PROJECT SUMMARY

1. Introduction

The Ghulam Faruque Group has submitted an Expression of Interest to the Private Power & Infrastructure Board (PPIB) of the Ministry of Water & Power, Islamabad, for the development of the Madian Hydropower Plant in the Upper Swat Valley, on Swat River 60 km north of the town of Mingora.
The Contract for conducting a bankable Feasibility Study was awarded to the German Consultant Fichtner GmbH to assess the technical, economic and environmental viability of the Project. Fichtner appointed Pakistan Engineering Service (PES), a local sub-consultant to assist in the elaboration of the feasibility study.

1.1 Scope of Work

The scope of the study is in brief as follows:

Phase I: Pre-Feasibility Study
- To review the previous work which had been done,
- To obtain any data deemed relevant by the Consultant,
- To assess the site conditions,
- To identify and compare any alternatives,
- To prepare a new topographic survey of the project area.
- To establish the long term hydrological basis for the Project.
- To produce a preliminary geological/geo-technical model of the Project.
- To carry out preliminary engineering studies comprising the power potential and determination of design capacity.
- To prepare preliminary layouts and designs, cost estimates, a financial / economic assessment together with a tariff calculation,

Phase II Feasibility Study of the Preferred Alternative
- To define the controlling topographic, hydrologic, sedimentological and geotechnical parameters for the design of the project,
- To carry out detailed geological mapping and detailed ground investigations, comprising seismic refraction, sub-surface drillings, investigation pits and laboratory tests.
- To review and optimize the layout and design of the selected alternative.
- To assess the Project in the context of the cascade scheme.
- To make an environmental and social impact assessment,
- To prepare a detailed cost estimate and calculate the total construction / implementation costs.
- To carry out a risk analysis indicating the technical, economical and financial viability of the proposed scheme, and
- To evaluate the financial and economic characteristics, and determine the tariff.

Phase III
- To present the draft Bankable Feasibility Study to the POE and PPIB.
- To review and complete the final Bankable Feasibility Study.

1.2 Previous Works

Comprehensive studies for assessment of the hydropower potential of the Swat catchment area were carried out between 1990 and 1995 and updated in 2006 by the so called Cascade Study (MAES, Mirza Associates Engineering Services (PVT) Ltd) proposing the development a cascade of five hydropower plants on the Swat Valley:

- Matiltan, 84 MW
- Gabral – Kalam, 101 MW
- Kalam-Asrit, 197 MW
- Asrit-Kedam, 209 MW
- Madian, 148 MW (subject of this feasibility study)

1.3 Objectives of the Feasibility Study Report

During Phase I of the Feasibility Study, layout alternatives of the Madian Hydropower Project were identified and studied on comparative basis. At the beginning of Phase II – Feasibility Study the Private Power & Infrastructure Board (PPIB) established the boundary conditions for the co-ordinated development of the hydropower projects on Swat River, the Asrit-Kedam and the downstream located Madian Hydropower Project (HPP).

The selected project concept of Madian HPP was adjusted to these boundary conditions and the preferred project layout designed at feasibility level. In accordance with the Terms of Reference for this Feasibility Study a design of the Madian Hydropower Project has been developed according to international best practice ensuring a reliable, sustainable and economical design of structures and equipment which complies with the best international hydroelectric engineering practice.

This Feasibility Report consists of the following seven volumes:

Volume I: Executive Summary

Volume II: Main Report (this Report)

Volume III: Report on Geology and Geological Field Investigations

Volume IV: Hydro-Meteorological Data Base

Volume V: Report on Topographic Survey

Volume VI: Environmental Impact Assessment Study and Resettlement Action Plan

Volume VII: Drawing Album

2. Location of Project and Integrated Development

2.1 General

The project area is located in the Swat District, north of Madian Town. Madian Town is located at a distance of approximately 200 km from Peshawar, the capital of NWFP and 60 km from Mingora, the district headquarters of Swat Valley.

Swat is one of the twelve districts constituting the NWFP of Pakistan. The highest administrative authority is the Deputy Commissioner / District Coordination Officer, who is assisted by three Assistant Commissioners for Alpuri, Daggar and Swat Sub-Divisions.

2.2 Project Area and Integrated Development

The Private Power & Infrastructure Board (PPIB) issued licenses to private investors for development of hydropower projects on Swat River and supervises the coordinated development of the projects. At present the hydropower projects Kalam – Asrit, Asrit – Kedam and Madian along Swat River are under development in parallel whereas work on the Gabral – Kalam Hydropower Project (HPP) was suspended.

The proposed weir site of Madian HPP is located on the Swat River some 14 km and the powerhouse just 1.2 km north of Madian town where the approximately 35 km long V-shaped gorge section of the Swat River ends.

On 12th September 2007 PPIB clarified the boundary conditions for the co-ordinated development of the Madian HPP and the upstream located Asrit-Kedam HPP. The corresponding normal reservoir operation (NOL) level for the Madian HPP is 1494.4 m asl (SoP).

Based on a NOL of 1494 and the minimum water level at the selected power outlet some 1.2 km north of Madian town of 1339.6 m asl, a maximum gross head of 154.4 m is available for power generation.

2.3 General Description of the Project Layout

The project concept is based on diversion of part of the flow from Swat River by means of a diversion weir and further through a system of power tunnels to the powerhouse where the water is returned to the Swat River some 14 km further downstream.

The mean annual river flow of Swat River is 118.5 m³/s at the selected weir site. River flow varies considerable around the year characterized by a high flow period (May to September) and low flow period (December to March).

In an average hydrological year such as e.g. the year 1995, daily river flow varied between 18.5 and 447.6 m^3/s around the mean value of 118.5 m^3/s.

Diversion of river flow is arranged by means of a 19 m high concrete weir structure upstream of the confluence with Kedam Nullah (stream). In the central part of the weir structure a spillway with 3 tainter gates is arranged discharging into a concrete stilling basin. At the left bank adjacent to the power intake two flushing outlets are foreseen to evacuate sediments that may deposit in front of the power intake.

During the high flow season in summer the sediment concentration in the river flow increases and may reach up to 4000 g/m^3 in an average year. The suspended sediments consist largely of clay and silt fractions, however, it consists in addition of some 25 % of fine sand including quartz minerals.
At the moment it cannot be assumed with sufficient reliability that the upstream located hydropower projects are in operation when the Madian HPP is commissioned. Therefore, the Project Sponsor in co-ordination with PPIB decided to develop the Madian HPP as stand-alone run-of river project with its own independent desanding facilities.

For diversion of the Swat River during construction of the weir with stilling basin and power intake, conventional diversion works are designed. The diversion works consist of a conventional upstream rock fill cofferdam sealed by jet grouting, a bore pile wall downstream cofferdam to be transformed in the stilling basin end sill and a diversion tunnel. The existing Madian-Kalam road will be relocated over a length of approximately 250 m

The headrace tunnel starts at the power intake and has a length of 11.8 km. Its alignment was selected for conventional drill and blast excavation method nearly parallel to the Swat River. Three adits are planned to ensure tunnel construction within a reasonable period. The desanding facilities are arranged 2.1 km downstream of the weir and consist of three desanding caverns with the corresponding ducts and gates for evacuation of sediments.

At the downstream end of the low pressure headrace tunnel a surge tank is designed to limit pressure rise in the headrace tunnel and ensure the required flexibility of the hydropower plant in operation. A vertical pressure shaft leads the flow to the elevation of the three Francis turbine units arranged in an underground powerhouse. The steel lined pressure tunnel and manifolds are kept short to achieve an economic design. Transformer and Switchyard are arranged underground as well in a cavern parallel and at 30 m distance from the powerhouse cavern. From the powerhouse cavern a short tailrace tunnel releases the flow back to Swat River. Table 2.1 presents the salient features of the Madian Hydropower Project.

Hydrological Features at Weir Site:		
Catchment Area	2,403	km²
Mean Annual Flow	118.5	m³/s
Diversion Flood	656	m³/s
$HQ_{1,000}$	1,450	m³/s
$HQ_{10,000}$	2,002	m³/s
Reservoir:		
Total Volume	480,000	m³
Normal Reservoir Operation Level	1494.0	m SoP
Max. Operation Level	1994.5	m SoP
Weir Structure:		
Crest Level of Weir	1496.0	m SoP
Max. Weir Height	18.0	m above river bed
Length of Weir Crest	77.0	m
Invert of Flushing Outlet	1477.0	m SoP
Spillway:		
Level of Spillway Crest	1482.5	m SoP
Number of Tainter Gates	3	
Width of Gate	7.6	m
Height of Gate	12	m
Desander:		
Design Discharge	129.0	m³/s
Design Particle Diameter	0.20	mm
Number of settling chambers	3	
Effective length of chamber	206.0	m w/o transition
Width of chamber	13.7	m
Average depth of chamber	16.8	m
Low-pressure Headrace Tunnel:		
Length	11.80	km
Net Diameter	7.00	m
Max. Flow velocity	3.35	m/s
Surge Tank:		
Diameter:	21.00	m
Height:	69.0	m
Pressure Shaft and High-Pressure Tunnel:		
Total length (shaft & tunnel)	180.3	m
Length of vertical shaft	120.8	m
Diameter	5.80	concrete lined
Flow velocity	4.88	m/s
Diameter	5.40	steel lined
Flow velocity	5.63	m/s
Steel lining	20 – 28	mm

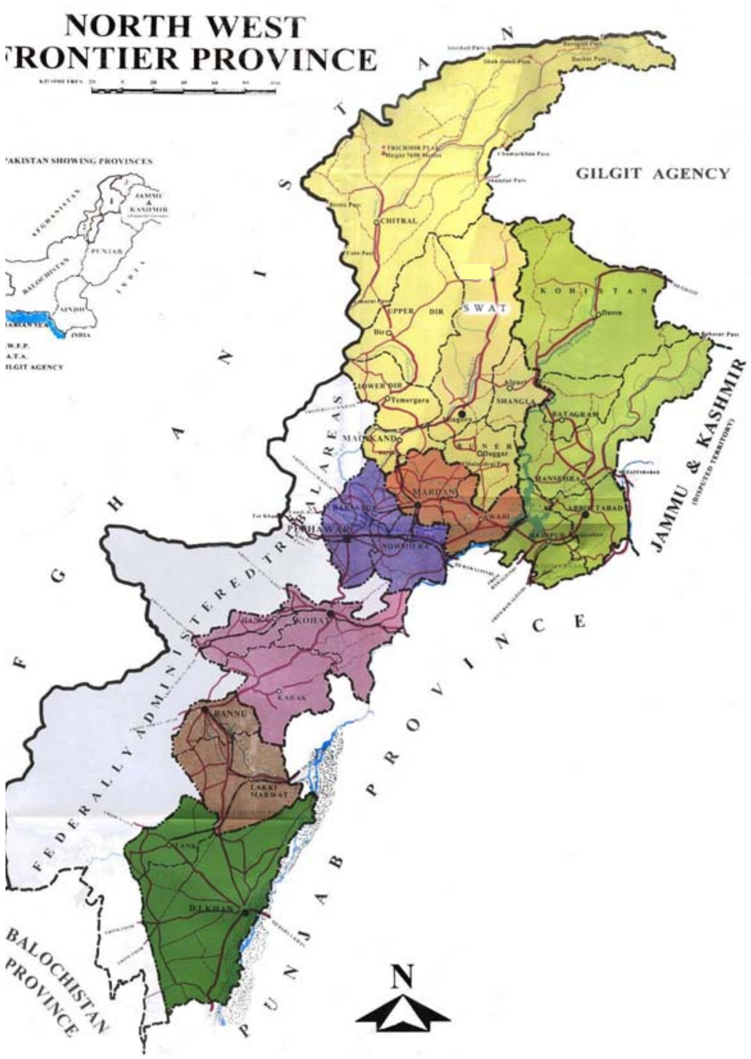
Powerhouse:		
No. of units	3	Vertical Francis
Installed Capacity	3 x 60.8	MW
Available Capacity (ex transformer 3 units in operation)	3 x 52.43	MW
Max. Turbine Design Discharge	43.0	m³/s
Cavern Width	20.0	m
Cavern Length	70.0	m
Turbine Setting	1336.0	m asl (SoP)
Electromechanical Equipment:		
No of Transformers	9	
Type of GIS Switchyard	SF6	
Voltage	220	KV
Tailrace Tunnel:		
Total length (w/ manifold)	93.6	m
Diameter	7.30	m
Diameter of manifold	4.20	concrete lined
Flow velocity	3.08	m/s
Additional Project Parameters:		
Mean Annual Energy	767.5	GWh
Plant Factor	0.56	
Estimated Construction Costs	366,163	1000 US $

Table 2.1 Salient Features of Project Components

3. Physical Conditions for Project Development

3.1 Location of Project Area

The Madian Hydropower Project (HPP) is located in the north of Northwest Frontier Province (NWFP) of Pakistan. The Province is surrounded by Northern Areas of Pakistan in the North, Kashmir in the East, Punjab Province of Pakistan in the Southeast, Balochistan Province in the Southwest and Afghanistan in the West, see Figure 3.1.



The area of the project is located in the Swat District, somewhat north of Madian Town, the tail of the national grid on the Swat River.

3.2 Hydrology and Sedimentation

Hydrologic information relevant for the hydropower project area and available in the Swat valley includes Kalam and Chakdara on the Swat River. Both stations are operated by Surface Water Hydrology Project (SWHP). Additional hydrological stations were installed by the Project Sponsor Madian Hydro Power Ltd. on the Swat River in 2006 at Kedam and Ramet on Swat River close to the weir site.

Code	Station	River	Coordinates		Catchment Area (km^2)	Elevation (m asl)	Record	
			Lat	Long			Start	End
35724502	Kalam	Swat	352810	723540	2,012	1921	1961	2007
35722503	Ramet	Swat	351640	723550	2,365	1585	2006	2008
35722504	Kedam Nullah	Kedam	351505	723508	55	1541	2006	2008
35722505	Kedam	Swat	351455	723505	2,529	1500	2006	2008
35726002	Chakdara	Swat	352915	723545	5,776	1951	1992	2006

Table 3.1: Hydrological Stations

<u>Precipitation Regime</u>

The precipitation regime in the Swat Valley is dominated by the occurrence of eastward moving extra tropical zones of low pressure, known locally as Western Disturbances, which bring humidity to the Swat catchment from the Atlantic Ocean and the Mediterranean Sea.

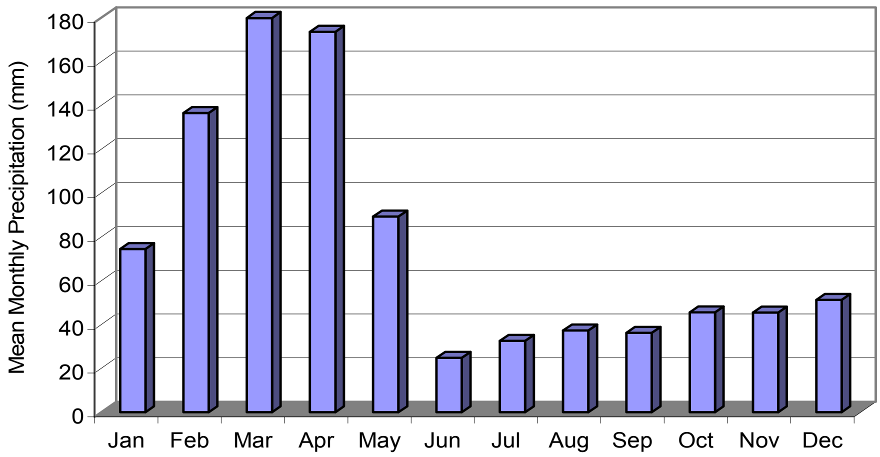


Figure 3.2: Kalam, Monthly Precipitation (1963-2006)

<u>Temperature Regime</u>

The Flows in upper Swat River are mostly snowmelt generated. It can be expected that largest flows occur during the summer period since precipitation in the winter season is largely in the form of snow. A combination of large precipitation in winter followed by high temperatures in summer, produce floods and large base flows.

The weir site is located downstream of the gauging station Ramet. The catchment area at the weir site is 2,403 km^2. At the site of the Power House downstream of Kedam gauging station the catchment area is 2,842 km^2, compared to 2,529 km^2 at Kedam.

Period	Flows (m^3/s)	
	Weir	**Power House**
Jan	23.57	28.52
Feb	21.61	26.26
Mar	27.17	32.40
Apr	78.72	88.35
May	191.70	234.14
Jun	298.38	431.69
Jul	302.92	440.34
Aug	227.33	291.51
Sep	128.84	143.36
Oct	57.45	65.07
Nov	36.40	42.56
Dec	27.81	33.21
Annual	**118.49**	**154.78**

Table 3.2: Mean Monthly Flows at Weir Site and Power House

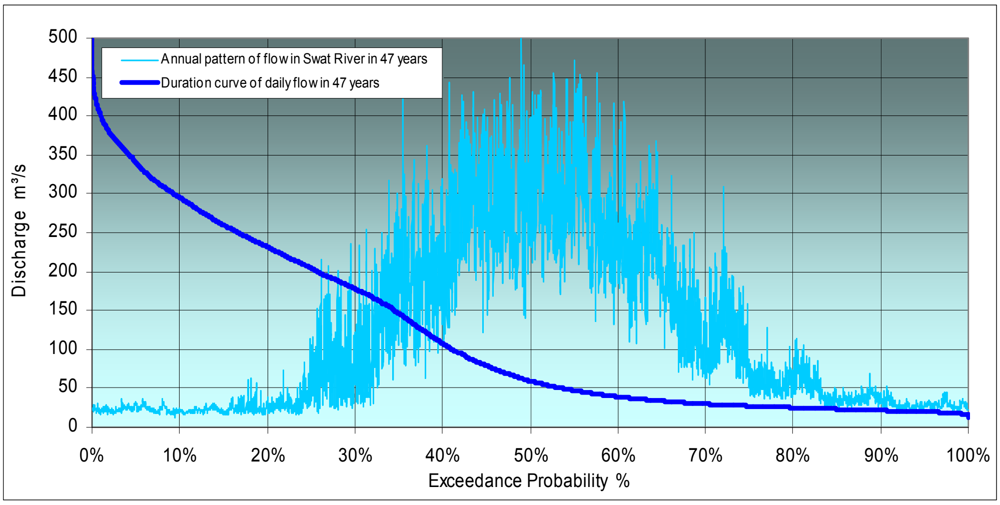


Figure 3.7: Weir Site, Flow Duration Curve

Maximum annual floods in the Upper Swat catchment have been recorded for the last 46 years at Kalam (1961-2006). The recorded maximum floods have a regular pattern and occur between May and July. The maximum floods recorded at Kalam are originated by snowmelt.

In September 1992 a large and deep low pressure front moved from the Indian Ocean and reached the north of Pakistan. At the same time, a Western Disturbance moved to the east, across the Swat and Upper Indus catchments. The run-off was the largest recorded at Kalam.

The event of 1992 demonstrated that rainfall can produce a significantly larger amount of run-off than snowmelt in the Upper Swat catchment and consequently may affect the site of the hydropower project. For a complete analysis of maximum floods in the Swat catchment, both floods of snowmelt and rainfall origin were analyzed.

3.2.1 Design Floods

Table 3.3 shows the maximum values determined in the flood analysis
.

Return Period	Maximum Floods (m^3/s)	
	Weir Site	Power H
2	445	502
5	530	596
10	587	659
20	656	731
50	712	796
100	860	1,065
1,000	1,450	1,785
10,000	2,002	2,405

Table 3.3: Design Floods for Madian Weir and Powerhouse Sites

From the results of the flood studies, it is concluded that the floods from snowmelt origin are relevant for the short periods of return, while for the larger periods of return, the floods estimated with the precipitation run-off model are more critical.

3.2.2 Suspended Sediment

For estimation of suspended sediments, series of data on sediment concentrations are available from the sites at Kalam, Kedam and Ramet. The relation between river flow and sediment transport for the gauging stations at Kalam and Kedam is shown in Figure 3.4. The solid curve in Figure 3.4 represents the mean rate of suspended sediment transport, while the dashed line represents a high estimate relevant for the required capacity of the desanding facilities.

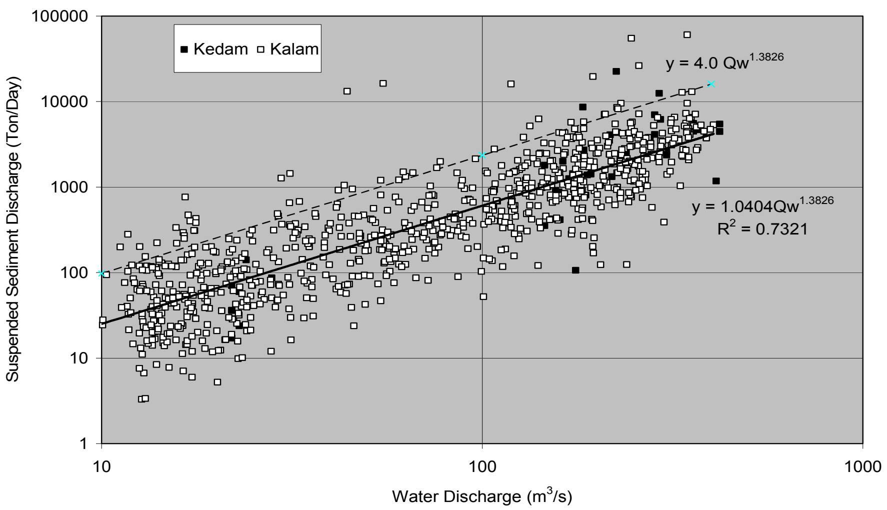


Figure 3.4: Suspended Sediment Concentration versus River flow at Swat River

3.3 Topography

This chapter summarizes the methodology applied, activities carried out and results obtained in the topographic survey for the Madian Hydropower Project which are presented in detail in Volume V of this Feasibility Report.

3.3.1 Scope of Work

Survey work sets the standard to which accurate and meaningful engineering designs can be achieved. It is important that all survey work of a project is carried out systematically and accurately in one uniform system of co-ordinates and elevations. A comprehensive topographic survey program was setup and executed by qualified subcontractors.

- Setup a project trigonometric network with a system of benchmarks
- Digital satellite based survey of the project area (DGPS) including the survey of benchmarks of the System of Pakistan (SoP) and Ground control Points (GCP)
- Terrestrial topographic survey of the area of the major project components such as
  - Weir site and reservoir area
  - Powerhouse and switchyard area
  - Area of adits for headrace tunnel construction and adjacent sites for dumping excess construction material
- Terrestrial topographic survey of river cross sections
  - In the reservoir area
  - upstream and downstream of weir site
  - upstream and downstream of powerhouse site
- Terrestrial topographic survey of lines of geophysical survey
- Terrestrial topographic survey of bore hole locations

The project area has a north-south extension from Madian town to Kedam village, i.e. from powerhouse site to the upstream boundary of the reservoir of approximately 15 km length. The large distance in combination with difficult conditions to access the steep and high valley of the Swat River with numerous deep cut in tributaries (nullahs) made a conventional terrestrial survey of the entire project area practically impossible. Therefore, the Consultant applied a combined approach comprising of a satellite imaginary based DGPS survey of the entire project area and conventional terrestrial survey of the area of the main project structures.

The terrestrial survey commenced in the early stage of the pre-feasibility study on 21.03.2007. The terrestrial survey work was carried out by a local sub-contractor in assistance with the Consultants topographer.

<u>Traverse Survey</u>
For horizontal and vertical reference of the terrestrial topographic survey for the Madian HPP closed loop traverse surveys were conducted. The traverse

survey started and ended at SoP BM Madian and followed the Madian - Kalam Road towards Khaluli.

- Closed loop traverse survey connecting the SoP-Benchmarks Madian and Khaluli (July/August 2007)
- Closed loop traverse survey covering all permanent benchmarks and connection all terrestrial surveyed areas within the project area. The traverse started and ended at SoP BM Madian (March/April 2008).

The terrestrial survey works comprised the following areas:

Weir Site/Reservoir Area:

- 45 river cross sections covering the weir site, the reservoir area and the river reach downstream of the weir site including Kedam gauging station and Kedam bridge
- 20 hectares of survey covering the following permanent project components
  - Weir, reservoir area
  - upstream and downstream cofferdams
  - diversion tunnel including intake and outlet
  - power intake

Power House Site:

- 26 river cross-sections between powerhouse sites and Madian town
- 53 hectares of survey covering the following permanent project components
  - surge tank
  - pressure shaft
  - powerhouse and power outlet
  - camp area and dumping site

Headrace Tunnel / Construction Adits:

- 2 hectares at access to desander caverns, area of tunnel portal of adit No. 1 and adjacent dumping site
- 15 hectares at area of tunnel portal of adit No. 2 and adjacent dumping areas
- 4 hectares at tunnel portal adit No. 3 and adjacent dumping areas
- Survey of side valleys to support the alignment and the design of the headrace tunnel;

Altogether 71 River cross sections of the Swat River were surveyed in two survey campaigns in March/April 2007 and in March 2008. The locations and spacing of the river cross-sections were carefully selected to meet the requirements of the corresponding hydraulic analysis.

