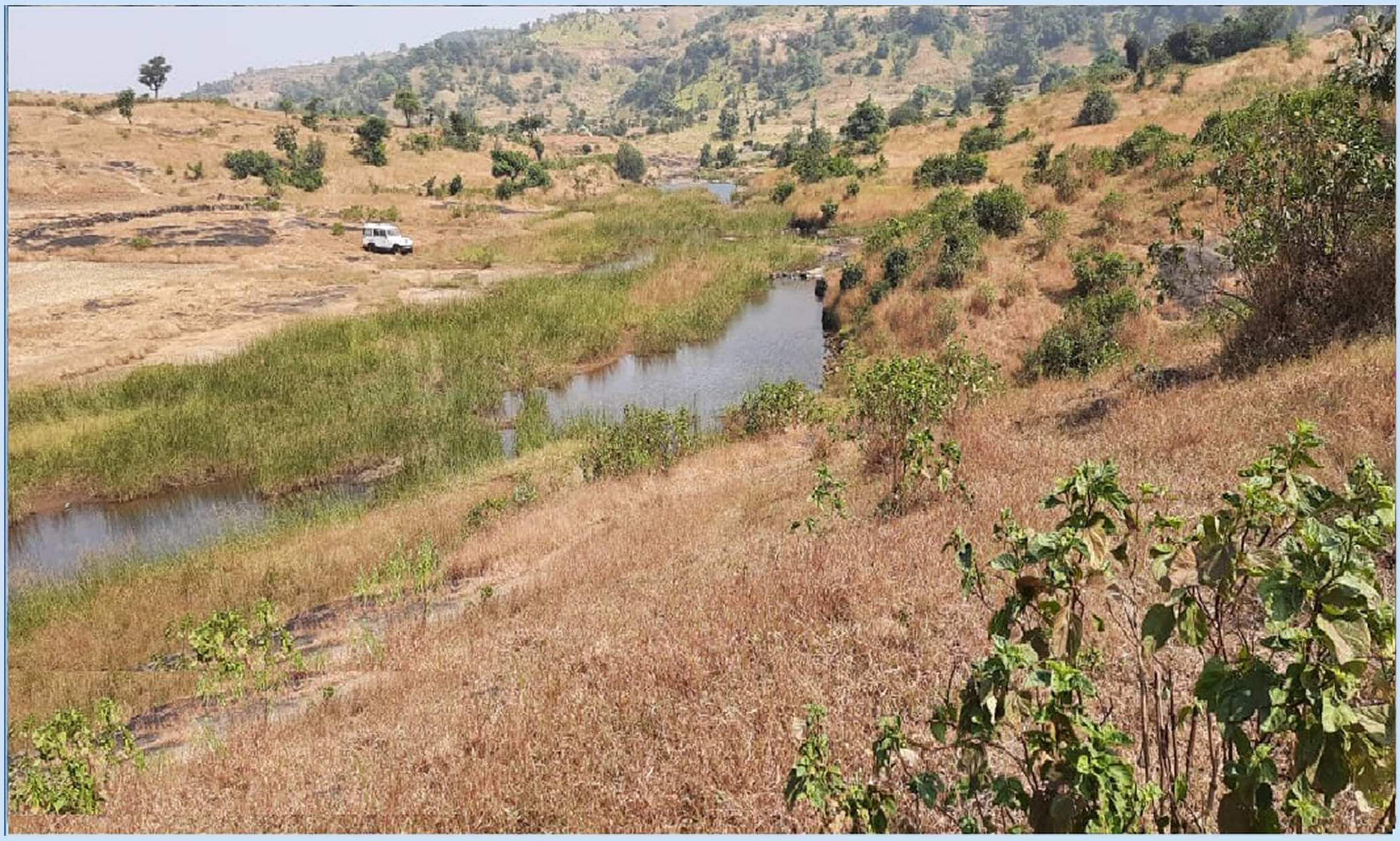
JSW ENERGY PSP TWO LIMITED

BHAVALI PUMPED STORAGE PROJECT
NASHIK, MAHARASTRA

PRE FEASIBILITY REPORT



Consultant

aarvee associates

architects engineers & consultants pvt. ltd.

An ISO 9001:2015 Certified Company

Ravula Residency, Srinagar Colony Main Rd., Hyderabad-82, India

Tel: +91-40-23737633; 48483456. Fax: +91-40-23736277

e-mail: aarvee@aarvee.net; web: www.aarvee.com

MARCH 2022

DOCUMENT RECORD

Project Name	Bhavali Pumped Storage Project
Name of Client	JSW ENERGY PSP TWO Limited
Doc No	AA/POWER/2373/FS/BPSP/01
Doc Title	Pre-Feasibility Report

Rev No	**Date of Issue**	**Description**
R1	16-03-2022	Pre-Feasibility Report Updated with respect to layout and Hydrology aspects
R0	20-06-2021	Pre-Feasibility Report

Table of Contents

Table of Figures

Index of Tables

SALIENT FEATURES OF THE PROJECT

NAME OF THE PROJECT			BHAVALI PUMPED STORAGE PROJECT
1		Location	
	a	Country	India
	b	State	MAHARASTRA
	c	District	Nashik, Thane
	d	Village near Power House	Kalbhonde village (shahpur Taluk -Thane)
	e	Village near Upper reservoir	Jamunde Village (Igatpuri Taluk- Nashik)
2		Geographical Co-Ordinates	
	a	Upper Reservoir (Proposed)	
		Latitude	19°36'31.69"N
		Longitude	73° 35'45.06"E
	b	Lower Reservoir (Proposed)	
		Latitude	19°34'56.38"N
		Longitude	73° 35'10.00"E
3		Access To Project Site	
	a	Airport	Mumbai Airport, 130km from project site
	b	Rail head	Igatpuri – 15 Kms from project site
	c	Road	Igatpuri; NH-160
	d	Port	Mumbai Port
4		Type of Project	
	a	Type	Pumped Storage Project with upper & Lower Reservoirs
	b	Storage Capacity	11017 MWH
	c	Rating	1500 MW
	d	Peak operation duration	7.34 Hours daily
5		Upper Reservoir (Proposed)	
	a	Live Storage	0.35 TMC (9.91 MCM)
	b	Dead Storage	0.23 TMC (6.51 MCM)
	c	Gross Storage	0.58 TMC (16.42 MCM)
6		Upper Dam	
	a	Type of Dam	Rock fill Dam & Concrete Gravity Dam
	b	Top of Dam	EL +748.000 m
	c	Full Reservoir level (FRL)	EL +745.000 m
	d	Minimum Draw Down Level (MDDL)	EL +728.000m

	e	Length of Dam	1035.00 m
	f	Max Height of Embankment	48.0 m (above Lowest NSL)
	g	Top Width of Embankment	10.0 m
7		Lower Reservoir (Proposed)	
	a	Live Storage	0.35 TMC
	b	Dead Storage	0.05 TMC
	c	Gross Storage	0.40 TMC
8		Lower Dam	
	a	Type of Dam	Concrete Gravty Dam
	b	Top of Dam	EL +303.000 m
	c	Full Reservoir level (FRL)	EL +300.000 m
	d	Minimum Draw Down Level (MDDL)	EL +270.000m
	e	Length of Dam	421.00 m
	f	Max Height of Dam	53.0 m (above Lowest NSL)
	g	Top Width of Dam	10.0 m
9		Intake Structure	
	a	Type	Diffuser Type
	b	Number of Vents	1 No.
	c	Size of Intake	40 m (W) x 13.0 m (H) including piers
	d	Length of Intake	43.00 m (covered with RCC slab at top up to Intake Gate)
	e	Elevation of Intake center line	EL +714.00 m
	f	Elevation of Intake bottom	EL +708.50 m
	g	Design Discharge of Intake (Turbine mode)	62.43 Cumec for one unit
	h	Trash rack type	Vertical with inclination of 15^o
	i	Size of Trash Rack	2 nos. of 12.25m(W) x 12.52m(H) & 1 no. of 12.5m(W) x 12.52m(H)
	j	Velocity through Trash rack	0.959 m/s
	k	Numbers & Size of Intake Service Gate	2 Nos. - 5.0 m (W) x 11.0 m (H) with Independent Rope Drum Hoist
	L	Numbers & Size of Intake Maintenance Gate	1 No. - 5.0 m (W) x 11.0 m (H) with Independent Rope Drum Hoist
10		Water Conductor System	
	I	Intake Tunnel	
	a	Type	Horse Shoe Tunnel

	b	Number of Tunnels	1 No.
	c	Diameter of Tunnel	11.0 m dia.
	d	Length of Tunnel	1617.45 m
	e	Design Discharge of Tunnel	374.58 Cumec
	f	Velocity in the Tunnel	3.733 m/sec
	II	7.7m dia Penstock	
	a	Type	Circular
	b	Number of Penstock	2 Nos
	c	Diameter of Penstock	7.70 m dia.
	d	Design Discharge of Tunnel	173.79 Cumec
	e	Velocity in the Tunnel	3.73 m/sec
	f	Length	185.16 m for each Tunnel
	g	Thickness of Steel Liner	32 mm
	h	Grade of Steel Plate	ASTM 517 Grade-F Steel
	III	5.5m dia Pressure Shaft	
	a	Type	Steel lined – circular
	b	Number of Pressure Shafts	6 Nos.
	c	Diameter of shaft	5.50 m dia.
	d	Length	43.0 m each
	e	Thickness of Steel Liner	28 mm
	f	Grade of Steel Plate	ASTM 517 GRADE-F
		Main Inlet Valve (MIV)	
	a	Size of MIV	4.00 m Diameter
11		Adit Tunnels	
	a	Adit to Penstock Bottom	410.00 m long 6.5m dia. D Shaped Tunnel
	b	Main access Tunnel	1420.00 m long 9.0 m dia. D Shaped Tunnel
	c	Adit to Transformar cavern	144.00 m long 6.5m dia. D Shaped Tunnel
12		Powerhouse	
	a	Type	Under Ground Powerhouse
	b	Center Line of Unit	El. +220.00 m
	c	Size of Powerhouse	135.40 m (L) x 18.00 m (W) x 50.00 m (H) at Generator Floor Level
	d	Size of Service bays	25 m (L) x 18.00 m (W) (Left Side Service bay)
	e	Service bay level	El. +232.82 m

	f	Crane Beam Level in Powerhouse	El. +245.32 m
	g	Size of Unloading Bay	15 m (L) X 18.00 m (W)
	h	Unloading Bay Level	El. +245.32 m
13		Tail Race Tunnel	
	I	Draft tube Tunnel	
	a	Type	Steel Lined - Circular
	b	Number of Tunnel	6 Nos
	c	Diameter of Tunnel	5.50 m each
	d	Length	97.7 m each
	e	Design Discharge in tunnel	62.43 m^3/s
	f	Velocity in tunnel	2.63 m/s
	II	Draft tube Tunnel	
	a	Type	Steel Lined - Circular
	b	Number of Tunnel	3 Nos
	c	Diameter of Tunnel	7.70 m each
	d	Length	98.0 m each
	e	Design Discharge in tunnel	124.86 m^3/s
	f	Velocity in tunnel	2.68 m/s
	II	Tail Race Tunnel	
	a	Type of Tunnel (Tunnel Part)	Horse Shoe Tunnel (Concrete Lined)
	b	Number of Tunnel	1 no.
	c	Diameter of Tunnel	11.0m dia.
	d	Length of Tunnel	158.615 m
14		Tailrace Outlet Structure	
	a	Type	Diffuser Type
	b	Number of Outlet	1 Nos.
	c	Size of Each Outlet	43.00 m (W) x 13.00 m (H)
	d	Length of each Outlet	73.00 m (covered with RCC slab at top up to Outlet Gate)
	e	Elevation of outlet centre line	EL +255.00 m
	f	Elevation of outlet bottom	EL +249.50 m
	g	Trash rack type	Vertical with inclination of 15°
	h	Size of Trash Rack	2 no's of 12.25m(W) x 12.52m(H) & 1 no of 12.50m(W) x 12.52m(H)
	i	Velocity through Trash rack	0.959 m/s

	j	Tail Race outlet Service Gate	2 Nos. - 5.0 m (W) x 11.0 m (H) with Independent Hydraulic Hoist
	k	Tail Race outlet Stoplog Gate	1 No. – 5.0 m (W) x 11.0 m (H) with Common Movable Gantry Crane
15		Electro Mechanical Equipment	
	a	Pump Turbine	Francis type, vertical shaft reversible pump-turbine
	b	Total No of units	6 no's (250MW each)
	c	Centre Line Of Units	EL +220.00 m
15.1		250 MW Turbines	
	a	Total No of units	6 Units
	b	Turbine Capacity	250 MW
	c	Turbine Design Discharge	62.43 m^3/s for each Unit
	d	Rated Head in Turbine Mode	447.0 m
	e	Pump Capacity	264 MW
	f	Rated Head in Pump Mode	455.50 m
	g	Synchronous speed	375.00 rpm
15.2		Generator-Motor	
	a	Type	Three phase, alternating current asynchronous, generator motor semi umbrella type with vertical shaft
	b	Number of units	6 Units
	c	Rated Capacity	Generator – 250 MW Pump Input – 264 MW
	d	Rated Voltage	18 KV
15.3		Generator Motor Transformer	
	a	Type	Outdoor Single-Phase Power transformers with Off-Circuit tap changer (OCTC)
	b	Number of units	18 Units
	c	Rated Capacity of each unit	120 MVA
	d	Rated Voltage	Primary – 18 KV ; Secondary - 400 kV adjustable range of the secondary voltage: -10% to +10%(3kV/tap)
16		420 kV Gas Insulated Switchgear	(GIS)
	a	Type of GIS	Indoor Type
	b	No. of GIS units	One No. with bus sectionaliser
	c	Location	Inside GIS Building above ground
	d	Scheme	Double Busbar Arrangement with bus sectionaliser
17		Power Evacuation	

	a	Voltage Level (KV)	400 KV
	b	No. of Transmission lines	One Double Circuit Transmission Line
	c	Conductor	Quad Moose
	d	Terminating at	765/400KV, PGCIL GIS Station at Padghe
18		Project Cost	
	1	Cost of Civil Works	2300.70 Cr.
	2	Cost of Power Plant Electro Mechanical Equipment including Transmission line	2877.84 Cr.
	3	Total Hard Cost	5178.54 Cr
	4	Interest during Construction	544.76 Cr.
	5	Total cost of the Project	5723.30 Cr
19		Conversion Cost (Excluding pumping cost)	
		Levellised Tariff	Rs 2.71/- per unit
20		Conversion Cost (Including pumping cost)	
		Levellised (At Rs 1.0, Pumping cost)	Rs 3.97/- per unit
		Levellised (At Rs 2.0, Pumping cost)	Rs 5.22/- per unit
		Levellised (At Rs 3.0, Pumping cost)	Rs 6.47/- per unit

CHAPTER - 1 INTRODUCTION

1.1 THE PROJECT

India with a billion population is leading the world's renewable energy revolution to achieve it's climate targets by 2050 and is on track to achieve 175 GW of RE capacity by 2022. Today, Wind & Solar, are the **lowest cost source of new energy**, however their **inherent infirm nature & non-schedulability** presents a huge challenge for integrating large RE capacities, while **maintaining grid stability**. Today, increasing RE capacities coupled with **ever changing dynamic demand curves** of the States/DISCOMs/STUs are leading to **sub-optimal utilization** of the existing base-load assets resulting in **high fixed cost pass through per kWh** and additional burden to the consumers.

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. The increasing energy demand of the country can only be met sustainably by developing the much required Flexible Energy Generation Assets immediately.

Wind-Solar-Pump Storage Hybrid Projects present a viable solution to the problem at hand and also for future wherein large RE capacities are being planned to be added to National grid. While battery storage solutions are still evolving, **integrating Wind & Solar** with time tested and proven **Pumped Storage** solutions presents an **optimal, economically viable & scalable solution** to supply **Schedulable Power On-Demand (SPOD)** with both base load and peak load capabilities to the Nation. Pumped Storage solutions provide the necessary scale (large volume of energy storage) and have a long life cycle resulting in lowest cost of delivered SPOD energy over the life of the projects. Developing such integrated projects in Wind-Solar resource rich locations along with Pumped Storage capacities independently, without impacting the existing natural water systems / irrigation systems is necessary to sustainably power the future needs of our country while maintaining grid stability.

JSW ENERGY has been in the process of evaluating suitable locations for such Hydro Storage and has identified the proposed Bhavali Pumped Storage Project near Igatpuri Taluk, Nashik District, Maharastra. After evaluating the site, JSW ENERGY had approached the Government of Maharastra (GoM) for necessary permissions and approvals for the proposed Pumped Storage capacity to be developed with 1500MW and one time filling of the PSP reservoir with 0.63 TMC (17.84 MCM) from the lower reservoir catchment which is a part of Bhatsa dam catchment.

1.2 SCOPE OF THE REPORT

The proposed PSP is a self-identified project by JSWNEL between Thane and Nashik districts of Maharastra state. M/s Aarvee Associates is associated with preparation of techno-commercial feasibility report for the project.

1.3 TYPE OF PROJECT

Pumped storage hydropower project is typically a configuration of two water reservoirs at different elevations that can generate power (discharge) as water moves down through a turbine; this draws power as it pumps water (recharge) to the upper reservoir. Pumped storage hydropower capabilities can be characterized as open loop-where there is an on-going hydrologic connection to a natural body of water-or closed loop, where the reservoirs are not connected to an outside body of water.

Low-cost surplus off-peak electric power is typically used to run the pumps. This project is operated when inexpensive electricity is available either from intermittent sources (such as solar, wind) and other renewable's, or excess electricity from continuous base-load sources (such as coal or nuclear) to be saved for periods of higher demand. Although the losses of the pumping process make the plant a net consumer of energy overall, the system increases revenue by selling more electricity during periods of peak demand, when electricity prices are highest and also helps in stabilising and for grid balancing.

Bhavali Pumped Storage Project (BPSP) is proposed with an installed capacity of 1500MW/11017 MWH. The Project comprises of upper & lower reservoirs with a gross storage capacities of 0.58TMC & 0.40 TMC respectively, out of which upper reservoir to be constructed on the hill top with maximum dam height of 48m to create the desired storage capacity while the lower reservoir will have maximum height of 53m constructed in a natural depression downhill. The scheme of operation for the project is with 7.34 Hours of peak power per day and 8.46 Hours for pumping back the water to the upper reservoir. Water will be used cyclically for energy storage and discharge. Evaporation losses, if any will be recouped periodically.

1.4 LOCATION OF THE PROJECT

The Geographical co-ordinates of the proposed Pumped Storage Project component of upper reservoir located near to Jamunde Village in Igatpuri Taluk of Nashik district with latitude 19°36'31.69"N, and Longitude 73°35'45.06"N and that of lower reservoir at Kalbhonde village in Shahpur Taluk of Thane district with latitude 19°34'56.38"N and longitude 73° 35'10.00"E (Refer).

The project is located near to Jamunde village located in Igatpuri Tehsil/Mandal of Nashik district and Kalbhonde village in Shahpur Taluk of Thane district in Maharastra, India. The site is easily approachable by NH-160 from Mumbai via Shahapur. It is located 50 kms from the district head quarters Nashik. Nearest railway head is in Igatpuri from where project site is located.

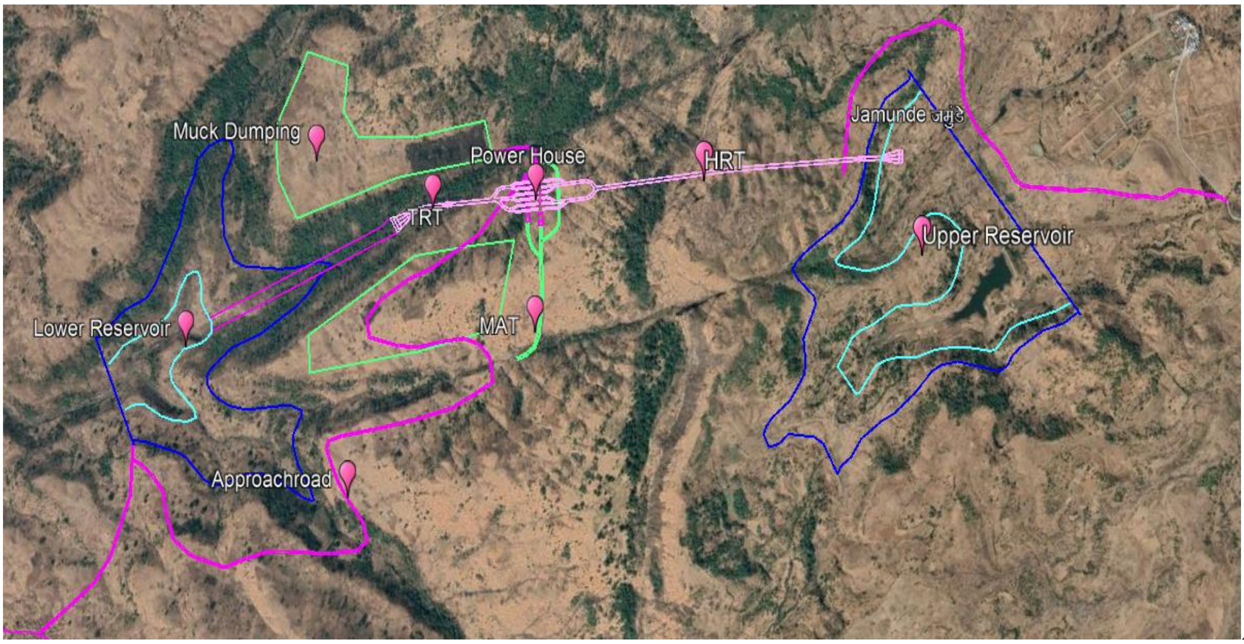


Figure 1: Project Location

1.5 GENERAL CLIMATIC CONDITIONS IN THE PROJECT AREA

The climate is generally dry, except south-west monsoon season. The tropical location and high altitude combine to give it a relatively mild version of a tropical wet and dry climate. The winter season is from December to about the middle of February followed by summer season which last up to May. June to September is the south-west monsoon season, whereas October and November constitute the post-monsoon season. The maximum temperature in summer is 42.5°C and minimum temperature in winter is less than 5.0°C. Relative humidity ranges from 43% to 62%. The normal annual rainfall in the district varies from about 500 mm to 3400 mm. It is minimum in the north eastern part of the district and increases towards west and reaches a maximum around Igatpuri in the western ghat. The variation in the precipitation between the driest and wettest months is 692 mm.

1.6 GENERAL DESCRIPTION OF TOPOGRAPHY, PHYSIOGRAPHY & GEOLOGY OF PROJECT AREA

1.6.1 Topography

The Project area is located in the Maharastra state between Igatpuri and Shahpur Tehsils/Mandals of Nashik and Thane district respectively. The Nashik district is located in the north western part of the state and is bounded by Dhule district in the north, Dangs and Surat district of Gujarat State in the northwest, Jalgaon in the east and northeast, Ahmednagar in the south, Aurangabad in the southeast, Palghar in the west and Thane in the southwest. The population in Nashik district as per 2011 census is 61,07,187 out of which 51.69% are males & 48.31% are females. While, Thane district is located in the western part of the state sandwiched between sahyadri ranges and is bounded by the Raigad and Pune towards its south, Nashik in the east, Arabian sea in the Palghar in the North. The Thane district is divided into Palghar and Thane districts in the year 2014. The population in the district as per 2011 census is 80,70,032 out of which 45.95% are males & 54.05% are females. The river Godavari originates from the Brahmagiri Mountain, Trimbakeshwar about 24 km from Nashik while Ulhas nad the Vaitarna are the major rivers of Thane. Rivers namely Damanganga, Vaitarna, Kadva, Aram, Mosam, Panjan, Manegad, Kashypi, Girna & Darna rivers flow through these districts.

1.6.2 Physiography

Nashik and Thane districts form part of Western Ghat and Deccan Plateau. Physiographically Nashik and Thane districts comprises of varied topography from plains to hill ranges. The main system of hills are Sahayadri's and its offshoots viz., Satmala, Selbari and Dolbari hill ranges. These hill ranges along with eastern & southern plains, Godavari valley are the distinct physiographic units. The northern part of the Nashik district falls under Tapi basin and is drained by easterly flowing Girna River along with its tributaries, whereas the southern part of the district falls under Godavari basin an is drained by Godavari River and its tributaries. Thane district is mainly drained by the west flowing rivers from Tapi to Tadri basin in the Western Ghats namely the Ulhas and Vaitarna rivers. Other important rivers are Damanganga, Ulhas, Vaitarna, Darna, Kadva, Aram, Mosam, Panjan and Manegad. The total geographical area of the districts is about 20,222sq.km. The study area ranges from El. 300 to 1300 m above msl. The hills of the district are part of Western Ghats. The uplands and slopes leading from the foot of the hills are utilized for growing dry crops periodically depending on the rain.

1.6.3 Geology

The entire area of the districts is underlain by the basaltic lava flows of upper Cretaceous to lower Eocene age. The shallow alluvial formation of Recent age also occurs as narrow stretch along the banks of Godavari and Girna Rivers flowing in the area. Basaltic lava flows occupies about 90% of the area. These flows are normally horizontally disposed over a wide stretch and give rise to table land type of topography also known a plateau. The volcanic portion consists of compact, stratified basalts, and an earthy trap. To the west they lie in flat-topped ranges, separated by valleys, trending from west to east. In some flows the basalt is columnar and then it weathers into the various shapes. The formation at the base of the traps is amygdaloidal, containing quartz in vertical veins, crystals and zeolitic minerals, especially apophyllite weathering into a grey soil. Alluvium occurs in small areas in the form of discontinuous patches along the banks and flood plains of major rivers like Godavari, Girna and their tributaries. In alluvium the granular detrital material like sand and gravel usually occurring as thin layer in the district yields water. The absence of laterite, which caps the summits of the hills to the south, is a curious feature in the geology of the area. The basalt is either fine textured or it is coarse and nodular.

1.7 HISTORICAL BACKGROUND OF THE PROJECT

1.7.1 Self-Identified Proposal

JSWNEL has self indentified the PSP and evaluated a suitable location for the project near Jamunde village and Kalbondhe village of Igatpuri & Shahpur Taluks respectively in Maharastra State. This PFR is for the Pumped Storage Project with 1500 MW /11017 MWH storage capacity, located near Khalbonde village, Shahpur Tehsil, Maharastra with 7.34 hours storage capacity. The Geographical co-ordinates of the proposed Pumped Storage Project component of upper reservoir is at latitude 19°36'31.69"N, and Longitude 73°35'45.06"N and that of lower reservoir with latitude 19°34'56.38"N and longitude 73° 35'10.00"E.

1.7.2 Earlier proposal

Techno-Commercial Feasibility Study Report of the project was prepared during July 2021. The project is being envisaged with installed capacity of 1500 MW with 7.34 hrs of peaking operation. The Upper & lower reservoir for the Pumped storage scheme with Full Reservoir Level of El. +745.00 m & El. 300.00m with a Minimum draw down levels of El. 728.00m & El. 270.00m respectively. The live storage capacity for pumped storage scheme required is 9.95 MCM (0.35 TMC). The proposed project will generate 1500 MW of power by utilizing net rated head of 447.0m. The water from the upper reservoir will be diverted through Power House and TRT to the proposed lower reservoir. The water will be pumped back to the upper reservoir through TRT-reversible turbines-pressure shaft-HRT to upper reservoir. The project also comprises of a lower intake in the lower reservoir to pump the water to upper reservoir. **As per the earlier studies,** the one time filling of the upper reservoir was proposed by pumping the water from the existing Bhavali dam, located downstream of the proposed upper reservoir.

The proposal consist the following components:

- Upper Reservoir and Rockfill Embankment
- Upper Intake
- Penstock
- Powerhouse and GIS
- Tailrace Tunnel
- TRT Intake/Lower Intake
- Lower Reservoir and Rockfill Embankment

1.7.3 Details of Present Proposal

The present proposal also envisages installation of 1500 MW with 7.34 hrs of peaking operation. The Upper & lower reservoir for the Pumped storage scheme remain same, with Full Reservoir Level of El. +745.00 m & El. 300.00m with a Minimum draw down levels of El. 728.00m & El. 270.00m respectively. The live storage capacity for pumped storage scheme required is 9.95 MCM (0.35 TMC). The proposed project will generate 1500 MW of power by utilizing net rated head of 447.0m.

In the present proposal, as per the suggestions of water resources department Govt. of Maharashtra, the onetime filling of the Lower reservoir is being carried out from the yield in the catchment of Bhatsa dam, as against pumping from Bhavali dam.

The present proposal consist the following components:

- Upper Reservoir (Rockfill Embankment & Concrete Gravity Dam)
- Upper Intake
- Penstock
- Powerhouse and GIS
- Tailrace Tunnel
- TRT Intake/Lower Intake
- Lower Reservoir (Concrete Gravity Dam)

1.8 ALTERNATIVE STUDIES

The main parameters considered during identification & finalization of the reservoirs were: proximity between the two reservoirs; capacity; topography & geological setup; reservoir water tightness & head. Typically in a Pumped storage hydropower project, the lower and upper reservoir locations are selected in local depressions at close vicinity which can be connected by a short water conductor system.

The site selection process of Pumped storage is carried out:

- Based on Topography, Geology, Water Source and Suitability of Project Components, relative positioning and environmental feasibility, a broader area for project is identified.
- Possible Location of all components with respect to the technical suitability requirements are marked on the identified area and macro level techno commercial viability is ascertained.
- Possible locations and alternative locations of Reservoirs are identified in the proposed area and their suitability is examined with respect to technical parameters. Once technical feasibility is

acceptable evaluation for social and environmental perspective is taken up to narrow down on the most suitable option.

- Possible layouts of the project are planned on the shortlisted locations of various components and again these are evaluated from Technical, Social and Environmental perspective to converge on project layout to be adopted.

1.8.1 Selection of Upper Reservoir

The Topography of the proposed area of upper reservoir depicts small depression around the top of hill area showing possibility of creation of reservoir. The capacity of the upper reservoir is proposed with a target live storage of 9.95 MCM (0.35 TMC), so as the scheme can be operated for a peaking power generation of about 7 hours.

The entire area of the proposed upper reservoir appears to be in forest and partly in private land, whereas actual assessment will be made at the time of the forest land diversion case of the project. The vegetation density in most of the reservoir is very low. The boundary of the project has been fixed keeping in view the safe distance from the nearby Villages. During detailed geological assessment, no adverse geological features were observed in this area and this location appears to be geologically suitable for water retention in the reservoir. No major social environmental issues are expected to be involved in this particular location. Keeping this in view, the present location has been selected for upper reservoir for further development of the project.

