7

Design of Hydraulic Steel Structure Equipment

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7. Design of Hydraulic Steel Structure Equipment

7.1 General

The feasibility layout and design for the Madian Hydropower Project comprises the following main components, which include hydraulic steel structure equipment:

- Concrete weir structure with gated spillway
- Power intake with raking machine and flushing structure
- Desander with gates at inlet and outlet
- Power waterways
- Tailrace and outlet structure
- Diversion tunnel

The gated spillway equipment includes:
- Three radial segment gates (7.6m x 12.0 m) with hydraulic drives
- One radial gate will be equipped with a flap gate (7.6m x 2.5m)
- Set of stoplog for maintenance (7.6m x 12.0 m)
- Gantry crane with capacity 50/10 t;

The power intake facilities include:
- One stoplog set (5.9m x 7.5m) at intake entrance
- Three trashracks (5.9m x 7.5m)
- One cleaning machine with hoisting facilities
- Three intake roller gate (W x H = 3.2m x 4.0m)
- One set of maintenance stoplog (3.2m x 4.0m)

The flushing facilities located between spillway and power intake consist of:
- two roller gates (2m x 3m)
- One set of maintenance stoplogs (2m x 3m) in front and behind
- Steel lining (length of 25 m) of the flushing channel / bottom surface

The three desander caverns are equipped with:
- three slide gates (3.2m x 4m) upstream of the desander cavern
- three slide gates (3.2m x 4m) downstream of the desander cavern
- desanding device with auxiliaries
- six sluice valves DN500 for sediment flushing

The power waterways will include these HSS equipment:
- one sliding gate (5.5m x 5.8m) for inspection & maintenance of pressure shaft and surge tank
- pressure shaft steel (5.4 m) lining starting from elevation 1375 m asl
- three manifolds before main inlet valve

The outlet structure at the end of the tailrace will be equipped with a stoplog (W x H = 6.1m x 7.3m).

The diversion tunnel will be locked after construction of the weir by means of a stoplog (8.0m x 9.5m).

All other hydraulic steel structure or mechanical equipment located in the powerhouse cavern is described in section 6 of the present report.

7.2 Design Criteria

For the feasibility design the following hydraulic and civil design criteria have been established in coordination with the Project Sponsor:

7.2.1 General Design Criteria

The properties of water in the Swat River were determined in the period 2006 to 2007 at Kedam gauging station by the Consultant (see Environmental Impact Assessment Study, Volume VI-a).

According to the elevation of the project area between 1495 m at the weir structure and 1340 m at the power outlet the gravity acceleration is applied as follows:

at mean sea level	9.810 m/s^2
at weir site (1495)	9.795 m/s^2
at powerhouse site (1340)	9.796 m/s^2

The hydrological regime and resulting discharge characteristics of Swat River are described in the previous Section 3 of this report. The design heads and discharges consider the rating curves for the design requirements as listed in the clauses of Section 4. The power waterways are designed for a maximum nominal discharge of 129 m^3/sec.

Particular attention is given to the potential impact of bed load and the expected rate of sediment transport during the flood season. Particular attention is paid to this aspect in the feasibility design and the corresponding provisions made in the specification of the equipment to cope with it.

This will also be achieved by an appropriate and proven wear resistant corrosion protection system, which is applied to all steel components exposed to water and not made of stainless steel. This system has to comply with ISO 12 944 and ISO 4628.

The hydraulic steel structure equipment described here below refers to state-of –the art design and international recognized standards are applied to the design.

The design of all gates, stoplogs and other equipment with the appurtenant drives has to fulfil the requirements according to the standards for hydraulic steel structures DIN 19704 (Criteria for design and calculation) and DIN 19705 (Recommendations for the design, construction and erection of hydraulic steel structural equipment) or equivalent British or American standards.

7.3 Spillway

The gated spillway consists of three radial gates for the spillway bays, one of them with hinged flaps on the top for fine regulation of the reservoir level and for spilling of floating debris. The radial gates are used for flood control and discharge of excess water. Operation control must be possible locally from the Local Control Room and remote from the Main Control Room.

