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IMPACT AND PUNCTURING OF JARI TUNNEL AND ENLARGEMENT OF EXISTING TAPPINGS FOR ADDITIONAL WATER SUPPLY AND POWER GENERATION

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By

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Introduction

Jari dam is constructed across a saddle along the rim of Mangla reservoir away from the main dam as shown in Figure 1. Jari dam is 4495.8 m long and has a height of 92.66m above river bed. Another ridge in the reservoir separates the Jari pocket from the main Mangla reservoir. The level of this ridge is cut to El. 335.89. Jari pocket separates from the main reservoir when the water level in the reservoir drops below El. 335.89 m. Jari pocket becomes part of the main reservoir when the water level in the reservoir rises above El. 335.89 m.

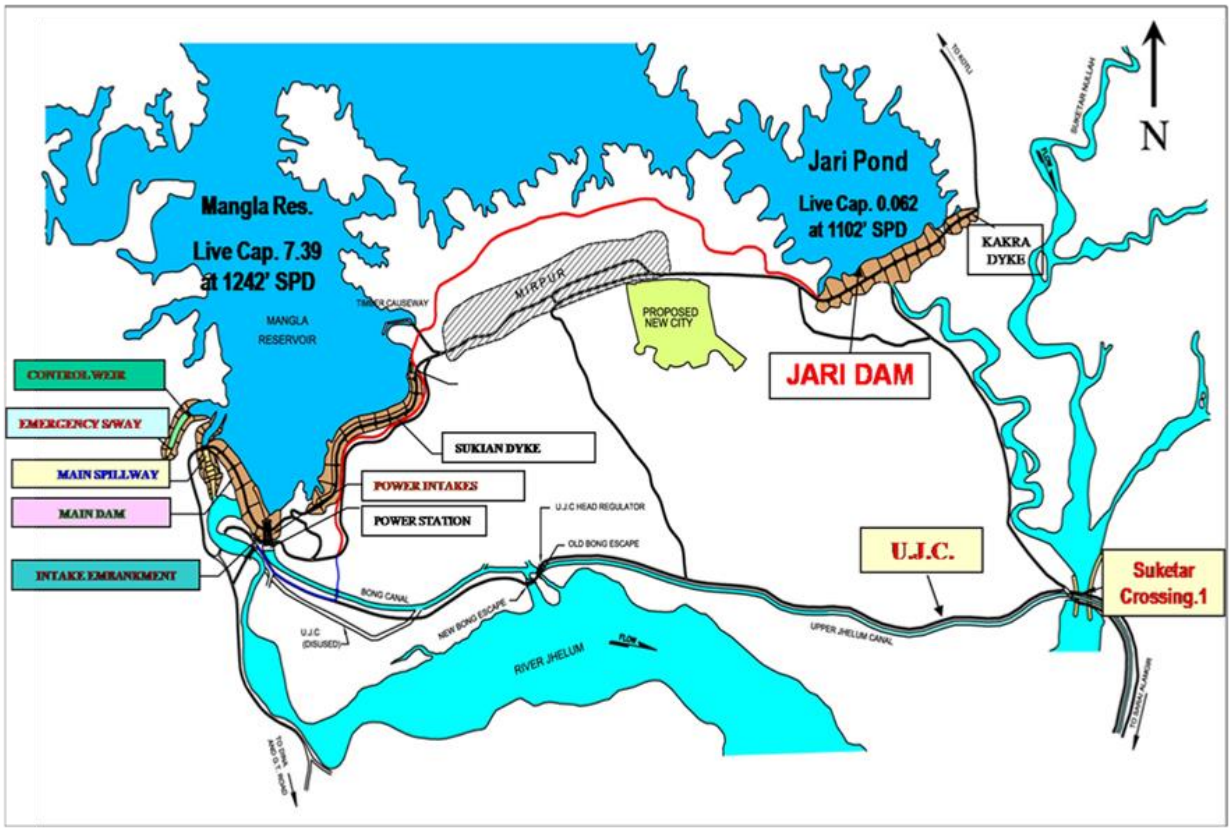


Figure 1: Location Map

Jari Tunnel

A 2.13 m (7 ft) diameter tunnel was constructed across Jari dam to release the trapped water in the Jari pocket. The tunnel invert level is at El. 320.04 m and the intake gate is 2.74 m (9 ft) long and 1.52 m (5 ft) wide. Plan and longitudinal section of Jari tunnel are shown in Figures 2 and 3 respectively. The lengths and diameters of various sections of the tunnel are given in table 1 below.

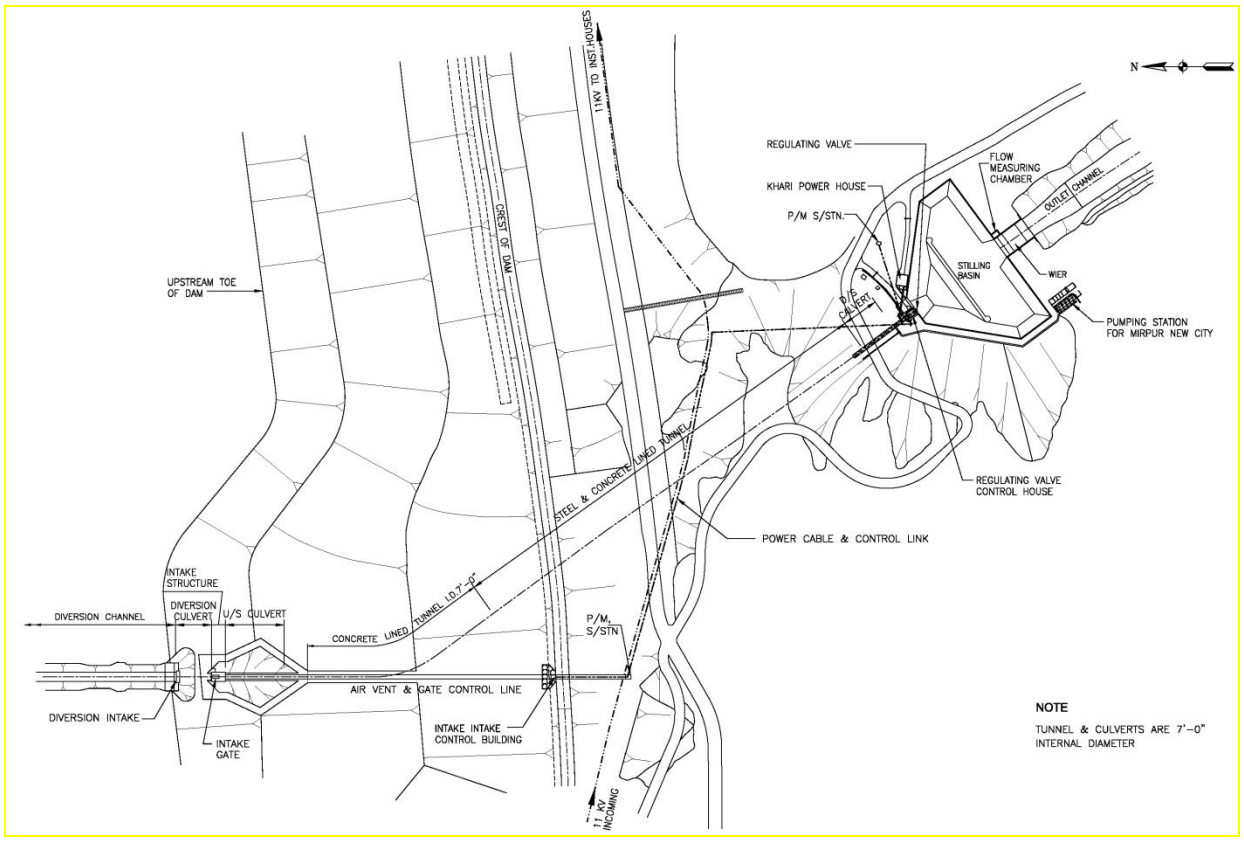


Figure-2: Jari Tunnel Layout Plan

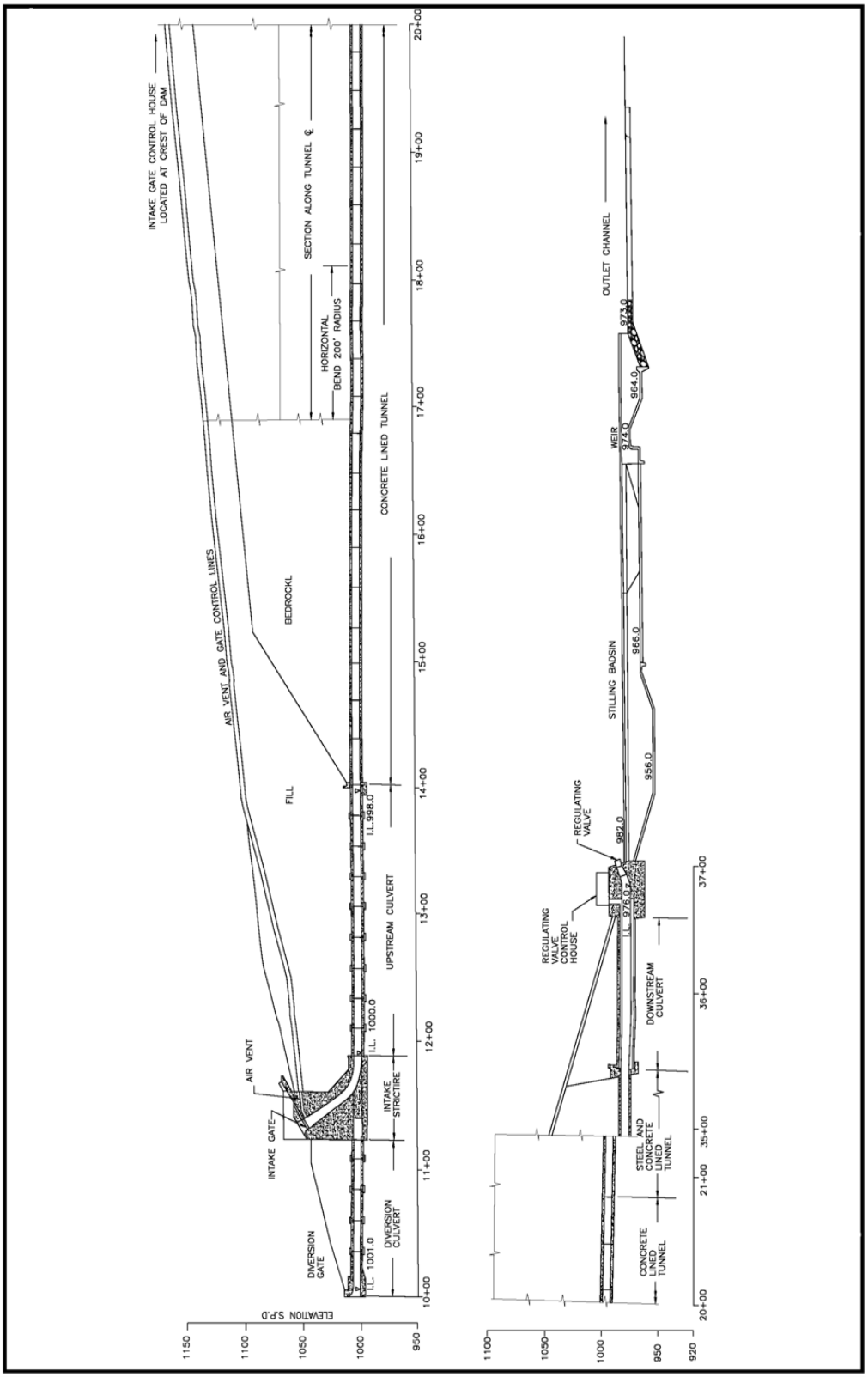


Figure-3: Longitudinal Section of Jari Tunnel

Table 1: Jari Tunnel Sectional Detail

Jari Tunnel	Section Length	Section Diameter
Concrete Lined Section	332.00 m	2.13 m
Steel and Concrete Lined Section	445.92 m	2.13 m
Downstream Culvert	34.75 m	2.13 m
RCC Valve Block	13.35 m	1.83 m

