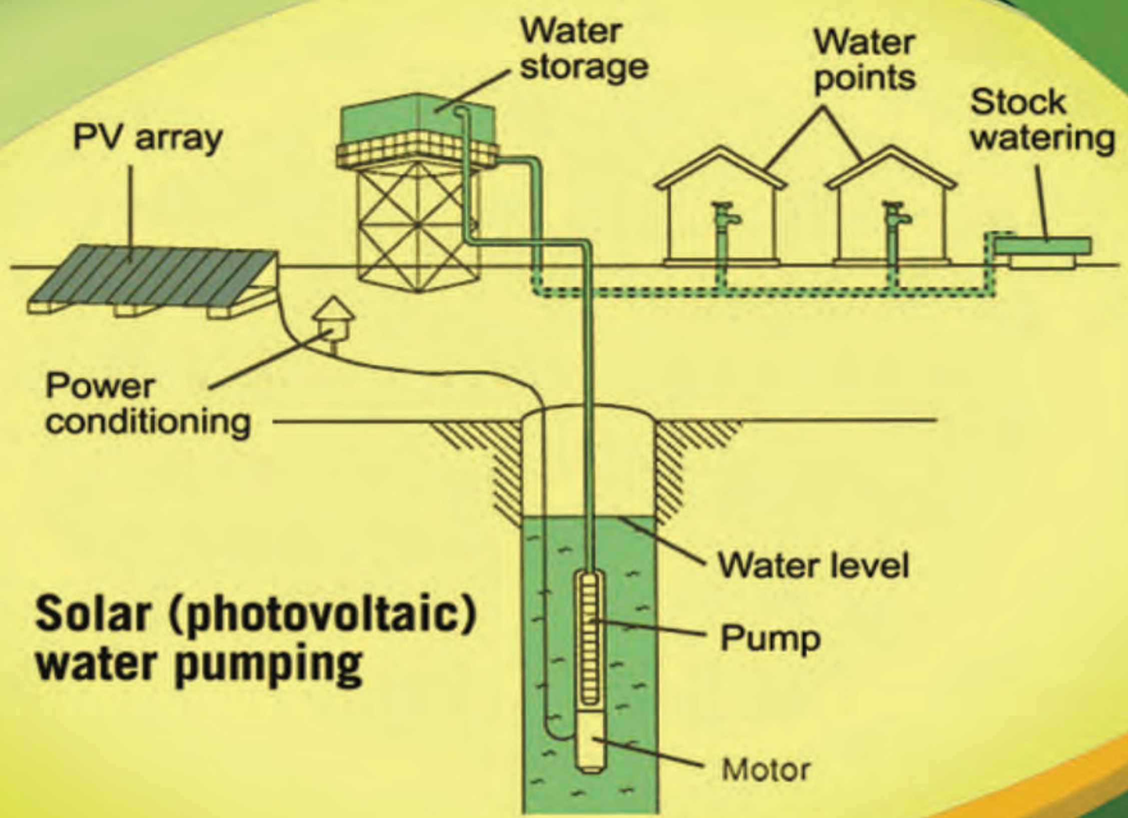

Training Manual

Solar PV Pumping System

Alternative Energy Promotion Centre (AEPC)

Alternative Energy Promotion Centre (AEPC)

Training Manual on Solar PV Pumping System

Prepared by:
GRID Nepal
in joint venture with
Center for Energy Studies
Institute of Engineering, TU

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Foreword

AEPC/RE-Source is a national platform established to build local capacity for promotion, development and expansion of renewable energy technologies. One of the activity of RE-Source is to identify unique CDS projects with higher impact potential and co-finance them with intent of delivering impact at scale through catalytic CDS intervention.

In this regard, RE-Source and Solar Energy Sub-component jointly have decided to support for developing training manual for solar PV pumping system and provide training to 20 Energy and Environment Officer (EEO) and planning officer of District Development Committee (DDC).

This volume of Training Manual in Solar Water Pumping System consists of technical details required for feasibility study, designing and implementation of institutional Solar Water Pumping Systems. The manual is with adequate information and guidelines to be used in training for engineers working in solar PV or for those interested to work in this sector.

Authors' team headed by Prof. Dr. Jagan Nath Shrestha, Dr, Ajay Kumar Jha and Er, Rajendra Karki have put their significant effort in preparing this manual and I would like to acknowledge their effort in this endeavor. I would like to thank Mr. Rudra Pd. Khanal, AEPC/RE-Source Coordinator , Mr. Pankaj Kumar, Programme Officer, Mr. Chaitanya P. Chaudhary, Programme Officer, NRREP/SESC, Mr. Niraj Rajaure, Programme Consultant and entire RE-Source family and SESC for their cooperation in preparing this manual.

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Abbreviations

2D	Two Dimensions
AC	Alternating Current
AEPC	Alternative Energy Promotion Center
AWG	Americal Wire Gauge
B/C	Benefit Cost
BPC	Break Pressure Chamber
BPT	Break Pressure Tank
BWG	Birmingham Wire gauge
C.G.I	Corrugated Galvanized Iron
CAD	Computer Aided Design
CAP	Community Action Plan
CBO	Community Based Organization
CDF	Continuous Demand Flow
CDS	Capacity Development Service
CES	Center for Energy Studies
CI	Cast Iron
CPWD	Central Public World Department
DC	Distribution Chamber
DC	Direct Current
DDC	District Development Committee
DEECCU	District Energy Environment and Climate Change Unit
DI	Ductile Iron
DT	Distribution Tank
DWRC	District Water Resources Committee
FC	Ferrocement
GI	Galvanized Iron
GPS	Global Positioning System
GUI	Graphical Users Interface
HDP	High Density Polyethylene
HGL	Hydraulic Grade Line
HH	Households
HP	Horsepower
HRF	Horizontal Roughing Filter
ICT	Information and Communication Technology
IOE	Institute of Engineering
ISCSTC	Short Circuit Current at Standard Test Condition
IRR	Internal Rate of Return
DT	Distribution Tank

LDPE	Light Density Polyethylene
LED	Light Emitting Diode
M&E	Monitoring and Evaluation
MPPT	Maximum Power Point Tracking
MS	Microsoft
MS	Mild Steel
NIPQA	Nepal Interim PV Quality Assurance
NPSH	Net Positive Suction Head
NPV	Net Present Value
NRREP	National Rural and Renewable Energy Program
O&M	Operation and Maintenance
OD	Outer Diameter
PRA	Participatory Rural Appraisal
PSI	Pound Per Square Inch
PV	Photovoltaic
PVC	Poly Vinyl Chloride
PVWPS	Photovoltaic Water Pumping System
PW	Present Worth
R&M	Repair and Maintenance
R.C.C	Reinforced Cement Concrete
RL	Reduced Level
RPM	Revolution Per Minute
RVT/RT	Resorvoir Tank
SSF	Slow Sand Filter
SWG	Standard Wire Gauge
TOR	Terms of Reference
UNEP	United Nation Environment Program
US - SWG	US Steel Wire Gauge
USDA	United States Department of Agriculture
UTC	Universal Time Coordinate
UV	Ultraviolet
VA	Velocity Area
VDC	Village Development Committee
VOCSTC	Open Circuit Voltage at Standard Test Condition
WGS	World Geographic System
WO	Washout
WSP	Water Supply Project
WUC	Water User Community
WUSC	Water Users and Sanitation Committee

Contents

1 Introduction

Objectives:

To give brief information about the solar PV pumping system technology and its comparison with other technologies for water pumping with the help of graphs and decision flow charts.

Time: 15 min

Lesson 1.1: Introduction to solar PV pumping Technology : 5 min

Lesson 1.2: Comparative study with other pumping system : 5 min

Lesson 1.3: Decision flow charts : 5 min

1.1 Background

From the time immemorial, the sun has been the prime source of energy for all forms of life on earth. The energy we derive from fuel-wood, fossil fuels, hydroelectricity and our food originates indirectly from the sun.

Solar energy is virtually inexhaustible. The total energy we receive from the sun far exceeds our energy needs. It is probably the most reliable form of energy available everywhere and to everyone, unlike other sources. With dwindling supplies of petroleum, gas and coal, tapping solar energy is a logical and necessary course of action.

According to Maslow's hierarchy of needs, water is the second most important need, after clean air, for survival of human being. According to UNEP report more than 6,000 children are killed by contaminated water every day, 3.5 billion people, about half the world's population, will face a water crisis by 2025.

The amount of water available to human beings on earth, the so-called Water Planet, is less than widely believed. The future of human beings depends upon on whether we can use the scarce water sources with care and efficiency. (AEPC, 2003)

1.2 Breakdown of Earth's Water

As per the UNEP report (http://www.unwater.org/stastics/statistics-details/en/c/211801/), breakdown of the earth's water is shown as below

- The Earth's total water volume: 1.4 Billion km^3
- Out of this, sea- water is 97.5% and fresh water is only 2.5%
- Out of available fresh water, glacier and eternal snow is 68.9%,
- Ground water and frozen soil is 30.8% and
- Lakes and rivers consists of only 0.3% (0.105 Million km^3)

1.3 Fresh Water Scarcity

Less than 0.01% of the water on the blue-clad planet is available to human being (http://www.worldwidelife.org/habitats/freshwaters). The seawater accounts for 97.5% of the water surface and most fresh water exists in the form of polar ice or deep underground water.

It is interesting to mention that if the earth were one meter in diameter, the amount of available water would be just a spoonful.

The shortage of "sparse and valuable" water has got more acute in the 21^{st} century as a result of the world population explosion, tripled in the past 100 years, while water consumption exploded six times in the same period.

About 2.8 billion people, or 40% of the world's population, are suffering from water shortfalls (Vital water graphics 2008).

Contaminated water causes some 80% of diseases in developing countries, and sales of mineral water are increasing sharply, even in developing countries.

One-fourth of the world population depends on underground water. In most rural areas water scarcity is even prominent. In practice a significant amount of water is being pumped out either from underground source, rivers, lakes or springs etc.

Nepal is not an exception. A significant number of people in all three geographic regions of Nepal are facing scarcity of potable water, resulting in undesirable water borne diseases. Among various alternatives, one of potential way to avail water is to pump water from appropriate sources using available electrical energy. In areas where national grid is not available and no other economic alternatives exist; Photovoltaic Water Pumping System (PVWPS) could be sustainable technology for rural drinking water and other uses. Due to high initial investment, such system seems relatively expensive. Therefore optimum designing of PVWPS needs critical engineering considerations. Apart from this, socio- economic analysis is a must to justify the application of chosen PVWPS in a given location for given conditions.

1.4 Photovoltaic Technology

Photovoltaic technology is a method of exploiting electrical power from photons (bunch of light particles) in the form of solar radiation. Insolation is the total energy received from the sun in a day in a unit surface area on the earth. The unit of insolation is Kilowatt-hour per sq. meter. per day. For Nepal, the yearly average insolation can be taken around 4.5 to 5.5 KWh/m^2/day (AEPC, 2003).

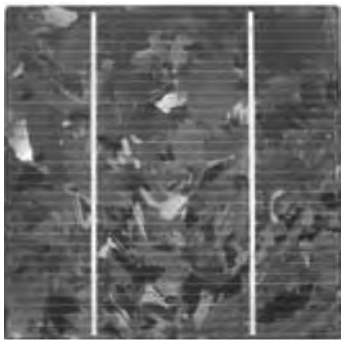
The PV system comprises of systematic arrangement of components designed for the purpose of supplying usable electric power for a variety of applications harnessing the power from the sun. Photovoltaic power capacity is measured in watts peak (Wp). Solar power is pollution-free during its use. The conversion principle of the photon into solar electricity is based on photovoltaic effect. When the PV modules are exposed to sunlight, they generate direct current (DC). An inverter then converts the DC into alternating current (AC). Photovoltaic power generation employs solar panels composed of a number of solar cells. In fact, individual PV cells are interconnected to form a PV module. This takes the form of a panel for easy installation. Solar array is a group of similar modules connected in series and parallel to increase the power delivered by the PV system. Series connection of modules increases the final array voltage whereas parallel connection of modules increases the output current keeping the voltage level as a single module. A small PV system has capability to power a single home or even an isolated AC or DC based device. Solar PV systems can be classified based on the end-use application of the technology. There are two main types of solar PV systems: grid-connected (or grid-tied) and off-grid (or stand alone) solar PV systems. Off-grid solar PV systems are applicable for areas without utility grid. Currently, such solar PV systems are usually installed at isolated sites where the power grid is far away, such as rural areas or off-shore islands. But they may also be installed within the city in situations where it is inconvenient or too costly to tap electricity from the utility grid. PV is a mature technology to convert sunlight into electricity. Some advantages of photovoltaic technology are given below:

- One of the cleanest forms of energy.
- Environment-friendly.
- Easy to install, operate and maintain.
- Long life (Solar panels can last up to 25 years or more).
- Modular design, hence easy to expand.
- Ideal for remote areas, where utility grid is not reliable.
- Safe to handle. Once installed properly, most devices can be used by laymen without risks.
- Freedom from utility grid, which is often not available especially in remote areas.
- Can be used as stand-alone or grid-connected systems as well as with other energy sources as hybrid systems.

1.5 Crystalline Silicon and Thin Film Technologies

PV cells are made of light-sensitive semiconductor materials that use photons to dislodge electrons to drive an electric current. There are two broad categories of technology used for the formation of PV cells, namely, crystalline silicon, which accounts for the majority of PV cell production; and thin film, which is newer and growing in popularity.

Mono-Crystalline Silicon PV Cell



Poly-Crystalline Silicon PV Cell

Fig. 1-1 Mono and Poly Crystalline Silicon PV Cells (AEPC, 2003)

Crystalline cells are made from ultra-pure silicon raw material such as those used in semiconductor chips. They use silicon wafers that are typically 150-200 microns thick. Thin film is made by depositing layers of semiconductor material barely 0.3 to 2 micrometres thick onto glass or stainless steel substrates. The following “family tree” (Fig. 1-2) gives an overview of solarcell technologies available today.

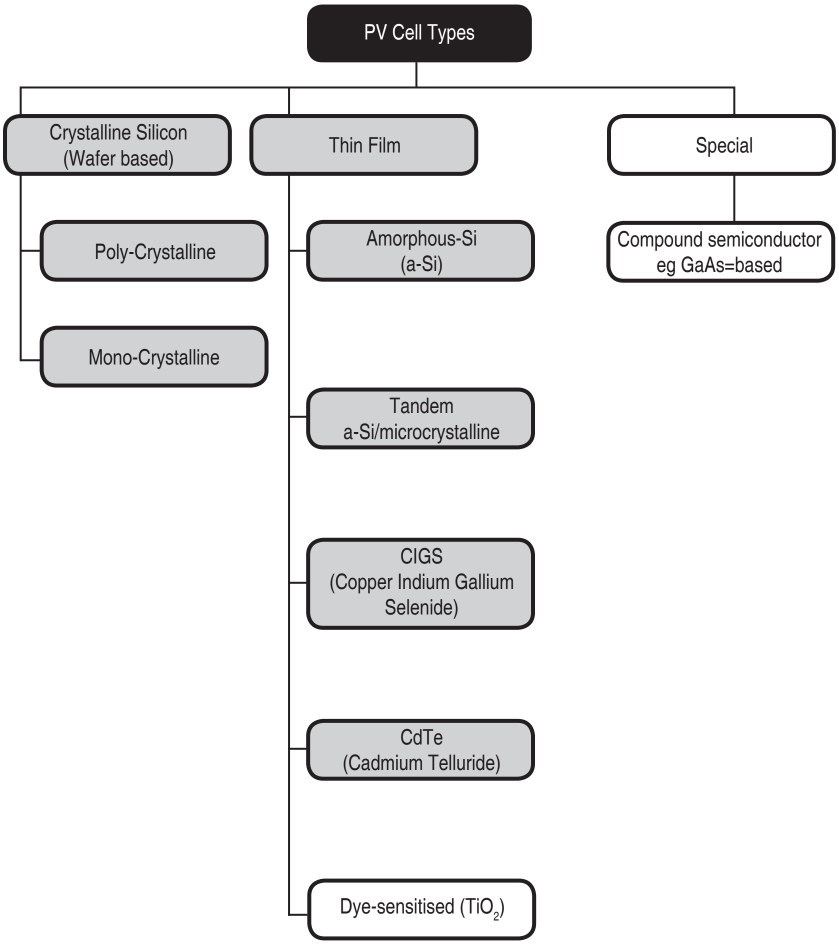


Fig. 1-2 PV technology family tree

1.5.1 Conversion Efficiency:

The conversion efficiencies of various PV module technologies are as follows:

- Mono-crystalline Silicon: 12.5-15%
- Poly-crystalline Silicon: 11-14%
- Copper Indium Gallium Selenide (CIGS): 10-13%
- Cadmium Telluride (Cd-Te): 9-12%
- Amorphous Silicon (A-Si): 5-7%

Mechanical and Electrical characteristics of a typical solar PV module (model MS – M100) is given in Annex I.

1.6 Solar PV Pumping System

In rural areas of Nepal, the unavailability of proper infrastructures and reliable sources of electrical energy has created many problems related to quality of life. The locals, having settlements far from the water sources and at much higher altitudes, have to walk for long hours to fetch water to perform household chores.

The problem can be overcome by installing two water tanks: one situated near the water source to collect water from its running source and the other near the village situated at a higher altitude with required head. After that, it will be incorporated with a high efficiency solar DC or AC water pumps to lift water from lower tank to the upper. The water collected at upper tank is distributed through normal pipelines. The only energy available at many of these remote sites is Solar Energy. So, one uses an array of Solar Photovoltaic modules to pump the water from the water source to the upper tank to be installed at higher altitude. During day time the Solar PV modules generate electrical energy which runs the pump and the water is pumped up from the source to the upper tank. At night time the pump stops automatically.

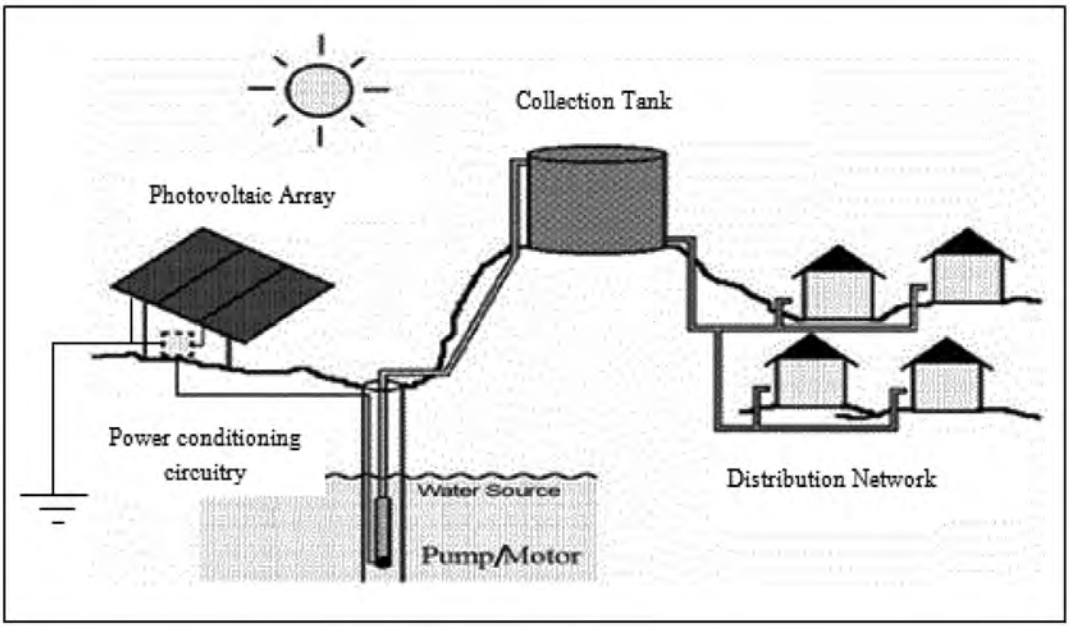


Fig. 1-3 Schematic PV pumping System (AEPC, 2003)

1.7 Alternative Sources of Power for Water Pumping

A wide variety of power sources are utilized depending upon local conditions. Each power source has various advantages and disadvantages and has specific applications where it is the favored energy source and determines the corresponding pumping technique (AEPC, 2003).

1.7.1 Human Labour Using Hand Pumps

Advantages:

- readily available in most places
- low investment cost
- can be flexibly deployed
- simple technology and easy to maintain

Disadvantages:

- high feeding cost and associated wages
- low output, limited by the strength of the human body to about 10 m^3 / day from a depth of 10 m or 5m
- diverts a valuable resource from more productive activities

1.7.2 Draught Animals

Advantages:

- readily available in most places

- medium investment costs
- convenient power output for small scale irrigation
- can be flexibly deployed

Disadvantages:

- high feeding costs involving extra food production
- feed required even when no power can usefully be utilized

1.7.3 Petrol or Diesel Fuelled Small Engines

Advantages:

- widely available technology
- high outputs possible on demand and portable
- low initial capital investment per unit of output
- easy to use

Disadvantages:

- fuel costs dominate and are increasing in real terms
- fuel shortages are common in many places
- spare parts are often hard to obtain in remote areas
- good maintenance difficult to obtain in remote areas
- relatively short useful life
- breakdown is common
- high imported element involving scarce foreign currency in most developing countries

1.7.4 Wind Pumps

Advantages:

- relatively mature renewable energy technology when used for stock watering
- low cost in areas with adequate wind potential
- zero fuel costs
- suitable for local manufacture
- relatively simple maintenance needs

Disadvantages:

- moderate output, fluctuating with wind speed
- critically site dependent

1.7.5 Water Wheels, Turbines, Ram Pumps and Current Turbines

Advantages:

- low cost, long life, low maintenance, fuel-free power source if suitable site conditions are available to exploit water power

Disadvantages:

- depends upon relatively rare site conditions, which limit the areas that could benefit, from this type of prime mover.

1.7.6 Solar Photovoltaic Pump

Advantages:

- energy resource is almost universally available
- high correlation between energy available and water needs
- low environmental impact and reliable

- zero fuel costs
- long life (PV modules more than 20 years)
- low maintenance and operation costs
- can be operated by unskilled labor
- suitable for systems of any size

Disadvantages:

- sophisticated technology, not suitable to local manufacturers
- high initial investment cost
- output fluctuation due to varying solar insolation

Water pumping applications can vary widely, both in their requirements and in the conditions under which pumping must take place.

The cost (unit water cost) considerably fluctuates depending upon the variables such as:

- volumes and timing of water required
- water source capacity and depth from which it is to be pumped
- replenishment rates of the source and seasonal variability of static head
- bore or well diameters and solar insolation characteristics

1.8 General Decision Flow Chart

Water can be pumped using wind energy, solar energy and diesel generator as some options. Each option has its own conditions for economic operation. The decision chart for selection of pump is shown below.

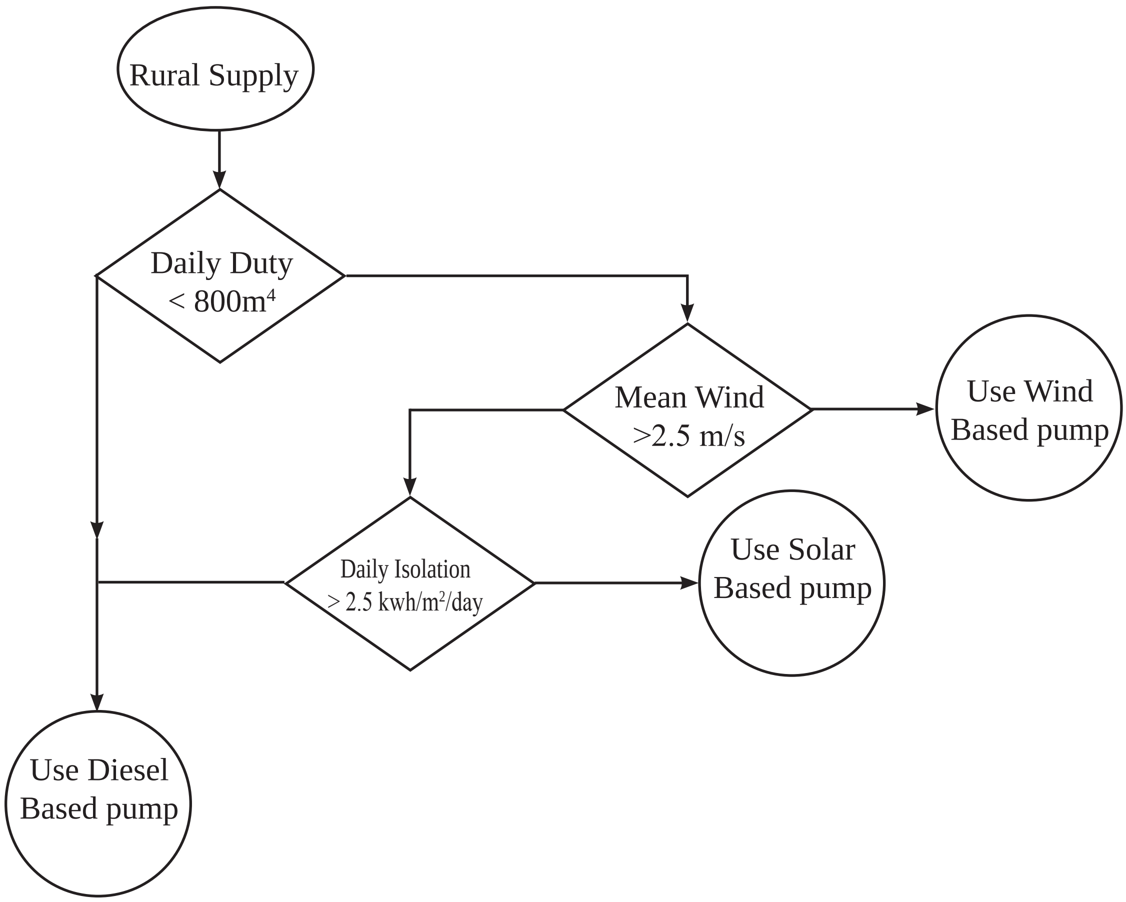


Fig. 1-4 Decision Flow Chart for the Selection of the water pumping technologies (AEPC, 2003)

2. Electromechanical Components

Objectives:

To explain the water pumping system configuration giving information about various electromechanical components of the solar PV pumping systems that would later help in design of those components.

Time: 40 min
Lesson 2.1: Water pumping system configuration : 10 min
Lesson 2.2: Water pumps : 15 min
Lesson 2.3: Motors and Integrated motor/pump machines : 5 min
Lesson 2.4: Power conditioning circuitry : 5 min
Lesson 2.5: Array mounting and mounting of water pumps : 5 min

2.1 Water Pumping System Configuration

There is a range of possible components and configurations for photovoltaic water pumping systems, as shown in figure 2-1. Selection of the most suitable components and configurations for each specific application and site is critical to the economic viability and the long-term performance of the system.

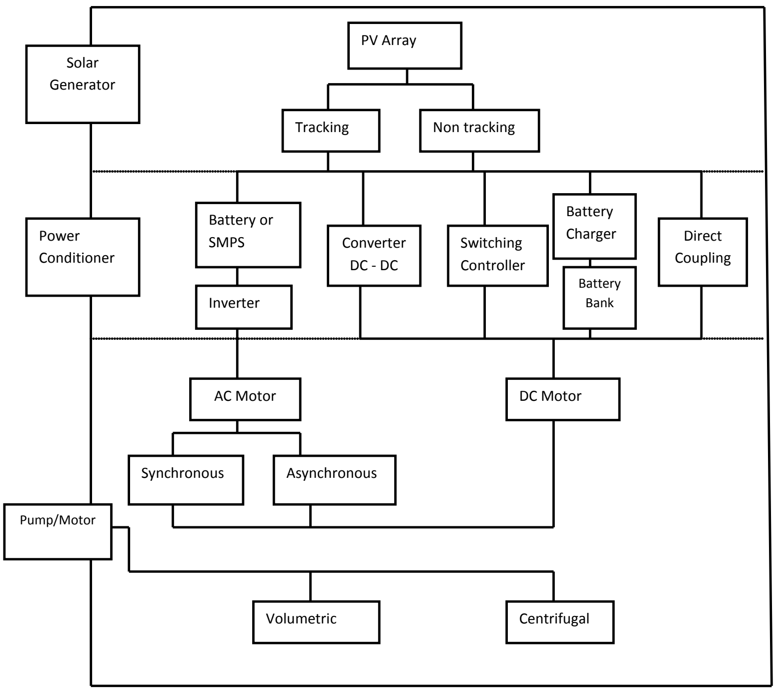


Fig. 2-1 Water Pumping System Configuration (AEPC, 2003)

In the simplest photovoltaic water pumping systems, the solar panels are directly connected to a DC motor that drives the water pump. For such simplified systems, DC motors and centrifugal pumps are virtually mandatory, due to their ability to be matched to the output of the solar PV array.

Volumetric (also known as positive displacement) pumps have completely different torque-speed characteristics and are not well suited to being directly coupled to solar panels. When volumetric pumps are used, it is therefore common for power conditioning / maximum power point tracking circuitry to be included between the solar panels and the motor / pump to convert the DC electrical energy into a suitable useable form. Similarly, ranges of motor types are used for water pumping systems, including DC series motors, DC permanent motor, DC permanent magnet brush less motor, AC asynchronous induction motors and AC synchronous motors.

As with the different types of pump, each motor has its advantages and disadvantages, which determine suitability to particular applications. In case of AC motors, an inverter must also be included between the solar panels and the motor.

2.2 Water Pumps

The two broad categories of pumps are generally used for PV powered pumping systems: centrifugal and volumetric (displacement) pumps.

2.2.1 Centrifugal Pumps

Centrifugal pumps have a rotating impeller that throws the water radially against a casing so shaped that the momentum of the water is converted into useful pressure for lifting. They are normally used for low head / low pressure applications, particularly if direct connection to the solar panels is required. They are well suited to high pumping rates and due to their compactness; wherever small diameter bores or well exists. Centrifugal pumps are characterized by the torque being proportional to the square of the speed (angular velocity of the impeller).

These pumps have relatively high efficiencies, but rapidly loose pumping performances as their speed reduces and in fact do not pump at all unless quite substantial spin speeds are achieved. This is a problem for a PV powered system when light intensity is reduced. Maximum speeds performance is achieved at high spin speeds, making them easy to match to motors, which tend to develop maximum torque (maximum efficiency) at similar speeds.

For conventional centrifugal pump designs, high efficiencies are only obtained for low pumping pressures and hence relatively small pumping heads of less than 25 meters. To overcome this limitation, either multistage or regenerative centrifugal pumps can be used.

Other advantages of centrifugal pumps include their simplicity (with a minimum of moving parts) and corresponding reliability, low cost, robustness, tolerance to pumping particulates and low starting torque. On the other hand, another potential limitation of centrifugal pumps is their inability to be self-priming. Consequently, they are frequently used as submersible pumps, preferably in conjunction with a submersible motor. Alternatively, self-priming centrifugal pumps where a chamber containing water at the side of the pump keeps the pump effectively submerged and hence primed is also used.

The major trade-off involved with the design and use of centrifugal pumps is the requirement for high efficiency versus the need for an impeller with long life and good tolerance of aggressive impurities in the water. High efficiency can be obtained with small clearances and narrow passages, but this is undesirable for pump reliability and the ability to pump liquids contaminated with particles. In addition, high efficiency can be obtained with a high speed impeller which again acts to shorten the life of the pump. In summary, pumps need to be designed and selected for specific application and environments.

2.2.2 Volumetric Pumps

Volumetric or positive displacement pumps are the other class of pumps often used for water pumping applications, particularly for lower pump rates from deep wells or bores. Examples of volumetric or positive displacement pumps are poster pumps, diaphragm pumps, rotary-screw type pumps and progressive cavity pumps.

Figure 2-2 provides basic guidelines for selection of the pump depending upon the total system head and daily pumped volume of water.

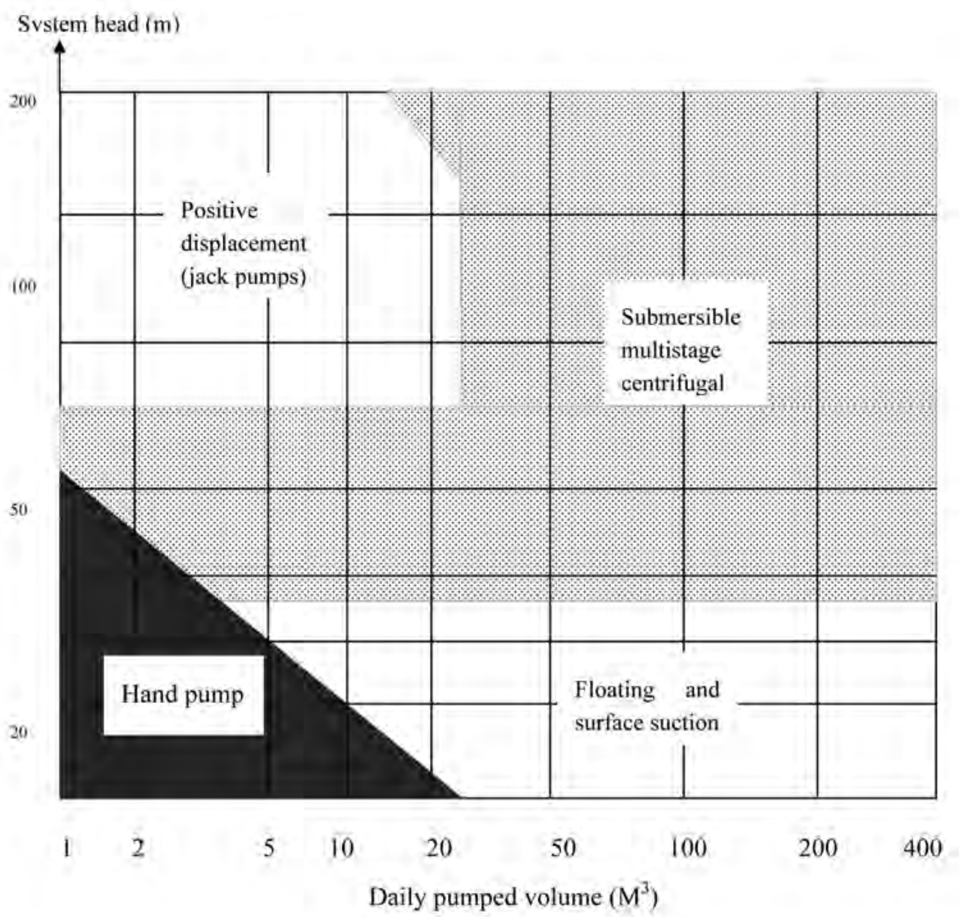


Fig. 2-2 Selection of the pump (AEPC, 2003)

From the above graph it is clear that centrifugal pump can pump more volume of water than other pump also these pumps are also suitable for higher heads.

2.3 Motors

2.3.1 DC Motors

The DC motor with high efficiency is desirable. The applications where DC motors are preferred are where direct coupling to the PV panels is required. However AC motors in general, tend to be cheaper and more reliable, which often complicates the choice. With current prices, AC motor is economic compared to DC motors for PV pumps where:

(Flow rate x water head) > 600m^4 / day.

The Brush less DC Motor has the permanent magnets in the motor and electronically commutates the stator to alleviate the need for brushes. General advantages and disadvantages of DC motor include:

Advantages:

- high efficiency
- no need for an inverter
- suitable for direct coupling to PV panels

Disadvantages:

- restricted range of brushless types available
- brushed type not submersible
- brushed type need higher maintenance
- relatively expensive
- not readily available in very large sizes.

2.3.2 AC Motors

A wide range of AC motors are commercially available, due to the wide range of applications for which they have been used for many years. However, with most of these, the emphasis has been on low cost rather than operating efficiency. In particular, small motors of about 1 KW or less suffer from very low efficiencies, making them not suitable to PV powered systems. In addition, they require costly inverters at their inputs, which have further added reliability problems.

Furthermore, to provide the high starting current, additional power conditioning circuitry is generally required. AC motors are, however, in general very reliable and relatively inexpensive, being typically half the cost of an equivalent size DC motor.

The two basic types of AC motors available are asynchronous induction motors and synchronous motors. However, standard induction motors produce extremely low starting torques, making them suitable only for low starting torque pumps such as centrifugal pumps, unless appropriately modified to increase the torque generated at high slip frequencies.

2.4 Integrated Pump / Motor Machines

As the PV powered water pumping industry develops, a wider range of motors and pumps are becoming available. It is therefore essential for an engineer designing such systems to keep up to date with new product developments and associated field-testing.

Recently, integrated pump / motor machines have become popular where the pump and motor are matched and interconnected within the same housing by the manufacturers. Such configurations act to simplify systems and provide high efficiencies when operating at or near their design point.

However, careful attention should be paid to performance losses and mismatch that results from using these machines away from the design point, such as with a different head or flow rate (AEPC, 2003).

Table 2-1 Types of Pump

Centrifugal	**Positive Displacement (Volumetric)**
Self-priming surface Jet pump Vertical turbine Submersible High speed impellers Large volumes Moderate head Loss of flow rate with higher head Low irradiance reduces ability to achieve head Possible grit friction	Helical cavity Jack pump Diaphragm Volumetric movement Lower volumes High head Flow rate less affected by head Low irradiance has little effect on achieving head Unaffected by grit

Table 2-2 Merits and demerits of different types of pumps (AEPC, 2003)

S.No.	Pump type	Merits	Demerits	Applications
1.	Self-priming Surface pump	Single impeller Can be used with common DC motors	Limited to atmospheric pressure for suction (maximum 7 m) Must be primed before each start up	Flood irrigation Moving water along the land through pipelines
2	Jet pump	Increased effective suction head (max. 30 m) Venturi could be place in front of the impeller chamber or at the input of the suction pipe	Decreased net flow Inefficient due to low net flow rate	Surface pumping
3	Vertical Turbine pump	Multi-stage impellers allowing deep pumping at high rates	Head limited by shaft length Efficiency is reduced due to twisting, friction Vibration and weight of shaft and bearings	Used for large scale irrigation with large AC or diesel motors
4	Submersible pump	Can pump water from high depth (300m) Water-proof motor connected directly to multi-stage impellers Brush less DC operation possible with electronic commutation	Low flow at high head AC motors require surface mounted inverter	Drinking water supply system Drip-irrigation system
5	Helical cavity pump	Can move very gritty water Can use MPPT to supply surge power High head applications	Torque, friction and vibration losses Small or moderate volume of water discharge	Drinking water supply system Drip-irrigation system
6	Jack pump	High head applications Both AC and DC motors can be used	Low discharge Needs frequent maintenance	Drinking water supply system
7	Diaphragm pump	Simple to operate Medium to high head	Low to medium flow rate	Small scale water supply system

2.5 Power Conditioning Circuitry

The role of power conditioning circuitry is to provide the motor/pump with the most suitable voltage / current combination, while ensuring the solar panels operate at their maximum power points. In effect, it alters the load impedance to match the optimum impedance of the array.

The circuitry of course must consume very little power to justify its inclusion, and in most systems, will typically consume 4 to 7% of total power. It is also expensive, usually costing more than the electric motor, while unfortunately often providing problems with regard to reliability.

As the light intensity falls, the current generated by solar panels falls proportionately while the voltage at the maximum power point remains approximately constant. However, for a motor / pump, as the current falls, the voltage also falls. Consequently, without power conditioning circuitry, as the light intensity falls, the solar array operates at a current and voltage progressively further and further from its maximum power point.

Maximum power point tracking (MPPT) circuitry may be included in any system to boost efficiency. A well-designed system using a centrifugal pump will automatically have an acceptable match between the solar array and sub-system over a wide range of insolation levels. In this instance, no control circuitry is warranted, other than perhaps water level switches or pressure switches. If, however, a MPPT is to be used, ensure internal transient protection is included, to minimize the risk of damage in the event of lightning strikes.

The pump efficiency, a function of head and flow rate, can usually note from the characteristic curve provided by the manufacturer. The typical values for the different types of pumps are listed in the Table 2-3.

Table 2-3 Typical values for pump performance parameters

Type of Pumps	Head (m)	Wire to water efficiency (%)
Centrifugal	0 - 5	15-45
Centrifugal with Jet	6 - 20	10-30
Submersible	21 - 100	30-50
Jack pump	100	35-60

The losses are shown in the following figure:

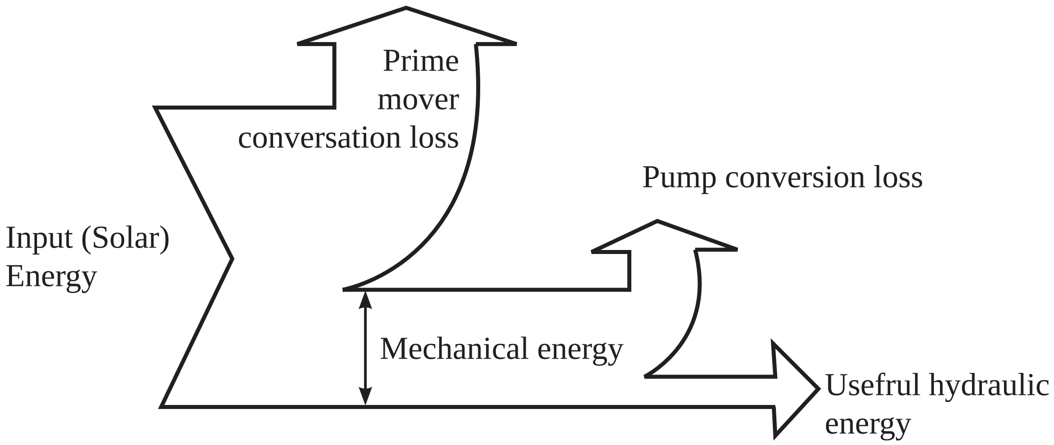


Fig. 2-3 Losses in Pump (AEPC, 2003)

2.6 Array Wiring and Mounting of Water Pumps

2.6.1 Array Wiring

Array cables should be heavy duty, with all connections in watertight function boxes with strain relief connectors. The gauge of wire should be selected so as to keep resistive losses to less than 3%. For reliability, splicing of the leads from the motor to the array output cable should utilize crimp-on connectors with resin filled heat shrink tubing or equivalent or equivalent, to ensure long lasting, dry connections. All wiring should be attached to support structures with nylon wire ties. PVC conduit should be used for the array output wiring to submerged motor/pump. For a submersed motor / pump, heavy duty doubly insulated cable is essential. Also, the array and mounting frames need to be grounded using substantial copper wire. Grounding through the motor / pump and well should not be relied upon as the system may be dismantled for various reasons. Lightning protection should be considered, and bypass and blocking diodes should be included where appropriate.

2.6.2 Array Mounting

All support structures should be anodized aluminum, galvanized or stainless steel and need to be designed to withstand the maximum possible wind loading for the particular location. Lock washers or equivalent should be used on all bolts to remove risk of them coming loose during the subsequent 20 years. The structures should be located as close as possible to the well to minimize wire lengths, and where necessary fencing may be utilized to protect from animals, theft, vandals, etc.

Tracking support structures can be useful to enable the solar panels to point more directly at the sun throughout most of the day. Motorized or passive tracking mechanisms, although cost effective in terms of electrical energy produced per unit cost, introduce considerable maintenance and reliability problems. However, a more feasible alternative is to use a manual tracking system, whereby a simple adjustment by an operator can take advantage of the changing sun position. One such regime is where a seasonal adjustment of the tilt angle is made four times each year, to compensate for the variation in the sun's angle of declination. Another form of adjustment allows for redirection of the solar panels twice a day taking greater advantage of both the morning and afternoon sun.

It should be noted that the concept of manually redirecting the solar panels is dependent upon the availability of an operator, which for some remote or inaccessible locations may not be feasible or practical. However, the studies have indicated that a simple manual tracking system requiring two adjustments per day could increase daily efficiency of the system as high as 30%. (See Annex II)

3 Water supply systems

Objectives:

After completing this chapter participant will be able to differentiate among different available options of 'water supply systems' in community level in the context of Nepal.

Time: 30 min

Lesson 3.1: Water supply systems : 30 min

3.1 Gravity Flow

Generally in rural hills where terrain is sloppy and settlements are located at relatively downhill, Water source located at higher elevation can be flowed to the community at lower elevation with the aid of earth's gravitational forces. There is no any external energy needed to deliver water from source to tap stand. This system further can be divided into following:

3.3.1 Open System

This is type of gravity water supply system in which safe yield of the source is more than the 'peak daily design demand' (tap flow) and no faucet on the tap stand are provided. Water is allowed to fall continuously through the faucet round the day. Where water in the source is abundant, there is no problem of waste water and settlements are located steep downhill relative to source, this type of system is generally adopted.

3.3.2 Closed System

When the safe yield of the source/s for a system is insufficient (or less than the required design demand tap flow) to meet the peak water demand showing the need of storage, then the system to be adopted is named as 'Close System' and further sub-classified as:

Fig. 3-1 Gravity Water Supply System

3.3.2.1 Continuous System

It is the water supply system in which water is made available to tap stand throughout the day (24hrs.). When water is required, faucet of tap post is opened and after fulfilling the demand faucet on tap post is closed thus not allowing running away the water in non-use hours. The water is available in the tap post on as and when required basis that is why it's name is termed as 'continuous system'. During non-use hours water is reserved in the 'reservoir tank' located at uphill side of tap post.

3.3.2.2 Intermittent System

When a water supply system is designed to feed the tap stand at certain interval of time then it is called 'intermittent system'. When safe yield of source is less than the daily design demand of community or water cannot be made available to the tap stand at, as and when required basis then this system can be adopted.

3.2 Pumping cum Gravity

This system typically can be the one in which, combined features of both the pumping water supply system and gravity flow water supply system satisfies. Water at certain reach is pumped and at other reaches water is made flow on gravitational forces. Typically, water source located at downhill from the community can be pumped up at elevated location and water is stored there on called reservoir. Water can then be

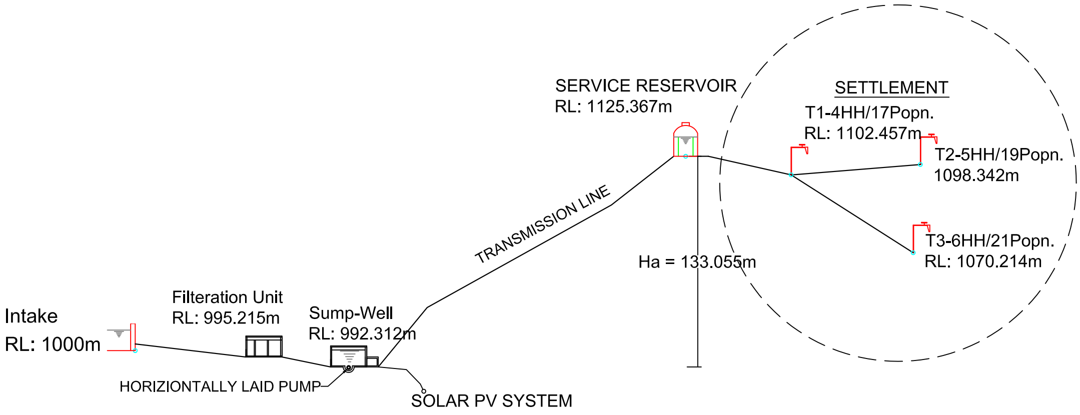


Fig. 3-2 Pumping cum. Gravity System

distributed to the community through the gravity flow system. Water from the source to the 'service reservoir' is made flow with the aid of external energy and 'reservoir tank' to the tap post is without use of any external energy-gravitational force. Different possible alternative layout-drawings of the PV pumping system is attached in the annex for through understanding of the system.

