CHAPTER 5

OPERATION & MAINTENANCE PRACTICES

Chapter Overview

The objective of this chapter is to give the miller a ready reference on proper installation, commissioning operation and maintenance aspects of various components of watermills. It also covers the easy on site methods to measure various related hydrological parameters of interest.

In order to have 360^0 coverage of various aspects to improve upon the deficiencies in the utilization of existing watermills, it is important to focus on good installation, operation and maintenance practices along with design improvements.

5.1 PARAMETERS FOR LAYOUT DESIGN

The power generated is calculated by using the following equation:

Power (kW) = 9.81 x efficiency of system x flow (m^3ls) x head (m)

The type of turbines and flow conditions determines the conversion efficiency but it is assumed to be between 0.5 and 0.6 at the preliminary stage of calculations. Thus the head (vertical height of water level in the fore bay above the exit nozzles, where it emits and hits the turbine blades) and the flow are the main parameters. Design flow or rated flow is the maximum amount of flow that can be diverted from the river for power generation and which easily available throughout the year and it is usually less than the minimum flow available in the river/stream during the dry season. This is mainly due to the utilization of water from the original stream for other purposes, for example, for drinking and washing, marine life, or irrigation. Thus, the flow should be estimated and measured during the dry season. The amount of flow to be left in the stream is determined and deducted from the total flow to arrive at the design flow depending on the needs, which would subsequently be used for the design of structures, turbines etc.

S.No.	Head (m)	Discharge (L.P.S.)
1	3-0	350
2	4-0	250
3	5-0	200
4	6-0	165
5	7-0	140
6	8-0	125
7	9-0	110
8	10-0	100

(**Table 5.1:** Different Head & Discharge Quantity for Generation of 5 kW)

In order to estimate the power demand of the village, total power demand is proposed to categorize into different sectors. Total power demand can be estimated by conducting survey as per the Performa given below:

- Domestic sector

Avg. no. of rooms/HH	No. of HHs	Lighting points		Other points*	
		Nos.	Duration of supply (hrs)	Nos.	Duration of supply (hrs)
1					
2					
3					
4					
>5					

* Fans, TV etc., HHs = House holds

(**Table 5.2:** Survey Performa for domestic sector)

- Institutional sector

Number in the village			**No. of lighting points required**							
Community Places	**Religious Places**	**Others**	**Institute**		**Community**		**Religious**		**Others**	
			L	**O**	**L**	**O**	**L**	**O**	**L**	**O**
Duration of supply in hrs/day										

L- Lighting, O-others (Fan, TV etc.)

(**Table 5.3:** Survey Performa for Institutional sector)

- Agriculture sector

Particulars	**No. of devices**	**Rating of device (W)**	**Avg. Working (hours/day)**	**Avg. operating (hours)**
Irrigation				
Others				

(**Table 5.4:** Survey Performa for Agriculture sector)

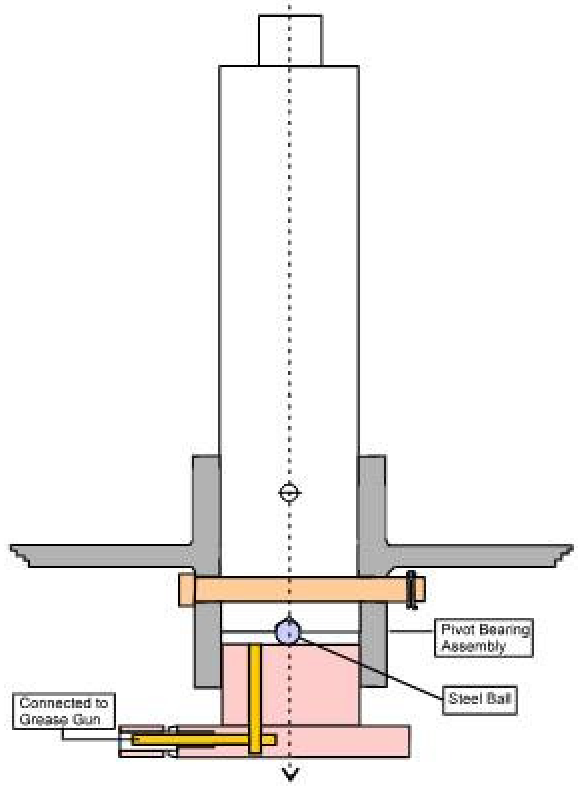
- Industry sector

SL. No.	**Type of industry**	**No.**	**Rating of the machine**	**Operating hrs (hrs/day)**	**Working days (days/year)**
1	Rice hullers				
2	Flour mills				
3	Oil mills				
4	Cotton threshing				
5	Others				

(**Table 5.5:** Survey Performa for Industry sector)

5.2 IMPROVED WATER MILL

Improved watermill is an efficient and long life machine useful for grinding cereals at a faster rate with minimal maintenance. The improved runner has enhanced the efficiency by 3-5 times over the traditional water mill. The improved runner can be easily installed and may be fitted with other parts of the existing water mills which are generally found in good conditions and have an insignificant effect on the output of the water mill.



(**Fig 5.1:** Schematic of Improved Watermill Assembly)

The newly designed water mill consists of the following components:

Runner

A runner has 16 - 20 blades and its diameter is about 50 cm. The complete runner is cast in single-piece.

Drive Shaft

A steel shaft of 50 mm diameter is used as a drive shaft. The upper end of the shaft is cut in rectangular form to fit the rynd/cam for upper stone attachment.

Bottom Bearing

A simple bottom bearing having a ball which is press fitted at the lower end of the shaft, which rests on a piece of hard steel.