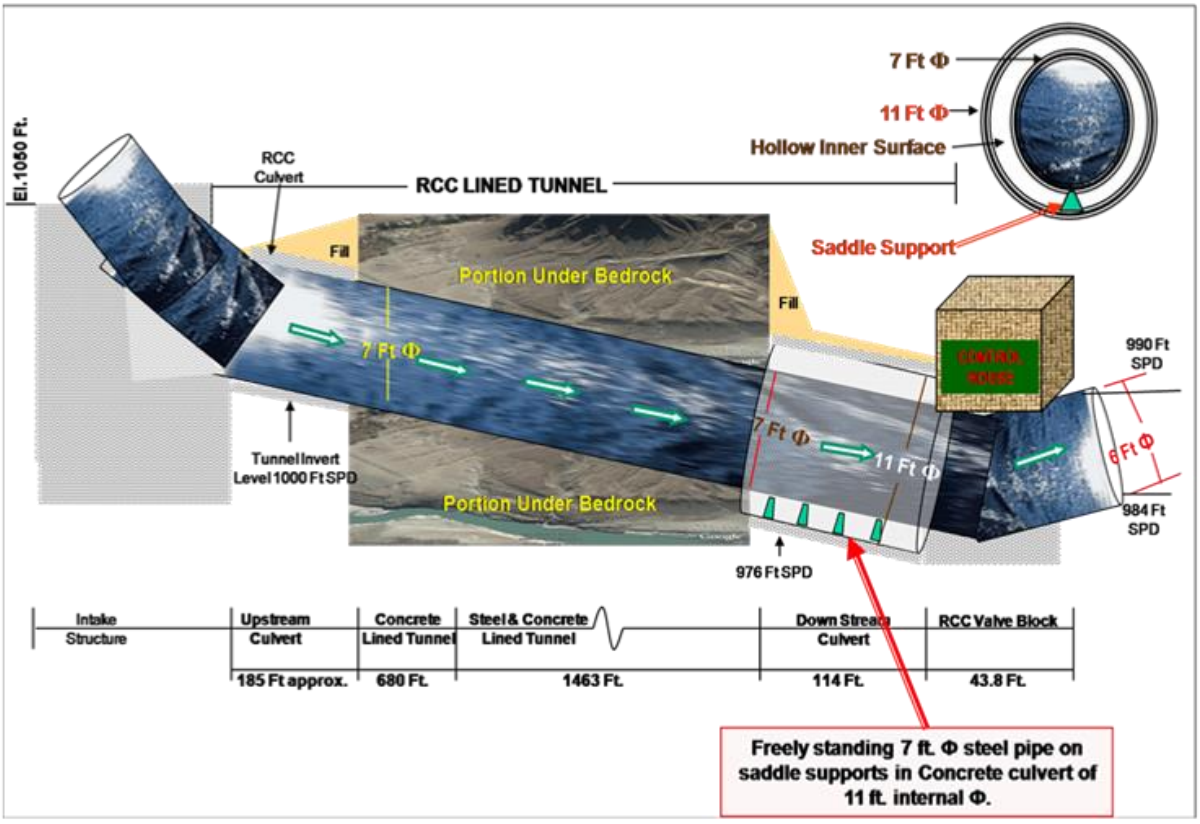


Figure-4: Schematic Diagram of Jari Outlet Works

Existing Tappings at Jari Tunnel

The Jari tunnel has four existing tappings along with a Howell Bunger Valve at the tunnel exit each fulfilling a separate function. A description for the tappings is given below,

Water Supply Tapping for New Mirpur City

The tapping off-takes from the top of Jari Tunnel approximately 13.11 m upstream of the Howell Bunger valve control room back wall and supplies 0.48 m^3/sec for water supply to New Mirpur City. The tapping has a capacity to withdraw 0.99 m^3/sec and is conical in shape having 914 mm diameter at start which gradually reduces to 711 mm. After the gradual contraction, the pipe takes a 90 degree bend towards right side leading to a pumping station to pump water to New Mirpur City.

Khari Powerhouse Tapping

The tapping for Khari powerhouse off-takes from the top of Jari tunnel approximately 6.4 m upstream of Howell Bunger Valve control room back wall to draw 1.42 m^3/sec for 1 MW hydropower generation. The tapping has a diameter of 1120 mm at start which gradually reduces to 800 mm. The 800 mm pipe takes a 90 degree bend towards the left side where a butterfly valve is provided. After the valve, a transition is provided that connects this 800 mm pipe to 1000 mm pipe which leads to the powerhouse. The water from this outlet is ultimately released in the stilling basin after power generation and is used for irrigation supplies to AJ&K.

Khari Irrigation Scheme Tapping

The 508 mm irrigation tapping is provided with a regulating valve to supply 1.42 m^3/sec discharge to AJ&K for Khari irrigation scheme. The water from this tapping discharges in the stilling basin at the end of the Howell Bunger valve.

Sluice Valve

A 152.4 mm diameter sluice valve is provided at the invert of Jari tunnel to drain the tunnel for inspection which is now used for water supply to army camp at Jari.

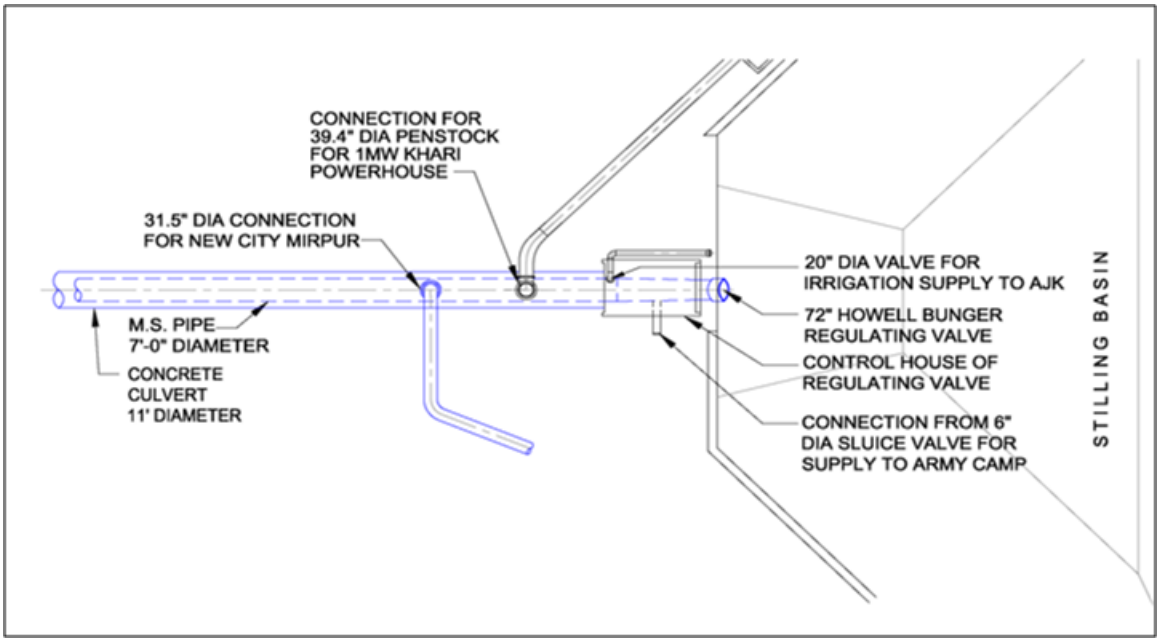


Figure-5: Schematic Diagram of Existing Tappings at Jari Tunnel

Studied Scenarios

A total discharge of 17.37 m^3/sec for AJ&K was allocated for various uses. A study was carried out to evaluate the technical and financial viability for providing 9.20 to 15.86 m^3/sec discharge from Jari Tunnel.

The 17.37 m^3/sec for AJ&K includes 1.53 m^3/sec that is being provided through upper Jhelum Canal. Therefore, maximum net requirement from the Jari tunnel tappings is 15.86 m^3/sec which includes the present withdrawals also. It is also desired to increase the hydropower generation to 3.5 MW from the Khari powerhouse tapping which is said to have the capacity to draw 4.25 m^3/sec. Alternatively, any other suitable arrangement may be studied for establishment of 3.5 MW powerhouse.

Technical viability of withdrawing 15.86 m^3/sec through the enlargement of one or more of the existing tappings has been carried out in the present study.

Scope of Hydraulic Studies:

The hydraulic analysis included the calculation of head loss, discharge, velocity and/or power through the conduit under consideration. The water hammer analysis included the calculation for maximum head rise at various locations in the conduit under consideration due to valve/gate closure. The detailed scope of hydraulic studies at the project is as follows:

1. To check if 3.5 MW power can be generated by passing 4.25 m^3/s through existing Khari Powerhouse Tapping.
2. To propose a 3.5 MW power house at a different location by bifurcating and enlarging the existing tapping and keeping the existing powerhouse as it is.
3. To perform Water Hammer Analysis for technically feasible options
4. To propose appropriate Enlargement of New Mirpur City Water Supply Tapping to pass the remaining discharge in the stilling basin for various uses in AJ&K
5. Establish technical viability of passing the entire 15.86 m^3/sec through the proposed New Mirpur City Water Supply Tapping in case the powerhouse is closed for maintenance and repair
6. Develop Discharge Rating Curves for studied New Mirpur City Water Supply Tapping
7. Perform Water Hammer Analysis for studied New Mirpur City Water Supply Tapping

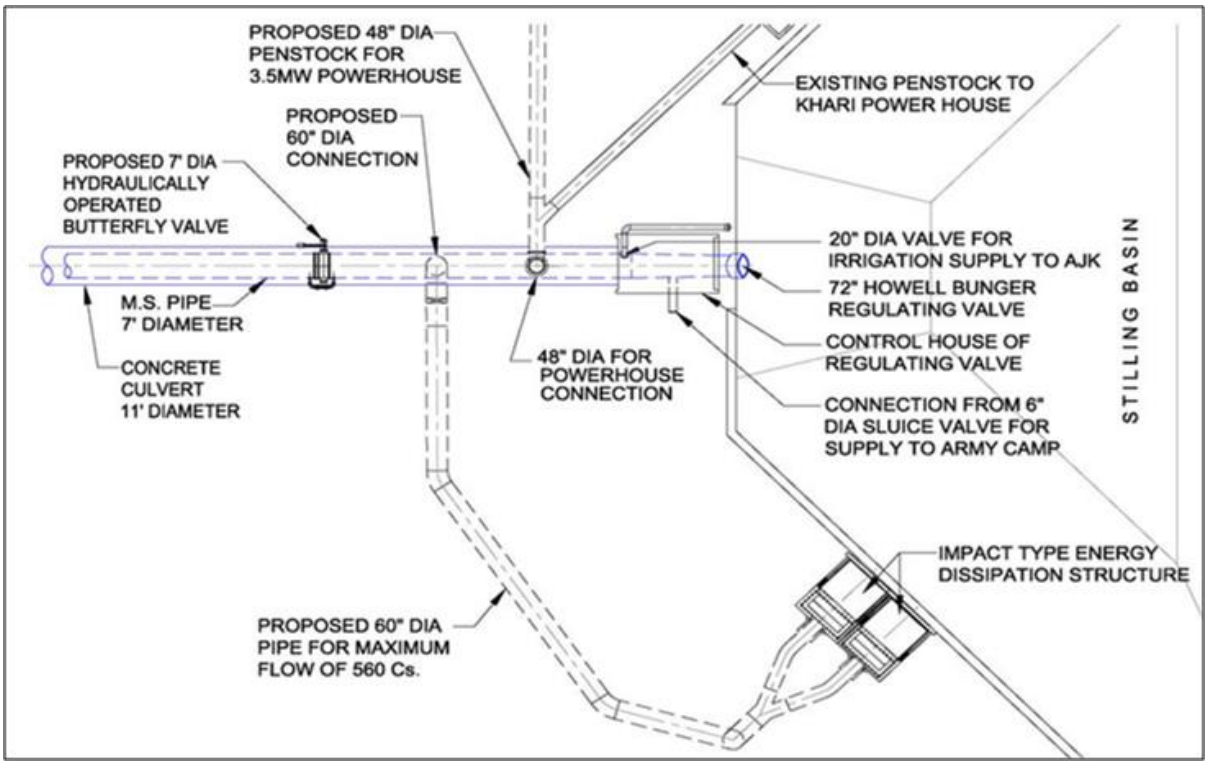


Figure-6: Schematic Diagram of Proposed Tappings at Jari Tunnel

Hydraulic Analysis

The hydraulic analysis performed at the project involved calculation of head losses, power generation, water hammer analysis, etc. The determination of head loss in the main tunnel and the respective tapping under consideration included calculation of major loss due to friction and other minor losses. The head losses due to friction were calculated from the following equation by Darcy Weisbach,

$$h_f = \frac{\lambda L}{D}\frac{V^2}{2g}$$

Where,

h_f = head loss

λ = Darcy Weisbach friction factor

L = conduit length

D = conduit diameter

V = flow velocity in the conduit

g = acceleration due to gravity

The Darcy Weisbach friction factor was calculated from the Cole Brook White formula.

$$\frac{1}{\lambda^{0.5}} = -2\log\left[\frac{e}{3.7\,D} + \frac{2.51}{R_e\lambda^{0.5}}\right]$$

Where,

e = absolute roughness in mm

e = 0.0007 for concrete lining

e = 0.0001 for steel lined sections and steel pipe

Re = Reynolds number

$$R_e = \frac{VD}{\nu}$$

Where,

ν = kinematic viscosity of water

Trash-rack, intake, transition, bend, gradual expansion, gradual contraction, bifurcation, exit and wicket gate/valve losses are collectively fall under minor loss category. Each minor loss is calculated from the following equation:

$$h_l = K\frac{V^2}{2g}$$

Where,

K = loss coefficient for the minor loss under calculation and the values are taken from Design of Small Dams by USBR

Hydraulic analysis for the existing and enlarged tappings was performed for power generation purposes and is given in section below. The power was calculated from the following equation,

$$P = \rho g \eta Q H_n$$

Where,

P = power in Watts

η = overall efficiency = $\eta_t \eta_g \eta_{tr}$

η_t = turbine efficiency

η_g = generator efficiency

η_{tr} = transformer efficiency

Q = discharge

H_n = net head = total head – head loss

For the power calculations the turbine, generator and transformer efficiencies are taken as 92.0%, 97.5% and 98% respectively.