<u>Madian HPP Benchmarks – Trigonometric Network</u>
For the Madian HPP a triangulation network based on SoP-coordinates was established in the project area. The system comprises of 8 concrete monuments covering the Swat valley between Madian and Kedam and including the SoP Benchmark Madian. All concrete monuments were tied to the SoP system based on the traverse between SoP BM Madian and Khaluli

and the corresponding surveyed closed loop traverse. The construction of the concrete monuments was carried according to the standards of SoP.

Figure 3.5: DGPS-Survey of SoP-Benchmarks in Swat Area at Madian (left) and Kalam in February 2008.

3.3.2 Results of Topographic Survey

The Consultant elaborated a Digital Terrain Model (DTM) of the entire project area in close cooperation with his German subcontractor TRIGIS. The DTM covers the town of Madian in the south and extends approx. 5 km north of the weir site. The extent of the DTM is as follows:

Area covered: 107.005 km²
Extension SW – NE 20.009 km

The locations and elevations of points of geotechnical investigations such as seismic refraction survey (SRS) and electric resistivity survey (ERS) lines were surveyed by the Consultant's sub-contractor T&M using a total station. Altogether 5950 m of survey lines comprising of hundreds of points were recorded in the field.

For the area of the major structural components of the Madian HPP a standard terrestrial topographic survey was conducted by the Consultant's sub-contractor T&M. With regard to published SoP elevations the closed loop survey achieved the following values indicating a deviation of 0.01 m as shown below:

Benchmark:	SBM Madian –	SBM Khaluli
Recorded Elevation	1349.88 m	1643.98 m
SoP published Elevation	1349.88 m	1643.97 m

It can be concluded that the accuracy achieved meets the requirements of a bankable feasibility study.

3.4 Geology and Seismology

Upon completion of the pre-feasibility study of the Madian HPP the Consultant elaborated a comprehensive field investigation program, prepared the corresponding contract documents and initiated contract negotiation with pre-qualified contractors in July/August 2007.

3.4.1 Program for Geotechnical Field Investigations

As a brief summary the scope of work conducted for the Feasibility Study of the Madian HPP comprises the following activities:

- Description and assessment of regional geology and tectonics
- Analysis of historic seismic activities, assessment of satellite images and assessment of seismic hazard risks
- Elaborate, conduct & supervise a geotechnical field investigation program, adjust it to the site and design specific requirements consisting of
  - Seismic Refraction Survey (SRS) and Electric Resistivity Survey (ERS); interpret results for design purposes
  - Core drilling at 16 bore holes in total, permeability testing, installation of piezometers for ground water table monitoring and interpret results for design purposes.
  - Geological Mapping including joint orientation measurements, scan line surveys etc.
- Elaborate, conduct, supervise a comprehensive program for Laboratory analysis and interpret results for design purposes,

The locations of boreholes for core drilling were defined for those spots where detailed knowledge on the surface of the rock, its strength, jointing, weathering and permeability are of utmost importance for the project design

At the weir site the Consultant defined a total of 8 boreholes, at the powerhouse a total of 5 boreholes and along the headrace tunnel alignment a total of 3 boreholes in the vicinity of the foreseen construction adits:

The data gathered from the individual boreholes were recorded in special bore-logs supplemented by photos of the core boxes, statistics on joint characteristics, weathering of joints, assessment of fragmentation of rock (in terms of RQD) and its permeability. Water pressure tests were carried out in nearly all bore holes and in a total of 11 boreholes piezometers were installed for a continued monitoring of the groundwater tables.

The geophysical survey represents together with the geological site reconnaissance the first step of geotechnical field investigation activities before start of core drilling. At the weir site the Consultant defined a total of 10 seismic refraction survey lines, at the powerhouse a total of 7 seismic refraction and 5 electric resistivity survey lines.

Sr. No.	Hole No.	Location	Coordinates		Depth (m)	Packer Test	Piezometer Instalation
			East (m)	North (m)			
1	MWD1	Weir site/R. Abut.	3,160,764	1,228,188	30	5	x *
2	MWD 1A	Weir site/R. Abut.	3,160,783	1,228,180	45	5	-
3	MWD 2	Weir site/River	3,160,811	1,228,163	40	5	x
4	MWD 3	Weir site/River	3,160,823	1,228,156	40	5	-
5	MWD 4	Weie Site/River/Intake	3,160,858	1,228,159	40	5	-
6	MWD 5A	Intake	3,160,916	1,228,139	70	3	x
7	MWD 5	Weir Left Abutment	3,160,868	1,228,123	45	5	x
8	MWD 6	Stilling Basin Right Bank	3,160,798	1,228,105	20	-	-
9	MSD 1	Surge Tank	3,156,268	1,217,509	90	7	x
10	MPTD 2	Pressure Shaft	3,156,257	1,217,466	150	3	-
11	MPCD 3	Ph Cavern	3,156,179	1,217,412	150	7	x
12	MPD 5	Open air PH	3,156,049	1,217,375	40	5	x
13	MPD 7	Power Outlet	3,156,012	1,217,329	15	-	-
14	MWA 1A	Desander Cavern / Adit 1	3,159,858	1,226,217	120	3	x
15	MWA 2	Darolai Nullah / Adit 2	3,158,332	1,223,988	85	3	x
16	MWA 3	Ain Nullah / Adit 3	3,156,709	1,220,650	95	-	x

Table 3.4: Summary of Borehole Location, Depth, Type & Quantity of Testing
x * existing piezometer of borehole DDH-8 used instead

The Consultant defined the number and type of laboratory tests to ensure that the required input data is at disposal for the feasibility design of all major structural components of the Project. Among others the total intact rock laboratory testing program at CMTL comprised of the following tests:

- 50 unit weight, porosity and Point Load Tests of intact rock;
- 27 & 10 uniaxial compression tests w/o & with strain measurements for Young's modulus and Poisson's ratio determination
- 10 petrographic analyses.

3.4.2 Geology of the Project Area

<u>Tectonic Setting</u>
The geology of the study area in Kohistan in North Pakistan is dominated by continental collision tectonics where three of the world's greatest and most active mountain ranges merge: the Himalayas, the Karakoram, and the Hindukush. With the Indian plate moving northward, a complex pattern of thrust and wrench faults has been developing. Several fault structures have been identified in the area in the northern vicinity of the project area.

<u>Lithology</u>
The project area is situated in the mid-western part of the Kohistan Tectonic Zone and consists entirely of (igneous) plutonic rocks. The rather uniform rock type at the site is a medium-grained slightly foliated gabbro, classified as Norite, a rock mainly composed of ortho-pyroxenes and basic feldspars.

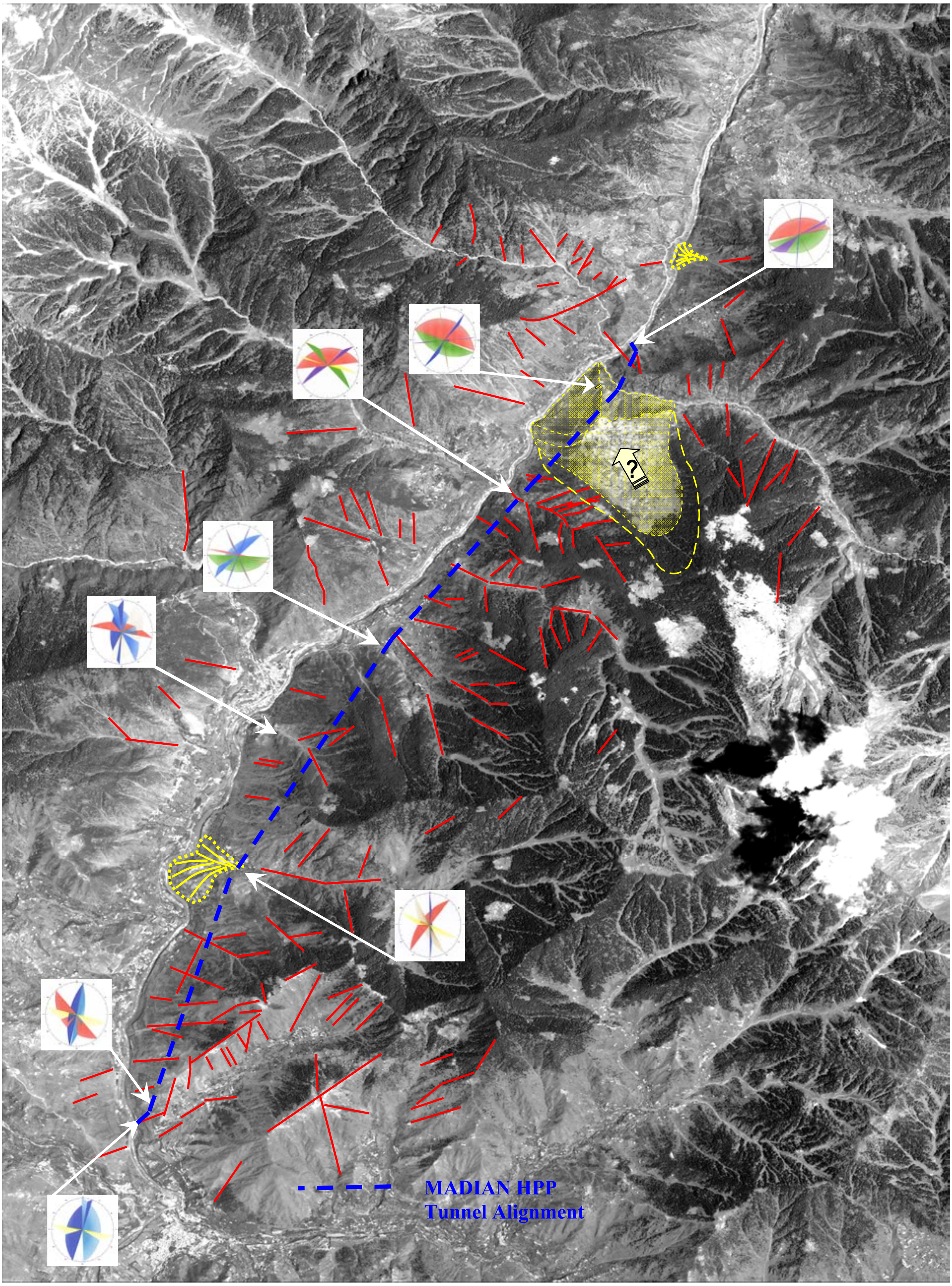


Figure 3.6: CARTHOSAT image of the study area with interpreation of fractures, a potential big old rockslide at Gornai village and some quaternary sediment bodies. The inserts of wing diagrams show the local predominance of joints and their intersections.

The Consultant proposes parameters for the Maximum Credible Earthquake (MCE) as safety level and the Operating Basis Design Earthquake (OBE) as serviceability level for the Madian Hydropower Project in Pakistan. Both earthquakes are selected according to established international standards, described in the ICOLD Bulletin 72 *"Selecting Seismic Parameters for Large Dams"* (ICOLD 1989).

The resulting value for horizontal peak ground acceleration at the Madian Hydropower Project site is 0.48 g for MCE. For OBE, a value of 0.26 g for the annual probability of exceedance of 1 / 475 is recommended. The proposed seismic design parameters are judged to be appropriate conservative for the Madian Hydropower Project site.

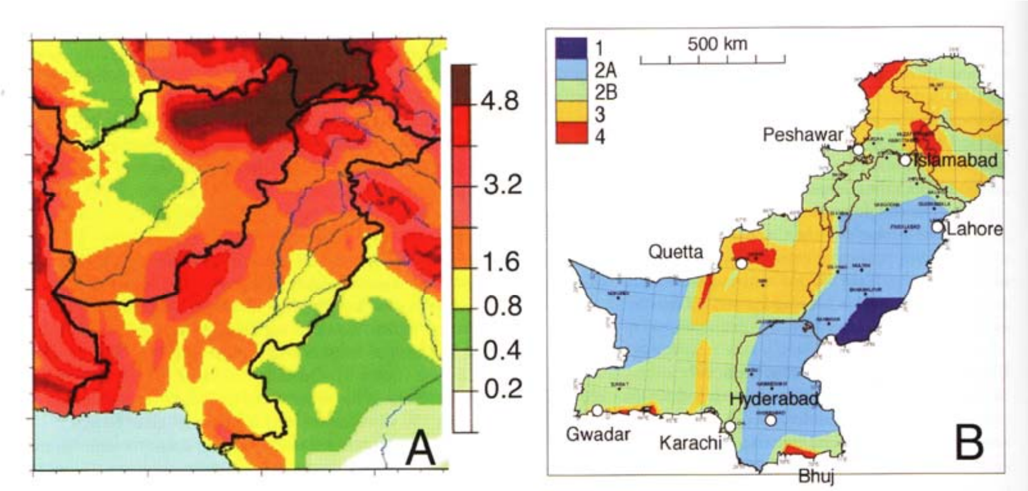


Figure 3.7: GSHAP hazard map of Pakistan, colour scale indicates peak ground acceleration (m/s^2) with 10% probabilistic exceedance within 50 years (Giardini et al. 1999); (B) recently revised hazard map after 2005 earthquake from working group on Pakistan Hazard 2006,
4 is most hazardous, 1 - least hazardous (Bilham et al. 2007)

3.4.3 Results of Geotechnical Site Investigation

The geological mapping of the project covered an area of $19.8km^2$ including

- Geological boundaries between bedrock and overburden;
- Areas of sheared and fractured bedrock were marked in the maps;
- Major shear zones were delineated;
- Geometry of rock discontinuities determined by scan line survey, marking joint strike, dip and features such as joint roughness;
- Bedrock wall strength assessed by use of Schmidt Hammer.

The total number of measured joint orientations considered in the present analysis is 845. In addition 258 joint measurements were evaluated from the joint scan-line survey at rock outcrops.

Altogether 16 boreholes with cumulative 1139 m were core-drilled; the deepest borehole attained 150 m depth. The data assembled is

- Drilling-operation observations, e.g., water losses
- Amount of core recovery
- Rock Quality Designation (RQD)
- Degree of weathering
- Joint spacing and Joint properties and fillings
- Groundwater levels
- Water pressure tests (Lugeon)

The groundwater tables have been measuring from the beginning of drilling operation on daily basis. After installation of piezometers the water levels were monitored on a regular basis. No extraordinary high external water pressure is to be expected.

3.4.4 Results of Laboratory Testing Program

Testing was executed according to the established testing program and the given technical specifications for this Feasibility Study of

- Rock core samples from bore holes
- Rock lump samples from potential quarry and weir site
- Sand samples from potential borrow pit
- Soil samples
- Water samples from bore holes

Testing of Concrete Aggregates

According to the limited availability of natural concrete aggregates at the project site and in view of the abundance of excavation material from tunnel and cavern excavation, the Consultant conducted sampling at project site of:

- Rock lump samples from the area close to the proposed rock quarry;
- Core samples from selected bore holes;
- Sand samples from the proposed borrow area at Kalam.

Rock samples were tested with regard to their compressive strength and abrasion (Los Angeles Test) as well on their potential alkali silica reaction.

Results of Petrographic Analysis

With the objective to obtain information on the mineralogical composition of rock material and concrete aggregates, the Consultant instructed execution of the following complete petrographic analyses:

Rock core and lump samples	No. 8
Fine aggregate (sand) sample	No. 1
Sample of joint coating material	No. 1

3.4.5 Engineering Geological Assessment

The geological mapping campaign and the geotechnical site investigations have revealed that in general the engineering geologiocal conditions are favorable for the construction of the Madian Hydropower Plant. Considering all factors, the prevailing rock of the project site can be classified as >good< in terms of Bieniawski's (1989) rock mass classification system, except for faults and shear zones.

Concrete Gravity Weir
The favourable morphology of the valley and the apparently outcropping rock on the left bank were the basis for this selection besides design requirements for the power intake and flushing structure. The riverbed is covered by river deposits of different size ranging from boulders to gravel and sand. The thickness of this loose alluvial material the same Quaternary sediments as on the right bank of Swat River have been encountered in boreholes. According to borehole MWD3, a maximum thickness of theses sediments of 30 m can be expected. The Norite rock below should not create any foundation problem nor from its strength (rock class B to C can be estimated) neither from its permeability. Grouting of the rock mass below the weir foundation will not be necessary except for the few first meters below the contact of alluvium and rock.

Reservoir Area
The extension of the reservoir area is limited to a length of 1.46 km. The sub-ground of the reservoir area is entirely formed by Norite rock with a cover of Quaternary and fluvial deposits. In any kind of artificial lake the hazard of landslides moving into the reservoir has to be assessed. Due to the limited extension and water depth of the reservoir at Madian HPP weir this hazard is minor.

Desander Caverns
The site of the caverns was investigated by one borehole, 130 m deep, and by the mapping of two rock outcrops along the nearby Ashkon Nullah. At the depth of interest for the construction of the desander caverns (100 to 130 m) the rock thus is in good condition. RMR is calculated to be 60 to 80 indicating a rock class of A to B. A total of 114 individual joint orientations were recorded on the right bank of Ashkon Nullah. The favourable orientation of the desander cavern longitudinal axis is thus found at an orientation of 30° (NNE - SSW) which should prevent the possible formation of voluminous rock wedges. The bolt support for desander caverns is evaluated by limit equilibrium wedge analyses and cross-checked by precedent experience collected in double logarithmic diagrams of rock quality and excavation span e.g. by Barton and Grimstad.

Headrace Tunnel
The headrace tunnel has a length of 11.8 km and internal diameter of 7.0 meters. It will be excavated along the left bank slope of Swat River between the intake area near Kedam Nullah and the surge tank near Kalaga Nullah.

The rock overburden along the tunnel alignment varies between 55 m (Ashkon Nullah, Station 2+500) and 440 m at Station 7+000 as shown in the geological profile of the headrace tunnel (see Annex A-6 of Volume III). The tunnel alignment was investigated at the planned three construction adit locations by boreholes MWA1A, MWA2 and MWA3 and in addition by boreholes MWD5 at the power intake and MSD1 at the surge tank axis. Based on the geological mapping and supported by the core drilling at five bore holes the expected headrace tunnel rock quality for the total length of 11,800 m length was defined as follows:

- 1,500 m of very good and good rock (class A, B) in Section 1,
- 900 m of fair rock (class C, D) in Section 1
- 2,800 m of fair rock (class C, D) in Section 2
- 2,750 m of very good and good rock (class A, B) in sections 3 and 4
- 3,300 m of fair rock (class C, D) in Sections 5 and 6.
- 550 m of poor to very poor rock in different sections (class E, F).

Surge Tank

The surge tank will be arranged at the end of the headrace tunnel, some 50 m upstream of the transition to the pressure shaft; it will have an excavated diameter of approximately 23 m and a depth of 78 m. The geological conditions for the surge tank have been investigated with a 90 m deep borehole (MSD1) and three seismic refraction lines. Even in greater depth, where the core quality of other bore holes uses to show improved rock mass characteristics, the rock quality is poor to very poor. The fracturing and jointing is classified as high.

Underground Powerhouse and Transformer Caverns

The powerhouse will be constructed in an underground cavern, about 70 m long, 20 m wide and 36 m high. The powerhouse will be located on the left bank of Swat River some 1.2 km upstream of Madian town. The cavern powerhouse and the surface powerhouse site were investigated by three bore holes, namely MCD3, MPD5 and MPD7.

VECTORS		
No.	Azi	Dip
1	260	50
2	232	38
3	317	49
4	252	48
5	274	17
6	239	68
7	255	58
8	183	40
9	249	32
10	259	68

PLANES		
No.	Azi	Dip
1	286	53
2	188	76
3	204	41
4	254	68
5	336	85

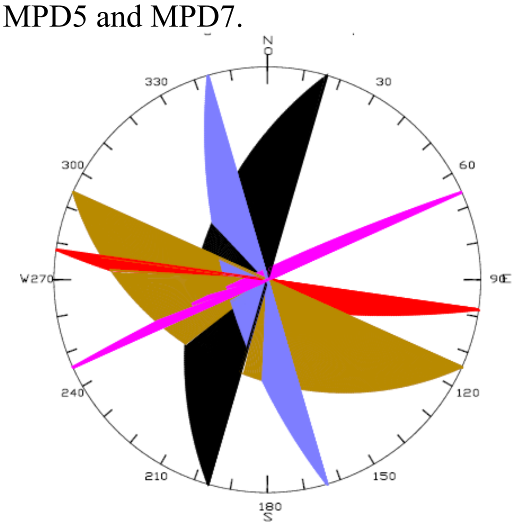


Fig. 3.8: Wing diagram of the predominant joint planes and their intersections of all joints measured in the powerhouse and the surge tank areas; dashed line: axis of cavern.

The total overburden above the powerhouse cavern will be about 100 m, 13 m of which have been cored as colluvial soil in borehole MPCD3. From 30 m depth on, the situation improves with another bad zone occurring between 38 and 42 m depth. From here on to the end at 125 m depth, the rock can be classified as fair to good meaning rock class C to B. Water pressure tests undertaken between 100 and 125 m depth provided Lugeon values between 2.0 and 9.4 which means that the rock mass is almost tight.

Major construction materials required for the Madian HPP are cement and aggregates, reinforcement steel (including mesh/mattresses) for concrete and shotcrete fabrication for all major structures including the lining of underground works. In addition slope and riverbed protection works require the use of riprap, gabion mesh and gabion fill material as well as geotextiles as non-mineral filter. According to the limited availability of natural concrete aggregate at the project site and in view of the abundance of excavation material from tunnel and cavern excavation, the concept for the use of concrete aggregates is as follows:

a) Initial phase: open a rock quarry at weir site and use crushed rock
obtain sand from existing borrow area at Kalam

b) Main phase: select and crush tunnel excavation material
obtain sand from existing borrow area at Kalam

In accordance with the selected concept of applying crushed rock from tunnel and cavern excavation and sand from the borrow area at Kalam as concrete aggregates the Consultant conducted sampling as follows:

a) Rock lump samples from the area close to the proposed rock quarry
b) Core samples from bore holes along the headrace tunnel
c) Sand samples were taken from Kalam borrow area

Rock strength and abrasion resistance proved to be adequate by carrying out tests of the unconfined compressive strength and conducting Los Angeles tests, respectively. The petrographic analysis and accelerated mortar bar tests confirmed that no alkali reaction of aggregates was observed and ordinary Portland cement can be used for concrete fabrication in combination with the proposed aggregates.

From the geological and engineering geological point of view the Madian HP Project is feasible. The foundation of the weir and the intake structures should not face a major problem. The headrace tunnel runs along the selected alignment largely in sound rock of class B to C. The section between Gornai Nullah and the Desander Cavern remains questionable and requires investigation and reconfirmation during the next planning stage.

3.5 Access to Site, Transport and Communication

3.5.1 General Aspects

In Pakistan a well-established aviation network is operated. The main airports are Karachi, Lahore, Islamabad, Quetta and Peshawar; they are national as well as internationally connected. The closest airport to Madian is at Peshawar, some 200 km distant from Madian.

The main seaport of Pakistan is Karachi on the Arabian Sea. It handles the bulk of the countries in- and export. A further seaport in Gwadar, Balochistan equally on the Arabian Sea is under construction. Pakistan has a well-developed road and railway network, serving all areas of its economy. The railway station situated nearest to the project area is Dargai, located some 120 km away from Madian.

The major electro-mechanical, electrical and heavy steel structure equipment components will be imported and can be expected to arrive at Karachi Port. From Karachi the equipment shall be transported to the project area located north of Madian Town, District Swat of NWFP. There are two general modes of transport which can be adopted for moving the equipment to the project area entirely by road or by rail from Karachi to Nowshera or Dargai, and further on road. From Karachi the trucks will reach Dargai and from Dargai onwards the trucks will move to the project area along the Dargai – Mingora - Madian section of the road.

Alternative I: from Karachi to Batkhela (shortest connection):	=	1521 km
Alternative II: from Karachi to Batkhela via Motorway	=	1695 km

The journey from Batkhela to Madian would be common along the same route for both alternatives.

Distance from Batkhela to Madian	=	119 km

Several examinations of the road conditions were conducted by the Consultant which indicate that serious difficulties are to be expected under prevailing transport conditions. The present road conditions are not good in some sections. There exist some narrow passages with roads in town centres along the way between Dargai and Madian, which may cause severe problems for transport of large and heavy equipment. Two bridges do not meet this criterion with an estimated carrying capacity below 30 tonnes, namely Ghari Pia Bridge (cracked abutment) and the Baily Bridge at Madian. The management of the National Highway Authority (NHA) informed the Consultant and the Project Sponsor on request that the road from Mingora to Kalam will be upgraded to a National Highway (7.3 m wide asphalt paved road) in the following years, however, no anticipated date of completion of these road works could be given.

