Mujigram-Shoghore Hydropower Project

Final Feasibility Report

Executive Summary
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Pakhtunkhwa Hydel Development Organization (PHYDO)

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Executive Summary

Introduction

Energy is the backbone of any country's economy. With rapid advancement in technology sector and improved lifestyle of community, provision of reliable energy to various sectors of economy for keeping the momentum of technological advancement and further improvement in lifestyle, role of power sector has become much more evident. Hydropower is one of the main sources for provision of cheap electricity to the economy at large. Till 1980's, the share of hydropower in overall energy mix was about 70 percent as thermal power was only 30 percent. However with the implementation of more thermal power generation projects it has dominated in the hydro-thermal mix. Electricity produced from hydro is much cheaper than any other type and much more reliable whereas, thermal power is more costly and is not environment friendly.

Pakistan is endowed with a hydro potential of more than 40,000 MW, which lies mostly in the province of Khyber Pakhtunkhwa (KP). The potential generally found in far flung areas of KP that includes Kohistan, Dir, Swat, Kaghan, Kalam and, Chitral valley etc. The Chitral District of KP, located in the northern part of Pakistan, has a substantial hydropower potential.

In order to explore and develop the medium and small hydro power potential in the province, the Government of KP created the Small Hydel Development Organization (SHYDO) in 1986-87 which in 1993 was converted in to a body corporate with revised nomenclature Sarhad Hydel Development Organization (SHYDO) under the SHYDO Act 1993. The SHYDO was mandated to identify, explore and develop the hydro potential of the Province. SHYDO has now been renamed as Pakhtunkhwa Hydel Development Organization (PHYDO).

The Chitral District of KP has considerable run-offs from snowmelt coming from very high altitudes between 3,000 m and 7,600 m.a.s.l. into the Chitral Valley which ranges in height from 1,200 to 1,500 m.a.s.l. To explore hydropower potential in the Chitral region an inventory of the potential sites was prepared during the years 1999 and 2000, by WAPDA/HEPO in close collaboration with the German Agency for

Technical Cooperation (GTZ) under the Programme for National Hydropower Development, under on agreement between the Governments of Germany and Pakistan.

As a result of this joint study, various sites were ultimately identified with high probability of being technically and economically feasible subject to detailed investigations leading to full scale feasibility studies. If properly harnessed, potential identified in this study is capable of meeting not only the local needs of the rural and urban areas of Chitral but also providing surplus power for use in the remaining area of the province of KP as well as contributing to the national grid through which it could be utilized in any part of the country.

In Chitral region twelve potential sites were identified which include Mujigram-Shoghore HPP site located on Lutkho River for which PHYDO has commissioned a consortium of consultants lead by Élan Partners (Pvt.) Ltd to conduct a detailed feasibility of this project site.

Background

The Project Mujigram-Shoghore HPP is located on right bank of Lutkho River, a tributary of Chitral River. Weir site is situated near Mujigram village approximately 3 km downstream of Garam Chashma whereas, the powerhouse is sited at Shoghore opposite to Ojhar Gol at a distance of 26 km from Chitral Town. Distance between weir site and power house is 13 km. Both the weir and power house sites are accessible through Chitral-Garam Chashma road built along right bank of Lutkho River flowing through Lutkho valley bounded by mountain chains which receive considerable snow fall during winters.

Project Setting

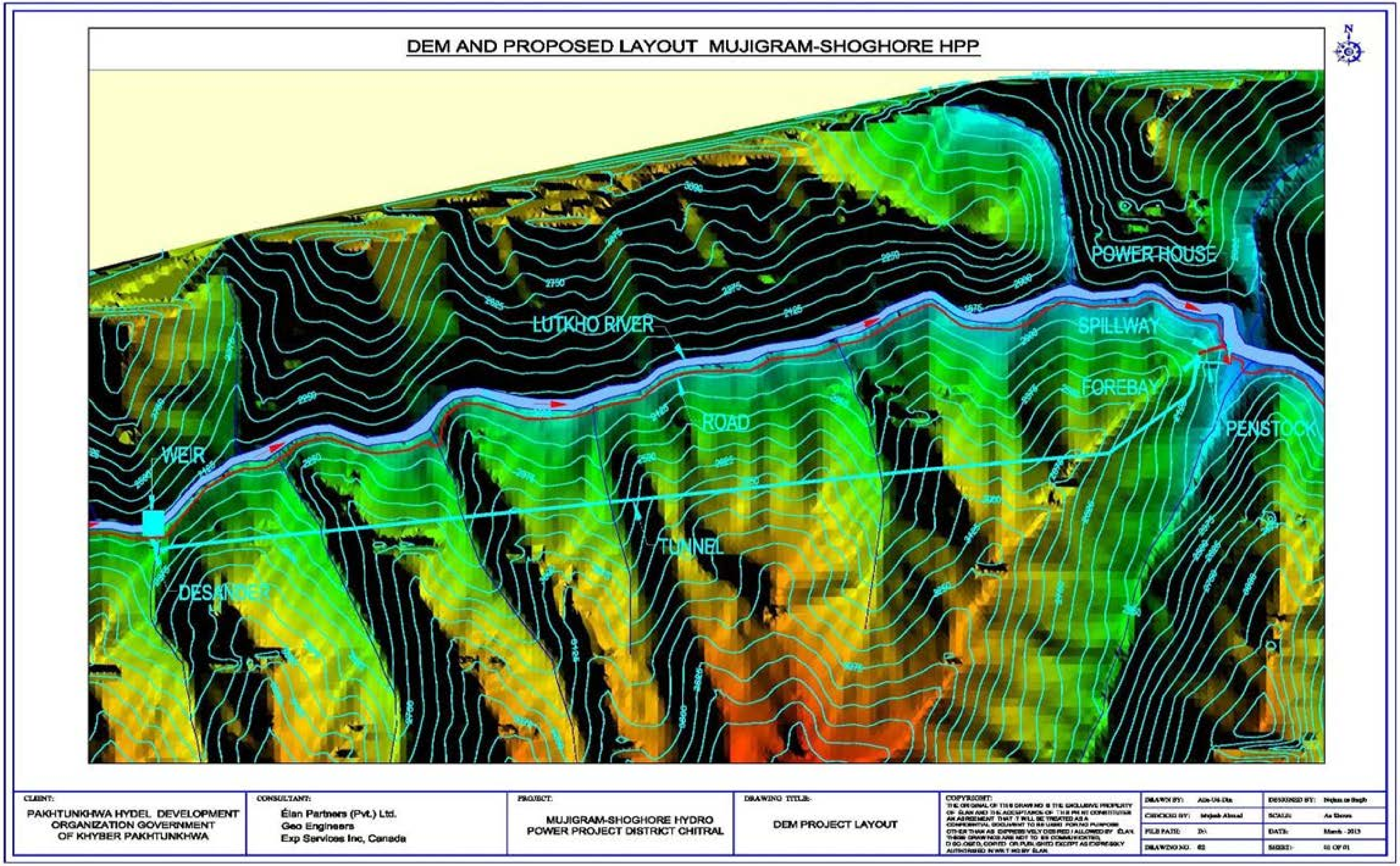
In June 2012, Élan Partners started collection & review of available information on Mujigram-Shoghore HPP, initiated field surveys and investigations, carried out initial visit to the project site in July 2012 and performed the geological reconnaissance of the project area and identified three locations for the weir site near Mujigram village and three locations for power house near Shoghore. These options were studied and deliberated upon to select the most appropriate location for the weir and power house. The comparative studies of layout alternatives showed that weir site (W03) and power house site (PH-01) were the most suitable options for project components. Layout of the recommended scheme includes a concrete face rock-fill (CFR) dam with over flow spillway and low level sediment flushing outlets, an intake structure, desanders with sediments sluicing arrangements, headrace tunnel, fore-bay, penstocks for a power house with three units and a tailrace duct.