Selection of Lower Reservoir

Various sites around the upper reservoir were looked into to locate the lower reservoir. The following alternatives were studied.

1st Alternative

Bhavali Reservoir

This existing reservoir has been created by construction of earth dam of 33.97 m high and 1550m long across river Darna. It has a live storage capacity of 40.79 mcm. The FRL of the Bhavali reservoir is at 609.75m. The FRL of upper reservoir is kept at 745m. There is a head difference of 138m. Considering a live storage of 9.91 mcm, the installed capacity of the PSP becomes 450 MW. To use the Bhavali reservoir as lower reservoir for PSP, it is required to raise the dam height, consequently the reservoir submergence area will rise. There is a possibility of submergence of road and agricultural land. The cost of raising dams, rerouting of roads and acquiring additional land may offset the benefits from a PSP of 450 MW only. That is why the alternative of selecting Bhavali Reservoir as lower reservoir for PSP has been discarded.

2nd Alternative

The lower reservoir site is selected below down a vertical cliff adjacent to upper reservoir. The Natural surface level is here around 270m. By planning the FRL at 300m, the head difference will be around 445m, which would make the PSP to have installed capacity of 1500 MW. In this alternative the water requirement of 17.84 MCM is proposed to be filled by lifting the water from the Bhavali Reservoir. But it has been informed by the Department of Water Resources, Govt. of Maharashtra that water from Bhavali reservoir cannot be spared because of pending litigation. Because of the pending litigation this alternative has been discarded.

3rd Alternative

In the alternative the lower reservoir proposed is same as the 2nd alternative but with a provision of water filling from self-yield of the catchment due to annual rainfall. The water requirement of the 17.84 MCM is proposed to be filled by the inflow into the catchment area of the lower reservoir which is of about 7.32 Sq. Km. The proposed lower reservoir is located within the catchment area of Bhatsa Reservoir at Shahpur taluk of Thane district. The water Resources Department, Govt. of Maharashtra has agreed in principle to allot the required amount without affecting the water planning of downstream Bhatsa Dam. Because of the economy of scale, the 3rd alternative seems techno-economically viable.

Selection of Project Layout

The following aspects have been considered for formulation of alternative layouts:

- Topography of the area and other factors like location, length of water conductor system etc.
- Maximum utilization of the available head at project site
- Development of economical and optimized layout
- Ease of Construction
- Minimal area of land acquisition to accommodate various project components

Accordingly, alternatives were worked out to develop a best possible layout. All the alternatives have been studied and discussed below with 6 units of 250 MW with Fixed speed Francis turbines and at the same location for upper and lower reservoir for the project. The power house and water conductor system has only been altered accordingly. The layout has been studied with two alternative schemes. They are as below:

1 Alternative - 1 Underground Powerhouse complex

2 Alternative - 2 Surface Powerhouse

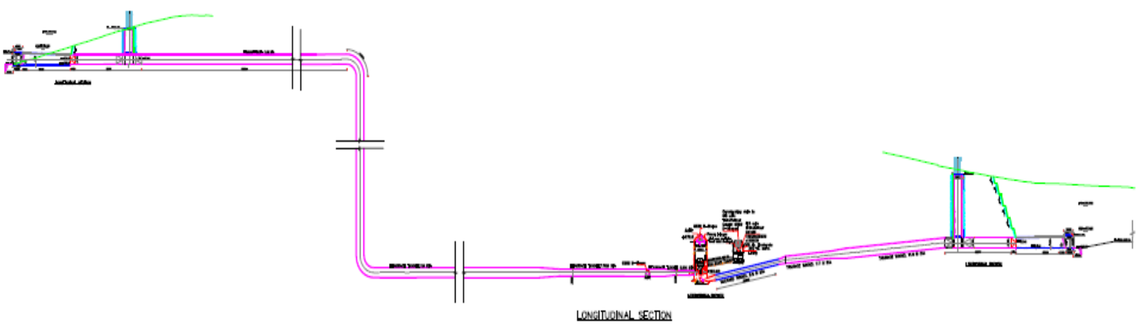
Alternative-1: The water conductor system comprises of one HRT & one TRT, which are bifurcated into 6 steel lined penstock tunnel/pressure shaft at **Underground power house** to feed six units of 250MW each. The water after generation will be led into lower reservoir through a TRT connected to Tailrace Outlet Structure.

Alternative-2: The water conductor system comprises of one HRT is bifurcated into 6 steel lined penstock tunnel/pressure shaft at **Surface power house** to feed six units of 250MW each**.** The water after generation will be led into lower reservoir through six Tailrace tunnels connected to Tailrace Outlet Structure.

Alternative-1:

The Alternative – 1 layout is proposed with underground power house option. All the project components in the scheme are underground.

Both the reservoirs are separated by a sloping cliff, suitable vertical and lateral cover are adequately available for the power house and its components, which will be housed in a competent rock. As such, geological surprises are not envisaged in this alternative. The typical L-section of this alternative is shown in Figure below

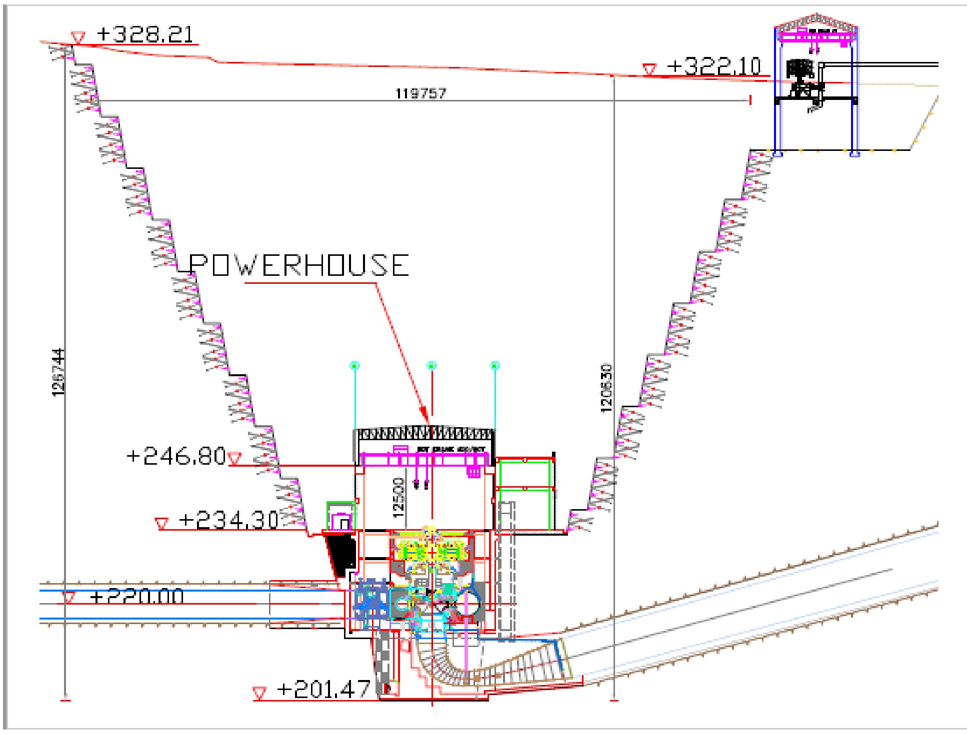


Alternative-2:

Alternative – 2 layout is proposed with surface powerhouse in the same alignment of Alternative – 1. The surface powerhouse involves deeper excavation since the pumped storage project is placed much below the Minimum Draw Down Level of lower reservoir because of technical requirement during pumping operations. The power house location is fixed with minimum excavation, of about 122m.

Excavation of a deeper pit requires at least cut slopes of 1H:6V with intermediate benches, necessitating about 120m at the top. Also, approaching the power house in such a deep pit requires deep cut for formation of road or alternatively a main access tunnel is to be provided.

Though the cost of open excavation is lesser compared to the cost of underground excavation, the quantity of excavation in surface powerhouse is about 4 times to the underground option, necessitating larger areas for project components and muck disposal. The L Section of surface power house is shown in the figure below



1.8.2 Comparison of the Alternative – 1 & 2

A comparison of the salient features of alternative -1 & 2 are given in Table bellow.

Table: Comparison of the Salient Features of Alternative- 1 & 2

Project Components	**Alternative - 1**	**Alternative - 2**
Power Intake	1 Nos	1 Nos
Head Race Tunnel & Pressure shaft	1 No of 11.0m dia & 1617.45m long is bifurcated into 2 no's of 7.70m dia & 185.16m long & bifurcated into 6 no's of 5.50m dia & 43.00m long Circular	1 No of 11.0m dia & 600.9m long is bifurcated into 2 no's of 7.70m dia & 1716.83m long & bifurcated into 6 no's of 5.50m dia & 69.45.00m

Project Components	Alternative - 1	Alternative - 2
	Shaped HRT	long Circular Shaped HRT
Upstream Surge Shaft/Chamber	-	1 No, 160.0m x 25.0m size
Power House	Underground Powerhouse	Surface Powerhouse
Tailrace Tunnel	6 No of 5.5m dia & 97.70m long is converge into 2 no's of 7.70m dia & 98 m long & 1 no of 11.0m dia & 158.615m long	6 No of 5.5m dia & 109.04m long is converge into 2 no's of 7.70m dia & 58.98 m long & 1 no of 11.0m dia & 105.85m long
TRT Outlet	1 Nos	1 Nos
Tailrace Channel (up to mouth of lower reservoir)	900.0m	650.0m
Construction Period	36 Months	48 Months
Project Cost	5723.30 crores	7035.35 crores

For assessment of the cost comparison all the two alternative layouts, basic civil cost for alternative-1, alternative-2 is 5723.30 crores, 7035.35 crores worked out respectively. Basic civil cost for alternative-1 and Alternative-2 the increased in percentage of cost is worked out to 22.9 %. Based on the economic viability it is concluded that the alternative-1 is best for this project.

1.8.3 Selection of Final Layout

Alternative – 1 layout has been adopted for Bhavali PSP considering the following reasons:

- Suitable location for underground powerhouse with adequate lateral and vertical cover and competent rock
- Alternate-2 involves deep excavation necessitating intricate supports and slope stability measures. Length of water conductor system is almost same in both the cases. However, surface option requires large area compared to the underground option.
- Muck generated in surface power house option will be about 4 times to under ground option. As such overall cost of the project remains almost similar.

- Alternate-2 with deep excavation closer to the lower reservoir poses seepage problem during operation. This option poses problems with storm water drainage also.

1.8.4 Description of Selected Alternative

Considering various factors and the economics of the cost for the project, the scheme under alternative – 1 is found to be technically feasible and the same is adopted.

A brief description of the project components along the proposed layout in Alternative 1 is given in subsequent paragraphs:

Proposed Scheme will involve construction of Rock fill Dam varying from 10 to 45m height for creation of upper reservoir. Intake structure with Trash Racks & Gates are located near to the upper reservoir. One number HRT is bifurcated into two no's of independent penstocks/Pressure shafts. Each penstocks/Pressure shafts will bifurcate into three numbers of penstocks at Power house. An underground Power House will be located on the downstream of the Intake structure and shall be equipped with six vertical-axis reversible Francis type units composed each of a generator/motor and a pump/turbine having generating/pumping capacity of 250MW/264MW.

The upper and lower reservoir are proposed with a live storage of 0.35 TMC. The Project will generate 1500 MW by utilizing a design discharge of 374.60 Cumec with rated head of 447.00m. The PSP will utilize 1584 MW to pump 0.35 TMC of water to the upper reservoir.

Gas insulated switchgear (GIS) will be provided suitably located nearby area of the Power House. Step up transformers will also be placed, which will be connected to machine hall.

One no. 400kV double circuit transmission line with Quad moose conductor will be connected to Powergrid Padghe 765/400 KV GIS substation. This double circuit transmission line will be used for both evacuation of generated power and input of power during pumping mode.

1.9 NATURAL RESOURCES OF THE STATE/REGION

The state of Maharastra is the third largest state in India with an area of 308 lakh hecatres and its cultivable area is 225 lakh hectares of which, 40% of the area is drought prone and about 7% of the area is flood prone. It is bordered by the states of Madhya Pradesh to the north, Chhattisgarh to the east, Andhra Pradesh to the southeast, Karnataka to the south, and Goa to the southwest. The state of Gujarat lies to the northwest, with the Union territory of Dadra and Nagar Haveli sandwiched in between. The Arabian Sea makes up Maharashtra's west coast.

The state of Maharashtra consists of five river basin systems namely Krishna, Godavari, Tapi, Narmada & West flowing rivers, out of which 55% of the dependable yield is available in the four river basins (Krishna, Godavari, Tapi and Narmada) east of the Western Ghats. These four river basins comprise 92% of the cultivable land and more than 60% of the population in rural areas. 45% of state's water resources are from West Flowing Rivers which are mainly monsoon specific rivers emanating from the Ghats and draining into the Arabian Sea. The Western Ghats form one of the three important watersheds of India, from which many South Indian rivers originate, like Godavari, Bhima, Koyna and Krishna.

The mineral-bearing zones of Maharashtra lie beyond the area of the basalts in eastern Vidarbha, southern Kolhapur and the Sindhudurg area. The Chandrapur, Gadchiroli, Bhandara and Nagpur Districts form the main mineral belt, with coal and manganese as the major minerals and iron ore and limestone as potential wealth. The Ratnagiri coast contains sizeable deposits of illimenite. The other minerals occurring are Barytes, Clay, Feldspar, Copper, Chromite, Graphite, Fluorite and Tungsten.

1.10 SOCIO-ECONOMIC ASPECTS

The project area is located in Igatpuri region in the Western Ghats of the country. 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.

1.11 LAND REQUIRED FOR THE PROJECT CONSTRUCTION

The total land required for construction of project components, reservoir area, muck dumping, construction camps and colony, etc., works out to be 256.16 Ha. out of which about 212.65 Ha is forest land area and 43.51 Ha is Private land. Break up of land required for different components is given Table 1 .

Table 1: Land Requirement for the Project

Sl. No.	Description	Area (in Sqm.)	Area (in Acre)	Area (in Hectare)	Forest Land	Private Land
1	Upper Dam & Reservoir	110650	228.72	92.56	60.21	32.35
2	Approach road to upper reservoir	23800	5.88	2.38	1.50	0.88
3	Lower dam & Reservoir	860000	212.52	85.947	75.72	10.28
4	Approach road to lower reservoir	83700	20.68	8.37	8.37	
5	HRT(Underground)	31200	7.71	3.12	3.12	
6	Power House(Underground)	15200	3.76	1.52	1.52	

7	TRT(Underground)	16500	4.08	1.65	1.65	
8	TRC	13200	3.26	1.32	1.32	
9	MAT(Underground)	16000	3.95	1.60	1.60	
10	Dumping Area & Job Facilities-1	240400	59.40	24.04	24.04	
11	Dumping Area & Job Facilities-2	233000	57.58	23.30	23.30	
12	Working Space-1	57500	14.21	5.75	5.75	
13	Working Space-2	57500	14.21	5.75	5.75	
	Total Land	**2561600**	**632.99**	**256.16**	**212.65**	**43.51**

1.12 POPULATION AFFECTED BY THE PROJECT

The proposed project involves in the construction of upper and lower reservoirs. Based on the studies carried out the project will involve in acquiring small portion of private land. Detailed socio-economic analysis of the people, property loss likely to be impacted by the construction of the project shall be planned in DPR stage.

1.13 ENVIRONMENTAL ASPECTS

Upper reservoir & lower reservoir will be constructed newly and the project will be operated by recirculating water between these reservoirs. There will be submergence of land required for the proposed upper & lower reservoirs. There are no habitations and agricultural lands in the proposed project area. Hence R & R related issues are not envisaged at this stage. Detailed Environmental and social Impact Assessment (ESIA) studies and Environmental Management Plan (EMP) studies to mitigate any adverse impacts shall be studied during the DPR stage.

1.14 INTER-STATE/INTERNATIONAL ASPECTS

All components of the Bhavali PSP are located within the administrative region of the state. The water will be cycled between two reservoirs with some evaporation losses which will be marginal in nature, no Interstate or International aspects are envisaged in the project. Detailed description of the same is given in the chapter on Interstate / International Aspects.

The location of the project is approximately 100km radial distance from the Arabian Sea coastline. Hence forth the project area is not close to any international waters or boundaries and no international aspect is involved.

1.15 DEFENCE ANGLE

The project area doesn't have any coastal belt, international borders or any defence activity in the vicinity

1.16 HYDROLOGY

The proposed storage project is being planned by creating a new upper & lower reservoir. Both the reservoirs do not have any natural streams. The Proposed PSP upper reservoir has a gross storage capacity of 16.42MCM (0.58 TMC). The live storage of PSP Upper reservoir is 9.95MCM (0.35TMC).

Operational pattern of PSP has been kept in such a way that 0.35TMC of water will be utilized for the proposed PSP. The project is a pumped storage scheme and hence, no consumptive utilization of water is required for its operation. The annual loss in the volume of the upper reservoir & Lower Reservoir due to evaporation works out to 0.991MCM will be recouped from annual rainfall or from the existing Bhatsa dam.

1.17 INSTALLED CAPACITY

The PSP is proposed with a Storage Capacity of 11017 MWH with Rating of 1500 MW. This Project comprises of 6 units of 250 MW. The installed capacity of a pumped storage scheme is influenced by the requirements of daily peaking power requirements, flexibility in efficient operation of units, storage available in the reservoirs and the area capacity characteristics. The Project will generate 1500 MW by utilizing a design discharge of 374.60 Cumec with rated head of 447.00m. The PSP will utilize 1584 MW to pump 0.35 TMC of water to the upper reservoir.

Table 2: Key parameters of Bhavali PSP

Sl. No.	Parameter	Unit	Value
1	Storage Capacity	MWH	11017
2	Rating	MW	1500
3	No. of Units	Nos.	6 (6X250 MW)
4	Rated Head in Turbine mode – 250 MW	m	447.0
5	Total Design Discharge for 250MW Units	Cumec	374.60
6	Design Discharge per unit of 250 MW	Cumec	62.43
7	Generation Duration	Hrs	7.34

8	Turbine Capacity – 6 Units	MW	6x250MW
9	Annual Energy Generation with 95% plant availability	MU	3820
10	Pump Capacity – 6 Units	MW	(6x264MW)
11	Rated Head in Pump mode – 262 MW	m	455.50
12	Pumping Duration	Hrs.	8.46
13	Annual Energy consumption	MU	4674

1.18 POWER EVACUATION

One no. 400kV double circuit transmission line with Quad moose conductor from PSP Substation will be connected to Powergrid Padghe 765/400 KV GIS substation. This double circuit transmission line will be used for both evacuation of generated power and input of power during pumping mode. The length of the transmission line is about 50km.

1.19 CONSTRUCTION PLANNING & SCHEDULE

It is proposed to construct the project within a period of 36 months excluding pre-construction duration of 6 months. Approach roads and establishment works are to be taken up in advance for earlier start of actual excavation of underground structures. Therefore, it is planned to get approach roads completed before the actual start of the works thereby reducing the overall construction duration.

1.20 COST AND BENEFITS OF THE SCHEME

The total estimated cost of the project including direct and indirect charges including Interest during construction is Rs.5723.30 Crores. For the installed capacity of 1500 MW, the cost per MW of installed capacity works out to be Rs. 3.82 Crores The project would generate designed energy of 3820 MU. Other benefit 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, voltage regulation etc.,

CHAPTER - 2 JUSTIFICATION OF THE PROJECT

2.1 GENERAL

The state of Maharastra is in the Western Region in India bordering with the Arabian Sea in the west, chattisgarh in the East, Andhra Pradesh towards southeast, Karnataka to the south, and Goa to the southwest. The state of Gujarat lies to the northwest, with the Union territory of Dadra and Nagar Haveli sandwiched in between. The state covers an area of 308 lakh hecatres with a population of 11.24 Crores as per 2011 census. It has coast line of 720kms. The important minerals occurring in the State are Coal, Iron ore, Manganese, Limestone, Bauxite, Dolomite, Silica sand, Kyanite & Sillimanite. The other minerals occurring are Barytes, Ilmenite, Clay, Feldspar, Copper, Chromite, Graphite, Fluorite, Tungsten. The Ratnagiri coast contains sizeable deposits of illimenite. The State of Maharastra is categorized into five basins namely Krishna, Godavari, Tapi, Narmada & west flowing rivers. Most of the tributaries form these prominent river basins. Godavari, Krishna and Tapi. Indravati, Wardha, Mnajira, Penganga and Purna are the major river systems of the state that forms part of these basins.

The current installed capacity of the state is 45165.62 MW as against 1,24,534.73 MW in Western region & 3,79,130.41 MW in the country as of 28th February 2021.

2.2 JUSTIFICATION OF PROJECT FROM POWER SUPPLY-DEMAND CONSIDERATIONS

Demand for the utilization of power has been on steady rise with average annual rate of about 8-9% in the country. The total installed capacity at the end of February 2021 stood at 3,79,130.41 MW with thermal power accounting for 61.50% (233170.72 MW), hydro power for 12.19% (46209.22MW) & Renewables including nuclear power accounting for 26.31% (99750.48MW). The energy generation is divided into six regions as shown in the Table 2.1.

Table 3: *Total Amount of installed capacity in the country*

Sl. No	Region	Thermal (MW)	Hydro (MW)	Renewables* (MW)	Nuclear (MW)	Total (MW)
1.	Northern Region	61,459.05	20,288.77	18,259.23	1,620.00	1,01,627.05
2.	Southern Region	55,199.99	11,774.83	44,094.34	3,320.00	1,14,389.16
3.	Eastern Region	27,387.05	4,639.12	1,581.90	0.00	33,608.07
4.	**Western Region**	**86,501.61**	**7,562.50**	**28,630.62**	**1,840.00**	**1,24,534.73**
5.	North Eastern Region	2,582.98	1,944.00	369.17	0.00	4,896.14
6.	Islands	40.05	0.00	35.22	0.00	75.27

Total	2,33,170.72	46,209.22	92,970.48	6,780.00	**3,79,130.41**

* includes renewables from solar, wind & small hydro (Source - CEA)

India desires to reduce the carbon emissions and achieve its set targets as a carbon free country by 2050 & 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 & hydro are the major sources with more viability while nuclear power has its own disadvantages whereas the hydro power majorly depends on the water as major source which is abundantly available in the country.

As per the ***Table 3*** the Western region has been maintaining 70: 30 ratio of thermal generation to renewable energy generation compared to other regions. There is a vast scope to reduce the dependency on the thermal generation and to increase the Renewables by solar, wind & hydro generations to meet the GOI mission to reduce dependency on fossils & 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 & 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 annual load generation & balancing report has estimated the country demand & anticipated power supply for the year 2020-21 as shown in the Table 2.2. The Gross Energy in the country has been assessed as 1408 Billion Units (BU) for the current year.

Table 4: *Peak & Energy demand in various regions of the country*

Sl.No	Region	Peak				Energy			
		Demand	Availabili-ty	Surplus(+) / Deficit (-)		Requireme nt	Availabili-ty	Surplus(+) / Deficit (-)	
		(MW)	(MW)	(MW)	(%)	(MU)	(MU)	(MU)	(%)
1.	Northern	70,200	74,543	4,343	6.2	4,21,300	4,41,030	19,730	4.7
2.	**Western**	**61,310**	**64,888**	**3,578**	**5.8**	**4,02,799**	**4,16,164**	**13,364**	**3.3**
3.	Southern	57,276	54,289	-2,987	-5.2	3,89,962	3,98,373	8,412	2.2
4.	Eastern	26,404	28,501	2,098	7.9	1,74,925	1,70,464	-4,461	-2.6
5.	North-	3,094	3,242	148	4.8	18,542	19,054	513	2.8

Eastern								
Total	1,99,348	2,17,507	18,160	9.1	14,07,527	14,45,085	37,558	2.7

Source CEA - Load Generation Balance Report 2020-21

As per the **Table 4** there is a surplus of energy anticipated in the Western region as on today. Although there is a peak demand & Energy generation as surplus of 5.8% & 2.6% of for the current year 2020-21. This may widen due to the increase in the energy demands with the rapid growth & industrialization as shown in Table 2.6. Thus an alternate balancing source of energy generation is required to meet the deficits in the region in the years ahead.

Western region comprises of Goa, Daman & Diu, Gujurat, Madhya Pradesh, Chhattisgarh, Maharastra , Dadra & Nagar Naveli. Out of 124.534 GW installed in the Western region the state of Maharastra with a total installed capacity of 44.165GW with anticipated surplus power of about state 3.5% for the year 2020-21. To overcome the retiring plants & due to rapid industrialization in the state & to achieve Government of India target of 450GW of energy by more reliable & balancing source is to be developed in the state.

Table**5** : *Installed capacity, peak & Energy demand of Western region*

Sl. No	State	Thermal (MW)	Hydro (MW)	Renew-ables* (MW)	Nuclear (MW)	Total (MW)	Peak		Energy	
							Demand (MW)	Availability (MW)	Require-ment (MU)	Availability (MW)
1.	Goa	559.94	2.00	7.83	0.00	595.77	722.00	740.00	4,492.00	4,705.00
2.	Daman & Diu	208.08	0.00	40.55	7.00	255.63	365.00	365.00	2,631.00	2,642.00
3.	Gujurat	23,359.78	772.00	12,530.96	559.00	37,221.74	19,400.00	19,996.00	116,447.00	120,131.00
4.	Madhya Pradesh	16,787.09	3,223.66	5,205.57	273.00	25,489.32	16,560.00	17,000.00	80,878.00	83,269.00
5.	Chhattisgarh	12,246.89	233.00	573.38	48.00	13,101.27	5,504.00	5,800.00	32,544.00	34,179.00
6.	**Maharastra**	**29,876.91**	**3,331.84**	**10,266.87**	**690.00**	**44,165.62**	**24,160.00**	**25,000.00**	**156,648.00**	**162,073.00**

7.	Dadra & Nagar Naveli	494.33	0.00	5.46	9.00	508.79	873.00	874.00	6,851.00	6,854.00
7.	Central-unallocated	2,968.59	0.00	0.00	228.00	3,196.59	0.00	0.00	0.00	0.00
	Total	86,501.61	7,562.50	28,630.60	1,840.00	124,534.70	61,310.00	64,888.00	402,799.00	416,164.00

2.3 POWER EVACUATION

The evacuation of the power from the pumped storage project will be acheieved from the 400KV gird substation through 400KV QMDC transmission lines. 400KV line is connected from the central pooling station of the pumped storage power. For the pump operations the same line shall be used to draw the power to the central pooling station.

One no. 400kV double circuit transmission line from PSP Central Pooling Substation will be connected to Powergrid Padghe 765/400 KV GIS substation or 400/220KV MSETCL Substation at Kharghar in Navi Mumbai. This double circuit transmission line will be used for both evacuation of generated power and input of power during pumping mode.

2.4 GENERATING CAPACITY IN THE COUNTRY/REGION/STATE

The total available generating capacity in the country, region & state from the various sources of power are as follows

Table6 : *Installed capacity in the country*

Sl.No	State	Thermal (MW)	Hydro (MW)	Renew-ables* (MW)	Nuclear (MW)	Total (MW)
1.	India	2,33,170.72	46,209.22	92,970.48	6,780.00	**3,79,130.41**
2.	Western Region	86501.61	7562.50	28630.62	1840.00	124534.73
3.	Maharastra	**29876.91**	**3331.84**	**10266.87**	**690.00**	**44165.62**

2.5 PEAK LOAD AND ENERGY REQUIREMENT IN FUTURE IN ALL INDIA/REGION/STATE

The power supply position in the country shows that there is a deficiency of 0.6% in meeting peak power and 0.3% deficiency in meeting the energy requirement.

Table7 : *Peak Load & Energy demand in the country*

Year	Energy				Peak			
	Requirement	Availability	Surplus(+)/Deficts(-)	Peak	Demand	Peak	Met	Surplus(+)/ Deficts(-)
(MU)	(MU)	(MU)	(%)	(MW)	(MW)	(MW)	(%)	(%)
2009-10	8,30,594	7,46,644	-83950	-10.1	1,19,166	1,04,009	-15157	-12.7
2010-11	8,61,591	7,88,355	-73236	-8.5	1,22,287	1,10,256	-12031	-9.8
2011-12	9,37,199	8,57,886	-79313	-8.5	1,30,006	1,16,191	-13815	-10.6
2012-13	9,95,557	9,08,652	-86905	-8.7	1,35,453	1,23,294	-12159	-9
2013-14	10,02,257	9,59,829	-42428	-4.2	1,35,918	1,29,815	-6103	-4.5
2014-15	10,68,923	10,30,785	-38138	-3.6	1,48,166	1,41,160	-7006	-4.7
2015-16	11,14,408	10,90,850	-23558	-2.1	1,53,366	1,48,463	-4903	-3.2
2016-17	11,42,929	11,35,334	-7595	-0.7	1,59,542	1,56,934	-2608	-1.6
2017-18	12,13,326	12,04,697	-8629	-0.7	1,64,066	1,60,752	-3314	-2
2018-19	12,74,595	12,67,526	-7070	-0.6	1,77,022	1,75,528	-1494	-0.8
2019-20	12,91,010	12,84,444	-6566	-0.5	1,83,804	1,82,533	-1271	-0.7
2020-21*	9,40,694	9,37,518	-3176	-0.3	1,84,033	1,82,888	-1145	-0.6

* Upto January 2021 (Provisional), Source: CEA

The 19th Electric power survey committee (EPSC) has projected on all India basis during the year 2021-22 & 2026-27 as 1566BU & 2047 BU. The peak demand has been estimated as 226GW & 299GW for the period 2021-22 & 2026-27 respectively. The peak load and energy demand for the various regions are estimated as below shown in the Table 2.6.