7.3.1 Radial Segment Gates

The spillway gates will regulate the river flow when the total discharge exceeds the discharge conveyed of the turbine. Spilling operation will occur more than 40% of the time each year. The gates shall have self closing tendency. The gate design must enable the gate and hoist to be operable under any upstream water level and flow conditions.

Basic data and design criteria of the radial gates are:

Clear width of one spillway bay opening	7.6 m
Gate height (approx.)	12.0 m
Freeboard	0.50 m
Clear width of flap gate	7.6 m
Flap height (approx.)	2.5 m
Sill elevation	1482.5 m asl
Gate sill in max. raised position	1495.5 m asl
Max Reservoir Level	1494.5 m asl
Crest elevation of the piers	1496.0 m asl
Max. operation load:	All hydraulic loads, dead weights and friction loads
Hoist	Oil-hydraulic
Gate and flap normal operation speed	0.3 m/min
Gate opening speed	0.3 m/min

Table 7.1: Basic data and design criteria of the radial gates

The gates shall be manufactured with class S 355 JO structural steel according to DIN EN 10025. The Spillway radial gates shall be designed according to DIN 19704.

Two servomotors connected to the gate arms shall operate each spillway gate. In an exceptional case of operation, if one servomotor of the radial gate fails, the remaining servomotor shall hold or must be able to lower down the gate. The hydraulic power units will be located on the spillway piers, in a common control room, together with the local control boards.

In the event of main power failure, the power supply for the hydraulic units will be by a diesel-powered generator. As an additional backup system, each hydraulic unit must be equipped with a hand pump to move the gates. Those hand pumps are installed at the hydraulic power unit.

The trunnion bearings for the gates shall be of spherical bronze bush type to allow more flexibility of the structures. Both trunnion and hinged flap bearings must be self-lubricating.

The frames shall consist of a sill beam profiled to be tangential to the spillway surface, and side frames consisting of a combined seal seat, and track for the leaf side guide wheels. The seal seats/track surface shall be machined to the tolerance permitted in DIN 19704. Side frames are extended to the top of the spillway piers. All seal seats will be of stainless steel, machined and polished.

7.3.2 Radial Gate with Flap Gate

In the left spillway bay a radial gate will be installed with integrated flap gate on top next to the flushing outlet. It shall be a torsion-rigid box type. The upper edge of the gate leaf will be fitted with a series of flow dividers to ensure aeration of the water for overshot operation. The gate will be equipped with lateral seals and bottom seal, resistant against wear and ambient conditions. The side seals must be adjustable from the downstream side. One, max. two cylinders shall operate the flap gate.

Clear width of one spillway bay opening	7.6 m
Total Gate height (approx.)	12.0 m
Freeboard	0.50 m
Clear width of flap gate	7.6 m
Flap height (approx.)	2.5 m
Max Reservoir Level	1494.5 m asl
Crest of the piers	1496.0 m asl
Max. operation load:	All hydraulic loads, dead weights and friction loads
Hoist	Oil-hydraulic
Flap normal operation speed	0.3 m/min

Table 7.2: Basic data and design criteria of the radial gate with flap

7.3.3 Stoplog for Maintenance

In order to enable in situ maintenance work at the radial gates and to enhance erection, one set of stoplogs for the spillway, to be installed upstream of the radial gates, is provided. These stoplogs will be stored at deck level 1496 m asl within the reach of the gantry crane (see Plate 13). All stoplogs elements shall have the same shape and dimensions. The stoplogs will be installed with the gantry crane. Balanced water level conditions between stoplogs and radial gate will be achieved by slightly lifting the upper stoplog element by means of the gantry crane.

Clear width of one spillway bay opening	7.6 m
Number of stoplog elements	4
Height of one stoplog element	approx. 3.0 m
Freeboard	0.50 m
Sill elevation of stoplogs	1482.5 m asl
Max Reservoir Level	1494.5 m asl
Crest elevation of the piers	1496.0 m asl
Placing stoplogs	Balanced water head conditions
Max. operation load:	All dead weights and friction loads
Sealing:	At downstream side
Lifting device:	Main gantry crane and lifting beam

Table 7.3: Basic data and design criteria of the spillway stoplogs

7.3.4 Gantry Crane

One gantry crane with an approximate lifting capacity 50/10 tons will be installed to serve the spillway. The final capacity of the crane shall be coordinated with the design of the spillway radial gates and stop logs in the tender design stage. The crane will be able to travel to the unloading platform located beside the spillway structure.