Wooden Bush

A simple wooden bush made of hard wood is oil soaked and then is used in the upper stone hole to hold the shaft straight and aligned vertical.

Rynd or Cam

Cam is used for revolving the upper stone over the bottom stone fitted with driving shaft.

Upper Stone Lift Mechanism

The lift mechanism is a steel bar having a rotating wheel at its upper end and pin at lower end. The lower end is fitted to the cross bar with the help of the pin.

Grinding Stones

Existing grinding stones can be used for new installation as these are found, generally in good conditions.

Flume/Chute

The existing flume can be reused by providing the lining of G.I. or PVC pipe use for the flume.

Feeding Mechanism

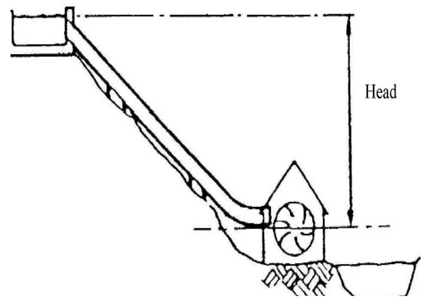
At existing sites, feeding mechanism consists of a hopper with a vibrator which can be reused.

5.3 SITE SURVEYING

On the basis of available data and survey it is observed that the efficiency of traditional water mills is of the order of 8 to 10 percent which is quite low. The water mills operate under a head of 2 to 8 meters and produce 0.5 – 1.0 kW mechanical output on an average.

5.3.1 Determining the Head

In selecting the site, the head available is most important parameter. The vertical distance between water level of forebay to turbine runner is the head, as shown in **Fig 5.2**.

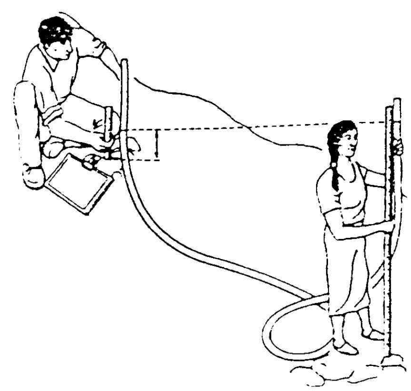


(**Fig 5.2:** Head Measurement)

Head can be measured by the following methods :

a. Using a Water-filled Tube

This is one of the commonly used methods to measure low heads because it is simple and cheap. The requirements for this method are : a 20 meter long transparent plastic tube having about 10-12 mm diameter, two graded rods, a measuring tape and some marking pins/pegs. Minimum two persons are needed to take the measurements as **Fig 5.3**.



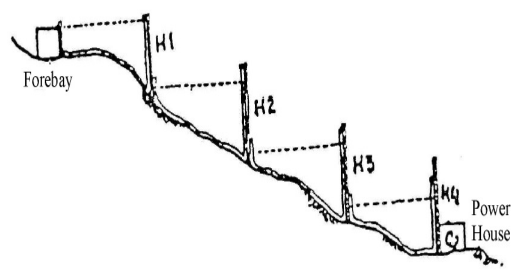
(**Fig 5.3:** Head Measurement using Water filled tube)

Procedure

i. Beginning from the site of the forebay, sediment free water is filled in the plastic tube. One end of the pipe should be held by the first person while the other person holds the other end, both about at shoulder height. All bubbles must be removed by stroking various parts of uncoiled tube.

ii. Now the second person should move slowly down the hill along the path of the proposed route of the penstock while still raising his end of the pipe and at the same time the first person should slowly lower his end of pipe to ensure that water does not spill from either end of the pipe. The second person should stop when first end of the pipe nearly reaches the ground level.

iii. The height of water in the pipe above ground level(h1 & h2) along with the sloping distance L(the sloping distance is not needed for measuring the gross head; but it can be used for computing the length of the penstock) is measured as **Fig 5.4.**



(Fig 5.4: Head Measurement Using Water Filled Tube (all level)**)**

iv. The positions (1 & 1') are marked with pegs and all the readings are recorded in the record sheet.

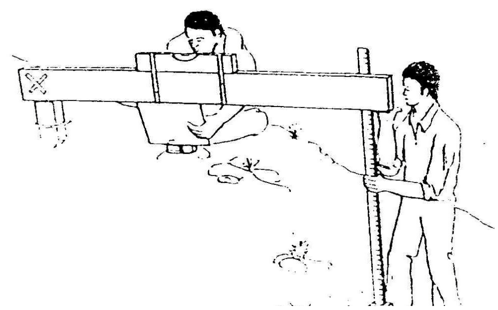
v. The second person must remain in the same position and continue to lower his end of the pipe while the first one should move to a new position (3) along the penstock route while raising his end of pipe until the water level reaches to head height at latter’s end and nearly touches the ground at the second person’s end.

vi. The new readings are taken and recorded at positions 2 & 3. The distance between the points along the slope is also measured. Readings are recorded.

vii. The process is repeated until one of person reaches the base mark for the turbine.

b. Using Sprit Level and Wooden Plank

Height differences between two positions can be measured by using a simple plank to which a spirit level has been attached, along with two graded rods. The procedure is same as earlier method **Fig 5.5**.



