CHAPTER I

Introduction

The development pattern in the Hindu-Kush Himalayan (HKH) region varies considerably from country to country and area to area. However, the overall picture in this formidable mountain range is rather bleak with a very few exceptions. Usually, under-development, poverty, inaccessibility and lack of other physical infrastructure are prevalent. Energy, a key ingredient for improving the living conditions and fuelling the development process, is usually in short supply and the inhabitants have to rely on local natural resources of fuel-wood and other biomass to meet their daily needs. In many mountainous areas, even this resource is scarce from the beginning or has depleted to an unsustainable level, resulting in soil erosion and other severe environmental problems.

More recently, electricity, especially for lighting, has come to be regarded as a necessity rather than luxury and the people living in the remote areas are demanding its availability. Similarly, mechanical power is needed for the normal tasks such as milling, oil expelling, etc, to reduce drudgery of daily chores and to improve the productivity. Consequently, more appropriate and relatively modem energy generation systems are needed to meet this ever-increasing demand in remote and under-developed mountain areas.

Mini or Micro-hydropower (MMHP) is considered to be an appropriate resource for meeting the above energy needs of the people of HKH region. This is especially true for the installations undertaken on the initiative of the beneficiary communities or local entrepreneurs in a decentralized manner and the equipment is also indigenous and low-cost. In fact, the experience in Nepal and elsewhere has clearly demonstrated that such plants, especially in the micro range (up to 100 kW), can be economically viable if certain supportive interventions are provided and the entrepreneur(s)/owner(s) possess reasonable capability to manage, operate and maintain these plants properly. This is indeed one of the reasons for preparation of five information manuals, including the current one to address some of the deficiencies, which have been identified through various studies and consultations.

1.1 Applicability of MHP

There are many areas in the HKH region, which are inaccessible, under-developed and the population is scattered, poor and mostly unaware of technological progress/benefits. For such areas, the isolated micro-hydropower (MHP) plants are usually the least-cost option. This is mainly because other options for supply of energy; such a grid extension, diesel power, etc; are more expensive and difficult to install or operate in the long run. Since small water streams are usually available in the most of the region, it is quite easy to construct MHP plants to meet the energy needs of a small village or a cluster of settlements. These needs may be for electricity mainly for lighting during the evenings; or for motive power to be used for agro processing, wood working and/or for other small-scale industries. For these applications, the size may range between 200 W to about 200 kW . In the lower range, i.e. up to 5 kW, the at such a low use would only be electricity for lighting, since running processing equipment may be for power would be difficult. In the medium range (5 kW - 50 kW), the application agro-processing/industry only, electricity only or a combination of both; while the larger sized plants (40 kW - 200 kW) would only generate electricity, which may be used for lighting and other domestic uses and for industrial applications. Obviously, therefore, the type of technology, level of sophistication of the equipment and the system of management and operation would be fairly different for each of the ranges.

In case of larger sized plants, attem utilise available power during the off-peak heating (including water heating) especially to utilise available power during the off-peak hours. This use of electricity in the form of heat can contribute significantly towards reducing burning of wood and other bio the needs of an area, a properly designed,, environment and health. In addition to meeting towards installed and managed MHP plant can also contribute significantly employment/income generation, improved living conditions and improved educational facilities.

1.2 About this Manual

This manual is one of the series of five, initiated and sponsored by ICIMOD aimed at practitioners such as: surveyors, scheme designers, manufacturers, installers, managers, operators and repairers. The current volume has mainly been prepared to improve the capabilities of technicians and professionals who:

- ♦ undertake surveys of sites proposed for run-of-river type MHP installations;
- ♦ prepare feasibility reports, covering;
  - physical feasibility; does the physical situation on site allow requisite power to be generated?
  - technical feasibility; is the site suitable to accommodate ttie various civil structures required for a MHP scheme?
  - sociological feasibility; is the local community willing and able to take on the commitments of a MHP scheme?
  - El economical feasibility; can the MHP scheme generate enough income? design its layout.

The target group is expected to have reasonable reading capability and some exposure to micro-hydro technology. They may not be qualified engineers but they should have some basic engineering (diploma/certificate level) qualification and more important, relevant experience.

The design of a MHP scheme is a complicated procedure; as all sites are different, having various problems and needs. Obviously, it is impossible to cover all the aspects of feasibility for all the ranges of MMHP. The information given in this manual, therefore, should be use(only for straightforward designs, meeting the criteria laid out in the chapters. For mor, complicated and larger schemes, say above 50 kW, a qualified engineer will have to make to design using more detailed manuals and books and site data.

As the name suggests, the manual only deals with the situation on site especially the layout; ie., the location and route of the civil structures such as dam/diversion weir, intake, power canal (sometimes called headrace), forebay, penstock, powerhouse and the tailrace. Design/selection of the electromechanical equipment is beyond the scope of this manual: except that the type and the size of the turbine may have to be decided at this stage. It is hoped that the information provided in this manual would enable the professionals to survey the site, measure/estimate various parameters, decide about the viability of the scheme and design the layout/location of the civil structures. It is expected that a person having some survey qualifications and experience would not need additional training to enable him to carry out the above tasks. Nevertheless, a training programme based on the contents of this manual would no doubt be more effective and beneficial.

CHAPTER 2

Basic Details of a MHP Scheme

In this chapter, an attempt has been made to describe the main features of a MHP scheme and their functions in addition to the considerations and the procedures for the site survey and design of the layout. Figure 2.1 shows the main features or components of a MHP scheme. These include a river from which a part of flow is to be diverted for power generation; a small weir, intake, power canal, forebay, penstock pipe, powerhouse and the tail race. Depending upon the size of the plant, length of canal, etc; many other components such as sluice gate, cross-irons, trash racks and valves may also be provided at various locations.

2.1 Main Components and Structures

The first man-made component in a run-of-river type MHP plant is a weir or a dam built across the stream to raise the level of water so that some of it can be diverted to enter the power canal through the intake mouth (Fig. 2.2). The weir does not stop the flow in the stream completely; it only raises the water level till a predetermined position is reached and maintained by resuming the flow in the stream over the weir. During the him-flow season, existence of the weir usually becomes unnecessary or even undesirable. Therefore, in many smaller installations, temporary weirs are built from boulders and stones which may be washed away during the high flow period and rebuilt during the dry season. In other cases, the weirs may be permanent structures sometimes having wooden gates to maintain a desirable water level.

As shown in Fig. 2.2, the intake is simply a window (sometimes also called intake mouth) in a well-constructed retaining wall to allow controlled flow into the canal and having some vertical bars or even a crude trash rack to prevent entry of stones or other such material. The intake can also be a very simple structure made of mud and stones and not having any bars or any regulating system; depending upon the size, sophistication and cost of the plant. It is usually desirable, however, to incorporate some components in the intake to control flow of water and debris into the power canal.

As shown in Fig. 2. 1, the power canal (also called head race) carries a requisite amount of flow from intake to the forebay safely. Thus its width, slope and cross-section are optimally selected/designed. The head race may also be constructed from a pipe in part or the whole of the length. If it was an open channel, it may be constructed from loam, stones and mortar and sometimes lined with a suitable sealant. In order to ensure that excessive flow does not enter and get transported to the forebay; spillways and sometimes gate(s) are also provided in the canal preferably nearer the intake. Similarly, gravel and silt is 'settled' from flowing water in one or more desilting basins through slowing down the flow by increasing the cross-sectional area particularly the width. Structures are also constructed to 'flush' out such accumulated silt at appropriate intervals.

The destination of water flowing in the canal is the forebay, where water enters the penstock pipe. The forebay is usually a small rectangular tank in which the mouth of the penstock is located duly covered with a trash rack to prevent entry of solid materials especially suspended materials such a leaves, branches, etc. An spillway, desilting chamber and a flushing gate are also usually incorporated in the forebay.

Penstock is the pipe of robust construction which transports water from the forebay to the nozzles in the turbine. Here, the potential energy of water gets converted into kinetic energy which in turn rotates the turbine. Penstock is usually the most expensive component out of the water transporting systems and is made from mild steel or 'high density polyethylene (HDPE)'. Usually, a valve is provided in the penstock near the lower exit to stop or control the flow. Sometimes, a valve or a stopper is also provided at its mouth in the forebay. The penstock has to be properly supported and anchored, since the flowing water (or when it stops) can cause forces and vibrations of significant magnitude.

The main job of the surveyors and particularly layout designers is to site (identify locations of the weir and intake, the power canal, the forebay, the penstock, the powerhouse and the tail race. Actually, the locations of the three main components, the intake, forebay and the powerhouse are the most crucial depending upon the minimum acceptable power that needs to be generated.

2.2 Parameters for Layout Design

As we know, 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 conversion efficiency varies with types of turbines and flow conditions; but at the preliminary stage of calculations, it is assumed to be between 0.5 and 0.6. Thus the head (vertical height of water level in the forebay above the exit nozzles, where it emits and hits the turbine blades) and the flow are the main parameters. The maximum amount of flow, that can be diverted from, the river to be used for power generation and which is available without problem all the year round, is referred to, as design flow or rated flow. It is usually less that the minimum flow available in the river/stream during the dry season. This is mainly because some amount of water may have to be left, flowing in the original stream, for other purposes eg., for drinking and washing, marine life, or irrigation. Thus, it is necessary to estimate or measure flow particularly during the dry season. Depending upon the needs, the amount of flow to be left in the stream is determined and deducted from the total flow to arrive at the design flow, which would subsequently be used for the design of structures, turbines, etc.

For example; if the measured flow in a stream was 150 I/s during the month of March, considered to be the driest month (therefore minimum flow); and about 30 I/s was to be retained in the stream; then the design flow available for the MHP installation would be 120 I/s. In this regard, few other factors also need to be kept in view. Minimum flow may vary during the dry seasons of different years; therefore, the choice of design flow should be made carefully. It is usually preferable to measure flows more than once during the dry season to get more reliable values or even during the dry seasons of two or more consecutive years. However, this may not be a serious problem in many situations where only a small portion of the minimum available flow is to be diverted for the MHP scheme.

We should be aware that flow determined or selected on the basis of information available at the time of site survey; may increase or decrease after the installation is complete. The owner manager may even be able to increase it subsequently after the completion of the plant at a little additional expenditure, by, say, raising the weir. In any case, the initial estimates are often not very accurate even though they may be based on actual measurements.

Determination or rather choice of the gross head would then be undertaken, through proper design and siting of the powerhouse, forebay and intake. This decision is very important since it would be difficult or quite expensive to change the layout and therefore, gross head afterwards. Siting of the above three components must, therefore, be an iterative process, whereby the locations may be changed many times to achieve the most optimum layout. Usually, a suitable location of the powerhouse may be identified first; immediately followed by the forebay to give the requisite gross head and then survey the path of the proposed head race to reach the intake. Obviously, the interconnecting components, ie., the penstock and the canal would also have to be located on the stable ground. If it was found that the path of the canal was not stable or it's construction would be difficult (e.g. steep slope, obstructing rock, very erodable soil, etc.); then, the process would have to be repeated and another suitable location of powerhouse, forebay, canal and intake would have to be found. Other geological aspects would also affect the selection.

Finally, the route of a small channel (tail race) transporting water exiting from the turbine back to the river also needs to be finalised; which, usually, is not a difficult process. In some rare cases, it may be possible to use this exist water for irrigation of the surrounding lands.

After finalising the location of the components of the MHP scheme, maps or sketches are prepared, showing distances, heights, angles, bends, etc. The locations are also demarcated on the ground.

After the completion of the preliminary survey and layout, it is usually necessary to carry out more detailed survey and investigation; measuring the distances, heights, etc., more accurately and determining or deciding the dimensions and sizes of the intake, canal, forebay, penstock (especially penstock) and the powerhouse. Flow may also be measured more accurately if possible during the dry season. The forebay, powerhouse and tail race may also be designed and sketches prepared. Other investigations would include geological and soil conditions, landslide and flooding possibilities and environmental considerations.

It is sometimes possible to complete all the surveys, measurements and the design work within one site visit, especially for a smaller plant; say, less 20 kW. However, it is advisable to conduct the second detailed survey one to three months after the preliminary survey and also to observe the changes if any in the terrain, the stream, forest cover, etc. These aspects are discussed in more detail in the subsequent Chapters.

CHAPTER 3

Data Collection and Design Process

As discussed in Chapter 2, in order to properly design a MHP plant, we need to collect information/data concerning various aspects; including, the power required, capabilities and keenness of the recipient communities/entrepreneurs, the potential of the site, and so on. This data/information would be collected through various sources, including promoters or owners of the plant, some other persons or individuals who were working or had worked in that area, and most importantly; through the site visits, discussions/meetings and surveys. In the following sections, the main aspects for which the information/data has to be collected, analysed and conclusions drawn has been discussed; in addition to the methodology to be used and different sources to be tapped to collect such data.

3.1 Information Collection before Site Visit

Considerable information should be collected before travelling to the site especially for the first trip; which would be useful for the travel, arrangements, comfortable stay, etc. If possible, information about the site, people, economy, the water source (or sources), weather, social conditions, etc; should also be gathered from different sources. Although the subsequent visit to the site and the surveys are inevitable; this pre-visit information would facilitate many aspects of the visit and may even decrease the length of stay at the site. The main source of the information would- the entrepreneur or representatives of the community pursuing the installation of the plant; ie., people who have approached the Organization to conduct the survey. Other sources may be personnel from some NGOs working in that area or employees of a bank, school or other office working and living in that area. It must be accepted that while finding such a person may be quite difficult, some efforts should made in this regard; mainly because if such person could be found and interviewed, his information may be more authentic and unbiased. Additionally, such a person may also be helpful in making arrangements for the trip and the stay.

For collecting information a from similar to one shown in Annex. 3.1 may be used; which includes sections on, location of site, travel route, mode, distances, etc; contact persons in the area staying arrangements; some ideas about number of consumers, their social and economic condition; and of course, some description about the water source and terrain. While collecting such information, it should be kept in mind that the person being interviewed may have little knowledge about things technical; therefore, the questions should be simple which he can understand and they may be-repeated. Still, the information thus gathered may not be accurate.

3.2 Preparations for Site Visit

During the visit, a number of surveys and other tasks would have to be performed, as briefly described below; for which preparations have to be made and equipment and other items need to be acquired and carried to the site.

- ♦ Arrival and stay in the Project area
- ♦ Meetings with community members/ leaders/ representatives, entrepreneurs
- ♦ Reconnaissance survey
- ♦ Demand survey
- ♦ Preliminary site survey
- ♦ Preparation of sketches/maps
- ♦ Photography at the site

First matter to be decided is the timing of the visit, which should be convenient from travel, stay and working at the site point of view. It should be a dry period (not too much rain) and not too hot or too cold. Otherwise, work at the site may be difficult. In Nepal the convenient period for surveys (including minimum flow) is between February and May. This period, however, may vary in other countries and/or sub-regions. Therefore, authentic information needs to be acquired in this regard from people of the area, Meteorology Department and other sources.

Usually, two persons should travel to the site; especially during the first visit. A qualified and experienced surveyor and an assistant; who can get along well and work together, should embark on such -a mission. Later, however, it should be possible to locate and engage one or more local persons to assist in the survey work and other tasks such as organizing meetings.

It is not easy to estimate the time duration for completing all the surveys, meetings and layout design. For an experienced surveyor, the minim ' um time needed at the site would be three days excluding the travel time if the site was easy, the community was helpful and adequate initial information-had been collected before hand. However, one should allow about 5-7 days for this first visit and the preliminary survey.

3.2.1 Survey and Other Allied Equipment

It would be very useful to acquire the maps for the project area also containing the topographical contours having scale of 1:50,000 or better. Such maps are not that easily available in some countries of the Himalayan region, but this is not the case in Nepal.

Choice of other survey material to be carried to the site would depend on the decisions made regarding the flow measurement (eg., weir, salt dilution, or float) and the equipment would have to be packed and carried accordingly. Since it is rather expensive and embarrassing to go back to bring some missed equipment; it is helpful to prepare a check, list (eg. Annex. 3.2) for making decision regarding what to carry. Most of the equipment, especially, the delicate optical equipment needs to be packed properly for transportation to the site.