The gantry cranes will serve to install the spillway stop logs and to assemble and erect the spillway radial gates with flaps. The basic framework and the various mechanisms comprising the crane shall be designed and fabricated to permit various maneuvers, necessary during the erection of the equipment, smoothly and accurately. The combination of movements of the gantry crane, the main and the auxiliary hoists shall be such that the hooks can sweep the largest possible surface area. The motor components producing the various movements shall be fitted with a progressively acting braking system which shall operate in case of any accidental or intentional cutting off of the power supply.

The design of the crane will consider the dead load, which includes the weight of all parts of the crane, except those parts specified as live load. The maximum live load will include the lifted loads, lifting beams, lifting devices, lower hoist block, hooks, ropes and trolley. Impact shall be taken as 15 % of the live load.

Lateral live loads caused by acceleration, wind, earthquake, collision forces and braking operation have to be considered during design and dimensioning.

Main characteristics of the gantry crane are:

Rail track elevation	1496.0 m asl
Distance between centres of railway lines	20 m
Total rail track length approx.	53 m
Hoisting capacity main hoist	approx. 50 tons
Hoisting speeds main hook:	
normal speed	1.6 m/min
creeping speed	0.3 m/min
Hoisting capacity auxiliary hoist	10 tons
Hoisting speeds auxiliary hook:	
normal speed	4 m/min
creeping speed	0.5 m/min
Gantry travelling speed	
normal speed	25 m/min
creeping speed	0.6 m/min
Trolley travelling speed	
normal speed	15 m/min
creeping speed	0.6 m/min
Crane control	
from an enclosed cabin fixed to the gantry crane frame	
Design criteria	
crane structure	FEM class A3
crane mechanism	FEM class M2

Table 7.4: Basic data and design criteria of the spillway gantry crane

7.4 Equipment of Power Intake

7.4.1 Stoplogs

To dewater the individual bays of the intake structure for maintenance of the trashrack and the intake roller gate, stoplogs can be installed upstream of the trashrack and immediately downstream of the fixed wheel roller gates. These stoplogs will be stored at deck level 1496 m asl (see Plate 13). Setting of these two stoplogs permits maintenance/inspection at one gate or trashrack while flow and power plant operation may proceed via the remaining inflow sections. All stoplog elements shall have the same shape and dimensions. The stoplog elements will be installed by means of a mobile crane.

Design data of stoplog before trashrack:

Type	Sliding gate
Clear width of the intake opening	5.9 m
Number of stoplog elements	4
Height of one stoplog element	3.0 m
Freeboard	0.80 m
Sill elevation of stoplog	1482.8 m asl
Max Reservoir Level	1494.5 m asl
Crest of the piers	1496.0 m asl
Placing stoplogs	Balanced water head conditions
Max. operation load:	All dead weights and friction loads
Sealing:	At downstream side
Lifting device:	Mobile crane and lifting beam

Table 7.5: Basic data and design criteria of the power intake stoplogs at trash rack

Design data of stoplog after the roller gate:

Clear width of the culvert	3.2 m
Number of stoplog elements	1
Height of one stoplog element	4.0 m
Sill elevation of stoplog	1483.0 m asl
Max Reservoir Level	1494.5 m asl
Crest of the piers	1496.0 m asl
Placing stoplogs	Balanced water head conditions
Max. operation load:	All dead weights and friction loads
Sealing:	At upstream side total circumference
Lifting device:	Mobile crane and lifting beam

Table 7.6: Basic data and design criteria of the power intake stoplogs at roller gate

Balanced water level conditions between stoplogs and radial gate will be achieved by slightly lifting the upper stoplog element.

7.4.2 Trashrack

The trashrack screen consists of 3 identical elements covering the inlet area with a clear width of 5.9 m and a clear height of 7.5 each (total area of 3 x 44.25 m^2) each split in three segments. The frames and screen segments will be fabricated from structural steel plates and sections which will comply with EN 10025 or other approved standards dealing with structural steelwork. The trashrack panels will be supported by means of a pre-caste concrete beam of fish belly shape as indicated in Plate 22.