Proposed layout of the embankment weir, headrace tunnel and power house has been marked on topographic map prepared with the help of Digital Elevation Model (DEM) and may be seen as **Figure ES-1.**

Following studies and surveys were undertaken as part of the feasibility study:

- Topographic Survey of the Project Area.
- Geological Survey of the Project Area.
- Geotechnical Investigations within the Project Area.
- Seismo-Techtonic Hazard Analysis.
- Hydrological Data Collection and Analysis.
- Environmental Impact and Mitigation Measures
- Transmission and Inter Connectively Study
- Investigation for Construction Material Availability.
- Identification of Aggregate Sources.
- Transportation Study.

Figure ES-1 Proposed Layout of Mujigram-Shoghore HPP



These studies were essential for hydraulic design of various components of the project, their layouts, calculation of power potential and selection of the most feasible equipment.

Going through the brief account of these studies would provide considerable information about the project to appreciate the quantum of work under taken and accomplished by the consultants to determine suitability of the project.

As a consequence of the in-depth study of hydrology of the project, it has been up scaled from 51 MW to 64.26 MW.

Scheme at a Glance

Hydrology	
Design Discharge	27 m^3/s
Design Flood at Weir site (10,000 Year Flood)	971 m^3/s
Design Flood at Power House Site	1815 m^3/s
Reservoir Length	848 m.
Reservoir Area	53483 m^2
Max. Reservoir Operating Level	2103 m.a.s.l.
Min. Reservoir Operating Level	2093.368 m.a.s.l.
Dead Storage Level	2085.26 m.a.s.l.
Reservoir Capacity	0.367 m^3
Dam Structure	
Type of Construction	CFRD
Height above River Bed	22 m
Crest Level	2105 m.a.s.l.
Spillway	
Type of Structure	R.C.C.
Number of Gates	3
Gate Type	Radial
Size of Gates (W xH)	7m. x 8m.
Discharge Capacity	800 m^3/s
Deck Elevation	2092 m.a.s.l.
Sill Elevation	2084 m.a.s.l.

...Continued, Scheme at a Glance

Power Intake	
Type	Lateral
No. of Gates	2
Gate Size (WxH)	6 m. x 6 m.
Deck Elevation	2092 m.a.s.l.
Sill Level	2084 m.a.s.l.
Minimum Operating Level	2093.37 m.a.s.l.
Connecting Tunnel	
Diameter	4.5 m.
Lengths	85 m.
Desander	
Type of Structure	Underground R.C.C.
Size of Chamber (LxWxH)	95 m. x 8.5 m. x 15.0 m.
No. of Chambers	03
Power Tunnel	
Inside Shape	Horse shoe
Dimension	4.5 m. x 6 m.
Length	13.75 km.
Gradient	1:1000
Velocity	1.70 m/s
Forebay	
Length	80 m.
Width	12m.
Depth	8 m.
Penstocks	
Type of Conctruction	Mild Steel
Diameter	4 m.
Total Length of penstock	480 m.
Power Generation	
Gross Head (HWL-Turbine centre line)	298 m.
Max. Net Head	280 m.
Min. Net Head	269 m.
Rated. Net Head	280 m.
Plant Design Discharge	27 m^3/s
Installed Plant Capacity	64.26 MW

…Continued, Scheme at a Glance

Power House	
Type	Surface
Size	52 m.x 20 m. x 12.22 m.
Type of Turbines	Pelton
No. of Units	03
Turbine Centre Line Level	1805 m.a.s.l.
Designed Annual Energy	277.72 GWh
Tailrace	
Type of Construction	R.C.C
Size (WxH)	6 m. x 4.5 m.
Shape	Retangular
Length	38 m.
Project Cost	
Item	US$ Million
EPC (Estimated)	146.600
Tax & Duties	1.52
Emergency Spare Parts	0.411
Contigencies @2% of Civil Cost, preparatory works and E&M	2.93
Transportation & Port Clearance 2% of Imports	0.608
Mobilization Payment to O&M Contractor	0.400
Start Up Expenses	0.200
Independent Engineer as per PPA	0.04
Implementation Consultant @ of 6% of EPC Cost	8.796
Total CAPEX	161.510
Financing Fees & Charges	4.790
Interest During Construction (IDC)	12.242
Total Project Cost	178.542
Capital Structure	
Equity	35.7084
Debt	142.8335
Total Project Cost	178.5419
Debt Equity Ratio	80:20
Generation Cost	US $ 2.778/MW

Project Location and Accessibility

Mujigram-Shoghore HPP is located on Lutkho River with weir near Mujigram village and power house in the vicinity of Shoghore village. Weir and Power house sites are 49 km and 26 km respectively from Chitral town of KP Province.

The project area is located on Survey of Pakistan sheets No. 37-P/12, 37-P/16, 38-M/9 & 38-M/13. The area is approachable through Chitral-Garam Chashma Road built at the foot hills along the right bank of Lutkho River. The site is 365 km from Peshawar and 455 km from Rawalpindi/Islamabad. The road between Chitral and the site is poorly maintained and currently in abysmal condition with damaged culverts and would require up-gradation well before implementation of the project at site. Chitral Town, the major city close to the project lies in the North-West of the country and is connected with Motorway M1 through metalled road starting from Rashakai Interchange and proceeding along cities/towns of Mardan, Dargai, Malakand, Chakdara, Dir, Drosh and approaches Chitral Town after crossing through Lowari Tunnel. Previously the road passed through Lowari pass at EL 3300 m.a.s.l. It was a dirt road studded with sharp turns and steep gradients.

However, with the completion of Lowari Tunnel and up-gradation of Dir - Chitral road would remain open throughout the year except for small periods of heavy snowfall along approaches to the tunnel.

Up-gradation of 40 kilometers of Garam Chashma Road in any case would be necessary to facilitate the movement of trailers and long trucks from Chitral to project site.

Any how during road survey conducted in May 2013, it was observed that upgradation and improvement of Chitral-Garam Chashma Road has been initiated from Chitral Town.

Field Survey and Investigations

A comprehensive program of field surveys and investigations was chalked out in July 2012 and implemented thereafter. As mentioned earlier, the program included topographic survey, geological survey and mapping, geotechnical investigations by drilling boreholes, Electrical Resistivity Survey (ERS) & digging of exploration pits for construction materials, sampling and permeability tests.

Starting from July, 2012 GETO Surveyors conducted topographical survey and mapping of the project area. For inaccessible areas along the proposed alignment of water carrying tunnel (Head Race), mapping with the help of digital elevation model (DEM) was carried out.

Similarly, geological survey of the project area, mapping of seismic fault lines, ERS and drilling of boreholes at the weir and power house sites were undertaken. Drilling at both the weir site and power house site was accomplished in April 2013. Borehole logging, sampling and performance of permeability tests were carried out during drilling of boreholes. The samples were collected, properly packed and sent to testing laboratories for acquisition of design parameters. Survey for construction materials and transportation survey too was undertaken. For details **Chapters 15 & 17 of Main Report** may be pursued.

Topographic Survey

Topographic Survey of the project area was conducted by professional surveyors under the guidance and supervision of the consultants to a scale of 1:10000 with 5 m contour interval. For the inaccessible areas along tunnel alignment, topographic maps were developed with the help of high resolution digital elevation models (DEM). River cross-sections upstream and downstream of weir axis and at power house location were taken. The cross sections on the upstream of weir axis were observed and mapped up to the point where back water would extend after building the embankment dam/weir. Water depths were taken by soundings at appropriate intervals to develop and plot a meaningful cross section.

Following prominent features were picked up during survey and have been incorporated in the plans.

- Existing houses, powerhouses, mills or other constructed buildings.
- Existing roads, passages watercourses/irrigation channels, electricity lines and poles, telephone lines and poles and retaining walls.
- Loose screed, trees and cultivated areas.
- Change in abrupt elevation marked differentially.

- All control points/bench marks marked and used.
- Boulders bigger than 1 m.
- Powerhouse
- Human settlements and buildings
- Roads, hydrographic features, electricity and telephone lines and roadside structures.
- Contact between overburden and rock exposed.
- Dominant land use and land forms (trees, cultivated areas, loose rocks)
- Steep slopes, drainage courses/nullahs.
- Ground control
- Multiple interval contours

Geological & Geotechnical Evaluation and Seismic Hazard Assessment

Geological Investigations were carried out for the project area in accordance with the norms and standards to meet the requirements of the feasibility level studies. The studies encompassing field and office work yielded geological mapping of the weir and power house areas. Preliminary selection of the most appropriate locations for building weir/embankment/dam, and power house were made during reconnaissance visit. The valley at the weir site is nearly 85 to 95 m. wide at the river banks level.