(**Fig 5.5:** Head Measurement Using Sprit Level and Wooden Plank)

5.3.2 Flow Measurement

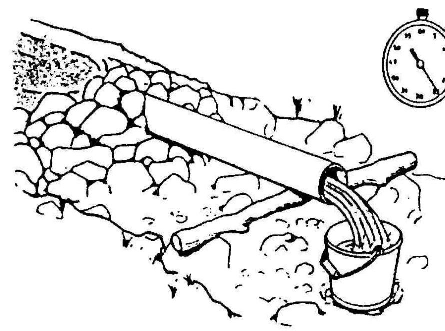
Volume of flow and nature of flow (turbulent or calm) determines the methods of flow measurement to be used at a particular stream. Strength of any site can be estimated with the help of the discussed data of that particular site. Depending on the season and utilization of water for other purposes at upstream there is always a variation in flow at the site. Therefore reliable discharge data is required to be collected for a period of atleast an annum.

Three methods of flow measurement are discussed below:

a. Bucket Method

Bucket Method is an efficient and handy method for a relatively small flow. Bucket or any other related container can be used as a measure and the entire water in the stream is diverted into the container with the help of a pipe or a trough and the time taken to fill the container is measured (**Fig 5.6**). The flow is given by:

Q = Volume of Container / No. of seconds to fill it

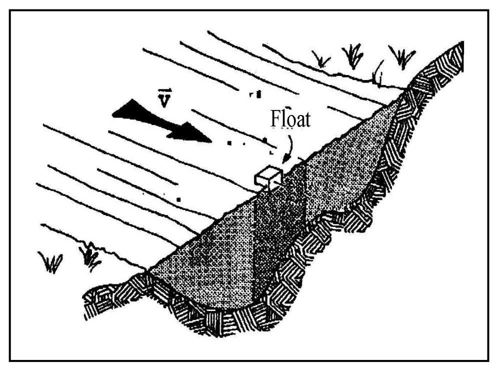


(**Fig 5.6:** Bucket Method)

b. Float Method

An object such as a piece of light wood is chosen which can partially submerge in water and is used at the centre of the stream as is shown in **Fig 5.7**. The surface velocity (Vs) of water is given by:

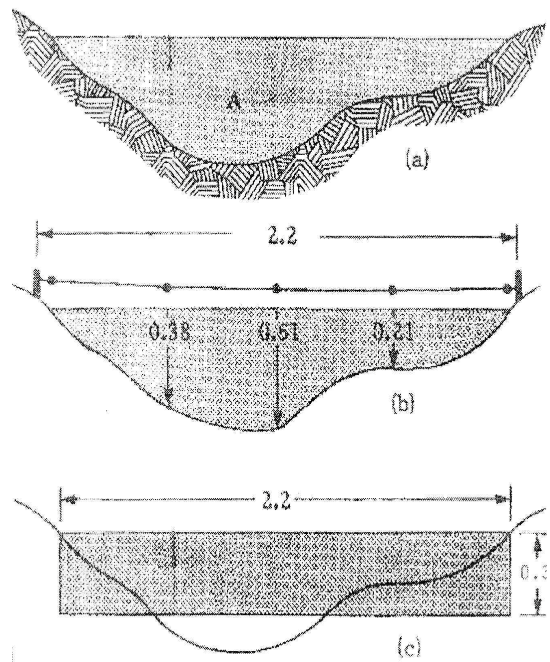
V_s(m/s) = Distance traveled by float (m) / Time taken (s)



(**Fig 5.7:** Float Method)

c. Weir method

Flow in the streams can be measured with the help of different weirs. Rectangular weir is the most convenient one since it can be constructed from wood on site with the help of an amateur carpenter. If a proper weir is available, the error chances are negligible or very less (±5 per cent). But in actual practice it is not possible to achieve this level of accuracy. The length L must be at least 3 times the height of flow h and h should be large enough to be measured accurately (say 50 mm or more) and the upper limit should be of 0.5 m at maximum.



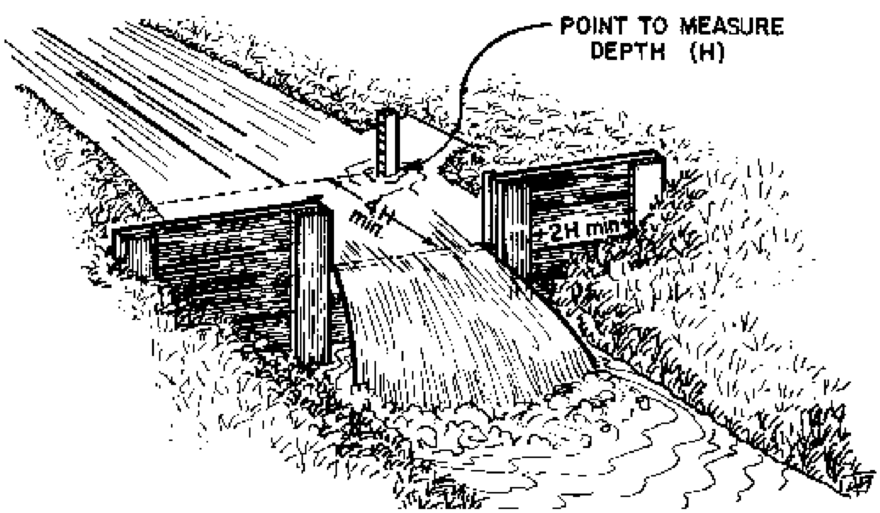
(Fig 5.8: Cross Section of Stream)

The precautions need to be taken while measuring the flow is:

For this measurement, a specially designed and constructed weir having a standard profile is needed of which the most common are triangular and rectangular cross-section ones. Many times, the weir is seen to be constructed permanently across canal and stream even after completion of the plant. It is convenient to install a portable weir at a given site location to take the measurements since only one vertical measurement of water depth needs to be taken. If calibrated properly, the results of measurement are relatively accurate, better than ± 10 percent.