3.5.2 Requirements for Transport of Equipment

The feasibility of transporting construction equipment with large dimension and heavy weight may govern the selection of construction methods, in particular in case of the long headrace tunnel and thereby its design. The minimum width of several bridges of 3.5 m represents a constraint to transport and requires particular attention.

Tunnel Excavation Equipment
Condition for the potential application of a Tunnel Boring Machine (TBM) is that transport of the equipment to site is technically feasible at reasonable cost. The Consultant inquired the relevant information for transport of a TBM to the Madian HPP site and progress of work with leading TBM manufacturers. For the particular conditions to construct an approximately 12 km long headrace tunnel with an excavated tunnel diameter of 7.0 to 8.0 m , the overall weight of a such a TBM would be in the order of 600 to 700 t. For the estimated excavated tunnel diameter the main dimensions of the heaviest and largest single piece would be:

Width / Height	3.6 m
Weight	60 – 70 tonnes

Earth Moving Equipment
Standard earth moving equipment will comprise bulldozers, excavators, front loader and trucks. The standard type would be a D6 (or equivalent) with an operating weight of 18 to 21 tonnes and a width including the blade of 3.36 m. The standard excavator could be a Cat 320D (or equivalent) with a width of 3.00 m which does not represent a difficulty for transport.

Transport Requirements for Permanent Equipment
The transportation of heavy permanent electro-mechanical and steel structure equipment to the site is an aspect which may govern design aspects in developing the Madian HPP.

Electro-Mechanical Equipment
With regard to the spiral casing, sufficient free overall width or height cannot be obtained. Therefore, the spiral casing needs to be transported divided in segments and erection-welded at site.

Electrical Equipment
The heaviest component to be transported to the site of a hydropower project is in most cases the 3-phase transformer. Alternatively single-phase transformer may be used instead. A 3-phase transformer would weigh more than 65 tonnes without oil. The alternative single-phase transformer weighs 28 tonnes without oil. Transport of the 3-phase transformer represents a major difficulty with regard to the carrying capacity and clear width of at least three of the existing bridges in the area of the city of Madian. Transport of the 3-phase transformer becomes feasible only in case that two existing bridges will be replaced by bridges with sufficient width, radii in their approaches and sufficient carrying capacity.

Hydraulic Steel Structure Equipment

Referring to the feasibility design the dimensions of the major equipment components are the spillway radial tainter gate with the dimensions H x W = 12.0 x 7.6 m and a distance between gate to trunion point of 14 m. In view of the prevailing limitations as regards in particular the width of the bridges in the area of Madian town, Bahrain and Kedam, the tender documents should specify that all large steel-structure equipment components need to be assembled at site and the contractor must do the corresponding provisions in the design and preparation of its camp.

Some of the roads in Swat District are not designed for transportation of heavy equipment. Certain road improvement work is under progress. Road conditions in Swat District would be conducive for transportation of heavy equipment with the exception of some bridges in the area of Madian town.

The Consultant recommends giving priority to transportation of equipment by road, in particular for the large pieces of construction and permanent equipment due to limitations in the available width along the railroad. The transportation by railway can be used for bulk material which can easily be unloaded from railway wagons and re-loaded on trucks. The final decision on the mode of transport between Karachi and Nowshera remains with the EPC Contractors.

As mentioned above the following bridges represent bottlenecks for transport of heavy and bulky equipment due to their maximum clear width of 3.5 m and estimated carrying capacity not exceeding 30 tonnes:

Ghari Pia Bridge	Cracked Abutment	(lack of capacity)
Madian Sadar Bazaar Bridge	Clear width 3.5 m	(limited width)
Bailey Bridge outside Madian	Clear width 3.5 m	(width & capacity)*

It would be advantageous for development of the Madian HPP if rehabilitation of the mentioned narrow or damaged bridges will be executed by National Highway Authority (NHA) before construction of the Madian HPP starts.

These above mentioned constraints have the following consequences:

1. According to present conditions at three bridges as regards both their clear width and their carrying capacity, TBM tunnel construction technique cannot be applied.

2. Single-Phase transformer shall be used instead of 3-phase transformers due to the limited capacity of the existing bridges.

Certain road improvement and maintenance in the area between powerhouse site and dam site of the Madian HPP is included in the present feasibility study and the corresponding Bill of Quantities (BoQ).

4. Civil Engineering Design

4.1 General

The feasibility layout and design for the Madian Hydropower Project comprises the following main components:

- Concrete weir structure with gated spillway and flushing structure
- Power intake on left bank adjacent to weir structure with raking machine
- Desanding facilities
- Power waterways consisting of headrace tunnel, pressure shaft, pressure tunnel, manifold, tailrace and power outlet
- Powerhouse with switchyard / transformer cavern
- Diversion works consisting of upstream and downstream cofferdam and diversion tunnel
- Access roads, permanent and temporary camps
- Dumping sites for deposition of surplus excavation material

4.2 Design Criteria

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

4.2.1 Design Floods

In view of the size of the weir structure and consequences of potential failure the following design floods are considered adequate as a conservative approach in accordance with the recommendations of ICOLD-Bulletin 82: "*Selection of Design Flood – Current Methods*".

Design Flood:	$HQ_{1,000}$ = 1450 m³/s	with one gate malfunctioning and normal freeboard (1.5 m)
Safety Check Flood	$HQ_{10,000}$ = 2002 m³/s	all gates open and minimum freeboard (1.0 m)

The powerhouse shall be operational up to the powerhouse design flood which is defined as the flood with a return period of 1000 years

Design Flood:	HQ1,000 = 1,785 m³/s
Recommended Max.Operation Flood	HQ 100 = 1,065 m³/s

The estimated construction period for the weir including stilling basin and power intake is 3 years. In accordance with common design practice a flood with a return period of 20 years is selected as diversion design flood:

Diversion Design Flood	Weir	HQ_{20} = 656 m³/s

4.2.2 Hydraulic Design of Desanding Facilities

Settling basins are required if the river flow contains high concentrations of suspended sediment which may cause severe damage to the turbine runners.

<u>Design Grain Diameter:</u> Critical Sediment Grain Size,
grain size to be removed to 95 per cent or more

- Head 20 - 50 m D = 0.30 mm
- Head 50 - 100 m D = 0.25 mm
- Head 100 - 300 m D = 0.20 mm

4.3 Design of the Weir Structure

The weir axis was selected according to the prevailing geological, topographic and design boundary conditions. The normal operation water level of 1494 m asl is based on the definition of PPIB to ensure the coordinated development of the Madian HPP and the upstream located Asrit-Kedam HPP on Swat River. The concrete weir structure across the Swat River has a crest length of approximately 65 m and a height above riverbed of 19 m. The spillway is equipped with three hydraulically operated tainter gates.

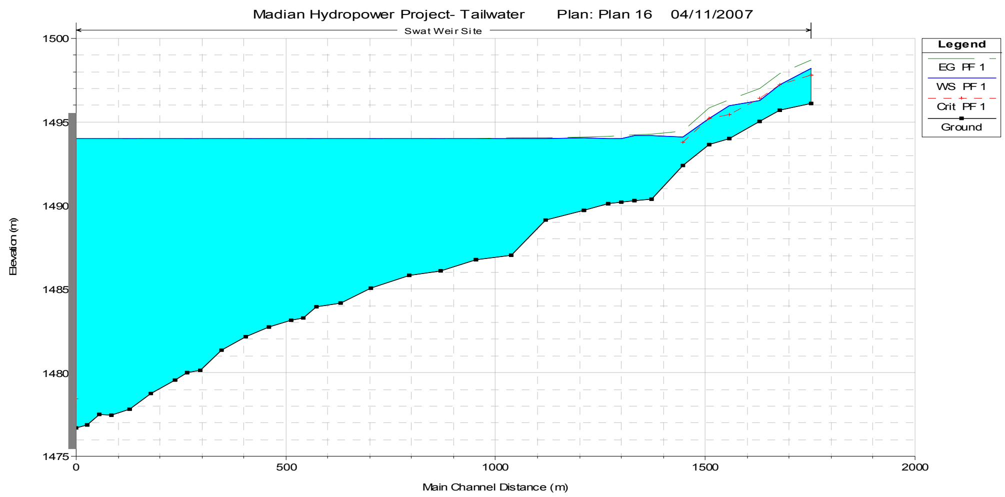


Figure 4.1 Profile through the Madian HPP Reservoir

The most left bank tainter gate is equipped with a fish belly flap on top for fine regulation of the flow and for flushing of floating debris. The inclined weir ogee is followed by a stilling basin at its end.

Max. water level	1,494	m asl (SoP)
Total storage volume	480,000	m^3
Length of the reservoir	1.46	km

Maximum reservoir level:	1494.5 m asl
Spillway crest elevation:	1482.5 m asl
Maximum head	12.0 m

The ogee crest structure is designed applying WES standard profile as defined by the Hydraulic Design Charts. The thickness of piers was selected to be 3.0 m to safely transfer forces in the main dam body. The dimensions of the spillway gates were selected as follows:

Number of Gates	3
Width x Height	7.6 x 12.0 m

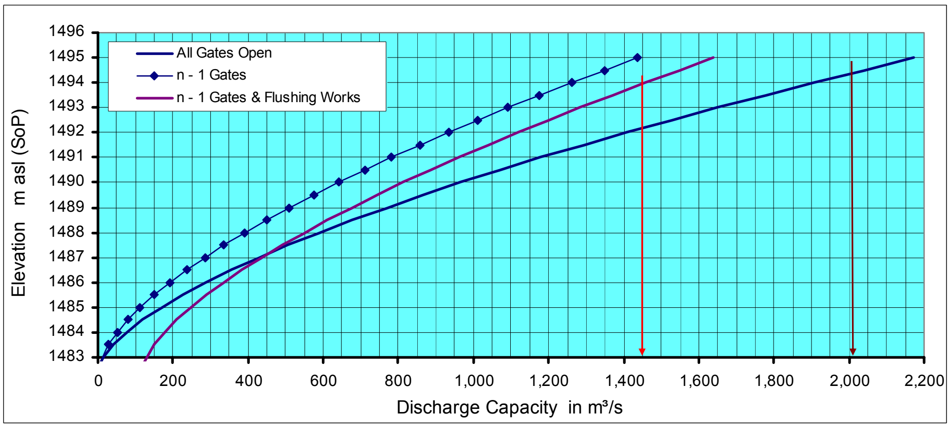


Figure 4.2: Discharge Capacity of the spillway of the Madian HPP Weir

In the event of the Safety Check Flood $HQ_{10,000}$ = 2002 m³/s at the required minimum freeboard of 1.0 m is the discharge capacity is sufficient for all 3 spillway gates being fully open

Spillway Discharge 2069 m³/s > 2002 m³/s

The hydraulic conditions from spillway crest to the stilling basin were determined for discharges between HQ_2 and $HQ_{10,000}$, i.e. 445 to 2002 m^3/s. As the result the stilling basin with the following dimensions was selected:

Invert of stilling basin	1472.0 m asl
Width of stilling basin	28.8 m
Elevation of river bed d/s	1476.1 m asl
Length of stilling basin	54.0 m

In order to maintain the power intake free of sediments, in particular of bed load that may accumulate upstream of the weir structure, a flushing structure is arranged in the left part of the weir structure close to the power intake. The flushing (or sluicing) gates discharge into a chute separated from the stilling basin to allow for its maintenance and repair while the stilling basin is in operation. The invert of the flushing ducts is arranged at riverbed level. To achieve a safe and optimized structural layout at low costs as regards in particular quantities of concrete and reinforcement, structural analyses computations were carried out for consideration of soil loads, water pressure and seismic loads including the dimension of the bore piles for

- Overturning of the Weir body
- Sliding of the Weir Structure
- Uplift of Weir Structure and Stilling Basin

4.4 Design of Diversion Works

The Consultant designed conventional river diversion works with the following components:

<u>Weir Structure</u>

1. Upstream rock fill cofferdam with sealing
2. Downstream cofferdam constructed on bore pile wall
3. Diversion tunnel on left river bank

<u>Powerhouse / Power Outlet</u>

1. Gabion cofferdam with sealing (PVC sealing)

In accordance with common design practice and the hydraulic design criteria a design flood for river diversion during construction with a return period of 20 years is selected resulting in the following discharge values:

Diversion Design Flood	Weir	HQ20 = 656 m³/s
Diversion Design Flood	Powerhouse	HQ20 = 731 m³/s

Therefore, the crest elevation of the upstream cofferdam is limited to elevation 1496.0 m asl. The following dimensions of the diversion works were defined:

Diversion Tunnel D-shaped	Width =	8.0 m
	Height =	9.2 m
	Length =	275.0 m

4.5 Conceptual Design of Power Waterways

The project concept consists of the following major components:

a) Power intake on left bank of Swat River
b) Desander basins, No. 3
c) Headrace tunnel, 11.8 km long
d) Surge tank
e) Vertical pressure shaft
f) Horizontal pressure tunnel
g) Manifold
h) Powerhouse
i) Tailrace and Power outlet

The Consultant developed a tunnel alignment for conventional drill and blast excavation method in a such a way that the rock cover shall not be less than approximately 50 m, in particular in the area of nullahs (depressions where perennial streams form in the rainy season).

In view of the length of the headrace tunnel of almost 12 km, conventional tunnel construction would need to proceed in parallel in several tunnel stretches. Aiming on an economic feasible construction period, a total number of 4 tunnel reaches with a maximum length of 3.6 km was defined. The location of the construction adits was defined taking into account the following criteria:

Headrace Tunnel	TBM Feasibility m	D&B Feasibility m
Reach 1		2,474
Reach 2		2,680
Reach 3		3,802
Reach 4		2,934
Total HR-Tunnel Length	11,893	11,890
Adit at Surge Tank	201	150
Constr. Adit No. 1		280
Constr. Adit No. 2		380
Constr. Adit No. 3		250
Total Adit Length	201	1,060

Table 4.1 Length of Headrace tunnel for TBM and Conventional Excavation

The headrace tunnel alignment was eventually defined as the result of a trade-off between additional costs resulting from extra headrace tunnel length and the cost of extra length of the construction adits.

As an alternative to the project layout proposed in the pre-feasibility study a layout with underground powerhouse was elaborated. The additional costs for the underground powerhouse (compared to an open air powerhouse), transformer and switchyard cavern and the required access and cable tunnel are almost compensated by the savings in the steel lining for the high pressure tunnel, excavation and slope protection works. The comparison of costs indicates that the design concept with underground powerhouses requires slightly higher investment costs compared to the concept with an open air powerhouse. The difference in cost between the two powerhouse alternatives is minor so that from the economical point of view both alternatives can be considered equivalent. Preference to an alternative can be made taking into account the following aspects such as:

- Risks during construction and operation
  (vandalism, terrorism, extraordinary floods, earth slides etc.);
- Costs during operation (maintenance, access etc.);
- Environmental and socio-economic impact.

4.5.1 Optimization of Installed Capacity

Optimization of the Madian HPP means to determine the waterway design discharge and respective installed capacity for which development of the project results in the economically most favourable configuration.

For optimization of hydropower projects commonly the following optimization criteria are applied:

a) Maximum Internal Rate of Return on investments (IRR);
   or minimum specific cost of generation in US c /kWh
b) Maximum Net Benefit.

From the prospective of a private project developer the preferred optimization criterion is that which provides the maximum rate of return on investment. All relevant project related costs and benefits are expressed in terms of their present value referring to the same date to be comparable.

By means of the Consultant’s hydropower optimization program HPC (Hydropower Costing) the design of the project components and the corresponding elaboration of the bill of quantities, costing and simulation of annual energy generation was performed. This procedure was applied to powerhouse design discharges in the range from 100 to 180 m³/s with 10 m³/s increments.

Optimization of Design Discharge - Base Case

Power Revenues	0,07	US$ / kWh	**Cost Fact :**	**1**	-	
O&M Cost	1,5	%	Net Head :	133	m	
Interest Rate	10,00	%	Forced Outage :	1	d	(Full Operation)
Life Time	60	Years	Increm. Discharge	10	m³/s	
Construc. Period	4	Years	CRF	0,10033	-	

Design Discharge	m³/s	100	110	120	130	140	150	160	170	180
Original Cost	US$	246,001	261,45	275,334	291,087	302,922	317,756	335,263	345,929	364,996
Orig. Ann. Energy	GWh	644,00	687,45	724,48	762,76	799,11	832,92	860,00	889,20	911,09
Installed Capacity	MW	120	133	145	157	168	180	192	203	215
Proj. Cost (Funct.)	Mill US$	249,057	261,389	274,331	287,915	302,171	317,133	332,836	349,316	366,613
Energy Reduction	GWh	2,850	3,134	3,419	3,704	3,989	4,274	4,559	4,844	5,129
Ann. En. (incl.Red.)	GWh	641,150	684,316	721,061	759,056	795,121	828,646	855,441	884,356	905,961
Ann. En. (Function)	GWh	640,765	683,193	723,012	760,221	794,821	826,811	856,192	882,964	907,127
Accum. Factor	-	1,16	1,16	1,16	1,16	1,16	1,16	1,16	1,16	1,16
Present Value Cost	Mill US$	288,968	303,276	318,293	334,053	350,594	367,954	386,173	405,294	425,363
Annual Benefits	Mill US$	44,854	47,824	50,611	53,215	55,637	57,877	59,933	61,807	63,499
Annual O&M Cost	Mill US$	3,736	3,921	4,115	4,319	4,533	4,757	4,993	5,240	5,499
Annual (B-O&M)	Mill US$	41,118	43,903	46,496	48,897	51,105	53,120	54,941	56,568	58,000
Present Value Bene	Mill US$	409,827	437,585	463,431	487,361	509,370	529,453	547,605	563,820	578,092
PV(B-C)	Mill US$	120,859	134,309	145,138	153,308	158,776	161,500	161,432	158,525	152,729
Cost / kWh	US$ / kWh	0,0511	0,0503	0,0499	0,0498	0,0500	0,0504	0,0511	0,0520	0,0531
Cost / kW	US$ / kW	2408	2280	2195	2128	2087	2044	2011	1997	1978
CRF	-	0,142	0,145	0,146	0,146	0,146	0,144	0,142	0,140	0,136
1/CRF	-	7,028	6,908	6,846	6,832	6,860	6,927	7,029	7,165	7,334
C/B (auxilliary Val.)	-	7,028	6,908	6,846	6,832	6,860	6,927	7,029	7,165	7,334
IRR	%	14,224	14,472	14,604	14,633	14,573	14,432	14,222	13,952	13,629

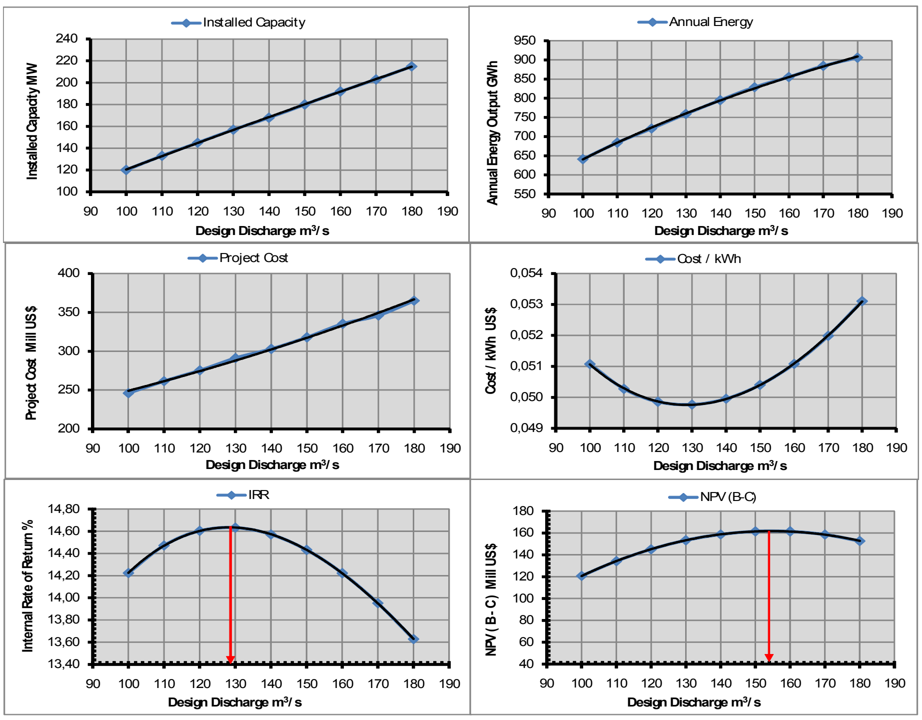


Table 4.2 Optimization of the Installed Capacity for Madian HPP

A flat rate tariff of 0.07 US $ / kWh was applied to the assessment of energy generation related benefits for determination of the annual benefits. The simulation of reservoir operation and powerhouse operation was based on series of 10-daily river discharges.

Based on the above described approach and an optimum power waterway design discharge of 129 m^3/s was obtained for the highest rate of return. The Consultant established alternative combinations of the number and capacity of turbine units and optimized the combination of rated turbine discharges of reasonable combinations of number and size of units in a way to maximize the annual energy generation simulating run-of-river operation based on daily river flow data. The corresponding optimum alternative combinations of number and rated discharge of turbine units are:

ALT 1:	3 units of identical size:	3 x 43 m^3/s
ALT 2:	2 large units and 1 small unit	2x50.5 + 1 x 28.0 m^3/s
ALT 3:	2 large units and 2 small units	2x41.0 + 2 x 23.5 m^3/s

As the next step the Consultant elaborated a project design for the three above alternative concepts applying the design and hydropower project assessment tool HPC and the corresponding cost estimation. The assessment of benefits from hydropower plant operation (run-of river) was carried out based on 46 years of daily river flow data.

The highest annual energy generation can be achieved by 2 large and 2 small units (ALT 3) which permit operation at high turbine efficiency during most of the time. The alternative with 3 identical units represents the least cost solution compared to any other alternative.

The alternatives with 3 turbine units (ALT 1 and ALT 2) are equivalent as regards their economic key parameters with a minor advantage for the concept with turbine units of identical size. In co-ordination with the Project Sponsor, the Consultant proposes the installation of 3 Francis units of identical size, i.e. ALT1. This recommendation can be considered conservative. The present analysis is based on the simulation of run-of-river operation. At times of extremely low river flow, the available flow might me not sufficient to operate a Francis unit safely on continuous basis at all time. However, with consideration of pondage operation, daily power generation can be maintained and an approximate additional annual power generation of 12 GWh achieved.

Based on the analysis the Consultant recommends installation of three identical turbine units with the installed capacity of 3 x 60.8 MW (ex turbine). For the assumed turbine characteristics this discharge corresponds to an optimum available capacity (ex transformer) of 3 x 52.43 = 157.3 MW for the Madian HPP. In view of the merits of the optional application of pondage operation, the Consultant makes the corresponding provisions in the feasibility design of the weir and intake structures to enable pondage operation between elevation 1494 and 1492 asl.

4.5.2 Optimization of Power Waterway Dimensions

As part of the overall project optimization, the dimensions of the power waterway conduit system are optimized applying the relevant economic parameters. The hydraulic design of the power waterway system is based on the following basic parameters and dimensions:

Rated Turbine Discharge:	3 x 43 m³/s
Full Supply Level	1494.0 m asl
Max./Min. Operation Level	1494.5 / 1492.0 m asl
Max./Min. Tailwater Level	1346.0 / 1339.6 m asl

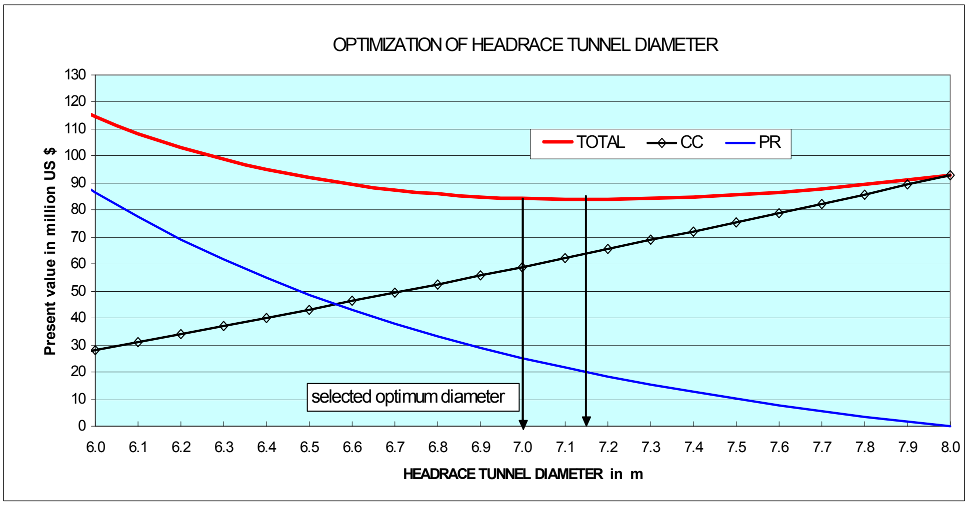


Figure 4.3: Optimization of Headrace / Tailrace Tunnel Diameter – Base Case

As indicated in Figure 4.3 the optimum headrace tunnel diameter is 7.15 m. A range of diameters from 6.95 to 7.40 m exists without a significant variation of the optimization criterion. With the aim to minimize investment cost for a headrace tunnel diameter of 7.0 m was selected.

