Arun-3 Hydropower Project (Roshan Sahani)

- **Introduction:**

The **Arun-III hydroelectric power plant** is a **900MW** run-of-the-river hydropower project under construction in Nepal. Scheduled for commissioning by 2024, it will be the **most extensive crucial hydroelectric facility** in the South Asian country.

❖ History:

SJVN was established in 2013 to plan, promote, organize and execute the Arun-III power plant. SJVN signed a Memorandum of Understanding (MoU) to run the project with the Government of Nepal (GoN) in March 2008. The Ministry of Science, Technology & Environment, GoN, approved the environmental assessment report for the project in August 2015. The hydropower plant construction commenced in May 2018, and completion is scheduled for 2023.

❖ Objectives:

The principal objective of SAPDC is to Plan, Promote, Organize and Execute the **900 MW Arun-3 Hydro-electric Project**. The Project Development Agreement (PDA) was signed on 25.11.14 between the Investment Board of Nepal (IBN), GoN, and SAPDC. This project is also an export-oriented project that is expected to generate **3000 jobs** during its construction phase in Nepal and India. SJVN would operate the power plant for a concession period of 30 years; then, the ownership would be transferred to the GoN.

- ## Basis of operation:

SJVN Arun-III Power Development Company (SAPDC), a wholly-owned subsidiary of India's Satluj Jal Vidyut Nigam (SJVN), is developing the project on a **Build-Own-Operate-Transfer (BOOT)** basis. SVJN is a joint venture between the Government of India and the Government of Himachal Pradesh.

SAPDC will operate the facility for **25 years**, excluding the construction period of five years, before transferring the ownership to the Nepal government.

Nepal will receive **21.9%** of the electricity generated at the power plant as free power during these initial 25 years of commercial operations.

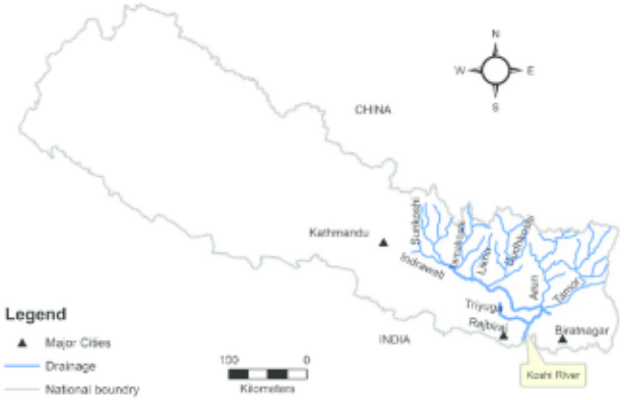
एसजेवीएन
SJVN

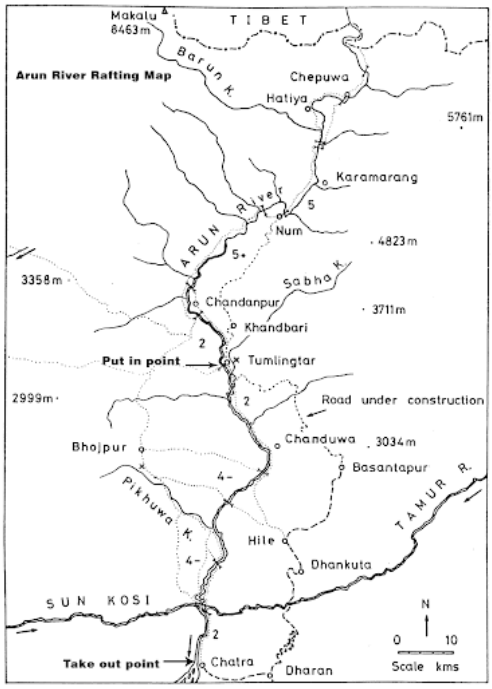
SJVN LIMITED
(A Joint Venture of Govt.of India & Govt. of Himachal Pradesh
A 'Mini Ratna' & Schedule 'A' PSU | ISO 9001:2015 Certified Company
CIN: L40101HP1988GOI008409

- **Salient Features:**

  - **Location** :

    The project is being constructed in the **Arun tributary** of the **Koshi River** in **Eastern Nepal,** in the **Sankhuwasabha district**. The nearest railway head being Jogbani, Bihar (B. Gauge), about 800km from the project site, with an airport being at Tumlingtar, about 70km from the site.

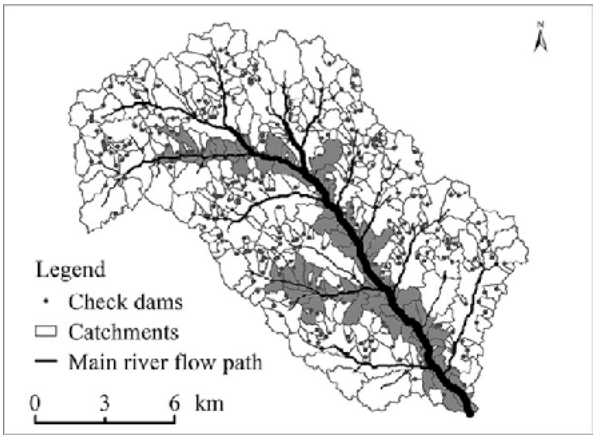




❖ Hydrology:

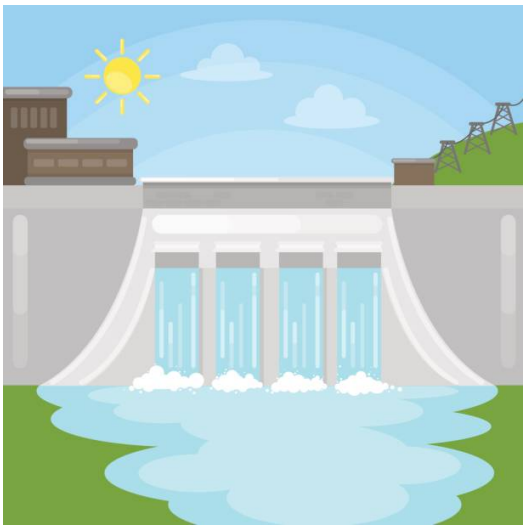
According to Wikipedia, "*Hydrology is the scientific study of the movement, distribution, and management of water on Earth and other planets, including the water cycle, water resources, and environmental watershed sustainability*." Its study includes:

- **Catchment area**- Catchment area is the whole area behind the dam, draining into a stream or river across which the dam has been built. The catchment area at the diversion site of Arun-3 Hydropower Project is 26747 sq. km.



- **Design flood**- Design flood denotes the maximum flood flow that could be passed without damage or severe threat to the stability of structures like dams. It is used to ensure the safety of the barrier against possible outbursts. This includes the study of PMF and GLOF.
    - PMF: PMF refers to Probable Maximum Flood. The flood can be expected from the most severe combination of critical meteorological and hydrologic varieties that are reasonably possible. The PMF for the Arun-3 Hydropower is found to be 8880 cumecs.
    - GLOF: GLOF refers to Glacial Lake Outburst Flood. It is caused due to failure of a dam containing a glacial lake. The GLOF capacity for Arun-3 Hydropower is 6830 cumec.

❖ Reservoir



A hydroelectric reservoir is an extensive collection of water behind a hydroelectric dam that uses the potential energy of water to generate electricity. This water is held back by the dama and can fall to generate electricity when needed.

- ➢ The whole Reservoir Level (FRL) is the highest reservoir level that can be maintained without passing water downstream through sluice (device for controlling water flow) ways. The submergence area at FRL is 66.3 ha (hectare). The reservoir capacity at FRL is 13.94 MCM (Million Cubic Meter). The elevation of FRL is 845 m.

- ➢ Maximum Water Level (MWL) - This is the water level that is likely to be attained during the passage of the design flood. It depends upon the specified initial reservoir level and the spillway gate operation rule. This level is also called the Highest Reservoir Level or the Highest Flood Level. The elevation of MWL is 847.73 m.

- ➢ Minimum Draw Down Level (MDDL) - The level below which the reservoir will not be drawn down. It maintains a minimum head required in power projects. The elevation of MDDL is 835 m.

- ➢ Inactive/Dead Storage (Below MDDL)- Inactive/Dead Storage is the reservoir capacity exclusive of and above

the dead ability. The stored water usually is not available because of operating agreements or physical restrictions. The slow storage capacity is 8.29 MCM.

- ➢ Active/Live Storage – The total amount of reservoir capacity available for release from a reservoir below the maximum storage level. It is total reservoir capacity minus inactive storage capacity. More specifically, it is the volume of water between the outlet works and the spillway crest. The active storage capacity is 5.65 MCM.

❖ Diversion Tunnel

A diversion tunnel is either a permanent or temporary tunnel built to divert something away from something else. The tunnel in this project is **429 m long**, with a **diameter of 11 m** capable of shifting **1300 cumec** of water away from the reservoir.

https://www.engr.psu.edu/ce/courses/ce584/Shotcrete/case%20study.html

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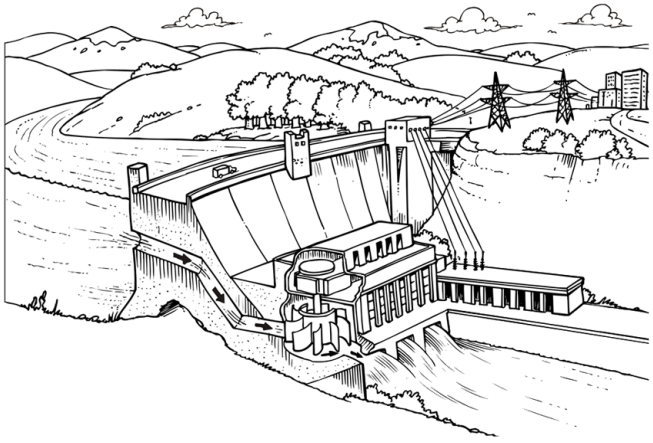
❖ Dam

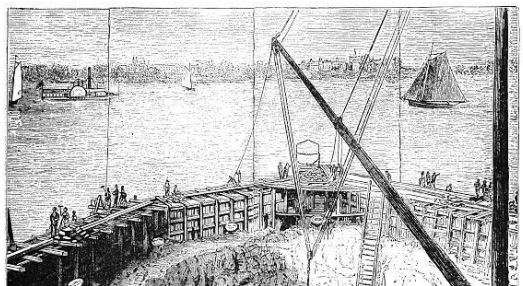
A concrete gravity dam is built for this hydropower project. A gravity dam is a structure designed to withstand loads by weight and resistance to sliding and overturning on its foundation. The barriers of this type are typically composed of unreinforced concrete.