3.3 Ground Water Supply System

Ground water is the water stored under the surface of earth in its saturation zone. Such zones may be found as a single, continuous or in separate strata. When water from these strata (aquifer) is extracted and carried up to earth surface to feed the water supply system then system is called 'Ground Water Supply System'. To develop a ground water supply system, following components are essential to exist:

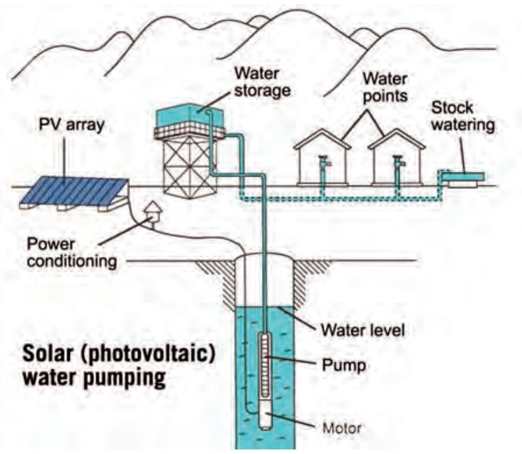


Fig. 3-3 Ground Water Supply System
(Source: http://www.siliconcpv.com)

- A ground water strata or aquifer
- A completed well/tube well.
- A mechanism to lift water up to ground level such as hand pumps or electrical pumps
- A system for water distribution

3.4 Rain Water Harvesting

Rainwater harvesting is the accumulation and deposition of rainwater for reuse before it reaches to aquifer. Thus accumulated water can safely be used for drinking water purposes and the water supply system is called 'Rain Water Harvesting-Water Supply System'. Rain water collection units can be built for either the individual households or settlements level, depending upon the requirement, budget and different other social parameters.

We are here mainly concerned with the 'Solar PV Pumping cum. Gravity' systems so here and onwards only that system will be focused.

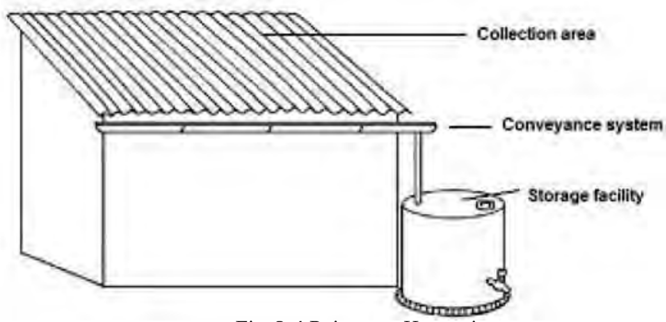


Fig. 3-4 Rainwater Harvesting

3.5 Fog Water Collection

This is the water supply system in which naturally occurring fog is condensed and collected to water tank by means of well designed fog-collector system. Fog, a cloud that touches the ground, is made of tiny droplets of water—each cubic meter of fog contains 0.05 to 0.5 grams (half the weight of a paper clip) of water. 'Fog collectors' look likes tall volleyball nets slung between two poles, but they are made of a polypropylene or polyethylene mesh that is especially efficient at capturing water droplets. When the fog rolls in, the tiny droplets of water cling to the mesh and as more and more cluster together, they drip into a gutter below that channels the water to a water tank. Fog collectors, which can also harvest rain and drizzle are best suited to high-elevation arid and rural areas; they would not work in cities because of the space constraints and water needs of an urban environment. This systems best works in the region, where there remains fog and light wind most often, generally above 1500m altitude (in context of Nepal).

Fig. 3-5 Fog Collection System
Source: http://www.fogqvest.org

4 Water Sources

Objectives:

After completing this chapter participant will be able to comprehend different water sources available in the earth and their mode of occurrences.

Time: 30 min

Lesson 4.1: Water Sources : 30 min

4.1 Surface Sources

Surface water is water on the surface of the earth as in the river/stream, lake and pond. It is lost through evaporation, seepage into the ground where it becomes ground-water used by plants for transpiration, can be abstracted by human for different purposes like agriculture, living and industry etc. The water available in the surface water source may be contaminated/polluted or fresh, so careful investigation of the source and surrounding environment should be carried out before selecting the surface sources for the water supply system. Generally environment around the source and possible pollution points in and around should be clearly identified with remedial measures.

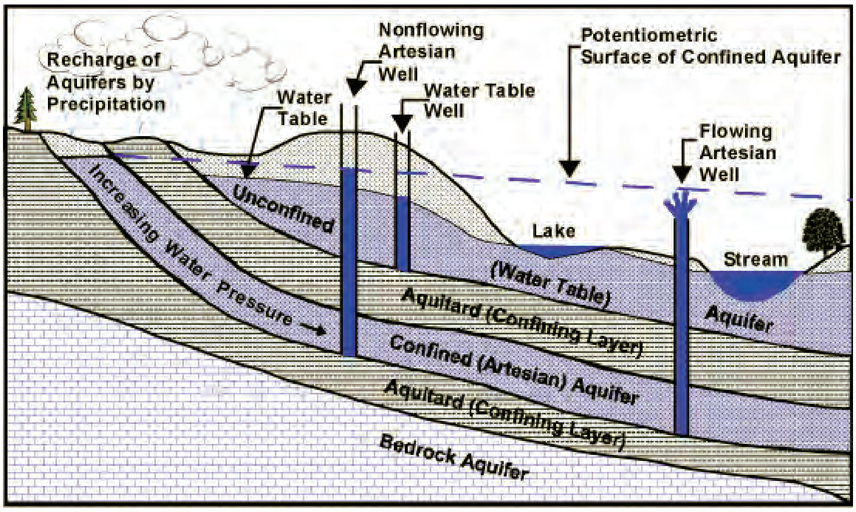


Fig. 4-1 Surface and Sub-surface water sources and its occurrences on the earth.

Spring: This is the natural outcrop of ground water on to the ground surface and flowing in the ground naturally. Spring water as it comes out from the earth is best water for the drinking purposes but they yield much less in quantity. For small villages and towns these are the best source of supply. They should be well preserved while using for water supply systems. The yield of sources whether it is surface or sub-surface greatly depends upon the hydrological cycle (or monsoon) in the region (reader are encouraged to go through other materials for hydrological cycle, the detail of which is beyond the scope of this manual) and geological features of the area: above all, source of water is rain for all the water sources.

River/Streams: These are the cumulative collection of small springs and rivulets from long run catchment. Since any river or stream run through different places along its progress, they derive contents from those sources during its course. Though, there is self-purification of stream/rivers (see BOD of river for further readings) takes place during its run but it requires certain parameters to satisfy. So, while choosing the river/stream as water supply system proper care should be taken like preservation of catchment, environment in and around the source. Appropriate treatment mechanism should also be established in the system to make water fit for consumption.

Lake/Pond: These are the accumulation of storm or spring water at natural depression made in the topography. Depending upon the source of supply (storm or spring) and environment around the lake/pond largely defines the quality of water in these sources. How these parameters shall be handled/maintained in the future defines the water qualities in the future. So, careful study of these parameters should be made before selecting lake/pond for water supply source.

4.2 Sub-surface Source

Sub-surface water, or groundwater, is fresh water located in the pore space of soil and rocks. It is also water that is flowing within aquifers below the water table. Sub-surface water can be thought of in the same terms as surface water: inputs, outputs and storage. The critical difference is that due to its slow rate of turnover, sub-surface water storage is generally much larger compared to inputs than it is for surface water. The natural input to sub-surface water is seepage from surface water. The natural outputs from sub-surface water are springs and seepage to the oceans.

Fig. 4-2 Open Well, Fetching Water

Open/Dug well: A dug well is an excavation or structure created in the ground by digging, driving, boring, or drilling to access groundwater in underground aquifers. The well water is drawn by a pump, or using containers, such as buckets, that are raised mechanically or by hand.

Wells can vary greatly in depth, water volume, and water quality. Well water typically contains more minerals in solution than surface water and may require treatment to soften the water. Proper covering of the open/dug well is necessary for the adoption in water supply system's source. Yield of open well indicates the ground water movement and discharge capacity of soil in the vicinity. There are number of theories and concepts developed for measuring the groundwater movement and discharge but they all may not suitable in our cases, so the simplest one is to withdraw the well water by some mechanical means (i.e. pump) for some hours in driest season and measure the water level difference in well before and after withdrawal gives the discharge capacity of well.

Tube well: Extracting of water from deep into the aquifer required for human

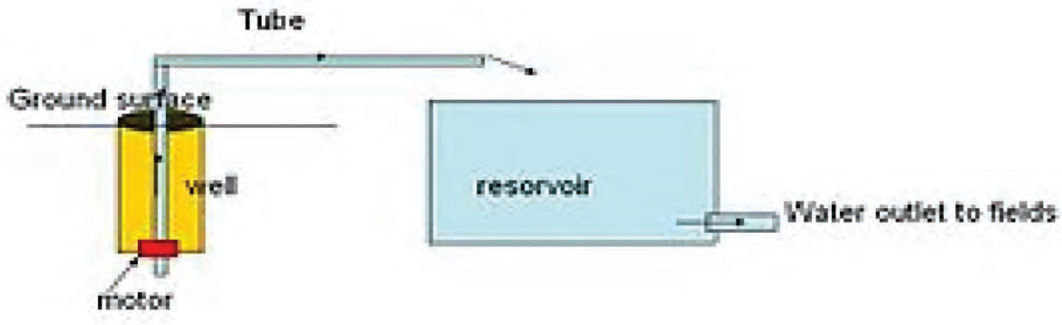


Fig. 4-3 Layout of Tube Well: Discharging into ground reservoir

consumption is tube well. The water may be extracted from one single aquifer, or more numbers of aquifers. The term deep is nothing to do with the depth of tube well instead it is associated with the layer from which we draw water. If a well draws water from surface layer (above the top impervious layer) then the well is not tube well. Since tube well it draw water below of impervious layer; aquifer, the water quality obtained is of best quality though, it should be checked for underground mineral contamination like iron and arsenic in terai region. As the penetration of tube well is in one or more impermeable underground strata, the depth of tube well generally varies in the range of 100ft or above. In plain area where other surface sources are in of scarce, tube well are the most reliable and best solutions for water supply projects. Measurement of discharge from the tube well is a complex process, and requires complex setup and knowledge, so for the sake of simplicity, the method suggested as in case of open well can be adopted for the tube well too.

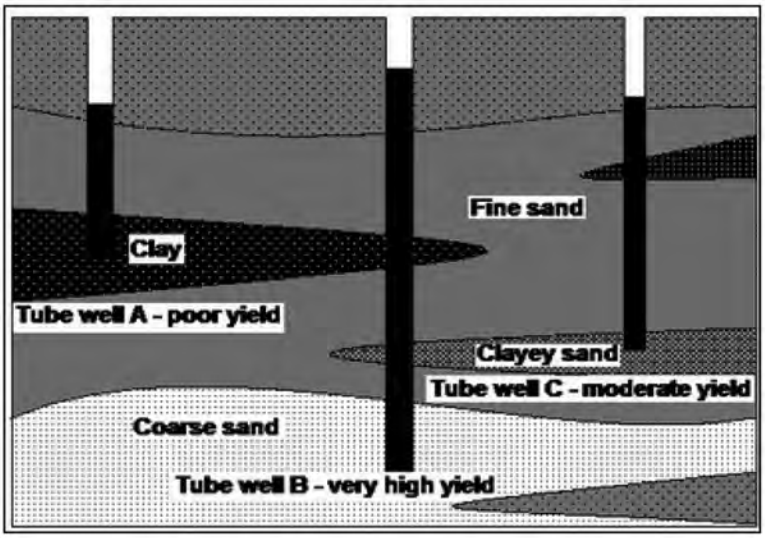


Fig. 4-4 Impact of Soil Type on Performance of Tube well

5 Solar PV Pumping Water Supply Systems

Objectives:

After completing this chapter participant shall

- Understand the concept of pumping WSP systems.
- Familiarize to 'Components of PV Pumping Systems'.
- Know the water treatment plant components and its placement sequences
- Know about Sedimentation and Detail Design of HRF, Slow Sand Filter.
- Pipe line materials
- Water disinfection and methods of chlorination in community water projects.

Time: 5hrs.

Lesson 5.1: PV Pumping System : ½ an hour

Lesson 5.2: Components of PV Pumping Systems : 2 hrs.

Lesson 5.3: Water treatment plant in community water supply projects: ½ hrs.

Lesson 5.4: Design Practice of HRF, SSF (slow sand filter) : 1 hrs.

Lesson 5.5: Water Disinfection and Chlorination : ½ hrs.

5.1 Introduction

It is the type of water supply system in which water at low height is pumped up at suitably elevated location, storing therein in balancing reservoir and supplied to the users through appropriately designed and laid gravity fed pipe network system. Water from lower elevation is pumped up with the aid of power generated through photovoltaic solar panel suitably designed and arranged in location. So some sort of energy is required to pump up the water at low height to suitably locate elevated land/ overhead tank and that energy, in this system, essentially be the 'Solar Photo Voltaic' power generation system. This system thus can also be referred as 'Pumping cum Gravity' water supply system.

Water supplied through this system is very costly and thus should only be for very essential household consumptive uses like drinking, cooking and utensils cleaning. Other common consumptive uses like bathing, cloth washing, cattle feeding etc. should be obtained from other supplementary means like downhill side located kuwa, pond, streams etc.

Design of water supply system poses the combined characteristics of both pumping

A reservoir stores water at non-consumption hours and supplies the stored water at peak hours of demand. Thus it plays role of balancing between supply and demand fluctuations, accordingly it is sometime termed as balancing reservoir or service reservoir or simply RVT (most common name used in WSP personnel.), and the RVT further is dealt in detail in subsequent chapters.

A sump-well is downhill side structure of RVT that get water from HRF/source and feeds to the RVT through pumping. Pump is generally located at sump-well. Sump-well further is described in detail later on.

and gravity fed technology to supply the water from source to the end users. There should essentially be a balancing reservoir at uphill side of the village that feeds the water to the distribution pipe network. Water is delivered from 'Source to the Sump-well' through gravity flow, 'Sump-well to Balancing Reservoir' through pumping and balancing reservoir to service tap stands through gravity fed pipe network.

Since water is supplied to the community in this system with the use of 'Balancing Reservoir' or simply 'Reservoir' the system is referred technically as closed system. Since the water in pumping system costs more and loss of every drop of water is the loss of money directly, thus an intermittent system of water supply system should be adopted.

5.2 Components of Solar PV Water Supply Systems

5.2.1 Spring Intake

A spring intake is provided to abstract water from a spring source. It also prevents outside water and other sources of pollutants from entering into the transmission main. The intake thus protects the water from getting contaminated. The water outlet points of the spring should be properly identified before intake construction is initiated. Very low yield spring source (< 0.05 lps) should not be tapped for. Proper drainage should be provided around the spring source to divert the run-off water and prevent it from damaging the intake. A drainage diversion ditch should be dug at a distance of at least 8 m above and around the spring to divert the surface water away. Special care should be taken to insure that the source is not affected and there is no leakage.

Spring intake should be constructed at the source or nearer to the source. It should be protected well from human intrusion, strom water possible contamination and vandalism.

5.2.2 Stream Intake

A stream intake is built when a stream is selected as the water source. The characteristic of a stream intake depends on the type of stream, its morphology and the expected maximum and minimum flows. The intake in a stream should be located to take advantage of its morphology. Since each river has its own unique characteristics, only a general guideline can be provided for design and construction. Configuration and other requirement for its design should be specifically assessed and pursued. Generally a sedimentation tank needs to be constructed with a stream intake.

5.2.3 Infiltration Galleries

Infiltration galleries are suitable for tapping sub-surface flow in river beds having a moderate depth of water bearing strata (sand). A minimum depth of about 3 m of aquifer below the minimum water level is considered necessary for construction of infiltration galleries.

The infiltration line (collection channels) consists of single or double row of perforated pipes or dry masonry channels. These may be laid parallel to the river axis either on the inside or outside of the river bed. The channels are laid with the grade 1 in 300 to 500 at appropriate depths for the purpose of extracting water. The perforated pipes or dry masonry channels are covered by gravel filter arranged in layers; coarser material closer to the pipes or channels.

Infiltration wells or galleries are appropriate only along the foothills. The river bed infiltration gallery should be located at a point where stream does not change direction and where water would be available throughout the year. When an infiltration gallery is recommended, a detail design should be prepared on the basis of site condition. A high level of supervision during installation is also required.

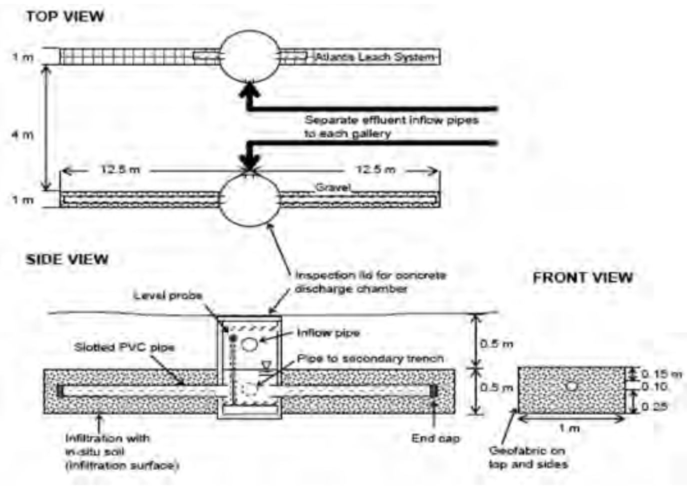


Fig. 5-1 Infiltration Gallery

5.2.4 Collection Chamber

As name suggest, this is a structure used to collect water from two or more than two water sources and providing head for downside structures. It eliminates the possibility of parallel running pipelines from sources As much as possible, this structure should locate minimum distance from two/more sources. If the source is spring and does not contain or very less amount of sediment load there is no need of collection chamber or water treatment unit, all these functions will be served by sump-well alone.

5.2.5 Water Treatment Units

Since water treatment is usually the most difficult element in any water supply scheme, it should be avoided whenever possible. The general statement that no treatment is the best treatment especially applies to rural water supply schemes which generally exhibit a poor infrastructural and institutional framework to adequately maintain water treatment facilities. The use of better water quality sources is, therefore, an alternative which will always have to be taken into serious consideration. If no other alternative is available, rural water treatment must concentrate on improving the physical and bacteriological water quality by locally sustainable treatment processes.

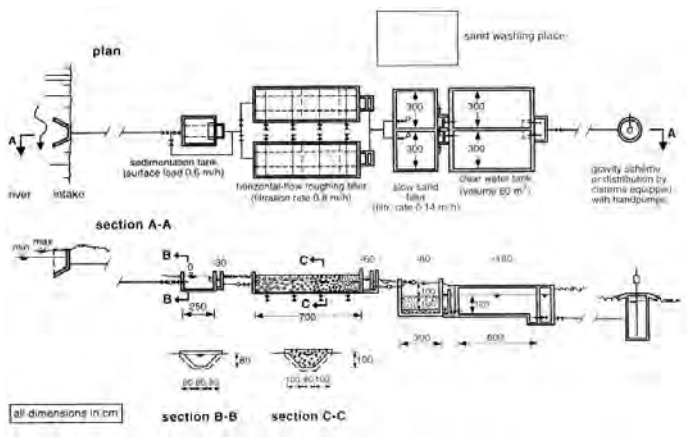


Fig. 5-2 Schematic Layout of Treatment Units
Source: Surface Water Treatment by Roughing Filters- A Design, Construction and Operation Manual (SANDEC-SKAT, 1996)

Surface water has to undergo a step-by-step treatment. Coarse solids and impurities are first removed by pretreatment, whereas the remaining small particles and microorganisms are separated by the ultimate treatment step. The required water treatment scheme is mainly dependent on the degree of faecal pollution, characteristics of the raw water turbidity and on the available type of surface water.

a) Removal of Coarse – Materials (Sedimentation)

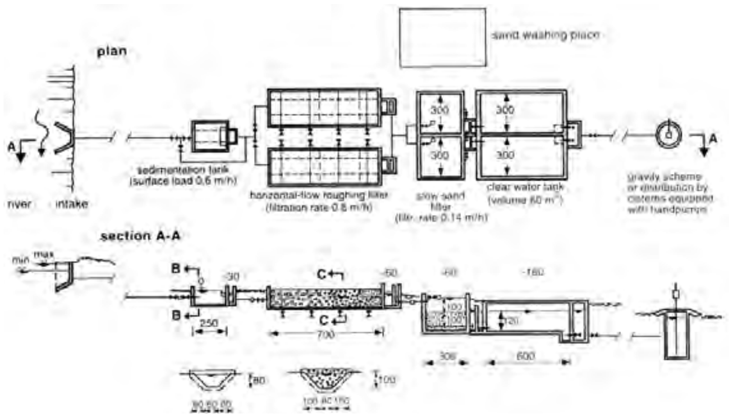


Fig. 5-3 Typical Section of Ferro-cement Sedimentation Tank

Separation of coarse solids from the water is preferably carried out by a plain sedimentation tank, since sludge removal from such tanks is less troublesome than from roughing filters. Simple sedimentation tanks can be designed. Ferro cement sedimentation tank simple in construction and very robust in function can be used in 'PV Pumping' a system that uses the water source as stream or river having high suspended load (it should be used only for water tapped from river/stream having high suspended /sediment load).

If there is cost implication depending upon the source type and sediment load, only sedimentation tank or horizontal roughing filter can be used to prevent harming the pump of the system.

b) Removing the finer material and biological contaminants (Filtration)

Filtration is a process of removing undesirable contaminants, suspended solids and gases from raw water in which water is passed through the bed of course materials. The goal of this process is to produce water fit for a specific purpose. Most water is disinfected for human consumption (drinking water) but water purification may also be designed for a variety of other purposes. Water coming from source might contain physical or biological parts that should be removed before pumping it to the service reservoir, so that pump health does not adversely affected (or clogged during operation).

5.2.5.1 Horizontal Roughing Filter

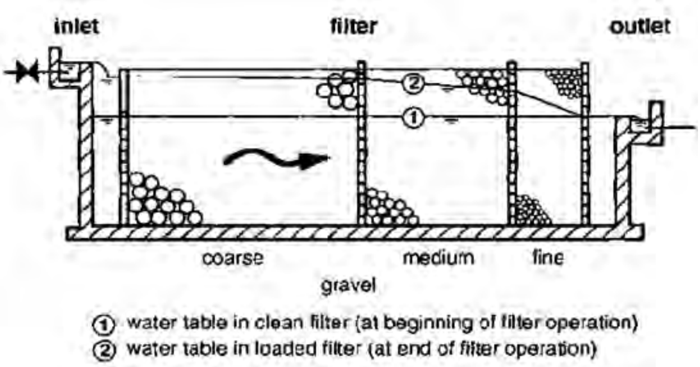


Fig. 5-4 Section of Horizontal Roughing Filter

Roughing filtration mainly separates the fine solids which are not retained by the preceding sedimentation tank. The effluent of roughing filters

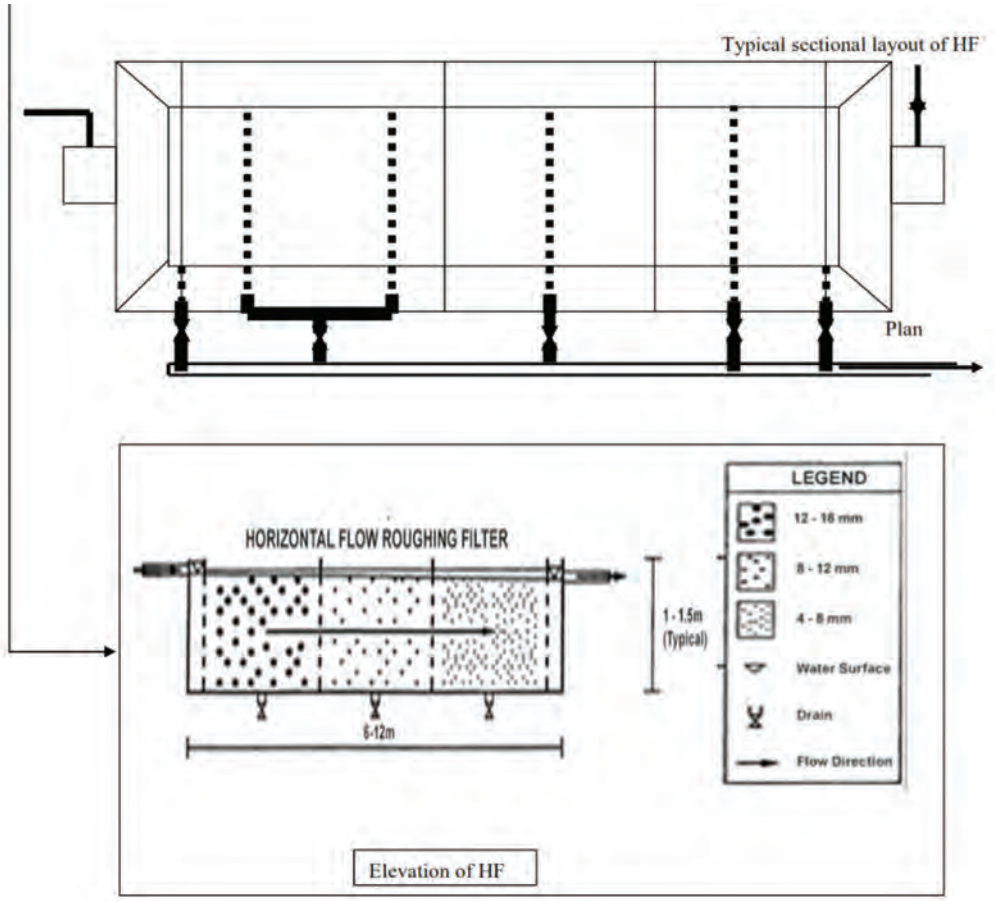


Fig. 5-5 Schematic Drawing of Horizontal Roughing Filter
Source: Design Guideline 1-12 Volumes, GON, DWSSD 2002)

should not contain more than 2-5 mg/l solid matter to comply with the requirements of the raw water quality for slow sand filters.

Coarse gravel filters mainly improve the physical water quality as they remove suspended solids and reduce turbidity. However, a bacteriological water improvement can also be expected as bacteria and viruses are solids too, ranging in size between about 10 - 0.2 mm and 0.4 - 0.002 mm respectively. Furthermore, these organisms get frequently attached by electrostatic force to the surface of other solids in the water. Hence, a removal of the solids also means a reduction of pathogens (disease-causing microorganisms). The efficiency of roughing filtration in microorganism reduction may be in the same order of magnitude as that for suspended solids, e.g. an inlet concentration of 10 - 100 mg/l can be reduced by a roughing filter to about 1 - 3 mg/l. The bacteriological water quality improvement could amount to about 60 - 99%, or the microorganisms are reduced to about 1 - 2 log. Larger sized pathogens (eggs, worms) are removed to an even greater extent.

Roughing filters are used as pretreatment step prior to slow sand filters. Slow sand filtration may not be necessary if the bacteriological contamination of the water to be treated is absent or small, particularly in surface waters draining an unpopulated catchment area, or where controlled sanitation prevents water contamination by human waste. However, physical improvement of the water may be required with permanent or periodic high silt loads in the surface water.

Excessive amounts of solids in the water lead to the silting up of pipes and reservoirs. For technical reasons, roughing filtration may therefore be used without slow sand filtration if the raw water originates from a well-protected catchment area and if it is of bacteriological minor contamination; i.e., in the order of less than 20 50 E. coli/100 ml.

5.2.5.2 Design Criteria of HRF

S.No	Design parameters	Recommended Values
1	VF= Q/(HxW) = Q/A	0.3 - 1.5 m/h
2	Vd= Qd/[(L1+L2+L3..)xW]	60-90m/h
3	Max headloss ΔH	30cm-40cm
4	H (recommended filter depth)	0.8-1.20m
5	Filter media fraction (gravel size)	
6	First Compartment L1 = 2-4m	dg = 20-12 mm
7	Second Compartment L2 = 1-3m	dg = 8-12 mm
8	Third Compartment L3 = 1-2m	dg = 4-8 mm
May be more compartments with other fractions of filter media		
List of symbols: dg (mm) - Gravel size L1,2,3 (m) – Filter length, W(m) – Filter width, H (m) - Filter depth A (m^2) - Filter cross- section area, ΔH (cm) - Headloss, Q (m^3/h) – Flow rate, Qd (m^3/h) – Drainage flow rate, VF (m/h) - Filtration rate, Vd (m/h) – Drainage rate,		

5.2.5.3 Slow Sand Filter

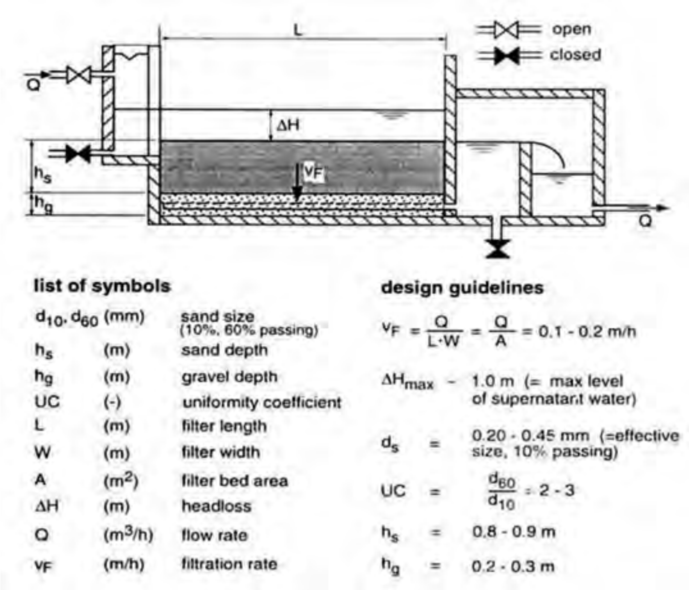


Fig. 5-6 Slow Sand Filter with Design Criteria

Source: Surface Water Treatment by Roughing Filterest- A Design, Construction and Operation Mannual (SAN DEC-SKAT, 1996)

The substantial reduction of bacteria, cysts and viruses by the slow sand filters is important for public health. Slow sand filters also remove the finest impurities found in the water. For this reason they are placed at the end of the treatment line. The filters act as strainers, since the small suspended solids are retained at the top of the filter. However, the biological activities of the slow sand filter are more important than the physical processes. Dissolved and unstable solid organic matter, causing oxygen depletion or even turning to fouling processes during the absence of oxygen, is oxidized by the filter biology to stable inorganic products. The biological layer on top of the filter bed, the so-called "scum", is responsible for oxidation of the organics and for the removal of the pathogens. A slow sand filter will produce hygienically safe water once this layer is developed.

The slow sand filter technology copies nature. The sand layers of aquifers convert unsafe surface water into good quality drinking water. Especially the harmful bacteria, viruses, protozoa, eggs, and worms are most effectively removed by physical and biochemical processes to a level which no longer endangers human health.

The layout of slow sand filters is simple and straightforward. As shown in Fig. above, a slow sand filter contains an open box filled with a sand layer of a depth of about 0.8 to 1.0 meter. The upper part of the filter box is filled with water flowing by gravity through the sand bed. The filtered water is then collected by an under drain system and conveyed to the clear water tank. The well-graded sand of the filter bed is relatively fine; i.e., its effective size ranges between 0.15 and 0.30 millimeter, but recent field experience revealed that also somewhat coarser sand can be used.

Slow sand filter operation is easy and reliable. Slow sand filters are usually operated at 0.1 to 0.2 m/h filtration rates. Consequently, an area of 1 m^2 sand produces about 2.5 to 5 m^3 of water per day. The flow rate is preferably controlled at the filter inlet, and the water level is maintained at a minimum level above the sand bed by means of a weir or effluent pipe located at the filter outlet. Effective biological treatment can only be achieved if a reasonably steady throughput is maintained. Therefore, a 24-hour operation is recommended as it makes maximum use of the available filter installations. The initial filter resistance of a clean sand filter ranges between 0.20 and 0.30 meter. The head loss gradually increases with progressive filtration time. The sand filter has to be cleaned when filter resistance amounts to about 1 meter.

Filter cleaning must be carried out once the supernatant water has reached its maximum permissible level; i.e., when maximum filter resistance of about 1 meter is attained for the designed filtration rate. Well-operated slow sand filters should at least achieve more than 1 to 3 months of filter runs. The term "filter run" is defined as the time between two subsequent filter cleanings. In order to realize such long filter runs, slow sand filters have to be supplied with relatively clear water.

5.2.5.4 Rapid Sand Filter

The rapid sand filter or rapid gravity filter is a type of filter used in water purification. Rapid sand filters use relatively coarse sand and other granular media to remove particles and impurities that have been trapped in a floc through the use of flocculation chemicals—typically salts of aluminum or iron. Water and flocs, flows through the filter medium under gravity or under pumped pressure and the flocculated material is trapped in the sand matrix.

Mixing, flocculation and sedimentation processes are typical treatment stages that precede filtration. Chemical additives, such as coagulants, are often used in conjunction with the filtration system. It is best suited for municipal water supply projects.

(Since much of paragraph has already been taken for water treatment units-this further has not been dealt in detail here).

Note: Readers are encouraged to go through other text book materials for further reading in the water treatment headings.

5.2.6 Water Treatment

Water from a slow sand filter with a well-developed biological layer is hygienic and safe for consumption, any further treatment, such as disinfection is, therefore, not necessary. As documented by numerous examples in many developing countries, provision of a reliable chlorine disinfection system in small rural water supply schemes is often not practicable. A regular supply of mostly imported chemicals, and accurate dosage of the disinfectant, is the two main practical problems encountered.

5.2.7 Sump Well

A sump well generally serves the dual function.

- Home for the pump (submersible) laying.
- Stores water during non-pumping hour and safely dispose of surplus water collected in excess of the pipe capacity,

Collect the flow from the intakes when more than one source is utilized (in case HRF is not provided). Each source should have its own individual pipeline to the sump-well for this purpose, Allow free flow to avoid creation of back pressure in the spring.

Generally, water is collected in a sump well and is then pumped to the service reservoir through transmission pipeline. Hence, designing of a sump-well is consisting of:

- determining the capacity of sump-well
- layout of electro-mechanical equipments

In a small (say up to 50 HH) having spring as water source there may not need of collection chamber, HRF and sum-well structures in sequence. These all structures together can raise the project cost. Only well built intake (intake with valve chamber) with sump-well in sequence can serve the purpose.

In sump-well pump should be secured well, for this pump can be laid horizontally (mostly the submersible pumps) and plain cement concrete blocks of dimension 30cm x 20cm x 12cm can be laid in sequence and tied the pump with these blocks by knot or strong steel wire of 6-8mm dia. After tying the pump with concrete blocks, it will not change its position due to vibration, during its operation hours. If horizontal pump is used instead, pump can be laid outside of sump-well in a small shed made especially for it, called pump house. The detail of pump-house is given in subsequent chapters.

5.2.7.1 Capacity of Sump-Well

When the source yield is less than the pumping rate or water from several sources are to be pumped at once, water is first collected in a sump well, the effective volume of which is determined from the formula:

$$V = \frac{3600\,(Qp.Q - Q^2) \times T \text{ cu .m.}}{S.Qp}$$

where,

S - no. of starts per hour

Qp - pumping rate (m^3/s)

Q - inflow rate (m^3/s)

T – no of pumping hours (hrs.)

The volume of sump is minimum, if the pumping rate equals twice the inflow rate, in which case above formula reduces to $V = \frac{900 \times Qp. \times T}{S}$

5.2.8 Pipeline

Pipelines are the carriage of water from source to service reservoir and service reservoir to tap posts. They are the heavy investment of any water supply projects. So, we need to first understand different alternatives within piping system to better optimize the cost of any projects.

Materials: Pipe of different materials is available in the market some of them are:

Fig. 5-7 HDPE Pipe

1) High Density Polyethylene Pipe (HDPE):

These are the most commonly used pipes in rural water supply systems in Nepal. HDPE is a polyethylene thermoplastic made from petroleum known for its large strength to density ratio. The density of HDPE is only marginally higher than that of low-density polyethylene, HDPE has little branching, giving it stronger intermolecular forces and tensile strength than LDPE. The difference in strength exceeds the difference in density, giving HDPE a higher specific strength. It is also harder and more opaque and can withstand somewhat higher temperatures (120 °C/ 248 °F for short periods. The HDPE pipe comes with following standards:

- NS : 40 - 2042 published by Nepal Bureau of Standards and Metrology
- The Pipes is supplied either as coils with a minimum inner diameter of 25 times the OD of the pipes (except 2,2.5, and 4 kg/Sq.cm. pressure ratings), as given below or in lengths of five meters.

Table 5 2: HDPE Pipe Properties

Pipe Size, mm	Pressure Rating, kg/cm²	Series	Supply length, m	Inner Coil diameter, m
16	10	V	300	0.50
20	10	V	300	0.50
25	10	V	200	0.70
32	6	IV	200	0.80
32	10	V	100	0.80
40	4	III	5*	
40	6	IV	100	1.00
40	10	V	100	1.00
50	4	III	5*	
50	6	IV	100	1.25

50	10	V	50	1.25
63	4	III	5*	
63	6	IV	50	1.50
63	10	V	25	1.50
All pipes above 63 mm dia, is supplied in 5 m length.				
* These pipes are supplied in coils as per the order of the client.				

A continuous line between 2mm to 5mm wide must be indelibly and clearly marked along the pipe surface according to the following code:

- 2.5 kg/cm^2 working pressure - red line
- 4.0 kg/cm^2 working pressure - blue line
- 6.0 kg/cm^2 working pressure - Green line
- 10.0 kg/cm^2 working pressure - Yellow line

Each pipe shall also have the following information marked on it:

Item number; pipe size - outer diameter; Series in Kgf/cm^2; Weight; Length; NS,IS, BS, etc, or relevant authoritative Standards mark.

Note: Pressure rating of pipe follows simple hydrostatic formula as below:
P = r x h
Where: r = 1000kg/m^3 (unit weight of water)
h = pressure column – height
Thus h=P/r

$$= \frac{10\text{kg} \times \text{m}^3}{\text{Cm}^2 \times 1000\text{kg}} = \frac{10 \times 100 \times 100\ \text{m}^3}{1000\text{m}^2} = 100\text{m}$$

So, 10kg/cm^2 pipe withstands 100m of water column height

2) Galvanized Iron (GI):

These are the iron pipes with outer surface coated with zinc in galvanization plant in factory. After iron pipe is manufactured from plant, these pipes are dipped in hot zinc plant for a certain period that coats the zinc to the pipe. These pipes are best for high pressure withstanding that HDPE pipe cannot bear. In pipeline these pipes are used only where water column height exceeds the pressure ratings of HDPE. A part from that in rural water supply projects, almost all fittings of the structures and pipeline are used of GI. So, GI pipe and fittings are popular building materials for rural water supply systems in Nepal. These pipes are commonly available in ½” to 4” in diameter. The Pressure rating of GI pipe is given in Annex-IX. GI pipe comes with both end threaded and one end with pipe socket. Following standards should meet by the GI materials:

Fig. 5-8 GI Pipes

- Nepal Standard NS : 199 - 2046 published by Nepal Bureau of Standards and Metrology or
- Indian Standards IS : 1239 (Part I) - 1990 published by Bureau of Indian Standards, Manak Bhawan, New Delhi, India.

This table gives more detail about the GI pipe properties.

GI pipes come in three categories:

1. Heavy duty
2. Medium duty and
3. Light duty

Generally, light duty pipe is not used in the water supply projects. Medium duty pipe and heavy duty pipes are frequently used in water supply systems in Nepal. These two pipes can be used in combination or alone as per required, as the case may be: water column height to be withstand by the pipe. For pressure rating of GI pipes pls. refer Annex-IX of this manual.

Table 5-3 GI pipe properties

Pipe	Weight per m	Thickness
15 mmØ GI pipe(medium duty)	1.284	2.60
20 mmØ GI pipe(medium duty)	1.658	2.60
25 mmØ GI pipe(medium duty)	2.53	3.20
32 mmØ GI pipe(medium duty)	3.279	3.20
40 mmØ GI pipe(medium duty)	3.788	3.20
50 mmØ GI pipe(medium duty)	5.319	3.60
65 mmØ GI pipe(medium duty)	6.349	3.60
80 mmØ GI pipe(medium duty)	8.85	4.00
100 mmØ GI pipe(medium duty)	12.99	4.50
125 mmØ GI pipe(medium duty)	16.95	4.85
150 mmØ GI pipe(medium duty)	20.00	4.85
200 mmØ GI pipe(medium duty)	33.2	6.00
15 mmØ GI pipe(heavy duty)	1.513	3.20
20 mmØ GI pipe(heavy duty)	1.969	3.20
25 mmØ GI pipe(heavy duty)	3.077	4.00
32 mmØ GI pipe(heavy duty)	3.968	4.00
40 mmØ GI pipe(heavy duty)	4.587	4.00
50 mmØ GI pipe(heavy duty)	6.369	4.50
65 mmØ GI pipe(heavy duty)	8.197	4.50
80 mmØ GI pipe(heavy duty)	10.417	4.80
100 mmØ GI pipe(heavy duty)	15.436	5.40
125 mmØ GI pipe(heavy duty)	18.52	5.40
150 mmØ GI pipe(heavy duty)	22.22	5.40
200 mmØ GI pipe(heavy duty)	43.5	8.00

Source: Design Guideline 1-12 Volumes, GON, DWSSD

3) CI (Cast Iron)

It comprises predominantly a gray cast iron tube and was frequently used uncoated, although later coatings and linings reduced corrosion and improve hydraulics. Cast iron pipe was superseded by ductile iron pipe, which is a direct development, with most existing manufacturing plants transitioning to the new material during the 1970s and 1980s. Little cast iron pipe is currently manufactured. These pipes are available in size ranging from 3" to 48" and class A-D. The class of pipe defines the wall thickness and outer diameter. Cast iron pipes are rarely used in these days even in urban water supply projects. These are mostly used for sanitary fittings in household connections in these days.

Fig. 5-9 Cast Iron Pipes

4) DI (Ductile Iron):

It is made of ductile iron and this is a direct development of earlier cast iron pipe, which it has suppressed. The ductile iron used to manufacture the pipe is characterized by the spheroid or nodular nature of the graphite within the iron. Typically, the pipe is manufactured using centrifugal casting in metal or resin lined molds. Protective internal linings and external coatings are often applied to ductile iron pipes to inhibit corrosion: the standard internal lining is cement mortar and standard external coatings include bonded zinc, asphalt or water-based paint. These pipes are available in different in size (3"-64", though custom size and ratings can be manufactured) and pressure ratings. Normally 150 to 350 psi (1 psi =0.0703kg/cm^2: 10.54 to 24.60kg/cm^2).These pipes are not commonly used in the rural water supply systems and not dealt in much here.

Fig. 5-10 DI Pipes

5.2.9 Transmission pipeline

A pipe that feeds a storage tank (reservoir tank) at certain interval of time (as per pump operation schedule) from a source (Sumpwell - Reservoir Tank; Reservoir Tank - Reservoir Tank) is called a Transmission Main. In solar PV pumping system it should also be designed with some peak factor (see. article 5.2.11 for calculating the 'peak factor'). So in this system, transmission main is also designed with the concept of closed flow. Since, transmission line designed with closed system, there is always the static pressure in pipe, in order to prevent pump damage from backwater flow during non-operation hours, and a check (reflux) valve should be provided after the pump down in the sump-well.

The design principle for the transmission main is givien in the article 8.1.4.1. But there are some special considerations during the design of pumping main that is discussed here:

The goal of selecting the pipe size of the system is maximize the pipe sizes used, while minimizing the costs of the pipe. As pipe sizes are increased, the system head loss, due to friction, is decreased. The size of the suction and discharge piping should be at least the size of the pump connections. Suction pipe should be one (1) to two (2) size larger than the pump connection, never smaller. A reducer can be used to in the suction line to allow for the suction pipe that is oversized.

The overall design of the piping system should be as straight and as short as possible, with a minimal about of bends or turns in the system. Sudden changes in pipe diameter will cause turbulence and head loss in a system, and, therefore, should be avoided.

A velocity of 2.1 to 6.8 meters per second is recommended, with a preference of the flow to below 4.8 meters per second. Velocities of more than 10.2 meters per second should be avoided

The larger pipe will also assist with the increase of the NPSH available and reduce pressure losses due to friction. The piping configuration and fittings on the suction must be closely considered to minimize friction losses. Any unnecessary fittings, valves or accessory items should not be designed or installed in the pump suction piping. A straight length of 4 to 10 pipe diameters should be designed into the suction piping prior to the pump suction connection. If this length is not possible, the use of straightening vanes or diffusers can be installed to ensure uniform flow.

5.2.10 Distribution Line

Pipeline connecting the reservoir tank to tap post is termed as distribution line. It carries the maximum demand flow (peak flow) in system. Mostly distribution line are laid as 'dead-end' pattern system and designed accordingly in rural water supply systems.

Distribution pipelines are used to supply water to the various consumers. Pipes of different diameters and lengths constitute a distribution network. Distribution pipe sizes are determined by the tap flow rate when the water is supplied through the stand post. The distribution system should supply water at adequate residual head and should be accordingly sized. Design of distribution line in solar PV pumping system as such, follows a simple gravity flow engineering principle (pls. refer article 8.1.4.2 for basis of design for distribution line).

The hydraulic grade line should as much as possible be 10 m above the ground level. Due to the nature of the ground profile, some-times, it may fall below the ground at critical points. In such case negative pressure would develop in the pipeline, which must be avoided. Few typical examples of hydraulic grade line are shown in Fig. 5.11

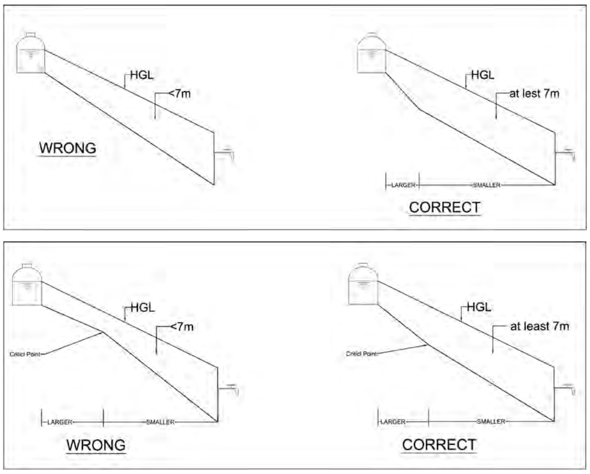


Fig. 5-11 Pipe line Profile and HGL

In a distribution system, the flow changes continuously due to the opening and closing of faucets. These changes may create high-pressure waves due to water hammer. This may affect pipe joints, threads, and fitting and in extreme cases, even the pipeline may burst.

It is for these reasons; the maximum pressure in the distribution main should not exceed a maximum static pressure 60 m even if pipe material with a permissible working pressure of 10 kg/m^2 is used. Only in cases of pipe sections aligned along areas and gullies that would not be habituated in the future, the static head can be increased to say 80 meters.

5.2.11 Reservoir Tank

A reservoir tank is constructed to balance between demand and supply of water. If the inflow rate (supply) is less than the outflow rate (demand) a reservoir tank is constructed to reserve the water in non-supply hours and providing that surplus water in peak hours. Since the water is supplied to the tap stands in the closed intermittent system, it is imperative in the 'Solar PV Pumping Systems' to provide a reservoir tank. Both the water coming from transmission main and going out from the distribution system is in the intermittent system, we can adopt the following consumption pattern for designing the reservoir tank.

Table 5-3: Consumption Pattern of Intermittent Inflow and Intermittent Outflow WSPs.