The design has to provide vibration-free performance and minimal head loss. A clear spacing between screen bars of 75 mm was selected and will be re-confirmed in the detailed design in co-operation with the turbine manufacturer. The screens have vertical screen bars. The edges of the bars should be designed to prevent or suppress flow induced vibration in flow direction. The trash rack shall be designed to withstand a differential head of not less than 3 m.

Suitable differential pressure sensors will be installed to register pressure differentials across screens to waterways. The sensors will activate an alarm, when the differential pressure reaches 0.5 m. If the differential pressure continues to rise and reaches 2 m, the sensor shall operate the roller gate closure or act otherwise to stop the flow.

7.4.3 Trashrack Cleaning Machine

The rake cleaning machine will be a movable portal raking machine with operator cabin and container for the removed trash. It will be designed in accordance with the inclination of the trashrack. A control cabinet shall be installed on the portal from where all operations of raking can be controlled.

The rake shall be arranged to travel up and down the trashrack screens, to bring trash to the operating level and to discharge it into the trash skip.

The main characteristics of the raking machine are as follows:

- mode of operation	local control and remote control (manual and automatic operation)
- elevation of operation deck	1496 m asl
- height of trashrack (inclined)	app. 7.5 m
- inclination of trashrack	15°
- width of each trashrack element	5.9 m
- clearance between trashrack bars	75 mm
- minimum thickness of trashrack bars	10 mm
- width of rake	3 m
- rake net capacity	3 tons

Determining the design force for the rake hoist, an additional charge of 20 per cent has been considered besides the dead weight and the sliding resistance.

The rake will be equipped with suitable rollers to ride on the trashrack bars and guide rails of the raking machine. The rollers will be located and sized to ensure that the rake is positioned for complete cleaning of the bar elements of the trashrack and for keeping the raked debris in and trash up to dumping them on the trash skip. The rollers will be equipped with rubber facings to avoid damage to the concrete apron. For management of trash a container will be placed next to the raking machine, the trash will be transported to the camp site, sorted (organic material, plastics etc.), recycled or treated according to the requirements.

7.4.4 Intake Roller Gate

The intake gates located downstream of the trashrack serve as emergency closure devices in case of failures or damages of downstream structures in the desander or waterways, extraordinary pressure difference at the trashrack etc.

The gate will seal upstream and have ballast for gravity closure against flow with adequate factors of safety against hydraulic forces and friction. The gates shall operate without failure or vibration under the most adverse combination of hydraulic flow and mechanical resistance due to friction, debris or other causes. Operation will be by a hydraulic servomotor set operating at deck level and coupled to the gate via steel linkage rods. Temporary maintenance platforms, handling equipment and dogging devices will be provided to facilitate raising and removal of the gate (Plate 22 indicates permanent installations). Filling of the headrace tunnel (e.g. after inspection) will be performed by opening slightly the gates.

All gate controls and hydraulic motors will be housed in a control building at the intake deck level. Emergency closure of the intake gate will be possible by remote control from the powerhouse and by an emergency closure control button at the intake. Gates will be designed, fabricated and erected in accordance with BS 5950 and DIN 19704 as applicable.

<u>Design data of roller gate:</u>

Type	Fixed Roller Gate
Number of gates	3
Clear width of opening	3.2 m
Clear height of opening	4.0 m
Sill elevation	1483.0 m asl
Max Reservoir Level	1494.5 m asl
Crest of the piers	1496.0 m asl
Operation	Open against max. differential head Close at max. flow
Max. operation load:	All dead weights and friction loads
Seal position:	upstream
Maximum allowable leakage	0.1 l/m of seal/sec
Operating mechanism:	Hydraulic Hoist

Table 7.7: Basic data and design criteria of the roller gates at power intake

7.4.5 Gate of Flushing Channel

The flushing structure is located left of the gated spillway in extension of the power intake structure. The two sliding gates are operated intermittently to flush the sand and gravel which may deposit in front of the power intake into the tailrace when required. In view of the expected high sediment load during the high flow season, particular attention has to be given to a rigid and wear resistant design.

The gates will seal upstream and have ballast for gravity closure against flow with adequate factors of safety against hydraulic forces and friction including a load resulting from 2 m high sediment deposition. They have to operate without failure or vibration under the most adverse combination of hydraulic flow and mechanical resistance due to friction, debris or other causes. The gate is designed to be opened safely under tailwater levels prevailing at the stilling basin end sill.