Water Hammer Analysis

The closure of a wicket gate or valve at the end of a conduit results in a head rise at the upstream side of the gate or valve which is called water hammer. As a result of this head rise, a pressure wave is generated that travels in the upstream direction and gets reflected from the free surface reservoir at the upstream end of the conduit travelling back towards the gate/valve. This wave motion results in the development of negative pressures in the conduit. This to and fro movement of the positive and negative pressure wave is gradually dissipated to zero by the friction of the conduit. The pressure wave velocity is calculated by the following equation,

$$a = \frac{1}{\sqrt{\rho\left(\frac{1}{K_w} + \frac{D C_1}{t E}\right)}}$$

Where,

a = pressure wave velocity

r = density of water

K_w = volume modulus of water

D = diameter of conduit

C_1 = factor for anchorage and support of conduit

t = thickness of lining of Tunnel or thickness of pipe/penstock

E = Young's modulus of elasticity of the lining or pipe material

The maximum head rise just at the upstream side of the gate/valve is calculated from the Allievi's chart as shown in Figure 7. To determine the maximum pressure rise from the Allievi's chart, two constants given below are to be calculated.

i. Pipeline Constant $K = \frac{a V}{2 g H_o}$

ii. Time Constant $N = \frac{a T}{2 L}$

Where,

H_o = total Head = reservoir level – elevation at centerline of wicket gate/valve

T = closure time of gate/valve

L = total length of the conduit up to gate/valve

For conduit with varying cross sections, varying anchorage & support and varying type of lining/pipe material, weighted average of pressure wave and flow velocities are calculated from the pressure wave and flow velocities of each section of the conduit. The weighted average values are used to calculate the pipeline and time constants for determining maximum pressure rise from Allievi's Chart.

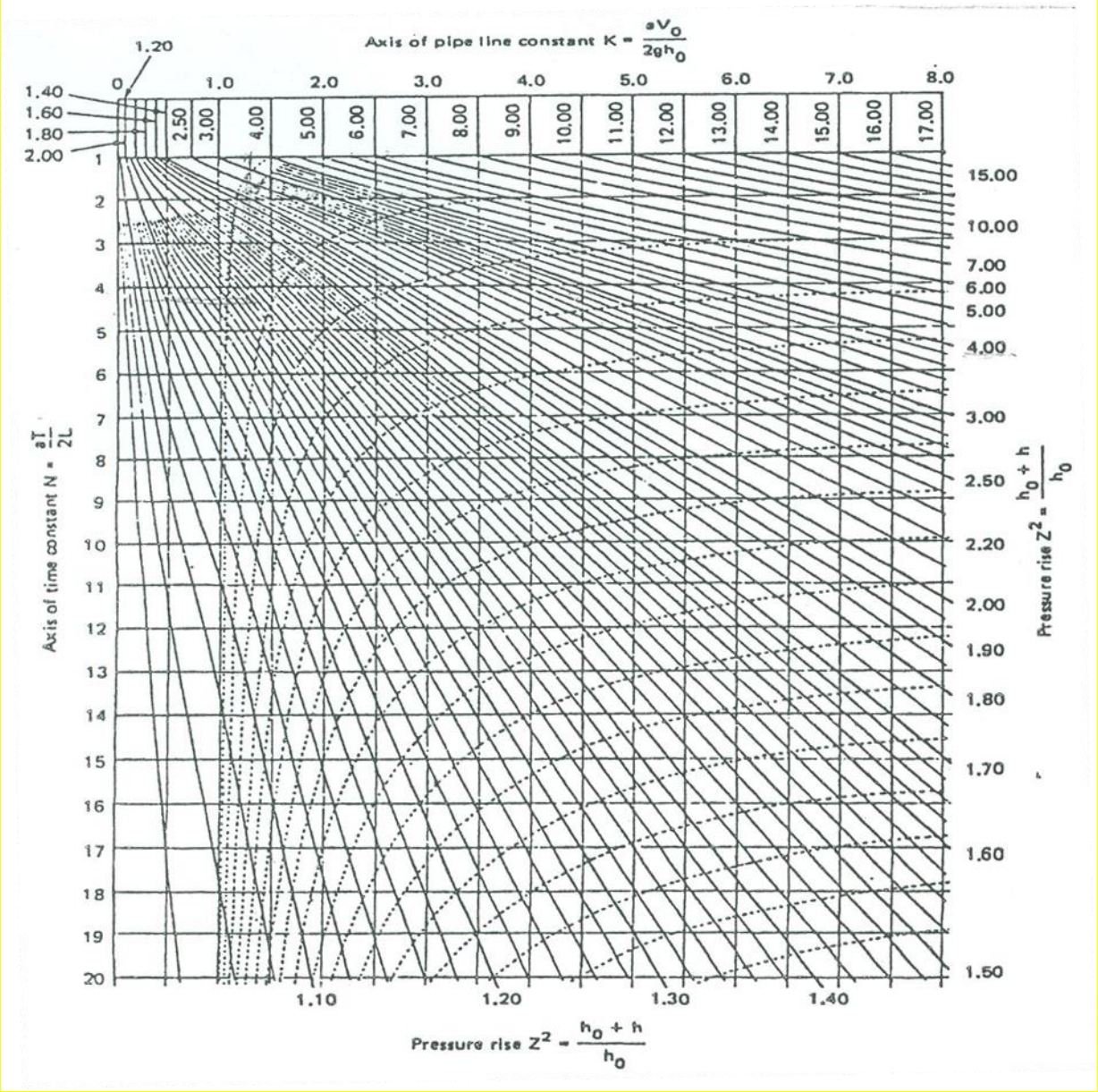


Figure-7: Allievi's Chart for Determination of Maximum Pressure Rise

Existing tapping 1m diameter for 1 MW Khari Powerhouse

The description of length and alignment for the concrete and steel lined section of Jari tunnel and existing Khari powerhouse tapping is given below,

Jari Tunnel

Six trash rack units	1.02m x 2.0m
Rectangular entrance	1.52 m x 2.74 m
Transition from rectangular to circular tunnel	2.13 m diameter tunnel
Length of 2.13 m dia concrete lined tunnel	332 m
Vertical bend in concrete lined tunnel	53 degrees
Horizontal bend in concrete lined tunnel	36 degrees
Length of 2.13 m dia steel lined tunnel	445 m
Free standing 2.13 m dia steel lined tunnel	28.5 m

Existing Steel Penstock

Diameters of conical off-take	1120 mm / 800 mm
Length of 800 mm pipe	2.33 m
Vertical bend after cone	90 degrees
Butterfly valve diameter	800 mm
Transition after butterfly valve	800 mm to 1000 mm
Horizontal bend after butterfly valve	15 degrees
Length of 1.0 m penstock	11 m

The maximum tail water level in the stilling basin considered was at El. 298.86 m. The raising of Mangla dam was taken into account and the maximum conservation level of El. 378.56 m was considered. The power calculations were performed by varying the reservoir level from maximum conservation level of El. 378.56 m down to El. 323.09 m.

The power calculations were carried out by passing 4.25 m^3/sec discharge through the existing penstock with afore-mentioned setting. The calculated Power versus Reservoir Level is plotted in Figure-8 and the summary of the calculations is given in Table-2.

The results of the analysis show that maximum power of 2.64 MW can be achieved at reservoir level of El. 378.56 m. Therefore, it is not possible to produce the desired power of 3.5 MW by passing 4.25 m^3/sec through the existing Khari Powerhouse tapping. The analysis also shows that flow velocity in the 1000 mm diameter penstock is 5.41 m/s which marginally exceeds the generally acceptable velocity limit of 5.0 m/s, but the velocity in 800 mm diameter pipe at the start of penstock is 8.45 m/s which greatly exceed the acceptable velocity limit of 5.0 m/s.

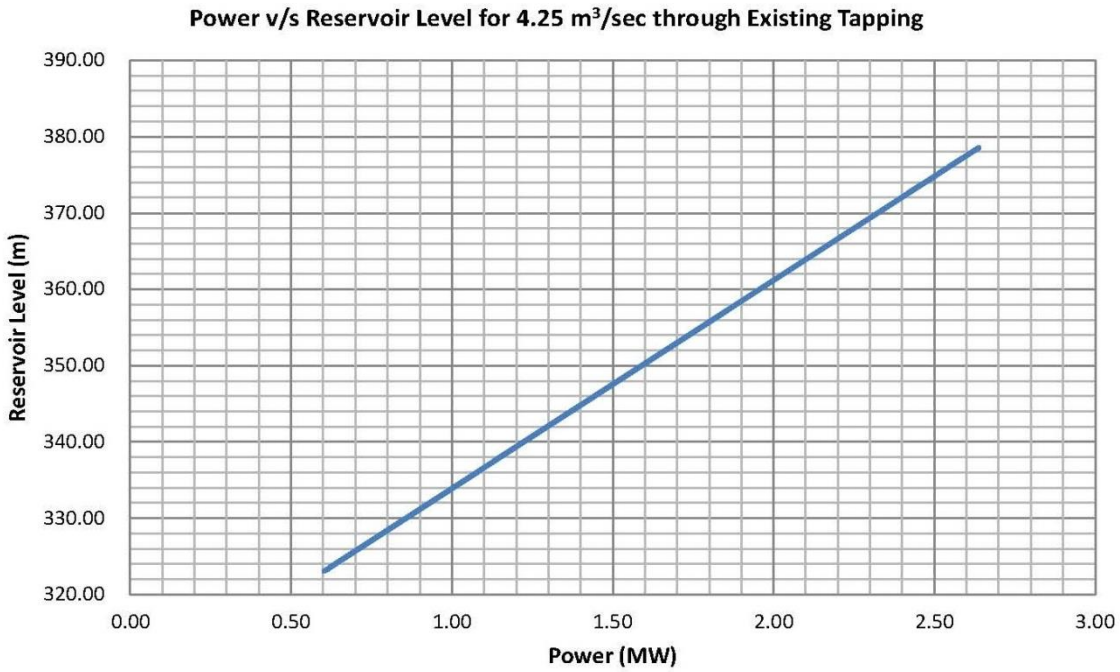


Figure-8: Power v/s Reservoir Level for 4.25 m^3/sec through Existing Tapping

Table-2: Summary of Hydraulic Analysis for 4.25 m^3/sec through Existing Tapping (1000 mm diameter)

