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# 1. HYDROPOWER ENGINEERING

## 1.1. HISTORY OF HYDROPOWER DEVELOPMENT

Wind and running water were the only available sources of mechanical power (Fig: 1-1), other than animals from the time immemorial. In the past waterwheels were used for milling, pumping and lifting water from a lower to a higher elevation for irrigation. Water wheels of various types are still used in many countries. In Northern Areas of Pakistan and Azad Jammu and Kashmir water wheels are being used for grinding grains. Ancient water wheels are undershot, breast shot and overshot type. However, under shot is the oldest type.

The attempts to improve the efficiency of the waterwheels contributed to the development of hydroelectric plants. Aiming at the improvement of the turbine efficiency, which went up to 60-70 % in mid 1850s, extensive theoretical work was done by mathematicians and engineers between 1750 and 1850. However, the utilisation of water turbines in the production of electricity became popular after the invention of dynamo or generator in 1880s. The birth of electric power supply was marked by the opening of 12.5 kW plant on the Fox River near New York USA. The supply of electricity to a number of consumers in parallel had been mastered. Improved design of generator and motor were presented in rapid succession and multi-phase motor proposed by Tesla in 1888 opened the practical use in industry. However, the use of arc lamps for lighting (which was supplanted by incandescent bulbs) dates back in 1822 in USA, 1876 in Germany, 1879 in Switzerland.

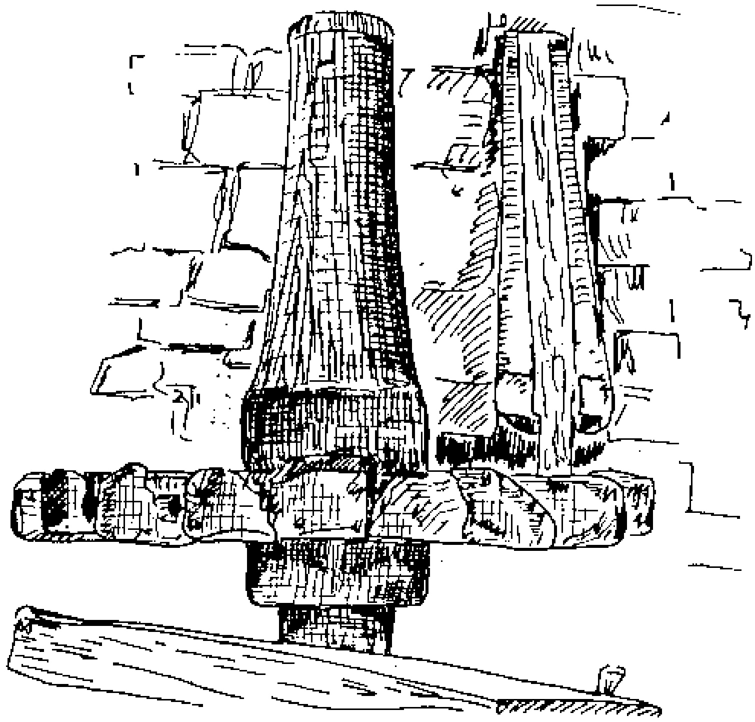

**Figure 1-1 Pre-Historic Use of Water Energy**

Many small hydroelectric plants were installed thereafter, to satisfy the local demand in most cases for lighting and small industry. The ability of hydroelectric plants to provide electricity for the large population centres was possible after a long distance transmission line was tested in 1891 (177 km from Lauffen to Frankfurt, Germany). With the development of high voltage transmission lines in early parts of the twentieth century and turbine technology, development of large-scale hydroelectric plants feeding into extensive distribution grid became popular. The same trend was observed for thermal plants in most industrialised countries. The development of hydropower increased during the second half of the 19th century, when the utilisation of low head hydropower potential was initiated.

For the generalisation of this 'synthetic' power using water, we will use the term hydropower in the subsequent chapters. Readers may find in the literature useful details on the history of development of hydropower.

## 1.2. MAIN ENERGY RESOURCES

The sources of energy that nature provides are renewable or non-renewable. The non-renewable sources of energy include natural gas, fossil fuels, coal, timber, etc. Renewable resources are water, solar, tidal, geothermal, nuclear etc. The exploitation of non-renewable resource has brought unprecedented impacts on the global environment at present stage.
The atmospheric contamination due to combustion of gases and global warming due to increase in $CO_2$ emission are the glaring examples of these impacts. Even the " World Conference on Environment" in Rio de Janeiro in June 1992 failed to slow down the $CO_2$ emission in the global sense. However, it had helped to create awareness among the nation about the problem (Victoria, 1995). Increasing prices of fossil fuels, results that petroleum resources will be exhausted in relatively short period of time. Their use for political purpose is adversely affecting worldwide economic and social development. The impacts of energy crisis are more severe in less developed countries, where development budget must be diverted to the purchase of imported petroleum products. Therefore, to reduce this dependence on imported fuels with high price volatility, most countries have initiated programmes to develop alternative source of energy based on renewable resources. The development of nuclear power has also constraints of its own at present level of technological development.

## 1.3. MAIN TYPES OF ELECTRIC POWER PLANTS

Electricity can be generated in different ways. In some cases fuel being used is totally consumed and in other cases only recycling is being done. However, generating electricity does impose some environmental problems, no matter how important this energy is contributing.

### 1.3.1. THERMAL POWER PLANTS

In these types of plants fossil fuels such as coal, natural gas and/or oil are being used as raw material. One kind of energy, which can be directly used, is being consumed to produce other type of energy. The following paragraphs contain a brief description of the main types of thermal power plants.

#### 1.3.1.1. COAL FIRED STEAM POWER PLANTS

Coal fired power plants have been the main means of power generation in many countries. The coal is fired beneath the boiler and water is used for the preparation of steam. The steam is then used to run the turbine, which drives generator for electricity production.

#### 1.3.1.2. OIL AND GAS STEAM FIRED PLANTS

These power plants are similar in design and operation to coal fired plants. However, these are normally smaller in size due to clean burning of oil and gas as compared to coal burning. In gas-fired boilers the primary combustion air is combined with gas prior to ignition and secondary combustion air is introduced into the furnace to complete the combustion process. In oil fired plant fuel must be vaporised before combustion can take place. Therefore, efficiency of an oil-fired plant depends upon fuel-air mixing and atomisation.

#### 1.3.1.3. DIESEL POWER PLANTS

These diesel power plants are based on the principle that the heat of compression causes auto-ignition due to high compression ratio and supplementary electric ignition is not required. However, some electrical starting aid is usually required. In these diesel engines fuel of any kind can be used. Diesel engines are very difficult to start under a load and must be connected to the generator by a variably coupled transmission system. Their use as emergency generator is very much proved.

### 1.3.1.4. COMBUSTION TURBINE

The combustion turbine is joule cycle with adiabatic compression, isobaric heating and adiabatic expansion. The work of such cycle is the difference between the work of expansion and that of compression.

### 1.3.1.5. COMBINED CYCLE TURBINE

It is a system in which hot turbine (combustion) exhaust gases are used to generate steam in a boiler to drive a steam turbine. The boiler may be designed for supplementary fuel firing and combustion turbine may be only a small part of the total plant. The system can produce additional power up to 40 %.

### 1.3.2. NUCLEAR POWER PLANTS

The most used types of reactors for power production in the world are boiling water reactors and pressurised water reactors. The energy generated fission process of fissile atom such as U235 is used to produce steam, which will be used to run a steam turbine. There are other types of reactors used for power production such as the heavy water reactor.

### 1.3.3. WIND MILL

It is also a well-known dependable technology, which has experienced considerable development in recent years, especially in developed countries. Now units with capacity up to 1.5 MW are being installed at different places, mainly wind parks. Wind energy for pumping water and generating electricity in small quantities is being used since many years. Wind units require less maintenance and can last for 10 to 20 years. Generated unit cost is normally high and depends on the regime of the wind at the site and height above ground of the propeller throughout the year. On the other hand, the specific cost is strongly affected by the economies of scale.

### 1.3.4. SOLAR /PHOTOVOLTAIC CELLS

It implies the direct conversion of the visible part of sunlight to electricity. It is one of the cleanest and ecologically most attractive methods of converting solar energy into high-grade energy. Solar cells require less maintenance and the cost of energy produced is essentially constant. Present costs of these systems are still high. It is considered as the energy source for the future. It is costly at present level of technology, however, it is projected that the intensive research could reduce the capital cost fourfold within next few years.

### 1.3.5. BIOMASS

There are different ways by which biomass resources can be converted into fuels suitable for thermal generation of electricity. The most important are:

- Biomass-fuelled steam generators
- Gasifier/engine generator
- Ethanol

Biomass fuelled steam generators are widely used in the forest industry and in agricultural processes (sugar mills). The unit cost of these systems is higher than that of oil, coal or gas fired boilers because of lower energy density of biomass fuel and expensive material handling systems.

Small biomass gasifiers producing a low energy combustible gas can be coupled with internal combustion engines to produce electricity. These units were widely used during World War II and today no standard units are being manufactured.

Biomass can also be converted to ethanol through fermentation of sugar crops. This technology is well established. Ethanol can be used to replace petroleum in internal combustion engine generator systems.

However, biomass (wood, straw, grain, etc.) systems can create significant environmental problems such as:

- Careless harvesting
- Disposal of ash or spillage from ethanol.
- Disruption of ecological cycle such as source of food, feed and fibre.

### 1.3.6. HYDRO ELECTRIC POWER PLANTS

Hydroelectric power is achieved by converting the potential and kinetic energy of water by electro-mechanical means. Hydraulic energy is a very attractive source of energy because it is:

- Renewable
- Non polluting
- National / domestic
- Oldest
- Reliable
- Flexible.

Hydropower can be a key to self-reliance for any country with sufficient potential because of being a completely national resource. It also helps to reduce dependence on imported fuels. The hydro energy exploitation offers an insurance against external factors. It is infinitely renewable and immune to fluctuations in the economy. It is the oldest kind of energy. Since some projects are labour intensive, they can help to reduce the unemployment.

## 1.4. ROLE OF HYDROPOWER

To save the life on earth for future generation, humankind has already started to think and act over the sustainable use of natural energy resources. In this context, the use of renewable sources of energy in general and hydropower in particular, play a vital role, if properly managed. Although, the future for the development of the solar, wind, tidal, geothermal, nuclear power is unlimited, these forms of energy are not in wide use because of present level of technological development, which requires highly sophisticated innovations. Additionally, there are also many environmental implications in using these sources of energy. However, hydropower is the source of energy, with environmental impacts that comparatively, can be mitigated. Based on the past experiences on the use of this energy elsewhere in the world and the present level of technological development, one can still find hydropower as a source of environmentally friendly renewable energy for many years to come. Since water is not only the source of energy but also the most important means to sustain the life by providing drinking water and irrigation at the local level and keeping the hydrological cycle in global level, it is highly desirable to exploit these resources judiciously.

## 1.5. BASIC THEORY OF HYDROPOWER

### 1.5.1. FUNDAMENTALS

Below some relevant concepts and important terminology are presented. These will be used in defining basic theory on which hydropower is based.

#### 1.5.1.1. WORK

Work is the transferred energy and is the product of force and distance moved. It is measured in lb-ft or Joules.

### 1.5.1.2. ENERGY
It is the capacity to do work. The work done by water in producing electrical energy is usually measured in kWh (kilowatt hours). The energy from water can either be potential energy (by virtue of position) or kinetic energy (by virtue of the movement).

### 1.5.1.3. POWER
Power is the rate of transferring energy or work per unit of time. It is measured in kW (kilowatt) and hp (horsepower). Power capacity is often used to refer rated capacity of the plant.

### 1.5.1.4. DEMAND
It is the amount of power needed or desired by the consumers connected to a network or power system.

### 1.5.1.5. LOAD
Is the rate at which electrical energy is actually delivered to or by a system.

### 1.5.1.6. DISCHARGE
Water discharge is the total volume of water passing through a fixed section of the plant in unit time.

#### 1.5.1.6.1. FULL GATE DISCHARGE
Is the flow condition, which prevails when the turbine gates or valves are fully open. The maximum discharge will flow through the turbine at maximum rated head and full gate opening.

#### 1.5.1.6.2. RATED DISCHARGE
It is the discharge, which at rated head produces the rated power output of the turbine.

### 1.5.1.7. HYDRAULIC HEAD
It is the elevation difference the water falls in passing through the plant.

#### 1.5.1.7.1. GROSS HEAD
It is the difference between headwater (water in the forebay or impoundment supplying the turbine) elevation and tail water (water at draft tube exit) elevation.

#### 1.5.1.7.2. NET HEAD
It is the effective head on the turbine and is equal to the gross head minus the hydraulic losses before entrance to the turbine and outlet losses.

#### 1.5.1.7.3. DESIGN HEAD
Refers to the effective head for which the turbine is designed for best speed and efficiency.

#### 1.5.1.7.4. RATED HEAD
It is the head at which full gate discharge of the turbine will produce the rated capacity of the generator.

#### 1.5.1.7.5. CRITICAL HEAD
Corresponds to the head at which full gate output of the turbine produces the permissible overload on the generator at unit power factor. This head will produce maximum discharge through the turbine. It is used in studies of cavitation and setting of turbine.

## 1.5.2. HYDRAULIC FUNDAMENTALS
Hydroelectric power is achieved by converting the potential and kinetic energy of the water into electrical energy by electro-mechanical means (Turbines and Generators). Therefore, the hydraulic fundamentals in hydropower engineering address the conversion of potential and kinetic energy into electric energy.

Now we develop the fundamental theory considering that a volume of water **dV** moves from position 1 to position 2 (Fig: 1-2) and the work done by this volume is

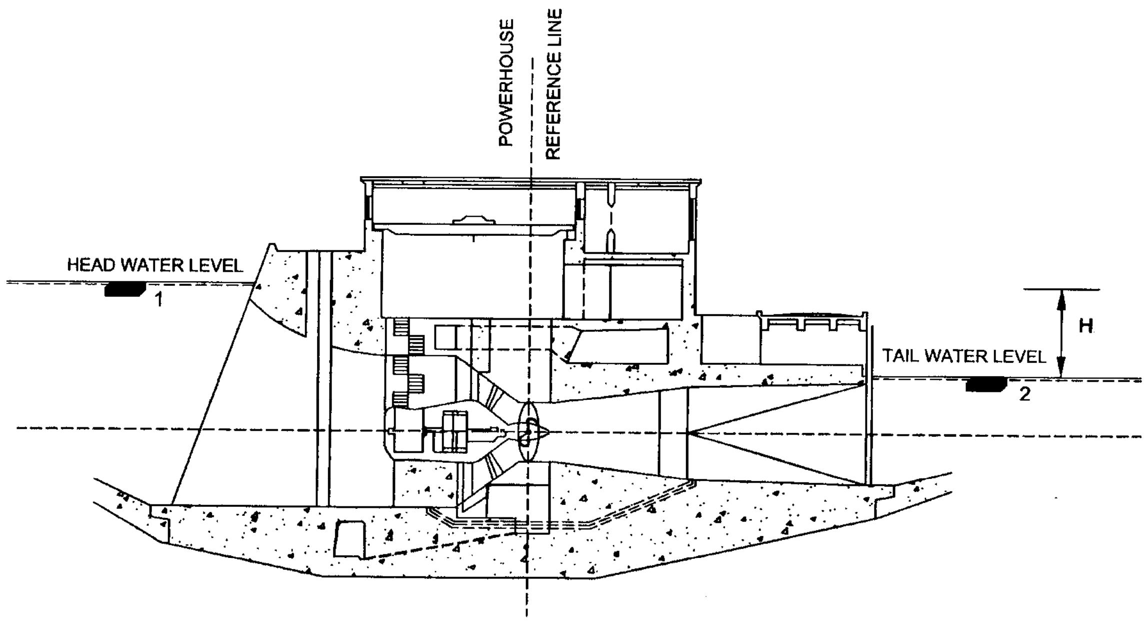


**Figure 1-2 Water Movement /Water Energy.**

WORK = FORCE * DISTANCE

dW = $\gamma * g * dV * h$ .......................................(1)

Where

| | | |
|---|---|---|
| dW | = | Work done by mass of water |
| $\gamma$ | = | Density of water |
| g | = | Acceleration due to gravity |
| dV | = | Volume of water |
| h | = | Vertical distance moved by the volume of water |

This equation actually represents the energy that the volume of water has at position 1 with respect to position 2.

Now if this volume of water takes some time **dt** to move from 1 to 2, then the flow of water **q** is determined as:

Discharge = Volume per unit of Time

q = dV / dt ....................................................................(2)

But the power extracted by the water is the rate of work done and can be mathematically written as:

Power = Work / Time
dp = dW / dt ..................................................................(3)

After substituting equation 1 in equation 3 we get

$dp = \gamma * g * dV * h / dt$

Equation 2 can also be written as $dV = q * dt$, therefore the previous equation can now be written as:

$dp = \gamma * g * dq * dt * h / dt$

which after integration over time reduces to:

$p = \gamma * g * q * h$

This equation actually gives the theoretical power expressed in $kg*m/s^2$. It is also expressed as:

$P = \gamma * g * q * h / 550$ (hp)
$P = \gamma * g * Q * H / 1000$ (kW)

Where

- $P$ = Power capacity, (kW)
- $Q$ = Discharge through turbine, $m^3/s$
- $\gamma$ = Mass of water, $kg*s^2/m^4$
- $g$ = Acceleration due to gravity, $m/s^2$
- $H$ = Gross head, m
- 1000 = Number of watts in 1 kW

But in SI system of units

$\gamma = 1\ kg*s^2/m^4$
$g = 9.806\ m/s^2$

Therefore, the actual output is reduced by the fact that the turbine and generator have losses in transforming the potential and kinetic energy into mechanical and electrical energy. Thus actual power output will be

$P = 9.806\ Q * H * \eta$ .....................................................(4)

Where

- $\eta$ = Overall plant efficiency
- $\eta = \eta_t * \eta_g$ (turbine efficiency * generator efficiency)

But actually

$\eta = \eta_t * \eta_g * \eta_t$ ( turbine * generator * transformer efficiency)

The discharge through turbine is generally a fraction of the water flowing in the river/canal/stream. It should be noted that this is not the maximum river/canal/stream discharge because normally due to economic, environmental and technical reasons it is not always possible to select the turbines for the maximum available flow. The choice of plant discharge is in most of the cases an economic problem rather than technical.

Gross head is the elevation difference between headwater and tail water. The headwater level may vary according to may factor such as the storage level when some sort of regulation is available (reservoirs, forebays, etc) or simply the rate of inflow in case of run-of-river plants Similarly, the tailwater levels may also depend on many factors, such as river discharge, interaction with downstream reservoirs, etc.

The effective head is calculated by subtracting losses from gross head. The losses (Fig: 1-3) may be such as;

- Losses at canal entrances.
- Energy losses in open channels.
- Entrance losses due to contraction.
- Losses due to expansion.
- Friction losses in the pipe/passage.
- Losses due to stop log slot, gate slot and transition.
- Losses due to trash racks
- Losses due to bends

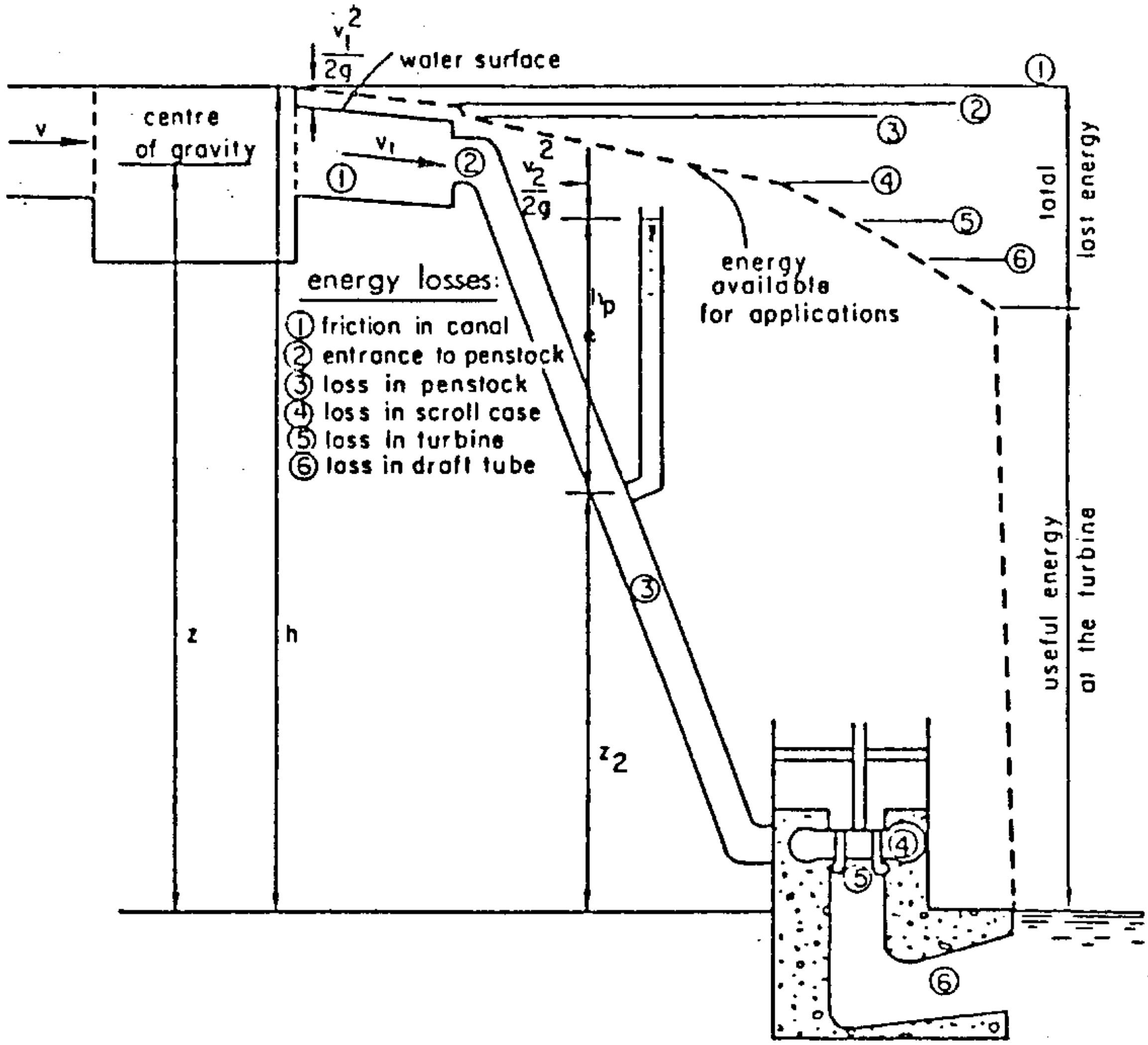


**Figure 1-3 Hydraulic Losses Through Turbine Passage**

## 1.6. CLASSIFICATION OF HYDRO POWER PLANTS

### 1.6.1. INTRODUCTION

There are a large variety of hydropower plants constructed in the world, in terms of their use, structure, purpose and technical characteristics. These are named differently such as low head plants, base load plants, storage plants, run-of-river plants, etc. To understand the different terminology used for the classification, it is important to mention the different types of plants being used in the world.

### 1.6.2. CLASSIFICATION ON THE BASIS OF TECHNOLOGICAL ASPECTS

Technologically hydropower plants can be classified such as:

1. Plants utilising the energy of flowing water (rivers, canals, etc) and of lakes fed by natural phenomena such as, rain, snow, etc.
2. Pumped-storage plants.
3. Plants utilising tidal energy of the ocean.

#### 1.6.2.1. PLANTS UTILISING THE ENERGY OF FLOWING WATER & LAKES

This type of power plants can be grouped into two main types such as

- Plants without storage (Run-of-river plants).
- Plants with storage.

#### 1.6.2.1.1. PLANTS WITHOUT STORAGE (RUN-OF-RIVER)

#### 1.6.2.1.1.1. NON-DIVERSION DEVELOPMENT

The best example of this type in Pakistan is Warsak hydropower station built on Kabul river, a major tributary of Indus river. Chashma hydropower project is another example of this type.

A barrage or dam is built across the river. The natural flow of the river is passed through the penstock /conveying pipe to turbines for conversion of water energy into mechanical energy and hence into electrical energy. None or very little regulation and storage of water are available in this type of power plants.

A run-of-river plant is one whose energy output is subject to the instantaneous flow of the river (Fig:1-4)

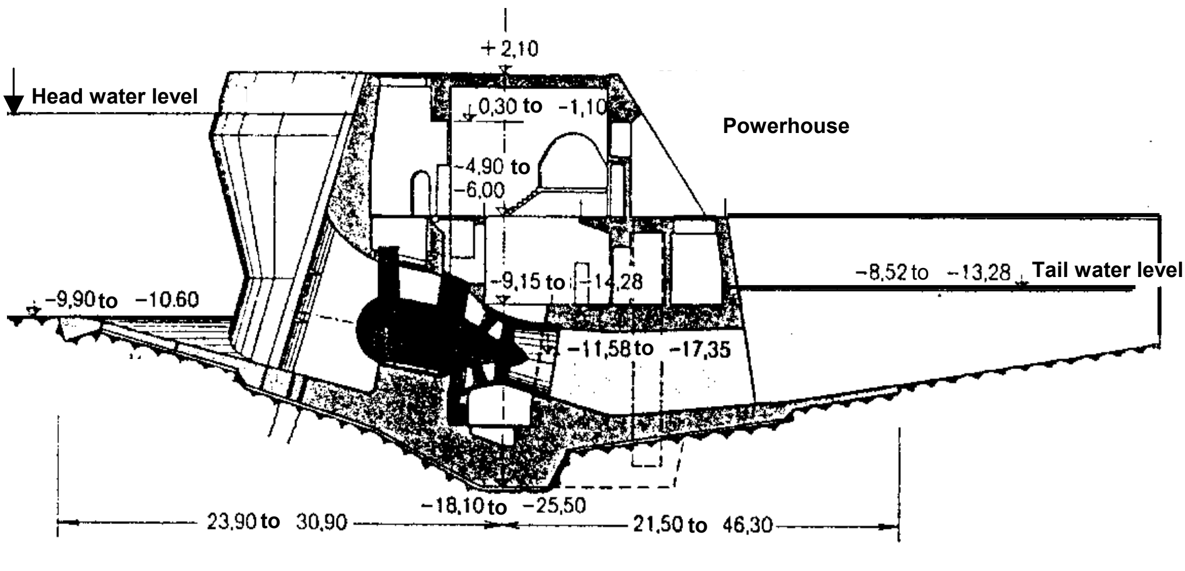


**Figure 1-4 Run-of-River Plant**

### 1.6.2.1.1.2. DIVERSION DEVELOPMENT (DIVERSION CANAL PLANTS)

A diversion structure such as dam, barrage, weir across the river/stream is built. The natural flow of water is diverted to the turbine through open canal/free flow tunnel/pressure tunnel and penstock. The slope of headrace is flatter than that of river/stream in case of open canal or free flow tunnel. Thus the difference in elevation between headrace and natural river/stream increases. Selecting a suitable site for the powerhouse allows the exploitation of the available head. (Fig: 1-5).

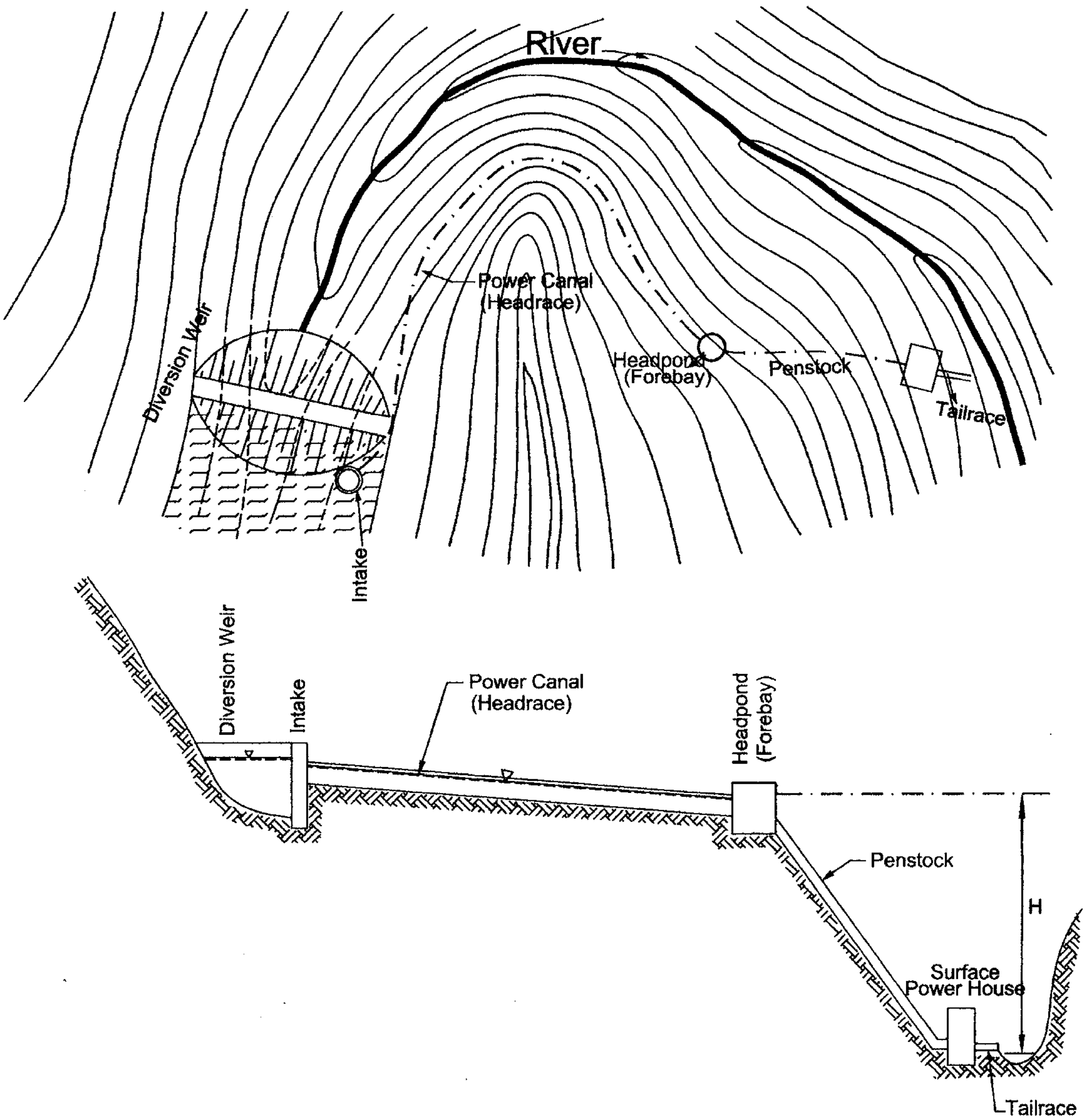


**Figure 1-5 Diversion Canal Plant**

The best example of this type of hydropower plant is Ghazi-Brotha presently under construction on Indus river downstream of Tarbela Dam project. The other small power plants of Northern Areas of Pakistan such as Kargha Nalluh, Gulmiti, Gupis as well as Darghai power plant on Upper Swat Canal in NWFP and the power plants in AJ&K such as Pattika, Khel and other suitable examples. The planned project of Neelum-Jhelum is an example, which considers a pressure tunnel arrangement.

### 1.6.2.1.2. PLANTS WITH STORAGE

### 1.6.2.1.2.1. NON-DIVERSION DEVELOPMENT

Constructing a dam across the river/stream creates storage, increasing the water depth, decreasing the hydraulic gradient and creating head. The storage can be daily, weekly, seasonal, annual, multi-annual and full-time. The reservoir helps in the regulation of discharges by storing water during high flow period and augmenting it during low flow period. These types of plants are very efficient to meet the energy demand (Figure 1-6).

The best examples of these types of plants in Pakistan are Tarbela and Mangla, built on river Indus and Jhelum, respectively. These multipurpose projects are vital for the country because they are used to satisfy irrigation water demand, provide flood control and generate power.

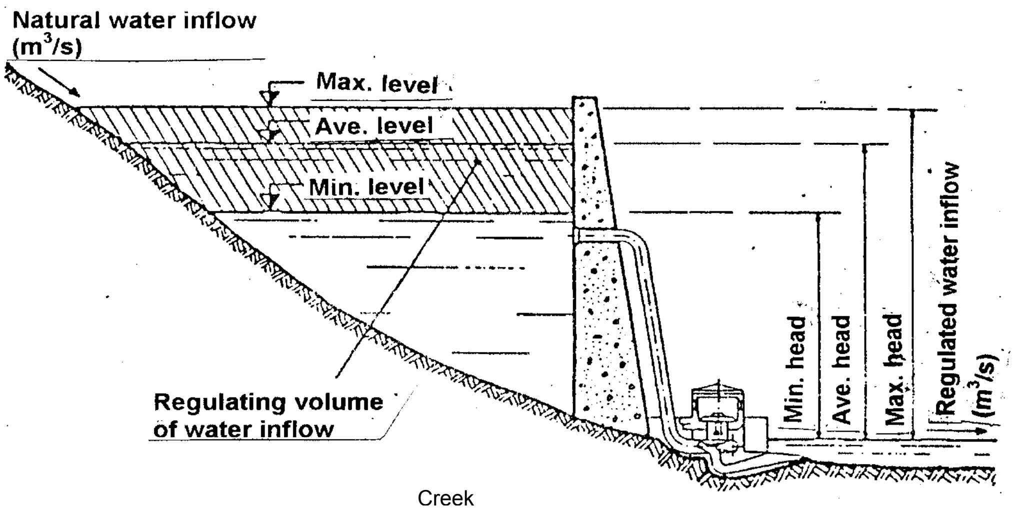


**Figure 1-6 Storage Plants - Non Diversion Development**

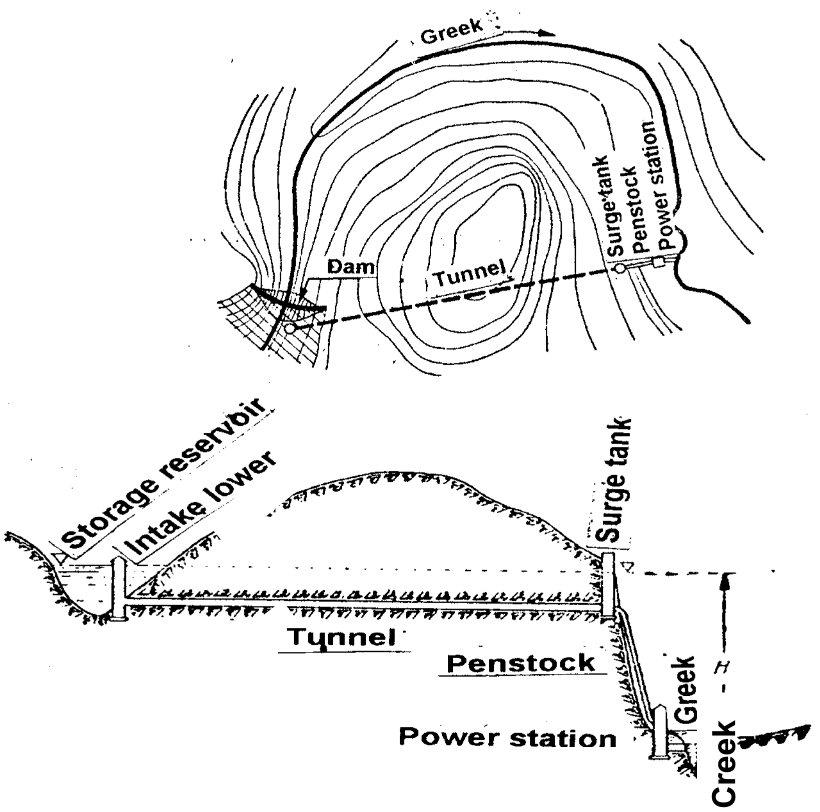


**Figure 1-7 Storage Plants - Diversion Development**

**1.6.2.1.2.2. DIVERSION DEVELOPMENT**

A diversion structure such as a dam across the river/stream is built. The natural flow of water is diverted to the turbine through an intake, pressure tunnel, surge tank and penstock. The tunnel alignment is such that the distance between the powerhouse site and dam is shorter than along the natural river course. The storage can be daily, weekly, seasonal, annual, multi-annual and full-time. The reservoir helps in regulation of discharge by storing water during high flow period and augmenting it during low flow period. (Fig: 1-7).

An example of this type of power plant is Allai Khwar hydropower station presently under planning on Allai Khwar nullah a tributary of Indus river upstream of Tarbela reservoir.

**1.6.2.2. PUMPED STORAGE PLANTS**

For this type of power plants two reservoirs are normally required. One reservoir is located at higher elevation than the other one. Normally, the lower storage is fed by a lake, river, or stream. In some cases water is pumped from the ocean. The water in the lower reservoir is pumped to the higher reservoir during periods when surplus and cheap energy is available. The pumped water then flows down through the turbines to produce power during period of peak demand. The powerhouse of this type of plants is equipped with high capacity pump-turbines (Fig: 1-8).

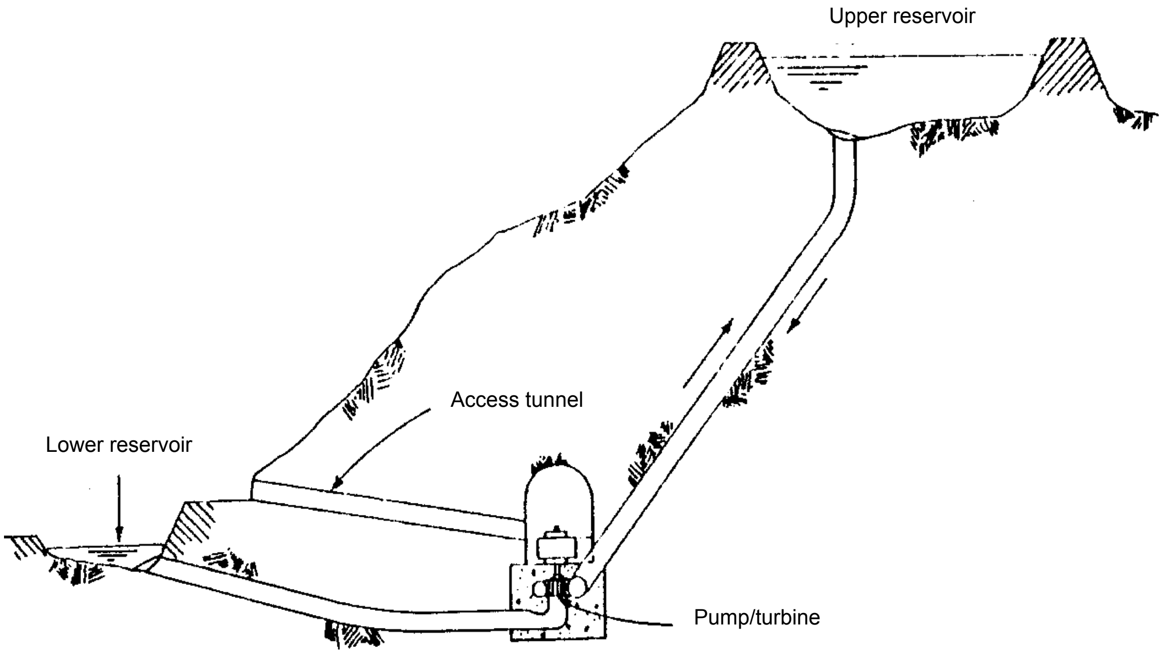


**Figure 1-8 Pumped Storage Plant**

In Pakistan, due to the characteristics of the system and the balance between supply and demand, pumped-storage plants have not been constructed until now.