Geology of weir site comprises of undivided metamorphic rocks of Epidotic mica schist of Devonian to Jurassic age. Geology along the tunnel alignment comprises undivided metamorphic rocks and momi gneiss (granitic Othogenciss). Length of Epidote mica schist extends 6200 m along the tunnel route. Geology of power house site comprises of Sarikot shale and Phillites and its length is 1359 m in the project area. Rocks travel in the direction of 50^o – 60^o north-west dipping at an angle of 70^o – 80^o in the north-east direction. Sarikot shale consists mainly of soft, thinly laminated, black slate and micaceousphyllite. Beds of brown wreathing dolomite and grey limestone with the presence of few thin beds of brown weathering calcareous sand stone are present.

River beds are composed of primarily boulders and sandy gravel rocks fallen from the slopes of mountains running parallel to the river. The gravels are mostly fine to coarse grained and originate from igneous and metamorphic rocks.

For geotechnical investigations, drilling and coring of samples was performed while drilling boreholes at regular intervals. The samples collected were properly packed, marked and sent to laboratories for testing. Boreholes drilled to a depth of 60 m reveal existence of over burden to that depth and beyond. This was further confirmed by ERS survey carried out in close proximity of the boreholes. Constant head permeability tests of underground strata reveal that permeability ranges between 0.00984 to 0.010043. Water pressure tests were also conducted which reveal Lugeon values ranging from 4.93 to 7.09.

Detailed neo-techtonic and seismic hazard assessment was carried out due to nearness of Reshun Fault in Chitral District. The other two faults in the vicinity of the project are Trich Mir Fault in the north and Main Karakuram Thrust (MKT). For results and recommendations reference is made to **Chapter 5 of Main Report**.

A study covering construction materials (**Chapter 15 of Main Report**) was also conducted to explore availability of good quality of aggregates as close to the project as far as possible for economy in construction costs. Deposits for fine aggregates were located on the banks of Chitral River in the vicinity of Chitral Airport and area near Ayun downstream of Chitral town. Laboratory tests confirm that the fine aggregate deposits meet ASTM specifications and are suitable for use in the project structures.

For coarse aggregates, a quarry would need to be developed and stone crushing plant installed for production for aggregates from rocks of marble stone existing on the right bank of Lutkho River near Shoghore.

Geology & Seismicity

As part of the field surveys and investigations, geological mapping was carried out by a team of experienced and knowledgeable geologists. Details about geological survey may be perused in **Chapter 4 of Main Report.**

Briefly stating, weir site geology comprises of undivided rocks of Epidotic mica schist of Devonian to Jurassic age. Geology along the tunnel alignment comprises of metamorphic rocks and momi gneiss (gramticothogenciss). River bed is composed of boulders and sandy gravels, and rocks fallen from the slopes of mountains running parallel to the river.

Geology of power house site comprises of Sarikot Shale and Phillites. The shale is composed of soft, thinly laminated black slate and micaceousphyllites. Beds of brown weathering dolomite and grayline stones with the presence of brown weathering calcareous sand stone are also encountered.

Seismic hazard analysis of the project site was performed to identify the earthquake hazards to the project components so that appropriate engineering measures could be taken to ensure safe and trouble free operation of all the project elements. Chitral region has three main tectonic blocks namely Wakhan Block, Braghil Block and Yar Khan Block. These are separated by major boundary faults including Trich Mir & Reshun faults. Main Karakurram Thrust fault has also potential fall out on the structures in the area. Careful evaluation of the faults, Peak Ground Acceleration (PGA) of 0.65 g is recommended with design basis earthquake of 0.325 g for power house. Similarly the Design Basis Earthquake (DBE) for weir should be 0.275 g 50% of Maximum Credible Earthquake (MCE) which is 0.55 g.

Detail of Boreholes are presented in **Table ES-1**

Table ES-1: Detail of Boreholes

Borehole No.	Location	Angle	Depth (m)
BH-01	Weir site-03 (Right Abutment)	90°	60 m
BH-02	Weir site-03 (Right Abutment)	90°	60 m
BH-03	Weir site-03 (Right Abutment)	90°	63 m
BH-04	Weir site-03 (Right Abutment)	45°	40 m
BH-05	Weir site-03 (Left Abutment)	45°	40 m
BH-06	U/S coffer dam	90°	40 m
PH-BH-07	Powerhouse	90°	55 m
PH-BH-08	Powerhouse	90°	40 m

Hydrology and Sedimentation

Lutkho River is one of the primary tributaries of Chitral River. It has its origin in the north-west of upper Chitral valley at an altitude of about 5500 m.a.s.l. Its confluence with Mastuj River lies 5 km upstream of Chitral Town.

Lutkho River has not long been gauged, therefore only limited historical data is available. GTZ studies performed in 2001 as part of the study titled **"Identification of Hydro Power Development Potential in Chitral Valley"** used only one year flow data observed during 1987 – 88 near Shah-re-Sham Village.

As a part of the contract, the consultants established a gauging station just downstream of Mujigram Bridge in September 2012. River flow and suspended sediment load is being religiously monitored and recorded. This gauging station would be operated for one year before its handing over to PHYDO for subsequent recording of the data. Although the period for observations at this newly established gauging station is too small for meaningful use for hydrology studies at the moment however it would provide an opportunity to carry out comparison with the data derived from recordings at Chitral on Chitral River.

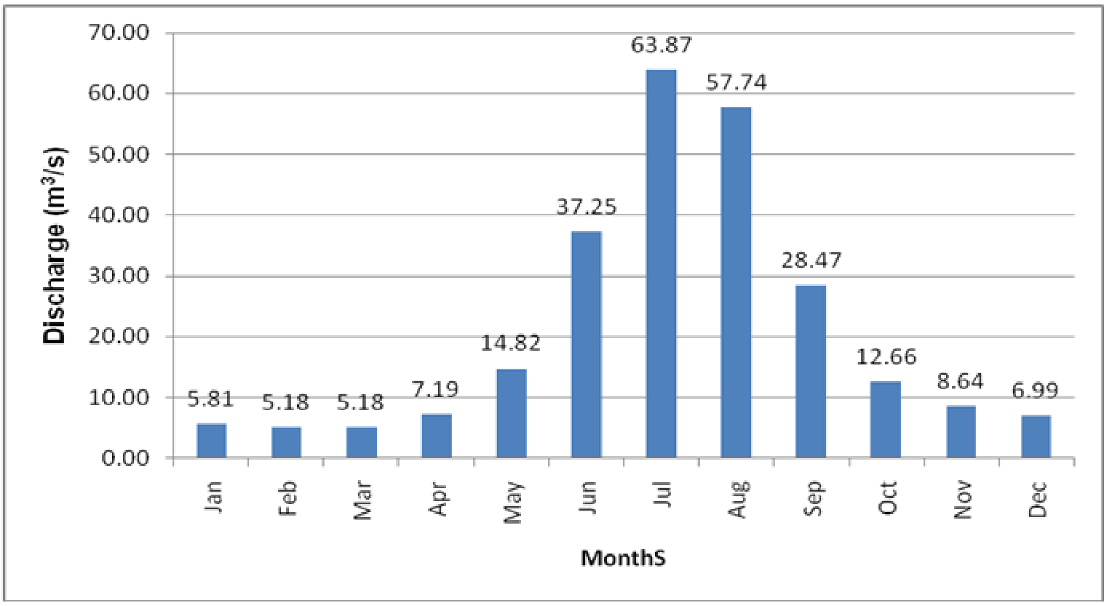
PHYDO established a gauging station at Shoghore in 2005. Therefore, the flow records from the gauging station cannot be considered long term, however, it was required for co-relations with other streams in the region where long term records were maintained. Chitral gauging station is probably the oldest station in Chitral valley where flow data of Chitral River is being recorded and maintained data since 1964, therefore recorded from this station was used to assess stream flows for Lutkho River employing different widely known and practiced relationships.