Proper clothing is also important including, shoes, caps, glasses, gloves, warm cloths and sleeping bags can make the visit and work at the site quite easy and even pleasant. Therefore, due attention must be paid to pack appropriate stuff for the travel; but not too much of it also; since it has to be manually carried by somebody.

3.3 Arrival at the Site

After arriving and settling down at the site or the village (where the team is to stay) safely and with all the equipment intact, the first thing to be done is to contact the concerned persons who are to look after the team and make arrangements for their stay, meetings and survey. The actual work would only start when the team has established these contacts and is comfortably settled into the lodgings and the arrangements for the further travel have been made to the villages of beneficiaries and the site.

Second important task would be to try to contact the concerned and important persons and discuss with them the work plan for the next few days. These initial meetings should also be helpful in assessing how keen these persons/cornmunity (or the entrepreneur and his partners/supporters) were about the installation and how much help/assistance they were prepared to offer to the team. Also, the message should be that this was their project and the team had come to assist.

The third task would be to organise a meeting of representatives of different ethnic/caste/religious/and economically diverse communities and whosoever, who would like to attend. The main objective of this first meeting would be to meet them and assess their keenness, capability and willingness to assist and work for the installation. Overall, the following aspects should be covered.

- Know and meet these various groups and build a rapport and trust.
- Explain to them why the team had come.
- Apprise them of as much information about the proposed MHP plant, need for their involvement in decision making, surveys, installation, management, operation and repairs, etc., plus other contribution.
- Collect additional information about the site, stream, consumers, previous survey, etc.
- Assess their keenness and capacity through their responses to what they were being told (avoid asking direct questions).
- Sense any inter-community conflicts; social, economic, related to land/water, etc.
- Ask them about how beneficial did they think the MHP would be for community and what they would be able to do.
- Ask them if they had any fears or misgivings about some negative effects of the MHP plant; say in terms of land use; diversion of water; effect on their ghattas, etc.
- Ask them if they really wanted an MHP to generate electricity for them and if they were willing to contribute in cash and kind to have it installed..
- Ask them how much power did they think they needed.

- Ask them who would be the manager of the plant; whether they would trust such a person and whether they thought he was competent and experienced enough to do the jobr
- Ask them whether it was appropriate to form a committee; and who would be proper people to work as members of the committee to look after the installation as well as operation of the plant. (The actual committee may -be formed later after more thorough consultations and assessment of the lead people).
- Ask them to identify some 4-5 suitably qualified people to assist in the survey work. Such persons should be interviewed later and if found suitable and willing to assist, should be assigned some tasks.

This meeting should be treated as preliminary one and most of the discussions should be informal and off-hand. The community leaders should not be given the impression that the team was following some pre-planned course. At the same time, some notes may be taken concerning the assessment, etc.

The structure and conduct of such a meeting has been suggested for a community owned/managed plant. It would also be useful to have a similar meeting with regard to an entrepreneur-owned plant. The main objective should be to judge the reaction of the people towards the plant and whether the owner was able to deal with the issues and concerns raised by the community members. In fact, the entrepreneur may be asked to organise such a meeting.

3.4 Reconnaissance Survey

This survey involves visual inspection of the site for few hours to familiarize oneself with the prevailing conditions; and having some idea about flow, elevation (whether the slope was gentle or steep to allow less or more head), the terrain, vegetation, land uses, water uses, etc. Photographs of the site, stream, terrain and the likely location of the civil structures may also be taken. Some community representatives and helpers should accompany the survey team to discuss especially the following.

- ♦ Whether any previous survey had been conducted; if yes, what were the results? Did any one have any records. Another survey would still be necessary; however, if proper records of a previous survey were available and could be judged to be reliable, some aspects of the present survey and layout design could be somewhat shortened.
- ♦ Were any sites already considered or identified for, say, powerhouse/mill, forebay, power canal and intake. Such discussions at the site would also be helpful to adjudge who owned the land where the powerhouse was proposed, would the intake be suitable, was there a proper location for digging/constructing a canal, and so on.

Some very rough estimates of flow may also made; using a float method for example. Similarly, the terrain should be inspected for siting a powerhouse then forebay, the canal and the intake. Some idea about the availability of head, say, by using an altimeter may also be made, to arrive at a very rough figure of the power potential of the site.

Thus the main objective of the reconnaissance survey is to; achieve familiarity with the site, consider/evaluate some locations for the main components and make a very rough estimate of the potential of the site.

3.5 Comprehensive Meeting with the Beneficiary Groups

At this stage, the survey team should have a very rough idea of the demand for the power (through discussions before site visit and during the preliminary meeting) and the power potential (from a previous or reconnaissance survey). Looking at the site, very rough estimates of costs can also be made. Keeping in view these figures; this should be the time to have a more comprehensive and decisive meeting with the community members, leaders, representatives, etc, from different ethnic/economic groups and some womeii representatives if possible. The main objective of the meeting should be to discuss and be clear about all the aspects including demand, power, costs, funding, contributions and other support, some .technical details, other end uses, management, tariffs, incomes, repair & maintenance, backstopping and so on. The team members should facilitate the discussions rather than lead them and make the community feel that they were talking about their own plant/property, its benefits and the needed efforts/responsibilities.

All the information regarding the above aspects should also be presented in the meeting and -.I discussions encouraged. The team members should observe and assess the possibility of cooperation and working together between the different ethnic/other groups; whether there were any real conflicts within the groups; their keenness to participate in and contribute for installation and latter manage and operate the plant successfully.

Assessment should also be made if most of the consumers would be willing or able to-pay for the electricity. The technical and managerial capabilities may also be assessed and conflicts/views regarding the land where the plant and its components are to be situated, must ii also be discussed and assessed. The desirable level of incomes and tariffs as well as type of tariff (fixed, metered, other) and their implications, should also be discussed and conclusions drawn if possible. Advantages of having a significant net positive income which may be used for betterment of the plant and its services in the long run should also be explained. If appropriate, facilitate formation of a User's Committee to look after the arrangements, at this -stage. Some suggestions or ideas about the industrial applications by villagers may also be evaluated and finalised if possible.

It may be necessary to interrupt the survey or even recommend abandoning of the installation became clear during the meeting that the capabilities, or interest of community were or serious conflicts existed about, say, water or land use. The meeting, for example may become unruly or may even break up.

3.6 Demand Survey

This survey can also be conducted before the comprehensive meeting or even before reconnaissance survey. However, it is better to take up this detailed work after the first go a head /stop decision has been made. This survey mainly concerns the counting of households and other potential consumers (shops, lodges, offices, temples, schools, etc.) who are ready to contribute and commit themselves for receiving power and paying for it, and their respective power demand.

The usual form of tariff for such low-cost plants is fixed rate based on power to be used or connected including some current limiting devices. Therefore, power needs of each consumer would be calculated in terms of number of bulbs/tube lights, radios, T.V., fans, etc.; and their respective wattage rating. The forms given in Annexures 3.3 to 3.7 may be used to record the power needs of customers (rounded up to nearest higher 50 or 100 watt figure). Some industrial uses discussed and agreed upon by the community may also be added. All the figures may then be added and a final figure for the total power needed at present, be determined after also allowing for the power losses in the transmission and distribution lines. This final figure would be the minimum present power demand and if the power potential of the site is significantly less than this value; then the installation process would have to be abandoned.

If the plant under consideration was entrepreneur owned; then the power needs for electricity and/or agro-processing, etc; may be estimated in a similar way and the minimum power demand computed.

Usually, the above minimum power demand may have to be increased after discussions with communities in order to cater for the needs of immediate future (next 1-2 years) when some other residents of the area who were not in a position to get power presently, would also ask for the connections. Necessary assessment of such future demand should also be made and added to the minimum power demand and thus compute the desirable power capacity of the plant. This additional future demand is usually about 10 to 50 per cent of the current minimum demand. The desirable power demand should be taken as the rated power of the MHP plant to be designed and installed.

Usually, the demand survey is not repeated during the next detailed site survey. Therefore, it should be accurate and thorough at this stage. Some reliable community members may, however, be requested to carry out a more thorough survey later, if considered necessary.

3.7 Preliminary Site Survey

This site survey would include flow measurement in the dry season (when the flow is minimum) and determination or selection of desirable/design head which would generate the required rated power by appropriately locating the powerhouse, forebay, the power canal and, the intake . The actual survey would include flow measurement, land survey, measurement of heights (heads), slopes and distances to achieve the above. These surveys and measured are described below.

3.8 Flow Measurement

The methods of flow measurement to be used at a particular stream would mainly depend upon the volume of flow and whether it is turbulent or calm. Very few natural streams are be non-turbulent specially in a mountainous terrain except for smaller sections. Methods of flow measurement are usually applicable in mountain streams in less countries.

Bucket method;	for flows up to 20 I/s.
Velocity-area method using a flow meter; or,	for larger streams (Q > 20 I/s) having at least Io cm depths at the deepest point
float	for any volume of flow in a calmer (less turbulent), stream.
Weir method;	for larger streams (Q > 50 I/s) a rectangular or triangular weir can be used.
Salt dilution method;	*for all* streams having smaller flows

Before describing the above methods of flow measurement, following aspects need to be mentioned.

- ♦ Location of the place of flow measurement should be chosen carefully so that depth of stream is adequate, and measurements can be made easily, flow is not diverted or breaks up into sections or seeps underground to rejoin the stream somewhere downstream.
- ♦ Timing of the measurement should also be such that the flow is steady (not changing significantly) during the period of measurements.

- It is useful to measure flow by using at least two different methods so that results Are more authentic. If, however, the difference in values is more than 20%, something may be wrong. Either the flow is changing, or at least one the measuring methods is not proper.
- Float method is not a very accurate method; therefore it's use should only be confined to the initial rough measurements.

The methods of flow measurement are briefly described below. The description should be adequate for those surveyors who are already familiar with concepts of flow and it's measurement. However, those who are totally new to the subject, may find it difficult to make accurate measurements. For such people, it is advisable to learn the methods of measurements from some other experienced persons. Or, if that was not possible, read more detailed textbooks on the subject.

3.8.1 Bucket Method

This is a very simple and accurate method if the flow is relatively small (say < 20 I/s). A bucket or other container 6f.known size is used as a measure and all the water in the stream is diverted into the container through a pipe or a trough and the time taken to fill the container is measured. The flow is given by:

$$Q = \frac{\textit{Volume of Container}}{\textit{No. of seconds to fill it}}$$

Care must be taken to channelise all the flow into the container. Usually, a dam is built around the pipe and the area is sealed temporarily with earth, plastic/rubber sheets, stones, etc., to prevent leakage. Preferably, the capacity of the container should be enough so that it fills up in more than 5 seconds to give a reasonable accuracy to the measurement.

3.8.2 Velocity-area Method

a. (Using a Flowmeter or Float)

This method is quite useful and reasonably accurate if a proper flow measuring gadget is available. The width, depth, area and average flow are measured at various points (streamlines) along a carefully selected cross-section of the stream. Then the average flow is computed (Fig. 3.2) by using the general formula for flow Q:

$$Q = \sum a_1 \text{ x } v_I = a_1 \text{ x } v_1 \quad a_2 \text{ x } v_2 \quad a_3 \text{ x } v_3 \quad \ldots..$$

Many types of flow/current meters are available which are light and quite easy to carry (Fig. 3.3), although somewhat expensive.

An -appropriate location must be selected preferably along a straight and non-turbulent length of the stream. The stream bed as well as the width should be reasonably uniform and not covered with protruding materials such as rocks. The water should also be adequate for most of cross-section; and the mean depth should be at least 100 mm, preferably more.

As explained in Figure 3.2, the cross-sectional area is divided into different sections and average velocity is measured by a current meter (flowmeter) at the centre of each section.

The sub areas are calculated as if the sections were a trapezoid, i.e.;

$$A = \text{average depth (d) x width (w)} = d_1 \quad d_2/2 \text{ x } w$$

Elaborate instructions and tables are provided with the current meters to determine the velocity properly and accurately. The depth at which the rotor must be located is also specified. A preferred depth for many types of meters is 0.6 of the total depth of water at that point. Many meters are also mounted on measuring rods so that the depth can be measured at the same time and the rotor can be easily located at the requisite depth.

b. Using a Float

A small floating object is chosen which should partially submerge in water such as a piece of light wood and used at the centre of the stream. A more elaborate float is shown in Fig. 3.4. The surface velocity (Vs) of water is then given by:

$$V_s(m/s) = \text{Distance traveled by float (m)/Time taken (s)}$$

However, V., does not represent the average velocity; since the water near the banks and the bottom of the stream moves at slower speed. Therefore, a correction factor 'C' needs to be introduced to determine average velocity V of the stream.

$$\text{i.e.; } V = C \times V_s$$

C varies between 0.4 to 0.95 for different conditions.

For example;	for shallow turbulent streams,	C = 0.45
	for small regular streams with smooth bed,	*C* = 0.65
	for large, slow, clear stream,	C = 0.75
	for large, deep, streams with smooth bed,	C = 0.85

The area of cross-section (A) is then calculated by measuring depths at different points on a chosen cross section as explained in the previous section and Fig. 3.2.

$$Q = V \times A = C \times V_s \times A$$

Accuracy of measurement in this case can be quite low, say, ±50 per cent error, or even higher. Therefore; as far as possible, other methods of measurement may be used. It is possible; however, to improve accuracy of measurement through experience by continuously comparing the flow measurement using different methods and choosing a correct value of factor C.

3.8.3 Weir Method

Many types of weirs can be used to measure flow in the streams. The most convenient one is the rectangular type mainly because it can be constructed from wood on site if an amateur carpenter was available there (Fig. 3.5). If the weir was made properly, the flow measurement can be accurate within ±5 per cent. However, it is unlikely to achieve this level of accuracy in most practical situations.

This weir can measure flows between 10 - 400 I/s. The length L should be at least 3 times the height of flow h (Refer Fig. 3.5). Additionally, h should be large enough to be measured accurately (say 50 mm or more) and the upper limit should not exceed 0.5 m. Following precautions need to be taken while measuring the flow.

- The crest of the weir should have a reasonably sharp edge (Fig. 3.5)
- The water flow over the weir should actually fall; ie., water level in the down-stream channel should be considerably lower than the cres,,,
- The crest of the weir should be at least '2h' higher than the up-stream bed.
- The crest should be as horizontal as possible so that the head 'h' is constant all over the length of the crest.
- Area surrounding the weir should be well sealed so that all flow passes over the crest. Head 'h' should be measured as accurately as possible and the measuring rod should be installed about '4h' distance upstream of the crest (Fig. 3.5)

Another useful weir is 90' triangular notch (commonly called V-notch). This is a more convenient measuring weir than the rectangular weir having just one dimension (90' angle). It needs to be produced accurately in a workshop (Fig. 3.5); but it is more suitable for handling small flows and a smaller version can be easily carried to the site and fixed to wooden planks in situ to carry out the flow measurements ranging'between 3 - 300 I/s. The equation for computing the flow is also shown in Fig. 3.5.

3.8.4 Salt-dilution Method

This method of flow measurement is proving to be quite convenient, accurate and quick for the small, shallow and turbulent mountain streams. If the conductivity meter is well calibrated and the measurement is carried out properly, the accuracy should be better than ± 7 percent; which is quite acceptable for MHP schemes. The meter which measures conductivity of water, is also a small device which can be carried around quite easily. Such meters are available in the cost range of 50 - 400 US$.

A known weight of dry and pure salt should be completely dissolved in a bucket full of water. The water should be mixed with stream water as quickly as possible but without muddying the water severely at a preselected location. About 30 - 50 meters down-stream, the probe of the conductivity meter should be immersed in the stream water nearer to the bed and the centre of stream and conductivity readings should be taken every 5 or 10 seconds (Fig. 3.6). The readings would rise, reach a peak, and fall back to the base level over a period of time. Usually two persons are needed to take the readings and record them.