**1.6.2.3. TIDAL POWER PLANTS**

The utilisation of the potential offered by the tidal cycles constitutes also a source of hydropower. The tidal fluctuations in some coastal parts of the world are relatively high. The difference in high tide level and low tide level is named tidal range. Some plants of considerable output are nowadays in operation in Canada, Britain, France and China. These plants work on water flowing back and forth (Fig: 1-9)

**Plan**

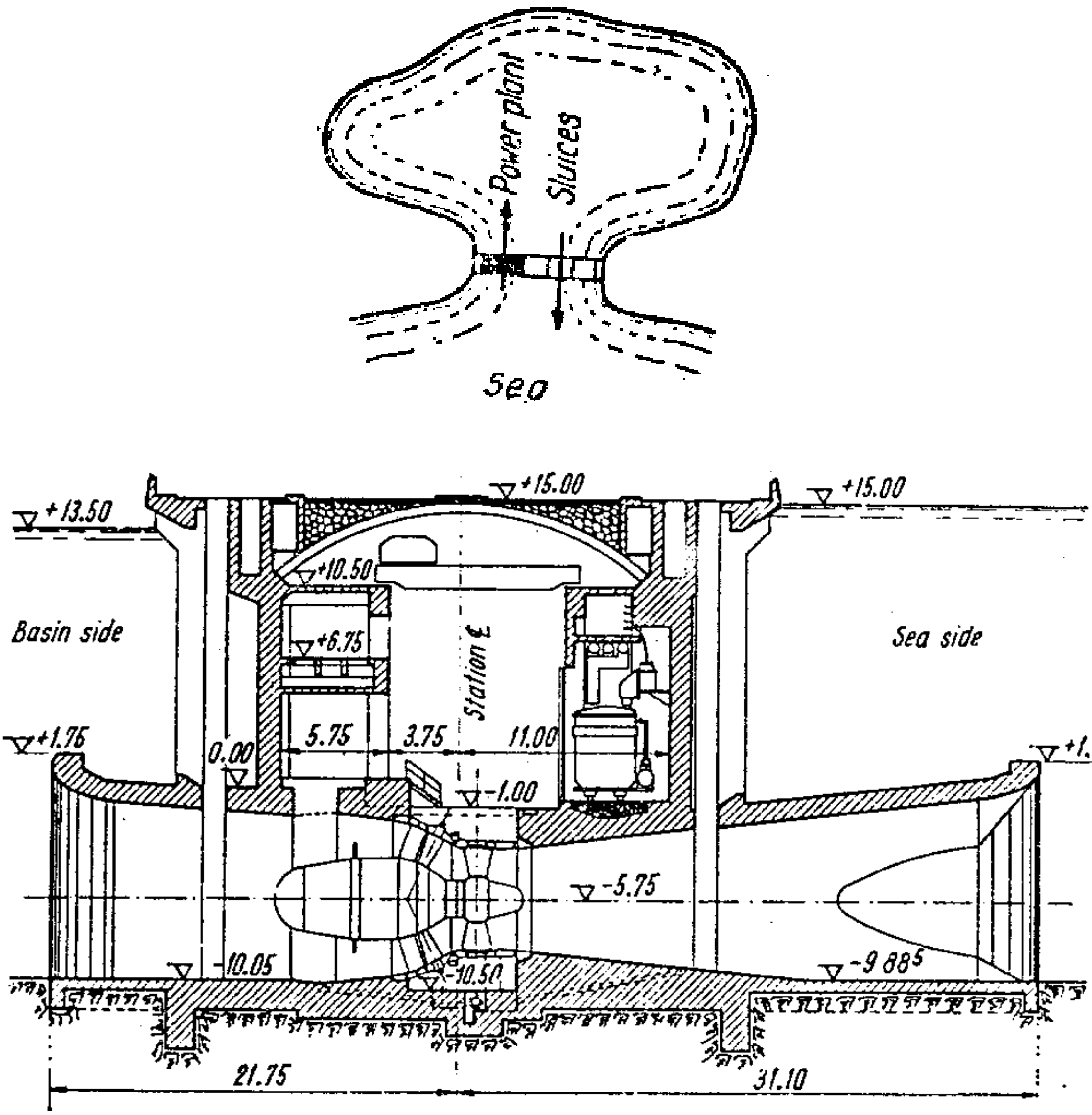


**Figure 1-9 Tidal Power Plant**

In Pakistan, tidal power plants have not been constructed until now.

### 1.6.3. CLASSIFICATION ON THE BASIS OF WATER ECONOMY

#### 1.6.3.1. SINGLE PURPOSE PLANTS

In this type of plants water is only used for production of electricity. The other uses such as irrigation, storage, etc. are not considered during economic life calculation. Warsak dam, Ghazi-Brotha and Chashma are good examples in Pakistan.

#### 1.6.3.2. MULTI - PURPOSE PLANTS

Production of electricity is just one purpose out of other purposes of the plants for which its economical life has been worked out. Other purposes are irrigation, navigation, flood control, recreation, industrial and municipal water supply, etc.

Tarbela and Mangla are good examples in Pakistan. In these projects irrigation is the first priority and production of electricity is secondary benefit.

#### 1.6.3.3. SUBSIDIARY PLANTS
Comprise the plants in which irrigation and other uses have the highest priority while production of electricity has lower priority. Nandipur, Shadiwal and other power plants in the irrigation system for which water availability is determined according to irrigation requirements are typical examples in Pakistan.

### 1.6.4. CLASSIFICATION ON THE BASIS OF ENERGY
#### 1.6.4.1. CLASSIFICATION ON THE BASIS OF ENERGY DISTRIBUTION
##### 1.6.4.1.1. ISOLATED PLANTS
Include the plants supplying electricity to a network independently, without co-operating with other generating plants. The plants are supplying electricity to isolated systems, which may include various villages, mines, sawmills, factories, etc. Almost all plants of the Northern Areas of Pakistan are working as isolated plants

##### 1.6.4.1.2. CO-OPERATING (INTER-CONNECTED) PLANTS
Comprise plants providing energy to consumers through an inter-connected network, which is fed by thermal, nuclear and other hydropower plants and supplying energy to all types of consumers. Now a days, mainly due to economic considerations, most of the developments are of co-operating type. Almost all medium and large hydropower plants in Pakistan are feeding the inter-connected system. Small plants are feeding isolated systems.

#### 1.6.4.2. CLASSIFICATION ON THE BASIS OF ENERGY DEMAND
##### 1.6.4.2.1. BASE-LOAD PLANTS
Base load plants are those, which are meeting the firm demand of the network. Energy available at all times (low flow) is called firm power.

##### 1.6.4.2.2. PEAK-LOAD PLANTS
Peak load plants are those, which due to water availability produce their maximum capacity during the peaking hours. Peak demand occurs daily but may have weekly and seasonal cycles. Hydropower plants, especially high-head, are suitable for peaking duty because they are more flexible to operate, can more easily follow load fluctuations and can be started and shut-down more rapidly than thermal and nuclear plants.

Tarbela and Mangla are being operated to cover the peak demands of the interconnected system in Pakistan.

##### 1.6.4.2.3. CLASSIFICATION ON THE BASIS OF ENERGY GENERATED
Classification of plants according to capacity is frequently adopted. However, it is very difficult to find a definite limit because the valuation of the capacity is different in almost every country. However, following are the main types being used in Europe and United State of America.

- Micro Capacity Plants < 100 kW
- Mini Capacity Plants 100 - 5000 kW
- Small Capacity Plants 5000 - 15000 kW
- Medium Capacity Plants 15000-50000 kW
- High Capacity Plants > 50000 kW

### 1.6.5. CLASSIFICATION ON BASIS OF TOPOGRAPHY
Hydropower plants can be grouped due to topographic set-up. The following three classifications may be considered:

- Low land plants
- Hilly Area plants
- Mountainous region plants

However normally low-head plants are constructed in the low lands, medium-head plants in hilly areas and high-head plants in mountainous regions.

### 1.6.6. CLASSIFICATION ON THE BASIS OF DESIGN HEAD

Classification according to head is the most logical basis especially from the point of view of the designer and the construction engineer. According to A. Ludin, E. Mosonyi and other authors, the following general limits can be given.

- Low-Head Plants <15 m Head
- Medium-Head Plants 15-50 m Head
- High-Head Plants >50 m Head

These suggested limits are not rigid and need not to be strictly followed. These three types are schematically depicted in Fig: 1-10 for a better understanding. However in America low-head plants are considered those with head less than 30 m.

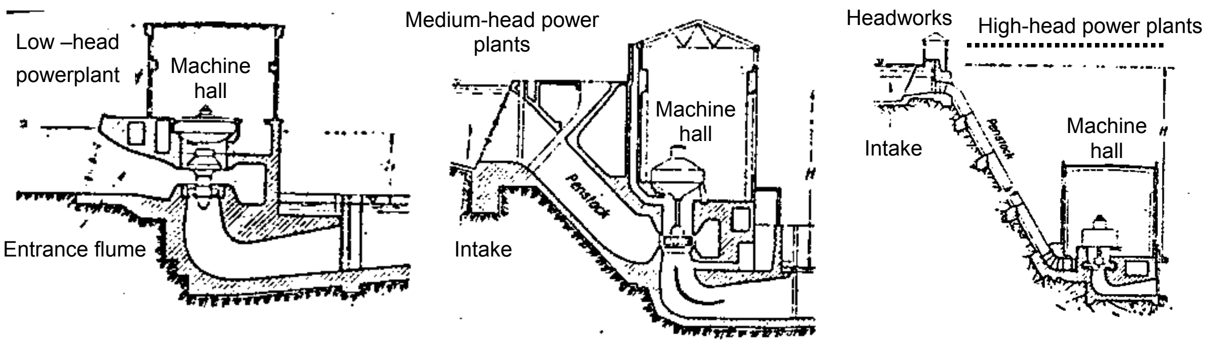


**Figure 1-10 Low, Medium and High Head Power Plants**

### 1.6.7. CLASSIFICATION OF HYDROPOWER PLANTS IN PAKISTAN

There is no clear classification being used in Pakistan. However, hydropower plants in Pakistan are classified according to energy generation and also according to head. Plants on irrigation canal such as Nandipur, Shahdiwal, Rasul, Chichoki Mallian, Darghi etc. are low head plants, but they are also called as “small hydropower plants” because their generation is less than 20 MW.

The plants such as Tarbela, Mangla and Warsak are higher capacity plants and are frequently referred to as “large hydropower plants”. They are also called medium head plants.

### 1.6.8. CONCLUSIONS

Each of above classifications does not give clear understanding about a plant. Most of the time small hydropower plants are confused with low-head plants. However, there are many identified/constructed low-head plants, which are of medium and high capacity. Therefore, to have better understanding about the plants, other characteristic features have also to be taken into consideration. Professor E. Mosonyi has grouped all the significant features as given in Table 1-1.

**Table 1-1 Classification of Hydropower Plants**

| Sr. No. | Important Features | | Low Head | Medium Head | High Head |
|---|---|---|---|---|---|
| 1 | Head | | $H_{max.} < 15m$ | $H_{max.}$=15-50m | $H_{max.} > 50m$ |
| 2 | Topography | | Lowland (Hilly country) | Hilly (Mountainous region) | Mountainous (Hilly country) |
| 3 | Discharge | | Large | Moderate | Small |
| 4 | Subsoil | | Loose sediments | Mixed (Loose and rock) | Rocks |
| 5 | Closure of River Valley | | Barrage with movable gates | Barrage with and without movable gates | Large Dam or small diversion structure |
| 6 | Run-of-river | | Yes | Occasional | Occasional |
| 7 | Canal Diversion | | Yes | Yes | Yes |
| 8 | Powerhouse | | Act as Dam | Toe of Dam | Occasionally at toe of Dam |
| 9 | Storage | | No | Daily or weekly | with or without |
| 10 | Character of Power | | Fluctuating | Slightly Fluctuating | Continuous |
| 11 | Energy Economy | | Base load plants | | Base and Peak load |
| 12 | Production cost | | High | Moderate | Low |
| 13 | Turbine | Type | Kaplan, High speed Francis | Francis, Kaplan | Pelton, low speed Francis |
| | | Size | Large | Medium | Small |
| | | Setting | Horizontal or vertical | Vertical | Horizontal |
| 14 | Generator | Size | Large multi-pole | Normal | |
| | | Gear | Direct or indirect | Direct | |
| 15 | Structure | Block | Yes | Yes or Separately | Separately or Yes |
| | | Entrance Flume | Yes | Yes | Surge tank |
| | | Penstock | - | Yes | Yes |
| | | Machine hall | Yes | Yes | Yes |

### 1.6.9. RECOMMENDATION

The classification of hydropower is not well defined in Pakistan. In our opinion, it is necessary to adopt a clear methodology of classification in the whole country to avoid confusion. It may also be the right time to take a decision, because a large number hydropower plants are likely to be built in near future. Classification according to head is much more technical for a common man and grouping on basis of plant capacity can also be misleading for a technical person.

Therefore, to have clear concept about type of a project, classification based on head and energy should be adopted. Grouping/Naming of projects such as low-head small hydro plants or small low-head hydro plants is a recommended solution.

## 1.7. SOCIO-ECONOMIC SET-UP

This is a very important aspect of hydropower planning which may even determine the chances of failure or success of a project, especially in rural areas. The socio-economic set-up of the region is studied to assess the electricity demand and also electricity purchase power of the population in a given region. It also affects the capacity of a proposed hydropower project if it will be operating in isolation supplying an isolated system. As in the case of power planning, load characteristics of the existing grid system or isolated systems for both internal and external potential market potential are important in developing a least cost energy expansion sequence for hydropower planning. Therefore, power demand forecast is a starting point of any hydropower study. For this we need to know the socio-economic set up of the region under consideration. The data collection methods and analysis of the load resources for low head and high head hydropower are dealt in detail in Module 20-A.2.3.1 and Module 24-A.2.4.1 respectively.

## 1.8. GEO-HYDROLOGICAL SET-UP

Unlike thermal power plants, hydropower plants are site specific, because they depend highly on the natural conditions such as: topography, hydrology, geology and ecological factors. The discharge in the rivers depends upon seasonal variation, being minimum in winter and maximum in summer months in case of Pakistan. The pattern of power demand is opposite to the pattern of water availability. Normally demand of electricity is higher in winter months than in summer especially in Northern Areas of Pakistan. Most of the sites for hydropower plants are relatively remote from population and industrial centres. Bringing the electricity generated to the consumers and integrating that capacity into the distribution network of the country requires extensive transmission lines. This capital cost of transmission lines will put hydropower under strain with other competitive non-hydro sources. However, being an indigenous renewable energy source, good sites will always be feasible even when the cost of transmission lines has to be added to total project cost.
The site geology is also very important, which initially affects the construction cost and later the maintenance cost.

Hydraulic energy is a form of non-polluting solar energy, which can easily be converted into electricity with an efficiency of up to 70 %. However, it does pose some environmental problems such as obstruction to migrating fishes, biological effects due to water levels and discharge, etc.

## 1.9. INSTITUTIONAL SET-UP

Due to its multi-disciplinary characteristics in planning, construction and organisation, the hydropower development requires well-organised institutions. Effective management is the key factor to determine the success of any hydropower project. Depending on the nature of organisation, the aim of an Institution in energy sector may be the planning, construction, operation, maintenance and distribution of the energy. Of course, evaluation of the capability of the power utilities to perform satisfactorily during construction and operation is other crucial aspect for long-term sustainability, which is often over looked or not considered on required level. Therefore, the concerned institutions should be strengthened and updated before any initiation for planning and implementation is made. Following main aspects should be considered for the institutional strengthening:

- Institutional capabilities
- Financial resources
- Human resources
- Technological achievements
- Information

The **institutional capabilities** should be considered before any decision is made for the sizing of the project. Philosophically, the institutional capability of the hydropower development organisation may be compared with the driving wheel of hydropower development vehicle (as Institution), which keeps the track leading towards the desired destination. (see fig: 1-11). Therefore, only robust institutional capability can ensure sustainable development.

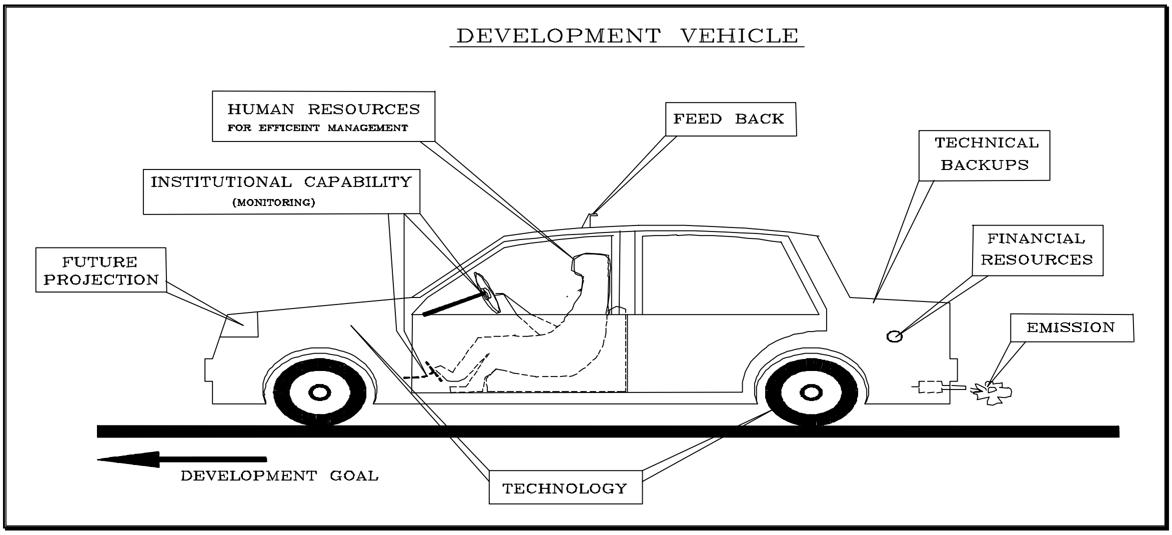


**Figure 1-11 A Model Conception of an Institution as a Development Vehicle.**

The **financial resources** may be interpreted as the fuel (source of energy) for the vehicle, without which there will be no motion. Due to the capital intensive and long gestation period, hydropower development was not always considered an economically viable option as compared with other competitors such as thermal plants. However, development of thermal plants has caused global warming due to emission of combustion gases as a result of burning of fossil fuels. In many countries of the world this sector is highly subsidised to make the tariff as low as possible. This sector is handled by public funds, which have other priorities such as health, education and infrastructure (roads, water supply). Given the importance of the source of energy, the concerned government should provide financial resources from its own sources or should seek the financial assistance from the lender agencies viz., (the World Bank (WB), the Asian Development Bank (ADB), Kreditanstalt fuer Widerausbau (KfW) etc. Donors have provided huge amount as financial assistance in the past. However, due to geo-politically changing world, these sources of funds are depleting at fast rate. On the other hand heavily subsidised sector may not pay back the loans taken from these agencies.

The strategy may be to attract private investors to release the public sectors funds to other non-economic sectors. Restructuring of the institution to provide incentive and policy and a gradual transformation of the responsibility to private investors in the generation, operation and distribution may be a possible way to stimulate the interest of private investors. There are many models of private sector's involvement already available in the market such as Build Operate and Transfer. After releasing this burden to private sector, the public sector may act, principally as the facilitator, monitor the activities of private sectors and to raise the revenue from them.

The **human resources** are the core/central part in the institution that can control over the development vehicle (Fig: 1-11). The success of management efforts highly depends on the proper training and incentive to these resources. Priority must be given to the maximisation of the use of national expertise in the hydropower development. Their research ability should be encouraged and the opportunities to learn from the success and the failure should be provided.

The project planning, implementation and operation also depend on the ability of human resources. Only in this way one can think about the in-house capacity building of an institution.

The **technological achievement** of the host country should be assessed prior to the selection of any hydropower project. Experiences show that hydropower projects, which were designed with highly sophisticated technology, require high operation and maintenance cost for the countries lacking the know-how. Therefore, the selection of hydropower projects should be in such a way that indigenous technology could be encouraged. Being the engine and the wheels of a developmental vehicle (Figure 1-11), it should be kept well functioning to reach a desired destination with less emission to the environment.

The **information network** being power of an institute implies that a strong database of all useful information is imperative. Therefore, future projection, project study reports, evaluation and auditing should be used as feedback and should be kept updated.

### 1.10. ENVIRONMENTAL AND POLITICAL SET-UP

Any developmental works invariably affect and are affected by the surrounding environment. This is also true for the hydropower development, which encounters a very large geo-political boundary. Therefore, the cumulative impact on environment is naturally high. Although hydropower does not emit $CO_2$, it creates some disruption to the endangered aquatic and tertiary species and displaces rural population/tribal people from the inundation area in long term. Experiences show that this type of impact is mainly related to the projects with large reservoirs. In any case, hydropower projects have impacts on physical, biological and socio-economic environments of the project area. Therefore, it is the responsibility of planners and engineers to be aware of such impacts and put their efforts to minimise negative impacts, if such impacts cannot be completely avoided.

The success of any hydropower, given its geopolitical characteristics, depends on the level of public involvement in the project right from the beginning. In the past, hydropower projects were highly politicised due to the vested interests of different groups blaming the government for not being transparent in the decision-making. This situation is even sensitive in the democratic political environment. This has created a hurdle in the smooth development of many hydropower projects and ultimately the economic loss to many countries. Therefore, political scenario and modalities of public involvement should be assessed before the decision is made.

The project proponent should include the national environmental policy in its planning process and should demonstrate the commitment of the project to safeguard the environment. Therefore, an environmental study (ES) is imperative for the project at the early stages of project preparation. Given the site-specific characteristics of the hydropower projects, the ES is also site specific. Therefore, the national Environmental Impact Assessment (EIA) guidelines should be followed as far as available. The EIA guidelines and directives of the lender agencies such as WB, ADB and others may be used as per requirement. As this subject is being a part of the hydropower planning, a detailed methodology for data collection and analysis is outlined in **Module 20-A.2.3.1** and **Module 25-A.2.4.2** for low head and high head hydropower, respectively.

# 2. PROJECT CLEARANCE PROCESS

## 2.1. GENERAL

A project has to go through different steps starting from its concept to implementation and operation. The important steps involved in the project cycle are:

- Planning
- Implementation
- Operation and Maintenance

The Government of Pakistan is responsible for any kind of development in the country. The development projects may be in public and private sectors.

Thus to keep the control on various steps involved in project development and also control on executing agencies, the Government of Pakistan has devised a project cycle which comprises:

- Approval
- Review and Monitoring
- Evaluation

Therefore, Government of Pakistan has set different criteria for projects in public and private sector for reporting and processing. The reporting and processing for public sector project is based on “Rules of Procedure for Economic Council” and for private sector project, on “Hydropower Policy May 1995”.

## 2.2. PROJECT CLEARANCE PROCESS FOR PUBLIC SECTOR

### 2.2.1. PROJECT REPORTING PROCESS

#### 2.2.1.1. GENERAL

To remain well informed about a development project, Government of Pakistan designed different forms for the purpose of planning, monitoring and reporting during different stages of project cycle such as; PC-II, PC-I, PC-III, PC-IV and PC-V.

- PC-I and PC-II deal with identification and preparation of projects for implementation
- PC- III deals with the progress monitoring of projects under planning and implementation
- PC-IV and PC-V deal with projects after implementation.

These forms should be filled by executing agency at the specified time and submitted to Government of Pakistan for information and approval. A small description of each proforma is given below and is arranged in the order of their requirement:

#### 2.2.1.2. PC-II PROFORMA

It deals with project proposal and is required for conducting surveys (identification of hydropower resources) and feasibility studies, in respect of large projects. The objective of this is to get full justification for undertaking the project before large resources are tied up. (Annexure I).

It should cover general description of the aims, objectives and coverage of the study. Previous studies in the same field should also be included. Duration of study and commencement/completion months is also a necessary part. It should contain cost estimate broken into local and foreign exchange expenditure. The date on which cost estimate is prepared should also be written. Requirement of personnel in all fields is the major requirement. In case of foreign exchange involvement, firm commitment from sponsor may be indicated.

**2.2.1.3. PC-I PROFORMA**

It is the basic form on which all projects are required to be drawn up. According to decision of Government of Pakistan, the PC-I should be prepared after detailed feasibility study has been completed. However, detailed design and drawings are not pre-requisite for the approval and preparation of PC-I (Annexure II).

Its preparation is the pivotal phase of the project cycle because after its approval project implementation will be taken up. Therefore, the sponsoring agency should give enough time to prepare the project. It ultimately helps in smoother and speedier implementation of a project and cost overrun and time could be avoided. It comprises three parts, namely:

**Part A " Project Digest". It contains**

- Name of the authorities responsible for sponsoring, execution, operation and maintenance.
- Time required for implementation.
- Provision in the current five-year plan.
- Objective of the project with over all development concepts.
- Cost of the project in local and foreign exchange.
- Annual requirement of expenditure after completion.

**Part B " Project Description and Financing".** It is actually the core of the PC-I and contains:

- Location
- Market analysis
- General description and justification
- Operation cost estimate.
- Capital cost and basis of cost estimate.
- Unit costs
- Technical description
- Financing arrangement
- Cash flow

**Part C " Project Requirement".** It should contain information on

- Manpower during implementation
- Facilities
- Material supplies and equipment

**2.2.1.4. PC-III PROFORMA**

This proforma is designed to furnish information on the progress of on-going projects on quarterly basis. It is required to be submitted by the executing agencies/departments within 20 days of the closing of each quarter. It shall include financial as well as physical progress of the subject project. Information regarding bottlenecks experienced during the execution period shall also be incorporated (Annexure III). This proforma is be submitted during planning and implementation phase.

**2.2.1.5. PC-IV PROFORMA**

The project completion report on PC-IV (Annexure IV) is to be furnished by every project director /executing agency only once, soon after a project is adjudged to be completed physically, whether or not the accounts of the project have been closed. It includes the full history of the project including financial and physical phasing, emphasising the risks taken and mistakes committed along with the remedial measures adopted and experience gained. It also includes the history of the number of persons employed.
To guide those who are charged with the execution and supervision of similar projects in future, some suggestions about prevention of delays and cost escalation is also included. This is also

very much needed in post evaluation process. It should include the comparison of planned performance with actual performance. The reasons to achieve planned performance should be explained in detail.

#### 2.2.1.6. PC-V PROFORMA

This is to be furnished on an annual basis for a period of five-years by the agencies responsible for operation and maintenance of the projects (Annexure - V). It should include the review of cost, expenditure and financial results as estimated in completion report. Reasons for variation in result may also be included for future guidance to planner and decision makers. The performance of the persons involved in operation and maintenance is the major part. Any difficulties experienced during operation should also be highlighted. Future suggestion to avoid any type of mistake may also be included.

### 2.2.2. PROJECT APPROVING PROCESS

#### 2.2.2.1. GENERAL

As soon as the PC-II/PC-I is received in the Planning and Development Division, its registration and circulation to all concerned sections of the division and all members of CDWP will be done. A chart showing flow of PC-II/PC-I within the Planning and Development Division and their processing through the CDWP/ECNEC is given in Fig 2-1.

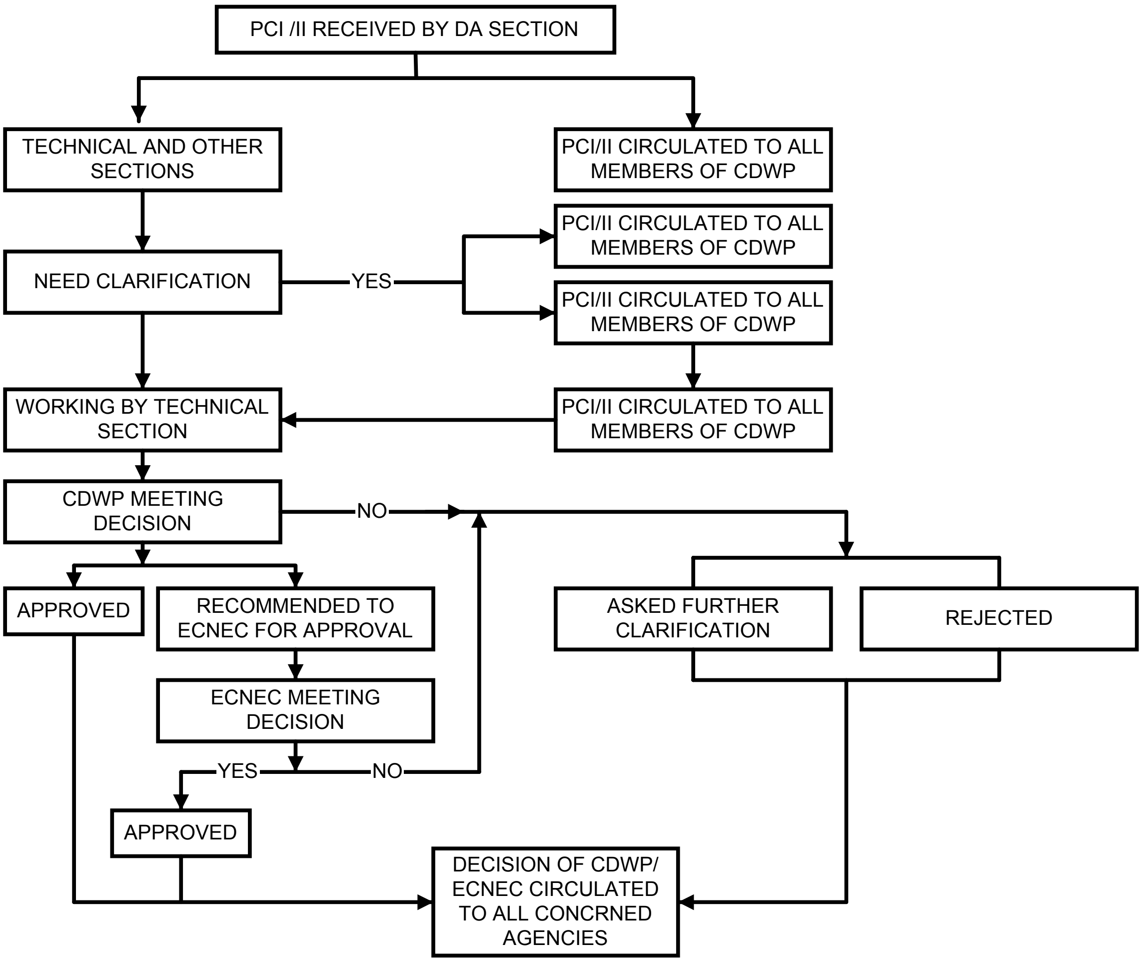


**Figure 2-1 Flow Chart.**

The Planning and Development Division as per the rules of business is responsible to prepare the appraisal of the project. The rationale behind the project appraisal is to provide to the decision makers financial and economic yardsticks for the selection or rejection from among the alternative projects. Project appraisal involves a careful checking of the basic data, assumptions and methodology used in project preparation, an in-depth review of the work plan, cost estimates and proposed financing, an assessment of the project organisational and management aspects, and finally the validity of the financial, economic and social benefits expected from the project.

A project is required to be approved within three months. Approval does not entitle the sponsoring agency to execute a project. In fact “approval in principle” needs to be qualified by mentioning clearly; to what extent and for what purpose the approval in principle is required.

There are different types of approval required for new and on-going projects, which are briefly discussed below.

**2.2.2.2. NEW PROJECTS**

**2.2.2.2.1. ANTICIPATORY APPROVAL**

The Chairman ECNEC, when satisfied, has powers to allow the execution of a scheme in anticipation of its formal approval by ECNEC. The request for anticipatory approval has to be submitted to the Cabinet Division for on-going and new projects in the prescribed proforma. The schemes approved on anticipatory basis have to be processed through formal channels and submitted to ECNEC for final approval. The anticipatory approval should not exceed 12 months.

**2.2.2.2.2. ADMINISTRATIVE APPROVAL**

The Federal Ministry in case of federally sponsored projects issues it and Provincial Department concerned in case of provincial sponsored projects. It is actually sanctioned for incurring expenditure.

**2.2.2.2.3. CONCEPT CLEARANCE**

The project in which foreign exchange in involved needs to be submitted to Concept Clearance Committee located in the Planning and Development Division on prescribed proforma to obtain its clearance for starting negotiation for aid by the Economic Affairs Division.

**2.2.2.3. ON-GOING PROJECTS**

If any agency during the financial year requires additional funds for some of its projects for inescapable reasons, the agency must approach the Planning and Development Division in either of two ways:

**2.2.2.3.1. RE-APPROPRIATION**

If some savings (on an other project) are available within the agency’s PSDP allocation, it requests Planning and Development Division for re-appropriation. After consideration of the case in relation to the implementation of the other projects, the Planning Division decides the case.

**2.2.2.3.2. SUPPLEMENTARY GRANT OR TOKEN MONEY**

If the saving is not available in the agency’s allocation, it requests the Planning and Development Division to allow a supplementary grant. The Planning Division decides each case on its merit and then recommends it to the Finance Division.

**2.2.3. PROJECT APPROVING BODIES**

**2.2.3.1. NATIONAL ECONOMIC COUNCIL (NEC)**

It is the supreme policy making body in the economic field and headed by the Country Chief Executive (President/Prime Minister).

It is in overall control of planning machinery and approves all policies and plans relating to development. Federal ministers in charge of economic ministries, Deputy Chairman of the planning commission and the Governors/Chief Ministers of the provinces are its members.

**2.2.3.2. EXECUTIVE COMMITTEE OF NATIONAL ECONOMIC COUNCIL(ECNEC).**
The Federal Minister of Finance heads it and its members include Federal Ministers of Economics, provincial Governors/Chief Ministers or their nominees and the provincial ministers concerned. It has the following functions:

- To sanction development schemes in public and private sectors.
- To allow moderate changes in the plan and in the plan allocations
- To supervise the implementation of economic policies laid down by the National Economic Council (NEC).

**2.2.3.3. CABINET COMMITTEE ON ENERGY**
A Cabinet Committee on Energy with the Prime Minister as its Chairman, Finance Minister as Vice Chairman, and Minister for Planning and development, Minister for Petroleum and Natural Resources and Minister for Water and Power as its members will be responsible to approve plans, policies and development schemes costing more than the powers of approval enjoyed by the Ministry or the concerned.

**2.2.3.4. ECONOMIC CO-ORDINATION COMMITTEE OF THE CABINET (ECC).**
It gives approval to the projects in private sector and keeps vigilance on the monetary and credit situation and makes proposals for the regulation of credit in order to maximise production and exports and to prevent inflation. It also attends to all urgent day-to-day economic matters and co-ordinates the economic policies initiated by the various division of the Government.

The Federal Minister for finance and Federal ministers of economic ministries as its members head it.

**2.2.3.5. CENTRAL DEVELOPMENT WORKING PARTY (CDWP)**
The Deputy Chairman of the Planning Commission heads the CDWP and is joined by secretaries of the federal ministries concerned and the heads of the planning departments of the provincial Governments as its members.

It scrutinises all the development projects prepared by the federal ministries, provincial Government, autonomous organisation, etc. for the purpose of approval by ECNEC.

It is competent to approve development project up to certain financial limits. Projects exceeding the limits are submitted for approval to ECNEC.

**2.2.3.6. DEPARTMENT DEVELOPMENT WORKING PARTY (DDWP)**
It is a body for approving development projects for federal ministries/divisions/departments according to their approved financial limits.

It is headed by the respective secretary/head of department. Its members are representatives of Finance Division and concerned Technical Section in the Planning and Development Division.

**2.2.3.7. PROVINCIAL DEVELOPMENT WORKING PARTY (PDWP)**
It is headed by the Chairman Development Board/Additional Chief secretary and includes Secretaries of the provincial departments concerned with development as its members. It scrutinises various projects for inclusion in the Annual and five-year plan. It is competent to

approve projects up to a certain financial limits. Projects exceeding this limit are submitted to the CDWP for approval.

### 2.2.4. PROJECT REVIEW AND MONITORING PROCESS

#### 2.2.4.1. GENERAL

The progress of a development project was reported by the every project director/executing agency on a prescribed proforma called PC-III. The most important thing for reporting progress is that financial and physical progress and bottlenecks should be reported realistically and promptly. This proforma should be submitted within three weeks of the closing of the quarter. The progress of the development project is being reviewed and monitored by the different divisions of the federal government which are described briefly below.

#### 2.2.4.2. REVIEW BY MINISTRIES/DIVISION

Federal Ministers should hold meetings with concerned agencies under the control of their ministries to review implementation of development projects once every month. Federal Ministers also review the progress of aid utilisation on the first Tuesday of every month.

#### 2.2.4.3. PROJECT REVIEW GROUP

It is a body in every Ministry and headed by the respective Secretary. Its responsibility is to follow-up action on the review reports prepared and circulated by the project Wing of the Planning and Development Division.

#### 2.2.4.4. PLANNING COMMISSION

Deputy Chairman of the Planning Commission is responsible to review the progress of implementation of development projects at least once in every quarter.

### 2.2.5. PROJECT EVALUATION PROCESS

It is the responsibility of the Government to take the evaluation of a project during implementation or after its completion. Therefore for proper evaluation, project authorities are responsible to provide data. PC-IV and PC-V are designed to serve this purpose. The main object of the evaluation is to prepare feedback for the future, which will be used for operational, analytical and policy purposes. It is the responsibility of the Project Wing of Planning and Development Division to prepare the evaluation report and circulate to concern authorities. NEC also decided that a Project Monitoring and Evaluation Cells (PME) should be developed in each Federal Ministry/Division.

## 2.3. PROJECT CLEARANCE PROCESS FOR PRIVATE SECTOR.

### 2.3.1. GENERAL

The Government of Pakistan announced the Policy Framework and Package of incentives for private sector power development in May 1995. The power generation will be based on indigenous resources, namely hydropower because of being cheaper will provide tariff relief to consumers and benefits economic growth to the relatively backward parts of the country.

A clear procedure has been framed which includes all steps in project development, which start from allocation of site and end on implementation of a project. The procedure depends upon how the project will be operated, i.e. it sells generated power to WAPDA/any other distribution network or self generation for industrial use. The development of a project is the responsibility of the Provincial Government.

### 2.3.2. PROJECT ALLOCATION PROCESS

#### 2.3.2.1. SELF GENERATION FOR INDUSTRIAL USE

Sponsors intending to install hydropower exclusively for self generation for industrial use would generally require no permission and would be free to choose any site/location. However, in case plant will be installed on irrigation canal, the technical clearance of the concerned provincial irrigation department shall be obtained. In case, it is intended to sell surplus power to an isolated network, a Power Purchase Agreement with the concerned network owner shall be required.

#### 2.3.2.2. BUILD-OPERATE-TRANSFER PLANTS

These are plants implemented for the sale of power to WAPDA or any other network owners.

##### 2.3.2.2.1. APPLICATION FOR SITE ALLOCATION

The application forms include the brochure of new hydropower policy and the Provincial Private Power Cell (PPC) will provide format for bank guarantee on receipt of the specified charges (Rs. 5000/-). The application will be accepted by PPC against a non-refundable fee such as:

| | | | |
|---|---|---|---|
| 0 - 20 | MW | Rs. | 30,000. |
| 21 - 50 | MW | Rs. | 100,000. |
| 51 - 200 | MW | Rs. | 200,000. |
| 201 - 300 | MW | Rs. | 400,000. |
| above 300 | MW | Rs. | 500,000. |

##### 2.3.2.2.2. LETTER OF INTEREST (LOI)

The letter of interest will be issued for the following possible cases, by the concerned PPC to the sponsors of the project after screening and evaluation of the proposal. It comprises:

- A site whose feasibility study is already completed in public sector and the cost of the feasibility study will be paid by the sponsor through PPC to the concerned agency, which conducted the feasibility study. The LOI remains valid for a period of six weeks. Within this period the sponsor has to furnish Performance Guarantee. The letter of interest automatically lapsed when the sponsor fails to furnish Performance guarantee.

- A site whose feasibility study is in progress in public sector and the sponsor can participate in the completion of the feasibility study at his own expense. The time frame required to complete the feasibility study in public sector will be specified in the LOI. The sponsor has to pay the cost of feasibility study and furnish performance guarantee within six weeks after completion of feasibility study.

- The sponsors of the project will be allowed to carry out the feasibility study at their expense, for which they have to furnish a bank guarantee of US$ 1000 (or equivalent in Pak Rupees) per MW within three weeks after obtaining the LOI. This bank guarantee is valid for the whole study period. The time period allowed for the feasibility study will be determined by the sponsors and concerned PPC. If the sponsor fails to complete the feasibility study in the specified time period, the bank guarantee will be executed and the LOI will automatically lapse.

- A performance guarantee will be furnished within six weeks period after the acceptance of the feasibility study by the PPC.

No Letter of Interest will be issued before the sponsor gets clearance of feasibility report/planning report from EPA and decide with WAPDA the point of interconnection in case produced power will be purchased by WAPDA.

##### 2.3.2.2.3. LETTER OF SUPPORT (LOS)

On receipt and acceptance of Performance Guarantee by the Provincial PPC a Letter for Support will immediately be issued to the Sponsors. After getting LOS sponsor can approach PPIB within six weeks for signing of the Implementation Agreement and Power Purchased Agreement. Sponsor has to apply PPIB within six weeks of the LOS. The Performance Guarantee is valid for eighteen months, during which sponsor has to achieve financial close.

The Performance Guarantee amount shall be Rs. 100,000 per MW based on the capacity for which LOS is being issued. The extension in financial close under normal circumstances will not be granted. However, under special circumstances a one time extension of a maximum of three months will be given by raising the guarantee amount by 100 % i.e. Rs. 200,000 per MW.

#### 2.3.2.3. TURNKEY-BASIS

Some reserved sites (sale of power to WAPDA) shall be solicited through open bidding. These sites may include sites for which feasibility studies have already been completed in public sector or raw sites. The proposals from private sector would be invited through press. A committee comprising representatives from Provincial PPC, PPIB and WAPDA will carry out evaluation of proposals. The first ranked party will be issued the LOI.

The remaining procedures will be similar as in case of Build-Operate-Transfer project.

### 2.3.3. VARIOUS APPROVALS/AGREEMENTS

#### 2.3.3.1. EPA APPROVAL

It is the responsibility of the sponsor to get clearance for his feasibility/planning report from the Environmental Protection Agency (EPA). The PPC should not issue LOI and LOS without clearance of EPA.

#### 2.3.3.2. WAPDA APPROVAL

It is the responsibility of the sponsor to decide and discuss with WAPDA the point of interconnection. It should be a part of feasibility/planning report. WAPDA decision in this connection should be available before issuance of Letter of Interest.

#### 2.3.3.3. WATER USES AGREEMENT

The sponsor has to sign and get permission from the concerned Provincial Department. Specially when the project will be constructed on irrigation canals, an agreement with Provincial Irrigation and Drainage Authority (PIDA) will be signed and the sponsor has to pay the cost of water on flat rate basis which is about Rs. 0.22 / kW.

#### 2.3.3.4. POWER PURCHASE AGREEMENT

An agreement will be signed with the owner of the network of distribution. It is the responsibility of the PPIB to co-ordinate the sponsor to get an agreement. This will be done before entering the implementation agreement.