Control will be by a hydraulic servomotor set operating at deck level and coupled to the gate via steel linkage rods. Maintenance platforms, handling equipment and dogging devices will be provided to facilitate raising and removal of the gate. All gate controls and hydraulic motors will be housed in a control building at the intake deck level. Emergency closure of the intake gate will be possible by remote control from the powerhouse and by an emergency closure control button at the intake.

Gates will be designed, fabricated and erected in accordance with BS 5950 and DIN 19704 as applicable.

<u>Design data of flushing gate:</u>

Type	Fixed Roller Gate
Number of gates	2
Clear width of opening	2.0 m
Clear height of opening	3.0 m
Sill elevation	1477.0 m asl
Max Reservoir Level	1494.5 m asl
Crest of the piers	1496.0 m asl
Operation	Open against max. differential head Close at max. flow
Max. operation load:	All dead weights and friction loads
Seal position:	upstream
Maximum allowable leakage	0.1 l/m of seal/sec
Operating mechanism:	Hydraulic Hoist

Table 7.8: Basic data and design criteria of the roller gates at flushing outlet

7.4.6 Stoplog

To have access to the flushing gate for maintenance purposes under any operating conditions, stoplogs will be installed upstream and downstream of the flushing gates (2 bulkhead gates upstream and 1 downstream). These stoplogs will be stored at deck level 1496 masl. The stoplog elements shall have the same shape and dimension and shall be designed to withstand the pressure generated of sediment deposition of up to 2 m height. The stoplog elements will be installed by means of a mobile crane. Balanced pressure conditions between stoplogs and roller gate in the flushing duct will be achieved by lifting the stoplogs slightly by the mobile crane.

Design data of stoplog elements of flushing gate:

Type	Sliding gate
Number of elements	3
Clear width of opening	2.0 m
Clear height of opening	3.0 m
Sill elevation	1477.0 m asl
Max Reservoir Level	1494.5 m asl
Crest of the piers	1496.0 m asl
Operation	Open/close at balanced water level
Max. operation load:	All dead weights and friction loads
Seal position:	to waterside
Maximum allowable leakage	0.1 l/m of seal/sec
Lifting device:	Mobile crane and lifting beam
Operating mechanism:	Hydraulic Hoist

Table 7.9: Basic data and design criteria of the stoplogs at flushing outlet

7.4.7 Steel Lining of Flushing Channel

The concrete structure of the flushing channel is subject to extraordinary wear and tear during flushing operation. Particularly during the high flow season several flushing operations per day may to necessary. Therefore it is planned to cover the entire flushing channel by a steel lining of 20 mm thickness, which will be also used as lost formwork. The steel lining starts at the pier nose and will end after the downstream stoplog. It may be envisaged to extend the steel lining of the bottom plate into the flushing channel

7.5 Desander

The civil design provides a single headrace tunnel and three underground desander caverns. From the headrace tunnel 3 manifolds branch of upstream and downstream of the caverns. For inspection and maintenance of each desander cavern gates are provided in the upstream and downstream manifolds. This concept ensures inspection and maintenance of a single desander cavern without suspending power plant operation and emptying the entire pressure tunnel.

7.5.1 Sliding Gate at Outlet

The sliding gates including all accessories and control cubicles are located in a gate chamber near the desander cavern which is connected by a gallery to the downstream access tunnel. It is not intended to inspect the caverns frequently, hence the gates are operated more or less in stand-by, however a safe and reliable operation must be ensured after long stand still times.

The gate will seal downstream and has ballast for gravity closure under balanced water conditions with adequate factors of safety against hydraulic forces and friction. They have to close without failure or vibration under the most adverse combination of mechanical resistance due to friction or other causes. The gate with hydraulic hoist will be installed in a hermetically sealed housing to prevent the chamber from flooding.

All gate controls and hydraulic motors will be located in the cavern chamber. Closure of the outlet gate will be only possible by remote control from the powerhouse and by a closure control button in the gate chamber.
Gates will be designed, fabricated and erected in accordance with BS 5950 and DIN 19704 as applicable.