- Precipitation – Runoff relationships
- Regional Stream Flow Analysis
- Hydrological Modeling of study area

Project Hydrology Assessment

Average monthly flows at Mujigram in Lutkho River derived from Chitral gauging station at Chitral (1964 – 2010) may be appreciated from the following Graph **Figure ES-2:**

Figure ES-2: Derived Average Monthly Flows at Lutkho-Mujigram from Chitral (1964 - 2010)



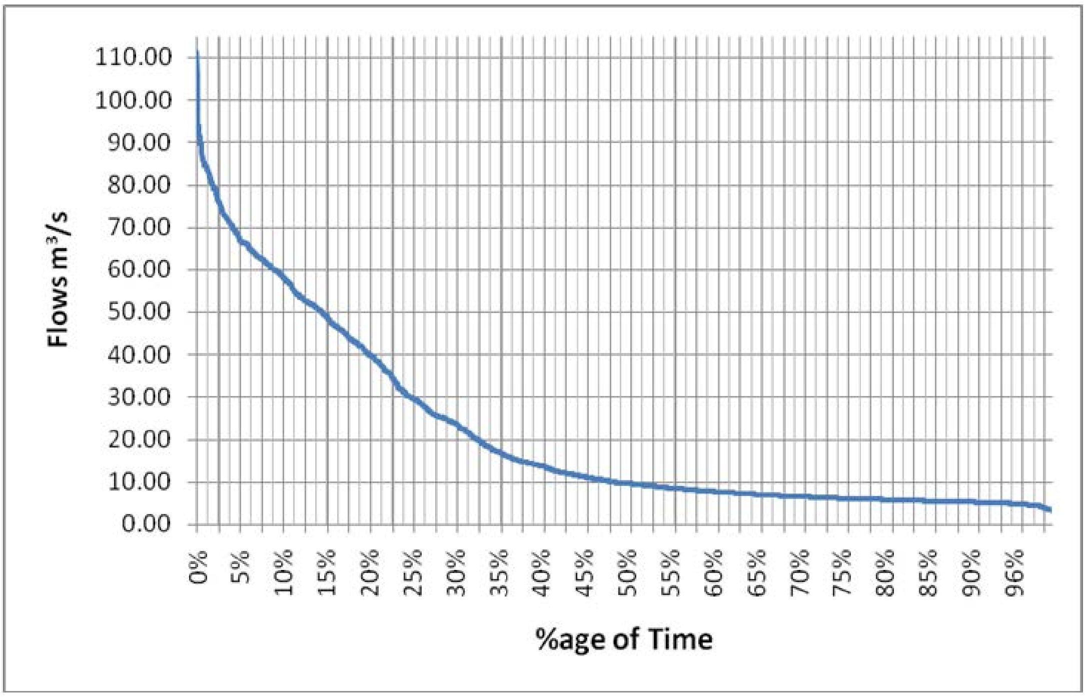
The derived monthly flows at Lutkho Mujigram from Chitral range from 5.18 m^3/s to 63.87 m^3/s. It may be appreciated that from June to September, a discharge of more than 25 m^3/s remains available. It would therefore, be feasible to generate energy at full output for around four months, and at part-load for the remainder of the year.

Flow duration data to determine availability of flows the proposed at weir site, derived from Chitral river flows at Chitral for the period from 1964 – 2010 may be seen in **Table ES-2** and flow duration curves appearing below **Figure ES-3**:

Table ES-2: Flow Duration Data

Time, %	Discharge, m^3/s
10	58.66
20	40.33
25	30.12
30	24
40	13.84
50	9.61
60	7.71
70	6.53
80	5.77
90	5.20
95	4.87
100	3.16

Figure ES.3: Mean Flow Duration Curve, Lutkho River at Proposed Weir Site



Flood Study

In the essence of long term recorded flood data for Lutkho River, estimation of flood has been carried out using Regional Analysis and Flood Frequency Analysis methods.

Floods at the intake and power house sites on Lutkho River calculated from the widely used relationship regional analysis is given in the **Table ES-3** below:

Table ES-3: Floods at Weir and Powerhouse Sites by Regional Analysis

Return Period (years)	Flood (m^3/sec)	
	Mujigram Weir	Shoghore Powerhouse
5	348.1	676.47
10	409.27	792.18
100	603.35	1142.42
1000	789.49	1477.33
10,000	970.59	1814.805

Sedimentation

Sediment transport studies were essential to estimate total sediment inflow to the reservoir, trap efficiency of the reservoir, trapped sediment load and life of reservoir with and without flushing or sluicing options.

Sediment generation in Lutkho River is glacially derived sediments, sheet erosion by rain, gully erosion and landslides on the mountains running along both the banks of the river.

Proposed embankment dam/weir height of 22 meter would create reservoir capacity of 0.418 (338.78 HF) with normal operating level (NOL) of 2013 would be 4.69 hectares (11.61 Acres) and a length of about 848 meters.

Lutkho River with drainage area of 955 km has a mean gradient of 3.6%. Being a river with steep bed carries appreciable sediment load largely due to glacial activities.

In the absence of long term recorded data, suspended sediment inflow to the reservoir has been computed by two approaches viz.

- By Regional Analysis
- From data measured by Shogo-Sin Consultants for the period from May to Dec 2009.

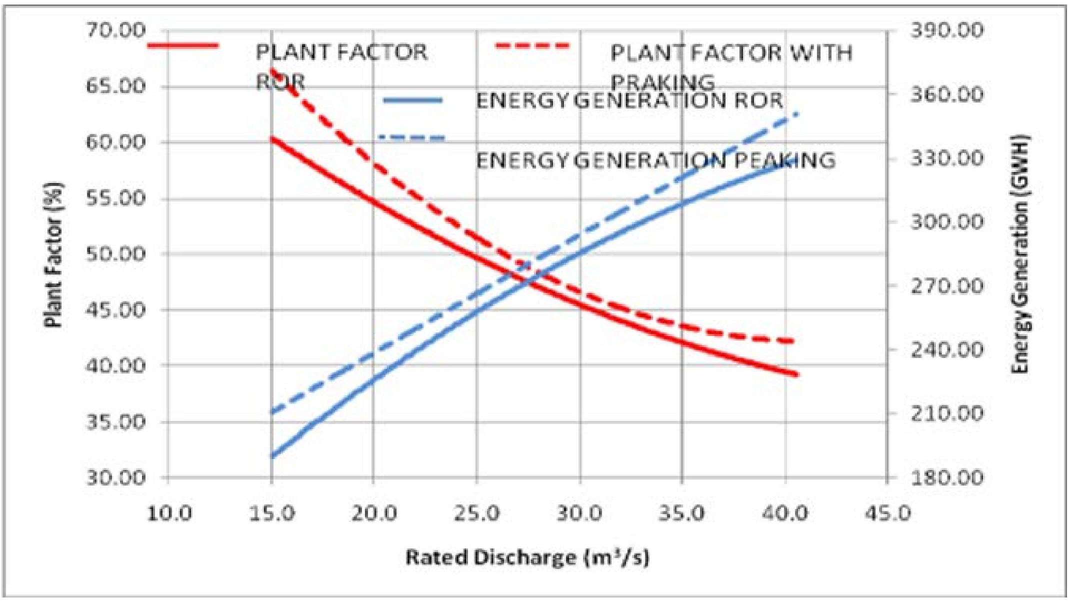
Suspended sediment load computed from Regional Analysis comes to 0.53 MT or 0.46 M. Tons with average density of 982.3 kg/m^3 of the deposited sediments, average suspended sediment load in terms of volume at the weir site equals to 0.46 M cm (382.12 AF).

Design Discharge

The most important parameter which has to be fixed very carefully for any hydropower project is the rated discharge for the turbines.