Community Tap (Peak Factor = 4.0)

Time Period		Hours		Cum. Inflow (lt.)	Cum. Consumption (lt.)	Surplus (lt.)	Deficit (lt.)
From	To	In	Out				
6:30 AM	9:30 AM	0.50	3.0				
9:30 AM	4:00 PM	6.50	0.0				
4:00 PM	7:00 PM	0.50	3.0				
7:00 PM	6:30 AM	0.00	0.0				

School Tap (Peak Factor = 6.0)

Table 5-4: Consumption Pattern for School Tap

Time Period	*Consumption*
10:00 am – 2:00 Pm (4 hours)	100 %

But care should be taken in different consumption pattern in different localities and consumption pattern suitable to that locality can also be adopted. If consumption pattern other than the standard is adopted peak factor should be adopted accordingly. Please refer the following example for 'Peak Factor' calculation procedure:

Total hour of supply = 3 hrs. (i.e. 6:30 am – 9:30am)
Percentage of 3hrs in 24hours (a day) = (3/24) x100% = 12.5%
Water demand in 12.5% of time = 50%, thus
Peak factor = 60/12.5=4.0

Reservoir tank can also be designed as intermittent inflow and continuous outflow system. Since there is every chance that any of the tap stands's faucet openings and loss of water in continuous outflow system (if a community is small one this pattern may be adopted-as water can be effectively preserved in a small community-otherwise this system should be discouraged), costlier water should not be spilled off. Following standard consumption pattern may be used to design the reservoir tank in this system:

Table 5-5: Consumption Pattern of Intermittent Inflow-Continuous Supply

Time Period		Inflow Hours	Water Consumption %
From	To		
5:00 AM	7:00 AM	0	25.0%
7:00 AM	12:00 AM	2.5	35.0%
12:00 AM	5:00 PM	5	20.0%
5:00 PM	7:00 PM	0	20.0%
7:00 PM	5:00 AM	0	0.0%

5.2.12 Tap stand

Tap stand is a structure visible to all. It is more than just a water supply system structure. Its design should therefore, conform closely to the social and cultural aspirations of the community. The stand post must be appropriately located. It must be aesthetically pleasant and robust. The central pad of the stand post should be made of masonry, while cement concrete paving with

> A multi-reservoir system water supply project has number of service reservoirs (RVTs). The settlements of the rural village generally are scattered in nature and it might not be possible to command the whole area with a single RVT. In such cases numbers of RVTs are located in parallel so as to command the whole settlements with ease. It has following features and advantage:
> 1) Separate RVT for separate settlement
> 2) It divides the project area in sub-projects area.
> 3) One sub-project operation performance does not disturb the another/others.
> 4) The ownership feeling of villagers to sub-project increases.
> 5) Operation and maintenance process gets easy.

plastered surface would be desirable on the outside. The drainage from the stand post should be taken away from it and safely disposed. When it is not possible to easily drain away waste water, appropriate soakage pit is provided.

The location of a stand post is governed by the population density, and by the settlement pattern. In areas having low population density, a stand post may be needed to serve only a few houses. The provision of a stand post may be determined by the following two factors:

a) Maximum desirable walking distance to fetch water, and
b) The number of people who are supplied water conveniently.

The number of people to be served by a stand post is also determined by the tap flow rate. A stand post should serve a maximum 100 users. The following stand post location criteria based on water carrying distance should be used as a reference.

Table 5-6: Maximum Distance of Stand Post Location from Users (Service Level)

Walking Distance	Desirable	In Exceptional Cases
Horizontal	150m	250m
Vertical	50m	80m

The criteria for locating stand posts should be clearly explained to the users who should decide the sites. Often the location of a stand post is influenced by certain groups. It can be avoided by selecting a location, which would be acceptable to all the users. To avoid complications, the following guidelines should be followed in locating a stand post:

- Accessible to all users all the time.
- Not located within a house or court yard.
- If the location is likely to create friction, the villagers should be persuaded to choose an alternate location.
- Located where waste water is drained away easily.

In some cases, few houses may exist along the transmission main route. These users may be served by tapping average flow from the transmission main. A storage tank of 1 m^3 capacity may be provided along with a stand post to distribute water to these household.

The population that would be benefited from a stand post should be accurately estimated. This would need detailed study of the cluster and settlement pattern.

5.2.13 Other Structures

These structures (some of them or all in any project) should be used in PV pumping system only in uttermost need has been felt. These structures, in one hand increases the technical complexity of project in the other they increases the possibility of water leakage and loss on the route. Every care should be taken to minimize the water loss/leakage in the route while making layout of the project.

5.2.13.1 Distribution Chambers (DC):

When we need a multi-reservoir system ‘PV Pumping Project’ to design, there comes a DC structure in the scene. A distribution chamber (DC) is used to proportionally divided inlet flow. Two main functions of the Distribution Tank are as follows: (1) to break water pressure and (2) to divide and distribute water to different supply clusters. The different types of tank used include masonry tanks, Ferro-cement tanks, and plastic tanks. Stone masonry with cement mortar is also implemented in projects, as it is easy to construct and easy to fit the pipes and fittings in the masonry tank. Stone masonry tanks have also proved easier to operate, maintain.

To divide the inlet flow of water, outlet pipe size and proper orientation (horizontal) allow the flow to be distributed at an approximate ratio regardless of variations in the inlet flow. In some cases the proper pipe combination can control the flow accurately enough to eliminate the need for globe valves. The outlet flows are controlled by outlet pipe size and orientation and will be independent of any oversized downstream pipelines.

The DC operates on the principle that open channel flow in two horizontal pipes (lower edge at the same height) will be approximately proportional to the pipes diameters.

(Diameter of pipe - 1/Diameter of pipe-2) = (Flow in Pipe-1/Flow in Pipe-2)

Important: The pipes must be placed LEVEL (with respect to lower edge) and in a 'Horizontal' orientation if the outlet flows are to be in a ratio approximately equal to that of the outlet diameters.

Three methods can be used to divide the flow:
A. Proper orientation and sizing of GI outlets
B. The pipeline from DC to RVT can be designed to control the flow naturally
C. An orifice can be placed in one or all of the outlets to control the flow (not recommended).

5.2.13.2 Uses Reservoir Tank as DC (RVT/DC)

This method can be used when the RVTs are in series. This will often be the case since many villages in Nepal follow a given route down a hill side. RVT/DCs eliminate the need for a separate distribution chamber, lowering project costs and future operation and maintenance requirements.

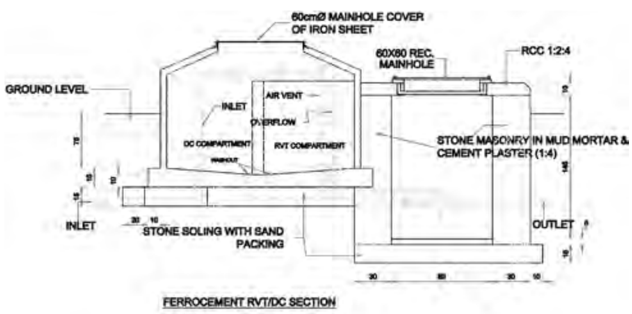


Fig. 5-14 Typical Section of Ferro-cement RVT/DC

The critical aspect of this approach is that it relies completely on the pipeline to control flow.

The RVT/DC is located at the site of the first sub-system tap stand. The two outlets are placed at different levels (5 cm), the distribution line being higher than the transmission line. The difference between the inlet CDF and outlet CDF (to the lower RVT) is equal to the RVT's sub-system's CDF. The main disadvantage of the RVT/DC is that a decrease in source will not be equally distributed since the transmission main outlet is lower and will always get preference in terms of flow.

> CDF stands for 'Continuous Demand Flow'. Total demand of water (in 24 hrs.) is converted into demand in per second.
>
> If total demand = 24000lit. (per 24hrs.)
>
> CDF=24000/(24*60*60)= 0.278lps.

The transmission outlet must be slightly lower for two reasons. If the sub-system users damage or over consume, the negative effect (empty RVT) must not be felt by the other sub-systems. In addition, the outlets cannot be at the same level because the distribution line is designed for peak flow whereas the transmission main is only designed for the remaining system's CDF. That is, if the tank was empty (minimum water level), the distribution line would receive a much greater proportion of the incoming water.

5.2.13.3 Break Pressure Tank (BPT)

When water flowing through pipe (close conduit) is brought in contact with open atmosphere, the hydrostatic pressure is reduced to zero. It is sometimes essential to reduce the flowing water pressure to zero due to following reasons:

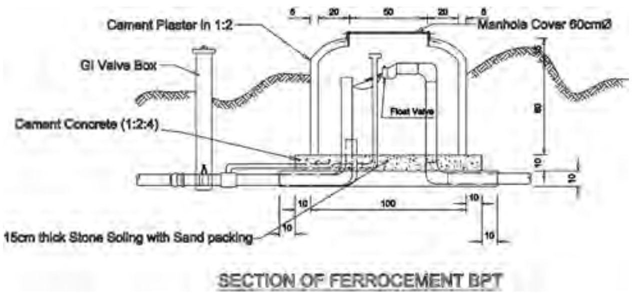


Fig. 5-15 Typical Section of Ferrocement BPT

- The total head of the pipe system at point exceeds than the rated head capacity of pipe material.
- The settlements of the village are located far-downhill side.
- Settlements are scattered with high altitude difference.

All those structures in which, water is disposed freely to open atmosphere can acts as a BPT. So Distribution Tank, RVT and RVT/DC are also acts as break pressure structures though their main functions may differ. Generally, standalone BPT is provided with float valve so as not to have overflow of water from this structure. Instead water is returned back to uphill located service reservoir (RVT) with the aid of 'Float Valve'. With the increase failure rate of float valves, BPTs are least preferred structures in any rural water supply systems.

5.3 Special Structures

These are the structures which are not used/required in common conditions. These structures are introduced in the system to address the special conditions posed by the pipeline route-terrain. It is believed that, less the special structures high the sustainability of the system. Special care should be taken while locating these structures along the route of pipeline.

5.3.1 Suspended Crossing

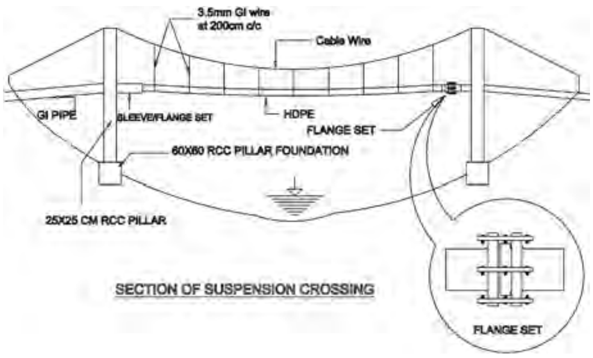


Fig. 5-16 Section of Suspension Crossing of Pipeline

Suspended crossings are required whenever, the pipeline crosses a river or stream or wide and deep gullies. Crossings may be also required to cross over an unstable terrain which may be subjected to erosion and landslides.

Three categories of crossings are often encountered.

- Gully crossing for a span up to 6 m
- Dry khola (Stream) crossing, and
- Suspended crossing when the span is greater than 6 m.

5.3.2 Gully Crossing

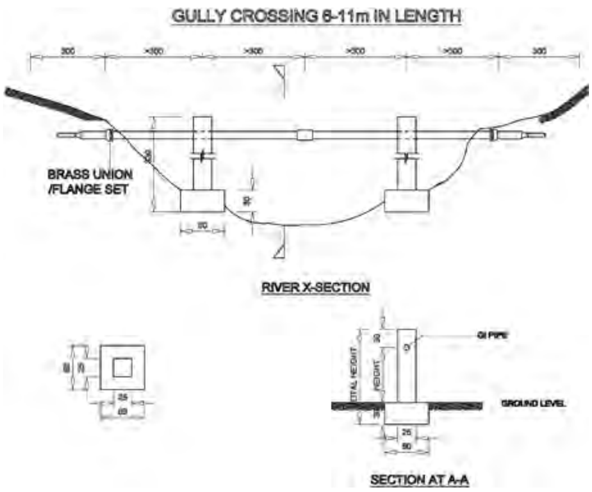


Fig. 5-17 Gully Crossing of Pipeline

Narrow and deep gullies up to 6 m spans can be crossed by a span of GI pipe above the bottom of the gully, clear of the maximum flood level and suitably anchored to the banks of the gully or using stone masonry wall, whichever is found to be suitable. Wide gullies or streams which dry up should be crossed by GI pipes buried at 1.5 to 2 m depth and anchored in the masonry or gabion walls to prevent it from getting washed away during flood times.

The pipe in the gully in the suspended crossing may be either of GI or HDP, depending upon costs and availability of materials. An HDP pipe, however, will require a protective covering using a higher diameter pipe wrapped around it, as this pipe will deteriorate quickly under exposure to sunlight, and would be likely to break within a few years.

5.3.3 Air Valve

Air valves are the structures that release the entrapped air pocket within the pipeline route along the longitudinal profile. When pipeline route passes through very zig-zag terrain; ups and downs along its route, air is entrapped in the high humps. Entrapped air makes obstruction in the flow of water and needs to be released, that is where ‘Air Valve’ is required. It should be borne in mind that air valves are always located in the highest elevation along the pipe-longitudinal profile. It is believed that minimum the number of air valve, minimum will be problem posed by the system (keep minimum number of air valve in the system-where unavoidable). So, while surveying the route of pipeline, care should be taken to pass route through the terrain having minimum numbers of zig-zags (undulations).

An air valve serves mainly the following three purposes:

- release air from the pipeline during the filling process
- release air from the pipeline during the normal operation of the water supply, and
- Prevent the development of vacuum in case a valve is closed upstream of the air valve.

5.3.4 Washout (WO)

Washout is a structure provided to get rid of the accumulated sediment in the pipeline that has been filled up due course of time while its operation. This structure is located at the lowest elevation along the longitudinal profile of the pipeline alignment. Normally, WO might not require locating in the 'PV Pumping Projects'. The water is pre-treated at horizontal roughing filter and pumped to service reservoir, so there is less chance to have sediment in the water after service reservoir. There is no need of have WO in the transmission line of 'PV-Pumping' projects. If WO is felt to require in the distribution line should be located at the deepest point along the pipeline alignment and analyzed properly whether there is possibility of accumulating the sediment along the route.

5.3.5 Support Pillars and Thrust Blocks

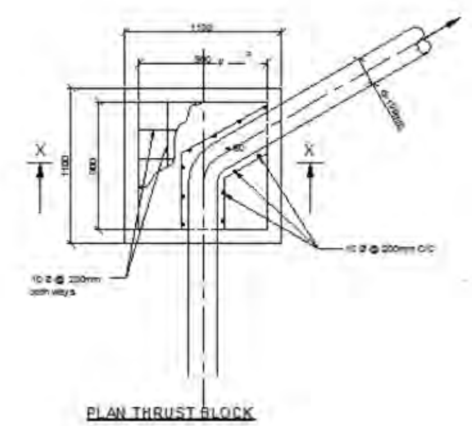


Fig. 5-18 Plan of Thrust Block

Transmission line or distribution line, if there is chance of pipeline to be passed from or above of the ground, there is every chance that pipe is vandalized and broken ultimately. These pipes should be properly secured in position and do not get swing in any circumstances. HDPE pipe should always be buried under ground but GI should pipe should not be. So, this situation is mostly in case of GI and in transmission line in PV pumping systems. The masonry structure built to support the pipeline is called 'support pillars'.

Pipe flowing full in bends exerts the force in vertical or horizontal direction due to unbalance internal force or centrifugal force, in order to counteract this force some external support should be provided and that is called 'anchor block'.

The spacing of support pillar should be judicially decided after laying out of GI pipe such that the pipe should not swing horizontally or vertically. Generally, it should be spaced about 8-10m distance (seeing the ground and rise of pillar) and near or on the fittings. There should be thrust block at the beginning and end of the pipeline and spaced around 5 to 6 pieces of hanging GI pipe length.

An example design of thrust block is given in Annex-XVI

5.3.6 Waste Water Ditch

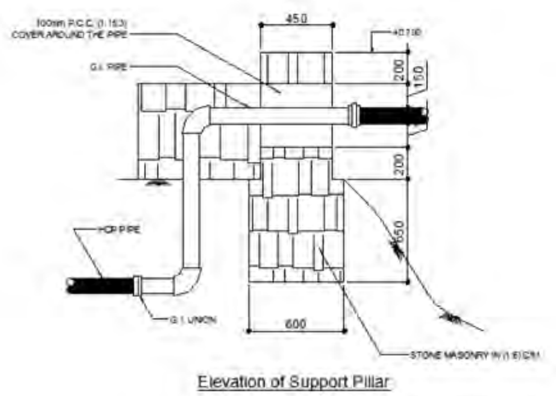


Fig. 5-19 Typical Section of Support Pillar

The water coming out from tap-post of PV pumping system is costlier water so it should be well preserved. However, it is impossible to control almost all of water flowing out from tap-post. The water flowing out from tap plateform should be well managed such that it should not create any social or environmental (it should not be the place for mosquito breeding) adverse impact. An earthen ditch (length & breadth3-6m and depth 0.5-0.8m) is sufficient to store the waste water. The bottom and side of the ditch can be dry stone lined so that the soil does not get muddy. If possible, the waste water collected in ditch can be utilized in kitchen gardening or vegetable farming with the unanimous consensus among the users of tap-post.

5.4 Pump House

In general no pump house is required when submersible pump-set is installed. But for housing of electrical components like, power distribution panel, motor control panel and if provided for the standby diesel power generator well house is constructed. Pump house can built above the slab of sump-well for reduction of cost. If pump-house is to be built above the sump-well slab, the slab should be built sufficiently strong to withstand the anticipated load and manhole cover of the sump-well should not be inside the pump house. It should be freely accessible for anytime.

Care should be taken while constructing the pump house:

- Pump house should not only be accessible during the construction phase, but also during the execution of operation and maintenance.
- Energy supply may be a decisive factor on the situation of the pump house.
- The pump house should be constructed in such a height that the mechanical and electrical equipments must be free from flooding.
- Special measures will be required and structural stability will have to be assured for pump house constructed near to a stream or a slope.
- Sufficient space for mechanical and electrical equipments in the pump room Pump room should have space for the pump operator to watch the equipment during operation and working space during maintenance. Store room for spare parts and tools should be provided. The flooring of the pump house should be strong enough and should not be damaged during repairmen of the machine. There should be sufficient space to move between them during maintenance purpose, but no unnecessary empty place. All space should be well lighted. The door of the pump room should be large enough and should open outwards to allow passage of all parts of the installation as well as to use it as an emergency exist. Drainage opening must be provided in the pump room.
- Never construct pump house in mud mortar joints

5.5 Foundation for solar panel mounting structures

Solar PV installations require support structures, commonly referred to as racking or mounting, to secure the panels to the ground or building roof. For ground mounted structures racking may be mounted onto foundations that are driven (I beams, channels or posts), or screwed (helical piles and earth screws). Ground systems are either fixed tilt or track the movement of the sun, either in one axis or two axes. Roof top racking are either ballasted with concrete pavers resting on ballast trays, or attached with penetrations onto the roof of the building, or fastened to metal seams with clips. There are also hybrid systems which are principally ballasted but also have attachments to compensate for seismic issues or where roof pitch typically exceeds 5 degrees. The size of installation, available surface area, type of incentive and utility program, building type and ground conditions predicate which system will be used.

Fig. 5-20 Roof Layout of PV Modules

Fig. 5-21 Ground Layout PV Modules

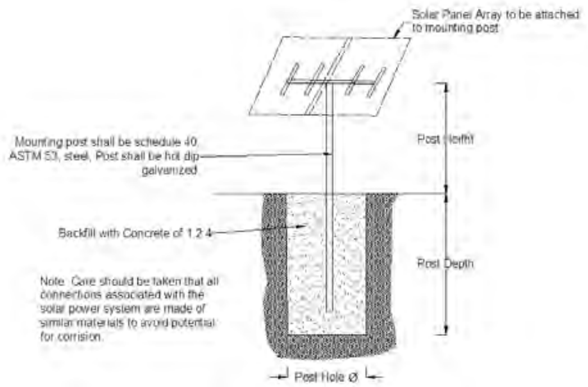


Fig. 5-22 Ground Mounted Solar Panel-Mounting Post and Footing Details
Source: Design of Small Photo Voltaicf (PV)
Solar-Powered Water Pump Systems USDA

If the solar panel is to be rest on roof, proper fastening of the panels into the roof is essential. In addition, the house owner should give no objection to keep the panels above his house. This will particularly reduce the chances of vandalism of panels but these panels should be such located that they should be easily accessible as and when required basis. They required frequent visit for inspection and that should not be obstructed. In small water supply projects, it could be feasible as there are few numbers of panels.

The footing design of the solar panel mounting structures is dependent on the following parameters:

- Tilt angle and tracking characteristics of the solar power system.
- Local design wind speeds where the solar power system is to be installed.
- Support and racking configuration.
- Overall solar module system size and weight.
- Local design codes and project requirements.
- Soil characteristics relative to friction, sliding, consolidation, slope stability, etc.

Table 5-7: Ground mounted solar panel mounting post selection table.

Post Height (ft)	Panels	Min. Post Dia. (inch)	Post Hole Dia. (inch)	Min. Embedment Depth (inch)	Concrete Volume (Cu.ft.)
4ft	Single Panel (A=13.9ft^2)	4	24	38	0.34
	Double Panel (A=27.8ft^2)	4	24	48	0.71
	Triple Panel (A=41.70ft^2)	4	30	54	1.16
	Quad Panel (A=55.6ft^2)	4	36	56	1.71
6ft	Single Panel (A=13.9ft^2)	4	24	38	0.34
	Double Panel (A=27.8ft^2)	4	30	50	0.92
	Triple Panel (A=41.70ft^2)	4	36	54	1.29
	Quad Panel (A=55.6ft^2)	6	36	60	1.92
8ft	Single Panel (A=13.9ft^2)	4	30	38	0.43
	Double Panel (A=27.8ft^2)	4	30	50	1.16
	Triple Panel (A=41.70ft^2)	6	36	54	1.44
	Quad Panel (A=55.6ft^2)	6	36	60	2.16

Note: Minimum post diameter, post hole diameter and post depth values have been designed for wind speed of 95mph. Sites where wind load exceed these values will need to be examined by a experienced engineer.

(Ref.: Design of Small Photovoltaic (PV) Solar-Powered Water Pump Systems -2010-USDA

For detail 'wind load' calculation pls. refer other materials. A good stuff available on 'Determining wind and snow load for solar panels' by SOLARWORLD)

5.6 Disinfection

In PV pumping system, if source is of well-preserved spring or spring fed stream and filtration unit is properly taken care of and functioning well, it is advisable not to adopt the below mentioned procedures. As this process involves sound technical know-how and additional structures that gives additional overhead to the villagers.

Pathogenic organisms found in water supply sources include a variety of bacteria of intestinal origin, intestinal parasites, viruses, and some larger organisms. The most common water borne diseases prevented by disinfection are as shown below:

Diseases prevented by Disinfection

Bacterial	**Viral**	**Parasitic**
Typhoid fever	Hepatitis	Amebiasis
Paratypoid	Rotavirus	Giardiasis
Childhoold bacterial	diarrhea	Crypotsporidium
Diarrheas		
Cholera		

Chlorination: Chlorine is the most commonly practiced disinfectant used in public water supply systems. A major advantage of chlorine is that it forms stable residues which are easy to measure. These residues also protect the distribution system from biological re-growth and provide a limited protection against contamination from cross-connections in the distribution system. Chlorinated lime ($CaO*CaOCl_2*3H_2O$) commonly known as Bleaching powder is most widely used disinfectant in Nepal which contain about 35% of chlorine and the method to use this described here:

5.6.1 Method of chlorination:

Chlorination can be fed to distribution system as continuous system or manually. In intermittent system manual system can also be practiced but it is laborious work not advisable to execute in continuous systems. A simple continuous system is described here with figure. Users can devise a new and more effective one to feed the chlorine into distribution system, understanding the concept well in advance.

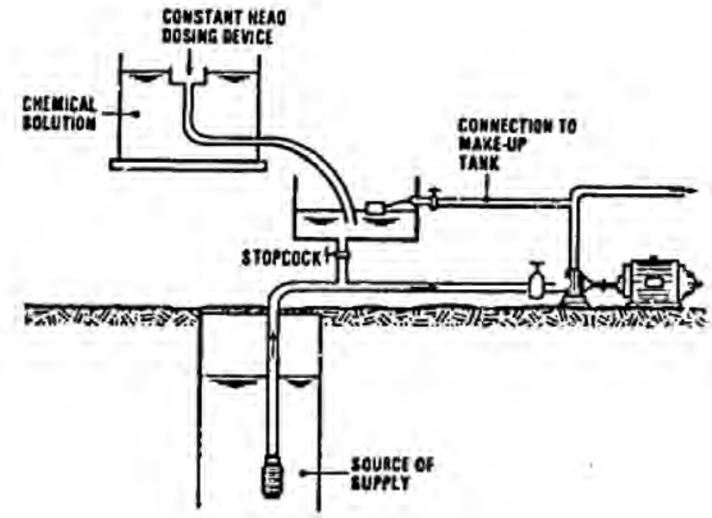


Fig. 5-23 Continuous Feeding Chlorination System

Source: Desinfection for Rural Community Water Supply Systems in Developing Countries-Technical Note USAID

One of the simplest and least expensive hypo-chlorination methods is the pot type. An earthen, plastic, or other locally available container is filled with a mixture of gravel, sand and bleaching powder. After several 6-8mm holes are drilled in the bottom of container, it is suspended in the RVT (or in water running pipeline directly) with its mouth uncovered. In these type chlorinators the concentration of chlorine is reduced with time and, as with most simple disinfection systems, the chlorine dosage is highest when usage is low and low when usage is high. Thus, the first users might experience a high chlorine dosage with resulting disagreeable taste and odor.

5.6.2 Calculation of doses

Table 5-7: Bleaching Powder Requirement for Water

S.No.	Type of water	Chlorine required, mg/l	Bleaching powder required, mg/l
1.	Deep well water	0.50-1.00	2.00-4.00
2.	Shallow well water	1.00-1.50	2.00-60.00
3.	Spring water	1.50-2.00	6.00-8.00
4.	Turbid river water	2.00-2.50	8.00-10.00

Calculation of Bleaching Powder Requirement:
Chlorine content in the commercial bleaching powder = 25%
Dose of chlorine =2.00 mg/l.
Water demand per day = 10,000.00 liters
Required quantity of chlorine = 10000*2/1000*1000 kg = 0.020 kg
Required quantity of bleaching powder per day = 0.020kg/0.25 = 0.080 kg = 0.080*1000gm= 80gm.

6 Feasibility Survey Procedure

Objective:

After completion of this chapter participant will be:

- Familiarize with the essential techniques of feasibility survey of WSPs; head measurement, discharge measurement.
- Computing total demand of community and comparing measured discharge vs. demand discharge.
- Deciding the feasible or unfeasible WSPs.
- Obtaining essential social data.

Time: 1 hrs.

Lesson 6.1: Head measurement with minor instrument : ½ hrs.

Lesson 6.2: Discharge measurement : ½ hrs.

Feasibility survey is very first step in any project to decide whether the project should considered for further consideration or not. Source yield, head measurement (tentative) and community interest into probable water supply project is sought in the feasibility survey. 'Tools and Techniques' involved in feasibility survey are discussed here in further details:

6.1 Head Calculation (GPS and minor instrument handling)

GPS: The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.

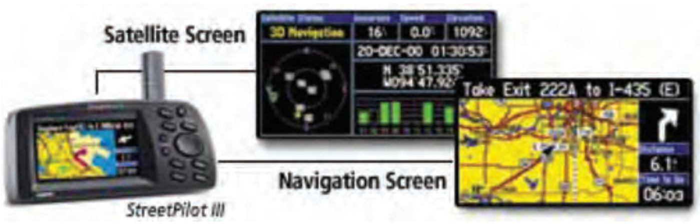


Fig. 6-1 GPS Hand Receiver

Essentially, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. The receiver can determine the user's position and display it on the unit's electronic map.

A GPS receiver must be locked on to the signal of at least three satellites to calculate a 2D position (latitude and longitude) and track movement.

GPS can advantageously be used to locate any point in the earth with reference to any datum line. Nevertheless, the height (altitude) given by the GPS is not of much accurate (despite from differential GPS) so it should not much rely on. Its work thus limited to the feasibility purpose only.

WGS-1984 system setup in GPS:

Menu>>Setup>>Enter>>Time i) Time format: 24 hr ii) Time zone: Other iii) UTC Offset: +5:45hrs

Units i) Position Format: hddd.dddd ii) Map Datum: WGS 84 iii) Units: Metric iv)

North Ref: True v) Angle: Degrees.

Altimeter: For very rough idea of the altitude of any point altimeter can be advantageously used. This is a hand held instrument working in the concept of barometric pressure. If more précised barometric altimeter used for the purpose, it can be more accurate and reliable then the GPS altimeter. As barometric pressure changes with the weather, surveyors must periodically recalibrate their altimeters when they reach a known altitude, such as a trail junction or peak marked on a topographical map. It directly gives the height (elevation) of any point so we can get elevation difference between two points, simply by deducting one from another.

Fig. 6-2 Altimeter

6.2 Discharge measurement technique

6.2.1 Bucket and Watch Method:

This is a simple method for measuring a very small flow of less than 5 l/s with very high accuracy.

Built the dam and tap flow similar to shown in the figure.

Find at least two bucket or other, similar containers which you can use to catch the water flowing through the pipe. You will also need a bottle or other, smaller 1-litre container.

Using the 1-litre container, count the number of litters needed to fill the buckets with water, in order to find how much each bucket will hold.

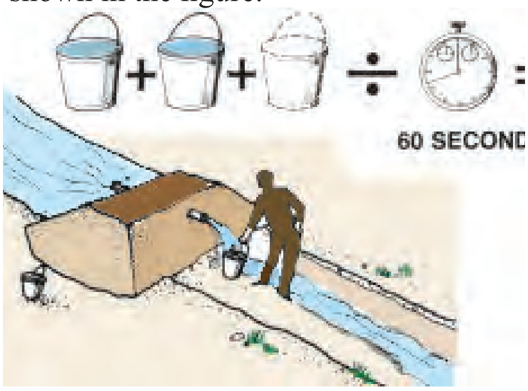


Fig. 6-3 Bucket & Watch Method of Discharge Measurement

Source: Irrigation Refrence Manual (Peace Corps, 1994)

Each of your buckets holds 10 litters; you collect 9 buckets in 1 minute; the total water flow in 1 minute is 10 l x 9 = 90 l; 1 minute = 60 seconds; total water flow in 1 second is 90 l ÷ 60 s = 1.5 l/s.

For small spring source: We simply fill up the bucket and count the time with the aid of stop watch and discharge (Q l/s) = capacity of bucket (lit)/time (in seconds).

Note: This is most widely used method of discharge measurement in small water supply projects.

6.2.2 Velocity Area Method:

This is a very simple method to measure approximate water flow in very small streams. We do not need any special equipment for this estimate.

Water velocity and cross-sectional area through which it traverses is easily calculated with the help of tape only and discharge can then be found as shown in the examples.

Example:

Step 1: Prepare a float: A good float may be a piece of wood or a bottle filled with weight as shown in figure.

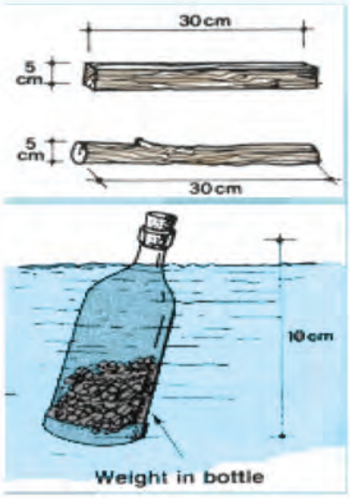


Fig. 6-4 Floats for VA method

Step 2: Where to measure: Find and mark a length AA to BB along the stream, which is straight for a distance of at least 10 meters. Try to find a place where the water is calm and free from water plants so the float will flow easily and smoothly.

Step 3: Find average velocity: You can calculate the average time the float has taken to travel from AA to BB. Add the three measurements and divide the sum by 3.

Find the surface water velocity (in m/s) by dividing the distance from AA to BB by the average time (in seconds) and multiply this result by 0.85 (a correction factor) to estimate the average water velocity of the stream.

Fig. 6-5 Area of Flow (Depth & Height)

Source: Irrigation Reference Manual (Peace Corps, 1994)

Step 4: Find average width:

Our width measurements were 1.1 m, 1 m, 1 m, 0.9 m, 1 m and 1.2 m; use 1 m for the average width.

Step 5: Find the average depth: Our depth measurements were 0.2 m, 0.6 m. 0.9 m. 1.2 m, 0.8 m and 0.3 m: the deepest one is 1.2 m, so the average depth is 1.2 m ÷ 2 = 0.6 m.

Step 6: To calculate the water flow (in m^3) multiply the average water velocity (in m/s) by the average width (in m) and by the average depth (in m).

Calculation:

AA to BB = 10 meters;
Average time = 20 seconds;
Surface water velocity = 10 m ÷ 20 s
or 10 ÷ 20 m/s= 0.5 m/s
Average water velocity = 0.5 m/s x 0.85 = 0.425 m/s.
Water flow = 0.425 m/s x 1 m x 0.6 m = 0.255 m^3/s.
Water flow = 0.255 m^3/s x 1 000 l = 255 l/s.

6.2.3 Weir Method (V-Notch)

The configuration of a weir allows flow rates to be determined by directly measuring the height of the water flowing over the weir. V-Notch type weirs are used since they are most accurate for low discharges. A V-notch weir can be bought or made

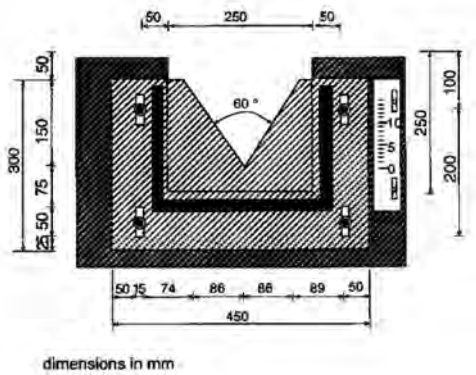


Fig. 6-6 V-Notch

by hand using dimensions as given in the figure:

The weir (wood or sheet metal) is placed in a dam which directs all of the flow into the notch of the weir. The weir must be placed perpendicular to the stream flow. The approaching stream must be straight and unobstructed for a minimum length of 10 times the weir notch width. The height of water flowing over the flowing over the weir is measured from the low point of the V-notch. This height is then used in the graph below to determine the flow.

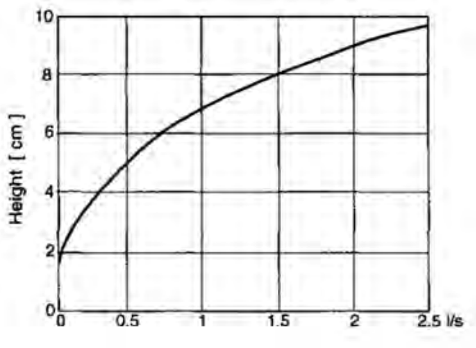


Fig. 6-7 V-Notch Height-Discharge Curve

These weirs can be permanently or temporarily made across the small stream (or medium size stream too) for flow measurement. They provide a very easy and accurate way to measure the discharge for low to medium discharge streams.

6.3 Overall demand calculation

The water demand should be calculated using the following parameters, and a demand vs. supply check should be made using the form.

i) Domestic Demand:-

No. of houses = n

Assume - present population = 5.4n

- Design period = 15 years
- Population growth = 2.3%* per year
- Demand = 25 liters per person per day

Therefore,

- Design population = 7.6n and
- Domestic demand = 190n liters per day, or 0.0022n liters/second

> Note:
>
> *(Nepal's population growth rate 2.27, household size 5.38 in average but different development region has different values. So, please follow according to the recent regional value. EDR -Population growth rate 1.87, household size 5.23; CDR - Population growth rate 2.65, household size 5.26; WDR - Population growth rate 1.92, household size 5.25; MWDR - Population growth rate 2.26, household size 5.58; FWDR - Population growth rate 2.71, household size 5.92.
>
> *Source: Preliminary results of pop. Census 2001,*
>
> *Central Bureau of Statistic, Nepal*

ii) School Demand:-

No. of school pupils = p

Assume - demand = 10 liters per pupil per day

Therefore,

School demand = 10p liters per day or 0.00016p liters/ second

iii) Health Post Demand:-

No. of health posts = h

Assume - demand = 2500 liters per health post per day

Therefore,

- Demand = 2500h litters per day, or 0.03h liters/ per second

v) DESIGN DEMAND IS THEREFORE EQUAL TO:-

- Demand = 190n + 10p + 2500h liters per day, or

0.0022n + 0.00016p + 0.03h liters per second

6.4 Demand vs. Source (supply)

The calculated design demand should be compared with the source's minimum yield measured during the dry season. Remembering that, for most of the year the flow from the source will be greater than the minimum yield, the following criteria should be used to confirm a project's feasibility:

- If minimum yield > design demand.
- If minimum yield > 0.75 x design demand: project is feasible but the use of alternative sources, if available, should be considered.
- If there is no any alternative source around the village 15 liters per person per head per day can be considered. This is the minimum design for the time being. This quantity cannot serve the increase population and also cannot be used for production purposes.

6.5 Socio-economic survey and present water supply situation

Project area delineation, demographic data collection and service level determination are carried as part of social survey. Active participation of local during data collection is must. Standard formats prepared for the purpose can be used in the survey. Amount of data to be collected depends upon the information to be drawn from the data and further processing required. As part of feasibility survey, settlements in the village, number and type of users may serve enough.

Present condition of water supply system, how people are fetching water, local market, market center of the village, prevailing wage rate in the village, availability of local and non-local construction materials, willingness to pay for the 'PV pumping system' of the villagers are some other information need to be drawn from the feasibility survey.

Depending upon the all these data furnished from the feasibility survey any project further can be analyzed for further takings.

7 Detail Survey

Objectives:

After completion of this chapter participants will be able to:

- Understand the techniques involved in the detail site survey of PV Pumping Systems.
- Do Profile leveling by 'abney level and 'auto level' instruments.

Time: 2.00 hrs.

Lesson 7.1: Process involved in detail survey i.e. technical and social survey: Time –½ hrs.

Lesson 7.2: Profile leveling by 'abney level': Time – ½ hrs.

Lesson 7.3: Profile leveling by 'auto level': Time – 1 hrs.

7.1 Technical Survey:

Any project seen feasible from the feasibility survey should be undertaken for the detail survey. Most of the survey data coming from the feasibility study should frequently matched during detail survey procedure. Detail survey is the next step of feasibility study, so these should be looked in conjunctions with another; not separate activities.

7.1.1 Profiling

Determination of ground surface elevations in a field in order to construct a profile map is necessary for determining land leveling requirements and placement structures, etc.

Fig. 7-1 Abney Level

Every surveyor working with 'PV Pumping System' should have, at a minimum, an Abney level; a surveying rod; a measuring tape (minimum of 30 meters); a carpenter's level; and a scientific calculator (capable of computing roots and powers of trigonometric relations). This will allow the surveyor to determine elevation differences, profiles, and area measurements. Some topographic mapping can be accomplished with this equipment. For significant leveling work, however, an engineer's level and/or transit are often required. This equipment is not often available to the surveyor. The theory and practice of land leveling is beyond the scope of this manual. The surveyor should consult appropriate references and obtain assistance from an engineer before undertaking significant land leveling.

1. **Abney Level:** is a hand held instrument used in surveying which consists of a fixed sighting tube, a movable spirit level that is connected to a pointing arm, and a protractor scale. Abney Level is an easy to use, relatively inexpensive, and, when used correctly, an accurate surveying tool. The Abney Level is used to measure degrees, percent of grade, topographic elevation, and chain age correction.

   By using trigonometry the user of a Topographic Abney Level can determine height and grade.

Figure 7-2 clearly shows the arrangement of abney survey and calculation procedure: In abney survey, any two adjacent sightings (stations) should be such that it represents the ground profile truly i.e. every change of vertical grade should be read. In general, in maximum two adjacent stations should be located within 30m of length. Surveying and recording should go side by side and there should be at least two persons capable for reading and recording alongside in each survey. The figure given below showed an example of field book recording style in abney survey:

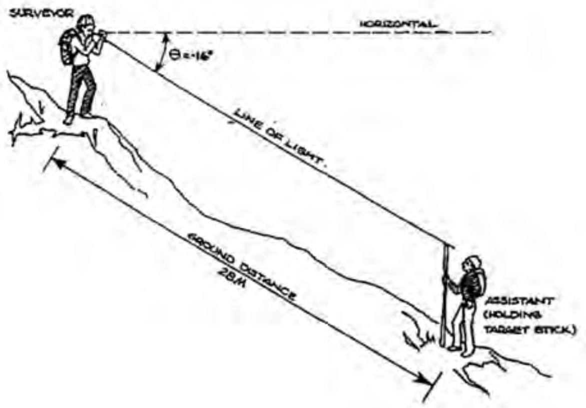


Fig. 7-2 Profile Survey by Abney Level

Source: Irrigation Reference Manual (Peace Corps, 1994)

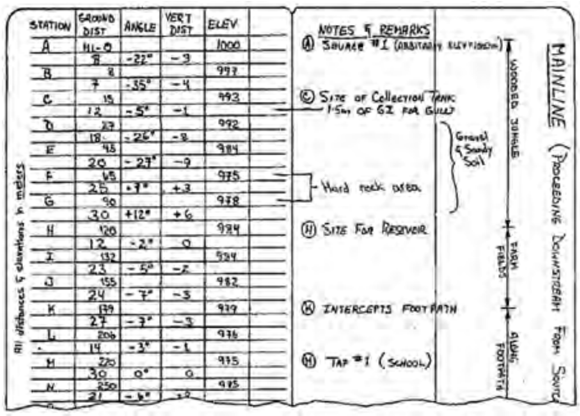


Fig. 7-3 Abney Level Survey-Field Book Recordings

Calculations of abney survey:
Height difference = D x sin θ

Where D is the ground distance measured by tape and θ is the average vertical angle between two adjacent stations. The reduced level of the source should be arbitrarily set using the altimeter's reading and all other reduced levels calculated there from (for detail calculation process pls. refer Table 8-2)

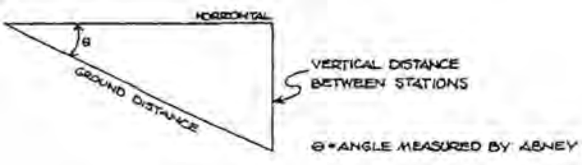


Fig. 7-4 Height & Distance from Abney Level

Correction for Abney Level: Abney Level should be always checked for accuracy before starting and after completion of the survey. If foresight and back sight angles are not of same magnitude then it can be error due to level bubble of abney not exactly in the center of its run. To correct this:

Place the abney above the carpenter's level in level surface (carpenters level should show the bubble to its center runs) and bring the Abney Arm to 00 if Abney Level bubble is not in its center run, bring it to there by adjusting the respective screws.

2. Auto Level:

Theory of Profiling

1. Profiling involves measurement of elevations (leveling) along a line, together with measurement of horizontal distances.

2. Distances must be measured on a straight line between points for which

elevations are taken.

Profiling Procedure
1. Setup and level instrument.
2. Sight Benchmark (point of known elevation) for Back sight reading.
3. Enter rod reading in Back sight (Bs column 2).
4. Add rod reading (column 2) to Benchmark (column 5) to get Height of Instrument (HI column 3).
5. Sight point to be determined (Foresight) and enter reading in Foresight (Fs column 4).
6. Subtract Foresight (column 4) from Height of Instrument (column 3) to get elevation of Foresight (column 5).
Turning Point
1. Rodman maintains position at Foresight.
2. Move setup, and level the instrument at new location (Tp 1).
3. Sight rod at Back sight (last foresight station) and enter reading in column
4. Add rod reading (column 2) to elevation of back sight (column 5) to get Height of Instrument (column 3).
5. Proceed with Foresight (steps 5 and 6 above).

Example: An example survey is presented in Figure below. Notation for this survey is presented in the following table:

Table 7-1: Auto level Survey Recording Format

1	2	3	4	5	6
	+		(-)		
Sta.	Bs	HI	Fs	Elev.	Notes
PtA	2.5	102.5		100	Assumed elev.
Pt B			11.5	91	
Tp1	4.2	95.2			Pt B.
PtC			12.3	82.9	

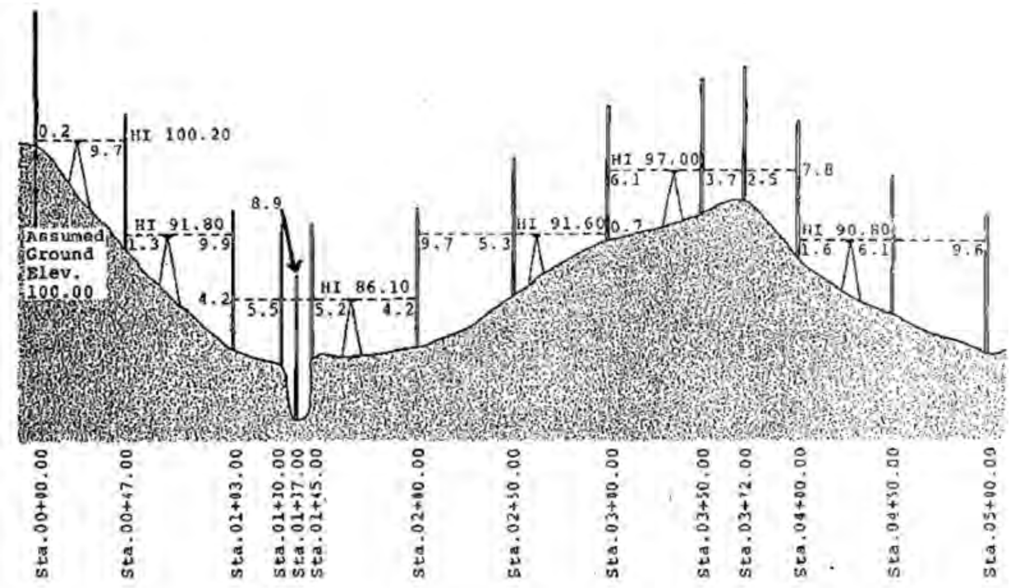


Fig. 7-5 Profile Leveling by Auto Level

Source: Irrigation Reference Manual (Peace Crops, 1994)

The steps used in the example problem are different from those used by professional surveyors. They have been simplified in an attempt to reduce confusion and are more than adequate for the type of surveying that is necessary in small-scale piped water systems. When using this method, always remember the following simple calculations:

1. Known elevation + Back sight reading = Height of Instrument

2. Height of Instrument - Foresight = Next Elevation

7.1.2 Social Survey

Community meeting with villagers at very first day of village entry for survey and at the end day of survey to verify the social and technical survey findings should be conducted. Both of these meetings should be jointly organized by social and technical personnel. These meetings are the major steps to know and verify the realistic need, people's aspiration and non/local resources need

HOUSEHOLD DATA COLLECTOIN FORMAT

TAP-STAND WISE HOUSEHOLD INFORMATION

Name of Project: Kalikasthan PV Pumping WSP VDC: Bharatpokhari

District: Kaski Ward No: 3 Tap No: 1 Tole: Kalikasthan

S.No.	Name of Household Owner	Population Distribution								Total			Remarks
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Total	
		0-6 yrs	0-6 yrs	6-15 yrs	6-15 yrs	15-60 yrs	15-60 yrs	60 yrs above	60 yrs above				
1	Ram Bdr. Chhetri	0	0	2	1	1	1	1		4	2	6	
2	Hari Gurung	0	1	1	2	1	1	0	1	2	5	7	
3	Rajan Khanal	1	0	0	0	1	1	1		3	1	4	
4	Saish Magr	1	1	0	0	1	1	0	0	2	2	4	
5	Raju Rana	1	0	1	1	1	1	0	0	3	2	5	
									Total	14	12	26	

Endorsement from teh Tap users for tap location (signature of each household owner).

Endorsment of landlord for granting the tap stand location for public use.

Fig. 7-6 Typical Household Survey Format

to construct the water supply projects. Team members should be well prepared for the meetings what information need to them and how to draw maximum information from the people/users. As much as possible, meeting should be made interactive and for this different community mobilization tools can be utilized. The team can conduct PRA exercise to draw information like number of water sources in the locality, type of water sources, local construction material available in the vicinity, major market areas and route to reach along with time and cost involved. A part from that, present condition of water fetching, peoples aspiration and willingness to pay for the 'PV Pumping System' should be discussed thoroughly. To discuss all these parameters is beyond the scope of this manual but major data that should be get from there is presented here:

7.1.3 Household Survey:

Preliminary data can be collected from the community meeting and later on every household should be visited to acquire the full fledged data required for water supply system design, cost-estimate preparation and further analysis. Standard formats can be prepared at office for data acquiring from the community and those can be used in survey. Below is a sample format that can be used for demographic data collection:

7.1.4 Demand Survey

People's aspiration regarding service level (number of households per tap post), local materials contribution, non-local materials contribution is well reflected in the mass (community) meeting. These aspiration expressed in the meeting should be recorded in well structured format for further proceedings. These aspirations resembles the community demand in boarder terms, if any of the demand seems to be discussed with locals, we can bring it in to discussion immediately and process for decision. For recoding the community demands systematically, we should prepare the formats representing the SESS policy guidelines and existing practice in ‘PV Pumping Systems’ and bringing those at the time of survey.