#### 2.3.3.5. IMPLEMENTATION AGREEMENT

After getting Letter of Support from concerned PPC, the sponsor has to approach PPIB to enter into Implementation Agreement. This is a kind of approval after which sponsor should proceed to construct the project.

### 2.3.4. PROJECT APPROVING BODIES FOR PRIVATE SECTOR

#### 2.3.4.1. PROVINCIAL PRIVATE POWER CELLS (PPC)

All the Provincial Governments have designated a window to specifically deal with and process all sponsor proposals and queries. It is responsible for the issuance of the Letter of Interest (LOI) and Letter of Support (LOS) to the sponsor of that site. PPC is also responsible to co-ordinate sponsor with other concerned departments such as PPIB, WAPDA etc. The Provincial Window will work on the pattern of PPIB.

#### 2.3.4.2. PRIVATE POWER AND INFRASTRUCTURE BOARD (PPIB)

A window has been designated in the Federal Ministry of Water and Power to deal and co-ordinate with the sponsors to negotiate the Power Purchase Agreement with concerned network owner and finally obtain the Implementation Agreement. LOI and LOS issued by Provincial Government will not bind Federal Government. Therefore, PPIB will execute IA/PPA, only after it was satisfied that:

- The interconnection of the project to the National Grid was technically and economically feasible.
- The feasibility of the project met the criteria laid down in the policy.

## 3. DEVELOPMENT PLANNING IN PAKISTAN

### 3.1. GENERAL

A plan is a body of economic and social policies expressed with quantified targets and objectives to be achieved during a laid-down period.
Planning is usually specified in terms of time and organisational factors. According to the horizon, plans are divided into:

- Short term
- Medium term
- Long term

### 3.2. ANNUAL PLAN

It is a short-term plan and has a very brief and limited horizon. It is also called annual development plan. It is normally part of the implementation side of five-year plan. It includes an evaluation of past performance, a presentation of the main targets, an assessment of the resources position, an outline of the investment programme and broad outlines of the economic policies.

The public sector development programme (PSDP) is an annual document, which lists all the public sector projects/programs with specific allocations made for each one of them in that particular financial year.

### 3.3. PUBLIC SECTOR DEVELOPMENT PROGRAMME (PSDP)

It is an annual document, which lists all the public sector projects/programmes with specific allocations, made for each of them in that particular financial year. It is the operational side of the five-year and annual plan. It is actually part of the country annual budget which deals with the development expenditure and indicates total cost of the project, foreign exchange component of the total cost, expenditure incurred up to the end of last financial year, PSDP allocation for the current financial year.

The following order of priority is generally maintained while selecting the projects for allocation in PSDP.

1. On-going projects at advanced stage of implementation.
2. Foreign-aided projects with high national priority.
3. Projects deal with emergencies such as flood relief etc.
4. New approved projects.

The preparation of PSDP starts in October/November each year. The Planning and Development Division is responsible for its preparation and all co-ordination required. After clearance from National Economic Council, the PSDP is integrated into the national budget for consideration by the National Assembly.

### 3.4. ROLL ON PLAN

It is a medium term plan and designed to bring flexibility into five-year plan in terms of financial position and project implementation. In this plan sectoral and project wise position is adjusted according to foregoing year.

### 3.5. FIVE-YEAR PLAN

Annual plan is handicapped due to shortage of time. Therefore, a five-year plan has reasonable time frame for manoeuvring and achievement of solid results.

The five-year plan is a general statement of objectives and targets relating to the economy as a whole and its various component sectors. It is not an authorising document in the sense that it does not authorise expenditure to the relevant operating agencies. It actually provides a broad framework.

### 3.6. PERSPECTIVE PLAN

It is a long-term (15-25 years) plan and its main purpose is to provide long-term economic and social policy framework so that the objectives to be achieved over a much longer period can be incorporated in a medium-term framework.

It actually gains sense of direction to the current economic polices. It establishes targets of massive improvement to be brought about in living standards by mobilising the resources and energies of the nation.

The period is arbitrary. On one hand, long enough to permit meaningful structural changes in the economy and on the other, not so long as to be without direct interest to the present work generation.

## 4. DEVELOPMENT OF A HYDROPOWER PROJECT

The development of a hydropower project requires a series of sequential steps which can be categorised such as:

- Planning Phase
- Implementation Phase
- Operation and Maintenance Phase

Each phase is based on the results from the previous phase and takes the project a step forward in its development.

The first phase is very important in the project development, because it leads to the decision whether the project will be implemented or not. It includes all types of investigations performed to determine the desirability of carrying out a project. These studies start from site identification and should be completed when construction starts.

Planning studies vary in scope, depth, details and intended audience and lead to important decisions and commitments made during planning phase. The planning studies are grouped into two such as:

- Resources inventories
- Site- specific studies The site-specific studies are normally organised in several consecutive studies such as:
- Preliminary/Reconnaissance Studies
- Pre-feasibility Studies
- Feasibility Studies.

These studies may prove negative, therefore should be arranged in self-contained steps. In each study the projects are investigated to the necessary depth to reach a conclusion on their capability and suitability for the required purpose. In consecutive studies the depth and detail of investigation is increased and projects pass suitable criteria. The projects are either included in the selected list or passed on to next phase of study. By doing these systematic studies less attractive projects are dropped at an early stage, resulting in saving time and money.

If the studies are done in a rational manner it is possible to ensure that unsuitable projects are not pursued longer than necessary. Therefore stepwise development will lead to a technically sound and economical viable project. However, it is time consuming and requires in some cases significant investments.

Reduction in planning time can be achieved through reduction of planning steps. Combining reconnaissance and pre-feasibility studies may save planning time. Definite plan studies can be taken with feasibility studies. However, feasibility studies should be kept intact and taken up as self-contained independent studies. The reduction in planning steps may lead to loss in reliability. It is however, advisable to retain all the required steps, because they reduce the risk of investigating unsuitable projects to completion.

The second phase covers engineering and construction of a project. It commences when the feasibility of project is accepted and lasts until commissioning of the project. The main activities consist of:

- Definite plan study and detailed design
- Tender document preparation
- Tendering and Contracting
- Construction Design for civil works, hydromechanical and electromechanical equipment.
- Construction of civil works, transmission works, manufacturing and erection of hydromechanical and electromechanical equipment.
- Commissioning of project.

The third and last phase in project development is operation and is the longest phase. It commences when project is commissioned and starts operation on commercial basis. Evaluation of all the activities in project development cycle is very important for proper feedback for future planning and design of such type of projects. Evaluation should contain difficulties encountered and remedial works provided. Lessons from failures and mistakes are the key issues of evaluation.

The development of hydropower projects requires a number of expertise in different fields such as:

- Power market surveys
- Power demand forecast
- Hydrology, sedimentology and meteorology
- Power studies
- Geodesy
- Geology, geological investigations and foundation engineering
- Seismologist
- Underground engineering
- Hydropower planning and design
- Hydraulic engineering
- Hydraulic structures
- Reservoir and dam engineering
- Hydraulic model studies
- Infrastructure planning
- Electromechanical engineering
- Hydromechanical engineering

- Control and protection
- Transmission engineering
- Tariffs
- Cost and quantity surveying
- Scheduling
- Power economy analysis
- Financial analysis
- Environmental engineering
- Ecology
- Social anthropology
- Socio-economy
- Project management
- Contract management
- Construction management
- Supervision
- Quality assurance and control
- Legal issues
- Public relation
- Operation and maintenance
- Communication
- Inspection services
- Documentation engineering

## 5. PLANNING PHASE

Planning studies vary in scope, depth, details and lead to important decisions and commitments made during the planning phase. The studies carried out during the planning phase are presented in the Figure 5-1.

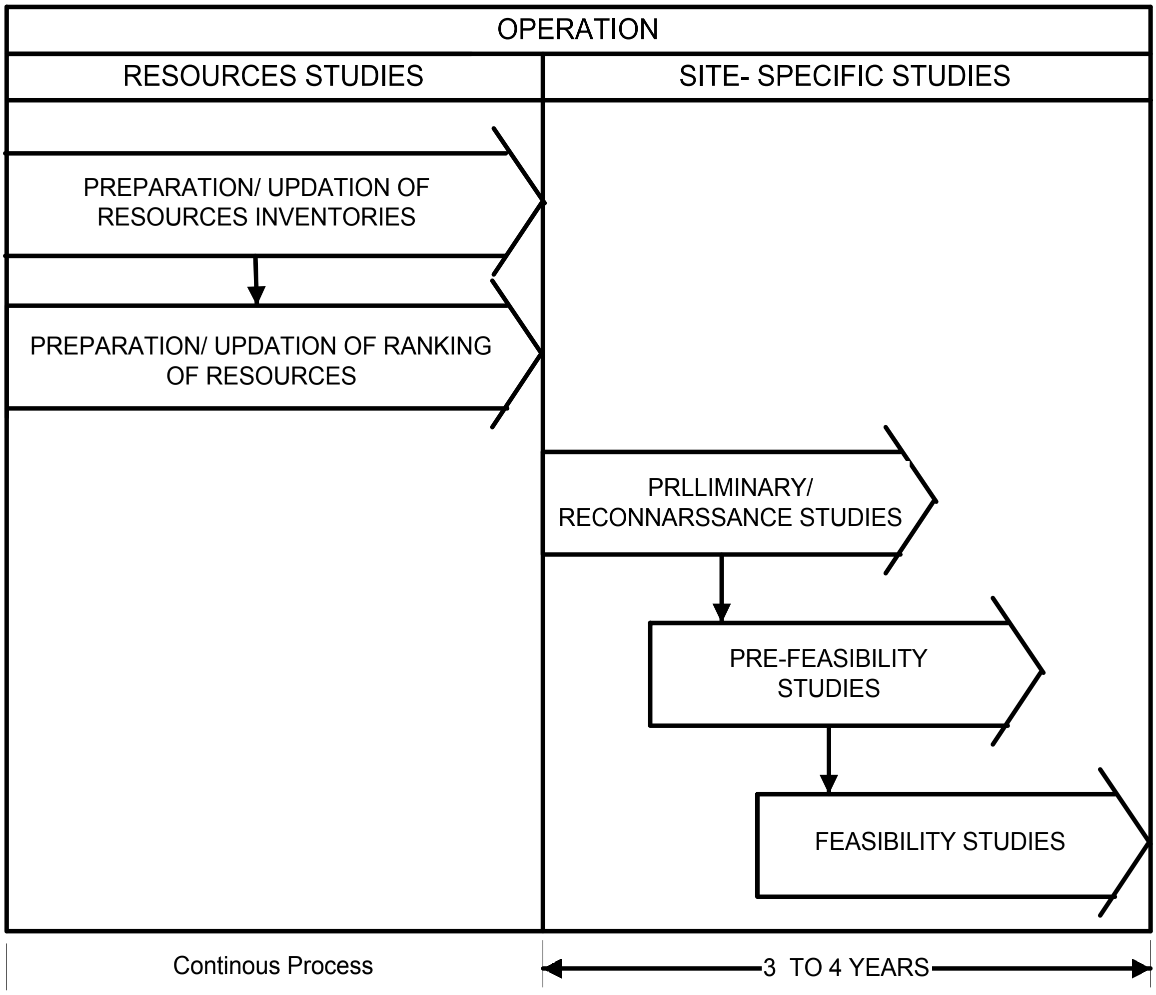


**Figure 5-1 Planning Flow Chart**

### 5.1. RESOURCES INVENTORY AND RANKING

It is the first step toward hydropower planning and then subsequent development. It is often called basic investigation.

The main purpose of these investigations is to identify, register and catalogue the hydropower resources existing in the river basins, areas, districts and provinces. These investigations may be carried out countrywide to prepare the inventories of the complete hydropower potential.

Flow data and data on topography is sufficient to establish the production and generating capability of a site.

The identified project sites are often ranked according to size, cost, electric demand, etc. The inventory of low head hydropower on existing canal falls and barrages within the irrigation system of the Indus River Basin is a good example in Pakistan.

Preparation of resources inventories and their updating is a continuous process and should not be stopped at any time.

## 5.2. SITE SPECIFIC STUDIES

### 5.2.1. RECONNAISSANCE STUDIES

These are normally the first steps of project oriented planning. These studies are of preliminary nature, but unlike basic investigations the hydropower inventories have defined terms of reference. The details and data requirement of these studies are of a regional nature. The level of detail and accuracy requirement of the data is much less. The identification studies of high-head hydropower potential in the north of Pakistan are good examples.

Reconnaissance studies are carried out for specific purpose such as to establish the available potential in a region, which can be developed to satisfy the forecasted electric demand of the region according to expected expansion of the electric network supplying the region.

Reconnaissance study is defined as the preliminary feasibility study designed to ascertain whether a feasibility study is warranted. Therefore, a reconnaissance study is an abridged feasibility study having as its major objective a preliminary economic evaluation and identification of the critical issues, which will be considered during feasibility study.

Reconnaissance studies are organised along the same lines as the other planning studies such as pre-feasibility, feasibility etc. Reconnaissance studies are concerned with project selection from inventories of resources as well as investigations, which are required for specific purpose. Several projects may be suitable to meet the demand and these may be developed in various ways. Therefore, during reconnaissance studies several project alternatives are to be investigated in order to select the best project.

The main objectives may be such as:

- Assessment of demand or define the electric power needs.
- Selection of candidate projects from the resources inventories which will meet the electric power demand.
- Studies/investigation of candidate projects and project alternatives to the best technical level.
- Technical ranking of candidate projects should be prepared and well recorded.
- Selection of a suitable project from the list of investigated candidate projects
- Estimation of preliminary cost and implementation schedule.

The following main activities are required in the performance of reconnaissance studies and are explained below in detail:

- Data collection
- Office studies
- Field work and final reconnaissance report

#### 5.2.1.1. DATA COLLECTION

The work on the reconnaissance study starts with the collection of relevant data and information. The main data and information required are:

- Infrastructure information, etc.
- Power market and demand forecast
- Hydrology
- Topography
- Geology and geo-technical engineering
- Environmental issues
- Socio-economic set-up

#### 5.2.1.2. OFFICE STUDIES

Basing on available data and information, the first step of the office study is to establish the main project parameters such as:

- Power demand forecast
- Flow and regulation
- Head
- Environmental constraints.

All these parameters are interdependent and subject to changes due to natural or human influence, except the available head which is to some extent constant. These parameters are subject to continuous revision and adjustments as planning progresses on the availability of better data.

The establishment of the hydrologic regime is very important and ranked first in order of priority as compared with others parameters. Flow varies over time as it is influenced with climate and its regulation totally depends upon its availability. Hydrology is the science that deals with the occurrence and availability of water. From the hydropower development point of view, the hydrologist has to establish availability of water for three cases such as: where, how much and when.

Hydrologic data should be based on long-term records, because the hydrological design parameters are based on the assumption that past history will be repeated in the future. In most cases long-term records are not available, then flow and flood estimates should be prepared on regional basis considering other physical parameters as meteorology, topography, soils, vegetation etc. These estimates are normally obtained based on correlations with other similar or neighbouring catchments where flow records are available. For estimation of flow, flood and power output computer packages such as WAPPO, HEC, etc. may be employed.

For the formulation of a project and its layout, suitable topographical maps of the area are required. Aerial photographs and satellite imagery are also very useful for the general studies and assessment of the regional set-up. The regional geological assessment of the area is frequently prepared on the basis of available literature. The site geology can only be assessed during field visits.

The project elements are selected while studying project layout alternatives and taking into account the most relevant design parameters. Some elements are common such as dams, intakes, waterways, powerhouses, etc. and others are project particular such as: regulation works, water transfer, multipurpose, etc. Several layout alternatives are usually investigated keeping in view their practicability regarding construction, supply, access, transport, environmental disturbance, etc. If reservoir is a project element, then dam height, storage level, spillway size, reservoir volume etc. should be established as part of the office studies. Basic engineering principles and methods are normally required during the planning and design of project elements.

The environmental investigations at reconnaissance level are necessary to determine any disturbances that a project could create, especially to assess the environmental impact attributed to its implementation. It is very much necessary to integrate environmental issues at an early stage, which will help to create awareness and minimize negative impacts and the implementation of remedial measures when necessary. It will also help in a better project formulation, which may be easier to accept by licensing authorities and the public. The environmental assessment at reconnaissance level may reveal that large potential problems could be associated with a given project, requiring more detailed surveys at later stages of investigation. The environmental constraints are natural and man-made and are therefore likely to change with the passage of time.

#### 5.2.1.3. FIELD WORK

The office studies should be followed by field visits, because plans prepared in office need verification in the field. The project layout and its elements are visualised in the actual surroundings to check and compare. Alternative solutions will then be finalised.

The following issues should be recorded properly:

- Terrain features such as location and placement of structure, Geo.-technical problems related etc.
- Infrastructure such as access to project elements, transmission lines, etc.
- Settlements and resettlement issues
- Availability of construction materials
- Environmental issues such as diversion of flow from one catchment to another, forest, etc.
- Multipurpose uses
- Diversion of flow during construction and construction of cofferdams.
- In case of reservoir and tunnel project special attention is to be paid to Geo.-technical and engineering geology
- Appraisal of discharge available.
- Study of existing and future water uses, such as irrigation and drinking.
- Verification of estimated head.
- Powerhouse, type, location and equipment.

#### 5.2.1.4. FINAL DESIGN

After verification all data and information the hydropower planner puts the final touches to the project formulation, which will comprise necessary drawings showing general layout, salient project features, elements and structures. The planning criteria used must be well documented.

Preliminary cost estimation should also be the part of this study. Besides the basic project cost, the estimate should include pre-construction cost such as, field investigations, engineering, acquisition of water rights (private power in case of Pakistan), land acquisition, management and owners costs, taxation. Allowance for physical contingencies about 25 % at reconnaissance level should be the part of estimate due to less information about project parameters. The calculation may be done manually, with help of spreadsheets or using computer packages such as HPC.

An implementation schedule should also be prepared giving an overview to the total time requirement for developing and implementing the project.

The economic viability of the project should be established. For reconnaissance studies power unit cost (cost per kW installed and unit cost of annual energy generation (cost per kWh) should be established. Computer packages can be employed for this purpose.
Finally, a detailed assessment of data requirement for feasibility study will be required.

#### 5.2.1.5. REPORT

Any reconnaissance report must conclude with a statement on the viability and suitability of the project under consideration. Reconnaissance reports start with an executive summary, which is followed by information on site conditions, hydrology, power potential, project layout, geology, environmental impact, project cost, construction planning and economic analysis. Data requirement for feasibility study should be indicated in the relevant chapters.

As stated earlier, it is the first step in project oriented planning. Therefore it is necessary to engage experienced hydropower planners at this stage. Experienced persons are necessary as basic data may be lacking or inadequate. Many decision have to be based on limited data backed by personnel experience. Therefore, engineers with planning, design and construction (for costing and scheduling) experience of hydropower projects are to be employed for the execution of the study in a rational and efficient manner. Normally a limited number of experts are fully engaged in the study and others consulted when needed.

The following experts are the minimum manpower requirements:

- Hydropower planners
- Hydrologists
- Geo-technical expert/ engineering geologist
- Support personnel

Hydropower planners will usually act as team leaders. They will also be responsible for conception of the projects, report writing as well as co-ordination with others team members and special expert.

### 5.2.2. PRE-FEASIBILITY STUDY

#### 5.2.2.1. GENERAL

A pre-feasibility study is the second organised step in the hydropower investigation and planning. These studies may proceed along the same line as the first phase of investigation; however, at this stage the project has already been identified, located and properly named.

In pre-feasibility study one or more project alternatives are proposed and studied before selection. Further investigation and processing is needed before selection. Identified projects normally have alternative layouts and components, which are not investigated in detail during the first phase. These layout alternatives are studied and investigated to find the best project development possibilities for which detailed field investigations are needed.

Pre-feasibility studies may change considerably the layout proposed at identification level in terms of sitting, components, arrangement of structures, sizing, etc. However, this may require in-depth and costly investigation at this level should be postponed.

The main purpose of the pre-feasibility study is to:

- Establish demand for the project.
- Formulate a plan for developing this project
- The project is technical, economical and environmental acceptable.
- Make recommendation for future action.

Pre-feasibility study is normally based on available data and information of reconnaissance level field survey. However, investigations should be made in sufficient detail and data presented should be of sufficient accuracy. The adequacy, sources, nature and reliability of the information used in investigations needs to be stated properly.

It may be an advantage if the first phase team, which worked at identification stage, also continues working on the project at pre-feasibility stage. However, a new team with different background and experience may be an advantage in introducing new ideas and concepts. The following aspects are to be investigated during pre-feasibility studies.

#### 5.2.2.2. HYDROLOGICAL STUDIES

Hydrological studies for pre-feasibility investigations are concerned with the source, extent, amount, occurrence and variability of water. These studies should cover present, past and future needs of water and include opportunities for control and development.

Surface water estimation is the main objective in hydropower planning. Water requirement for hydropower production should cover the amount and characteristic and total volume of water for generation. Normally there are a few locations on which gauging stations are in operation and long-term records are available. Therefore, mostly estimates of run-off have to be prepared at unguaged sites. The estimates should include monthly flows and flow duration curves. They should also provide adequate information to establish the minimum, maximum, average and critical conditions. Short records may be statistically extended with help of records of other stations.
When applicable, the groundwater potential of the rivers should also be the part of water resources inventory. It should include extent, thickness of aquifer and estimate its economic yield. All this information can be collected from available records and may be supplemented with limited field observations.

Sediment quantity and quality is very important in connection with hydropower development and deals with silting, life of reservoir and turbine cavitation, etc.

Quality of water should also be assessed in terms of its physical and chemical properties. Especially important in this regard are BOD, DO, dissolved solids, sodium concentration, boron content etc.

Existing water rights should be recognised and protected. The cost of acquiring the rights for hydropower development should be estimated and included in the project cost. The present and future water uses for other purposes such as irrigation, industrial, domestic navigation, etc. should be estimated.

Estimates of flood during construction as well as the design flood for the relief structures should be made.

#### 5.2.2.3. POWER STUDIES

These studies consider a balance between supply and demand.

Power market studies should be carried out as a first step to assess the present and future power requirements. These studies should take into account the socio-economic set-up, especially population and population growth-rate, type and number of consumers, consumption patters, potential economic and industrial growth, etc.

The expected power and energy output of the hydropower projects should be established on basis of available natural resources, especially head and discharge. These should be compared with the system requirements to assess the suitability of the project to satisfy the system requirements. The regulation of flows to meet the fluctuations in power demand may be considered.

#### 5.2.2.4. LAYOUT PLANNING

A comprehensive layout plan will be prepared and should be supplemented with sufficient number of drawings, which will be used for preparation of the bill of quantities and project costing. General topographic map (GT. Sheet) at a scale 1:50,000 with contour interval of 20 to 40 m are not enough for pre-feasibility level layout planning. At least a basic topographic survey and maps on scale 1:10,000 are needed at feasibility level.

The usual practice is to propose in the office layout alternatives and placing of different structures such as dam, intake, waterway and powerhouse on topographic maps and then to carefully check them in the field. Estimation of reservoir area and volume will also be based on these maps.

### 5.2.2.5. GEOLOGY AND FOUNDATION ENGINEERING

engineering geologist should determine the suitability of foundation conditions for dams and other major structures from field examination. Seismic refraction and test pits may be needed if problematic conditions are found. However, core drilling may not be required during this phase of investigation.

General geologic maps are also very much needed for the classification of land, groundwater, etc. which may effect the physical proposed layout plan. During field examination, location and quantity of suitable construction materials should be made.

### 5.2.2.6. SEISMIC STUDIES

These studies should be made on the basis of available seismic catalogues record and seismic sources (i.e. active faults). The works may be carried out in the office and complemented with field visits. Peak ground acceleration and velocity should be estimated for different type of soils and structures.

### 5.2.2.7. ENVIRONMENTAL STUDIES

A comprehensive initial environmental study (IES) is performed. These studies should be in line with the reconnaissance studies. However, in depth studies are normally part of feasibility study. The acquisition of land, resettlement of population and in-stream water requirements are the major aspects to be considered in the environmental study. These problems should be properly assessed and suitable solutions should be considered.

### 5.2.2.8. ESTIMATION OF COST

Estimation of cost should cover construction cost, cost of camps and land acquisition, and annual operation and maintenance cost. Construction cost is estimated on basis of the major construction items such as, excavation, cofferdams, embankments, dewatering, concrete, number and type of generating units, electro-mechanical equipment, etc. The difficulties related to climate, altitude and construction material should also be addressed because these can have an effect on the performance and efficiency of manpower and equipment, construction time, etc.

General costs such as land acquisition, establishing of construction camps, mobilisation and demobilisation of equipment are also part of project cost. Annual operation, maintenance and replacement cost can be estimated from experience on similar projects.

### 5.2.2.9. ECONOMIC AND FINANCIAL STUDIES

The economic analyses will provide a basis for comparison of projects competing for funds and a basis for selection of the best project. A detailed financial analysis is usually not necessary at this level. However, a benefit-cost ratio should be estimated to check the financial viability of the project in general.

### 5.2.2.10. FUTURE INVESTIGATION PROGRAMME

A complete procedure for data collection should be provided to meet the deficiencies. A detailed recommendation for feasibility investigation should be made and should include time schedule, manpower and equipment and money requirement.

### 5.2.2.11. PRE-FEASIBILITY REPORT

All the aspects discussed above should be well documented in the pre-feasibility report. Availability and reliability of the data used should be clearly mentioned, especially the possible impact on the selected alternatives.

A clear statement should be made in respect of technical, economical and environmental feasibility of the project. It should give clear indication whether or not to study the project in more detail.

### 5.2.3. FEASIBILITY STUDIES

#### 5.2.3.1. GENERAL

Feasibility studies are carried out to determine the technical, economical and environmental viability of a project. This phase of investigation consist of a detailed investigation and study, which is directed towards achieving the ultimate permission, financing, final design and construction of the project under investigation.

A feasibility study also serves as basic document for financing. Therefore, it should follow the rules set by national and international finance institutions. The main purpose of this phase of investigation is to establish and define the engineering and operation plan and to determine whether the potential development is technically and economically feasible.

Feasibility studies are sufficiently detailed and ensure that during detailed engineering, the feasibility of the project is not impaired due to major alterations in the plan. The main part of feasibility studies for hydropower development is given and described below and presented graphically in Figure 5-2.

a) Data collection

b) Project parameters optimisation
- Power and Energy Estimation
- Power system studies
- Water resources studies
- Geology and foundation conditions
- Seismic Studies
- Construction materials
- Existing infrastructure study

c) Layout Optimisation
- Project Layout
- Sediment and control measures
- Number and size of units
- Auxiliary equipment
- Transmission planning

d) Environmental Studies
- Assessment of environmental disturbance
- Assessment of mitigation measures

e) Engineering Design
- Intake structure and sediment excluders
- Headrace and tailrace
- Powerhouse
- Dimensioning and preparation of specifications for hydro turbine and electrical equipment
- Construction facilities

f) Estimation of Project cost
- Estimation of project cost
- Estimation of operation, maintenance and replacement cost
- Estimation of environmental cost
- Construction planning and budgeting
- Estimation of contingencies and other costs

g) Economic and Financial Analysis

- Economic analysis
- Financial analysis

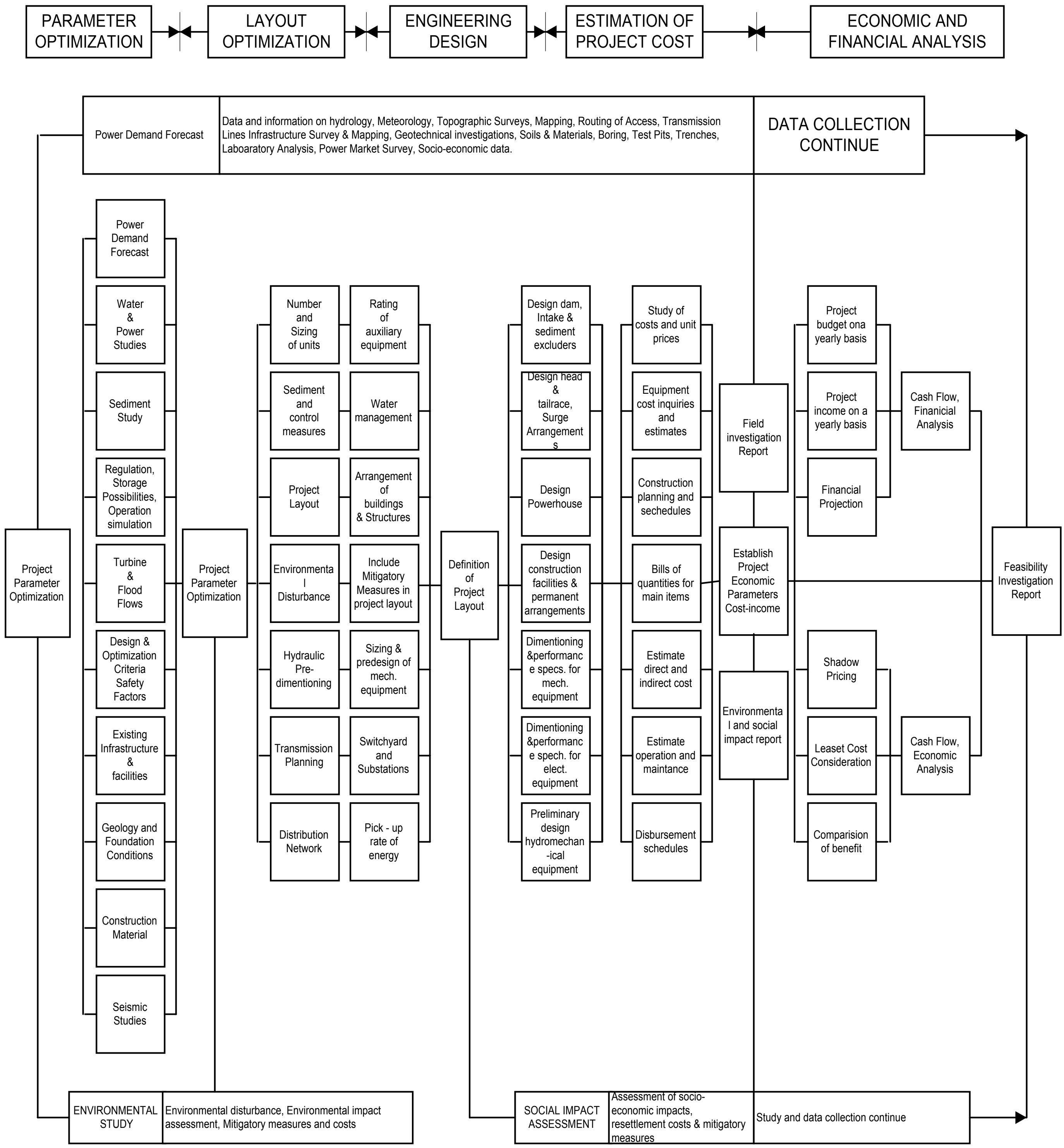


**Figure 5-2 Feasibility Study Flow Chart**

#### 5.2.3.2. DATA COLLECTION

The main data requirements are listed below

- Socio economic data
- Population
- Income distribution
- Power market
- Tariffs
- Hydrology
- Topography
- Geology and Foundation conditions
- Seismic Data
- Environment
- Temperature, climate, rainfall, humidity, etc.
- Infrastructure

#### 5.2.3.3. PROJECT PARAMETER OPTIMISATION

##### 5.2.3.3.1. WATER RESOURCES STUDIES

The main hydrological parameters must be established during this phase of study. Rating curves and flow duration curves need to be developed with great care. Flood estimation should be performed aiming at the maximum possible reliability because it affects the design of the diversion during construction, bottom outlets and spillways.

When records are not available, then a comprehensive river gauging program has to be implemented and operated to update and improve existing records. River regulation studies should be carried out considering the maximum realistically thinkable number of alternatives. In this context, the availability of flow for hydropower development has to be established by taking care to other water uses, such as irrigation, domestic, industrial, navigation, etc.

Powerhouse tail rating curve is very important due to setting of turbine and safety from flood.
Other hydrological parameters such as sediments and water quality should be estimated with the necessary level of detail.

##### 5.2.3.3.2. POWER STUDIES

The estimation of power and energy output of a project depends upon physical parameters, namely head and discharge. The general equation to calculate power is:

$$\mathbf{P = 9.81 * \eta * H * Q\ (kW)}$$

The head is determined as the mean difference level between inlet and outlet of a hydropower installation. Normally improvement in head cannot be made without major changes to the project. The head available in a river stretch can be concentrated at one place by construction of a dam.

Flow availability can be improved up to some extent by regulation, which implies the storage of water during periods of abundance and/or low demand (i.e. wet months, off-peak hours) and releasing it during periods of shortage and/or high demand (i.e. dry months, peak hours, etc).

The efficiency of plant is another important factor, which in some cases is difficult to improve after commissioning. The efficiency tends to decrease with wear, aging, etc. and need to be monitored to ensure a good return on investment.

The power demand, which the project has to meet, is established at early stages. This is due to the fact that size and number of generating units as well as their timing may be influenced by the system demand. The development of the market is important the consumption of the power produced and thus the sale volume and consequently the financial viability of the project.

These aspects are covered in detail as part of the studies related to the power market and demand forecast and usually comprise of:

- Data of load according to its classification such as, households, industry, public, schools, public utilities, etc.
- Collection of already conducted studies and their evaluation.
- Historical trend and growth rates of the various consumers groups.
- Population growth rate.
- Anticipated economic development.
- Tariff and tariff policy.
- New substitution
- Other supply alternatives.
- Distribution of load by geographical areas.
- Demand forecast for at least 10 to 20 year assuming

    - High growth rates
    - Medium growth rates
    - Low growth rates.

**5.2.3.3.3. TOPOGRAPHY**

Feasibility study should be based upon reliable topographic maps. At least the following map base is necessary:

- Site Maps (Dam, intake, sediment excluder, forebay, Powerhouse, etc.)
- Scale may be 1:1000 or 1:500 or 1:200 with contour intervals of 1 meter.
- Reservoir area
- Scale may be 1:2500 or 1:5,000 with contour intervals of 5 meter.
- Catchment area
- Scale may be 1:50,000 or 1:25,000 with contour intervals of 5 meter.
- General maps
- Scale may be 1:5,000 or 1:10,000 with contour intervals of 5 meter.

These survey works should start immediately so that reliable coverage could be developed.

**5.2.3.3.4. GEOLOGY AND FOUNDATION CONDITIONS**

The comprehensive field investigation program recommended at identification or pre-feasibility level should provide the basis to develop and implement a detailed investigation program as early as possible, obviously keeping in view the local conditions, such accessibility, weather, etc. Pre-feasibility studies are usually based mainly on surface investigations. Therefore, for feasibility study subsurface investigations are always necessary. The following field investigations may be taken up:

- Core drilling: It is an excellent but costly method. When properly done, a significant amount of information, such as physical properties of rock, water tightness, depth of weathering, faults zones, etc. can be obtained.
- Seismic refraction: It is normally used to reduce the amount of drilling works. This method is based on the fact that sound waves are affected by the medium they travel through and are reflected when hitting a denser medium. However, their results need to be calibrated with core drilling.

- Hydraulic fracturing or hydro cracking: This is normally applied when waterway working under pressure such as tunnels, shafts, and similar will be constructed.
- Pilot tunnels, shafts, trench and test pits are other investigation methods, which may be done according to site conditions and information requirements.
- Simple drilling: It is used in case of deposited soil to find out the lithology, permeability, density, etc. of the subsurface.
- Reservoir area should be investigated for reservoir tightness, change in ground water level and quality, risk of landslides to rapid drawdown, stream erosion and formation of deltas, etc.
- Laboratory testing is required to analyse the samples taken in the field.

#### 5.2.3.3.5. CONSTRUCTION MATERIALS

The study area should be surveyed and mapped in order to find suitable and sufficient construction materials within acceptable distance. Construction materials usually comprise earth, clay, rock, filter materials, concrete aggregates and timber.

Other materials, such as cement, bricks, reinforcing steel, etc are obtained from the local and/or international markets.

The availability and selection of the construction materials is very important and may affect the cost of the project and the type of the structures selected.

Laboratory test should be performed to check the suitability of the construction materials. Some drilling works may be needed for a better assessment of the quantity and quality of the materials.

#### 5.2.3.3.6. ASSESSMENT OF SEISMIC RISK

The data about the seismic activity should be collected from those countries and organizations, which are keeping telemetric records such as USA (NOAA), China, USSR, etc. Additional data may be obtained from local networks operated for specific projects.

The maximum credible earthquake (MCE) is estimated through the identification of likely sources, such as active faults. Office and field investigations with a suitable coverage of the area (200 to 400 km radius) are required for this purpose.

The operational basis earthquake (OBE) is determined with the help of recorded data. This may be possible with the help of telemetric records as well records of local networks. It is always better if seismic records are available near the site, however this occurs very seldom. Especially for large projects, the installation of recording equipment should be undertaken as early as possible.

#### 5.2.3.3.7. INFRASTRUCTURE

Data regarding existing infrastructure should be collected and studied very carefully, whether, it will meet the requirements of contemplated project during construction and operation. The most important infrastructure to consider comprises: transmission system, distribution system, access condition of the project area, road network, railway, telephone, telegraph, etc.

If the existing infrastructure is not adequate, then the required cost of its development should be assessed. The available infrastructure for transportation and its limitation generally affect the size of hydro-mechanical equipment.

### 5.2.3.4. LAYOUT OPTIMISATION STUDIES

The layout optimisation will be done on the basis of technical and economical criteria. The plans developed in pre-feasibility studies are improved and optimised. Different alternatives are analysed, adapted and tested. Technical merits and demerits of each alternative are discussed separately and selection is based on the comparison of these merits. Different alternatives for main project feature are studied. Any new alternative, which may be proposed should be discussed in detail and properly documented.

The feasibility design is normally termed as preliminary design. However, it should be sufficiently detailed so that reliable cost estimate can be prepared.

The main project features, which need to be investigated in different alternative/type, are given below:

- Dam
- Spillway, Bottom outlet
- Gates
- Navigation lock
- Log floating facilities
- Fish bypasses
- Diversion works, coffer dams, diversion tunnel/canal
- Intake
- Sediment trap (Sand trap and gravel spill)
- Headrace Canal/tunnel
- Tailrace canal/tunnel
- Surge bay/forebay
- Penstock/pressure shaft
- Valves
- Powerhouse structure (open, slope type, underground)
- Type, size and number of hydro-mechanical equipment
- Type, size and number of electrical equipment
- Transmission Work
- Construction materials
- Access to project area
- Colonies, School, hospital, recreation, etc.
- Mobilisation and demobilisation
- Construction camps

All main features should be studied in detail considering different layouts and types, keeping in view construction, operation and maintenance of the contemplated project. The best layout and type should be selected on the basis of technical and economical attractiveness. The reasons on which other types and layout options were discarded should be mentioned in detail. The different types and layout arrangements are described in other modules and chapters of these documents. After selecting a suitable layout, detailed drawings should be prepared, which will provide the basis for project costing.

#### 5.2.3.5. ENVIRONMENTAL STUDIES

The environmental issues regarding hydropower development have to be discussed for the construction and operation periods separately. The environmental studies should be performed in close co-ordination and as an integral part of feasibility study. There are only two main environmental issues to consider:

- Physical disturbances caused by the project and its components and their impact on project planning/layout.
- The impact assessment and their mitigation measures

During planning, the first issue can be handled by the planner aiming at reducing the disturbances to minimum. This can be achieved through proper selection of layout, project components, structures, design discharge, etc.

The assessment of environmental impact is a separate study and normally done through consulting engineers specialised in this field. The direct and indirect impacts are analysed and studied carefully. The impact such as:

- Flora and fauna
- Soil
- Watershed management
- Fish
- Water uses
- Water rights
- Resettlement
- Handling of excavated materials
- Scenic beauty of the valley
- Seismicity due to reservoir impounding
- Irrigation practices
- Effluent discharging in to river
- Noise level
- Wildlife and their breeding

To make a proper assessment of the environmental impacts, the data regarding existing environment has to be collected with proper care and if some investigation is necessary, should be performed as a part of feasibility studies.

### 5.2.3.6. PROJECT LAYOUT OPTIMISATION

The layout optimisation is done on the basis of the different features of the project, such as:

- Different type of weirs and dams will be studies and suitable type and size will be selected according to site conditions. A discussion on the types of dams is presented in the module **Project Components**.
- Various types of spillways should be studied and the suitable layout, size and type should be selected to suit the site conditions, design flood, operational requirements, etc.
- The intake, sediment handling facilities and waterways are optimised keeping in view hydrological and topographical conditions, the design discharge and operational requirements.
- The number and size of hydro turbines plays an important role in the project optimisation. A large number of units are desirable because it increases the quality and reliability of the supply. However, this option may be costly and may create maintenance problems, especially for developing counties that need to import spare parts because the manufacturing capabilities are limited. The size of the units may also create some transportation problems when the accessibility to the site is constrained by width and capacity of bridges, railways, etc. These limitations should be kept in mind while selecting the layout, size and type of units.
- The type of turbine is very important in project sizing. Some turbine types are being manufactured exclusively by one company, having some sort of monopoly. In countries where manufacturing facilities are limited, the selection of such equipment has to be carefully done. Standardised units may have some economical benefits, but these units are usually available only for small capacities.
- Transmission of produced energy is an important parameter in project layout optimisation. The interaction of the project with the system should be studied before deciding the size of

the plants. Load flow, short circuit and stability analyses are normally required for medium and especially for large projects.