From the graph drawn between rated discharges, plant factor and energy generation; it is easy to fix the most advantages rated discharge. From the graph given below, it is found that a discharge in the range 25 to 30 m^3/sec with plant factor at 50%, the annual generation comes to about 250 GWh. We have therefore, selected 27m^3/sec as the optimum rated discharge. See **Figure ES-4.**

Figure ES-4: Selection of Rated Discharge



Turbine Selection

1. Basic Data:

   The Mujigram-Shoghore hydro power project is a high head project with the net head of 280 m with rated discharge of 27m^3/s available for about 28% of time. The estimated average annual energy production has been calculated to be 267 GWh, with a Plant Factor of 48.74%. Three turbines (3 units of 9 m^3/s each) are proposed for the estimated rated head to achieve maximum energy production at all times.

2. Turbine Types:

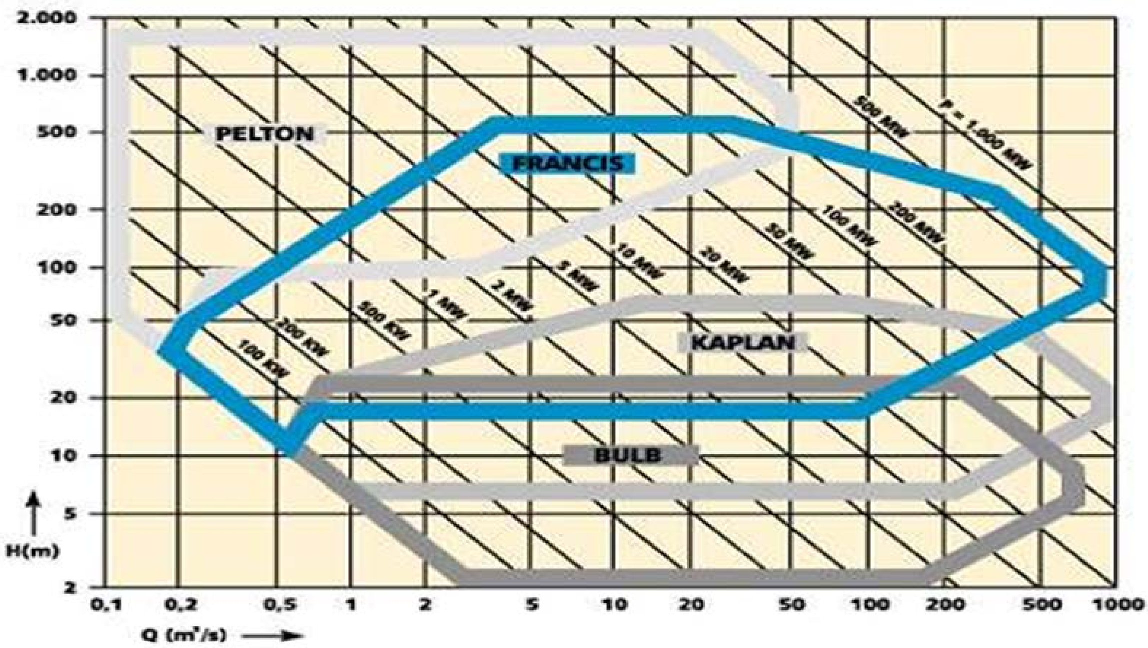
   For the head and flow regime which governs the operation of a hydropower project, both Pelton and Francis turbines lie in the operational range for Mujigram-Shoghore HPP. However, to decide that which one is the most suitable option, a comparative study and analysis has been carried.

   The Francis turbine's efficiency is reduced if operates below 50 percent load for a long time and lead to serious cavitations problems. Moreover, inspection and repair of Francis Turbines is comparatively tedious and replacement of worn out parts is a time consuming job.

However, in case of Pelton turbines, flow can be regulated through the wheel without any loss and can work satisfactorily with moderately silt laden water as it can withstand abrasive action of sediments and yet maintain good efficiency.

As the turbine selection chart gives the options of selecting Francis or Pelton turbines, however, keeping in view the above mentioned analysis we suggest that type of turbine selection will be dependent on reliability of operations, cost effectiveness and availability in the market. See **Figure ES-5.**

Figure ES-5: Turbine Ranges According to Head and Specific Speed



Number of Units

Plant size/installed capacity and configuration i.e. number of units installed to correspond this capacity have been decided on the basis of following considerations as discussed below.

1. Operational reliability
2. Optimization of Plant
3. Cost Benefit analysis

Operational Reliability

Reliable operation is mandatory for maximum output; therefore, in the selection of plant size and number of units, this aspect governs the criteria for smooth operation of the plant. It is an established fact that by increasing the number of units the total project cost will be affected but it is a general practice to select more than one unit to account for redundancy to avoid total energy loss during any maintenance or annual/periodic maintenance of turbines.

Optimization of Plant

Optimization of a hydropower plant is carried out to ensure that plant remains operational for longer periods of time in a year i.e. higher plant factors were available and more annual energy generation achieved even where the given plant size remains the same.

So, it is ascertained that 3 units give us maximum energy generation output and plant factor with same rated discharge as compared to 2 & 4 units. Therefore, we have selected three units as optimum plant size as shown in **Table ES-4** below

However, this type of analysis must be accompanied by an economic or financial analysis which has been performed in this study as discussed below.

Table ES-4: Optimization of Plant at Rated Discharge of 27m^3/s

Units (No.)	Energy Generation (GWh)	Plant Factor (%)
2	231.97	42.37
3	266.83	48.74
4	266.74	48.72

Power and Energy Production Estimates

Having evaluated head losses for machine components, head race and penstock profile, a net head of 280 m has been worked out from site topography. Therefore, the installed capacity will be as under:

$$P\ (kW) = 9.81 \times Q \times H \times \eta t \times \eta g$$

Where,

P	=	Power output in kW		
Q	=	Design discharge in m^3/sec		
H	=	Design net head	=	280m
ηt	=	efficiency of turbine	=	88%
ηg	=	efficiency of generator	=	96%

Flow duration curve method of estimating power and energy has been used for evaluating the generation and energy output of Mujigram-Shoghore Hydropower Project. Energy estimations (without peaking operation) have been done for the period of 1964-2010 to analyze long term performance of the plant at rated discharges of 27, 36 and 40.5 m^3/s which show an average annual energy generation of 274.35 GWh, 312.24 GWh and 328.18 GWh with Plant Factor of 48.74%, 42.77% and 39.96% respectively.

Peaking Operation of Plant

It is very important to assess the provision for peaking operation of plant. Energy calculations with consideration of peaking with the help of reservoir operations have also been done. The results show that there is no significant increase in the energy generation/plant factor for 27, 36 and 40.5 m^3/s which show that an average annual energy generation of 274.35 GWh, 312.24 GWh and 328.18 GWh with Plant Factor of 48.74%, 42.77% and 39.96% respectively shall be achieved.

Considering the prevailing energy crisis in the country and the increasing acceptability of higher tariff by the government, the Mujigram Shoghore Power Plant been evaluated for peaking capacities considering two different scenarios i.e. one for low periods and the other with the surplus availability of water during high flows as discussed below;

- Analysis for the months of November to February

  Analysis of low flow months for peaking reveals that not enough flows are available to generate extra energy by utilizing storage capacity, however advantage of higher tariff for peak hours generation will have positive impacts on financial returns of project but it must be kept in mind that very small off peak generation will be possible in this case. The energy calculations with peaking and without peaking scenarios have been done.

- Analysis for the months of June to September

  Analysis of high flow months in which snow melting rate is higher reveals that water in excess of rated discharge is available which means storage of water can be done during off peak hours and can be utilized during peak hours for daily peaking.

  This can be done in two ways. One is by providing an additional unit for peak operation and the other is to enhance unit capacities for higher rated discharge so that low flow utilization is also ensured by selecting machines with high efficiencies at low flows, say up to 20% of rated discharge.

Cost Benefit Analysis

The results of analysis of peaking operation of the plant for various rated discharges (27, 36 and 40.5 m^3/s) show that there is no significant increase in energy generation/plant factor, however advantages of higher tariff for peaking generation may contribute to economic viability of the project. Therefore plant sizing and optimization necessarily requires a cost benefit analysis incorporating incremental costs and incremental benefits.