Sharp-crested weirs and broad-crested weirs are the two types of weirs that exist. The only type used in the measurement of irrigation water is the Sharp- crested weir. The sharp edge in the crest causes the water to spring clear of the crest, and thus accurate measurements can be made.

While selecting a specific type of weir for a given application the following facts should be taken into account. The head should lie between 0.06m and 0.6 m for the expected rate of flow. For the rectangular weirs, the head should be of one-third of the weir length at maximum. Weir length should be selected so that the head for design discharge will be near the maximum, subject to the limitations in 1 and 2. In order to make correct measurements, the weir should be set properly and the head must be read at a point some distance upstream from the crest, so that the reading is not affected by the downward curve of the water. That distance should be at least 4H. The proper method of measuring H is shown in **Fig 5.9**. The rectangular-notch weir is illustrated in **Fig 5.9** below and this is the oldest and most popular type of weir in use because of its simple construction. [52]



(**Fig 5.9:** Rectangular-Notch Weir)

The discharge equation for the rectangular-notch weir is:

Equation gives discharge values for rectangular-weir notch lengths of up to 1.20 m and depths of flow or head of up to 0.45 m.

$Q = 1495 H^{3/2} (L – 0.2 H)$…………………………………..………………(5.1)

Where :

Q = discharge (gpm), (1 gpm = 4/60 lps)

L = length of weir notch (ft),

H = head on the weir (ft), measured at a point no less than 4 H upstream the weir.

In the construction and installation of weirs, the following general rules must be observed:

i. A weir should be perpendicular to the direction of flow in a channel that is straight for a distance upstream from the weir at least ten times the length of the weir crest.
ii. The crest and sides of the weir should be straight and sharp-edged. The crest of the rectangular weirs should be leveled and the sides should be constructed at exactly the proper angle with the crest. Each side of the V-notch weir should make a 45° angle with a vertical line through the vertex of the notch.
iii. The channel upstream should be large enough to allow the water to approach the weir in a smooth stream, free from eddies, and with a mean velocity not exceeding 0.1m foot per second.
iv. Avoid restrictions in the channel below the weir that would cause submergence. The crest must be placed higher than the maximum downstream water surface to allow air to enter below the nappe.

5.4 INSTALLATION PROCEDURE

Step I: Ensure the Tools

Good quality and well maintained tools are required for installation of the improved system. All the tools such as (Hammer, Sheet cutter, File, Grease Gun, Hacksaw, Plumb, Screw driver, Draw bar, Sprit level, Spanner, Wood saw, Chisels) should be checked.

Step II: Dismantling of Traditional Water Mill Components

Dismantling of all components of traditional water mill should be done in order to fit the improved components.

Step III: Fitting of Bottom Bearing

A centre mark should be made on the cross bar to confirm alignment of the shaft in proper vertical position with respect to the cross bar over foot bearing at lower end and upper grinding stone at upper end. The plate of bearing is fixed by putting the nails with the cross bar by taking this mark as the centre of bottom bearing spindle.

Step IV: Shaft Fixing with Runner

The shaft should be placed through the hole of lower grinding stone from upstream side after the runner is placed over the bottom bearing from downstream side. After the shaft is aligned with the runner, the pin is putted through the holes of runner hub and shaft in order to fit the runner with the shaft and then the wooden bush is putted inside the hole of lower grinding stone over the shaft.

Step V: Fitting the Remaining Components

First of all the runner should be fitted with the shaft and then the rynd is fixed at the upper end of the shaft. The upper grinding stone must be placed over the lower grinding stone and all the remaining components should be fixed properly.

Step VI: Alignment of Water Jet

One of the most important requirements of the water mill installation is the alignment of the chute. In new runners, water jet must strike 3 blades inside the runner. Water generally flows towards outside direction as the runner is 'outward' flow type.

5.5 OPERATION

The system should be correctly operated. Managers and operators must persist full knowledge about the functioning and working of the equipments. Technical specifications must also be known and properly recorded in the Operations & Maintenance Manual provided by the installer.

Some measures should be taken during starting, stopping and running of unit. If a problem occurs at any point (for example, unusual sound is noticed) then the unit should be stopped and the problem should be rectified before starting or running the unit.

The specified procedure should be followed for cleaning the civil works as applicable.

a. All components should be visually inspected (e.g. Bottom bearing, Runner, Shaft, Pin, bush, stones, hopper, lift mechanism and vibrator etc.)
b. The jet of water should be aimed properly to the runner blades.
c. Sufficient gap should be maintained between the stones so that upper stone can rotate smoothly in the beginning.
d. The discharge should be slowly increased so that stone can up speed along with the wheel pick
e. The desired gap should be maintained through the lift mechanism based on the desired quality of flour.

5.6 MAINTENANCE

5.6.1 Maintenance of Chute Inlet

The joint should be maintained properly in order to make the flow smooth from power channel to the chute.

5.6.2 Maintenance of Water Chute

Due to prolonged usage, the surface of water chute gets worn out and the surface in contact with water becomes rough, resulting in loss of head due to friction. This surface should be made smooth by its proper maintenance.

5.6.3 Bottom Bearing Ball

Sometimes the alignment of the shaft gets disturbed due to the thrust of the water jet through chute resulting in wobbling in the runner. The hub of the runner and the foot bearing may get damaged due to this. The alignment of the shaft should be regularly checked by the owner/operator so that if there is any misalignment then it can be rectified immediately.