The topmost level of the damn is call crest level. The components like railway track, roadway for vehicle movement are placed here. The elevation of the top level of the dam is 849m.
The bottom-most level of the river at the point where the dam is built is called river bed level. The elevation of the river bed level is 790m.

The height of the dam above the river bed is 59m. Since a barrier is a massive structure, the foundation should be technically sound to sustain the high stresses caused due to various factors. The elevation of the deepest foundation level is 769m. The height above the deepest foundation level is 80m. The length and width of the dam at the top are 233m and 7m.

❖ Cofferdam

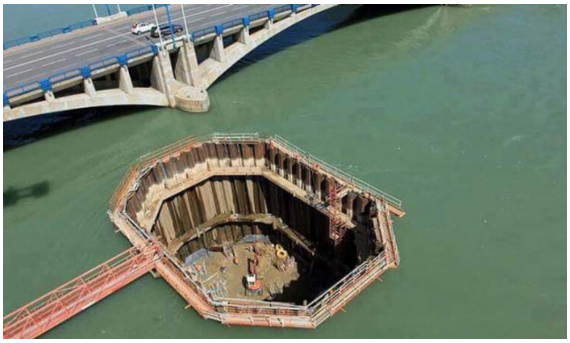


According to Wikipedia, "*A cofferdam is an enclosure built within a body of water to allow the enclosed area to be pumped out. This pumping creates a dry working environment so that the work can be carried out safely.*"

During the Arun-3 Hydropower dam construction, two cofferdams are constructed, one upstream and one downstream.

a. Upstream Coffer Dam:

In this project, the upstream cofferdam is constructed as a concrete dam with its top-level at El 818 m at the height of 27 m and its length measuring 108m.



b. Downstream Coffer Dam:

It is constructed as a rockfill dam with its top-level at El 794.25 m and its height 5.25 from the river bed, and its length 70.64m.

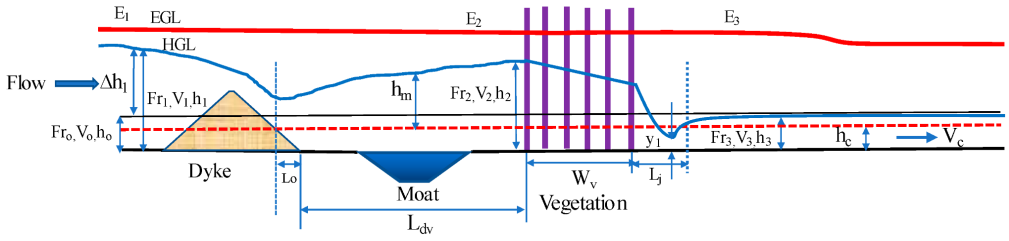
❖ Spillway

According to Wikipedia, "*A spillway is a structure used to provide the controlled release of water from a dam or levee downstream, typically into the riverbed of the dammed river*

itself. In the United Kingdom, they may be known as overflow channels."

Design flood: It denotes the maximum flood flow that could be passed without damage or severe threat to the stability of structures like dams. The Probable Maximum Flood (PMF) of this site is 8880 cubic meters per second. PMF is mainly used as a security assessment for existing barriers to avoid dam failures and catastrophic floods. The Glacier Lake Outburst Flood (GLOF) of this site is 6830 cubic meters per second.

Energy Dissipation System: As water passes over a spillway and down the chute, potential energy converts into increasing kinetic energy. Failure to dissipate the water's power can lead to scouring and erosion at the dam's toe (base). This can cause spillway damage and undermine the dam's stability. Thus, the trajectory bucket system (SKY JUMP) is used as an energy dissipation system. It is used to advantage when the river bedrock is too weak to withstand a roller action.

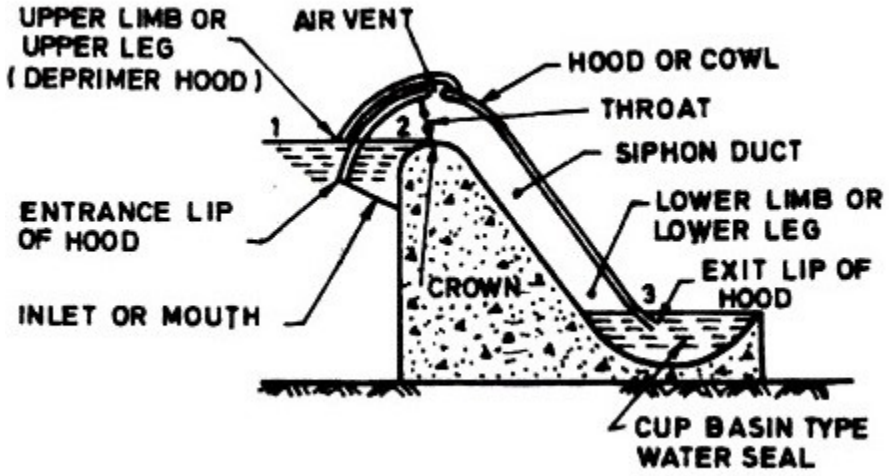


The two spillways present in this dam are:

a. Sluice Spillway:

There are five sluice spillways in this project, each of width 9m and height of 14.85m. The crest level of this spillway is El. 795 m.

b. Overflow Spillway:



This spillway acts as a safety valve on a dam and is designed to safely pass a large amount of water. A single overflow spillway is provided with a width of 5m and a height of 3 m. The crest level of this spillway is El. 842 m.

Crest level: The topmost level is kept a little above the maximum reservoir water surface. The FRL is at the crest level of the spillway. The elevation of the crest level of the sluice gate is 795m, and the overflow spillway is 842m.

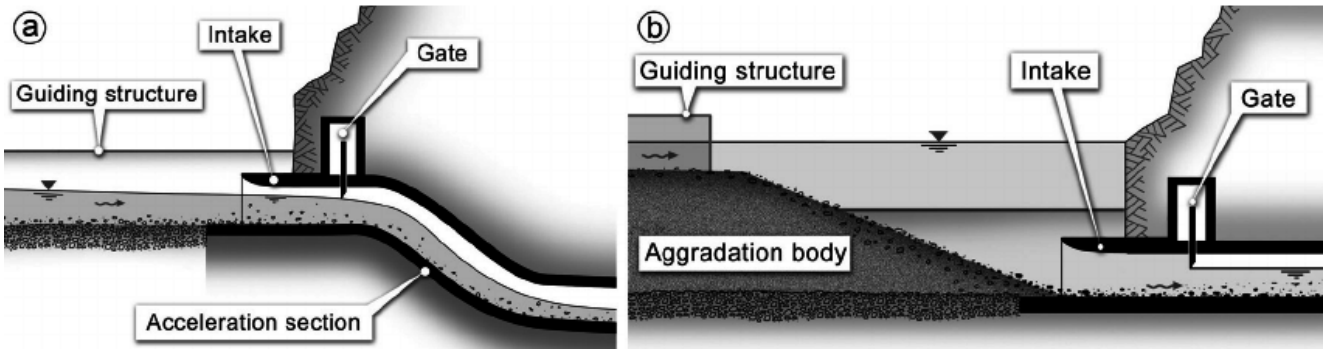
❖ Power Intake:

The type of power intake used is straight intake with bell mouth. There will be two intakes used. Intake structures are used to withdraw water from rivers or reservoirs. These intakes can create swirling flows, leading to air-entraining vortices and

increasing head loss. This situation can be avoided through proper intake design, including a sufficient entry size and submergence depth. The elevation of the essential top-level is 849m, and the height of the invert level is 819m.

❖ Intake Tunnels

Intake tunnels are used to safely withdraw water from the reservoir and discharge it into the hydroelectric plant. Two tunnels, horseshoe-shaped, having a diameter of 7m, are built for power intake. Their length is 231 m each, and the Ceiling Level (C.L) of the intake tunnel is El. 822m.

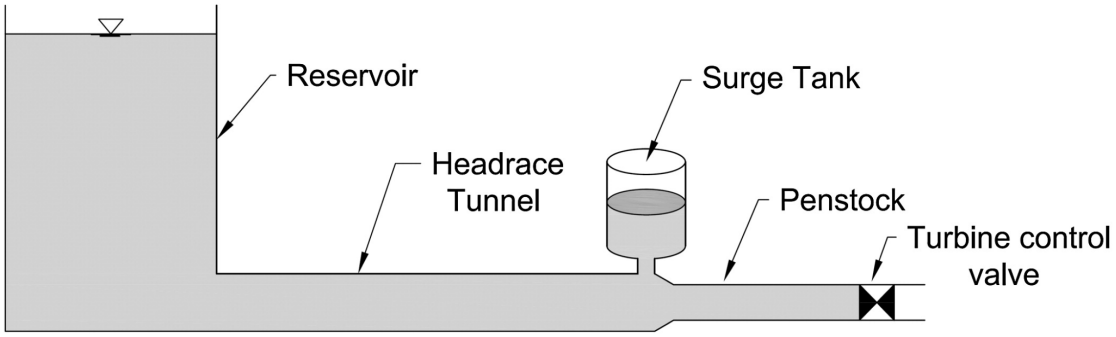


❖ Head Race Tunnel

HRT can be defined as a structure that carries water from intake to the powerhouse for energy generation. The tunnel is horse-shoe-shaped with a diameter of 9.5m. The length of this tunnel is 11837m and is capable of discharging 344.68 cumecs

of water. This tunnel consists of 4 adits (a horizontal tunnel) of width 4m and height 4m. The specifics of the adit is given below:

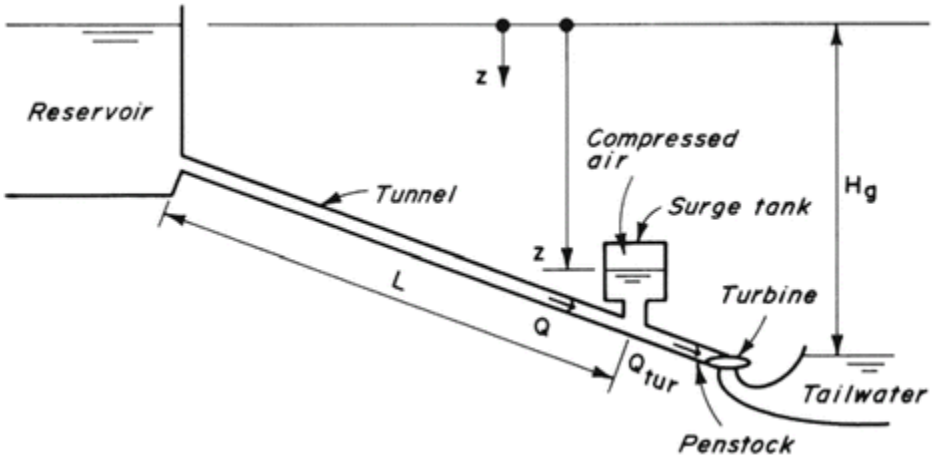
Adit	Adit Length	RD of HRT	Distance between Adits
1	504m	790m	
2	683m	5156m	4366m
3	387m	8272m	3116m
4	333m	11786m	3514m



❖ Surge Shaft

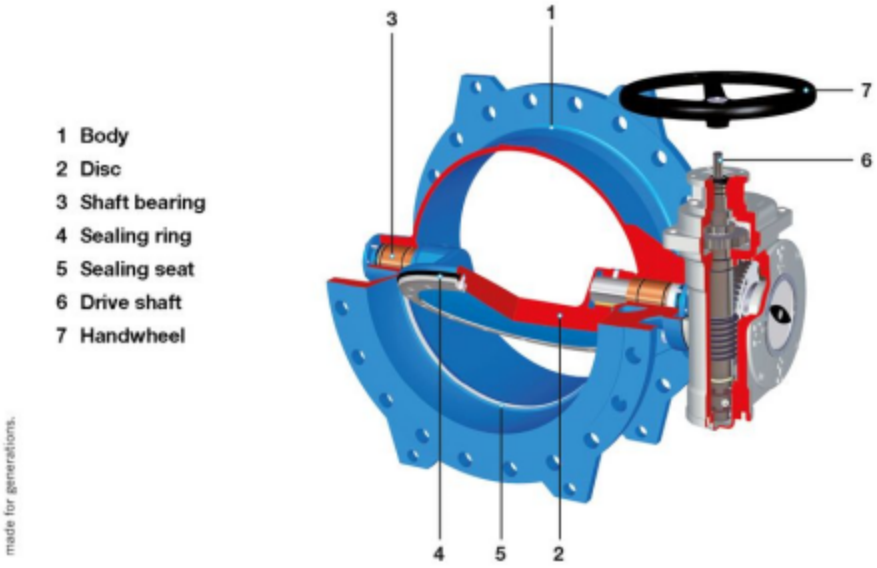
The surge shaft is an important component of a hydropower project. It is provided at the end of the headrace tunnel to

account for the water hammering effect. It dissipates the water inertia preventing the pipes from bursting and thus makes the project stable. The surge shaft is above the ground and consists of a restricted orifice. It is circular and has a diameter of 24m. Its height is 155 m, and the elevation of its top is El.946. It has two gates, each of width 5.5 m and height 5.5m.



❖ Butterfly Valve Chamber

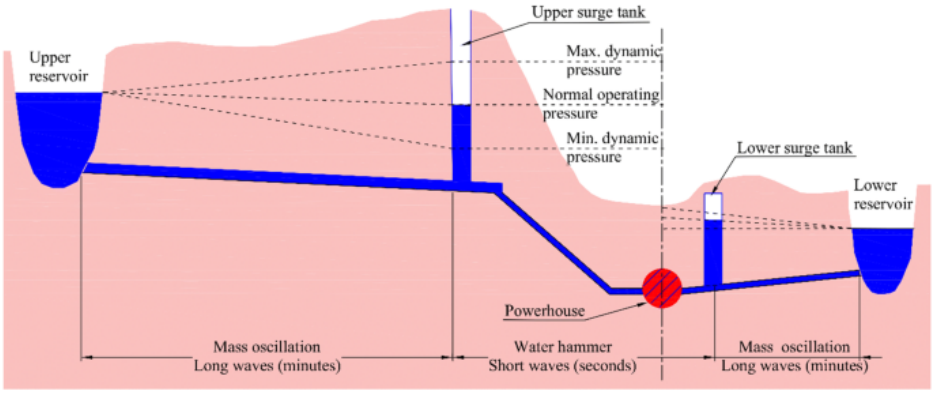
According to Wikipedia, "*A butterfly valve is a valve that isolates or regulates the flow of a fluid. The closing mechanism is a disk that rotates.*"



Butterfly valves are generally favored because they are lower in cost than other valve designs and lighter in weight, meaning less support is required. The disc is positioned in the center of the pipe; passing through the disc is a rod connected to an actuator outside the valve.
Two butterfly valves of a diameter of 5.5m are used in the chamber. The size of this chamber is 83.05m (Length) * 12m (Width) *21m (Height)

❖ Pressure Shaft

Pressure shafts are underground circular openings like tunnels in which a fully pressurized flow of water is expected, like in pipes. They can be simply realized as pressurized headrace tunnels but with smaller diameters and more excellent slopes. In hydropower projects, it is used to transport water from the source to the powerhouse where turbines are located.