The readings are taken continuously until conductivity values decrease back to normal values (ie., all the salted water has passed the probe). A graph of change in conductivity with time is then plotted and the area under the curves computed (Fig. 3.7). If a graph paper is used the area can be calculated easily by counting the squares. The temperature of the stream should also be measured. The discharge (flow) Q is then calculated by the following equation.

$$Q = \frac{\textit{Mass of salt (Kg)}}{\textit{Conversion factor k (Kg/m3/ohm}^{-1}\textit{)}\ \mathbf{x}\ \textit{area under he curve (ohm- 'S)}}$$

The conversion factor k is dependent upon the temperature and it's value is given in the manual for the conductivity meter. More detailed instructions for flow measurement are also provided in the manuals.

Following must be kept in mind while using the salt-dilution method and the conductivity meter.

The area-curve should be smooth and should have adequate peak. It should not be distorted. If it is distorted as shown in the examples of Fig.3.7; follow the instructions given on -each of the distorted figures.

- It is desirable to repeat the measurement process two or three times to achieve reliable results (if the results do not match, recalibrate the instrument or contact the supplier).
- An electronic integrator is also available to calculate the area automatically when the readings are fed into it. However, this may be an unnecessary additional expenditure if the measurements are not taken frequently.
- The method is suitable for small flows and fast streams. However, if the stream is too shallow or very fast then the results may be misleading. Therefore, a relatively calm section of the stream should be selected for measurements.
- Use about I 00 gm. of salt for every 0. 1 m'/s of flow.
- The length of the stream between where salt is added and the probe is inserted, should be between 30 to 50 meters.
- Sometimes a coefficient is written on the probe which must be applied to the equation to get the correct value of flow.

3.9 Determining the Head

As explained earlier also, the choice of head depends upon selection of location of the powerhouse and the forebay; and consequently, the route of canal and intake. The surveyor should first calculate the value of desirable gross head from the power equation. He should start tentatively by selecting a suitable site for the powerhouse and the forebay and then measure the height and the distance between the two. If the height of the forebay above the base (floor) of the powerhouse is adequate; the ground is stable and route for the penstock is relatively short; then, he may proceed to find a suitable route for the power canal and the site for intake. Thus the process of 'determining the head' actually involves a lot of survey including measurement of distances (both horizontal and along a slope), heights, angles/bends and so on. At the same time, the geological and other conditions of these locations must also be examined and evaluated so that they are fit for constructing such structures and no natural or human/animal damage would occur to them over the years.

In fact, some experts would suggest a reverse process; ie., after having a general idea about the area where the MHP plant and its components ' are to be located, a suitable site for the intake should be selected first; and then following the route of the canal, forebay, penstock and the powerhouse may be sited. This method may be more appropriate if the value of the head was not so critical. However, whatever the method is to be followed, it is certain that the survey and selection process has to be repeated many times; selecting location/route of one or the other component and siting the others, encountering problems and starting with another location, and so on.

In the following sections, the requisite and desirable characteristics of each of the locations of the civil structures are mentioned.

Powerhouse and Forebay

- The powerhouse is easily accessible and nearer to the consumption centres.
- Adequate area is available for all the proposed facilities and mechanical units.
- The location is firm and out of the way of possible landslides, falling stones, floods,etc.
- It is above the 50-year flood level of the stream.
- A tail race can be easily constructed to carry water leaving the turbine to the stream.
- The requisite land for the powerhouse, penstock and forebay is available and can be acquired easily.

(If cost was a crucial factor or only small area was available, then possibility to construct a portable robust structure to just cover the turbine and generator of an electrical scheme may also be explored for small plants).

- ♦ The choice of location of powerhouse and the forebay gives the desirable head.
- ♦ The penstock being an expensive component, should be as short as possible and its path should be straight and without serious obstructions (protrusions and depressions). Thus the slope needs to be fairly steep.
- ♦ The path of penstock should also be on firm ground and not liable to slide down, due to heavy rains, landslides, etc.

If both available flow and head were more than necessary; then, it would be advisable to increase the head and minimise the design flow. This approach would reduce the cost of mechanical equipment and transportation. But, as (almost) always, there is a catch 22; by increasing the head; the length of canal would increase which makes it more vulnerable to damage; the length of penstock would also increase but the diameter would decrease.

Power Canal

The third site to select and survey is the path of the power canal from the proposed forebay to the intake. Following desirable characteristics should be considered.

- ♦ The path is stable, and out of harm's way such as storm gulleys, landslides, falling rocks, etc.
- ♦ The construction of the canal is possible and it would not be too expensive.
- ♦ The path does not contain obstructions due to which construction would be difficult, expensive, or the life would be short (e.g., a hard vertical or near vertical cliff; a large storm gully, terrain susceptible to erosion, landslides, etc). If such a @ituation exists then the construction of the canal is seen as the most serious problem; and good approach would be to select a suitable route for the canal first on any of sides of the stream and then select intake, forebay and powerhouse.
- ♦ Sometimes an acqua-duct (covered if necessary to prevent damage from falling stones) or a pipe may be used for part of the route to cross a gulley or a depression (Fig. 3.8).

- Similarly, possibility of building a canal or installing a pipe may also be explored around a large rock (on the hill side), if it comes in the way of the normal path of the canal.
- This approach would be advisable since in many situations, it may not be possible to locate a terrain without any obstructions or other problems.
- Depending upon the geological conditions (level of erosion, greenery, obstructions) construction types of different sections of the canal may also be tentatively decided at this stage.
- Usually, the power canal should be constructed in such a way that minimum amount of rain water enters it. To achieve this, a drainage channel may be provided wherever necessary and possible. Additionally, more spillways may be provided at appropriate locations to prevent damage to the canal and forebav due to additional flow caused by rain water.
- A minor gradient is to be provided along the canal path. Typically, a gradient between 2 to 4 m. per km. (1: 125 to 250) is considered adequate for earthen channels. However, if the number of bends is large or the cross-section is nonuniform over the whole length; then the gradient may be increased a bit to compensate for the losses, and to ensure that the velocities in the canal are within the permissible range as categorised below for different soil types.

Type of Soil	**Velocity Range**
Sand	0.3-0.4 m/s
Sandy loam	0.4 - 0.6 m/s
Clayey loam	0.6 - 0.8 m/s
Clay	0.8 - 2.0 m/s

Intake

- Usually the site of intake should also be reasonably suitable to accommodate the construction of a weir down-stream of the intake mouth.

- Intake should be sited at such a place that the stream is relatively permanent; say flowing over a bed rock and not prone to silt accumulation.
- The stream should not have a large gradient up-stream of the intake.
- The stream should be relatively straight both up-stream and down-stream of the intake to avoid damage by sharply turning flood waters. If really necessary, the intake may be placed on the outside of a bend; but not on the inside (Fig. 3.9a). However, if silt load was higher in the stream, this may also be a problem.
- Sometimes, intake can be protected by locating **it** under or down-stream of a large boulder.

Weir

- Sometimes, a weir may not be needed; since the inherent features in the stream may automatically divert adequate water to the intake during the dry season. Sometimes, a temporary weir or a partial diversion dam can be built for smaller schemes; which may be washed away during the high floods; but may be rebuilt easily during the low-flow period; when it is really needed (Fig. 3. 10b).
- Since considerable silt or gravel. is likely to accumulate at the foot of the weir; it should be constructed about 50 meters or so down-stream of the intake.
- A permanent weir can also be build from gabions, stone masonary, or concrete, depending upon the level of high flows and debris carried during such periods.

3. 10 Measuring the Head

Once suitable locations of all civil structures have been selected; the available head and the distances between these structures should be measured. Measurement of head may be carried out by using one or two of following methods.

3.10.1 Using a Clinometer (Abney Level)

The clinometer (also called Abney level) is a smaller version of line level and is used to measure vertical angles. Preferably incorporating a range finder, it can be ased to measure the slope angle; and subsequently, the gross head (Fig. 3.11). The accuracy available from this rather small and cheap instrument is better than ± 5 % for measuring the head. The other equipment needed is a measuring tape (30 m), two equal length strong sticks (-1.5.m long) and marking pins or pegs.

Procedure

1. Place one stick/ranging rod on the starting point of the survey, say, location of turbine base in the powerhouse. and the second stick on the 1" intermediate point, less than 30 meters away-
2. Measure the straight sloping distance L, between the points 1 and 2 and record (Fig. 3. 1 1).
3. Place the Abney level on the top of the first stick and sight on the top of the second; turn the spirit level, till it shows centre in the spilt eyepiece; and record the measured angle (x,.
4. Move the first stick to another location preferably along the route of the penstock, less than 30 meters away.
5. Repeat operations 2 and 3 from the 2" stick aiming at the I" stick; record the slope distance 1,2 and angle a2'
6. Move the 2nd redundant stick to the next intermediate position and repeat operations 2-5, till the base of the forebay is reached.

3.10.2 Using a Water-filled Tube

This is one of the simplest and cheapest methods to measure low heads. The equipment needed is; a 20 meter long transparent plastic tube having about 10-12 mm diameter, two graded rods, a measuring tape and some marking pins/pegs. Usually, two persons are needed to take the measurements (Fig. 3.12). This method can be quite accurate if the surveyors are experienced. However, it should be repeated three or more times to ensure that no mistakes were made.

Procedure

1 Starting from the site of the forebay, fill the plastic tube with sediment free water. You should hold one end the pipe while your assistant holds the other end; both about shoulder high. Remove all bubbles by stroking various parts of uncoiled tube.

2. Ask your assistant to walk slowly down the hill along the path of the proposed route of the penstock; he should keep raising his end of the pipe while you slowly lower yours to ensure that water does not spill from either end of the pipe. The assistant should stop when your end of the pipe nearly reaches the ground level.

3. Measure the heights of water in the pipe above ground level (h, & h2) and 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).

   Also mark both positions (1 & '.1) with pegs and record all the readings in the record sheet.
4. Direct your assistant to stay in same position and continue to lower his end of the pipe; while you move now to a new position (3) along the penstock route while raising your end of pipe until the water level reaches about head high at your end and nearly touches the ground at your assistant's end.
5. Read and record the new readings at positions 2 & 3. Also measure the distance between the points along the slope. Record the readings.
6. Repeat the process until one of you reaches the base mark for the turbine.

3.10.3 Using a Water Filled Tube with Pressure Gauge

This method is similar to the one described above but relatively simpler; since an aneroid pressure gauge is used to measure the pressure and head.

The procedure of measurements is also similar but the water height above the ground is measured at the higher position only while pressure reading is taken at the lower position. The record sheet may also be similar to the previous one; except that the second entry for the height is replaced by pressure reading, which is later converted into height reading.

- ♦ The pressure gauge should be properly caliberated in the office or in situ frequently.
- ♦ Air bubbles should be completely removed from the tube.
- ♦ The measurements should be repeated two or three times.

If the surveyor can practice the water filled tube method properly, there is no need to use the pressure gauge method, which incorporates an additional instrument and which may be inaccurate.

3.10.4 Using Altimeters

Conventional aneroid type barometers/altimeters are usually difficult to use and can be quite erroneous. The new digital altimeters Are easy to use and cheaper (- 200-500 US$) and can be used for initial and rough measurements especially for h igh head (< 100 m). The method of measurement with the altimeter simply involves taking the reading wherever needed; say at the site of turbine, the forebay, the intake; etc; and computing the differences in readings to find head, gradient, etc. However, it should be noted that the readings are affected by changes in altitude, atmospheric pressure and temperature. Therefore, another more accurate method of height measurements would have to be used later. For this- reason, the altimeters are not that popular.

3. 10. 5 Other Methods

Many other methods of head measurement are also available and professional surveyors would have no problem using them. For example; a simple plank to which a spirit level has been attached, along with two graded rods can be used to measure height differences between two positions. However, the equipment is heavy and cumbersome to use. Similarly, more accurate and expensive levels and theodolites can also be used for this purpose; which would need considerable practice and skill to master. Consequently, for MHP schemes having head less than 100 meters, the Abney level and water tube may be the two fairly accurate, cheap and easy to use methods.

3.11 Methods Used for Other Surveys

The other surveys to be carried out while visiting a prospective MHP site are; distance measurements both horizontal as well as along a slope; and land/area surveys, so that sketches/maps may be prepared or updated for future use. The two dimensional (area) surveys also include measurement of distances, slopes and angles which have to be integrated to prepare two- or even three-dimensional maps; and for calculating lengths of canals, transmission lines, etc.

The distances are usually measured by tapes or 'chains'. The later are more sturdier than tapes in rough field conditions. The bends or turns can be measured on the ground or by using optical instruments such as Abney level. Some pegs or pins are also needed to drive them into the ground to mark the various points (starting points, end points or intermediate points) from

which distances have been marked and the readings taken. These readings and markings are then recorded in the measurement books and then reproduced on drawing sheets to prepare maps of the areas, sometimes including elevations (maps in vertical plane) or combination of both, such as topographic maps.

It is usually not possible to describe all techniques of carrying out these surveys in a manual of this size. However, reasonable common sense and some prior familiarity with the equipment and methods should be able to help the surveyors in carrying out the actual measurements. For example, it can be safely assumed that every one knows how to measure a straight distance between two points, or to measure an angle between two straight lines by using methods of geometry.

Example 3.1

A survey conducted to assess the dermand concluded that at least 26 kW power was required at present to meet the existing demand of about 200 interested consumers. However, there were about 75 additional prospective consumers; who, if eventually connected, would need additional peak power of 8 kW. The flow measurement indicated that 180 I/s water was available during the dry season; it was learned that the flow is known to fall below this value in some dry seasons. It was also concluded through discussions with the community members that a minimum of 30 I/s must be allowed to flow in the stream at all times and not diverted for the MHP plant.

Following decisions need to be taken at this stage.

What should be the design flow; and, what should be the minimum and desirable head.

Decision Methodology

Design Flow. The measured flow is 180 I/s out of which 30 I/s need to be deducted. Thus the design flow(Qd) should be 150 I/s or lower; since it has been suggested that the flow may decrease even further during some dry seasons. Some available options are:

a) Use the available figure of 150 I/s and be prepared to accept lower power for one or two months in some dry seasons in future;

b) Wait for further' survey to see if a higher but viable gross head (hg) was available and thus flow could be easily reduced while still achieving the desirable power by using the higher head;

C) The demand survey and discussions with communities might also have indicated that it would not be a serious problem to accept less peak power (less than desirable value but equivalent to or higher than minimum value) during the three/four months of dry .season. Thus, even a higher value of flow, say 180 I/s may be selected as Q, (but it would not be advisable to go higher than this value).'

Minimum Desirable Head. The **minimum** (acceptable) power is 26 kW. Thus, using a simple equation which should incorporate all the losses (including the head loss) the minimum desirable gross head hg is given by:

hg **=** P15Q = 2615 ***x*** 0. *150 = 34.7 or 35 meters (the Q is in m^3ls)*

if a more appropriate lower flow value was used; then,

hg **=** 2615 x 0. *12 = 43 meters*

if the desirable value of power was used then:

hg **=** (26 8)15 x 12 = 57 meters

Therefore, the maximum head that would be needed is 57 meters and the minimum acceptable one would be 35 meters.

Although some idea about the available head might have been formed during the reconnaissance survey, a good decision would be ' to complete the preliminary survey to determine the head range that is easily available without having to extend the canal too long.

Example 3.2

The preliminary survey of the site has revealed that with the given location of the powerhouse, two locations of forebay and other allied upstream structures were possible including the canal and a suitable intake.

i) hg = 32 in, length of penstock 48 meters and length of canal about 650 meters,

hg = 48 in, length of penstock 73 in and length of canal 1 100 meters. How do we go about deciding the design flow and design gross head. *Decision Methodology*

It seems that it may not be advisable to shift the location of powerhouse because the land is easily available and accessible. The location is also suitable for extending the transmission lines and disturbance to the surrounding lands is minimum. Therefore, main decision that needs to be taken is to select a suitable head and flow.

For most practical purposes, it is useful to have high head and low flow suggesting the second choice; i.e., hg = 48m.

However, the respective canal length is too long. Using design flow of 120 I/s (the most suitable value) the power is $P = 5Q$ hg **=** *5* x 12 ***x*** 48 *28.8 kW*

It may be advisable to re-survey the route of the canal to judge weather such a long canal would be stable enough in the long run. The geological conditions may also be investigated to ascertain whether there was possibility of slip, excessive run off (rain water flow) from the top or other such problems.