Design data of flushing gate:

Type	Sliding Gate with housing
Number of gates	3
Clear width of opening	3.2 m
Clear height of opening	4.0 m
Sill elevation	1475.0 m asl
Max Reservoir Level	1494.5 m asl
Operation	Open against max. differential head Close at max. flow
Max. operation load:	All dead weights and friction loads
Seal position:	downstream
Maximum allowable leakage	0.1 l/m of seal/sec
Operating mechanism:	Hydraulic Hoist

Table 7.10: Basic data and design criteria of the sliding gates at the desander inlet

7.5.2 Sliding Gates at Inlet

The sliding gates including all accessories and control cubicles are located in a gate chamber at the inlet to the desander cavern. Also for these gates a safe and reliable operation must be ensured after long stand still times.

The gate will seal upstream and has ballast for gravity closure under balanced water conditions with adequate factors of safety against hydraulic forces and friction. The gate with hydraulic hoist will be installed in a hermetically sealed housing to prevent the chamber from flooding.

All gate controls and hydraulic motors will be located in gate chambers connected by a gallery to the upstream access tunnel. Closure of the inlet gate will be only possible by remote control from the powerhouse and by a closure control button in the gate chamber.

Gates will be designed, fabricated and erected in accordance with BS 5950 and DIN 19704 as applicable.

Design data of flushing gate:

Type	Sliding Gate with housing
Number of gates	3
Clear width of opening	3.2 m
Clear height of opening	4.0 m
Sill elevation	1475.0 m asl
Max Reservoir Level	1494.5 m asl
Operation	at balanced condition
Max. operation load:	All dead weights and friction loads
Seal position:	upstream
Maximum allowable leakage	0.1 l/m of seal/sec
Operating mechanism:	Hydraulic Hoist

Table 7.11: Basic data and design criteria of the sliding gate at the desander outlet

7.5.3 Desander

Suspended sediments (sand and silt) transported by Swat River and entering the headwork of the Madian HPP will unavoidably result in a certain wear and tear. The extent of the abrasion depends largely on the concentration, size and mineralogical characteristics of the sediment particles on one hand and the turbine type and runner speed on the other. This abrasion and the resulting need for overhaul and replacement of runners cannot be avoided, however, the frequency of repair works can be reduced by arrangement of desanding facilities.

The Consultant studied possible alternative types of desanding facilities that may be applied to the feasibility design of the Madian HPP assessing their technical merits and demerits.

Reference is made to ORTMANN (2006) who presents a state of the art assessment of desanding facilities. Among hydropower projects with desanding facilities implemented during the last 20 years, the long basin type desander is the design most frequently applied.

Long basin-type desander: Subdivision is made for the type of flushing system, intermittent or continuous flushing (System Büchi, Bieri, Serpent Sediment Sluicing System - 4S).

The Consultant selected a concept which permits continuous operation of the power plant by means of intermittent (or if required continuous operation of the desander basin). A concept was selected for the design and operation of the desander basin which represents a modification of the so called “Bieri”-Desander Design (Switzerland) applying elements of the recently developed so called “4-S” Design (Norway). The selected design is different from the Bieri-Type desander as regards the type of valve that seals the desander basin and controls the release of sediments from the settling basin into the flushing ducts.

Instead of using two moveable metal sheets as it is the case in the standard Bieri system, the Consultant introduced a system that uses a hydro-pneumatic sealing similar as a small rubber weir. The rubber sealing consists of a number of individual cells operated similar as an inflatable hose as e.g. applied at rubber weirs. At high internal pressure the system seals the bottom of the desander basin and at reduced pressure it provides a small slot for the sediments to slide into the flushing duct where water with sufficient speed evacuates the sediment. Under normal operation conditions the desander caverns are operated continuously under pressure. Intermitted flushing of the chamber is possible by operating the pneumatic rubber seals proposed by the Consultant. These rubber weir type-seals separate the desanding cavern from the below parallel running flushing ducts. The seals may open automatically when a certain quantity of sand has accumulated or can be operated at pre-defined intervals by reducing the internal pressure in the rubber seals.