7.1.5 Overall Demand Calculation

The technicality of overall demand calculation is same as that of feasibility study as presented in previous pages but only difference is the social data collecting procedures in the detail survey and feasibility survey. The social data collection work in the detail survey should be in more detail and in depth. The demand calculation work in the detail survey should be conducted after the detail demographic data collection work is over.

8 Detail Design

Objectives:

After completion of this chapter participant will be able to:

- Calculate detail water demand of WS system.
- Determine reservoir size based on inflow and outflow conditions.
- Present survey data in appropriate format and RL calculation at critical points.
- Draw profile of pipeline.
- Transmission line and Distribution line design.

Time: 5 hrs.

Lesson 8.1: Water demand calculation and RVT sizing : ½ hrs.

Lesson 8.2: RL Calculation of critical points and presentation in graph: 1hrs.

Lesson 8.3: Transmission line design : ½ hrs.

Lesson 8.4: Distribution line design : 3 hrs.

Civil engineering work always consists of in two fold viz. field work and office work. Once the data is acquired from field appropriately and accurately, office works becomes easier and sounder one. So, proper planning and preparation should be done before making move for the field job. Office job now has become easier and like a fun due to advent of newest technology in ICT. Different free applications/software for field data analyzing, presentation, design and cost-estimate report preparation is now available. Only need for now is to become familiar with them and apply for our specific needs. In addition, we can develop small customized or tailored application with the knowledge of some programming language to fit our specific needs. Detail design and cost-estimation report preparation is an official work that demands for more skill and knowledge. In depth analysis of the field obtained data, presentation those in proper format and detail social and engineering analysis of the same is carried out to produce some tangible output in the form of report as part of office work. Following subsequent chapters are dedicated to this in detail:

8.1.1 Water Demand and Tap Flow Calculation

It is the very first step in design and cost-estimate report preparation task. Without having correct water demand estimation of the villagers, system cannot be judicially designed. It is therefore very important to determine the water demand for each and every tap post to design the pipe main up to and after that tap post in the system along with the RVT sizing requirements. Water demand calculation basis is same as that given in the article 5.3 (in previous chapter) and that can be presented in the simple spreadsheet format for the sake of simplification. Please refer the table 2-8 for the format.

The amount of water required for a rural community depends on factors like the economic level of the community, their consciousness and other physical and social aspects. In case of a bazaar, the demand would be higher due to commercial activities and the transient population.

In solar PV Systems following water demand purposes should be fulfilled:

- Domestic Demand (drinking, bathing, utensils washing and cooking etc.)
- Institutional Demand (school, health post and VDC building etc.)
- Requirement for livestock and poultry (drinking purposes for poultry farm)
- Likely wastage amongst all users (allowance for wastage: some percent may be added)

All these demands are discussed earlier in detail; here we are going to place these demands in simple spreadsheet format for detail calculation purpose:

Table 8-1: Example of a Spreadsheet to Compute the 'Water Demand'

SCHEME NAME : Kattike WSP
SUPPORT ORGANIZATION :
LOCATION : WARD NO : 4,5,6 VDC : Sundarijal DISTRICT : Kathmandu
Name of Community : Sundarijal
Required Datas:
Peak Factor: 3
Per Capita Demand : 25 lpcd
Per Capita Demand for Students: 10 lpcd Minimum flow rate 0.10 lps

Discription of Tap			Domestic Water Demand				Institutional Water Demand						Tap Flow Calculation					
Tap No.	Cluster Name or Locality	Ward No.	Nos of HH	Present Population (P)	Base Population (PO)	Design Population (Pn)	Total Domestic Demand	No. of Pupil in School	Other Institutional Demand	Total Institutional Demand	Live Stock Demand	Total Water Demand	Average Tap Flow	Peek Factor	Peek Flow	Design Flow	Adjusted Peek Factor	Remarks
			(Nos.)	(Nos.)	P(1+r)^n1	P(1+r)^(n1+n)	(lpd)	(Nos.)	(lpd)	(lpd)	(lpd)	(lpd)	(lps)	(Factor)	(lps)	(lps)	(lps)	
[1]	[2]	[2-1]	[3]	[4]	[5]	[6]	[8]	[9]	[10]	[11]	[11-1]	[12]	[13]	[14]	[15]	[16]	[17]	[18]
	RVT1																	
1	Deaurai tole	5	4	31	32	43	1,075					1,075	0.02	3.00	0.07	0.10	4.55	
2	Majh Tole	5	4	32	33	44	1,100					1,100	0.02	3.00	0.07	0.10	4.35	
3	Tallo Tole	5	1	8	9	11	275					275	0.01	3.00	0.02	0.10	16.67	
4	Raju ko Rukh	5	2	19	20	27	675					675	0.01	3.00	0.04	0.10	7.14	
	sub total		11	90	94	125	3,125	-	-	-	-	3,125.00	0.07	12.00	0.20	0.40	32.70	
	RVT2																	
5	Bhirbari	6	3	17	6	7	175					175	0.00	3.00	0.01	0.10	25.00	
6	Goreto	6	3	16	17	22	550					550	0.01	3.00	0.03	0.10	9.09	
7	Majh Tole	6	5	20	21	28	700					700	0.02	3.00	0.05	0.10	6.67	
8	June Tole	6	2	18	19	25	625					625	0.01	3.00	0.04	0.10	7.69	
9	School,SHP	6	-	-			-	150		1,500		1,500	0.02	3.00	0.05	0.10	5.88	
10	Majh Bari	6	3	14	15	20	500					500	0.01	3.00	0.03	0.10	10.00	
11	Jaubari	6	1	8	9	11	275					275	0.01	3.00	0.02	0.10	16.67	
	sub total		17	93	87	113	2,825	150	-	1,500	-	4,325.00	0.08	21.00	0.23	0.70		
	Grand Total		28	183	181	238	5950	150	0	1500	0	7450	0.14	33.00	0.42	1.10	32.70	

NOTE : 1 Peak factor of 3 has been adopted
2 Design Tap Flow has been adjusted for the Peak flow by rounding off to nearest 0.01lps.
3 If flow is less than 0.1 lps then it has been adjusted to 0.1 lps and if flow is greater than 0.25 lps provide additional tapstand.

8.1.2 RVT Design

The size of the reservoir for a particular community water system is a function of the community's total demand, the community's consumption patterns, and the continuous demand flow (CDF) from the source to the reservoir tank (RVT). Among the above three parameters the second one i. e. the consumption pattern of the community varies drastically from one community to another since every consumers consumes the water as per their conveniences depending upon his/her habits which further depends on season to season and other factors. Hence, the study of the consumption pattern is not practical to do on each and every new project site. Therefore, the following consumption pattern (intermittent type) is tacitly assumed for PV pumping systems. However, for a small community where there is less chance of misuse of water, all the members of WSP system are much aware and preservation of water has been highly practiced 'CLOSED CONTINIOUS' system can be designed and RVT design varies accordingly.

Service Reservoir Designed by two methods as discussed in previous pages:

a. RVT Sizing in 'Intermittent Inflow-Intermittent Outflow WS System':

SCHEME NAME : **Kattike WSP**

LOCATION : **WARD NO :** **4,5,6** **VDC :** **Sundarijal** **DISTRICT :** **Kathmandu**

a) Scheme Information

a.1	Reservoir Tank No:	2			
a.2	Served Standposts	5 to 11			
a.3	Average Design Demand to be Supplied through Reservoir	0.050	l/s =	4325.000	l/day
a.4	Available Minimum flow from the Source (Safe Yield)	2.000	l/s		
a.5	Adjusted/Optimized supply to Reservoir from Source	0.300	l/s =	25920.0	l/day
a.6	Total Design Flows of all Standposts :	0.700	l/s		

b) Reservoir tank sizing - assuming Intermittent Inflow and Intermittent Outflow System

Maximum Required supply hours based on Supply from Source	10.29	hours
Maximum Required supply hours based on Demand	1.72	hours
Adopted hours of Supply	**4.00**	hours

Recommended Supply Hours and Period

First Shift	**6:30 AM**	**To**	**9:30 AM**
Second Shift	**4:00 PM**	**To**	**7:00 PM**

Time Period		Hours		Cum. Inflow	Cum. Con-sumption (lt)	Surplus	Deficit
From	To	In	Out	(lt)		(lt)	(lt)
6:30 AM	*9:30 AM*	0.50	2.0	540	5040		4500
9:30 AM	*4:00 PM*	6.50	0.0	7560	5040	2520	
4:00 PM	*7:00 PM*	0.50	2.0	8100	10080		1980
7:00 PM	*6:30 AM*	0.00	0.0	8100	10080		1980

Max Surplus/Deficit 4500 lt = 4.50 cum

Provide Reservoir Capacity of **5.00** cum

c) Recommended Reservoir Size

Recommended Size for RVT 02 = ***5.00*** ***cum*** ***Time to Fill the RVT*** ***4.63*** ***Hr***

b. RVT Sizing by 'Intermittent Inflow-Continuous Outflow'

SCHEME NAME : Kattike WSP
LOCATION : WARD NO : 4,5,6 VDC : Sundarijal DISTRICT : Kathmandu

a) Scheme Information

a.1	Reservoir Tank No	2			
a.2	Served Standposts	5 to 11			
a.3	Average Design Demand to be Supplied through Reservoir	0.050	l/s =	4325.000	l/day
a.4	Available Minimum flow from the Source (Safe Yield)	2.000	l/s		
a.5	Adjusted/Optimized supply to Reservoir from Source	0.300	l/s =	25920.0	l/day
a.6	Total Design Flows of all Standposts :	0.700	l/s		

b) Reservoir tank sizing - assuming Intermittent Inflow, Continuous Outflow System

Time Period From	To	Inflow Hours	Water Consumption (%)	Cummu. Supply (lt)	Cummu. Demand (lt)	Surplus (lt)	Deficit (lt)
5:00 AM	7:00 AM	0	25.0%	0	1081		1081
7:00 AM	12:00 AM	2.5	35.0%	2700	2595	105	
12:00 AM	5:00 PM	5	20.0%	8100	3460	4640	
5:00 PM	7:00 PM	0	20.0%	8100	4325	3775	
7:00 PM	5:00 AM	0	0.0%	8100	4325	3775	

Maximum Surplus/Deficit	4640	lt		
Minimum required Reservoir capacity	4.64	cum	4.63	Supply hours to meet the demand
Provide Reservoir of capacity	5.00	cum	116%	of Average Demand

c) Recommended Reservoir Size

Recommended Size for RVT 02 = 5.00 *cum* ***Time to Fill the RVT*** 4.63 *Hr*

8.1.3 Pipeline profile (final alignment data calculation and plotting)

a. Abney Level Survey Calculation

Pipeline route selection is a very tactical issue in surveying duration. A well thought pipeline route should show minimum number of undulations longitudinally and most efficient route to pass the water. In rural water supply scheme, abney level is sufficient to get the ground profile picture as discussed above. After having the field book in hand that should be presented in proper format and process further for calculation and pipeline design purpose. To mark the high, low point and other remarkable points along the pipeline, drawing of pipeline profile can be done in graph paper as used to do traditionally but it consumes the much time. So, this data processing tasks should be processed in appropriately designed spreadsheet and CAD software that reduces the time and cost as well as the final result produced will be appealing one.

Table 8-2: Abney Level Data Calculation

Station Name		Distance	Cumulative	Angle						Average	Rise/Fall	RL (m)		Remarks
				ForeSight			BackSight							
From	To	(m)	Distance(m)	Degree	Minute	Second	Degree	Minute	Second	Angle		From	To	
Intake to Horizontal Roughing Filter														
Intake	P1	12.25	0.00	-5	40		5	30		-5.58333	-1.225	3000.00	2998.78	
P1	P2	12.25	12.25	-5			5	10		-5.08333	-1.1025	2998.78	2997.67	Kholsi
P2	P3	7.45	19.70	-4	30		4	20		-4.41667	-0.586	2997.67	2997.08	Forest, OS
P3	HF	7.35	27.05	-30			29	30		-29.75	-3.675	2997.08	2993.40	Forest, OS
HF to Sump-Well														
HF	P4	7.7	34.75	-32	30		32	20		-32.4167	-4.158	2993.40	2989.24	Forest, OS
P4	P5	17.45	52.20	-2	10		2	10		-2.16667	-0.698	2989.24	2988.55	Forest, OS
P5	SW	4	56.20	0	-50		0	40		0.08333	0	2988.55	2988.55	Forest, OS
Sump-Well to Service Reservoir														
SW	P6	22.3	78.50	10	40		-10	30		10.5833	4.014	2988.56	2992.55	Uncultivated land,BMS
P8	P7	18.9	100.80	15	30		-15	20		15.4167	5.103	2992.56	2997.66	Uncultivated land,BMS
P9	P8	21.58	119.70	20	30		-20	-30		20	7.3372	2997.66	3005.00	Uncultivated land,BMS
P10	P9	19.36	141.28	18	50		-18	40		18.75	6.1952	3005.00	3011.19	Uncultivated land,BMS
P11	P10	34.35	160.64	17	20		-17	20		17.3333	7.305	3011.19	3018.50	Uncultivated land,BMS
P12	P11	20.25	184.99	20			-20	0		20	6.885	3018.50	3025.38	Uncultivated land,BMS
P13	P12	8.25	205.24	12	50		-12	40		12.75	1.815	3025.38	3027.20	Uncultivated land,BMS
P14	P13	15.36	213.49	18	10		-18	10		18.1667	4.7616	3027.20	3031.96	Uncultivated land,BMS
P15	P14	14.7	228.85	14			-14			14	3.528	3031.96	3035.49	Uncultivated land,BMS
P16	P15	17.25	243.55	18			-18			18	5.3475	3035.49	3040.84	Uncultivated land,BMS
P17	RVT	16.35	260.80	17	30		-17			17.25	4.905	3040.84	3045.74	Uncultivated land,BMS

b. Auto-level Survey Calculation

Profile survey concept is given in detail in article 6.1.1, here only the presentation of data in systematic way is shown. It should be noted that Auto-level survey work should only be conducted or feasible where the project area is relatively less distance from road head (less transportation) and utmost accuracy is desired (like in case of transmission line of project). If the project is lies in remote place, it is cumbersome to carry the auto-level. Data acquired by abney is in-acceptable range, if done with proper care: accuracy checking is done before start and after completing of each day of survey, foresight and back-sight reading in every station. Following table shows the systematic recording and computation of Auto-level survey:

Station Name	Distance (m)	Cumulative Distance(m)	Staff Reading B.S.	I.S.	F.S.	Level difference Rise	Fall	RL (m)	Remarks	Reference RL
Service Reservoir to Tapposts										
RVT	0	260.80	1.215					3045.74		3045.74
P1	50	310.80	0.085		3.912		2.697	3043.043		
P2	50	360.80	2.015		4.225		4.14	3038.903	Cable crossing- 50 m span	
P3	110	470.80	0.500		0.200	1.815		3040.718	BMS soil	
Tap 1	60	530.80	0.500		2.142		1.642	3039.076	BMS soil	
P4	65	595.80	2.992		0.105	0.395		3039.471	BMS soil	
P5	50	645.80	1.490		4.250		1.258	3038.213	BMS soil	
P6	43	688.80	0.350		0.185	1.305		3039.518	OS	
J1	40	728.80	0.100		4.060		3.71	3035.808	OS	
J1 to Tap 2										
J1	60	788.80	2.090		5.000		4.9	3035.808	OS	
P8	95	883.80	0.001		4.650		2.56	3033.248	OS	
Tap 2	30	913.80	0.105		4.740		4.739	3028.509	OS	
J1 to Tap 3										
J1	30	943.80	1.140		3.660		3.575	3035.808	OS	
P10	80	1023.80	1.301		4.480		3.34	3032.468	OS	
P11	20	1043.80	1.301			1.301		3033.769	OS	
Tap 3	30	1073.80	0.201		4.732		3.431	3030.338	OS	

These data when calculated properly should be plotted to note the important points for pipeline design. Once the pipeline ground profile drawing is over, designer will be in easy position to process design further. There are plenty of freeware and paid versions of longitudinal profile drawing applications (Free WSP by Softwell in one of them) in the market those can be used for the purpose. If those software are not available in time, simple MS-Excel 'line draw chart' functionality can be used to visualize the longitudinal profile in paper. Below is the example of longitudinal profile of ground section:

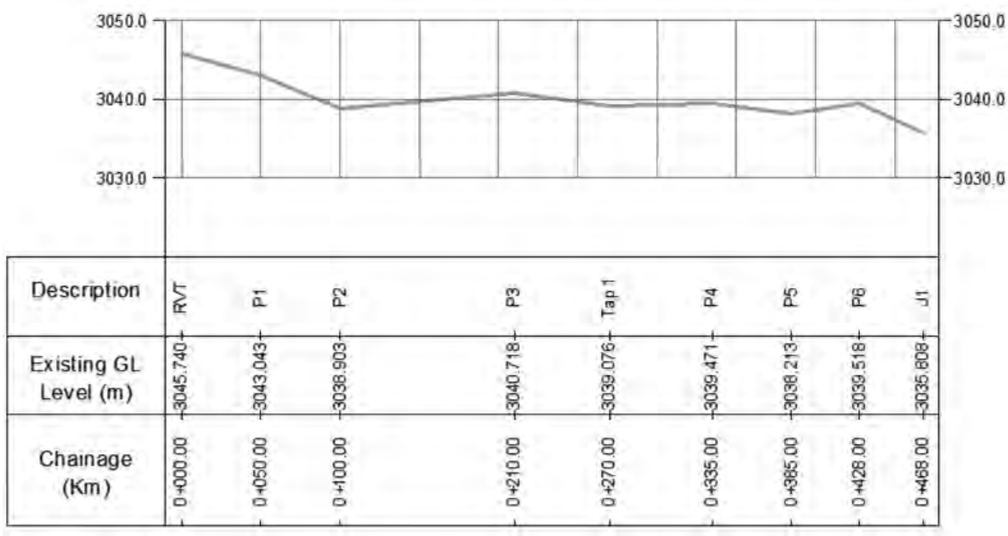


Fig. 8-1 Ground Profile of Pipeline

8.1.4 Pipeline Design

Pipeline design is the final step to complete the WSP design process. It consists of choosing the appropriate type (HDPE, GI, DI) and size of the pipe used in the different section of the system. The pipeline transfers water from the source to the service area. Pipelines require high investment outlay, and hence careful consideration is necessary for its design. Choosing its alignment, size and material, therefore, calls for utmost caution. Proper selection of pipe alignment route is essential to ensure that the pipeline is laid through stable terrain to minimize disruptions later on. Before starting the pipeline design process, designer should have through knowledge of different terminologies and technology used in PV water supply systems and s/he should have completed the following tasks:

- Complete sketch of layout plan (structures location, RL, users information)
- Social data compilation completed (household, population-tole wise)
- Total water demand (in terms of CDF i.e. lps)
- Source yield and tapped yield from source
- Profile survey data calculation
- Water demand tap-stand-wise
- Sump-well and service reservoir design
- Pipeline profile plotting in suitable scale

Designing the appropriate pipe type and size is the core technical part of any water supply system designing process. Solar PV pumping system pipeline design consist of different approaches for transmission and distribution pipeline design; compared to that of any gravity flow WSP design process.

8.1.4.1 Transmission line:

Diameter for most economical flow velocity should be selected. From experiences it has been found that, flow velocity in the pumping main may be selected as v = 0.5 to 1.5 m/s .Lower velocity for long pipeline and higher for short pipeline.

Steps for transmission line design:

a) The economic size of the pipe in pumping is given by the Lee's formula and practiced in exercise in example below.

Lee formula: $D=1.22\sqrt{Q}$

Where D= diameter of pipe in m and (bore hole of pipe)

Q = discharge through pipe in m

b) Velocity of flow = $V = Q/A \rightarrow 4Q/D^2$

c) Coefficient of friction $f = 1.14 - 2 \times \log\{K/D+21.25/(VD/0.00114)^{\wedge}0.9\}^2$ (Swamee and Jain equation)

Where, K (absolute roughness of pipe material)=0.1 for HDPE and 1 for GI

D=bore hole of pipe

d) Head loss from the pipe $HL = f \times L \times V^2/2gD$ where, D in m. (Darcy's Weisbach formula)

e) Total Dynamic head for pump = level difference between sump-well and service reservoir+ head loss + suction head

Combination of the both GI and HDPE can be made in transmission, but while doing so water hammer pressure in transmission line should be considered and only if pipe is capable to withstand that pressure HDPE pipe should be used.

Measures for preventing damage by water hammer should be introduced and the design of the delivery pipeline should be done in such a way that water hammer do not occur. Possibilities of water hammer occurrence are followings:

- The water feed line length is more than about 20 times the actual head and
- the actual head is 10 m or higher.
- The flow velocity in the water feed line is 1 m/s or higher.
- There is a raised portion in the water feed pipeline. In this case , air trap or water column separation may occur.
- The friction head loss in water feed line is over 30 to 40% of the water feed pressure.
- The pump is started while the discharge valve is open.
- The valve operation time is short

a) Total head for the pump

Total pumping head is determined by using following formula:

$H_{Total} = H_a + h_f + v_d^2/2g + 10(P_d - P_s)/r$ (m)

Where, H_a - actual pumping head (the vertical height between the suction water surface and the discharge water surface (m)

h_f - total loss in head in piping (m)

$v_d^2/2g$ - Discharge velocity head (m)

P_d - Pressure exerted on the discharge water surface (Kg/cm^2)

P_s - Pressure exerted on the suction water surface (kg/cm^2)

r - Specific weight of the liquid (Kg/l)

When both the suction and discharge water surfaces are open to the atmosphere, the total dynamic head of the pump is calculated by the equation:

$H_{Total} = H_a + h_f + v_d^2/ 2g$

When total pumping head is very high it may not be possible to pump in one stage. In such case multi stage pumping is to be done. Water is pumped from the collection chamber/sump well of the first station to the collection chamber /sump well of second pump station and from there it is again pumped to higher level. Number of stages may be two or more .When staging pumping stations technical and economical analysis are to be done . In general maximum total pumping head should not exceed 200 meters. On selecting the material and thickness of pipes and fittings possible water hammer pressure must be considered.

Water hammer (or, more generally, fluid hammer) is a pressure surge or wave caused when a fluid (usually a liquid but sometimes also a gas) in motion is forced to stop or change direction suddenly (momentum change). A water hammer commonly occurs when a valve closes suddenly at an end of a pipeline system, and a pressure wave propagates in the pipe. It is also called hydraulic shock. When a pipe is suddenly closed at the outlet (downstream), the mass of water before the closure is still moving, thereby building up high pressure and a resulting shock wave.

This can be calculated by following formula:

$$P_h = \frac{V}{\sqrt{\frac{g}{w}\left[\frac{1}{K} + \frac{d}{t.E}\left(1 - \frac{1}{2m}\right)\right]}}$$

Where,

V = velocity of flow in pipe(m/s)

g = acceleration due to gravity(m/s^2)

w = specific weight of water (N/m^3)

K = Bulk modulus of water(N/m^2)

d = bore of pipe-opening(m)

t = thickness of pipe(m)

E = Young's modulus of elasticity of pipe material(N/m^2)

1/m = Poisson ratio

Water hammer should be accounted along with the total head of the pumping system as the pipe used for the system should be capable enough to handle the total head + water hammer otherwise, pipe material will get burst. Pipe used near the pump and far from the pump can be separately designed as the total pressure near the service reservoir gets retired so low pressure rating pipe can be used at that end.

The optimum use of the formula is given in example of following pages.

Example of finding pumping head and design of Transmission line

Data :

1. Total water demand per day = 48.00 cu.m.

2. Type of source: Spring

3. Safe yield: 1.0 l.p.s.

4. Total length of the pumping main = 200 m.

5. Level difference between the source and reservoir = 110 meters

6. Altitude of the source: 1295 m above sea level.(MSL)

7. Average temperature of water: 200C

1. Find the pumping rate:

Let us select the pumping rate in such a way that 48 cu.meter water is pumped in 12 hours. Then the pumping rate,

Q_p = 48000/(12 x 60 x 60) = 1.111 l.p.s.

2. **Find sump capacity**

As the source yield is less than the pumping rate, water to be pumped should be first reserved in a sump well. The effective (wet) volume of which may be calculated by using formula:

$$V = \frac{3600\,(Q_p.Q - Q^2)}{s.Q_p} \times T = \frac{3600\,(1.111 \times 10^{-3} * 5 \times 10^{-4} - (5 \times 10^{-4}))^2 * 12}{2 * 1.111 \times 10^{-3}} = 5.94 \text{ cum}$$

Choose 6m3 capacity stone masonry tank of standard dimensions.

3. **Total Pumping Head and Transmission Line Sizing**

FINDING OF TOTAL PUMPING HEAD AND TRANSMISSION LINE DESIGN

Sample Project

Distance of pumping main, L	= 200.00 m	
Total level difference between Source and proposed reservoir	= 110.00 m	
The discharge to be pumped, Q	= 4000.00 L/h	
	= 1.111 lps	
By Lea's formula, economic size of pumping main, D is given then:		
D = 1.22 x sqrt(Q) where, Q is in m3/sec		
Hence, D	= 40.66 mm	
However available size of GI pipe nearest to this size is	= 50.00 mm	
Hence, use50 mmØ GI pipe having bore	= 50.00 mm	
Calculation of head loss :		
Here, discharge, Q	1.11 Lps	
For 50 mmØ GI pipe		
Pipe bore, D	= 50.00 mm	
For length, L	= 200.00 m	
Pipe material being used	GI	
Velocity of flow, V = Q/A = 4Q/πD²	= 0.57 m/s	
Absolute roughness	= 1.00 mm	<<(For GI-1 & HDPE - 0.1)
Coefficient of friction, *f*	= 0.0507	<<f = 1/(1.14 - 2 x log(k/d +21.25/(VD/0.00114)^0.9)^2
Using Darcy-Weisbach equation		
Headloss, H_1 = *f*.L/D.v²/2g	= 3.64 m	
Total headloss	= 3.64	
Total head for pumping = Level difference + headloss + Suction head	m	
Depth of sump-well	= 2.00 m	
However take the dyanimic level of water for submersible pump as 1.2 m below the sumpwell		
ynamic level of water below the sumpwell for submersible pump as	= 1.20 m	
Total dynamic head, H	**= 116.84 m**	

4. **Computing 'Water Hammer' Pressure and Checking the Pipe Capacity**

Water Hammer Pressure

Since the pump is closed suddenly, which results the water hammer pressure at the delivery pipe. The water hammer pressure, Ph is given by;

$$P_h = \frac{V}{\sqrt{\frac{g}{w}\left[\frac{1}{K} + \frac{d}{t.E}\left(1 - \frac{1}{2m}\right)\right]}}$$

Where,

V = velocity of flow in pipe(m/s)
g = acceleration due to gravity(m/s²)
w = specific weight of water (N/m³)
K = Bulk modulus of water(N/m²)
d = bore of pipe(m)
t = thickness of pipe(m)
E = Youngs modulus of elasticity of pipe material(N/m²)
1/m = Poisson ratio

For galvanised iron pipe and for above condition

V = 0.57 m/s
g = 9.81 m/s²
w = 9810.00 N/m³
K = 2060.00 N/mm²
d = 50.00 mm
t = 3.60 mm
E = 210.00 kN/mm²
1/m = 0.270

Max. water hammer pressure, Ph = 0.768 N/mm²
= 7.83 kg/cm²

Max. pressure that should be withstand by conduit material:
(static pressure+water hammer pressure = 19.37 kg/cm²

This pressure may withstand by GI medium duty pipe with flange joints.

8.1.4.2 Distribution line

a) System flow rate

In order to design the pipeline, the flow that each branch of the supply network has to convey should be known. Once the tap flow rates in the stand posts are fixed, the system flow rate automatically follows. Cumulative addition of tap flow rates to be served by the pipe under consideration yields the system flow rate. A flow diagram of the scheme should be prepared indicating the flow from each tap and the accumulated flow in the branch and the main pipes. The flow required for various storage tanks has to be also worked out at this stage.

a. Basis of Design

Once the flow, which a pipe section has to transmit, is known, its diameter should be sized next. The basis of pipe line design is governed by the theory of flow of water under pressure in a pipe line, which is briefly discussed below.

Flow of water in pipe line results in loss of energy (head) during transmission. For a pipe of length L, following factors govern the head loss:

i. Velocity, V

ii. Pipe diameter, D

iii. Density of water, μ

iv. Viscosity of water, μ

v. Type of internal surface of pipe, k, and

vi. Friction factor,f

The most rational formula that incorporates these entire factors is the Darcy Weisbach's equation which is as follows:

$$h_1 = \frac{fLV^2}{2gD}$$ ....(1)

Substituting,

$$V = \frac{Q}{A} = \frac{Q}{\pi D^2}$$ In equation (2)

We get,

$$h_1 = \frac{8fLQ^2}{\pi^2 gD^2}$$ .... (3)

To calculate diameter equation (3) has to be transposed as

$$D^5 = \frac{8fLQ^2}{\pi^2 gh_l}$$ .... (4)

All terms in the right hand side of equation (4) must be known to calculate the diameter D. Of these, Q, L and g are known while hL can be set by the designer. This leaves only one unknown factor *f*. Experiments over the last 100 years have shown that friction factor *f* is not a simple constant but varies depending upon flow condition, type of liquid, flow velocity, pipe diameter and the pipe material. Studies have shown that it depends simultaneously on (ρ, V, μ, D, k) whose functional relationship has been developed by Colebrook and White as

$$\frac{1}{f^{0.5}} = -2log\left(\frac{k}{3.7 \times D} + \frac{2.51}{R_6 \times f^{0.5}}\right)$$

Where Re = ρVD/μ = Reynolds's Number

k/D = Relative Roughness Ratio

f = Friction Factor

Friction factor thus calculated should be used in equation (4) to compute the diameter. Other factors that need to be known for calculating *f*, are k, D, μ which depends on temperature, and velocity V. For High Density Polyethylene (HDP) pipes the following surface roughness factor should be adopted.

k = 0.1 mm

For GI pipes and HDP transmission mains between a stream source and sedimentation tank in which deposition is likely to occur, the value of k should be adopted as

k = 1 mm

Both sides of the equation (6) contains *f*. It, therefore, can be solved only by an iterative method, which is a cumbersome exercise. Hydraulic calculation can be done by using spreadsheet program designed for the purpose containing the format shown in Table 8-8. Similarly tables derived on the basis of equations (4) and (5) allow computation of head loss for the range of flow encountered in designs of gravity flow community water schemes. When spreadsheets are designed for computing the 'Hydraulic Calculation' the following factors should be adopted.

k = 0.1 mm or 1 mm

ρ = 1000 kg/m^3

μ = 0.001 N/m^2 at 4°C

Flow in pipes also results in other type of losses known as minor losses. This loss is caused when water flows through valves, fittings, and when flow direction and area is changed. In pipes, whose length is greater than 1000 times the diameter, these losses are insignificant and can be neglected. Only in case of pump systems and treatment network, estimation of minor losses might be critical. The residual head provided at a stand post is sufficient to take account of minor losses.

Minor losses can be estimated by equation (6).

$$Minor\ Loss = factor \times \frac{V^2}{2g}$$

Minor losses are not considered in the design of pipes.

For designing of the distribution pipeline, spreadsheet containing formulae can be prepared or readily available spreadsheet for the purpose can be utilized. Result of such prepared spreadsheet should be checked with already approved design of similar systems otherwise it may come to bite you later on. Here is a simple format for the spreadsheet is presented.

Table 8-4 Pipeline Design Spreadsheet

PIPELINE DESIGN

(HYDRAULIC CALCULATIONS)

Pipe Class abbreviation: HC, MC, DI, CI, HS Steel

Soil Codes: GMS, OS, HR, BMS, SR, MR, HS, SS

DTO, Kathmandu

SCHEME NAME : **Kattike WSP** **SOURCE NAME :** **SAFE YEILD :** 0.5

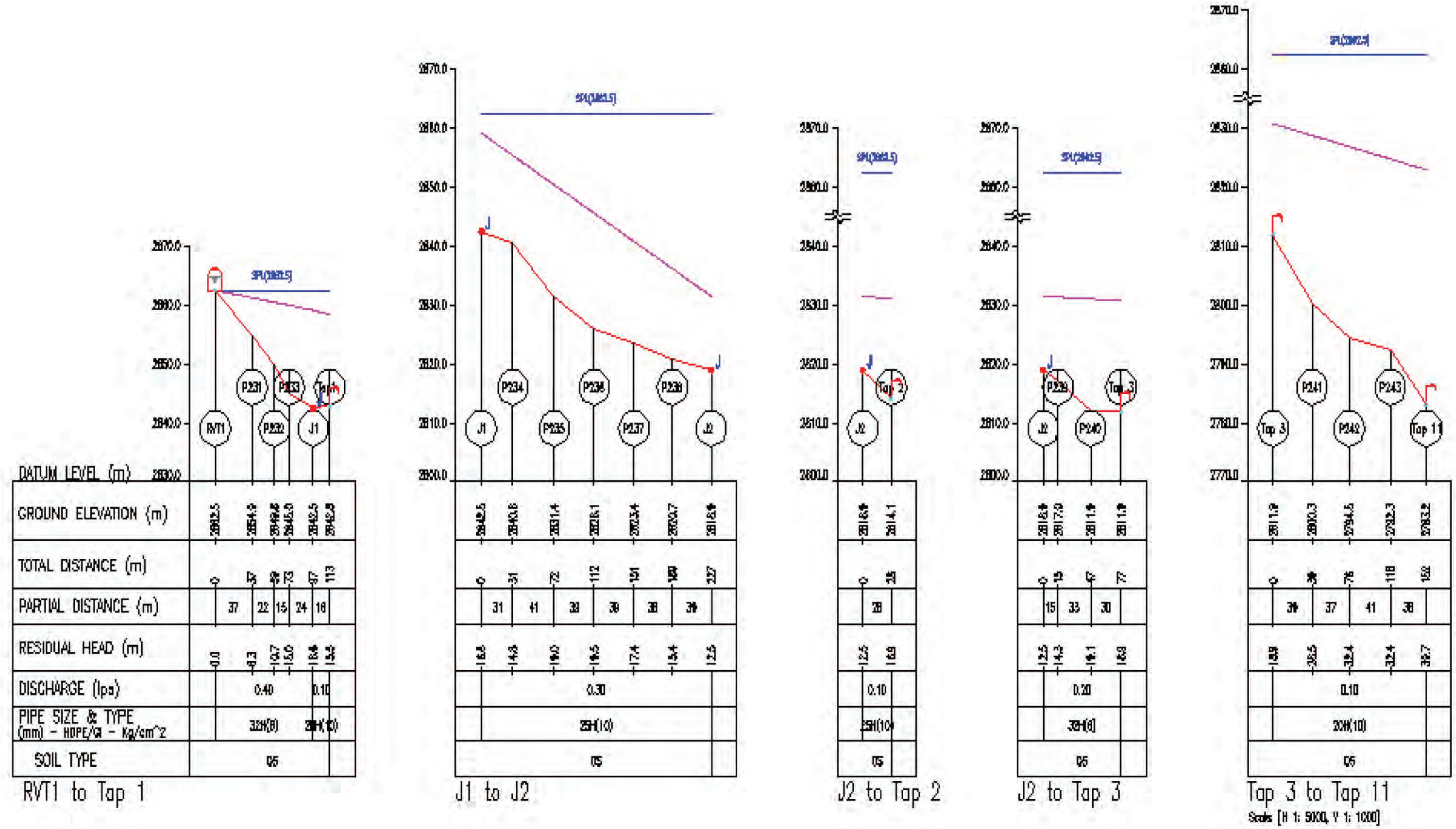
LOCATION : **WARD NO :** **4,5,6** **VDC : Sundarijal** **DISTRICT : Kathmandu**

Sheet No. : 1 of 1

Pipe Line Design from CW Method

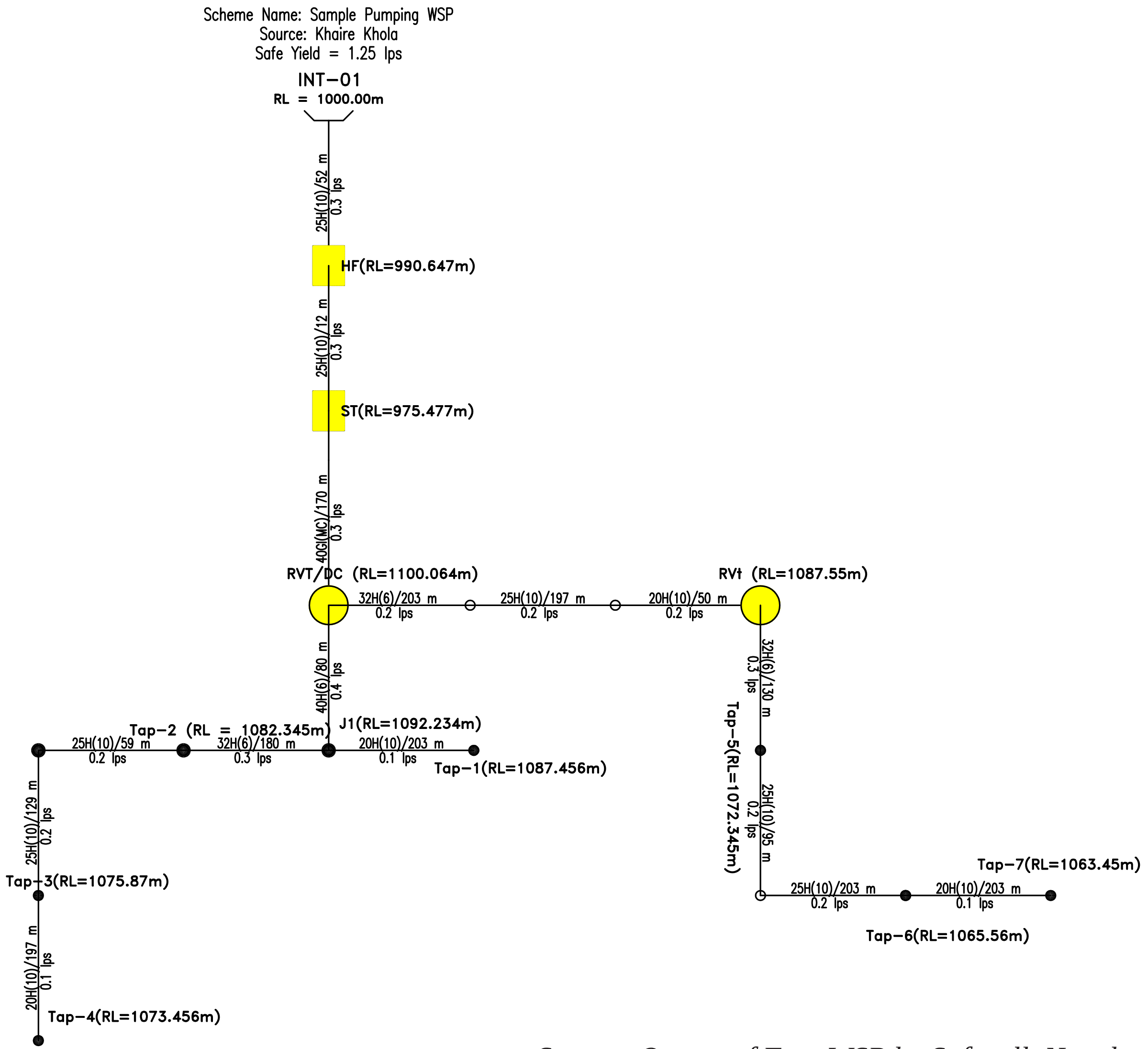
S. No.	Pipe Line From	Pipe Line To	Length Actual (m)	Length Design (m)	Design Dis. Q (lps)	Direction (UL/UR/DL/DR) (L/R/U/D)	Reduced Level From (m)	Reduced Level To (m)	Level Diff. (m)	New Static Level (m)	Total Head Available (m)	Max. Static Pressure (m)	PIPE USED HDPE O.D. (mm)	PIPE USED HDPE Class (kg/cm²)	PIPE USED HDPE I.D. (mm)	PIPE USED G.I. N.B. (mm)	PIPE USED G.I. Class	Friction Factor	Head Loss (m)	Residual Head (m)	Flow Velocity (m/s)	Hydraulic Gradient Line From (m)	Hydraulic Gradient Line To (m)	Soil Type	Remarks
[0]	[1]	[2]	[3]	[4]	[5]	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
	RVT1 to Tap 1																								
1	RVT1	P231	36.5	40.15	0.400	R	2862.48	2854.892	7.59	2862.48	7.59	7.59	***32.00***	***6.00***	***26.90***			0.0340	1.27	6.32	0.70	2862.48	2861.21	OS	
2	P231	P232	22	24.2	0.400	R	2854.892	2849.756	5.14	2862.48	11.45	12.72	***32.00***	***6.00***	***26.90***			0.0340	0.76	10.69	0.70	2861.21	2860.45	OS	
3	P232	P233	14.75	16.225	0.400	R	2849.756	2844.954	4.80	2862.48	15.50	17.53	***32.00***	***6.00***	***26.90***			0.0340	0.51	14.99	0.70	2860.45	2859.94	OS	
4	P233	J1	23.7	26.07	0.400	R	2844.954	2842.476	2.48	2862.48	17.46	20.00	***32.00***	***6.00***	***26.90***			0.0340	0.82	16.64	0.70	2859.94	2859.12	OS	
5	J1	**Tap1**	16.15	17.765	0.100	D	2842.476	2842.758	-0.28	2862.48	16.36	20.00	***20.00***	***10.00***	***14.90***			0.0423	0.83	15.53	0.57	2859.12	2858.29	OS	
	J1 to J2																								
1	J1	P234	31.15	34.265	0.300	R	2842.476	2840.575	1.90	2862.48	18.54	21.91	***25.00***	***10.00***	***18.90***			0.0359	3.79	14.75	1.07	2859.12	2855.33	OS	
2	P234	P235	41	45.1	0.300	R	2840.575	2831.352	9.22	2862.48	23.98	31.13	***25.00***	***10.00***	***18.90***			0.0359	4.99	18.99	1.07	2855.33	2850.34	OS	
3	P235	P236	39.45	43.395	0.300	R	2831.352	2826.089	5.26	2862.48	24.25	36.39	***25.00***	***10.00***	***18.90***			0.0359	4.80	19.45	1.07	2850.34	2845.54	OS	
4	P236	P237	38.9	42.79	0.300	R	2826.089	2823.375	2.71	2862.48	22.16	39.11	***25.00***	***10.00***	***18.90***			0.0359	4.74	17.42	1.07	2845.54	2840.80	OS	
5	P237	P238	38.1	41.91	0.300	R	2823.375	2820.717	2.66	2862.48	20.08	41.76	***25.00***	***10.00***	***18.90***			0.0359	4.64	15.44	1.07	2840.80	2836.16	OS	
6	P238	**J2**	38.5	42.35	0.300	R	2820.717	2818.926	1.79	2862.48	17.23	43.55	***25.00***	***10.00***	***18.90***			0.0359	4.69	12.54	1.07	2836.16	2831.47	OS	
	J2 to Tap 2																								
1	J2	**Tap 2**	28	30.8	0.100	D	2818.926	2814.064	4.86	2862.48	17.41	48.42	***25.00***	***10.00***	***18.90***			0.0426	0.46	16.95	0.36	2831.47	2831.01	OS	
	J2 to Tap 3																								
1	J2	P239	14.5	15.95	0.200	D	2818.926	2817.033	1.89	2862.48	14.44	45.45	***32.00***	***6.00***	***26.90***			0.0383	0.14	14.30	0.35	2831.47	2831.33	OS	
2	P239	P240	32.5	35.75	0.200	D	2817.033	2811.949	5.08	2862.48	19.38	50.53	***32.00***	***6.00***	***26.90***			0.0383	0.32	19.06	0.35	2831.33	2831.01	OS	
3	P240	**Tap 3**	30	33	0.200	D	2811.949	2811.862	0.09	2862.48	19.15	50.62	***32.00***	***6.00***	***26.90***			0.0383	0.29	18.86	0.35	2831.01	2830.72	OS	
	Tap 3 to Tap 11																								
1	Tap 3	P241	38.6	42.46	0.100	D	2811.862	2800.255	11.61	2862.48	30.46	62.22	***20.00***	***10.00***	***14.90***			0.0423	1.99	28.47	0.57	2830.72	2828.73	OS	
2	P241	P242	37	40.7	0.100	D	2800.255	2794.467	5.79	2862.48	34.26	68.01	***20.00***	***10.00***	***14.90***			0.0423	1.91	32.35	0.57	2828.73	2826.82	OS	
3	P242	P243	40.5	44.55	0.100	D	2794.467	2792.347	2.12	2862.48	34.47	70.13	***20.00***	***10.00***	***14.90***			0.0423	2.09	32.38	0.57	2826.82	2824.73	OS	
4	P243	**Tap 11**	35.5	39.05	0.100	D	2792.347	2783.159	9.19	2862.48	41.57	79.32	***20.00***	***10.00***	***14.90***			0.0423	1.83	39.74	0.57	2824.73	2822.90	OS	

Table 8-5: Pipeline Profile Property (Result of Hydraulic Calculations)



'Final Hydraulic Calculations' should be checked by plotting it 'either in a graph or with the help of software.

Table 8-6: Schematic Drawing



Source: Output of Free WSP by Softwell, Nepal

b. Flow Velocity

While sizing the pipe diameter, minimum and maximum flow velocities in the selected pipe should also be considered. Minimum velocity in the pipe line should be fixed to wash sediment particles which should not be allowed to settle at any point. The velocity must be sufficient to move sediment along with water.

To destroy excess head, small sized pipes are used, which however, increase the flow velocity. At velocities greater than 3 m/s air and water tend to mix affecting flow and the head loss. Also at high velocities when the faucets are suddenly closed the phenomenon of water hammer may also occur.

Hence, the following minimum and maximum velocity limits should be adopted.

Minimum Velocity

Transmission mains from stream intake to storage tank need special attention.

This is because river water may bring with it sediment particles that enter the supply line.

Preferable minimum flow velocity shall be:

- in downhill stretches 0.4 m/s
- in uphill stretches 0.5 m/s

Maximum Velocity

When a valve is instantly closed, the maximum velocities in the pipes that may allow water hammer pressure within the permissible limit of the pipe are theoretically obtained as

- on HDP pipes class 6 kg/cm^2 : v = 2.3 m/s
- on HDP pipe class 10 kg/cm^2: v = 2.8 m/s

A balance thereof must be struck between destroying excess head and the danger of creating a flow condition where high pressures due to water hammer can easily develop. Hence, maximum velocity in pipelines should be restricted to:

- Desirable 2.5 m/s
- Exceptional 3.0 m/s

c. Static Head

The static head in a pipeline refers to the difference in elevation between a point considered in the supply line and the open higher end of that pipeline where the water is exposed to atmospheric pressure. This, in most of the cases, can be a Storage Tank or a BPC. Static head occurs in the pipeline when a pipe flowing full is closed and the flow velocity becomes zero.

Following static head can be adopted for the design:

a) Transmission Main

- For HDP pipes pressure class 10 Kg/cm^2 not more than 80 m
- For GI pipes pressure class conforming to BS 1387 medium grade not more than 160 m
- For more than 160 m use welded joints for pipe & fittings

b) Distribution Lines

- Acceptable 60 m
- Exceptional cases 80 m
- With self-closing taps (e.g. Jayson Taps) 20 m

d. Residual head

The dynamic head remaining at the end of a pipe section is referred to as residual head. The residual head at a stand post, BPC or storage tank is required to account for :

- Appurtenance head loss, which is caused by the design flow rate passing through a faucet, float valve etc.
- Pipe installation loss, which is caused when the design flow rate passes through the pipe within the stand post structure. .
- Safety head, to provide safety against survey inaccuracies.

For public tap stand post following Residual head has been recommended

Table 8-7 Residual Head

Structure	Residual Head (m)
<u>Stand post</u>	
ideal	5-10
acceptable	up to 15
BPCs and Storage Tanks	10-15

If the residual head exceeds the specified values at the stand post, the excess head over the minimum required should be controlled by installation of a ferrule at the main line or an orifice near the stand post or a flow regulating key at the stand post (Used in Western Development Region).

If the residual head is high, excess head should be burned off by installing an orifice plate.