If the channel route is fairly safe and if some minor vulnerable sections can be stabilised by using concrete or good retaining walls; then this choice may be made.

However, if the canal site was vulnerable, then the first option may be examined. Using the desirable flow value of 120 I/s would obviously not give the needed power. Therefore, we would have to use flow of 150 I/s or even higher.

At 150 I/s flow; *Power = 5* x 0. *15 x 32 = 24 kW*

Obviously, the available power is not adequate; therefore we would have to consider whether; we:

a) Accept this lower value of power which is not much lower than the minimum needed (26 kW). If we do this we can still design our power plant for higher output; say, 30 kW; which it would be able to generate for 6-8 months of the year; but the consumers would have to do with less power for the remaining period. But it is clear that chances of increasing the power supply in future are slim. One suggestion would be to have a meeting with the communities/recipients and discuss both options; particularly, the last option and arrive at a concensus through discussions. It may even be necessary to have another meeting and gathering at a later date. The aspects to be decided should be considered in the following order.

    I . The first option of using k = 48 in be pursued and the canal be investigated more thoroughly to assess its suitability. If the site is not judged to be suitable; then;

    2. The option of generating 24 kW be examined in more detail and discussions held with the communities whether they would be happy with this low value of power in the long-run also. If this was judged to be not possible; then,

    3. Third option of installing a larger (- 30 kW) plant and accepting less power for few months be accepted. Again the community may be encouraged to decide after identifying and discussing the implications.

If this was also not acceptable to the community; then the recommendation from the surveyors should be; to not to go ahead with the installation.

Note. This example was deliberately presented in this way to inform the readers that such surveys and the ensuing decisions are almost never straight forward or simple mathematical calculations.

3.12 Survey for the Transmission Lines

After the location of the powerhouse has been fixed which is not likely to be changed, a survey may be carried out to fix the route of the transmission lines and measure their respective lengths. This survey mostly involves measurement of distances and sometimes heights if some hills are to be crossed. The main figures to be calculated are the lengths of wires to be installed and other allied equipment such as poles, insulators, lightning arresters and so on.

The figures for the lengths may also be used for calculating the costs.
The following may be kept in mind while designing the layout for the transmission lines.

Ideally, the transmission lines may travel along straight lines to minimise costs and to avoid lateral loads on the poles. However, this is rarely possible; it may be necessary to avoid some cultivated lands, a bunch of trees, houses, etc. Still, the basic principle should be to avoid bends and diversions as far as possible.

If the lines are to pass through cultivated land, the poles must be located on the intervening banks between two pieces of land so that they are relatively safe and the farmer's land is also not adversely affected.

The crossing of the transmission lines through. a thick forest should be avoided, if not possible its alignment should be cleared of trees.

3.13 Preparation of Sketches

During and after completing the survey it is necessary to prepare sketches of the area for reference as well as future work of survey and installation. It is also advisable to mark the locations of the sites on the ground with pegs or other such materials. The sketches, etc., would have to be improved and proper drawings prepared. In all, preparation of following sketches would be desirable.

I . Overall sketch of the area (say at 1:10,000 scale) showing the relevant portion of the stream and the nearby beneficiary settlements. The distances between the main features may also be included. Some height figures may also be mentioned but the detailed contours would not be needed (eg., Fig. 3.13)

2. More detailed sketch of the MHP location including the powerhouse, penstock, forebay, power canal, intake and the relevant portion of the river. The scale should be around 1: 1,000. The contour lines traversing the main components may also be shown along with the altitude values if possible. Otherwise, only the altitude values (absolute or relative) may be shown for the main locations as well as important sub-locations.

3. The results of survey for the transmission lines may also be shown or superimposed on the first sketch; but it would be desirable to have a separate sketch since the transmission lines are affected by different land and topographical features such as cultivated land and boundaries between them; forest, high intervening hills,, etc. The lengths of transmission lines may also be scribed along the lines.

If possible, these sketches may then be redrawn into drawings of reasonable quality so that they may be used later for detailed survey, installation, etc.

3.14 Organising a Second Meeting

After most of the survey has been completed, some rough calculations have been made about the power potential and costs have been roughly estimated; it would be useful to have another meeting with the most of members of the communities. The participation should be as large and wide ranging as possible. In such a meeting, apprise them of the costs, possible problems or short-commings, and the end uses. It would also be useful to facilitate the formation of a Users Committee. In addition:

- reiterate the work involved, responsibilities, duties, and possible problems to be faced by the communities, in the management of the plant;
- prepare and agree upon a draft of an agreement between the community and the sponsor(s);
- discuss the possibility of other end uses, including agro-processing, saw milling, a workshop, etc; especially to use power during the off-pear period during the day. Adequate information may also be provided regarding the costs, power needs, methods of operation and maintenance, incomes, etc., for such machinery; if electricity was the main output of the plant, it may be more beneficial and even cost effective to use electrical motors situated at convenient locations to drive the industrial units;
- identify key persons/leaders of different communities/groups for further consultation in future;
- discuss further the other uses of water (present as well as figure ones) and assess any signs of conflict or difference of opinion. Try to assist in resolving such differences; discuss tariffs for domestic, commercial and industrial uses and put forward suggestions in this regard;
- work out some initial figures for incomes, expenditures and net incomes for the benefit of the users/owners;
- also, inform them how such incomes could be used in the best interest of the plant, its services and benefits to the communities:
- facilitate formation of a User or Management Committee having few members (- five); who are most interested and informed about the installation and operation.

The main objective of the meeting is to motivate and apprise the communities about the benefits of the MHP plant as well as the efforts, Organisation and hard work that is needed to make it a success.

3.15 Other Aspects during Preliminary Survey

A number of other aspects also need to be looked into, surveyed, assessed and analysed to arrive at conclusions or even opinions about the probability of the success of the plant (in terms of income, service, long term performance, etc). These aspects include the following.

Assessment of the Community

The community needs to be assessed concerning the following aspects.

- ♦ Keeness of the most community members for the MHP and electricity; and their willingness to actively support and work for the survey, installation, etc. As discussed earlier also, ideally, the community members or leaders should initiate efforts to install the plant in their area. Sometimes, however, the promoting agencies may also initiate the activities leading to a possible installation. In both cases, but more so in the second case, the communities and their leaders have to be motivated to provide assistance and contribution right from the beginning. The communities and their leaders would also have to be assessed as to how keen they were to support the installation process and contribute; which would also indicate the level of success of plant after it comes into operation. This assessment should be made more or less informally through dialogue, discussions and meetings. The level of support and assistance provided during the survey would also indicate their enthusiasm for the plant.

- ♦ Learn about conflicts within the communities and/or between different communities; and whether they would be able to collaborate' with each other. Other uses of water, eg., irrigation, washing, drinking, etc., should also be examined and opinions formed.

  Similarly, there may be differences of opinion regarding use of land for power house, channels, etc. The main concern here is whether one or more communities would be able to work together to make installation as well as the operation of the plant a success.

- ♦ Another aspect to be assessed is whether the community or some of its members (which need to be identified) have some **attitude for** business, management and things technical. Querries should be made concerning business experience (keeping shops/lodges, buying/selling agricultural commodities, etc.); and technical experience regarding water mills (ghattas), diesel mills, transport or some other machinery. Such investigation would also be helpful to identify prospective operators and even managers. This assessment may also be undertaken mainly through discussions with shop owners, traders, and community leaders.

These discussions may also be formal; however, more authentic information can be gathered through informal discussions in tea shops or other social places with different people.

- The third aspect should be the assessment of the capability of the households to pay the initial installation charges (which may be a few thousand rupees); including the wiring from the pole to the bulbs within the houses.

Obviously, there would be many families who would find it difficult to pay for the connection immediately. However, the aspect to assess is whether large proportion (say 70 per cent or more) of the potential customers was like that; then it means problem.

During the survey of the households, some idea about their total incomes (particularly cash incomes) may be made and a figure may be arrived at as to how many customers would get connected immediately after the powerhouse begins to supply electricity.

3.16 Environmental Aspects of MBP

A small-scale run-of-river type MHP plant installed in a remote area, is probably the least harmful option to the environment during construction, operation and in terms of materials used for construction. Nevertheless, some negative environmental impact is possible; especially, if the plant is not properly designed/installed. Most of the problems would relate to flow of water from stream to the forebay through the canal or to the powerhouse through the penstock. Following possibilities should be examined/investigated and precaustionary measures taken in this regard.

- Seepage of water from the canal, forebay or penstock causing damage to downstream lands, houses, etc., or causing erosion/landslides, should be minimised and a drainage system provided wherever possible.

  Breaching of the canal would cause more serious damage in a short time to the land or crops. Proper design and construction of the canal is again the answer.

Since the flow in such channels is usually quite low, the damage is almost never excessive. Also, the villagers/communities are capable of repairing the damage quite quickly. Nevertheless, it would not be a very good thing if the canal keeps breaking down frequently. Thus the design, construction and maintenance should be adequate.

Some tree or bush cutting may be necessary to construct the powerhouse, the civil structures and transmission lines. While this damage is never extensive or even significant, care should be exercised to fell minimum number of trees or bushes; which is usually possible by choosing an appropriate route for the canal & transmission,

Some minor environmental problems may also be encountered when the flow in the original stream becomes very low or it dries up completely. Although the dried up portion of the stream may be very small; usually less than I km; it may be inconvenient for some people who use it for drinking and washin-. The marine life may also be adversely affected in this portion. In this regard, **the** following precautionary measures are advisable.

Li Minimum prescribed flow should be left in the stream; even though this means reducing the power output.

13 If it is very necessary to divert riost of water for power generation; an study may be made to learn whether the effect on some fish or other important marine life would be severe.

El Also investigate how many people/families take water from the dried up portion of the stream for their normal daily needs; and whether they would face difficulties.

3.17 Financial Analysis & Viaibility

At this stage, when surveys are complete and the layout has been finalised, the costs, both capital as well as running costs may be calculated*'.

All costs must be included; eg; electromechanical equipment; civil works, construction materials, labour, transportation, tools & spares and so on. However, the expenditures for which cash payment must be made should be listed separtely as opposed to contributions or acquisitions in kind; such as free labour, free construction materials, free land and so on.

The running costs should mainly include; salaries of manager and operators, consumables and spares (grease, bushes for generator, bearing set) cleaning & maintenance of canal and civil works, and so on.

Then, an attempt should be made to estimate the incomes, from sale of electricity to various consumers (domestic, commercial, social/services and industrial). On this basis, net incomes may be calculated. For entrepreneur owned plants, the minimum acceptable net income should be 15 per cent of the capital investment; however, a more acceptable value is 20 per cent

(simple payback period 5 years or less)

However, for community-owned and managed plants which are to generate electricity for lighting and other domestic uses (radio, TV, etc), such high incomes are usually not possible. For such plants, a net income of about 5 per cent of the capital, would usually be considered satisfactory and viable; which would mainly be used for major repairs and-replacement of parts. However, if a loan is to be repaid, then, the yearly installment should also be included in the running expenses and the tariffs can be fixed accordingly to receive adequate cash income which is sufficient for loan repayment and a net income.

It should be made clear to every one concerned that above are only estimates; the actual expenditures and incomes may be considerably different. However, the more experienced and qualified the surveyors/estimators are; more accurate would be the estimates.

It should be emphasised again, that efforts must be made to utilise the maximum amount of energy available from the plant resulting in enhanced income without any additional investment. The possible end uses and industries must be discussed with the entrepreneurs or community leaders. Extra efforts would be needed to collect and provide information regarding the equipment, costs, operational techniques, training available, estimating the incomes and so Qn. Prospective entrepreneurs may also need information regarding possible sources of funding and procedures for getting loans. All - these additional but necessary efforts would be worthwhile for the promoters since it would mean increased financial viability of the plants and good name for an enviromnent-friendly energy source for the inaccessible and under-developed mountain areas.

3.18 Survey or Feasibility Report

The final outcome of the site visit, surveys and assessments would be a feasibility or survey report including the data, sketches/drawings, results, estimates and conclusions. This report may be prepared at the site or in the office after returning from the site and the final findings/conclusions should be whether the plant was viable; technically, financially and/or service wise. Almost all the information and data collected should be included in the Report.

An indicative table of contents is given below.

Location and description of project area. Economics and social conditions.

Description of site including settlements, population, households, shops, etc. (include sketch/map).

Main communities and lead persons

Demand survey; data-analysis, power demand estimate (minimum and desirable values) including possible and committed industrial end uses.

Reconnaissance survey & results (include sketch/map).

Meetings and discussions with entrepreneurs, community members/leaders and results of assessment (keeness, capabilities/cooperation/conflicts, economic, technical).

Preliminary Survey and results regarding:

· flow measurement

13 geological aspects/problems

13 layout survey and head measurements

'D location of civil structures and sizes (head, penstock length, forebay size, canal length, intake size type/structural details, weir type and size); include sketches/drawings

Some specific features or problems of the site/layout.

Is desirable or minimum power available; comments and recommendations whether to go ahead.

Other important aspects, e.g.; water uses, environmental aspects, social conditions and suggestions (e.,g funding to provide cheaper connections to poorer families).

Survey for transmission lines, distances, sizes, losses.

Costs, incomes and financial analysis.

Conclusions and specific suggestions.

Although many contents have been mentioned above; it is advisable to make the main report short (less than 20 pages). Some forms **filled** during the survey or some other papers may also be included. as annexures. The data in the Initial Inquiry Form may also be corrected and provided in the same or another form and other sketches, tables, etc., may also be included if necessary.

If the constraints on size permit, a few photographs of the site, especially those identifying locations of civil structures, should also be included in the report.

CHAPTER 4

Detailed Site Survey

4.1 Justification and Objectives

Preliminary survey discussed in Chapter 3 should indicate whether a MHP scheme is technically and financially viable. The main purpose of such a survey is to; determine the power available from the proposed scheme (ie., head and flow available), **fix** the locations of major structures and estimate the project costs. For MHP schemes in the lower range (installed capacity less than 20 kW), such preliminary survey is usually adequate to proceed to the design phase which might have been made somewhat more detailed. However, for schemes with installed -capacity exceeding 20 kW, a second more detailed survey becomes essential since more and precise data are required. Hence, compared to the preliminary survey a more indepth study is carried out in the detailed survey phase. The justifications for an additional detailed survey for larger MHP schemes are as follows.

Large investment is involved; therefore more accurate survey data should be collected to authenticate previous results.

Components such as lengths and bends for mild steel penstock, are pre-fabricated at the workshop and if the survey work is not accurate enough they will not fit at site; resulting in increased expenses and delays.

If the ground slopes and other technical parameters are not accurate enough, construction of the civil structures may be problematic.

Inaccurate estimates of the flow and head may result in under- or over-sizing the plant.

It is very important to involve the entrepreneur or the community members/ leaders/beneficiaries in the planning process of respective plants. It is the entrepreneurs and the community members who will operate and manage the schemes and therefore they need to be involved in the decision making process from the beginning. Furthermore, in case of disputes such as the headrace route traversing through a farmer's field, they are more likely to amicably resolve them.

There should be a gap of about two to three months between the preliminary and detailed surveys; so that the detailed survey can still be undertaken during the dry season. If possible, the gap should be about a year to include one monsoon season so that any changes at the site such as signs of slope instability and flood levels can be observed.

The detailed site survey of a MHP scheme includes the following aspects as described in the subsequent sections.

4.2 Flow Measurement

For streams having significant flow from snow melt the minimum discharge usually occurs during mid-winter (early February) and for those that originate from spring sources, this happens just prior to the pre-monsoon rains (April-May). If the site visit for the detailed survey is made during the low flow period, then the minimum discharge available for the proposed MHP scheme can be determined without further hydrological analysis.