The discharge in the flushing ducts is controlled by the flushing gates situated at the junction to the central flushing tunnel. In the flushing tunnel the water-sediment mixture continues by free flow and enters Swat River close to the confluence with Ashkon Nullah. The desanding caverns as well as the flushing tunnels shall be concrete lined lined. The pump/compressor system for the rubber hose sealing system with accessories and control devices will be installed in a common control room together with the panels of the sluice valves. There are a number of advantages of removing deposited sediments by the above method:

- continual operation of the sedimentation unit,
- minimal use of liquid when removing sediments,
- simple means of operating the unit,
- possibility of adjusting the unit to the characteristics of the sediment in the inflowing fluid and any requirements concerning sediment content after it has passed the sediment trap.

Reference is further made to hydropower projects with desanding facilities operating under similar conditions similar as to Madian HPP (Table 4.20).
In the tender design stage the proposed hydro-pneumatic valve shall be tested in co-operation with the potential supplier/manufacturer (BIERI).

7.5.4 Sluice Valve

The sluice valves are installed at the outlet of the flushing ducts of the desander caverns just upstream of the junction with the flushing tunnel.

When the desanding basin is filled to a certain level with sediments, the flushing procedure will be initiated. Simultaneously, the sluice valves are opened to flush the sediment to the flushing tunnel and return the flow to Swat River. Their design and corrosion protection must be proved to resist wear and tear under the adverse operating conditions of heavy suspended water and the high flow velocities during flushing.

Design data of flushing gate:

Type	Standardised Sluice Valve
Number of valves	6
Nominal Diameter	DN 500
Nominal Pressure	PN 6
Operation	Open against max. differential head Close at max. flow
Maximum allowable leakage	0.1 l/m of seal/sec
Operating mechanism:	Electric or hydraulic actuator

Table 7.12: Basic data and design criteria of the flushing gate at the desander

7.6 Power Waterways

7.6.1 Bulkhead at Surge Tank

The bulkhead is located at the surge tank and serves as maintenance gate to dewater the pressure shaft between surge tank and powerhouse. The gate is only operated under no flow condition, when the turbines are at standstill.

The bulkhead will seal upstream and has ballast for gravity closure with adequate factors of safety against hydraulic forces and friction. Appropriate guide rollers shall ensure a fail-safe positioning of the bulkhead in the slot once lowered.

A by-pass valve of sufficient size shall be integrated in the bulkhead to refill the pressure shaft within the admissible time. It is operated by a mechanical opening /closing mechanism.

All gate controls and the winch drive with motor will be located in a machine room beside the surge tank. All operation will be only possible on the local control board located in the machine room.

Design data of bulkhead:

Type	Sliding Gate
Number of gates	1
Clear width of opening	5.5 m
Clear height of opening	5.8 m
Sill elevation	1449.0 m asl
Max water level	1494.5 m asl
Operation	Open /close at balanced condition
Max. operation load:	All dead weights and friction loads
Seal position:	upstream
Maximum allowable leakage	0.1 l/m of seal/sec
Operating mechanism:	Winch drive with steel drums

Table 7.13: Basic data and design criteria of the maintenance gate at surge tank

7.6.2 Pressure Shaft Steel Liner and Manifold

The pressure shaft is split into a concrete lined section of nominal internal diameter of 5.8 m starting at the surge tank and a steel lined part to the high pressure side. The steel liner of nominal internal diameter of 5.4 m starts at a level of approx. 1375 m asl and comprises of the following sections:

- A vertical section with constant internal diameter of 5.4 m and a length of approx. 25 m;
- The upper circular end of the liner has to be stiffened with an adequate ring to keep the shape and guarantee the transition to the concrete lined pressure shaft of 5.8 m diameter; transition at internal steel lined shaft diameter from 5.4 m to 5.8 m;
  A 90° segmented and fabricated bend from the vertical to the horizontal steel liner.
- A horizontal section with constant internal diameter of 5.4 m and a length of approx. 20 m, external stiffeners where required.
- The manifold with three branches.