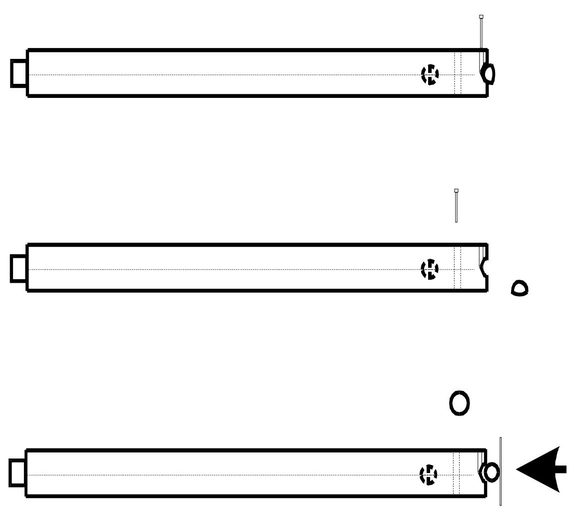
5.6.4 Maintenance Tips for Bearing

a. Position - Bearing can be centrally mounted or overhung type
b. On smaller machines a service life of 5 years is acceptable.
c. Bearings must be properly aligned, either by use of self-aligning types or by adjusting of the bearing housings. There must never be more than two bearings on one shaft. Poor alignment will cause bearing failure and will be evident in the first year of operation of the turbine.
d. Commissioning Test
e. The bearing must turn freely. The bearings should not rattle.
f. When the turbine has run for some minutes, bearing housing should not be overheated.

g. Overheating indicates the bearings are damaged or severely worn and should be replaced.
h. When the turbine has run for two hours, place your hand on the bearing housing; if it is too hot to allow you to keep your hand there, the temperature will be over 60^0 C. This usually indicates that the bearing housing contains no grease or contains too much grease.

5.6.5 Alignment of the Shaft

The shaft fitted bottom bearing ball revolves over the foot bearing spindle. This ball can wear out over a period of time. The ball should be periodically replaced. However, proper lubrication may increase the life of the ball. Proper lubrication must be ensured by the Owner/ operator before starting the system. A hole has been embedded at the end of the shaft. The ball inside the hole in the shaft can be drawn outside by striking the nail with hammering device. The wooden batten is stroked on the outer surface of the shaft for inserting the new ball in the given hole of the shaft as shown in **Fig 5.10**.



(Fig 5.10: Procedure of the replacing the ball)

5.6.6 Maintenance Check List and Schedule

The maintenance of the system should be monitored properly by filling the Performa given in Table below:

Item	Daily	Weekly	Monthly	Observations/Action Taken
Power Canal				
Foreign objects in channel		√		
Correct flow level in channel	√			
Leakage from channel		√		
Flume				
Leakage in Flume	√			
Alignment of nozzle with runner	√			
Upper Grinding Stone				
Conditions of grooves/dressing		√		
Lower Grinding Stone				
Condition of grooves/dressing		√		
Rynd				
Fitting with upper stone	√			
Fitting with coupling of gearbox	√			
Bush				
Clearance over shaft			√	
Fitting with lower stone			√	

Shaft		
Alignment with stone		√
Alignment with runner		√
Alignment with bottom bearing		√
Runner		
Condition of blades		√
Fitting of hub with shaft through pin		√
Bottom Bearing		
Greasing/oiling	√	
Surface of ball		√
Surface of spindle		√
Hopper		
Mounting of hopper		√
Walls surfaces of hopper		√
Vibrator		
Tightening with hopper		√
Contact with upper stone	√	

(**Table 5.6:** Maintenance Check List and Schedule)

5.6.7 Penstock Installation

The civil works for penstock involves installation of the pipe and the construction of the support piers and the anchor blocks as specified in the design layout. The procedure is as follows:

Step1: Clear all vegetation along the penstock route and mark the centre line by fixing a tight string.

Step2: Fix the turbine along with the manifold and gate/valve to the machine foundation.

Step3: Start the installation of the penstock from the machine foundation by connecting the first link of penstock (usually a bend) to the turbine manifold and proceed upstream, which is usually more convenient method.

Step4: As the pipe installation work progresses upstream, construct the support piers at the required locations.

5.6.8 Construction of Forebay

The procedure for the construction of the forebay is as follows:

Step1: At the proposed location, mark the excavation lines for this structure according to the design as discussed earlier.

Step2: Excavate the ground to the required depth and shape.

Step3: Compact the earth surface using a manual ram after completion of the excavation work.

Step4: Then construct the structure as per the design. The forebay and other water retaining structures are usually built using stone masonry in 1:4 cement mortar.

Step5: After completion of the gates and masonry work, plaster the water retaining surface (i.e. inside surface) of the forebay. About 12 mm thick 1:2 cement mortar is recommended for the plaster.

5.6.9 Construction of Power Channel

Once the canal type (or types for different lengths) has been selected and the sizes have been worked out, the actual construction procedure involves the following stages:

a. Setting out of the course of the canal and marking the centre line with pegs.
b. Preparing the bench for the canal.
c. Fixing the excavation lines.
d. Excavating the canal.

e. Constructing / lining the canal.

The kuchcha power channels are generally available at the existing water mill sites and can be used easily and by excavation their capacity can be enhanced.

For rectangular channel, the excavation is done from the sides down to the required depth. For trapezoidal sections, the excavation is done at the central part without exceeding the bottom width lines vertically down to the required depth. Then excavate the slope sides (without exceeding the top width) meeting the bottom width at the required depth.

The channel bed slope should be checked frequently with the help of a leveling instrument.

After the completion of excavation work, the construction of the lining of the canal can commence if provided for in the design. For stone masonry in cement mortar canals the minimum thickness for bed and side walls should be 150 mm since thinner walls require more stone work of the lining (dressing & sizing) and may not have the required strength. The ratio of the mortar should not be less than 1:4 cement/sand because this is a water retaining structure. 1:2 cement/sand mortar should be used for plaster work in the headrace canal. The thickness of the plaster should be about 12 mm.