Reservoir Water Level	Total Head	Head Loss	Net Head	Discharge	Velocity in Penstock 1.0 m dia.	Velocity in 0.8 m dia. Penstock after cone	Power
	H_t	H_L	H_n	Q			P
m	m	M	m	m^3/s	m/sec	m/sec	MW
378.56	79.71	7.78	71.93	4.25	5.41	8.45	2.64
375.00	76.14	7.78	68.37	4.25	5.41	8.45	2.51
372.50	73.64	7.78	65.87	4.25	5.41	8.45	2.42
370.00	71.14	7.78	63.37	4.25	5.41	8.45	2.32
367.50	68.64	7.78	60.87	4.25	5.41	8.45	2.23
365.00	66.14	7.78	58.37	4.25	5.41	8.45	2.14
362.50	63.64	7.78	55.87	4.25	5.41	8.45	2.05
360.00	61.14	7.78	53.37	4.25	5.41	8.45	1.96
357.50	58.64	7.78	50.87	4.25	5.41	8.45	1.87
355.00	56.14	7.78	48.37	4.25	5.41	8.45	1.77
352.50	53.64	7.78	45.87	4.25	5.41	8.45	1.68
350.00	51.14	7.78	43.37	4.25	5.41	8.45	1.59
347.50	48.64	7.78	40.87	4.25	5.41	8.45	1.50
345.00	46.14	7.78	38.37	4.25	5.41	8.45	1.41
342.50	43.64	7.78	35.87	4.25	5.41	8.45	1.32
340.00	41.14	7.78	33.37	4.25	5.41	8.45	1.22
337.50	38.64	7.78	30.87	4.25	5.41	8.45	1.13
335.00	36.14	7.78	28.37	4.25	5.41	8.45	1.04

Reservoir Water Level	Total Head	Head Loss	Net Head	Discharge	Velocity in Penstock 1.0 m dia.	Velocity in 0.8 m dia. Penstock after cone	Power
	H_t	H_L	H_n	Q			P
m	m	M	m	m^3/s	m/sec	m/sec	MW
332.50	33.64	7.78	25.87	4.25	5.41	8.45	0.95
330.00	31.14	7.78	23.37	4.25	5.41	8.45	0.86
327.50	28.64	7.78	20.87	4.25	5.41	8.45	0.77
325.00	26.14	7.78	18.37	4.25	5.41	8.45	0.67
323.09	24.23	7.78	16.45	4.25	5.41	8.45	0.60

In order to achieve the target of 3.5 MW through the existing Khari powerhouse tapping, calculations were carried out by passing 5.76 m^3/sec through the existing tapping. The summary of the calculations is given in Table-3 and plot of Power versus Reservoir Level is shown in Figure-9.

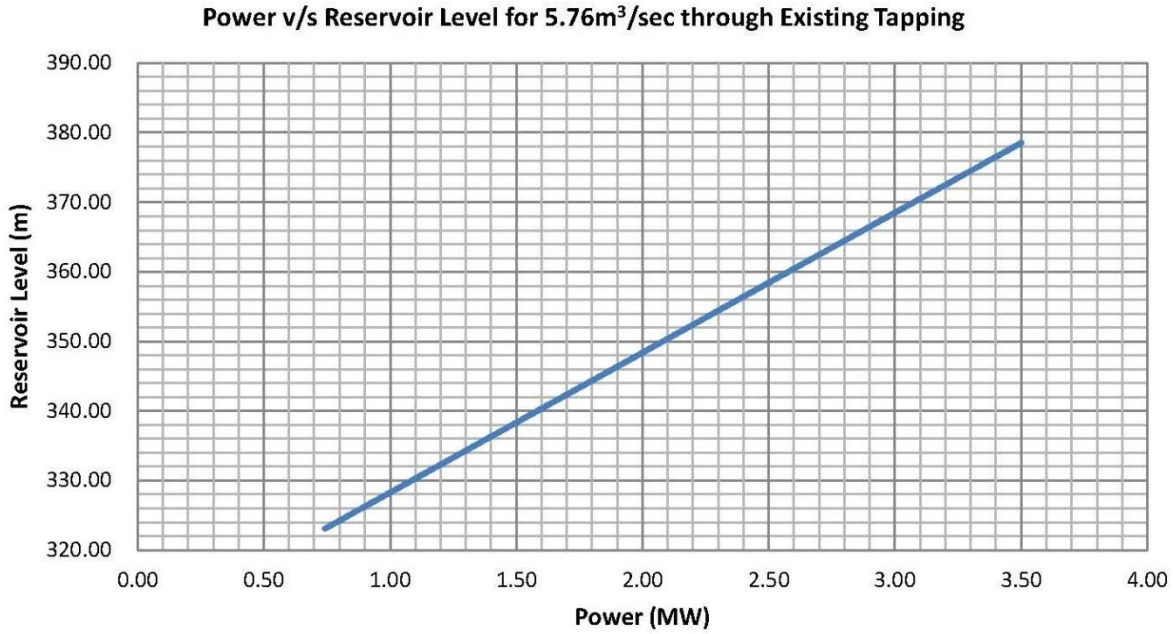


Figure-9: Power v/s Reservoir Level for 5.76m^3/sec through Existing Tapping

Table-3: Summary of Hydraulic Analysis for 5.76 m^3/sec through Existing Tapping (1000 mm diameter)

Reservoir Water Level	Total Head	Head Loss	Net Head	Discharge	Velocity in 1.0 m dia. Penstock	Velocity in 0.8 m dia. Penstock after cone	Power
	H_t	H_L	H_n	Q			P
m	M	M	m	m^3/s	m/sec	m/sec	MW
378.56	79.71	9.32	70.39	5.76	7.34	11.46	3.50
375.00	76.14	9.32	66.83	5.76	7.34	11.46	3.32
375.00	76.14	9.32	66.83	5.76	7.34	11.46	3.32
372.50	73.64	9.32	64.33	5.76	7.34	11.46	3.20

Reservoir Water Level	Total Head	Head Loss	Net Head	Discharge	Velocity in 1.0 m dia. Penstock	Velocity in 0.8 m dia. Penstock after cone	Power
	H_t	H_L	H_n	Q			P
m	M	M	m	m^3/s	m/sec	m/sec	MW
370.00	71.14	9.32	61.83	5.76	7.34	11.46	3.08
367.50	68.64	9.32	59.33	5.76	7.34	11.46	2.95
365.00	66.14	9.32	56.83	5.76	7.34	11.46	2.83
362.50	63.64	9.32	54.33	5.76	7.34	11.46	2.70
360.00	61.14	9.32	51.83	5.76	7.34	11.46	2.58
357.50	58.64	9.32	49.33	5.76	7.34	11.46	2.45
355.00	56.14	9.32	46.83	5.76	7.34	11.46	2.33
352.50	53.64	9.32	44.33	5.76	7.34	11.46	2.21
350.00	51.14	9.32	41.83	5.76	7.34	11.46	2.08
347.50	48.64	9.32	39.33	5.76	7.34	11.46	1.96
345.00	46.14	9.32	36.83	5.76	7.34	11.46	1.83
342.50	43.64	9.32	34.33	5.76	7.34	11.46	1.71
340.00	41.14	9.32	31.83	5.76	7.34	11.46	1.58
337.50	38.64	9.32	29.33	5.76	7.34	11.46	1.46
335.00	36.14	9.32	26.83	5.76	7.34	11.46	1.33
332.50	33.64	9.32	24.33	5.76	7.34	11.46	1.21
330.00	31.14	9.32	21.83	5.76	7.34	11.46	1.09
327.50	28.64	9.32	19.33	5.76	7.34	11.46	0.96
325.00	26.14	9.32	16.83	5.76	7.34	11.46	0.84
323.09	24.23	9.32	14.92	5.76	7.34	11.46	0.74

The calculation results show that 3.5 MW hydropower can be achieved by passing 5.76 m^3/sec through the existing tapping at reservoir level of El. 378.56 m. The flow velocities through the 1000 mm diameter penstock and 800 mm diameter pipe at start of penstock are 7.34 m/s and 11.46 m/s respectively. These velocities greatly exceed the limiting velocity of 5.0 m/s. The velocity in the 800 mm diameter pipe exceeds limiting velocity for abrasion i.e. 9.14 m/s (30.0 ft/s). *Therefore, it was concluded that the existing Khari powerhouse tapping was not technically viable for the generation of 3.5 MW power*.

Proposed Enlargement of Tapping (1219 mm) for 3.5 MW Powerhouse

As discussed previously it was not possible to generate 3.5 MW from the existing Khari powerhouse by increasing the discharge to 4.25m^3/sec. The increase in discharge from 4.25m^3/sec to 5.76m^3/sec to generate 3.5 MW power resulted in increased flow velocities exceeding the maximum permissible limit. This induced the possibility of abrasion in 800 mm pipe of the penstock.

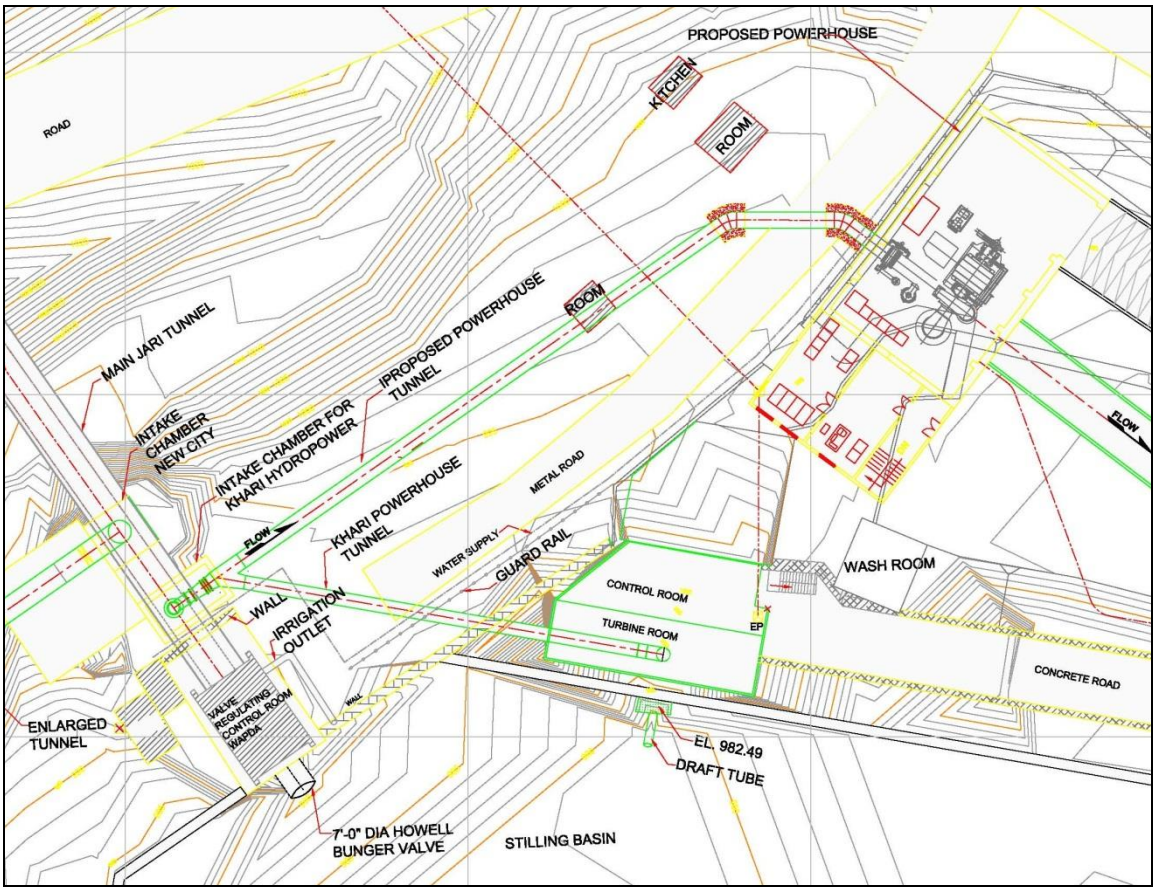


Figure-10: Plan of Proposed Powerhouse

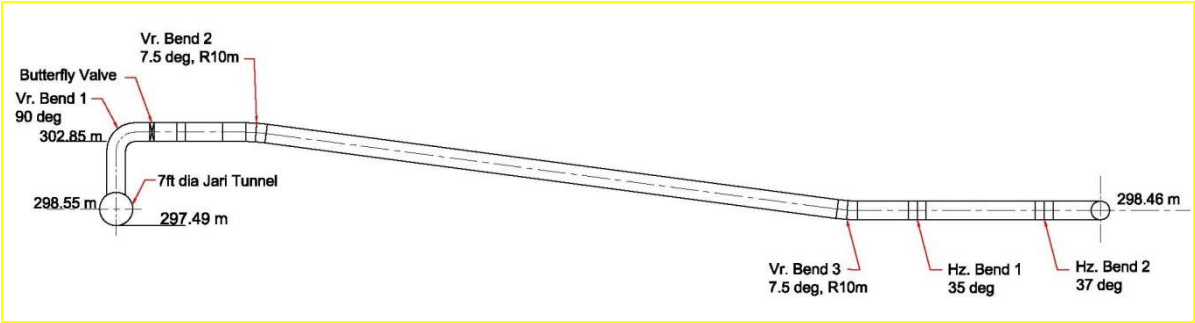


Figure-11: Longitudinal Section of the Proposed Penstock for 3.5 MW Powerhouse

Therefore, it was proposed to provide the 3.5 MW powerhouse at separate location while keeping the 1 MW powerhouse intact. Plan of the proposed scheme is shown in Figure 10 and the longitudinal section of the proposed penstock is shown in Figure 11. It was also proposed to use the tapping of existing Khari powerhouse for the proposed scheme and enlarge the entire length to 1.2 m diameter. The tapping will bifurcate after the 90 degree bend to branch towards the proposed powerhouse while keeping the existing 1 MW penstock intact. The tapping proposed will pass 5.66 m^3/sec to produce 3.5 MW power at reservoir level of El. 378.56 m. The flow velocity in the entire penstock will remain as 5.0 m/s so as not to exceed permissible velocity limit. The description of the tapping is given below:

Proposed Penstock

First vertical bend after tapping	90 degrees
Power tunnel length between tapping and bifurcation	7.74 m
Butterfly valve diameter	1.2 m (48 inch)
Bifurcation diameter	1.2 m
First horizontal bend	35 degrees
Second horizontal bend	37 degrees
Second vertical bend after bifurcation	7.5 degrees
Third vertical bend after bifurcation	7.5 degrees
1.2 m diameter penstock from bifurcation to powerhouse	57.64 m

The summary of the hydraulic analysis for the proposed scheme is given in Table 4 and the plot of Power versus Reservoir level is shown in Figure 12. The results show that 3.5 MW power is achieved for the proposed configuration with reservoir level at El. 378.56 m by passing 5.66 m^3/sec discharge through the penstock. The power reduces as the reservoir level lowers. 3.0 MW power can be achieved at reservoir level of El 367.5 m. So far the reservoir level of El. 378.56 m has not been achieved. Normally the reservoir is filled up to the normal pond level by the end of the monsoon season if adequate flows are available. After the monsoon season low flow season starts and the reservoir starts depleting.

The hydraulic analysis shows that the proposed scheme is technically viable and 3.5 MW power can be produced from the proposed powerhouse. However, when the reservoir level is low and it is not possible to produce power from this facility, the existing 1 MW unit can be operated.

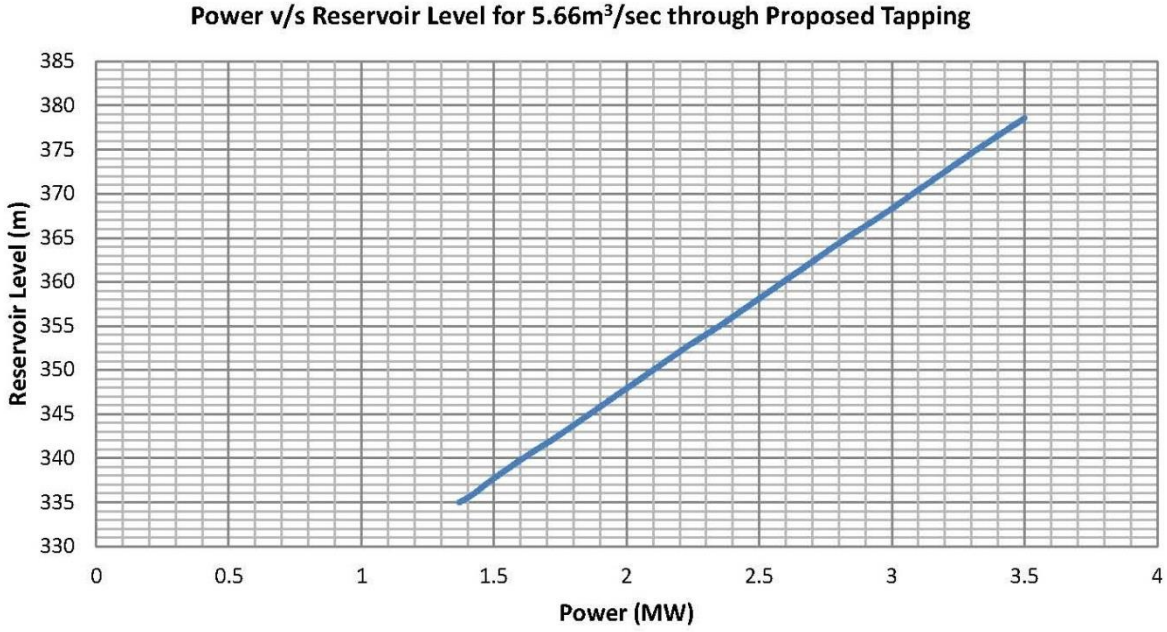


Figure-12: Power v/s Reservoir Level for 5.66m^3/sec through Proposed Penstock for 3.5 MW Power Unit

Table-4: Summary of Hydraulic Analysis for 5.66 m^3/sec through Proposed Penstock (1219 mm diameter)

Reservoir Water Level	Total Head	Head Loss	Net Head	Discharge in Penstock	Velocity in Penstock	Power	Max. Discharge Capacity of Penstock
	H_t	H_L	H_n	Q	V	P	
M	m	m	m	m^3/s	m/s	MW	m^3/s
378.56	79.71	8.09	71.62	5.66	5.01	3.50	80.95
375.00	76.14	8.09	68.06	5.66	5.01	3.32	78.96
372.50	73.64	8.09	65.56	5.66	5.01	3.20	77.53
370.00	71.14	8.09	63.06	5.66	5.01	3.08	76.07
367.50	68.64	8.09	60.56	5.66	5.01	2.96	74.59
365.00	66.14	8.09	58.06	5.66	5.01	2.83	73.08
362.50	63.64	8.09	55.56	5.66	5.01	2.71	71.53
360.00	61.14	8.09	53.06	5.66	5.01	2.59	69.96
357.50	58.64	8.09	50.56	5.66	5.01	2.47	68.34
355.00	56.14	8.09	48.06	5.66	5.01	2.35	66.69
352.50	53.64	8.09	45.56	5.66	5.01	2.22	64.99
348.94	50.09	8.09	42.00	5.66	5.01	2.05	62.50
350.00	51.14	8.09	43.06	5.66	5.01	2.10	63.25
347.50	48.64	8.09	40.56	5.66	5.01	1.98	61.46
345.00	46.14	8.09	38.06	5.66	5.01	1.86	59.61
342.50	43.64	8.09	35.56	5.66	5.01	1.74	57.71
340.00	41.14	8.09	33.06	5.66	5.01	1.61	55.74
337.50	38.64	8.09	30.56	5.66	5.01	1.49	53.70
335.00	36.14	8.09	28.06	5.66	5.01	1.37	51.58
332.50	33.64	8.09	25.56	5.66	5.01	1.25	49.36
330.00	31.14	8.09	23.06	5.66	5.01	1.13	47.05
327.50	28.64	8.09	20.56	5.66	5.01	1.00	44.61
325.00	26.14	8.09	18.06	5.66	5.01	0.88	42.03
323.09	24.23	8.09	16.14	5.66	5.01	0.79	39.95

Water-Hammer Analysis for 3.5 MW Powerhouse Tapping

Water-hammer analysis was carried out to determine the maximum pressures in the Jari tunnel and penstock for the case when full load rejection takes place and the wicket gate/valve at the turbine are closed in a short period of time. The maximum pressures have been calculated for six and ten second wicket gate closure times separately.

As explained above Allievi's charts have been used to determine the maximum pressures. Weighted average of pressure wave velocity and flow velocity has been used for the determination of maximum pressure at the wicket gates from Allievi's chart. The pressure at other locations in the tunnel was determined by assuming linear decrease of the head rise up to the reservoir. Head losses in the penstock and Jari tunnel have been neglected for the determination of water-hammer pressure. The summary of the results of water hammer analysis is given in Table 5.

The calculations show a total head rise of 184.17 m at the turbine and 176.18 m in the free standing tunnel in the culvert for six second wicket gates closure time. For ten second

wicket gates closure time total head rise is 134.11 m at the turbine and 129.95 m in the free standing tunnel in the culvert. The structural analysis was carried out to evaluate the structural stability of the tunnel. The tunnel to be safe against the total head developed due to full load rejection in both cases (wicket gates closure times of 6 & 10 seconds). A relief valve should also be provided at the turbine which automatically opens when load rejection takes place to protect the Jari tunnel from water hammer pressures.

Table-5: Summary of Water Hammer Calculations for Proposed 3.5MW Powerhouse

Location	Diameter	Flow Velocity	Distance from intake	Tunnel C.L. Elevation	Reservoir Elevation	Static Head	Head Rise	Total Head
	(m)	(m/s)	(m)	(m)	(m)	(m)	(m)	(m)
Wicket Gates Closure Time = 6 sec								
At start of steel lining	2.13	4.44	332.00	305.26	378.56	73.30	39.59	112.89
At start of tunnel in culvert	2.13	4.44	778.00	303.43	378.56	75.13	92.77	167.91
At tapping for Khari power house	2.13	4.44	806.50	298.55	378.56	80.01	96.17	176.18
At Turbine	1.20	5.01	873.25	298.52	378.56	80.04	104.13	184.17
Wicket Gates Closure Time = 10 sec								
At start of steel lining	2.13	4.44	332.00	305.26	378.56	73.30	20.56	93.86
At start of tunnel in culvert	2.13	4.44	778.00	303.43	378.56	75.13	48.17	123.30
At tapping for Khari powerhouse	2.13	4.44	806.50	298.55	378.56	80.01	49.94	129.95
At Turbine	1.20	5.01	873.25	298.52	378.56	80.04	54.07	134.11

New Mirpur City Tapping (Existing 800 mm diameter)

A discharge of 5.66m^3/sec was to be utilized for the proposed 3.5 MW power generation while the remaining 10.19 m^3/sec out of the 15.86 m^3/sec was required to be delivered to the stilling basin for irrigation and other purposes. In case of powerhouse shut down for repair or maintenance purposes or due to lack of adequate head for power generation, the entire discharge had to be released through this proposed tapping.

It has been proposed to enlarge the existing New Mirpur City Water Supply Tapping and dispose the required discharge in the stilling basin after energy dissipation. The plan and longitudinal section of the proposed tapping is shown in Figure-13 and 14 respectively. The hydraulic analysis was carried out for four different enlargement options i.e. 1676.4 mm (66”), 1524 mm (60”), 1372 mm (54”) and 1219 mm (48”) pipes.

The flow velocity in the conduit was kept limited to 9.14 m/s (30.0 ft/s) so as not to induce abrasion in the conduit. The energy of the discharge from this tapping was planned to be dissipated by constructing impact type energy dissipater at the end of the pipe adjacent to stilling basin wall as shown in Figure 19 and 20. To meet the discharge limitations of the impact type energy dissipaters it has been proposed to provide two units of energy dissipater adjacent to each other each having a maximum capacity to dissipate energy of 7.93 m^3/sec.