Table8 : Peak load & Energy demand projections

SLNo	Region	Energy Demand (MU)		Peak Demand (MW)	
		2021-22	2026-27	2021-22	2026-27
1	Northern	4,68,196	6,16,345	73,770	97,182
2	**Western**	**4,81,501**	**6,27,624**	**71,020**	**94,825**
3	Southern	4,20,753	5,50,992	62,975	83,652
4	Eastern	1,71,228	2,17,468	28,046	35,674
5	North-Eastern	23,809	34,305	4,499	6,710
6	A & N Islands	475	632	97	129
7	Lakshadweep	62	73	11	13

All India	15,66,023	20,47,434	2,25,751	2,98,774

The projected energy & peak demand for the southern states are as shown below:

Table9 : Projected energy & peak demand for the Western states

Sl.No	Region	Energy Demand (MU)		Peak Demand (MW)	
		2021-22	2026-27	2021-22	2026-27
1	Goa	5593	6932	858	1096
2	Gujurat	136159	178693	21429	28387
3	Chhattisgarh	37840	51088	6208	8518
4	Madhya Pradesh	99871	125394	15676	19682
5	**Maharastra**	**189983**	**249628**	**28866**	**39828**
6	Dadar & Nagar Haveli	9343	12373	1291	1798
7	Daman & Diu	2712	3517	426	553
	Eastern Region	**4,81,501**	**6,27,624**	**71020**	**94825**

2.6 ADDITION TO GENERATION CAPACITY IN FUTURE IN STATE

The likely capacity addition to the generating capacity in the future from 2019 to 2027 in the state are given in **Table 10**

Table 10: List of upcoming major power projects in the state

Sl.No	Description	Capacity (MW)
	Thermal Power	
1	Bhusawal TPS Unit-6	660
2	Paras Unit-5	250
3	Nasik Unit -6	660
4	Dondaicha Project	5 X 660 = 3300
5	Uran GTPS Block-1 & Block-II	1120
6	Chandrapur STP	1000
7	Koradi TPS	1980

8	Parli TPS	250
	Sub Total	**9220**
	Hydro Power	
1	Koyna Left Bank	80
	Sub Total	**80**

2.7 NECESSITY OF THE PROPOSED PUMPED STORAGE PROJECT

Although the state of Maharastra has surplus generation as on February 2021 from Table2.4 the state has more potential to to become net exporter of power by producing clean energy for the Western region & Southern region to close the gap peak demand & energy deficit.

From the above Table2.3 it is clear that the state has 67.64% of generation from the thermal generation & 32.35% from the renewables. But GOI aims to base 40% of the total installed power generation capacity on non-fossil fuel resources by 2030 which includes 175GW Energy from the renewables i.e., majority of 100GW from the solar power, 60GW from the wind power in the country by 2022. out of 100GW the state of Maharastra has a target of 22.045GW of solar energy generation. Currently only 10.266 GW has been accomplished into the grid achieving 46.5% of the renewable energy target. With growing demands of energy in the country this generation will be further ramped up by 2026-27 as shown in Table2.6.

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 the 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 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.

2.8 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 – on-line 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 – off-line 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 – on-line generation equipped with automated generation control that can respond rapidly, on a seconds 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.

CHAPTER - 3 BASIN DEVELOPMENT

3.1 THE COURSE OF THE WATER SOURCE

The Bhavali Pumped Storage Project is to be constructed by the installation of a Pump Storage with reversible turbines (total installed capacity 1500 MW) between a newly proposed upper reservoir & lower reservoir with the available water resources near Jamunde Village. Upper reservoir is proposed at an elevation of EL 745.00m between the hills, while the lower reservoir is proposed at an elevation of EL 300.00m between the hills of Kothale and Kalbhonde villages.

3.2 POWER POTENTIAL OF THE RIVER BASIN AND STAGES OF DEVELOPMENT

The Proposed upper reservoir is on a small stream which is a part of Godavari Upper sub basin & the lower reservoir is located on a stream which is a tributary of Ulhas River. The amount of water required for one time filling will be from the self yield of the catchment of the proposed Lower reservoir, which is a part of the catchment area of Bhatsa dam sub-basin within Ulhas basin. Bhatsa Dam is located near village Shahapur on Bhatsa river, a major tributary of Ulhas river. Bhatsa dam is constructed to provide irrigation, water supply and power generation. The installed capacity of the Power Plant in Bhatsa dam is 15 MW.

The Ulhas originates from the north of Tungarli near Lonavala, flows for a short distance before descending near Bhor ghat. The river has many tributaries; two important of them (within the boundaries of this district) are Barvi and Bhatsa.

3.3 WHETHER TRANS-BASIN DIVERSION OF WATERS INVOLVED

The proposed project is a pumped storage, wherein the water is stored either in the upper or lower reservoir and will be re-utilized with in the system. Because of one time filling of the system the evoporational losses are to be balanced in the proposed project from the yield generated during the monsoon season. Thus, there will no interference in the annual yield of the basin and the existing dams.

3.4 FITMENT OF THE SCHEME IN THE OVERALL BASIN DEVELOPMENT

The Pumped Storage Hydel Project is proposed to produce electricity mostly to meet the peak hour demand. The water used for generation of power during peak hour demand will be pumped back to upper reservoir using energy available from RE sources during low demand/excess generation hour. So, same water will always go on recycling. This concept has been accepted universally economical to meet the peak hour demand. This proposed project will enhance the power generation during critical hour of need with no consumptive use of water.

3.5 FITMENT OF THE SCHEME IN THE POWER POTENTIAL ASSESSMENT STUDIES CARRIED OUT BY CEA

In the perspective of the pumped storage power potential assessment studies carried out by CEA, the present proposal of 1500W Pumped storage development is not covered.

3.6 EFFECT OF FUTURE UPSTREAM/DOWNSTREAM DEVELOPMENTS ON THE POTENTIAL OF PROPOSED SCHEME

The proposed project will not require regular inflows. It will always be re-utilized between the upper and lower reservoir. The project does not interfere with any river's daily flows, there will not be any adverse effect on the proposed project even in case of any development in U/s and D/s in future.

3.7 ROR VS STORAGE ASPECTS

Bhavali PSP is the on-stream pumped storage development proposed with one time filling of the reservoir from the yield in the lower reservoir catchment, which is an intercepted catchment of existing Bhatsa Dam on Bhatsa River. This will not affect any upstream and downstream river valley developments. The proposed project does not entail for any RoR vs Storage study required for conventional hydro power developments.

CHAPTER - 4 INTER-STATE & INTER-NATIONAL ASPECTS

4.1 INTER-STATE ASPECTS

The Geographical co-ordinates of the proposed Pumped Storage Project component of upper reservoir located near to Jamunde village is at latitude 19°36'31.69"N and Longitude 73°35'4.06"N, lower reservoir near to Kalbhonde village with latitude 19°34'56.38"N and longitude 73°35'10.00"E (). This project is located in the Godavari upper Sub Basin. The project is located near Jamunde village located in Igatpuri Tehsil/Mandal of Nashik district and bodering with Shahpur Tehsil of Thane district in Maharastra, India at an elevation of RL 735m. Hence there are no inter-state aspects involved in the project.

The water will be cycled between the newly created upper reservoir & lower reservoir only i.e. without any consumptive use except for evaporation losses.

Also, the proposed project has two type of requirements i.e. one time filling initially (to be spanned to 2-3 seasons) and second make up water requirement for losses, both these requirements can be met from the surplus yield from the self catchment.

One-time water requirement will be captured in 2-3 seasons based on directions of State Govt as per water availability situation in those years for which state will make arrangements accordingly.

As the Consumptive use of the project is only 0.991 MCUM (to recoup the evaporation loss), which is less than 10 MCUM, therefore no ISM issue is involved in the project.

4.2 INTERNATIONAL ASPECTS

The state of Maharastra is the Western most state in India & has no international boundaries, therefore does not entail to international aspects.

CHAPTER - 5 SURVEY & INVESTIGATIONS

5.1 GENERAL

The following survey & investigations were carried out for the project and are briefly discussed in this Chapter:

- Topographical survey
- Geology & Geotechnical investigations
- Construction material investigations

5.2 TOPOGRAPHICAL SURVEY

Detailed topographical survey is not available for the project area and the same could not be undertaken during the study period. Hence, topographical survey drawings of the project area required for formulation of layouts and finalizing the location of project components has been prepared using latest available 1 Arc-second (30 m resolution) Digital Elevation Model (DEM) of the project area obtained from Shuttle Radar Topography Mission. Contours at 1 m interval have been extracted for the entire project area and to cover the catchment area of upper and lower reservoirs. Topographical map (47E10 & 47E14) of Survey of India were referred for investigation, reconnaissance and for finalizing the project layout.

5.2.1 Reconnaissance Survey

Bhavali Pumped storage project with 1500/11017 MWH storage capacity is located at Igatpuri district in Maharastra. Bhavali PSP is an on stream project in which the upper & lower reservoirs are to be constructed newly beside Bhavali reservoir on the Darna River. The water required for the Pumped storage operation will from the self catchment of lower reservoir which is part of Bhatsa dam catchment, for onetime filling for the reservoir operations.

A reconnaissance survey is made for proposed location of upper and lower reservoir, possible intake and exit locations, penstock tunnels, power house area and TRC. All salient features of the area are noted during the reconnaissance survey.

5.2.2 High precision topographical Survey

The high precision topographical survey shall be carried out during the DPR Stage by UAV Technology of survey Grade in augmentation with DGPS and Total Station when required. The overall process involves the following

1. Mission & Flight Planning
2. Provision of Ground Control Points (GCPs by GPS)
3. Data Acquisition by UAV

4. Processing of UAV data to generate Ortho, Point cloud data, bare earth, DEM and Contours
5. Extraction of topo features

5.3 GEOLOGICAL AND GEO-TECHNICAL INVESTIGATIONS

The proposed PSP is located in the Western ghats bodering between Igatpuri taluk of Nashik district and Shahpur taluk of Thane district in Maharastra. The entire area is underlain by the basaltic lava flows of upper Cretaceous to lower Eocene age. The shallow alluvial formation of Recent age also occurs as narrow stretch along the banks of Godavari and Girna Rivers flowing in the area. Basaltic lava flows occupies about 90% of the area. These flows are normally horizontally disposed over a wide stretch and give rise to table land type of topography also known a plateau. The volcanic portion consists of compact, stratified basalts, and an earthy trap. To the west they lie in flat-topped ranges, separated by valleys, trending from west to east. In some flows the basalt is columnar and then it weathers into the various shapes. The formation at the base of the traps is amygdaloidal, containing quartz in vertical veins, crystals and zeolitic minerals, especially apophyllite weathering into a grey soil. The river beds are covered with Alluvium which occurs in small areas in the form of discontinuous patches along the banks and flood plains of major rivers like Godavari, Girna and their tributaries. In alluvium the granular detrital material like sand and gravel usually occurring as thin layer in the district yields water. The absence of laterite, which caps the summits of the hills to the south, is a curious feature in the geology of the area.

5.3.1 Regional Geology

The entire area of the State forms a part of the “Peninsular Shield” composed of rocks commencing from the most ancient rocks of diverse origin, which have undergone considerable metamorphism. It represents a fairly stable block of earth crust that has remained unaffected by, mountains, building movements, since the advent of the Palaeozoic era.. Over these ancient rocks of Precambrian era lie a few basins of Proterozoic era and of permocarboniferous periods which are covered by extensive sheets of horizontally bedded lava flows comprising the Deccan trap. More than 80% area of the State is covered by these Deccan trap, which have concealed geologically older formations. The most important economic minerals such as coal, iron ore, manganese ore, limestone, etc. are found in these geologically older formations. Some of the subsequent movements in the crust have been of the nature of normal and block faulting which have laid down certain portions bounded by tensional cracks of faults giving rise to basins in which sedimentary beds of the Gondwana age have been deposited. Particularly in the Vidarbha region giving rise to the limestone as Penganga beds and coalfields of the Pench-Kanhan valley, the Umred – Bander field the Wardha valley and Vidarbha valley. The Western coast has been formed as a result of the faulting along the coast from Ratnagiri to Mumbai. Further north in Thane district there exists a series of hot springs arranged almost in linear represents that they are situated on a line of fracture. Western Ghats comprising Deccan trap lava flows, which are several hundred metres thick near the coast and which gradually thins out east wards. Near Panvel, near the west coast the Deccan traps show westerly slopes indicating designated as Panvel flexure.

5.4 SEISMICITY

The project area falls under Zone III as per IS-1893 (Part 1) 2002, Seismic Zoning Map of India.

5.5 HYDROLOGICAL & METEROLOGICAL INVESTIGATIONS

The available hydrological and meteorological data has been collected from various open sources.

- Rainfall & Climate data
- Stream Flow data
- Silt rate

CHAPTER - 6 HYDROLOGY

6.1 INTRODUCTION

Bhavali PSP is located bordering Thane & Nashik Districts of Maharastra. The project with 1500 MW of Pumped Storage capacity is proposed for the development near Jamunde and Kalbhonde village. Bhavali PSP will comprise of two reservoirs upper reservoir and lower reservoir (both are to be constructed newly).

The present proposal envisages a Pump Storage project between two newly created reservoirs, by installing reversible Francis turbines (total installed capacity 1500 MW) near Kalbhonde village. One time filling of the PSP reservoir with 0.63 TMC (17.84 MCM) will be carried out from the yield in the self catchment of lower reservoir. The lower reservoir catchment is an intercepted catchment of existing Bhatsa dam. The proposed project is a pumped storage project and hence no consumptive use of water has been envisaged for power generation. As such hydrological study is required to the extent to see the water availability for one time filling of the reservoir and the quantity of water required for refilling the reservoirs due to evaporation loss.

6.2 OBJECTIVES OF THE STUDY

The objective of the study is to assess the various parameters for project planning and design of proposed PSP scheme.

- To assess the water availability for running the proposed PSP scheme through out the year
- Estimate the design flood for PSP Upper & Lower Reservoir
- To assess the demand of water for refilling the reservoir due to evaporation, pumping operation etc. No consumptive loss of water is envisaged.
- To estimate the sediment loads

6.3 RIVER SYSTEM

Both upper and lower dams of Bhavali PSP are proposed to be constructed new. The one time filling of the PSP reservoir will be carried out from the yield in the self catchment of lower reservoir. The lower reservoir catchment is an intercepted catchment of existing Bhatsa dam. Bhavali PSP is located near village Bhavali on Darana river, of Godavari upper sub-basin. Darna is a minor right-bank tributary of Godavari in the Nashik District, Maharashtra. Rising north of the Kalsubai range, it drains Igatpuri, Nashik and Niphad Talukas of Nashik District. It's Confluence with Godavari is situated at Darnasangvi.

The Darna rises on the northern slopes of the Kulang hill fort in the Sahyadris about 13 km. south-east of Igatpuri. Though the straight line distance from the source to its confluence with the Darna is only about 50 km., it has a very long and winding course which measures about 80 km.

Bhatsa Dam has a catchment area of 388. 50 Sq. Km and that of proposed lower reservoir is 7.32 Sq. km. So the contribution of catchment interrupted by the proposed lower reservoir of Bhavali PSP towards water yield at Bhatsa Dam is minimal. Moreover. during monsoon in most of the years, water spills through Bhatsa dam as the reservoir level reaches FRL.

6.4 CLIMATE

The project site has a tropical climate. When compared with winter, the summers have much more rainfall. The average annual temperature is 24.2 °C and average precipitation here is about 2084 mm. The least amount of rainfall occurs in January. The average in this month is 1 mm. In July, the precipitation reaches its peak, with an average of 693 mm. The temperatures are highest on average in April, at around 28.2 °C , January is the coldest month of the year.

	January	February	March	April	May	June	July	August	Septem-ber	October	November	December
Avg. Temperature °C (°F)	21.4 °C (70.5) °F	23.4 °C (74.1) °F	26.4 °C (79.5) °F	28.2 °C (82.8) °F	27.6 °C (81.6) °F	24.6 °C (76.3) °F	22.7 °C (72.9) °F	22.5 °C (72.5) °F	23.2 °C (73.8) °F	24.7 °C (76.4) °F	23.8 °C (74.8) °F	22 °C (71.5) °F
Min. Temperature °C (°F)	15.5 °C (59.9) °F	17 °C (62.5) °F	19.5 °C (67.1) °F	21.5 °C (70.7) °F	22.5 °C (72.5) °F	22.5 °C (72.4) °F	21.6 °C (70.9) °F	21.3 °C (70.3) °F	21.2 °C (70.1) °F	20.7 °C (69.2) °F	18.8 °C (65.8) °F	16.5 °C (61.8) °F
Max. Temperature °C (°F)	28.2 °C (82.7) °F	30.5 °C (86.8) °F	33.8 °C (92.8) °F	35.8 °C (96.4) °F	34.1 °C (93.4) °F	28.2 °C (82.7) °F	24.8 °C (76.6) °F	24.7 °C (76.5) °F	26.6 °C (79.9) °F	29.7 °C (85.4) °F	29.6 °C (85.2) °F	28.4 °C (83.1) °F
Precipitation / Rainfall mm (in)	1 (0)	1 (0)	1 (0)	3 (0.1)	25 (1)	375 (14.8)	693 (27.3)	576 (22.7)	297 (11.7)	88 (3.5)	19 (0.7)	5 (0.2)
Humidity(%)	47%	42%	35%	42%	61%	85%	94%	94%	89%	66%	52%	49%
Rainy days (d)	0	0	0	1	4	18	22	22	18	8	2	1
avg. Sun hours (hours)	9.8	10.2	10.7	11.0	9.6	5.2	3.1	3.3	5.0	9.0	9.8	9.7

Figure 2: Climate details in the project area - Average values

The variation in the precipitation between the driest and wettest months is 692 mm. The variation in annual temperature is around 6.8 °

6.5 HYDRO METEOROLOGICAL DATA

South-west monsoon sets in by July and ends by September receiving maximum part of its annual rainfall during it. The monsoon entering through the west and south-west coast of the basin meets the Sahyadri Range sweeps across the interior of the peninsula. The crest zone of Sahyadri about 25 km wide is the belt of heaviest rainfall in the Maharashtra region.

Based on daily rainfall data (0.5 X 0.5) of the last 34 years collected from IMD, annual rainfall of the basin varies from 755 mm to 1531 mm. The average annual rainfall in the basin is 1096.92 mm. It is found that the rainfall varies temporally and spatially across the basin. In Godavari the high rainfall zone in the Western Ghats the annual rainfall varies from 1000 to 3000 mm in this reach. January and February are the driest months in the basin with the annual rainfall ranging from less than 0.5 mm to 55 mm. During the next three months, upto end of May, it varies from less than 1 mm to 50 mm. The maximum rainfall recorded was 1531 mm in 1990 and minimum was 755 mm in 1952.

6.6 WATER AVAILABILITY AT PROJECT LOCATION

The proposed storage project is being planned on the allocated water for utilization from surplus flows of Bhatsa dam. The onetime filing of the PSP reservoir will be carried out from the yield into the lower reservoir, part of Bhatsa dam catchment. The upper reservoir and the lower reservoirs are constructed on a small stream. The catchment area of the Upper reservoir is 4.40 Sq.Kms and of the Lower reservoir is 7.32 Sq.Kms.

The upper dam is constructed on a small stream which joins Bhavali dam. However, the water into the upper reservoir is not obstructed for filling the upper reservoir, either during the construction or operation of the PSP scheme. As such, the Hydrological studies for upper reservoir is carried out to finalise the design flood for the upper dam.

The lower dam is constructed on a small stream on the head reaches of Bhatsa dam catchment. The department of water resources Govt. of Maharashtra have recommended to utilize the water that flows through the stream in the proposed lower reservoir. The Hydrology & Dam Safety Sub-division, Nashik has confirmed that the proposed lower reservoir would have sufficient yield from rainfall to fill the both upper and lower reservoirs in two years. The water requirement for one time filling of reservoirs is 17.84 MCM and for annual replenishment due to evaporation is 0.991 MCM. The salient features of the Bhatsa Dam are enclosed as **Annexure – 6.1**.

As such, hydrological studies for the lower dam are carried out to assess the specific yield in to the reservoir through rainfall-runoff correlations and the design flood. Further, the assessment is made for water availability to run the proposed PSP scheme through out the year and the demand of water for refilling the reservoir due to evaporation, pumping operation etc. No consumptive loss of water is envisaged.

Water Availability Study

The analysis is based on the rainfall data of Kothale rain gauge station from 1973 to 2019. The dependability analysis of rainfall is carried out as given in **Annexure – 6.2**. The results of dependability analysis are given below.

Sl. No.	Dependability	Rainfall (mm)
1	90%	967.0
2	75%	2328.0
3	50%	2894.2

The water yield at proposed Lower Dam is estimated by two methods.

Method 1

The catchment area up to the lower dam of Bhavali PSP is 7.32 sq km. The cumulative annual rainfalls in the lower reservoir catchment in 90%, 75% and 50% dependable year are estimated to be 7.07 MCM (0.967 x 7.32 x 10^6 m^3), 17.04 MCM (2.328 x 7.32 x 10^6 m^3) and 21.186 MCM (2.8942 x 7.32 x 10^6 m^3). Considering a runoff factor of 0.60, the yield at proposed lower dam shall be 4.21 MCM, 10.224 MCM and 12.71 MCM respectively.

Method 2

The rainfall correlation formula developed at Bhatsa site in the integrated state water plan of Maharashtra is given below.

R=0.7890*P-128.0288

Where R = Runoff in mm

P = Rainfall in mm

Using the above formula, the water available at 50%, 75% and 90% dependability comes to 15.778 MCM, 12.508 MCM and 4.65 MCM respectively.

Out of these two methods, the yield estimated by method 1 is on the conservative side, which will be used for further studies. As per Method 1, the 90% dependable yield at the proposed lower reservoir is 4.21 MCM. So it will take four monsoon seasons for one time filling of 17.84 MCM water in lower and upper reservoirs. As per Method 1, the 75% dependable yield at the proposed lower reservoir is 10.224 MCM. So it will take two monsoon seasons for one time filling of 17.84 MCM water in lower and upper reservoirs.

Impact on Bhatsa Dam

Bhatsa Dam has a catchment area of 388. 50 Sq. Km and that of proposed lower reservoir is 7.32 Sq. km. So the contribution of catchment interrupted by the proposed lower reservoir of Bhavali PSP towards water yield at Bhatsa Dam is minimal. Moreover. during monsoon in most of the years, water spills through Bhatsa dam as the reservoir level reaches FRL. This aspect is also confirmed with WRD Department, wherein the spillage from Bhatsa dam in a 75% dependable year is 64.970 MCM of water.

6.7 EVAPORATION

The evaporation volume from reservoir is assumed to be exactly proportional to submerged area, which of the upper reservoir varies from 0.69 Sqkm (at FRL) and 0.35 Sqkm (at MDDL) and the lower reservoir varies from 0.52 Sqkm (at FRL) and 0.11 Sqkm (at MDDL). The submerged areas of the upper reservoir at each medium storage capacity between FRL and MDDL are used for estimating annual losses due to evaporation. The annual losses due to the evaporation from the PSP reservoir is 0.991 MCM estimated at 10% of live storage. This annual loss will be recouped during the monsoon season. However detailed analysis shall be carried out during FSR/DPR Stage.

6.8 SEDIMENTATION

The estimated silt load for the proposed reservoirs has been arrived based on "Compendium on Silting of Reservoirs in India (2015)" published by CWC .

As per the CWC publication, a sediment rate of 715 m^3/sq.km/year is based on the average sediment rate in the Reservoir located for the Deccan Peninsular East flowing rivers including Godavari and South Indian Rivers excluding the western ghat reservoirs.

An average sedimentation rate of about 715 m^3/km^2/year has been considered for the project.

6.8.1 Sediment Volume

As per I.S. guidelines 12182-1987 "Determination of effects of sedimentation in planning and performance of reservoir", feasible service time of the reservoir for hydro power shall not less than 70 years.

The upper reservoir have small catchment draining into the reservoir. The area (C.A.) of upper reservoir is 4.4 Sqkm. The total sediment volumes for 70 years at upper Reservoir is calculated as following

Sediment volume of upper reservoir = 715 × 4.4 × 70 = 0.22 MCM

The estimated annual sediment volumes for upper dam is 0.003 MCM. The ratios of the annual sediment volumes to gross storage capacity of upper dam is negligible. Thus, the reservoir sediment problem is insignificant.

The lower reservoir has a catchment area of 7.32 Sqkms draining into the reservoir. The total sediment volumes for 70 years at upper Reservoir is calculated as following

Sediment volume of upper reservoir = 715 × 7.32 × 70 = 0.36 MCM

The estimated annual sediment volumes for upper dam is 0.005 MCM. The ratios of the annual sediment volumes to gross storage capacity of upper dam is negligible. Thus, the reservoir sediment problem is insignificant.

The Minimum Drawdown Level (MDDL) of the upper reservoir is kept at EL. 728.0m (based on optimum head requirement) with corresponding dead storage capacity of 6.46 MCM as against the estimated sediment volumes of 0.22 MCM.

The Minimum Drawdown Level (MDDL) of the lower reservoir is kept at EL. 270.0m with corresponding dead storage capacity of 1.36 MCM as against the estimated sediment volumes of 0.36 MCM.

The estimated sediment volumes is contained well below the dead storage itself and has no effect of sediment in the reservoir. Detailed sedimentation analysis will be carried out during FSR/DPR stage.

6.9 DESIGN FLOOD

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 latest Indian Standards and guidelines of the Central Water Commission (CWC), the design flood for a hydraulic structure may be one the following:

- Probable Maximum Flood
- Standard Project Flood
- Flood of Specified Frequency (T-Year Flood)

The design flood may be the maximum probable flood or the standard project flood or a flood corresponding to some desired frequency of occurrence depending upon the standard of security that should be provided against possible failure of the structure.

As per IS 11223:1985, inflow design flood for the safety of a dam is the flood for which, when used with standard specifications of other factors as mentioned in subsequent clauses, the performance of the dam should be safe against overtopping and structural failure, and the spillway and its energy dissipation arrangements, if provided for a lower flood, should function reasonably well.

The selection criteria depend upon the functional importance, with judicious combination of safety and economy in the event of failure.

As per the Manual of Estimation of Design Flood (CWC) and IS 11223:1985, the criteria for adopting the design flood depends upon the classification of the dam, based on storage capacity and hydraulic head is furnished in Table 11.

Table 11: Design flood adoption criteria

S.No.	Classification	Gross storage (MCM)	Hydraulic head (m)	Design flood
1	Small	0.5 to 10	7.5 to 12	100 – year flood
2	Medium	10 to 60	12 to 30	SPF
3	Large	>60	>30	PMF

Floods of larger or smaller magnitude may be used if the hazard involved in the eventuality of a failure is particularly high or low. The relevant parameters to be considered in judging the hazard in addition to the size would be:

- distance to and location of the human habitations on the downstream after considering the likely future developments.
- Maximum hydraulic capacity of the downstream channel at a level at which catastrophic damage is not expected.

The Bhavali PSP upper & lower reservoir can be classified as "Large" by hydraulic head criterion being more than 30m.

The flood discharge worked out based on unit hydrograph. The PMF is estimated to 240.40 cumecs, 421.70 cumecs for both upper and lower reservoirs respectively.

Annexure 6.1

Salient Features of Bhatsa Dam

Project	**Bhatsa Multi-purpose Project**
River	At confluence of Bhatsa and Chorana river in the Ulhas Basin
Lat/Long	19^0 31' 00"/ 73^0 25' 15"
GCA	48,901 ha
CCA	29,378 ha
Annual industrial/domestic water supply	426.80 MCM
Hydro Power Generation	15 MW installed capacity with 70 MU average annual energy generation
Catchment Area	388.50 sq km
Main Dam	
Type	Masonry Dam
Length	959 m
Top elevation	145.07 m
Height of dam above lowest river bed level	85.1 m
Lowest river bed level	59.97 m
Spillway	
Type of spillway gates	Ogee
Length	60 m
Location of spillway	Central (Chainage 374 m to 434 m)
Crest level	134.07 m
Number of bays	5
Discharge capacity at MWL	10242.075 cumec
Size of spillway gate	12 m wide and 8 m high
Reservoir	
Maximum water level	145.07 m
Full Reservoir Level	142.07 m
MDDL	79.20 m
Live storage	942.10 MCM
Gross storage	976.10 MCM
Reservoir spread area	27.2457 sq km
Year of start of construction	1969
Date of completion	2005
Year of first impoundment	2005

Annexure 6.2

Table 12: Rainfall Dependability Analysis

Year	Rainfall (mm)	Rainfall Sorted in Descending Order	Rank	Dependability
1973	3551.6	7784.0	1	2.1%
1974	2428.1	7047.6	2	4.2%
1975	3280.2	6456.2	3	6.3%
1976	7047.6	4917.0	4	8.3%
1977	3380.9	4719.1	5	10.4%
1978	2484.8	3849.6	6	12.5%
1979	2802.5	3574.8	7	14.6%
1980	3547.5	3551.6	8	16.7%
1981	3247.9	3547.5	9	18.8%
1982	**2328.0**	3538.0	10	20.8%
1983	3390.0	3515.4	11	22.9%
1984	2749.2	3506.4	12	25.0%
1985	2483.2	3390.0	13	27.1%
1986	2248.3	3380.9	14	29.2%
1987	1955.3	3316.2	15	31.3%
1988	3515.4	3298.8	16	33.3%
1989	1898.8	3280.2	17	35.4%
1990	2736.5	3247.9	18	37.5%
1991	2286.2	3243.1	19	39.6%
1992	2703.8	3237.7	20	41.7%
1993	3298.8	3201.0	21	43.8%
1994	3574.8	2969.6	22	45.8%
1995	2126.8	2902.1	23	47.9%
1996	2560.1	**2894.2**	**24**	**50.0%**
1997	3316.2	2802.5	25	52.1%
1998	3237.7	2749.2	26	54.2%
1999	2902.1	2736.5	27	56.3%
2000	2446.6	2703.8	28	58.3%
2001	3201.0	2633.1	29	60.4%
2002	2580.4	2580.4	30	62.5%
2003	3506.4	2560.1	31	64.6%
2004	3849.6	2484.8	32	66.7%
2005	4917.0	2483.2	33	68.8%
2006	4719.1	2446.6	34	70.8%
2007	3243.1	2428.1	35	72.9%
2008	3538.0	**2328.0**	**36**	**75.0%**
2009	1858.5	2286.2	37	77.1%

2010	2633.1	2248.3	38	79.2%
2011	**2894.2**	2126.8	39	81.3%
Year	**Rainfall (mm)**	**Rainfall Sorted in Descending Order**	**Rank**	**Dependability**
2012	2969.6	1955.3	40	83.3%
2013	7784.0	1898.8	41	85.4%
2014	6456.2	1858.5	42	87.5%
2015	472.0	**967.0**	**43**	**89.6%**
2016	568.0	741.0	44	91.7%
2017	741.0	568.0	45	93.8%
2018	471.0	472.0	46	95.8%
2019	**967.0**	471.0	47	97.9%

CHAPTER - 7 RESERVOIR

7.1 UPPER & LOWER RESERVOIRS - CATCHMENT AREA, SUBMERGENCE & ANNUAL INFLOW

The upper reservoir is proposed near Jamunde village, upstream of the existing Bhavali dam and the lower reservoir is formed in a local depression near Kalbhonde village. The upper reservoir is formed with rockfill embankment & Concrete gravity Dam with TOB at EL +748.00m and the lower reservoir is formed with Concrete gravity Dam with TOB at EL +303.00m. The proposed storage project is being planned on the allocated water of 0.63 TMC (17.84 MCM) from Bhatsa dam for utilization by recirculation between the reservoirs. The Geographical co-ordinates of the upper reservoir is at latitude 19°36'31.69"N, Longitude 73° 35'45.06"E and that of lower reservoir with latitude 19°34'56.38"N and longitude 73° 35'10.00"E. The upper & Lower Reservoirs have a catchment area of 4.4sq.km & 7.32sq.km, draining into the reservoirs respectively.