For selection of optimum diameters of the short pressure shaft / tunnel an empirical approach was applied. The optimum diameter of the concrete lined part of the vertical pressure shaft results in a diameter of 5.8 m. In its lower third the shaft is steel lined. Starting from the steel lined section the conduit diameter reduces to 5.4 m. The corresponding design flow velocities coincide well with prototype data of a number of similar hydropower plants.

4.6 Hydraulic Design of Power Waterway System

4.6.1 Headrace Tunnel and Surge Tank

The first section of the headrace tunnel with an internal diameter of 7.0 m is arranged from the power intake to the desander caverns (situated some 2.1 km downstream of the power intake). The second section starts downstream of the desander caverns and proceeds to the surge tank.

At the surge tank a maintenance gate is arranged to close the headrace tunnel during times of maintenance and inspection of the pressure shaft and manifold system without the need to empty and re-fill the entire headrace tunnel (0.36 million m³ water).

In accordance with common design practice and the hydraulic design criteria, the cross sectional area of the cylindrical surge tank is selected 70 % larger than the THOMA-Criterion (actual safety factor 1.7) to ensure adequate stability of plant operation. For load acceptance of the turbine units and subsequent full load rejection the following scenarios and load cases were considered:

LC-UP1)	Load acceptance from partial load, not exceeding 50 % total load increase; subsequent full load rejection;
LC-UP2)	Load acceptance of two units after synchronization; subsequent full load rejection;
LCDP1)	Full load acceptance of one turbine followed by another turbine after a certain time interval; this interval is to be adjusted to detect the most unfavourable moment;
LCDP2)	Load reduction by 50 per cent and subsequent complete load acceptance.

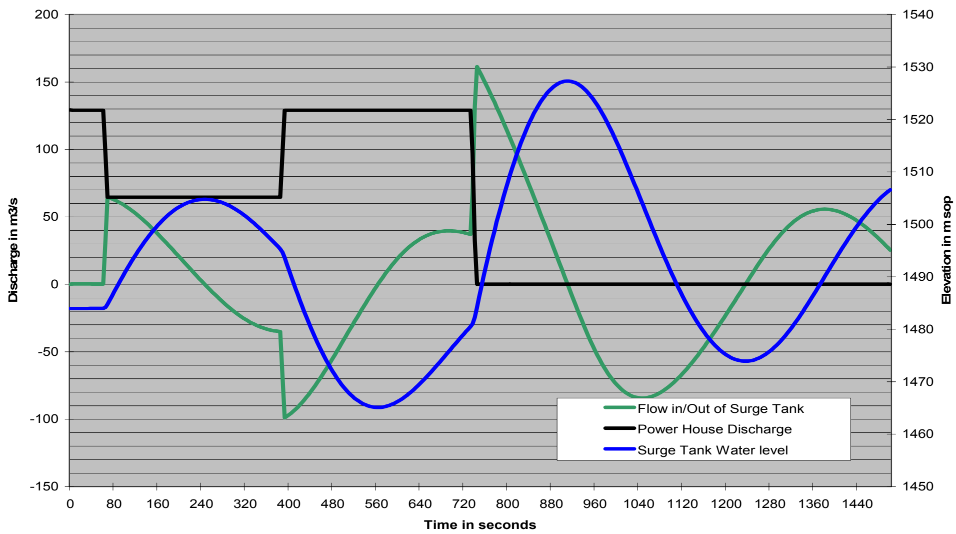


Figure 4.4: Surge Tank: Combined Load Case–Maximum Upsurge

4.6.2 Pressure Shaft, Pressure Tunnel and Manifold

For ease of construction by means of the raise boring method the 5.8 m diameter pressure shaft is designed vertical. In view of the expected internal tunnel pressure and the rock mass characteristics in the pressure shaft area, concrete lining is required. In view of the internal pressure (transient analysis) steel lining is required in the lower third of the pressure shaft only. The two vertical bends of 90 degrees are arranged applying a radius of 17.4 m (R = 3.0 x D) thus representing a good compromise between economic design and low head losses. In the lower part the pressure shaft is steel lined and has an internal diameter of 5.4 m. The lining thickness increases from 20 to 28 mm towards the powerhouse cavern. The 10 m long horizontal steel lined pressure tunnel connects the pressure shaft with the manifold system. The internal diameter of the steel lined pressure tunnel is 5.4 m. At the end of the pressure tunnel consecutively three manifolds branch off the main tunnel at an angle of 55 degrees. Each manifold has the internal diameter of 3.0 m including the confusor arranged as transition to the safety butterfly flap of 2.5 m nominal diameter. A straight alignment is provided towards the turbines over a length of at least 10 times the conduit diameter.

The head losses of the waterways are in the order of 14.7 m for operation under rated conditions as shown in Table 4.3.

Underground Powerhouse , Section through Unit No. 2

Reach No.	Length [m]	Area [m²]	Perimeter [m]	Diameter [m]	Roughness [mm]	local head loss coefficient	Description of local head loss	Flow velocity	Head loss [m]
Intake	68.00	12.57	12.57	4.00	0.60	0.330	inlet loss, trahrack etc.	3.42	0.330
Headrace	1997.00	38.48	21.99	7.00	0.60	0.111	various bends	3.35	1.984
Desander inlet	33.50	12.57	12.57	4.00	0.60	0.000		3.42	0.065
Desander	256.00	173.04	46.63	14.84	0.60	0.000	Dividing flow & bend 55°	0.25	0.001
Desander Outlet	112.00	12.57	12.57	4.00	0.60	0.860	R/D=3	3.42	0.732
Headrace	9401.00	38.48	21.99	7.00	0.60	0.035	surge tank	3.35	9.062
Pressure Shaft	111.47	26.42	18.22	5.80	0.60	0.369	2 x bend 90°, R/D = 3	4.88	0.732
High Pressure Tunne	66.65	22.90	16.96	5.40	0.10	0.000		5.63	0.184
Manifold	55.80	7.07	9.42	3.00	0.10	0.040	dividing flow 55 °	6.08	0.431
Turbine inlet	6.60	5.73	8.48	2.70	0.10	0.050	confusor, butterfly valve	7.51	0.216
Draft tube extension	53.80	13.85	13.19	4.20	0.60	0.570	combining flow 55°	3.10	0.361
Tailrace Tunnel	84.02	41.85	22.93	7.30	0.60	1.100	outlet, gate slots	3.08	0.598
							Head loss hl =		14.697
							hl = N x 10^{-6} x Q²		883.158

* draft tube loss is included in turbine efficiency

Table 4.3 Head Loss Characteristics of Waterways, Underground Powerhouse

For verification of pressure conditions along the power waterways, a transient analysis was carried out based on the method of characteristics. The load cases considered in this transient analysis are similar as to the hydraulic design of the surge tank

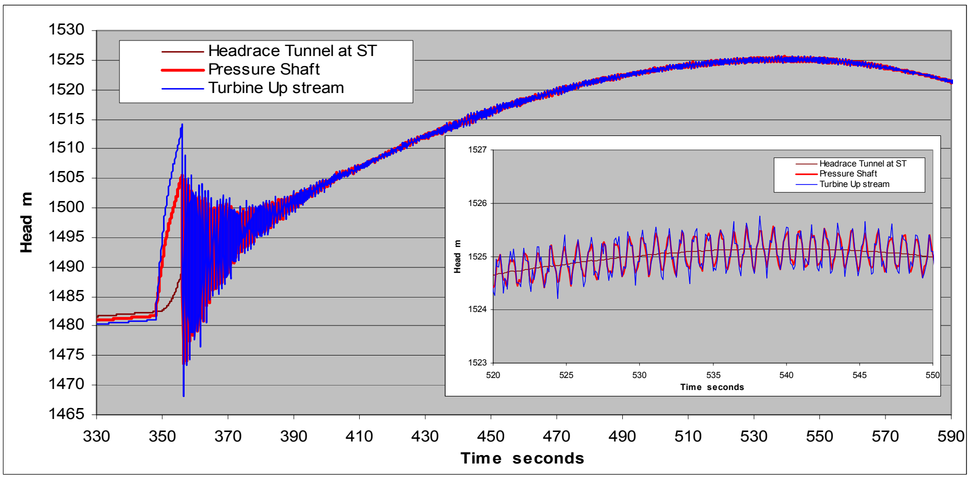


Figure 4.5 Fluctuation of Head in the Upstream Waterway System after Full Load Rejection of 3 units

The hydrodynamic pressure rise as the consequence of transient phenomena is limited to 23 % of static head in the headrace tunnel. In this case a maximum head of 1530 m applies to the headrace tunnel design equivalent to 8 bar of internal water pressure as the design parameter.

4.7 Hydraulic Design of the Desander System

Sediments in suspension will unavoidably result in a certain wear and tear, in particular at the turbine runner. The extent of the abrasion depends largely on the concentration, size and mineralogical characteristics of the sediment particles etc. This abrasion and the resulting need for overhaul and replacement of runners cannot be avoided. Desanding facilities are arranged to control or better say to reduce the frequency of the required change and overhaul of turbine runners.

During the high flow season the Swat River has the potential to transport large quantities of sediments in suspension as well as bed load. Sediment concentrations of up to 10,000 ppm have been recorded in Swat river. From the petrographic analysis of rock and sand samples it can be assumed that quartz minerals may make up to 10 % of the suspended sediments.

The topographical and geological conditions make the arrangement of open air desanding basins impossible in the case of the Madian HPP due to the narrow valley and steep valley slopes. For this reason, underground desanding facilities are arranged for the Madian HPP. The Consultant analysed the existing desander types and flushing systems and elaborated a modified Bieri – desander flushing system. The desanding works consist of three 206 m long desander caverns. Manifold systems branch off the headrace tunnel upstream and downstream to the headrace tunnel. The Consultant determined the required dimensions for the long basin desander applying his program DESANDER which is based on the theoretical approaches of CAMP and SARIKAYA. The results of the design and thus the key parameters of the desander caverns are given in Table 4.4

Desander:		
Design discharge	129	m³/s
Number of settling chambers	3	
Effective length of chamber	206	m (without transition)
Width of chamber	13.7	m
Average depth of chamber	16	m
Mean velocity	0.2	m/s
Grain size to be excluded	0.20	mm

Table 4.4 Technical Key Parameters of the Desander Works

Particle Diameter mm	Settling velocity mm/s	Rate of Removal %
0.40	58.0	100.0%
0.20	22.0	98.0%
0.15	15.0	82.0%
0.10	9.0	56.0%
0.06	3.5	22.0%
0.02	0.4	0.0%

Table 4.5 Rates of Removal of Suspended Sediments at the Desander Caverns

Approximately 98 % of the sediments are removed from the water sediment mix at the desander works of the sediment fraction of the design particle diameter of 0.2 mm. For fractions with larger particle size the removal rate approaches 100 % and for particles of 0.1 mm diameter the removal rate is still above 50 %. Table 4.5 demonstrates that the selected desander design is adequate.

4.8 Powerhouse and Tailrace

The proposed underground powerhouse is a conventional cavern structure for three identical Francis units with vertical axis of 60.8 MW installed turbine capacity and a runner diameter of 2.22 m. Within the powerhouse the main inlet butterfly valve of nominal diameter of D = 2.5 m is arranged immediately upstream of each turbine unit. After passing through the turbines, the water is discharged via the draft tube extension into the common tailrace tunnel and from there to the outlet bay. Each draft tube can be closed by a draft tube flap gate for maintenance or repair of a turbine unit. The distance between the turbine unit centre lines is 15.15 m.

The tentative dimensions of the powerhouse cavern are as follows:

Width	20.0 m	Length	73.5 m
Height	35.0 m at draft tube, (31.0 m	at valve floor)	

On both lateral walls of the cavern crane beams of reinforced concrete are arranged anchored to the rock for the overhead travelling crane. A single service and erection bay is provided in the northern part of the cavern at elevation 1345.45 m. For access to the powerhouse cavern and further to the transformers cavern a common access tunnel is provided of 5.5 m diameter.

The No. 10 single phase transformers are arranged in a small cavern which is arranged at 30 m distance from the powerhouse cavern. Aiming on a high reliability it was decided to consider a SF6 gas insulated switchyard arranged underground adjacent to the transformer cavern. The transformer cavern is approximately 9.0 m wide, 7.4 m high and 64 m long whereas the switchyard cavern is 13.7 m in width and 10.5 m in height. The turbine setting is defined according to the requirements to prevent cavitation at the turbine units at elevation 1336.0 m asl based on the minimum tailwater level of 1339.6 m asl for the selected turbine and the prevailing hydraulic conditions.

The turbine draft tube extensions form a manifold system that joins into a single tailrace tunnel of 93 m length and 7.3 m diameter. At its end a power outlet structure at the left bank of the Swat River is arranged. The elevation of the invert at the outlet structure is selected at elevation 1336.0 m asl. The working and access platform are arranged at elevation 1355.0 m asl safely above the above the maximum flood water levels of Swat River.

5. Design of Electro-Mechanical Equipment

5.1 General

The mechanical equipment and main mechanical auxiliaries in the powerhouse consists of following items:

- three vertical shaft single-stage Francis-turbines including hydraulic/electronic turbine governors
- butterfly valve in front of each turbine with auxiliaries

Auxiliary mechanical systems such as:
- cooling water system
- drainage and dewatering system
- ventilation and air conditioning system
- oil treatment plant
- compressed air system
- mechanical and welding workshop
- three sets of draft-tube flap gates
- powerhouse-overhead travelling bridge crane
- fire fighting system

5.2 Design Criteria

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

Sediment and grain size analysis:
Silt and sediments of finer fractions may pass the turbine units with a sediment concentration of up to 4000 ppm. The petrographic analysis of rock and sand samples revealed a possible maximum content of quartz minerals of 10 %. The chemical analysis of the sediments and their hardness is recommended to be performed in the tender design phase that particular design features such as special coatings or extreme wear resistant materials can be chosen based upon the results of this analysis.

Hydrological and hydraulic conditions:
On the basis of the available hydrological data and the assumed operation regimes, the expected maximum peak capacity is presently assumed to be some 157 MW. During the present feasibility study phase the number and size of the turbines was optimised. The significant variation of flow in Swat River in combination with the run-off river operation concept results in the selection of three Francis units of identical size (3 x 52.43 MW rated output capacity). During the high flow season for more than 4 to 5 months each year the turbine units will run continuously under full load. During the low flow period of 4 months only one turbine unit will be operated mostly under part-load operation conditions.

5.3 Selection of Turbines

The net head and discharge are such that only vertical axis Francis turbines can be considered. The outlet structure of the turbine tailrace spills into the riverbed at riverbed level of 1339.6 m asl. For the present turbine layout we defined the setting of the turbine at level 1336.0 m asl, which gives enough safety for overload conditions.

Characteristics	Unit	Intake/ Powerhouse
PMF	m asl	1494.5
FSL (Full Supply Level)	m asl	1494.0
MSL (Minimum Supply Level)	m asl	1492.0
TWL_{min} (Tailwater Level Minimum)	m asl	1339.6
TWL (at 129 m^3/s)	m asl	1341.1
TWL_{max} (Tailwater Level Maximum at PMF)	m asl	1346.0
H_{gross} (range)	m	146 – 154
h_l (1 unit operation / 43 m^3/s)	m	2.2
h_l (3 unit operation / 129 m^3/s)	m	14.7
H_{net} (1 unit operation / 43 m^3/s)	m	151.7
H_{net} (3 unit operation / 129 m^3/s)	m	138.2
Q_{avail} (inflow)	m^3/s	10 - 400
Q_{turb} (maximum design discharge)	m^3/s	43

Table 5.1: Main hydraulic data of turbine layout

The units are supposed to be operated mainly as run-off-river plant. The turbine is selected to operate continuously under part load conditions The primary operation mode for this run-off-river plant will be level regulation.

Characteristic	Unit	Data
Type	-	Francis
Number of Units	-	3
P at maximum design Q	MW	54.3
H rated	m	139
Q maximum design	m^3/s	3 x 43
Runner diameter	mm	2220
Setting	m asl	1336.0
Rated speed	rpm	333
P overload at rated head	MW	55.4
P max. (one unit operational only)	MW	60.8

Table 5.1: Main parameters of turbine layout (capacity given ex turbine unit)

It remains to discuss, clarify and specify in the tender documents the configuration and integration of the Madian HPP into the existing grid and the extent of the required black-start capability. In the present feasibility design provision are made for black-start and isolated grid operation.

5.4 Design of Francis-Turbine Equipment

The spiral-case of welded construction serves as inlet-structure to the radial oriented stay- and guide-vanes, which convey the incoming water from axial to rotational flow.

The guide-vanes made of stainless steel and optionally covered with hard-ceramics permit the regulation of the incoming-flow. The guide-vane stems are supported by one lower and two upper self lubricating bearings, which can be adjusted, exchanged and maintained without dismantling head cover or bottom ring. The turbine is controlled by an electronic governor, which transforms each electronic signal into a hydraulic action to be executed by the hydraulic governor. For maintenance- and commissioning purposes the governor can be operated from the local control panel of the electronic governor, but under normal operation it is remote-controlled from the control room in the powerhouse or from each other place to be designated.

Particularly the long lasting conditions of part-load operation have to be considered seriously and the runner shall be designed to allow a continuous, fail-safe operation without increased vibration, noise and draft tube pressure pulsations as well a free of cavitation operation.

The runner is a weld construction of high alloy steel made of pre-fabricated cast or forged blades and rings. Depending on the results of the chemical analysis and hardness of the suspended sediment the advantages of a hard or soft-coating of the runner have to be evaluated in the tender design. The runner is bolted to the turbine-flange. Multi-stage labyrinth rings reduce the losses of water.

The draft-tube cone made of ordinary steel is bolted on its upstream side to the runner cone and welded downstream to the draft tube.

5.5 Powerhouse Outlet / Draft Tube Flap Gate

Three sets of draft tube flap gates are foreseen for repair and maintenance of the draft-tube and the turbine. For safety reasons and to protect the outlet structure from inundation and silting, flap gates for each unit are supplied. Each flap gates is operated by means of a hydraulic hoist, which is installed above the housing of the flap gate.

Clear width of flap gate	app. 5.5 m
Clear height	App. 2.5 m
Max tailwater level	1346.0 m asl
Sill elevation	1327.9 m asl
Operation	Open/Close under balanced no-flow condition
Hoist	Oil-hydraulic hoist drive
Flap normal operation speed	0.3 m/min

Table 5.2: Main data of draft tube flap gates

5.6 Main Inlet Valve

In front of each turbine, one butterfly-valve is installed as emergency- and repair shutdown-valve of the turbine. The butterfly valve type was selected since the alternative spherical valve type results according to common experience in significantly higher equipment costs and requires larger dimensions for access facilities and capacity of lifting equipment.

Characteristic	Unit	D1 (b)
Number of Units	-	3
Nominal diameter DN	mm	2500
Nominal pressure PN	bar	20

Table 5.3: Main data of main inlet butterfly valves

The opening of the valve is effectuated by means of one or two hydraulic pistons, the closing by means of a counterweight, which closes the valve under all flow conditions.

5.7 Main Lifting Equipment

The required total maximum lifting capacity of the EOT powerhouse crane is determined by the generator rotor which will weigh around 180 tons. The weight of all other pieces of equipment to be handled by the main hook will be much less than 100 tons. An auxiliary hook of 10 tons capacity will be provided on the crane and will run along the main bridge beam; this will be used for handling smaller equipment and for normal maintenance work such as runner removal, etc. The present proposed capacity of the crane should be reviewed during the tender stage when the suppliers confirm the actual weight of the generator rotors.

During the installation of the turbine embedded parts, a lifting capacity of roughly 25 tons will be required for assembly of the draft tube and spiral case. The temporary construction crane will be available for this work. Details of this temporary lifting facility will be given in the civil works specifications of the tender documents. The required total maximum lifting capacity of the EOT crane is supposed to be around 10 tons for installation and assembly of the switchyard and transformer components. The present proposed capacity of the crane should be reviewed during the tender stage.

For maintenance and operation of the entire power plant facilities a mobile crane will serve to handle equipment on the various sites. The lifting capacity is estimated to be around 20 tons with a jib of 10m. Within the design phase the lifting capacity has to be adapted to the maximum load of equipment to be handled and the required effective working area.

5.8 Mini-hydro Francis Turbine for Ecological Release

The applicable turbine is selected according to the head and discharge available. The unit will use the ecological flow which is to be released at Madian HPP weir site to the downstream river reach. The available head and discharge (per definition) are almost constant over the 365 days per year except during operation of the flushing facilities. The unit is supposed to be continuously operated as run-off-river plant.

A standardized horizontal Francis turbine is the most economical solution under such conditions. For the low head application and the discharge many manufacturers offer standardized skid mounted units, which are delivered workshop tested to the power plant. The runner will be directly coupled to the synchronous low-voltage generator, which is connected to the local medium voltage grid available at the intake. The unit is fully automatically controlled from the central control room. In the following Table 5.4 the basic characteristics of the selected turbine are given:

Characteristic	Unit	Data
Type	-	Horizontal Francis
Number of Units	-	1
P rated	kW	510
H rated	m	15.8
Q rated	m^3/s	3.6
Runner diameter	mm	650
Setting	m asl	1478
Rated speed	rpm	600
P max.	kW	540

Table 5.4: Main data of auxiliary turbine

Immediately upstream of the turbine a butterfly-valve is installed as emergency- and repair shutdown-valve of the turbine with a nominal diameter of 800 mm, operated by a hydraulic servomotor.

6. Design of Electrical Equipment

This chapter summarizes the feasibility design of the electrical equipment of the Madian HPP to be installed at the major project structures such as powerhouse, weir/power intake and desander caverns. The design concept is based on the assumption to interconnect the Madian HPP to a 220 kV high voltage transmission line at the switchyard as informed by PPIB in a meeting in September 2008. The single line diagram 220/11/0.4 kV is included in Volume 7, Plate 60.

Main Supply Scheme at Power Cavern

The applied connection scheme between the generators and their respective step-up transformers will be of conventional arrangement, with generator circuit-breaker and with tap-off to the excitation transformers and to the unit auxiliary transformer. As step-up transformers, three banks each of three single-phase units will be foreseen (plus one spare single-phase unit) and located in the power cavern in dedicated transformer rooms. The transformer terminals will be suitable for connection of isolated single-phase bus ducts on the 13.8 kV side. The 230 kV terminals will be equipped with bushings for connection of 220 kV power cables to the 220 kV GIS switchgear located in the power cavern as well (separate room).

The 220 kV GIS switchgear will comprise a double bus bar scheme, ensuring reliability and flexibility during normal and also during exceptional operating conditions. Two 220 kV power cable connections will lead out of the switchyard cavern through a cable tunnel up to a 220 kV terminal gantry with surge arresters provided for the 220 kV public grid overhead line side. The 220 kV gantry will be located close to the cable tunnel outlet structure.

The study considers the existing Madian conventional open-air type 220 kV switchyard located on a appropriate terrain in a distance of about 2 km from the Madian HEP and considers a double 220 kV overhead line (using suspension type intermediate towers, if necessary) up to the 220 kV terminal gantry close to the HEP power outlet structure (not part of the Madian HPP and not detailed further in this Study).

Auxiliary Supply Scheme at Power Cavern

Under normal condition supply of auxiliary power will be through one of the two 100% unit auxiliary transformers feeding the 400 V station service board. Alternatively station auxiliaries (about 50% of total auxiliaries) may be fed from the synchronous emergency diesel generator set, in case of complete power failure (also used in case of black-start).

For normal starting of a turbine-generator unit, the feeding of the 400 V station service board and all station auxiliaries will be effected by using the 220 kV grid supply through the unit step-up transformer and the unit auxiliary transformer, while the generator circuit-breaker is open. UPS systems will comprise the 2 x 100% redundant 110 VDC-, 24 VDC-, 48 VDC-, 400 V safe AC-systems and one emergency diesel system.