- All types of powerhouses should be considered and the most suitable for the site condition should be selected.
- The economic benefits of the selected layout may be compared with other alternative supply sources, such as thermal power plants of different type.
- The flow chart for layout optimisation on the basis of least cost solution is given in Figure 5-3.

The design level of feasibility study is termed preliminary design. However, it should be sufficiently detailed to ensure realistic and practical solutions and reliable cost estimates. When a layout reaches an acceptable level it should be drawn on topographic maps and described in detail. All studied alternatives should be documented properly. Merits and demerits and the reasons on which some alternatives are discarded should be properly recorded. All drawings relating to selected alternative are an integral part of investigation report.

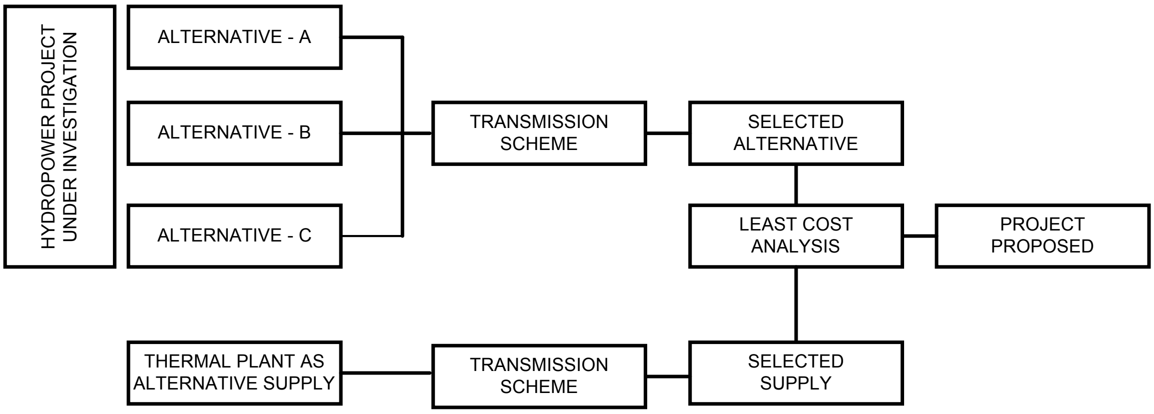


**Figure 5-3 Project Optimisation Flow Chart**

### 5.2.3.7. ENGINEERING DESIGN

After the selection of a project layout the engineering design of civil, mechanical and electrical equipment will be taken up. Civil design relating to regulation work, waterways, powerhouse, etc. should be carried out. The design consists of hydraulic design, static analysis and structure design. The design should be made for static and dynamic conditions. Dewatering system design and foundation design is also an essential part of the feasibility design.

Dimensioning of electromechanical and hydro-mechanical equipment and preparation of specification should be carried out. Different configuration of single line diagram should be studied and finalised. Drawing should be sufficiently detailed and can be used in project costing.

### 5.2.3.8. ESTIMATION OF PROJECT COST AND SCHEDULING

Construction cost estimates are made on the basis of main construction and equipment items and miscellaneous costs. The cost of civil work depends upon actual volume of works such as dewatering, excavation, concrete, reinforcement, etc. and unit prices adapted to the actual location. The unit prices should preferably be based on international competitive bidding. The cost of equipment should be based on budgetary prices obtained from approved manufacturers and suppliers. However, comparisons of costs with the planners' own cost estimates are necessary to make necessary adjustments.

When detailed information is not available, construction costs other than main items are sometimes worked out on the basis of percentages of the estimated costs of main items. These costs include items such as:

- Transportation of equipment.
- Mobilisation and demobilisation of construction machinery.
- Land acquisition, resettlement, right of way etc.
- Administrative cost
- engineering, supervision and investigation cost
- Audit and accounts
- Insurance, taxes, workmen compensation, import charges, etc.
- Physical contingencies.
- Interest during construction for financial analysis.

The costs estimate should be prepared for local and foreign cost component. Inflation in cost should be accounted for when applicable. Therefore, it is important to fix a date to the estimates so that their validity date is known.

The construction schedule should be prepared by considering all construction techniques and equipment required for the construction of the project. The project cost needs to be phased according to the construction schedule.

### 5.2.3.9. ECONOMICAL AND FINANCIAL ANALYSIS

The economic investigation will provide a basis for comparison of projects competing for funding and a basis for selection of best project for implementation. The basic elements in economic and financial investigation are:

- Project implementation and operation costs
- Project benefits. These can be direct and indirect. In hydropower the direct benefits are obtained from the sale of electric energy. However, those benefits, which can be quantified on monetary basis, are considered in the economic analysis and other intangible benefits may be discussed during preparation of project appraisal report.

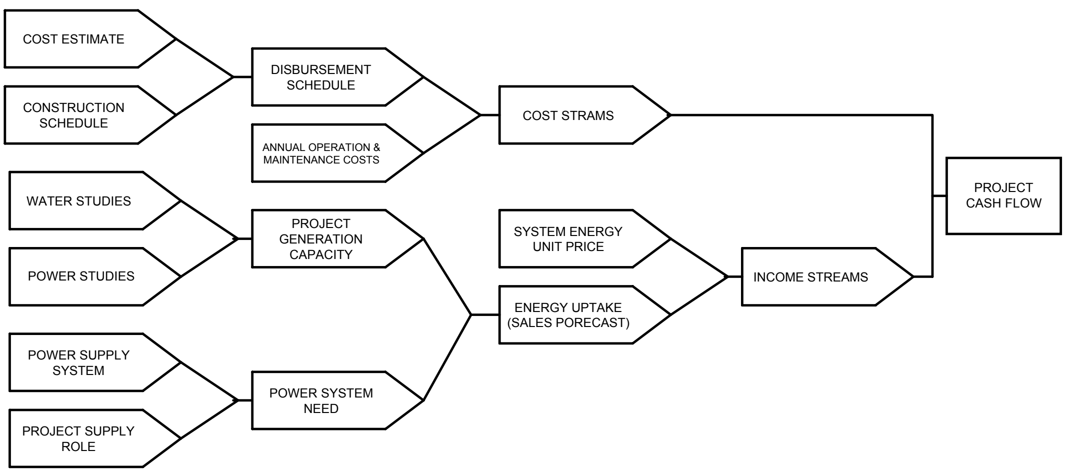


**Figure 5-4 Economic Analysis Flow Chart.**

The economic analysis can be carried out by the following techniques:

- Net Present Worth (NPW).
- Economic Internal Rate of Return (EIRR).
- Benefit/Cost Ratio (B/C Ratio).

It is important to note that all either techniques may be used, although the use of all of them may give a more comprehensive picture about the economic viability of the project. The economic feasibility of a project means that project has more benefits than costs over the project life and economic analysis can be done according to this Figure 5-4.

The financial feasibility basically implies that the project is able to repay the financing required for its development. The technique used for financial analysis is normally the Financial Internal Rate of Return (FIRR). The FIRR totally depends upon the expected income according to energy produced and tariff as well as the financing terms. A simplified financial analysis flow chart is presented in Figure 5-5.

Normally the power utilities do not finance the construction of hydroelectric projects totally with own resources. The practice is to cover partially the cost with own equity and the remaining investment is financed through bank loans. Therefore, it is usually required to prepare the feasibility studies with sufficient level of detail and reliability in order to ensure financing. In any case, the feasibility should be realistically prepared to avoid cost overruns and extended construction periods, which increase the financial cost of the projects to unbearable levels.

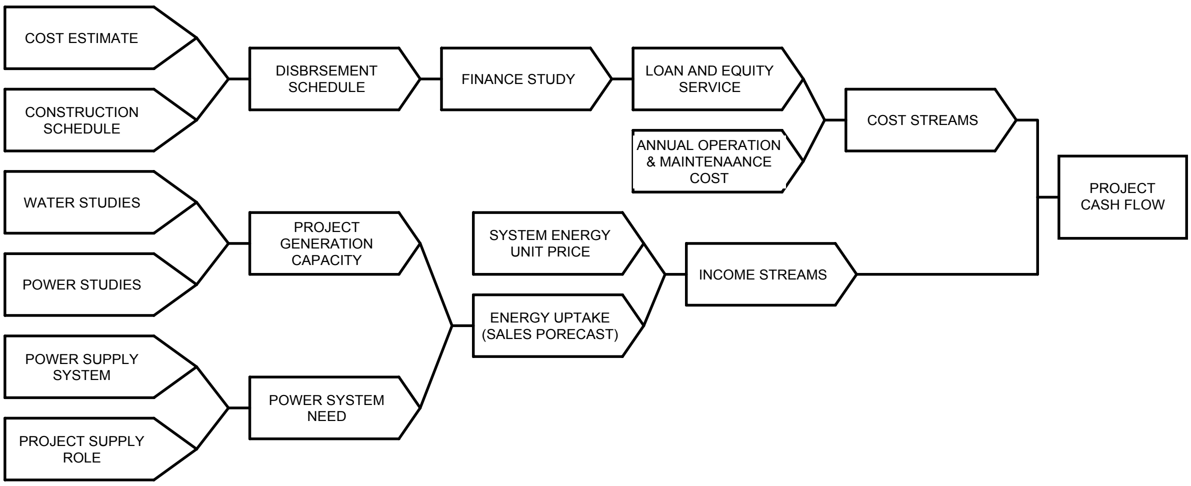


**Figure 5-5: Financial Analysis Flow Chart.**

### 5.2.3.10. FUTURE PROGRAM

This will be given at the end of each report and will include the future steps to be taken for project implementation. In this chapter the planner should highlight the field investigations needed before starting project construction. Other studies and activities such as preparation of tender document, pre-qualification of consultants and contractors, detailed engineering etc. should clearly be defined.

### 5.2.3.11. FEASIBILITY REPORT

All the investigations and studies carried out during feasibility study should be properly documented for future use. The feasibility report should be self explanatory and properly organised. The report must contain at least:

- Summary
- Project area description.

- Hydrology and sedimentation.
- Power and energy potential and project operation.
- Geology, foundation conditions and construction material.
- Seismic risk evaluation.
- Environmental impact assessment.
- Project layout studies and optimisation studies.
- Civil engineering design
- Hydro-mechanical and mechanical design.
- Electrical design
- Project quantities and costs.
- Construction planning and scheduling.
- Economic analysis.
- Financial analysis.
- Future program.

## 6. IMPLEMENTATION PHASE

### 6.1. GENERAL

If the technical and financial feasibility of the project is proven and the reliability of the information is adequate, then the owner has to decide about its implementation. It is very important to note that many feasible projects are not implemented due to various constraints, mainly financial, environmental, etc. On the other hand many projects having poor profitability are implemented. Project implementation is a multidisciplinary job (Figure 6-1), which includes:

- Approval and Appropriation of funds
- Pre-qualification and hiring of consultants
- Detailed design
- Preparation of Tender/contract documents.
- Pre-qualification of contractors
- Preparation of construction design and engineering design
- Preparation of operation manual
- Construction supervision
- Construction of civil works
- Supply and erection of equipment
- Testing, Commissioning and Commercial operation
- Preparation of completion reports

All the above-mentioned activities are very specialised and usually the owner does not have the staff to perform all these activities. Therefore, when a decision for implementation of project has been made, the owner has to decide about the following:

1. Establish an organisation responsible to perform on behalf of the owner
2. Appointment of a competent consulting engineer, generally called the engineer.
3. Hiring/engaging of competent contractors and suppliers for construction, manufacturing, erection and commissioning of the plant, generally known as the contractor.

Therefore, it is evident from above that following are the main participants in implementation:

- owner/owner organisation
- consultant/engineer
- contractor

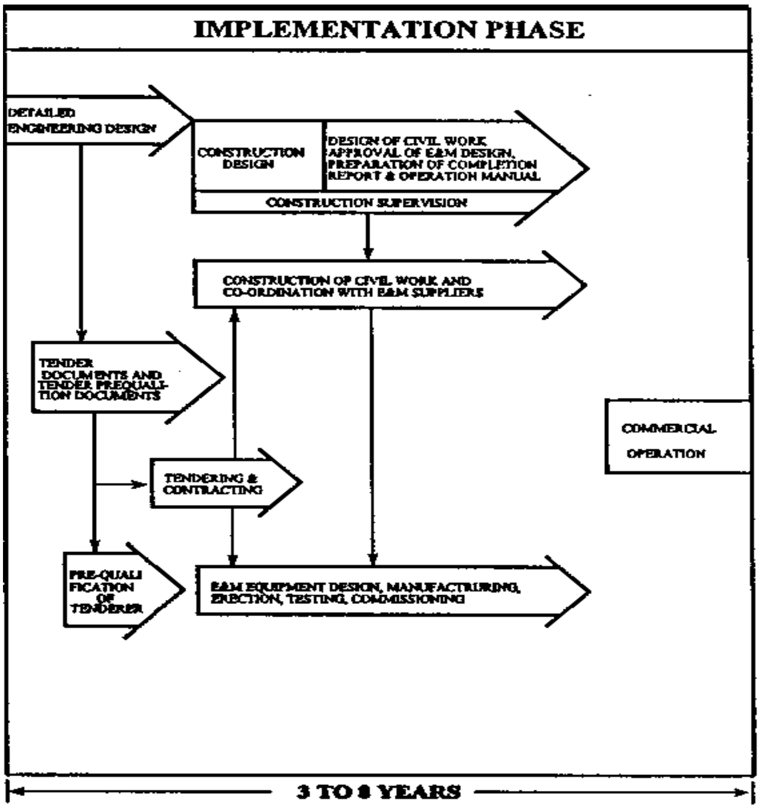


**Figure 6-1 Implementation Flow Chart.**

In the following text the role of each party and its respective activity is described briefly.

### 6.2. OWNER

The owner will always have the central role. He is responsible to make or approve all decisions and arrange financing. The owner should concentrate on management, supervision, monitoring and inspection and have the contractors carry out all the actual work, including testing, topographic surveying, measurement, etc. To manage all activities the owner needs a sizeable organisation. Therefore, this organisation should be staffed, equipped, and have resources to carry out the followings main task:

- Administrative services
- Co-ordination
- Quality assurance
- Engineering services
- Inspection services
- Contract administration
- Progress monitoring
- As-built documentation
- Approves bills for payment

A brief description of these is given below.

#### 6.2.1. ADMINISTRATIVE SERVICES

The owner's field organisation is responsible to administer security guards, handling of visitors, public relations, health services, sanitation, communication, transport, etc.

### 6.2.2. CO-ORDINATION
When more than one contractor or suppliers are involved in the construction of a project the co-ordination between all parties is the responsibility of the owner's field organisation. It is very important and should be done very carefully so that overlapping or delay in construction/supply should be avoided. Sometimes a full consulting firm can be hired for this purpose.

### 6.2.3. QUALITY ASSURANCE
The objective of quality assurance is to do the right things, the right way, using the right resources and to get the right result on time at the right cost. It means to do everything right the first time and every time.

To promote quality and assure that quality is achieved a quality assurance system has to be organised under a Quality Assurance Manager, who is subordinate to the Project Director. Therefore, a Quality Assurance System shall promote quality in its widest sense. It monitors processes and procedures to ascertain that quality is achieved, and shall take steps to have conditions, procedures and processes improved if found lacking in the context of quality achievement. The main task of all quality assurance work is to promote quality consciousness in the organisation and to create an active environment for improvement of quality.

Quality assurance should involve the whole organisation and should be instigated by the management. Quality assurance is also charged to project consultant but actually it is the responsibility of the owner's organisation.

### 6.2.4. ENGINEERING SERVICES
The main engineering services, design, etc. are carried out by project consultant's design office. However, the owner's field organisation will have an engineering office at the site to tackle the day-to-day engineering tasks and construction problems. The site engineering office will also be responsible to manage the documents and drawings, investigation and testing, adaptation of designs to the terrain, documentation of changes, scheduling, monitoring of progress, etc.

### 6.2.5. CONTRACT ADMINISTRATION
An office set up for this purpose will carry contract management on the owner's part. The main task of this is to see that the contracts are executed in accordance with contract conditions. It is also responsible to keep track of bonds, guaranties, retention money, insurance policies, etc. It also supervises the issuance of certificates of acceptance, certificates of completion and other similar documents.

### 6.2.6. INSPECTION SERVICES
A team should be organised for this purposes at site. It should be responsible to monitor that specifications are being followed and adhered to and that the owner gets what he pays for. Another responsibility is that to monitor the progress and take measures in case of delay this team is responsible for the control and approval of the project components during and after construction and manufacturing. It means that the material to be used shall be tested and approved and the manufacturing of electro-mechanical equipment should be controlled and checked by visiting the factories at intervals. The inspection should continue during assembly, erection, testing and commissioning.

### 6.2.7. PROGRESS MONITORING
The monitoring of progress and taking appropriate measures in case of any delay is the responsibility of a small cell established for this purpose in owner's field organisation.

### 6.2.8. PAYMENT OF BILLS
The approval and make arrangement for payment of contractor or supplier bills is the responsibility of the owner's field organisation.

### 6.2.9. AS-BUILT DOCUMENTATION
The preparation of as-built drawing, completion report and other documents is the responsibility of the owner's field organisation.

## 6.3. CONSULTANTS
Hydropower projects are highly technical and are more awe-inspiring economically. Therefore, to get maximum protection from outside risk, the owner should hire competent consulting engineers. If this appointment is wisely made, the owner will enjoy a measure of security through; all-round quality assurance, sound advice on technical and economical matters, competent design and contract draftsmanship, stringent supervision of construction and manufacturing and tight control of costs. In this context, the consulting engineers have to perform the following main tasks:

- Detailed engineering design.
- Tendering and contracting.
- Final and construction design.
- Construction supervision.
- Preparation of operation and maintenance manual for civil engineering works.

### 6.3.1. DETAILED ENGINEERING DESIGN AND DEFINITE PLAN DESIGN
#### 6.3.1.1. GENERAL
Following approval of a project and having secured the appropriation of funds for construction, the detailed design is undertaken, which will provide basis for tender document on which tenders for construction can be invited. The detailed design will also provide a base from which the operating agreement can be negotiated. The detailed engineering studies must consists of:

- Detailed field investigations
- Specifications
- Final design
- Cost estimate
- Construction schedule
- Design report and data books

#### 6.3.1.2. DETAILED FIELD INVESTIGATIONS
Engineering survey, geological explorations and similar work accomplished during feasibility investigations are usually carried out to the extent needed to prove technical feasibility and provide basis for preliminary design and reliable cost estimate. The purpose of the detailed investigations is to extend and supplement the information developed during feasibility investigations.

Detailed topographic survey and foundation exploration should be carried out as needed to determine the exact location of the project structures and works and to provide the detailed information required for preparing the final designs and specifications.

Deposits of construction materials such as earth, rock, and concrete aggregates should be thoroughly explored and tested. The borrow areas should be properly located and mapped.
An objective of the detailed design investigations is to assemble and carefully co-ordinate design data to ensure that all elements of the project are considered relative to the best available information and to enable design to be based on the best available data.

#### 6.3.1.3. LOCATION OF WORKS
Location and sites for camps, site installation, rigging areas, spoil dumps, borrow areas, etc. are chosen and shown on maps and drawings. Transmission line routes are located on maps and set in the field, as are sites for switchyard and substations.

#### 6.3.1.4. SPECIFICATIONS

The detailed engineering studies include the preparation of general and detailed specifications for the construction and supply of the project. The specifications will set the quality of the work to be performed and the standards to be used by the contractors and equipment manufacturers. Specifications must include the terms of payment. The specifications will also propose methods of construction and any special conditions or procedures to be observed during construction.

#### 6.3.1.5. FINAL DESIGN

The design should be sufficiently detailed to provide the basis for writing performance requirements and specifications. The design drawings should show the location and dimensions of all component parts of the structures. They should be based on foundation and other natural conditions, the capacity and function of the structures and accepted engineering practices with respect to allowable loads, stresses, strength of materials, materials to be used, suitable construction processes and similar factors.

The design of the equipment should show the exact location, limiting dimensions and design characteristics. Construction drawings showing placing of reinforcing steel and shop drawings for structural steel or equipment should not be included in the detailed design. However, particular information for the preparation of such drawings should be included.

#### 6.3.1.6. COST ESTIMATE

Comprehensive and detailed estimates of cost and quantities should be prepared for each identified structure. It should include the quantities for all works and supplies because they will become the basis on which the construction contractors may compute their unit prices and prepare their tenders. They will also form the basis for comparison of bids. The lump sum items should be avoided as much as possible.

The estimates should include the engineer's estimate of unit costs and total costs. These estimates should under no circumstances be revealed to the public or the contractors competing for the work prior to award of the contract. They are prepared for the sole information and guidance of the responsible authority for awarding the construction or supply contracts.

#### 6.3.1.7. CONSTRUCTION SCHEDULE

A firm schedule for construction and supply of the project should be developed. The schedule should show the planned dates for initiation of construction and completion of the individual project parts. It should also provide a firm estimate of funds requirement and a disbursement schedule.

While preparing construction schedule availability of manpower, materials and equipment and the rates at which construction can be obtained should be considered.

The construction schedule should co-ordinate closely with the overall objective of the project and the time at which various project services are to be provided.

#### 6.3.1.8. DESIGN REPORT AND DATA BOOKS

All information, computations, considerations, etc. on which the detailed design is based should be compiled in a design report. Data from field investigations, laboratory tests, etc. should be compiled in data books for future use and reference. All the drawings should be compiled into a separate volume and will be used in tendering.

### 6.3.2. TENDERING AND CONTRACTING

#### 6.3.2.1. GENERAL

The project implementation will involve three key parties such as:

- The owner or Principal, who defines the project and provides financing for implementation
- The engineer/Planner/Designer, who makes the plan and designs according to the instructions/requirements/definitions of the owner. The quality control is also responsibility of the engineer.
- The contractor and supplier, who is responsible of actual construction of works and also responsible of manufacturing, erection and commissioning of electro-mechanical equipment.

The working relationship and responsibilities of the key parties shall be established through contracts made between the owner and other parties. There are three main type of contract arrangements being used in hydropower development.

For awarding a contract, a document is needed which will govern the tender and becomes the documentary basis for implementation of a project. It is generally called contract document and it will be prepared by the project consultants. Each type of contract arrangement has a different set of contract documents, but here only the conventional contract documents are discussed, which are being used on most of the projects financed by international financing organisations, such as ADB, World Bank, etc.

Tendering procedures consisting of many tasks have to be followed for the selection of bidders and award of contract.

#### 6.3.2.2. CONTRACT ARRANGEMENTS

The type of contract arrangement employed is important for the organisation and management of the construction process and for the decisions to be made during the implementation of the project. The following main contract arrangements are being used:

- Traditional Contracting
- Turnkey Contracting
- Construction Management (CM)
- Engineering, Procurement and Construction (EPC)

The type of contract arrangement to be used is governed by several conditions such as the owner’s organisation capability, capacity and strength; status of the project; financing institution requirement; country traditions; owner’s project monitoring needs and requirements of preparing owner’s organisation for operation. The advantages and disadvantages of these contract arrangements with small definitions are given in the following section.

##### 6.3.2.2.1. TRADITIONAL CONTRACTING

It means employing consulting engineer, contractors and suppliers for implementation of project. All the contracts are made between the owner and various contractors/suppliers and consulting engineers. The consulting engineers will provide design, contract documents, assist in selecting contractors/suppliers and provide technical supervision during construction. The owner provides a site organisation charged with contract administration and management, supervision and inspection services, etc. The construction of the project is let to a contractor through a tendering and contracting process and normally lowest bidder will be preferred. Before bidding all aspects such as structures, materials, quality and performance are clearly defined.

It is the model used on most projects and also preferred by international financing agencies and when their procedures are followed, it is named as International Competitive Bidding (ICB).
The traditional contracting model is time consuming due to orderly implementation process, especially in pre-construction phase. To get better quality and less cost through hiring a number of contractors also leads to increased implementation time and hence cost due to price

escalation, interest during construction, increased co-ordination services, supervision, overheads, etc.

The requirement of early decisions during the implementation phase from the owner, for which he is not yet prepared, may affect the whole project during and after construction. This model is presented in Figure 6-2.

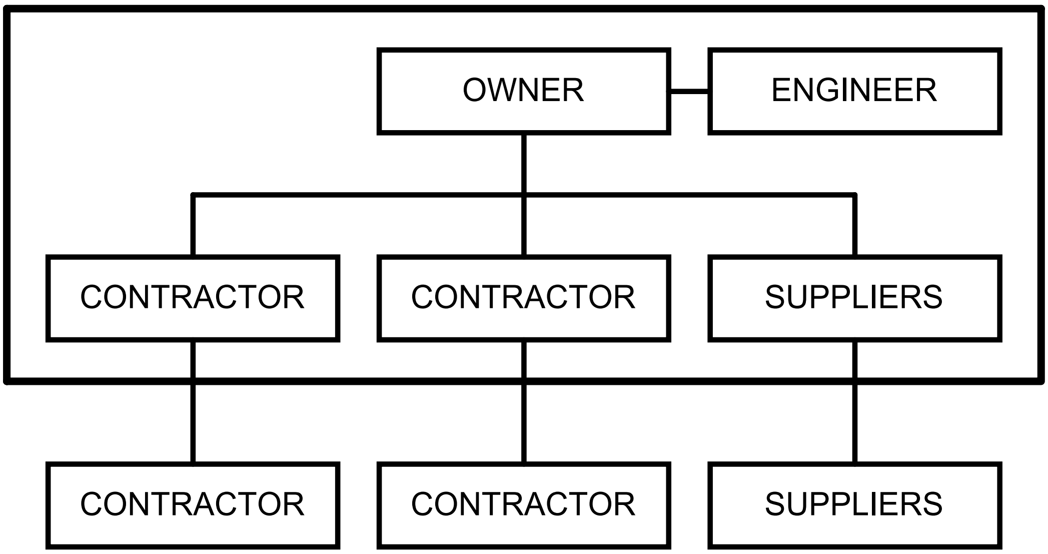


**Figure 6-2 Traditional Contract Flow Chart**

The traditional contract has a number of options for letting construction to a contractor through tendering and contracting. In this case the following contract options/models are available:

- Co-ordinated contract
- Main contract
- General contract

These models are briefly discussed below. However, in all cases, planning and design is the responsibility of the consultants who work under a separate contract with owner.

There are several type of contracts used in connection with international competitive bidding such as:

- Unit price contracts
- Lump sum contracts
- Cost plus contracts
- Variation of cost plus contracts.

**6.3.2.2.1.1. CO-ORDINATED CONTRACTS**

The construction of civil works and supply of electro-mechanical equipment is divided into several parts, which are awarded separately to contractors and suppliers. Each contractor and supplier is responsible for his own part. This option gives opportunity to higher specialists, local contractors, etc., but extensive co-ordination is needed which will be the responsibility of the owner. In this type of contract the main responsibility falls on the owner. This model is illustrated in Figure 6-3.

**6.3.2.2.1.2. MAIN CONTRACTS**

The contract is divided into two or more parts and awarded to two or more independent contractors. The bulk of the construction work is awarded to one main contractor who carries out the work himself or sublets parts to subcontractors. But the main responsibility falls on the main contractor. The equipment supply is awarded under a separate contract to owner appointed suppliers. This part is not the responsibility of the main contractor, but can include this subcontractor in his contract for duties such as supply of labour, transport, catering, etc. In this type of contract the major responsibility of co-ordination and construction management falls on main contractor, however, owner himself needs a separate construction manager. This model is illustrated in Figure 6-4

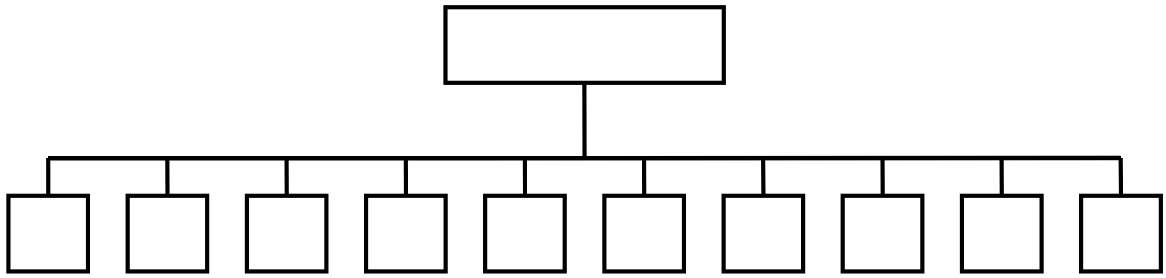

**Figure 6-3 Coordinated Contract Flow Chart**

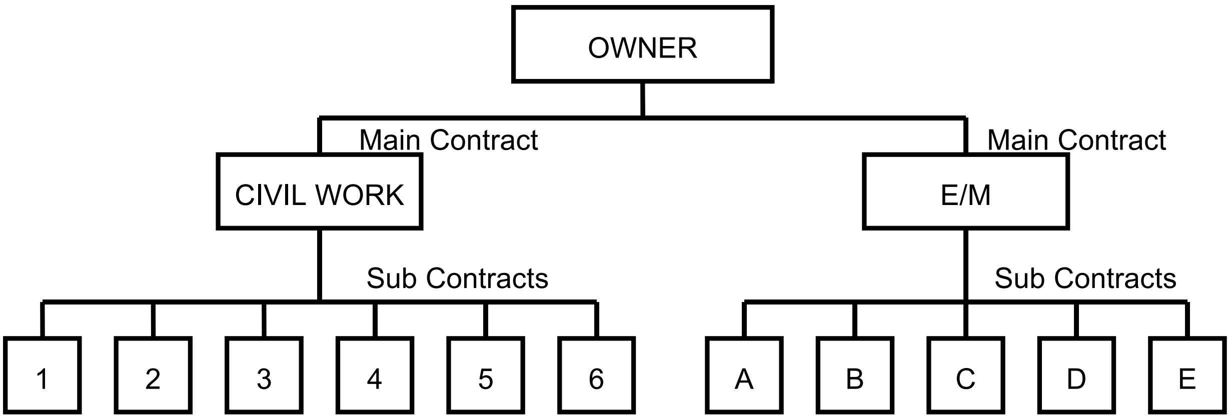


**Figure 6-4 Main Contract Flow Chart**

**6.3.2.2.1.3. GENERAL CONTRACTS**

The complete construction is awarded to one contractor. The general contractor may sublet a part of construction to subcontractors. But the subcontractors have to be approved by the owner. However, the overall responsibility of the construction is towards the general contractor. The owner's contract manager, who has the control functions, will look after the owner's interest. This model is illustrated in Figure6-5.

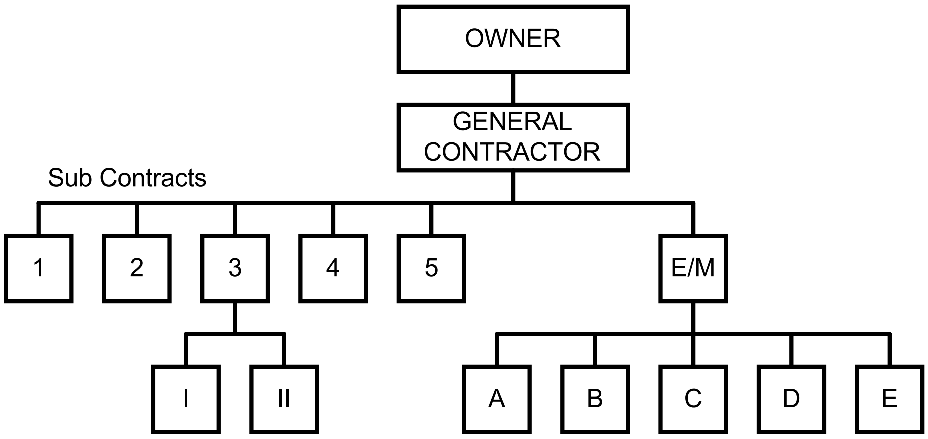


**Figure 6-5 General Contract Flow Chart**

### 6.3.2.2.2. TURNKEY CONTRACT

It considers employing a general contractor who is responsible to design, construct the project and to make it ready for commercial operation by the date stipulated in the contract at a contracted fixed price. The contract price is often in the form of lump sum. Only one contract is required between the owner and general contractor. The turnkey contractor generally carries out the part of the actual work and subcontractors, suppliers and consulting engineers, carry out the major work. The general contractor subcontracts works, supplies, and services in his own name, without any approval of the owner. He charges a fee on all subcontracts and suppliers as he carries the responsibility and risk. The model being used is given in the Figure6-6.

The use of turnkey contracts may shorten the actual construction time. However, a turnkey bid is dependent on the same sequence and time consuming planning and design as the traditional contracting. The turnkey bid must be based on final design if not the detailed design.

The turnkey contract arrangement may define the final project cost better than other contractual arrangement, but the final cost may be higher, because the turnkey bidder takes a large risk factor to absorb all risks.

The turnkey contractor is free to pursue his policy in order to have minimum risk and cost as the owner's influence on project implementation is negligible. The owner may have to pay for the worst case if the anticipated problems do not materialise and the contractor has the opportunity to make a handsome profit. The preparation of turnkey bid is very costly, and interested general contractors may be often few, which may drive the contract cost to higher levels.

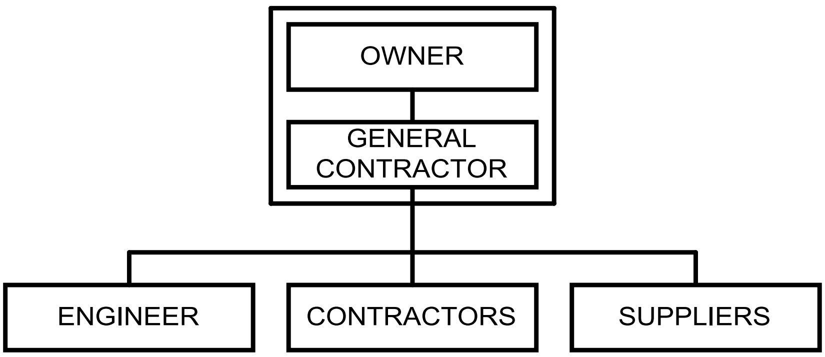


**Figure 6-6 Turnkey Contract Model.**

#### 6.3.2.2.3. CONSTRUCTION MANAGEMENT (CM)

The Construction Management (CM) model allows the owner to implement his project, to be his own General contractor, without having the necessary organisation, the know-how or the staff of technical and administrative personnel available in his organisation.

The owner, who is also the general contractor, engages a CM company to manage his project. The CM Company may be a consulting engineering company specialised in this type of services, having extensive hydropower know how and construction management expertise and experience. The CM Company has the necessary resources to carry out the project implementation on behalf of the owner, employing consultants for engineering services and contractors and suppliers for construction and supply of works. All the contracts are made between the owner and the consultants, contractors and suppliers.

Project implementation may start before final design/contract documents are completed, because the planning and design do not follow the strict sequence as in case of ICB. CM Company is charged with and is responsible for project implementation at optimal cost using the shortest possible time to complete the project. As soon as engaged, the CM prepares budgets and implementation schedules based on preliminary project design. The CM covers all activities from planning to commissioning, including co-ordination of the work of the consultants engaged. They are also responsible for quality, for which they are likely to be specially insured. The model is illustrated such as in Figure 6-7.

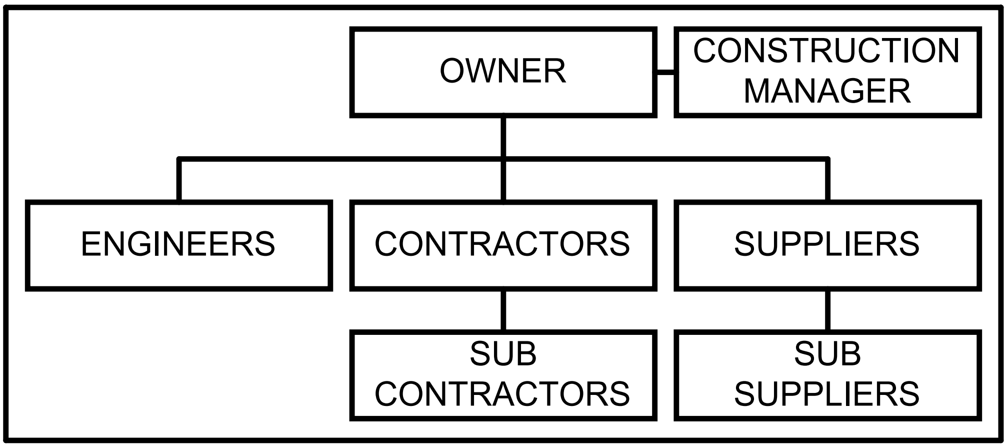


**Figure 6-7 Construction Management Contract Model.**

The CM model provides good cost control. The project is only charged with net costs, and the owner has the full benefit of cost saving from utilisation of market opportunities, not to pay for worst case as in case of turnkey model, cost saving solution, good ideas, etc.

The CM is usually paid a fixed fee, which is independent of the final project cost. This fee covers project management, co-ordination of design, procurement, contract and construction management, administration of subcontractor/suppliers and quality assurance. The fixed fee may or may not include the cost for support personnel at the site.

#### 6.3.2.3. TENDER/CONTRACT DOCUMENT

For contracting the works or supply, documents are needed which will govern the tender and form the documentary basis for the contracts between the owner and contractors and suppliers. These will be prepared by consulting engineers in case of international competitive bidding (ICB). Tender documents and contract document are basically the same. The contract is in reality the successful tenderers' tender amended to incorporate all amendments resulting from the tender and contract discussions, including the signed contract form.

The contract documents are prepared by the project consultant and mainly consist of the following:

- Contract conditions
- Engineering documents

The contract conditions deal with the legal aspects and compiled mainly into one separate volume while the engineering documents take care of technical side of the work and compiled into three or more volumes.

#### 6.3.2.3.1. CONTRACT CONDITIONS

This volume deals with the legal aspects of the tender documents. It consist of five important parts such as:

- Instruction to tenderers
- General conditions of contracts
- Special conditions of contract.
- Special and technical provisions
- Various forms

These parts are briefly described below.

##### 6.3.2.3.1.1. INSTRUCTION TO TENDERERS

This part mainly deals with the information to the tenderers on the conditions governing the tender, on timing, and how to proceed. This part contains information about:

- Scope of work
- Conditions effecting the work
- Tender documentation
- Preparation of tender
- Submission of tender
- Modification and withdrawals of tender
- Tender date
- Opening of tender
- Insurance
- Tender validity
- Performance security
- Sufficiency of tender
- Evaluation of tenders
- Preference for domestic tenderers
- Rejection or award of contract
- Joint site visits
- Pre tender meeting
- Repatriation of expatriate employees
- Financial assistance to contractor

##### 6.3.2.3.1.2. GENERAL CONDITIONS OF CONTRACTS

This part is most important in contractual sense. It defines the rights and the responsibilities of the contractual parties, the owner and the contractors. Most of the time these are written without the involvement of the supposed contractor and therefore, focused too much on owner’s interest. In order to avoid such type of problems, it is better to consult some good example if available. Federation International des Ingenieurs Conseils (FIDIC) has approved some conditions of contract for works of civil engineering construction, which can be used as a reference example.

However, some contract conditions such as; price escalation, time schedules and delays fines, payment and advance payment, must be given special attention due to their influence on price. This part contains all clauses, which apply to the contact such as:

- Definition and scope of work
- Responsibility of owner, engineer and contractor.
- Language and law
- Performance bond
- Retention money
- Watching and lighting
- Care of work
- Insurance of work and workmen
- Payment condition for contractor
- Clearance of site during and after construction
- Quality of materials and workmanship and tests
- Period of maintenance
- Variations
- Subcontractors appointment
- Default of contractors
- Special risks
- Arbitration
- Default of employer
- Increase or decrease of costs
- Rate of exchange
- Etc.

**6.3.2.3.1.3. SPECIAL CONDITIONS OF CONTRACTS**

Special conditions are used to complete and supplement the general conditions of contract and are especially needed when a standard general condition is used. These conditions deal with:

- Access
- Transport
- Communication
- Construction power
- Construction camps
- Safety precautions
- Medical care
- Taxation and duties
- Law
- Language
- Currency and currency regulation
- Etc

**6.3.2.3.1.4. SPECIAL PROVISIONS**

This part contains the legal and general information such as:

- Site conditions, which include temperature, rainfall data, hydrology, geology, etc.
- Description of work in technical terms
- Drawings preparation and process for incorporating changes.

- Inspection and tests
- Standards and specifications in general terms
- Measurements and payments
- etc.

**6.3.2.3.1.5. FORMS**

The various forms are needed to ensure that tenderers will comply with the intention laid down for contract. These forms are necessary part of the contract conditions. There is a large number and large variety of forms. However, the most important are:

- Form for contract agreement
- Form for performance bond
- Form for performance bank guarantee
- Tender and appendices

**6.3.2.3.2. ENGINEERING DOCUMENTS**

This part of the documents deals with the technical aspects and is compiled in three or more volumes. This part is entirely prepared by the engineering consultant and is based on detailed engineering design. This part cover following main aspects:

- Specifications, general and technical
- Drawings
- Bills of quantities

This will be prepared for civil works, mechanical and electrical works separately. It is better to compile the specifications and bills of quantities into one volume and drawings in a separate volume. For tender drawings one or more volumes are required.

**6.3.2.3.2.1. TENDER DRAWINGS**

The work starts with the review and updating of information given in preliminary design (feasibility study). The important information collected during interim period is taken into consideration especially concluding remarks given by agencies that have reviewed and commented the feasibility study. These drawings should be sufficiently detailed to inform the tenderers about all aspects of the construction and supply. However, the drawings cannot be used for construction but they will become the basis for preparation of construction drawings. These drawings should be based on complete engineering design.