7.2 UPPER & LOWER RESERVOIRS – ELEVATION AREA CAPACITY

Elevation-Area-Capacity details of proposed reservoirs have been worked out from the contour maps prepared for the project area. The area enclosed between successive contours is calculated and the volume between any two elevations is calculated using the following formula:

$V = H/3*[A_1 + A_2 + (A_1 \times A_2)\text{^} 0.5]$

Where V = Volume between two contours (Mm^3);

H = Contour interval/ Difference in elevation (m);

A_1 = Water spread area at first contour level (Mm^2); and

A_2 = Water spread area at second contour level (Mm^2)

The incremental volume of the reservoir between two contours thus obtained is summed up to estimate gross storage capacity of reservoir at different elevations.

7.2.1 Upper Reservoir

The water spread area and the gross storage capacity of upper reservoir at various elevations is shown in Table 13 The gross storage capacity of the upper reservoir is 16.42 MCM (0.58 TMC)

Table 13: Elevation-Area-Capacity of Upper Reservoir

Sl.No	Elevation (m)	Water-spread Area (Sqm)	Water-spread Area (MSqm)	Capacity (Cum)	Capacity (Mcum)	Cumulative Capacity (Mcum)	Cumulative Capacity (TMC)
1	700	34835	0.000	0	0.000	0.000	0.00
2	701	45687.38	0.046	40139	0.040	0.040	0.00
3	702	56540.07	0.057	51017	0.051	0.091	0.00
4	703	67392.77	0.067	61887	0.062	0.153	0.01
5	704	78245.47	0.078	72752	0.073	0.226	0.01
6	705	89098.16	0.089	83613	0.084	0.309	0.01
7	706	100671.31	0.147	116831	0.117	0.426	0.02
8	707	112244.46	0.159	152911	0.153	0.579	0.02
9	708	123817.60	0.171	164886	0.165	0.744	0.03
10	709	135390.75	0.183	176861	0.177	0.921	0.03
11	710	146963.90	0.195	188836	0.189	1.110	0.04
12	711	158936.32	0.207	200810	0.201	1.311	0.05
13	712	170908.74	0.217	212091	0.212	1.523	0.05
14	713	182881.17	0.228	222665	0.223	1.745	0.06
15	714	194853.59	0.239	233239	0.233	1.979	0.07
16	715	206826.01	0.249	243813	0.244	2.222	0.08
17	716	217399.21	0.260	254387	0.254	2.477	0.09
18	717	227972.41	0.271	265182	0.265	2.742	0.10
19	718	238545.61	0.282	276201	0.276	3.018	0.11
20	719	249118.81	0.293	287219	0.287	3.305	0.12
21	720	259692.00	0.304	298238	0.298	3.604	0.13
22	721	270709.89	0.315	309256	0.309	3.913	0.14
23	722	281727.79	0.329	321659	0.322	4.234	0.15
24	723	292745.68	0.342	335465	0.335	4.570	0.16
25	724	303763.57	0.356	349271	0.349	4.919	0.17
26	725	314781.46	0.370	363076	0.363	5.282	0.19
27	726	328586.25	0.384	376882	0.377	5.659	0.20
28	727	342391.04	0.401	392290	0.392	6.051	0.21
29	728	356195.83	0.418	409323	0.409	6.461	0.23
30	729	370000.62	0.435	426356	0.426	6.887	0.24

Sl.No	Elevation (m)	Water-spread Area (Sqm)	Water-spread Area (MSqm)	Capacity (Cum)	Capacity (Mcum)	Cumulative Capacity (Mcum)	Cumulative Capacity (TMC)
31	730	383805.41	0.452	443389	0.443	7.331	0.26
32	731	400836.95	0.469	460421	0.460	7.791	0.28
33	732	417868.48	0.496	482450	0.482	8.273	0.29
34	733	434900.02	0.523	509555	0.510	8.783	0.31
35	734	451931.55	0.550	536660	0.537	9.320	0.33
36	735	468963.08	0.577	563764	0.564	9.883	0.35
37	736	496064.62	0.604	590868	0.591	10.474	0.37
38	737	523166.15	0.623	613918	0.614	11.088	0.39
39	738	550267.68	0.642	632863	0.633	11.721	0.41
40	739	577369.21	0.661	651807	0.652	12.373	0.44
41	740	604470.74	0.680	670752	0.671	13.044	0.46
42	741	623414.56	0.699	689696	0.690	13.733	0.48
43	742	642358.38	0.642	670573	0.671	14.404	0.51
44	743	661302.21	0.661	651807	0.652	15.056	0.53
45	744	680246.03	0.680	670752	0.671	15.726	0.56
46	745	699189.85	0.699	689696	0.690	16.416	0.58

7.2.2 Lower Reservoir

The water spread area and the gross storage capacity of upper reservoir at various elevations is shown in Table 14 The gross storage capacity of the upper reservoir is 11.28 MCM (0.40 TMC)

Table 14: Elevation-Area-Capacity of Lower Reservoir

Sl.No	Elevation (m)	Water-spread Area (Sqm)	Water-spread Area (MSqm)	Capacity (Cum)	Capacity (Mcum)	Cumulative Capacity (Mcum)	Cumulative Capacity (TMC)
1	250	3601	0.000	0	0.000	0.000	0.00
2	251	6323.54	0.006	4899	0.005	0.005	0.00
3	252	9046.54	0.009	7645	0.008	0.013	0.00
4	253	11769.55	0.012	10378	0.010	0.023	0.00
5	254	14492.55	0.014	13107	0.013	0.036	0.00
6	255	17215.55	0.017	15835	0.016	0.052	0.00
7	256	23005.65	0.046	30524	0.031	0.082	0.00
8	257	28795.75	0.052	49143	0.049	0.132	0.00

Sl.No	Elevation (m)	Water-spread Area (Sqm)	Water-spread Area (MSqm)	Capacity (Cum)	Capacity (Mcum)	Cumulative Capacity (Mcum)	Cumulative Capacity (TMC)
9	258	34585.84	0.058	55163	0.055	0.187	0.01
10	259	40375.94	0.064	61182	0.061	0.248	0.01
11	260	46166.04	0.070	67200	0.067	0.315	0.01
12	261	52182.18	0.076	73218	0.073	0.388	0.01
13	262	58198.33	0.082	79293	0.079	0.468	0.02
14	263	64214.47	0.089	85426	0.085	0.553	0.02
15	264	70230.62	0.095	91559	0.092	0.645	0.02
16	265	76246.77	0.101	97692	0.098	0.742	0.03
17	266	82378.42	0.107	103824	0.104	0.846	0.03
18	267	88510.07	0.117	112087	0.112	0.958	0.03
19	268	94641.72	0.128	122536	0.123	1.081	0.04
20	269	100773.37	0.138	132984	0.133	1.214	0.04
21	270	106905.02	0.149	143432	0.143	1.357	0.05
22	271	117350.44	0.159	153880	0.154	1.511	0.05
23	272	127795.87	0.172	165597	0.166	1.677	0.06
24	273	138241.30	0.185	178615	0.179	1.855	0.07
25	274	148686.73	0.198	191632	0.192	2.047	0.07
26	275	159132.16	0.211	204649	0.205	2.251	0.08
27	276	172146.73	0.224	217665	0.218	2.469	0.09
28	277	185161.31	0.236	230304	0.230	2.699	0.10
29	278	198175.88	0.249	242558	0.243	2.942	0.10
30	279	211190.45	0.261	254812	0.255	3.197	0.11
31	280	224205.02	0.273	267066	0.267	3.464	0.12
32	281	236457.58	0.285	279319	0.279	3.743	0.13
33	282	248710.14	0.298	291906	0.292	4.035	0.14
34	283	260962.69	0.311	304832	0.305	4.340	0.15
35	284	273215.25	0.324	317757	0.318	4.658	0.16
36	285	285467.80	0.337	330682	0.331	4.988	0.18
37	286	298392.24	0.350	343608	0.344	5.332	0.19
38	287	311316.67	0.366	357860	0.358	5.690	0.20
39	288	324241.11	0.381	373458	0.373	6.063	0.21
40	289	337165.54	0.397	389055	0.389	6.452	0.23

Sl.No	Elevation (m)	Water-spread Area (Sqm)	Water-spread Area (MSqm)	Capacity (Cum)	Capacity (Mcum)	Cumulative Capacity (Mcum)	Cumulative Capacity (TMC)
41	290	350089.98	0.412	404653	0.405	6.857	0.24
42	291	365686.61	0.428	420251	0.420	7.277	0.26
43	292	381283.24	0.381	404453	0.404	7.682	0.27
44	293	396879.87	0.397	389055	0.389	8.071	0.29
45	294	412476.50	0.412	404653	0.405	8.475	0.30
46	295	428073.13	0.428	420251	0.420	8.896	0.31
47	296	447349.47	0.447	437676	0.438	9.333	0.33
48	297	466625.81	0.467	456954	0.457	9.790	0.35
49	298	485902.15	0.486	476231	0.476	10.267	0.36
50	299	505178.49	0.505	495509	0.496	10.762	0.38
51	300	524454.83	0.524	514787	0.515	11.277	0.40

7.3 SEDIMENTATION DATA & STUDIES

7.3.1 Rates of sedimentation

The estimated silt load for the proposed reservoirs has been arrived based on "Compendium on Silting of Reservoirs in India (2015)" published by CWC.

As per the CWC publication, a sediment rate of 715 m^3/sq.km/year is based on the average sediment rate in the Reservoir located for the Deccan Peninsular East flowing rivers including Godavari and South Indian Rivers excluding the western ghat reservoirs.

7.3.2 Quantity of sediment (Tonnes or M cum during the life of the Reservoir)

The Minimum Drawdown Level (MDDL) of the upper reservoir is kept at EL. 728.0m (based on optimum head requirement) with corresponding dead storage capacity of 6.46 MCM as against the estimated sediment volumes of 0.22 MCM.

The Minimum Drawdown Level (MDDL) of the lower reservoir is kept at EL. 270.0m with corresponding dead storage capacity of 1.36 MCM as against the estimated sediment volumes of 0.36 MCM.

The estimated sediment volumes is contained well below the dead storage itself and has no effect of sediment in the reservoir. However, it is suggested to undertake sediment observations of the river/nallah at dam sites during DPR stage for detailed planning of reservoirs.

7.3.3 Sediment studies

The sedimentation studies for fixing the life of reservoir are carried out as per BIS : 5477.

7.3.4 Sedimentation in the reservoir after feasible service time

The new zero elevation for the lower dam after feasible service time, i.e. 70 years, was EL. 718.0 m which is below the Minimum draw down level of EL. 728.00 m.

7.4 FIXATION OF STORAGE AND RESERVOIR LEVELS-APPROACH- CRITERIA

The main parameters considered during identification & finalization of the reservoir is: proximity of the upper and lower reservoir; capacity; topography & geological setup; reservoir water tightness & head. Reconnaissance of the entire area around the proposed Project was carried out utilizing available Survey of India (SOI) Toposheets (1:50,000 scale), satellite imageries & google maps to identify possible locations for upper reservoir. Detailed topographic maps with one meter contour interval were used for developing area capacity curve for upper reservoir which indicated that sufficient capacity will be available as per the design requirement, and accordingly the height & length of embankments / dams is worked out. Storage and Reservoir levels are also verified based on sedimentation studies, water requirement for one cycle of operation and achieve target capacity of 1500 MW. Based upon the differential head available between two proposed reservoirs, it is proposed to operate the scheme between EL +745.0m and EL+ 300.0m.

Table 15: Key parameters of Reservoirs & Dams

Sl. No.	Parameter	Unit	Upper Reservoir	Lower Reservoir
1	Live Storage	TMC	0.35	0.35
2	Dead Storage	TMC	0.05	0.23
3	Gross Storage	TMC	0.58	0.40
4	Full Reservoir Level (FRL)	m	EL 745.00	EL 300.00
5	Minimum Draw Down Level (MDDL)	m	EL 728.00	EL 270.00
6	Max Height of RCC Dam	m	45.0	50.0

7.5 SADDLES PRESENT ALONG THE RIM OF THE RESERVOIR

No significant saddles are present in the foreshore of the reservoir

7.6 LIFE OF RESERVOIR IN YEARS WITH BASIS

As per I.S. guidelines 12182-1987, feasible service time of the reservoir for hydropower shall not less than 70 years.

7.7 WATER TIGHTNESS OF THE RESERVOIR

Geological maps on 1:250000 scale & 1:50,000 scale prepared by the Geological Survey of India were procured and studied to understand regional geological setup in and around the Project area. Small water body exists in the proposed upper reservoir area. Hence, no significant seepage is anticipated through the bed or through the foundation of the dam as per the prevailing geological condition. Adequate seepage control measures shall be considered after detailed geological mapping and investigations.

7.8 ANNUAL LOSSES

(a) Evaporation:

The total annual evaporation loss from both the reservoirs works out to 0.991 Mcum.

(b) Seepage in the reservoir

No seepage losses are anticipated.

7.9 FLOOD ABSORPTION

The PMF of the upper dam & lower dam are works out to 240.40m^3/s, 421.70m^3/s respectively.

7.10 EFFECT ON SUB SOIL WATER TABLE IN THE ADJOINING AREAS PARTICULARLY DOWN STREAM OF THE DAM.

Effect on sub soil water table in the adjoining areas will be nominal as the reservoir area is small.

7.11 RESERVOIR RIM STABILITY

Details given the geology chapter.

7.12 AREA OF SUBMERGENCE / LAND ACQUISITION (HA)

The construction of upper and lower dam will result in submergence of land which has to be acquired from concerned agencies like forest department, private parties etc. The area of land to be acquired for upper and lower reservoirs is as below.

Upper Reservoir – 92.57 Ha; Lower Reservoir – 65.70 Ha

7.13 PISCICULTURE

Not envisaged for the project.

7.14 NEED AND RECOMMENDATION FOR SOIL CONSERVATION MEASURE IN THE CATCHMENTS

There is no need for soil conservation measure in the catchment.

CHAPTER - 8 POWER POTENTIAL AND INSTALLED CAPACITY

8.1 INSTALLED CAPACITY

The installed capacity of Bhavali PSP is proposed based on the operating levels of the upper and lower reservoir with a rated capacity of 1500 MW.

8.2 LOCATION & RESERVOIR DETAILS

8.2.1 Upper Dam

The latitude and longitude at the upper dam site are 19°36'31.69"N, 73° 35'45.06"E. The area capacity characteristics developed for the reservoir at this Upper Dam location are enclosed at Table 13

The gross storage in the upper reservoir at FRL (EL. + 745.00 m) and MDDL (EL. +728.00 m) are 16.42 MCM and 6.46 MCM respectively. The maximum live storage will be 9.96 MCM.

8.2.2 Lower Dam

The latitude and longitude at the lower dam site are 19°34'56.38"N, 73° 35'10.00"E. The area capacity characteristics of the Lower Dam location are enclosed at Table 14.

The gross storage in the lower reservoir at FRL (EL. 300.00 m) and MDDL (EL. 270.00 m) are 11.28 MCM and 1.36 MCM respectively. The maximum live storage is 9.92 MCM.

8.2.3 Fixation of Reservoir Parameters

The Full Reservoir Level (FRL) of upper dam has been kept in order to acheive the maximum potential at site duly meeting the required storage capacity. The selection of installed capacity and operating levels of the upper and lower reservoirs have been arrived by carrying out detailed operation simulation studies of the scheme.

8.2.4 Minimum Draw Down Level

The minimum draw down for the reservoirs has been arrived at from the consideration of silt storage, requirement of water seal above intake and head variations. Considering a sediment rate of 715 cum/sq. km/year, the silt volume in 70 years would only be a small proportion of the dead storage and therefore does not influence the selection of MDDL. The MDDL has been fixed for Upper Reservoir and Lower Reservoir at EL + 728.00m and at EL + 270.00m respectively from the above considerations mentioned and requirement of live pondage for proposed installation of 1500 MW for about 7.34 hours.

8.3 OPTIMISATION OF INSTALLED CAPACITY

The installed capacity of the proposed PSP is dependent on

i) On the allocated water and

ii) Reservoir storage and head available at the site.

The daily load factor of operation of the scheme, which in turn determines the hours of operation in a day, depends on the power system requirements. The proposed PSP with installed capacity of 1500 MW of Pumped Storage capacity developed on technical feasibility, site suitability and associated requirements and demand from various State DISCOMs/STUs and other consumers.

The installed capacity of the power plant is dependent on the reservoir storage for about 7.38 hours of generation and head available at site. The assessment of storage requirement in the reservoirs for power generation has been carried out on the basis of daily operation.

8.4 ENERGY GENERATION

The plant has been proposed to be operated on daily cycle basis. The annual energy generation from the scheme is 3820 MU and the annual input power required is 4647 MU; Cycle efficiency of the scheme is 82.68%.

Installed Capacity & Energy Generation

CASE -1 **6 X 250**

Rated Head	=	447.00	m	No of units	**6**	
Maximum Head	=	470.50	m			
Discharge per Unit	=	62.43	Cumecs			
Efficiency Of Generator	=	98.24%				
Efficiency Of Turbine	=	92.95%		Combined Efficiency	91.32%	
Unit Capacity (KW)		250000	Say	250000	KW	
Power in MHP	=	339674	HP			

Total Installed Capacity of the project		**1500**	MW	
No of Days of utilization considering 95% machine availablity		346.75	Days	
Design Discharge for 250 MW	=	374.60	Cumecs	(Turbine Mode)
Total Design Discharge in Turbine Mode		374.60	Cumecs	
No of Hours for utilising 0.35 TMC (In Turbine Mode)	=	0.35 / 13236.62	X10^3 / X 60	X10^6 / X 60
	=	7.34	Hrs	
Annual Energy Generation	=	3820	MU	
Annual Energy Generation for 7.34 Hrs	=	3820	MU	
Plant Load Factor (Turbine)	=	29.07%		
Design Discharge for 264 MW	=	325.19	Cumecs	(Pump Mode)
Total Design Discharge in Pump Mode		325.19	Cumecs	
Total Pump Capacity	=	**1584**	MW	
No of Hours for utilising 0.35 TMC (In Pump Mode)	=	0.35 / 11490.82	X10^3 / X 60	X10^6 / X 60
	=	8.46	Hrs	
Annual Input Energy Required	=	4647	MU	
Plant Load Factor (Pump)	=	33.49%		
Cycle efficiency	=	82.21%		

CHAPTER - 9 DESIGN OF CIVIL STRUCTURES

9.1 GENERAL

The Bhavali Pumped storage project is located near Jamunde & Kalbhonde Villages bodering Nashik and Thane districts, Maharastra. The project is envisaged to generate electricity during the peak hours.

The catchment area at the upper dam site is 4.4 sq. km. The upper reservoir has Gross storage of 16.416 MCM (0.58 TMC) and Dead storage 6.461 MCM (0.23 TMC). The lower reservoir has Gross storage of 11.28 MCM (0.40 TMC) and Dead storage 1.357 MCM (0.05 TMC). The proposed PSP consists of 1035m long rockfill embankment & Concrete gravity Dam at the upper reservoir & 421m long Concrete gravity Dam at the lower reservoir.

The proposed Pumped Storage project envisages utilization of available head between newly constructed upper reservoir and lower reservoir. An Underground Power House (UGPH) will be located in between two reservoirs. Both the reservoirs are interconnected through water conductor, the generator and turbines installed at the power house in between the reservoirs.

9.2 SELECTION OF LAYOUT GENERAL

The concept of pumped storage Projects are broadly categorized in two types as under: -

- Closed-loop pumped storage projects are not continuously connected to a naturally-flowing water feature.
- Open-loop pumped storage projects are continuously connected to a naturally-flowing water feature.

The Proposed scheme is categorized as open loop Pump Storage type. The Upper reservoir is proposed as an artificial reservoir at higher elevation to gain the available head. The lower reservoir is proposed on the natural depression at the downhill.

9.3 PROPOSED LAYOUT OF THE PROJECT

The proposed pumped storage project has been proposed with upper and lower reservoir with Full Reservoir Levels of EL +745.00, EL +300.00 m and Minimum draw down levels of EL +728.00, EL +270.00m. An artificial Reservoir is proposed as upper Reservoir which is constructed by forming an embankment/bund with top elevation EL +748.0m. The live storage capacity for pump storage scheme required is 9.955 MCM (0.35 TMC). The proposed project will generate 1500 MW of power by utilizing net rated head of 447.00 m. The water from the upper reservoir will be diverted through Power House and TRT to the lower reservoir. The water will be pumped back to the upper reservoir through TRT-Reversible Turbines-pressure shaft-HRT to upper reservoir.

The project comprises of a lower intake at the lower reservoir to pump the water to upper reservoir.

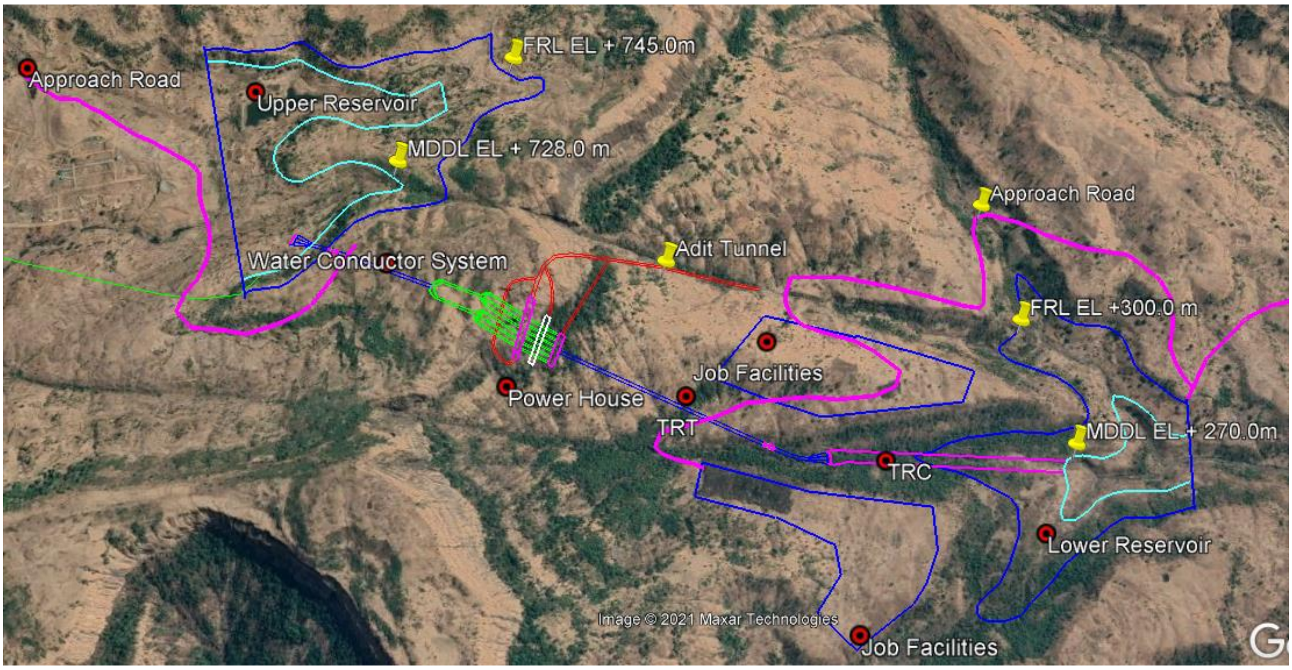


Figure 3: Project Layout

The proposed civil components of the project are as follows:

- An artificial upper and lower reservoir is formed with rockfill embankment & RCC Dam. The length of embankment dam is order of 1035 m at the upper reservoir with height of 48m and 421m at the lower reservoir end with a maximum height of 53m.
- An upper intake with inclined trash rack.
- 11m dia one number of HRT tunnel with a length 1617.45m.
- Two Pressure shaft of 7.7m diameter & length 185.16m trifucating into 5.5m tunnels & 43.00m long
- An underground power house of 135.40 m (L) x 18.00 m (W) x 50.00 m (H) housing six vertical shaft reversible Francis turbines and generator unit of 250 MW each.
- Transformer Cavren of 170.0 m (L) x 15.00 m (W) x 24.00 m (H)
- Tail Race outlet structure.
- Six number of Tail race tunnel of 5.5m converging to form 1 No's of 11m dia & 158.615m long
- Tail race outlet structure & Tail race channel of 900m long.

9.4 UPPER RESERVOIR & LOWER RESERVOIR

The salient features of the upper & lower reservoir are as shown in Table

	Upper Reservoir	Upper Reservoir
Live Storage	0.35 TMC	0.35 TMC
Dead Storage	0.23 TMC	0.05 TMC
Gross Storage	0.58 TMC	0.40 TMC
Upper Dam		
Type of Dam	Rock fill & Concrete gravity	Concrete gravity Dam
Top of Dam	EL +748.000 m	EL +303.000 m
Full Reservoir level (FRL)	EL +745.000 m	EL +300.000 m
Minimum Draw Down Level (MDDL)	EL +728.000m	EL +270.000m
Length of Dam	1035.00 m	421.00 m
Max Height of Dam	48.0 m (above Lowest NSL)	53.0 m (above Lowest NSL)
Top Width of Dam	10.0 m	10.0 m

9.4.1 Free Board for Upper Reservoir Embankment/Bund

Free board is the vertical difference in elevation between still water level and the dam crest. Its purpose is to provide protection against waves.

The evaluation of the height of the waves originating in the reservoir as a result of exposure to wind is calculated to arrive at the requirement of Free board for Newly Proposed upper & lower reservoir.

The available dam free board and the wave wall height placed on the dam crest were evaluated considering the following aspects:

- Selection of an appropriate wind speed, valid for the studied area and representative of the worst conditions;
- Geographic and effective fetch for the selected dam location and reservoir;

The wind speed was selected as per IS 875-III.

The historical series shows an absolute maximum wind speed of 140.4 Km/h was used to evaluate the wave height.

The effective fetch and wave height are calculated as per IS:10635 “Freeboard requirement in embankment dams – Guidelines”

The effective fetch length is given by the following equation:

Effective fetch length = $\Sigma fi*\cos 2\theta \ / \ \Sigma\cos\theta$

where:

fi = distances from the dam centre to the shore

θ = corresponding angles (the centre line is the direction with maximum fetch)

The effective fetch and wave height are calculated as per USBR Design standards No.13.

The following table shows the results of computed free board for the reservoirs.

Table 16: Free board of Upper Reservoir

As per IS : 10635 (Free board requirement in Embankment Dams)		
	Upper Reservoir	Lower Reservoir
FRL/MWL	+745.00m	+300.00m
FB	+3.00m	+3.00m
TBL	+748.00m	+303.00m

9.4.2 Upper Reservoir Surface Treatment

The upper reservoir surface area needs to be treated to prevent erosion of bed material and entering of the material in the water conductor system during its daily depletion (i.e. generation). Accordingly provision has been kept for the surface treatment which could be in the form of surfacing by impervious material/layer, grouting, development of a 3.5 m deep x 10 m wide trench in reservoir bottom and around the intake structure. This aspect shall be studies in detail after geotechnical investigations are carried out during DPR.

9.5 UPPER INTAKE

An upper intake is proposed on the upper reservoir. The function of upper intake structure is to allow the smooth entry of water from the upper reservoir into the water conductor system/penstock. Flow velocity in the Intake is capped at 0.959 m/s whereas it would be of the order of 3.73 m/s in the water conductor system. As per IS Code "Guidelines for design of intakes for hydroelectric projects" generally velocity allowed in penstock are in range of 3 m/s to 6m/s. Though, higher velocities have been allowed.

Intake structures are designed, so as to provide smooth entry with transition from lower velocity to higher velocity, without turbulence and air entrainment into the water conductor system.

9.5.1 Submergence below Minimum Drawdown Level

Required submergence for the intake to avoid air entry due to vortex should be estimated. The minimum draw down level (MDDL) for the operation will be checked accordingly based on submergence required, penstock diameter and dead storage level. Submergence has been estimated based on Gordon's criteria and provision made in IS 9761:1995.

9.5.2 Design Computation of Upper Intake

Hydraulic design of intake comprises intake setting, intake dimensioning, and sizing of trash rack structure. The results are presented in subsequent sections.