6.1 Electrical Equipment within the Power Cavern

6.1.1 Main Generating Equipment

The closed-cycle air-cooled generators will be equipped with air-water heat exchangers, connected to the plant cooling water system. For all load conditions maximum air temperature will be limited to 40°C. The power and speed of the generators are dictated by the turbine, with its calculated output at the shaft coupling at design heads and design flow. Considering the respective turbine power output, a typical generator efficiency of approx. 98% and a power factor of 0.85 (which allows the generation of the necessary reactive power for voltage regulation at the 220 kV grid).

All windings of stator and rotor will be provided with a class „F“ insulation system. As the long-term performance of the insulation system is affected by the maximum operating temperature of the windings, the rated output of the generators will be related to a temperature rise to class „B“ insulation. The rated generator voltage will be considered with 13.8 kV, which is a typical standard voltage and appropriate for generators of this size. However, for optimization of the generator and bus bar design, the final selection may be left open to the supplier.

Turbine power			
			Remarks:
P_{rated}	MW	54.3	3 units running at maximum design discharge (at full capacity nominal). Minimum power delivered to each generator at class B temperature rise!
P_{max}	MW	60.8	Only 1 unit is running. Maximum power delivered to a (each) generator at class F temperature rise!
Nominal speed	rpm	333.3	
Rated frequency	Hz	50	
Generator power			
Generator efficiency	%	98.0	
nominal power factor	-	0.85	
P_{S_rated}	**MVA**	**63**	Minimum power each generator at class B temperature rise must be able to deliver!
P_{S_max}	**MVA**	**70**	Maximum power a (each) generator at class F temperature rise must be able to deliver!

Table 6.1: Design Parameter for Generator Design

For the dimensioning of the civil layout the following generator dimensions were estimated:

• Rotor diameter	approx.	4000 mm
• Outer stator diameter	approx.	6100 mm
• Shaft length	approx.	5000 mm
• Weight of complete rotor	approx.	152 tons

Due to the limitations of transport dimensions and weights, the stator housings will be divided and delivered in sections and the winding at the joints will be completed on site. The rotor will be assembled completely at site, including stacking of the rotor rim and fixing of the poles.

6.1.2 Step-Up Transformers

Due to the transportation weight restrictions, single-phase transformers are considered in this stage of the project. The rating of each oil-immersed closed single-phase transformer will be 24 $^{1}/_{3}$ MVA (corresponding to 73 MVA for the three-phase transformer bank). The detailed requirements of the on-load tap-changer will be investigated in the tender design stage once corresponding load-flow studies for the grid and the power plant are available. Because of the indoor location in the power cavern, the cooling-type of the transformers will be OFWF (oil forced cooling / water forced re-cooling). Each transformer bank of three single-phase transformers will be installed in a separate cavern-cell with concrete partition walls for fire protection. One spare single-phase transformer will be provided and stored in a separate cavern-cell adjacent to the active transformers. This arrangement allows the replacement of any transformer in a short time.

• Number of single-phase transformers	9 + 1 (spare)
• Type	single-phase, two windings
• Rated bank output of 3 single-phase transformers	73 MVA
• Frequency	50 Hz
• Type of cooling	OFWF
• Rated voltage:	
• High voltage winding	230/√3 kV
• Low voltage winding	13.8 kV
• Rated power frequency withstand voltage (rms value)	460 kV
• Rated lighting impulse withstand voltage (peak) BIL	1050 kV
• Type of tap changer	on-load tap-changer
• Range of tapping	± 12 x 1.25% = ± 15%

Table 6.2: Design Parameter of Single Phase Transformers

6.1.3 Unit Auxiliary Transformers: 13.8/0.42 kV

Two three-phase transformers will be provided for auxiliary power supply from the generator bus ducts of unit No. 1 and 3. The rating of each dry-type (cast-resin) transformer will be 1250 kVA, where each transformer will be suitable to feed the total auxiliary power demand in the power cavern. The voltage ratio will be 13.8 / 0.42 kV.

6.1.4 220 kV GIS Switchgear

A 220 kV SF_6 gas-insulated switchgear (GIS) will be installed in a separated room in extension of the transformer cavern. The switchgear scheme includes a double bus bar system to ensure reliability and flexibility during normal and during exceptional operating conditions. The switchgear will consist of six bays. The technical characteristics of the GIS will be as follows:

• Insulation medium	SF_6
• Maximum operation voltage	245 kV
• Rated power frequency withstand voltage (rms value), across open switching device and/or isolating distance, at minimum operating gas-pressure	460 kV
• Rated power frequency withstand voltage (rms value), phase to phase and phase to earth, at minimum operating gas-pressure	530 kV
• Rated lighting impulse withstand voltage (peak), phase to phase and phase to earth, at minimum operating gas-pressure	1050 kV
• Rated short-circuit breaking current	25 kA for 1 second
• Rated bus bar current	1000 A
• Rated current for generator, line and coupling bay	630 A / 1000 A / 1000 A

Table 6.3: Design Parameter of 220 kV GIS Switchgear

6.1.5 220 kV XLPE Cables

The connection between the HV terminals of the step-up transformers and the corresponding feeders in the GIS will be executed with 220 kV XLPE copper cables.

• Maximum operation voltage	245 kV
• Rated voltage (Uo/U)	127/220 kV
• Short duration power frequency withstand voltage (rms value)	460 kV
• Rated lighting impulse withstand voltage (peak)	1050 kV
• Rated power per 3-phase cable system	190 MVA

Table 6.4: Design Parameter of 220 kV XLPR Cable

6.1.6 Auxiliary Electrical Equipment

400 V AC Auxiliary Power Supply

The auxiliary power requirements of each unit will be provided through the three unit auxiliary boards, each one fed from the main distribution board. The 400 V main distribution board itself will be fed either from the two unit auxiliary transformers, rated 1250 kVA each and connected to the generator bus system of unit No. 1 and 3.

UPS Systems

UPS systems will comprise the 2 x 100% redundant 110 VDC-, 24 VDC-, 48 VDC-, 400 V safe AC-systems and one emergency diesel system as follows:

Diesel Generator Set

The 400 V emergency diesel-generator set will be required to provide the necessary emergency and black-start power supply. The unit will start and build-up voltage automatically within 15 sec. Shut-down of the diesel engines will be by means of fuel shut-off solenoid. As a result from preliminary estimations of the essential loads to be supplied by the diesel generator set, a rated output of 630 kVA will be sufficient.

Electrical Protection Systems

All electrical protection systems will be of the digital (numerical) type and will comprise the following sub-systems:

- Generator Protection System
- Step-Up Transformer Protection
- Station Service Transformer Protection
- 220 kV GIS Switchgear Protection

11 kV Switchgear

Protection comprises 3-phase over-current- and earth-fault relays in the incoming feeders. The over-current relay will be of the inverse-time type with instantaneous tripping set at a high level. The relays will be installed in the relay compartment of the 11 kV panels.

400 V Switchgear

Protection of the 400 V system will be provided by magnetic thermal trip units mounted on the circuit-breakers. In the case of fuse isolators combined with contactors only thermal overload protection will be required. Under-voltage relays on each bus bar will supply the criteria for the automatic change-over device for the different supply sources.

Fire Detection System

A decentralised fire alarm system with detection and release function will be provided for the entire power station and the corresponding galleries. The system will consist of one central unit (main fire alarm panel) supervising the sub-units located in the different areas of the cavern.

Fire Fighting Systems
The necessity of fire-fighting systems for sites such as oil tanks, cable ways, cable spreading room and the main control room will be defined in the tender design phase of the Project.

Electrical Workshop and Laboratory
A suitable equipped workshop and laboratory for maintenance and repair of the electric and electronic equipment will be located in the power cavern.

Control and Monitoring System
For reliable, efficient and safe operation of the power station a monitoring and control system will be provided suitable for supervisory, control and monitoring of each individual unit as well as common equipment in the power cavern, desander cavern and weir site / power intake. A modular, screen-prompted control system will be used, with references documented for relevant power stations. Provisions will be made to adapt the DCS for future remote monitoring from a remote grid dispatch centre.

Telephone System
The entire power station will be equipped with a telephone system consisting of a main exchange. This system will take over the internal and external telephone traffic of the power station area. The system will enable the telephone communication for at least 40 internal subscribes and 5 external lines via OPGW.

6.2 Main Electrical Equipment outside the Power Cavern

Power Supply at Weir Site
The power supply at the weir site, including the weir control building and the power intake, will be connected through an 11 kV transmission line (loop-in) to the local 11 kV grid.

The following equipment will be foreseen at weir site:

- One 11 kV switchgear with two feeders
- One auxiliary transformer 11/0,42 kV, 630 kVA
- One 400 V main distribution and sub-distribution boards
- Two 100% UPS systems, battery backed-up
- One synchronous hydraulic turbine-generator approx. 650 kVA at 400 V
- One synchronous 400 V emergency diesel generator set 150 kVA
- One satellite DCS

220 kV Terminal Gantry
A 220 kV terminal gantry will be located close to the cable tunnel outlet structure. It will consist of a lattice steel construction, to which the public grid 220 kV overhead lines will be connected on the external side and the 220 kV XLPE cable will be connected on the internal side.

7. Design of Hydraulic Steel Structure Equipment

7.1 General

The 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 stop log for maintenance (7.6m x 12.0 m)
- Gantry crane with capacity 50/10 t;

The power intake facilities include:

- One stop log set (5.9m x 7.5m) at intake entrance
- Three trash racks (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 stop log (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 stop logs (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 bulkhead gate (W x H = 6.1m x 7.3m). The diversion tunnel will be locked after construction of the weir by means stop logs (8.0m x 9.5m).

7.2 Spillway

Radial Spillway Gates
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. The gates shall have self closing tendency.

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

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. Two servomotors connected to the gate arms shall operate each spillway gate. The hydraulic power units will be located on the spillway piers, in a common control room, together with the local control boards.

Stop log for Maintenance
In order to enable in situ maintenance work at the radial gates and to enhance erection, one set of stop logs for the spillway, to be installed upstream of the radial gates, is provided. The stop logs will be installed with the gantry crane.

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.

7.3 Equipment of Power Intake

Stop logs

To dewater the individual bays of the intake structure for maintenance of the trash rack and the intake roller gate, stop logs can be installed upstream of the trash rack and immediately downstream of the fixed wheel roller gates. These stop logs will be stored at deck level 1496 m asl. Setting of these two stop logs permits maintenance/inspection at one gate or trash rack while flow and power plant operation may proceed via the remaining inflow sections. All stop log elements shall have the same shape and dimensions.

Trash rack

The trash rack 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 trash rack panels will be supported by means of a pre-caste concrete beam of fish belly shape. 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.

Trash rack Cleaning Machine

The rake cleaning machine will be a movable portal raking machine with operator cabin and container for the removed trash. The main characteristics of the raking machine are as follows:

Roller Gate

The intake gates located downstream of the trash rack serve as emergency closure devices in case of failures or damages of downstream structures in the desander or waterways, extraordinary pressure difference at the trash rack etc. All gate controls and hydraulic motors will be housed in a control building at the intake deck level.

Design data of roller gate:

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

Flushing Gates

The flushing structure is located left of the gated spillway in extension of the power intake structure. The two sliding gates 2 m wide and 3 m high are operated intermittently to flush the sand and gravel which may deposit in front of the power intake into the tailrace when required. The gates will seal upstream and have ballast for gravity closure against flow with adequate factors of safety against hydraulic forces and friction. Control will be by a hydraulic servomotor set operating at deck level and coupled to the gate via steel linkage rods. The concrete structure of the flushing channel is subject to extraordinary wear and tear during flushing operation. Therefore it is planned to cover the entire flushing channel by a steel lining of 20 mm thickness. The steel lining starts at the pier nose and will ends after the downstream stop log.

Stop log

To have access to the flushing gate for maintenance purposes under any operating conditions, stop logs will be installed upstream and downstream of the flushing gates (2 bulkhead gates upstream and 1 downstream).

7.4 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.

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 selected a conceptual design of the desander basins which permits continuous operation of the power plant by means of intermittent (or if required continuous) flushing of the desander basin based on a modified so called “Bieri”-Desander Design (Switzerland) applying elements of the recently developed so called “4-S” Design (Norway). Hydropneumatic valves seal the desander basins against the flushing duct and are opened periodically when required. 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. 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.
For inspection and maintenance of each desander cavern gates are provided in the upstream and downstream manifolds 3.2 m wide and 4 m high. This concept ensures inspection and maintenance of a single desander cavern without suspending power plant operation and emptying the entire pressure tunnel. 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. The gate has ballast for gravity closure under balanced water conditions with adequate factors of safety against hydraulic forces and friction.

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 these adverse operating conditions of heavy suspended water and the high flow velocities during flushing.

7.5 Power Waterways

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 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:

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.

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

8. Power and Energy Potential

8.1 Methodology and Basic Parameters

For the design of the Project the following design water levels are defined:

Normal Operation Level:		1494.0 m asl
Minimum Operation Water Level:		1492.0 m asl *
Maximum Reservoir Level:		1494.5 m asl **
Powerhouse Design Discharge	Q =	129.0 m³/s
Maximum Gross Head	H_{max} =	154.4 m
Minimum Gross Head	H_{min} =	146.0 m

* In case active storage is provided for temporary additional releases not considered in the present comparison
**in the event of the design flood a surcharge of 0.5 m may establish.

Simulation of hydropower plant operation and the corresponding energy calculations were based on daily flow data of the available records of 47 years of Kedam gauging station.

The calculation of the available gross head for power generation takes into account the head pond level at Madian weir site and the tailwater level at the power outlet. The net head was determined reducing the head losses of the power waterway system from the gross head applying the head loss characteristics. The available power and energy generation were simulated applying the corresponding efficiency curves for the turbine units and the generator. The transformer efficiency was assumed constant in this study.
For the power waterway system a head loss of 14.7 m was determined at maximum turbine design discharge at all 3 units at rated head. For discharges smaller than the maximum design discharge, the head loss can be estimated applying the following relationship based on the assumption of an even distribution of flow through the 3 turbine units:

$$h_l = 883.158 \times 10^{-6} \times Q^2$$

where h_l = head loss in m
Q = powerhouse discharge in m³/s

Accordingly head losses are

at rated conditions	Q = 129 m³/s	14.7 m*
at a discharge of	Q = 86 m³/s	6.5 m*
at a discharge of	Q = 50 m³/s	2.2 m

* even distribution of flow at all three units

Based on the corresponding optimization of the number and size of turbines (see Section 4.10), the following arrangement of turbine units was selected:

ALT 1 3 identical units (Base Case) 3 x 43 m³/s

In the result of this optimization and the corresponding electro-mechanical design the following key parameters were considered in the simulation of hydropower plant operation and the corresponding estimation of annual energy generation. The optimum powerhouse design discharge for the Madian Hydropower Project was determined to be 129 m^3/s.

E&M key parameters:

Maximum Design Discharge:	43.0 m^3/s
Minimum Unit Design Discharge	17.2 m^3/s
Rated Discharge	39.0 m^3/s
Maximum Design Head:	151.7 m
Maximum Power*:	58.5 MW
Power* at Maximum Design Discharge:	3 x 52.43 MW
Power* at Rated Discharge:	3 x 48.4 MW
Maximum turbine efficiency:	94.5 %

* Power ex transformer

Turbine efficiency was assumed as given in Figure 8.1, typical generator and transformer efficiencies (constant 0.99) were assumed correspondingly.

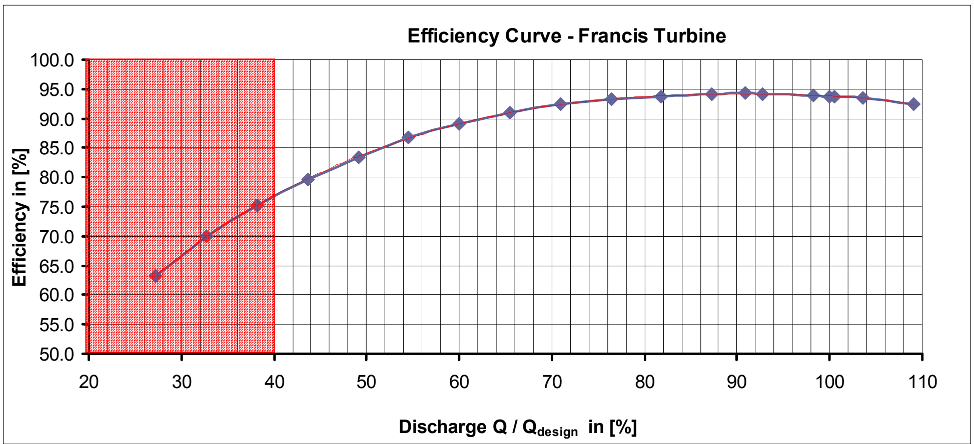


Figure 8.1: Turbine Efficiency as a Function of Turbine Discharge

For the defined Normal reservoir Operation Level (NOL) of 1494 m the weir structure has a height of 19 m above river bed and creates a reservoir with a length of approximately 1.46 km. The total volume of the reservoir would be 0.48 million m^3. Regular pondage operation is not foreseen, however, at times of extremely low river flow a certain pondage may be allowed to ensure operation of a single unit for a limited number of hours.

Transients may be caused by the future operation of the immediately upstream located Asrit Kedam HPP (presently in development) from unforeseen changes in the mode of operation which need to be compensated at the Madian weir site. Therefore, a reservoir with a certain storage capacity is of advantage at Madian HPP weir site to guarantee and improve conditions for turbine operation (and turbine efficiency) at times of extremely low river flow.

8.2 Simulation of Annual Energy Generation

For the assessment of the benefits from power generation, simulation of plant operation was carried out based on 47 years of historical daily river flow data (period 1961-2007) based on records of Kalam gauging station.

The simulation of Madian HPP operation reveals that the annual energy generation may vary between 688.4 and 851.9 GWh (see Table 8.1) with an average of 767.5 GWh, i.e. annual energy generation varies between 89.7 and 111.0 % of the mean annual generation.

Year Month	Min Peak En GWh	Mean Peak En GWh	Max Peak En GWh	Percent of Annual Generation
Jan	0.00	14.08	26.47	1.83%
Feb	0.00	8.53	23.64	1.11%
Mar	5.58	20.99	49.61	2.74%
Apr	41.61	67.73	101.16	8.82%
May	96.14	113.92	116.63	14.84%
Jun	111.40	112.11	112.81	14.61%
July	115.05	115.82	116.53	15.09%
Aug	113.97	116.26	116.75	15.15%
Sep	60.08	94.64	112.87	12.33%
Oct	38.23	50.78	77.45	6.62%
Nov	23.17	30.77	47.21	4.01%
Dec	12.07	21.89	33.50	2.85%
Total	688.41	767.52	851.88	100.00%
		May - September		72.02%
		November - March		12.54%

Table 8.1: Minimum, Average and Maximum Monthly and Annual Energy Generation - Simulation Period of 47 years of RoR Plant Operation

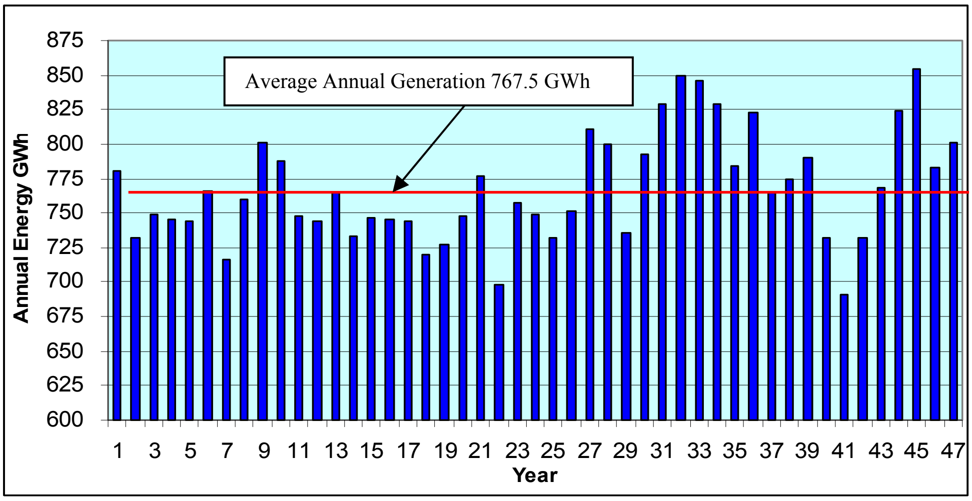


Figure 8.2: Variation of Annual Energy Generation of the Proposed Madian HPP

Figure 8.2 demonstrate that energy generation is nearly the same in the period from May to August when about 60 % of annual energy generation is realized at full load conditions, i.e. during 33 % of time 60 % of annual energy would be produced. During this period the available power would be in general above 150 MW.

RoR Month	Max Daily Energy GWh	Min Daily Energy GWh	Mean monthly Energy GWh	Max Daily Power MW	Min Daily Power MW	Mean Monthly Power MW
Jan	1.05	0.75	25.96	43.6	31.4	34.9
Feb	1.05	0.54	23.64	43.9	22.6	35.2
Mar	2.52	0.97	49.61	105.0	40.2	66.7
Apr	3.78	2.01	96.74	157.3	83.7	134.4
May	3.77	3.75	116.55	156.9	156.3	156.6
Jun	3.76	3.70	111.91	156.8	154.2	155.4
July	3.74	3.70	115.29	155.7	154.3	155.0
Aug	3.78	3.71	116.29	157.3	154.5	156.3
Sep	3.77	2.11	97.32	157.3	87.8	135.2
Oct	2.55	1.05	48.97	106.3	43.7	65.8
Nov	1.05	0.69	25.18	43.8	28.8	35.0
Dec	0.89	0.72	24.42	37.2	29.8	32.8
Total Annual Energy Generation			851.88	GWh in a wet hydrological year (2005)		
RoR Month	Max Daily Energy GWh	Min Daily Energy GWh	Mean monthly Energy GWh	Max Daily Power MW	Min Daily Power MW	Mean Monthly Power MW
Jan	0.00	0.00	0.00	0.0	0.0	0.0
Feb	0.00	0.00	0.00	0.0	0.0	0.0
Mar	1.09	0.00	16.70	45.5	0.0	22.5
Apr	2.95	0.88	51.96	122.8	36.8	72.2
May	3.78	3.25	115.28	157.3	135.5	154.9
Jun	3.76	3.75	112.61	156.8	156.1	156.4
July	3.77	3.75	116.44	156.9	156.1	156.5
Aug	3.77	3.76	116.75	157.2	156.5	156.9
Sep	3.77	1.62	77.35	157.3	67.7	107.4
Oct	1.80	1.06	42.68	75.1	44.2	57.4
Nov	1.34	0.60	26.57	56.0	25.2	36.9
Dec	0.64	0.00	12.07	26.5	0.0	16.2
Total Annual Energy Generation			688.41	GWh in a dry hydrological year (2001)		
RoR Month	Max Daily Energy GWh	Min Daily Energy GWh	Mean monthly Energy GWh	Max Daily Power MW	Min Daily Power MW	Mean Monthly Power MW
Jan	0.65	0.51	17.76	27.0	21.4	23.9
Feb	0.78	0.50	17.68	32.4	20.7	26.3
Mar	1.32	0.00	20.61	55.1	0.0	27.7
Apr	3.78	0.92	62.61	157.4	38.5	87.0
May	3.77	3.30	115.68	157.3	137.3	155.5
Jun	3.75	3.72	112.04	156.2	155.0	155.6
July	3.74	3.70	115.41	155.8	154.4	155.1
Aug	3.76	3.74	116.10	156.6	155.7	156.0
Sep	3.77	2.57	94.23	157.2	107.0	130.9
Oct	2.62	1.28	55.44	109.0	53.4	74.5
Nov	1.31	0.84	31.63	54.6	35.0	43.9
Dec	0.85	0.62	22.90	35.2	25.8	30.8
Total Annual Energy Generation			782.10	GWh in a mean hydrological year (1995)		

Table 8.2: Variation of Power and Energy Generation with time for hydrological wet, dry and average year of plant operation

During the period from December to March energy generation is low and amounts to 8.0 % of annual energy generation in a dry year, 14.1 % on average and 17.5 % in a wet year. For run-of-river operation the power plant is assumed operational when the river flow available for power generation is

equal or above 40 % of the maximum turbine design discharge (44 % of rated discharge), i.e. higher than 17.2 m³/s.
Simulation of power plant operation reveals that the power plant could not be operated during 4 days in March as the consequence of low river flow in a mean hydrological year, such as e.g. 1995 (99.0 % plant availability). For a wet hydrological year such as the year 2005, plant operation simulation shows that power generation could continuously proceed around the year. If power plant operation is permitted with a limited draw down (up to 2 m) on the basis of e.g. two periods of operating the power plant for 3 to 5 hours per day, power generation can be maintained each day of the year.