**6.3.2.3.2.2. SPECIFICATIONS**

Tender drawings alone cannot provide all information about the construction. Therefore, information about quality requirements, performance procedures, standards, restrictions, and timing are required by the tenderers to make their bids. These informations are generally called specifications and are grouped under two headings such as;

- General technical specifications
- Special technical specifications

General specifications mainly deal with the scope of work, contractor construction camps, care of site, diversion and dewatering, quality assurance, testing and laboratories, supply of electricity, co-operation with other contractors, etc. and generally defined in one chapter. In case of electro-mechanical equipment manufacturing, types of test, packing, marking, transportation and permanent nameplates, test upon completion, erection, spare parts equipment documentation, maintenance, etc. are defined under general technical specifications. An important part is training of owner’s personnel prior or during commissioning and maintenance period.

Special technical specifications are usually divided into chapters covering different types of works such as, earthworks, concrete work, reinforcement, turbines, generators, transformers, circuit breakers, etc. The measurement and payment should be defined clearly for each item. The numbering of specifications should be well organised because the bill of quantities will use the same numbering system.

**6.3.2.3.2.3. BILLS OF QUANTITIES**

Drawings and specifications give the information about what, where and how to do the work, but in bill of quantities volume of work is defined. These will be arranged in same manner as specifications. Bills of quantities has two parts such as:

- Bills of specific types of works
- Schedules of particulars

Bills of quantities consist of standard forms containing, item numbers, description of pay items, units of measuring. The bill of quantities gives the volume of work, unit price according to measuring unit and the total, which is the multiplication of quantity and unit price. Each sheet is added, and the total entered on the summary sheet and added to determine the grand total. The total of the summary sheet constitutes the tender sum and is entered in the tender form.

Schedules of particulars contain the details about equipment, personnel and the basic price and date on which unit price is based. The list of equipment and personnel is used when evaluating the tenderers capacity and capability while the basic price list is used as base for future price escalation.

A typical form used for bills of quantities for civil and electro-mechanical equipment is given Figure6-8.

| ITEM | Description | Unit | Quantity | RATES | | Amount |
|---|---|---|---|---|---|---|
| | | | | Figures | Rate in Words | |
| D223 | | | | | | |
| D224 | | | | | | |
| **Sub Total** | | | | | | |

**Figure 6-8 Performa for Bill of Quantity.**

**6.3.2.3.3. IMPORTANT ISSUES IN CONTRACT DOCUMENT**

Three parties involved in project implementation may easily differ in their business outlook. Business ethics and moral codes may vary widely, thus emphasising the need for clear and adequate contract documents.

Drafting of contract documents is a difficult and time-consuming process. However, the conditions of contract drafted by FIDIC constitute a very good template to base on. It covers all the relevant questions in connection with the agreement between owner and contractor. But conditions relating to the owner’s protection often give rise to controversies and will therefore be dealt with more detail. It is important to note that all costs relating to protection are ultimately paid by the owner and reasonable protection requirements may keep the cost down.

**6.3.2.3.3.1. SYSTEM OF SAFEGUARDS**

With the implementation of a hydroelectric project the owner seeks maximum protection against outside risks. These outside risks may be:

- Subjective
- Objective

The subjective outside risks mean those risks related to professional or financial inadequacy on part of any firm/contractor directly selected by the owner for project implementation. The system of safeguards relating to subjective outside risks protection for the owner are being done through guarantees such as:

- Bid and Performance Bonds
- Retention Moneys

The objective outside risks refer primarily to hazards such as floods, slides, etc. potential inherent in the location of the project and includes the whole range of accidental loss, damage or injury which may occur at any major work site. The system of safeguards for the protection of the owner against objective outside risks is of different nature, usually based on and backed by insurance policies. These protections are:

- Care of works and damage to persons and property
- Contractor's, all risks and third party liabilities

The fourfold defences normally erected in contract documents to protect the owner against subjective and objective hazards as defined above serve a specific purposes and none of them can be safely dispensed with. The apparent perfection of these interlocking safeguards, however, often has anomalies in their application. These anomalies are such as:
Sometimes payments for claims are directly paid to the owners and not to the contractors, treating that the owners arrange the policy, but they hardly go out to arrange it. It creates problems in case of composite projects where a number of contractors and supplier are engaged and it is very difficult to make borderline between each contract.

Contractors are not allowed to use free market for insurance, resulting more premiums and extra cost to owner.

- Full value cover under the CAR insurance
- High Performance Bonds.

It is recommended that if the owner, prior to tender invitation, arranges an overall insurance cover in respect of loss or damage to the works and to property and liability for loss, damage or injury to third parties will be considerably beneficial and help to keep the project cost down. As mentioned earlier, all costs relating to protection are ultimately paid by the owner and reasonable protection requirements may keep the cost down.

**6.3.2.3.3.2. TROUBLE SPOTS**
The following contract clauses normally give rise to questions and disagreements:

- Penalties for exceeding time limits stated in contracts are difficult to accept for a contractor who is doing his best. They may be accepted easily if balanced by prize money in case of early completion
- Price escalation
- Advance payment, the size of which will influence the price.
- Payment schedules and conditions
- Underground conditions, special attention has to be given to specifications of underground excavation and their support work.
- Alternative proposals for construction, which are based on contractors concept.

### 6.3.2.4. TENDERING PROCEDURES

A tendering procedure flow chart in connection with public tender with pre-qualification is presented in Fig. 6-9.

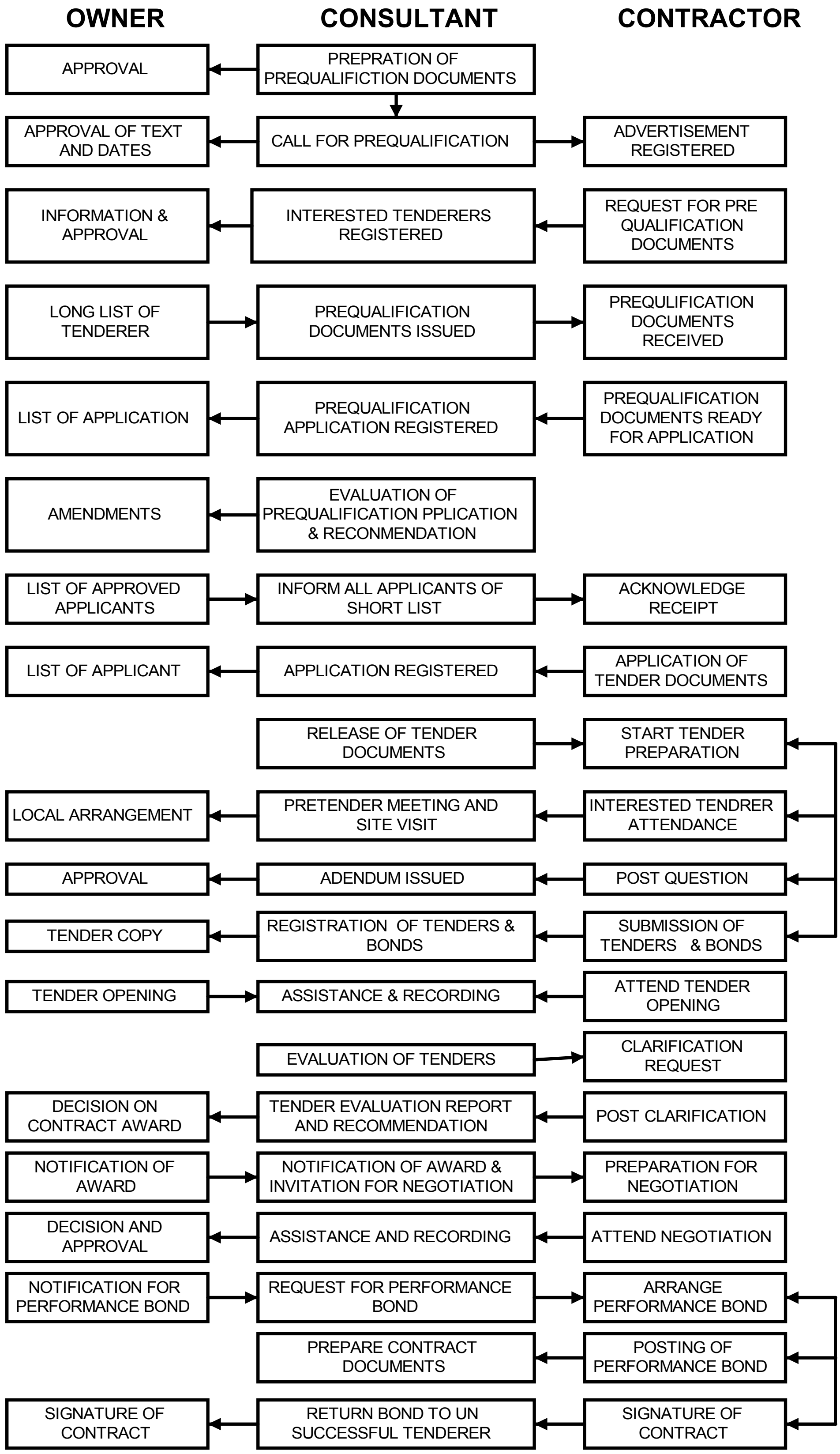


**Figure 6-9 Tendering Procedure Flow Chart.**

The following main items and steps are required in the tendering process in connection with public tender with pre-qualification and is supervised by the project consultant:

- Type of tender
- Advertisement
- Pre-qualification Documents
- Pre-qualification Report and Short Listing of Tenderers
- Invitation to Tender
- Purchase of Tender Documents
- Pre-tender Meetings and Joint Site Visits
- Amendments to Tender Documents
- Bid Bond
- Tender Opening
- Tender Evaluation and Evaluation Report
- Tender Award and Invitation to Contract Negotiations
- Posting of Performance Bond, Guarantees, etc.
- Signing of Contract

Some of the main items required in tendering process are briefly described below.

**6.3.2.4.1. TYPES OF TENDER**

Several types of tenders are being used. The distinction between types is not related to the tender itself but rather to the process of screening the tenderers who may participate. There are three ways of tendering:

- Public tender
- Public tender through pre-qualification
- Tender by invitation

All these tenders can be used in the construction of civil engineering works. Tender through invitation is often used in connection with tendering for electro-mechanical equipment. Public tender through pre-qualification is preferred for international tendering for civil engineering works.

**6.3.2.4.2. PUBLIC TENDER**

All qualified tenderers/contractors may tender, screened by class. Class refers to predetermined qualification conditions made by the owner thus dividing contractors in various competence classes (categories). These types of tenders are usually advertised in the newspapers.

**6.3.2.4.3. PUBLIC TENDER WITH PRE-QUALIFICATION**

Attendance is restricted through pre-qualification. Interested contractors apply for pre-qualification for this specific work and pre-qualification is held in order to screen out unqualified and undesirable contractors/firms. This type of tender is also invited through public advertisement.

**6.3.2.4.4. TENDER BY INVITATION**

Invitation to tender is issued to qualified firms/manufacturers after canvassing to register interest, actual capacity, production programs, order books, etc. This type of tender will not be invited through advertisement.

**6.3.2.4.5. ADVERTISEMENT**

The first step in public tender with pre-qualification is to advertise the project. The text of advertisement is important in attracting the attention of capable contractors. The advertisement should be made through daily newspapers locally and if possible also internationally. Advertisement through engineering journals is also very helpful. Advertisement should be comprehensive and should contain details about all technical information, local information and some information about quantum of works involved in the project. Information about source and type of financing is also very important for attraction of the competent contractors.

### 6.3.2.5. PRE-QUALIFICATION DOCUMENT

The pre-qualification of tenderers is time consuming and therefore, usually starts before the tender documents are ready for issue. All pre-qualified contractors are equal and only price and time schedule should be considered when evaluating/conforming tenders.

Pre-qualification will be focused on both technical as well as the financial ability of the interested contractors/firms.
The project consultants normally prepare the pre-qualification documents. Some organisations such as World Bank, Asian Development Bank, FIDIC have drafted these document and can be used as template. The Pre-qualification documents must comprise of the following:

- Project digest.
- Scope of work.
- Evaluation criteria.
- Details about required information

Under project digest all information regarding project area, country, region, infrastructure, energy supply, etc. should be given. The reasons of pre-qualification must be described properly. Information about financial arrangements and mode of payment are also very helpful to attract competent contractors.

The description of the scope of work must contain all details about different works such as; concrete work, dewatering, excavation, dredging, installation of equipment, etc. It must contain a description of the quantity and required quality of each work item. This is the most important part of the document and should be drafted carefully.

The contractors are usually asked to submit following information:

- Financial capability.
- Experience of the firm.
- Personnel.
- Equipment

The financial statement must give the answer about the net worth and working capital of the firm. A certificate from any bank or auditor should be attached. Experience of the firm must contain, length of experience, nature and type of works undertaken by the firm, performance certificate from the owners and value of each performed contract. Under “personnel” contractor should provide details about number of qualified personnel and their experience. The quantity and quality of equipment available with the contractor is also an important topic of the pre-qualification documents.

At the end, the documents must contain the evaluation criteria. The criteria should be self-explanatory and in order to help the contractor to make self-assessments.

### 6.3.2.6. FINAL/CONSTRUCTION DESIGN

#### 6.3.2.6.1. CIVIL ENGINEERING WORKS

In the civil engineering works, final design and work drawings is done in continuation of detailed engineering design made along with tender documents during the definite plan phase. These drawings are prepared without the involvement of the contractor and are available when the contractor moves to start construction works.

The final design must make certain that the various project components will withstand the stresses they will be subjected to from the loads, climatic conditions, etc. The design must be based on approved standards and norms, accepted quality of materials and specified safety margins. The work drawings are prepared to such a detail and scale that the contractor can base his work on them directly without having to prepare additional details himself.

The final design made will not meet the site requirements sometime and has to be adjusted accordingly. A major problem in underground excavation is that the ground conditions only become known as the excavation advances and the real ground conditions can be observed. Therefore, it is better to make the actual design with the excavation work and this procedure is known as the “ Design as you go” and usually named as construction design.

#### 6.3.2.6.2. ELECTRO-MECHANICAL WORKS

Normally the suppliers are responsible for the design of their own equipment. They carry out all the final engineering design and prepare work drawings based on detailed design and specifications given in the tender/contract documents.

The role of the consultant in this case is to control and approve the manufacturers design, drawings, quality, materials, procedures, etc. as per contracted specifications and quality requirements.

### 6.3.2.7. CONSTRUCTION SUPERVISION

All the engineering services such as, design, tendering and contracting are normally carried out by the consultant. Due to their supervisory role they are also charged with the quality assurance of the whole project. Therefore, the consultants are liable to the work carried out by themselves and also by contractors and supplier. The consultants normally organise for such activities usually managed under construction supervision. The construction supervision consist of:

- Quality assurance
- Progress monitoring
- Inspection services
- Erection, acceptance and commissioning

Through the construction supervision the consultant assumes the responsibility for the quality of the works such as investigations being done during construction, construction of civil engineering works, erection, testing and commissioning of electro-mechanical equipment. The consultant must keep control on all the construction activities such as placing of reinforcing steel, size and quality of reinforcing steel, quality of concrete, proper formwork, quality of aggregates being used, etc. He must check that all the civil engineering structures are constructed as per drawings and specifications provided by the consultant. The material to be used is also properly tested and meets the required specifications.

The consultant is also responsible for the supervision of erection and commissioning of the electro-mechanical equipment. He will, on the behalf of the owner, accept the work and issue the provisional acceptance certificates.

## 6.4. CONTRACTORS AND SUPPLIERS

It is also very important to have competent contractors and suppliers. Selection of competent Contractors and Suppliers is the foundation for successful project implementation. This selection helps very much during construction and also during operation.

The following activities are required from any contractor or supplier before he gets the contract:

- Pre-qualify
- Obtain tender documents
- Study tender documents and available information on the country, region and project.
- Arrange co-operation with local contractors.
- Obtain price quotations and information on prices, availability of skilled and unskilled manpower, materials and equipment, transport, infrastructures energy supplies, etc.
- Attend pre-tender meeting
- Make site visit
- Post questioning about tender document or project.
- Estimate cost of mobilisation and demobilisation.
- Evaluate country risk.
- Obtain quotation for insurance.
- Establish overall risk factor.
- Prepare basic prices schedules, list of personnel, list of equipment, etc.
- Prepare basic unit price for each item of work.
- Prove financial competence.
- Prepare own cash flow based on payment conditions, construction schedule, etc.
- Establish financing risk, based on escalation, etc.
- Obtain tender bond.
- Obtain commitment for good performance bond.
- Submit tender and attend tender opening meeting.
- Signing of tender
- Submit bond
- Attend negotiation meeting
- Sign contract document
- Obtain letter of acceptance

### 6.4.1. CONTRACTORS

The responsibility of a contractor is to carry out actual construction of the work according to the design and specifications given in the tender document. The consultant will produce the design and the drawings. He is also responsible for quality, time and cost control.

The contractor must be equipped with laboratories, technicians, survey crews, etc. He is responsible for his crew and construction equipment, which he requires for the construction of the project.

The civil work contractor normally supplies the unskilled labour and utilities and the logistics, which are usually included in his contract. He is also responsible for lodging, catering, transportation, etc. for the other contractors and suppliers.

The contractor is also responsible for the maintenance and repair of faulty construction during guarantee period, which is normally one year in case of civil engineering works.

### 6.4.2. SUPPLIERS

The supplier is responsible for designing, manufacturing, erection, testing and commissioning of electro-mechanical equipment according to the specifications given in the tender documents.

The electro-mechanical equipments are entirely manufactured in the workshops and factories owned by the supplier or subcontractors. In hydropower mostly three different suppliers are involved such as:

- Supplier for the turbines and generators
- Supplier for transformers, switchgear, protection equipment, etc.
- Suppliers for power cables, cranes, telecommunications, low voltage cables, fire fighting, ventilation, etc.

It is the responsibility of the supplier to have sufficient equipment and instruments as required during erection, testing and commissioning.

The preparation and training of owner organisation for operation and maintenance is also the responsibility of the supplier. The operation and maintenance manual has to be prepared and submitted to the owner before final handing over of the project.

The supplier is also responsible for the maintenance and replacement or repair of faulty equipment during guarantee period, which is normally two years in case of electro-mechanical equipment.

## 7. OPERATION AND MAINTENANCE PHASE

Operation and maintenance is the last phase in the life of a hydropower project and by far the longest.

It commences when projects are completed or in case of staged development, when the first stage is operational i.e. upon commissioning of the installations. The flow chart in Figure 7-1 schematically shows the main activities involved during this phase.

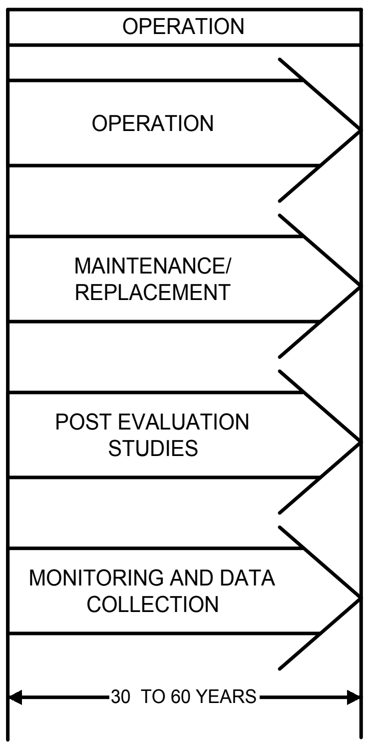


**Figure 7-1 Operation and Maintenance Flow Chart.**

In many countries power utilities have attained all or large part of the whole electricity supply of the country and are organised as single entities. Such organisations are responsible for all tasks required in the electricity supply system such as:

- Generation
- Transmission
- Distribution

These large organisations are often unwieldy to run and many become inefficient. Expected economies of scale are seldom found in such organisations as they become quite unmanageable because of their size. There is now a tendency in many countries, for the purpose of efficiency, to split such large organisations into smaller, more easily manageable units. Such units may be responsible for generation or transmission or distribution and are organised as independent companies, owned by the public or public shareholders. These units may be organised to operate one or two plants and their distribution system. Therefore, these units normally need the following staff:

- administrative
- technical
- support

The size of the various staff depends on the installation and on the managerial responsibility and the operative and maintenance arrangements adopted.

In high labour cost countries plants are being operated automatically and controlled remotely. Specialised teams covering several plants carry out station maintenance and repairs. Large maintenance and overhaul tasks are usually contracted to specialised workshops or manufacturers.

In countries where labour cost is low or the technical infrastructure or local resources are found wanting, large self-sufficient organisations are formed to run the power installation.

Operation and maintenance can only be done with experienced staff and such staff is simply not available in the remote areas. To secure necessary operation and maintenance staff, it is necessary to train personnel with required educational background and provide sufficient incentives to continue working after training is completed.

Operation and maintenance plans are usually provided by the consultant and consist of detailed description of the work, scope, and performance. Tools, materials and spare parts involved are also included in the work program. Major maintenance work could be planned for and restricted to periods when generating units can be taken out of service without causing shortage in the supply system, which can be determined by water and power studies.

Post evaluation of each activity during operation and maintenance is also another major task that has to be undertaken. This is very important and will become feed back for future experience. Preparation of monitoring report and collection of data regarding operation and maintenance is also very much important and should be planned on scientific basis

# 8. HYDROPOWER IN PAKISTAN
## 8.1. EXISTING HYDROPOWER STATIONS
### 8.1.1. RENALA HYDROPOWER PLANTS
The late Sir Gaunga Ram constructed the plant in 1925 to supply power to low head pumps installed for lift irrigation. The plant is located on Lower Bari Doab Canal at RD 161+000 in a by pass arrangement. Lower Bari Doab canal is off taking from Balloki Headwork at River Ravi. The station is situated near Renala Town in Okara District of Punjab Province. The powerhouse (Figure 8-1) is equipped with 5 (five) horizontal Francis turbines (Vessel type) manufactured by Vicker England. Turbines were installed in open flume and intakes were equipped with manually operated steel gates. Each turbine unit has 4 runners interconnected with horizontal shaft and generator is coupled with turbine shaft through a gear. The generators were manufactured by English Electric Co. England and have rated output of 275 kVA. Control room, generators and transformers are enclosed in powerhouse building.

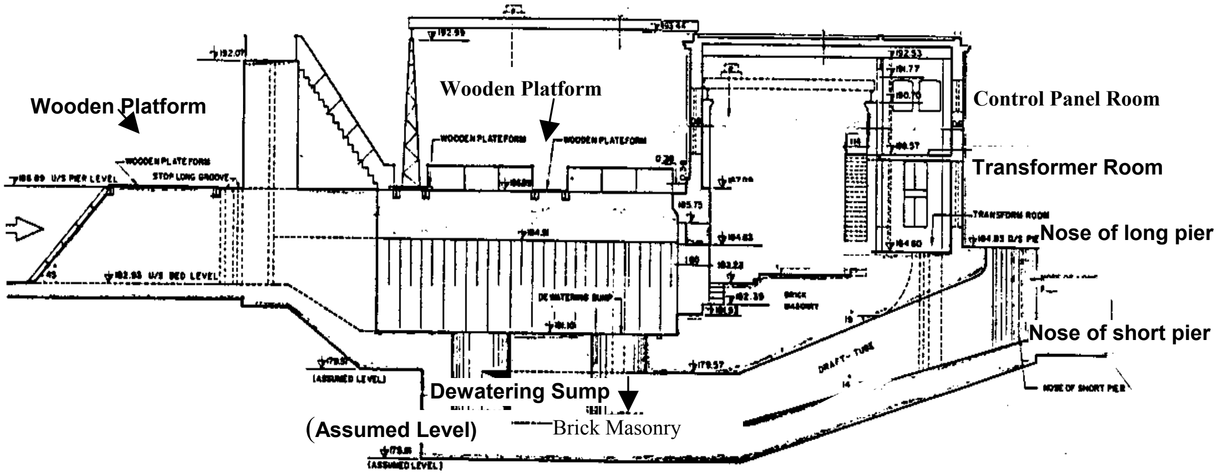


**Figure 8-1 Renala Power Station-Powerhouse Cross Section Through Turbine Axis**

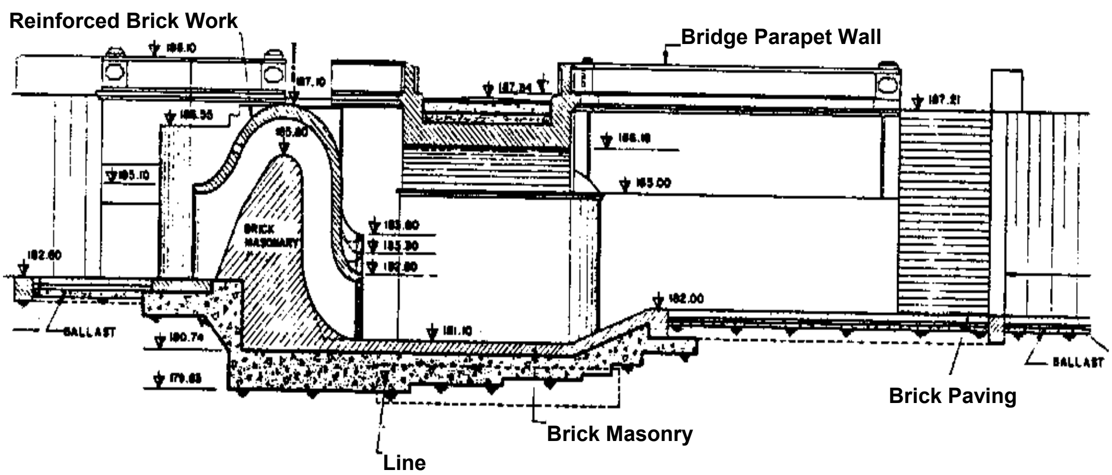


**Figure 8-2 Spillway Cross Section.**

The headrace and tailrace having total length of 1084 m are unlined and can pass maximum discharge 71 $m^3/s$ required for powerhouse. A syphonic spillway as shown in Figure 8-2 with maximum capacity 160 $m^3/s$ is provided in the main canal to pass the surplus discharge and maintain the upstream water level. The spillway was constructed with brick masonry (Figure 8-2).

The runners have been replaced during 1983-1989 and some repair of electrical equipment has also been carried out. Some parts of electrical equipment replaced in 1950.

### 8.1.2. RASUL HYDEL STATION

The plant was constructed and commissioned by Irrigation Department of the Govt. of Punjab Province in 1952. A power channel, about one mile in length, taking-off from right side of the Upper Jhelum Canal at RD 244+000, feeds the turbines through steel penstocks. The Upper Jhelum Canal off-takes from Mangla Dam. The powerhouse as originally envisaged, was to have three turbo-generator units, two working and one standby. All the civil works including headrace, forebay, penstock and powerhouse were constructed for three units. But the third unit was not installed. The powerhouse is equipped with 2 turbines (vertical Kaplan) having a total capacity of 22 MW. No spillway is provided at this station. However, a syphonic spillway was also foreseen in the original concept of 1946, but not constructed due to cost considerations. It was to off-take from right bank of headrace and then curving around the powerhouse was to fall back into tailrace downstream of draft tube. The tailrace joins the Lower Jhelum Canal below its head regulator, which lies at Rasul Headworks on Jhelum river downstream of Mangla Dam.

### 8.1.3. CHICHOKI MALIAN HYDEL STATION

The powerhouse is equipped with 3 turbines (vertical Kaplan) having a total installed capacity of 13 MW. This station was commissioned in 1959 on Upper Chenab Canal Lower. The powerhouse is located at RD 221+000 of the Upper Chenab Canal Lower, which off-takes from the Upper Chenab Canal Upper at Bambanwala fall. The Upper Chenab Canal Upper off-takes from the Marala Barrage on the Chenab River. The powerhouse was constructed in by-pass arrangement without temporary diversion of the canal. However, after construction of powerhouse canal was diverted toward the powerhouse. Spillway is placed in the old bed of the canal. The tailrace discharges into the old canal.

### 8.1.4. SHADIWAL HYDEL STATION

The plant was commissioned in 1961 with total capacity of 14 MW on Upper Jhelum Canal Lower, off-taking from Mangla Dam. The powerhouse is located at RD 420+000 downstream of the off-take of Rasul power channel. The power station is equipped with 2 vertical Kaplan turbines (Figure8-3). The canal acts both as a link and as an irrigation canal. In low flow period when Khanki Headworks command is short of flows it act as link canal. The powerhouse has a spillway, which was provided laterally on left bank of the canal at about 100 m upstream from the powerhouse. Spillway has 6 gates and two out of them are syphonic type. Powerhouse is equipped with two trash racks. Coarse trash rack is installed at bridge about 50 m upstream of powerhouse and being used for crossing. Fine trash rack is installed at the turbine intake. A mobile crane is provided for installation of stop logs, trash rack cleaning and major repair. The control room is provided in a separate building about 10 m from powerhouse. The tailrace will out fall into the Chenab River upstream of Khanki Headworks.

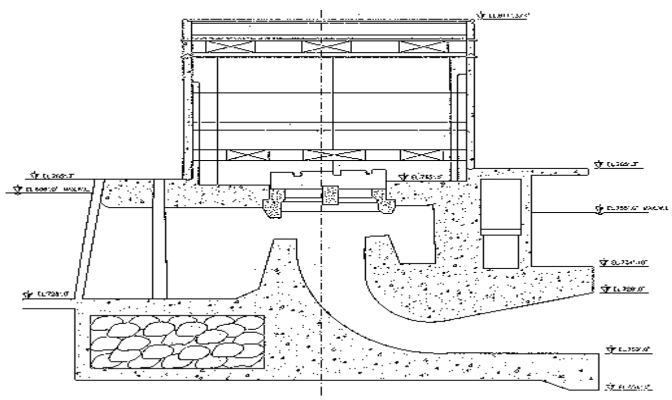

**Figure 8-3 Shediwal Power Station-Powerhouse Cross Section.**

### 8.1.5. NANDIPUR HYDEL STATION

The power station was constructed in 1965 on Upper Chenab Canal Lower, upstream of Chichoki Malian Hydel Station. The powerhouse is equipped with 3 vertical Kaplan turbines having a total installed capacity of 13.6 MW. The powerhouse is equipped with upstream and downstream gates, which are being operated by a gantry crane. Mechanical trash rack cleaner is also provided. A service bay for small repair is provided on the right side of powerhouse building. The control room is provided very close to the service/loading bay. The spillway is placed on left bank of the canal at about 100 m from powerhouse. The spillway has 6 gates operated automatically. Two out of them will work as siphons.

### 8.1.6. JABBAN HYDEL STATION

In 1938 Malakand-1, medium head plant was constructed in Malakand irrigation system of North-West Frontier Province (NWFP) with a capacity of 7 MW. Later on, it was augmented up to 20 MW. The powerhouse fed by the Upper Swat Canal off-takes from the Amandra headworks on the Swat River. The powerhouse is located in foothill of Malakand hills where Upper Swat Canal out comes from Beton Tunnel.

### 8.1.7. DARGAI HYDEL STATION

In 1954 Dargai, having a capacity of 20 MW, was also constructed on the same system. The out flows from Jabban(Malakand-I) powerhouse are fed to power canal which led to forebay of the Dargai Station. This power station is also named Malakand-II. The tailrace discharges into the Swat canal, upstream of trifurcation structure from where Abazai canal and Machai canal off-take.

### 8.1.8. KURRAM GARHI-1 AND 2

Both power stations commissioned in the year 1957 on the Katchkot Feeder off-taking from the Kurram Garhi Headworks on the Kurram River in NWFP. Both powerhouses are equipped with 2 Francis turbines each. The gross head of each station is 18.9 m and the discharge is 15.8 $m^3/s$. Both stations have a capacity of approximately 2 MW.

### 8.1.9. WARSAK DAM PROJECT

Warsak dam project is located on the Kabul river in the province of NWFP about 19 miles north west of Peshawar. The dam is approached from Peshawar by two roads i.e. Peshawar-Michni-Shabkadar Road and Peshawar-Jamrud Warsak road. The later road passes through the historical Khyber Pass.

Kabul river rises in Afghanistan and has a total catchment area of 26,000 sq. miles. The main tributaries are Panjsher, Logar, Alingar and Kunar. The Kunar river has a catchment area of 9,500 sq. miles and contributes more than half the discharge of the Kabul river. Kunar river drains the snow griddle Chitral valley of Pakistan.

The project was first conceived in 1947 just at the dawn of independence. In 1948, M/s Merz, Randell, Vetten (M.R.V.) Pakistan was appointed as consultant by Central Engineering Authority Pakistan, the owner of the project. First report was submitted in December 1949 by the consultant. First proposal consists of rock fill compacted dam with concrete spillway and underground powerhouse. On the request of owner in December 1950 consultant submitted two alternative designs such as:

- Rock fill dam with underground powerhouse.
- Concrete dam with surface powerhouse.

The project was financed by Canada under Colombo Plan Aid and agreement was signed between the two Governments in November 1954. Before this in 1952 Government of Pakistan decided that Warsak dam project is the concern of Central Government and project will be executed by Central engineering Authority.

M/S H.G Acres and Company Limited being the consultant submitted their final proposal in February 1955, which was finally accepted by the Government of Pakistan. This proposal consisted of 460 ft. long concrete gravity dam with maximum height of 220 ft. The spillway having discharge capacity of 540,000 $ft^3/s$, consisting of 9 bays each, 40 ft high gates incorporated as an overall structure with the dam. A surface type powerhouse (Figure 8-4) with switchyard at the roof is located on the right bank below the downstream face of the dam. A 35 ft. diameter tunnel was used for diversion during construction and was constructed on left bank. The intake structure and power tunnel 39 ft. diameter are located on right bank.

A 35 miles long with 10 ft. diameter concrete lined irrigation tunnel is located on right bank to irrigate 100,000 acres of land. Powerhouse was equipped with 4 kaplan units, each of 40 MW under a head of 125 ft.

M/S Angus Robertson Limited, the contractors came in 1955 and started their work in October 1955. The works remained in progress during the middle of 1960. The first and second units were commissioned in May 1960 while the third and fourth in July 1960. The diversion tunnel was plugged during January 1960.

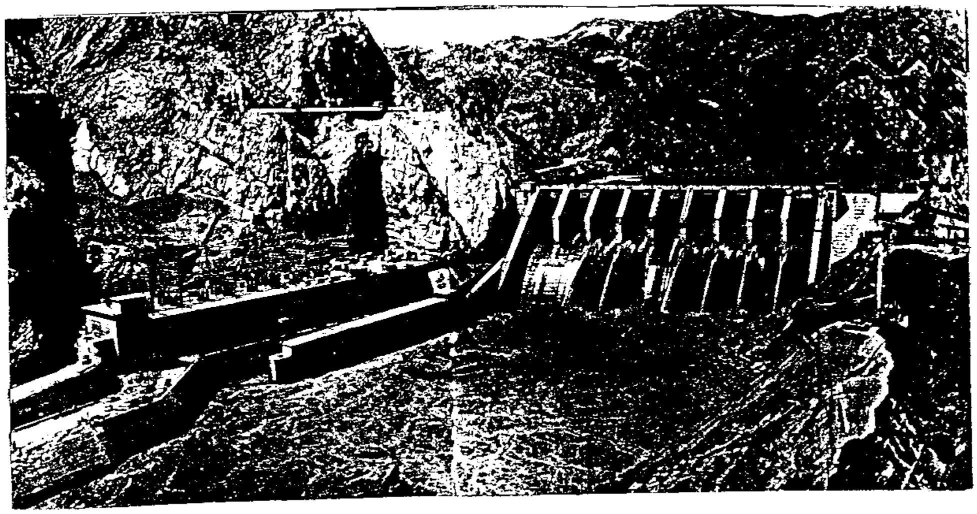

**Figure 8-4 Warsak Dam and Powerhouse**

**8.1.10. MANGLA DAM PROJECT**

The scheme for creating reservoir as primarily function and power generation as secondary function on Jhelum river at Mangla was initiated by Central Design of the Punjab Irrigation Department in 1951. The project has not been designed as flood control structure. The feasibility report was prepared by Tipton and Hill in 1954 under the kind control of Dams Investigation Circle created in 1952 by Government of Pakistan. In December 1957 an agreement was signed by Binne and Partners in association with Harza and Preece, Cardew and Rider with President of Pakistan as consulting engineers. The consulting firms submitted the interim project report in 1958 recommending the construction of a 366 ft high dam to create a 5.35 MAF reservoir.

Later in 1959, when it became apparent that an agreement would be reached between Pakistan and India on the terms of the “Indus Water Treaty signed in 1960”, the Government of Pakistan appointed West Pakistan Water and Power Development Authority (WAPDA) as implementation agency. To effectuate the provisions of the treaty, massive multipurpose works

such as two large reservoirs, one on Jhelum river and one on Indus river for impounding and regulation of water, five barrages and three link canals for water diversion were foreseen.
Main civil engineering contract was awarded on January 20, 1962 to Mangla Dam contractors (M.D.C) a consortium of following American companies:

- Guy F. Atkinson (Sponsor)
- Chicago Bridge & Iron Co.
- S.J Grove & Sons Co.
- Charles L. Harney Inc.
- C J Langenfelder & Son Inc.
- Ostrander Construction Company
- R A Trippeer, Inc.
- Walsh Construction Company

The contract price for this contract was Pakistani Rs. 1658 million equivalent to US $ 350 million at exchange rate of 1962 to 1967. But the project was (Figure8-5) completed in Pakistani Rs. 2069 which included three turbo-generators of 100 MW capacity each.

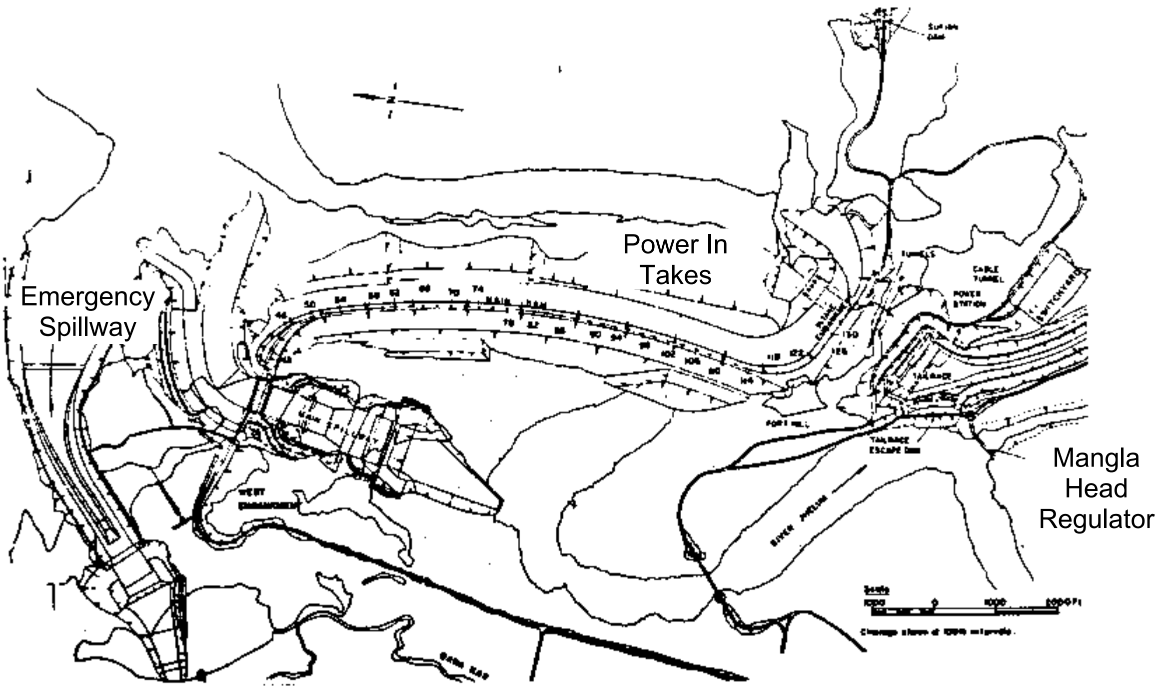


**Figure 8-5 Mangla Dam Plan**

Before starting actual construction at site in July 1962, a temporary road bridge of Calendar Hamilton type was constructed in 1960 across Jhelum river. The construction of Mangla Dam was completed by the end of 1967 with the following main components.