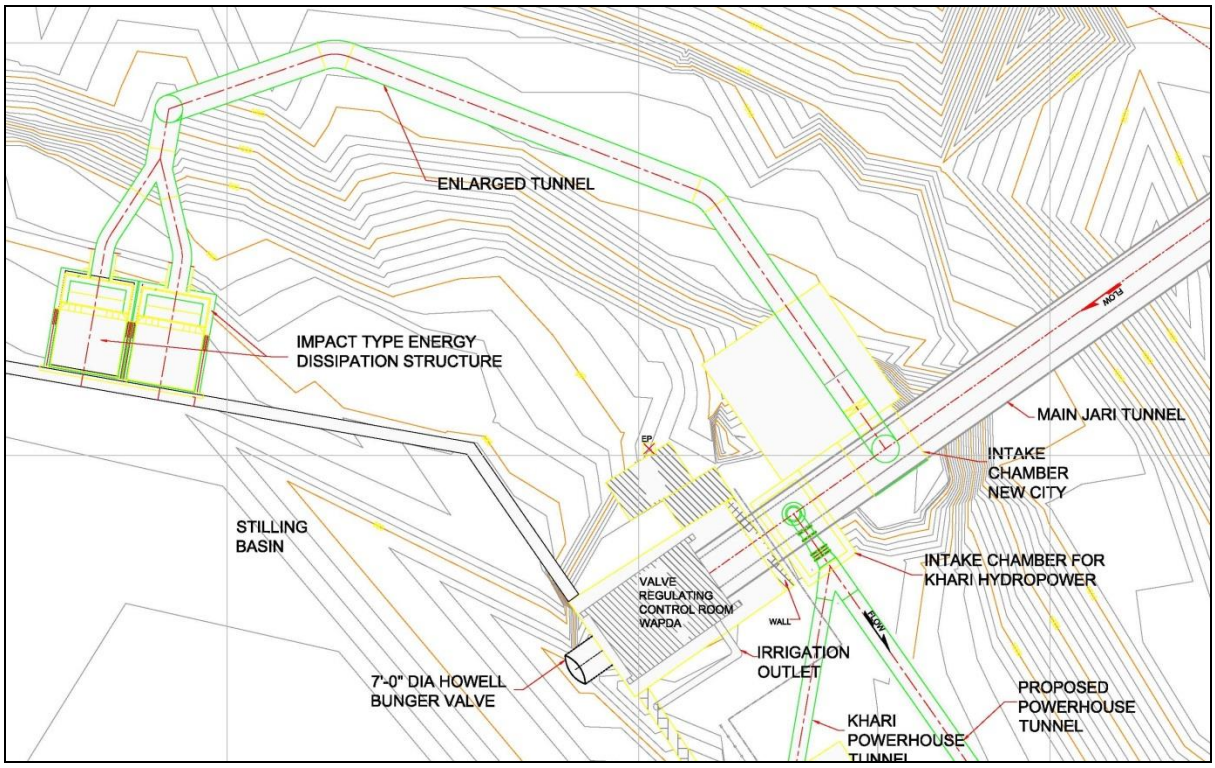


Figure-13: Plan of Proposed New City Mirpur Water Supply Tapping

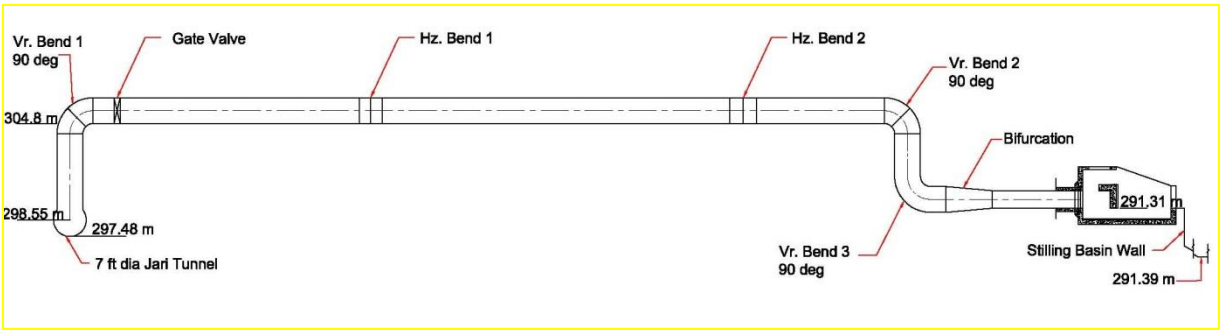


Figure-14: Longitudinal Section of Proposed New City Mirpur Water Supply Tapping

The configuration of the proposed water supply tapping is given below,

Proposed Irrigation and Water Supply Tapping

First vertical bend after tapping	90 degrees
Pipe length between tapping and bifurcation	67.81 m
Gate Valve	After 90 degree bend
Diameter before Bifurcation	1219mm (48”), 1372mm (54”), 1524mm (60”), 1676.4 mm (66”)
First horizontal bend	34.14 degrees
Second horizontal bend	39.89 degrees

Second vertical bend before bifurcation	90 degrees
Third vertical bend before bifurcation	90 degrees
Pipe between bifurcation and exit	5.71 m
Diameter of each leg of pipe after bifurcation	1.14 m

The summary of hydraulic analysis of the proposed enlargement for 1524 mm (60") tapping at 10.19 m^3/sec and 15.86 m^3/sec are given in Tables-6 and 7. The plot of wicket gates opening versus reservoir level for these discharge through 1676.4 mm (66"), 1524 mm (60"), 1372 mm (54") and 1219 mm (48") tappings are shown in Figures 15 to 18.

The results of the performed hydraulic analysis show that 1524 mm (60") tapping is most suitable to pass 10.19 m^3/sec and 15.86 m^3/sec discharge as the velocity in both cases remains below the limiting value of 9.14 m/s (30 ft/s). The 1372 mm (54") tapping is appropriate for passing 10.19 m^3/sec discharge as the flow velocity is 6.90 m/s which is within acceptable limits, whereas for 15.86 m^3/sec discharge the velocity rises to 10.73 m/s which may induce abrasion in the pipe. The 1219 mm (48") tapping is appropriate for passing 10.19 m^3/sec discharge as the flow velocity is 8.73 m/s which is within acceptable limits, whereas for 15.86 m^3/sec discharge the velocity rises to 13.58 m/s which may induce abrasion in the pipe.

Therefore, it was recommended that 1524 mm (60") enlargement of New Mirpur City Water Supply Tapping should be adopted ensuring the structural stability of the enlargement.

Table-6: Summary of Hydraulic Analysis for 1524 mm (60") Irrigation & Water Supply Tapping (15.86 m^3/sec)

Reservoir Water Level	Total Head	Head Loss	Net Head	Tapping (1524mm)		1.14m dia pipe (After Bifurcation)		Gate Valve Opening
				Discharge	Velocity	Discharge	Velocity	
m	m	m	M	m^3/s	(m/sec)	m^3/s	(m/sec)	(%)
378.56	78.68	74.82	3.85	15.86	8.69	7.93	7.73	36.81
375.00	75.11	71.26	3.85	15.86	8.69	7.93	7.73	38.09
372.50	72.61	68.76	3.85	15.86	8.69	7.93	7.73	39.04
370.00	70.11	66.26	3.85	15.86	8.69	7.93	7.73	40.03
367.50	67.61	63.76	3.85	15.86	8.69	7.93	7.73	41.06
365.00	65.11	61.26	3.85	15.86	8.69	7.93	7.73	42.15
362.50	62.61	58.76	3.85	15.86	8.69	7.93	7.73	43.29
360.00	60.11	56.26	3.85	15.86	8.69	7.93	7.73	44.50
357.50	57.61	53.76	3.85	15.86	8.69	7.93	7.73	45.79
355.00	55.11	51.26	3.85	15.86	8.69	7.93	7.73	47.17
352.50	52.61	48.76	3.85	15.86	8.69	7.93	7.73	48.66
350.00	50.11	46.26	3.85	15.86	8.69	7.93	7.73	50.29
347.50	47.61	43.76	3.85	15.86	8.69	7.93	7.73	52.08
345.00	45.11	41.26	3.85	15.86	8.69	7.93	7.73	54.10
342.50	42.61	38.76	3.85	15.86	8.69	7.93	7.73	56.43
340.00	40.11	36.26	3.85	15.86	8.69	7.93	7.73	59.21
337.50	37.61	33.76	3.85	15.86	8.69	7.93	7.73	62.76
335.00	35.11	31.26	3.85	15.86	8.69	7.93	7.73	68.00
332.50	32.61	28.76	3.85	15.86	8.69	7.93	7.73	84.21
330.00	30.11	26.26	3.85	15.86	8.69	7.93	7.73	98.96
327.50	27.61	25.85	1.76	10.72	5.88	5.36	5.22	100.00
325.00	-	-	-	-	-	-	-	-

Table-7: Summary of Hydraulic Analysis for 1524 mm (60") Irrigation & Water Supply Tapping (10.19 m^3/sec)

Reservoir Water Level	Total Head	Head Loss	Net Head	Tapping (1524 mm)		1.14m dia pipe (After Bifurcation)		Gate Valve Opening
				Discharge	Velocity	Discharge	Velocity	
m	m	m	m	m^3/s	(m/sec)	m^3/s	(m/sec)	(%)
378.56	78.68	77.08	1.59	10.19	5.59	5.10	4.97	13.79
375.00	75.11	73.52	1.59	10.19	5.59	5.10	4.97	15.19
372.50	72.61	71.02	1.59	10.19	5.59	5.10	4.97	16.20
370.00	70.11	68.52	1.59	10.19	5.59	5.10	4.97	17.25
367.50	67.61	66.02	1.59	10.19	5.59	5.10	4.97	18.33
365.00	65.11	63.52	1.59	10.19	5.59	5.10	4.97	19.45
362.50	62.61	61.02	1.59	10.19	5.59	5.10	4.97	20.60
360.00	60.11	58.52	1.59	10.19	5.59	5.10	4.97	21.81
357.50	57.61	56.02	1.59	10.19	5.59	5.10	4.97	23.06
355.00	55.11	53.52	1.59	10.19	5.59	5.10	4.97	24.36
352.50	52.61	51.02	1.59	10.19	5.59	5.10	4.97	25.72
350.00	50.11	48.52	1.59	10.19	5.59	5.10	4.97	27.15
347.50	47.61	46.02	1.59	10.19	5.59	5.10	4.97	28.65
345.00	45.11	43.52	1.59	10.19	5.59	5.10	4.97	30.24
342.50	42.61	41.02	1.59	10.19	5.59	5.10	4.97	31.94
340.00	40.11	38.52	1.59	10.19	5.59	5.10	4.97	33.74
337.50	37.61	36.02	1.59	10.19	5.59	5.10	4.97	35.69
335.00	35.11	33.52	1.59	10.19	5.59	5.10	4.97	37.81
332.50	32.61	31.02	1.59	10.19	5.59	5.10	4.97	40.14
330.00	30.11	28.52	1.59	10.19	5.59	5.10	4.97	42.74
327.50	27.61	26.02	1.59	10.19	5.59	5.10	4.97	45.72
325.00	25.11	23.52	1.59	10.19	5.59	5.10	4.97	49.24
323.09	23.20	21.61	1.59	10.19	5.59	5.10	4.97	52.50

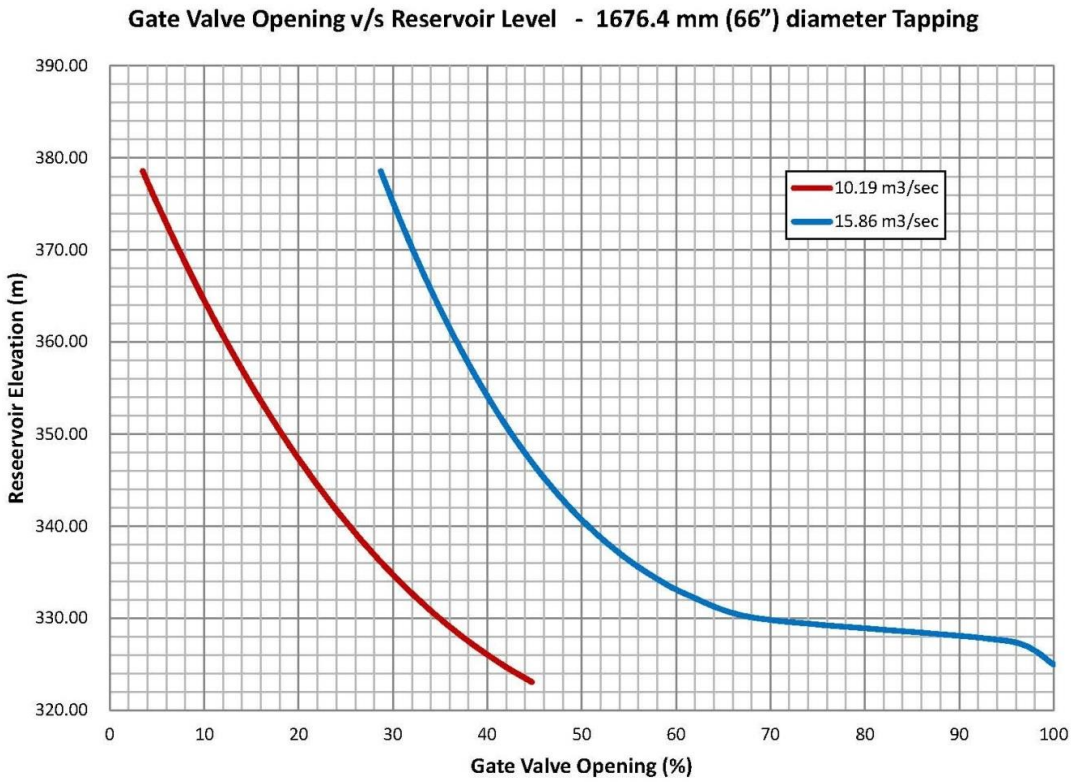


Figure-15: Gate Valve Opening v/s Reservoir Level - 1676.4mm (66") diameter tapping