Hydraulic Design:

Hydraulic design of Trashrack & Sizing of Intake (Upper Reservoir)

Design of Trashrack (As per IS:11388-2012)

Design Discharge at Trashrack/intake (Turbine Mode)		=	374.58 Cumec
Height of Intake Tunnel, d		=	11 m
Vertical Height of opening at intake		=	13 m
	H	<	1.5d
Trashrack Angle with vertical		=	15 deg
Effective height of trashrack (with angle of inclination)		=	13.459 m
Total Width of Opening at Intake (including pier)		=	40 m
Width of Pier		=	1.5 m
No. of piers		=	2
Clear width of Opening at intake		=	37 m
Provided Width-1 of Opening at Intake (excluding pier)		=	12.25 m
No. of Openings at each Inake (width-1)		=	2 no's
Width-2 of Opening at Intake (Excluding Pier)		=	12.50
No. of Openings at each Inake (width-2)		=	1
Total Width of Opening at Intake/Trashrack (excluding pier)		=	37.00 m
Provided Gross effective area of trashrack		=	497.968 m^2
Assuming Ratio of net area/gross area r		=	0.85
Net area of trashrack (after deduction of bar area)		=	423.273 m^2
Velocity at Trashrack (without clogging)		=	0.885 m/s

The velocity through trash rack has been provided less than or equal to 0.885 m/s. Therefore, 2 sets of trash racks each 12.25 m & 1 set of 12.50 wide panels of 12.520 m inclined height has been provided. The clogging is not considered for the design of trash rack since,the reservoir is a closed on four sides hence, no clogging is expected in the reservoir

Fixation of Invert Level at Intake/ Trashrack

Shape of Intake tunnel – Circular-Shaped

Diameter of Intake tunnel, D	=	11 m
Sectional area of Intake tunnel, A	=	94.985 m^2
Average Velocity in Intake tunnel, v	=	3.944 m/s

Submergence Calculations From Center Line of Intake Tunnel (IS:9761-1995)

Froude number Fr		=	V/SQRT(gD)	
	=	0.380	>	0.333
Submergence Depth from Center Line	=	IF{Fr>=1/3,[0.5+2*(Fr)]*D,(1.0*H		
		=	13.852 m	
		=	13.860 m	
C/L elevation of Intake tunnel		=	714 m	
Minimum submergence required (i.e. Required MDDL)		=	727.86 m	

Provided MDDL at Intake		=	728
	Provided MDDL	>	Required MDDL
Provided bottom level at Intake		=	708.50 m

Submergence Calculations From Intake Invert Level

Froude number Fr		=	V/SQRT(gH)
Velocity at Intake Entrance, V		=	0.72
	= 0.0638	<	0.333
	IF{Fr>=1/3,[0.5+2*(Fr)]*D,(1.5*H)}		
Submergence Depth from Invert Level		=	19.500 m
Invert elevation of Intake at Start		=	708.50 m
Minimum submergence required		=	728 m
Calculated MDDL		=	728 m
Provided MDDL at Intake		=	728
	Provided MDDL	<	Required MDDL

Type & Sizinge of Intake

Type of Intake		=	Diffuser Type
Flare Angle of intake wall with intake tunnel wall		=	13.5 deg
Width of Intake with 13.15 deg.		=	14.5 m
Length of transition from start of Intake tunnel to Intake		=	60.40 m
Angle of Intake Slab from Intake to start of Intake Tunnel		=	1.9 deg
	Provided angle	<	10 deg

Therefore, The intake of Size 37 m wide
13 m high has been proposed

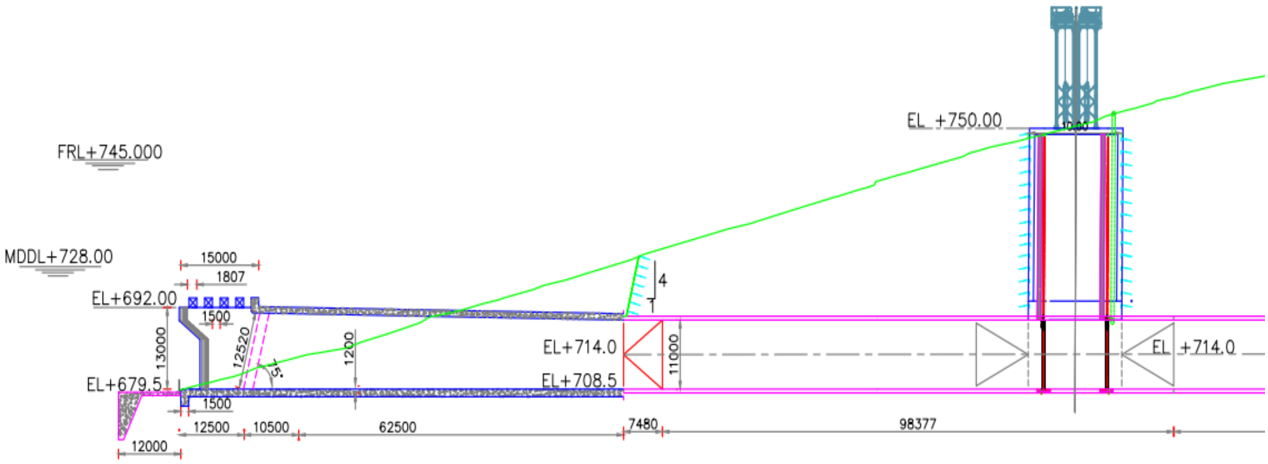


Figure 4: L-Section of Upper Intake

9.6 WATER CONDUCTOR SYSTEM

Alignment and profile of the waterway is also one of major elements to be optimized in the selection of optimum general layout, because it governs other layouts of structures such as switchyard, access tunnel etc.

Following aspects are considered while finalising the alignment of the waterway from the intake to the tailrace outlet;

- Shortest possible Length of waterway.
- Bends are to be avoided as far as possible.
- Both intake and tailrace outlet are to be aligned in such a way that pumping and generation mode have favourable flow characteristics.

9.6.1 Penstock

The Project is proposed with six generating units, in which water will be feed by one power intakes. Main penstock will be bifurcated near the powerhouse to feed water to the independent generating units. As the flow in penstock is quite high (187.29 Cumec,), the size of the penstock shall be of the order of 6m & 8m dia. based on economical diameter calculation. The penstock shall be steel lined penstock and the flow velocity works out to be 4.02 m/s for the design discharge of 187.29 Cumec.

9.6.2 Economical Diameter of Penstock

The length of the main penstock is of the order of 1617.45m whereas that of the three, six branch penstocks are 185.16m & 43m. Computation of economical diameter of penstock is worked out as per empirical formula based on IS Code 11625:1986.

The basic parameters and procedure for computation of economical diameter of penstock as per IS 11625 are summarized below.

Cost (Ep): Annual cost is computed based on the total cost of the structure. The annual cost is the sum of (i) annual interest on the total cost, (ii) annual depreciation and (iii) the annual operation and maintenance cost

Benefit (Et): Benefit from revenue from sale of energy against reduction of friction losses in the penstock (larger size penstock will have less velocity and therefore less head losses). The cost and benefits shall be worked out in terms of (d_e), where d_e is required to be optimised. In order to get the optimised (economical) diameter of penstock, the annualized penstock cost (E_p + E_t) is to be differentiated with respect to penstock diameter and equated to zero as below:
The above computation shall be worked out based on the steel thickness required for design head (hoop stress). But in some cases, where design head is comparatively less and the size of penstock is large, the handling thickness will be higher than the designed thickness. Therefore, the optimisation study is required to be checked out for handling thickness criteria also. Both design criteria is adopted for the optimisation study of the size of the penstock.

Based on IS code 11625:1986, economical diameter of main penstock works out to be 7.7 m and 5.5 m for branch penstock. But to restrict the higher velocity in the penstock tunnel diameter of main penstock is provided as 7.7 m & 5.5m.

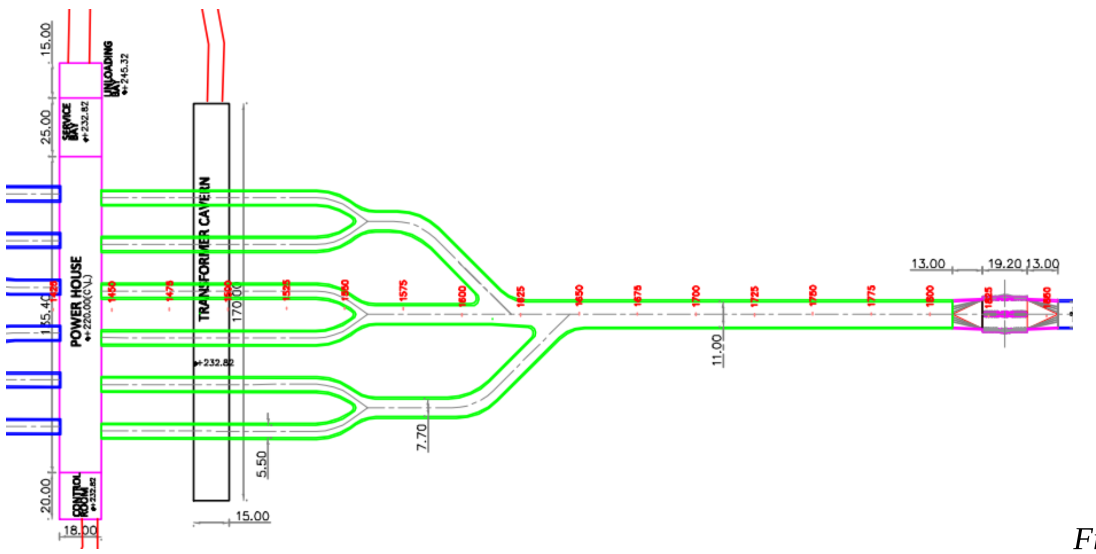


Figure 5: Plan of Penstock

9.6.3 Criteria for Surge Tank (Upstream & Down stream)

The average ground level at this location is about EL + 700.0m. The layout plan are shown in drawing nos. AA/POWER/2373/CIVIL/001. The proposed alignment is analyzed for requirement of surge shaft.

The requirement of surge tank in the water conductor system has been assessed based on the following thumb rule:

- Criteria for requirement surge tank based on L/H Ratio:
- Surge tank is not required when L/H ratio is less than 5
- Surge tank may be required when L/H ratio is in between 5 & 10 to control mass oscillation in Water Conductor System
- Surge tank is required when L/H ratio exceeds 5

Where,

L = Length of pressurized tunnel

H = Net head for power generation

L/H = 1845.61/447 =4.128

Criteria for requirement of surge tank based on Water Acceleration time (TW):

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

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

Where L = Length of water conductor

V = velocity of flow in water conductor

H = Net head

g = Acceleration due to gravity

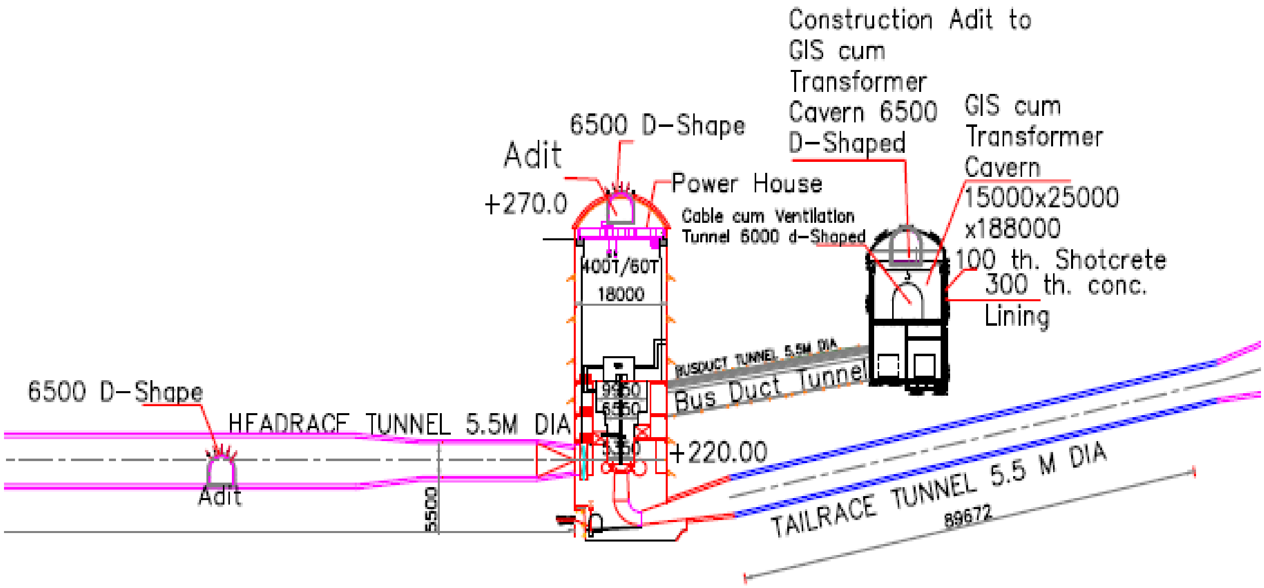
In the present case, L = 1845.61m, H = 447 m and V = 3.733 m/s which gives an acceleration time, Ta of 1.571 seconds and hence there is no requirement for a surge shaft. However, detailed transient analysis shall be carried out during DPR stage.

9.7 UNDERGROUND POWERHOUSE AND UNDERGROUND TRANSFORMER CAVERN

A water conductor system comprising two number steel lined pressure tunnels bifurcated into six unit penstock to feed 6 nos. of vertical shaft reversible Francis turbines. The units shall be housed in an underground powerhouse cavern located inside left bank of existing reservoir. Water from each machine is led through respective draft tubes to tail race tunnel and then lead the water back to existing reservoir. A transformer cavern is envisaged parallel to the powerhouse cavern for housing transformers and GIS.

9.7.1 Powerhouse Cavern

Powerhouse cavern of length 195.5m (including service bay and control blocks) and cross-section 18.0m (W) x 50.0m (H) has been provided to house 2 nos. vertical shafts reversible Francis turbines spaced at 18.5m c/c. The centre line of machines has been kept at El. 220.0m. The Main Inlet valves (MIV) shall also be housed inside the cavern with MIV floor at El. 214.05m. The turbine and generator floors shall be at El. 201.42m and El. 232.82m respectively. The powerhouse operating floor shall be at El. 232.82m and powerhouse crown at El. 277.50m.



F

iaure 6: L-Section of PH, TRT

A dewatering gallery has been provided on the upstream side of the units that runs along the entire length of the powerhouse and leads to drainage sump. The dewatering sump has been provided adjunct to the drainage sumps.

Water from the machines shall be released into tailrace tunnel through draft tubes. The draft tube bottom shall be at El. 209.60m.

Service bay (unloading cum erection bay) of 40m length has been provided at the same level as the operating floor i.e. El. 232.820m on the eastern side of the powerhouse. Two EOT cranes of capacity 400 tonne each, with auxiliary hook of 50/10 tonne have been provided for facilitating erection and maintenance of the equipment with top of crane beams at El. 270.00m.

Control block of 20m length has been provided opposite to the service bay on the western side of the powerhouse to accommodate control room, battery room, electrical & mechanical workshops conference room and office facilities.

9.7.2 Transformer Cavern

Transformer cavern of 170m (L) x 15m (W) x 30.0m (H) has been located 39.5m downstream of powerhouse cavern. Each generating unit at the powerhouse will be directly connected to three single phase generator step-up transformers through isolated phase bus. Total of seven (7) single-phase transformers, including one spare shall be located in the transformer cavern at El. 232.82m. Gas Insulated Switchgear (GIS) shall be housed on the floor above the transformers at El. 247.62m.

9.8 TAIL RACE TUNNEL (TRT)

One no. of 11.0 m diameter and 158.615 m long circular shape concrete lined TRT has been proposed. TRT will be provided with suitable rock support system depending upon the geological strata. Actual support system will be decided after geological investigations and analysis at DPR stage. The economical diameter of TRT works out to be 11.0 m and the calculation for the same is attached below.

9.9 LOWER INTAKE/PUMP INTAKE

A lower intake adjacent to lower reservoir is proposed on the right bank of the Nallah. The function of lower intake structure is to allow the smooth entry of water from the lower reservoir to the upper reservoir. Flow velocity in the reservoir is negligible whereas it would be of the order of 3.944 m/s in the tail race tunnel.

The hydraulic design of lower intake is done in similar lines as of the upper intake (refer Cl.10.5).

9.9.1 Design Computation of Lower Intake

Hydraulic design of intake comprises intake setting, intake dimensioning, and sizing of trash rack structure. The results are presented in subsequent sections.

Data:

Full reservoir level (FRL)	:	EL 300.00 m
Minimum drawdown level (MDDL)	:	EL 270.00 m
Design discharge of water conductor system	:	374.60 Cumec (pump mode)
Diameter of TRT	:	11.0 m
Sill level of Intake	:	EL 249.50 m

Intake Dimension:

The intake structure comprises of one intake located on the right bank of the river adjacent to the proposed lower reservoir. For provision of gates, the intake structure is proposed with one bays, 43 m (W) x 85.05 m (L) separated by a 1.5 m thick Piers. The height of the intake structure is 13.00m. Dimensions of the intake bays have been fixed considering equivalent flow area of TRT. For minimizing losses, profile of the intake roof and sides has been streamlined. The intake shall draw water from the trash racks provided above the intake floor at an angle of 15° with the vertical.

9.9.2 Trash rack

The sizing of trash racks has been worked out with following considerations;

a) Flow at MDDL gives minimum depth of flow.

b) Net area of trash rack bars is assumed as 65% of the gross area.

c) Total of 50% of the net area of the trash rack is assumed to be clogged with trash.

The floor level of the intake approach is set at EL 249.50 m having a flow depth of 20.50 m from MDDL. It is proposed to provide 3 trash rack bays of 12.25 m width each. This gives a flow through velocity on net area of 0.959 m/s for design discharge and 1.438 m/s in clogged condition. As per IS 11388:1995, the flow velocity through trash racks shall be limited to 0.75m/s for Manual cleaning of racks and to 1.5 m/s for mechanical cleaning of racks. Hence, the flow through velocity is within the limit even for manual cleaning of the rack.

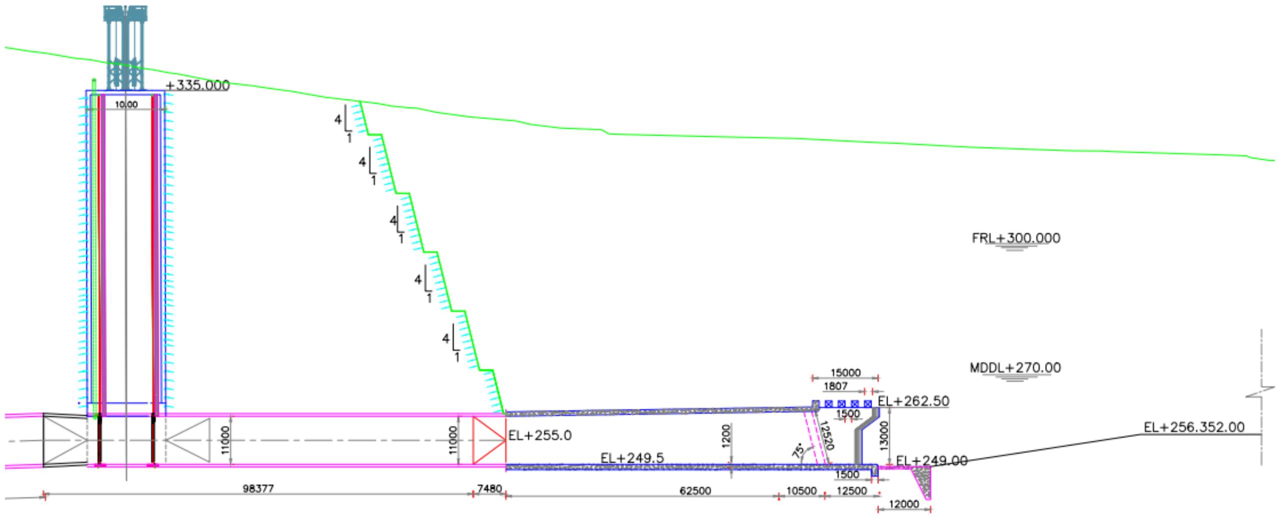


Figure 7: L-Section of Lower Intake/Pump Intake

Hydraulic design of Trashrack & Sizing of Intake (Lower Reservoir)

Design of Trashrack (As per IS:11388-2012)

Design Discharge at Trashrack/intake (Turbine Mode)		=	374.58 Cumec
Height of Intake Tunnel, d		=	11.0 m
Vertical Height of opening at intake		=	13.0 m
	H	<	1.5d
Trashrack Angle with vertical		=	15 deg
Effective height of trashrack (with angle of inclination)		=	13.459 m
Total Width of Opening at Intake (including pier)		=	40 m
Width of Pier		=	1.5 m
No. of piers		=	2
Clear width of Opening at intake		=	37 m
Provided Width-1 of Opening at Intake (excluding pier)		=	12.25 m
No. of Openings at each Inake (width-1)		=	2 no's
Width-2 of Opening at Intake (Excluding Pier)		=	12.5
No. of Openings at each Inake (width-2)		=	1
Total Width of Opening at Intake/Trashrack (excluding pier)		=	37 m
Provided Gross effective area of trashrack		=	497.968 m^2
Assuming Ratio of net area/gross area r		=	0.85

Net area of trashrack (after deduction of bar area)	=	282.182 m^2
Velocity at Trashrack (without clogging)	=	1.327 m/s

The velocity through trash rack has been provided less than or equal to 1 m/s. Therefore, 2 sets of trash racks each 12.25 & 1 set of 12.5 m wide panels of 12.52 m inclined height has been provided. The clogging is not considered for the design of trash rack since,the reservoir is a closed on four sides hence, no clogging is expected in the reservoir

Fixation of Invert Level at Intake/ Trashrack

Shape of Intake tunnel – Circular-Shaped

Diameter of Intake tunnel, D	=	11 m
Sectional area of Intake tunnel, A	=	94.985 m^2
Average Velocity in Intake tunnel, v	=	3.944 m/s

Submergence Calculations From Center Line of Intake Tunnel (IS:9761-1995)

Froude number Fr	=	V/SQRT(gD)
	=	0.380 > 0.333
Submergence Depth from Center Line	=	IF{Fr>=1/3,[0.5+2*(Fr)]*D,(1.0*H
	=	13.852 m
	=	13.860 m
C/L elevation of Intake tunnel	=	255 m
Minimum submergence required (i.e. Required MDDL)	=	268.9 m
Required bottom level of intake/trash rack	=	249.5
Provided MDDL at Intake	=	270
Provided MDDL	>	Required MDDL
Provided bottom level at Intake	=	249.50 m

Submergence Calculations From Intake Invert Level

Froude number Fr	=	V/SQRT(gH)
Velocity at Intake Entrance, V	=	0.72
= 0.0638	<	0.333
		IF{Fr>=1/3,[0.5+2*(Fr)]*D,(1.5*H)}
Submergence Depth from Invert Level	=	19.500 m
Invert elevation of Intake at Start	=	249.50 m
Minimum submergence required	=	269 m
Calculated MDDL	=	269 m
Provided MDDL at Intake	=	270
Provided MDDL	>	Required MDDL

Type & Sizinge of Intake

Type of Intake	=	Diffuser Type
Flare Angle of intake wall with intake tunnel wall	=	13.5 deg
Width of Intake with 13.15 deg.	=	14.5 m
Length of transition from start of Intake tunnel to Intake	=	60.40 m
Angle of Intake Slab from Intake to start of Intake Tunnel	=	1.90 deg
Provided angle	<	10 deg

Therefore, The intake of Size 43 m wide & 13 high has been proposed

HEAD LOSS IN WATER CONDUCTOR SYSTEM:

Head loss in water conductor system is computed as 4.5 m in turbine mode and 4.0 m in pump mode.

9.10 DRAWINGS OF CIVIL STRUCTURES

All the preliminary drawings of Civil Structures are appended as **Appendix-A.**

CHAPTER - 10 DESIGN OF HYDRO-MECHANICAL EQUIPMENT'S

10.1 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.

10.2 INTAKE TRASH RACKS (UPPER RESERVOIR)

The susceptibility of large inlets to clogging by debris and trash needs to be considered when estimating their hydraulic capacities. In most instances, trash racks will be needed. Trash racks and safety gates are critical elements of inlet structure design and serve several important functions. The trash rack design shall be studied during the DPR Stage.

The salient features of the trash racks are given in ***Table 17***

Table 17: Salient Features of Intake Trash Racks (Upper Reservoir)

Parameter	Unit	Particulars
Trash Rack Panel Size	m	12.25 (w) x 12.52 (h) – 2 nos 12.50 (w) x 12.52 (h) – 1 nos
Total Number of panels	no	3
Sill elevation	m	708.50m
MDDL	m	728.00m
FRL	m	745m
Deck elevation	m	721.5m
Cleaning of Trash racks		TRCM (with hydraulic grappler)

10.3 INTAKE SERVICE GATE (UPPER RESERVOIR)

Intake Service gate is intended to regulate water through the intake will be lowered during inspection and maintenance of penstock. Fixed wheel gate having downstream skin plate and sealing is proposed for the intake and shall be operated under balanced head condition by means of crack opening. Intake Gate will be operated by adequate capacity of Rope Drum Hoist. The design shall be studied during the DPR Stage.

The salient features of the gate are given in ***Table 18***

Table 18: Salient Features of Intake Service Gate (Upper Reservoir)

Parameter	Unit	Particulars
Clear opening size	m	5.0 (w) x 11.0 (h)
Type of gate		Fixed wheel Gate
Number of vent	no	2
Number of gate	no	2
Sill elevation	m	708.5 m
MDDL	m	728.0m
FRL	m	745.0m
Deck elevation	m	750.0m
Design head	m	50.00m
Type of hoist		Fixed Rope drum hoist
Operating condition		Lowering under flowing water and lifting under balanced head

10.4 INTAKE SERVICE GATE (LOWER RESERVOIR)

Intake gate is intended to regulate water through the intake will be lowered during inspection and maintenance of Tail Race Tunnel. Fixed wheel gate having downstream skin plate and sealing is proposed for the intake and shall be operated under balanced head condition by crack opening. The gate will be operated by adequate capacity of rope drum hoist.

Table 19: Salient Features of Intake Service Gate

Parameter	Unit	Particulars
Clear opening size	m	5.0 (w) x 11.0 (h)
Type of gate		Fixed wheel Gate
Number of vent	no	1
Number of gate	no	1
Sill elevation	m	249.5 m
MDDL	m	270.0 m
FRL	m	300.0m
Deck elevation	m	335.0m
Design head	m	80.10m
Type of hoist		Fixed Rope drum hoist
Operating condition		Lowering under flowing water and lifting under balanced head

10.5 INTAKE MAINTENANCE GATE (LOWER RESERVOIR)

Maintenance gate is mainly intended to undertake maintenance and repair of the Intake gate and used at upstream side. Fixed wheel vertical gate is proposed for the intake with filling valves at the top of the gate. The gate leaf shall consist of upstream skin plate and sealing. The gate shall be operated after balancing the water pressure upstream and downstream side of bulkhead gate by means of adequate capacity of Rope Drum Hoist.

The salient features of the gate are given in ***Table 20***

Table 20: Salient Features of Intake Maintenance Gate

Parameter	Unit	Particulars
Clear opening size	m	5.0 (w) x 11.0 (h)
Type of gate		Fixed wheel Gate
Number of vent	no	2
Number of gate	no	2
Sill elevation	m	249.5 m
MDDL	m	270.0 m
FRL	m	300.0m
Deck elevation	m	335.0m
Design head	m	80.10m
Type of hoist		Fixed Rope drum hoist
Operating condition		Balanced water head

10.6 INTAKE TRASH RACKS (LOWER RESERVOIR)

The susceptibility of large inlets to clogging by debris and trash needs to be considered when estimating their hydraulic capacities. In most instances, trash racks will be needed. Trash racks and safety gates are critical elements of inlet structure design and serve several important functions.

The salient features of the trash racks are given in ***Table 21***

Table 21: Salient Features of Intake Trash Racks

Parameter	Unit	Particulars
Trash Rack Panel Size	m	1no of 12.50 (w) x 12.52 (h) 2no of 12.25 (w) x 12.52 (h)
Number of bays	no	3
Total Number of panels	no	3
Sill elevation	m	249.5 m
MDDL	m	270.0 m
FRL	m	300.0m
Deck elevation	m	262.5m

10.7 PENSTOCK

A 7700 mm & 5500mm diameter steel lined pressure shaft takes-off from Intake to carry 374.60 m^3/sec discharges to the machine.

Economic diameter studies were carried out for assigning a suitable diameter for the single penstock. The result shows that a 7700mm & 5500mm diameter conduit, steel lined, back filled with concrete is required.

Depending upon the head to be resisted, thickness of the plates varies from 32mm to 50mm. Maximum thickness has been restricted to 50 mm to exclude requirement of stress relieving and for ease in handling. Carbon steel conforming to ASTM A517 Grade F steel plates has been provided.

Length of each ferrule has been restricted to 2.5mtr for ease in handling. All field welded circumferential joint shall be radiographed at the contractor's workshop whereas 10% of the field joints shall be radiographed. The entire field joint shall also be subjected to ultrasonic examination. The elevation of center line the penstock at intake is at EL 714.00 m and in machine hall EL 201.42 m. The length of transit is 7.70m. Penstock diameter will be 7.70m and its length is 185.16 m and it divides into six branches for each unit of diameter 5.5 m and length is 43 m each.

The penstock shall be designed FRL + dynamic head. In machine hall at penstock center line the static head is 525.00 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 out surface of penstock as the critical pressure is less than the external pressure.

Main Technical Parameters

i	No. of generating Units	6
ii	No. of Penstock	2
iii	No. of Bifurcation	6
iv	Discharge in each penstock	374.60 m^3/sec
v	Size of Inlet of transition	Square of 7700mm x 7700mm
vi	Size of outlet of transition	Circular of diameter of 7700mm
vii	Inner diameter of Penstock	7700 mm
Vii	Diameter of branch pipe each	5500 mm
ix	Length of penstock	1617.45 m Main Penstocks & 185.16m each of six branches after bifurcation + 7.7 m (transition)
xi	Thickness of penstock plate	32 mm to 50 mm
xii	FRL	745.00m
xiii	Centre line Penstock at Intake	714.00 m
xiv	Centre line Penstock at machine Hall	220.00 m

xv	Design head	447.00 + 35% pressure rise at turbine CL
xvi	Reference codes	IS 11639 Part 2
xvii	Penstock Plate Material	Carbon steel conforming to ASTM A517 Grade F or equivalent

CHAPTER - 11 DESIGN OF ELECTRO-MECHANICAL EQUIPMENT'S

11.1 GENERAL

The Bhavali Pumped Storage Scheme envisages installation of reversible Pump Turbines and Generator–Motors along with associated auxiliaries having capacity matching with the outcome of the power potential studies detailed in Chapter No CHAPTER - 8. It is proposed to house these machine units along with auxiliaries in an underground complex comprising of Service Bay, Machine Hall, Transformer cavern, Gas Insulated Switchgear Hall, Control Block etc.