The bifurcations will have an optimized shape to minimize head losses and an internal reinforcing structure. The splitting of bifurcation for site installation will be made depending on the size of construction and tunnel excavation. Three pipelines will be site-erected and installed with an internal diameter of 3.0 m including the required bends to the upstream conical pipe of the butterfly valves with nominal internal diameter of 2.5 m. The design pressure will be 20 bar. An external pressure of max 5 bar is estimated based on the recorded groundwater tables in the bore holes (see Section 3.4 and Volume III of this Feasibility Study Report). However the external pressure has to be verified during the detailed tender design taking into consideration the latest available data at that stage

The design method of "E. Amstutz, Schweizerische Bauzeitung No. 28, 1969" or “Buckling of circular rings and cylindrical tubes under external pressure, S. Jacobsen” will be applied. Stiffeners or anchors will be included at Tender Design stage to guarantee the required safety against buckling. The following standards may become applicable for the design of the steel liner and the manifold:

- European Standards
- DIN Standards
- American Codes, ASME, AWS, ASCE
- CECT (Recommendations for the Design, Manufacture and Erection of Steel Penstocks of Welded Construction for Hydroelectric Installations, published by the European Committee for Boiler Making and Kindred Structures)

The steel plates (stiffeners, steel liner a. s. o.) shall comply with the EN 10028-3, P355NL1 or P460NL1 standard or equivalent. Once erected the steel liner will be pressure tested with a factor of 1.5 of max. operating pressure. A corrosion allowance of 1 mm and adequate anti-corrosion protection are defined in the present feasibility design.

7.7 Tailrace Outlet Bulkhead Gate

The bulkhead gate located at the outlet of the tailrace, where the flow is returned to Swat River, will close the tailrace in case of an outage of the powerhouse or any maintenance works in the tailrace tunnel. For this purpose a bulkhead gate of sliding gates type is foreseen including all accessories and control cubicles, which are located in the control building integrated in the gate structure. The gate will seal to the riverside and has ballast for gravity closure under balanced water conditions with adequate factors of safety against hydraulic forces and friction. Closure and opening of the gate will be possible by a mobile crane.

Provisions are to be made to re-suspended sediments that may have settled immediately downstream of the gate during the time of closure, such as e.g. a pipe with a number of ejectors embedded in the bottom slab downstream of the gate through which air may be injected under high pressure by means of a mobile compressor

<u>Design data of outlet gate:</u>

Type	Sliding Bulkhead Gate
Number of gates	1
Clear width of opening	6.1 m
Clear height of opening	7.3 m
Sill elevation	1336.0 m asl
Max Water Level	1346.0 m asl
Operation	at balanced condition
Max. operation load:	All dead weights and friction loads
Seal position:	downstream / to riverside

Table 7.14: Basic data and design criteria of the maintenance gate at surge tank

The gate may be slightly lifted (by a mobile crane) and a single turbine unit may be operated under partial load so that the flow is removing flushing the sediments towards the riverbed. The bulkhead gate will be designed, fabricated and erected in accordance with BS 5950 and DIN 19704 as applicable.

7.8 Stoplog for Diversion Tunnel

In order to close the diversion tunnel intake once the construction of the weir is accomplished and to plug the intersection with the headrace tunnel with concrete, one set of stop logs (concrete and/or steel) will be provided.

Diversion tunnel inlet dimensions (W x H): 8.0 x 9.2 m
Sill elevation: 1478.0 m asl
Design water level: 1494.5 m asl

Design data of Diversion Tunnel Stoplogs:

Clear width of diversion tunnel inlet	8.0 m
Number of stoplog elements	11
Height of one stoplog element	approx. 1.5 m
Freeboard	0.50 m
Sill elevation of stoplog	1478.0 m asl
Max Reservoir Level	1494.5 m asl
Crest elevation of the piers	1496.0 m asl
Placing stoplogs	Balanced water head conditions
Max. operation load:	All dead weights and friction loads
Sealing:	At downstream side
Lifting device:	Mobile crane and lifting beam

Table 7.15: Basic data and design criteria of the diversion intake stoplogs

Setting the stoplogs at the diversion tunnel intake structure shall proceed during the low flow period after completion of the weir structure and partial removal of the upstream cofferdam.

Either elements shall be provided that permit safe setting against flow in the diversion tunnel up to elevation 1483.5 m asl, or a 4 m high cofferdam shall be arranged at the intake structure using material from the upstream cofferdam. When setting of stop logs is completed up to elevation 1482.5 flow starts passing over the spillway (gates open) and the stop log elements can be set above elevation 1483.5 m asl in dry conditions.