During the site visit the flow measurement should be undertaken using at least two different methods discussed in Chapter 3 but more accurate ones if possible. For example, if a visual inspection of the flow indicates that it is less than 20 I/s then the bucket method would be accurate and reliable. For flows above 20 I/s, if possible, one of the two methods should be the use of the conductivity meter (salt dilution method). If the conductivity meter is in good condition and properly calibrated, it can measure flows very accurately as discussed in Chapter 3. However, the flow measurements derived using a conductivity meter should be independently checked using another method such as the weir method or a current mf:,,ter. This is because errors can be easily made with the conductivity meter and the equipment can also malfunction at site. For example, improper calibration or salt that has impurities can produce different flow results. Similarly, if the voltage of the batteries drop, the measurement will be grossly inaccurate.

It may be possible to use the weir method during the detailed site survey if a suitable location has been identified during the initial survey and the surveyor has measured the width of the river at the measurement site.

It is recommended that the surveyor undertakes flow measurements at least twice at a time. and on two different days. If all measurements are consistent, then the average figure should be used. If one set of measurement data is significantly different, then the reason for this should be sought; such as heavy rainfall during the previous night or low voltage of the conductivity meter. If a reasonable explanation cannot be found, then further measurements should be undertaken until the results become consistent. Con ' sistent results on two consecutive days using two different methods is the best indication of accurate and reliable flow measurement. Float method is not recommended for detailed flow measurements.

The flow measurement results can also be subjectively verified at site through discussions with the local community members. They are familiar with the flow conditions of the river. The following questions can be used as guidelines while discussing low flow conditions with the local community members.

Low flow questions

Is this the least flow (water level) or does it decrease further? If so by how much? 1/3 of the present level? Half the present level, etc.?

Has this been a normal year or exceptionally wet or dry year?

What is the lowest water level that you have observed at the proposed intake area and how many years ago was that?

Although, it is not generally necessary to determine the flood flows of the source stream, the flood levels are important, especially at the intake and the powerhouse sites. Structures (orifice, trashrack, etc) that are below the flood level can be damaged or get washed away during the annual flood. If the flood level is known, then permanent structures can be located safely and above the level.

The annual floods deposit sand/silt particles at the river banks and wash away the vegetation. Observing the level of such deposits and changes will indicate the annual flood levels. If there is exposed bed rock along the river banks, then the colour above and below the flood level on such rock is different. It is usually darker below the annual flood level.

The local community members are usually familiar with flood conditions and therefore the site observations cai-i be verified by carrying out discussions with them. The following questions can be used as guidelines while discussing flood conditions with the local community members

Floodflow questions

How high was the flood level at the proposed intake site during the last monsoon?
What is the highest flood level you have observed at this site in the last 20 years?
What is the highest flood level that you have observed in the last 20 years at the proposed powerhouse site?
Does the river carry large boulders during the annual floods? What is the largest size of boulder that the river can move during the annual floods?

4.3 Optimizing Location of Civil Structures

Before undertaking site measurements, the surveyor should inspect the proposed locations and routes a few times and verify that **the** layout selected during the preliminary survey is indeed - optimum. Changes such as relocation of structures should only be made if it becomes necessary in light of new observations. **For** example, if the headrace canal or penstock routes appear to be unstable or have been swept by landslides, then they will have to be relocated. Similarly, the recent monsoon flood levels may indicate relocating the intake and the powerhouse structures Flood issues have been covered in the previous section.

4.3.1 Site stability

It is essential to have some understanding of slope stability to identify possible problem areas so that the proposed scheme can be safely located. If a geologic al map of the project area is available, the surveyor should take it to site. Usually the scale of such geological maps are too small to cover the details required for the MHP project, but they will be useful for a general understanding of the area.

Locating all MHP structures on stable grounds will keep the design simple, lower construction costs and minimise future risks due to landslides or other instability problems. The presence of any of the following features would indicate unstable slopes.

Widening of landslip zones which may affect civil structures.

Widening or deepening of storm gullies along the route of canal and penstock.

Cracks along the ground slope (also known as tension cracks); the ground downhill of the crack line is liable to slide.

Trees leaning downslope or bending upwards from the base which indicates that the hillside is moving.

Water springs or seepage at base of slope which can cause slides on the slopes above if the drainage path is blocked.

Fresh rock faces exposed on a cliff indicates the falling of rocks which can damage the headrace or penstock routes below.

Presence of soft, weatherable rock which can easily erode during the rains. Open joints or cracks in rock.

Overhangs and loose rock.

Fresh debris and stoiie deposits at base of slope. Exposed tree roots indicating surface soil erosion.

Steeper profile at the base of slope.

Dead or overturned woody plants and grass clumps.

The following features indicate a stable slope along a hillside or a rockface at the proposed site.

Presence of complete vegetation cover at the proposed site.

A straight and even slope profile of the hillside.

Rock surfaces covered with moss, lichen or a weathered skin.

Hard, impermeable rock with few joints or cracks.

Well-packed debris, especially with fine material packed into voids between coarse material.

Well-established trees and shrubs standing vertically.

Stable storm gullies.

Often, slope instability is triggered by surface or ground water flow. Surface water and springs can be diverted from the civil structures by constructing catch drains along the canal and'penstock routes. Landslides are less likely to occur on a dry slope than a saturated one. Therefore, if instability problems are expected due to surface or ground water, their locations as well as the proposed alignment of the catch drain should be noted while at site. Catch drains are small canals that divert surface water (such as due to rain) away from the structures and keep the slopes relatively dry.

During the detailed site survey, signs of slope stability as discussed above should be investigated in the following key areas:

Above, and below the proposed headrace and penstock routes;

Below the proposed location of a settling basin or a forebay tank-,

Above and below the proposed location of the powerhouse.

Instability in these areas can weaken the support around the foundations through land slipping away or collapsing, or damage to structures through falling debris.

If changes need to be made; or if relocation of other structures is considered necessary due to variations at site, such changes should be made before undertaking site measurements.

The following additional aspects should be considered to optimize the locations of structures.

Weir and Intake

The proposed intake location should be such that it is possible to divert the flow from the river and towards the headrace, either naturally or by constructing a simple and low height'weir. The stream should be straight both upstream and downstream of the intake as discussed in Chapter 3. The river bed should be permanent at the intake site so that it does not meander or change its course leaving the intake dry.

If it becomes necessary to locate an intake along a river bend, then it should be located on the outside of the river bend but not exactly on the bend as discussed in Chapter 3 (Figure 3.9). The sediment load is relatively high on inside of the bend and as the flow recedes in the river the water course moves away from this location. On the other hand, locating the intake right on the outside of the bend makes it vulnerable to flood damages. Therefore, the ideal intake location is along an straight stretch of the stream; but if that was not possible, on the outside of the bend but upstream of it. This ensures the availability of flow during the dry season and minimises sediment load.

Headrace Canal

The canal should be diverted away from the river course as early as possible to minimize damage due to high floods. If signs of instability such as landslip, tension cracks or falling rocks are observed, the headrace alignment should be changed to avoid such unstable areas. For steep sections of the route, HDPE pipe may be a viable option.

Settling Basins

Generally, the first settling basin should be located as close to the intake as possible so **that** the sediments are removed early and the maintenance of the canal is minimized. The proposed location should be such that it is possible to flush the sediments without causing soil erosion or damages to other structures. If the stream is not far away the sediments can be discharged back into it. If possible, the second structure should be combined with the forebay to minimise cost especially when the length of the canal is short. However, if the canal was very short, one basin may be sufficient.

Forebay

Similar to the settling basin, the location of the f ' orebay should be such that it is possible to safely discharge the entire flow in case of sudden valve closure in the powerhouse (due to

system malfunction). If this structure cannot be combined with the settling basin, then another structure should be provided to settle the sediments.

Penstock Route

The penstock route should start where the ground profile gets steeper and should be kept as straight as possible since bends require anchor blocks and additional expenses. The flatter the ground slope, the longer would be the penstock. Ideally, a ground slope of around 450 (Ivertical:lhorizontal) is optimum. If the ground slope is steeper than this, then it will be difficult to lay penstock manually, construct support piers and anchor blocks. If signs of instability such as landslip, tension cracks or fallinc, rocks are observed, the penstock location

c'

should be changed to avoid such unstable areas.

Anchor Blocks

Anchor blocks should be located at the bends in penstock and near the powerhouse on a firm and stable ground. One anchor block should also be provided on straight penstock if its length exceeds 50 m.

Support Piers

These piers support the weight of the penstock pipe and water between the anchor blocks wherever it is laid above ground. It is usually economical to construct more support piers than to increase the thickness of the pipe to avoid it's sagging.

Powerhouse

There should be adequate space for a powerhouse with **the** required dimensions to **fit** the electromechanical equipment at the chosen location. Apart form being on stable grounds, the proposed location should also be safe from floods. Finally, it should also be possible to discharge the tail water safely back into the river.

4.4 Head Measurement

As discussed in Chapter 3, the head measurement involves determining the vertical height from the forebay to the powerhouse floor (turbine centreline). If the penstock route is straight and short (say less than 20 m), and an Abney level is not available, the head can be determined using the tube method. If the route also has vertical bends, then the tube method should not be used since such bends cannot be measured using this method.

For MHP schemes that have only a few vertical bends and a penstock length limited to say 50 in, the Abney level is generally the most appropriate equipment for measuring the head. it is

relatively inexpensive (- US$ 200) and weighs less than I kg. As discussed in Chapter 3, a record sheet should be prepared and all bend angles should be accurately recorded. Measurements should,always be taken at intermediate points where there are changes in the

ground profile. It is important to mark the measureinedt points on the ground by sinking wooden pegs or stones (or painting) so that installation is done accurately.

Most MHP schemes do not have horizontal bends, ie., the penstock alignment is straight on plan even if it may have a few vertical bends. However, for schemes where horizontal bends cannot be avoided, a theodolite or a similar measuring instrument becomes necessary. This is because it is not possible to measure horizontal angles with an Abney Level. Similarly, if the penstock length is long (> 50 in) or if the MHP scheme is more than 50 kW, a theodolite should be used to achieve higher and necessary accuracy. Use of such an equipment may require an experienced surveyor and additional cost. However, the cost of such a professional survey is almost always Justified compared to the added expenses due to an inaccurate survey work. It should be noted that an optimally designed scheme can reduce the project cost by 20 per cent or even more, and an accurate survey is a key to optimise the design.

4.5 Measuring and Demarcating Other Locations

The detailed site survey should also include measuring and demarcating the locations of all structures. Unless a theodolite is used to measure the head (in which case the same equipment can be used to measure otlier locations), an Abney level and a 30m tape is generally suitable for this purpose. The measurement should be carried out from the intake to the powerhouse and tailrace following the route identified and finalised during the preliminary and the detailed survey.

The detailed survey should include measuring the width and water depth at the proposed intake location. With the Abney level the river gradient upstream and downstream of the intake should also be measured. Then the ground slope and length along the headrace canal route should be measured. Similar to the head measurement described earlier, intermediate points where there are changes in the ground slopes should be measured. This will be useful in determining the canal bed slope during the design phase. The locations and levels (with respect to the intake or the powerhouse) of all major structures such as the settling basin, forebay, anchor blocks, support piers and the powerhouse should be measured and recorded during the detailed survey. The locations and lengths of the settling basin flushing system and spillways should also be measured at this stage. Similarly, all important features noticed during the site visit such as the locations of cliffs, landslide-prone areas and gullies should be recorded. Finally, the locations and routes of all structures should be marked on site (such as sinking wooden pegs or painting on rocks) so that they can be located without any difficulty during the construction phase.

It is advisable to finalize all survey calculations at site even if it takes a day or two longer. If errors are found in the survey data or if some additional information is required, it will be easier td,verify them at the site. It will be significantly more expensive if such errors are found at a later stage in the design office and a subsequent site survey is required.

It is also recommended that the surveyor. takes a ser ' ies of photographs that can be combined to show the general layout from the intake to the powerhouse as well as locations of all major structures. These photographs will be useful in recalling the features of the scheme in the

desi(yn office later or for further discussions such as when expert advice is sought for. Finally, **t@**
the surveyor should also prepare at least a general plan of the scheme and the adjoining area using an appropriate scale as discussed in Chapter 3.

4.6 Final Decision

Based on the site observations and survey work, the decision should be made whether to proceed for construction work for schemes with less than 20 kW of installed capacity or detailed design phase for larger schemes.. If major technical difficulties are found during the site visit such as long and difficult headrace crossing or landslide areas requiring significant retaining structures, the decision could be made not to proceed further. The surveyor or the designer should bear in mind that not all the sites are feasible and a decision Dot to proceed further with unfeasible schemes saves further expenditures.

If the scheme is technically feasible (e.g. headrace and penstock routes are along stable alignment), then a decision should be made to proceed further.

4.7 Survey Report

After completion of the survey work, a report should be prepared describing all aspects of the scheme. Such a report is usually prepared in the office when the team returns back from the **field** and in consultation with other senior staff. The report should cover the following.

Results of flow measurements; review of sites, other survey changes in the layout if any and, the reason thereof; results of the meetings; and the final decision in reasonable details.

In addition, the following maps/sketches/drawings along with all the forms, record sheets, etc., **filled** during the detailed survey should also be **included** as annexes.

LI General plan of the project area including the location of the scheme and the community that it serves.

C3 General plan of the MHP scheme showing the locations of all civil structures.

cl A plan and cross sections for the sites of the above structures.

Availability and cost of construction materials including cement.

Site photographs with clear labels indicating the locations of the major structures.

The available power may also be calculated using a more accurate power equation, P = 9.81 x -q x Q x k,,t as opposed to an approximate one used in Chapter 3. The efficiency **'Tl'** would depend upon the type and quality of the turbine and k,,t may be calculated from the measured head (h.) after determining and deducting the friction losses in the penstock.

CHAPTER 5

Design of Scheme

The design of a MHP scheme involves specifying the locations, sizes, materials and other parameters of all components which are to be constructed or installed at the site. An ideal design should be such that based on it, an experienced installer should be able to construct the scheme independently or with nominal assistance from the designer.

The design of the scheme is primarily based on the information obtained during the various surveys. Therefore, it can only be as good as the results of these surveys. The design process is iterative since the dimensions and other parameters of the MHP components are interdependent.

5.1 Diversion Weir

A weir should be constructed to raise the water level in the river upstream, if the river flow cannot be naturally diverted into the intake during the low flow period. In rare cases, it may be possible to locate a suitable natural weir comprising of large boulders which requires minimum additional construction work such as placing more boulders or gabions. However, the most comm. on weir type suitable for the MHP plants is the temporary weir ' constructed or repaired every year after the annual floods. For schemes located in remote areas, this option is appropriate and economical since such a weir does not require cement or skilled labourers. Usually, two types of temporary weirs are prevalent.

A weir across the whole width of the stream, the main design parameter being the height (Fig. 5.1).

Diversion dam which extends along the length of the stream but gradually moving towards the centre to divert more water (Fig. 3.10.b). This type of dam is suitable for low flows and for continuous demand at a particular time. It can be further extended if more river flow needs to be diverted.

More permanent weirs constructed from gabions, masonry or concrete, should be considered only if the river does not move boulders during the floods, the site is less than a day's walk from the roadhead and. there is a scarcity of water during the dry season. Permanent weirs can be constructed of plum concrete (1:3:6 with 40% plum), or stone masonry in 1:4 cement mortar. Gabion weirs are semi-permanent structures which usually require some annual maintenance.

For both permanent and temporary weirs, the height should be kept as low as possible but enough to divert the required flow and the slopes shou ' id be gradual so that boulders can roll over them. In order to determine. the height of a temporary or permanent weir the river depth/level during the dry season must be known along with the upper height of the orifice

(intake mouth discussed in section 5.2). The intake height should be such that the water level rises above the upper edge of the orifice. For temporary weirs the height may have to be increased or decreased during the operation of the plant.

5.2 Intake

The intake should be so designed that the head loss is minimal and the entry of excessive flow (during floods) as well as bed load and other floating debris is minimised. Side intakes are most commonly used in MHP schemes since they are simple and less expensive than other types and most suitable for run-of-river type plants.