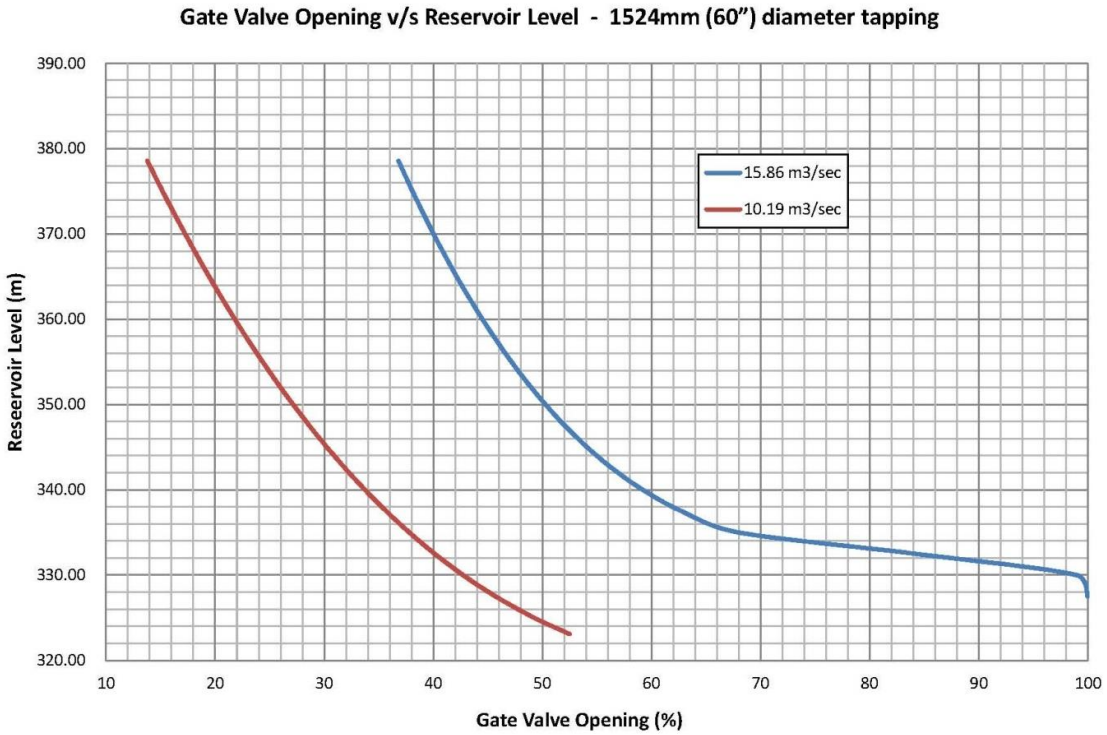


Figure-16: Gate Valve Opening v/s Reservoir Level - 1524 mm (60") diameter tapping

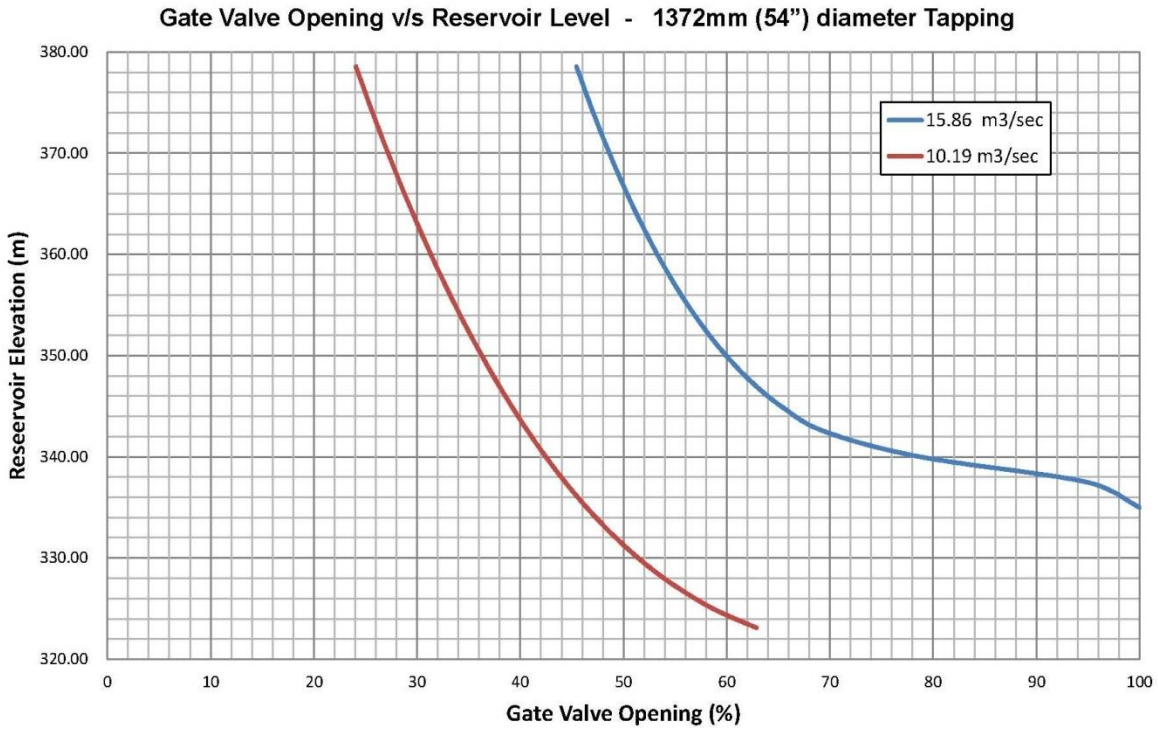


Figure-17: Gate Valve Opening v/s Reservoir Level - 1372 mm (54") diameter tapping

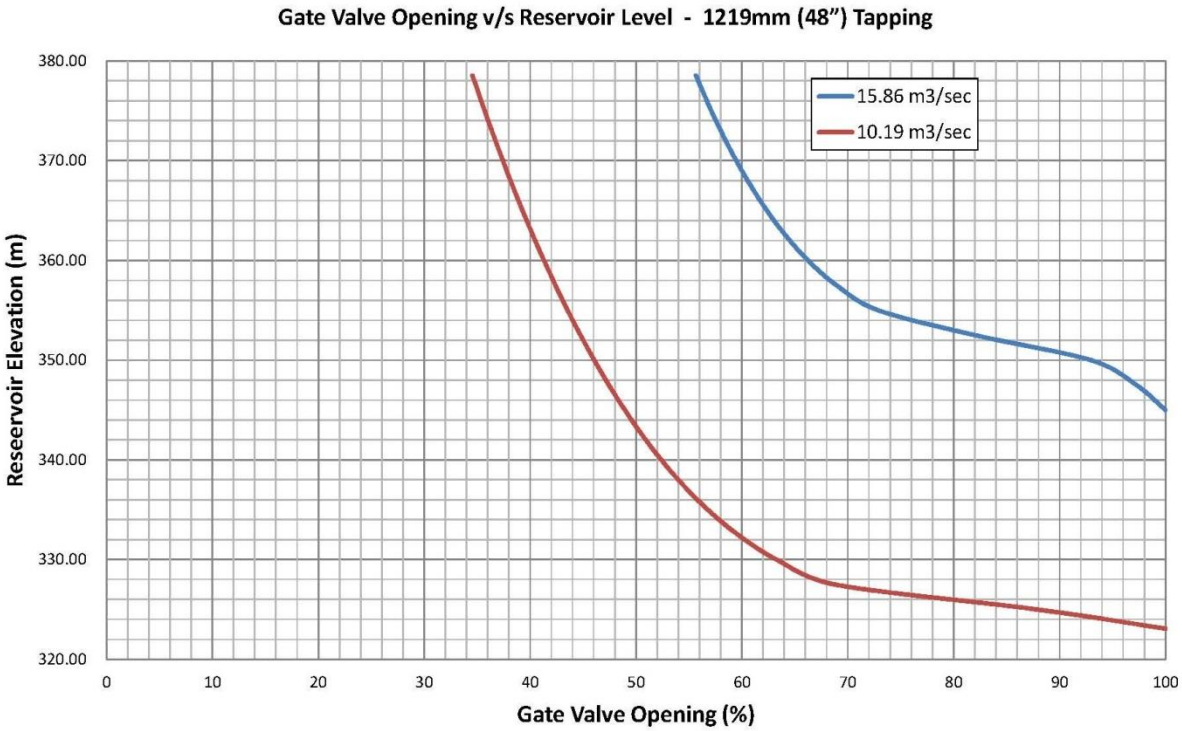


Figure-18: Gate Valve Opening v/s Reservoir Level - 1219mm (48") diameter tapping

Water-Hammer Analysis for New Mirpur City Water Supply Tapping

Water hammer analysis was performed to establish the impact of gate valve closure of New Mirpur City Tapping on the Jari Tunnel. The analysis have been carried out for the 1676.4 mm (66”), 1524 mm (60”), 1372 mm (54”) and 1219 mm (48”) tappings for 15 second and 30 second closure time of the gate valves. Allievi’s chart has been used for the determination of maximum head rise at the location of the valve. Tables-8 and 9 show the summary of the results of water hammer analysis. The total head developed in the tunnel at the location of the tapping is 93.01 m for 15.86 m^3/sec flow in the 1524mm (60”) pipe considering the gate valve closure time of 30 sec. The total head developed in the tunnel at the location of the tapping is 94.06 m for 15.86 m^3/sec in the 1219mm (48”) pipe. The gate valve closing time of 30 seconds is proposed for the1524mm (60”) pipe as the total head developed in case of 15 seconds would be greater than the case of 30 seconds closure time.

Table-8: Summary of Water Hammer Analysis for 1524 mm (60") diameter Water Supply Tapping (15.86 m^3/sec from tapping, no flow from powerhouse)

Location	Diameter	Discharge	Flow Velocity	Distance from intake	Tunnel CL Elevation	Reservoir Elevation	Static Head	Head Rise	Total Head
	(m)	(m^3/s)	(m/s)	(m)	(m)	(m)	(m)	(m)	(m)
Gate Valve Closure Time = 15 sec									
At start of steel lining	2.13	15.86	4.44	332.00	305.26	378.56	73.30	11.99	85.29
At start of Tunnel in culvert	2.13	15.86	4.44	778.00	303.43	378.56	75.13	22.10	103.23
At 1524mm Enlarged Tapping	2.13	15.86	4.44	779.68	298.55	378.56	80.01	28.88	108.90
At Valve in 1524mm Enlarged Tapping	1.52	15.86	8.69	808.32	305.56	378.56	73.00	29.19	102.2
Gate Valve Closure Time = 30 sec									
At start of steel lining	2.13	15.86	4.44	332.00	305.26	378.56	73.30	5.40	78.70
At start of Tunnel in culvert	2.13	15.86	4.44	778.00	303.43	378.56	75.13	12.65	87.78
At 1524mm Enlarged Tapping	2.13	15.86	4.44	779.68	298.55	378.56	80.01	13.00	93.01
At Valve in 1524mm Enlarged Tapping	1.52	15.86	8.69	808.32	305.56	378.56	73.00	13.14	86.14

Table-9: Summary of Water Hammer Analysis for 1524 mm (60") diameter Water Supply Tapping (10.19 m^3/sec from tapping, 5.66 m^3/sec from powerhouse)

Location	Diameter	Discharge	Flow Velocity	Distance from intake	Tunnel CL Elevation	Reservoir Elevation	Static Head	Head Rise	Total Head
	(m)	(m^3/s)	(m/s)	(m)	(m)	(m)	(m)	(m)	(m)
Gate Valve Closure Time = 15 sec									
At start of steel lining	2.13	15.86	4.44	332.00	305.26	378.56	73.30	11.39	84.69
At start of Tunnel in culvert	2.13	15.86	4.44	778.00	303.43	378.56	75.13	26.70	101.83
At 1524mm Enlarged Tapping	2.13	15.86	4.44	779.68	298.55	378.56	80.01	27.44	107.45
At Valve in 1524mm Enlarged Tapping	1.52	10.19	5.59	808.32	305.56	378.56	73.00	27.74	100.74
Gate Valve Closure Time = 30 sec									
At start of steel lining	2.13	15.86	4.44	332.00	305.26	378.56	73.30	5.70	79.00
At start of Tunnel in culvert	2.13	15.86	4.44	778.00	303.43	378.56	75.13	13.35	88.48
At 1524mm Enlarged Tapping	2.13	15.86	4.44	779.68	298.55	378.56	80.01	13.72	93.72
At Valve in 1524mm Enlarged Tapping	1.52	10.19	5.59	808.32	305.56	378.56	73.00	13.87	87.02

Impact Type Energy Dissipater

Energy dissipation of the flows exiting from the water supply tapping is essential before releasing the flows into the existing stilling basin. Therefore, an appropriate energy dissipation arrangement was required to dissipate the energy of the exiting flows without causing any damage to the existing basin.