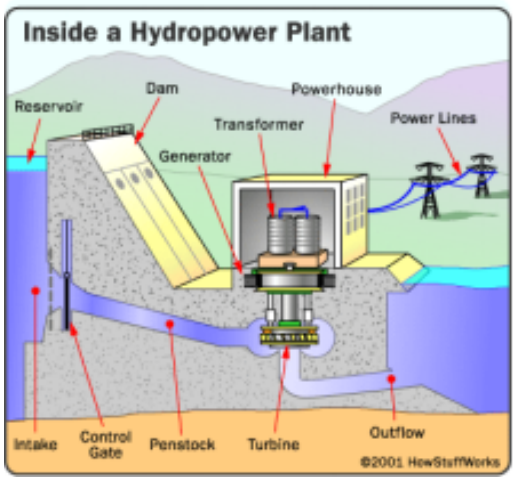
There are two pressure shafts each, circular and 5.5m in diameter. Each of the shafts bifurcates into two pipes of 4m diameter. The length of the post differs from each other. However, the size of the branches is the same.

Pressure Shaft	Length
Pressure Shaft-1	432 m
Pressure Shaft-2	404 m
Branch-1	70 m
Branch-2	58 m
Branch-3	70 m
Branch-4	58m

❖ PowerHouse complex

The powerhouse of a hydroelectric development project is where the potential and kinetic energy of the water flowing through the water-conducting system is transformed into mechanical energy of rotating turbines and further converted to electrical power by generators. The powerhouse complex built

is underground on the left bank. It is situated in the far downstream area. The cavern is of length 179.50 m, width 22.5 m, and height 49.5 m.



The planned elevation between the free level of a water supply and the point of free discharge or the level of free discharge surface is called the design head. For this project, the design head is 286.21 m.

The total vertical distance between the turbine and the inlet is called the gross head. The awful head for this project is 307.67m.
There are four turbines in this project which are Vertical Francis turbines, each of 225MW. The turbine's rated speed is 250rpm (rotation per minute) and can generate a total voltage of 15.75KV (Kilo Volt). Twelve single-phase transformers are used in this project, each of 92MVA (Mega Volt Amperes).

The elevation of the various floors of the powerhouse complex is shown in the table below:

Floor Level	Elevation
Service Bay Floor Level	*El.* 539m
Generator Floor Level	*El.* 534m
Turbine Floor Level	*El.* 529m
Distribution Centre Line Level	*El.* 525m

MIV(Main Inlet Valve) Floor Level	*El.* 520.5m
Maximum Tail Water Level	*El.* 536.46m

❖ Transformer Hall

The size of the transformer hall is 146.14 m (Length) * 16 m (Width) * 23 m (Height). The elevation of the transformer hall level is 552m. The volume of water that passes through a hydroelectric power plant per unit time is called discharge. The design discharge per unit is 86.17 cumec. The energy generated in a 90% dependable year is 3924.03 MU (Mega Unit). The ratio of the mean load to the maximum load for a specific period is called the load factor. The formula gives it.

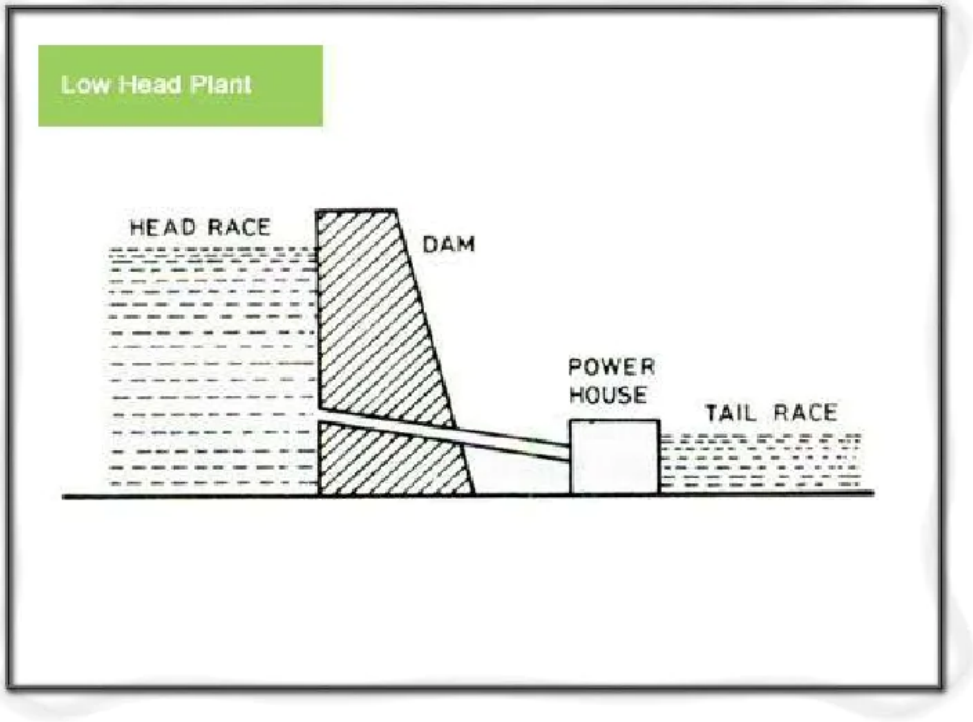
$$Load\ Factor\ (\%)\ =\ \{Mean\ load\ (KW)/Max\ load\ (KW)\}\ *\ 100$$