5.6.10 Tailrace

The water coming out from the turbine is carried back to the river by the tailrace and a part of it is located inside the Powerhouse. Usually the tailrace is relatively short and on a plane ground where likely hood of serious damage is minimum. Inside the powerhouse tailrace is usually built from stone masonry and properly covered by a RCC or stone slab. It is an open channel mainly an earthen one outside the powerhouse. In some rare cases, it is constructed from cement-stone masonry if the area outside the powerhouse is fairly expensive; say an irrigated cultivated land in order to prevent any leakage to the surrounding area. Tailrace may get damaged by sinking of the ground or by erosion if the slope of tailrace is high.

The startup procedure for Water and Turbine:

a. Follow the specified procedure for cleaning up the civil works as applicable.
b. Visually inspect all equipment (e.g. turbine, generator, control panel etc.)
c. Ensure that penstock and turbine valves are closed.
d. Turn on water at intake.

5.7 ROUTINE MAINTENANCE

One of the keys to reliable operation is the routine preventive maintenance, i.e., regular inspection, lubrication, cleaning, replacing worn items and responding to concerns identified during inspections immediately rather than waiting for machinery to break down before taking action. Every day the following items should be inspected and corrective action taken if necessary.

Before Start Up

a. Clean the trash racks at the intake, desilting basin and forebay.
b. Check whether' sufficient water is flowing -through the headrace.
c. If not; the plant load should be reduced accordingly or it should not be started at all.
d. Flush the forebay and desilting basin during the monsoons (every other day if the debris amounts are less).

During Operation

a. Check the temperatures and vibration level of housings/casings of bearings of turbine and generator.

b. Check the leakage from valves, turbine housing, or base frame.

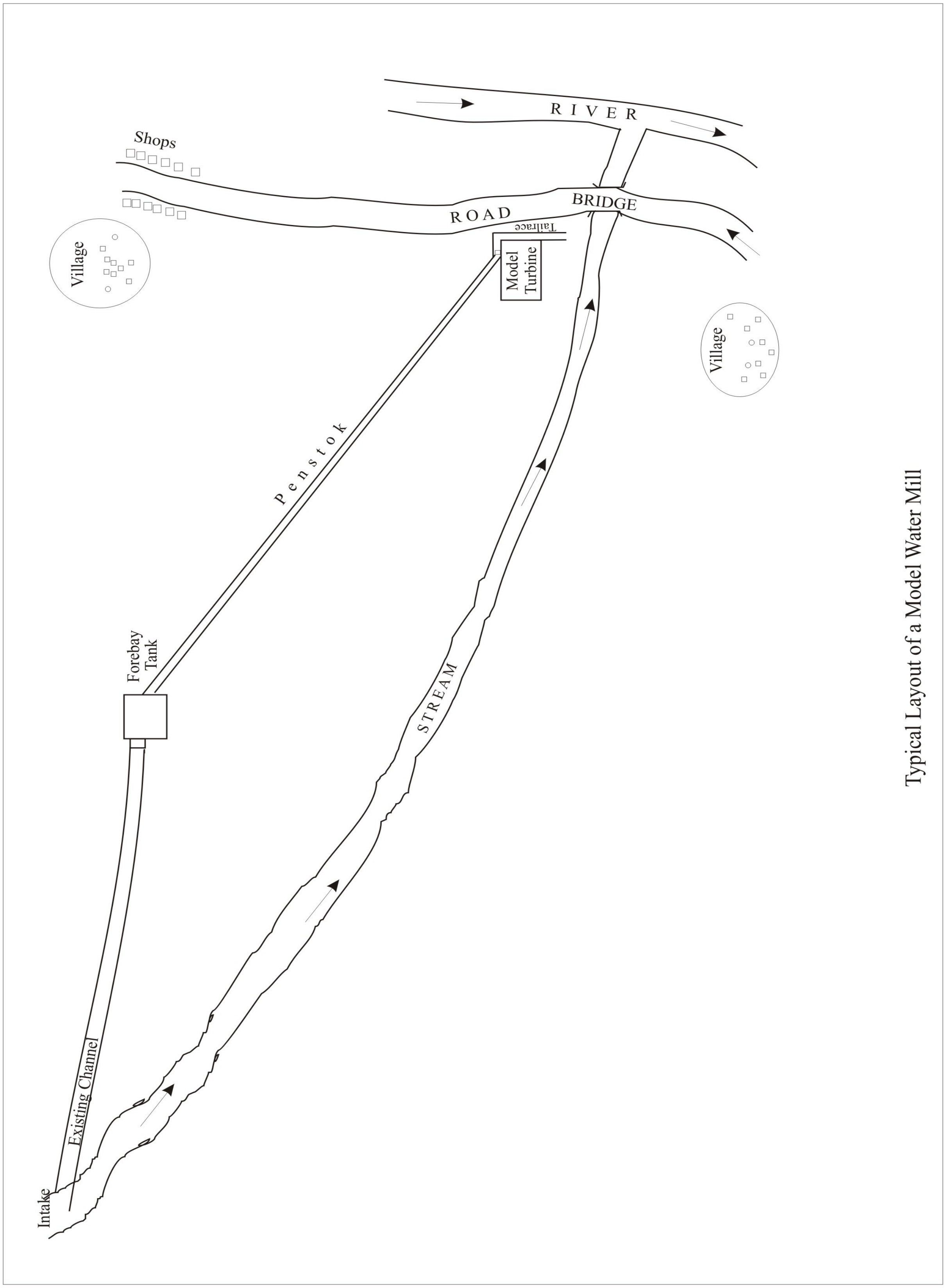
c. If the leakage is excessive from any location, repairs should be organized straight way r in due course as the situation demands.