A standard USBR Type IV Impact Energy Device was selected for this purpose and checked for its technical viability. There were many reasons for the selection of an impact type energy dissipation device. The particular type of impact type energy dissipater is well suited for pipes and outlets especially like the one proposed at this project.

A layout plan, section and elevation sketch for the energy dissipater is shown in Figure 19 and 20.

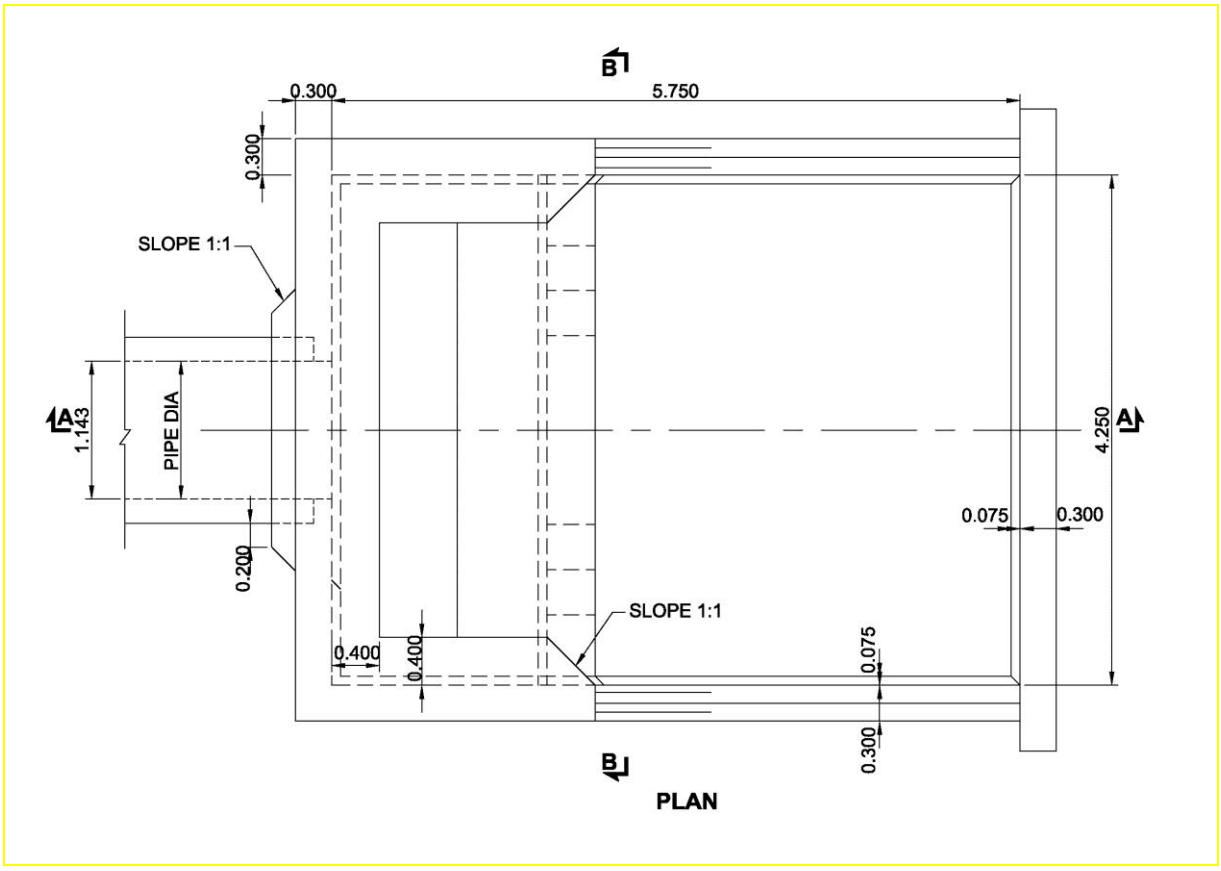


Figure-19: Plan of Impact Type Energy Dissipater (USBR Type VI)

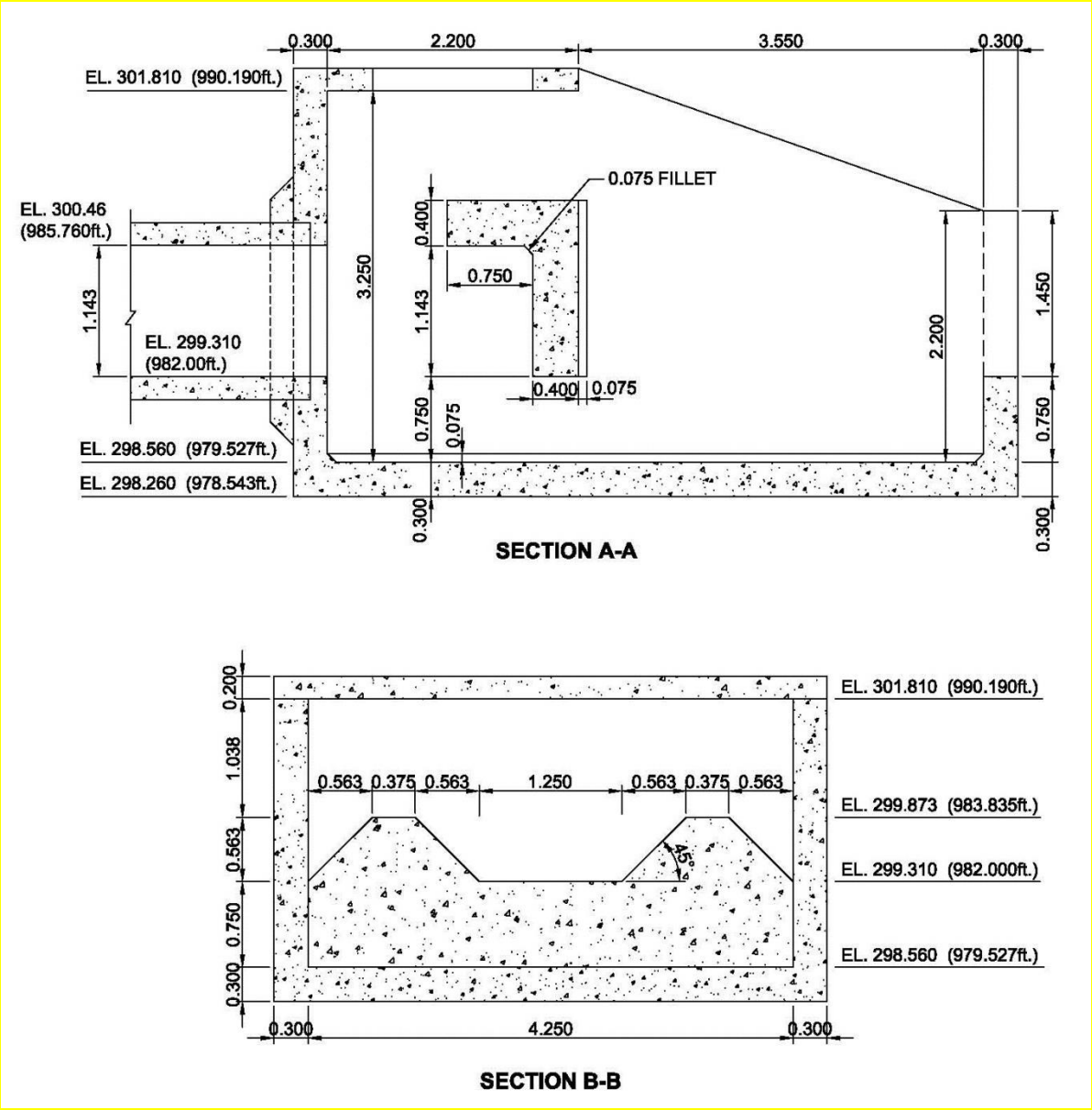


Figure-20: Section of Impact Type Energy Dissipater (USBR Type VI)

The limitation imposed from the United States Bureau of Reclamation recommends a maximum discharge of 11.32 m^3/sec (400 ft^3/sec). The design for a discharge greater than this specified limit is not recommended by the bureau. Usually the discharge of 10.19m^3/sec will pass through this tapping when Khari powerhouse is in operation. However when powerhouse is closed for maintenance or repair, the entire discharge of 15.86m^3/sec will pass through the outlet which exceeds the USBR recommended discharge limit. Therefore, a bifurcation was provided at the end of the water supply outlet and at the end of each bifurcation branch an impact type energy dissipater is provided. Each branch and energy dissipater will take half the discharge and thus meet the USBR requirements.

In comparison to a stilling basin, the same level of energy dissipation can be achieved through an impact type dissipater as from a hydraulic jump for the same Froude number values. An appropriate tailwater level is an essential requirement for proper energy dissipation in a

stilling basin. The jump sweeps out when the tailwater level is lower than required limit. A drowned jump is formed when the tailwater level is above the required limit. The main requirement for a proper hydraulic jump is its formation at the toe of the glacies. Therefore, tailwater levels are to be controlled at all times for thorough out energy dissipation process whereas no such tailwater requirements are to be maintained for the successful performance of an impact type energy dissipater.

Also, limited space is required for the provision of such an energy dissipation device as compared to a stilling basin that needs large dimensions. Limited space was available for the provision of a proper energy dissipation arrangement. Impact type energy dissipation device was hence found to be the best choice.

Impact of Directly Falling Jets in the Existing Stilling Basin

An option of allowing the flows to fall directly in the existing stilling basin downstream of the outlet structure is not suitable because the water jet from the water supply outlet will fall in the middle of the basin and energy dissipation could not be guaranteed since the design of existing stilling basin is not in accordance with the currently provided outlet. The jets would then fall directly at the center of the stilling basin and the excess energy will travel to the outlet channel.

If the energy at the exit end is not fully dissipated within the stilling basin damage is likely to occur at the stilling basin floor and outlet channel. Hence the USBR type VI Impact Energy Dissipation structure was proposed at exit end of water supply outlet keeping in view the existing stilling basin and outlet channel.

The exiting flow jets from the water supply outlet will impact the cantilever baffle beam at the center of the energy dissipater device and the energy is dissipated. The lower end elevation at the cantilever is kept the same as the outlet invert. An end sill is provided in design of the impact type dissipater. It raises the level of water with the dissipater in the form of a pool providing a water cushion. The flows then fall freely in to the stilling basin without causing any damage.

Existing Khari Irrigation Tapping 508mm (20”) diameter

A regulating Howell Bunger Valve of 508 mm (20”) diameter was installed in 1992 for 50 cusecs irrigation supply to Khari irrigation area. The Khari outlet pipe is directly welded on Jari tunnel and not reinforced with wrapper and collar plates as per ASME standard.

Presently the piping of 508 mm (20”) diameter regulating valve is rusted heavily which needs immediate attention by WAPDA/AJ&K Irrigation Authorities to avoid any mishap or catastrophe. Further, the water supply of 1.41 m^3/sec is normally used through Khari Powerhouse and the Khari irrigation tapping is used infrequently.

Since the water discharge of 9.20 to 15.86 m^3/sec is proposed to be utilized through enlarged tapping of 1219mm (48”) diameter for 3.5 MW powerhouse and the 1524mm (60”) New Mirpur City enlarged water supply tapping, it was envisaged that the Khari irrigation tapping may be abandoned considering the conditions described above.