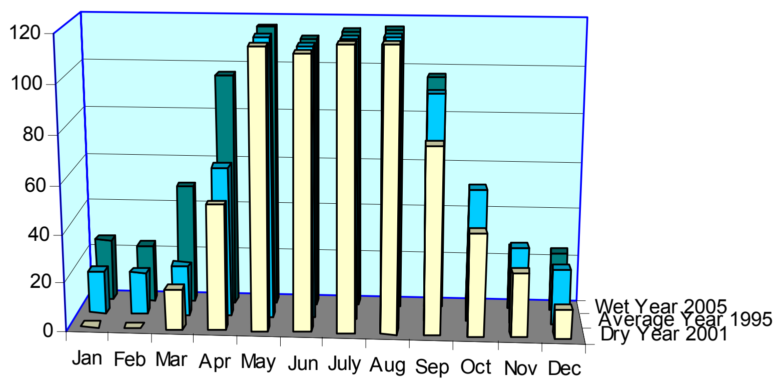


Figure 8.3: Annual Energy Generation of the Proposed Madian HPP

8.3 Interpretation of Results and Recommendations

The maximum available power of the Madian Hydropower Project is 157.3 MW (ex transformer). The available power of a single turbine unit in operation at maximum design discharge (43 m³/s) is 57.5 MW.

In the present simulation of operation of the Madian HPP, no pondage operation is considered at times of low river flow. By means of pondage operation in a dry year such as 2001, annual energy generation may be lifted from 688.3 GWh to 709.9 GWh or even 717.0 GWh, which is an increase by 3 to 4 % with little additional investment. According to the simulation of power plant operation based on daily river flow data of 47 years (period 1961-2007), the application of the concept of pondage operation was found to be advantageous.

8.4 Plant Simulation for the Economic and Financial Analysis

In co-ordination with the Project Sponsor and based on the official Draft Power Purchase Agreement (DPPA), common operation conditions shall be

applied for the economic and financial analysis of the Madian Hydropower Project. Accordingly provisions are made for unforced (scheduled) outages and forced (unscheduled) outages.
According to the DPPA the following assumptions are made:

Unforced Outages	20.00 days/year	(480 hours/year)
Forced Outages	5.54 days/year	(133 hours/year)

The Consultant considered that unforced outages are scheduled for the low flow period when river flow and energy production would be low, e.g. in the month of February. The Consultant considers that forced outages may rarely occur in the low flow season. Therefore, 5 days of forced outages is assumed in the high flow season and 0.54 days in the low flow season.

These assumptions result in reduction of the theoretically possible annual power generation by 25.2 GWh to 742.5 GWh as indicated in Table 8.3. The corresponding reduction of the annual energy generation is adjusted in the months of February and August.

Month	Energy Generation GWh
Jan	14.1
Feb	2.3
Mar	21.0
Apr	67.7
May	113.9
Jun	112.1
July	115.8
Aug	97.51
Sep	94.6
Oct	50.8
Nov	30.8
Dec	21.9
Total	742.5

Table 8.3: Mean Annual Energy Generation - Simulating 47 Years of Plant Operation with Provisions for Scheduled and Forced Outages

9. Bill of Quantities and Cost Estimates

9.1 General

This report summarizes selected key parameters for the estimation of costs of the Madian Hydropower Project and the cost estimate itself for all its major components. Basic costs of labour, material, consumables and equipment were inquired, unit costs calculated and compared with unit rates of hydropower projects of similar size and type presently under development in Pakistan. The cost estimate includes the following main plant components and cost elements:

- land acquisition
- land clearing and access;
- mobilisation cost and site infrastructure;
- surveys and investigations (e.g. hydraulic model tests);
- civil works:
- material disposal sites;
- manufacturing, transport erection, installation, testing and commissioning of:
  - hydraulic steel structures,
  - electro-mechanical and electrical equipment,
- environmental and social impact mitigation costs;
- taxes and import duties;
- administration and legal costs;
- engineering and supervision costs;
- finance and insurance;
- Sponsor's costs prior to commercial operation; etc.

9.2 Basis of Cost Estimation

The following assumptions were made by the Consultant based on his experience in coordination with the Project Sponsor as the basis for the present Feasibility Study:

June 30th 2007	**1 US$**	**= 60.63 Rps. (PAK)***
June 30th 2008	**1 US$**	**= 67.98 Rps. (PAK)**

* defined in coordination with client (November 2007)

Table 9.1: Basic Exchange Rate for Local to Foreign Currency

All costs will be expressed in the foreign currency US$. Local market prices and rates will be converted to foreign currency applying the exchange rate of the Central Bank of Pakistan at the selected reference dates. In co-ordination with the Project Sponsor the reference date applied to the present feasibility study is June 30th 2008, which corresponds to the end of the fiscal year 2008.

9.3 Estimation of Direct Project Costs

The direct costs of a hydropower project are commonly estimated separated for the following major components based on the major items/elements.

a) Civil works;
b) Hydraulic steel structure equipment;
c) Electro-mechanical and
d) Electrical equipment;

9.3.1 Estimation of Civil Costs

The cost estimates shall be prepared on the basis of representative unit rates for the various construction activities and the respective quantities.

The Consultant followed the following approach:

1. Collect basic costs of materials, fuel, energy, consumables, labour, equipment etc ex factory and at site (cost of transport).
2. Calculate unit rates for relevant items of civil works for application to the BoQ;
3. Collect unit rates used in feasibility studies and tendering of Hydropower Projects of similar type and magnitude;
4. Compare, analyse and conclude on most appropriate unit rates for application to the BoQ of the Madian HPP.

The financial <u>cost of labour rate</u> were obtained from basic salaries used for different categories of labours on projects near Swat NWFP as shown in National Statistical Bulletin issued by the Federal Government of Pakistan and calculated and up-dated with the exchange rate based on 30th June 2007.

There is a large number of hydropower projects under development in Pakistan which provide a reasonable orientation for the plausibility of the calculated unit rates. The Consultant collected and analysed unit rates of civil works of the following hydropower projects to a reasonable extent similar in type and size to the Madian HPP:

1.) Malakand-III,
2.) Patrind HPP
3.) Golen Gol HPP
4.) Diamer Basha Dam Project
5.) Dubeer Khawar HPP
6.) Khan Khawar HPP

Since the units rates presented in the BoQ of the six above projects refer to different reference dates, they were escalated to the level of

June 30, 2007 applying an appropriate inflation rate per annum on local and foreign currency rates and the corresponding currency exchange rate of the Central Bank of Pakistan.

Based on the unit rates established in the Consultants unit cost data base and the detailed Bill of Quantity of the Project, the cost of the civil works was

MADIAN HYDROPOWER PROJECT	COST IN (USx1000)		COST IN
			Million US $
	LOCAL	FOREIGN	TOTAL
DIVERSION WORKS	**4.201,2**	**4.588,5**	**8,790**
U/S coffer Dam	920,2	746,2	1,666
D/s Coffer Dam	239,2	185,6	0,425
Diversion Tunnel	3.041,8	3.656,7	6,699
CONCRETE WEIR	**5.895,3**	**7.088,0**	**12,983**
Main Weir Body	4.530,6	3.990,4	8,521
Foundation Treatment (Borepiling)	722,9	2.313,2	3,036
Grouting	641,8	784,4	1,426
RESERVOIR PROTECTION WORKS	**1.771,9**	**869,2**	**2,641**
HEADRACE	**47.015,0**	**66.565,4**	**113,580**
Intake	933,2	912,1	1,845
Tunnel	45.495,8	64.814,5	110,310
Construction adits	586,0	838,8	1,425
Desander Cavern	**9.974,6**	**14.730,5**	**24,705**
Caverns	9.632,6	14.211,2	23,844
Construction adits	341,9	519,3	0,861
PRESSURE SHAFT / TUNNEL	**823,5**	**1.152,7**	**1,976**
Pressure Shaft	339,4	486,3	0,826
Pressure Tunnel	155,4	227,0	0,382
Manifolds	328,7	439,4	0,768
TAILRACE TUNNEL	**1.582,8**	**1.838,2**	**3,421**
Draft tube Extension & Tailrace Tunnel	1.006,6	1.310,7	2,317
Tailrace tunnel & Power Outlet	576,2	527,5	1,104
SURGE TANK	2.482,1	3.487,9	**5,970**
POWERHOUSE CAVERN, TRANSFORMER & SWITCHYARD GALLERY	**4.762,8**	**5.817,1**	**10,580**
Powerhouse Cavern	3.206,1	3.709,6	6.915,7
Transformer & Switchyard Cavern	603,8	732,3	1.336,1
Cable Tunnel	203,8	286,2	490,0
Access Tunnel	749,1	1.089,1	1.838,2
ACCESS ROADS & BRIDGES	489	224	**0,713**
TOTAL	**78.997,8**	**106.361,4**	**185.359,2**

estimated as given in Table 9.2

Table 9.2: Costs of Civil Works of Madian Hydropower Project

9.3.2 Estimation of Costs of Hydraulic Steel Structure Equipment

The cost estimate of the hydraulic steel structure equipment for the Madian HPP is based on tender costs of hydropower projects of similar type and magnitude worldwide.

No.	DESCRIPTION	UNIT RATE Local US$	Foreign US$	Total US$
1	Diversion Tunnel Intake Stoplogs	302,400	100,800	403,200
2	Spillway Gates and Stopglogs	452,484	3,167,391	3,619,875
3	Flushing Outlet - Steel Liner and Gates	317,835	476,753	794,588
4	Power Intake, Gates, Stoplogs, Raking Machine	466,298	1,398,895	1,865,194
5	Desander gates	1,027,688	1,027,688	2,055,375
6	Headrace Tunnel Maintenance Gate	36,094	252,656	288,750
7	Pressure Shaft/Tunnel Steel Liner	1,884,157	332,498	2,216,655
8	Powerhouse	55,420	387,942	443,363
9	Tailrace Outlet	192,938	64,313	257,250
	SUBTOTAL	4,735,314	7,208,935	**11,944,249**

Table 9.3: Cost of Hydraulic Steel Structure Equipment for the Madian HPP

9.3.3 Estimation of Costs of Electro-mechanical Equipment

The equipment costs were estimated based on recent tender prices of projects of similar type of equipment from qualified manufacturers on the basis of equipment lists broken down into CIF prices, transportation to site, erection and commissioning

No.	DESCRIPTION	UNIT	QUANTITY	UNIT RATE Local US$	Foreign US$	Total US$
1	Turbines	Lumpsum	1	1.872.687	13.108.807	14.981.493
2	Butterfly valve, D=2.5m	Lumpsum	1	382.592	2.678.143	3.060.735
3	Cooling Water System	Lumpsum	1	166.461	1.165.227	1.331.688
4	Drainage and Dewatering System	Lumpsum	1	69.359	485.511	554.870
5a	Low Pressure Compressed Air System	Lumpsum	1	26.356	184.494	210.851
5b	Low Pressure Compressed Air System	Lumpsum	1	33.781	236.469	270.251
6	Air Conditionning and Ventilation System	Lumpsum	1	188.779	1.321.452	1.510.231
7	Oil Treatment Plant	Lumpsum	1	16.579	116.053	132.632
8	Mechanical Workshop Equipment	Lumpsum	1	31.905	223.335	255.240
9	EOT Crane Powerhouse 210 t	Lumpsum	1	118.134	826.935	945.069
9	Elevator	Lumpsum	1	33.281	232.967	266.248
10	Fire Fighting System	Lumpsum	1	99.575	697.022	796.597
11	Auxiliary Francis unit - 520kW	Lumpsum	1	150.799	1.055.592	1.206.390
	Subtotal			3.190.287	22.332.008	**25.522.295**
	-Miscellaneous items	%	2,5			638.057
	TOTAL	in	US$			**26.160.353**

Table 9.4: Cost of Electro-mechanical Equipment for the Madian HPP

9.3.4 Estimation of Costs of Electrical Equipment

The equipment costs were estimated based on recent tender prices of projects with similar type of equipment as above.

No.	DESCRIPTION	UNIT	QUANTITY	UNIT RATE Local US$	Foreign US$	Total US$
1	Synchronous generators 63 kVA, 333 r	Lumpsum	1	2.525.473	17.678.311	20.203.784
2	Step-up transformer 230/13.8 kV	Lumpsum	1	882.853	6.179.969	7.062.822
3	220 kV SF6 Switchyard	Lumpsum	1	742.180	5.195.259	5.937.438
4	220 kV Terminal Gantry & Auxil.	Lumpsum	1	76.431	535.017	611.448
5	13.8 kV generator busbars & auxil.	Lumpsum	1	353.368	2.473.575	2.826.943
6	Protection Systems	Lumpsum	1	261.487	1.830.407	2.091.894
7	Control and Monitoring System	Lumpsum	1	332.464	2.327.247	2.659.711
8	Electrical Equipment at Dam Site	Lumpsum	1	171.090	1.197.629	1.368.718
9	El. Equipment at Desander Cavern	Lumpsum	1	92.523	647.664	740.188
10	Emergency Diesel 630 kVA	Lumpsum	1	54.576	382.031	436.607
	Subtotal					**43.939.553**
	-Miscellaneous items	%	0			0
		in	US$			**43.939.553**

Table 9.5: Cost of Electrical Equipment for the Madian HPP

9.4 Estimation of Indirect Project Costs and Contingencies

Consideration of Indirect Costs and Contingencies
As common practice in bankable feasibility studies, the concept of indirect costs is applied to civil costs and includes preparation of the construction sites, camp installation, site administration, bonds, insurances and contractor's profits. Indirect costs are taken to 25 % of the direct cost.

The costs related to land acquisition, compensation payments and resettlement were determined to amount to

RAP Cost: 129.395 million Rupees equivalent to 2.134 million USD

A provision for Contingencies is required irrespective of the level of planning, to account for some element of uncertainty which will still remain in the estimation of quantities and costs. For the feasibility study of the Madian HPP the provisions given in Table 9.6 were applied.

Consideration of Import Charges
The Consultant inquired the extent of import charges which would apply for import of electro-mechanical, electrical and particular hydraulic steel structure equipment to be adequately considered in the estimation of costs. In total 7.0 % of import charges are therefore applied to the above mentioned imported equipment and considered in the Bill of Quantities and the estimation of costs to account for import and related charges.

9.5 Estimation of Costs for Project Development

Estimate for Cost of Engineering and Administration
The cost of all required activities for Engineering and Administration, setting up the legal and institutional framework of the Project is estimated applying a percentage of the total project cost. Assuming the provision of services for tender design, assistance in the tender process and supervision of construction, erection and commissioning by a leading international consultant, an estimate of 6 % of cost of civil works and 3 % hydraulic steel structure, electro-mechanical and electrical equipment works is made.

Estimate for Cost of Client's Own Costs
The cost of all related expenditures of the Client in the course of developing the Project is estimated applying a percentage of the total cost of the project. As a common approach an estimate of 1.0 % of the total project cost is made taking into account the requirements of legal support for negotiation of the Power Purchase Agreement (PPA) and other related activities in the volatile North Western Frontier Province of Pakistan.

9.6 Total Construction Cost and Basic Project Cost

As discussed in the previous sections the total project cost is calculated applying provisions for indirect costs, contingencies, import charges, engineering and administration and client's own costs.

Cost item	(%)
Indirect civil costs (% of direct civil costs)	25
Contingencies (% of direct + indirect costs)	
- civil	10.0
- electro-mechanical	7.5
- electrical	7.5
Engineering and administration	6.0 / 3.0
Client's own costs	1.0

Table 9.6 : Indirect Costs and Contingencies

COST CATEGORY	Charges	Local 1000 US$	Foreign 1000 US$	Total 1000 US$	% of Total
CIVIL COSTS		78.998	106.361	185.359	50,6%
CONTINGENCIES	10,00%	7.900	10.636	18.536	5,1%
INDIRECT COST	25,00%	21.724	29.249	50.974	13,9%
ENGINEERING / ADMINISTRATION	6,00%	6.517	8.775	15.292	4,2%
SUBTOTAL CIVIL COSTS		115.139	155.022	270.161	73,8%
STEEL STRUCUTRE EQUIPMENT		4.735	7.209	11.944	3,3%
CONTINGENCIES	7,50%	355	541	896	0,2%
IMPORT CHARGES & FEES	7,00%	542	0	542	0,1%
ENGINEERING	3,00%	153	232	385	0,1%
SUBTOTAL STEEL STRUCTURE EQUIPMENT		5.786	7.982	13.768	3,8%
ELETRO-MECHANICAL EQUIPMENT		3.270	22.890	26.160	7,1%
CONTINGENCIES	7,50%	245	1.717	1.962	0,5%
IMPORT CHARGES & FEES	7,00%	1.722	0	1.722	0,5%
ENGINEERING	3,00%	105	738	844	0,2%
SUBTOTAL ELECTRO-MECH. EQUIPMENT		5.343	25.345	30.689	8,4%
ELECTRICAL EQUIPMENTS		5.492	38.447	43.940	12,0%
CONTINGENCIES	7,50%	412	2.884	3.295	0,9%
IMPORT CHARGES & FEES	7,00%	2.893	0	2.893	0,8%
ENGINEERING	3,00%	177	1.240	1.417	0,4%
SUBTOTAL ELECTRICAL EQUIPMENT		8.975	42.571	51.545	14,1%
SUBTOTAL w/o ENGINEERING		128.290	219.934	348.224	95,1%
SUBTOTAL		**135.243**	**230.920**	**366.163**	**100,0%**
EIA MITIGATION AND RESETTLEMENT		2.134	0	2.134	0,6%
OWNERS OWN COST	1,00%	1.301	2.309	3.610	1,0%
TOTAL		**138.678**	**233.229**	**371.907**	**101,6%**

Table 9.7 : Summary of cost of the Madian Hydropower Project at level of prices 30. June 2008

9.7 Operation, Maintenance and Repair Costs

The Consultant assessed the operating costs for the project based on the technical data elaborated within the scope of previous tasks. These costs will be divided into:

- maintenance costs for all productive assets;
- operation costs;
- personnel costs, including expenses for technical staff required to supervise and to operate the system;
- training costs;
- Administration costs associated with the project, including such cost items as office costs, insurance, equipment and materials.

Recurrent annual fixed costs for operation, maintenance and repairs (OMR) during the period of operation were calculated as a percentage of the initial investment costs.

The following percentages were applied:

- Civil structures : 0.5%,
- Electro-mechanical equipment, including hydraulic steel structures : 2.0%

According to common experience in the operation of hydropower plants and in view of the assumed concession period of 30 years, an overhaul of equipment (electro-mechanical, electrical and hydraulic steel structure) will be assumed as follows:

a) Electrical control and protection equipment after 15-20 years of operation (16.6 % of electrical equipment cost);

b) Electro-mechanical equipment components after 20-25 years of operation; (15 % of electro-mechanical equipment cost);

c) Hydraulic Steel structure equipment components (and valves) after 30 years (end of concession period) of operation.

This overhaul does not form part of the annual OMR cost.

10. Social and Environmental Impact Assessment

Following national and international requirements, an Environmental Impact Assessment (EIA) and a Resettlement Action Plan (RAP) have to be prepared for the Madian Hydropower Project. In order to fulfil this demand two reports have been written, both as stand alone report which form Volume VI of the Feasibility Study Report:

- Feasibility Study: Environmental Impact Assessment (EIA);
- Feasibility Study: Resettlement Action Plan (RAP).

10.1 ENVIRONMENTAL IMPACT ASSESSMENT STUDY

Herewith, the Environmental Impact Assessment to the Madian HPP is presented assessing the environmental impacts of the project and presenting an Environmental Management Plan (EMP). For transparent presentation and evaluation, a tabulated evaluation procedure has been applied. On the basis of a points scale, the severity of the particular environmental impact together with its general trend - that is negative or positive - is described.

10.1.1 Legal and Institutional Framework

Pakistan Environmental Protection Act (PEPA-1997) provides guidance for the protection, conservation, rehabilitation and improvement of the environment, for the prevention and control of pollution and for promotion of sustainable development. Aim of this EIA study is to bring the Project in line with following international guidelines:

- OP/BP 4.01 + Annexes '*Environmental Assessment';*
- OP/BP 4.04 '*Natural Habitats*';
- Environmental Assessment Sourcebook Vol. II, Sectoral Guidelines of the World Bank (Chapter 8 "Dams and Reservoirs");
- Pollution Prevention and Abatement Handbook 1998;
- Environmental, Health, and Safety Guidelines replacing Part III of the Pollution Prevention and Abatement Handbook 1998;
- International Finance Corporation (IFC) Environmental, Health and Safety Guidelines;
- Report of the World Commission on Dams (WCD);
- Large Dams, Learning from the Past, Looking at the Future (IUCN and The World Bank; Workshop Proceedings Gland, Switzerland, April 11-12, 1997);
- Equator Principles of private donor banks.

EIA and RAP of Madian Hydropower Project will be filed with NWFP EPA Peshawar for their approval. Because it will be a private financed project the Private Power and Infrastructure Board (PPIB) is also involved in the development of the Project.

10.1.2 Baseline Conditions

The investigation area covers the Swat valley from upstream of the weir site including the future reservoir to the power house site.

The Swat River
The Swat River starts from Kalam town in the valley at the confluence of Ushu River and Gabral River. The native fish fauna of these waters, prior to the introduction of trout, was *Schizothorax species* and *Orienus species*, locally known as Swati fish. Also *Noemacheilus* species occurred. The introduction of trout (*Salmo trutta fario/brown trout and Oncorlrynchus mykiss/rainbow trout*) started in 1961. Consequently, the trout population has been established, which has replaced the indigenous fish breeds.

Terrestrial Fauna and Flora
The Flora of the region is characteristic for a dry temperature and can be assessed to be rich. Sixty-five species of trees and shrubs belonging to the Dicot families exist. Over the last 50 years the number of animal species has been decreased dramatically. A lot of species are endangered by the destruction of habitats.

Health Aspects in Project Area
HIV is currently not a dominant epidemic in the adult population of Pakistan. Children mostly suffer from acute respiratory infection, asthma and pneumonia.

10.1.3 Significant Environmental Impacts

Table 10-1: Ranking of environmental impacts during the construction and operation phase of the proposed Madian Hydropower Project

CONSTRUCTION PHASE		
Impact on/of	**Extent of impact**	**Comment**
Land acquisition and use	■	Land acquisition and use will be compensated. For this purpose a Resettlement Action Plan as a stand alone report was developed that will be adopted when final design has been fixed.
Excavated material	■ ■ ■	Dumping of the excavated material is a big challenge of the Project. Because it is a run-of-river design with a long headrace tunnel a lot of material will be excavated. Dumping of this material has impacts on many issues as air quality, noise aspects, traffic, landscape, flora and fauna, tourist activities etc. Some of the material will be reused as concrete aggregates, for gabions and slope protection.
Traffic	■ ■	Needless truck movements will be avoided by proper truck management; dumping sites are selected close to the adits on the left river bank helping to reduce transportation routes. Near powerhouse conveyors may be used for transport of excavation material. Transport of excavated material through the City of Bahrein will be avoided. However, construction material and machines coming from Madian to the weir site have to cross the cities of Madian and Bahrain. Together with other projects going on in the region this will sum up to a considerable amount of traffic during construction.

CONSTRUCTION PHASE		
Impact on/of	**Extent of impact**	**Comment**
Air quality	■ ■	The measures in order to reduce the traffic are suitable to reduce the negative impact on air quality (see traffic above). In addition, water shall be sprayed continuously to reduce dust emissions of construction activities.
Noise aspects (on public)	■ ■	The measures in order to reduce the traffic are suitable to reduce the noise impact on the public (see traffic above)
Ecology of Swat River	■	Only a short river section (about 240 m) will be diverted during the construction of the weir structure. Other parts remain untouched except for a short period when the coffer dams in the river will be closed. A certain sediment run off might occur during this time period.
Terrestrial fauna and flora	■ ■	Large areas for dumping the excavation material will be necessary. The area of the reservoir will be flooded and terrestrial habitats will disappear.
National parks, wildlife sanctuaries and other protected areas	**O**	No national parks or other protected land are located within the Project area.
Historical and cultural sites	**O**	No historical and cultural sites are located within the Project area. If archaeological remnants are found the construction work will be ceased immediately and the relevant authority will be informed.
Landscape	■ ■	Increased truck traffic and dust emission will influence the overall picture of the landscape.
Health and Safety of Workers	■	Proper workers' camp will be provided to the workers. A Health and Safety Plan for the construction period will be developed and implemented by the construction contractor. Training of workers will be performed regularly.
Solid and liquid wastes	■	Around 400 workers in peak periods will generate significant amounts of liquid and solid wastes. The liquid sanitation waste water will be treated at workers' camp site
Socio-economy	✦ ✦✦	Around 400 workers (skilled and unskilled) will find employment during the construction period in peak times. In addition, related services (hotels, shops selling articles for the daily life etc.) will benefit from the Project. Because of the very conservative social structures of population committed to principles of Islamic Shariah HIV/AIDS does not play any role and the adverse effects on the local community will be very limited.
Tourism	■	The construction activities will affect tourist activities in the Swat valley. However, hotel managers do not expect severe negative impacts on the number of tourists, whose number has already decreased because of the political situation. There is the hope that projects like Madian HPP will bring more stability to the region.