If water supply system is to be designed for household connections too, following minimum residual head is desired to maintain at connections points (generally ferrule point):

- Single storey building 5 m
- Two-storey building 10 m
- Three-storey building 15 m

e. Design of Orifice

There may be points in a system where the residual head at a discharge point is excessively high. This can particularly happen to tap stands. For such cases, it is possible to install a device (orifice) which creates high frictional losses in only a short length of pipeline. Design of such orifice can be done by this formula:

$$Q = CA\sqrt{2gh}$$

Where,

Q=flow

C= Coefficient of Orifice (generally-0.6)

A=cross-sectional area of orifice

g=gravitational acceleration

h=head loss through orifice

Knowing value of Q,C,g, and h it can be calculate the area of the required orifice and then diameter of the orifice.

9 Report preparations

Objectives:

After completion of this chapter, participant will be able to:

- Understand minimum requirement of the reporting standard
- Keep uniformity among the report across the organizations.

Time: 1 hrs.

Lesson 9.1: Pre/Feasibility study reporting requirement and standards : ½ hrs.

Lesson 9.2: Detail design and cost-estimate report preparations and standards : ½ hrs.

All the activities throughout the project cycle should be documented properly. It is proposed to record all activities during need assessment, project implementation and operation phase of the project. Each project file should contain minimum of following documents but not limited to this:

9.1 Need assessment by the community and request for a water supply project.

Community opting for a water supply project should discuss their need for water supply project, identify the potential water sources and agree on their participation and capital cost/operation and maintenance cost contribution. Representatives of the community should then produce a formal request to the concerning VDC and VDC should endorse and forward the request to DDC for pre-feasibility study. DDC will approve the request and forward to the concerning line agencies.

9.2 Pre-feasibility/ feasibility study Report

The pre-feasibility/feasibility report should contain the following information

I. Delineation of project area
II. Household and Population to be served
III. Present water supply situation in the proposed area
IV. Water demand - present and future
V. Measured and estimated safe yield of source
VI. Layout plan with tentative location of different components with approx. elevations of source and proposed service reservoir (tentative pumping head)
VII. Tentative Pipe Length (source to service reservoir and distribution line)
VIII. Willingness to pay for the project contribution (upfront capital contribution and O & M cost) by users and other kind contribution.
IX. No source dispute guarantee from VDC
X. Availability of local materials (like sand, stone, wood, skilled and unskilled labor)
XI. Tentative project cost.
XII. Costing module for feasibility study is given the following chapter.

The feasibility study report of a scheme should clearly state the viability of the project in terms of technical, social and economical aspects. Thus the report will contain tentative technical design and cost estimates of the schemes. The base line information on socio-economic, health, hygiene and sanitation status should be recorded so that these data could be compared later to monitor and evaluate the project benefits.

9.3 Registration of WSUC

For the effective coordination to different stakeholders and implantation of project, community organization (CBO) should be formed and should have acquired the legal identity. After the identification of project area and benefiting households the general meeting of the beneficiaries should form a 7-11 Members Water Users' and Sanitation Committee (WUSC) that should socially and geographically inclusive. The WUSC endorsed by VDC/Municipality will apply in a prescribed form for registration to 'District Water Resources Committee (DWRC)'. The DWRC will issue registration certificate after doing necessary examination of the situation and that should be produced by community at the time of project implementation agreement.

9.4 Detail Project Report

9.4.1 Detailed Survey, design and Cost-Estimates Report

Detailed survey and design is carried out after the projects are selected for implementation. The detailed survey is done to collect accurate information to design and fix exact positions of different components of the project. The detailed design report will have all information as in the feasibility study report and should come in prescribed format. The following checklist gives the minimum contain of the report but necessary to limit on following:

a) Intake -site plan, working drawing,protection works,
b) Transmission Main- layout plan, ground profile, pipe design and other structure in route.
c) Treatment plant- design parameters, site plan with contours (contours if possible), working drawings
d) Service Reservoir- R.T sizing, site plan with contours, working drawings
e) Distribution line- - layout plan, ground profile, pipe design, flow diagram and other structure in-route
f) Tap stand post- location plan, drainage facilities, working drawings
g) Operation and maintenance system

After completing the detail design of the project, next step to prepare the detail cost-estimate report of the proposed project. This should be prepared in prescribed format and software. It should clearly show detail cost breakdown of different construction (water supply and sanitation components) works in water supply and sanitation component. The provisions for administrative cost, tools and plants, community awareness or empowerment programs and contingencies should also be clearly stated in the cost-estimate report.

Detail design and cost-estimate report should be compiled in volume and should be as brief and concise as possible. It should not be too big to carry on hand as much as possible understandable to the all target users.

9.4.2 Social Report

i. Detail demographic and socio-economic report

The detail survey should be jointly conducted by social and technical professional. Any social or technical dispute that arises during the survey should be jointly handled by team and any queries regarding project implementation of villagers should be well satisfied by the team. Detailing of household, population and education status of the community should be interviewed and recorded in the prescribed format at the time of survey by social professional and analyzed and presented elegantly in the final report. A part form, present water supply situation, economic condition of the villagers and accessibility to different infrastructures of the villagers also should be included in the report.

ii. Supervision, Monitoring & Evaluation Plan and Periodic Progress Report

How the project progress will be kept in track, what are the inputs and outputs in definite time interval should be well defined in advance during project development phase. This plan should be made at project level (at community) and should be attached in the project report. For achieving this 'Community Action Plan' (CAP) can be the best tool. CAP should well define the positions like

a) What is the work
b) Where the work is to be executed
c) When the work is to be executed
d) Who will be the responsible for that
e) How the work will be executed

A part from that, the project plan for internal and external supervision and monitoring should be well-defined. It should include detail plan of supervision (who, when and how), monitoring (at community level and external) and evaluation of final output and liquidation of the project.

9.4.3 Community Training Records

Training like any other activities in a project, is meant to help in smoth, effective and efficient execution of work and complete the project in given time with desired outputs. Community training need should be accessed at the time of survey by social professional (like account keeping, leadership, maitenance worker etc.) and prescribed for the implementation in the project report. Training that can be started at local level or should sent outside the community (need project implementating agency support) should be categorized accordingly. The detail cost-estimate required to conduct the trainings should be included in the detail project report.

10 Construction Procedure of Structures

Objectives:

After completion of this chapter, participant will be able to:

- Understand the basic ideas about construction of civil engineering structures
- Understand the construction procedures of intakes, ferrocement structures and tap stand posts etc.

Time: 1 and ½ hrs.

Lesson 10.1: Site inspection for construction of structures, preparation of construction materials and basic construction technology
: ½ hrs.

Lesson 10.2: Construction procedures of different structures : 1 hrs.

10.1 Site Inspection for Construction:

Before starting of the construction work, a team of technical person should verify physically, all the locations of the proposed structures and visit from intake to last tap sand. It is the last available time for the whole project team to correct the work if any error persists in design or layout. Any structure's built location should be firmly made, stable zone and not prone to landslide or flood hazards etc. If some of those elements are unavoidable in small scale, proper protective measures should be adopted at the site.

Any structure site should not be drastically changed then the survey, it may affect other parameters like head, flow velocity or capacity range of the pipe materials etc. If it is unavoidable to change the construction location of the structures approval should be taken from the concerned design engineer.

10.2 Construction Materials

All the construction materials used for the construction should meet the standard specification as designated in the implementation guideline. Below are some of the materials that should have respective quality standard for use (for further readings pls. refer other standard specification books.)

Steel works

Different types of steel items are used in construction of water supply system are:

- Chicken wire: It should be finely woven of in hexagonal shape made from steel wire of not less than 1mm thickness (20gauge). The outer side of the wire should be finely zinc coated.
- Plain wire of 3.5 mm: It should be of correct diameter while measuring by a gauge meter to nearest of 0.0001m. The wire should be finely coated with zinc and should not be peeled off before using. It should show the 755gm of weight in 10m of its run.
- Reinforcement bars: These bars used for water supply system should preferably be the TOR steel rod, exhibiting brown in color. No any deformation other than factory made shape. No oil or grease stacked on its surface and surface should show clear not attacked by the corrosion.

Cement:

Ordinary Portland cement is used for mortar. The cement, which is already set and hard, should not be used; Cement should be screened if some small particles are mixed. All the cement should be stored in dry store till it is used.

If the cement used is damaged or inferior in quality, the structure may leak or damage. So cement should be checked property.

Sand

Sand should be clean. It should be free from organic and chemical matters, which makes mortar weak. For e.g. there should not be Clay, Lime & Mica. Adopting bottle test method should check the quality of sand. If the sand is found to be inappropriate due to quality, then it should be collected from another place. Don't use the sand of landslide area or also don't use very fine sand because it won't produce good mortar. The Ferro cement tank should not be built where the good quality sand is not available.

Water

The water should be fresh and free from silt and decomposed waste materials. The strong and durable mortar needs clean water. As the water requirement is high for the construction of Ferro cement tank, there should be well management of sufficient supply of water. For this purpose, the pipe may be laid from the Source to RVT.

10.3 Construction Methods

Mixing of Mortar

In construction of Ferro cement tank, one of the important things is to make strong and proper mixture of cement, sand and water in right proportion. The mixture should be workable and at the same time should form a paste as well so that the mixture could be applied in thick layers. The mortar mixed in the right proportion will allow working easily and quickly. It is important to have consistence in the ratio of the mixing hence a measuring pot (Tin or Bucket is advisable not the Shovel and iron pan) is helpful for this purpose. In Ferro cement RVT tank, which we are going to construct, a mixture of 1:2 cement and sand is used for the mortar. Reducing the cement will weaken the mix whereas increasing the cement will increase the possibility for the crack.

Strong and workable mortar can be prepared by using one's experiences. It's difficult to find exact required ration of water quantity due to different factors, such as:

- Whether the sand is dry or wet.
- Whether sand is fine or rough.
- Whether weather is sunny and dry or humid or cold.

Dry mixture is stronger than wet mixture. If the mixture is drier, it will be problem to apply by Iron pan and cannot be compacted property. Excessive wet mixture does not bond with the iron component like Roads. Hence a proper proportion of water is important to work with.

Plastering

Immediately after the preparation of mix it should be applied to the structure. The mortar should not be used if it is mixed ½ hour its application, However it could be used for other purpose. A wet jute bag/sheet can be used to retard the setting time of the mix.

Karni is used for the plastering, care should be taken to ensure that all the items like binding wire and rods are well covered by the plaster. Holes and spaces should be filled property. Plastering should be started from the bottom and carried to top.

In Ferro-cement tank, It is better to apply the second coat of mortar in the same day as the first was applied. If this is not possible due to inadequate setting of the first coat, the previous coat should be applied with rich solution of 1:2 cement sand mix can be done.

Curing

Any construction work done by cement should be kept wet for at least 21 days in terai and 28 days in hill region. There are number of ways to keep the cemented surface wet for days. Depending upon the orientation of surface and these methods can effectively be applied. Tank should be covered by wet jute bags/sheet to control the setting time. This is important, wherever the sun is bright; water should be sprinkled over the jute sheet daily at least for the 7 days. The strength of the tank depends considerably on how much curing is done. If the weather is hot and dry a frequent application of water is required within a day. Proper curing with water is vital for its strength and this is an important stage of construction.

Formworks

The function of the formwork is to support the structure before it is set and gains the full strength, formwork should be strong enough to bear the load of content, which it supports. If the form works gets disturbed and unstable during the time of setting then cracks might take place in the structure.

Generally HDP pipes are used for ferro-cement tank construction and bamboo posts are required to give proper support. For horizontal slab or vertical beam type structures locally available smooth planks can be used and these can be supported vertically by bamboo posts.

10.4 Ferro cement Tank Construction

Ferro cement tank construction process is often looked as difficult job involved for newbie in water supply projects which is why the whole process of construction sequence Ferro cement RVT is presented here:

The construction should be started only after the collection of local materials like, stone, gravel & sand.

Measurement work:

First mark the position and sixes of tank and valve box in the ground

a) Measure 100 cm more diameter than that of external diameter of tank.
b) Measure 100 cm x 240 cm for rectangular valve box.

Foundation Excavation:

After the measurement is transferred in the ground, foundation should be excavated as per following procedure:

a) Excavate 105 cm deep within the diameter for the Reservoir.

b) Excavate 140 cm deep for the valve box.

Laying of service pipes:

Next stage is to fix the service pipes.

- washout pipes should be placed in the middle of tank,
- Outlet & overflow pipes should be 15 cm away from the inner side of wall.
- Inlet pipe should be in other side of the tank this should we more than 15 cm from inner side of wall.
- Check the arrangement of overflow, washout & inlet pipes whether the gap between these pipes is 20 cm or not. The mouth of wash out should be 10cm below of outlet.

Soling

Soling is done by stone, gravel and sand and should be free from soil. Max 20 cm soling is required for up to 4 m^3 RVT and 25 cm soling for more than 4 m^3 capacity of RVT. 15 cm soling is enough for valve box.

Concrete Floor

One should make enough concrete and mortar. So, first prepare the well platform for this purpose. It can be made of C.G.I sheet or large size stones. There should be enough space for two people to work and this should be leveled so that water and cement does not flow.

Before concreting, reinforcement roads bent in 90 should be fixed in place, which helps to make monolithic structure of tank. Fix these in spacing as shown in design and drawing. Measure accurately and check the position of roads, because the position cannot be changed after concreting.

After fixing the rods bent in 90, 1:2:4 cement concrete is poured around the roads to fix in its position. The floor should be casted 10 cm more than the outside diameter of the tank. Floor should be slopped toward the center of tank. 5 cm slope is required for up to 4 m^3 tank and 10 cm for more than 4m^3 tank.

Formworks

HDP pipes are used for from works because this is available easily & easy to shape it. The pipe used is of 32 mm diameter. First, coil the pipes against the rods fixed vertical starting from bottom to top. As you proceed from bottom to top, use bamboo post to support the coil for fixing it in position & giving the required shape. Don't be greedy in shuttering. Use enough bamboo at 90 each other.

Reinforcement in Ferro cement wall

Firstly, each rebar's bent in 90 are fixed with straight vertical bars. Each vertical straight bar should be long enough for the height of tank and a margin for bending to connect the roof bars.

Next, first layer of chicken wire tied with the rebar to cover the whole area of outer surface of tank. There should be at least 20 cm overlap between the two-wire messes. Then 3.5 mm GUI wire should be provided to cover the whole wall of the tank over the chicken wire net. The wire is tied with the rebar at each intersection. Finally, you should cover the second layer in whole outer face of the tank by chicken wire mess. Vertical rebar, chicken wire mess and simple wires should be fixed tightly by means of using binding wire. To do so, it takes more time but this job should be done correctly and carefully.

Plastering of dome/roof of FC tank

Now the outer surface of tank is ready for plastering. This needs of 2 coats of same thickness. First coat is quite difficult because the mortar does not stick easily and the reinforcement should be covered totally by mortar.

First coat should be 15 mm thick. The surface should not be fine rather should be slightly rough so as that the second coat stick easily. When the first coat is set, then only second coat is applied. First coat should be dried fully. Before applying second coat, wet jute sheet should cover the first coat to retard the setting action. Second coat should be smooth and fine. The 1:2 ratio mortars are used for both coats.

Painting of tank

After completion of tank and curing, covers can be fixed on its position. Then all the outer surface of tank should be painted with white/snowcem paints, the painting should be done at least after 7 days from the date of completion of tank. This allows the tank to be properly dry up.

Filling the tank by water

Filling the tank with water is done slowly. The tank should not be filled with water in at a time, generally in a newly constructed tank. The water should be filled up gradually in a week time not suddenly in full depth. This is to avoid sudden loading of the tank. This will prolong the life of the tank.

Backfilling of Trench

After filling operation, backfilling should be done around the excavated trench of tank. In carrying this job, care should be taken to prevent from being damaged by the tools used for the backfilling.

Fencing of Tank

A fence has to be erected around the tank in order to protect the tank from children and animals. It job can be done before or during the construction of tank.

10.5 Stream Catchments

The construction of stream catchments is done with stone masonry work in cement mortar. The Dam with cement and stone masonry is built when the flow of stream is to be diverted from the construction site. If the water is flooded over the newly constructed dam, downstream could be damaged. So for this purpose, the temporary dam is constructed to divert this water first. As far as possible, the dam is constructed during the period of dry season.

First, the setting our of the dam is done with the wooden page and thread. Than 40 cm deep trench is excavate at the construction site. Depending upon the soil condition, 5 cm thick 1:3:6 constructed is laid at the bottom. The stone masonry wall in cement sand mortar is constructed over this floor.

The length of dam depends on the width of the stream. There is different length of dam for each stream catchments intake. Height of dam depends on the following parameters:

(1) Intake pipe should be at least 40 cm below the water level. This will allow the sediment particles to settle at the bottom.
(2) Dam should be made at least 20 cm higher than the water level (recorded highest water level within few years). It is necessary to ask villagers about this matter. It is built so as not to enter the water around the dam even during highest flood.
(3) Height of dam should be at least 80 cm above the steam bed.

On construction of dam, spillway is constructed to allow the sudden flow. Spillway is constructed in such a portion of dam from that portion the water from dam can be discharged our as an overflow. Spillway of diverting the water from dam does functions as an over flow.

At least 2 nos. of GI Pipes of 3" diameter is laid as washouts near the intake pipe. It is to clean the sediment particles collected just upstream of Dam. Washouts are fixed at the bed level of the river and closed by the end caps.

A. G. I. outlet pipe with the strainer is directly inserted inside the dam and is extended to sedimentation tank. The GI strainer fitted to outlet pipe at the dam separates the coarse particles.

After completion of wall, dam is plastered with 1:2 cement sand mortar. The trench is filled with soil and compacted. Subsequently, dry stone masonry wall is built to protect the bank of the river. At the downstream side of spillway, a dry stone soling is to be done.

Dry stone masonry wall is built around the outlet pipe of the intake structure to protect the strainer pipe. Dry stone is packed across the width of the stream from 4-5 m upstream of the dam to project the Dam from big boulders carried by flood during rainy season. This dam is constructed with bid boulders of 1 to 1.5 m in size and packed up to spillway level.

10.6 Spring Intake

Spring water flows on the ground surface from one or many points. In order to collect the water, catchments wall and an intake tank is built near/at the source with stone masonry in cement mortar. A valve box should be constructed to keep the valve safe. It can be made with stone masonry in mud mortar.

- Before starting any work, local materials such as stones, aggregates and sand should be collected in site. Stone breaking, production of aggregates and transportation of these materials in site should be carried out through the community contributions.
- Before starting of foundation excavation, the water course should be diverted by excavating a canal or laying of pipe above the intake. The working site should be dry as far as possible.
- Later, foundation should be excavated for catchments wall, intake tank and valve box. This should be done as per technical drawings and consultations of supervisor. A little bit wider area is excavated than the exact size of intake to make easy to work. In excavation of foundation of catchments wall, it should be excavated up to impermeable strata like rock bed so that water does not seep thought it.
- Outer dimensions of catchments wall, intake tank and valve box should be marked on the ground as per drawings. This should be set with bamboo pegs

and thread.

- A 15 cm stone and aggregate soling is done in trench. This will prevent water from percolation through the bottom of catchments wall. Soling should be compacted adequately with clay. Soiling is not necessary in hard rock area.
- A 1:2:4 cement concrete of 10 cm thickness is poured over the soiling. Concrete should be well compacted. The width of the concrete pad should be 10 cm. more than the width of the wall of the catchments and the intake tank.
- A cutoff wall is caste with 1:2:4 cement concrete of 20cm width and 50cm deep/ OR as per required.
- Above the concrete floor, 35 cm wide walls of catchments and intake tank should be built with stone masonry in 1:4 cement mortars.
- Service pipes in intake wall are fitted as mentioned below.
  - o Washout: A 2" GI pipe as washout is provided to wash the tank as and when required.
  - o Overflow: A 2"G.I. pipe as an overflow is fitted to drain the excessive water of tank. This pipe should be sufficiently long so that the drained water does not erode the strata immediately downstream the intake. This pipe is generally 5-10 m. in length.
  - o Outlet: An outlet pipe is the pipe from where the pipeline starts. Size of the outlet pipe should be one size bigger than the H.D.P. pipe immediately down. A HDP strainer is fitted on it and should be positioned at 10 cm above the concrete floor.
- All service pipes are fitted inside the valve box through the partition wall of intake tank. It protects the pipe. At each interface, the walls should be roughened to increase the bond between the pipe and wall before fitting GI pipe. A 1:1 cement mortar should be poured around the pipe and left for some days.
- The height of the tank should be built as per drawing. The height of the catchments should be 45 cm more than that of tank height.
- Now the valve box can be built with stone masonry in 1:4 cement mortars, Its height is to be as of intake tank. An outlet pipe of 63 mm HDP is laid inside the valve box immediately over the stone soling. It drains out the water collected inside the valve box.
- A wooden form work of 7 cm height should be fixed inside and outside over the wall of the intake and valve box. It will provide support for the concreting. A R.C.C. beam should be built along the waterway of intake. Refer the drawing for required reinforcement.
- Within wooden formwork, 1:2:4 mixture of concrete of 7 cm thick is poured. A prefabricated Iron manhole frame one for intake and another for valve box is placed in slope between slab and frame.
- After sufficient hardening of R.C.C. And removing the wooden formworks, A 35 cm wide catchments walls built with stone masonry in cement mortar.
- A c cm thick concrete is poured above the catchments wall. It may require wooden formwork.
- Concrete floor, inner wall of tank and outer surface of catchments wall should be plastered in two coats. The first coat 1:3 cement sand mortar and the second coat 1:2 cement sand mortar.
- External surface of intake tank, valve box and catchments walls in finished with pointing 1:3 cement mortars.

- Dry stone is packed in between source and passage to the intake where water enters. This acts as a filter and helps to keep out suspended particles. This wall can be easily dismantled and rebuilt during maintenance work.
- The excavated portion around the backside of the catchments wall should be filled with small stones and aggregates as filter pack through which water can percolate. This should be done up to level of dry stone masonry wall. Above all a clay plaster of 15 cm sloping outwards should be applied this is to keep out the rain water from entering into the chamber. It is recommended practice to use a thick sheet of a plastic just beneath the clay layer.
- Rest of the space around the intake tank, valve box and catchments, should be backfilled with ordinary soil in such a way that it prevents the rainy water from flowing into the intake structure.
- A channel should be excavated around the intake structure to keep out the rainwater and other surface water. It prevents the source water from contamination. This channel should be 20-25 cm deep with stone soiling on edge and should be above 5-10 m from intake.
- A fence should be erected around the intake to protect the intake structure being damaged from man & animals.
- A retaining wall should be made around the intake if it is needed. For this it is recommended to consult with the supervisor.

10.7 Distribution Tank

Distribution tank is constructed of Ferro cement. This tank is small and circular in shape and is divided into two sections by Ferro cement partitions. Supply pipeline divides into two branches inside the tank. The Control valve installed in one branch will regulate the flow at both branches. Two separate pipes are connected to two section of the tank to reservoirs.

The method of construction is similar to the Construction method of Ferro cement tank, given in article-8.3.1, some more consideration during the construction of DC are:

- The reinforcement of partition wall should be continued to the reinforcement of the external wall. For this purpose, before plastering, reinforcement of external wall of tank where this is to be continued to partition a hook shape arrangement is to be provided.
- Chicken wire, GUI wire and the reinforcement bars used for the partition. The way of fixing these items are not different from that in external wall.
- Two washout pipes are provided one at each section.

10.8 Pipe Line

The trench digging should be done through the survey line. Required depth of trench of pipeline is 90 cm (3’-0”). The required width of trench should be approximately 40 cm wide. This depends also on the people who excavate the trench. Generally, trench excavation and pipe laying is carried starting from source to down wards.

Laying: Upon completion of 100 m excavation of trench, depth and alignment of pipeline should be cheeked by overseer or technician. If the trench is found correct by supervision, pipe can be joined and backfilled property. Timely backfilling is important because the cattle may drop into the trench. Similarly if it rains before backfilling the sides may fall down and re-digging might add the work for the

Community.

HDP pipes are available in 25 to 300 m. Coil. They are uncoiled in the site itself. During this activity care should be taken that no stretch of the pipe is damaged. For this A stick of Bamboo is inserted in the coil and holds it by a person another person gradually bulls an end a laid in the ground for the jointing.

A wooden peg must close the end of the pipes before the work is halted for that day. This is protecting from entering any things into the pipe. Before joining the end of the pipe must be checked thoroughly and carefully. On doing so, if there is any case for flow interruption after backfilling, there will not be necessary to see the pipe by re excavating the trench and cutting the pipe. Joints should be checked whether it is proper or not by moving the pipe up and down.

Backfilling: After laying the pipe in trench all the length should be backfilled with soil leaving unfilled 2.3m in joint sections. Upon distribution of water the joints should be checked for. In this manner leaking joints can be found easily and immediately. In the backfilling of first 15-20 cm depth of trench the soil from the sides should be dropped and compacted by foot by the villagers.

For the first layer, there should not be stones leaves and bushes in the soil. After backfilling 50 cm with this type of soil, holder or stones also may be placed over this. Backfilling is done in layer. Once a layer of 20-30 cm is filled and compacted the other layer is placed on the top of it. A slight heap formation on the backfilling will equalize with G.I. after it became naturally compacted in due course of time. If the backfilled trench is depressed much it will became drainage channel upon rain. This will, in future might expose the pipe. So this is very important point to be bear in the mind.

The raised portion by backfilling should be made. The soil around the pipe should be well compacted. The grass should be planted above and side of raised portion so as not to deposit new soil. Backfilling the steep sloped trench and high steps of paddy land, stone masonry wall is necessary on the trench. This prevents the trench from sliding.

GI pipe is required to cross the small streams and to suspend the pipe across the difficult sections. But if this is not available, next alternative should be thought. In this condition, larger sized HDP pipe can be used to cover the first one.

The useful life of HDP pipe can be increased considerably by careful laying and backfilling. A little effort given during this stage will increase years of life.

Blockages: The water flow will be stopped partially of fully due to blockage inside pipe. This blockage of flow in pipe could be due to the following reasons.

a) Solid materials inside the pipe.
b) Air blocks

Solid materials: The blockage due to solid things is due to presence of stone, stick, woken plugs and dirt's inside the pipe, usually, this will interrupt in certain stretches of pipe only. It is easy to detect as the air can flow through the solid materials.

The sections of joints reduced section of the pipe, valve. Tee etc. are the usual place for the blockage. If the pipe joints are not buried it's easy to find the internal blockages of pipe. Swinging the pipes and hearing the flow of water can find the location of pipe blockage.

After finding the blockage, it should be remove off. This is done by cutting the pipe in accurate point and removing the blockages materials and finally pipe should be jointed under supervision.

Air: The air, which is collected and pressured inside the pipe, can stop the flow of water. Generally the collected air inside the pipe can block the first water flow. This is the reason that the water could not throw the air trapped inside the pipe. When the water flows inside the pipe, the trapped air is compressed in a small volume and it stops the water flow. The location of blockages due to air can be found:

(i) On the top of pipe line:

(ii) At the point of low pressure :

Generally, if the pipe line route is through the irrigation canal, where the gradient is low the air blocks can occur. Similarly in low pressure stretches usually are near of source.

(iii) Below the tank made without provision of outlet and air vent:

Air blocks can be found supervising on these places. Hear the sound of water swinging the pipe. After finding the location of Air blocks, it is necessary to remove it. There are many means to remove it.

I. hole is made at that point by hot nails and after releasing the air, it should be closed by nails brass which is more practical and easiest means.

II. By providing air valve where air blocks occur more frequently.

10.9 Horizontal Roughing Filter Construction

1. 'Horizontal Roughing Filter' structure is simple in construction mostly adopted of masonry structure and methodology followed same as in previous pages of masonry structures. Materials and labors required as per design and cost-estimate of the HRF is prepared in advance at the site and below mentioned construction sequence can be followed:
2. Digging of trench (foundation) as per detail drawing of the HRF. Generally, HRF is constructed half below the ground.
3. HRF of three compartment trench is dug at once and bottom plate upon which whole structure rests is casted at first above the dry stone soling with sand of thickness 15cm.
4. Two walls of extreme ends are constructed solid while two intermediate walls are semi-solid (perforated separate walls), weep wholes are left at specified distance as specified in the design.
5. Inlet and Outlets of HRF are placed at same level in opposite site and collected through water trough at specified height as per design and drawing.
6. Other construction process is same as that of general masonry structure but gradation of sand is most important in this structure and given in table below:

Table 10-1: Guidelines on size and length of filter material for different types of water

Type of Solid Matter	Filtration Rate (Vf)	Gravel sizes of different Fractions	Length of Filter
Settle able Solids	0.6 – 1 m^3/h	16-24mm	200-400cm
		12-18mm	
		8-12mm	

Suspended Solids	4-0.8m³/h	12-18mm	100-300cm
		8-12mm	
		4-8mm	
Plankton, algae	0.3-0.5m³/h	8-12mm	50-150cm
		4-8mm	
		2-4mm	

1. River bed gravels are found to be best for the HRF filter media, if not found filter materials as expected, the values given above should not be taken too rigid. Gravel from quarry can also be sieved through meshes or perforated steel plates used as sieves.
2. The filter media used for roughing filters has to be clean and free from organic material. It is therefore important to wash the aggregates thoroughly in order to remove all loose and dirty material from the surface of the filter media. If this recommendation is not followed, the effluent quality of the roughing filter will be poor and result in rapid clogging of the filter.
3. The total area of the open joints in separation walls should ideally amount to 20 to 30% of the total filter cross section and be equally distributed over the entire cross section to maintain an even flow throughout the horizontal-flow roughing filter

11 Water Pumping System Design

Objectives:

To give detail knowledge on designing and selection of various electromechanical components of Solar PV Pumping System with the help of figures, charts and workout examples.

Time: 1 hour and 45 min

Lesson 11.1: Water pumping system design	: 5 min
Lesson 11.2: General approach for designing	: 10 min
Lesson11.3: Directly coupled and battery powered system	: 5 min
Lesson 11.4: General approach for designing	: 1 hour
Lesson 11.5: Wire sizing	: 15 min
Lesson 11.6: Tracking and non tracking system	: 10 min

11.1 Introduction

PV powered water pumping has versatile applications ranging from residential use, agricultural sector to small-scale industrial purposes. The design of each system poses ample challenges due to complications that arise due to the large range of water sources, consumer requirements and system configurations. However, a close scrutiny and consideration of modifying parameters for each condition solve the problems related to design aspects.The basic design principles are given here with some worked out examples at the end.

11.1.1 Basic Steps in System Design

Designing a PV water pumping system has two very important aspects:

a) Selection of the most suitable system component types- this is crucial in providing a low maintenance, long life system of reliability;

b) Matching of system components – this is a difficult area requiring considerable know-how and expertise, and will ultimately be responsible for the performance of the system with regard to efficiency of operation.

One of the most important questions to be asked before designing a particular system is: "what level of reliability is necessary and to what extent can maintenance be carried out?" The answer to this question leads to preference toward either a directly-coupled system with attributes concerning simplicity, reliability, low maintenance and long life, or a system, which sacrifices these features in order to gain better efficiency. However, these features enhances issues regarding increased complexity, higher maintenance, poor reliability and shorter life expectancy related to power conditioning circuitry, inverters and perhaps batteries. Other constraints influence the type of system selected, and each system needs to be designed on its own merits. No one PV Water Pumping System design will be ideal for all locations. PV based water pumping system probably introduces the greatest variability of system design with regard to configuration and component selection.

Several computer simulation and design tools are now available to assist designers. However, their uses require a high level of water pumping knowledge and good data on site selection and component performance.

11.2 General approach for designing

The general approach to designing a system can be summarized as follows:

1) Determine the volume of water to be pumped each day,
2) Determine the total head
3) Calculate the pump rate from the number of sunlight hours (based on peak sun)
4) Select the pump referring to catalogues of reputed manufacturers concerned
5) Select appropriate size of solar PV array

However, prior to following these guidelines, it is useful to ascertain whether a directly coupled system (no batteries, no inverter and no power conditioning circuitry) is feasible for the particular application. If so, such a system is strongly recommended, even though its use provides little flexibility in component choice and system configuration. However, there are occasions when directly coupled systems are unsuitable. These include:

- When pumping heads are too large to be able to use a centrifugal pump with reasonable efficiency;
- When suitable DC motors are not available, such as with some large systems (greater than 10 HP) where little choice exists, or when a submersible motor is necessary and no brush less DC motors are available at a suitable price;
- When the pumping rate in bright sunshine exceeds the water source replenishment rates;
- When it is essential batteries be used for energy storage (i.e. where “availability” of pumped water must be very high and tank storage is unsuitable) e.g. portable units;
- Locations characterized by excessive cloudy weather making the poor part-load efficiencies of a directly coupled system unacceptable.

It should be recognized that the PV water pumping industry is evolving rapidly, with the potential to make any preferred design criteria obsolete in a matter of years. For instance, the preference to avoid power conditioning circuitry and the like could change if new developments, combined with field experience, indicated adequate reliability and performance could be achieved, or if a new type of positive displacement pump or AC motor proves vastly superior and more economical.

Table 11-1 Comparison between directly coupled and battery powered system

Connection	Merits	Demerits
Directly coupled to array	Simplicity Reliability Low maintenance Low cost Quick to install	Low efficiency No water at night
Battery powered	Predictable supply Higher efficiency Supply of starting surge current Availability of water when required	Maintenance complexity High cost Charge control failure

11.2.1 Feasibility of Directly Coupled System

A directly coupled system is one where a low starting torque (such as a centrifugal pump) can be driven by a DC motor that receives its power directly from the solar panels. No batteries, inverters or power conditioning circuitry are used, other than perhaps safety cut-out relays activated by level, flow or pressure sensing transducers. When the sun shines brightly, the system operates and water is pumped either for storage or direct use.

An approach for designing directly coupled PV powered water pumping must include the following considerations:

1. The volume of water to be pumped and over what period. The volume to be pumped may vary significantly throughout the year and in fact may be entirely non-critical for some months of the year, as for some irrigation applications. This will have important implications regarding array tilt angles.

   For instance:

   a) if the demand profile throughout the year is reasonably constant (such as for a domestic water supply) , a tilt angle in the vicinity of latitude +20º will be necessary to give the most uniform insolation levels throughout the year falling on the solar panels ;
   b) if the amount of water to be pumped out is to be uniform throughout the year , but with a definite bias towards summer months (such as for drinking water), a tilt angle in the vicinity of latitude +10º will probably be desirable;
   c) if the annual amount of water to be pumped is to be maximized (such as with a large storage reservoir) a tilt angle in the range latitude -10º to latitude should be used :
   d) if the water pumped during summer months is to be maximized (such as for some irrigation applications) a tilt angle in the vicinity of latitude -20º will be preferable, to ensure the solar panels point directly at the summer sun. In general, increasing the tilt angle will provide more uniform pumping throughout the year.
2. The pumping head and its seasonal variations must be known and where possible, information regarding water source replenishment rates should be obtained.
3. The inclusion and economics of water storage should be considered in conjunction with consumer needs.
4. Any available insolation data should be obtained and (used in conjunction with the local conditions e.g. for determining the light intensity incident on the solar panels at certain angle during morning, noon or afternoon).
5. Select a pump to suit, the range of operating heads, and physical dimension constraints imposed by the application and one that will pump the required volume of water when operating at its maximum efficiency point. It is essential the torque / speed characteristics of the selected pump to be known, to facilitate system matching.

11.3 General approach for design

11.3.1 Head Calculation

Total pumping head is determined by using following formula :

$H_{Total} = H_a + h_f + vd^2/2g + 10(P_d - P_s)/r$ (m)

Where, H_a - actual pumping head (the vertical height between the suction water surface and the discharge water surface (m)

h_f - total loss in head in piping (m)

$vd^2/2g$ - Discharge velocity head (m)

P_d - Pressure exerted on the discharge water surface (Kg/cm^2)

P_s - Pressure exerted on the suction water surface (Kg/cm^2)

r - Specific weight of the liquid (Kg/l)

When both the suction and discharge water surfaces are open to the atmosphere, the total dynamic head of the pump is calculated by the equation:

$H_{Total} = H_a + h_f + vd^2/ 2g$ (m)

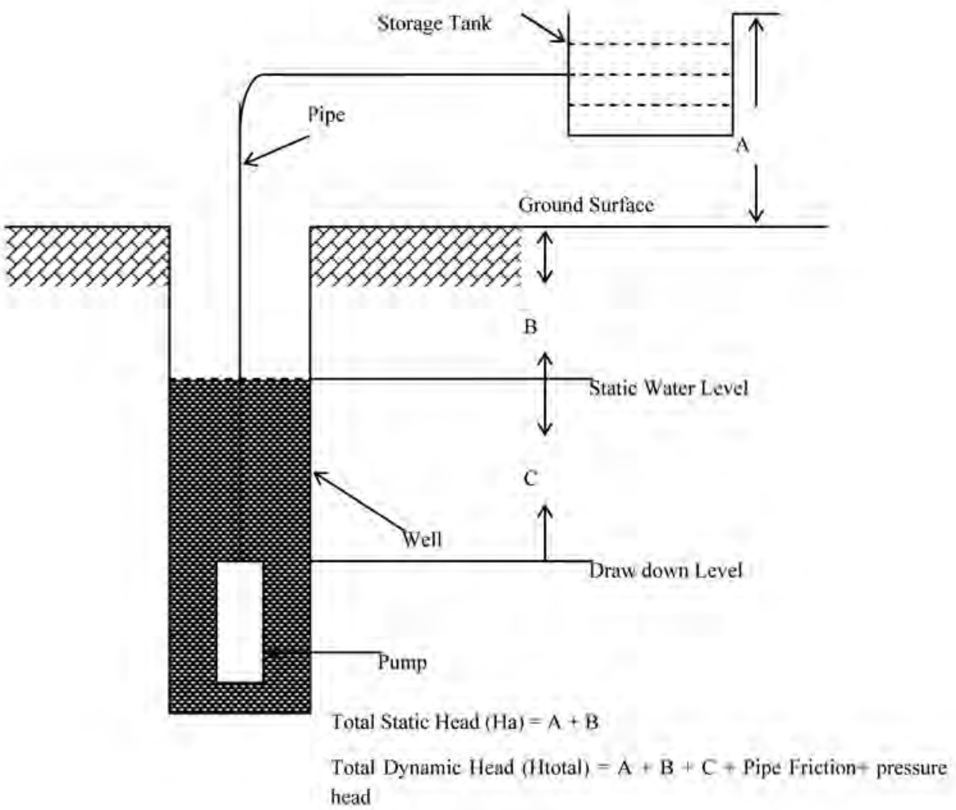


Fig. 11-1 Schematic diagram of water pumping system

When total pumping head is very high, it may not be possible to pump in one stage. In such case multi stage pumping is to be done. Water is pumped from the collection chamber/sump well of the first station to the collection chamber /sump well of second pump station and from there it is again pumped to higher level. Number of stages may be two or more. When staging pumping stations technical and economical analysis are to be done. In general maximum total head is not exceeded 200 meters. On selecting the material and thickness of pipes and fittings possible water hammer pressure must be considered.

1.2.2 CHOICE OF PUMP:

1.2.2.1 Surface Centrifugal pump:

Surface pumps are generally suitable for regions where the water level is within 7 m below ground level (http://d-lightpower.com/surfacepump.html). A surface or centrifugal pump is normally placed at ground level. The pump is suitable for pumping from shallow bore wells, open wells, reservoirs, lakes and canals. The solar pump is driven by a permanent DC motor connected directly to an array of solar panels. The surface centrifugal pump is presented in Fig. 11-2. Such type of pumps are usually designed for high flow rates and low heads. The permanent magnet DC motor driving the surface pump is powered by a matching solar array to maximize efficiency. An enclosed impeller design ensures smooth operation. Made of cast iron, these pumps are finished with anti-corrosive primer, followed by silver colored polyurethane paint.

Fig. 11-2 Surface Centrifugal Pump (http://www.aurore.in)

Table 11-2 Example of water discharge for various head using surface pumps (http://www.aurore.in)

Total dynamic head (m)	Water output (lit/day)	
	900Wp	1800Wp
6	1,10,000	1,43,000
8	1,04,500	1,37,500
10	75,000	1,21,000
14	68,750	1,10,000

Table 11-3 Example of pump system (http://www.aurore.in)

Model	AV-900 RM	AV-1800 RM
Array Capacity	900 Wp	1800 Wp
Solar Panel Size	75 Wp	75 Wp
Solar Modules TBP 1175, 75 Wp	12	24
Support Structure	1	2
Pump Capacity	1 hp	2 hp

Maximum Total Head	14 m.	14 m.
Maximum Suction Head	7 m.	7 m.
Water Discharge Size	52 mm	65 mm
Water Output @ 10 m. head	75,000 lit/day*	1,40,000 lit/day*
Array Junction Box	1 No.	1 No.
Installation Kit	1 Set	1 Set
User Manual	1 No.	1 No.
2" HDPE Pipe	10 m.	10 m.

11.3.2.2 Submersible pump:

A submersible pump is one that is immersed in water. It pumps water by displacement. Most deep wells use submersible pumps. These pumps are costlier but have a longer life and greater reliability than surface pumps. Such type of pumps is designed for high head and medium flow application. They are multi-stage pump and has high efficiency micro-computer based inverter. The inverter optimizes the power input and thus enhances the overall system efficiency.

Fig. 11-3 Submersible Pump (http://www.auFeasibility Study

Table 11-4 Example of water discharge for various head using submersible pumps

(http://www.aurore.in)

Total Dynamic Head (m)	Water Output (lit/day)	
	1100 Wp	1800 Wp
7	55,000	72,000
10	50,000	67,000
25	30,000	47,000
30	29,000	39,000
50	7,000	20,000

Table 11-5 Example of submersible pump system components (http://www.aurore.in)

Model	AV-1100 GF	AV-1800 GF
Array Capacity	1100 Wp	1800 Wp

Solar Panel Size	75 Wp	75 Wp
Solar Modules TBP 1175, 75 Wp	16	24
Support Structure	1	2
Pump Capacity	0.75 hp	0.75 hp
Maximum Total Head	50 m	50 m
Maximum Suction Head	7 m	7 m
Water Discharge Size	40 mm	40 mm
Water Output @ 10 m. head	29,000 lit/day	39,000 lit/day
Array Junction Box	2 Nos.	2 Nos.
Installation Kit	1 Set	1 Set
User Manual	1 No.	1 No.
2” HDPE Pipe	50 m	50 m

11.3.2.3 Lifespan of the pump:

The exact life span of the pump varies from model to model. Life-time of pumps is hard to specify. The submersible pumps usually last a long time, since they are made of stainless steel. However, when there is a lot of sand or silt in the water, the moving parts will wear out quickly, reducing the life of the pump.

The surface pumps are made of much less hi-tech materials (cast-iron and MS steel) and rust a lot. But again, parts can be replaced, and by doing so the life-time of the pump can be extended almost indefinitely. There is a difference between physical life-time and economical life-time. At some point the repairs become so costly, that replacing the pump is more economical. This economical life-time varies depending upon the field conditions and maintenance.

11.3.2.4 Choosing the right pump:

The two basic types of pumps- centrifugal and positive displacement are generally used. These pumps can be driven by AC or DC motors. DC motors are preferable for the PV applications, because they can be directly coupled to the PV array output. Centrifugal pumps with submersible motors are the optimum for PV applications because of their efficiency, reliability and economy. However, for deep wells Jack pumps may be necessary. Jack pumps are the piston type of positive displacement pumps that move chunks of water with each stroke. However they require very large currents, therefore they are connected through batteries.

Most of the renowned and reliable pump manufacturers provide very reliable chart for the selection of appropriately rated motor/pump combination. The only input required is the yearly average peak sun for the given locality, daily water requirements (m^3) and the total dynamic head. The manufacturers provide the system performance and instantaneous output graphs as illustrated below.

Similar charts are available for pumps of various capacities meeting the daily water requirements and pumping head.

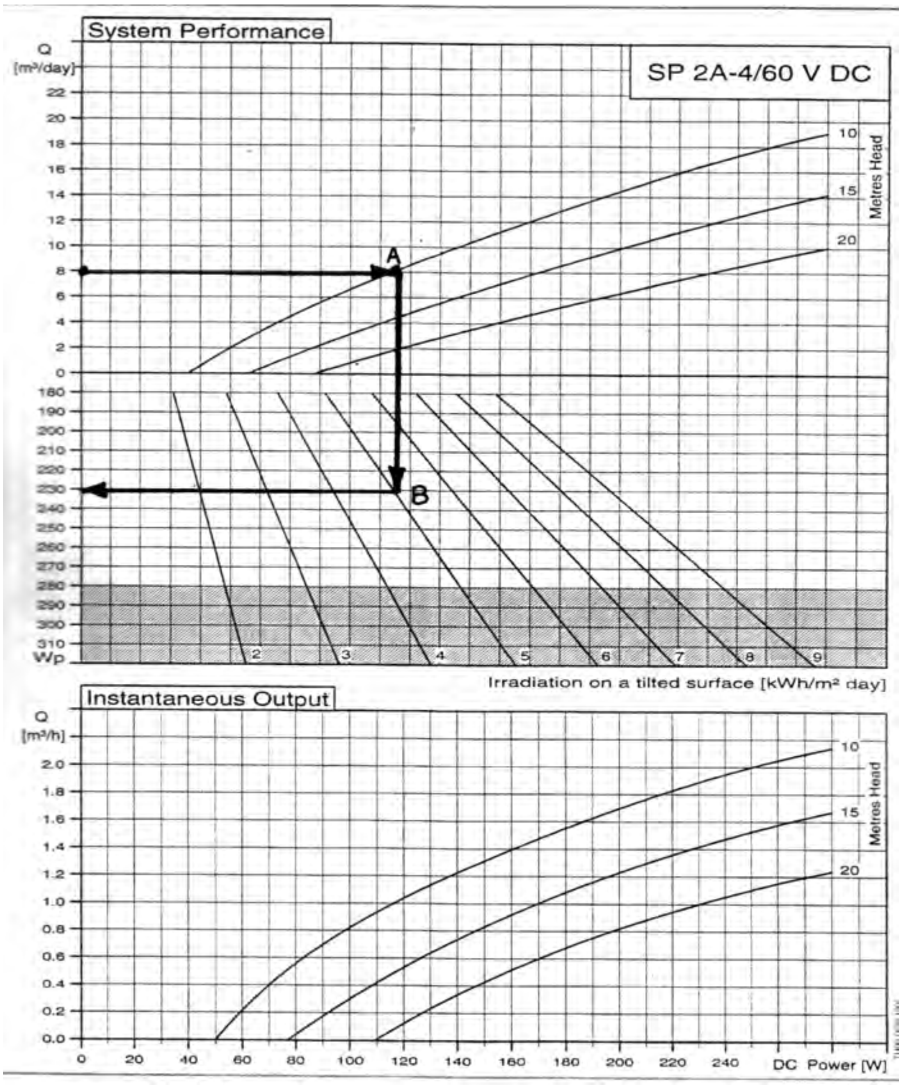


Fig. 11-4 System Performance and Instantaneous output chart (AEPC, 2003)

The steps in selecting appropriate pump would be as follows:

- consider the upper graph of the above sample figure
- draw a straight line from the point in m3/day axis until it intersects with the curve with the required head in meters
- from the point of intersection A draw straight line down until it meets with the curve for given peak sun of the locality (intersection B)
- Finally draw horizontal line from B to the Y axis with Wp indication. And the reading in this axis is the required array power in Wp.

The example in the above figure is for daily water requirement of 8 m^3 with total dynamic head of 10 m in a locality with 5 peak sun. In this case the required array power is 230 Wp. The Grundfos pump model number SP 2A-4/60 V DC can be used to fulfill these requirements. Now if the water requirement or the total height is greater than that mentioned in the curve, select the curve for higher capacity pump.

The results obtained from the manufacturers chart must also be verified by the results of calculations based on previously described formula. Alternately, the results of the calculation may also be verified using manufacturers charts. Solar pumps are available in different capacities. The surface pumps can be used to lift water from a maximum depth of up to 7 m. Sometimes, the pump can be installed inside the well up to 10 m deep. For wells deeper than that, a submersible pump is more advisable.