**RESERVOIR**

- Live Storage = 5.36 M acre ft
- Dead Storage = 0.52 M acre ft
- Maxi Storage = 5.88 M acre ft
- Maxi Elevation = 1202 ft
- Mini Elevation = 1050 ft

**TWO EARTHFILL DAMS**

**a) Main Dam**

- Crest Elevation = 1234
- Maximum height = 454 ft
- Crest length = 2 miles
- Sill of intake gate = 953

**b) Sukkian Dam**

- Maximum height = 144 ft
- Crest length = 3.2 miles

**c) Jari Dam**

- Maximum height = 274 ft
- Crest length = 1.5 miles

**1. SPILLWAY**

- Maximum capacity = 0.9 to 1.1 M cfs
- Crest Elevation = 1086
- Number of Gates = 9 radial type

**2. TUNNEL**

- Number = 5
- Purpose = Diversion/power
- Construction = ¾ portion steel lined
- Inner Diameter = 26 ft
- Length = 2000 ft

**3. POWERHOUSE**

- Length = 891.5 ft
- Maximum Height = El 780 to 923
- Gross Head = 367 ft
- Net Head = 347 ft
- Number of Units = 10
- Rated capacity = 100 MW each
- Rated Discharge = 4050 cfs
- Average Energy = 5720 GWh/ Annum
- Tail Water level = El 835

**4. TURBINES**

- Type = Francis
- Rated Head = 295 ft
- Rotational Speed = 166.6 RPM

**5. GENERATORS**

- Rated Capacity = 115 MW
- Terminal Voltage = 13.2 kV

**Table 8-1 Commissioning of Turbines**

| Unit No. | Tunnel No. | Year of Commission | Country |
|---|---|---|---|
| 1 | 1 | July, 1967 | Mitsubishi of Japan |
| 2 | 1 | July, 1967 | Mitsubishi of Japan |
| 3 | 2 | March, 1968 | Mitsubishi of Japan |
| 4 | 2 | June, 1969 | Mitsubishi of Japan |
| 5 | 3 | December, 1973 | Czechoslovakia |
| 6 | 3 | March, 1974 | Czechoslovakia |
| 7 | 4 | May, 1981 | Mitsubishi of Japan |
| 8 | 4 | July, 1981 | Mitsubishi of Japan |
| 9 | 5 | September, 1993 | Czechoslovakia |
| 10 | 5 | July, 1994 | Czechoslovakia |

### 8.1.11. TARBELA DAM PROJECT

Tarbela Dam project is on Indus River in the North West Province of Pakistan about 64 km Northwest from Islamabad and about 51 km upstream of the Attock bridge where the Grand Truck road crosses the Indus. The project takes it’s name from the former village of Tarbela which prior to inundation was situated on the left bank of the Indus River where Siran River meets Indus about 6 km upstream of the dam site.

Tipton and Hill prepared the feasibility report in 1954 under the control of Dams Investigations Circle created in 1952 by Government of Pakistan. The report envisaged a construction of dam on the Indus River at Tarbela, which would impound 4.2 M acre- feet of live storage. In August 1959 the Government of Pakistan established the Tarbela Dam Organisation (TDO) under the sponsorship of the Water and Power Development Authority (WAPDA). Harza as general consultant to WAPDA started site investigations. In February 1960, Tippetts-Abbett-McCarthy-Stratton International Corporation (TAMSPAN) was appointed as project consultant for Tarbela Project in association with TAMS.

In January 1964, TAMS submitted the project summary report recommending construction of an earth dam 485 feet high at the Bara site to create a reservoir of 11.1 m. acre-feet gross storage capacity (Figure 8-6) Before this, in 1962 the consultant submitted the project planning report. The technical feasibility and economic soundness of the project was confirmed by the four firms (Charles T. Main, Stone & Webster, Hunting Technical Services and Sir Alexander Gibb and Partners) retained by World Bank. However, a World Bank study was completed in 1967. It recommended construction of a dam with optimum height and powerhouse having ultimate installed capacity of 2.1 M Kilowatts. In 1967, contract documents were issued to the approved list of prospective bidders.

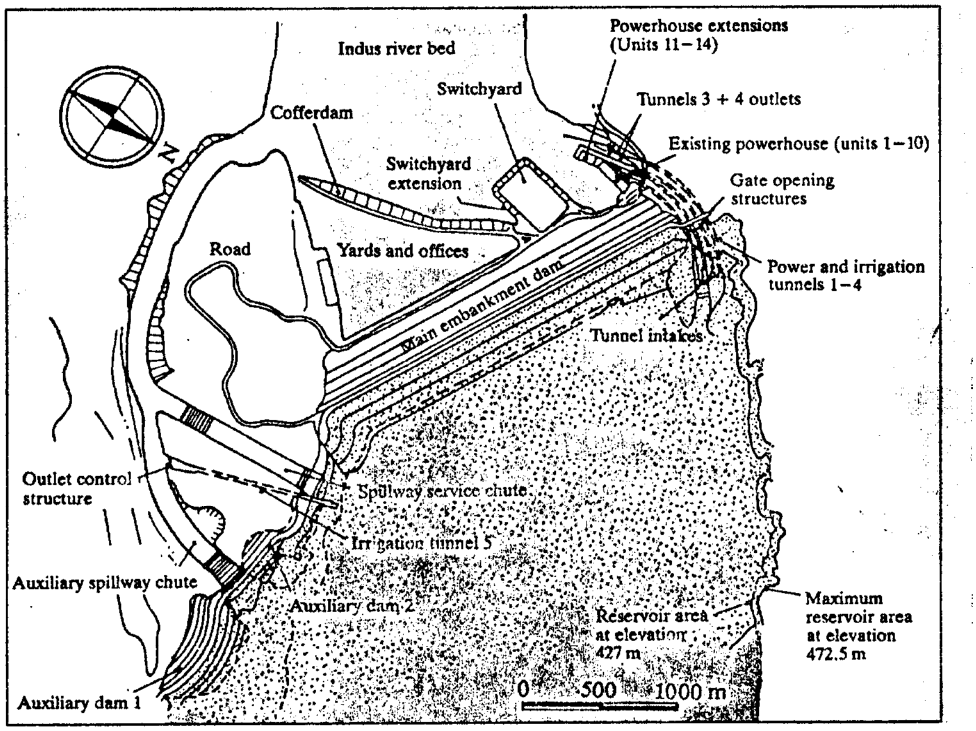


**Figure 8-6 Plan of the Tarbela Dam Project.**

Financing agreement was signed on 2 May 1968 and contract for construction of Tarbela was awarded to Tarbela Joint Venture on 14 May 1968. The President of Pakistan held groundbreaking ceremony on November 4, 1968.

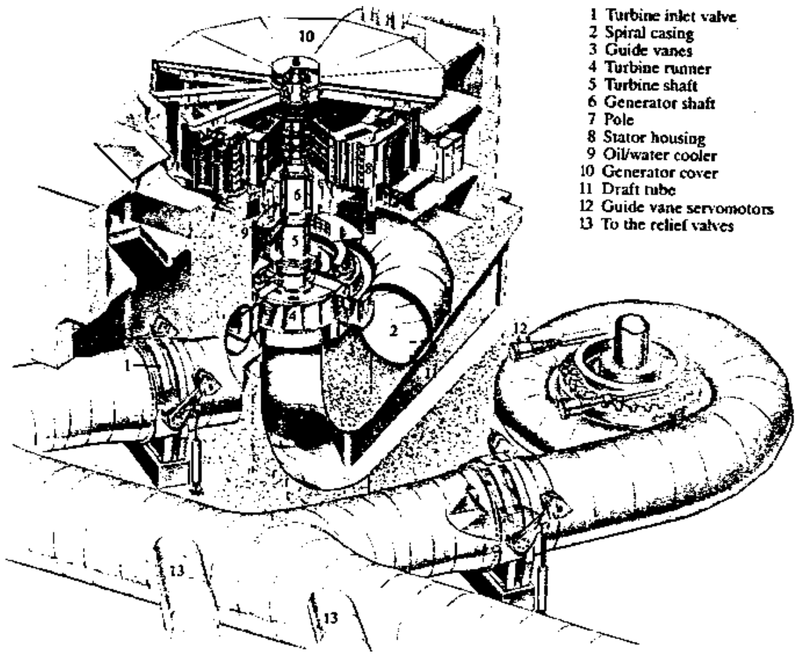


**Figure 8-7 Section through one of the Generating Units Tarbela 11 to 14.**

The construction of Tarbela Dam was completed by the end of 1977 with the following main components:

**RESERVOIR**

- Length = 97 km
- Maximum depth = 137 m
- Live Storage = 11,600 M $m^3$
- Dead Storage = 2,300 M $m^3$
- Maximum Storage = 13,900 M $m^3$
- Maximum Elevation = 472 m.a.s.l

**TWO EARTHFILL DAMS**

- Crest Elevation = 477 m.a.s.l

**1 MAIN EMBANKMENT DAM**

- Maximum height = 143 m
- Crest length = 2,743 m

**2 AUXILIARY DAM No. 1**

- Maximum height = 105 m
- Crest length = 713 m

**3 AUXILIARY DAM No. 2**

- Maximum height = 67 m
- Crest length = 293 m

**SERVICE SPILLWAY**

- Maximum capacity = 17,400 $m^3/s$
- Number of Gates = 7 radial type (15.2 * 18.6 m)

**AUXILIARY SPILLWAY**

- Maximum capacity = 22,500 $m^3/s$
- Number of Gates = 9 radial type (15.2 * 18.6 m)

**RIGHT TUNNEL**

- Number = 4
- Purpose = Diversion/power
- Construction = Concrete lined and steel lined
- Inner Diameter
- Tunnel 1, 2, 3 = 13.3 m
- Tunnel 4 = 11 m
- Length = 731 to 833 m

**GANDAF IRRIGATION TUNNEL**

- First Stage only length with gate shaft, intake and underground stilling basin = 509 m

**LEFT BANK TUNNEL**

- Length =1120.1 m
- Construction = Concrete up to gate shaft and steel lined d/s gate shaft
- Inner Diameter = 13.7/11 m
- Main Gates = two on each 4.7 * 14.2 m

**POWERHOUSE**

- Number of Units = 14
- Rated capacity = 175 MW each first 10 units.
- Rated capacity = 432 MW each additional 4 units.

**TURBINES**

- Type : Francis

Up to 1984 the cost of the Tarbela Project, including resettlement costs has amounted to approximately 12.9 billion Rupees. About 43 percent has been in foreign exchange.

**8.1.12. SMALL HYDROPOWER PROJECTS IN AJ&K**

The development of the hydropower potential started with the small power station of 200 kW constructed at Bheriwala Katha near Pattika in Neelum river catchment. The powerhouse was constructed in 1976. The project has 40 m head, 1.5 km long headrace and 100 m tailrace. The powerhouse is equipped with one Ossberger turbine which is being fed through steel penstock from forebay.

Kel hydel station has capacity of 200 kW situated near Kel Village in Neelum river catchment. The gross head is about 42 m. It is located on Naril nullah which is out falling into Baral nala, a major tributary of Neelum River.

Lipa hydel station has 100 kW capacity and is located on Qazi Nag Nar, a left bank tributary of Neelum river.

Chinari hydel station of 100 kW capacity is located on Kathai nala a tributary of Jhelum River. The project was constructed in 1976.

**8.1.13. NWFP SMALL HYDROPOWER PROJECTS**

A number of small hydel stations are being operated by SHYDO since many years. The details about these are given below

**Table 8-2 Small Hydropower Station in N.W.F.P.**

| Sr. No. | Scheme Name | No. of Units & Type | Power (KW) | Date of Commission |
|---|---|---|---|---|
| 1. | Chitral Town | 2 (F)<br>2 (C) | 1000 | 1975<br>1981 |
| 2. | Shishi | 3 (F) | 300 | 1984 |
| 3. | Garam Chashma | 1 (F) | 100 | 1979 |
| 4. | Booni | 2 | 24 | 1985 |
| 5. | Jalkot | 3 (F) | 150 | 1982 |
| 6. | Keyal | 2 (F) | 200 | 1985 |
| 7. | Ranolia | 3 (F) | 150 | 1982 |
| 8. | Kund | 2 (F) | 200 | 1982 |

### 8.1.14. EXISTING STATIONS IN NORTHERN AREAS

The development of small hydroelectric stations in the Northern Area of Pakistan was started in 1965, when WAPDA constructed two powerhouses having a combined capacity of about 600 kW. The electricity produced by these stations was used for lighting in Gilgit and Hunza city. About 4 projects were installed in 1960-70. The development of hydropower remained increasing in 1970-80, about 13 projects were installed. However, in 1980-90 the maximum installation was carried out, which goes up to 29 projects. In 1990-2000, about 6 projects were put in to operation and about 23 remained under construction.

The installed capacity of all these stations varies between 50 kW to 5000 kW. Most of these stations having capacity less than 250 kW. About 5 stations have capacity 1 MW and above. Kargah-VI has the maximum capacity about 5 MW. The total installed capacity of these stations is about 24.238 MW. The following tables give some details about the existing stations.

**Table 8-3 Existing Plants in Northern Areas**

| Sr. No. | Scheme Name | Head (m) | Discharge ($m^3/s$) | No. of Units & type | Power (MW) | Date of Commission |
|---|---|---|---|---|---|---|
| 1 | Kargha-I | 120 | 26 | 2 (F) | 0.4 | 1965 |
| 2 | Kargha-II | 200 | 15 | 2 (I) | 0.56 | 1977 |
| 3 | Kargha-III | 134 | 42 | 2 (F) | 0.75 | 1989 |
| 4 | Kargha-IV | 134 | 42 | 2 (F) | 0.75 | 1989 |
| 5 | Kargha-V | 134 | 14 | 2 (I) | 0.25 | 1983 |
| 6 | Kargha-VI | 671 | 20 | 4 (P) | 5 | 1993 |
| 7 | Kargha-VII | 220 | 36 | 2 (I) | 1.25 | 1990 |
| 8 | Single-I | 180 | 11 | 1 (I) | 125 | 1978 |
| 9 | Single-II | 300 | 12 | 1 (F) | 250 | 1989 |
| 10 | Sher Qila | 187 | 11 | 1 (F) | 135 | 1980 |
| 11 | Juglot-I | 187 | 11 | 1 (I) | 135 | 1977 |
| 12 | Nomal | 187 | 11 | 1 (I) | 135 | 1977 |
| 13 | Naltar | 100 | 8 | 1 (F) | 100 | 1966 |
| 14 | Chalt | 100 | 8 | 1 (F) | 50 | 1966 |
| 15 | Hassanabad-I | 120 | 26 | 1 (F) | 200 | 1965 |
| 16 | Hassanabad-II | 375 | 9 | 2(F) | 500 | 1986 |
| 17 | Hassanabad-II (2) | 105 | 32 | 1(F) | 250 | 1986 |
| 18 | Minapin | 180 | 11 | 1 (I) | 125 | 1979 |
| 19 | Sumayar | 180 | 11 | 1 (I) | 125 | 1984 |
| 20 | Chatorkhand | 380 | 8.85 | 1 (I) | 200 | 1980 |
| 21 | Danyor | 190 | 20 | 2 (I) | 400 | 1987 |
| 22 | Khyber | 375 | 20 | 1 (F) | 500 | 1987 |
| 23 | Manthoka | 302 | 11.5 | 1 | 250 | 1991 |
| 24 | Gupis | 142 | 14 | 6 (F) | 750 | 1987 |
| 25 | Budalas | 105 | 32 | 3 (F) | 750 | 1987 |
| 26 | Chilas | 120 | 26 | 1 (I) | 200 | 1978 |
| 27 | Astore | 190 | 11 | 2 (I) | 270 | 1976 |
| 28 | Thore | 180 | 11 | 1 (I) | 125 | 1984 |
| 29 | Tangir | 120 | 26 | 1 (I) | 200 | 1982 |

Note: I= Impulse, F= Francis, P= Pelton

**Table 8-4 Existing Plants in Northern Areas**

| Sr. No. | Scheme Name | Head (m) | Discharge ($m^3/s$) | No. of Units & type | Power (MW) | Date of Commission |
|---|---|---|---|---|---|---|
| 30 | Darel | 180 | 22 | 1 (I) | 250 | 1984 |
| 31 | Parshing | 180 | 22 | 1 (I) | 200 | 1986 |
| 32 | Ratu | 120 | 26 | 1 (I) | 200 | 1987 |
| 33 | Gorikot | 180 | 11 | 2 (I) | 250 | 1986 |
| 34 | Lous | 250 | 35 | 2 (F) | 1250 | 1989 |
| 35 | Skardu-I | 120 | 26 | 2 (F) | 400 | 1973 |
| 36 | Skardu-II | 190 | 20 | 4 (F) | 800 | 1987 |
| 37 | Khaplu | 190 | 11 | 1 (I) | 135 | 1978 |
| 38 | Parkuta | 190 | 11 | 1 (I) | 135 | 1987 |
| 39 | Sermlk | 180 | 11 | 1 (I) | 125 | 1980 |
| 40 | Shigar | 190 | 11 | 1 (F) | 135 | 1986 |
| 41 | Kachura-I | 180 | 11 | 2 (F) | 250 | 1982 |
| 42 | Kachura-II | 180 | 11 | 1 (F) | 250 | |
| 43 | Tolti | 180 | 11 | 2 (F) | 250 | 1986 |
| 44 | Olding | 180 | 9 | 1 (F) | 125 | 1987 |
| 45 | Hashupa | 180 | 9 | 1 (I) | 100 | 1986 |
| 46 | Stak | 120 | 26 | 1 (I) | 200 | 1987 |
| 47 | Mondi | 120 | 26 | 1 (I) | 200 | 1987 |
| 48 | Kiris | 200 | 10 | 1 (I) | 250 | 1988 |
| 49 | Thaly | 260 | 10 | 1 () | 250 | 1980 |
| 50 | Jalalabad | 220 | 60 | 2 | 1250 | |
| 51 | Garbuchung | 347 | 10 | 1 | 250 | |
| 52 | Basho | 300 | 23 | 2 | 1000 | |
| 53 | Harpo | 300 | 11.5 | 2 | 500 | |

Note: I= Impulse, F= Francis, P= Pelton

## 8.2. HYDROPOWER PROJECTS UNDER CONSTRUCTION

### 8.2.1. CHASHMA HYDROPOWER PROJECT

The project is presently under construction with a capacity of 184 MW and will be equipped with 8 bulb type turbines. The construction supervision and design is being done by Sogreah and CNR of France under joint venture with Pakistani firms, Associated Consulting engineers (ACE) Ltd, National engineering Services of Pakistan (NESPAK) Ltd. and Mirza & Associates. The main contractor is Hyundai of South Korea with Pakistani contractors under joint venture. The turbines are supplied by Fuji of Japan.

The feasibility study completed in 1987 by WAPDA in collaboration with GTZ, originally envisaged the construction of a 270 MW power station, with 12 bulb type turbines with rated discharge of 250 $m^3/s$ per unit. The project layout was proposed in a by-pass on the right side of the barrage (Figure 8-8). The Chashma Right Bank Canal passes over the draft tube through an aqueduct. The road to D.I.Khan will pass over the aqueduct (Figure8-9). Flood discharges will flow through the existing barrage, which will also perform as emergency spillway during load rejection. Layout on the left side was not considered economical due to the provision of a large crossing structure for Chashma-Jhelum Link Canal, which has a capacity of more than 600 $m^3/s$. Installation of turbo-generators within the barrage structure was not considered technically feasible, due to safety of the existing structures and reduction in discharging capacity of the barrage. The tender documents were prepared and floated in 1988, however, not accepted due to disputes on water rights between the provinces.

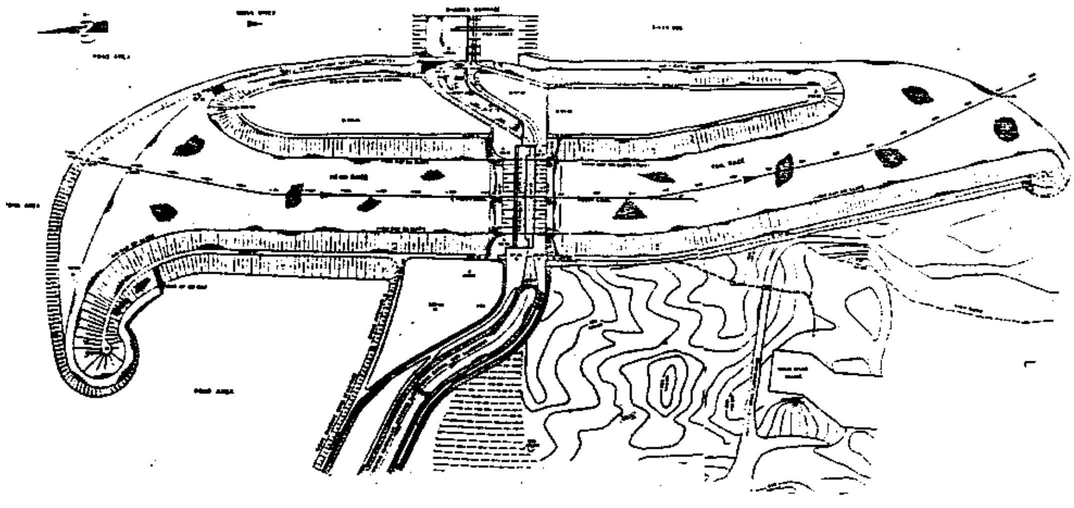

**Figure 8-8 Chashma Hydropower Project Layout**

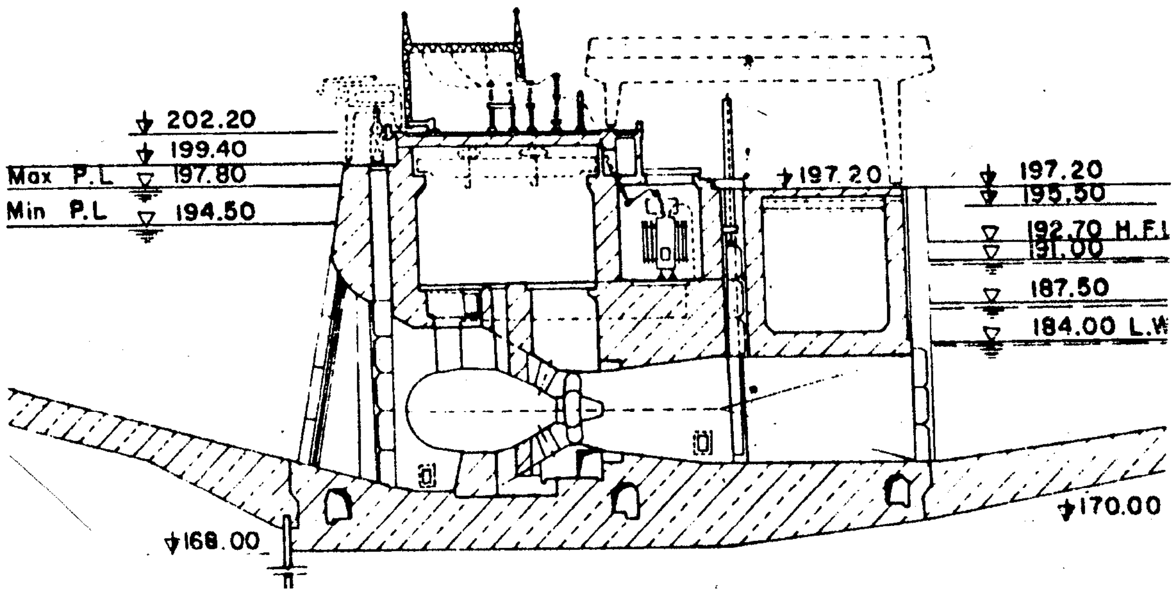


**Figure 8-9 Chashma Powerhouse Cross Section**

### 8.2.2. GHAZI-BAROTHA HYDROPOWER PROJECT

Ghazi-Barotha hydropower project is located on the Indus River, which is one of the world's major rivers, with an average flow of 2350 $m^3/s$ at Tarbela Dam. The project will develop the hydraulic head available between the tailrace at Tarbela and the confluence of the Indus and Haro Rivers for power generation. The upstream limit of the project area has been taken as Tarbela Dam. From Tarbela, the river flows in a broad alluvial valley at an average gradient of about 1 in 700. The Kabul river joins the Indus river about 48 km downstream of Tarbela. After its confluence with Kabul river, the Indus river enters the 8 km long Attock gorge. Downstream of the gorge, the river flows in narrow confines for about 7 km until the Haro river joins it, near

Gariala, the downstream limit of the project area. In this reach, the Indus River drops by about 76 m in a distance of about 63 km. The project is a typical canal diversion project as shown in Figure8-10.

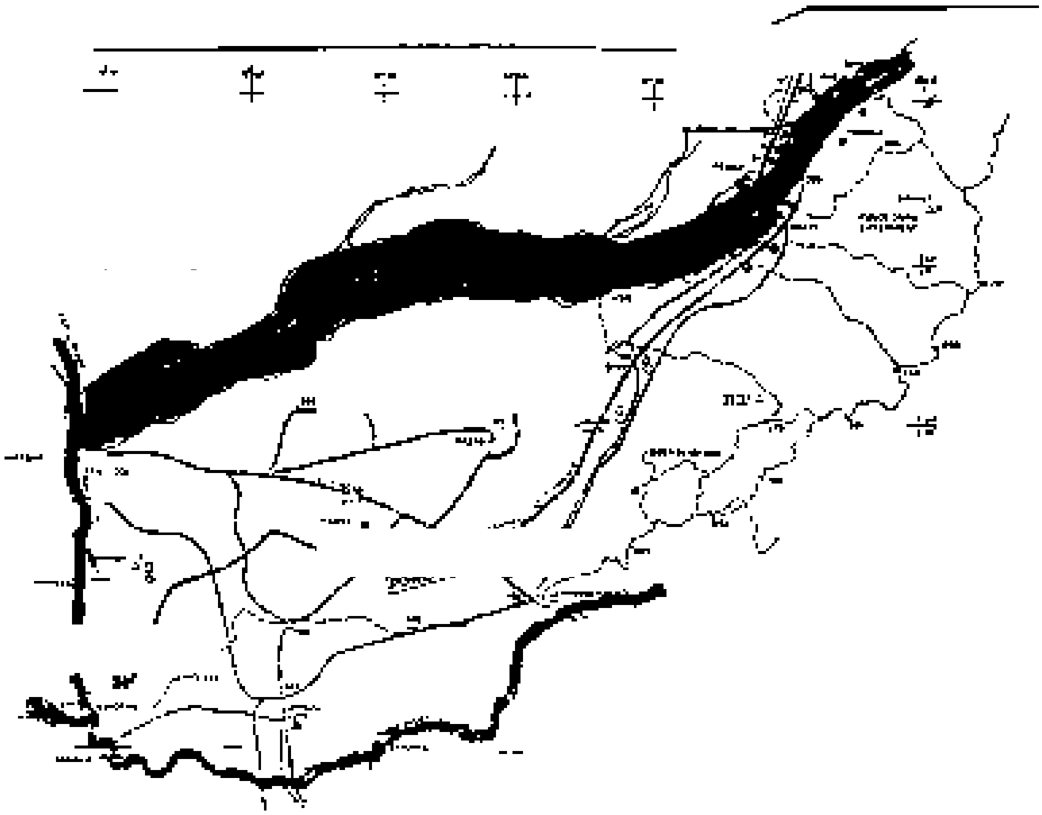

**Figure 8-10 Ghazi-Barotha Layout Plan**

The project site was identified during 1958 and during 1987 WAPDA, HEPO prepared a pre-feasibility report which became the basis for detailed feasibility study. Pakistan Hydro consultants a Joint Venture of:

- National engineering Services Pakistan (Pvt) Ltd.
- Associated Consulting engineers ACE (Pvt) Ltd.
- Ewbank Preece Ltd.
- Harza engineering Company International LP.
- Binnie & Partners (Overseas) Ltd.

was appointed as consultant to take up feasibility study, detailed engineering and tender document. The feasibility study was submitted in August 1991. The feasibility report envisaged the project, which comprises of a barrage on Indus river, power canal of 52 km length and power complex near the confluence of the Indus and Haro rivers.

The barrage will be located across the Indus River about 7 km downstream from Tarbela Dam. Barrage will have three functions such as; divert water into the power canal, raise the water level at the entrance of the power canal so that the head available for the project will be as high as practicable and create a pond to re-regulate the peaking outflows from Tarbela powerhouse on daily basis. The barrage will consist of standard bays, under sluice bays, dividing island, guide bank, fuse plug, road connection to the right bank, gated head regulator for power canal and skimming platform to reduce the entry of sediments into power canal. The barrage layout is shown on Figure-8-11.

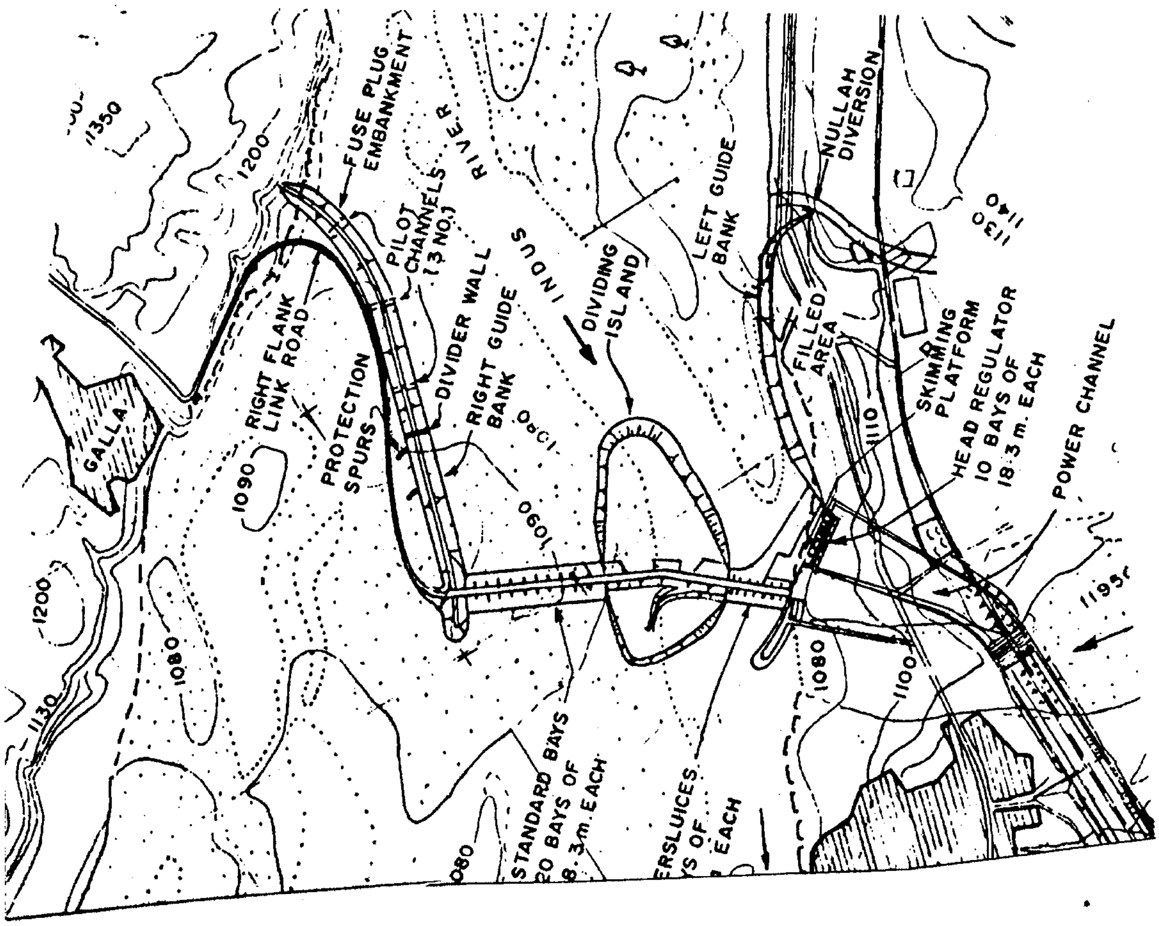


**Figure 8-11 Ghazi-Barotha - Barrage Plan**

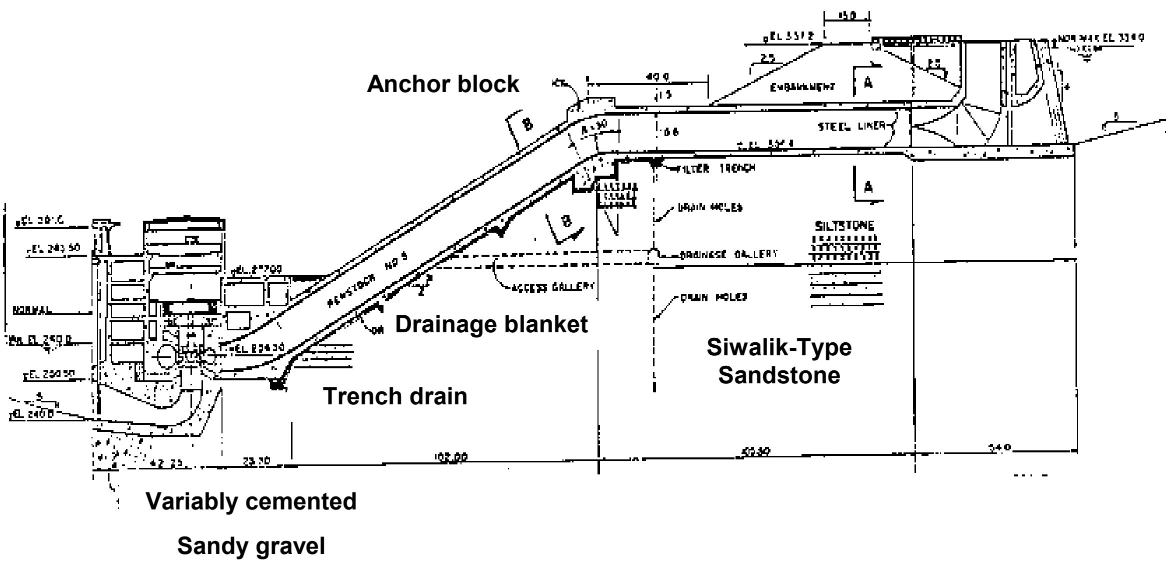


**Figure 8-12 Ghazi-Barotha Powerhouse Cross Section**

Power canal extends from the Ghazi area to the left bank of the Indus river between Attock-Cherat range and the confluence with the Haro river. The power canal with its service road, embankments and spoil banks will occupy an area of about 2,700 ha extending over a length of about 52 km. The power canal is concrete lined with under drainage arrangement. The maximum capacity of the canal is about 2,000 $m^3$/s and it is the biggest in the world for such long length. About 45 cross drainage structures are provided in the power canal. Of these, 26 structures are super passages, 3 will be culverts and the remaining 16 will be direct inlets to the channel. About 6 overflowing escape structures are provided to limit the water level and will be built on the channel's right bank. A tail regulator is provided to control water level fluctuations. A total of 33 bridges are proposed.

The power complex is located near the confluence of Indus and Haro rivers. The function of the power complex will be to use the water delivered by the power canal to generate power and energy before returning to the Indus river. The power complex consists of powerhouse, power intake structure, penstocks, head pond, forebay and siphon spillway as bypass structure. A head pond of 5 M $m^3$ capacity is provided for daily peak demand duration of 4 hours. The open cut powerhouse is a reinforced concrete structure and will house 5 Francis turbines as on Figure8-12.

**MAIN DATA**

**BARRAGE**

- Maximum Flood = 46,200 $m^3$/s
- Gated Section = 24,900 $m^3$/s
- Fuse Plug = 23,300 $m^3$/s
- No of Bays in Standard Section = 20
- Gate Size = 18.3 m * 7.3 m
- Crest Level = 333 m.a.s.l.
- No of Bays in Undersluice Section = 8
- Gate Size = 18.3 m * 5.4 m
- Crest Level = 326.00 m.a.s.l.

**POWER CANAL**

- Design Flow = 2,000 $m^3$/s
- Manning's n = 0.016
- Longitudinal Slope = 1:10,000
- Full Supply Depth = 9.0 m
- Bed Width = 76.6 m
- Total Length = 52,027 m
- Power Canal Headregulator
- No of gates = 10
- Gate Size = 18.3 m * 5.4 m

**POWER COMPLEX**

- Penstock Diameter = 10.6 m
- No of Penstocks = 5
- Turbine
- No and Type = 5 Francis
- Design Output = 260 MW
- Full Gate Output = 291 MW
- Net Head = 68 m
- Design Flow = 400 $m^3$/s
- Generators Capacity = 285 MW Each

- Annual Energy Output = 7,709 GWh

**HEADPOND & FOREBAY**

- Area = 367 hectares
- Live Volume = 16.2 M m3
- Full Supply Level = 334 m.a.s.l.

## 8.3. PLANNED HYDROPOWER PROJECTS

### 8.3.1. KALABAGH DAM PROJECT

Kalabagh dam project would be located on the river Indus about 16 km southwest of Pakistan's capital Islamabad. The proposed dam site is about 193 km downstream from the Tarbela dam, a large reservoir on the Indus river. The Jinnah Barrage is located some 26 km below the Kalabagh Dam site. The total catchment area at dam site is about 110,500 sq miles which is about 70% larger than the Tarbela catchment. Catchment area includes the catchment of Kabul, Haro, Swat, Soan, Indus above Tarbela and other small streams directly out falling into Indus river below Tarbela dam. The annual average discharge of the river Indus at the dam site is about 89 MAP. Flows are highly seasonal, 84% of the discharge occurring during the Kharif season and 16% during the Rabi season. However, operation of Tarbela reservoir modifies these seasonal proportions to 79% and 21%, respectively.

After Kalabagh dam site the Indus river enters into the plains of the Punjab and no dam site exists for a large reservoir. Therefore, Kalabagh dam site presents a unique opportunity to impound the run-off from the largest catchment area and to use the water for irrigation, to suppress flood peaks and to generate electricity.

Engineering Investigations for Kalabagh dam started in 1953, when Government of Pakistan engaged M/S Tipton and Hill of USA to investigate the possible site in the canyon of Indus river upstream of Kalabagh. After preliminary investigation consultants submitted their feasibility report in 1956. However, the search for dam site in this gorge dates back to almost 1942, when Mr. J.L. Savage the famous dam designer of the Bureau of Reclamation went upstream in a launch from Kalabagh town. In 1962, M/S Chas T. Main of USA was deputed by World Bank to appraise the technical and economic feasibility of Tarbela, which was declared to be first storage on river Indus. They also studied Kalabagh dam as a possible alternative to Tarbela.

In 1972 Associated Consulting engineers (ACE) Ltd. were appointed to undertake the feasibility study of the project. The feasibility study report was published in 1975 by recommending implementation of the project and with provision for sediment sluicing to extend the useful life of the reservoir. In 1882, Kalabagh consultant a joint venture of five consulting engineering firms such as

1. Binnie and Partner (Overseas) Ltd.
2. Harza engineering Company International.
3. Preece, Cardew and Ridder Ltd.
4. Associated Consulting engineers (ACE) Ltd.
5. National engineering Services (Pakistan) Ltd.

were appointed to take full development proposal and prepare detailed design including specifications and tender document. The project planning report was published in 1984, by Kalabagh consultant and recommended a dam site where river is about 396 m wide. The river bed is at 207.26 m.a.s.l and is composed of sand and gravel alluvium up to 26 m thick. A broad ridge about 1372 m from the river on the left bank forms the left abutment. On the right bank of the river the dam will extend 1524 m across a gravel terrace area to abut against a bedrock spur which climbs to higher ground. Two service spillways will be built on the right bank. One is orifice type while the other is gated over flow type spillway. Powerhouse and silt sluicing low level outlet tunnel are placed on left bank. The dam will be embankment type with a clay core taken through overlying gravel to bedrock and with shoulder of rolled sandstone and gravel. Internal drains with suitable filters will be provided. The downstream shoulder will be surfaced with a layer of cobbles and the upstream shoulder will be protected against wave action by riprap. Plan and few sections of structure are shown in Figure8-13.