Extent of impact:

■ ■ ■	=	high negative
■ ■	=	medium negative
■	=	low negative
O	=	nil
✦	=	locally positive
✦✦	=	regionally positive

OPERATION PHASE		
Impact on/of	**Extent of impact**	**Comment**
Microclimate and GHG	■	The effect on the microclimatic conditions will be minimal due to the small size of the reservoir surface. Most of the organic materials as trees, shrubs etc. will be removed before filling the reservoir. This reduces the generation of green house gases to a minimum.
Swat River ecology	See discussion	There will be a minimum water release also during the dry season (ecological flow). Due to this Project and when looking on the other hydropower projects in the Swat Valley in development the Swat River itself will undergo major alterations. It will be converted from a white water river to a cascade of headponds with river reaches where less water will flow than before. Very limited knowledge is available about the ecological features of the river, therefore no overall assessment is given.
Terrestrial fauna and flora	■	The reservoir represents a migration obstacle for big mammals. However, most of bigger animals have been disappeared since decade due to high population pressure (e.g. hunting).
Landscape	■	The character of the landscape down in the valley will be changed. A section of a fast flowing white water river will be converted into a lake.
Seismic aspects	■	The project will be designed to withstand the max. credible earthquake (MCE) without major damages and OBE-1 without damages.
Substations	■	Concerning EMF there will be no negative impacts on workers' health coming up. The handling of SF6 has to be done very carefully considering the presented guidelines
Deposits from desander	■	The sand of the desander will be flushed regularly during times of high water. In winter time flushing will not be required.
Water-related vector diseases	■ ■	There might be an increase of water-related diseases after constructing the planned reservoirs in the Swat valley. In order to manage these health problems, a concerted action of all HPPs owners/operators together with relevant regional and national health authorities will be necessary. This has still to be agreed.
<u>Socio-economic aspects:</u> Employment	✦ ✦✦	The effect on employment of people during operational period will be limited. Some skilled and unskilled workers will find jobs during operation of Madian HPP.
Tourist activities	○	The angler attitude will change from white water fishing to fishing in a lake with other species as before. Other tourist activities will not be affected except for the landscape has changed. Overall it is assumed that the number of tourists will not decrease.
Water supply downstream the weir site	■	The operation of the Project will not affect irrigation downstream of the weir. Farmer use other water sources such as tributaries and wells. Those households downstream the weir which use presently water from Swat River as drinking water source. They will be provided with clean drinking water as long as they are not connected to a drinking water system such as under development in Bahrain village.

The Swat valley topography, with its Swat River, offers possibilities for the development of a number of hydropower projects in a cascade system. At present, there are four hydropower projects proposed on the Gabral-Swat River system. These projects are Gabral-Kalam, Kalam-Asrit, Asrit-Kedam, and Kedam-Madian. This may amplify the environmental impacts of the individual HPPs. The development of the Daral-Khwar HPP located between weir and powerhouse site of the Madian HPP includes the installation of a drinking water supply and sewerage system with treatment plant. This will help to improve the water quality of the Swat River.

10.1.4 Environmental Management Plan

An environmental management and monitoring programme is pursued during construction stage and operation stage of the Project to protect and provide safeguards for a continuing healthy environment in the project area. After the Project becomes operational the Plant Manager with the assistance of staff on behalf of Madian Hydropower Ltd. will be overall in charge and responsible for management and monitoring of the hydropower project. The purpose of mitigation measures is to manage the Project in a manner that minimises adverse impacts and maximises secondary benefits.

Construction Phase
From the findings of the study as summarised above it can be concluded that a significant negative impact only results from the deposition of excavated material. The amount of the excavation material can not be mitigated. On the other hand, this kind of HPP reduces considerably the size of the reservoir that would have been much bigger in the case of a dam with storage for daily peaking operation. The amount of excavated material affects many environmental aspects as there are traffic, air quality, noise, landscape, terrestrial fauna and flora etc. Regarding these aspects, however, mitigation measures are possible. Concerning socio-economic aspects, the impacts of the Project are locally and regionally positive.

Operational Phase
During to operational phase no high negative impacts will occur. Main focus in the assessment is given on the ecology of the Swat River. Consequently a general final assessment of the extent of the impact could not be given. Even without exact knowledge it can be stated that the river ecology will be subject to certain changes. A 1.5 km long river reach will be converted into a lake (reservoir), in the downstream located 13 km long river reach the discharge will be reduced with all its consequences for the ecology. Regarding water-borne vector diseases, the Project may cause medium impacts. For all other aspects during operational phase the impacts of the Project will be low negative or even nil.

10.2 RESETTLEMENT ACTION PLAN

The objective of this report on Land Acquisition and the Resettlement Plan is to describe involuntary resettlement impacts and mitigation measures of Madian Hydropower Project according to World Bank/IFC resettlement criteria and guidelines. Madian HPP will require permanent and temporary land acquisition. Permanent land will mainly be needed for the reservoir area, for permanent access roads and for the dumping sites of excavated material. This causes the main impact of the Project related to land acquisition issues.

The Consultants' team consisted of three ESIA specialists who visited the project area in April and June 2008 to collect data on the project layout and its impacts on environmental and socio-economic aspects. All collected data are based on the status of the feasibility design of June 2008. For changes coming up in further stages of Project development (e.g. need for additional access roads, extension of dumping areas etc.) 15% of the total costs are added for contingencies.

Community consultations, especially with affected persons including owners of lands, houses, trees were performed to assess community response to the proposed Project. Interviews were held with officials of the government departments, the representative of the only NGO, and other resource persons.

10.2.1 Legal and Institutional Framework

Under Pakistan Environmental Protection Act 1997, environmental protection agencies at federal and provincial levels are functional. Besides, National Environmental Quality Standards (NEQS) are applicable country-wide. Draft National Resettlement Policy 2002 has yet to be approved for implementation.

The Land Acquisition Act (LAA 1894) with amendments is used as the core legal document. However, its legal process often takes too long because of legal formalities and courts interventions. Instead, it would be preferable to go for direct negotiations with owners of land and other assets affected by the Project. This methodology minimises the subsequent grievances as the decisions with the affected persons have to be made in consensus.

World Bank/IFC policies address losses of land, assets and resources which people suffer as a result of development projects. For operations requiring involuntary resettlement, resettlement planning is an integral part of the project design. These policies require compensation for lost assets at replacement costs to both titled and non-titled landholders.

10.2.2 Baseline Data

Besides some hamlets consisting of one or two houses, there are seven villages/ towns in the project area with a current (2008) population of 44,900 and average size of 8.3 persons per household. The literacy ratio within the project area is 20.5%, male 43.1% and female 13.5%. Main diseases are diarrhoea and malaria. Children mostly suffer from respiratory infections. No cases of HIV/AIDS have been reported. Health facilities in terms of availability of doctors, basic health units and trained birth attendants are very limited.

HIV is not currently a dominant epidemic in the adult population of Pakistan.
The water supply for drinking purposes obtained from the Swat River and springs does not meet WHO Guidelines in terms of bacteriological quality. With absence of a solid waste disposal system/ human excreta, the sanitation conditions are inadequate. Farming and livestock rearing are major occupations in the project area, followed by forestry and construction labour. Villagers also depend on off-farm income sources, like work opportunities in down country and even abroad, particularly in Saudi Arabia/ Gulf states.

10.2.3 Results of Resettlement Survey

Land Acquisition
Project implementation will need acquisition of a total 39.438 ha land (state land, farmland, wasteland). Out of this total, 36.638 ha will be acquired on permanent basis and the remaining 2.800 ha on lease for 5 years.

Affected Houses
Only 15 houses with a total of 176 persons will be directly affected by the Project. 2 of these houses will be affected by reservoir impounding, 8 due to their location in areas to be utilised for dumping of excavated material, 3 in the vicinity of the diversion works, 1 due to relocation of the road at the weir site and 1 due to the proposed access road to the weir site along the left bank of the Swat River. With reference to the type of construction all houses are category C houses except 1 which is of category B. (Type B Houses: Masonry in cement mortar, timber roof; Type C Houses: Stone in mud mortar with timber roof)

Affected Persons
Only 176 persons will be directly affected because parts of their farmland/ wasteland/ river bed will be acquired permanently or temporarily for project implementation. A land area of 36.638ha will be acquired permanently and 2.8 ha will be acquired temporarily. The Resettlement Plan is elaborated in accordance with World Bank/IFC policy guidelines.

Affected Trees
A total of 1,423 trees will be felled. Thereof, 950 are fruit trees and 473 are firewood and timber trees.

The RAP Report has considered all options available for physical resettlement of the population displaced as a result of development projects like Madian HPP. These options include no resettlement, on-site resettlement, partial resettlement, resettlement to multiple/ nearby sites, resettlement to margins of developed areas, and resettlement to distant sites.

10.2.4 Income Restoration Programmes

In the case of Madian Hydropower Project the aspects of both extent of population displacement and loss of land, particularly farmland, are not significant. Also, the affected persons, without any exception, have readily and willingly opted for cash compensation as they all intend to start business ventures by using this cash. It is hard to find replacement land in the project area. Besides, “land-for-land” strategy, according to World Bank/IFC practice, has remained a difficult policy to implement. The strategy for income restoration of affected persons, therefore, should be based on training programmes in terms of small business, computer skills, health care technology and education.

10.2.5 Institutional Arrangements

The project sponsor, Madian Hydro Power Limited (MHPL) will establish an administrative unit, the Environmental and Resettlement Cell (ERC) consisting of two members: an environmental specialist and a resettlement specialist. The cell will help overcome lack of institutional mechanisms for environmental/ resettlement planning, implementation, monitoring and evaluation, which MHPL not yet possesses in implementing the EMP and RAP. Thus, MHPL, as implementing agency, will have to depend on external technical support for implementing the environmental and resettlement related activities. For this purpose it will need two implementation Consultants (Environmental and Resettlement Specialists) to provide technical assistance in environment and resettlement planning, implementation, monitoring and evaluation.

The Environment and Resettlement Cell (ERC) will update the data on land and affected persons. Furthermore, it will assess the amount of compensation and prepare a requisition to be submitted to DRO Swat for initiating the process of land acquisition. DRO Swat is formally responsible for acquiring the identified lands from the respective land owners and for paying compensation money to the affected persons, according to the procedure laid down in the Land Acquisition Act 1894, or as decided by MHPL through direct negotiations with the village community.

The resettlement budget consists of costs for permanent land acquisition, temporary land acquisition, compensation for lost assets including houses and trees and costs to be increased on hiring resettlement expertise. The replacement cost of land is based on current market prices. The market value was assessed on the basis of recent transactions and consultation with the affected persons and other community members. Total resettlement cost is estimated as Rs. 129.385 million.

Within the project cycle, the implementation schedule, covering a period of 5 years plus pre-project period, provides the time frame for commencement and completion of the resettlement activities. These activities include community consultants, site demarcation, resettlement training workshop, payment of compensation grievance redress, taking over of land and other assets, construction work, return of temporarily acquired land and monitoring and evaluation.

11. Project Implementation

The duration of the individual construction activities, and of the project as a whole, shall be made considering the logistics for construction, i.e. taking into account the design in conjunction with the corresponding construction methods and construction equipment. The present section, addresses the aspects of the construction planning in the required detail:

11.1 Construction Planning

Once the project layout and dimensions of the main structures are defined, a detailed construction and implementation schedule for the project is prepared on the basis of construction planning (the logistics of constructing the project), construction scheduling (how long it will take), and construction methods (how it will be done).

For construction of the headrace tunnel by conventional drill and blast excavation method, three temporary and two permanent access tunnels (adits) will have to be constructed. The distance between weir and power house is approximately 13 km. The project's civil works in general can be roughly divided to be three mostly independent construction sites:

1. weir site incl. river diversion
2. headrace tunnel incl. desander caverns and surge tank
3. power house, transformer caverns, penstock and tailrace

With the objective to minimize the time required for construction in an economically reasonable way, work will proceed at the three major construction sites in parallel. For the site transports river crossings and temporary access roads will have to be constructed. For the permanent maintenance access to the desander caverns a permanent bridge and road to the relevant adit has to be built.

11.1.1 River Diversion and Weir Construction

For river diversion at the Weir Site a diversion tunnel of approx. 290 m length will be established. The tunnel can be sealed by stop logs at the intake portal. After finishing the weir construction the diversion tunnel will be closed, the coffer dams removed and a concrete plug installed after setting the stop logs at the intake to seal the Diversion Tunnel towards the Headrace Tunnel. The upstream river closure will be established by a rock-fill cofferdam with an adequate sealing to reduce ground water flow into the construction pit.

The construction scheduling for the weir site works is governed by the seasonal variation by the flow of Swat River. The diversion tunnel will be started immediately after first mobilization and establishing the road from Kedam bridge to the downstream portal.

Year	Season	Construction Activity	
1	low flow high flow	access road to d/s portal and portal, excavation right side moraine, bore pile sealing wall right side (1.), diversion tunnel excavation and rock support and concrete works	relocation of Kedam road, u/s portal, bore pile wall at right side of construction pit (3.)
2	low flow	u/s coffer dam 1st stage, cut-off wall, coffer dam 2nd stage	d/s coffer dam 1st stage, bore pile cut-off wall (4.), d/s coffer dam 2nd stage
	high flow	excavation of construction pit, construction pit drainage	completion of bore pile sealing wall (1.), bore pile weir support (2.)
3	low flow high flow	concreting: weir body, stilling basin slab and end sill, wing walls, piers, lateral intake, flushing section	embedded parts and steel lining, bridge, stop logs at intake, flushing gates)
4	low flow	closing weir and lateral intake by stop logs, removal of u/s and d/s coffer dams	erection of main gates and remaining steel structures), plug for diversion tunnel, completing headrace tunnel, portal and transition structure, external works
	high flow		
5	low flow high flow	finalizing external works, testing and commissioning	

Table 11.1 Construction Sequence at Weir Site

11.1.2 Underground Excavation and Rock Support

The main parts of the underground excavation works are:

- Diversion Tunnel
- Headrace Tunnel
- Desander Caverns
- Surge Tank
- Pressure Shaft and Tunnel
- Power House, Transformer/Switchgear Cavern
- Tailrace Tunnel

Since the deployment of a Tunnel Boring Machine (TBM) is not feasible in respect of transport conditions, traditional drill and blast method will applied. The tunnel and cavern excavation cycle will be: drilling - blasting - mucking / loading - transport / dumping - shotcrete - rock bolts. The biggest portion of the underground works is the excavation of the 11.5 km long headrace tunnel and Desander Caverns.

These structures cover about **85 %** of the total excavation volume. The main objective of the project planning is time and cost minimization.

The Headrace Tunnel will be sub-divided into 4 sections. With this division in construction sections, it will be possible to work simultaneously at minimum at six fronts basically independently from each other. Taking into account the other locations for rock excavation it is envisaged to mobilize a total of eight sets of underground excavation equipment for tunnels and chambers. By shifting these sets within the critical pass, it will be possible to minimize the underground excavation and rock support works to a net period of less than two years.

Surge Tank and Power House Area

These structures comprise of various shapes and rather large dimensions. The construction sequence is determined by access facilities and technical requirement. E. g. the pressure shaft requires access from top and bottom, the surge tank shall be drilled from top to bottom and excavated from bottom to top (raise boring), and the tunnels should be excavated against the slope due to expected groundwater conditions in the power house area.

11.1.3 Progress Estimation

The progress for tunnel excavation and rock support is estimated for each tunnel section and respective rock quality in accordance with the geological profiles and required rock support measures.

Rock Support / Rock Class	**Progress [m/d]**	**remarks**
B / II	5.5	full face, 3 m advance
C / III	4.5	full face, 2.2 m advance
D / IV	3.2	roof & bench, 2.5 m advance
E / V	2.2	roof & bench, 1.5 m advance

Table 11.2: Excavation and Rock Support Progress for Headrace Tunnel

Table 11.3 shows the anticipated progress for the caverns taking into account the reported rock quality, shape of structures and adjacent structures such as ventilation, access tunnels etc. for the power house cavern.

Structure	**Rock Class**	**Progress [m³/d]**
Desander Caverns	III	230
Surge Tank	IV	180
Power House, Transformer Cavern	III	180

Table 11.3: Excavation and Rock Support Progress for Cavern Construction

11.1.4 Underground Concrete Works

The main underground concrete structures are:

- Tunnel Lining
- Desander Cavern, Manifold and Transition Structures
- Surge Tank Concrete Lining and Structures
- Power House Equipment Foundations and other Structures

Similar to the excavation volumes for this project, the major concrete quantities were estimated for the concrete lining for the Headrace Tunnel etc. for consideration in the estimation of the required time for execution.

Headrace and Tailrace Tunnel Lining

Following the tunnel excavation and rock support works the concrete tunnel lining will be the subsequent critical path of the civil works. It is envisaged to work on four locations simultaneously with four sets of equipment to achieve a reasonable progress. There are suitable special hydraulically operated slip form and conventional formwork tunnel lining machines available on the market, so the works can be performed continuously in a highly automated system. Coordination is required for concrete production, e. g. for desander caverns. If sufficient capacity for batching is installed, there will be no negative impact on the general progress. For this concept the critical path for the civil works will be tunnel excavation and concrete tunnel lining resulting to a total period of approx. 4 years after mobilization.

Concrete works in the caverns can start as soon as access to the construction sites is clear. For access the access tunnel to power house and tailrace tunnel can be used. Close coordination with turbine and equipment suppliers is essential due to embedded parts and first and second stage concrete during erection/installation of equipment. For feasibility study purposes sufficient time is considered in the construction schedule according to the consultants' professional experience.

11.2 Further Steps for Project Implementation

The implementation of the project is distinguished in three main stages:

- Stage I: Pre - Construction Activities
- Stage II: Construction Works
- Stage III: Commissioning, Testing and Training

The implementation schedule was prepared with the assumption that the Project will be implemented as a turnkey project (EPC-Contract). Thus, the detailed design engineering will be carried out under the responsibility of the general contractor and will not be part of the pre-tender process.

11.2.1 Stage I - Pre-Construction Activities

The Pre-Construction Activities, extend over an estimated period of 36 months. The corresponding activities are subdivided in two parts, i.e.:

a) Feasibility Study
b) Tendering and Contracting

The presently contracted engineering services for the development of the Madian Hydropower Project are structured in the following three stages:

- Phase I: Identification and comparison of project alternatives. Preparation of Pre-Feasibility Study.
- Phase II: Optimisation of preferred alternative. Preparation of Draft Feasibility Study.
- Phase III: Project review by POE and PPIB. Preparation of Final Feasibility Study.

The Feasibility Study was originally planned for a period of 18 months. As the consequence of the Force Majeure situation in the project area in the period from October 2007 to January 2008 the period for completion of the feasibility study is extended to 21 months. Phase I and II of the Feasibility Study are completed with the submission of this feasibility report. The review of the Feasibility Report by the various institutions including the Private Power and Infrastructure Board (PPIB) and their Panel of Experts, the due consideration of their remarks by the Consultant and the final approval of the Feasibility Study Report will form part of Phase III of the Project which is expected to continue till January 2009.

11.2.1.1 Tendering and Contracting

After the approval of the Feasibility Study by PPIB and POE, the preparation of tender documents is scheduled to start. During or even ahead of the preparation of the tender documents some additional technical activities are required such as hydraulic model tests in particular of the weir structure with power intake and flushing structure.

The preparation of the tender documents consists mainly of the preparation of general and particular (technical) specifications of all project components, the preparation of the tender documents, pre-qualification of contractors and manufacturers, floating of tenders, evaluation of bids and finally the contract negotiations with the contractor and the contract negotiations for the power purchase agreement (PPA). A minimum period of 24 months needs to be considered for these activities which shall be completed by early 2011.

11.2.2 Phase II - Construction Works

The construction schedule was elaborated assuming that the execution of works will be assigned to an experienced contractor with sufficient resources in terms of experience staff, adequate machinery and equipment. Further more it was assumed, that the works particularly the tunnelling works will not be interrupted during the winter period due to climatic conditions at the project site. However under extreme condition as observed in December 2007 and January 2008, the climatic conditions may cause a certain delay in execution of the works.

The turbine-generator units need be ordered as soon as possible after the contract has been signed, as a period of 24 months shall be considered for the designing and manufacturing of the units. Erection is expected to take a period of approximately 12 to 18 months for all three units. The design and manufacturing of the hydraulic steel structures for weir, intake, desander caverns, surge tank and powerhouse will be carried out more or less simultaneously to that of the turbine generator units in a 12 months period. 18 month are considered for design and manufacturing the remaining electrical equipment. After the award of contract, the mobilization and site installation is considered to be done within a three months period. Detailed design engineering and preparation of the construction design drawings will commence together with the mobilisation of the contractor and will accompany the construction works till completion.

The preliminary implementation period of Madian Hydropower Project which goes over a total period of 102 month, can be summarized as follows:

- **Phase I: Pre-Construction Activities**
  Start: first quarter of the year 2007
  Period: 48 month
  End: first quarter of the year 2011

- **Phase II: Construction Work**
  Start: first quarter of the year 2011
  Period: 54 month
  End: end of second quarter of the year 2015

- **Phase III: Testing and Commissioning**
  Start: first quarter of the year 2015
  Period: 4 month
  End: end of second quarter of the year 2015

- **Commercial Operation of the Plant: mid 2015**

The above given period for construction and implementation of the Project is a so-called minimum requirement and based on the assumption that an experienced and qualified contractor executes the works without being affected by any type of political destabilization or other security relevant incidents which have occurred in the project area in the past years.

12. Economic and Financial Analysis

The economic and financial analysis of the Madian Hydropower Project serves to answer two key questions:

(1) Economic analysis: Is the project beneficial for the economy of Pakistan?
(2) Financial analysis: Is the project profitable for the investor?

Economic and financial analyses use a similar approach to answer these questions but differ in their concepts of determining project costs and benefits.

(a) Direct and indirect effects: While the financial analysis deals only with the costs and benefits incurred by the investor, the economic analysis also includes indirect costs and benefits which are caused by the project but incurred, or enjoyed, by third parties.

(b) Valuation of benefits: The direct benefits of Madian HPP are the additional capacity and energy provided by the project. From the investor's point of view, as reflected in the financial analysis, the value of these benefits is equal to the revenues from the sales of capacity and energy.
From the economy's point of view, as reflected in the economic analysis, these benefits are equal to the cost of the most economically attractive alternative project which would produce the same output.

(c) Pricing of costs and benefits: The economic analysis should consider the true costs and benefits of the project to the economy. Market prices, as used in the financial analysis, do not always reflect the true economic costs because government interventions into the market process through price controls, taxes, duties, subsidies etc., as well as monopolistic practices result in distorted prices of labour, materials, capital, land etc. Therefore market prices need to be converted into economic prices.

12.1 Project Costs and Project Benefits

The construction costs of the Project amount to US$ 366.2 million. Adding environmental and owner's cost, total project costs amount to US$ 371.9 million. An estimated 63% of the total cost is incurred in foreign and 37% in local currency. Including financing fees and interest during construction, total financing requirements are estimated at US$ 438.4 million.

The Reference Date for this cost estimate is July 1, 2008. Since then, prices for relevant inputs have increased, and are expected to increase further during the construction period. Over the past 2-3 years, rising demand in the construction sector in general and in the power sector in particular has led to drastic increases in prices for steel, cement and other raw materials.

During the following years, equipment prices may be expected to increase at lower rates, but it is unknown when the prices will stabilize or even drop.

Item	US$ '000
Civil Works	270,161
Steel structure equipment	13,768
Electro-mechanical equipment	30,689
Electrical equipment	51,545
Subtotal construction cost	**366,163**
EIA mitigation and resettlement	2,134
Subtotal with EIA cost	**368,297**
Owner's cost	3,610
Total project cost	**371,907**
Interest during construction	58,354
Financing fees	8,098
Subtotal financing cost	66,453
Total financing requirements	**438,359**

Table 12-1: Project cost at Reference Date

The National Electric Power Regulatory Authority (NEPRA) has developed a mechanism for adjustment of the tariff ("tariff re-opener") at later stages of project development: at the EPC stage, when the EPC contract has been concluded, and/or at the COD stage, when final costs, including interest during construction, are known.

12.1.1 Project Benefit – Power and Energy Output

As described in more detail in Section 8, Madian HPP is capable of generating 767.5 GWh in an average mean year, 688.4 GWh in an average dry year, and 851.9 GWh in an average wet year.