The choice of solar pump depends on the quantity of water required and the depth at which water is available. To design a system, however, it is necessary to view the whole picture and consider all the resources. So, the final installation must be based on a thorough site study by the experts concerned.

Attention!

Water to be pumped:

- Sand content generally should not be more than 50gm/m^3
- pH should be in between 5 to 9
- Chloride content should be not more than 500 ppm at 30 deg C
- Temperature should be within 40 deg C

Selected solar submersible pump with built-in motor should have the following Features:

- Main switch incorporated
- Maximum power point tracking
- Fault indication
- Protected against overheating
- Protected against overloading
- Protected against voltage transients
- Protected against too low and too high input voltage
- Protected against earth leakage
- Protected against dry run

11.2.3 Array sizing

The hydraulic energy (E_H) required to pump water can be calculated by using the following formula

$E_H = \rho gVH/\eta_p$

Where

V: total volume required per day, in m^3

H: total dynamic head, in m

ρ: density of water, in 1000 Kg/m^3

g: acceleration due to gravity, 9.81 m/sec^2, and

η_p: pump efficiency, 30% to 50% (in normal cases)

Example 1: Determine the hydraulic energy needed to pump 1500 l/d from a depth of 40 m. The efficiency of the pump is 30%.

Solution:

The hydraulic energy (E_H) = $\rho \times g \times V \times H/\eta_p$

Given,

$\rho = 1000$ kg/m^3

$g = 9.81\ m/s^2$

$V = 1.5\ m^3/day$

$H = 40\ m$

$\eta_p = 0.30$

Therefore,

$E_H = (1000\ kg/m^3 \times 9.81\ m/s^2 \times 1.5\ m^3 \times 40\ m)/0.3 = 0.545$ KWh

(1 kWh = 3.6 MJ)

The size of array can be determined by

$P = E_H / (S \times F_m \times F_t)$

Where:

E_H : Hydraulic energy needed, KWh/day

S: Average daily solar insolation – peak sun in hours

F_m: Array / load mismatching factor, usually $F_m = 0.8$

F_t : Temperature derating factor for array power loss due to heat (In general, 0.8 for warm climate and 0.9 for cool climate).

Example 2: A surveyor collected following data from a rural village.

Population:	300
Number of cattle head:	60
Average water consumption (human):	30 litres/day/person
Average water consumption (cattle):	40 litres/day/cattle
Monthly average solar insolation at optimum tilt:	5.5 kWh/m^2/day (Jan-May and Oct-Dec)
	4.5 kWh/m^2/day (June-Sept)
Ambient temperature at pumping site:	25 degree Celsius
Pipe friction loss (equivalent) including discharge velocity head :	1 m
Static head:	25 m
Draw down level:	5 m

Calculate hydraulic energy, PV power and no. of modules rquired.

Solution:

Daily Water required = 300 people x 30 l + 60 cattle x 40 l = 11.4 m^3

Total dynamic head = static head + friction loss + draw down = 25+1+5 = 31 m

Design solar insolation = 4.5 kWh/m^2/day (minimum value selected for worst case)

$F_t = 0.8$

$F_m = 0.9$

Discharge of water from the pump = total volume of water required/minimum available peak sun (in hours) = 11.4 m^3 / 4.5 hours = 2.53 m^3/hours

$E_H = \rho$ x g x V x H/η_p

= (1000x9.81x11.4x31)/(0.5 x3.6) = 1.926 kWh

P = E_H / (S x F_m x F_t) = 1.926/ (0.8x0.9x4.5) = 0.594 kWp = 594 Wp

The current delivered can be determined by

Iarray = P/system voltage

Iarray = 594/48 = 11.37 A

In case of a single module cannot deliver the required current, number of modules are needed to connect in parallel. The number of required modules can be calculated by

N_p = Iarray/ Imp

Where I mp is the current at maximum power of the module

Imp = 4.3 A for Module MS-M100 manufactured by MACRO-SOLAR (Annex I)

N_p = 12.37/4.3 = 2.876 =3

N_p is usually rounded upto the next highest integer value.

System Voltage depends upon the selected pump/power conditioner to be used selected pump.

Then, number of strings of parallel-connected modules to get required system voltage can be calculated by

N_s = Nominal system voltage/ nominal module voltage

N_s = 48/12 = 4

Finally, the total number of modules can be determined by

$N_t = N_p$ xN_s

N_t = 3x4 = 12

The array consists of 12 PV modules with 4 in series and 3 strings in parallel.

Example 3: Nowadays there are various software developed by manufacturers of sophisticated PV based water pumping systems. One needs to mention location with solar insolation value, the total head needed including frictional losses and total volume of water needed per day.

The detail solution related to PV based water pumping system using software LORENTZ COMPASS 3.0.10.77, for insolation of 4.5 kWh/m^2/day, total head 20m and volume of water required 40 m^3/day is given in Annex XIII

11.4 Wire Sizing

Wire sizing is the selection of the wires of appropriate size and type. It is one of the critical aspects of Solar Pumping system design. In fact, it is important to choose proper size wire in Solar Pumping system to ensure safe operation and minimize voltage as well as power losses.

11.4.1 Size and Types of Wires:

Wires can be solid or stranded, bare or insulated, ordinary PVC insulated or with UV protection type insulation. Solid wire consists of a single wire of required cross-sectional area; whereas stranded wires are made of multiple numbers of wires of smaller cross-sectional area. Often AC house wiring is done with solid wire or stranded wires. This is because, owing to the high system voltage (220 V in Nepal), the relative magnitude of the current flowing through the wires is low. But in PV applications including Solar Pumping System, the DC voltage level is relatively lower than the AC, and therefore for same load the magnitude of the current will be relatively large. For higher currents, the cross-sectional area of the wire size must be larger. Solid wires with larger cross-sectional area become stiff and difficult to work with, so stranded wire is often used in PV installations.

Wire can be made of aluminum or copper. Aluminum wire can be considered for very long wire runs (e.g. national grid transmission lines), because it costs less than equivalent copper wire. But for most wiring applications in PV systems, copper wires are used.

Type of insulation used in wire is also important in PV. Indoor wire, not exposed to the outdoor environment can have ordinary PVC insulation. But the outdoor wire must have special insulation (UV resistant insulation) so that the insulating material will not deteriorate over time due to exposure to UV light. The wires need not to be directly exposed to the sunlight to deteriorate, as even light reflected on the back of the modules from the ground will eventually weather the wire insulation.

The standard unit of size of the wire is square millimeter. But in practice various other standards are in place: these are American Wire Gauge (AWG), Standard Wire Gauge (SWG) Brimingham Wire Gauge (BWG), US Steel Wire Gauge (US-SWG) and number based sizing system such as 7/22, 3/20 etc. However, the wire size in the given standard can be converted in to sq. mm using appropriate conversion table or consulting the wire manufacturer's specification sheet. It is also the usual practice to specify the size of the wire in diameter (instead of cross-sectional area). The standard wire gauge chart is given in Annex VII

11.4.2 Wire Sizing Methodology

There are two factors that dictate the selection of wire size. Properly selected wire size must satisfy both the factors equally.

11.4.2.1 Ampacity Based Sizing

The sizing of the wire based on the current handling capacity (the capacity that does not produce overheating of the wire) is the first approach in wire sizing. The household AC wiring is based on this principle only as the voltage drop in the wire does not play major role in AC applications. The current handling capacity (or Ampere-Capacity or Ampacity) of the wire is chosen to be slightly greater (usually 25%) than the maximum load current that will flow through the wire. The wire specification chart usually specifies the Ampacity for given wire size in the form of a table.

While calculating the DC load current, the total real power required to operate the load is to be divided by the system voltage. But for AC load currents, the apparent power needs to be divided by the system voltage. Since for reactive AC loads apparent power is higher than the real power, Ampacity of the wire need to be higher.

11.4.2.2 Voltage Drop Based Sizing

For the wire to be used in low voltage, high current applications voltage drop across the wire is another important factor to consider. All conductors have some small resistance, which causes a loss of voltage in a circuit depending on the size and length of the wire. The specific value of voltage drop (voltage factor) for given wire size is expressed in terms of volt/meter. The voltage drop in wires causes less voltage applied to the load from array. Less charging voltage means less energy stored and less voltage at load means unstable operation of the load. Therefore the national standards specify the maximum allowable voltage drop in each segment of the wire. The selected wire may meet the Ampacity requirements but may not be suitable with regards to the allowable voltage drop. The Nepal Interim PV Quality Assurance (NIPQA) has specified the following level of voltage drop (V) in each wire segment:

Less than 5% between CR and loads

Less than 3% between array and CR and CR to inverter

The voltage drop in each wire segment can be calculated using the following formula:

ΔV= Max. current flowing through the wire x Wire length (both way) X Voltage factor

NIPQA has specified the formula for determining the wire size (in sq. mm) based on both Ampacity and voltage drop requirements:

$S = (0.3\ LIm)/ \Delta V$

Where is,

S = Required wire size (cross-sectional area of the copper wire in sq. mm)

L = Length of the wire in meters

Im = The max. current in Amp

ΔV = Max. allowable voltage drop in percent

It is to be noted here that the above formula takes care of voltage factor as well as the Ampacity level of the copper wire and is included in the multiplier coefficient equaling to 0.3. The size of the wire for each segment is to be calculated using the above formula. The wire sizing requires great deal of attention. The main effect for the load case is the reduced voltage level to the loads, impairing performance of some of the voltage critical loads.

11.4.3 Power conditioning

DC-DC converters: DC-DC converters are solid state electronic devices which change the input voltage and current levels to different output levels. Usually in a photovoltaic system, a converter lowers the incoming voltage level to a specified level for the pumping system. As converters have more than one output voltage, the pumping system can be changed as per requirements and availability of water. The converters can be useful to directly match the output characteristics of an array to a specific load. Thus, a DC-DC converter can be selected based on output voltage, maximum output current, efficiency, interference level and overload/reverse polarity protection.

Inverters: Inverters are required in systems which supply power to AC loads. Inverters convert the DC output of the PV array to standard AC power similar to that supplied by utilities. In general, all system control functions are integrated into the inverter. An inverter is selected based on surge capability, continuous power output, efficiency, voltage regulation, total harmonic distortion, waveform and serviceability.

12 Testing and commissioning procedure of Solar PV pumping system

Objectives:

To give detail information regarding care to be taken while installation of various electromechanical components of the solar PV pumping system

Time: 20 min

Lesson 12.1: Installing solar array : 10 min

Lesson 12.2: Electrical Installation : 10 min

12.1 Installing the Solar PV Array

12.1.1 Location of the Solar PV Array

A location with an unrestricted sun exposure through the day and through the year needs to be chosen, as full exposure of the solar array is critical for full performance of a solar-direct system. The fuel to drive the solar pump is the sunlight. The array can be placed several tens of meters or more from the wellhead/water source. No loss of performance will occur if the electrical wire is sized properly, but the cost of wire will increase significantly.

12.1.2 Shading

The pump stops completely on shading a small portion of a PV array. Each PV module (panel) contains a series of solar cells (typically 36 or 72 cells). The cell that is shaded acts like a resistor and thus reduces the output of the entire array. The power will be reduced disproportionately on shading of just a few cells and may stop the pump. A Solar Path finder is a device that is especially useful in forested areas or in the areas with obstructions nearby. The site can be surveyed to determine where shadows may cast at any time of the year by using this Solar Pathfinder. Details about it can be found at www.solarpathfinder.com.

In order to clear rain spatter, growing vegetation and snow, the bottom edge of the array should be placed at least 50 centimetres the ground. One must consider the fact that trees and perennial plants will grow taller in the coming years.

12.1.3 Solar Array Assembly Methods

Solar Array can be installed in the following two ways:

I. Assembly of the array includes wiring and all, which is to be done on the ground, and then the entire assembly is to be lifted onto the pole or roof. A system of 300 watts or more may require the assistance of a backhoe, boom truck or crane to lift it over the pole.

II. Array is to be assembled piece-by-piece on the pole or roof. In case of the pole being higher than 2 m, a temporary platform needs to be constructed, like a scaffold assembly.

Mounting panels on roof is generally cheaper than mounting on the poles. But if roof is shaded or facing the wrong way, a pole must be used. Pole mounting provides better cooling for panels than roof mounting. The panels should be attached with stainless steels bolts or screws, not nails, which can loosen over time.

12.1.4 Solar Array Mounting Rack

The mounting structure may be of fixed type or tracking type, and wind resistance and safety must be considered for its operation. A solar tracker is a special pole-mounted solar array rack that tilts automatically to follow the daily path of the sun. The daily water yield increases by 40-50% during summer, but it becomes less effective in winter and cloudy weather.

12.1.5 Orientation / Setting of Tilt angle of the Solar Array:

In Nepal, the photovoltaic array is usually tilted at 30° towards south. Maximum performance can be achieved on tilting the photovoltaic array towards the sun. Adjustment of the tilt angle can be done in both tracking and non-tracking system where the optimum tilt angle is determined by the location (latitude), which also varies with the time of the year. There may be three options:

I. **Year-round compromise** (no seasonal adjustment): Set the angle equal to the latitude of the location and "forget it". This is practical because people often forget to adjust the array.

II. **Seasonally adjusted** On comparison to option I, it increases the daily water production by about 8%. Here, the adjustment is to be done twice per year.

III. **Seasonal use only** If the pump is to be used no more than half of the year, set the array to the appropriate seasonal angle and "forget it".

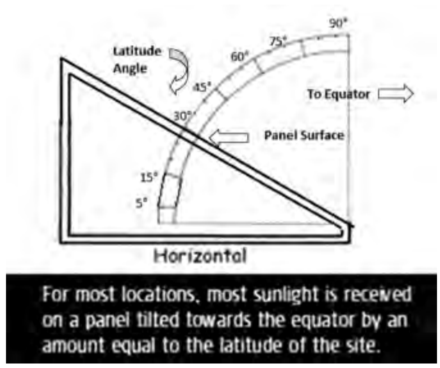


Fig. 12-1 Tilt Angle of Solar Arrays

12.2 Electrical Installation

12.2.1 Power Conditioning, Junction Box and Electrical Conduit

Location: The risk of lightning damage can be reduced by positioning the controller close to the solar array, not to the pump.

Protection from solar heat: In extremely hot locations, electronic devices may not be reliable if they are not protected from heat. The controller must be mounted in the shade; extreme heat may trigger a thermal switch in the controller and cause it to turn off. An ideal location is directly under the solar array, on the north side of the mounting pole. In case of the shade being unavailable, a piece of sheet metal can be cut and bolted behind the top of the controller. On bending the sheet over the controller provides the shade to it.

Location of controller: It is necessary to mount the controller vertically to keep out rainwater. It is preferable to mount it on the North Side of a pole or other structure, this helps to reduce solar heating. This may also allow easiest access without hitting your head on the lower (south) edge of the array.

12.2.2 Junction Box:

The cable connections are protected in enclosures known as junction box that provides the necessary connectors. Some of the solar panels, such as Kyocera and Sharp come with serviceable junction boxes. However, most solar panels require wiring the junction box before installation. A solar junction box is installed directly on to the back of every PV panel produced and serves as the interface between the conductor ribbons on the panel and the DC input and output cables. Solar junction boxes contain bypass and blocking diodes to protect the panel from reverse current during hours of darkness, if the panels are in shade or if covered by debris (e.g. leaves).

12.2.2.1 Connection process:

Firstly, it is needed to unscrew the 4 screws in order to open the junction box. Inside, there will be more screws. But it is needed to unscrew only two screws - the ones on the bottom left and right, under which there should be a positive and negative sign. It is not required to disconnect the mounting and diode connection screws. Then, bring the wires into the junction box via a conduit or directly with a cable using a rainproof cable connector.

12.2.2.2 Mounting the junction box to a pole:

The junction box can be mounted onto the solar array support pole. It clamps to fit around the mounting pole. This makes a very strong assembly that is easy to adjust.

12.2.3 Electrical conduit

Once the array wiring design, wire size and junction box are decided, it is needed to decide the number and rating of the fuses and switches. The ratings of the fuses or circuit breakers are generally kept about 1.5 times the maximum current flowing. The interconnections among the components are accomplished after installation of each component independently. The outdoor wiring must be protected from human activities, weather and from chewing animals. For this purpose, it is essential to use electrical conduit (pipe). Use of strong, high quality outdoor cable is recommended in case of not using the conduit. Where cables enter the junction box, install sealed strain-relief cable clamps.

12.2.4 Keeping the electrical conduit and junction box sealed

It becomes prominent for animals, insects, water and dirt to enter through the holes, so the unused holes must be sealed. Keeping in mind this fact, each hole is supplied with a rubber plug that can be kept in place for this purpose. It is important to note that the grounds of system failures are the loose connections.

12.3 Installation Line Diagrams

The schematic diagram for water pumping system can be prepared in similar manner as done with non-pumping applications. However, additional safety device like water level sensor has to be installed in the system. Moreover, the power conditioning devices such as maximum power tracker, if required by the pump, may be installed in the system. The suggested installation line diagram for various configurations is given in the figure below.

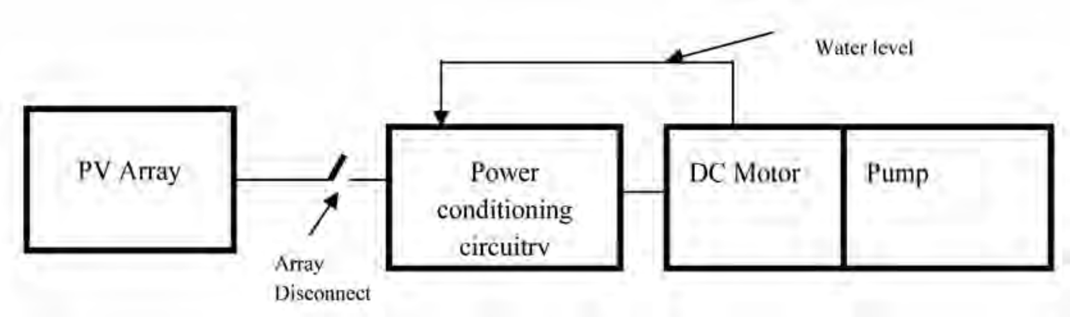


Fig. 12-2 Directly coupled DC motor/pump (AEPC, 2003)

13 SAFETY

Objectives:

To give detail information about the types of safety equipments to be used for the protection of solar PV pumping system, their detail descriptions and ways of use.

Time: 25 min

Lesson 13.1: Grounding and Lightning protection : 15 min

Lesson 13.2: Warning siphon appliances : 10 min

Safety is a full-time and the responsibility of every employee. Practicing safety requires:

- Good work habits and a clean work area
- Proper equipment and its uses
- Awareness of hazards and how to avoid them
- Training in CPR (cardiopulmonary resuscitation) and First Aid
- Periodic reviews of safety procedures

13.1 Grounding and Lightning Protection

The purpose of grounding any electrical system is to prevent unwanted currents from flowing (especially through people) and possibly causing equipment damage, personal injury, or death. Lightning, natural and man-made ground faults, and line surges can cause high voltages to exist in an otherwise low-voltage system. Proper grounding, along with over current protection, limits the possible damage that a ground fault can cause. One conductor of a PV system (>50 volts) must be grounded, and the neutral wire of a center tapped three wire system must also be grounded. If these provisions are met, this is considered sufficient for the battery ground (if batteries are included in the system). A ground is achieved by making a solid low resistance connection to a permanent earth ground. This is often done by driving a metallic rod into the earth, preferably in a moist location. A single ground point should be made. This provision will prevent the possibility of potentially dangerous fault current flowing between separate grounds. In some PV systems where the PV array is located far from the load, a separate ground can be used at each location. This will provide better protection for the PV array from lightning surges. If multiple ground points are used, they should be bonded together with a grounding conductor.

- All exposed metal parts shall be grounded (equipment ground).
- The equipment grounding conductor should be bare wire or green wire.
- The equipment grounding conductor must be large enough to handle the highest current that could flow in the circuit.

One can get injured working on any PV system. Cuts, bumps, falls, and sprains hurt just as much and cause as much lost time as the electrical shock and burn hazards generally thought of. Although, most safety suggestions are just plain commonsense, people still get hurt in industrial accidents. Fortunately, few have been hurt working on PV systems-no deaths have been reported. The goal is to reduce the number of injuries to zero. This requires good work habits, an awareness of potential hazards and a program where safety rules are frequently reviewed.

In solar water pumps, one of the most common causes of electronic controller failures is the surges induced by lightning. Damaging surges can be induced from lightning that strikes a long distance from the system, or even between clouds. The following instructions greatly reduce the risk of damage:

Location of the pump controller: Place the controller close to the solar array, not the pump. This will reduce the risk of lightning damage.

Construct a discharge path to ground: Static electricity accumulated in the above-ground structure will discharge by the means of a properly made discharge path to ground (earth), which helps prevent the attraction of lightning. A well-grounded conductive structure can divert the surge around the electrical circuitry, in case the lightning strike occurs at close proximity, thereby, greatly reducing the potential for damage. The controller has built-in surge protectors, but they help only if the system is effectively grounded.

Earth connection-Create an effective discharge path: It establishes a “drain field” for electrons. Some suggestions for grounding, in order of their efficacy, as illustrated below:

I. The best possible ground rod is a steel well casing located near the array. Drill and tap a hole to make a strong bolted connection to the casing with good metallic contact. Bolt on a brass terminal lug. After the connection is made, seal the connection with silicone sealant or other waterproof compound to prevent corrosion. Protect the ground wire(s) from physical damage so they are not stressed by being stepped on, etc.
II. Install a copper plate or other specialized grounding devices designed for the purpose. Some systems use salts to improve the conductivity of the surrounding soil.
III. Install one or more copper-plated ground rods at least 8 feet (2.5m) long, preferably in moist earth. Where the ground gets very dry (poorly conductive), install more than one rod, spaced at least 10 feet (3m) apart.
IV. If the soil is rocky and does not allow ground rods to be driven, bury bare copper wire in a trench at least 100 feet (30m) long. If a trench is to be dug for burial of water pipes, ground wire can be run along the bottom of the trench. The wire size must be minimum 16 sq. mm or double 10 sq. mm. Connect one end to the array structure and controller. Or, cut the ground wire shorter and spread it in more than one direction.

Dry or rocky locations: To achieve good grounding at a dry or rocky site, it is needed to emphasize grounding and lightning protection more seriously and to coordinate the effort with other earth-excavating procedures that need to be done. For more detail, visit: www.lightning.org.

Bond (interconnect) all the metal structural components and electrical enclosures: Interconnect the PV module (solar panel) frames, the mounting rack, and the ground terminals of the disconnect switch and the controller, using wire of minimum size 6 mm2, and run the wire to an earth connection.

Ground connections at the controller: The controller and junction box have redundant ground terminals inside. They are all connected in common with the metal enclosures of both the controller and the junction box. Ground connections can be made to any of these points.

Ground connections to aluminum: This applies to connections at the solar array framework, and at the controller's enclosure box. Connections to aluminum must be made using terminal lugs that have an aluminum-to-copper rating (labeled "AL/ CU") and stainless steel fasteners. This will reduce the potential for corrosion.

Do not ground the positive or the negative of the power circuit: The best lightning protection results from grounding the metallic structure only and leaving the power system ungrounded. This is called a "floating" system. With a floating system and a good structural ground, lightning induced surges tend to reach ground through the structure, instead of the power circuit. When high voltage is induced in the power circuit, the voltage in negative and the positive sides tend to be nearly equal, thus the voltage between the two is not so high, and not usually destructive. This method has been favored for many decades by most engineers in the remote power and telecommunications fields.

Solar array wiring: Bind the array wires close together, or use multi-wire cable. Avoid forming loops. This helps induced voltages in each side of the circuit to equalize and cancel each other out.

Wire twisting for long runs: Twisting wires together tends to equalize the voltage induced by lightning. It reduces the voltage differential between the wires. This reduces the probability of damage. This method is employed in telephone cable, and in many other applications. Some power cables are made with twisted conductors. To twist wires, one can alternate the direction of the twist about every 30 feet (10 m). This makes the job much easier.

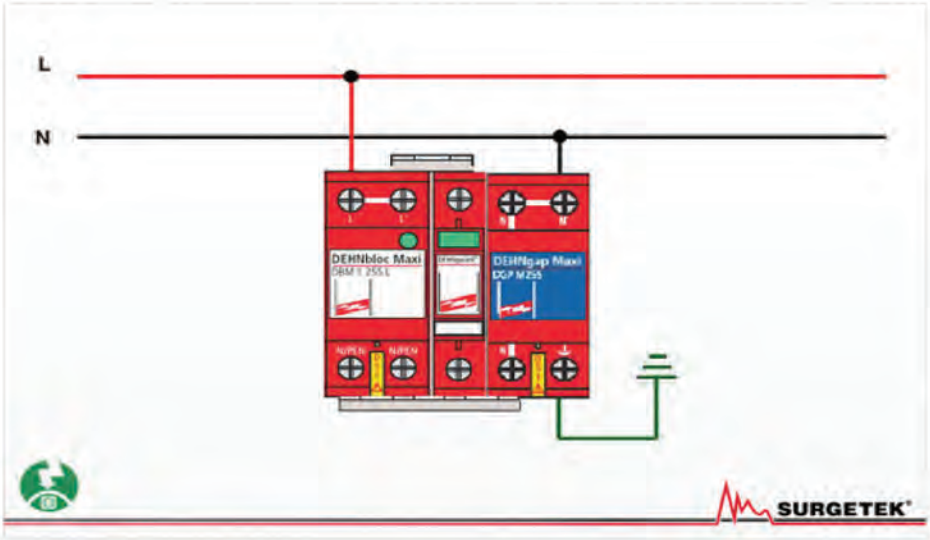
Float switch cable: A long run of control cable to a float switch in the storage tank can pick up damaging surges from nearby lightning. The best protection is to use shielded, twisted-pair cable. Shielded cable has a metallic foil or braid surrounding the two wires.

Low water probe cable: A long horizontal run of wire to the low-water probe at the pump can pick up damaging surges from nearby lightning. Wire twisting is helpful. The best protection is to use shielded and twisted-pair cable. This product is suitable for direct burial, but not for submersion in the well. At the wellhead, make a transition to submersible probe wires.

13.2 Surge Protectors/ Surge Arresters

The solar PV pumping system needs effective lightning and surge protection. Due to open area and large space requirement, solar PV pumping system is especially threatened by lightning discharges during thunderstorms. Causes for surges in the PV systems are inductive or capacitive voltages deriving from lightning discharges as well as lightning surges and switching operations in the upstream power supply system. Lightning surges in the PV system can damage PV modules and inverters/ controllers. This can have serious consequences for the operation of the system. A surge protector performs well for expensive equipment. However, when comes the protection of large equipment that work under high voltage, surge arresters are best. Surge arresters are less expensive compared to surge protectors. The use of surge protectors has been increasing rapidly. This is because of its features and higher capability of protecting expensive equipment from surges.

Size and type of surge protection to be used with PV system depend upon size of PV array, maximum Iscstc, number of strings, max. voltage Vocstc, MC connectors and



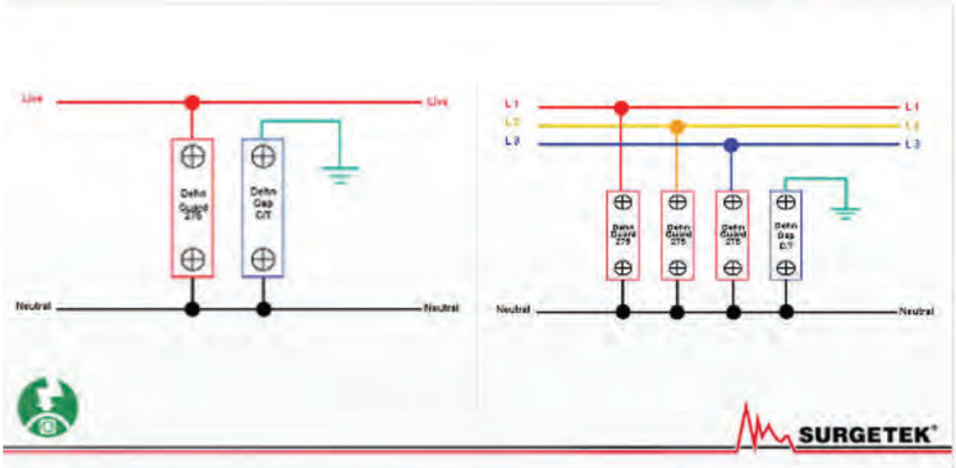


Fig. 13-1 Surge Protectors

fuse protections and protective fuses both is AC and DC sides. As an example, PV surge protection panel system as refered by CITEL (French company) is given below.

Table 13-1 PV Surge Protection Panels

SN	Voltage, V DC	Current, A	No. of strings, surge protection	Device/ CITEL
1	600	20	3	SPV 50-600-3ST
2	800/1000	25	3	CPV 50-1000-3ST
3	800	63	6	CPV 50-800-6ST
4	800	125	13	CPV 50-800013ST

13.3 Additional Lightning Protection

The controller has built-in surge protection devices. However, additional grounding measures or surge protection devices are recommended under any of the following conditions:

1. Isolated location on high ground in a severe lightning area
2. Dry, rocky, or otherwise poorly conductive soil
3. Long wire run (more than 100 feet / 30m) from the controller to the water

source, or to the float switch. Additional lightning protection devices (surge arrestors) can be obtained from the pump supplier. The device(s) for the controller's PV input, float switch and probe connections, must be rated for DC. The device(s) for the controller's AC output to the motor must berated for 3-phase AC. In each case, the clamping (bypass) voltage should be 90V or higher, but not much higher. In extreme cases, it is best to employ the service of a local lightning protection expert.

Solar Array Disconnect Switch in the Junction Box: The disconnect switch is used for a safety disconnect between the solar array and the controller. During installation and maintenance, switch off the disconnect switch to prevent shock and arc burn hazard. Overload protection (fuses or circuit breaker) is not required in the solar array circuit. Short circuit current from the solar array can never reach the ampacity (maximum safe amps capacity) of the recommended wire. The controller has internal overload protection.

13.4 Care to be taken while Installation in a Surface Water Source

Positioning the pump: The pump may be placed in an inclined, vertical or horizontal position, as desired. To reduce the intake of sediment, do not place the intake very close to the bottom. The pump has usually a small "vent hole" near the top. If the hole is not submersed, it will suck air and prevent the pump from performing fully. The purpose of this hole is to allow water to fill an internal gap, to conduct heat away from the rubber stator.

River or stream: Secure the pump from logs and debris that may float downstream. Use stainless steel wire rope or chain instead of plastic safety rope (plastic rope will weaken in sunlight). Consider digging a shallow well near the stream. This will allow filtration of the water through the earth, and will protect the pump from floating debris or human tampering.

Position of the low-water probe: The low-water probe must be positioned vertically, within 10°. Normally, it is to be installed on the pipe above the pump outlet. This will only work if the pump is installed vertically. If the pump will not be vertical, find an alternative way to mount or suspend the probe, so that it is higher than the pump, and in a vertical position.

Is a flow sleeve required?: NO, not within the normal temperature range. The pumps high-efficiency motor generates very little heat. A conventional submersible pump requires a flow sleeve to assist motor cooling when installed in open water (not confined by a narrow casing). It is a piece of a 4-6" pipe that surrounds the pump to increase flow around the motor.

Depth of submersion: The pumps may be submersed as deep as necessary to ensure reliable water supply. The lift load on the pump is determined by the vertical head of water starting at the surface of the water in the source. Increasing the submergence of the pump (placing it lower in the source) will not cause it to work harder or to pump less water. Avoid placing the pump close to the bottom where it will pick up sediment.

Filtration at the pump intake: The pumps will tolerate small amounts of sand, but it is required to filter out larger debris that is normally found in a pond or stream. It can be constructed a simple coarse screen to protect the pump and to reduce the nuisance of debris in the water system. One method is to wrap the pump with about 6-8 layers of loosely-woven fabric or screen, of a material that will not decay or rust. Some suggestions are fiberglass window screen, agricultural shade cloth, or weed-barrier fabric (available from nursery and landscaping suppliers). Bind the fabric or screen with all-stainless hose clamps, rubber, or polypropylene rope. Do not use nylon; it softens with submersion in water. An improved method is to construct a sealed pump enclosure from 4-6” plastic pipe, with many holes or slots to let water in. Then, wrap the screen around that enclosure. This will distribute the flow through a much larger area of screen. After cutting holes or slots in the plastic pipe, wipe the inside carefully to remove plastic shavings and dust.

13.5 Warning for Siphon Applications

If a pump system has a vertical lift of less than 33 feet up from the surface of the water source, and then the water flows downhill to a lower point, a siphon effect may cause suction at the pump outlet. This will cause an upward thrust on the motor shaft, resulting in damage to the motor. Prevent this by installing an air vent or a vacuum breaker at the high point on the pipe.

13.5.1 Operating the pump (An Example)

13.5.1.1 Switch

Power On/Off: When switched off/on during operation, it resets all system logic.

Indicator lights system (green): The controller is switched on and the power source is present. In low-power conditions, the light may show even if there is not enough power to run the pump.

Pump on (green): Motor is turning. Sequence of flashing indicates pump speed.

Pump overloads: green changes to red.

Source low (red): The water source dropped below the level of the low-water probe. After the water level recovers, the pump will restart, but this light will slowly flash until the sun goes down, power is interrupted, or the power switch is reset. This indicates that the water source ran low at least once since the previous off/on cycle.

Tank full (red): Pump is turned off by action of the remote float switch (or pressure switch or manual switch, whichever is wired to the “remote float switch” terminals.

RPM indication: Pump speed can be read off by the flashing sequence of the pump on LED.

Starting the pump: Be sure there is not a closed valve or other obstruction in the waterline. Switch on the array disconnect switch in the junction box, and toggle the power switch on the controller. It is normal to leave the switches on at all times, unless it is desired to have the system off. A solar-direct pump should start under the following conditions.

1. Clear sunshine at an angle of about 30° (depends upon locaiton)or more from the surface of the solar array.
2. Cloudy conditions, if the sunshine is bright enough to cast some shadow.

3. Low-water probe submersed in the water source (or bypassed in the controller) –Water-low light Off.
4. Full-tank float switch is not responding to a full tank – Tank-Full light Off.

When sunshine is insufficient: When sunshine on the array is present, but too weak for the pump to run, it will attempt to start about every 90 seconds. During each attempt, it will be seen the pump on light come on. When pump runs slowly (pump on) under weak sun conditions. When pump stops from a sudden shadow on the solar array, if a shadow suddenly passes over the array, like if one walk in front if it, the controller will lose track of the input voltage. It may make rapid on/off noises and a high-pitched noise, then stop. This does not indicate a problem. The pump will attempt to restart after the normal delay.

Time delays

1. After pump stops due to insufficient sunshine – 120 sec
2. After full-tank float switch resets – 2 to 3 sec
3. After low-water probe regains contact with water in the source - 20 min but the indicator light will slowly flash for the rest of the solar day, or until power is disrupted or the controller is turned off/on.

To force a quick start: To test or observe the system, it can be bypassed the normal time delays. Switch the power switch off then on again. The pump should start immediately if sufficient power is present.

Pump vibration: Most pump models use a helical rotor pump end. A slight vibration is normal with these pumps. If noise is disturbing, try changing the position of the pump. The pump models with centrifugal pump end similar to conventional pumps. They should produce no significant vibration.

Pump overload (pump on light shows red instead of green): The system has shut off due to an overload. This can happen if the motor or pump is blocked or very difficult to turn and is drawing excessive current (hard to turn). Overload detection requires at least 250 Watt output of the solar array. This can be caused by a high concentration of solids in the pump, high water temperature, excessive pressure due to high lift or a restriction in the pipe, or a combination of these factors. The controller will make 3 start attempts before shutting down the system. The system on LED will be off and the red overload LED on. The system will not reset until the on /off switch is turned off and on again.

14 Repair and Maintenance

Objectives:

To give detail information regarding the types of preventive maintenance and breakdown maintenance work to be done in solar PV pumping system. Again, this chapter also includes the common types of problems that occur in such systems and their troubleshooting methodology.

Time: 45 min

Lesson 14.1: Routine Maintenance and Preventive maintenance : 30 min

Lesson 14.2: Troubleshooting : 14 min

14.1 Routine Maintenance and Preventive Maintenance

It does not take much time and money to regularly maintain a solar PV pumping system but it may take a lot to repair the system if it fails. Regular maintenance makes the difference between a PV pumping system that works without problems for years and one that is always breaking down. While installing PVWPS every care must be taken to minimize the cable losses as far as possible by keeping pump and PV arrays as close as possible. The PV array is to be installed carefully at a proper location to avoid shadowing of any part of the array or other obstructions throughout the year. The array should be inclined facing south in case of Northern Hemisphere. Solar pumps should not normally require more than a simple maintenance, which only demand rather basic skills. The main problem with them is lack of familiarity.

14.1.1 PV Array

- Check the PV array/panel mounting to make sure that it is strong and well attached. If it is broken or loose, repair it.
- Check that the glass is not broken. If it is, the PV array/panel will have to be replaced.
- Check the connection box to make sure that the wires are tight and the water seals are not damaged.
- Check to see if there are any shade problems due to vegetation or new building. If there are, make arrangements for removing the vegetation or moving the panels to a shade-free place.

14.1.2 Wires

- Check the wire covering (insulating sheath) for cracks or breaks. If the insulation is damaged, replace the wire. If the wire is outside the building, use wire with weather-resistant insulation.
- Check the attachment of the wire to the building to make sure that it is well fastened and cannot rub against sharp edges when the wind blows.
- If someone has changed the

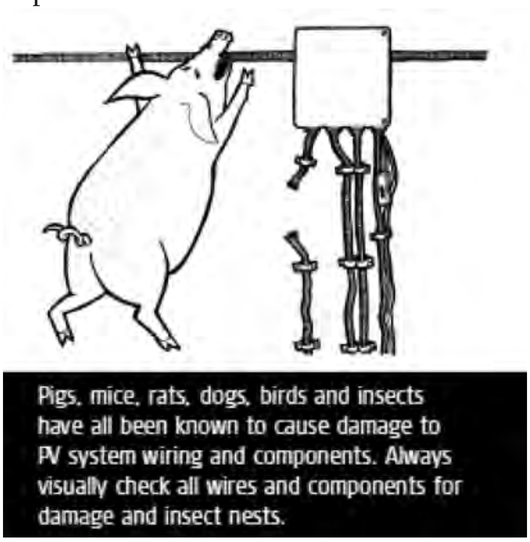


Fig. 14-1 Damage of wires by Animals

wiring since the last check, make sure that it is the correct size, that it has suitable insulation, that the connections are properly made and that it is fastened securely in its new place.

- If someone has added more wires to the PV system to operate additional appliances, advise the owner that this may seriously lower the reliability of the system. Advise increasing the panel and to handle the increased load.
- Check the connections for corrosion and tightness.

14.1.3 Power Conditioner

- Check that the junction box is still firmly attached. If it is not, attach it correctly with screws.
- Keep the junction box clean.

14.1.4 Appliances

- Turn on each appliance and check that it is working properly.
- Check that appliances are mounted securely. If loose or incorrectly mounted, attach them securely.
- Clean all exposed parts of each appliance. Clean light bulbs and plastic covers.

14.1.5 Pump:

- In case of submersible pump electrical connections have to be checked at least once every six months
- The brushes, if any, are to be changed after six months of continuous use.
- The inverter connected to the pump has to be checked at least once a month for proper operation.

Besides there are a number of simple faults that can arise which needs immediate corrections:

- Poor electrical connection caused by dirty, wet or corroded terminal or plugs
- Blocked strainers and filters on the pump
- Failure of suction pump due to loss of prime caused by faulty foot-valve or air leaks in suction line (specially in case of surface pump)
- Leaking pipe and hose connections
- Leaking pump gland seal
- Some pumps need frequent replacement parts as suggested by its manufacturers
- In case of positive displacement pumps, loosening of belts and chains may occur hence requiring tension adjustments.

In many cases the manufacturers may have special recommendations for routine and preventive maintenance. These recommendations have to be strictly followed for proper and safe operation of the complete system.

In each station there must be card mentioning the dates when routine and preventative maintenance are carried out. If any fault has been observed it must be registered in this card. This card must be accessible all the time at the site.

14.1.6 Monitoring and Evaluation of Installed water pumps

The purpose of Monitoring and Evaluation (M&E) is to make sure that the system works properly and satisfy the users as foreseen in the design phase and in the long run it becomes sustainable.

Monitoring and evaluations of installed pumps should be carried out after one month of complete and successful installation to answer the following questions:

- Is the system performing as per the specification of supplier (this may include parameters like discharge of water at specified total dynamic head, ambient temperature and insolation)?
- Has the system brought positive social changes in the area?
- Have the suggestions and comments of users group been incorporated?
- Have the users paid back the loan component in time if any?

The same procedure mentioned above should be repeated after six months, twelve months after a complete successful installation. Then after, monitoring and evaluation be carried out once every six months.

14.2 Trouble Shooting

Well-designed, well-installed and well-maintained solar PV systems are reliable and can have a long trouble-free life, but sooner or later there will be a failure. The process of finding the cause of the failure is called troubleshooting. The process of making the system work properly again is called repair.

14.2.1 Types of System Failure

There are three types of solar PV system failure:

Each type of system failure has a different cause and troubleshooting methods are different.

Failure type 1: The system stops working entirely. None of the appliances work.

Failure type 2: Some appliances work normally, others do not.

Failure type 3: The system works but runs out of power too quickly.

Each type of system failure has a different cause and troubleshooting methods are different.

14.2.1.1 Failure type 1: Total system

If the system fails completely, the reason is usually a broken wire, poor connection or controller failure. The problem is to isolate the fault in the system.

1. **Fuse or circuit-breaker problem:**
   Make sure that all appliances are switched off. Check any fuse or circuit-breaker in the panel to the whole circuit.
   Corrective action: Disconnect the loads at the controller. If the fuse is blown, replace it with the correct type and ampere capacity of fuse. If the circuit-breaker is tripped, turn it back on. If the fuse or circuit breaker blows again, there is a problem with the wiring between the panel or with the controller. Continue with this checklist. If the fuse or circuit-breaker does not blow, reconnect the load and turn the appliances on. If the fuse or circuit-breaker blows again, there is a short in the appliance wiring or in an appliance.

2. **Faulty panel or panel wiring:**
   Disconnect the leads to the panel terminals of the charge controller. Check the voltage across the two wires from the panel when the sun is shining. If the voltage is less than 12 V, there is a problem with the panel or the panel wiring. If the voltage is 12 V or more, measure the amperes from the panel. If the amperes are very low for the panel that is installed, the connections to the panel may be loose or corroded. Also the panel may be damaged.
   Corrective action: Disconnect all the panels and carefully check that each one is working properly (voltage and amperage). Replace panels that are not working well.
   Clean all terminals and wires: Reconnect the panels, making sure that the correct wires are connected to the correct terminals. Also make sure that the panels are not shaded.
3. **Faulty controller:**
   Check the voltage at the panel connections on the controller when the sun is shining. If the voltage at the pump connection is less than 13.5 V and the voltage at the panel connection is more than 14 V, the controller has probably failed. Some types of complex, computerized controllers cannot be tested with simple voltmeters. If that type of controller is thought to have failed, one have to replace the controller with one known to work properly and wait to see if that cures the problem.
   Corrective action: Replace the controller.
4. **Faulty wiring between controller and pump**
   Measure the voltage at the pump connections and controller connections. If the voltage is more than 0.5 V lower at the controller, there is a wiring problem.
   Clean all connections and wires: Replace wires in connectors and terminals and tighten all connections. Make sure that the wire connecting the controller and the pump is the correct size for the current being carried.
5. **Fuses or circuit-breakers**
   Check all fuses and circuit-breakers. If they have opened the circuit there is a short circuit in the wiring or appliances. Check all appliances and the wiring from the controller to the appliances.
   Corrective action: Fix shorted wiring or faulty appliances, replace fuses and reset circuit-breakers.
6. **Wiring between controller and appliances**
   Turn on at least one appliance and check the voltage at the load connections on the discharge controller.
   Corrective action: Clean all connections, replace all wires that are damaged or that are not the correct size for their length.
7. **Faulty switch**
   If there is one switch that controls all appliances, it may be the problem. Using a short wire, connect across the switch terminals. If the appliances work, then the switch is faulty.
   Corrective action: Replace the switch.
8. **Controller failure**
   Measure the voltage at the load terminals. If the load terminal voltage is zero or much lower than other terminal voltage, the discharge controller

may not be working properly.
Corrective action: Replace the controller.

14.2.1.2 Failure type 2: Some appliances work but some do not

This type of failure is rarely due to PV panel. It may be caused by:

1. **A faulty appliance switch**
   Use a short wire and connect the switch terminals together. If the appliance works, the switch is faulty.
   Corrective action: Replace the switch.
2. **An appliance has been wrongly connected**
   Check the connection at the appliance. Make sure that wire of the appliance is connected to the wire (+) of the controller.
   Corrective action: Connect the wires correctly.
3. **The wire size is too small or too long**
   Measure the length of the wire run.
   Check to see if the wire is too small for its length.
   Corrective action: Replace the wire with one of the correct size.
4. **Connections are loose or dirty**
   Remove wires from all connections between the appliance and the controller. Clean the wires and terminals. Replace the wires and tighten the connections.

14.2.1.3 Failure type 3: The system works but runs out of power

This is the most common problem with solar PV systems and can be caused by many things acting alone or in combination. This may be caused by:

1. **Too little energy from the panels**
   The reason for this may be shading, damaged panels, wiring too small or too long, dirty or loose connections, panels not facing in the right direction or dirt on the panels.
   Corrective action: Remove the cause of the shade or move the panels so they are no longer shaded and are facing in the right direction, clean and replace the panels if damaged, check the wiring on the panels.
2. **Incorrect adjustment of the charge controller**
   This may prevent the getting energy for the pumps. In some cases a special controller tester will be available but, when it is not, it can be checked by asking the user to keep appliance use to a minimum for several sunny days. Come to the site in the late afternoon of the third or fourth sunny day while the sun is still shining. Check the voltage at the connections and at the panel terminals of the controller. If the two voltages are about the same and they are both above 13 V for a 12 V system, or 26 V for a 24 V system, then the charge controller is probably working properly.
   Corrective action: Replace the controller and send the old one for repair.

14.2.2 Troubleshooting

- **Inspect the system: Many problems can be located by simple inspection.**
- **Inspect the solar array: 1. Is it facing the sun? (For details, see solar array orientation)**
  Is there a partial shadow on the array? If only 10% of the array is shadowed, it can stop the pump.
- **Inspect all wires and connections**

1 Look carefully for improper wiring (especially in a new installation).
2. Make a visual inspection of the condition of the wires and connections. Wires are often chewed by animals if they are not enclosed in conduit (pipe).
3. Pull wires with your hands to check for failed connections.

- **Inspect the controller and junction box**

1. Remove the screws from the bottom plate of the controller. Move the plate downward (or the controller upward) to reveal the terminal block where the wires connect.
   Indicate a failure of the electronics. Look for burnt wires, bits of black debris, and any other signs of lightning damage.
2. Open the junction box. Is the power in switch turned on? Pull on the wires to see if any of them have come loose.
3. Inspect the grounding wires and connections.
   Most controller failures are caused by an induced surge from nearby lightning where the system is not effectively grounded. Ground connections must be properly made and free of corrosion.

- **Check the low-water probe system:**
  If the controller indicates "Source low" when the pump is in the water, inspect the low-water probe system. The probe is mounted on, or near the pump. If inspection is not feasible, it can be bypassed the probe or test it electrically.

1. If the probe is not being used, there must be a wire between terminals 1 and 2.
2. The probe is a cylindrical plastic device mounted on or near the pump. It contains a small float on a vertical shaft. The float must be able to move up to indicate that it is submerged, and down to indicate that it is dry.
3. The probe must be positioned vertically (within about 10°).
4. The probe or a probe wire may be broken.
   Inspect the wires for damage.
5. Does the pump run when the probe is out of the water? This can happen if the float in the probe is stuck. In surface water, this can happen from algae, a snail, or other debris.

- **Check the full-tank float switch**
  If the controller indicates "tank full" when the storage tank is not full, inspect the float switch system. If the system has a float switch, it will be mounted in the tank. If inspection is not feasible, it can be bypassed the switch or test it electrically.