5.2.1 Design of Side Intake

A side intake can be designed either as an extension of the headrace canal (without any proper orifice) as shown in Fig. 5.1 or as a rectangular orifice (Fig. 3.9). If designed as an extension of the headrace canal, the procedure is to design a canal (discussed in section 5.3) capable of conveying the design flow and extend it to the side intake at the river bank. The initial length of the headrace that is in the flood zone of the stream is sometimes made wider to allow for seepage, especially if this section is of a temporary nature. A disadvantage of this type of intake is that it is not automatically possible to limit excess flows from entering the headrace during floods.

A rectangular orifice **is** an especially constructed opening in the side wall along the river bank as shown in Fig. 5.2, which allows the design flow to enter into the headrace but limits excess flows during floods. It should be sized such that it is submerged for the design discharge during the low flow season since this will limit excess flows during floods. An alternative to an orifice is to install a gate irrunediately downstream of the intake. This allows more control on the flow by varing the opening of the gate. However, such gatel, require more maintenance work and are also more vulnerable to flood damages.

The discharge through an orifice for submerged condition is:

Q= AxV= AC

where:

Q is the discharge through the orifice in m'/s

* is the velocity through the orifice in m/s

* is the area of orifice in in'

hriver - hheadrac, is the difference between the river and the headrace canal Water levels (Fig. 5.2).

C is the coefficient of discharge of the orifice. For a sharp edged and roughly finished fully submerged concrete or masonry orifice structure, this value is as low as 0.6 and for carefully finished and smooth opening, it can be up to 0.8. If it is economically feasible to construct such an orifice then the excess flow can be minirnised during the monsoons.

River flow leqel **h river - li headmice**

river

A **DA** ***rum***

A section through weir A sectiovi **,IlrOUgh5Ljbmerged**

0 r i6ce

Fig. 5.2 A **section through** a **weir and** a **submerged orifice**

The size of the orifice is calculated as follows.

Assume an initial velocity through the orifice which is less than 3 m/s. Then calculate the required area of the orifice opening using Q = V x A.

For a rectangular opening, A = W x H where W is the width and H is the height of the orifice. Set H such that the water surface level at the headrace canal immediately downstream of it is slightly hi-her than the upper edge of the orifice. This ensures that the orifice is submerged. Calculations for the water level in the headrace are discussed in section 5.3.

Now calculate h,i,,, for the design flow conditions. This can be done by either rearranging the orifice equation (since all other parameters are known) or by trial and error. The h,i,,, is the water depth that needs to be maintained in the river during normal conditions. If the actual level in the river is less during low flow for practical orifice size a weir crest level will have to be equal to hri,e, (Fig. 5.2).

If the flood level in the river is k nown, the flow through the orifice for such condition should be calculated using h,i,, = flood level (which can be determined by noting flood marks or information from the local community). With known flood flow in the headrace, the water level in the canal can be calculated as discussed in section 5.2. The excess flow will have to be spilled back into the river or nearby gullies. Note that if a weir is placed across the river, the flood level may be somewhat higher than before since the weir raises the water level. For temporary weirs this is not a problem since they normally get washed away. If a permanent weir is used, allowances should be made for this when calculating hri,,@r (such as by adding the weir height above the measured flood level).

5.2.2 Trashracks for side *intakes*

A coarse trashrack should be placed at the intake mouth to prevent floating logs, cobbles and boulders from entering the headrace canal and hence causing damage. Such a trashrack is fabricated using flat steel plates, angles or bars (square or circular, about 25 mm diameter) that are welded together at fixed intervals. Since the course trashrack can get continuously impounded by cobbles and other large particles, it needs to be strong. A bar spacing from 50 mm to 200 mm is generally adequate depending on the size of cobbles that the river carries during floods.

5.3 Headrace canal

Many types of headrace canals are used in MHP schemes, as described below, depending upon the materials and methods of construction.

Simple earthen or unlined canals

These are constructed by simply excavating the ground to the required canal shape and 4re the most economic type. Such canals can be used on stable ground where seepage (which usually exists) is not likely to cause instability problems such as landslides. Compaction of the earth and planting vegetation on the canal banks will increase stability and reduce seepage.

Stone **masonry in mud mortar canals**

The second more stronger option is stone masonry in mud mortar. Compared to an earthen canal, there will be less seepage from this type of canal but its construction will require more labour, materials and funds. These canals should be used where small amount of seepage does not cause slope instability or where flow is.limited (i.e. higher flows cannot be allowed in the canal to compensate for seepage).

Stone masonry **in cement mortar** canal

The advantage with this type of canal is that compared to earthen or stone-mud canils, seepage is minimal. However, this is significantly expensive than the above two types due to the cost of cement involved. Therdfore, a stone masonry in cement mortar canal should ordy be used at locations and for portions where the soil type is porous leading to high seepage losses or if seepage is likely to trigger landslides.

Concrete canal

Concrete canals are rarely used in MHP schemes. except for short lengths at difficult locations, since they are more expensive than cement mortar canals. There is virtually no seepage through such canals. However, if the area is not stable then the whole structure can slide unless properly restrained or supported.

Covered canals and pipes

Where stones and other debris are likely to fall from above the headrace route, the canal can either be covered or pipes may be used. Flat stones are an economical way of covering canals and an expensive alternative is to use reinforced concrete slabs. Buried pipes such as HDPE also offer protection from falling debris. Another advantage of HDPE pipes is that they are flexible and can adjust to some ground movements.

5.3.1 Design of Headrace canals

The canal dimensions and cross sections are governed by the following criteria.

Flow and velocity

The cross sectional area should be such that the velocity is within the limits for the design flow (Table 5. 1); and freeboard should be allowed for excessive flow.

Side slopes

The stability of canal side walls depend on their slopes for a given type of material used to construct them. For example, vertical side wall of a simple earthen canal will not be stable over a long period compared to stone masonry in cement mortar or concrete. The side slope (N) in this chapter is defined as the ratio of.the horizontal length divided by the vertical length of the canal wall as shown in Fig. 5.3. The recommended side slope for different types of canal is presented in Table 5. *1*.

Headloss and seepage

Headloss can be mininiised by maintaining the canal route on even to gently sloping ground. Headloss is also governed by the type of canal as well as the number and magnitude of bends. There are less frictional and head losses as the water flows over a smooth surface of cement plaster. The frictional losses are indicated by the roughness coefficient "n" which are given in Table 5.2. for different types of canal.

Table 5.2 Roughness Coefficients for Different Canals

Canal **type**	**Description**	**Roughness coefficient In.**
Earth	Clay, with stones and sand, after ageing	0.020
	Gravelly or sandy roams, maintained with minimum vegetation	0.030
	Lined with coarse stones, maintained with minimum vegetation	0.040
Rock canals	Medium coarse rock muck	0.037
	Rock muck from careful blasting	0.045
	Very coarse rock muck, great irregularities	0.059
	Rubble masonry in mud mortar	0.025
Masonry **canals**	Brickwork, bricks, also clinker, well pointed: cement mortar	*0.015*
	Normal masonry: cement mortar	0.017
	Coarse rubble masonry, stones only coarsely hewn, cement mortar	0.020

Concrete canals Smooth cement finish 0.010

Concrete when wood formwork is used, unplastered	***0.015***
Tamped concrete with smooth surface	0.016
Coarse concrete lining	0.018
Irregular concrete surfaces	0.020

Design Procedure for Canals

I . Decide on **the** canal type according to site conditions considering stability and seepage factors (refer to page 53).

2. For the type of canal selected, choose a suitable velocity (V) by referring to Table **5. 1;** and note the corresponding roughness coefficient (n) from Table 5.2.

3. Calculate the cross-sectional area (A) from the equation: A = **Q**

4. Usink, Table 5.1 decide on the side slope (N).

5. Calculate the required dimensions using the following equations:

· x I(] *N'@)* - 2 *x* N, (where X optimizes the canal shape) (2)

A

hheadrace @ (3),

N

hhea(!racc is the depth of water in the canal as shown in Fig. 5.3

B = X **x hheadrace 9** B is the bed width as shown in Fig. 5.3.

T = *B* (2 *x hh,,,d,,,,, x N)* (4),

T is the top width as shown in Fig. 5.3.

Note that in case of a rectangular canal, N = 0 and X = 2.

If because of conditions at site, an optimum canal shape is not possible (such as narrow canal width), then either the width or the height should be selected to suit the site conditions.

7. The velocity must be less than 90% of the "critical velocity limit"

VI *(5)*

X 9

to ensure uniform flow in the canal. if the canal velocity is greater than 0.9V, then repeat calculations with lower velocity (ie., start from step 2).

8 . Calculate the wetted perimeter (P) using the following equation:

P = *B* 2 *x hi,,,,d,,,,, x* @(I *N2* (6),

9. Calculate the hydraulic radius (R) as follows:

R = *AIP* (7)

10. The slope (S) can now be found from Maniiing's equation:

nxV

0.667 (8)

R

11. Now calculate the head loss in the canal as follows.

Head loss = L x S where L is the length of the canal section. If the slope of the canal varies at different sections, calculate the head loss for each section and add them up. If the loss is too high or if the actual ground slope is different than ' he calculated canal slope, repeat calculations with different velocities.

12. Allow a freeboard of about 300 mm for flows up to 500 I/s.

5.3.2 Design of a Spillway

The excess flow that enters into the intake during flood flows needs to be spilled as early as possible. This is achieved by incorporating a spillway close to the intake. If the headrace canal is long, another spillway may be required along the canal section such that the entire design flow can be diverted if the canal is blocked due to falling debris from above or landslides.

Finally, a third spillway is almost always required at the forebay to spill the flow in case of sudden valve closure at the powerhouse such as during emergencies. The sizing of spillway is based on the following equation.

Lspi <u>*Q.flood - Q(It@vigri*</u> (9)

'wa@ 1.-6 x *(hfli)od -hp)l.*

Where Qn,,w is the flood flow that enters the intake in M3/S Qdesign is the design flow in the headrace canal h,low is the height of flood level in the canal hsp is the height of the spillway crest from the canal bed.

A spillway section is shown in Fig. 5.4.

The design procedure involves first calculating the maximum height of the water level in the canal during the flood (hfl,.d). Then the height of the spillway crest level (kp) is set such that it is above the design water level by about 50 mm. This ensures that part of the design flow is not spilled which would decrease the power output. 'l.6' is a coefficient for a broad crested weir of the spillway with round edges which is easy to construct.

5.4 Settling Basin

The settling basin for a MHP scheme (Fig. 5.5) should have the following characteristics.

The settling area should be large enough to reduce the velocity sufficiently to settle the sediments in the basin.

Easy flushing of the deposited silt should be possible.

It should have the required volume to store the settled particles until they are flushed.

The discharge and sediments flushed from the. basin should be safely led into the river or a nearbv gully without causing erosion problems or damages to other structures.

Sharp bends before or within the basin should be avoided since they cause turbulent flows and prevent the settling of particles.

To reduce costs, one settling basin should be combined with the forebay, if possible.

5.4.1 Design of SeUling Basins

The design of the settling basin is based on the following assumptions.

Particles having diameters larger than or equal to 0. 3 mm are, only settled.

A reasonable sediment emptying frequency of the basin is twice a day (ie., 12 hours) during monsoon period. It may not be convenient to empty the basin more often since this will interrupt power production. Similarly, if the flushing interval is increased a larger storage capacity will be required. Since the silt load in the river is less during the dry season, the emptying frequency then could be as low as twice a week.

The density of sediments is about 2600 kg /M3 when dry. However, when submerged, they occupy more space -and therefore the density decreases. This is measured in terms of packing factor. In this case the packing factor is about 50%, ie., the density of sediment decreases by half when submerged.

The concentration of suspended particles in the river flow varies seasonally and also depends on factors such as geology and vegetation cover of the catchment area.

Therefore, it may be difficult to obtain data on sediment concentration. In such a case, it is reasonable to design the settling basin for 5 kg/n@ of sediment concentration for

monsoon flows.

The design procedure is as follows.

1 . Choose a suitable basin width, W, which is 2 to 5 times the width of the headrace canal, depending upon the available width at the site (larger the better).

2. Calculate the settling length (L,,,,Ii,,g) using the following equation:

Lsettling <u>*2Q*</u> (10)

W *X VI-,Ili,.,*

Where Q is the design flow in m@ls.

Use **Vvertical =** 0.03 m/s which is the fall velocity for 0.3 mm particles.

Normally, the length of the settling basin should be between 4 -10 times the width.

3. Calculate the expected silt load,Sl,,,dl in the basin using the following equation;

Sl,,,d **=** Qx Tx C (i 1)

where;

SI.ad = silt load in kg stored in the basin

Q = discharge in **M3/S**

T = Silt emptying frequency in seconds. Use 12 hours= 12 x 60 x 60 = 43,200 S

C = Silt concentration of the incoming flow in kg/m@ as discussed earlier.

Use 0.5 kg/m" in the absence of actual silt concentration data.

Dsettling == Depth of settling (water depth above **Dcollection)**

4. Now calculate the volume of the silt load using the following equation:

so 1 (12)

where;

vo@il, = Volume of silt stored in the basin in **M3.**

Sdensiry @ Density of silt = 2600 kg/n@, Unless other reliable data is available, this value

should be used.

Pfactor = Packing factor of sediments submerged in water = 0.5 (50%).

The settling zone should have the capacity to store the calculated value of VO,il,. This storage space is achieved by increasing the depth of the basin for the area calculated earlier.

Now calculate the average collection depth required, d,,,Ilcction

Dr.ollecti.on= *(13)*

Lv(!Illitpg x TV

Tapered entry length evenly distributes the incoming flow in the basin (Fig. 5.5). The entry length should be at a 1:4 slope as shown in the figure. The exit length can be sharper, i.e., up to 1:.7. Note that the exit length is not required if the settling basin is combined with the forebay.

5.5 Forebay

If an earthen canal is constructed between the settling basin and the forebay, sometimes high velocity in the canal (such as during monsoon) can cause erosion and carry sediments to the forebay. In such cases the forebay should also be designed to serve as a secondary settling basin. However, if the headrace upstream of the forebay consists of HDPE pipe or of cement masonry canal and the settling basin is functioning well, there may be no need for secondary settling.

Apart from the need for secondary settlement, another function of the forebay is to provide adequate submergence for the penstock mouth so that the transition between open channel to pressure flow in a pipe can occur smoothly. If the submergence head (depth of water above the crown of penstock pipe) as shown in Fig. 5.6 is not suffic@ient, the pipe will draw in air and the flow in the penstock will fluctuate. The minimum submergence head required for the penstock pipe is as follows:

$$h_{submergence} \quad 1.5 \frac{V^2}{2g} \qquad (14)$$

where; V is the velocity in the penstock.

The minimum size of the forebay should be such that a person can get in and be able to clean it. Even if sediment load is not to be generally expected in the forebay, it may sometimes reach this structure, eg., when the settling Pasin is filled up quickly during the monsoon or, rain water enters the canal. If a person can get into the forebay and clean it occasionally or during the annual maintenance period, this will not be a problem. This is another reason for providing the gap between the bottom of the penstock pipe and the floor of the forebay as shown in Fig. 5.6.

Incorporating a gate at the entrance of the penstock will make the maintenance work of the turbine easier. The gate can be closed, thus emptying the penstock and work can continue on the turbine. However, a rapid closure of this gate may create a negative pressure (i.e., vacuum) inside the pipe and can even cause it to collapse. Placing an air vent as shown in Fig. 5.6 will prevent such a situation since air can be drawn from the air vent pipe into the penstock.

The trashrack at the forebay should be placed at 1:3 slope for both efficient hydraulic performance and ease of cleaning (such as by raking). The spacing between the trashrack bars should be about half the nozzle diameter for Pelton turbines and half the spacing between blades for crossflow turbines. This prevents the turbines from being obstructed by sediments and minimises the chances of surge.

5.6 Penstock

The sizing of the penstock pipe requires selecting an appropriate diameter and wall thickness so that the headloss is minimal and the pipe is strong enough to withstand the high pressure (surge) due to sudden blockage of flow. The length of the pipe can be determined from the

survey data.

Mild steel and HDPE pipes are the most common penstock materials used in MHP schemes. HDPE pipes are usually economical at low head and flows and are also easy to join and repair. They are also flexible enough to accommodate small, angle bends or radial expansions due to pressure surges and are light. The disadvantage is that these pipes can degrade from ultraviolet rays (sun light) and temperature variations and hence need to be buried.