Taking the maximum possible forced and scheduled outages (according to Draft Power Purchase Agreement) into consideration, average annual generation of Madian HPP is estimated at 742.5 MW in a mean year, 669.7 in a dry year and 826.9 in a wet year. The contracted capacity of Madian HPP is assumed to be 157.3 MW. Over the 12 months of the year, the capacity of the plant varies considerably. In January, the capacity may be as low as 23.9 MW in an average year, 0 MW in a dry year, and 34.9 MW in a wet year. The project cannot provide capacity with a certain degree of reliability ("firm capacity").

12.2 Economic Analysis

The economic analysis of Madian HPP is carried out as a conventional cost-benefit analysis, where the costs of the hydropower project are compared with its benefits. The costs of the project comprise all costs incurred during implementation and subsequent operation of the project, i.e. investment costs, reinvestment costs and operation and maintenance costs.

The benefits of the project are equivalent to the avoided costs of thermal generation, because without the project the equivalent power and energy would have to be provided by thermal power plants within the grid.

Most of WAPDA's plants are run on indigenous gas and furnace oil. With increasing shortage of gas, furnace oil is the most widely used fuel. It is therefore assumed that energy from Madian HPP is used to substitute furnace oil. Furthermore, hydro generation prevents greenhouse gas emissions which would otherwise result from thermal generation. Therefore the avoided cost of CO_2 emissions has to be considered explicitly in the economic analysis of Madian HPP.

12.2.1 Parameters and Assumptions

The economic analysis is based on the following parameters / assumptions:

General

The evaluation period is 30 years, equivalent to the concession period. According to the Policy for Power Generation Projects 2002 (§37), the evaluation of hydropower projects is based on a discount rate of 12%. A Standard conversion factor of 0.9 is used to convert the market prices for local goods and services to economic shadow prices.

Madian HPP

Annual energy generation is 742.5 GWh in a mean year (base case), 669.7 GWh in a dry year and 826.9 GWh in a wet year (sensitivity cases). The economic project cost at the Reference Date thus amount to US$ 353.4 million as compared to the financial project cost of US$ 371.9 million. Civil works are assumed to have a lifetime of 60 years; thus at the end of the evaluation period a residual value of 50% is considered. For steel structures, electromechanical and electrical equipment an economic lifetime of 30 years is considered in the present analysis. The economic operation and maintenance costs are determined by applying the SCF of 0.9 to the financial O&M costs resulting in US$ 2.94 million. The water use charge is not considered in the economic analysis.

Thermal alternative

Considering WAPDA's plant mix, the thermal alternative is assumed to be a combined cycle plant capable of dual-firing with natural gas and furnace oil. Fixed operation and maintenance costs are part of the capacity costs of the thermal alternative which are not considered in this analysis. Variable O&M costs of a CC plant are assumed to be 0.3 US cents/kWh.

Item	Unit	Base case	Sensitivity
General parameters			
Evaluation period	Years	30	-
Discount rate	%	10%	8%, 12%
Standard conversion factor	-	0.9	-
Madian HPP			
Installed capacity	MW	157.3	
Firm capacity	MW	0	
Average annual energy	GWh	742.5	dry 669.7/wet 826.9 (-10%/+11%)
Economic investment cost	US$ million	353.4	+10%/+20%/-10%
Economic lifetime civil works	Years	60	
Economic lifetime equipment	Years	30	
O&M costs	US$ million	2.94	
Water use charge	Rs./kWh	n.a.	
Thermal alternative			
Type of plant	-	Comb.Cycle	
Variable O&M costs	USc/kWh	0.3	
Type of fuel	-	furnace oil	100% local gas / 100% internat.gas / 60% FO:40% gas
Fuel price	US$/GJ	13.5	3.2 / 9.0 / 9.4
Fuel cost	USc/kWh	9.7	2.3 / 6.5 / 6.8
Cost of CO_2	US$/ton	10	
Specific CO_2 cost	USc/kWh	0.6	0.4 / 0.4 / 0.5

Table 12-3: Parameters and assumptions for economic analysis

12.2.2 Results

Based on these assumptions, Madian HPP has an EIRR of 15.8%. The EIRR indicates the actual profit rate of the total investment outlay. Thus, the economic analysis confirms that Madian HPP is economically feasible.

Economic indicator	Value
EIRR	15.8
NPV (US$ '000)	182,666
B/C ratio	1.66

Table 12-4: Results of economic analysis

Sensitivity Analysis

The sensitivity analysis serves to test the effects of changes in key parameters used in the economic evaluation. The following parameters are tested in the sensitivity analysis:

- Change in investment cost.
- Change in energy generation.
- Change in fuel cost.
- Change in discount rate.

Madian HPP is still economically feasible under adverse conditions for all discount rates from 8% to 12%. The most important parameter for economic project feasibility is the fuel price. When the energy from Madian is compared to a mix of gas/furnace-oil generated energy, the project has an EIRR of 11.8% and a B/C ratio of 1.19 at a discount rate of 10%, while it is no longer feasible at a discount rate of 12%. When the energy generation from Madian is assumed to replace gas-generated energy at low local gas prices, then EIRR drops to 4.0% and B/C ratio to 0.48.

12.3 Financial Analysis

The financial analysis of Madian HPP serves to assess the financial performance of the project over the concession period. Project profitability is usually measured by the Financial Internal Rate of Return (FIRR) and the Net Present Value (NPV). For the calculation of FIRR and NPV it is sufficient to compare the project costs with the revenues in a simple cash flow analysis.

In order to capture all aspects of financial performance it is necessary to set up a financial model which:

- establishes the financing plan for the project,
- projects revenues and costs, based on the plant operation, and
- generates a complete set of financial statements of the project company over the concession period.

The financial statements comprise profit and loss account, sources and applications of funds, cash flow statement, and the balance sheet. All financial statements together provide a concise picture of the financial performance of the project company and allow quantifying the risks associated with the project.

- The profit and loss account compares operating revenues and operating costs, calculates the profit for the year, and determines how much of the profit is distributed; dividend payments depend on the profit as well as the available cash as determined in the cash flow statement.

- The cash flow statement synchronizes the cash outflow with the cash inflow. In addition to costs and revenues, the cash flow shows inflows from loans and equity and outflows for debt service and dividends.

- The sources and applications of funds statement synchronizes the sources of funds with the applications of funds and serves to assess the liquidity of the project company. This statement provides similar information as the cash flow statement, but inflows and outflows are arranged in a slightly different way. The resulting net cash flow is identical in both statements.

- The balance sheet describes the development of assets and liabilities of the project and shows the financial position of the project company at the end of each year.

The financial model for the Madian HPP is set up on a quarterly basis over the construction period and on a semi-annual basis over the operation period. The model is used to derive the tariff which covers the costs of the project and provides the project company with a reasonable profit.

12.3.1 Parameters and Assumptions

Further to the project cost and project output described in section 12.1, the financial analysis is based on the following parameters and assumptions:

Construction is assumed to start on January 1, 2011. Commercial operations date is assumed to be after 54 months of construction, on July 1, 2015. The concession period of 30 years ends on June 30, 2045. The price base for cost estimation and tariff calculation ("Reference Date") is July 1, 2008, and the exchange rate at the reference date is 67.98 Rs./US$. The discount rate for calculation of the levelized tariff is 10%. Assets are depreciated over the concession period on a straight line basis over 30 years. At the end of the concession period, the civil works will still have a residual technical lifetime of 30 years. The project company will be completely exempted from the payment of income tax. However, dividend payments will be subject to a withholding tax of 7.5%.

The parameters and assumptions are summarized in Table 12-.

Item	Unit	Parameter	
Contracted Capacity	MW	157.3	
Net Electrical Output	GWh	742.5	
Time schedule			
Construction period	Months	54	
Start of construction	Date	1 Jan 2011	
Commercial operations date (COD)	Date	1 July 2015	
Concession period	Years	30	
Prices			
Discount rate for levelized cost calculation	%	10%	
Price base	Date	30 June 2008	
Exchange rate 30 June 2008	Rs./US$	67.98	
Depreciation			
Civil works	Years	30	
Steel structure/E&M/electrical equipment	Years	30	
Environmental cost	Years	10	
Owner's cost	Years	30	
Commercial data			
Accounts receivable (revenues)	Days	45	
Accounts payable (O&M cost)	Days	45	
Inventory	Months	1	
Interest on overdraft	% p.a.	10%	
Interest earned on accounts	% p.a.	5%	
Income tax	%	0%	
Withholding tax on dividends	%	7.5%	
Funding			
Debt:equity	%	80:20	
Target ROE	%	20%	
Loan conditions:		Debt 1	Debt 2
Repayment period (excl. grace p.)	Years	10	10
Grace period (= construction)	Years	4.75	4.75
Interest during construction	% p.a.	8%	8%
Interest	% p.a.	8%	8%
Up-front fee (one-off)	%	1%	1%
Commitment fee on outstanding bal.	% p.a.	0.50%	0.50%

Table 12-5: Parameters and assumptions for financial analysis

The debt : equity ratio is assumed to be 80 : 20. There may be two loans, one for the foreign currency component, one for the local currency component. Both loans are assumed to have an interest of 8%, a grace period equal to the construction period, and a repayment period (excluding the grace period) of 10 years.

With project costs of US$ 371.9 million and additional financing costs of US$ 66.5 million, total financing requirements amount to US$ 438.4 million. These are assumed to be financed with 20% equity (US$ 87.7 million) and 80% debt (US$ 350.7 million), as shown in the table below.

Uses of Funds	000 US$	Sources of Funds	000 US$
Construction cost	366,163	Equity (20%)	87,672
Environmental cost	2,134	Debt 1	219,922
Owner's cost	3,610	Debt 2	130,766
Subtotal project cost	371,907	Total debt (80%)	350,688
Financing cost	66,453		
Total uses	**438,359**	**Total sources**	**438,359**

Table 12-6: Funding of project cost

12.3.2 Tariff Structure

Pursuant to NEPRA's Tariff Standards and Procedure Rules a power tariff should allow the licensee to recover the costs incurred for power generation as well as provide a reasonable rate of return on the investment which reflects the risks assumed by the investor. The structure of the tariff to be paid for power and energy from Madian HPP has not been determined. The Draft Standardized Hydro Power Purchase Agreement (PPA) refers to a capacity price to be paid for the tested capacity and an energy price to be paid for the net electrical output. Further details on tariff components, payment mechanism and indexation shall be regulated in a Schedule attached to the Standardized PPA which, however, is not available yet. The tariff calculation for Madian HPP is based on the information provided in the Policy for Power Generation Projects 2002 and the PPA schedule on tariff, indexation and adjustment of a recent hydropower project.

According to the Power Policy:

- the hydropower tariff has two parts: a Capacity Purchase Price (CPP) in Rs./kW/month and an Energy Purchase Price (EPP) in Rs./kWh;
- there may be a limit to the share of the CPP in the overall tariff; considering the low energy-related costs of hydropower projects, the CPP will be approximately 60% to 66%, and the EPP 40% to 34% of the levelized tariff;

In accordance with these rules, the Reference Tariff for Madian HPP:

- is based on the project cost at the Reference Date June 30, 2008.
- comprises a CPP in US$/kW/month and an EPP in US cents/kWh.
- The debt-related component of the CPP matches the debt service and thus is reduced to Zero after the loans have been repaid.
- The non-debt related CPP component (ROE and Fixed O&M) and the EPP are constant over the term of the PPA.

12.3.3 Results

The Madian HPP Project has a levelized tariff of 8.92 US cents/kWh at a discount rate of 10%. The EPP is 3.03 US cents/kWh, thereof 2.81 US cents/kWh for variable O&M costs and 0.22 US cents/kWh for the water use charge. The CPP declines from 38.29 US$/kW/month in the first year to 5.22 US$/kW/month after the loans have been repaid. Of this non-debt-related CPP, the equity related component amounts to 3.66 US$/kW/month and the Fixed O&M component to 1.56 US$/kW/month.

Tariff Component	Unit	Tariff
Levelized tariff	USc/kWh	8.92
EPP (34%)	USc/kWh	3.03
CPP (66%)	USc/kWh	5.89
EPP	USc/kWh	3.03
Variable O&M	USc/kWh	2.81
Water use charge	USc/kWh	0.22
CPP – First year	US$/kW/m	38.29
CPP – after debt service	US$/kW/m	5.22
Return on equity	US$/kW/m	3.66
Fixed O&M	US$/kW/m	1.56

Table 12-7: Reference Tariff

Figure 12-1 below shows the development of the reference tariff over the 30 year term. The CPP which is expressed in US$/kW/month has been converted to US cents/kWh for this purpose.

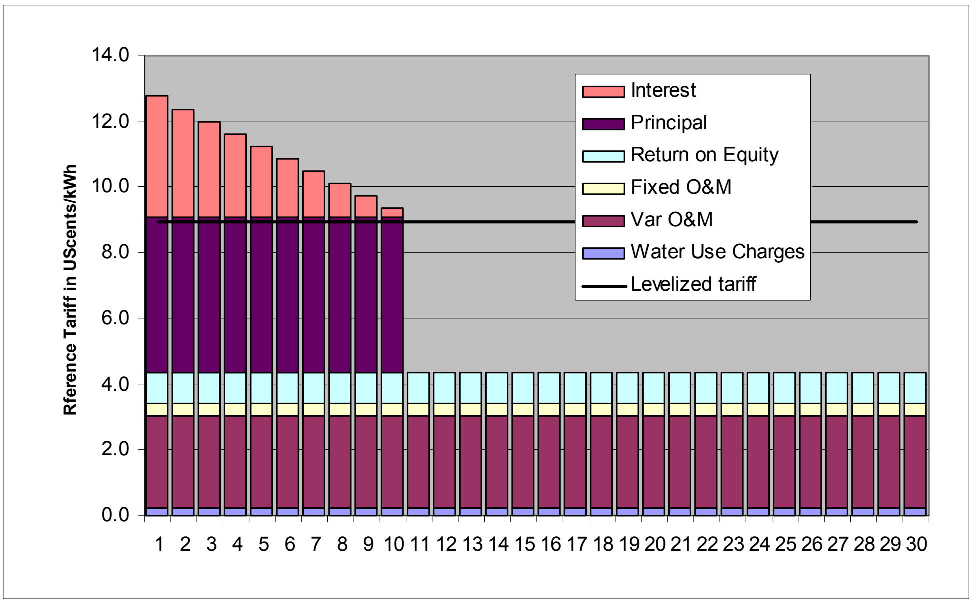


Figure 12-1: Development of Reference Tariff

The tariff as determined above is sufficient to cover the debt service, the fixed and variable O&M cost and water use charge and to provide the investor with a return on equity of 20% before the deduction of the dividend withholding tax and 18.9% after tax. The FIRR is 13.5%, and the NPV at a discount rate of 10% is US$ 80.9 million. The project has an average debt service coverage ratio (DSCR) of 1.56, which is acceptable to lenders. The minimum DSCR of 1.27 occurs only in the first half year of operation.

Financial indicator	Value
Financial Internal Rate of Return (FIRR)	13.5%
NPV (at discount rate 10%) US$ '000	80,867
Return on Equity (ROE)	20.0%
Min. DSCR	1.27
Max. DSCR	1.76
Average DSCR	1.56

Table 12-8: Financial indicators

Risk and Sensitivity Analysis

The key parameters with an impact on the project results are the investment cost, the project output in terms of energy, and the financing conditions. Changes of these parameters are tested in the sensitivity analysis:

Investment cost

Increases in the investment cost may arise due to under-estimation of quantities or increases in real prices. A cost overrun of +20% as well as a corresponding cost reduction by 20% are considered in the sensitivity analysis. When the investment costs change before the tariff has been fixed, the tariff will be adjusted accordingly either at the EPC stage or the COD stage, so that the financial performance of the project will not be affected.

The table below shows the project tariff for changes in the investment cost by +20% and -20%.**Fehler! Verweisquelle konnte nicht gefunden werden.** Since the capacity costs have a high share in the tariff, the tariff changes almost at the same rate as the investment costs.

Case	Unit	Base Case	Cost Increase by 20%	Cost Decrease by 20%
Sensitivity parameter				
Project cost	US$ '000	371,907	446,288	297,525
Change	% of Base Case	100%	120%	80%
Impact on tariff				
Levelized tariff	USc/kWh	8.92	10.57	7.27
Change	% of Base Case	100%	119%	81%
EPP	USc/kWh	3.03	3.59	2.47
CPP – First year	US$/kW/m	38.29	45.61	30.97
CPP – after debt service	US$/kW/m	5.22	5.92	4.52

Table 12-9: Sensitivity analysis: Tariff at different investment cost

Energy

The Reference Tariff is based on the hydrology of a mean year. For the purpose of the sensitivity analysis the effect of changes in energy generation is tested, assuming a decrease in generation by 10% (equivalent to the generation in an average dry year) and also an increase in generation by 11% (equivalent to the generation in an average wet year). The table below shows the results of the analysis. The levelized tariff increases by 10% when the energy generation is reduced by 10%.

Case	Unit	Base Case	Energy Decrease by 10% (dry year)	Energy Increase by 11% (wet year)
Sensitivity parameter				
Annual energy generation	GWh p.a.	742.5	669.7	826.9
Change	% of Base Case	100%	90%	111%
Impact on tariff				
Levelized tariff	USc/kWh	8.92	9.86	8.04
Change	% of Base Case	100%	110%	90%
EPP	USc/kWh	3.03	3.35	2.73
CPP – First year	US$/kW/m	38.29	38.23	38.37
CPP – after debt service	US$/kW/m	5.22	5.16	5.30

Table 12-10: Sensitivity analysis: Tariff at different energy generation

Combined impact of increases cost and reduced energy generation

When a 20% increase in investment cost coincides with a 10% decrease in energy generation, the levelized tariff increases to 11.7 USc/kWh, as shown in the table below.

Case	Unit	Base Case	Cost +20% Energy -10%
Levelized tariff	USc/kWh	8.92	11.69
Change	% of Base Case	100%	131%
EPP	USc/kWh	3.03	3.97
CPP – First year	US$/kW/m	38.29	45.55
CPP – after debt service	US$/kW/m	5.22	5.87

Table 12-11: Sensitivity analysis: Tariff at +20% cost and -10% generation

Financing conditions

The financing conditions affect the tariff at which the project is financially feasible in two ways: a change in the interest rate affects the interest during construction as well as the debt service during operation, and a change in the loan term affects the profile of the debt service. The table below shows the project tariff for alternative interest rates and loan terms. An increase in the interest rate by 2%-points increases the levelized tariff by 0.7 US cents/-kWh, and an equivalent decrease reduces the tariff by 0.7 US cents/kWh. An extension of the loan term tends to reduce the tariff. The adjustment of the tariff to the actual financing conditions at financial close ensures that the financial performance of the project is not affected.

Case	Unit	Base Case	Higher interest	Lower interest	Longer term	Longer term
Sensitivity parameter						
Interest rate	% pa.	8%	10%	6%	8%	8%
Loan term	years	10	10	10	15	20
Impact on tariff						
Levelized tariff	USc/kWh	8.92	9.62	8.26	8.82	8.74
Change	% of Ref.	100%	108%	93%	99%	98%
EPP	USc/kWh	3.03	3.27	2.80	2.99	2.97
CPP – First year	US$/kW/m	38.29	42.94	33.94	32.34	29.39
CPP – after debt service	US$/kW/m	5.22	4.86	5.56	5.34	5.42

Table 12-12: Sensitivity analysis: Tariff at different financing conditions

12.4 Summary and Conclusions

The Madian HPP project has total costs of US$ 371.9 million in prices at the Reference Date June 30, 2008. Total financing requirements including interest during construction and financing fees amount to US$ 438.4 million, thereof US$ 87.7 million (20%) financed with equity and US$ 350.7 million (80%) financed by debt.

The project requires a levelized tariff of 8.92 US cents/kWh to provide the investor with a return on equity of 20% which reflects the risks associated with the project. Since the CPP matches the debt service profile, the project has a healthy cash flow during the loan term with an average debt service coverage ratio of 1.56. The financial internal rate of return of the project at the proposed tariff is 13.5%. The uncertainty of future price developments and the associated financial risk make it necessary to provide for tariff adjustments once the final project costs and financing parameters are known.

Item	Unit	Parameter
Contracted capacity	MW	157.3
Annual generation	GWh	742.5
Project cost	US$'000	371.9
Total financing requirements	US$'000	438.4
EIRR	%	15.8
Economic NPV	US$'000	182.7
Economic B/C ratio	-	1.66
Levelized tariff	USc/kWh	8.92
EPP	USc/kWh	3.03
CPP (levelized)	USc/kWh	5.89
CPP - First year	US$/kW/m	38.29
CPP - after debt service	US$/kW/m	5.22
Share of CPP	% of lev. tariff	66%
FIRR		13.5%
NPV (at disc rate 12%)	US$ '000	80,841
Return on Equity (ROE)	%	20.0%
Min. DSCR	-	1.27
Max. DSCR	-	1.76

Table 12-13: Summary of results

13. Conclusions and Recommendations

The Madian HPP is a run-of river hydropower project based on the concept of diverting flow from Swat River near Kedam village and exploiting the gradient of the Swat River of 11 m per km on average over a 13 km long river reach. By this concept some 154 m head can be obtained for power generation which permit an installed capacity of 3 x 60.8 MW, a maximum available capacity ex generator of 157.3 MW and a mean annual energy generation of 767.5 GWh at a project cost of 371.9 million US$. The present Feasibility Study of the Madian Hydropower Project serves to answer three key questions:

(1) **Technical Feasibility**:
Is the project technically feasible under consideration of the prevailing hydrological, topographic, geological, infrastructure, environmental and socio-economic boundary conditions?

(2) **Economic Feasibility**:
Is the project beneficial for the economy of Pakistan?

(3) **Financial Viability**:
Is the project profitable for the investor?

The three above stipulated aspects have been analysed at the required level of detail in this Feasibility Study. The first two questions can be clearly answered with: Yes, Madian Hydropower Project is feasible and it is worth to continue developing the Project till implementation.

Concluding statements regarding the third question can be given only when the Project Sponsor and the Power Purchaser have reach on the respective agreements. The potential that such an agreement can be beneficial for both parties has been demonstrated in this Feasibility Study.

13.1 Summary of Results of Feasibility Study

In accordance with the requirements of a bankable feasibility study and the corresponding terms of reference the Consultant conducted comprehensive field investigations comprising:

- Supplementary hydro-meteorological survey and field studies
- Detailed topographic survey of the project area
- Comprehensive geotechnical field and laboratory investigation program
- Study of conditions to access the project area
- Environmental Impact Assessment Study and Resettlement Action Plan in accordance with international standards

The design of alternative project layouts and the finally preferred alternative for the Madian HPP were elaborated based on the site specific conditions derived from the detailed geotechnical field and laboratory investigations as well as the topographic survey.

The Project and its components were optimized applying unit rates which were verified with local and international market prices and rates of similar projects under development.

The Consultant analysed the economic feasibility of the project in comparison with alternative thermal power generation and determined the Economic Internal Rate of Return of the Project being 15.8 % and the Benefit Cost ratio of 1.66.

The Consultant conducted a sensitivity and risk analysis which verified that the Madian HPP is economically feasible even under adverse conditions such as higher investment costs and unfavourable hydrological conditions.

In the financial analysis the Consultant considered the legal and institutional framework for development of hydropower projects by private investors in Pakistan which is in the process of being established. Pursuant to NEPRA's Tariff Standards and Procedure Rules a model for calculation of the power tariff was developed that permits the licensee to recover the costs incurred for power generation as well as provide a reasonable rate of return on the investment which reflects the risks assumed by the investor.

13.2 Recommendations – Project Implementation

For Project implementation, the following major activities are considered:

- Stage I: Pre - Construction Activities: 48 months
- Stage I.1: Feasibility Study
- Stage I.2: Tender Design, Pre-qualification and Contracts
- Stage II.: Construction Works, Commissioning, Testing/Training: 54 months
- Stage I: Commercial Operation of the Plant: mid 2015

The construction schedule is based on en estimated overall construction period of 4 years and 6 months. The critical path of construction works is defined by the excavation and lining of the 11.8 km long headrace tunnel.

Annex A-1-1: Photo Documentation of Access to Project Site

Photo 1: Madian Sadar Bazaar Bridge (3.5 m wide)

Photo 2: Temporary Baily Bridge at Northern Outskirt of Madian Town (3.5 m wide)

Annex A-2: Selected Drawings of Location and Layout of Madian Hydropower Project

Annex A-2-1: Project Location of Madian Hydropower Project
Drawing SW 00 A100

Annex A-2-2: Overview - Madian Hydropower Project
Drawing SW 00 A700

Annex A-2-3: General Project Layout – Weir Site
Drawing SW 00 A401

Annex A-2-4: General Project Layout – Desander Area
Drawing SW 00 A402

Annex A-2-5: General Project Layout – Powerhouse Site
Drawing SW 00 A403

Annex A-2-6: Powerhouse Cavern – Cross-Section
Drawing SW 00 G002