Environmental and Social Impact Assessment

Environmental and Social Impact Assessment (ESIA) of the proposed Mujigram-Shoghore Hydropower Project has been carried out as the part of feasibility study of the project. ESIA study has been conducted in accordance with the Guidelines of Pakistan Environmental Protection Agency (Pak-EPA) and other international environmental legislations and guidelines including World Bank Environmental and Social Safeguard Policies.

Aim of the ESIA study is to ensure that proposed development is to be carried out in sustainable manner with minimum adverse impacts on natural and socio-economic environment of the area.

ESIA study provides information on project activities, baseline environmental and social conditions of the project area, positive and negative social and environmental impacts of the proposal and their mitigation measures. Recommendations on environmental management and monitoring measures and institutional arrangements for environmental management and monitoring also make key part of the ESIA study.

In order to conduct the ESIA study, detailed surveys of project area were carried out by environmental and social experts. During the site surveys, primary data related to physical environment (ambient air quality, surface and ground water quality, ambient noise and quality of soils), biological environment (flora, fauna and wildlife including aquatic and terrestrial flora and fauna) and socio-economic environment (demography, education, health facilities, economic status and socio-cultural features) was collected by various experts in their respective areas of expertise. On the basis of data collected, environmental and social baselines of the project area was developed including physical, biological and socio-economic baselines. Desk studies and secondary literature review related to environmental and social aspects of the project have also been carried out while developing the environmental baselines.

On the basis of proposed project activities and their interaction with environmental and social baseline, adverse and beneficial environmental and social impacts of the proposed project have been identified in detail. According to the findings of ESIA report, most of the impacts of proposed project fall under the range of medium to high significance. Appropriate mitigation measures have also been suggested for each adverse impact whereas; for beneficial impacts, enhancement measures have been suggested in ESIA report. Environmental and social sustainability of the project can be ensured by adopting these mitigation and enhancement measures.

The Environmental Management and Monitoring Plan (EMMP) have been prepared for the project which provides:

- A description of the mitigation measures (actions) that PHYDO and its contractors will implement;
- Designation of responsibility for ensuring full implementation of the required actions;

- Parameters that will be monitored to track how effectively actions and mitigation are implemented;
- Time for implementation of the action to ensure that the objectives of mitigation are fully met.

Separate Resettlement Plan (RP) has also been prepared for the project. The purpose of RP is to identify the Project Affected Persons (PAPs), to what degree they will be affected (i.e. what type of loss they will suffer) and how they will be compensated to ensure that they are not adversely affected by the project or left in a worse situation than in a “without project” case. In all cases, the overall aim of RP is to at least restore, if not enhance, the livelihoods of PAPs. Resettlement Plan also identify: i) policy and legal framework for compensation payments and relocation; ii) institutional framework for participation and implementation; and iii) responsibilities for monitoring the implementation measures.

Besides the environmental and social surveys conducted during the ESIA study, separate site visits have also been carried out to collect the primary data related to the resettlement study. During the site surveys following major activities have been carried out:

- Assessment of lands and other assets likely to be impacted by the proposed project;
- Consultation with Project Affected Persons (PAPs);
- Socioeconomic census of PAPs;
- Consultation with relevant institutions such as revenue department, forest and agriculture department and communication and works department.

Power Potential & Plant Operation

Energy generation stimulations were conducted on the basis of historical flow conditions (in flows) of Lutkho River. The project has been planned as run off the river project, however, storage capacity of 0.367 Mm^3 above minimum operation level would be created by damming it. Owning to the gross head of 298 m available within the concession area and flows available from the hydrology of Lutkho River, the project falls in the category of a high head – medium discharge hydropower projects. Pelton turbines have been proposed for the project considering its advantages over other options within this range of head and discharge.

In order to find out an optimum discharge, energy simulations were performed with different values of rated discharges. Cost benefit analysis by drawing comparison between plant factor and energy generation trends with incremental costs shows that the most advantageous rated discharge would fall between 20 – 30 m^3/sec at which the plant factor would be nearly 50%. Annual generation expected would be around 265 GWh. In this back drop optimum rated discharge of 27 m^3/sec has been selected. The study shows that 3 units would give us optimum energy generation output.

Transmission Interconnection

Presently electricity supply to Chitral city is fed through 33 kV circuit from 66/33 kV Dir grid station by PESCO. The Circuit is about 88 km long which originates from 66/33 kV Dir grid station, crosses over Lowari top and passes through 33/11 kV Drosh grid station and terminated at 33/11 kV Jutilasht grid station about 10 km away from Chitral city. The section of the circuit which crosses over the Lowari top has to remain under weather stresses due to heavy rainfall or snow falls badly hitting this section thus resulting in cut-off of the supply of electricity to Chitral city from national grid. When this situation arises, the Chitral city and surrounding area are partially supplied electricity from micro hydel power stations situated in the valley through existing 11 kV PESCO network.

Various options for dispersal of power from Mujigram-Shoghore HPP to the national grid have been envisaged in **Chapter 12 of Main Report**. Briefly in Option-I, a 132 kV transmission line may originate from Mujigram-Shoghore HPP and will be directly connected to proposed 220/132 kV Chitral grid station. In Option-II the evacuation of generation from Mujigram-Shoghore HPP to proposed 220/132 kV Chitral grid station may be carried out through two 132 kV transmission lines. One transmission line will be directly connected with 220/132 kV proposed Chitral grid station and other will be connected with 132 MW Shogo-Sin HPP via an In/Out arrangement. In Option-III 132 kV double circuit transmission line may originate from Mujigram-Shoghore HPP and will be directly connected to 132 kV bus bar of Shogo-

Sin HPP which is about 6 km downstream of Mujigram-Shoghore HPP, from where the combine generation of both hydro projects will be transmitted to 220/132 kV proposed Chitral grid station.

Construction Materials

For any project involving civil works, large quantities of coarse aggregate, fine aggregate, cement, pozzolans, fly ash, construction chemical and reinforcing steel are required besides fill material for hydropower projects involving construction of rock fill dams. Availability of construction materials in close proximity of the project substantially reduces the cost.

During geological survey and mapping of the project area, sources of coarse aggregate, fine aggregate and fill material were identified. Following sources of aggregates have been identified.

Coarse Aggregate

Marble exposed along road from Shoghore to Chitral can be quarried for production of good quality coarse aggregate. Besides marble, significant deposits of Granodiorite and limestone were identified a few kilometers downstream of Chitral Town where existing quarries can either be expanded or new quarries developed. Laboratory tests conducted on the samples testify their suitability on the project.

Materials for Embankment Dam

Fill materials shall be required for the main embankment section as well as for the upstream and downstream coffer dams. The proposed main embankment section of Concrete Face Rock Fill Dam (CFRD) has been divided into following material zones;

- Rock-fill (W)
- Sandy gravel bedding material (B)
- Sandy gravel transition material (S1)
- Downstream slope protection (P)

The types of rocks which are expected from these excavations comprise slate, and some portion of phyllite. These rocks are quite suitable for use as random rock fill for the shoulders of the proposed embankments. Materials for sandy gravel bedding and sandy gravel transition zones can be produced from any of the following two options;

- Processing of river bed alluvium
- Processing of scree deposits

A number of deposits for the impervious fill materials have been identified near Shoghore and also upstream of Mujigram & Garam Chashma.

Fine Aggregate

For fine aggregates, two potential sites were identified. One of the two is near Chitral airport and the other area is near Ayun. Although these two deposits are in sufficient quantities to meet the project requirements yet, fine aggregates can be produced from crushing suitable rocks present in the vicinity of the project area.

Other Materials

As cement is abundantly available in the country and factories around Wah and Islamabad can meet the project demand. Slag cement is also produced by a number of plants in the south and is amply available in the country.

Steel re-rolling mills in Islamabad, Nowshera and Peshawar produce rebars meeting ASTM A615 standards from the billet produced by Pakistan steel. These mills met the requirements of Tarbela, Ghazi Brotha and other projects in the region therefore, no shortage is foreseen.

Lutkho River water is quite suitable for use on the project and can be easily managed.