5.6.1 Design of penstock pipe

Pipe diameter

The following equation should be used to select the pipe diameter if the penstock length is less than 100 m:

D = 41 X *QO- 18 (15)*

where D is the pipe diameter in mm and Q is the design flow in I/s.

If the penstock pipe is longer than 100 m, a detailed analysis is required which is beyond the scope of this manual and other texts should be referred to.

Pipe thickness

The thickness of the pipe depends on the pipe diameter, the material and the type of turbine selected. The surge effect is different for different types of turbine and hence the pipe thickness can differ even when the design flow, static head and the pipe materials are similar.

The sizing of wall thickens for Pelton and crossflow turbines are as follows.

For a Pelton turbine use the following method to calculate the surge head:

1 . Calculate the pressure wave velocity 'a' using the equation below. 1400 (16)

2.lxlO9x d

Ext

where;

the value of Young's Modulus (E) for mild steel is 210 x **109** N/n@ and for HDPE it is 0.2 to 0.8 x 109 N/m@.

d is the pipe diameter in m

t is the wall thickness in m

2. Then calculate the surge head (h,u,,,), using the following equation:

av I

hsu,ge *(I 7)*

g n

where:

n is the number of nozzles in the turbine(s). Note that in a Pelton turbine it is highly unlikely for more than one nozzle to be blocked (by silt/stones) instantaneously. Therefore, the surge head is divided by the number of nozzles (n).

The velocity in the penstock, V*4Q* (18)

)zd**2**

3. Now calculate the total head:

hiotal = hgross ***h,.rge*** **(19)**

4. If the pipe is mild steel, it is subject to corrosion and welding or rolling defects.
Its effective thickness will be less than what it is in the beginning (t). Therefore, for mild steel, assume an initial thickness (t) and to calculate **t,ff,,,iv,** using the following guidelines:

a) If the pipes are joined by welding divide the initial thickness by 1. I
b) If the pipe is prepared by rolling flat sheets, divide the initial thickness by 1. 2

C) Since mild steel pipe is subject to corrosion, subtract 1 mm for every 10 years of plant life or a part there of

For example, the effective thickness of a 4 mm thick flat rolled and welded mild steel pipe designed for a 10 years life is:

4 _ I = 2.03 *mm*

teffective **1.1** xl.2

Note that this does not apply for HDPE pipes where the effective thickness is the same as the thickness of the pipe in the beginning.

5. Now calculate the safety factor (SF) from the following equation:

SF, ***t@ffeciive X*** S (20)

5xh..... , xlo'xd

where;

S is the ultimate tensile strength of the pipe material. in Nln@. For mild steel S is usually taken as 350 x 10' N/m. For HDPE the value is between 6 - 9 x **106** N/M2.

d is the internal diameter of the pipe in m.

6. If SF < 3.5, reject this penstock option and repeat calculation for a higher thickness.

In a crossflow turbine, instantaneous blockage of water is not possible since there is no obstruction at the end of the manifold; unless, an additional valve is also provided. Therefore surge pressure,can develop only if the runner valve is closed rapidly.

A simple procedure to determine the thickness of the pipe for a crossflow turbine is to add 20% to the gross head to allow for surge pressure, i.e., **Notal @-- 1.** 2 x hgross' This results in a more conservative value for the surge head but its contribution to the increase in the thickness would be insignificant since crossflow turbines are used for low head schemes.

Once the total head is known, the procedure is the same as for the Pelton turbines (ie., start calculations from step 4 of tie Pelton turbine).

5.7 Anchor blocks

An anchor block is a mass of concrete fixed into the ground and holding the penstock to restrain the pipe movement in all directions. It is constructed of plum concrete which is 1:3:6 (1 part **cement,** 3 parts sand, 6 parts aggregate) with about 40% boulders placed everdy around the block as shown in Fig. 5.7. The boulders add weight to the block and therefore increase stability while decreasing the cement volume required. For MHP schemes with a gross head less than 60 in and a design flow of less than 200 I/s, the following guidelines can be used to determine the size of an anchor block.

For straight sections, locate one an ' chor block after every 30 in length of penstock by placing 1 **M3** of plum concrete for a pipe diameter of 300 mm. If the pipe diameter is less, say 200 mm, then (200/300) **x** **1** m' = 0.67 m@ of concrete volume is required for every 30 m straight length.

At penstock bends less than 45', double the concrete volume than what is required for a straight section. For example if the pipe diameter is 350 mm and the bend is 20', then

M3 **M3**

(350/300) **x** 2 = 2.33 of concrete is required for the anchor block.

If the bend angle is larger than 45', then the required concrete volume is three times that for a straight section.

For larger MHP schemes, a more detailed calculation is required which is beyond the scope of this publication.

5.8 Support piers

Support piers restrain the vertical forces of the penstock due to the weight of the pipe and water. However, they allow the axial movement due to thermal expansion or contraction

(Fig. 5.8).

Support piers are generally constructed out of stone masonry in 1:6 cement - mortar. Placing a metal plate above the support pier where the penstock pipe rests, minimizes frictional effects and increases the useful life of the pipe. Another semi-circular strip circumventing the penstock, is usually bolted to the pier to provide some control over the unwanted movements.

For welded mild steel pipes or flange connected one having British Standard specifications (minimum flange thickness = 16 mm), Table 5.3 should be used to determine the spacing of

the support piers.

Note that in Table 5.3 the support pier spacing is the horizontal (plan) length and not the sloping length of the pipe. For flanged mild steel piples that do not meet the British Standard, one support per individual pipe length should be used and the pier should be placed in the middle. Also note that support piers are not required for buried pipes.

For small MHP schemes < 60 m and Q < 200 I/s) if the penstock pipe is less than 1 m above the ground, Fig. 5.8 can be used as a guide for the shape of the support pier. The minimum length and width at the base should be 1 m x I m and the top width parallel to the penstock alignment should be 0.5 m. The width at the top of the support pier at right angle to the penstock pipe route should be about 1 m and the up@,ill wall surface should be perpendicular to the penstock pipe. Based on the soil condition a minimum foundation depth of 300 mm should be provided.

For larger schemes or if the penstock pipe is more than 1 m above the ground, a detailed calculation is required which is beyond the scope of this publication.

5.9 Expansion joints

Above ground penstock pipes are subjected to expansion or contraction in length **due** to changes in the ambient temperature. The change depends on the change in temperature and the type of pipe material used. Table 5.4 can be used to determine **the** changes in lengths for mild steel pipes of various lengths and temperature ranges. For intermediate values, the expansion lengths can be extrapolated. Note that the maximum expected temperature variation should be used (such as when the pipe is empty during mid summer afternoon and **the** least winter temperature).

A sliding type of expansion joint shown in Fig. 5.9 is commoniv used in MHP schemes; which can be placed between two consecutive pipe lengths and can either be welded or bolted to the pipes. The stay rings are tightened which compress the packing and prevent leaking. Jute, rubber or similar type of fibre is used for packing. The penstock pipe expansion or contraction is acconunodated by the gap in the expansion joint. Therefore, the gap in the expansion joint should be about twice the expansion length derived from Table 5.4.

5.10 Powerhouse

The main function of the powerhouse is to protect the electromechanical units from rain and other whether effects. Costs can be brought down if the construction is similar to **other** houses in the area. The powerhouse walls can be built of stone masonry in mud mortar with cement pointing on the surfaces. The roof can be covered with corrugated galvanized iron (CGI) sheets. The powerhouse should have adequate space so that all electromechanical equipment can fit in and be easily accessible for operation and repair work. If agro-processing units are also installed inside the powerhouse, additional space should be provided so that it is not overcrowded when people get in with their grains. While sizing the powerhouse, first all electromechanical units should be drawn to scale and laid out such that they fit in the plan area of the drawing.

The machine foundations should be constructed out of reinforced concrete so that all the loads including the dynamic forces of the generator and the turbine are properly supported and the alignment is not disturbed over the years.

5.11 Turbine type, size and accessories

Crossflows and Peltons (*5.* 10) are the two most commonly used turbines in MHP schemes. The type and size of the turbine to be selected for a, particular site depends on the net head **,t** hgross - losses) and the design flow.

Generally, crossflow turbines are used for high flow and low head schemes and are suitable for heads of less than 50 m. Conversely, Pelton turbines are used for high head, low flow schemes and are the only alternative if the net head exceeds 100 m. Note that Pelton turbines can also be used for a lower heads (50 in > h > 100 m). A single jet Pelton turbine is usually less expensive than a multi jet one. However, a single jet may require a large runner and the penstock pipe may also have to be thicker for surge requirements as discussed earlier.

The Nomogram shown in Fig. 5.11 can be used to select an appropriate turbine based on site conditions. The selection procedure is as follows.

First draw a straight line connecting the turbine shaft power and the net head. Note that the turbine shaft power = 1. 1 x power output. This allows for about 10 % loss in the generator.

> Now select a suitable turbine shaft speed (RPM) and extend a line from this point so that it is perpendicular to the previous line (turbine shaft power to head) as shown in Fig. 5. *1* 1. This second line will point to either a single jet Pelton, multi-jet Pelton or a crossflow turbine. If the line ends at the overlap region on turbine types, then both types are feasible. If the line ends beyond the crossflow range, try again with a different RPM.

Note that turbine shaft speed of 400 RPM to 1500 RPM are suitable range for 1500 RPM generator. If possible for electrification schemes, the turbine shaft speed should be set at 1500 RPM which allows for direct coupling between the generator and the turbine since most MHP generators are designed to operate at 1500 RPM@ However, this is only possible with fast

running Pelton turbines. For the crossflows, the usual rated speed is between 400 -to 1000 RPM. In such cases, a belt drive having requisite speed ratio will be required. Once the turbine type and the RPM are known for a fixed head and flow, their price can be obtained from the manufacturer.

5.12 Generator type and size

Induction or synchronous type generators are mostly used in MHP schemes. Induction generators are inexpensive and appropriate for very small schemes up to 10 kW. For larger schemes, the induction generator load controller may not be very reliable. For the required power output, Table 5.5 below should be used to select the type of generator.

Table 5.5 Selection of generator type

Description Very small schemes Small schemes 10 kW to Medium to large
up to 10 kW 20 kW schemes, over 20 kW-
Type of generator Induction, Single or 3 Synchronous, 3 phase Synchronous, 3
phase, only phase only
2' choice; 2 nd choice; Induction, 3
Synchronous hase only
p

Once the generator type has been determined, the required nominal generator output power in kVA should be calculated using following equation.

Generator nominal rating in kVA = Power output in kW/ (A x B x C x D) (21)

Note that the Power output is the available power in kW calculated using the power equation. The factors A, B, C and D can be found from Table 5.6.

Table 5.6 Factors affecting generator rating

	Ambient temp. in oc		20	25	30	35	40	45	*50*	*55*
A	Factor	1.10	1.08	1.06	1.03	1.00	0.96	0.92	0.88	
B	Altitude in m	*1000* - 0	*150*	2000 -@@ 0	2500	300	3500	4000	4500	
	Factor	1.00 0.96 1 0.93 1 0.90 1 0.86 _, 0.83					0.80	0.77		
C	ELC factor	correction Without Electronic Load Controller						1.00		
With Electronic Load Controller				0.83						
LD- L	Power	factor@@	When only light bulbs are used					0.95		
		When tube lights and other appliances are used					0.80			

Example

Determine the generator rating for a MHP scheme designed for a power output of 20 kW. The site is located at 1700 m above sea level and the ambient temperature inside the powerhouse during mid summer afternoons can be up to 35 IC. An ELC will be used in the plant and the villagers also plan to use tube lights.

Calculations

A = 1.03 for 35 IC

B = 0.96 - (0.03/500) x 200 = 0.95 for 1700 m altitude.

C = 0.83 with ELC

D = 0.80 when tube lights are used

Required generator rating (kVA) = Power-output in kW/(A x B x C x D)

= 20/(1.03 x 0.95 x 0"83 x 0.80)

= 31 kVA

Note that if the calculated rating (kVA) of the generator is not available in the market, the next higher one should be selected. In the alove example, a 35 kVA generator may have to be purchased. However, since the calculations such as the above are never really accurate, a 30 kW generator may also be considered; especially if the cost differences are significant.

5.13 Transmission line

The power generated in the plant needs to be distributed to the consumers via the main transmission and distribution lines.

Selection of underground or overhead lines

Transmission lines can either be buried (underground) or installed overhead on the poles. Overhead lines are more commonly used since they are less expensive and easier to install than underground lines. Overhead lines are also easy to repair and maintain. However, when houses are more densely located or heavy snowfall is expected during winter, underground transmission lines may be a viable alternative; which, if properly installed and protected, would need very little maintenance.

Selection of high voltage or low voltage

If the powerhouse is far from the villages (load centres), high voltage transmission may be required along with step-up and step-down transformers to reduce line losses. However, this is an expensive option. In such a case the transmission voltage is stepped up to 1 1 kV via the transformer at the powerhouse and stepped down to 400 V at the village with another transformer. Then a low voltage (400 V for three phase and 220 V for single phase) distribution line is used. The general rule is to use low voltage transmission line if the product of the power produced and the length of transmission is less than 54 kw.km (i.e., Power output x transmission length < 54 kW.km). Also note that if the installed capacity exceeds 10 kW, three phase transmission line should be used.

Sizing of overhead transmission cables

Aluminum Conductor Steel Reinforced (ACSR) cables are generally used for overhead transmission lines of MHP schemes. These are available in various sizes and are named after certain animals (the larger the cable diameter the larger the type of animal)! The parameters required to size the conunonly used ACSR cables are presented below in Table 5.7.

Table 5.7 ACSR Transmission line parameters

Name	Equivalent Aluminum Area (MM2)	Current rating in still air (Amp)	Resistance (D./km)
Squirrel	20.7	76	1.374
Gopher	25.9	85	1.098
Weasel	31.2	95	0.9116
Rabbit	52.2	.135	0.5449
Dog__	103.6		0.2745

PVC Insulated Armoured or Unarmored cables are used for underground transmission lines. These cables have insulated cores placed inside a PVC pide for protection against moisture, **and** other adverse effect when buried. The armoured PVC cables have an additional strip of steel strands inside the PVC pipe for protection against dynamic loads such as due to vehicular movement. More detailed design of underground cables is beyond the scope of this manual.

The following procedure is used to calculate the transmission line conductors for overhead lines.

Determine the power factor (D in Table 5.6)

Calculate the current transmitted

Single phase; I = (22)

V **x** *Po -v,er -factor (D)*

Three phase; I = **-** p (23)

,F3x V **x** *Power factor (D)*

Where; I = Current in ampere.

p = Power in watt.

v = Voltage, 220 V for single phase and 400 V for three phase.

Select a cable size from Table 5.7 so that the current rating is higher than the calculated current (I).

Estimate the transmission line length (L) in km from the survey data.

Determine the resistance R in 0/km of the selected cable from Table 5.7 or form manufactures' catalogue. Note that the values may vary slightly between manufacturers.

Calculate the voltage drop **(Vd,,,P)** as follows:

Three phase: V,,,@, = I x L *x R* (24)

Single Phase: *V*,,,,,= 2xIxLxR (25)

If the calculated Vd,,,p is higher than 13% (preferably 10%) select the next higher size conductor and repeat calculations.

Calculate the loss of power (P,,,,) in the transmission line as follows:

PI,,,, = *I2* **x** L ***x*** R (26)

This equation is used foi determining the maximum power that can be used by the consumers (Installed capacity - Pl,,,s) for which they can be billed.

CHAPTER 6

Financial Analysis and Feasibility

A MHP scheme will be sustainable only if all of the following conditions are met.

The scheme is technically feasible,

It is socially acceptable and

It is financially viable.

A technically feasible MHP scheme is one where the head, flow and locations are such that the scheme can be physically constructed at the selected site. This was covered in the previous chapters.

A MHP scheme is socially acceptable and feasible if the community members are capable and prepared to manage it and willing to use and pay for the power produced. This subject has also been dealt with in Chapter 3.