The annual load factor is found to be 50.98%. Also, the weighted average efficiency of the TG Set (Turbine-Generator) is 93%.

❖ Tail Race Tunnel

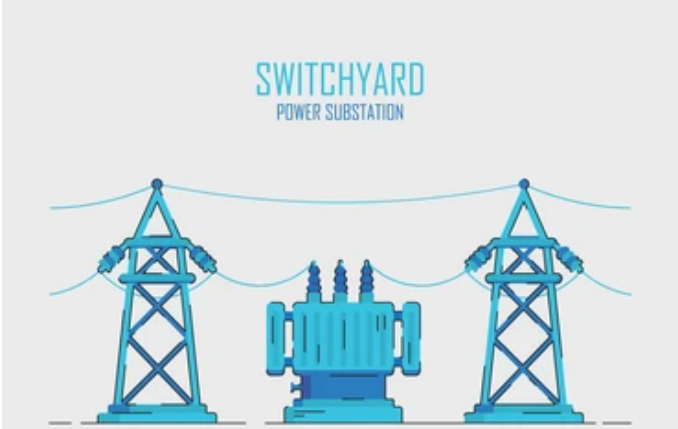
The tailrace, containing tailwater, is a channel that carries water away from a hydroelectric plant. The water in this channel has already been used to rotate turbine blades or the water wheel itself. This water has served its purpose and leaves the power generation unit or water wheel area. In hydroelectric dams, the tailrace is at a much lower level than the height of the reservoir

behind the dam. Water flowing from a hydroelectric plant in the tailrace eventually joins the natural flow of water.
There is only one tailrace tunnel horseshoe-shaped, having 10m diameter and 151.97m length.



❖ Switchyard

Switchyard is the point of power network where the transmission lines and generating



units are connected through circuit breakers and other switchgear via bus bars and transformers. It acts as an interface between the power plant electrical system and the tailrace electrical grid. In this project, the switchyard is of the length of 160m and width 80m and is at an elevation of El 557 m.

- **Physical Progress Till Date (*31st May 2021*)**

- **Major Civil Works**

➔ <u>Package-C1</u>

- Workforce: 1266 staffing is used.
- Machinery: The major equipment such as four boomers, 8 ROC's, 4 shot Crete machine, 2 Batching plants (30 Cum/H), 1 Crusher plant of 50 TPH & 2 of 10 TPH, 9 DG Sets, four concrete pumps, nine grout pump, eight compressors, 18 excavators, 3 JCB Excavator, 52 dumpers, seven dozers, three wheel loaders, six cranes, etc. are available at the site.

- Progress:

Description	Total Qty.	Unit	Comm. Progress up to May 2021	Balance Qty.
HRT through Adit-1(D/s face Heading Exc.)	**2310**	m	1613	697
Adit-1 HRT U/s Benching Exc.	**790**	m	744	46
Kerb Concrete-Left Side	**790**	m	744	46
Kerb Concrete – Right Side	**790**	m	744	46

Coffer Dam	**45000**	Cum	-	1500
Dam Stripping (On Right Bank)				
Up to deepest foundation level i .e. EL-769m	**19,41,765**	Cum	1581960	359805
Dam Stripping (On Left Bank)				
Up to deepest foundation level i.e EL 769m	**6,01,227**	Cum	243700	357527

➔ <u>Package-C2</u>

- Workforce: 1243 workforce is used.
- Machinery: The major equipment such as eight boomers, 5 ROC's, two raise climbers, 1 Gantry Crane (10m Span 151), 15T, six concrete pumps, 8 shot Crete machines, 5532 kVA DG sets, 14 compressors, 15 excavators, 5 JCB excavator, five batching plants (30 cum./ hr.), seven grout pumps, three loaders, four-wheel. Loader, 39 dumpers, etc., are available at the site.