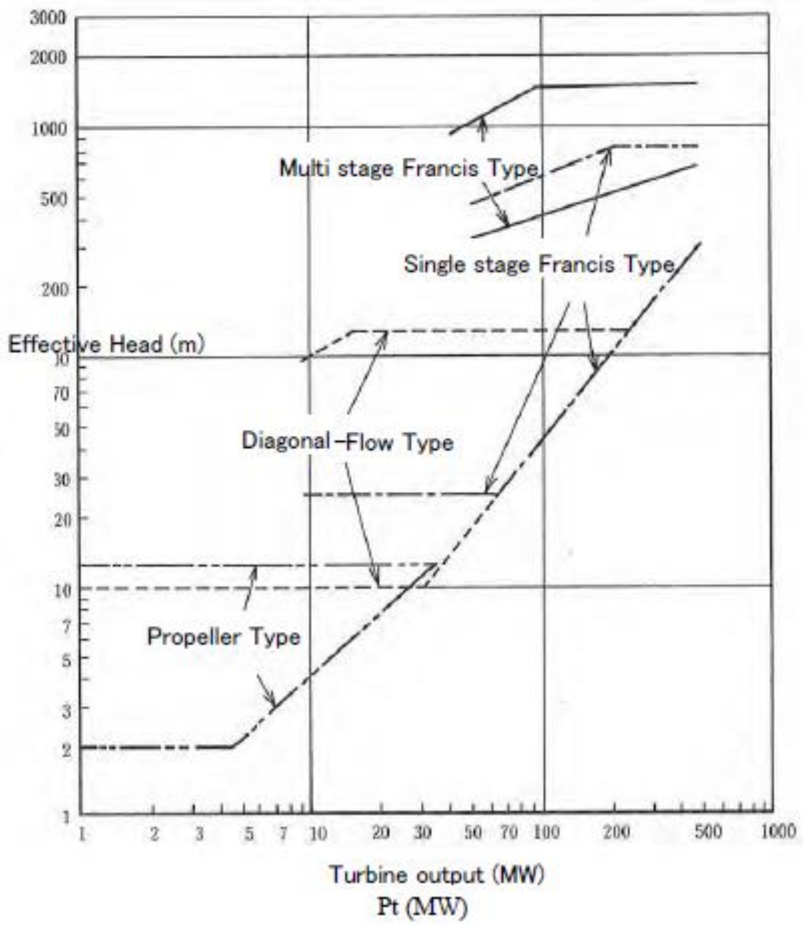
The general arrangement of the powerhouse showing the powerhouse structure, Pothead yard and approach road etc. are shown in the powerhouse complex layout. The configuration of the plant is proposed with installation of Six (6) units of Reversible Pump Turbine and Generator Motors in an Underground Powerhouse.

11.2 SIZING AND TECHNICAL SPECIFICATION OF MAIN PLANT EQUIPMENT

11.2.1 Pump-Turbine

Operating Levels & Hydraulic Parameters:

Full Reservoir Level of Upper Reservoir, FRL(U)	745.00	m
Minimum Draw Down Level of Upper Reservoir, MDDL(U)	728.00	m
Full Reservoir Level of Lower Reservoir, FRL(L)	300.00	m
Minimum Draw Down Level of Lower Reservoir, MDDL(L)	270.00	m
Maximum Gross Head, Hg max = FRL(U)-MDDL(L)	475.00	m
Minimum Gross Head, Hg min = MDDL(U)-FRL(L)	428.00	m



Based on the gross head range of 337 m to 402 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.

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

Average Head Losses (Turbine mode)	*HL*	*4.50*	*m*
Average Head Losses (Pump mode)	*HL*	*4.00*	*m*

Average Upper Reservoir Elevation	*FRLmean(u) =MDDL(U)+ FRL(U) /2*	736.50	*m*
Average Lower Reservoir Elevation	*FRLmean(L) =MDDL(L)+ FRL(L) /2*	285.00	*m*
Average Gross Head	*GH = (FRLmean(u)+FRL mean (L)) / 2*	451.50	*m*
Max Net Pump head	*Hn pump = Hg max+ Pump Losses(HL)*	479.00	*m*
Minimum Net Turbine Head	*Hn pum = (MDDL(u) - FRL(L)-HL*	423.50	*m*
Net Average Design Head(Turbine)	*Hn(Tur)=Hg-HL*	470.50	*m*
Rated Pumping Head	*GH+ HL (pump)*	455.50	*m*

11.2.2 Pump Turbine Sizing & Dimension

The following input has been used for the Pump Turbine sizing:

Installed Capacity per Unit (Turbine Mode) -Larger Unit	250	MW
Installed Capacity per Unit (Pump Mode) -Larger Unit	264	MW
Assumed Weighted Average Efficiency of Turbine, η_t	92.95	%
Assumed Weighted Average Efficiency of Generator, η_g	98.24	%
Assumed Weighted Average Efficiency of Pump, η_p	92.00	%
Assumed Weighted Average Efficiency of Motor, η_m	98.50	%
Rated Turbine Unit Discharge -Larger Unit	62.43	Cumec
Rated Pump Unit Discharge - Larger Unit	54.20	Cumec
No of Units	6	
Acceleration due to gravity, g	9.81	m/s^2
Installed Capacity per Unit (Turbine Mode) -Larger Unit	250	MW
Installed Capacity per Unit (Pump Mode) -Larger Unit	264	MW

Assumed Weighted Average Efficiency of Turbine, η_t	92.95	%
Assumed Weighted Average Efficiency of Generator, η_g	98.24	%

11.2.3 Pump Turbine Rated Speed

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 as well as empirical relations of head and specific speed as provided in standards/ guidelines such as IS: 12800-Part II. For economic considerations, the trend is towards selection of turbines with higher specific speeds.

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

As per IS :12800 , corresponding to Pump rated head of 455.50 m, the trial specific speed is 28.00 metric. The trial synchronous speed (Ns') thus works out to be = $n_{st'}$ x H_n^0.75/Qp^0.5= 346 **rpm**

The nearest value of synchronous speeds can be 375 rpm for a conventional design of the Synchronous Motor Generator with nearest even number of pair of poles.

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

- Higher and flatter generating efficiency curve: The unit is operated at 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 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. Variable-speed operation allows a wider operating head range without cavitation and/or a higher unit setting as compared to 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 lower speed, reducing the power that is required to bring the pump on line. This advantage is normally only applicable for 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 to handle additions to the powerhouse that will be required for the electronic equipment and additional transformers.

Comparison of Primary Characteristics

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 Minutes
100 Percent Generation to 100 Percent Pumping	Generally Less than 6 to 10 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

Taking into account all the aspects as stated above, the speed of the Pump Turbine is adopted as 375 rpm for Pump Turbine under constant speed option. However this aspect will be further validated in consultation with the manufacturer during DPR stage.

11.2.4 Cavitation and Turbine Testing

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 and thus results in pitting.

To avoid cavitation, the absolute pressure within the pump turbine must be such that vapour pressures will not be encountered or created. This is done by keeping the unit elevation sufficiently low relative to Minimum Draw Down Level of the Lower Reservoir to ensure proper absolute pressures. This differnce between the Minium Draw Down Level of the Lower Reservoir elevation and the runner blade centerline elevation is the 'setting' of the unit.

As per the IS: 12800 –Part 2, the Cavitation Coefficient corresponding to specific speed of 28 as per the below graph is approximately 0.12.

11.2.5 Estimation of Major Dimensions of the Pump Turbine

The major dimensions of the Pump Turbines have been estimated as per the IS: 12800 (Part-II)

Dimensions of 250MW Unit

A-1 DATA

Unit Capacity	=	250.00	MW
Max Head(Turbine)	=	470.50	m
Rated Head	=	447.00	m
Minimum Head	=	423.50	m
Maximum Pumping Head	=	479.00	m
Rated Pumping Head	=	455.50	m
Minimum Pumping Head	=	432.00	m
Turbine Generator	=	277.78	MVA

A-2 OVERALL DIMENSIONS

From IS 12800 (part 2) : 1989 Fig No. 1 and 2 specific speed may be taken as

n_{st} = 98.00

n_{sp} = 28.00

Speed of the Machine in Turbine mode = n = $n_{st} \times H_t^{5/4} / \sqrt{(P_t \times 1.358)}$

n = 345.693 RPM

Nearest Synchronous Speed = **375.000 RPM**

Rated Pump Discharge √Qp = nsp x Hp3/4

n

√Qp = 7.36 m3/sec

Qp = 54.20 m3/sec

Discharge for pump **54.20 m3/sec**

Pump Input:

For Preliminary Dimensions Pump Efficiency may be taken as 92%

Pp =9.81 QpHp/(Ep x 1000)

Pp =	263.24	MW	Say	264.000	MW

Pumping Turbine Setting:

H s	<=	H b -	σ Hp -	H v		
H b	=	Barometric Pressure				
	=	10.3	-	EL of Power station in meters of water column		
		10.3		900		
	=	10.3	-	250		
		10.3		900		
	=	10.022 m				
H v	=	Vapour Pressure				
	=	0.4 m from mean sea water level at 30 o c				
σ	=	From fig 4 of IS 12800 (Part-2) : 1989 for a specific speed of				
		28.00 rpm				
	=	0.12				
H s	<=	10.02 -	54.66 -	0.400	=	-45.04

With a further margin of	4 m	The center line of distributor should be set at below Minimum Water Drawl Level of Lower Reservoir	**-50 m**

Size of Runner:

D1 = 60 Ku √(2gHp)

∏ n

From IS 12800(part 2):1989 Fig No.6 peripheral velocity coefficient Ku = 0.98

D1 = 4.721 m **Say** **4.72**

Dimensions of Spiral Case:

From IS 12800 (part 2) : 1989 Fig No. 7 Recommended Velocity at design head = 16.8 m/s

Inlet Diameter = √(Qp X 4) / √(11.5 X ∏)

= 2027 MM

Say **2030** MM

From IS 12800 (part 2) : 1989 Fig No. 8

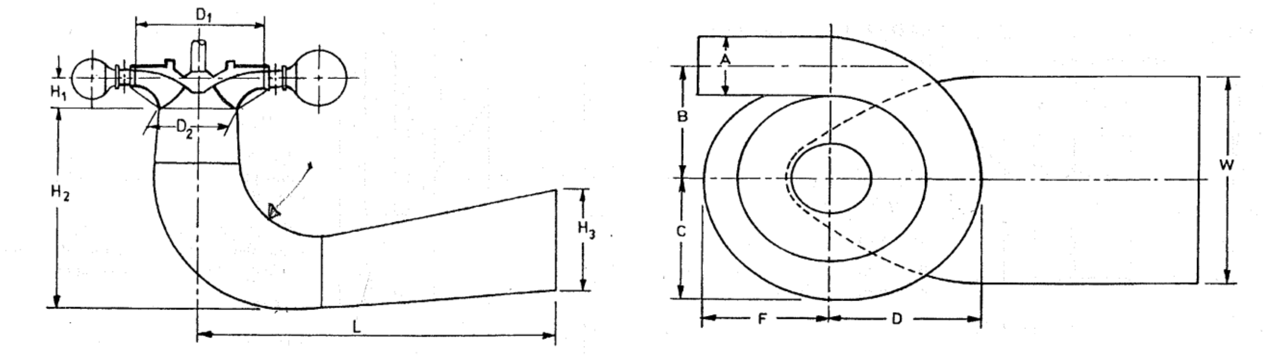
A	=	1	X	2.03	=	2.03	m
B	=	0.95	X	4.72	=	4.48	m
C	=	1.05	X	4.72	=	4.96	m
D	=	1.1	X	4.72	=	5.19	m
E	=	0.95	X	4.72	=	4.48	m

Dimensions of Draft Tube:

From IS 12800 (part 2) : 1989 Fig No. 9

H1	=	0.21	X	4.72	=	0.99	m
H3	=	0.83	X	4.72	=	3.92	m
H1 + H2	=	1.9	X	4.72	=	8.97	m
L	=	3	X	4.72	=	14.16	m

W = 1.32 X 4.72 = 6.23 m



Weight of Runner:

From IS 12800 (part 2) : 1989 Fig No. 10

Weight of the Runner = **8** **Tonnes**

Axial Hydraulic Thrust:

P H = k D2 H Max

From IS 12800 (part 2) : 1989 Fig No. 11

k = 0.6

P H = **6291 tonnes**

Generator Parameters:

A) Air Gap Diameter (Dg)

Total pair of poles (P) = 8

Synchronous Speed of the Generator ns= $\frac{60 \text{ X } f}{P}$ rpm

Were, frequency (f)= 50 Hz in India

ns = $\underline{60 \text{ X } 50}$ rpm

8

ns = 375.00 rpm

$$Dg = \frac{60 \times Vr}{\pi \times n}$$

From IS 12800 (part 2) : 1989 Fig No. 12

V r = 82

$$Dg = \frac{60 \times 82}{\pi \times 375.00}$$

Dg = 4.18 m

B) Outer Core diameter (Do)

Do = Dg (1+(π/2p))

Do = 5.00 m

C) Stator Frame Diameter (Df)

Df = Do + 1.2 meters

Df = 6.20 m

D) Inner Diameter of Generator barrel (Db)

Db = Df + 2.0 to 2.4m

= 8.4 m

E) Outer Diameter of Generator barrel (D)

D□ = Db + 1.5m

= 9.90

F) Core Length of Stator (Lc)

$$Lc = \frac{W}{ko\ Dg2\ n}$$

Where,

W = 277778 KVA (PF 0.9 of Unit Capacity)

From IS 12800 (part 2) : 1989 Fig No. 13

Ko	=	6.2	
Dg	=	4.18	m
n	=	375.00	rpm

$$Lc = \frac{277778}{6.2 \text{ X } 4.18 \quad 4.18 \quad 375.00}$$

= 6.850 m

Say 6.9 m

G) Length of Stator Frame (Lf)

Lf = Lo + 1.5

= 8.35 m

H) Weight of the Generator Rotor:

From IS 12800 (part 2) : 1989 Fig No. 14 Weight/Meter core length = **100** T/meter

Weight of the Rotor = Weight/Meter X Core Length

= **685.02 Tonnes**

I)Load on each arm

hj	=	Total weight of the rotor parts+ axial thrust				
hj	=	685.024	+	8	+	6291.17
hj	**=**	**6984**	**Tonnes**			

Let there be	8	arms in the bearing bracket,
Load on each arm=	873.024	Tonnes

J) Capacity of EOT crane

Crane Capacity = Weight of Rotor

Crane Capacity = 685.02

Available = **400 Tonnes**

Hence, Two cranes (2) of 400 tonne capacity with 60 tonne auxillary hook is proposed in the powerhouse as it is available next standard size.

K) Overall dimensions of power station

I) Length of the Power Station

The extremities of scroll case/draft tube/generator

in longitudinal direction are at 10.46m on opposite side of the transverse

center line of the machine.

Adding 2 to 4m to these dimensions, the size of the unit bay in longitudinal direction or unit spacing work out to be 14.46m ***Say*** **15.0**

Ls = Length of erection bay = 0.7 to 1.5 times the unit bay size

Ls = 1.15 X 15.00 = 18.00 m

II) Width of the Power Station

As per fig. 21 & 22 and clause 6.3 of IS 12800 part 1:1993

The distance of the outer face of down stream columns from longitudinal center

line of machine = 5.23 + 1.0 + 1.5

= 7.73 m

The distance of the inner face of upstream columns from longitudinal center

line of machine = 5.23 (extremity of draft tube/scroll case/generator barrel)+

2.5 (for accommodating control valve, the same space can also be used for approaching draft tube)

= 7.73 m

Total Width of Power station = 15.46 m

Say = 16.00 m

L) Total height of Machine

From IS 12800 (part 2) : 1989 Fig No. 15

H1+H2 = 8.969 m

H4 = Lf + hj + K (K varies from 5.5 to 7.0m)

H4 = 17.087 m

Unloading the heaviest equipment from the trailors. For this purpose a height of 7.0 to 8.5m between the erection bay floor and highest hook level may be sufficient.

Considering = 8 m

Thickness of the concrete below the lowest point of the draft tube may be taken from 1 to 2.5m depending upon the type of foundation strata

Considering = 3 m

A minimum clearance above the service gangway of the crane for the movement of working personnel may be 2 to 2.5m and the clearance between the highest part of the gantry crane and ceiling of power house should be 6m considering under ground power house top cavern. With this consideration the height of the power house ceiling above the top level hook may generally vary from 9 to 11.5m depending upon the width of the machine hall and capacity of the gantry crane.

Considering = 11 m

Considering the above parameters the height of the machine hall from the bottom of the concrete level below draft tube

Total height = 49 m

OVERALL DIMENTIONS OF THE POWER HOUSE

WIDTH OF POWER HOUSE	=	**16.0**	m
HEIGHT OF POWER HOUSE	=	**49.0**	m

11.2.6 Specific Design & Quality Requirement

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 undesirable 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.

11.2.7 Governors

The governor stability for the unit shall be established during DPR stage by computing the speed rise and pressure rise under full load rejection as well as acceptance cases taking into account the grid conditions.

11.2.8 Expected Performance Data

The technical particulars of Governor are represented below:

Table 22: Technical Particulars of Governor

Sl.No.	Particulars	Value
1.	Wicket gate Servomotor Operating Time	
a)	Opening time adjustable	15 - 30 s
b)	Closing time adjustable (closing in two speed sequence will be required to reduce transient over speed and pressure rise)	8 to 12 s
2.	Range of adjustments	
a)	Speed adjustment at no load	± 10%
b)	Gate limitation	0 – 100%
c)	Permanent speed droop	0 – 10%
d)	Temporary speed droop	0 – 100%
3.	Static Performances	
a)	Dead band of governor (speed sensitivity) (The governor dead band is defined as the smallest relative frequency which can still be perceived to have an appreciable effect on actuator governing the governor main control valve.)	Less than 1/ 1000 of a relative frequency variation.
b)	Dead time (dead time for action on the Guide vanes, following frequency Variation)	Less than 0.2 s
c)	Speed stability at no load	± 1/ 1000
4.	Dynamic performance	
a)	Over speed at full load rejection under most unfavourable load and head conditions	Less than 45%
b)	Max pressure rise at full load rejection under most unfavourable load and head conditions	Less than 35%

Each pump turbine will be provided with a digital, microprocessor type PID governor. The governing system will be connected to and be fully compatible with the power station control and monitoring equipment. It will be possible to control turbines from main control room in auto mode and from unit control board (UCB) in manual as well as auto mode.

The following functions will be included in the governor:

- Speed control at no load operation
- Automatic start and stop sequences including automatic synchronisation
- Power output control
- Frequency regulation
- Load sharing between units in "joint control" mode
- Emergency shutdown on electrical as well as mechanical failures

11.2.9 Main Inlet Valve

Each turbine will be provided with a Spherical type inlet valve installed in the power house upstream of the respective turbine with a nominal diameter matching with the Inlet Diameter of the Spiral casing. The discharge opening of the valve would match the inlet diameter of the scroll case. The valve would be provided with maintenance seal on the upstream and service seal on the downstream. The opening and closing of the valve would normally be done under balanced water condition. The opening of the valve would be done through pressurized oil system. The closing of the valve, however, would be carried out with the help of counter weight. The valve body and valve rotor would be made of cast steel. The material for valve seals will be stainless steel (13% Cr & 4% Ni).

The inlet valve will comprise of valve body and rotor, double acting servomotor(s) for opening and closing operation of the valve, control gear for operation, penstock inlet pipe, outlet pipe with compensator and dismantling joint, and other essential accessories and auxiliaries viz. by-pass valves, sealing valve, air valve, piping with valves, for water, air and oil, master switch, slide valves with electromagnets etc.

A dismantling joint will be provided with MIV on the downstream end to facilitate installation and dismantling of the valve and to permit replacement of the upstream and downstream seals and gaskets.

The Bypass valve would facilitate opening of the MIV under same water pressure at the upstream and downstream ends.

The valve opening and closing time will be adjustable to a closing time range of 50-60 sec. and opening time range of 50-120 sec.

The valve will be designed for automatic control with electric start and stop impulses from the control room. In addition to automatic control, independent manual control system will also be supplied for local operation.

Lugs and Lifting Eyes will be provided for convenience in handling the assembled valve.

11.2.10 Motor- Generators

Two (2) numbers of 327MVA Vertical synchronous motor generators are proposed to be installed in the power house. The Motor-Generators are to be directly coupled to the hydraulic pump turbines to match their speed. The output capacity of the Synchronous 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.

a) Design

The Motor Generator shall be designed to withstand transient situations that can be foreseen during its lifetime without any harmful deformation, displacement or mechanical damage to any of its parts or to the generator foundations, such as but not limited to:

1 Transferred Electric Voltage Surges
2 Short circuit between two or three phases at terminals and external earth faults
3 Multiple disconnections-connections of the connected transmission lines
4 Faulty synchronization
5 Magnetic unbalance due to pole winding failure
6 Runaway conditions.

b) Insulation

Modern motor- generators have an epoxy type insulation system which permits its operation at a class F temperature rise (120°C) as this is defined in IEC 60034-1. Most of the manufacturers have their own patent name for the insulation system, all of which however are very similar.

The long term performance of the insulation system is affected by the maximum operating temperature of the windings. Ageing of the insulation is manifested by partial discharges which increase exponentially and eventually can cause electrical breakdown of the insulation. A convenient method of checking the performance of the insulation is a measurement of partial discharges within regular periods.

In view of increased rate of degradation during operation at high temperature, it is recommended that temperature rise corresponding to class B insulation is adopted for the maximum continuous output under normal conditions. Class B temperature rises are 25°C less than for class F (i.e. 90K).

c) Accessories

Accessories to be provided with the generator shall include braking and jacking system, oil mist collector, brake dust collector device, carbon brush dust collector devices, HS Lubricating System etc. The Motor- generators shall be provided with space heaters to avoid condensation during humid conditions when the generator is not operational.

Cooling water shall be provided for cooling the circulating air inside generator, air coolers shall be provided at the stator frame in the barrel of the generators. Oil coolers for thrust and guide bearings shall be provided and connected with the unit cooling water system.

Further all kind of sensors for monitoring, protection and indications for safe operation of the unit shall be provided.

d) Terminal Voltage

The rated voltage of 15-18 kV is appropriate for motor- generators of the proposed size as per the Figure below but the adopted voltage level is 18kV which can be further discussed with the manufacturer during detailed engineering stage.

e) Temperature Rise Limit of Windings

Generator stator and rotor winding temperature rise, while delivering maximum output continuously at any voltage and frequency in the specified operating range shall not exceed the following temperature rises over the temperature of the cooling air not exceeding 40 degree C.

Stator	90°C
Rotor	100°C

f) Other Design Parameters

- The motor- generator shall be capable of withstanding a three phase short circuit test at the generator terminals when operating at rated MVA and power factor with 10% over voltage for a period not less than 3 sec.
- The motor-generator shall be capable of withstanding occasional excess current equal to 1.5 times the rated current for not less than 30 seconds each time.
- The motor-generator shall be designed and constructed to be capable of safely withstanding maximum runaway speed for a period of fifteen (15) minutes (with cooling water flow intact) without incurring damage from stresses under such conditions
- 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.

11.2.11 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:

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) Tyristor starter 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.

11.2.12 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 bumplessly 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 Stabilisers and comprise of Voltage Regulator Panel, Field Breaker Cubicle with Field Suppression, Thyristor Rectifiers and Excitation Transformers.

11.2.13 Online Monitoring Systems

In order to assess the service life of the generators, it is important to monitor the significant parameters of the generator which affect the life of motor-generators. For this purpose it is recommended that the generators should be provided with

- Vibration monitoring,
- Shaft current monitoring,
- Stator winding partial discharge monitoring, and
- Rotor air gap monitoring

11.3 AUXILIARY ELECTRICAL SERVICES

11.3.1 Main Step up Transformers

18 (Eighteen) numbers (with 2 No's of spare units) of 120 MVA, 18/400kV, Single phase generator transformers will be provided for stepping up of generation voltage to Transmission voltage level for synchronization with the grid. Each transformer will be suitable for parallel operation. The transformers will be provided with oil forced water forced (OFWF) type cooling arrangement.

The transformers will be provided with necessary protective and monitoring devices including Buchholz relay, oil temperature and winding temperature indicators, pressure relief device etc.
Lightening impulse voltage for windings shall be as below:

- HV winding – 1425kVp
- LV winding – 95kVp

1 minute power frequency withstand voltages;

- HV winding – 630kVrms
- LV winding – 38kVrms

Transformers will be provided with off circuit tap changer at the HV side, with range of +2.5% to -7.5% in steps of 2.5%.

The transformers will be installed on rails which will provide movement of the transformers from their respective positions to the service bay. Necessary jacking and pulling arrangements will be provided for the transformers. Fire protection wall will be provided between the transformers as per TAC guidelines.

11.3.2 Generator – Transformer Connections

Isolated phase bus ducts conforming to IS 8084 will be provided for connection between the generator and generator step up transformers. Tentative current rating of the main run bus ducts would be 18000 A.

The bus ducts will be complete with continuous type Aluminium enclosure, conductor supported on support insulators with self-aligning arrangement, wall frame assembly, seal off bushing, flexible connections at the termination points, the tap off bus ducts for connection with LAVT cubicle, Excitation Transformer, Unit Auxiliary Transformer etc.

On the neutral side, the bus ducts, after forming star will be connected with the neutral grounding cubicle which will house the grounding transformer and the grounding resistor.

11.3.3 420kv Gas Insulated Switchgear & Pothead Yard

Being Underground Power House, it is proposed to provide a 420kV gas insulated switchgear with five (5) bays comprising of 2 (Two) generator incomers, 2 (Two) feeder bays and 1 (One) bus coupler bay.

The bus bar scheme adopted is double bus scheme with a bus coupler. The GIS equipment will be located on the floor above the step up transformers in the transformer deck. The connection between the transformers and the GIS bays would be done through 420kV SF6 gas insulated bus ducts (GIBD). Important parameters of the 420kV GIS are as below:

Technical Parameters of GIS

Technical particulars	Data/ value

Rated Voltage	420 kV (rms)
Rated frequency	50 Hz
Grounding	Effectively earthed
Rated power frequency withstand Voltage (1min) phase to earth	650 kV (rms)
Impulse withstand voltage (1.2/ 50/ µs) Line to earth	1425 kVp
Switching impulse voltage (phase to earth)	1050
Rated short time withstand current (1 sec)	40 kA (rms)
Rated peak withstand current	100 kA (peak)
Guaranteed maximum gas losses for complete installation as well as for all individual sections in %	As per IEC 62271-203
Rated normal current, rms	Not less than 2000 A

The metal-enclosed gas insulated switchgear, including the operating devices, accessories and auxiliary equipment forming integral part thereof, will be designed, manufactured, assembled and tested in accordance with the IEC 62271-203 publications including their parts and supplements as amended or revised to date.

11.3.4 Control and Monitoring System

A SCADA system (Supervisory Control and Data Acquisition) comprising of Distributed digital control, monitoring and information system for the entire power plant will be provided.

The control system will be configured in mainly three control levels:

- The **first level** will be station control level which would comprise a number of functional systems for supervisory control and human machine communication.
- The **second level** will be local control level, which would comprise a number of functional groups such as units, AIS, station service etc.
- The **third level** will be the equipment control level, which can directly and manually control equipment such as governor, DVR etc. and mainly used for testing and adjustment.

11.3.5 Protection System

The electrical protection system for the generators, generator transformers, 420kV GIS, 420kV feeders, auxiliary transformers etc. will be provided with numeric type integrated protection relays, with 100% redundancy.

1. **Generators**

The following protections will be provided for the generators:

- Differential (87G)
- 95% stator earth fault (64G1)
- 100% stator earth fault (64G2)
- Backup impedance (21G)
- Negative phase sequence (46G)
- Loss of excitation (40G)
- Reverse power (37/ 32G)
- Pole slipping (98G)
- Stator overload (49S)
- Over voltage (59G)
- Under frequency (81G)
- Dead machine (27/ 50G)
- Rotor earth fault (64R)

2. **Generator transformers**

The following protections will be provided for the generator step up transformers:

- Generator transformer differential (87T)
- Restricted earth fault protection (64T)
- IDMT over current protection (51)
- Neutral grounding back up earth fault protection (51NGT)
- Over fluxing protection (99T)
- Monitoring of insulation of low voltage bushing (59T)
- Buchholtz relay (63)
- Winding temperature protection (49T)
- Oil temperature protection (49)
- Pressure relief valve (PRV)

3. **Feeders**

The outgoing feeders will be provided with the following protections:

- Distance protection (21)
- Directional instantaneous definite minimum time (IDMT) type earth fault relay
- Two stage over voltage protection

4. **Station Auxiliary Transformer**

The station auxiliary transformer will be provided with following protections:

- Differential protection (87R)
- Restricted Earth Fault protection (64R)
- Buchholtz relay (63)
- Winding temperature protection (49T)
- Oil temperature protection (49)
- Pressure relief valve (PRV)

5. **Station Service Transformers and Unit Auxiliary Transformers**

The transformers will be provided with the following protections:

- Restricted earth fault protection (64)
- Instantaneous and IDMT over current protection on high voltage winding (50/ 51T)
- Neutral grounding back up earth fault protection (51 NGT)
- Winding temperature protection (49T)

11.3.6 Earthing System

The earth mat system will comprise of closed circuit conductor grid of steel flats laid over the excavated surface of powerhouse, transformer, switchyard and will extend to the tail race area.

The earthing conductor will be of adequate cross section to safely withstand the system fault current for time duration of fault clearance by the remote/ backup protective system. Sufficient allowances will be provided for corrosion of the embedded conductor on account of chemical properties of soil and also due to galvanic action with other embedded systems.

The earthing system will be designed with the following objectives;

- To provide low impedance path to fault currents to ensure prompt and consistent operation of protective devices during ground faults.
- To keep the maximum voltage gradient along the surface inside and around the project complex within safe limits during ground faults.

11.3.7 Power, Control and Instrumentation Cables

11kV XLPE cables will be used for connection between stations auxiliary transformers and the 11kV switchgear, and 11kV switchgear to the station service transformers.

1.1kV grade PVC insulated Al power cables will be used inside the powerhouse for supplying power to various auxiliaries, while for control cables 1.1kV grade PVC insulated Cu cables conforming to IS 1554 will be used. The cables will be Fire Resistant Low smoke type.

The instrumentation cables including fibre optic cables used will be immune to electromagnetic interference. The number of pairs/ cores required will be as per the requirement of the system.

All the accessories like cable glands, ferrules, cable trays, conduits of adequate sizes as required for the installation of cables will be provided.

11.3.8 Illumination System

The indoor illumination scheme will have mainly twin tube light fitting and high pressure metal halide/ mercury vapor lamps. Emergency DC lamps will also be provided in the machine hall, control room, stairways etc. Outdoor illumination will be accomplished through sodium vapor lamps and fluorescent tubes. The lux levels of the illumination system shall be designed in compliance with IS 6665.

11.3.9 Electrical Workshop

Electrical workshop will be maintained in the powerhouse for testing of various electrical equipment and installations. It will be equipped with testing and measuring instruments like meggers, HV test kit, primary injection relay testing kit, BDV measuring equipment, oil testing kit, portable oscilloscopes etc.

For generator testing, equipment for HV testing, Tan δ measurement, partial discharge measurement, tachometer etc. will also be kept.