Transportation Study

Projects, involving safe transport of large sized and heavy equipment to areas long distance away from the seaport is challenging in developing countries especially when the projects are located in mountainous regions. Since, Mujigram and Shoghore are nearly 1840 km from Karachi port, it needed careful planning and required focused study of the roads, their grades, curvature of bends, adequacy of culverts and bridges and underpasses so that transportation of equipment could be safely carried out.

Although option for transport of equipment from Karachi to Dargai by railway was available but due to near collapse of Pakistan Railways, this option has been ruled out. Transport of equipment, therefore, would be made by road on low bed trailers. Transportation of equipment will pose no serious problems, since experienced and well equipped transporters are available in country who successfully handled equipment for Tarbela, Ghazi Brotha, and Nuclear Power plants at Chashma and large industrial plants in the northern parts of the country.

Karachi – Hyderabad – Rahim Yar Khan – Multan – Lahore - Rawalpindi – Mardan – Dargai – Chakdara – Dir – Darosh – Chitral – Shoghore is the recommended route which is generally followed for transportation of goods from seaport to Chitral and beyond.

Project Construction Planning

General

Based on the project scope, bill of quantities, sequence of activities and their inter-dependence, the expected weather and hydrological conditions at site, available working days, a construction period of four (04) years has been envisaged excluding period for preconstruction activities, testing & commissioning of the plant. Implementation schedule assumes that the contract will be awarded to an experienced and qualified contractor with experience of executing similar projects and exposure to local conditions including harsh weather and remoteness from a nearby town.

Contract Packaging

This project is anticipated to be executed under EPC contracting under which, the contractor manages all engineering design and construction activities together with series of civil construction and permanent equipment supply, installation and commissioning packages.

It is expected that contracts will be awarded to a number of civil works contractors with capabilities to undertake construction of different elements of civil works.

- River diversion and dam/weir construction, power tunnel intake and desanders.

- Power tunnel including forebay and spill weir, valve chamber and penstock.

- Power house complex and switchyard.
- Relocation of a section of Shoghore-Garam Chashma Road.
- Power house equipment, switch yard and hydro-mechanical equipment like gates hoists, trash racks, steel liners etc.

Construction Sequencing

Generally, construction of weir/embankment dam, diversion tunnel, weir intake structure, headrace tunnel, power house, tailrace channel would proceed in parallel followed by installation of mechanical and electrical equipment. Sequence of activities has been incorporated in the implementation schedule.

- Mobilization
- Project Infrastructure building
- Diversion tunnel
- Embankment dam/weir/spillway
- Power canal intake, desanders and flushing channels
- Head race tunnel, forebay and penstock
- Construction of power house and switch yard

Construction Equipment

A list of major construction equipment may be seen hereunder however, selection of the equipment shall be judiciously made by the contractor keeping in view his construction methodology and schedule of completion.

- Stone crushing plant for aggregate production.
- Dozers
- Dump trucks
- Front end loaders
- Jumbo drilling machine

- Rock bolting jumbo
- Pressure grouting equipment
- Shot-creting machine
- Stand by Emergency generators
- Air Compressors
- Axial flow ventilating fan
- Concrete batching plant with cement silos
- Transit mixers
- Concrete pumps
- Rebar bending machines
- Blasting machines
- Vibratory roller/compactor
- Concrete vibrating equipment
- Water pumping equipment
- Road Grader
- Boursers
- Tractor with trolley

Project Schedule

Figure Es-1 shows the schedule of activities, it includes a pre-construction period and construction period. Pre-construction schedule includes major activities leading to award of contract. Key activities include completion of additional studies and investigations as required, financial close and environmental approvals.

Figure ES-1: Project Activities Schedule

Sr. No.	Item of Work/Activity	Years																													
		2014				2015				2016				2017				2018				2019				2020				2021	
		1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd
1.0	**Preconstruction Activities**																														
-	ICB Process			■	■	■	■																								
-	Financialo Close							■	■	■	■	■	■																		
-	Detailed Design									■	■	■	■																		
2.0	**Project Construction Work with Detailed Engineering Design of Project Components**																														
-	Mobilization													■																	
-	Project Infrastructure building														■	■	■														
-	**Construction of:**																														
-	Embankment Dam/Weir															■	■	■	■	■	■	■	■								
-	Intake Structure																	■	■												
-	Desanders																			■	■										
-	Power Tunnel															■	■	■	■	■	■	■	■	■	■						
-	Forebay																					■	■								
-	Penstocks																							■	■						
3.0	**Power House Including Tail Race**																														
-	Construction of Power House & Tailrace															■	■	■	■	■	■	■	■	■	■	■	■	■	■		
-	Procurement of Equipment																	■	■	■	■	■	■	■	■	■	■				
-	Swtichyard Construction																					■	■	■							
-	Errection																								■	■	■				
-	Testing & Commissioning																											■	■		
-	Trial run & handing over																													■	■
-	Transmission Line																			■	■	■	■	■	■	■	■	■	■		

Project construction schedule is split into major work areas that are grouped according to nature of the structures such as embankment dam/weir, intake structure, desanders, power tunnel forebay, penstock and power house etc. The schedule has been developed by selecting the sequence of activities and duration of tasks keeping in view the local conditions and production rates based on scope of work.

Overall construction period from notice to proceed to commercial operation of the units is expected to take about 48 months. The duration of testing and commissioning, trial run and heating over is expected that the entire power plant will be fully operational in four years excluding period for financial close.

Cost Estimates

Project cost is estimated to be 178.54 million US dollars, as shown in the **Table ES-5** below for project cost estimates, these cover cost of civil works, electro-mechanical equipment, and switchyard. While preparing overall cost estimates additional allowances for shipment and transport, erection commissioning and testing charges, engineering and supervision, management costs, contingencies and regulatory duties have been made.

June 2013 price level has been considered whereas exchange rate at 100 PKR = 1 US$ has been taken.

Financial and Economic Analysis

Financial and economic analysis have been carried out to see that with the proposed investment the project is economically and financially viable or not. The details of economic and financial evaluation is presented in the subsequent paragraphs.

Economic Analysis

The purpose of this economic analysis is to see justification of the project from an economic perspective and to demonstrate that the proposed investment is an economical viable option. The analysis compares net benefits from implementing Mujigram-Shoghore Hydropower Project against an equivalent thermal plant.

Table ES-5: Project Capital Cost

Item	US$ Million
EPC	146.600
Taxes & Duties	1.52
Emergency Spare Parts	0.411
Contingencies @ 2 % of Civil Cost, Preparatory Works and E&M	2.93
Transportation & Port Clearance 2% of Imports	0.608
Mobilization Payment to O & M Contractor	0.400
Start up Expenses	0.200
Independent Engineer as per PPA	0.04
Implementation Consultant @ of 6% of EPC Cost	8.796
Total CAPEX	161.510
Financing Fees & Charges	4.790
Interest During Construction (IDC)	12.242
Total Project Cost	178.542
Capital Structure	
Equity	35.7084
Debt	142.8335
Total Project Cost	178.5419

Methodology

The economic viability of a project can be established with either “Marginal cost” or “Alternative cost” methods.

Long Run Marginal Cost (LRMC)

A classic definition of LRMC of generation is defined as the levelized cost of meeting an increase in demand over an extended period of time. It is calculated by determining the difference in the NPV of two optimal generation development (installation) programs over an extended period (say 30 years). Each of the optimal generation programs utilizes existing generation plant, committed developments and the most efficient new generation entry. Sunk costs are not included in the analysis.

An important aspect of this definition is that it determines the marginal cost of supply based on utilizing existing and new generating capacity. Consequently, this definition can yield very different LRMC results depending on the current demand/supply balance and the amount of committed new generation. When excess capacity exists, additional energy can be supplied at close to short run marginal cost, as there is sufficient capacity to supply the additional demand. When there is no excess capacity the marginal cost of producing additional energy includes the full costs of capacity and operations.

The above description of LRMC is mostly suited under the scenario when existing power generation capacity is capable of meeting the demand and additional capacity is planned in the system to meet the growing demand.

The alternative cost method has been used extensively in case of feasibility of Basha Dam and Neelum-Jhelum hydropower projects. Based on the analysis on the above projects, the consultants have rejected the LRMC option for economic evaluation of the project. Rather in both of the above projects alternative generation options have been adopted for economic evaluation.