1. If a float switch is not being used, there must be a wire between the terminals.
2. Inspect the float switch. Is it stuck in the up position?
3. There are two types of float switch, normally-open and normally-closed. Check to see that the wiring is correct for the type that is used.

- **Force a quick start**
  If it is restored a connection or bypass the probe or float switch, there is no need to wait for the normal time delay. Switch the on/off switch (or the power source) off then on again. The pump should start immediately if sufficient power is present.
- **Electrical Testing**

A “multimeter” is required and a clamp-on ammeter is helpful.

Test the solar array circuit

1. Open circuit voltage: This is “idle” voltage. It is normally high because no current is being drawn (it’s doing no work).

   Short circuit current or spark test: This is helpful if the pump is trying to start or does not seem to get full power. Disconnect the array from the controller before making this test.

   (A short circuit at the array will only cause current slightly higher than normal.) If there is no a DC amp meter, a spark that can jump 1/4” (6 mm) indicates a good probability that the array is working properly.

3. Voltage under load (with pump running)
4. Current under load was connected to the controller with reverse polarity? No lights will show on the controller. This will not cause damage.

   Test the motor circuit (resistance test with power off), make this test if there is proper voltage at the controller input but the motor does not run. It will confirm the condition of the entire motor circuit, including the motor, pump cable and splice.

   Test the running current of the motor circuit (AC amps), this is one of the most useful trouble shooting techniques because it indicates the force (torque) that the motor is applying to the pump. For greatest ease, use a clamp-on ammeter, available from local electrical equipment suppliers. It allows to measure current without breaking connections.

   The current stays nearly constant as voltage and speed vary. The measurements may vary by as much as 10% and more if temperature is out of the normal range. Comparing the reading with the standards provided by manufacturers, this will indicate whether the workload on the motor is normal for the lift it is producing.

   Future changes may indicate pump wear, or change in the level of the water source.

   Higher current (especially pump overload light) may indicate:

1. The pump may be handling excessive sediment (sand, clay).

   The total dynamic head (vertical lift plus pipe friction) may be higher than expected it is.

3. There may be an obstruction to the water flow- sediment in the pipe, ice in the pipe, a crushed pipe or a partially closed valve. (Is there a float valve at the tank?)
4. Helical rotor models: Water may be warmer than 72°F (22°C). This causes the rubber stator to expand and tighten against the rotor (temporarily, non damaging).
5. Helical rotor models: Pump may have run dry. Remove the pump stator (outer body) from the motor, to reveal the rotor. If there is some rubber stuck to the rotor, the pump end must be replaced.

   To reset the over load shut off (red light), switch the pump controller off and on.

   Lower current may indicate:

1. In a deep well, the level of water in the source may be far above the pump intake, so the actual lift is less than expected. This is not a problem.
2. The pump head may be worn, thus easier to turn than normal (especially if there is abrasive sediment).

3. There may be a leak in the pipe system, reducing the pressure load.
4. Helical rotor models: Water may be colder than 46°F (8°C). This causes the rubber stator to contract, away from the rotor. The pump spins easier and produces less flow under pressure.
   Test the low-water probe circuit
   If the controller indicates "source low" when the pump is in the water, the low-water probe system may be at fault. When the water level is above the probe, the switch in the probe makes contact. That causes the applied voltage to drop toward zero. The systems "sees water" and allows the pump to run. If the voltage is greater than 3V, dry shut off is triggered.
   The low-water probe has an internal 1K resistor in series with the switch. When closed (in water), the normal resistance is around 1000. To bypass the low-water probe (and activate the pump), connect a small wire between the probe terminals in the junction box. Restart the controller. If the pump runs, there is a fault at the probe or in the probe wiring. The wires may be shorted (touching each other) or open (broken) or the moving part on the probe may be stuck with debris, or the probe may be out of its normal, vertical position.

- **Test the full-tank float switch**
  If the controller indicates "Tank full" when the tank is not full, the float switch or pressure switch system may be at fault.

1. If the remote switch circuit is not being used, there must be a wire between the terminals.
   There are two types of float switch, "normally open" and "normally closed".
   Check to see that the wiring is correct for the type that is used.
3. Most float switches are "normally open". Disconnect a wire from the terminals, and the pump should run. Connect a wire between the terminal, and the pump should stop.
4. Most pressure switches (and some float switches) are "normally closed". Connect a wire between the terminals, and the pump should run.
   If the pump responds to the bypass tests above but not to the float switch, the wires may be shorted (touching each other) or open (broken), or the switch may be stuck

- **If the pump runs but flow is less than normal with debris, or out of its correct position.**

1. Is the solar array receiving shadow-free light? (It only takes a small shadow to stop it.) Is it oriented properly toward the south, and tilted at the proper angle?
2. Be sure you have the right pump for the total lift that is required, out of the well up the hill. In the case of a pressurizing system, the pressure head is equivalent to additional lift (1 PSI = 2.31 feet) (1 bar =10 m).
3. Be sure all wire and pipe runs are sized adequately for the distance.
4. Inspect and test the solar array circuit and the controller output, as above. Write down the measurements.
   There may be a leak in the pipe from the pump. Open a pipe connection and observe the water level. Look again later to see if it has leaked down. There should be little or no leakage over a period of hours.
6. Measure the pump current and compare it with the table in the previous

section.

7. There is a “max. RPM” adjustment in the controller. It may have been set to reduce the flow as low as 50%.

   Has the flow decreased over time?

1. Is the AC motor current lower than normal? The pump end (pumping mechanism) may be worn from too much abrasive particles (sand or clay) in the water.
2. Is the AC motor current higher than normal? Does not start easily in low light?

   This is likely to be related to dirt in the pump and/or pipe.

3. Look in the water tank or pipes to see if sediment has been accumulating.
4. Run the pump in a bucket to observe.
5. Remove the pipe from the pump outlet (check valve) and see if sand or silt is blocking the flow.
6. If the check valve itself is clogged with dirt.
7. To help prevent dirt problems.
8. After years of use, it may be necessary to replace the pump end.

- **Electrical Testing**

  These tests are extremely helpful when trying to assess the performance of a system, or locate a fault.

  Obtaining and using a multimeter Measuring current (amps) is easiest if you have a clamp-on ammeter.

  Probe input. Some meters give a choice of probe sockets. The negative (black) probe always goes in the common socket. The + (red) probe input varies, and is specified below.

  Part 1 – Testing the Solar Array (DC)

  This test refers to a 48V solar array with a pump set. The system voltage may vary. The current is determined by both the array and the load (current draw of the pump system). If the pump is not under full load (like in a bucket), the current may be as little as 1 amp.

  Range if the meter is “auto-ranging”, this does not apply. Otherwise, use the range than the reading expected. For example, in Test1, “normal” voltage is around 80. The proper range may be 100V or 200V, depending on the meter design.

  Access open the junction box for access to the terminals. The appearance of the wiring may vary.

  Monitoring a Solar PV Pump System: Observe the output of the pump at the point of discharge? If not, it may not know if it malfunctions. Consider installing a water meter, or additional valves so that the flow can be directly observed.

  Monitoring the water level in the storage tank: Will you be able to observe the level of water in the tank? If one cannot easily see into your storage tank, here are some methods of tank monitoring.

  - Dipstick in the air vent
  - Float with a visible rod that protrudes through the top of the tank
  - Clear sight-tube alongside the tank
  - Precision pressure gauge

15 Financial Analysis

Objectives:

To give detail information about the method of total cost estimation of the solar PV pumping system project and ways of evaluation of the economic feasibility of the project through various analysis.

Time: 40 min

Lesson 15.1: Project Cost Estimation : 10 min

Lesson 15.2: Feasibility Analysis : 30 min

As like other project or schemes, Solar Pumping System involves investment and other resources and has to borne risk. It is needed to perform or assess financial evaluation to minimize the risk of investment and maximize the benefit from the scarce investment resources. A Solar Pumping System needs sufficient amount of investment and is expensive. Such project involves risk because most of the cost must be met at the beginning. Thus, the promoter of the project needs to convince the investor as well as financers (a private company, funding agency and/or banks) that the project is financially feasible and the investment is therefore safe. Different financial aspects of the project are to be looked into for exploring its financial viability.

15.1 Project Cost Estimation

In order to do the financial analysis of the project, total cost of the project is to be known. Total cost comprises of expenditures to be incurred in different components of the systems such as equipments, construction, transportation, erection and commissioning etc. In fact, detail listing of the equipments and other items is to be prepared for costing. Cost-estimate report should contain all the component of PV pumping system (civil and electro-mechanical) and presented in easily understandable format to all concerned authorities. It should follow the standard practice of engineering and should not be customized by project-wise or implementing organization-wise. For achieving the uniformity along all the organizations and keeping standard of the report, it is advised to use the standard software or spreadsheet program across all the involved partners. Here is the example of spreadsheet format meant for calculating the project cost quickly (mostly useful for pre/feasibility study task) and efficiently. It uses the costing of different components for a base year and base region (base year is taken -2071 and base region is taken for center region) and for another year and another region multiplies by some factor, seeing their geographic hardship and market access, COST-INDEX. It is simple to use and fast to the result. This method is already practiced in other countries and organization like in India CPWD (central public work department), seeing our situation different from them, this method advantageously can be utilized for costing of projects in feasibility stage by an organization. The costing of equipments should be based upon quotation received from companies. The investment cost and annual expenditure estimation formats are presented in Annex III. It is necessary to project the income as well as expenditure to be incurred for the period of next 10 years after commissioning of the project. The expenditure should include the salaries of directly involved people. The expenditure is to be divided at least into two broad headings- investment cost and operational cost.

Problem: In a PVPS project, Annual Income: Rs.418,800

Water charges for drinking: Rs.418,000

Annual Expenditure: Rs.375,983

Annual discount: Rs.109,633

Annual interest: Rs.152,950

Annual salary: Rs. 24,000

Annual maintenance: Rs. 87,400

Contingencies: Rs. 2,000

Profit: Rs.42,817

Profit = Annual Income - Annual Expenditure

= Rs.418, 800 - Rs.375, 983

= Rs.42, 817

15.2 Feasibility Analysis

It is done with the study of cash flow analysis and finding of payback period, net present value, and internal rate of return and B/C ratio etc. The cash flow format is presented in Annex III.

15.2.1 Simple Payback Period

Simple Payback Period = Initial Cost / Uniform annual benefit

The payback period should be used as a screening method only. It reflects liquidity, not the profitability of project.

Problem: The estimated cost of proposed PVPS project is cost Rs.1, 748, 000 and subsidy is provided to the tune of Rs.437, 000. The annual income estimated from the project is Rs.418, 800 while the annual expenditure is estimated at Rs.113, 400.

$$\text{Simple payback period} = \frac{\text{Rs.1, 748, 000} - \text{Rs. 437,000}}{\text{Rs.418, 800} - \text{Rs.113, 400}}$$

$$= \frac{\text{Rs.1311, 000}}{\text{Rs.305, 400}} = 4.29 \text{ years}$$

That is to recover the investment made in the proposed project can be backed in 4 years and 3 months. In case the subsidy is not provided to the project, then it would require 5 years and 9 months to get investment back.

$$\text{Simple Payback period} = \frac{\text{Rs.1, 748,000}}{\text{Rs.418, 800} - \text{Rs.113, 400}}$$

= 5.72years

15.2.2 Discounted payback period

The major drawback of simple payback period is that it ignores the time value of money. To counter this limitation, discounted payback period can be used. The discounted payback period is the amount of time that it takes to cover the cost of a project, considering discounted cash flows. It means a discounted payback period gives the number of years it takes to break even from undertaking the initial expenditure without ignoring the time value of money. In the discounted payback period it is needed to determine the present value of each cash inflow taking the start of the first period as zero point at specified discount rate. The discounted cash inflow for each period is given by the projects that have a negative net present value will not have a discounted payback period.

$$\text{Discounted Cash Inflow} = \frac{\text{Actual Cash Inflow}}{(1 + i)^n}$$

Where,

i is the discount rate

n is the period to which the cash inflow relates

15.2.3 Net Present Value (NPV)

The net present value is an equivalence method of analysis in which a project's cash flows are discounted to a single present value.

$NPV = A0/(1+i)^0 + A1/(1+i)^1 + \ldots.. + AN/(1+i)^n$

Where,

A is annual cash flow

iis discounted rate

NPV>0 : Accept

NPV<0: Reject

NPV=0: Remain indifferent. In order to calculate net present value, the format is presented in Annex III.

15.2.4 Net Future Worth

The net future worth (NFW) is used to determine a project's value at commercialization (a future date), not its value when we begin investing (the present).

NFW (i) = PW (i) (F/P, I, N)

Where,

I is discounted rate

N is no. of years

15.2.5 Capitalized Equivalent

It is a constant annual net cash flow. In the project with lengthy service lives, it is recommended to apply.

CE (i) = A/i

Annual equivalent criterion

AE (i) = PW (i) (A/P, I, N)

Where,

I is discounted rate

N is no. of years

15.2.6 Benefit/Cost Ratio

This method is the ratio of total discounted income to total discounted cost.

B/C ratio = Total discounted income/ Total discounted cost

It is generally used to find out the relationship between investment cost of the project and the benefit produced by the unit of investment. If benefit /cost ratio is less than one, while dividing benefits by the cost, it means project expenditure is greater than the expected income or benefit. So the project will not be financially or economically viable. If benefit/cost ratio is greater than one, it means benefits will be more than the cost incurred. The project will yield more income or benefit and will be viable. If benefit /cost ratio is one, benefit from the project will be equal to cost of the project. The projects whose benefit/cost ratio is greater than 1 will be feasible for undertaking according to this method. In order to determine, benefit to cost ratio, the format is presented in Annex III.

15.2.7 Internal rate of return

The internal rate of return (IRR) is the discount rate at which NPV is zero. At this rate, discounted annual expenditure and discounted annual income will be equal. In order words, internal rate of return will indicate expected maximum interest rate from the investment.

For a project, if

IRR>MARR: Accept

MARR is the minimum attractive rate of return.

IRR<MARR: Reject

In order to calculate internal rate of return, the format is presented in annex.

15.2.8 Sensitivity Analysis:

Sensitivity analysis is undertaken to how much risk will be there if changes occur in some of the items of the NPV, benefit/ cost or IRR analysis. The future is quite uncertain. The cost and interest may go up due to various reasons. Demand of service or goods may go down. These things may naturally have impact upon economic and financial feasibility of the project. What will happen internal rate of return, if the project cost increases than earlier estimate? In such situation the estimated IRR goes down and IRR will then be less than market rate of interest. Then the project will be risky. Thus, it is recommended to do sensitivity analysis before investing for a project.

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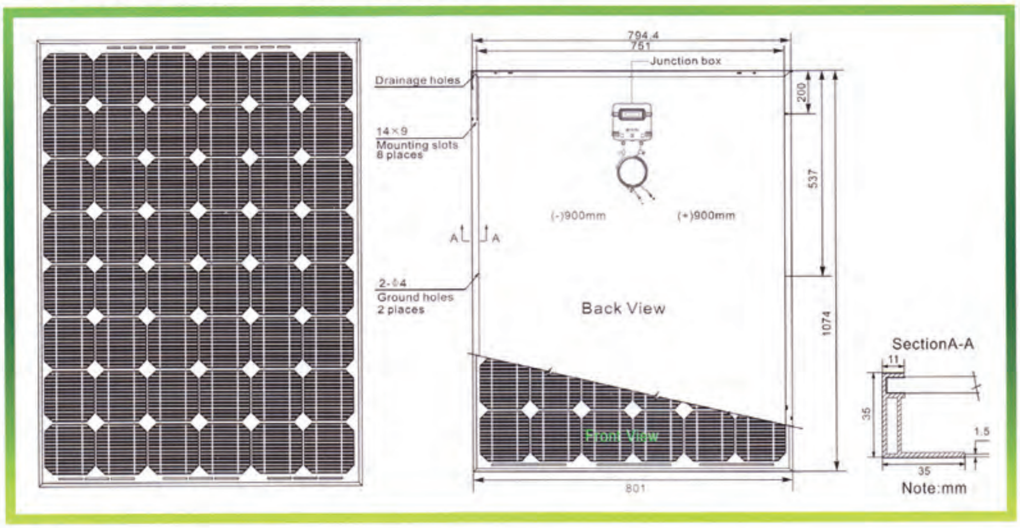
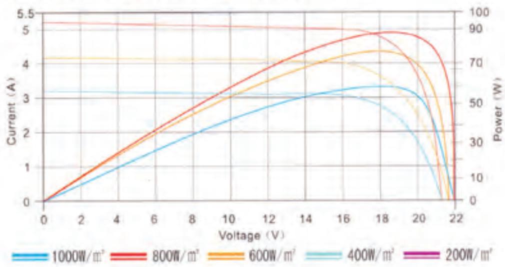
Annex I: Macro – Solar Module MS-M100 Characteristics

MACRO-SOLAR
MACRO-SOLAR TECHNOLOGY CO.,LTD.

Mechanical Characteristics



Characteristics Curve



Electrical Characteristics

Module MS-M100 (48)

Encapsulation		Glass/EVA/Cells/EVA/TPT		
Size and Number of cells		125mm×125mm	48/6×8PCS	
Maximum power(Pmax)	W	100W	105W	110W
Tolerance			±3%	
Open Circuit Voltage(Voc)	V	29.28V	29.28V	29.28V
Short Circuit Current(Isc)	A	4.74A	4.90A	5.08A
Maximum Power Voltage	V	23.28V	23.52V	23.76V
Maximum Power Current(Imp)	A	4.30A	4.46A	4.63A
Max.Sys.Oper.Voltage	V		1000V	
Diodes			3by-pass	
Dimension	MM		1074×801×35	
Weight	KG		10.00	
Operate Temp.scope	℃		-40/+85	
Relative humidity			0 to 100%	
Resistances			227g steel ball fall down from 1m height and 60m/s wid	
Warranty			Pm is not less than 90% in 10 years and 80% in 25 years	

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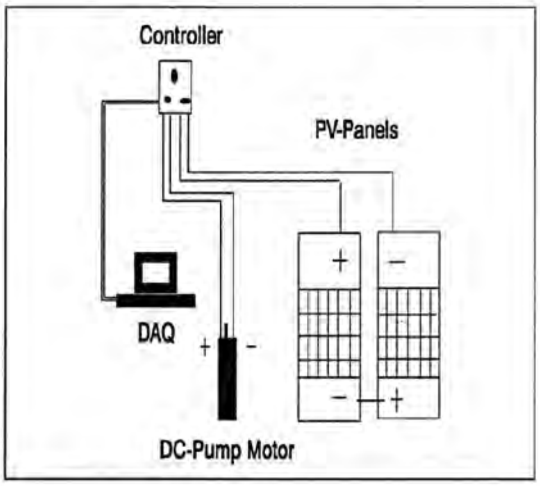
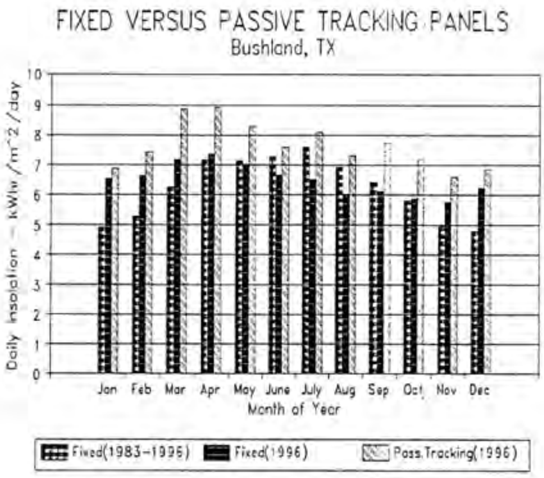
Annex II: A Case Study on Performance of Tracking and Non – Tracking Solar PV Pumping System

A case study on performance of Tracking and Non-tracking solar PV pumping system (By R.N. Clark and B. D. Vick)

Two 100 Watt solar water pumping systems, each consisting of two 53 W photovoltaic panels and a diaphragm pump, were installed to provide water for livestock. The pumps were set at a depth of 30 m and the systems were identical except that one set of photovoltaic panels was mounted on a passive tracking device and the other set of panels was mounted in a fixed position. The passive tracking system was observed ‘flipped over’ out of the direct rays of the sun when the wind was gusting from the southwest. However, the passive tracking system pumped enough additional water during the early mornings, late afternoons, and days with low winds to average slightly more water pumped than the fixed system. Daily water volumes averaged 1,705 L/day for the system with the fixed solar panels and 1,864 L/day for the tracking system. Although the passive tracking system pumped slightly more water, the difference in average daily rates was not enough to warrant purchasing the tracker.





Annex III: Tables for Calculation of Investment Costs and Feasibility Analysis

1. Investment Cost:

S. N.	Description	Qty	Rate	Amount
I.	Solar Panels			
II.	Pumps			
III.	Pipes			
IV.	Wires			
V.	Controllers			
VI.	Land			
VII.	Construction of storage tanks			
VIII.	Transportation			
IX.	Miscellaneous			

2. Annual expenditure estimation:

S. N.	Description	Amount
I.	Annual salary of operators	
II.	Depreciation of equipments	
III.	Repair and maintenance	
IV.	Annual Interest	
V.	Other expenses	
VI.	Total	

3. Cash Flow

Year	Expenditure	Repayment of loan	Revenue	Annual net cash flow	Cumulative cash flow

4. Net Present Value

Year										
Annual expenditure										
Annual income										
Discount factor (%)										
Annual net present value										

5. B/C Ratio

Year										
Annual expenditure										
Annual income										
Discount factor (in interest rate %)										
Discounted expenditure										
Discounted income										

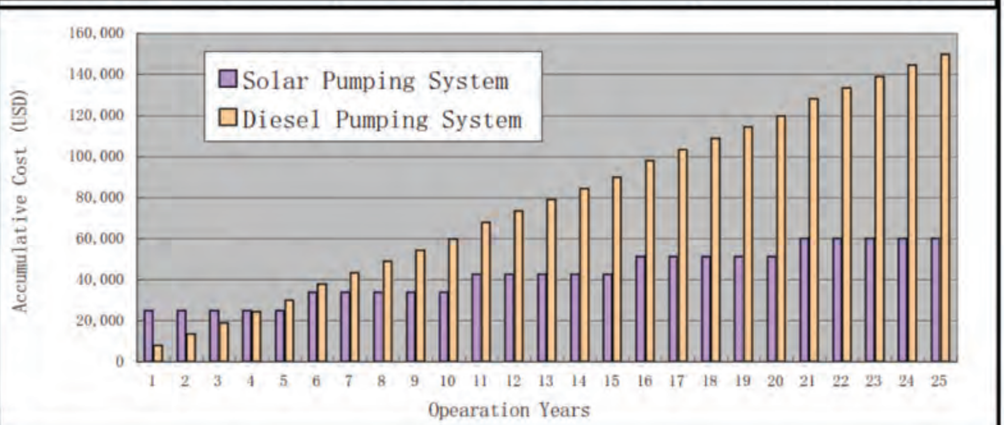
6. Internal Rate of Return

Interest rate	Year	Invest. Cost	R & M Exp.	Depreciation	Total Ex	Total income	Discount factor	Total discounted cost	Total discounted income	Net cash flow

Annex IV: Comparison of Solar and Diesel Pumping Systems

深圳市天源新能源有限公司
Shenzhen Solartech Renewable Energy Co., Ltd

Comparison of Solar and Diesel Pumping Systems

	Solar Pumping System			Diesel Pumping System		
Project Information	Daily Water Supply	160m³/day		Daily Water Supply	160m³/day	
	Lift Head	28m		Lift Head	28m	
	Opeartion Time	8 hours		Opeartion Time	12 hours	
	Solar Array	8kw		Diesel Generator	5kw	
	Pump	5. 5kw		Pump	2. 2kw	
	Inverter	7. 5kw		Oil Consumption	7L/day	
Initial Input	Item	Lifetime	Cost (USD)	Item	Lifetime	Cost (USD)
	Solar Array	25 years	7140	Diesel Generator	5 years	1110
	Inverter	5 years	3170	Pump	5 years	710
	Pump	5 years	1590	Accesories	5 years	800
	Bracket	25 years	3970	Construction		160
	Accesories	5 years	3170			
	Construction		6350			
	Subtotal		25390	Subtotal		2780
Operation	Item		Cost (USD)	Item	Cost (USD)	Cost (USD)
				Labor Cost	3/day	1095/year
				Oil Cost	9/day	3285/year
				Storage&Transport	3/day	1095/year
	Subtotal		0	Subtotal		5475/year
Maintenance	Item	Lifetime	Cost (USD)	Item	Lifetime	Cost (USD)
	New Inverter	5 years	3170	Diesel Generator	5 years	1110
	New Pump	5 years	1590	Pump	5 years	710
	New Accesories	5 years	3970	Accesories	5 years	800
	Subtotal		8730	Subtotal		2620
Cost Comparison						
Conclusion	The cost of solar pumping system will be equal to diesel water pumping system in around 4 years, as the PV panel price goes down while oil price rises up, the benefit time could come ealier. Solar pumping system also owns the advantages of free maintenance, noiseless and non-pollution.					

Annex V: Solartech PSD600 DC Solar Pump

Solartech

Solartech PSD600 DC Solar Pump

Max. Flow: 20m^3/day, Max. lift: 100m

Agriculture Irrigation	Living Water Supply	Livestock Breeding	Desert Control	Solar Swimming Pool

Features

- High efficient DC brushless motor requires less solar array. Rich social benefits.
- Optional centrifugal pump for big flow and helical rotor pump for high lift.
- High efficient semiconductor device used in main circuit. High reliability. Up to 98% conversion efficiency of controller.
- Independent intellectual property of dynamic VI maximum power point tracking (MPPT) algorithm. Fast response and good stability. 99% MPPT efficiency.
- Full automatic operation. Complete protection functions. Integrated with water level monitor to prevent overflow and dry running.
- Full aluminum alloy case. IP52 protection grade. Ambient temperature: -20 ~ +60℃.

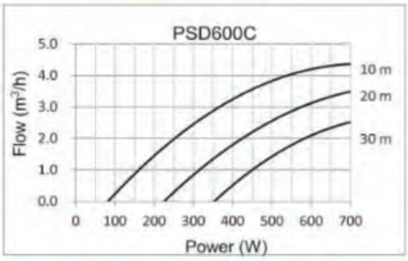
Specifications

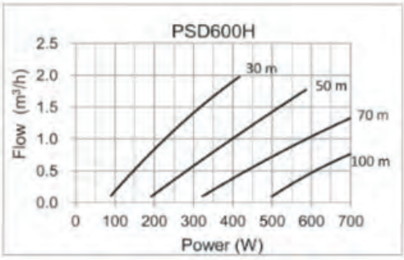
Model	Rated Power	Max. Flow	Max. Lift	Daily Water Supply	Outlet Dia.	Pump Dia.
PSD600C	600W	4.5 m³/h	30 m	10 - 20 m³	1"1/4	4"
PSD600H	600W	2 m³/h	100 m	5 - 10 m³	1"1/4	4"

Solar Array Configuration

Max. Input Power	Max. Input Current	Max. Open Circuit Voltage	Recommended MPP Voltage
1000W	15A	150VDC	60 - 120VDC
Recommended Design	**Solar Panel**	**Connection**	**Total Power**
Configuration 1	190W / 35Vmp	2 pcs x 2 strings	760W
Configuration 2	250W / 30Vmp	3 pcs x 1 string	750W

Performance Curve





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Annex VI: Solartech 0.37 – 55kW AC Solar Pump Model List

Solartech 0.37-55kW AC Solar Pump Model List								
Model	Pump Spec.	Pump Power	Water Head	Daily Water Flow	Outlet Dia.	Adapting Well Dia.	Recommended Open Circuit Voltage	Recommended MPP Voltage
SPA4370010	3PH 220V 50Hz	0.37kW	47m - 32m	1m^3 - 10m^3	30mm 1"1/4	100mm	350-450VDC	280-350VDC
SPA4370010-2	3PH 220V 50Hz	0.37kW	47m - 32m	1m^3 - 10m^3	30mm 1"1/4	100mm	185-450VDC	150-350VDC
SPA4370020	3PH 220V 50Hz	0.38kW	29m - 20m	10m^3 - 20m^3	30mm 1"1/4	100mm	350-450VDC	280-350VDC
SPA4370020-2	3PH 220V 50Hz	0.39kW	29m - 20m	10m^3 - 20m^3	30mm 1"1/4	100mm	185-450VDC	150-350VDC
SPA4550010	3PH 220V 50Hz	0.55kW	70m - 48m	1m^3 - 10m^3	30mm 1"1/4	100mm	350-450VDC	280-350VDC
SPA4550010-2	3PH 220V 50Hz	0.55kW	70m - 48m	1m^3 - 10m^3	30mm 1"1/4	100mm	185-450VDC	150-350VDC
SPA4550020	3PH 220V 50Hz	0.55kW	40m - 28m	10m^3 - 20m^3	30mm 1"1/4	100mm	350-450VDC	280-350VDC
SPA4550020-2	3PH 220V 50Hz	0.55kW	40m - 28m	10m^3 - 20m^3	30mm 1"1/4	100mm	185-450VDC	150-350VDC
SPA4550040	3PH 220V 50Hz	0.55kW	23m - 15m	20m^3 - 40m^3	40mm 1"1/2	100mm	350-450VDC	280-350VDC
SPA4550040-2	3PH 220V 50Hz	0.55kW	23m - 15m	20m^3 - 40m^3	40mm 1"1/2	100mm	185-450VDC	150-350VDC
SPA4750010	3PH 220V 50Hz	0.75kW	81m - 56m	1m^3 - 10m^3	30mm 1"1/4	100mm	350-450VDC	280-350VDC
SPA4750010-2	3PH 220V 50Hz	0.75kW	81m - 56m	1m^3 - 10m^3	30mm 1"1/4	100mm	185-450VDC	150-350VDC
SPA4750020	3PH 220V 50Hz	0.75kW	60m - 41m	10m^3 - 20m^3	30mm 1"1/4	100mm	350-450VDC	280-350VDC
SPA4750020-2	3PH 220V 50Hz	0.75kW	60m - 41m	10m^3 - 20m^3	30mm 1"1/4	100mm	185-450VDC	150-350VDC
SPA4750040	3PH 220V 50Hz	0.75kW	29m - 19m	20m^3 - 40m^3	40mm 1"1/2	100mm	350-450VDC	280-350VDC
SPA4750040-2	3PH 220V 50Hz	0.75kW	29m - 19m	20m^3 - 40m^3	40mm 1"1/2	100mm	185-450VDC	150-350VDC
SPA4750060	3PH 220V 50Hz	0.75kW	15m - 8m	40m^3 - 60m^3	50mm 2"	100mm	350-450VDC	280-350VDC
SPA4750060-2	3PH 220V 50Hz	0.75kW	15m - 8m	40m^3 - 60m^3	50mm 2"	100mm	185-450VDC	150-350VDC
SPA4750100	3PH 220V 50Hz	0.75kW	7m - 6m	60m^3 - 100m^3	50mm 2"	100mm	350-450VDC	280-350VDC
SPA4750100-2	3PH 220V 50Hz	0.75kW	7m - 6m	60m^3 - 100m^3	50mm 2"	100mm	185-450VDC	150-350VDC
SPA41K1010	3PH 220V 50Hz	1.1kW	93m - 63m	1m^3 - 10m^3	30mm 1"1/4	100mm	350-450VDC	280-350VDC
SPA41K1010-2	3PH 220V 50Hz	1.1kW	93m - 63m	1m^3 - 10m^3	30mm 1"1/4	100mm	185-450VDC	150-350VDC
SPA41K1020	3PH 220V 50Hz	1.1kW	79m - 54m	10m^3 - 20m^3	30mm 1"1/4	100mm	350-450VDC	280-350VDC
SPA41K1020-2	3PH 220V 50Hz	1.1kW	79m - 54m	10m^3 - 20m^3	30mm 1"1/4	100mm	185-450VDC	150-350VDC
SPA41K1040	3PH 220V 50Hz	1.1kW	43m - 27m	20m^3 - 40m^3	40mm 1"1/2	100mm	350-450VDC	280-350VDC
SPA41K1040-2	3PH 220V 50Hz	1.1kW	43m - 27m	20m^3 - 40m^3	40mm 1"1/2	100mm	185-450VDC	150-350VDC
SPA41K1060	3PH 220V 50Hz	1.1kW	23m - 12m	40m^3 - 60m^3	50mm 2"	100mm	350-450VDC	280-350VDC
SPA41K1060-2	3PH 220V 50Hz	1.1kW	23m - 12m	40m^3 - 60m^3	50mm 2"	100mm	185-450VDC	150-350VDC
SPA41K1100	3PH 220V 50Hz	1.1kW	12m - 8m	60m^3 - 100m^3	50mm 2"	100mm	350-450VDC	280-350VDC
SPA41K1100-2	3PH 220V 50Hz	1.1kW	12m - 8m	60m^3 - 100m^3	50mm 2"	100mm	185-450VDC	150-350VDC
SPA41K5010	3PH 220V 50Hz	1.5kW	128m - 87m	1m^3 - 10m^3	30mm 1"1/4	100mm	350-450VDC	280-350VDC
SPA41K5010-2	3PH 220V 50Hz	1.5kW	128m - 87m	1m^3 - 10m^3	30mm 1"1/4	100mm	185-450VDC	150-350VDC
SPA41K5020	3PH 220V 50Hz	1.5kW	99m - 68m	10m^3 - 20m^3	30mm 1"1/4	100mm	350-450VDC	280-350VDC
SPA41K5020-2	3PH 220V 50Hz	1.5kW	99m - 68m	10m^3 - 20m^3	30mm 1"1/4	100mm	185-450VDC	150-350VDC
SPA41K5040	3PH 220V 50Hz	1.5kW	51m - 33m	20m^3 - 40m^3	40mm 1"1/2	100mm	350-450VDC	280-350VDC
SPA41K5040-2	3PH 220V 50Hz	1.5kW	51m - 33m	20m^3 - 40m^3	40mm 1"1/2	100mm	185-450VDC	150-350VDC
SPA41K5041	3PH 220V 50Hz	1.5kW	60m - 39m	20m^3 - 40m^3	40mm 1"1/2	100mm	350-450VDC	280-350VDC
SPA41K5041-2	3PH 220V 50Hz	1.5kW	60m - 39m	20m^3 - 40m^3	40mm 1"1/2	100mm	185-450VDC	150-350VDC
SPA41K5060	3PH 220V 50Hz	1.5kW	29m - 15m	40m^3 - 60m^3	50mm 2"	100mm	350-450VDC	280-350VDC
SPA41K5060-2	3PH 220V 50Hz	1.5kW	29m - 15m	40m^3 - 60m^3	50mm 2"	100mm	185-450VDC	150-350VDC
SPA41K5130	3PH 220V 50Hz	1.5kW	10m - 7m	100m^3 - 130m^3	50mm 2"	100mm	350-450VDC	280-350VDC
SPA41K5130-2	3PH 220V 50Hz	1.5kW	10m - 7m	100m^3 - 130m^3	50mm 2"	100mm	185-450VDC	150-350VDC
SPA41K5100	3PH 220V 50Hz	1.5kW	20m - 12m	60m^3 - 100m^3	65mm 2"1/2	150mm	350-450VDC	280-350VDC
SPA41K5100-2	3PH 220V 50Hz	1.5kW	20m - 12m	60m^3 - 100m^3	65mm 2"1/2	150mm	185-450VDC	150-350VDC
SPA42K2010	3PH 380V 50Hz	2.2kW	163m - 111m	1m^3 - 10m^3	30mm 1"1/4	100mm	625-750VDC	500-600VDC
SPA42K2020	3PH 380V 50Hz	2.2kW	145m - 90m	10m^3 - 20m^3	30mm 1"1/4	100mm	625-750VDC	500-600VDC
SPA42K2040	3PH 380V 50Hz	2.2kW	79m - 51m	20m^3 - 40m^3	40mm 1"1/2	100mm	625-750VDC	500-600VDC
SPA42K2060	3PH 380V 50Hz	2.2kW	50m - 27m	40m^3 - 60m^3	50mm 2"	100mm	625-750VDC	500-600VDC
SPA42K2130	3PH 380V 50Hz	2.2kW	17m - 12m	100m^3 - 130m^3	50mm 2"	100mm	625-750VDC	500-600VDC
SPA42K2100	3PH 380V 50Hz	2.2kW	30m - 18m	60m^3 - 100m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA43K0020	3PH 380V 50Hz	3kW	187m - 114m	10m^3 - 20m^3	30mm 1"1/4	100mm	625-750VDC	500-600VDC
SPA43K0040	3PH 380V 50Hz	3kW	105m - 65m	20m^3 - 40m^3	40mm 1"1/2	100mm	625-750VDC	500-600VDC
SPA43K0060	3PH 380V 50Hz	3kW	67m - 37m	40m^3 - 60m^3	50mm 2"	100mm	625-750VDC	500-600VDC
SPA43K0061	3PH 380V 50Hz	3kW	79m - 43m	40m^3 - 60m^3	50mm 2"	100mm	625-750VDC	500-600VDC
SPA63K0100	3PH 380V 50Hz	3kW	40m - 24m	60m^3 - 100m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA63K0130	3PH 380V 50Hz	3kW	23m - 16m	100m^3 - 130m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA63K0250	3PH 380V 50Hz	3kW	18m - 9m	130m^3 - 250m^3	76mm 3"	150mm	625-750VDC	500-600VDC
SPA44K0020	3PH 380V 50Hz	4kW	225m - 149m	10m^3 - 20m^3	30mm 1"1/4	100mm	625-750VDC	500-600VDC
SPA44K0040	3PH 380V 50Hz	4kW	145m - 89m	20m^3 - 40m^3	40mm 1"1/2	100mm	625-750VDC	500-600VDC
SPA44K0060	3PH 380V 50Hz	4kW	94m - 55m	40m^3 - 60m^3	50mm 2"	100mm	625-750VDC	500-600VDC
SPA44K0100	3PH 380V 50Hz	4kW	50m - 32m	60m^3 - 100m^3	50mm 2"	100mm	625-750VDC	500-600VDC
SPA64K0100	3PH 380V 50Hz	4kW	56m - 36m	60m^3 - 100m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA64K0130	3PH 380V 50Hz	4kW	30m - 22m	100m^3 - 130m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA64K0131	3PH 380V 50Hz	4kW	37m - 27m	100m^3 - 130m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA64K0250	3PH 380V 50Hz	4kW	26m - 13m	130m^3 - 250m^3	76mm 3"	150mm	625-750VDC	500-600VDC
SPB64K0500	3PH 380V 50Hz	4kW	17m - 6m	150m^3 - 500m^3	76mm 3"	150mm	625-750VDC	500-600VDC
SPA45K5040	3PH 380V 50Hz	5.5kW	172m - 111m	20m^3 - 40m^3	40mm 1"1/2	100mm	625-750VDC	500-600VDC
SPA45K5060	3PH 380V 50Hz	5.5kW	113m - 62m	40m^3 - 60m^3	50mm 2"	100mm	625-750VDC	500-600VDC
SPA45K5100	3PH 380V 50Hz	5.5kW	67m - 44m	60m^3 - 100m^3	50mm 2"	100mm	625-750VDC	500-600VDC
SPA65K5100	3PH 380V 50Hz	5.5kW	75m - 48m	60m^3 - 100m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA65K5130	3PH 380V 50Hz	5.5kW	53m - 39m	100m^3 - 130m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA65K5250	3PH 380V 50Hz	5.5kW	35m - 21m	130m^3 - 250m^3	76mm 3"	150mm	625-750VDC	500-600VDC
SPB65K5500	3PH 380V 50Hz	5.5kW	25m - 10m	150m^3 - 500m^3	76mm 3"	150mm	625-750VDC	500-600VDC
SPA47K5040	3PH 380V 50Hz	7.5kW	237m - 147m	20m^3 - 40m^3	40mm 1"1/2	100mm	625-750VDC	500-600VDC
SPA47K5060	3PH 380V 50Hz	7.5kW	137m - 75m	40m^3 - 60m^3	50mm 2"	100mm	625-750VDC	500-600VDC
SPA47K5100	3PH 380V 50Hz	7.5kW	87m - 57m	60m^3 - 100m^3	50mm 2"	100mm	625-750VDC	500-600VDC
SPA67K5100	3PH 380V 50Hz	7.5kW	114m - 67m	60m^3 - 100m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA67K5130	3PH 380V 50Hz	7.5kW	67m - 50m	100m^3 - 130m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA67K5250	3PH 380V 50Hz	7.5kW	44m - 25m	130m^3 - 250m^3	76mm 3"	150mm	625-750VDC	500-600VDC
SPA67K5251	3PH 380V 50Hz	7.5kW	52m - 30m	130m^3 - 250m^3	76mm 3"	150mm	625-750VDC	500-600VDC
SPB67K5500	3PH 380V 50Hz	7.5kW	33m - 15m	150m^3 - 500m^3	76mm 3"	150mm	625-750VDC	500-600VDC

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Solartech 0.37-55kW AC Solar Pump Model List

Model	Pump Spec.	Pump Power	Water Head	Daily Water Flow	Outlet Dia.	Adapting Well Dia.	Recommended Open Circuit Voltage	Recommended MPP Voltage
SPA69K2100	3PH 380V 50Hz	9.2kW	140m - 85m	40m^3 - 100m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA69K2130	3PH 380V 50Hz	9.2kW	83m - 60m	100m^3 - 130m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA69K2250	3PH 380V 50Hz	9.2kW	62m - 40m	130m^3 - 250m^3	76mm 3"	150mm	625-750VDC	500-600VDC
SPB69K2500	3PH 380V 50Hz	9.2kW	42m - 20m	130m^3 - 500m^3	76mm 3"	150mm	625-750VDC	500-600VDC
SPA611K100	3PH 380V 50Hz	11kW	159m - 97m	40m^3 - 100m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA611K130	3PH 380V 50Hz	11kW	105m - 77m	100m^3 - 130m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA611K250	3PH 380V 50Hz	11kW	72m - 46m	130m^3 - 250m^3	76mm 3"	150mm	625-750VDC	500-600VDC
SPB611K500	3PH 380V 50Hz	11kW	50m - 23m	150m^3 - 500m^3	76mm 3"	150mm	625-750VDC	500-600VDC
SPA613K100	3PH 380V 50Hz	13kW	189m - 115m	40m^3 - 100m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA613K130	3PH 380V 50Hz	13kW	120m - 88m	100m^3 - 130m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA613K250	3PH 380V 50Hz	13kW	81m - 52m	130m^3 - 250m^3	76mm 3"	150mm	625-750VDC	500-600VDC
SPB613K500	3PH 380V 50Hz	13kW	59m - 27m	150m^3 - 500m^3	76mm 3"	150mm	625-750VDC	500-600VDC
SPA615K100	3PH 380V 50Hz	15kW	208m - 127m	40m^3 - 100m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA615K130	3PH 380V 50Hz	15kW	135m - 99m	100m^3 - 130m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA615K250	3PH 380V 50Hz	15kW	88m - 58m	130m^3 - 250m^3	76mm 3"	150mm	625-750VDC	500-600VDC
SPB615K500	3PH 380V 50Hz	15kW	67m - 31m	150m^3 - 500m^3	76mm 3"	150mm	625-750VDC	500-600VDC
SPA618K130	3PH 380V 50Hz	18.5kW	143m - 109m	100m^3 - 130m^3	65mm 2"1/2	150mm	625-750VDC	500-600VDC
SPA618K250	3PH 380V 50Hz	18.5kW	101m - 63m	130m^3 - 250m^3	76mm 3"	150mm	625-750VDC	500-600VDC
SPB618K500	3PH 380V 50Hz	18.5kW	83m - 39m	150m^3 - 500m^3	76mm 3"	150mm	625-750VDC	500-600VDC
SPC822K270	3PH 380V 50Hz	22kW	86m - 70m	210m^3 - 270m^3	65mm 2"1/2	250mm	625-750VDC	500-600VDC
SPC822K330	3PH 380V 50Hz	22kW	70m - 55m	270m^3 - 330m^3	76mm 3"	250mm	625-750VDC	500-600VDC
SPC822K420	3PH 380V 50Hz	22kW	55m - 48m	330m^3 - 420m^3	76mm 3"	250mm	625-750VDC	500-600VDC
SPC822K540	3PH 380V 50Hz	22kW	48m - 36m	420m^3 - 540m^3	100mm 4"	250mm	625-750VDC	500-600VDC
SPC822K700	3PH 380V 50Hz	22kW	36m - 25m	540m^3 - 700m^3	100mm 4"	250mm	625-750VDC	500-600VDC
SPC826K270	3PH 380V 50Hz	26kW	105m - 85m	210m^3 - 270m^3	65mm 2"1/2	250mm	625-750VDC	500-600VDC
SPC826K330	3PH 380V 50Hz	26kW	85m - 65m	270m^3 - 330m^3	76mm 3"	250mm	625-750VDC	500-600VDC
SPC826K420	3PH 380V 50Hz	26kW	65m - 55m	330m^3 - 420m^3	76mm 3"	250mm	625-750VDC	500-600VDC
SPC826K700	3PH 380V 50Hz	26kW	44m - 30m	540m^3 - 700m^3	100mm 4"	250mm	625-750VDC	500-600VDC
SPC830K270	3PH 380V 50Hz	30kW	125m - 105m	210m^3 - 270m^3	65mm 2"1/2	250mm	625-750VDC	500-600VDC
SPC830K330	3PH 380V 50Hz	30kW	105m - 85m	270m^3 - 330m^3	76mm 3"	250mm	625-750VDC	500-600VDC
SPC830K420	3PH 380V 50Hz	30kW	85m - 70m	330m^3 - 420m^3	76mm 3"	250mm	625-750VDC	500-600VDC
SPC830K540	3PH 380V 50Hz	30kW	70m - 52m	420m^3 - 540m^3	100mm 4"	250mm	625-750VDC	500-600VDC
SPC830K700	3PH 380V 50Hz	30kW	52m - 35m	540m^3 - 700m^3	100mm 4"	250mm	625-750VDC	500-600VDC
SPC837K270	3PH 380V 50Hz	37kW	150m - 125m	210m^3 - 270m^3	65mm 2"1/2	250mm	625-750VDC	500-600VDC
SPC837K330	3PH 380V 50Hz	37kW	125m - 100m	270m^3 - 330m^3	76mm 3"	250mm	625-750VDC	500-600VDC
SPC837K420	3PH 380V 50Hz	37kW	100m - 80m	330m^3 - 420m^3	76mm 3"	250mm	625-750VDC	500-600VDC
SPC837K540	3PH 380V 50Hz	37kW	80m - 60m	420m^3 - 540m^3	100mm 4"	250mm	625-750VDC	500-600VDC
SPC837K700	3PH 380V 50Hz	37kW	60m - 40m	540m^3 - 700m^3	100mm 4"	250mm	625-750VDC	500-600VDC
SPC845K270	3PH 380V 50Hz	45kW	180m - 145m	210m^3 - 270m^3	65mm 2"1/2	250mm	625-750VDC	500-600VDC
SPC845K330	3PH 380V 50Hz	45kW	145m - 120m	270m^3 - 330m^3	76mm 3"	250mm	625-750VDC	500-600VDC
SPC845K420	3PH 380V 50Hz	45kW	120m - 98m	330m^3 - 420m^3	76mm 3"	250mm	625-750VDC	500-600VDC
SPC845K540	3PH 380V 50Hz	45kW	98m - 72m	420m^3 - 540m^3	100mm 4"	250mm	625-750VDC	500-600VDC
SPC845K700	3PH 380V 50Hz	45kW	72m - 50m	540m^3 - 700m^3	100mm 4"	250mm	625-750VDC	500-600VDC
SPC855K270	3PH 380V 50Hz	55kW	200m - 170m	210m^3 - 270m^3	65mm 2"1/2	250mm	625-750VDC	500-600VDC
SPC855K330	3PH 380V 50Hz	55kW	170m - 155m	270m^3 - 330m^3	76mm 3"	250mm	625-750VDC	500-600VDC
SPC855K420	3PH 380V 50Hz	55kW	155m - 125m	330m^3 - 420m^3	76mm 3"	250mm	625-750VDC	500-600VDC
SPC855K540	3PH 380V 50Hz	55kW	125m - 95m	420m^3 - 540m^3	100mm 4"	250mm	625-750VDC	500-600VDC
SPC855K700	3PH 380V 50Hz	55kW	95m - 65m	540m^3 - 700m^3	100mm 4"	250mm	625-750VDC	500-600VDC