11.3.10 Communication System

This project will set up an optical fiber composite overhead ground wire as the main communication channel for transmitting, scheduling, and exchanging users telephone, protection, telecontrol and image information, and set aside trapezoidal modulation channel. SDH optical transmission equipment and PCM multiplex equipment are set at both ends.

Communication system for powerhouse, transformer area, Switchyard and Dam site will consist of internal telephone system and paging system. Paging system will consist of public address system and visual display unit.

The telephone system will consist of an Electronic private automatic branch exchange EPABX along with associated telephone sets.

Possibility of providing Voice over IP (VoIP) phones may be explored during tendering stage.

11.4 AUXILIARY MECHANICAL SERVICES

11.4.1 EOT Crane

2(Two) Electric Overhead Travelling Cranes of 450/60/10 tons capable of operating in tandem with total capacity matching with the heaviest component to be handled is proposed to be installed in the powerhouse for erection and maintenance purpose. The crane will be cabin/ pendant/ radio controlled. The crane will be provided with all accessories including runway rails, down shop leads (DSL), bumpers etc. and will conform to IS 3177. The inching operation will be provided for all motions of the crane. The crane capacity would be reviewed at the detailed engineering stage in consultation with the motor - generator supplier.

One no. of 10 tons EOT Crane is proposed to be installed in the GIS hall for handling the GIS equipment.

11.4.2 Cooling Water System

The cooling water system is provided to cater to the requirements of Generator air coolers, Bearings, Oil Pressure Unit and Step Up Transformers.

The cooling water system will be a single circuit closed loop circulation with heat exchanger placed in the tail water pool to enhance the cooling affect. Hence this type of cooling water system does not require a primary water circuit.

The closed loop circuit of the cooling water system will comprise of pumping systems mainly 7 (Seven) pumps, 6 main and 1 standby. The pumped water will be routed through a common cooling water header. The water requirements of the units and transformers will be met through this header. The spent water will be collected in the return header of the cooling water and flowed through a heat exchangers (pipe type) immersed in the tail pool. The water after cooling from the heat exchanger will then be pumped back through the pumping system to the common cooling water header. Heat exchanger shall be constructed of Stainless steel SS 316L material and designed considering the water temperature leaving & entering the heat exchanger at a difference of 5°C.

Each Unit shall have independent cooling water circuit.

11.4.3 Drainage and Dewatering Systems

The dewatering system will be provided for emptying the units for inspection/ maintenance. A dewatering sump will be provided between the units and connected with the draft tubes through pipes.

Six submersible pumps will be provided in the sump for pumping out the water to tail pool above the maximum tail water level.

The drainage water will also be collected in a drainage sump located between the units and pumped through 6 submersible pumps to the tail pool above the maximum tail water level.

For automatic operation of the pumps, level controllers will be provided in the dewatering and drainage sumps.

In addition, for protection against flooding, two submersible pumps of adequate capacity along with necessary level sensors for automatic starting will be installed on the MIV floor and the control panels for these pumps will be located in the control block.

11.4.4 Fire Protection

Water based fire protection system will comprise of automatic high velocity water spray system for the generator transformers and station auxiliary transformers, and low/ medium pressure fire hydrant system for the Power Station and Switchyard. A microprocessor based fire alarm/ detection system complete with all accessories will be provided for audio/ visual annunciation in case of fire. Water for fire protection system will be obtained by pumping water from tail race to a storage tank by installation of 1 (One) main and 1 (One) standby centrifugal pumps. The fire water storage tank will be placed at an elevation suitable to provide sufficient head/ pressure for the fire protection system.

Water based fire protection system will be supplemented with chemical fire extinguishers. Generators will be provided with CO2 based fire fighting system.

The fire protection system will conform to the NFPA 851 guidelines for fire protection of the hydro generating station.

11.4.5 Ventilation and Air Conditioning

The ventilation and air conditioning system will be sized and configured to provide sufficient air circulation as well as temperature and humidity control for the satisfactory operation of the equipment and comfort of the personnel. Temperature will be controlled by means of air to water heat exchangers.

The air for circulation will be pressurized through blowers in the Fresh Air Unit located on the top floor in the Control block and this treated air will be routed through bus ducts to the lower floors.

Exhaust fans will be provided in the machine hall for maintaining the necessary air changes. Control rooms, office rooms and conference rooms etc. will be provided with air conditioning.

The corrosive/ foul gases from toilets and battery bank room will be exhumed through spark resistant exhaust fans.

Ventilation system will be compliant with IS 4720 and the air duct construction will be as per IS 655. The system will be designed as per ASHRAE guidelines.

11.4.6 Compressed Air System

LP compressed air system comprising of main and standby compressors along with a main receiver and unit receivers will be provided for generator braking and station service purposes.

High pressure compressed air system or Nitrogen bottles shall be provided for hydraulic control of Governor and MIV. The HP compressed air system will be suitably connected with the LP system with pressure reducers for redundancy of the LP system for generator brake operation.

The compressors and receivers will be located in the control block, on the floor below the machine hall. The service air supply to the following floors will be provided through connecting pipes, valves and couplings;

- Machine hall,
- Generator floor,
- Turbine and MIV floor,
- Transformer area,
- Electrical and mechanical workshop.

11.4.7 Electrical Lifts and Elevators

The powerhouse will be equipped with one elevator with sufficient capacity to transport 4 persons between various floors of the powerhouse; the elevator will be located in the Control block of powerhouse.

The elevator will be provided with landing arrangement at various powerhouse floors. It will operate on the following floors;

- Machine hall/ service bay floor,
- Generator floor,
- Turbine floor

11.4.8 Workshop Equipment

A limited workshop facility will be provided in the powerhouse for carrying out the normal operation and maintenance jobs of electro mechanical equipment. The workshop will be equipped with following machine tools:

- Turning machine,
- Mechanical Workbench,
- Power hacksaw,
- Drilling machine,
- Grinding machine,
- Welding set etc.,

11.5 POWER EVACUATION ARRANGEMENT

It is proposed to provide two outgoing bays for evacuating power at 400kV level from Bhavali PSP. As per Power Evacuation Study, it is recommended to construct double circuit 400 kV line with ACSR Quad Moose conductors from the Project to 765/400 kV PGCIL Substation in Padghe

However, the various options for evacuation of power from the project shall be further studied in consultation with the Transmission Utilities.

CHAPTER - 12 CONSTRUCTION PLANNING, EQUIPMENT PLANNING AND SCHEDULING

12.1 BASIC FOR STUDY

Construction methodology and equipment planning has been devised with an objective to mitigate the adverse impact to surrounding environment during the construction period of the project. The construction cost and construction period depend to a great extent on the method adopted to carry out the works and equipment deployed for the same. Alternative methods/equipment has to be exercised in selection of most efficient construction method/equipment so as to optimize construction cost and time. These two factors are inter-related and, generally, any attempt to reduce one results in increasing the other.

This chapter describes the preliminary construction planning and equipment planning of the project. However, detailed construction planning and equipment planning including detailed computation will be done at DPR stage.

Equipment planning depends upon

- Topography of the area
- Accessibility of various working areas
- Speed of construction
- Construction specifications of project components
- Economy of construction
- Optimum utilization of plant
- Shift pattern for continuous working system

The project involves execution of large quantities of excavation, Filling of material and concreting in above ground and underground works. In view of the substantial magnitude and nature of the construction activities, mechanized construction has been considered for all the activities so as to achieve a good quality job at a faster rate for completion of the project within the stipulated time. Special attention has been paid for equipment planning for underground works which entail restricted work space and geological constraints. Before a particular type of equipment and its number are proposed a proper assessment of construction requirements and BOQ of each component of the project is made including the time required to complete the various activities involved.

12.2 MAJOR PROJECT COMPONENTS

The project involves construction of the following major components.

- Upper Reservoir (Embankment/Dam)

- Lower Reservoir (Dam)
- Upper Intake
- HRT
- Penstock
- Powerhouse and Transformer Cavern
- Tailrace Tunnel
- TRT Intake/Lower Intake
- Adits for Tunnels

12.3 SCHEDULED WORKING HOURS

Cycle time of operations is the criteria for hourly/daily output of machinery/work force. However, actual progress of work is dependent upon several other factors such as power interruptions, minor break downs, time for meals and other needs of the work force, stray rains etc. It is a general practice to consider 50 minutes as the actual working time per hour (83%). When the work is carried out in more than one shift, there is further reduction in daily production hours due to time required for change in shift and for daily maintenance needs of plant and machinery.

Equipment planning has been done based on the number of working days available. For Equipment planning aspects, as recommended in code IS 11590:1995 and CWC Guidelines for River Valley Projects, following scheduled working hours in a year with 200 working days for all above ground construction activities, has been considered in Table 23

Table 23: Scheduled Working Hours

Shift	Working month/yr	Working days/month	Working hr/day	Annual Production Hrs.
Single shift work/day	8	25	6	1200
Two shift work/day	8	25	11	2200
Three shift work/day	8	25	15	3000

12.4 SPEED OF TRUCKS AND DUMPERS

Loaded and empty speed of trucks and dumpers as per CWC recommendations has been considered as under:

Table 24: Speed of Trucks and Dumpers

Description	Speed (kmph)	
	Loaded	Empty
Underground Works	15	20
Above Ground Works	20	25

12.5 BASIC FACTORS

As per CWC recommendation, following factors for Excavator and Loader have been adopted.

Table 25: Basic Factors for Excavator and Loader

Factors	Value
Sand and Gravel	95.0%
Common Earth	85.0%
Rock well blasted	67.5%
Rock poorly blasted	45.0%

12.6 STAND BY EQUIPMENT

Stand by equipment for various shift working has been considered as under:

Single shift work/day	10%
Two shift work/day	20%
Three shift work/day	30%

12.7 PROJECT IMPLEMENTATION SCHEDULE

It is planned to complete the main construction and commissioning of the project in a period of 36 months including commissioning of six units. The pre-construction period for 6 months has been considered for preparation and award of works and construction of roads & bridges etc.

12.8 PROJECT LOCATION & SITE ACCESS

The upper reservoir is located near Jamunde village in Igatpuri Tehsil/Mandal of Nashik district while the lower reservoir is located near Kalbhonde village of Shahpur Tehsil of Thane district of Maharastra. The project site is located 50kms from Nashik district. The site is easily approachable by NH-160 from Mumbai via Shahapur. Nearest railway head is in Igatpuri from where project site is located. The nearest airport is located in Mumbai which is about 130kms from the site. The nearest sea port is the Mumbai Port located at a distance of about 130kms.

The Upper reservoir site is accessible from Mumbai Nashik highway near Igatpuri town which is a National Highway. Further from Igatpuri town to upper reservoir site the length of the route is 13kms via Naigaon, Bhagatwadi, Nandgaonsado, Bhavli Kh, Gavhande upto Jamunde Bituminous top roads are existing and can be used for the access to site after strengthening where ever required. the roads are bituminous top which is located 1.5kms from the AH-47 Highway. From Jamunde to Upper Reservoir site a new access road is to be laid which would be about 2kms for the project use to transport the machinery and materials required.

The Lower reservoir site is accessible from shenve-Dolkhamb State Highway-44 near Dolkhamb. The Lower reservoir site is about 25kms from the Dolkhamb via Talwade, Roadvahal, Dhakane, Kothale to Kalbhonde village. Roads upto Kothale village are Bituminous top and can be used for the access to site. Road to Kalbhonde village is Earthern/Mud Road shall be strengthened for the machinery movement. Road from the Kalbhonde to lower reservoir site to be laid which would be about 2kms. An Access road connecting the lower dam and dumping facility is to be laid which would be about 4.5kms.

12.9 CONSTRUCTION MATERIALS

12.9.1 Cement

Cement material is brought from the Nashik to the Igatpuri by means of existing railway line means to the Igatpuri railway station. From Igatpuri railway station the Bagged cement material is transported by means of road ways to the site which is 13kms away from the upper reservoir. For lower Reservoir area the cement materials are to be transported to Asangaon Railway station and to be transported to the lower reservoir through trucks to the lower reservoir site.

12.9.2 Steel

Steel yards nearer to the project site with sizeable quantities of reinforcement steel and structural steel shall have to be stocked and replenished as per the requirement. Steel plates for pressure shaft liner and penstock to be imported to suit the design requirements if necessary through the Sea route.

12.9.3 Aggregate

The material from the near by river bed may be suitable for aggregate purpose and shall be tested in the laboratory during the DPR stage. Excavated rock from headrace tunnel, powerhouse and tailrace tunnel shall be crushed and classified to various sizes of aggregate in batching and mixing plant at suitable locations.

The approximate quantity of the construction materials required for the PSP are shown in *Table 26*.

Table 26*: Approximate Quantity of Construction Materials*

SL.No	Item	Qty	Units
1	Sand	96493.71	Cum
2	Coarse Aggregate	217110.84	Cum
3	Quarry for Clay	808192.48	Cum
4	Filter Media	894882.75	Cum
5	Rip Rap	306269.61	Cum
6	Rockfill	4159539.82	Cum

CHAPTER - 13 PROJECT ORGANIZATION

13.1 GENERAL

The Bhavali PSP envisages construction of Rockfill Embankments/ RCC Dam for the Upper reservoir, RCC Dam for lower reservoir, Power Intake structure, HRT, Steel Lined Pressure Shafts/Penstock, Power House, Tail Race Channel, Tail Race outlet structure other infrastructure works.

The project is planned to be completed in a period of 36 months including 6 months devoted mainly for creation of infrastructure facilities including road and other facilities. The construction of the various project components are proposed to be carried out through contracting agencies entrusted with suitable contracts.

All civil, hydro-mechanical and electro-mechanical works are executed in different packages of contract as listed below

Civil Works

Package I: Civil works of Rockfill Embankment/RCC Dam for Upper & lower reservoir, HRT, Penstocks upto Power Hoose.

Package II: Civil works of Power House, Draft Tube Tunnel, Tail Race Intake Structure, TRC and Switch Yard

Hydro-Mechanical Works

Package III: Hydro Mechanical works comprising of gates, hoists, erection & fabrication of Pressure Shaft pipes.

Electro-Mechanical Works

Package IV: Generating Units (Turbine & Generator), Cooling Water System, Drainage/Dewatering System, Unit Control & Automation, BFV, EOT Crane, Air Conditioning, Ventilation etc. Fire Fighting, Transformers (Generator Transformer), Switchgear Switchyard & Protection metering, Transformer, DC System (Battery & Battery Charger), UPS etc., complete.

Transmission Line Works

Package V: Transmission line works

A competent consultant will be appointed for the preparation of technical specifications, detailed designs and construction drawings for various components of the project and for the construction supervision.

Keeping in view the size of the project involving huge investments and massive engineering activities, it is essential that the progress of various activities be kept under a constant vigil at various levels in order to check any avoidable straying from the schedule of construction. Hence, the organization of the project has been planned to ensure very close coordination to avoid time and cost over-runs.

13.2 PROJECT ORGANIZATION

The works of PSP would be looked after by a project team set up for the purpose under the overall control of M/s JSWNEL. The unit is proposed to be headed by Project Director for the overall management of the project. All the project services would be accountable to the Project Director. The Project Director would be assisted by the project head in turn assisted by two divisional heads under the construction & services division. All major engineering services will in turn be headed by a General Manager of each department to look after the planning & control, civil, Electrical, P & M, Hydro & Mechanical, Electro & Mechanical, geology, store, C & P, Infra, Environmental Health & Safety, quality control, quality services division, administration, financial and accounts aspects of the projects. Each sector head would be assisted by the senior Managers (Team Leads) with a team of staff members corresponding to that particular sector.

13.3 PROPOSED ORGANIZATION STRUCTURE

The proposed organization Consists of: Project Director, Project Head, Divisional Heads, Sector Heads, Team Leads & Team members.

Sector Heads along with team leads and team members are responsible for the delivery of the respective services allocated to them.

The Project Director shall be responsible for the over all execution of the project assisted by the project head.

The Project head shall be of Senior General Manager acts as bridge between project director and the divisional heads and is responsible for the internal & external co-ordination, communication related to the Project.

The Divisional Heads shall be of General manager and are responsible for the maintaining proper communications and synergies between the sectors that are handled under the project.

The Sector Heads shall be of Assistant General Manager/ Senior Managers and assisted by an administration wing headed by a Team Lead (Manager) posted along with the staff members at Project Headquarters to look after the various engineering sectors such as planning & control, civil, Electrical, P & M, Hydro & Mechanical, Electro & Mechanical, geology, store, C & P, Infra, Environmental Health & Safety, quality control, quality services division, administration, financial and accounts. The Manager would be assisted by necessary administrative personnel and administration, medical, security and liaison staff in-charge of various duties.

While the General Manager assumes responsibility for all aspects of the project, officials under the General Manager have to ensure that their reports etc. reflect up to date status of the project at that point of time. They would periodically review the progress of works, identify the problem areas, suggest remedial measures, see through the implementation of such measures and have a realistic forecast of the status of the project.

To achieve the above objective, the Managers shall ensure that they and their personnel are interacting regularly on a day-to-day basis with all the concerned personnel of the project whose work has a direct impact on the progress of their work and take corrective measures, wherever called for, in order to adhere to work schedule.

Manager (Civil construction) would be responsible for taking up Package- Infrastructure Civil Works for creating infrastructure facilities. The Senior Manager (Civil) would be assisted by two Engineers (Civil) along with supporting staff (as per requirement for the initial 3 months) for construction of offices, buildings, roads, water supply as well as procurement of materials, construction & maintenance of stores, etc.

Manager (Electrical) would be assisted by two Engineers (Electrical) to look after the infrastructure requirements for Power house electrical & mechanical works, switchyard, transmission system, construction equipment and workshops, construction power, communication & transport, etc.

Manager (Mechanical) would be assisted by one Engineers (Mechanical) to look after the infrastructure requirements for workshop facilities, fabrication yards, construction equipment, construction power, communication & transport etc.

Financial Wing would be headed by Sr. Manager (Finance) along with one Accounts Officers and supporting staff, who would be reporting to the General Manager on the financial and account matters.

CHAPTER - 14 INFRASTRUCTURE FACILITIES

14.1 GENERAL

The Bhavali PSP project is located near Jamunde Village on the tail end of the Bhavali dam, a tributary of the Darna River in the Nashik district of Maharastra state.

This chapter covers the preliminary studies of infrastructure planning of the project; however detailed infrastructure planning will be done at DPR Stage.

14.2 PROJECT LOCATION

The Geographical co-ordinates of the proposed Pumped Storage Project component of upper reservoir located near to Jamunde village is at latitude 19°36'31.69"N, and Longitude 73°35'45.06"N and that of lower reservoir at Kalbhonde village with latitude 19°36'31.69"N and longitude 73°35'45.06"E.

14.3 PROJECT ACCESS

The project is located near Bhavali village located in Igatpuri Tehsil/Mandal of Nashik district in Maharastra, India. The site is easily approachable from Mumbai- Nashik express way. It is located kms from the district head quarters of Nashik. Nearest railway head is in Igatpuri from where project site is located at around 13kms. The nearest airport seaport is at Mumbai which is 130kms from the project site.

14.4 INFRASTRUCTURE FACILITIES

14.4.1 Project Office and Colony 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 there 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. On the basis of manpower requirement, accommodation and its area has 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

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 with following amenities.

Water Supply

Water for construction 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 reservoir 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.

Sanitation and Sewage

All Site-offices, workshops, laboratory and other work-sites shall be provided with toilets, water supply and septic tanks.

The Project-colony and camps outside the project-area shall be provided with a properly maintained and operated sewerage system including septic tanks and sewage disposal facilities.

If required Mobile toilets will be provided in the construction area and kept in good condition.

Medical Facilities

In order to cater for the medical care and emergency needs of the project workers, it is proposed to set-up a 4 bedded medical Hospital/dispensary for treatment of construction related injuries, common sickness under the charge of a qualified medical officer supported by sufficient support staff in the Project-colony.

Project site shall also have Emergency Medical Centre with life-saving facilities and medical aids.

Well-equipped ambulances shall also be provided at the Colony-Hospital and also at the construction site.

Adequate medical equipment, stretchers, medical oxygen cylinders etc. shall always be kept in ready to service position. Sufficient stock of medicines shall be kept at these Hospitals.

Communications

A proper communication system is proposed to be established at the site linking the project site activity centres and maintaining communication with the following modes:

- Walkie-Talkies Set
- Telephones
- Public Mobile Phones
- Internet and Emails

Fire Protection

Adequate and appropriate arrangement shall be provided for protection and prevention of fires. Water outlets shall be provided through the pipelines near all offices, workshops camps and other fire prone areas. Wherever, required ABC type fire extinguishers shall be provided in sufficient quantities. If required special extinguisher shall be provided at fuel stations and electrical installations and special warning sign for not using water for extinguishing fire in electrical installations shall be displayed.

Workers shall be given training to use fire extinguishers and tactically handle the situation in case of fire so as to minimize the damage.

14.4.2 Project Roads

The project area is accessible with bituminous road via Mumbai Nashik Expressway road upto Igatpuri town & from there a bituminous road is available upto the Jamunde road. From Jamunde 2kms of raod is to be laid to the project work site. For power house approach tunnel and a new road is to be developed.

An approach road shall be constructed connecting lower reservoir from the Kalbhonde village of about 2kms to the dam site. From dam site to the dumping yard 4kms road is to be constructed. A total of 8.20 km of approach road in the project area is envisaged to be constructed. The detailed planning of access to various components shall be done in DPR stage.

14.4.3 Muck Dumping area

The huge excavated material shall be utilised in the construction of embankment dam/ RCC Dam with processing the excavated material. Moreover the excavated material from underground works of tunnel and powerhouse will also be utilised for processing of aggregates for concrete. An area of 45.41 Ha has been earmarked in the downstream area. The total muck generated for the proposed PSP is shown in Table 27.

Table 27: Muck Disposal Component Wise

Sl.No	Item		Qty	Units
1	Dams	=	114739.25	cum
2	Intake (U/S & D/S)	=	670745.13	cum
3	Tunnels	=	338136.58	cum
4	Adits	=	160780.00	cum
5	Power House & Transformer carven	=	288271.58	cum
6	Surge shaft	=	257054.00	cum
7	TRC	=	4387500.00	cum
	Total		**6217226.54**	cum
8	Considering 60% wastage		3730335.93	cum
9	Swelling 40%		**5222470.30**	cum
10	Total area proposed	=	454100	sq.m
11	depth of filling	=	12	m
12	Quantity can be filled	=	**5449200.00**	cum

14.4.4 Batching and Crushing Plant

One set of Batching and crushing plant each will be installed at project site to facilitate the processing of coarse and fine aggregates to be used in concreting works.

14.4.5 Project Stores

A project stores shall be constructed in the project area for construction material, consumables, spares and other miscellaneous items.

Cement storage of required capacity shall be provided for storing the cement.

Shaded yard for reinforcing steel and structural steel shall be constructed for stocks and fabrication works. Reinforcing steel cutting and bending yard and Steel fabrication shop shall also be established in the vicinity of steel stock yard.

14.4.6 Explosive Magazine

An explosive magazine of required capacity shall be provided at identified location at project site sufficiently away from the human habitat and working areas. Explosive Magazine shall have an isolated chamber or space for storing Detonators which shall, in no case, be stored in the bare vicinity of gelatine or other explosive material.

The area around the magazines shall be secured by appropriate Boundary wall and fencing with a lockable gate. Round the clock strict security vigil shall be maintained by deploying well trained and capable armed guards.

All the precautions shall be taken while placing in or removing the material to and from the Explosive Magazine in general and as prescribed by the Law of State. Complete record of explosives, detonators and all other such material shall be maintained meticulously which may be demanded by state authorities any time or at the time of filling return for the use of explosive.

Any registration or approval required for establishing explosive magazines as per the Law of the country or state shall be obtained.

14.4.7 Fuel Station

It is necessary to provide a fuel station for catering the fuel and lubricants requirement of the construction activities, two 60kl Fuel station shall be established at the Project site.

In addition to this an area of about 150 m^2 (Equivalent 15 m x 10 m) shall be provided for lubricants for meeting the lubricants requirements of the works.

Further 2 numbers of 10kl Diesel tanker will be provided at site for carrying the diesel from depot to site storage facility. Lubricant drums shall be transported by trucks. In addition, two 2kl diesel bowsers shall be used for filling the equipment and DG sets at work site itself.

14.4.8 Work Shop

a) HM Workshop

A fully equipped self-sufficient heavy equipment workshop shall be established to provide quick repairs and maintenance of heavy construction equipment so that availability of equipment is maintained and the work does not suffer for repairs and maintenance of equipment.

This workshop shall be established by the civil contractor. This facility may be transferred to the owner after completion of construction for its use as mechanical workshop and garage during Operation and Maintenance.

b) Light Vehicle Workshop

One light vehicle repairing facility shall also be maintained at the project site in order to provide regular services and repairs to the project vehicles.

c) Electrical Workshop

An electrical workshop shall be established at the Project site to provide services to electrical installations and equipment such as power systems, DG sets, transformers, pumps etc. and also lighting of Project and camp. This will also ensure uninterrupted power supply for construction works.

14.5 CONSTRUCTION POWER

The power required during the construction stage of the project would be obtained through the available alternatives. However it has been given to understand that due to the availability of grid power in the project area during the construction period of 3 years, it is envisaged to install a new substation to obtain power from Existing grid.

However, if power is required from DG set, it is envisaged to install Diesel Generating sets to power the machineries proposed to be used during that period. The requirement of power for the machineries/ equipment proposed to be used for construction works at various project sites including Upper Reservoir, Powerhouse, project resident colonies & camps, etc. has been worked out as per construction program and planning.

14.6 QUALITY ASSURANCE AND QUALITY CONTROL

In order to assure and maintain quality standards of the construction material and construction works, arrangements will be made to facilitate field laboratory tests as per the applicable standards. For this purpose, a fully equipped laboratory shall be installed for carrying out the prescribed tests on site.

One centralized Quality Control laboratory shall be established near main batching and mixing plant for undertaking various tests and concrete mix design studies etc.

Experienced senior engineers/technicians well versed in various aspects of quality assurance will manage quality assurance and quality control program strictly in accordance with prescribed standards and ensure that the specified tests are carried out and the results interpreted in the manner stipulated in the prescribed project Quality Assurance Manual and standards.

CHAPTER - 15 ENVIRONMENTAL AND ECOLOGICAL ASPECTS

15.1 INTRODUCTION

The proposed Bhavali PSP is located near Jamunde village of Nashik district bodering with Thane district of Maharastra. Project consists of upper reservoir near Jamunde village in Igatpuri Mandal of Nashik District & the lower reservoir is proposed near Kalbondhe village in Shahpur Mandal of Thane district. The Proposed upper reservoir is operated with a live storage of 0.35 TMC. The filling of the reservoir will be taken from the Bhatsa Dam inflows. The total design discharge for the proposed scheme is 374.58 cumecs with the rated head of 447.0m. The location of the project is as shown in .

Regulatory Environmental Clearance (EC) process involves three major steps as stipulated in EIA notification of September 2006, viz. Scoping, Public Consultation and Appraisal.

Water resources development projects will interfere with the environment in the proposed area and its surroundings. Proper assesment of environmental impacts and its mitigation measures during the planning stages of the projects will help in reducing the adverse impacts. A brief description of environmental impacts with the proposed Pumped Storage Project is presented in the chapter. However, detailed EIA & EMP Studies shall be carried out in DPR stage.

15.2 STUDY AREA OF THE PROJECT

Study area for environmental study will be delineated as Project area or the direct impact area within 10 km radius of the main project components like Power House, Balancing reservoirs and approach road etc.

15.3 ENVIRONMENTAL BASELINE STATUS

Data on the existing environment quality is to be collected to understand the present setting of the environment at the project site. To complete the EIA study, it is important to collect baseline data for various physico-chemical and biological environmental components in the project study area comprising Vegetation Community Structure, Wildlife, Soil Quality, Noise levels, Ambient Air Quality, Traffic density. In the present study, the base line status has been reviewed mainly on the Secondary data that was collected around the project area.

15.3.1 Physiography

The project area is located in the Southern part of Nashik district bodering with Thane district. The project area lies in Goadavari upper sub-basin. The study area of the proposed project is comprised of hilly terrian of Western ghats with steep to moderately sloping, exposed rocks, and scrub vegetation. The study area ranges from El. 250 to 1300 m above msl.

15.3.2 River System

Both upper and lower dams of Bhavali PSP are proposed to be constructed new. The one time filling of the PSP reservoir is proposed from water allotment from Bhatsa dam. Bhavali PSP is located near village Bhavali on Darana river, of Godavari upper sub-basin. Darna is a minor right-bank tributary of Godavari in the Nashik District, Maharashtra. Rising north of the Kalsubai range, it drains Igatpuri, Nashik and Niphad Talukas of Nashik District. The conjunction with Godavari is situated at Darnasangvi.

The Darna rises on the northern slopes of the Kulang hill fort in the Sahyadris about 13 km. south-east of Igatpuri. Though the straight line distance from the source to its confluence with the Darna is only about 50 km., it has a very long and winding course which measures about 80 km. (refer Fig No Error: Reference source not found)

15.3.3 Geology

The pumped storage project is proposed between the upper reservoir & lower reservoir on tail end of Bhavali Dam in Nashik district. The scheme comprises of upper reservoir, lower reservoir, water conducting system, Pressure shaft, Surge shaft, Access tunnel, Under ground power house & tail race system.

The proposed PSP is located in the Western ghats of Igatpuri and Shahpur taluk of Nashik & Thane districts in Maharastra. The entire area is underlain by the basaltic lava flows of upper Cretaceous to lower Eocene age. The shallow alluvial formation of Recent age also occurs as narrow stretch along the banks of Godavari and Girna Rivers flowing in the area. Basaltic lava flows occupies about 90% of the area of the district. These flows are normally horizontally disposed over a wide stretch and give rise to table land type of topography also known a plateau. The volcanic portion consists of compact, stratified basalts, and an earthy trap. To the west they lie in flat-topped ranges, separated by valleys, trending from west to east. In some flows the basalt is columnar and then it weathers into the various shapes. The formation at the base of the traps is amygdaloidal, containing quartz in vertical veins, crystals and zeolitic minerals, especially apophyllite weathering into a grey soil. The river beds are covered with Alluvium which occurs in small areas in the form of discontinuous patches along the banks and flood plains of major rivers like Godavari, Girna and their tributaries. In alluvium the granular detrital material like sand and gravel usually occurring as thin layer in the district yields water. The absence of laterite, which caps the summits of the hills to the south, is a curious feature in the geology of the area.

15.3.4 Seismicity

The project area falls under Zone III as per IS-1893 (Part 1) 2002, Seismic Zoning Map of India.