The salient data of the project is as follows:

**1 Hydrology (Indus River at site)**

- Catchment = 110,500 Sq. miles
- Maximum Recorded Flood (1929) = 1,200,000 ft3/s
- Average Annual Flow = 91.4 MAF

**2 Reservoir**

- Storage Capacity
- Gross = 7.9 MAF
- Live = 6.1 MAF
- Retention Level
- Maximum = 278.89 m.a.s.l
- Minimum = 251.46 m.a.s.l

**3 DAM**

- Type : Zoned Fill Embankment with Clay Core
- Maximum Height Above River Bed = 79.25 m
- Total Length = 3353 m
- Total Fill Volume = 60 mill Cu Yard

**4 Spillway**

- Overflow Spillway Capacity = 30302 m3/s
- Orifice Spillway Capacity = 27754 m3/s

**5 Power Facilities**

- Unit Size = 300 MW
- Penstock :712 No.
- Turbine = Francis Type
- Turbine Design Head = 51.82 m
- Powerhouse = Indoor Type
- Installed Capacity
- Initial = 2400 MW

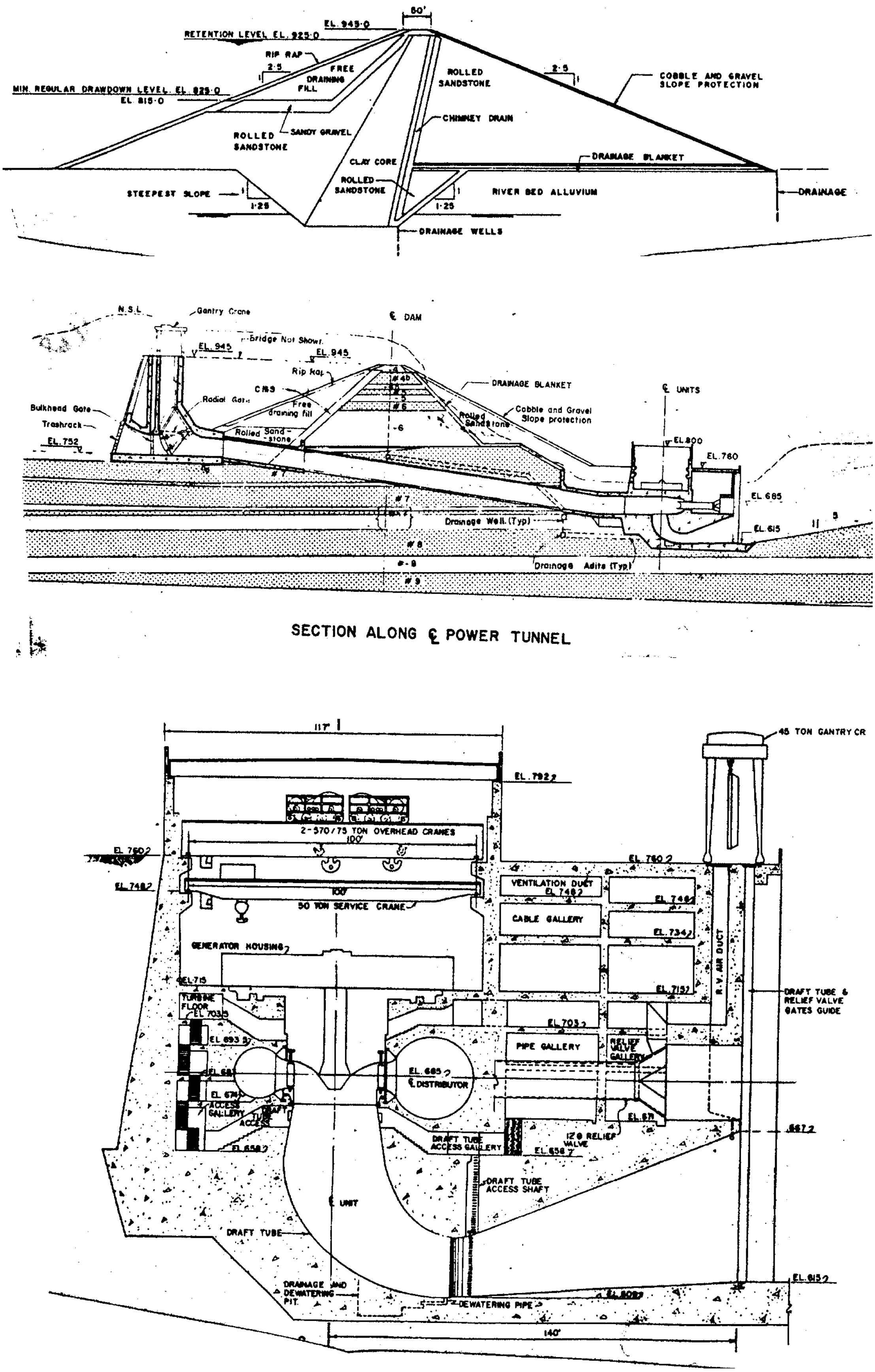


**Figure 8-13 Kalabagh Dam - Plan and Few Structure Cross Sections**

- Ultimate = 3600 MW
- Average Annual Energy = 11400 GWh

**6 Cost**

Estimated total Investment (June 1994) =Rs. 173 Billion

Kalabagh dam is a multi-purpose project with a live storage capacity of 6.1 MAF. It has the following purposes:

- Replacement of the lost live storage capacities of Tarbela and Mangla reservoirs.
- Provision of additional storage of Indus river.
- Extension of irrigation facilities to new area.
- Generation of a large amount of hydroelectric power.
- Regulation and control of the flood peaks of the Indus to minimise the flood hazards.
- Increasing the managing capability of water distribution and power generation systems through conjunctive use of the Tarbela and Kalabagh reservoirs.

### 8.3.2. BASHA DAM PROJECT

The Basha dam site is located on the Indus river, 314 km upstream of Tarbela dam and some 165 km below the town of Gilgit. It will be the third large reservoir on the Indus river. The dam site is accessible by way of Karakoram Highway. The small town of Chilas is situated some 40 km away.

According to the pre-feasibility report published on October 1984, prepared by Montreal engineering Company, Limited, Canada, the earth-rock fill dam of 920 m length, 200 m height and with total reservoir storage of about 9.0 $km^3$ has been proposed. The central core and concrete cut-off to bedrock will be provided (Figure 8-15). The area of reservoir at full supply level is 112 $km^2$. An overflow spillway with concrete lined chute, flip bucket and plunge pool is provided. The spillway will be equipped with 6 gates having 16.6 m width and 20 m height. Intermediate and low level outlets will be constructed on extreme right side of the dam (Figure 8-14).

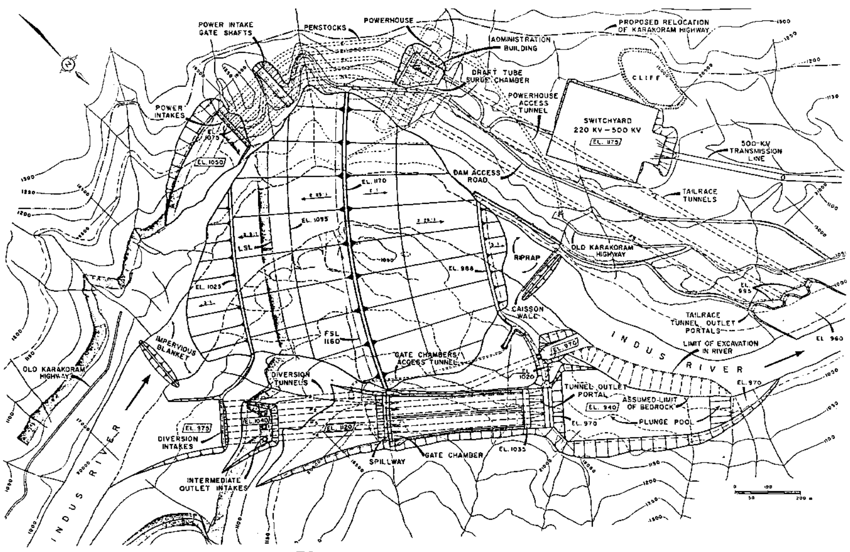


**Figure 8-14 Basha Dam Layout Plan.**

The underground powerhouse houses 12 vertical shaft Francis turbine with full output of 287.2 MW each. The powerhouse is located on the left bank on the toe of dam. The tailrace tunnel falls out into Indus river.

The total installed capacity of the powerhouse is about 3360 MW and with annual average generation of about 14129 GWh.

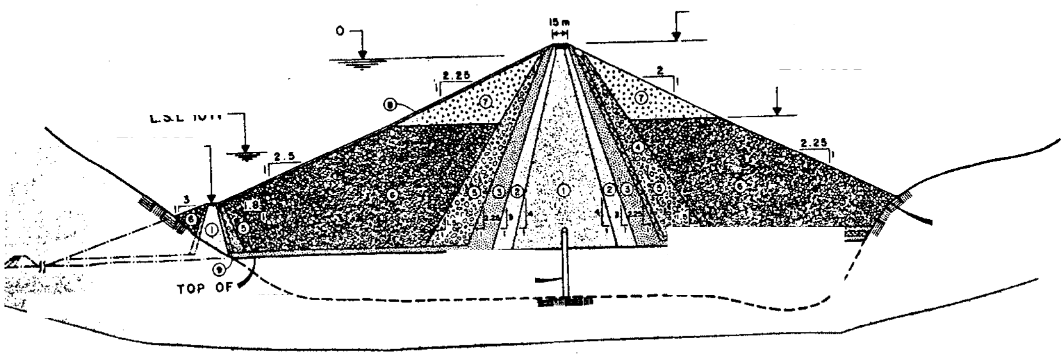


**Figure 8-15 Basha Dam Cross-Section.**

### 8.3.3. ROHRI HYDROPOWER PROJECT

Feasibility study was conducted by WAPDA with technical collaboration of GTZ and recommended the installation of two pit type turbo-generators. The installed capacity is 16 MW. To ensure a continuous flow of irrigation water, two bottom outlets are provided as emergency flushing structures in case of load rejection and maintenance of turbines. The project envisages the construction of powerhouse, raising of canal bank from head regulator to RD 15+000, lowering of canal bed between RD 15+000 and RD 118+000, construction of bridge at RD 118+000 and strengthening of existing bridge structures along affected canal reaches. The powerhouse will be equipped with two pit-type turbines. The annual energy generation is about 102 GWh. The powerhouse will be connected to national grid through Rohri Grid station which is about 6 km from project site. The powerhouse cross section through turbine axis and cross-section of the bottom outlet is shown in Figure: 8-16.

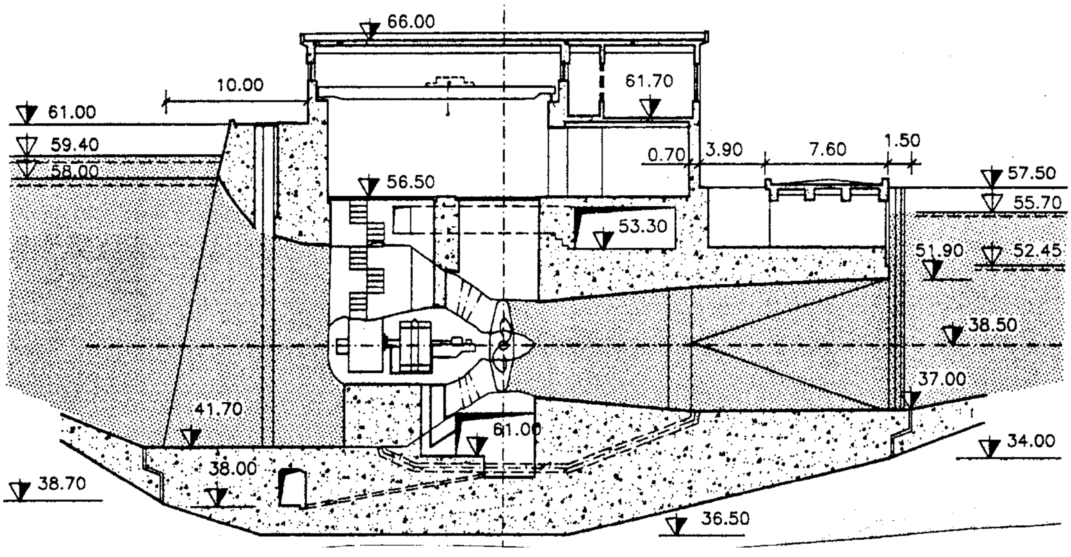


**Figure 8-16 Cross Section of Powerhouse and Bottom Oulet of Rohri HPP.**

The project was approved and allotted to a French Consortium for implementation on turnkey basis with a new concept. Powerhouse will be equipped with 4 Kaplan turbines in vertical axis. The turbine will operate under syphonic arrangement. The spillway will be placed at $40^0$ angle with powerhouse on right side and discharge on downstream of existing fall structure at RD 15+000.

### 8.3.4. JINNAH HYDROPOWER PROJECT

A consortium of consulting firms conducted the feasibility study through a grant of Overseas Development Agency (ODA) of United Kingdom. The study envisages the construction of a 144 MW power station consisting of 16 pit type turbo-generators. The powerhouse will be placed is by-pass arrangement on right side of the barrage. The road to Kalabagh and Banu will pass over the powerhouse draft tube. The headrace will be placed by puncturing the existing right guide bank at about 800-m from barrage centre line. The powerhouse will be placed in line of barrage. The report was not approved by the Government of Pakistan due to lack of hydraulic model studies concerning sedimentation, which were done at Nandipur Irrigation Research Institute and concluded by the end of October, 1997.

The feasibility study is updated in the light of sedimentation study results and recommended the installation of 8 Units with 12 MW capacity each.

Project has been allotted to a private investor M/S Maraubni of Japan for implementation on Built-Operate-Transfer basis.

### 8.3.5. TAUNSA HYDROPOWER PROJECT

The feasibility study has been completed by a consulting firm through a grant of Canadian International Development Agency (CIDA) of Canada. The study recommended the construction of a 120 MW power station consisting of 8 pit type turbo-generators. The powerhouse is proposed to be placed in by-pass arrangement. The D.G.Khan canal crosses headrace through aqueduct on upstream of the powerhouse (Figure: 8-17). The railway line also crosses the headrace between aqueduct and powerhouse structure. The highway will pass over the deck of powerhouse draft tube. The report was not approved by the Government of Pakistan due to lack of hydraulic model studies regarding sedimentation, which are presently under way at Nandipur Irrigation Research Institute.

Project has been allotted to a private investor M/S Independent Energy of USA. for implementation on Built-Operate-Transfer basis.

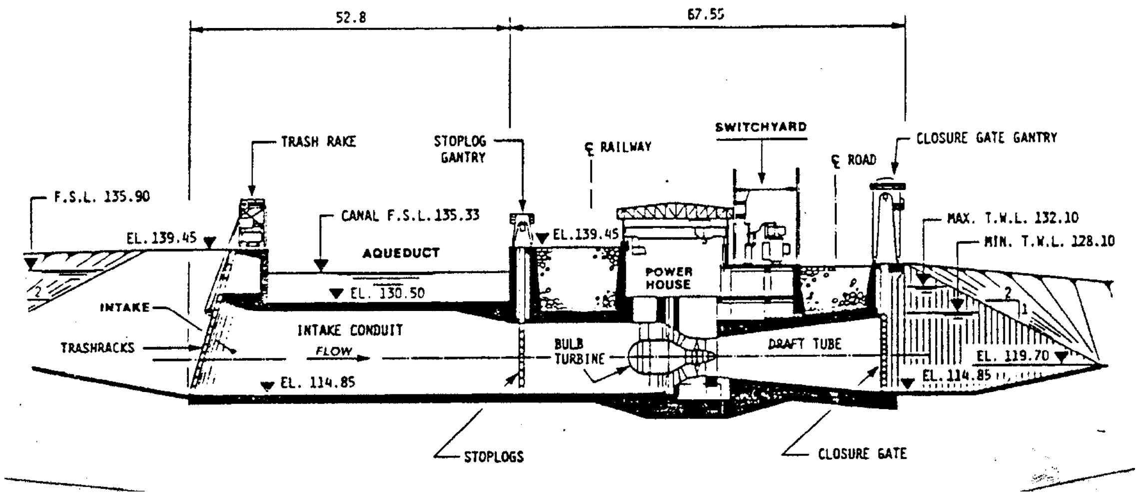


**Figure 8-17 Taunsa HPP Powerhouse Cross-Section**

### 8.3.6. GUDDU HYDROPOWER PROJECT

Draft feasibility report was prepared by WAPDA with technical assistance of GTZ. Study concluded the construction of a 33.5 MW power station. The powerhouse will be equipped with 5 pit-type Kaplan turbines in horizontal setting. The feasibility report envisaged construction of powerhouse on left side in by-pass arrangement. The powerhouse is placed in the bed of the Ghotki Canal, which will cross powerhouse through an aqueduct. Temporary diversion is foreseen for the Ghotki Canal during construction. The report could not be finalised due to lack of hydraulic model studies (Layout and Sedimentation), which are presently in progress at Nandipur Irrigation Research Institute.

### 8.3.7. CHASHMA-JHELUM LINK TAIL HYDROPOWER PROJECT

Feasibility report was prepared by WAPDA in collaboration with GTZ. Since the discharges in the canal are decided according to the irrigation requirements, based on historic data the feasibility report originally envisaged the construction of a 22.5 MW power station. The study was revised after the signing of a Water Accord among the provinces and the capacity of the project was increased to 33.75 MW. This project was identified during the planning of the canal and was not implemented due to lack of funds, because the Tarbela Dam was under-construction at the same time. It was ranked first in canal projects in Ranking Study prepared by WAPDA-GTZ.

The feasibility report envisages construction of power project in by-pass arrangement on right side of the tail regulator. The power canal will off-take at angle of $40^0$ with the canal centre line. The proposed intake is bell mouth shaped with small crest. The power canal will be lined with concrete. The powerhouse will be placed in the line of third fall. The powerhouse is equipped with three Kaplan turbines each having capacity of 11.25 MW. The intake of the powerhouse is of special type and made of concrete (Figure8-18). The tailrace will join canal downstream of third fall.

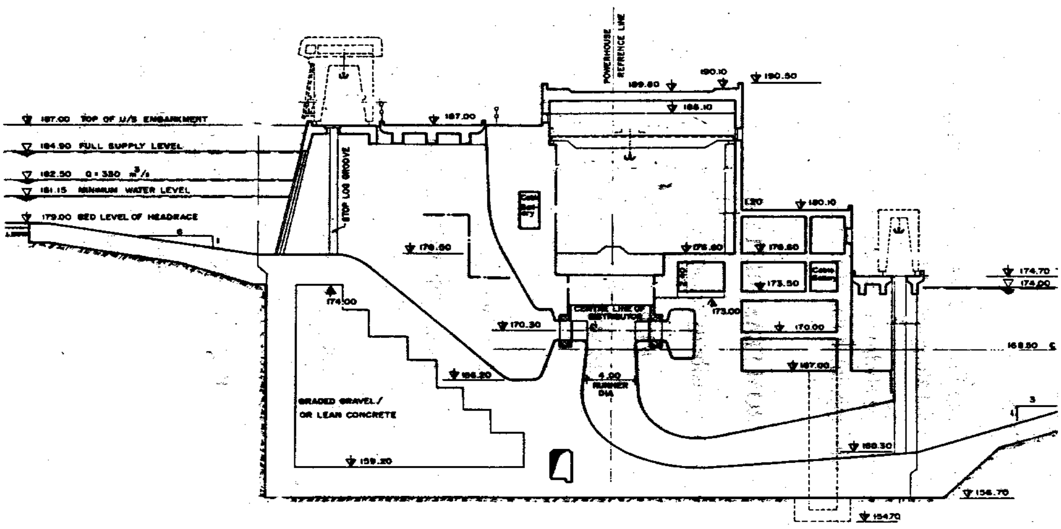


**Figure 8-18 C.J.Link Tail HPP Powerhouse Cross-Section**

### 8.3.8. D.G.KHAN LINK-III CANAL HPP

This project was identified during preparation of Inventory of Low Head Hydropower Potential. About four falls exist in the head reach of Link-III of D.G.Khan canal off-taking from Taunsa Barrage. It is a non-perennial canal. The project envisages the combination of 3 falls and will generate 7.2 MW. Feasibility study was taken up by HEPO with technical assistance of GTZ and could not be finalised due to lack of funds for field investigations. However, a Pre-feasibility report was published which envisaged installation of 2 turbines in by-pass arrangement (Figure: 8-19).

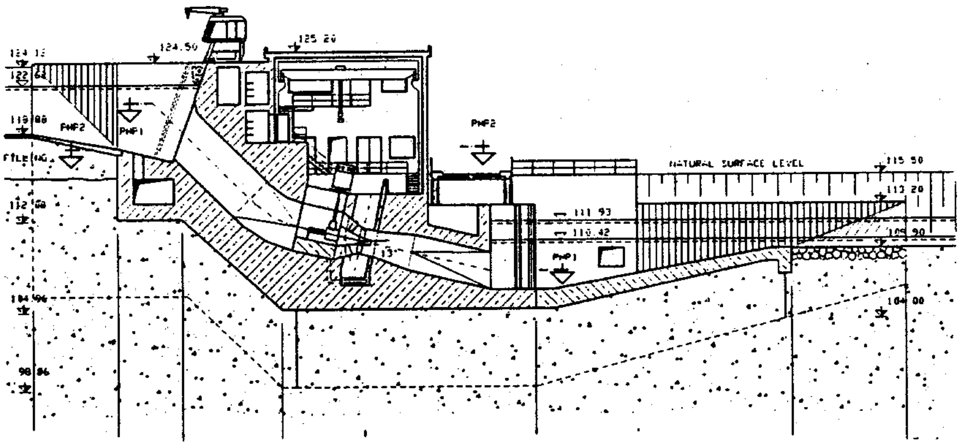


**Figure 8-19 D.G.Khan Link-III HPP Powerhouse Cross Section**

## 8.3.9. NEELUM-JHELUM HYDROPOWER PROJECT

The project was identified during Inventory and Ranking study of main Indus conducted by Montreal engineering Company of Canada. The pre-feasibility report was prepared by HEPO-WAPDA in 1987 and feasibility study by Norconsult in 1996. The project utilises a gross head of about 420 m by diverting the Neelum River water from Nauseri to the lower limb of Jhelum River through a 32.5 km long tunnel system (Figure: 8-20). A 135 m long and 45 m high concrete gravity dam with four radial gates will be constructed (Figure: 8-21). A peaking reservoir of 2.8 million $m^3$ is selected which allows peaking for 4 hours or more during the dry season at full power plant capacity. The intake structure is located close to the diversion dam and includes six intake gates. Six intake culverts connect the intake with the sedimentation basin. The sediment basin contains three surface basins. Each basin is 23 m wide, 300 m long and 20 m deep. The flushing will be done conventionally. A diversion tunnel for construction period is designed only for dry season flow, and cofferdams must therefore be rebuilt after each flood season.

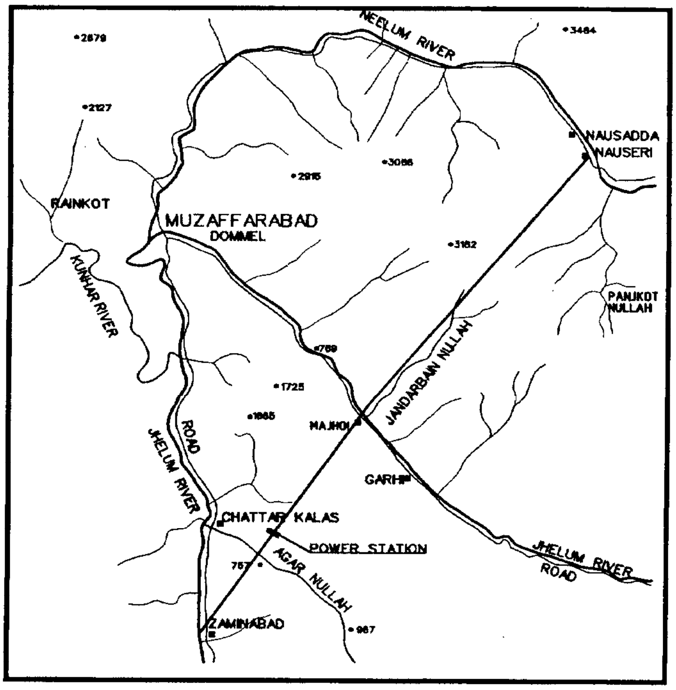


**Figure 8-20 Layout of Neelum-Jhelum HPP.**

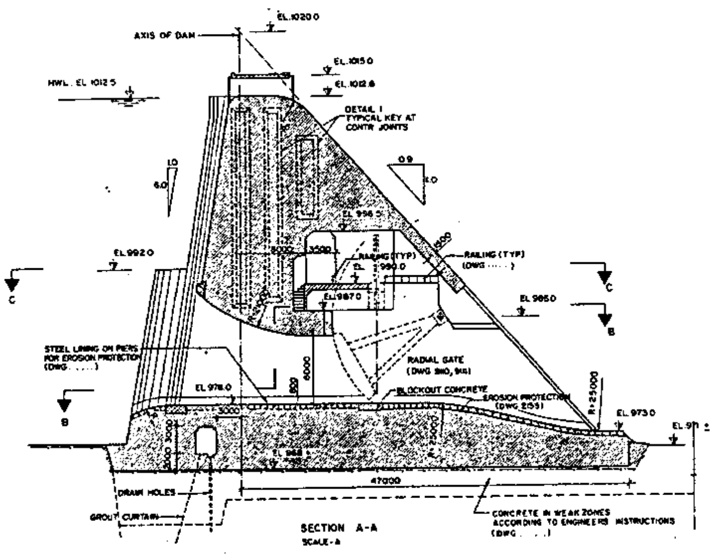


**Figure 8-21 Neelum-Jhelum HPP- Dam Cross-Section**

The total length of the headrace tunnel system is about 28.5 km. The upstream 11.2 km stretch of the tunnel is designed as twin tunnel system each cross section of 46 $m^2$. The remaining tunnel down to surge chamber has only one tunnel with cross section of 80 $m^2$. The upstream tunnel of about 13.7 km. stretch is horizontal and may be used for daily peaking storage purpose.

The surge chamber system consists of a 330 m high 70 $m^2$ cross section concrete lined vertical shaft, and a 1250 m long surge tunnel inclined at 8 % with a cross section of 80 $m^3$. The five steel lined penstock tunnels are about 100 m long and steel lining has a diameter of 3.4 m. The underground powerhouse has been proposed with 5 units each with installed capacity of 195 MW (Figure 8-22). The maximum rated discharge is 280 $m^3/s$. The powerhouse cavern is 153 m long, 19.4 m wide and about 35 m high from the turbine floor. The 15 single phase transformers will be placed in a separate hall, 120 m long and 15 m wide.

hall, 120 m long and 15 m wide.

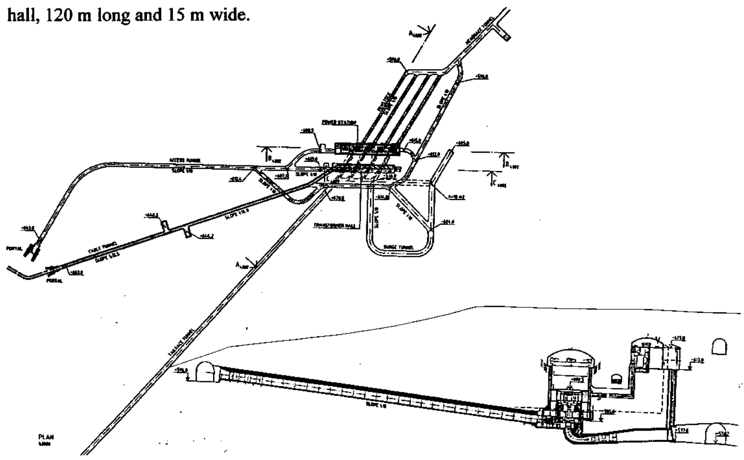

**Figure 8-22 Neelum-Jhelum HPP- Powerhouse Cross-Section**

The main access tunnel to the powerhouse is 750 m long with cross section of 47 $m^2$. For construction and emergency escape purpose an extra access tunnel is included. The tailrace tunnel is 3.6 km. long and has a cross section of 80 $m^2$. The tailrace tunnel falls out into Jhelum river at Zaminabad.

**8.3.10. ALLAI KHWAR HYDROPOWER PROJECT**
The Allai Khwar hydropower project will be a stand-alone project, using a head of some 700 m by diverting the Allai Khwar flow to the Indus river through a narrow ridge separating these rivers (Figure 8-23). Various alternatives have been proposed.

One of them requires a waterway length of about 3 to 3.6 km. A concrete gravity or concrete arch dam of about 140 m height will divert the water. The intake is provided in the body of the dam with sediment flushing system just downstream of the dam. The powerhouse is proposed to be underground and will be equipped with 2 Pelton turbines. The output of each unit is 100 MW. The dam will create a reservoir of 31.7-million $m^3$ capacity. A very special feature of the project is that a bypassing sediment flushing system will be provided at the root of the reservoir. The height and type of proposed dam and the required sediment handling arrangements make this alternative expensive.

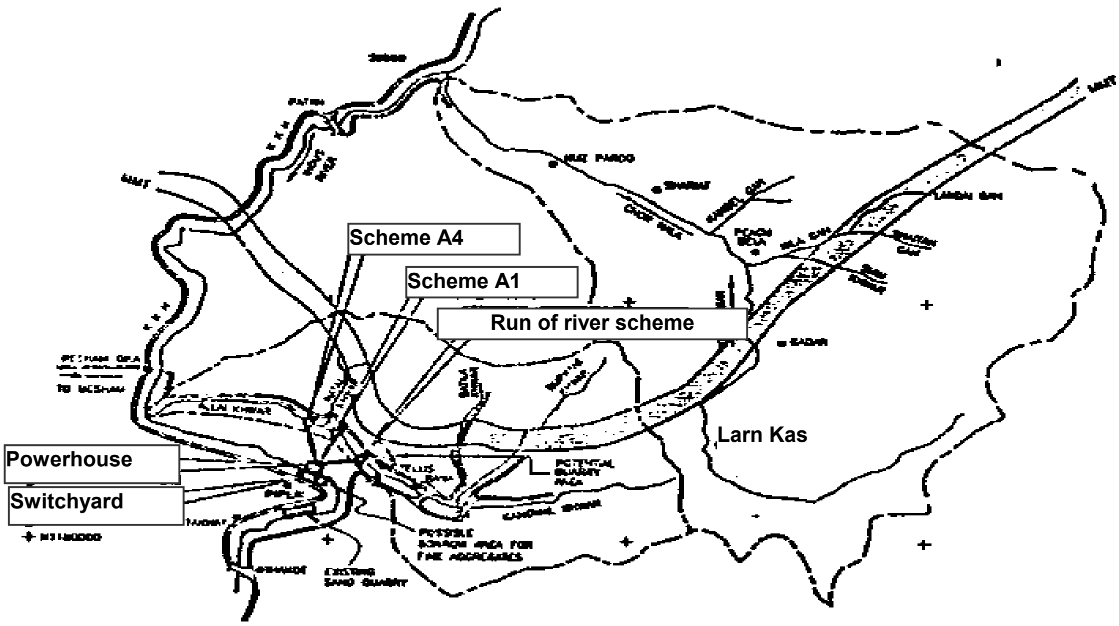


**Figure 8-23 Allai Khwar HPP-Layout and Infrastructure Plan**

The other alternative considers the construction of a smaller dam and reservoir (run-of-river) with a total installed capacity of about 120 MW. The dam site is very near to the previous one. It has the possibility of constructing a sand trap on the downstream side of the dam, which may reduce the cost and difficulties of handling of sediments. This option may be favoured due to lower investment cost and higher rate of return.

**8.3.11. GOLEN GOL HYDROPOWER PROJECT**
Golen Gol hydropower project is a run-off river project. It was initially planned to generate 31 MW of power into two phases. It was designed to cater the power demand in Chitral District for the next two decades as an isolated scheme. However, the connection of Chitral District with National Grid makes the project to be studied for its full potential. Therefore, scheme has been designed for the generation of 106 MW consisting of three units in one phase with average energy output of 436 GWh.

It is located on Golen Gol a major tributary of Mastuj river. The project area lies in the Mastuj valley of Chitral District surrounding with mountains ranging from 4875 to 5800 m.a.s.l. Chitral District is one of the twelve districts of North West Frontier Province (NWFP) of Pakistan. It is accessible by road and air, but dependent on weather conditions. The road passes through famous Lowari Pass at an altitude of 3200 m.a.s.l. The district is divided into six tehsils and eleven Union Councils. In Chitral district major attractions for tourism are Kalash valleys, Garam Chashma, Chitral valley and Trichmir about 7788 m.a.s.l., the highest peak of Hindukush range. Chitral district is also famous for hand woven and knitted woollen garments and clothing of fairly good quality. It has population of 208,256 persons with average growth rate of 2.8 %.
The project alignment is placed on the left bank of Golen Gol. The weir site is about 2 km from Golen village on upstream side. The powerhouse site is located on left bank of Mastuj river near confluence of Golen Gol. The weir consists of overflow section and flushing section. Flushing section is placed in front of lateral type intake on left bank. The coarse rack is provided on the intake. Overflow section is designed as gravity dam. After intake water enters in to gravel spill section which is about 36.5 m long. The sand trap of three chambers is proposed after gravel spill system. The water conduit system consists of open channel and pressure tunnel. Tunnel will be used for storage to deal with daily peak load. The powerhouse (Figure 8-24) in open will be placed at toe of outcropping rock. The penstock connects pressure tunnel to powerhouse through double chamber surge bay. The tailrace embedded into ground out falls in to Mastuj river.

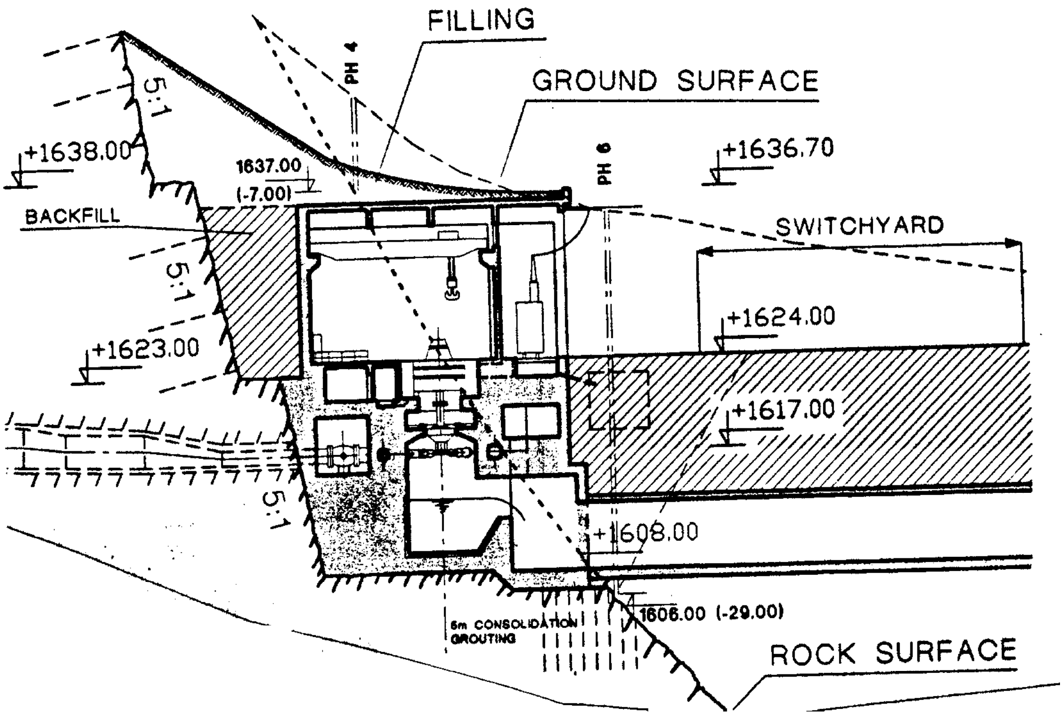


**Figure 8-24 Golen Gol Powerhouse**

## 8.3.12. MALAKAND III HYDROPOWER PROJECT

This project was first identified and quantified by Swabi SCARP consultants in April 1994. An auxiliary tunnel parallel (Figure 8-25) to Benton tunnel is proposed to meet the irrigation requirement of Upper Swat canal which has to be remodelled for increased water requirement. The Upper Swat canal was constructed in 1918. It off-takes from Amandra Headworks on Swat river. A 6 km long canal carries water from Amendra to foot of the Malakand hills. There, a 3.5 km long Benton tunnel pierces the Malakand hills and passes water into Dargai Nullah. The 6.25 km long pitched channel starting 2300 m downstream of the outlet of the Benton Tunnel was constructed parallel to Dargai Nullah, to lead the water to a trifurcator such as Abazai Branch running in a westerly direction, Machai Branch in easterly direction and a wasteway canal.

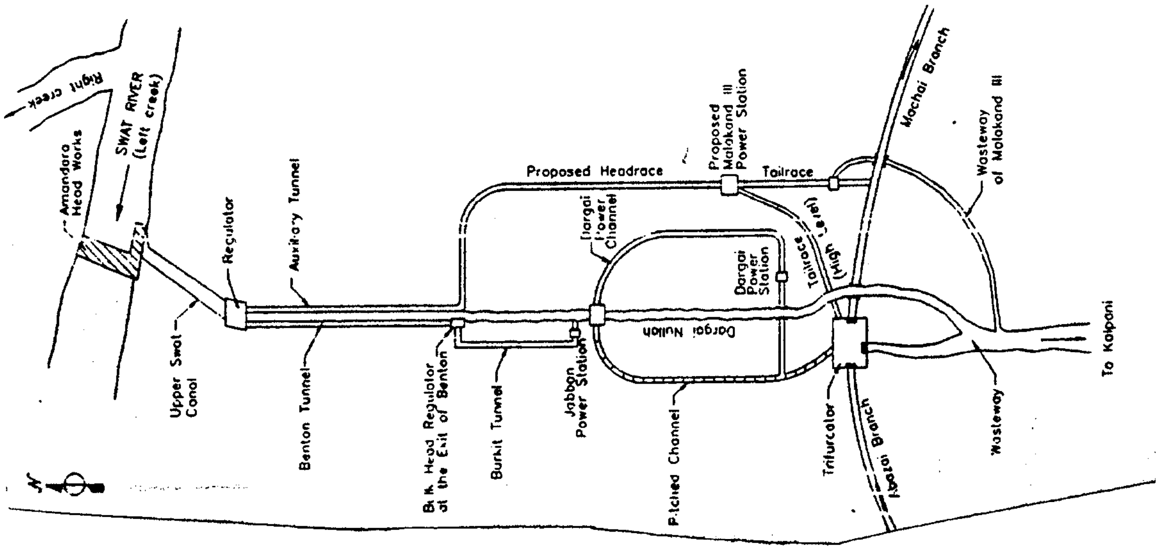


**Figure 8-25 Malakand - III HPP - Layout**

The head available between Benton Tunnel outlet and trifurcator is being used by two powerhouses Jabban & Dargai 20 MW capacity each. Jabban powerhouse was constructed at the outlet of the Benton tunnel in 1937 and Dargai near trifurcator in 1953.

The Malakand-III has a gross head of 191 m and design discharge capacity of 85 m3/s. The open headrace after auxiliary tunnel run parallel to Dargai power canal and will be placed about 80 m higher than Dargai power canal.

A sediment basin is proposed just downstream of auxiliary tunnel. The headrace will lead to forebay, from where water is fed to turbine through steel penstock. Three units of Francis type turbines will be installed (Figure 8-26). The project is allocated to private entrepreneur Messers B.C. Southern Hydro limited. A feasibility study was done by a joint venture of three firms such as Associated consulting engineers limited, Pakistan engineering services (PES) Ltd and Bangash, Ali and Karim Consulting engineering (BAK). The feasibility report recommends the following main project element such as:

**HEADRACE**

- Open Channel length = 3135 m
- Nos. Tunnel free flow with length = 2603 m

**SEDIMENT EXCLUDER**

- Chamber = 5 No.
- Total length = 172 m

**FOREBAY**

- Length = 50 m
- Width = 14 m
- Depth = 13.21 m

**PENSTOCK**

- Length = 760 m
- Diameter = 4 m

**POWERHOUSE**

- Length = 41.8 m
- Width = 20.3 m
- Depth = 31.8 m

**TURBINES**

- Type Francis in vertical
- Head = 183.5 m
- Discharge per unit = 51 $m^3/s$

**TAILRACE**

- Type Concrete lined
- Length = 1 km

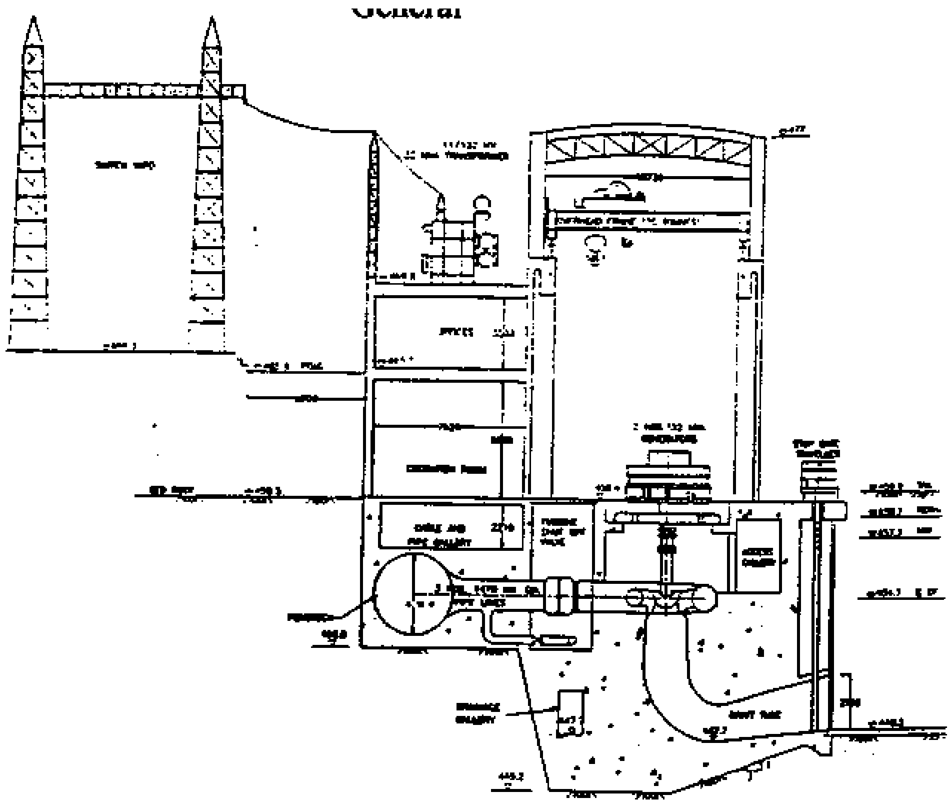

**Figure 8-26 Malakand - III HPP Powerhouse**

**8.3.13. LOW HEAD IN PUNJAB AREA**

**8.3.13.1. BALLOKI-SULEMANKI LINK RD 106+000 PROJECT**

This project was first investigated in a Ranking study by Water and Power Development Authority under technical co-operation of the German Agency for Technical Co-operation (GTZ). This report was published in May 1985. The project was ranked 2nd in projects along canals. In 1987 project was allotted to Army Welfare Trust of Pakistan for implementation in private sector. Army Welfare Trust engaged Associated Consulting engineers (ACE) Ltd. in association with Harza engineering International to undertake the feasibility study. The feasibility report was published in July 1987. Later on Army Welfare Trust decided not to develop the project.