Accordingly to express economic feasibility of the project the “alternative cost” method has been used mainly because of the fact that under the current power-mix in Pakistan, a thermal based plant will have to be established to meet energy needs if the hydro is not built. The purpose of the analysis is to take the life cycle cost of the hypothetical thermal plant and compare it with the life cycle cost of the Mujigram-Shoghore Hydropower Plant.

In this case a Combined Cycle Gas Turbine (CCGT) plant is used for comparison with the proposed hydro scheme as their sizes can be closely matched with a CCGT.

In this case it has been assumed that the proposed plant will produce 275.83 GWH over project cycle.

Net benefits have been established by subtracting annual cost aggregates of the thermal equivalent alternative from the respective cost aggregates of the proposed hydropower plant. Accordingly for the proposed hydropower plant, the net benefits were used to calculate EIRR and in addition, NPV has been calculated based on the economic discount rates.

Thermal Power Parameters

Our base case assumptions for the thermal equivalent are summarized in **Table ES-6**

Table ES-6: Technical Characteristics and Assumptions for the Thermal Equivalent

Specific Capital Cost	1,200 US$/kW
Fixed O&M	22,000 US$/MW/yr
Plant Availability (annual)	63
Economic Discount Rate	10%
Construction Period	4 year

Results and Discussions

The economic model results are expressed in three key parameters:

- The Net Present Value (NPV)
- The Economic Internal Rate of Return (EIRR)
- The Benefit Cost Ratio (BCR)

The NPV represents the additional discounted total life-cycle cost to the economy if a particular scenario is not realized and the alternative thermal (CCGT) power station is constructed in its place. The EIRR is defined as a discount rate over the construction/rehab period and operating life of the project which balances the gross incomes of the proposed hydropower plant with their Capital costs.

The economic model results are summarized in the following **Table ES-7**

Table ES-7: Mujigram-Shoghore Economic Comparison Indicators (30-year life-cycle)

Benefit Cost Ratio (B/C)	3.702
Net Present Value (NPV)	US$ 751.4 Million
Economic Internal Rate of Return (EIRR)	19%

The results of the economic analysis show very clearly that construction of Mujigram-Shoghore HPP is viable from economic point of view as compared with a thermal equivalent project. The EIRR is higher than the acceptable levels under prevailing market requirements and at the same time the positive NPV also shows the project viability. Basically the prevailing vulnerability of gas prices in the world market favor hydropower facility.

Further, a thermal alternative is more sensitive to the increase in gas prices. Under current market trends and expectations thermal generation in the future will not be favored against hydro projects, even if those impose significant environmental and social costs that not quantify in this analysis.

Financial Analysis

Methodology

This section provides a description and discussion of anticipated financing conditions and the proposed levelized tariffs (average of scaled end and distribute rates) required to achieve financial viability. The financial model developed for the purpose is based on information currently available as well as provisions available in the prevailing power policy and applicable framework of the Government of Pakistan. For future costs and revenues reasonable assumptions have been applied as provided by the sources.

The financial model is primarily in the form of a discounted cash flow series which evaluates the net cash flow without taxes received over the construction period and operating life of the project. A range of key financial indicators are developed through the model to support the investment decision. At present, a 30-year project operating or life cycle period has been assumed for financial evaluation although the asset life is likely to be longer than this and may even extend beyond 50 years. Any expected residual value has not been counted for the purpose of this financial analysis as it would further support the implementation of hydropower facility. It should be noted that the positive financial analysis would be even more favourable in such case.

It is assumed that the source of financing would be primarily from international lending institutions. All assumptions as well as the loan repayment period and the interest rate are shown in following **Table ES-8**. However, the final decision on financing will be based upon the market condition at the time immediately preceding the financial of the project.

A levelized tariff has been calculated using annual discount rates of 10%. The project would be built to be interconnected with the national transmission grid and it is assumed that the project power output will be delivered to the grid as generated using the prevailing river flow. It is also assumed that PHYDO is not supposed to sell electricity to ultimate consumers' and will only sale power to NTDC at plant's out going bus bar as being done with other IPPs plant. Accordingly losses incurred in power transmission and distribution has not been taken in to account.

Table ES-8: Financial Data – Data for the Tariff Calculations

	Value
Plant Price US$ Million	146.60
Financial Assumptions	
Debt	80%
Equity	20%
Six Month KIBOR	9.50%
Foreign Debt (LIBOR)	0.50%
Margin for WC	3.00%
Premium for Rupee Loan	3.00%
Premium for $ Loan	3.00%
Equity IRR	18.00%
Withholding Tax on Dividends	0.00%
Discount Rate	10.00%
Financing Fee	3.00%
Insurance	1.35%
Emergency parts	1.35%
Taxes & Duties	5%
Variable O & M rate	0.0300
Fixed O & M	0.02

The financial analysis does not take into consideration the Certified Emission Reduction (CER) credit from the Clean Development Mechanism (CDM) of the Kyoto Protocol.

The transmission line cost has not been included in the Project cost on the assumption that power transmission is the responsibility of the power purchaser under the prevailing practice in Pakistan.

One should note that the average plant factor takes into account the equipment, the flow conditions of the Latkho River as well as technical advancement available at the time of writing of this report.

For the financial evaluation a 30-year project operation has been assumed for both power plants but it is expected that the equipment and infrastructure will last longer than this. All general project data applied in the model are summarized in the **Table ES-9.**

The total annual generation and others technical values applied in the model are summarized in the **Table ES-10**

Table ES-9: General Project Data

Description	Units	MSHP
Project Term	Years	30
Investment Start	Date	2014
COD	Date	2018
Construction Period	Years	4

Table ES-10: Technical Data

Description	Units	MSHP
Best Efficiency Output [Installed Capacity]	MW	64.26
Average Plant Factor	%	49%
Total Annual Generation	GWh	275.83

Model Results

A number of key financial indicators are determined through the financial model, over an operating life spanned over the project period (30 years).

Levelized Tariff determines how competitive the project is likely to be. It represents the average real electricity tariff that would be required over the evaluation period to return a zero NPV for discount rate at 10%. It is quoted in US c/kWh.

Net Present Value (NPV) represents the present value (in July 2013 terms) of the net cash flows from the project, before any corporate tax that may be applicable.

The Internal Rate of Return (IRR) represents the real discount rate at which the project's (NPV) before tax is zero.

Outcome of the financial model is shown in the **Table ES-11**.

Table ES-11: Results

Description	Units	MSHP
ROE	%	18%
Levelized Tariff	US c/kWh	8.77
Internal Rate of Return	%	11.9
Benefit-Cost Ratio	-	1.15

Conclusions

Following are concluded from the study:

- On the basis of detailed analysis of power potential and plant operation options, it has been concluded that a rated discharge of 27 m^3/s with 28% of availability of time giving 269.63 GWh average annual energy generation under normal operating conditions with plant factor of 48.74% & is the most suitable option. It must also be noted that with same rated discharge, peaking operation of plant increases the plant factor to 49.33%, giving additional energy of 14.11 GWh.

- The financial model developed and analysis done for this project indicate that it is an overall economically and financially feasibility project. Although assumptions were required to establish the base case, key values in these assumptions were varied to show their sensitivities and arrive at more robust results. The analysis also shows that the project is more sensitive to the variation in energy potential and/or the discount rate and the increase in capital cost. However, it is less sensitive to variations in operating costs. Also the variations induced in the key parameter do not affect the overall financial feasibility of the project.

Recommendations

A power plant with installed capacity of (3 x 21.42) 64.26 MW is recommended for further study.

- Observations and recordings of flow and sediment data should be continued to build up a data bank to make available as much data as possible for detailed design stage.
- Model studies of the spillway, intake structure and desanders may be carried out to confirm the following:
  - Functioning of low level outlets at the dam/spillway
  - Sediment flushing
  - Efficiency of desanders
- Integrated planning of dispatch and transmission of power produced by the Chitral Valley projects to the National Transmission and Dispatch Company.

In view of the power shortage in the country, the project is recommended to be implemented on fast track.