This chapter covers the general financial aspects of MHP schemes. It should be noted that financial considerations for entrepreneur and community-owned schemes are different. A private entrepreneur-owned scheme needs to generate return on the investment, similar to any other business venture. On the other hand, conununity owned schemes may not be **profit** driven. As long as sufficient income can be generated to meet the annual operation and maintenance expenses and to pay a portion of the community loan, they may be considered to be financially viable.

6.1 Detailed Cost Estimates

An accurate cost estimate of a proposed MHP scheme is a prerequisite for a fmancial analysis and is based on the design of the scheme as well as material, labour and transportation costs. The detailed drawings can be used to determine the excavation quantity, masonry and concrete work. Similarly the cost of electromechanical equipment including the transportation and installation charges can be obtained from the manufacturers. Thus, a detailed cost estimate can be prepared as shown in Annex. 6. 1.

Once the detailed cost estimate has been prepared, the cost under the major headings should be tabulated (Table 6. 1). Note that as shown in Table 6. 1, allowance should be made for contingencies. This will allow for uncertainties in the cost estimate. If most of the cost figures such as labour rates and material costs are accurate, a contingency of 10 per cent is adequate. Also note that if the scheme is constructed more than a year after the cost estimates, then the contingency should be increased accordingly to reflect the prevailing material and labour costs.

Apart from construction costs, there may also be other costs such as design and supervision cost (for the technicians) as well as management or supervision cost of the entre reneur or

some community members responsible for the coordination of the project. If there are such expenses, they should also be included in the cost estimate.

6.2 Financial Analysis

Financial analysis of a MHP scheme can be undertaken once the total cost has been determined. Depending on the type of ownership, the simplified methods discussed below can be used to assess the financial viability of the scheme. It should be noted that the financial analysis discussed below is preliminary and should be used only as an indication of whether the proposed scheme appears to be financially viable enough to start the construction. For larger plants, a more in-depth analysis may be carried out which is beyond the scope of this publication.

Table 6.1: Summary of costs

No	Description	Aniount (Rs)
1	Intake	a
2	Headrace	b
3	Settling basin	c
4	Forebay	d
5	Penstock	e
6	Anchor block	f
7	Support pier	9
8	Powerhouse and machine foundation	h
·	Electro-mechanical installation in powerhouse including transportation	i
10	Transmission line and poles	
11	@SUBTOTAL	a. b c d e f g h i j
12	10% Contingency	I = kxO.10
13	TOTAL CONSTRUCTION COST	m k 1
14	Design, supervision and management costs	
15	TOTAL PROJECT COST	in n

An entrepreneur may not install a MHP scheme unless his annual profit is higher than the commercial bank interest rate or equal to what he can expect had he invested in other business with equal risk. Therefore, for such schemes a minimum annual profit on investment (POI) of 20 per cent (preferably 25 per cent) should be used as the criteria for financial viability.

As mentioned earlier, a community owned scheme is not usually driven by profits. Therefore, for such schemes a minimum net annual income of 2 per cent (preferably 5 per cent) should be used as the criteria for financial viability.

The minimum annual profit can also be ensured by adjusting the tariff but note that an unaffordably high tariff rate may result in the rejection of the scheme by the consumers. The

consumers may not subscribe to the power produced (for electricity and agro-processing) if they can not afford the tariff.

If the scheme is eligible for subsidy, this sum should not be included in the financial analysis, since the entrepreneur or the community does not have to pay it back.

The following procedure should be used to determine the financial viability of a MHP scheme.

First determine the principal sum (total investment) that the entrepreneur needs to invest as follows.

$$P = T - S$$

Where;
P is the principal sum
T is the total project cost and
S is the subsidy received

Calculate the total annual income from the scheme. This can include both income from the sales of electricity and agro-processing.

Estimate the total annual expenditure of the scheme. Depending on site specific conditions, such annual expenditure can be different for different schemes which should include any payment made to keep the plant operating. Table 6.2 belgw presents an example of various annual expenditures that can be expected in a MHP scheme.

Table **6.2: Annual expenditure**

No	**Description**	**Amount (Rs)**
I	Salaries for operators and manager	**a**
·	Annual scheme maintenance cost (use 2% of total project cost if other information is unavailable.)	**b**
3	Interest on loan	c
4	Other expenditures (travel, communications, etc.)	**d**
5	**Total annual expenditure**	**e = a b c d**

It is recommended that studies of existing MHP schemes be conducted to estimate the actual percentage of the total project cost required for annual maintenance. In the absence of such data 2% of the total project cost is recommended to be used as annual maintenance cost as shown in Table 6.2.

Even with regular maintenance, the electromechanical units such as the turbine and the generator will have to be completely replaced once their useful life is over. Setting aside a certain percentage of the total project cost each year will provide sufficient funds for replacement of such equipment in the future. It is recommended that studies be also conducted on existing schemes- to determine the average percentage of the project cost required for this. In the absence of,such information 3% of the total project cost is recommended to be set aside for replacement of such major parts.

Example

Determine the transmission line wire size for a MHP scheme that has an installed capacity of 20 kW. The survey data shows that the transmission line is 1.5 km long and the villagers may use bulbs, tube lights and other appliances.

Calculation

Power out x transmission length = 20 kW x 1.5 km = 30 kW.km (<54 kW. Km); therefore, low voltage transmission is possible.

Since the installed capacity is higher than 10 kW, three phase generation and transmission system will be required.

Power factor = 0.8

Transmitted current : $I = P / \sqrt{3} \times V \times \text{Power factor (D)} = 20{,}000/\sqrt{3} \times 400 \times 0.8$

$= 36$ A

For I = 36 A, choose SQUIRREL (Rated I = 76 A) which is the smallest size ACSR over head transmission line.

From Table 5.7, R = 1.374 Ω/km

$$V_{driop} = I \times L \times R$$
$$= 36 \times 1.5 \times 1.374$$
$$= 74 \text{ V}$$

$\% V_{drop} = (74/400) \times 100\% = 18.5\ \% > 13\%$, NOT ACCEPTABLE

Try WEASEL, R = 0.9116 Ω/km

$$V_{drop} = I \times L \times R$$
$$= 36 \times 1.5 \times 0.9116$$
$$= 49 \text{ V}$$

$\% V_{drop} = (49/400) \times 100\% = 12.3\% < 13\%$, ACCEPTABLE

Check the power loss in the transmission line:

$$P_{loss} = I^2 \times L \times R$$
$$= 36^2 \times 1.5 \times 0.9116$$
$$= 1772 \text{ W} = 1.77 \text{ kW}$$

Therefore only 20-1.77 = 18.23 kW is available for the consumers from this scheme.

* * * * * * * * * * * * * * * * ** * ** * * * * * *

- ♦ The annual profit can now be calculated as follows

Annual profit = Annual income – Annual expenditure – Replacement fund

- ♦ For enterpreneur schemes; if the annual profit is 20% or hgiher of the Principal, accept the scheme as financially viable. If it is less than 20% reject the scheme
- ♦ For community schemes; if the annual profit is at least 2% of the Principal, accept the scheme as financially viable. If it is less than 2%, reject the scheme.

The example below illustrates the above methodology

Example 6.1

An enterpreneur is considering whether he would install a MHP scheme. The installed capacity is 15 kW and the total project cost is Rs. 1,020,000. The expected subsidy from the government is Rs. 306,000 and he plans to draw a loan of Rs. 500,000 form the bank at an annual interest rate of 16%.

The enterpreneur's monthly income is estimated to be as follows

1. 60 W bulbs x 100 @ Rs. 75 per bulb/month
2. 40 W bulbs x 150 @ Rs. 50 per bulb/month
3. 25 W bulbs x 120 @ Rs. 35 per bulb/month
4. Income from agroprocessing Rs. 9,000/month (average)

The enterpreneur's monthly expenses on salaries are as follows.

1. Salary to operator: Rs. 2000/month
2. Salary to the manager: Rs. 2500/month

Determine whether the scheme is financially viable

FINANCIAL ANALYSIS

A. Principal

Principal (P) = Total project cost – Subsidy

Or, P = Rs. 1,020,000 – Rs. 306,000 = Rs. 714,000

B. Annual Income

Sales of electricity

1. 60 W bulbs: 100 bulbs x Rs. 75 per bulb/month x 12 months = Rs. 90,000
2. 40 W bulbs: 150 bulbs x Rs. 50 per bulb/month x 12 months = Rs. 90,000
1. 25 W bulbs: 120 bulbs x Rs. 35 per bulb/month x 12 months = Rs. 50,400

Agro-processing : Rs. 9,000/month x 12 month = Rs. 108,000

Total annual income = Rs. 338,400

C. Annual expenditure

Annual expenditure

No.	Description	Amount (rs.)
1.	Salaries for operators and manager: Rs (2000 + 2500)/month x 12	54,000
2.	Annual scheme maintenance cost: assume 2% of total project cost Rs. 0.02 x 1,020,000	20,400
3.	Interest on loan: Rs. 0.16 x 500,000	80,000
4.	Total annual expenditure	154,400

D. Replacement Fund

Set 3% of the total project cost for replacement fund:
= 0.03 x 1,020,000
= Rs. 30,600

E. Annual Profit

Annual profit = Annual income – Annual expenditure – Replacement fund
= 338,400 – 154,400 – 30,600
= 153,400
= Rs 153,400
% Annual Profit = (annual profit/Principal) x 100
= (153,400/714,000) x 100

Or Annual profit = 21.5%

Therefore, this scheme is financially viable for the enterpreneur. Note that as the enterpreneur pays part of the loan component annually, the profit will increase since the interest on loan will decrease.

If all of the above conditions remain similar, this scheme will also be viable as a community owned scheme since the acceptable profit margin is lower. The community may decide to lower the tariff rates such that the annual profit is about 5 percent.

ANNEXURES

Annex 3.1

MHP Initial Energy Form

To be filled in consulation with the Entrepreneur, Community facilitators(s) and other relevant personal:

1. Information regarding location Date: …………………….

   Name of main customer/community leader ……………………. Position …………………….

   Address: ……………………..……………………………..………………………..…………

   Name of Main Village : ……………………. District …………………….

   VDC: ……………………..…………………………. Ward No. …………………….

   Other Village(s) ……………………. Name of stream : …………………….

   Nearest Road head : ……………………. Days Walk ………………………..……

   Nearest Airport ……………………. Days Walk …………………….

   Travel route details ……………………..……………………………..…………………….

   Has this proposal been discussed with the VDC, Chairman, Chairman, the community Yes/No

   Names of other important community leaders and concerned persons

   Name : ……………………. Position …………………….

   Name : ……………………. Position …………………….

2. Power Potential Information

   Flow estimates Width of stream in wet section ……………………. m

   in dry season …………………….. m

   Depth of stream in wet season …………………….. m in dry season …………………….. m

Has any Survey been done in the past ? Yes /No

If yes, how much flow, head, power was determined ?

Are there water falls in the stream ? Yes/No

Does the stream dry up at any time of the year ? Yes/No

Which is the driest month of the year ? ………………………………

How many hours/days walk is it to the spring of the stream ? …………………

Is the stream water used for any of the following ?

- Irrigation Yes/No, Up/Down stream
- Drinking water supply Yes/No, Up/Down stream
- Ghattas Yes/No, Up/Down stream
- MHP installations Yes/No, Up/Down stream
- Others ……………………………, Up/Down stream3

- Is there exiting channel which can be used? Yes/No

Summary

How can the flow be measured?

Weir ? Yes/No

Float method ? Yes/No

Velocity-area method ? Yes/No

Salt gulp method? Yes/No

Others ………………………………

- How many Ghattas can be run, one after the other in dry season? ……………..

Summary

Type of appropriate head measured method

…………………………………………….

…………………………………………….
…………………………………………….
…………………………………………….

3. Geological Information

Are any of the following features present along the proposed canal route, if so, approximately how much?

Cultivated land	Yes/No	………… m	Steep hillsides	Yes/No	………… m.
Slop areas	Yes/No	………… m	Cliffs	Yes/No	………… m
Gullies	Yes/No	………… m	Landslides	Yes/No	………… m
Flooding	Yes/No	………… m			

Are there any other features affecting the stability of the proposed channel? Yes/No. If so what;
……….……………….……………….……………….……………….……………….……………….…………….

4. Climate Information about Project Area

Does it ever snow at the proposed MHP site? Yes/No. If yes, how long does it stay on the ground ? ……….……………….……………….……………….……………….……………….…………….
……….……………….……………….……………….……………….……………….…………….

Annual rainfall …………. Do monsoon rains come every year ? ………….…………….

If yes, how long do they last ? ……….……………….……………….……………….…………….

Type of vegetation and forests? ……….……………….……………….……………….…………….

What Crops are grown? ……….……………….……………….……………….……………….…………….

Is there a; weather station in the area? Yes/No

5. Potential End Uses of MHP

Would any of following be useful?

Rice Huller	Yes/No	Flour Mill	Yes/No
Oil Expeller	Yes/No	Generator	Yes/No
Saw Mill	Yes/No	Paper Mill	Yes/No

Workshop Yes/No Vegetable/Fruit dryer Yes/No

Other ……………………………………………………………………………………………………
……………………………………………………………………………………………………..

6. Electricity Requirements

	No.	Estimated electrical Consumption in kW	Names of villages
Households	………..	……………………..	……………………..
Shops/cafes	………..	……………………..	……………………..
Hotels/Lodges	………..	……………………..	……………………..
HMG & other offices	………..	……………………..	……………………..
Industry	………..	……………………..	……………………..
Other	………..	……………………..	……………………..

7. Socio-economic Information

How much can you/the community invest ? Rs. …………………………………

Can you/the community get a loan ? Yes/No Rs. …………………………………

Is there any other funding available to you/the Community, e.g.; from Government, NGO's, other donors, etc. and if so, how much ? Rs. …………………………………

Total financial capability Rs. …………………………………

Are there any conficts between parts of the community ? Yes/No

If yes, describe ; Rs. ……………………………… …………………………………

………………………………………………………………………………………

Surveyor's view of capability of communities to pay for Electricity …………………

………………………………………………………………………………………

………………………………………………………………………………………

How far is the proposed MHP site from main villages which would benefit from the plant?

The nearest village Name ……………… km ………………. Min walk …….. hh ………

The 2nd nearest village Name ……………… km ………………. Min walk …….. hh ………

The 3rd nearest village Name ……………… km ………………. Min walk …….. hh ………

Which of the following are locally available?

Firewood	Yes/No,	if yes, cost per load, ……………………………………
Kerosene	Yes/No,	if yes, cost per litre, ……………………………………
Diesel	Yes/No,	if yes, cost per litre, ……………………………………

Which of the following exist?

Ghattas	Yes/No,	if yes, how many, ……………………………………………..
		What distance ………………….km ………………….min walk
MHP mill	Yes/No,	if yes, how many, ……………………………………………..
		What distance ………………….km ………………….min walk
Diesel mill	Yes/No,	if yes, how many, ……………………………………………..
		What distance ………………….km ………………….min walk
Grid line	Yes/No,	if yes, what distance, …………. Km …………………min walk

Industry (describe) ………………………………………………………………………………

List local prices of building materials, wages and transport

			Locally available
Wood	…………………….	Rs. /………………..,	Yes/No
Stone	…………………….	Rs. /………………..,	Yes/No
Sand	…………………….	Rs. /………………..,	Yes/No
Gravel	…………………….	Rs. /………………..,	Yes/No
Semi skilled labour	…………………….	Rs. /day,	Yes/No
Mason	…………………….	Rs. /day,	Yes/No
Carpenter	…………………….	Rs. /day,	Yes/No
Technician	…………………….	Rs. /day,	Yes/No
Transport from road head			
Standard loads	…………………….	Rs. /50 kg load,	Yes/No
	…………………….	Rs. /kg	
Difficult loads	…………………….	Rs. /50 kg load	Yes/No
	…………………….	Rs. /kg	

8. Community contribution in Kind

Would the community provide:

Land for MHP Plant	Yes/No …………	Local wood.	Yes/No …………..
Sand/Stone/Gravel.	Yes/No		
Construction Labour	Yes/No		
Manual Transport Labour	Yes/No		