In 1992 GOP through Ministry of Water and Power Private Power Cell invited proposal for the development of project in private sector. Only MK Power Consortium, a joint venture of Messers Macro Services (Pvt) Ltd. of Pakistan and Messers Kaverner Boring Ltd. of United Kingdom submitted a proposal. A letter of support has been issued on 29.8.1994. The proposed project is to be located in by-pass arrangement on right side of the Balloki-Sulemanki Link-I near RD 106+250. Balloki-Sulemanki Link-I which off-takes from Balloki Headworks on river Ravi. The project site is about 52 km from Lahore and 18 km from Chunian Town in the Kasur District of Punjab. The Mk Power Consortium submitted a feasibility report which envisages, construction of powerhouse in by-pass arrangement near RD 106+250. The centre line of the power canal is about 185 m from the centre line of B.S.
Link. The powerhouse will be equipped with 3 pit type turbines with 3.86 MW capacity each. The annual energy is about 68.3 GWh. The existing fall structures will be remodelled and equipped with gates and will act as emergency spillway during operation and maintenance.

**8.3.13.2. BALLOKI-SULEMANKI LINK-I TAIL PROJECT**

The project was identified and studied by WAPDA under technical co-operation programme with GTZ in 1984. It was ranked 4th under canal projects in ranking study published during 1985. This report envisages construction of powerhouse in by-pass on the right side of canal. The salient features of this project are:

- Discharge = 230 m3/s
- Head = 3.2-3.6 m
- No of units = 4
- Installed capacity = 6 MW
- Annual energy = 46 GWh

The Government of Pakistan decided to develop this project in private sector. Government of Punjab issued LOI in favour of M/S Shaukat hydropower Limited under Hydel Policy 1995. Associated Consulting engineers (ACE) were appointed as consultants for preparation of feasibility study.

The feasibility report envisages construction of powerhouse in by-pass near tail of Balloki-Sulemanki (B.S) Link-I. B.S.Link-I was off-taking from Balloki Barrage on Ravi river. It was constructed in 1954 by the Irrigation and Power department Government of Punjab, to feed the Sutlej river valley canals after India diverted the flows of Sutlej river. It has approximate length of 85 km. It out-falls in Sutlej river about 16 km upstream of Sulemanki Barrage. The first part about 22 km of canal is unlined while lower part about 63 km is brick lined.

The canal was designed for discharge of 425 $m^3/s$, but restricted up to 340 $m^3/s$ due to operating difficulties. In 1960, B. S. Link-III a non-perennial canal was constructed which off-takes from B. S. Link-I at RD 72+000 and runs parallel up to tail regulator. Both the canals out-fall into same channel. Near tail regulator canal runs in heavy fill.

The feasibility report prepared by private sponsor envisages construction of powerhouse in by-pass on right side of tail regulator. Powerhouse will be equipped with 2 pit-type turbines of 9.65 MW capacity (Figure: 8-27). The turbine will generate 74 GWh of energy. The existing tail regulator will be remodelled for its use as emergency spillway in future. It is proposed in the feasibility report that B. S. Link-I will run with its maximum while the surplus water will be passed through B. S. Link-II.

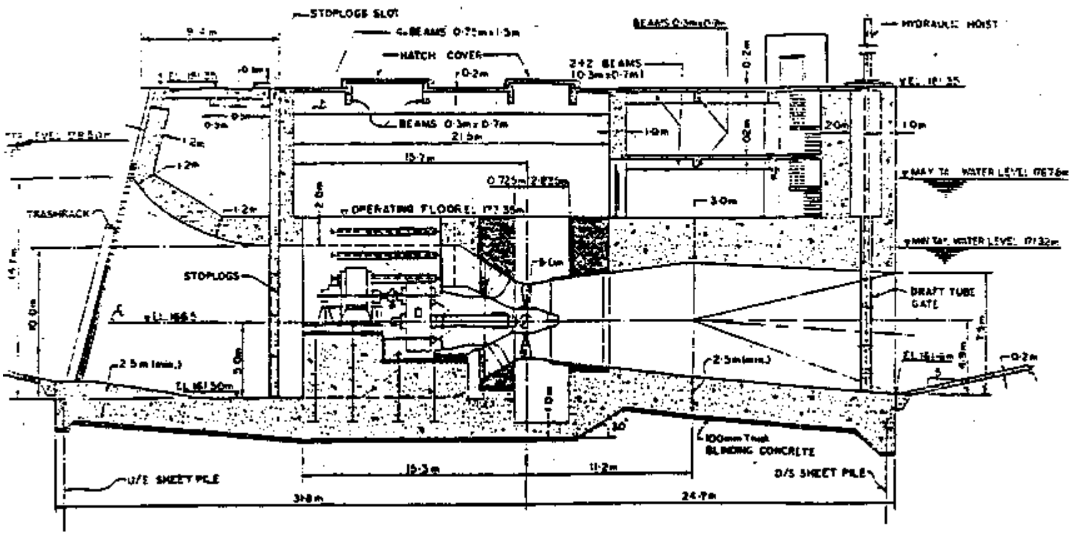


**Figure 8-27 B.S.Link Tail HPP Powerhouse**

### 8.3.14. DEVELOPMENTS IN PRIVATE SECTOR

The hydropower Private Policy of the Government of Pakistan envisages privatisation of high and low head potential in the country. The low head hydropower projects are primarily being dealt by the Power Development Board of the Provincial Governments.

The development of 45 sites on canal falls, having installed capacity of about 286 MW, is now being offered to the private sector by the Punjab Government. The available head varies between 0.61 to 8.5 m. Out of these, about 27 sites have head less than 2.5 m. About 10 sites are along non-perennial canals.

Letter of interest for about 21 sites with total installed capacity of about 200 MW and few letters of support have been issued (Table 8-3).

**Table 8-5 Sites taken Up by Private Sector.**

| Sr. No. | Name of Sponsor | Location | MW | LOS Issued | PPIB | Remarks |
|---|---|---|---|---|---|---|
| 1. | International Development company, 116 L, LCCH Lahore Cantt | L.J.C RD 0+00 | 8.5 | | | HEPO |
| 2. | -do- | Gujrat Br. RD 000-2000 | 3 | | | HEPO |
| 3. | -do- | U.J.C RD 36+660*** | 9 | | | IR |
| 4. | -do- | R.Q.Link RD 000 | 8.5 | | | HEPO |
| 5. | -do- | U.J.C. RD 63+000 | 8 | | | IR+HEPO |
| 6. | -do- | U.J.C. RD 34+756 | 10 | | | IR+HEPO |
| 7. | Independent Energy Partners, INC. Executive Centre, 92 Commercial Area Cavelary Ground Extension Lahore Cantt. | New Bong Escape U.J.C. RD 27+000 | 45 | | | IR |
| 8. | -do- | L.C.C (M) RD 0+000 | 5 | | | IR+HEPO |
| 9. | -do- | U.J.C. RD 36+860 | 3 | | | HEPO |
| 10. | -do- | B.S.Link I RD 0+000 | 19 | | | IR+HEPO |
| 11. | -do- | U.C.C. RD 0+000 | 10 | | | IR+HEPO |
| 12. | Amin Bros. engineering (Pvt) Ltd. 19-B DI Gulberg-III Lahore | Q.B.Link RD 271+655 | 9 | | | HEPO |

| | | | | | | |
|---|---|---|---|---|---|---|
| 13. | Philap Power, 1st floor Centre Point, Gulberg-III Lahore | Main Line U.C.C RD 133+296 Head of U.C.C (L) | 6 | 27-1-97 | 26-2-97 | IR+HEPO |
| 14. | M.K. Power Rawalpindi. | B.S. Link I RD 106+000 | 10 | 26-8-94 | | Ranking |
| 15. | Shaukat Hydel, Fortress Stadium Lahore | B.S. Link I (Tail) | 9 | 11-10-94 | | Ranking |
| 16. | Syed Bhais (Pvt) Ltd, P.O 483, 200 Ferozpur Road Lahore | U.C.C (L) RD 221+000 | 6 | | | |
| 17. | Syed Bhais (Pvt) Ltd, P.O 483, 200 Ferozpur Road Lahore | U.C.C (L) RD 225+000 | 2.5 | | | |
| 18. | Punjab Power (Pvt) Ltd, IEP Bidg, Liberty Market, Gulberg-III Lahore | L.B.D.C RD 329+056+RD 340+850 | 4.5 | | | IR+HEPO |
| 19. | Albario Trading Corp. Resul Bidg. 50 Shahrah-e-Quid-e-Azam, Lahore | U.C.C (L) RD 283+100 | 8 | 2-2-97 | 14-3-97 | IR+HEPO |
| 20. | Power Tek Ltd, 3-Chairman House Road, Faisalabad | Q.B.Link RD 379+265 | 10 | | | HEPO |
| 21. | State engineering Projects Co. (Pvt) Ltd. Saeed Plaza Jinnah Avenue, Islamabad | U.C.C (L) RD 128+000 | 7 | | | IR+HEPO |

## 8.4. IDENTIFIED HYDROPOWER PROJECTS

### 8.4.1. HYDROELECTRIC INVENTORY AND RANKING

This was the first systematic step to achieve an inventory of hydropower potential available in Pakistan, which was carried out during 1980-82 under the assistance ship of Canadian International Development Agency (CIDA). The study area was that part of the Indus river basin lying in the northern areas of Pakistan. For the purpose of study, the Indus river catchment was divided in to three sub-basin such as:

- Indus basin upstream of Tarbela Dam.
- Jhelum river upstream of Mangla Dam.
- Those parts of Kabul, Swat and Chitral basin situated in Pakistan.

A total of about 25 schemes were inventoried and studied in various configurations. A total capacity of about 16584 MW can be achieved. The detail about these schemes is given in this table.

**Table 8-6 Hydropower Project along Main River**

| Sr. No. | Scheme Name | River | Head (m) | Discharge (m3/s) | Height of Dam (m) | Power (MW) | Energy (GWh) |
|---|---|---|---|---|---|---|---|
| 1. | Tungas | Indus | 214 | 962 | 127 | 625 | 2809 |
| 2. | Yulbo | Indus | 238 | 990 | 140 | 710 | 3190 |
| 3. | Bunji | Indus | 402 | 1025 | 210 | 1290 | 5793 |
| 4. | Rakhiot | Indus | 120 | 1858 | 140 | 670 | 3010 |
| 5. | Basha | Indus | 165 | 2337 | 200 | 3600 | |
| 6. | Dasu | Indus | 215 | 2099 | 235 | 2712 | 12181 |
| 7. | Pattan | Indus | 150 | 2254 | 104 | 1172 | 7577 |
| 8. | Thakot | Indus | 138 | 2337 | 60 | 1043 | 6897 |
| 9. | Thakot | Indus | 288 | 2337 | 205 | 2415 | 15972 |
| 10. | Kanch | Gilgit | 190 | 207 | 200 | 122 | 549 |
| 11. | Sher Qila | Gilgit | 121 | 234 | 130 | 86 | 395 |
| 12. | Kohala | Jhelum | 167 | 349 | 36 | 85 | 382 |
| 13. | Abbasian | Jhelum | 53 | 809 | 80 | 90 | 406 |
| 14. | Azad Patan | Jhelum | 48 | 833 | 70 | 86 | 385 |
| 15. | Mahl | Jhelum | 53 | 825 | 75 | 93 | 419 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 16. | Karot | Jhelum | 52 | 834 | 70 | 93 | 419 |
| 17. | Neelum-Jhelum | Neelum | 125 | 316 | 30 | 76 | 341 |
| 18. | Naran | Kunhar | 352 | 49 | 195 | 177 | 513 |
| 19. | Suki Kinari | Kunhar | 940 | 64 | 160 | 332 | 1303 |
| 20. | Patrind | Kunhar | 105 | 106 | 130 | 133 | 307 |
| 21. | Kalam | Swat | 139 | 88 | 160 | 116 | 269 |
| 22. | Mirkhani | Chitral | - | - | 307 | - | - |
| 23. | Khazana | Panjkora | 111 | 74 | 115 | 110 | 413 |
| 24. | Kalangai | Swat | 131 | 254 | 145 | 256 | 998 |
| 25. | Munda | Swat | 198 | 285 | 205 | 492 | 1507 |

### 8.4.2. COMPREHENSIVE PLANNING IN JHELUM RIVER CATCHMENT

In 1987, it was decided to prepare an inventory of hydropower potential available in the Jhelum river and its tributaries. The study was sponsored by German Government through technical assistance programme. The German Government appointed GTZ (German Agency for technical co-operation) to assist WAPDA - HEPO in the study. The Jhelum river catchment was studied and presented under three sub-catchment given below:

- Punch river basin
- Jhelum river basin
- Neelum river basin

The potential identified in each basin was presented separately in small and medium capacity. The small identified projects were considered for local demand, while medium capacity for inter-connection to the national grid.

The two basins were completed and about 1677 MW of potential was identified through 28 projects. Out of these projects about 14 are medium sized and 14 are of small capacity. The medium capacity projects are tabulated below.

The Neelum river catchment was not completed due to some access problems.

**Table 8-7 Jhelum River Catchment Identified Potential of Medium Capacity**

| Sr. No. | Scheme Name | River | Head (m) | Discharge (m3/s) | Height of Dam (m) | Power (MW) | Energy (GWh) |
|---|---|---|---|---|---|---|---|
| 1. | Sehra | Punch | 65 | 130 | 37 R | 65 | 398 |
| 2. | Kotli | Punch | 95 | 130 | 82 R | 97 | 597 |
| 3. | Barali | Punch | 55 | 150 | 50 R | 66 | 398 |
| 4. | Rajdhani | Punch | 67 | 160 | 67 CG | 86 | 507 |
| 6. | Chakotti-Hattian | Jhelum | 154 | 120 | 32 CG | 139.1 | 1118.8 |
| 7. | Hari Ghel-Tain Dehlkot | Mahl | 316 | 22 | 20 | 52.6 | 273.7 |
| 8. | Hariyola-Zamanabad | Aghar | 330 | 4.7 | Tiroler | 12.4 | 148.4 |
| 9. | Chakothi Sehri | Jhelum | 189 | 120 | 32 CG | 171.4 | 1379 |
| 10. | Abbasian | Jhelum | 52 | 550 | 80 CG | 245 | 1593 |
| 11. | Karot | Jhelum | 51 | 550 | 70 CG | 240 | 1614 |
| 12. | Mahl | Jhelum | 52 | 550 | 75 CG | 245 | 1630 |
| 13. | Azad Pattan | Jhelum | 47 | 550 | 70 CG | 221 | 64 |
| 14. | Nakar Channa | Khaner Kas Tributary of Jhelum | 285 | 4 | Tiroler | 8.7 | 42 |

CG = Concrete Gravity Dam, R=Rock fill Dam,

The details about projects less than 5 MW capacity is given below:

**Table 8-8 Less Than 5 MW Potential in Jhelum River Basin**

| Sr. No. | Name of Basin | No. of Schemes | Power Potential (MW) | Energy (GWh) | Remarks |
|---|---|---|---|---|---|
| 1. | Punch river | 8 | 9.61 | 64.58 | |
| 2. | Jhelum River | 6 | 10.62 | 71.57 | |
| 3. | Neelum River | 2 | 7.4 | | Study not completed |

### 8.4.3. COMPREHENSIVE PLANNING IN NORTHERN AREAS

After the completion of comprehensive planning of Jhelum river catchment, identification of hydropower potential available on the tributaries of Indus river lying in the Northern Areas of Pakistan was taken up during 1992-1996 under study title of " Comprehensive Planning of Hydropower Resources on Tributaries of Indus River in Northern Areas". The study was carried out under technical co-operation programme with GTZ, German Agency for Technical Co-operation.

The whole area was divided into 12 regions for study purpose. Northern area of Pakistan is a mountainous area and has an area of about 72,300 km$^2$. It has common border with Afghanistan, China and Indian occupied Kashmir. The identified potential which is more than the local demand can be connected to the national grid is given in table below.

**Table 8-9 Identified Potential More than 5 MW in Northern Area**

| Sr. No. | Scheme Name | River | Head (m) | Discharge (m3/s) | Height of Dam (m) | Power (MW) | Energy (GWh) |
|---|---|---|---|---|---|---|---|
| 1. | Daintar | Daintar river tributary of Hjunza river | 390 | 1.36 | ROR | 4.2 | 36.02 |
| 2. | Jaglot Alt.-I | Jaglot Gah tributary of Hunza river | 840 | 0.80 | ROR | 4 | 34.24 |
| 3. | Naltar-III | Naltar Gah tributary of Hjunza river | 347 | 2 | ROR | 5.5 | 46.04 |
| 4. | Naltar-V | Naltar Gah tributary of Hjunza river | 433 | 5 | ROR | 17.3 | 101.25 |
| 5. | Phandar-II | Ghizar river tributary of Gilgit river | 222 | 6.98 | ROR | 12.3 | 102.33 |
| 6. | Baru | Baru Gah tributary of Ishkuman river | 313 | 2.99 | ROR | 7.7 | 65.15 |
| 7. | Skardu-III | Satpara Lungma tributary of Indus river | 220 | 2.9 | ROR | 4.9 | 33.92 |
| 8. | Basho-II | Basho Lungma tributary of Indus river | 320 | 1.26 | ROR | 3.3 | 27.53 |
| 9. | Basho-III | Basho Lungma tributary of Indus river | 530 | 1.01 | ROR | 4.3 | 36.63 |
| 10. | Turmic | Turmic nullah tributary of Indus river | 500 | 3.71 | ROR | 15.3 | 130.61 |
| 11. | Harpo | Harpo nullah tributary of Indus river | 702 | 2.61 | ROR | 15 | 150.46 |
| 12. | Talu | Talsalo nullah tributary of Indus river | 1102 | 0.95 | ROR | 8.7 | 65.30 |
| 13. | Doian | Astore river tributary of Indus river | 350 | 82 | 50 | 230 | 1382 |
| 14. | Chhantir | Chhantir tributary of Ishkuman river | | | | 16 | 77 |
| 15. | Altit | | | | | 250 | 1240 |
| 16. | Kachura-IV | | | | | 32 | 151 |
| 17. | Parishing-IV | | | | | 13 | 68 |

**Table 8-10 Identified Potential More than 5 MW in Northern Area**

| Sr. No. | Regions | No. of Schemes | Power (MW) | Remarks |
|---|---|---|---|---|
| 1. | Chilas | 7 | 17 | |
| 2. | Astore | 15 | 443 | |
| 3. | Gilgit | 13 | 61 | |
| 4. | Hunza | 10 | 65 | |
| 5. | Ishkuman | 10 | 25 | |
| 6. | Yasin | 11 | 16 | |
| 7. | Skardu | 11 | 36 | |
| 8. | Shyok | 7 | 4 | |
| 9. | Rondu/Harmosh | 4 | 46 | |
| 10. | Kharmang | 11 | 12 | |
| 11. | Khunjerab | 6 | 3 | |
| 12. | Ghizar | 8 | 40 | |

### 8.4.4. COMPREHENSIVE PLANNING IN NWFP

Small hydel development Organisation (SHYDO) which was incharge to run the small hydropower station for rural area electricity, has started preparation of an inventory of hydropower potential available on the tributaries of Kabul, Swat, Chitral and Indus river. The study was conducted under technical assistance programme from GTZ (German Agency for Technical Co-operation). For the purpose of this study area of N.W.F.P. was divided into 7 regions:

- Region-1 Upper Chitral
- Region-2 Lower Chitral
- Region-3 Kohistan
- Region-4 Swat Valley
- Region-5 Indus Swat/Mangohra West
- Region-6 Kaghan Valley
- Region-7 Dir Kohistan

The total potential of 560 MW was identified. The details of the projects, which are of interest for interconnection to national grid are given below.

**Table 8-11 Identified Potential having capacity more than 5 MW in N.W.F.P.**

| Sr. No. | Scheme Name | Region | Head (m) | Discharge (l/s) | Power (MW) | Remarks |
|---|---|---|---|---|---|---|
| 1 | Shaid Ali Gol | Region - 1 | 210 | 5349 | 9.0 | Peak |
| 2 | Mastuj 1 | Region - 1 | 18 | 41452 | 6.0 | Peak |
| 3 | Mastuj 2 | Region - 1 | 45 | 24700 | 8.9 | ROR |
| 4 | Rosh Gol A2 | Region - 1 | 345 | 2511 | 7.7 | Peak |
| 5 | Trich Gol A3 | Region - 1 | 500 | 7240 | 29.7 | Peak |
| 6 | Trich Gol 1st Phase | Region - 1 | 500 | 4210 | 12.0 | ROR |
| 7 | Turkho A2 | Region - 1 | 66 | 18800 | 9.9 | ROR |
| 8 | Barum Gol | Region - 1 | 550 | 2288 | 10.0 | Peak |
| 9 | Lutkho | Region - 2 | 60 | 13365 | 6.4 | ROR |

| | | | | | | |
|---|---|---|---|---|---|---|
| 10 | Arkari A | Region - 2 | 305 | 5580 | 24.0 | Peak |
| 11 | Arkari B | Region - 2 | 335 | 5580 | 26.4 | Peak |
| 12 | Golen in Chattar | Region - 2 | 410 | 1800 | 10.4 | Peak |
| 13 | Golen A in Ustur | Region - 2 | 365 | 2200 | 11.3 | Peak |
| 14 | Golen B in Ustur | Region - 2 | 445 | 2200 | 11.8 | Peak |
| 15 | Golen A near Golen | Region - 2 | 480 | 2625 | 17.8 | Peak |
| 16 | Golen B near Golen | Region - 2 | 500 | 2625 | 18.5 | Peak |
| 17 | Ayun | Region - 2 | 160 | 2300 | 5.1 | Peak |
| 18 | Khan Khwar 2 | Region - 3 | 150 | 6.0 | 6.5 | Peak |
| 19 | Allai Khwar | Region - 3 | 620 | 2.5 | 10.9 | Peak |
| 20 | Daral Khwar | Region - 4 | 310 | 2.15 | 5.2 | Peak |
| 21 | Lilauni/Alpurai | Region - 5 | 225 | 4.0 | 7.0 | Peak |
| 22 | Serai/Karora 1 | Region - 5 | 330 | 7.0 | 18.1 | Peak |
| 23 | Balkanai | Region - 5 | 173 | 4.0 | 5.2 | Peak |
| 24 | Karora New | Region - 5 | 125 | 8.0 | 7.5 | Peak |
| 25 | Besham 1 | Region - 5 | 250 | 32 | 63.0 | Peak |
| 26 | Thakot 1 | Region - 5 | 220 | 6.0 | 10.3 | Peak |
| 27 | Jabori 1 | Region - 5 | 125 | 8.0 | 7.8 | Peak |
| 28 | Gande Gar | Region - 7 | 355 | 4.0 | 5.8 | Peak |
| 29 | Bibior | Region - 7 | 100 | 15.0 | 12.3 | Peak |

The identified potential, which will meet the local demand, are:

**Table 8-12 Identified Potential having capacity less than 5 MW in N.W.F.P.**

| Sr. No. | Name of Catchment | No. of Schemes | Power Potential (MW) | Remarks |
|---|---|---|---|---|
| 1. | Upper Chitral | 18 | 36.50 | |
| 2. | Lower Chitral | 49 | 48.80 | |
| 3. | Kohistan | 32 | 36.67 | |
| 4. | Swat Valley | 11 | 20.11 | |
| 5. | Indus Swat/Mangohra West | 1 | 3.12 | |
| 6. | Khagan Valley | 7 | 14.03 | |
| 7. | Dir Kohistan | 17 | 15.07 | |

### 8.4.5. RANKING AND INVENTORY OF LOW HEAD POTENTIAL

In early 1980s, when Kalabagh dam project was under planning, it was realised that large hydel projects have a long implementation period. At the same time, the development of other identified projects was considered expensive and time consuming due to remoteness of the sites. Therefore, the low head projects were taken up due to;

- Short gestation period.
- Availability of infrastructure.
- Close to the load centres.
- Required civil works are fully or at least partially developed.

### 8.4.5.1. RANKING STUDY

Ranking study "Low Head Hydro Power at Barrages and Canal Falls" of ten (10) identified sites (Table 8-11) along exiting barrages and canal falls were completed in 1984 by WAPDA-HEPO in collaboration with German Agency for Technical Co-operation (GTZ). The aim of this co-operation has been the transfer of technical know-how and experience to WAPDA personnel through on-the-job-training. The objective of the ranking study was to establish an overall ranking on the basis of the basic characteristics and reconnaissance level layouts.

The advantage of these locations is the utilisation of the existing canals and structures (canal falls and barrages), built in past for bed stabilisation and water diversion, thus resulting in substantial saving in overall cost of the project. The site of Khanki Headwork was not studied in view of remodelling plans by the Punjab Irrigation Department.

### 8.4.5.2. INVENTORY

In early 1990s, a comprehensive inventory of the available hydel potential at existing canal falls and barrages was undertaken. This was considered as complementary work to the ranking study of the pre-selected sites and comprised almost all barrages and main canals and their distributaries. The inventory of barrages and canal falls is presented separately for the sake of simplicity.

**Table 8-13 Selected Sites for First Ranking Study**

| Sr. No. | Location |
|---|---|
| 1. | Jinnah Barrage on Indus River |
| 2. | Chashma Barrage on Indus River |
| 3. | Taunsa Barrage on Indus River |
| 4. | Guddu Barrage on Indus River |
| 5. | Khanki Headwork on Chenab River |
| 6. | Chashma-Jhelum Link Canal Tail |
| 7. | Balloki-Sulemanki Link I Canal RD 106+000 |
| 8. | Balloki-Sulemanki Link I Canal Tail |
| 9. | Rohri Canal RD 15+000 |
| 10. | Rohri Canal RD 118+000 |

#### 8.4.5.2.1. DAMS/BARRAGES/HEADWORKS

Pakistan rightly claims to have the largest irrigation system in the World, which consists of dams, barrages, head works and canals. The main irrigation system comprises 8 dams, 15 barrages and 6 head works. Most of these structures lie in Punjab province (Table 8-12).

Efforts were made to collect the data regarding upstream and downstream water levels and downstream discharges at the above mentioned locations (Fig: 8-28). Thirteen* locations out of 22 were studied in detail, whereas, the remaining nine could not be studied due to limited available data. The data was collected for the years 1979 to 1987 for all locations except Khanpur dam, for which only 1988 and 1989 data was available. The data before 1979 was not considered reliable due to erratic operation of Tarbela. The data of the remaining locations is still needed.

The dams, barrages and headworks were classified according to the seasonal variability and availability of stream flows. Therefore, estimation of power potential was made according to different ranges of discharge. For this purpose, an upper range from 100 to 600 $m^3/s$ and a lower range from 10 to 150 $m^3/s$ were established. Khanpur dam was analysed for 4 and 8 $m^3/s$. The results are given in Table 8-13. Only 4 sites out of 13 have capacity less than 5 MW. The total installed capacity could be in the range of 35 to 175 MW.

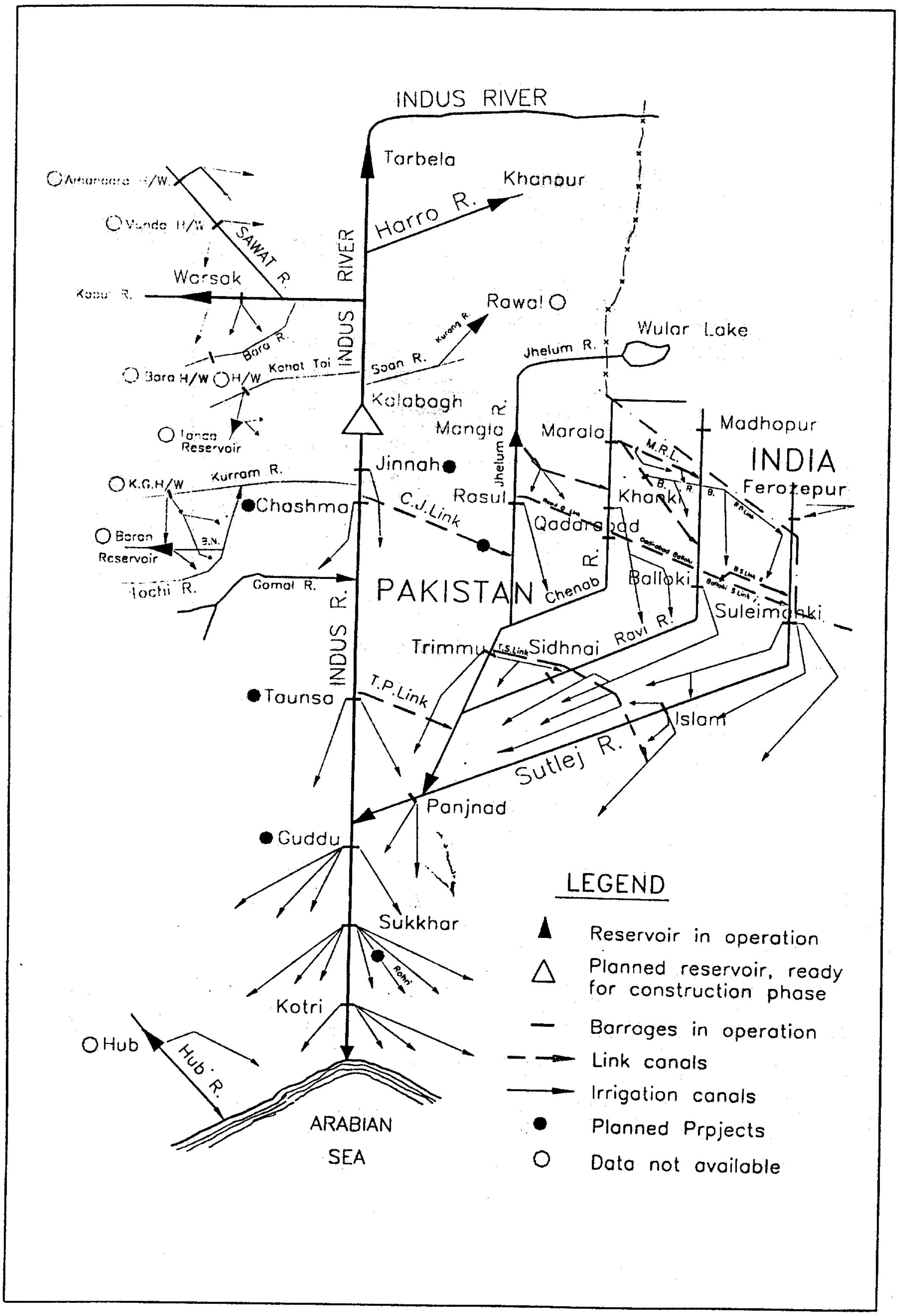


**Figure 8-28 Irrigation System of Pakistan- Schematic Diagram**

**Table 8-14 Dams/Barrages/Headworks in Pakistan**

| Sr. No. | Name Of Structure | River | |
|---|---|---|---|
| 1 | Tarbela Dam | Indus | NWFP |
| 2 | Khanpur Dam | Haro | NWFP |
| 3 | Rawal Dam * | Korang | Punjab |
| 4 | Mangla Dam | Jhelum | Punjab |
| 5 | Warsak Dam | Kabul | NWFP |
| 6 | Tanda Dam * | Kohat Toi | NWFP |
| 7 | Baran Dam * | Baran | NWFP |
| 8 | Hum Dam * | Hub | Balochistan |
| 9 | Jinnah Barrage | Indus | Punjab |
| 10 | Chashma Barrage | Indus | Punjab |
| 11 | Taunsa Barrage | Indus | Punjab |
| 12 | Guddu Barrage | Indus | Sind |
| 13 | Sukkur Barrage | Indus | Sind |
| 14 | Kotri Barrage | Indus | Sind |
| 15 | Rasul Barrage | Jhelum | Punjab |
| 16 | Marala Barrage | Chenab | Punjab |
| 17 | Qadirabad Barrage | Chenab | Punjab |
| 18 | Trimmu Barrage | Chenab | Punjab |
| 19 | Panjnad Barrage | Chenab | Punjab |
| 20 | Balloki Barrage | Ravi | Punjab |
| 21 | Sydhnai Barrage | Ravi | Punjab |
| 22 | Sulemanki Barrage | Sutlej | Punjab |
| 23 | Islam Barrage | Sutlej | Punjab |
| 24 | Khanki Headwork | Chenab | Punjab |
| 25 | Amandara Headwork * | Swat | NWFP |
| 26 | Munda Headwork * | Swat | NWFP |
| 27 | Bara Headwork * | Bara | NWFP |
| 28 | Tanda Headwork * | Kohat Toi | NWFP |
| 29 | Kurram Garhi Headwork * | Kurram | NWFP |

Note: The complete data of the (*) project was not available.

Preliminary estimates of power and energy output were made on basis historic data. Detailed studies may allow higher outputs. Cost per unit of energy generated was not established due to non-availability of sufficient site data.

**Table 8-15 Hydro Power Potential at Barrages/Dams**

| RIVER | BARRAGE | HEAD (m) | | DESIGN DISCHARGE | | POWER (MW) | ENERGY (GWh) |
|---|---|---|---|---|---|---|---|
| | | Max. | Min | $m^3/s$ | av.% of Time | | |
| INDUS | SUKKUR | 3.5 | 0.5 | 100<br>600 | 85<br>50 | 2.91<br>15.41 | 15.01<br>59.71 |
| | KOTRI | 7.4 | 2.4 | 100<br>600 | 40<br>28 | 5.94<br>29.32 | 17.58<br>70.35 |
| JHELUM | RASUL | 7.0 | 4.1 | 100<br>600 | 45<br>20 | 4.98<br>23.12 | 16.76<br>61.08 |
| CHENAB | MARALA | 4.6 | 2.5 | 100<br>600 | 65<br>35 | 3.80<br>18.88 | 17.84<br>68.71 |
| | KHANKI | 2.3 | 0.5 | 100<br>600 | 50<br>25 | 2.17<br>8.47 | 6.00<br>18.65 |
| | QADIRABAD | 5.6 | 1.5 | 100<br>600 | 50<br>25 | 3.76<br>17.70 | 13.05<br>47.97 |
| | TRIMMU | 5.1 | 1.9 | 100<br>600 | 65<br>30 | 4.03<br>18.38 | 21.48<br>64.42 |
| | PANJNAD | 5.2 | 1.6 | 100<br>600 | 55<br>25 | 4.17<br>19.49 | 16.10<br>51.50 |
| RAVI | BALLOKI | 4.0 | 1.8 | 10<br>150 | 75<br>25 | 0.35<br>4.10 | 2.08<br>13.07 |
| | SIDHNAI | 5.2 | 1.6 | 10<br>150 | 55<br>20 | 0.42<br>4.65 | 1.70<br>11.80 |
| SUTLEJ | SULEMANKI | 2.7 | 1.0 | 10<br>150 | 60<br>15 | 0.41<br>4.68 | 2.40<br>11.17 |
| | ISLAM | 6.5 | 3.3 | 10<br>150 | 45<br>10 | 0.55<br>6.69 | 2.41<br>12.54 |
| HARO | KHANPUR DAM | 39.56 | 19.45 | 4<br>8 | 75<br>5 | 1.30<br>2.59 | 9.43<br>18.86 |

Min = 34.79 MW
Max. = 173.48 MW

### 8.4.5.2.2. CANAL FALLS

Pakistan rightly claims to own the largest network of irrigation system in the world. It consist of

- Indus Basin Irrigation System.
- Balochistan River Irrigation System.

Indus Basin is one of the largest single integrated System of irrigation, which is fed by river Indus and its left and right tributaries. In 1947, with the inception of Pakistan, India announced the intention of using all waters which flows from India to Pakistan and closed the canals. The dispute was solved and an agreement" Indus Water Treaty 1960" was signed between Pakistan and India. As a result of this treaty, the rivers mainly Indus, Jhelum and Chenab were reserved for Pakistan while India was allowed to divert the waters of Ravi, Sutlej and Bease. Pakistan constructed , dams, barrages and link canals to compensate the effect of water diversions by India. To meet the irrigation requirement, a part of the flows of Indus, Jhelum and Chenab river can be diverted through link canals and barrages to the lower reaches of the rivers exploited by India.

A river is usually an independent system of irrigation while barrages and headwork along with the off-taking canals constitute a sub-system of the river. However, in Indus basin it is not possible to take all the rivers independently, because these are inter-linked through link canals. Due to this situation, in order to classify the available information, the Indus system has been divided into three systems namely:

- Indus River Irrigation System
- Left Tributaries Irrigation System
- Right Tributaries Irrigation System

Longitudinal sections of the canal and other drawings of the respective fall structures were collected from the field offices of the concerned Provincial Irrigation Departments. The collected data in the form of design, existing and proposed water levels and discharges was tabulated. Seasonal variations in flows like Rabi and Karif were also recorded. The full supply discharge and difference of full supply water levels were used for power potential estimation. The falls with site limitation such as siphon, transition, etc. were not considered even with reasonable head.

The inventory of canal falls (perennial and non-perennial canals) comprises a total of 586 sites. The head available at these falls varies between 0.03 to 13.83 m. Most of them have head less or equal to 1.0 m. The power potential at each canal fall was evaluated. Gross potential available is about 550 MW.

In order to select some suitable sites from long inventory tables, a selection criteria was established as follows:

Minimum head of 2.5 m (Only 45 falls have head more than or equal to 2.5 m).

Only perennial canals were considered. Non-perennial canals were not considered due to their restricted operation and economical limitation at present.

Selection of sites as per regulation in Pakistan (WAPDA is responsible for sites having capacity of 5 MW and above and projects less than 5 MW fall under the responsibility of Provincial Governments).

Further, individual falls (Table 8-14) and combination of 2 or more falls (Table 8-15) were studied. For combination of falls maximum distance of 100 RD (1 RD = 1000 feet) was taken as limit. The conclusion of this work is that a total of about 180 MW could be exploited with projects having capacity above 5 MW. Development of sites with less than 5 MW capacity were studied on individual falls only and about 40 MW potential can be available. However, the number of sites less than 5 MW capacity may be increased by considering combination of falls.

Energy estimation was not done due to non availability of historic flow pattern. Optimisation studies were also not carried out, which may allow higher output. Cost per unit of energy generated was not established due to non-availability of streamflow time series.

**Table 8-16 Hydroelectric Potential of Individual Falls Development Above 5 MW**

| No. | Province | River | Barrage/ Dam | Canal | R.D. (1000ft.) | Head (m) | Discharge ($m^3$/s) | Power (MW) |
|---|---|---|---|---|---|---|---|---|
| 1 | PUNJAB | CHENAB | MARALA | Upper Chenab Canal | 0+000 | 2.69 | 477.14 | 10.5218 |
| 2 | PUNJAB | CHENAB | PANJNAD | Panjnad Canal | 0+000 | 2.84 | 270.91 | 6.3090 |
| 3 | PUNJAB | INDUS | CHASHMA | Chashma Jhelum Link Canal | 0+000 | 2.75 | 614.48 | 13.8565 |
| 4 | SIND | INDUS | KOTRI | Kalri Baghar Feeder Lower | 0+000 | 5.01 | 194.11 | 7.9744 |
| 5 | SIND | INDUS | SUKKUR | Nara Canal | 25+000 | 2.31 | 566.32 | 13.0233 |

Potential = 51.688 MW

**Table 8-17 Hydro Potential of Combined Falls Development above 5 MW**

| No. | Province | River | Barrage/dam | Canal | No. of Falls | Development Stretch Length (km) | Head (m) | Discharge ($m^3$/s) | Power (MW) |
|---|---|---|---|---|---|---|---|---|---|
| 1. | NWFP | SWAT | AMANDARA | Machai Branch Canal | 7 | 12.73 | 19.18 | 48.73 | 7.6730 |
| 2. | NWFP | SWAT | AMANDARA | Machai Branch Canal | 6 | 18.00 | 19.09 | 40.66 | 6.3640 |
| 3. | NWFP | SWAT | AMANDARA | Machai Branch Canal | 6 | 16.78 | 17.70 | 40.66 | 5.9010 |
| 4. | PUNJAB | CHENAB | KHANKI | Lower Chenab Canal | 2 | 12.25 | 3.53 | 230.58 | 6.6740 |
| 5. | PUNJAB | CHENAB | MARALA | Upper Chenab Canal Lower | 2 | 11.09 | 5.02 | 266.69 | 10.9780 |
| 6. | PUNJAB | CHENAB | MARALA | Upper Chenab Canal Lower | 2 | 5.21 | 3.02 | 230.64 | 5.7110 |
| 7. | PUNJAB | JHELUM | MANGLA | Upper Jhelum Canal | 3 | 2.85 | 3.54 | 275.81 | 8.7006 |
| 8. | PUNJAB | RAVI | BALLOKI | Lower Bari Doab Canal | 3 | 18.98 | 6.49 | 182.25 | 9.6980 |
| 9. | PUNJAB | RAVI | BALLOKI | Lower Bari Doab Canal | 3 | 21.45 | 8.28 | 195.95 | 13.3040 |
| 10. | PUNJAB | SUTLEJ | SULEMANKI | Pakpattan Canal | 2 | 3.84 | 4.50 | 160.16 | 5.3200 |
| 11. | SIND | INDUS | SUKKUR | Nara Canal | 2 | 7.62 | 3.91 | 566.34 | 18.1570 |
| 12. | SIND | INDUS | SUKKUR | Nara Canal | 2 | 18.29 | 5.06 | 542.75 | 22.5190 |
| 13. | SIND | INDUS | SUKKUR | Rohri Canal | 2 | 8.00 | 3.87 | 248.79 | 7.8950 |

Potential = 128.8946 MW

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