15.3.5 Meteorology

The climate is generally dried climate except south-west monsoon season. The tropical location and high altitude combine to give it a relatively mild version of a tropical wet and dry climate in the district. The winter season is from December to about the middle of February followed by summer season which last up to May. June to September is the south-west monsoon season, whereas October and November constitute the post-monsoon season. The maximum temperature in summer is 42.5°C and minimum temperature in winter is less than 5.0°C. Relative humidity ranges from 43% to 62%. The normal annual rainfall in the district varies from about 500 mm to 3400 mm. The average maximum in the district is wind speed of 17 Kmph.

15.3.6 Water Quality

The data on surface and ground water shall be collected to evaluate the quality of the water in the proposed area during DPR stage. The water quality in the study area, in general as per physical examination is good. Except for agricultural activities there are no sources of pollution of water bodies in the area. All the samples of surface water shall be collected & tested during the DPR stage as per the Water Quality standards of BIS & CPHEEO.

15.3.7 Flora

The project area has rich forest cover in terms of area & richness of flora. The area is well known owing to its great diversity of medicinal and endemic species. The steep hill slopes of the area have typical cliff vegetation dominated by Tripogon spp. Small clumps of succulent Euphorbia are also seen EriocaulonUtricularia dominated Ephemeral Flush Vegetation is seen on gently sloping rocky areas. Pogostemon deccanensis forms dense patches in the water logged areas. Typical basalt plateau endemics such as Cyathocline lutea, Senecio dalzellii, Smithia purpurea entirely cover the rocky plateau top. Several grasses (Heteropogon, Dichanthium, Ischaemum, Themeda) form dense growth during late monsoon period. Ceropegia anjanerica is found in large numbers in association with clumps of Senecio dalzellii, Celosia argentea, Lepidagathis sp. and Justicia betonica. Other western ghat specialists found on the plateau are Tricholepis amplexicaulis, Desmodium alysicarpoides, Heracleum sp, Pinda cocanensis, Paracaryum malabaricum, etc. other endemic and threatened species like Frerea indica, Ceropegia spp. Habenaria sp, Dendrobium microbulbon, etc are commonly seen. medicinal and religiously important plants like Heracleum grande, Terminalia chebula, T. Bellarica, Embelia basaal, Desmodium sp, Curcuma pseudomontana, Eriolaena quinquilocularis, Neuracanthus sphareostachys etc. are seen in Nashik and surrounding markets like Ghoti, Igatpuri, Tryambakeshwar. List of flora and their status shall be studied during DPR stage.

15.3.8 Wild Life

A variety of the endengered distinctive animals such as Panthera tigris(tiger), Acinoyx jubatus(chitta), Axis axis(spotted deer), Boselaphustragocamelus (Nilgai), Melursus urisnus (aswal) are found in this district.

The common mammals found in the study area Taras (Hyaena hyaena), Jackal (Canis aureus), Khokad (Vulpes bengalensis), Chowsingha (Tetracerus quadricornis), Dukkar (Sus scrofa), Ud manjar (Paradoxurs hermaphroditus), Bibalya (Panthera paradus), Barking deer (Mmntiacus muntjak), Sasa (Lepus nigricollis), Salu (Sayal) (Hystrix indica), Khar (Funa mbulus), Ranmanjar (Felis chaus), Sambar (Cervus unicolar), Llandga (Canis lupus), Mongoose (Harpester edwardsi), Monkey (Macaca mulatta), Hanuman wanar (Langur sp.), Jalmanjar (Smooth ottar), Bat (Cynopterus petropus).

The commonly found reptiles in the study area are (Nag) Naja naja, Rat snake (Varanus inelicus), Common crait (Bungurus caeruleus), Russel viper (Vipera russelli), Garden lizard (Calotes versicolor), Chamaeleon (Chaemeleon vulgatis), Ghorpad (Qtyas mueosus).

The commonly found birds in the study area are Grey heron (Ardea cinerea), Indian pond heron (Ardeeola grayil), Cattle egret (Casmerodius albus), Large egret (Casmerodius albus), Little erget (Egretta garzetta), White naked strok (Cionia episcopus), Great cormorant (Phalacrocorax carbo), Black ibis (Pseudibis papilosa), Greater flamingo (Phenicopetrusruber), Lesser whisting duck (Dendrochgna javanica), Common shelduck (Tadorna tadoma), Pintail (Anus acuta), Shikra (Accipiter badius), Booted eagle (Hietraetus pennatus), Lesser spotted eagle (Aquilla pomarina), Cinerious vulture (Aeqypius monachus), Crested serpent eagle (Spilornis cheela), Peregrine falcon (Falco peregrinus), Grey francolin (Famcolinus pondiceranus), Indian peafowl (Pavo cristatus), Pruple moorthen (Porphyrio porphyrio), Black winged stilt (Hinantopus himantopus), Yellow watteled lapwing (Vanellus malbaricus), River tem (Stema curntia), Brown rock pigeon (Columba livia), Red collored dove (Streptopelia trangcubarica), Rose ringed parakeet (Psittacula krameri), Brainfever bird (Hireoxoxxyx varius), Indian cuckoo (Cuculus micropterus), Asia koel (Eudynamysscolopacea), Greater coucal (Centropus sinensis), Barm owl (Tyto alba), Spotted owletta (Athene brama), Sykes nightjar (Caprimulgus mathrnttensis), Alpine swift (Tachymarpits melba), Small blue kingfisher (Alcedo atthis), Indian roller (Coracips bengalensis), Indian grey hornbill (Ocyceros birostris), Coppersmith barbet (Megalamia haemcephala), Yellow fronted pied woodpeeker (Dendrocopas maharattensis), Common swallow (Hirundo rustica), Brown shrike (Lanius cristatus), Eurasian golden oriole (Oriolus oriolus), Black drongo (Dicrurus macerocerus), Common myna (Acridotheres tristis), House crow (Corvussplendens), Jungle crow (Corvus macrorhynches), Red vented bubul (Pycnonotus cafer), Common babler (Turdoides caudatus), Forest wagtail (Dendronanthusindicus), Small sunbird (Nactarinia minima). A detailed description of wildlife in the project area shall be conducted during DPR stage.

15.4 SOCIO-ECONOMIC PROFILE

The collection of data on the socio-economic status has been delinated with in 10km radius of the main project components such as upper reservoir, lower reservoir, water conducting systems, power house, muck disposal area etc., the proposed area liesbetween the Igatpuri Tehsil of Nashik district and Shahpur Tehsil of Thane district.

The socio-economic includes

- 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 all the project affected persons with their names, education, land holdings, other properties, occupation, source of income, land etc.

15.5 PREDICTION OF IMPACTS

Majority of the environmental impacts attributed to construction works are temporary in nature, lasting mainly during the construction phase and often do not extend much beyond the construction period. However, as the construction phase of Pumped Storage Project is large and extend upto four years, if these issues are not properly addressed, the impacts can continue even after the construction phase for longer duration. Even though the impacts due to construction are temporary in nature, they need to be reviewed closely as they could be significant due to the nature and intensity of the impacts.

15.5.1 Impact on Land

The impact on the land manly occurs due to the construction works, migration of labours, vehicular & heavy machinery movement in the area. Extension of the construction timeline beyond the scheduled construction may have impact for longer duration although which is temporary in nature.

a) Impacts due to immigration of Construction Workers

At the time of peak construction work in the project, Majority of people are required than the planned persons who have there permanent shelters in nearby villages or temporary homes constructed for the project purpose. Majority of the people will be migrating from other areas. Only the migratory manpower will stay at site camp. Immigration of such a large population for a long duration in remote area can cause serious impact on various environmental resources including socio-economic profile of local population.

The congregation of large number of construction workers during the peak construction phase is likely to create problems of sewage disposal, solid waste management, tree cutting to meet fuel requirement, etc. Appropriate mitigating measures will suggested in EMP, which needs to be implemented to minimize such impacts. This population is expected to reside in the project area at any given time.

b) Impact due to Construction of Main Project Components

For construction of main project components major activities are excavation and concreting. Excavation will have impact in terms of muck generation. Excavation and concreting process will require use of various construction equipment such as batching plants, aggregate processing plants, dumper trucks, excavators, dozers, shotcrete machines, jack hammers, generators, pumps, etc. leading to generation of pollution in terms of emissions, wastewater, noise and solid waste.

c) Operation of Construction Plant and Equipment

During the construction phase, various types of equipment will be brought to the site and construction plants and repair workshops will be set up. These include crushers, batching plant, drillers, earth movers, rock bolters, etc. The siting of these construction equipment would require significant amount of space. In addition, land will also be temporarily acquired, i.e. for the duration of project construction; for storage of the quarried material before crushing, crushed material, cement, steel, etc.

The siting of these construction plant/ equipment's would require clear piece of land. Proper siting of these facilities will reduce the impact due to their location. Their locations have been identified, keeping in view the technical and economic criteria; however, same can be further refined during set up, keeping in view:

- ❖ Proximity to the site of use
- ❖ Sensitivity of forests in the nearby areas
- ❖ Wildlife, if any, in the nearby area
- ❖ Proximity from habitations
- ❖ Predominant wind direction

- ❖ Natural slope and drainage

Such activities are planned on government land and completely avoiding the forest area; to minimize the impacts of tree cutting. Land will be restored once the project construction is complete.

Operation of construction plants and machinery, will have impact on ambient air quality due to fugitive emissions associated with material handling; emission due to operation of DG sets to meet the power requirements and other equipment; impact on water quality due to waste water generation and impact on soil due to solid and hazardous waste generation and impact on soil due to solid and hazardous waste generation. Management of such impacts with operation control and appropriate pollution control equipment is essential to minimize their effect on surrounding environment including local population and wildlife and same is discussed in Environment Management Plan.

d) Muck Disposal

Construction work would involve soil and rock excavation. Excavated muck is expected to be utilized for rockfill and aggregate for construction. Total quantity of muck proposed to be disposed in designated muck disposal area, after considering swelling factor. This muck would requires disposal, with minimum environment impacts. Muck, if not securely transported and dumped at pre-designated sites, can have serious environmental impacts, such as:

- ❖ Can be washed away into the natural water bodies which can cause negative impacts on surface and ground water quality.
- ❖ Can lead to impacts on various aspects of environment. Normally, the land is cleared before muck disposal. During clearing operations, trees are cut, and undergrowth perishes as a result of muck disposal.
- ❖ In many of the sites, muck is stacked without adequate stabilization measures. In such a scenario, the muck moves along with runoff and creates soil erosion like situations.
- ❖ Normally muck disposal is done at low lying areas, which get filled up due to stacking of muck. This can sometimes affect the natural drainage pattern of the area leading to accumulation of water or partial flooding of some area which can provide ideal breeding habitat for mosquitoes.
- ❖ A detailed Muck Disposal Plan will be prepared to minimize the impact and addressed in Environmental Management Plan.

e) Road Construction

A network of roads would be required to approach various project components for construction, operation and maintenance. It has been assessed that about 8km length of new road is required to be constructed to access the power house from the lower reservoir and Upper reservoir. The total land required for the construction of new road is 16.38 ha. It is proposed to develop the existing cart track for use of project project roads. As such, no adverse impact is envisaged with road construction.

f) Impact due to Acquisition of Land

For the development of the Bhavali PSP, Approximate land that would be required for construction of project components, reservoir area, muck dumping, construction camps and colony, etc are estimated below. Total land required for the construction of proposed activities is approximately 240.15 Ha.

Major impact of land acquisition is permanent change of land use, which is unavoidable. Additionally, land acquisition has impacts on local population by way of loss of their agriculture land and hence livelihood and also impact on flora and fauna by way of loss of forest land and clearing of vegetation on acquired land. These impacts will be mitigated by implementing Landscaping Restoration and Green Belt Development Plan and Biodiversity Conservation and Wildlife Management Plan, and the detailed study will be taken in EMP studies.

g) Impact on Water Quality

Sewage from Construction Sites due to worker 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 have to be taken to check such disposal into the natural water bodies. In order 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.

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.

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.

h) Impact on Terrestrial Flora

Due to the increased level of human interference in and around the project area will have a major impact on the flora. Tree cutting for fuelwood, construction of houses, furniture by the workers to meet their requirements also impact the flora. Normally in such situations, lot of indiscriminate use or wastage of wood is also observed, especially in remote or inaccessible areas. Thus, it is necessary to implement adequate surveillance to mitigate the adverse impacts on terrestrial flora during project construction phase.

i) Impact on Terrestrial Fauna

Disturbance to Wildlife

During the period of construction, large number of machinery and construction workers are mobilized, which results in the disturbance of wildlife population in the vicinity of project area. The operation of various equipment's will generate significant noise, especially during blasting which will have adverse impact on fauna of the area. The noise may scare the fauna and force them to migrate to other areas. Likewise setting of construction plants, workshops, stores, labour camps etc. could also lead to adverse impact on fauna of the area. During the construction phase, accessibility to area will lead to influx of workers and the people associated with the allied activities from outside will also increase. Increase in human interference could have an impact on terrestrial ecosystem.

The other major impact could be the blasting to be carried out during construction phase. This impact needs to be mitigated by adopting controlled blasting and strict surveillance regime and the same is proposed to be used in the project. This will reduce the noise level and vibrations due to blasting to a great extent.

j) Impact on Noise Environment

Sources of noise will be from the vehicles, heavy machinery and equipment for excavation and stationary equipment, including concrete batch plant located at the construction sites, explosions, drilling machines and quarrying and crushing activities.

k) Impact on Air Quality

The sources and activities that might affect the air quality in the project area are vehicular movement, dust arising from unpaved village roads and domestic fuel burning. The air environment around project site is free from any significant pollution source. Therefore, ambient air quality is quite good in and around the project area.

l) Traffic Analysis

Traffic analysis shall be carried out to understand the existing load carrying capacity of the roads near to the project site and connecting main roads in the area.

m) Impact on Socio-economic Environment

Positive Impacts on Socio-Economic Environment

The following positive impacts are anticipated on the socio-economic environment of the local people of villages of project area during the project construction and operation phases:

- A number of marginal activities and jobs would be available to the locals during construction phase.
- Developer bringing large scale investment to the area will also invest in local area development and benefit will be reaped by locals. Education, medical, transportation, road network and other infrastructure will improve.
- The availability of alternative resources provided by developer in the rural areas will reduce the dependence of the locals on natural resources such as forest.
- With increased availability of electricity, small-scale and cottage industries are likely to come up in the area.
- The proposed project site is well connected by road. Efforts to be made to develop eco-tourism, which could earn additional revenue.

Negative Impacts on Socio-Economic Environment

Positive impact on socio-economic environment may also bring certain amount of negative impact due to influx of outside population. Workforce will reside in that area for around four years and also there will be influx of drivers and other workers on temporary basis. This influx of people in otherwise isolated area may lead to various social and cultural conflicts during the construction stage. Developers need to take help of local leaders, Panchayat and NGOs to ensure minimum impact on this count.

Increased incidence of Diseases

Large scale activity in the area due to the proposed project may become a cause of spread different types of diseases in the project area due to following reasons:

- Project requires long-term input of labour from outside the area.
- Project requires that significant numbers of project employees be separated from their families for long periods of time
- Project involves the creation of large, temporary construction camp(s).
- Increases mobility of people in and out of the area (job seekers, formal and informal service providers).
- Requires participation / resettlement of the local population.

n) Impact During Operation Phase

On successful completion of the construction, land used for construction activities will be restored. Construction workers will move to another project site. By ensuring all the mitigation and management measures to minimize the impact of construction phase, large part of the area will be restored to pre-construction stage. However, there will be some permanent changes such as reservoir formation, powerhouse and project colony. The project is planned as a clean source of renewable energy as there are no significant pollution generation during project operation. There is no air and water pollution from the project operation. Similarly generation of solid and hazardous waste is also insignificant.

Other impacts of the construction phase include formation of reservoir impacting the water quality, pollution generation from colony and plant and positive as well negative impacts on socio-economic environment mainly due to improved infrastructure in the area.

Proposed pumped storage project consists of artificial upper and lower reservoir and water will remain in circulation from upper to lower during power generation and vice versa during non-generation hours on daily basis. Reservoir water requirement will be met once and thereafter only small quantity will be added to compensate for evaporation losses/leakages.

During the operation phase, due to absence of any large scale construction activity, the cause and source of water pollution will be much different. Since, only a small number of O&M staff will reside in the area in a well-designed colony with sewage treatment plant and other infrastructural facilities, the problems of water pollution due to disposal of sewage are not anticipated. The treated sewage will be reused for gardening and green belt around the colony.

15.6 ENVIRONMENTAL MANAGEMENT PLAN

15.6.1 Biodiversity Conservation & Wildlife Management Plan

In view of the anticipated impacts, the main objectives of biodiversity conservation and wildlife management plan shall be follows:

- ❖ Maintenance of ecological balance through preservation and restoration of wherever it has been disturbed due to project developmental activities,
- ❖ Conservation and preservation of natural habitats in catchment and project area
- ❖ Rehabilitation of critical species (endangered, rare and threatened species), with provisions for in situ or ex situ conservation,

- ❖ Mitigation and control of project induced biotic and/or abiotic pressures/ influences that may affect the natural habitats,
- ❖ Habitat enhancement in project area and catchment area by taking up afforestation and soil conservation measures,
- ❖ Creating all round awareness regarding conservation and ensuring people's participation in the conservation efforts and minimizing man-animal conflict

15.6.2 Muck Dumping Plan

The project would generate substantial quantity of muck from the excavation of various structures. The total quantity of muck likely to be generated from excavation including construction of roads after the utilization of muck for different project components and after considering the swell factor of muck the area allocated is about 45.41 Ha has been identified.

15.6.3 Solid waste management from labour camps

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
- ❖ Storage/Segregation
- ❖ Collection and Transportation
- ❖ Disposal

15.6.4 Public Health Delivery System

Medical services at secondary level play a vital and complimentary role to the tertiary and primary health care systems and together form a comprehensive district based health care system. Following activities are proposed:

- ❖ Ambulances with all the basic Medicare facilities and small DG set, etc. to cater for villages in the project area.
- ❖ Budget for running the ambulances including driver, fuel and maintenance.
- ❖ First aid posts including sheds, furniture and basic equipment.
- ❖ Budget for running the first aid post including cost of medico, para-medico/Nurses and attendant, consumables, etc.
- ❖ Budget for strengthening existing medical facilities.
- ❖ Budget for Health Awareness/ Vaccination Camps.

15.6.5 Energy Conservation Measures

Fuel for cooking and space heating is an essential requirement and in the absence of adequate fuel availability they will resort to tree cutting for use of fuel wood. Therefore, adequate arrangements such as Community kitchen, Supply of Kitchen fuel, efficient cooking facilities and Solar Lantern.

Landscaping, Restoration & Green Belt Development Plan

The proposed project would involve construction of artificial reservoir, power house, adits, residential and staff colonies, roads, batching plants, etc. These activities will result either in the modification or destruction of the existing landscape of the area. Therefore, restoration work should be carried out in these disturbed landscape to similar or near-similar pre-construction conditions and land use.

Green belt development will comprise of plantations at various places like alongside roads, around the periphery of reservoir rim, and at different project offices and colonies.

15.6.6 Air & Water Management Plan

Various mitigation and management measures have been planned to reduce the impacts of air, noise and water pollution and implement safety measures to ensure that impacts on these counts are reduced to minimum possible during the entire construction phase. To implement such measures, it is important to prepare a budget of such measures and include in the project cost so that lack of fund should not constrain their implementation.

Cost for mitigation measures and monitoring of Air, Water and Noise quality in the project area will be covered under Environmental Monitoring Plan.

15.6.7 Environmental Monitoring Plan

Monitoring shall be performed during all stages of the project (namely: construction and operation) to ensure that the impacts are no greater than predicted, and to verify the impact predictions. The monitoring program will indicate where changes to procedures or operations are required, in order to reduce impacts on the environment or local population. The monitoring program for the proposed project will be undertaken to meet the following objectives:

- ❖ To monitor the environmental conditions of the project area and nearby villages;
- ❖ To check on whether mitigation and benefit enhancement measures have actually been adopted and are proving effective in practice;

CHAPTER - 16 COST ESTIMATE

16.1 GENERAL

The Bhavali PSP project is located between Jamunde Village in Nashik and Kalbondhe Village of Thane districts, Maharastra on the tail end of Bhavali Dam constructed on Darna river. It is envisaged to utilise the inflows from the of Bhatsa Dam near for the proposed PSP scheme.

The proposed Pumped Storage project envisages utilization of available head between newly constructed upper reservoir and lower reservoir. An Underground Power House (UGPH) will be located in between two reservoirs. Both the reservoirs are interconnected through water conductor, generator and turbines installed at the power house in between the reservoirs.

16.2 BASIS OF PROJECT COST

The cost of the project has been worked out on the basis of preliminary designs and drawings as referred and annexed in 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 Maharastra and local prevailing rates are adopted for the items not covered by the SSR wherever quantification has not been possible at the present stage of design, lumpsum provisions have been made based on judgement / experience of other projects.

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

A. Direct Cost

I. 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

B. Indirect Cost

Capitalization of Abatement of Land Revenue

Audit and Account Charges

Total (B) - Indirect Cost

Total Cost (A+B)

16.3 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 are likely to undergo changes like additional cost to be incurred due to changes at the detailed design stage specially 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

BHAVALI PSP					
GENERAL ABSTRACT					
Sl No.	**Head of A/c**	**Particulars**	**Cost of Civil works in Lakhs**	**Cost of Electrical works in Lakhs**	**Total Cost in Lakhs**
		A. Direct Cost			
	I	**I WORKS**			
	A	Preliminaries:	3430.00		3430.00
	B	Land:	5040.00		5040.00
	C	Works: Upper dam & Lower dam	45029.97		45029.97
	J	Power Plant Civil Works:			
		1. U/S Intake	4126.15		4126.15
		2. D/S Intake	6177.18		6177.18
		3. HRT	47252.19		47252.19
		4. Power House	13873.95		13873.95
		5. Pressure Shaft	11424.00		11424.00
		6.TRT	15276.86		15276.86
	K	Buildings:	2870.00		2870.00
	M	Plantation: Site Plantations	200.00		200.00
	O	Miscellaneous: Telephone, O & M of inspection vehicles etc.,	2925.00		2925.00
	P	Maintenance: Maintenance charges during construction	1470.00		1470.00
	Q	Special Tools and Plants	200.00		200.00
	R	Communications: Service Roads	3136.00		3136.00
	X	Environment & Ecology	12000.00		12000.00
	Y	Loss on stock: @ 0.25% on total	365.08		365.08
	S	Power Plant Electrical Works		232500.00	232500.00
		Infrastructure Development for Power Evacuation		12500.00	12500.00
		Cost of infrastructure for Pumping and other miscellaneous works	4000.00		4000.00
		Total I-Works	**178796.37**	**245000.00**	**423796.37**
	II	Establishment Charges Civil – Rs. 90.00 Crores plus 3.00% of cost exceeding Rs. 1500 Crores E&M – Rs. 67.50 Crores plus 2.25% of cost exceeding Rs. 1500 Crores	9863.89	8887.50	18751.39
	III	Tools & Plants: Ordinary T & P @ 1% of I – works less B-land	1737.56	2450.00	4187.56
	IV	Suspense	NIL	NIL	NIL
	V	Receipts & Recoveries: Q – Special Tools & Plants @ 15% of capital cost	-30.00	0.00	-30.00
		Sub Total (A)	**190367.83**	**256337.50**	**446705.33**
		B. Indirect Charges			
		Audit and Accounts @ 0.5% of I Works	500.00	612.50	1112.50
		Sub Total (B)	**190867.83**	**256950.00**	**447817.83**
		GST @ 12 %	22904.14	30834.00	53738.14
		Sub Total '(C)	**213771.97**	**287784.00**	**501555.97**
		Price Escalation	14551.98	0.00	14551.98
		GST @ 12 % on Price Escalation	1746.24	0.00	1746.24
		Sub Total (D)	**230070.19**	**287784.00**	**517854.19**
		Interest During Construction			**54476.66**
		Total Project Cost			**572330.84**

A-Preliminary: INR (3430 Lakhs.)

This head covers the provision for the Surveys and investigations like topographical survey, geological/geotechnical investigations. Construction material availability, route survey, Construction of access roads/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 (5040 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 5040 Lakhs has been made under this head.

C– Works: INR (45029.97 Lakhs.)

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

J – Power Plant Civil Works: INR (98130.33 Lakhs.)

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

K – Buildings: INR (2870.00 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 plinth area basis for the type of construction involved as per prevailing rates in project area.

M – Plantation: INR (200 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 structure. The provision is made on the lump sum basis.

O– Miscellaneous: INR (2925.00 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 (1470.00 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 (200 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 (3136 Lakhs.)

The cost is based on the construction cost of road and bridges in similar area 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 with in project area, widening, strengthening of existing road.

X– Environment and Ecology: INR (12000 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 (365.08 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 (18751.39 Lakhs.)

Provision for establishment has been made Civil – Rs. 90.00 Crores plus 3.00% of cost of I-works minus 1500 Crores if exceeding Rs. 1500 Crores. E&M – Rs. 67.50 Crores plus 2.25% of cost of Electrical works under I-works minus 1500 Crores if Electrical works exceeding Rs. 1500 Crores.

III– Tools and Plants: INR (4187.56 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.

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 (-30 Lakhs)

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

16.4 ELECTRICAL WORKS AND GENERATING PLANT INCLUDING TRANSMISSION LINE

S-INR (245000.00 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.

16.5 PROJECT COST

The total project cost has been estimated at 572330.84 Lakhs at June 2021 price level as given below:

SI.No.	Component	Cost In Lakhs.
1	Civil and HM Works	230070.19
2	E&M Works	287784.00
3	**Total Hard Cost**	**517854.19**
4	**IDC**	**54476.66**
	Total Project Cost (INR Cr.)	**5723.30**

CHAPTER - 17 ECONOMIC EVALUATION

17.1 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 benefits. The economics of the project, where existing facility is required to meet the demand could be computed considering system requirements and the ability of the scheme for meeting the demand. When a Hydro 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 Bhavali 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.

17.2 GENERATION BENEFITS FROM THE PROJECT

In a year, the planned power generation will be 3820 MU considering the rate of 7.34 hours per day for 365 days operation @ 95% machine availability.

17.3 ANNUAL REQUIREMENT OF PUMPING ENERGY

The input energy required for pumping works out to 4647 MU for 365 days operation @ 95% machine availability.

17.4 PROJECT COST

The total project cost has been estimated at 5723.30 Crore at June 2021 price level as given below:

SI.No.	Component	Cost In Lakhs.
1	Civil and HM Works	230070.19
2	E&M Works	287784.00
3	**Total Hard Cost**	**517854.19**
4	**IDC**	**54476.66**
	Total Project Cost (INR Cr.)	**5723.30**

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**"), repayment 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.

17.5 PHASING OF EXPENDITURE

The project is scheduled to be completed in 36 months in all respects excluding pre construction period of 3 months. The phasing of the expenditure worked out on the basis of proposed construction programme is summarized in ***Table 28***.

Table 28: Phasing of Expenditure

6 Monthly Phasing	Capital Expenditure (Crores)
Pre Construction	164.66
6	637.38
12	780.61
18	911.91
24	818.23
30	880.55
36	985.75

17.6 INTEREST DURING CONSTRUCTION

Interest charges during construction would depend on phasing of expenditure. IDC has been considered for scheduled completion period of 36 months excluding preconstruction period. The Interest during Construction period is expected to be Rs.544.77 Crore.

17.7 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.

17.8 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 @ 4.47% 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 – 16.50%
- Auxillary consumption – 1.20%
- Charges for pumping energy – Rs 3.0 per unit; Rs 2.0 per unit; Rs 1.0 per unit and Free power

Table 29: Levellised Tariff

1	Conversion Cost (Excluding pumping cost)	
	Levellised Tariff	Rs 2.71/- per unit
2	Conversion Cost (Including pumping cost)	
	Levellised (At Rs 1.0, Pumping cost)	Rs 3.97/- per unit
	Levellised (At Rs 2.0, Pumping cost)	Rs 5.22/- per unit
	Levellised (At Rs 3.0, Pumping cost)	Rs 6.47/- per unit

CHAPTER - 18 CONCLUSION AND RECOMMENDATION

The present report summarizes the findings and outcome of the Feasibility stage study are as follows.

- Bhavali PSP will be constructed between Janunde and Kalbondhe village of Igatpuri and Shahpur Tehsil respectively in Maharastra state.
- The pumped storage scheme is developed between two newly constructed upper and lower reservoirs
- The upper reservoir is proposed with FRL of EL +745.0m and MDDL of EL +728.0m; The lower reservoir is developed with FRL of EL +300.0 and MDDL of EL+270.0m.
- The live storage capacity of these reservoirs is at 0.35 TMC. One time filling of the upper reservoir is carried out from self catchment c lower reservoir.
- 1500MW of peak hour energy will be generated using the water by recirculation. Also being pumped project no adverse impact is envisaged in hydrological regime of Nallah.
- The power house and the associated components are proposed underground.
- Based on the preliminary geological studies, no adverse geological conditions are envisaged for reservoirs and underground works.
- Being a compact project with construction of upper reservoir at hillock, the project infrastructure facilities are confined to about 224 Ha.
- The construction period works out to three years excluding pre construction activities of 3 months.
- Based on preliminary engineering and costing the total project cost works out to 572330.84 Lakhs (5723.30Cr). The per MW cost is approx. 3.85 Cr.
- The levellised tariff works out to INR 6.47/- per unit with Rs 3.0/- per unit for pumping energy and considering various financial assumptions. However, tariff can be reduced by following ways, which will be explored at next level of study in consultation with the project developer:
    - Possibility of getting interest concession.
    - The developer may spend the equity first and then loan to minimize interest during construction.
    - Possibilities of reduction in interest rate after completion of project as risk reduces thereafter.
    - Reduction of O&M charges

- Longer loan repayment period
- Possibility of getting Off-Peak energy for Pumping at Lower Rate by exploring other Non-Conventional/Renewable source.

Following points may also be considered during assessing of the feasibility of the proposed PSP:

- Curtailment/ reduction of energy generation from thermal and fossil fuels to reduce the carbon foot prints considering the climate changes and therefore promoting the renewable energy.
- Pump storage schemes as a renewable source provides ancillary services to stabilize the grid.

BASED ON THE FINDINGS OF THE PRE-FEASIBILITY STUDY, THE PROJECT IS RECOMMENDED FOR FURTHER STUDY AT DETAILED PROJECT REPORT STAGE.