Item	**Daily**	**Weekly**	**Monthly**	**Observation/ Action Taken**
Intake Weir				
For debris	√			
Wall for cracks			√	
Silting up		√		
Power Channel				
Foreign objects in channel	√			
Correct flow level in channel	√			
Leakage from channel		√		
Water diverted for irrigation/for other use	√			
Channel surfaces			√	
Erosion under/around channel			√	
Forebay				
Forebay trash rack clear of debris	√			
Leakage			√	
Level of silt not above maximum		√		
Penstock				
Leakage	√			
Joints leaking/condition		√		
Anchor block cracking			√	

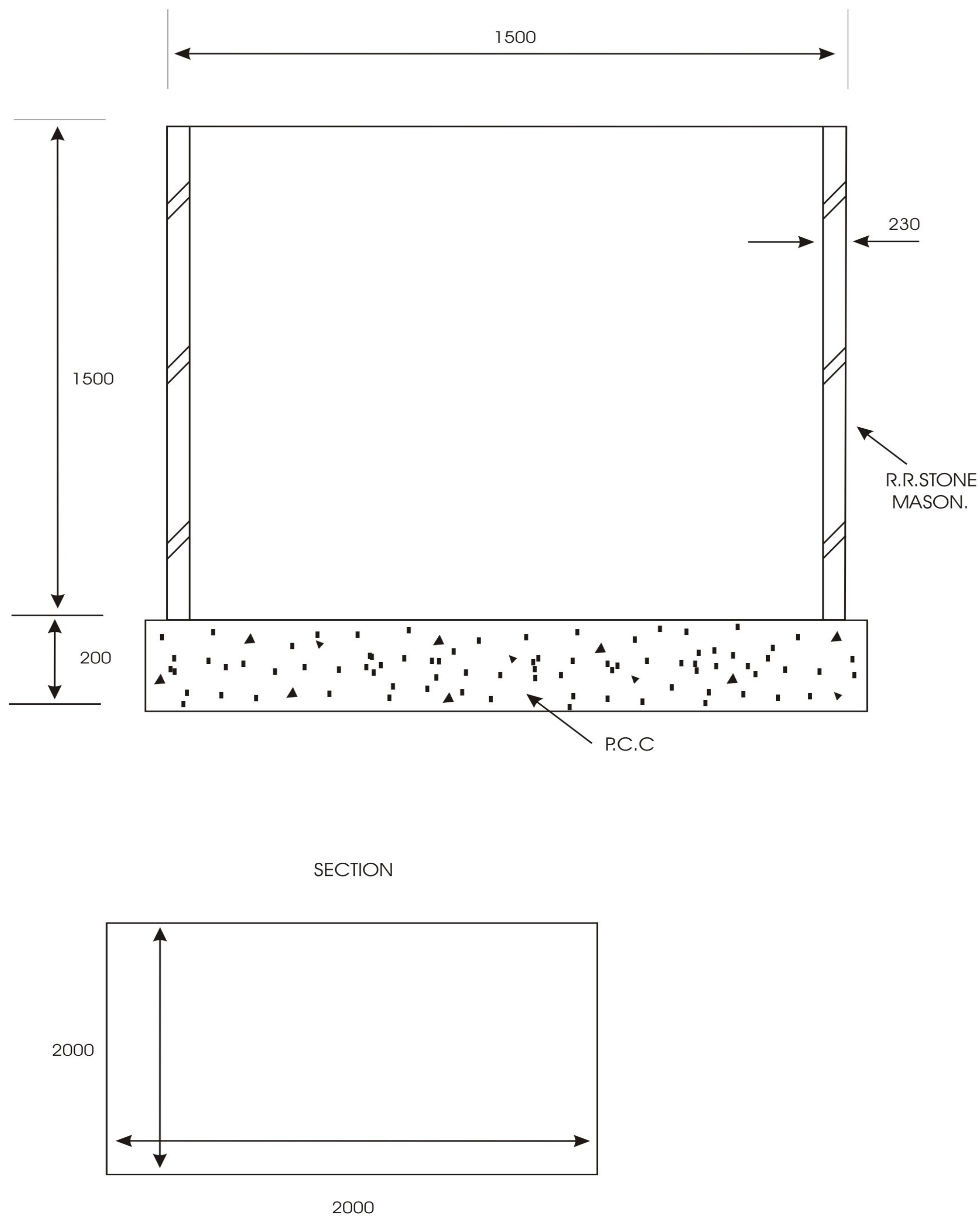
Erosion around anchor blocks			√
Power House			
Any leaking valves	√		
Powerhouse clean	√		
Prime mover/Turbine			
Turbine speed satisfactory	√		
No unusual noise from turbine	√		
Control valve assembly			
Function of valve		√	
Lubrication		√	
Leakage at sealing		√	
Runner			
Foreign objects in runner vanes	√		
Condition of runner vanes			√
Clearance of runner with nozzle		√	
Vibration	√		
Shaft and Bearings			
Temperature of bearings	√		
Condition of Rollers / Balls			√
Condition of housing			√
Alignment of housing	√		
Tailrace			
Leaks from tailrace		√	
Foreign objects in channel	√		
All tailrace surfaces sound and crack free			√
Check for erosion under/around tailrace			√
General			

Spare parts available	√
Tools in correct place and in good condition	√
Meeting with consumers	√