- Progress:

Description	Total Qty.	Unit	Comm. Progress up to May 2021	Balance Qty.
Adit-2 U/s HRT Heading etc.	2056	M	518	1538
Adit-2 D/s HRT Heading etc.	1558	M	1066	492
Adit-2 D/s Benching	1558	M	102	1456
Adit-3 U/s HRT Heading etc.	1558	M	528	1030

Adit-3 D/s HRT Heading ex.	1757	M	445	1312
Adit-4 U/s HRT Heading exc.	1757	M	578	1179
Adit-4 U/s HRT Benching	1757	M	180	1577
Butterfly Valve Chamber Crown excavation from EL 801.1 to 779.7 m	18384	Cum.	12976	5408
Excavation of Chamber at bottom Penstock	83	M	52	31
Branch 2 at bottom pressure shaft	58	M	28	30
Vertical Pressure Shaft-1(Height)	250	M	25	225
Bus Duct No-1	50	M	39	11
Bus Duct No-2	50	M	43	7
Bus Duct No-3	50	M	50	NIL
Bus Duct No-4	50	M	42	8
Escape Tunnel -2	102	M	23	79
Escape Tunnel -1	50	M	4	46
Collection Gallery	83	M	34	49
Transformer Hall Benching from EL 575 to 551 m	56800	Cum.	56050	750
Machine Hall Benching	1,45,000	Cum.	97200	47800
Draft Tube-2	118	M	17	101
Surge shaft Pilot Exc. from bottom	155	M	136	19

Coffer Dam: The work of the Cofferdam was temporarily closed until the restoration of dyke.

Dam Stripping:

Right Bank: Mucking from El 880 to 870 m, 870 to 830 is in progress. Bench drain at El 880 m is in progress. Supporting work between EL 875 to 870 between Ch u/s 30 to u/s 15 is in progress. R.C.C cladding wall between Ch d/s 155 to d/s 190 & between Ch D/s 120 to d/s 135 is in progress.
Left Bank: Excavation work EL 844 to 815 from Ch. U/S 15 to D/S 120 m is in progress.
Head Race Tunnel (HRT): The excavation complete progress is up to El 5589m.

Cumulative HRT Heading Excavation (PKG C-1 & PKG C-2)

Description	Total Qty.	Unit	Comm. Progress up to May 2021	Balance Qty.
TOTAL	11837	m	5589	6248

- **ELECTRO-MECHANICAL WORKS**

The designs and drawings approval is in progress. Spiral inlet pipe unit-1 MDCC is issued. Material has been received at the site. PowerHouse EOT Crane has been transported to a warehouse of BHEL in the Nepal side. Further transportation is held up due to Covid-19 lockdown. DT cone and DT liner of Unit-1 & 2 are under inspection and dispatched. Unit-1

assembly of the stator with its soleplate is done, and unit -2 Fabrications has been started. Unit-1 Rotor machining is in progress, and unit-2 fabrication has been created. Site enabling store has been developed. The indoor plants' store foundation and the plinth have been set. As approved by IBN, PEB Structure and other T&P items are held for transportation from Siliguri due to the Covid-19 lockdown.

- **HYDRO-MECHANICAL WORKS**

The Materials Quality Assurance Procedure (MAP) has been approved. The design and drawings, as well as the .manufacturers, have been approved. The fabrication has been completed, and the item reached Itahari, Nepal.

- 1st stage Embedded parts: Draft tube Gate, Stop log for Spillway Flap Gate, Intake Bulkhead gate, Main Intake Gate, Adit Gate & Trash rack panels, Surge Shaft gate, Spillway Flap Gate, Tailrace Outfall gate

- 2nd stage Embedded Parts: Main Intake Gate & Stop log for spillway flap gate, Bulkhead for Main Intake Gate, Draft tube gate, Surge Shaft Gate.

- Gate Assembly: Trash Rack Panels-64 no’s, Main Intake Gate, Bulkhead for Main Intake, Stop log for spillway Flap Gate, Surge Shaft gate & Tail race Outfall gate.

- Steel Liner: Surge Shaft gate & Main Intake gate.

- Air vent pipe for Draft tube Gate

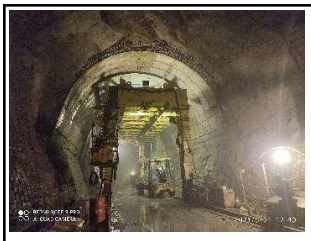
- Instrumentation pipe for Draft Tube gate

● Under Progress:

- 2nd stage Embedded Parts: TRT Gate, Spillway Flap Gate, Adit Gate.
- Gate Assembly: Spillway, The indoor Flap Gate, Adit Gate
- Rope Drum Hoist assembly: Mechanical components of Main Intake Gate & Draft Tube Gate

Image Gallery

			
Coffer Dam Damaged due to unprecedented High Flow	Coffer Dam concrete work	Right Bank Dam Stripping	Left Bank Dam Stripping

			
Y-Junction	HRT Face-2 Heading	HRT Face-3 Heading	HRT Face-4 Heading
			
HRT Face-5 Heading	HRT Face-6 Heading	HRT Face-7 Heading	Bifurcation Facility Area
			
SS Pilot Hole Exc. From Top	Surge Shaft Pilot Hole at Bottom	BVC Exc.	Machine Hall Exc.
			
Transformer Hall Exc.	Bus Duct-1	Bus Duct-2	Bus Duct-3
			
Bus Duct-4	Escape Tunnel	Collection Gallery	Vertical Penstock PS-1 Exc.

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