(**Table 5.7:** Maintenance Check List and Schedule)

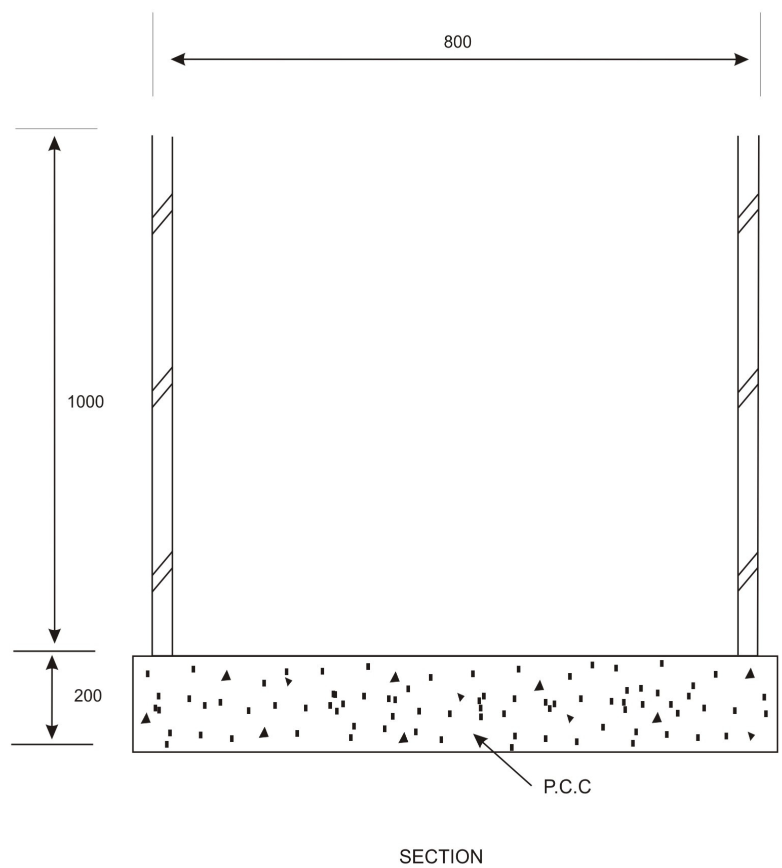


(Fig 5.11: Layout of model Watermill)



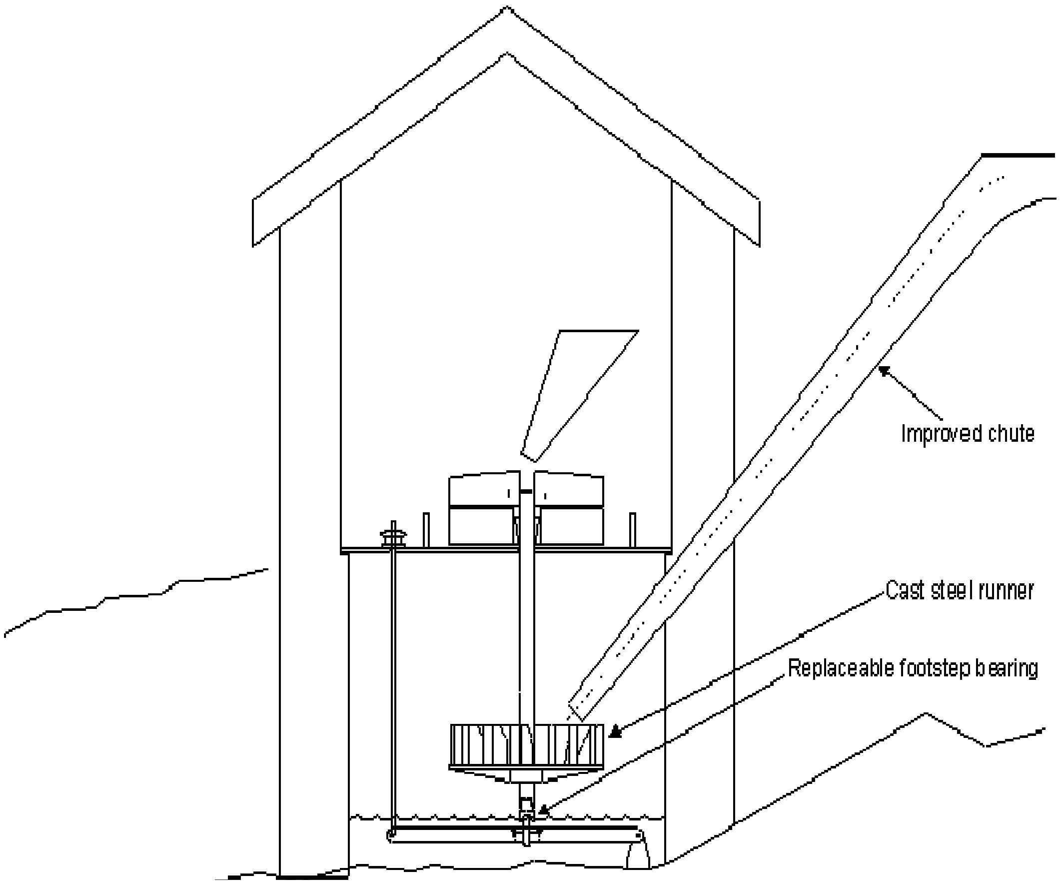
Forbay Section & Base Slab

(Fig 5.12: Forebay Section and Base slab)



Tail Race Section

(Fig 5.13: Tailrace Section)



(Fig 5.14: General Arrangement Drawing of Improved Watermill)