Performance based on 6kWh/m^2/day of solar radiation. **May 1, 2014**

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Annex VII: Standard Wire Gauge Table

Standard Wire Gauge	Diameter		Turns of wire		Cross-sectional area		Res. per length (for copper wire)		Mass per length		Current Capacity / A	
	in	mm	in^{-1}	mm^{-1}	kcmil	mm^2	Ω/km	Ω/kft	lb/ft	kg/m	750 kcmil/A	500kcmil/A
0000000 (7/0)	0.5	12.7	2	0.0787	250	127	0.136	0.447	0.759	1.13	333	500
000000 (6/0)	0.464	11.8	2.16	0.0848	215	109	0.158	0.519	0.654	0.973	287	431
00000 (5/0)	0.432	11	2.31	0.0911	187	94.6	0.182	0.598	0.567	0.844	249	373
0000 (4/0)	0.4	10.2	2.5	0.0984	160	81.1	0.213	0.698	0.486	0.723	213	320
000 (3/0)	0.372	9.45	2.69	0.106	138	70.1	0.246	0.807	0.42	0.625	185	277
00 (2/0)	0.348	8.84	2.87	0.113	121	61.4	0.281	0.922	0.368	0.547	161	242
0 (1/0)	0.324	8.23	3.09	0.122	105	53.2	0.324	1.06	0.319	0.474	140	210
1	0.3	7.62	3.33	0.131	90	45.6	0.378	1.24	0.273	0.407	120	180
2	0.276	7.01	3.62	0.143	76.2	38.6	0.447	1.47	0.231	0.344	102	152
3	0.252	6.4	3.97	0.156	63.5	32.2	0.536	1.76	0.193	0.287	84.7	127
4	0.232	5.89	4.31	0.17	53.8	27.3	0.632	2.07	0.163	0.243	71.8	108
5	0.212	5.38	4.72	0.186	44.9	22.8	0.757	2.48	0.137	0.203	59.9	89.9
6	0.192	4.88	5.21	0.205	36.9	18.7	0.923	3.03	0.112	0.167	49.2	73.7
7	0.176	4.47	5.68	0.224	31	15.7	1.1	3.6	0.0941	0.14	41.3	62
8	0.16	4.06	6.25	0.246	25.6	13	1.33	4.36	0.0778	0.116	34.1	51.2
9	0.144	3.66	6.94	0.273	20.7	10.5	1.64	5.38	0.063	0.0937	27.6	41.5
10	0.128	3.25	7.81	0.308	16.4	8.3	2.08	6.81	0.0498	0.0741	21.8	32.8
11	0.116	2.95	8.62	0.339	13.5	6.82	2.53	8.3	0.0409	0.0608	17.9	26.9
12	0.104	2.64	9.62	0.379	10.8	5.48	3.15	10.3	0.0329	0.0489	14.4	21.6
13	0.092	2.34	10.9	0.428	8.46	4.29	4.02	13.2	0.0257	0.0383	11.3	16.9
14	0.08	2.03	12.5	0.492	6.4	3.24	5.32	17.4	0.0194	0.0289	8.53	12.8

15	0.072	1.83	13.9	0.547	5.18	2.63	6.56	21.5	0.0157	0.0234	6.91	10.4
16	0.064	1.63	15.6	0.615	4.1	2.08	8.31	27.3	0.0124	0.0185	5.46	8.19
17	0.056	1.42	17.9	0.703	3.14	1.59	10.9	35.6	0.00952	0.0142	4.18	6.27
18	0.048	1.22	20.8	0.82	2.3	1.17	14.8	48.5	0.007	0.0104	3.07	4.61
19	0.04	1.02	25	0.984	1.6	0.811	21.3	69.8	0.00486	0.00723	2.13	3.2
20	0.036	0.914	27.8	1.09	1.3	0.657	26.3	86.1	0.00394	0.00586	1.73	2.59
21	0.032	0.813	31.3	1.23	1.02	0.519	33.2	109	0.00311	0.00463	1.37	2.05
22	0.028	0.711	35.7	1.41	0.784	0.397	43.4	142	0.00238	0.00354	1.05	1.57
23	0.024	0.61	41.7	1.64	0.576	0.292	59.1	194	0.00175	0.0026	0.768	1.15
24	0.022	0.559	45.5	1.79	0.484	0.245	70.3	231	0.00147	0.00219	0.645	0.968
25	0.02	0.508	50	1.97	0.4	0.203	85.1	279	0.00121	0.00181	0.533	0.8
26	0.018	0.457	55.6	2.19	0.324	0.164	105	345	984μ	0.00146	0.432	0.648
27	0.0164	0.417	61	2.4	0.269	0.136	127	415	817μ	0.00122	0.359	0.538
28	0.0148	0.376	67.6	2.66	0.219	0.111	155	510	665μ	990μ	0.292	0.438
29	0.0136	0.345	73.5	2.89	0.185	0.0937	184	604	562μ	836μ	0.247	0.37
30	0.0124	0.315	80.6	3.18	0.154	0.0779	221	726	467μ	695μ	0.205	0.308
31	0.0116	0.295	86.2	3.39	0.135	0.0682	253	830	409μ	608μ	0.179	0.269
32	0.0108	0.274	92.6	3.65	0.117	0.0591	292	957	354μ	527μ	0.156	0.233
33	0.01	0.254	100	3.94	0.1	0.0507	340	1120	304μ	452μ	0.133	0.2
34	0.0092	0.234	109	4.28	0.0846	0.0429	402	1320	257μ	383μ	0.113	0.169
35	0.0084	0.213	119	4.69	0.0706	0.0358	482	1580	214μ	319μ	0.0941	0.141
36	0.0076	0.193	132	5.18	0.0578	0.0293	589	1930	175μ	261μ	0.077	0.116
37	0.0068	0.173	147	5.79	0.0462	0.0234	736	2410	140μ	209μ	0.0617	0.0925
38	0.006	0.152	167	6.56	0.036	0.0182	945	3100	109μ	163μ	0.048	0.072
39	0.0052	0.132	192	7.57	0.027	0.0137	1260	4130	82.1μ	122μ	0.0361	0.0541

40	0.0048	0.122	208	8.2	0.023	0.0117	1480	4850	70.0μ	104μ	0.0307	0.0461
41	0.0044	0.112	227	8.95	0.0194	0.00981	1760	5770	58.8μ	87.5μ	0.0258	0.0387
42	0.004	0.102	250	9.84	0.016	0.00811	2130	6980	48.6μ	72.3μ	0.0213	0.032
43	0.0036	0.0914	278	10.9	0.013	0.00657	2630	8610	39.4μ	58.6μ	0.0173	0.0259
44	0.0032	0.0813	313	12.3	0.0102	0.00519	3320	10900	31.1μ	46.3μ	0.0137	0.0205
45	0.0028	0.0711	357	14.1	0.00784	0.00397	4340	14200	23.8μ	35.4μ	0.0105	0.0157
46	0.0024	0.061	417	16.4	0.00576	0.00292	5910	19400	17.5μ	26.0μ	0.00768	0.0115
47	0.002	0.0508	500	19.7	0.004	0.00203	8510	27900	12.1μ	18.1μ	0.00533	0.008
48	0.0016	0.0406	625	24.6	0.00256	0.0013	13300	43600	7.78μ	11.6μ	0.00341	0.00512
49	0.0012	0.0305	833	32.8	0.00144	730μ	23600	77500	4.37μ	6.51μ	0.00192	0.00288
50	0.001	0.0254	1000	39.4	0.001	507μ	34000	112000	3.04μ	4.52μ	0.00133	0.002
Note:	1. All values are rounded to three significant figures. Values less than 1×10−6 are shown with appropriate SI prefixes to avoid a large number of leading zeros.											
	2. The IACS value of 58.0 MS/m is used as the conductivity of copper.											
	3. These calculations do not take into account AC effects such as the skin effect - perform suitable calculations before using in a high-frequency application. Grid mains frequencies (50-60 Hz) should not have a noticeable effect, as the skin depth is over 8mm.											
	4. A density of copper of 8920 kg/m3 is used to derive the mass											
	5. An allowance of 750 kcmil/A is generally sufficient for calculating current capacity. The more relaxed 500 kcmil/A is an absolute maximum.											
	6. The values are guidelines − exact values will depend on the type of wire and operating conditions such as ambient temperature, thermal conductivity of the surroundings.											

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Annex VIII: Costing of PV Water Pumping System Including Civil Components

Name of Project: Sample

District: Kathmandu VDC: Sundarijal Ward No: 3,4

Household: 65 Population: 351

Base Year : 2071

Base Region: Centeral Region

PV PUMPING SYSTEM COSTING MODULE

S.no.	Description	Unit	Quantity	Rate	Cost Index	Regional Index	Amount	Remarks
A. Civil Structures								
1	Spring Intake with Valve Chamber	No.	1.00	92,000.00	1.00	1.00	92,000.00	
2	Spring Intake without Valve Chamber	No.	-	71,765.00	1.00	1.00	-	
3	Collection Chamber	No.	-	82,000.00	1.00	1.00	-	
4	Sedimentation Tank	No.	-	320,000.00	1.00	1.00	-	
5	Horizontal Roughing Filter	No.	1.00	250,000.00	1.00	1.00	250,000.00	
6	Sump-Well (12m3 masonry tank)	No.	1.00	292,000.00	1.00	1.00	292,000.00	
7	Distribution Chamber	No.	-	84,000.00	1.00	1.00	-	
8	Ferrocement Service Reservoir (1m3 -capacity)	No.	-	143,998.00	1.00	1.00	-	
9	Ferrocement Service Reservoir (2m3 -capacity)	No.	-	153,994.00	1.00	1.00	-	
10	Ferrocement Service Reservoir (3m3 -capacity)	No.	-	163,817.00	1.00	1.00	-	
11	Ferrocement Service Reservoir (4m3 -capacity)	No.	-	170,283.00	1.00	1.00	-	
12	Ferrocement Service Reservoir (5m3 -capacity)	No.	-	187,379.00	1.00	1.00	-	
13	Ferrocement Service Reservoir (6m3 -capacity)	No.	-	199,523.00	1.00	1.00	-	
14	Ferrocement Service Reservoir (7m3 -capacity)	No.	-	203,575.00	1.00	1.00	-	
15	Ferrocement Service Reservoir (8m3 -capacity)	No.	-	208,967.00	1.00	1.00	-	
16	Ferrocement Service Reservoir (9m3 -capacity)	No.	-	218,508.00	1.00	1.00	-	
17	Ferrocement Service Reservoir (10m3 -capacity)	No.	-	236,256.00	1.00	1.00	-	

18	Ferrocement Service Reservoir (12m3 -capacity)	No.	-	244,406.00	1.00	1.00	-	
19	Ferrocement Service Reservoir (14m3 -capacity)	No.	1.00	260,218.00	1.00	1.00	260,218.00	
20	Ferrocement Service Reservoir (16m3 -capacity)	No.	-	267,901.00	1.00	1.00	-	
21	Ferrocement Service Reservoir (18m3 -capacity)	No.	-	282,415.00	1.00	1.00	-	
22	Ferrocement Service Reservoir (20m3 -capacity)	No.	-	289,077.00	1.00	1.00	-	
23	Tap Stand Post	No.	10.00	25,000.00	1.00	1.00	250,000.00	
24	Solar PV Panel Resting Structures	No.	1.00	20,000.00	1.00	1.00	20,000.00	
	Sub-total						1,164,218.00	
B. Pipeline								
B.1 GI Pipe								
1	GI Pipe (80mm) HC	R.M.	-	968.00	1.00	1.00	-	
2	GI Pipe (65mm) HC	R.M.	-	822.00	1.00	1.00	-	
3	GI Pipe (50mm) HC	R.M.	300.00	657.00	1.00	1.00	197,100.00	
4	GI Pipe (40mm) HC	R.M.	-	447.00	1.00	1.00	-	
5	GI Pipe (32mm) HC	R.M.	-	388.00	1.00	1.00	-	
6	GI Pipe (25mm) HC	R.M.	-	303.00	1.00	1.00	-	
7	GI Pipe (80mm) MC	R.M.	-	845.00	1.00	1.00	-	
8	GI Pipe (65mm) MC	R.M.	-	678.00	1.00	1.00	-	
9	GI Pipe (50mm) MC	R.M.	-	532.00	1.00	1.00	-	
10	GI Pipe (40mm) MC	R.M.	-	387.00	1.00	1.00	-	
11	GI Pipe (32mm) MC	R.M.	-	337.00	1.00	1.00	-	
12	GI Pipe (25mm) MC	R.M.	-	258.00	1.00	1.00	-	
13	GI Pipe (20mm) MC	R.M.	-	170.00	1.00	1.00	-	
14	GI Pipe (15mm) MC	R.M.	-	133.00	1.00	1.00	-	
	Sub-total						197,100.00	
B.2 HDPE Pipe								
1	HDPE 16mmÆ-10kgf	R.M.	-	20.42	1.00	1.00	-	
2	HDPE 20mmÆ-10kgf	R.M.	200.00	29.75	1.00	1.00	5,950.00	

3	HDPE 25mmÆ-10kgf	R.M.	500.00	44.81	1.00	1.00	22,405.00	
4	HDPE 32mmÆ-10kgf	R.M.	700.00	74.15	1.00	1.00	51,905.00	
5	HDPE 40mmÆ-10kgf	R.M.	-	114.11	1.00	1.00	-	
6	HDPE 50mmÆ-10kgf	R.M.	-	176.71	1.00	1.00	-	
7	HDPE 32mmÆ-6kgf	R.M.	-	50.17	1.00	1.00	-	
8	HDPE 40mmÆ-6kgf	R.M.	-	77.70	1.00	1.00	-	
9	HDPE 50mmÆ-6kgf	R.M.	-	120.32	1.00	1.00	-	
10	HDPE 63mmÆ-6kgf	R.M.	-	188.70	1.00	1.00	-	
	Sub-total						80,260.00	
C. Earthwork in excavation and Filling in pipline trench								
1	E/W for excavation of trench in OS	R.M.	1,700.00	100.85	1.00	1.00	171,445.00	
2	E/W for excavation of trench BMS	R.M.	-	178.16	1.00	1.00	-	
3	E/W in filling work	R.M.	-	66.11	1.00	1.00	-	
	Sub-total						171,445.00	
D. Solar Component								
1	Pannels	Watt	1,500.00	150.00	1.00	1.00	225,000.00	
2	Pump	HP	7.50	31,000.00	1.00	1.00	232,500.00	
3	Armoured Cable	R.M.	50.00	400.00	1.00	1.00	20,000.00	
	Drop Cable	R.M.	10.00	320.00	1.00	00	3,200.00	
	Switch on/off	No.	2.00	600.00	1.00	1.00	1,200.00	
	Series Cable red and black	R.M.	50.00	150.00	1.00	1.00	7,500.00	
	Water proof switch box	No.	2.00	3,500.00	1.00	1.00	7,000.00	
4	Lightening Arrestor	Set	1.00	80,000.00	1.00	1.00	80,000.00	
5	Surge Protector	Set	1.00	10,000.00	1.00	1.00	10,000.00	
6	Mounting Frame	Set	1.00	75,000.00	1.00	1.00	75,000.00	

7	Controller	Set	1.00	35,000.00	1.00	1.00	35,000.00	
8	Other Accessories (silicon glue, cable tie, cable shoe, flexible pipe etc.)	L.S.	1.00				15,000.00	
9	Installation Charge, Testing and Commisioning	L.S.	1.00				70,000.00	
	Sub-total						781,400.00	
E. Transportation								
1	Earthen Road	KM	-	2,250.00	1.00	1.00	-	
2	Gravelled Road	KM	5.00	1,750.00	1.00	1.00	8,750.00	
3	Mettaled Road	KM	10.00	1,250.00	1.00	1.00	12,500.00	
4	Portering	KM	-	34500	1.00	1.00	-	
	Sub-total						21,250.00	
F. Tools		No.	1.00	30,000.00	1.00	1.00	30,000.00	
G. Training			1.00	10,000.00	1.00	1.00	10,000.00	
	TOTAL COST						1,674,273.00	

Annex IX: Working Pressure of G. I. Pipes (IS: 1239)

(Threaded)

Inner Diameter (mm)	Class	Thickness (mm)	Effective thickness (mm)	Working Pressure (m)
15	L	2.00	0.55	168
	M	2.65	1.20	367
	H	3.25	1.80	551
Inner Diameter	Class	Thickness (mm)	Effective thickness (mm)	Working Pressure (m)
20	L	2.35	0.54	143
	M	2.65	0.89	216
	H	3.25	1.49	361
25	L	2.65	0.89	172
	M	3.25	1.49	288
	H	4.05	2.29	443
32	L	2.65	0.89	137
	M	3.25	1.49	229
	H	4.05	2.29	352
40	L	2.90	1.14	154
	M	3.25	1.49	201
	H	4.05	2.29	309
Inner Diameter (mm)	Class	Thickness (mm)	Effective thickness (mm)	Working Pressure (m)
50	L	2.90	1.14	123
	M	3.65	1.49	204
	H	4.50	2.29	296
65	L	3.25	0.71	61
	M	3.65	1.11	95
	H	4.50	1.96	168
80	L	3.25	0.71	52
	M	4.05	1.51	110
	H	4.85	2.31	169
100	L	3.65	1.89	107
	M	4.50	1.96	111
	H	5.40	2.86	163
125	L	-	-	-
	M	4.85	2.31	107
	H	5.40	2.86	133
150	L	-	-	-
	M	4.85	2.31	91
	H	5.40	2.86	113

NOTE: 1. Allowance equals the three groove as per American Standards.

2. Formula used S= PD/2T

S=320 Mpa = 3264 m. of water.

Annex X: Head Loss Due to Friction in Galvanized Iron Pipes Per 100 Meters of Pipe Length, m.

				Discharge				Pipe diameter, cm.	
l/s	4.0	5.0	6.0	7.0	8.0	10.0	12.5	15.0	20.0
1.0	3.7	1.1	0.43	-	-	-	-	-	-
1.2	5.0	1.6	0.58	0.27	-	-	-	-	-
1.4	7.3	2.2	0.83	0.37	-	-	-	-	-
1.6	9.2	2.8	1.10	0.50	0.23	-	-	-	-
1.8	11.8	3.7	1.40	0.62	0.29	-	-	-	-
2.0	15.5	4.5	1.70	0.73	0.37	-	-	-	-
2.2	16.2	5.2	2.15	0.90	0.44	-	-	-	-
2.4	20.5	6.4	2.50	1.07	0.52	0.16	-	-	-
2.6	23.5	7.5	2.90	1.27	0.62	0.18	-	-	-
2.8	27.5	8.7	3.30	1.47	0.70	0.22	-	-	-
3.0	32.0	10.0	3.80	1.68	0.83	0.25	-	-	-
3.5	42.5	13.5	5.30	2.30	1.10	0.33	-	-	-
4.0	56.0	17.5	7.30	3.00	1.50	0.45	0.13	-	-
4.5	71.5	22.5	8.80	3.80	1.85	0.55	0.17	-	-
5.0	87.0	28.0	10.80	4.70	2.30	0.68	0.22	-	-
5.5	-	33.0	12.40	5.70	2.70	0.83	0.26	0.095	-
6.0	-	40.0	15.50	6.80	3.20	0.96	0.32	0.118	-
6.5	-	47.0	18.30	8.00	3.80	1.15	0.36	0.140	-
7.0	-	54.0	21.50	9.30	4.50	1.30	0.42	0.17	-
7.5	-	62.0	24.00	10.60	5.20	1.50	0.47	0.18	-
8.0	-	70.0	28.00	11.60	6.00	1.80	0.55	0.21	-
8.5	-	80.0	31.00	13.30	6.80	2.00	0.62	0.23	-
9.0	-	90.0	36.00	15.00	7.50	2.20	0.68	0.27	-
9.5	-	100.0	38.00	17.00	8.30	2.50	0.76	0.29	-
10	-	-	43.00	19.00	9.40	2.80	0.85	0.32	0.065
12	-	-	63.00	27.00	13.00	4.00	1.23	0.47	0.10
14	-	-	86.00	37.00	18.00	5.50	1.65	0.63	0.13
16	-	-	-	47.00	23.00	7.20	2.20	1.05	0.22
18	-	-	-	60.00	30.00	9.00	2.80	1.05	0.22
20	-	-	-	72.00	37.00	11.00	3.30	1.30	0.27
22	-	-	-	86.00	45.00	13.50	4.10	1.60	0.33
24	-	-	-	-	52.00	16.00	4.80	1.90	0.40
26	-	-	-	-	62.00	18.70	5.60	2.20	0.47
28	-	-	-	-	72.00	22.00	6.60	2.50	0.55
30	-	-	-	-	80.00	25.00	7.50	2.80	0.63
35	-	-	-	-	-	33.00	10.30	4.40	0.85

Annex XI: Equivalent Lengths of Valves, Sudden Cross-Sectional Changes and Bends, m

Nominal pipe size mm	Glove valve	Angle valve Ball check	Return bend Swing check	Standard tee Square elbow	Standard elbow Reduced tee 1/2	Medium elbow Reduced tee 1/4	Long elbow Run of standard tee	45 deg. lbow	Gate valve
40	12.20	6.40	3.05	2.13	1.22	1.22	0.91	0.60	0.30
50	15.24	8.22	3.96	3.05	1.52	1.53	0.91	0.76	0.30
65	18.30	10.05	4.60	3.66	1.83	1.83	1.22	0.91	0.46
80	24.40	12.20	5.50	4.60	2.43	2.13	1.52	1.22	0.61
100	35.00	16.76	7.01	6.10	3.35	2.74	1.83	1.52	0.76
150	48.77	24.40	10.97	9.14	4.88	4.27	2.74	2.30	1.07
200	68.58	33.53	15.24	12.20	6.10	5.50	4.27	3.05	1.37

Nominal pipe size mm	Sudden enlargement Equivalent L's in terms of d			Borda entrance	Ordinary entrance	Sudden Contraction Equivalent L's in terms of d		
	d/D = 1/4	d/D = 1/2	d/D = 3/4			d/D = 1/4	d/D = 1/2	d/D = 3/4
40	1.37	0.91	0.30	1.22	0.76	0.61	0.46	0.30
50	1.52	1.07	0.30	1.52	0.91	0.76	0.61	0.30
65	1.83	1.37	0.45	1.83	1.07	0.91	0.76	0.46
80	2.43	1.57	0.61	2.44	1.37	1.22	0.91	0.61
100	3.35	2.13	0.76	3.35	1.83	1.52	1.22	0.76
150	4.88	3.05	1.07	4.60	2.74	2.30	1.70	1.07
200	6.10	4.27	1.37	5.80	3.66	3.05	2.30	1.37

Annex XII: Data Chart of Lorentz Solar Pump

LORENTZ

FLOW CHART FOR ETAPUMP® HR

Calculated on 6 kWh/m²/day

Gallons indicated are Imperial Gallons

WATT [W]	Pump Type	Fixed Array m³/day	Fixed Array Gal.	Tracked Array m³/day	Tracked Array Gal.	Pump Type	Fixed Array m³/day	Fixed Array Gal.	Tracked Array m³/day	Tracked Array Gal.
	15 m / 50 ft			Wire: 4 mm²		**20 m / 67 ft**			Wire: 4 mm²	
180	HR-14	12.0	2 640	17.4	3 830	HR-04	6.0	1 320	8.7	1 920
240	HR-14	16.0	3 520	23.2	5 110	HR-14	12.6	2 780	18.2	4 020
350	HR-14	21.0	4 630	30.4	6 700	HR-14	18.0	3 960	26.0	5 750
480	HR-20	27.2	6 000	39.5	8 700	HR-14	22.0	4 850	31.9	7 030
720	Centric	44.0	9 690	63.8	14 050	HR-20	29.0	6 380	42.0	9 260
	30 m / 100 ft			Wire: 4 mm²		**40 m / 133 ft**			Wire: 4 mm²	
180	HR-04	5.7	1 250	8.2	1 820	HR-04	4.0	880	5.8	1 280
240	HR-04	6.7	1 470	9.7	2 140	HR-04	5.5	1 210	8.0	1 760
350	HR-14	14.0	3 080	20.3	4 470	HR-04	6.9	1 520	10.0	2 200
480	HR-14	18.0	3 960	26.0	5 750	HR-14	14.2	3 130	20.6	4 540
720	HR-20	25.0	5 500	36.3	7 980	HR-14	20.0	4 400	29.0	6 390
	50 m / 166 ft			Wire: 6 mm²		**60 m / 200 ft**			Wire: 6 mm²	
240	HR-04	5.0	1 120	7.4	1 630	HR-04	3.9	860	5.6	1 250
350	HR-04	6.2	1 360	9.0	1 980	HR-04	5.6	1 230	8.1	1 790
480	HR-14	11.0	2 420	15.9	3 510	HR-07	8.6	1 890	12.5	2 750
720	HR-14	17.8	3 920	25.8	5 690	HR-07	11.0	2 420	15.9	3 510
	70 m / 233 ft			Wire: 10 mm²		**80 m / 266 ft**			Wire: 10 mm²	
350	HR-04	4.7	1 040	6.8	1 500	HR-04H	4.4	970	6.3	1 400
480	HR-04	6.0	1 320	8.7	1 920	HR-04H	5.7	1 430	8.2	1 820
550	HR-07	8.9	1 960	12.9	2 840	HR-07	7.8	1 720	11.3	2 490
720	HR-07	10.2	2 250	14.8	3 260	HR-07	9.4	2 070	13.6	3 000
	90 m / 300 ft			Wire: 10 mm²		**100 m / 333 ft**			Wire: 10 mm²	
350	HR-04H	4.2	930	6.1	1 340	HR-04H	3.8	840	5.5	1 210
480	HR-04H	5.5	1 210	8.0	1 760	HR-04H	5.1	1 130	7.4	1 630
550	HR-07	6.7	1 480	9.7	2 140	HR-04H	5.7	1 260	8.2	1 820
720	HR-07	8.7	1 920	12.6	2 780	HR-04H	6.4	1 410	9.3	2 050
	110 m / 366 ft			Wire: 10 mm²		**120 m / 400 ft**			Wire: 10 mm²	
480	HR-04H	4.8	1 060	7.0	1 540	HR-04H	4.5	990	6.5	1 440
550	HR-04H	5.4	1 190	7.8	1 730	HR-04H	5.2	1 150	7.5	1 660
720	HR-04H	6.2	1 370	9.0	1 980	HR-04H	6.0	1 320	8.7	1 920
	130 m / 433 ft			Wire: 16 mm²		**140 m / 466 ft**			Wire: 16 mm²	
480	HR-04H	4.2	930	6.1	1 340	HR-04H	4.1	900	5.9	1 310
550	HR-04H	4.9	1 080	7.1	1 570	HR-04H	4.6	1 010	6.6	1 470
720	HR-04H	5.8	1 280	8.4	1 850	HR-04H	5.6	1 240	8.1	1 790
	150 m / 500 ft			Wire: 16 mm²		**160 m / 533 ft**			Wire:16 mm²	
480	HR-04H	3.8	840	5.5	1 210	HR-04H	3.4	750	4.9	1 090
550	HR-04H	4.4	970	6.4	1 400	HR-04H	4.2	930	6.1	1 340
720	HR-04H	5.3	1 170	7.7	1 700	HR-04H	5.1	1 130	7.4	1 630

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The calculations are based on Uni-Solar US64 panels. Flow rates may vary plus / minus 10 %. All systems are selected for optimum performance. Each system can handle an additional 15 % in case of unexpected draw-down in bore. For battery-powered pumping system, request data for 24 and 48 Volt flow-chart.

170 m / 566 ft to 230 m / 750 ft use ETAPUMP HR-03H, ask agent for flow rates.

Annex XIII: Sample Calculation for Solar PV Pumping System by LORENTZ for 20 m Head and 40 m^3 Discharge

LORENTZ

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Wednesday, 06 August 2014

DESIGN 20M 40M3

Solar pumping project

Parameter

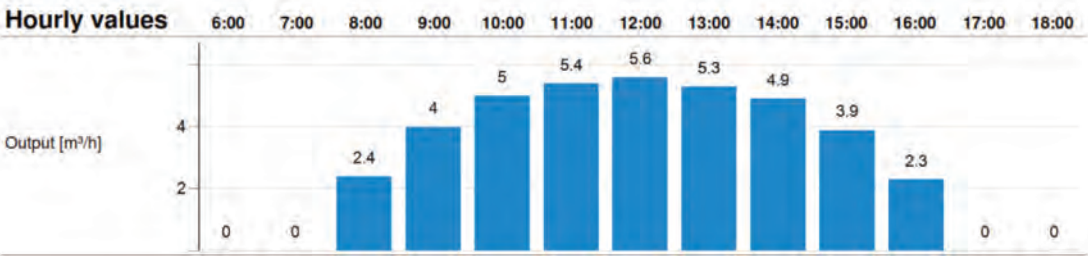
Location:	4.5 kWh/m² per day)	Total dynamic head:	20 m
Required daily output:	40 m³; Sizing for 4.5 kWh/m²	Motor cable:	25 m
Dirt loss:		Pipeline:	-

Products

Products	Quantity	Details
PS1800 C-SJ8-7	1 pc.	Submersible pump system including controller, motor and pump end
LC120-12P	8 pc.	960 Wp; 8 x 1 modules; 27 ° tilted
Motor cable	25 m	4 mm² 3-phase cable
Accessories	1 set	Well Probe, Surge Protector, PV Disconnect 440-20-1

Daily output at 4.5 kWh/m² 39 m³

Hourly values



	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00
Energy [kWh]	0	0.12	0.27	0.42	0.53	0.58	0.60	0.57	0.52	0.40	0.26	0.12	0
Irradiation [kWh/m²]	0	0.12	0.28	0.45	0.59	0.66	0.70	0.66	0.59	0.45	0.28	0.12	0
Ambient temp. [°C]	15	15	16	18	20	22	24	25	25	25	25	24	24

1/5 Created by LORENTZ COMPASS 3.0.10.77
All specifications and information are given with good intent, errors are possible and products may be subject to change without notice.
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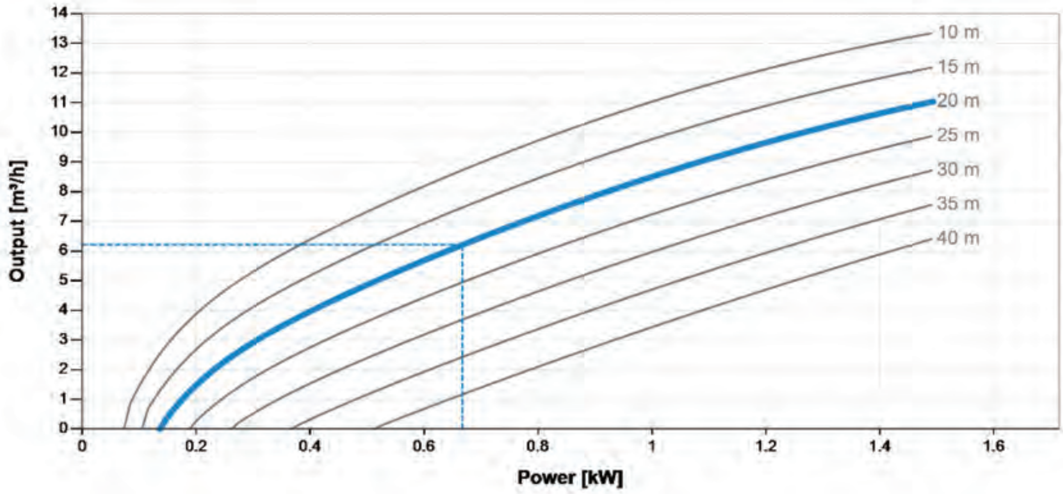
DESIGN 20M 40M3

Solar pumping project

System characteristic



			Min.	800 W/m², 20 °C	Max./STC*
PV generator	Cell temperature	[°C]		46	25
	Temperature loss	[%]		11	-
	Dirt loss	[%]		0	-
	Pmax	[Wp]		687	960
	Vmp	[V]		123	137
	Imp	[A]		5.6	7
	Voc	[V]		159	174
	Isc	[A]		6.3	8
	Pout	[W]		687	-
	Vout	[V]		123	-
	Iout	[A]		5.6	-
Motor cable	Power loss	[%]	0.79	1.9	2.3
Pump system	Motor power	[W]	137	667	1,495
	Motor voltage	[V EC]	62	88	121
	Motor current	[A]	2.2	7.6	12
	Motor speed	[rpm]	2,025	2,400	3,010
	Flow rate	[m³/h]	0	6.2	11
	Efficiency	[%]	0	50	53

*STC: Standard test conditions for photovoltaic modules, 1000 W/m² solar irradiance, 25 °C cell temperature

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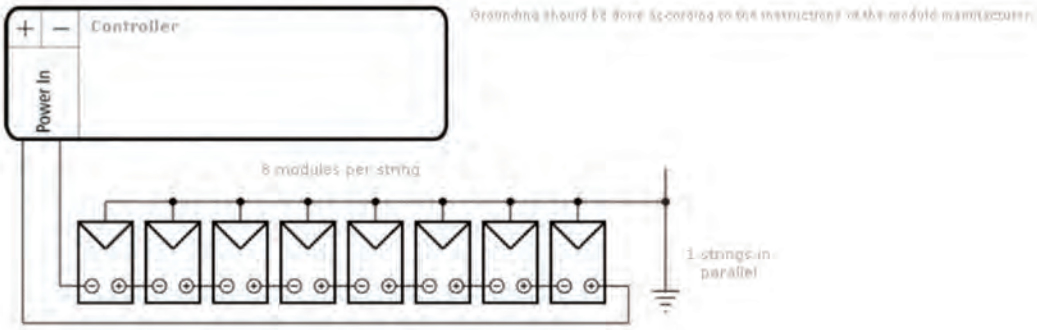
Solar pumping project

Wiring diagram



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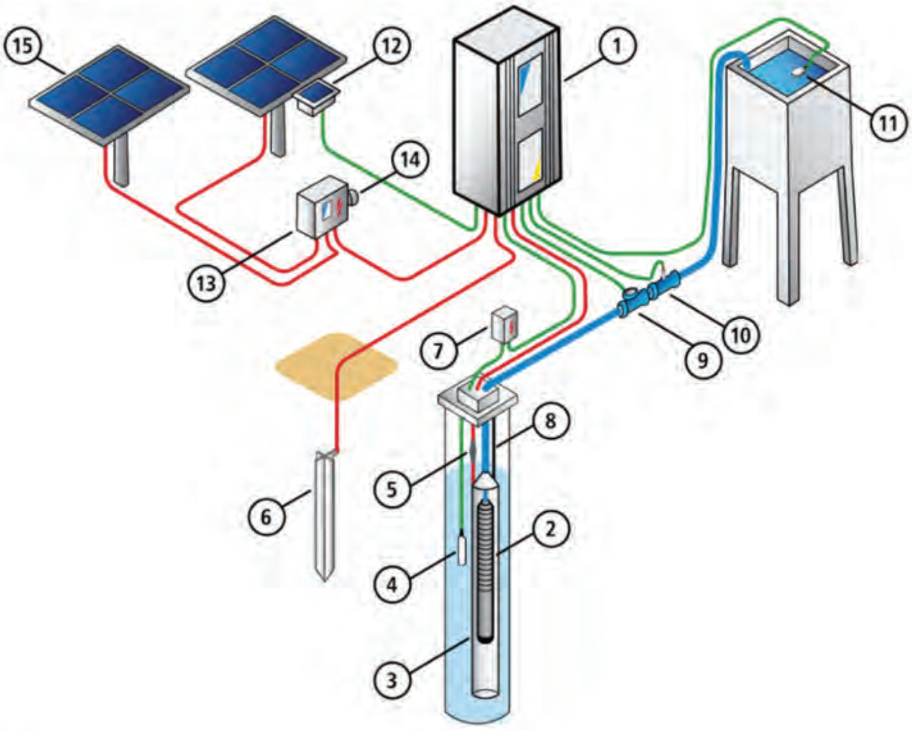
DESIGN 20M 40M3

Solar pumping project

System Layout



1: PS Controller	**11:** Float Switch
2: Submersible Pump	**12:** Sun Switch
3: Stilling Tube	**13:** PV Disconnect
4: Well Probe	**14:** Lightning Surge Protector
5: Cable Splice Kit	**15:** PV Generator
6: Grounding Rod	
7: Surge Protector*	
8: Safety Rope	
9: Water Meter	
10: Pressure Sensor	

*It is recommended to install a Surge Protector at each controller sensor input.

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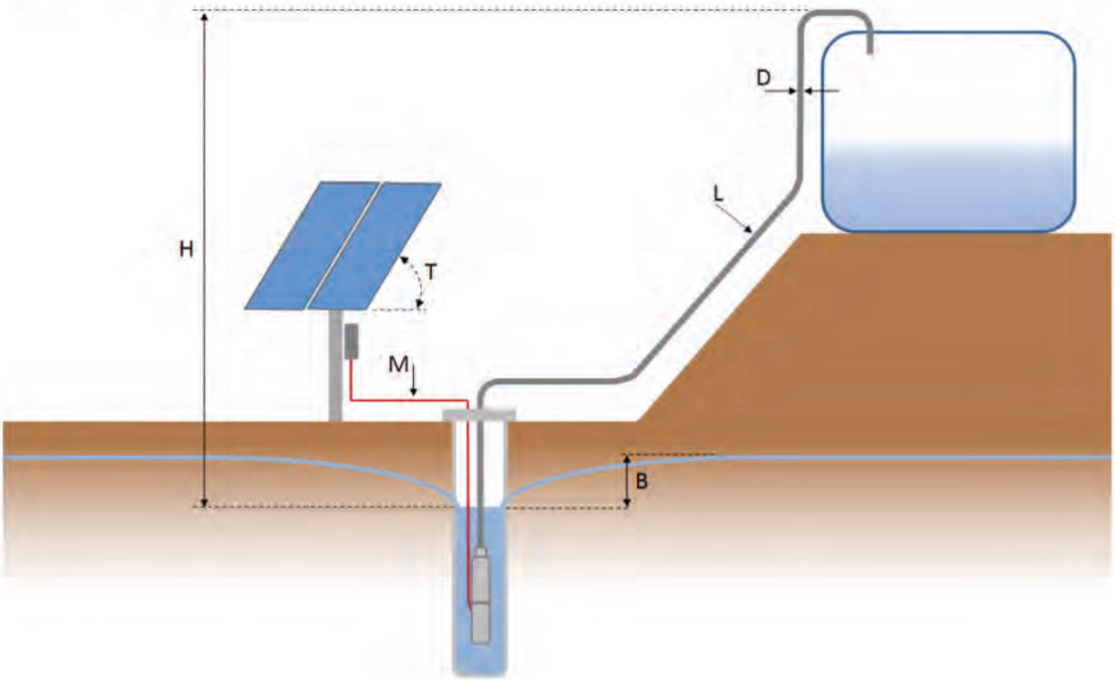
DESIGN 20M 40M3

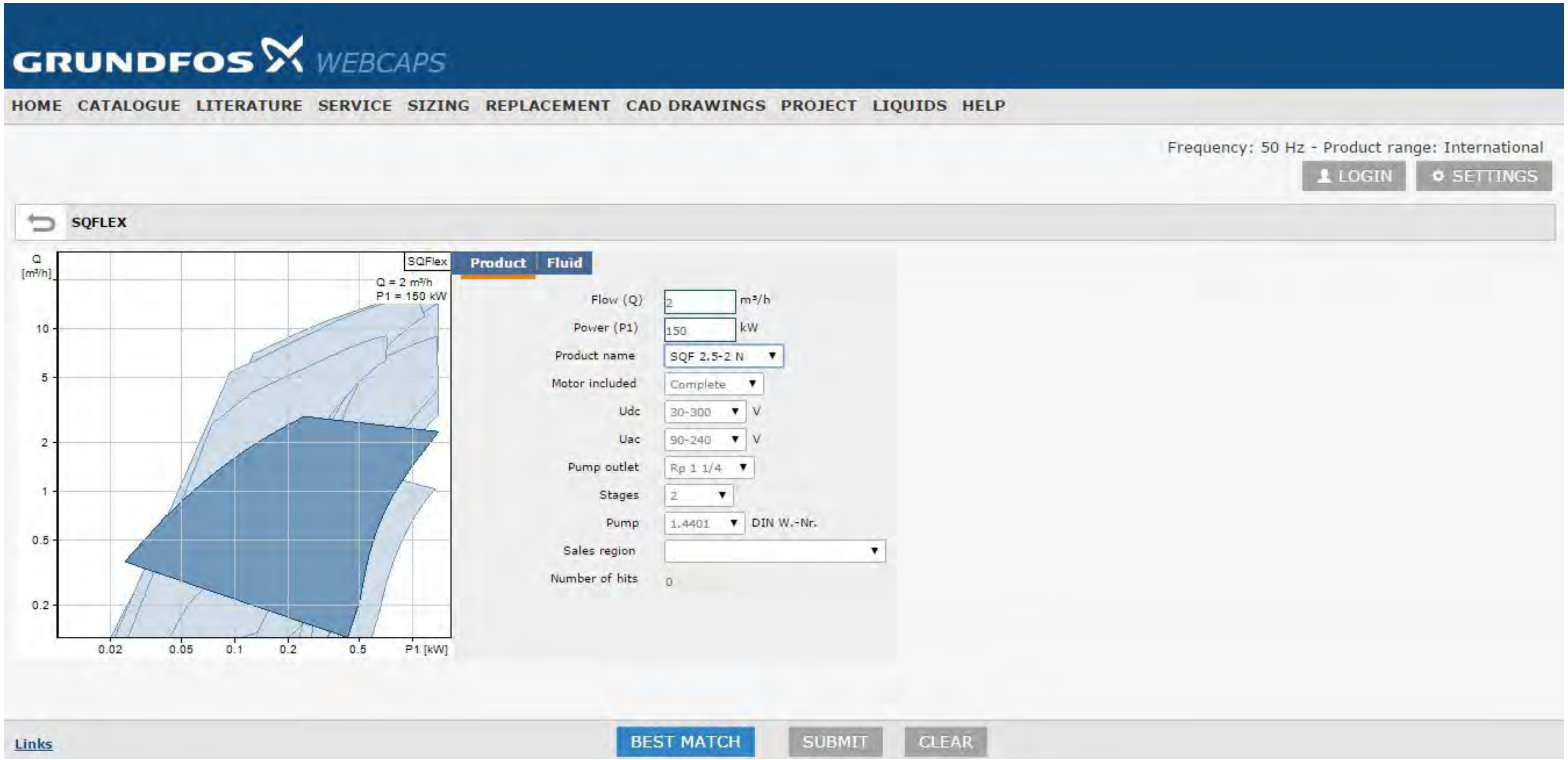
Solar pumping project

Sizing Layout

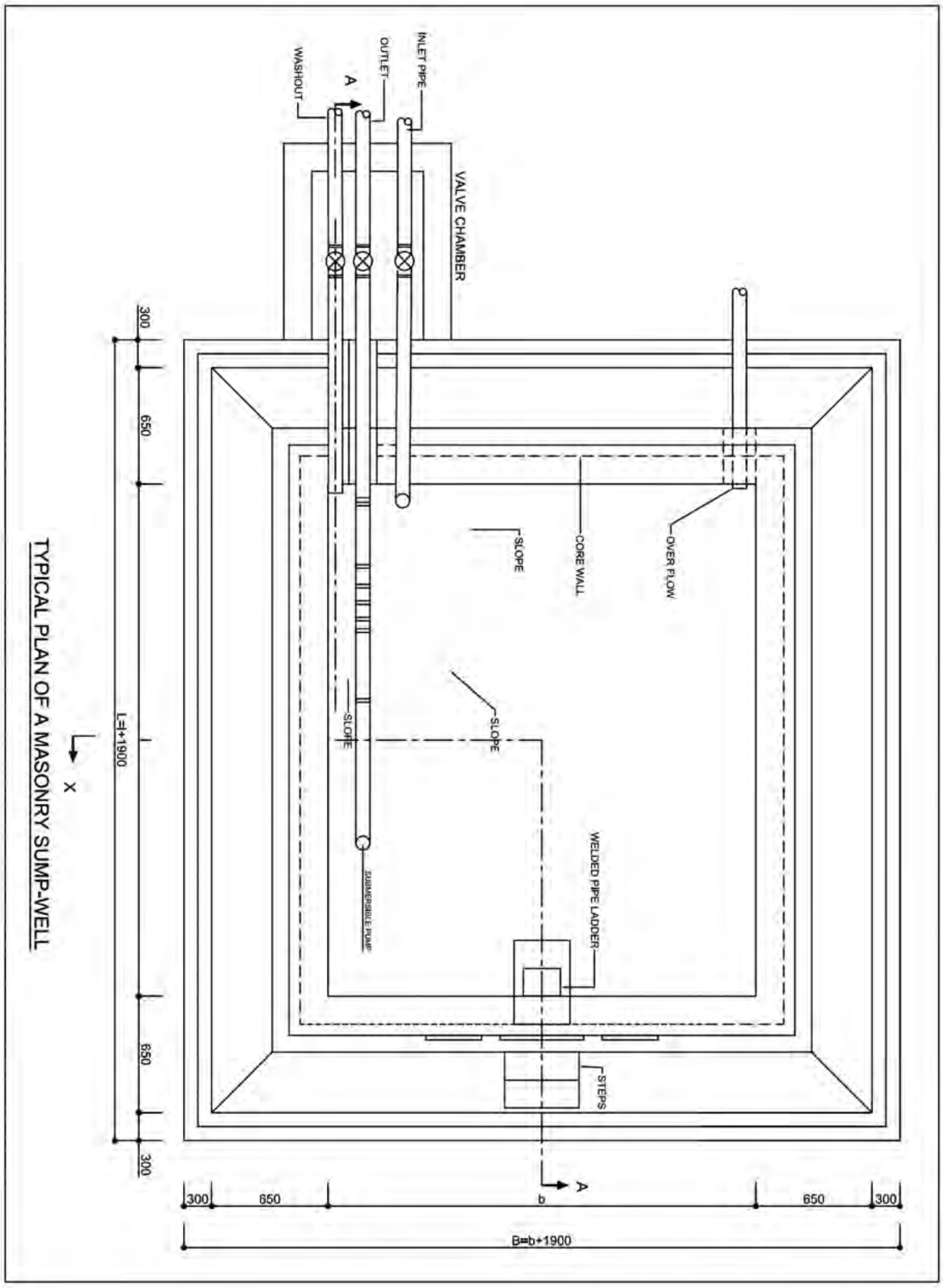


H (Static head):	Vertical height from the dynamic water level to the highest point of delivery.
T (Tilt angle):	Angle of the PV generator surface from the horizontal plane.
M (Motor cable):	The cable between controller and pump unit.
L (Pipeline):	Entire pipeline from the pump outlet to the point of delivery. Ellbows and armatures must be added as an equivalent length of pipeline.
B (Drawdown):	Lowering of water level depending on flow rate and recovery rate of the well.
D (Pipeline inner diameter)	

Example


GRUNDFOS WEBCAPS
HOME CATALOGUE LITERATURE SERVICE SIZING REPLACEMENT CAD DRAWINGS PROJECT LIQUIDS HELP
Frequency: 50 Hz - Product range: International
LOGIN
SETTINGS
SQFLEX
Q [m³/h]
10
5
2
1
0.5
0.2
0.02
0.05
0.1
0.2
0.5
P1 [kW]
SQFlex
Q = 2 m³/h
P1 = 150 kW
Product
Fluid
Flow (Q)
2
m³/h
Power (P1)
150
kW
Product name
SQF 2.5-2 N
Motor included
Complete
Udc
30-300
V
Uac
90-240
V
Pump outlet
Rp 1 1/4
Stages
2
Pump
1.4401
DIN W.-Nr.
Sales region
Number of hits
0
Links
BEST MATCH
SUBMIT
CLEAR

Annex XIV: Drawing of Sump Well



Annex XV: Protection of Solar Power System from Lightning by SOLARINSURE

How to protect your solar power system from lightning

Lightning is a common cause of failures in photovoltaic (PV) and wind-electric systems. A damaging surge can occur from lightning that strikes a long distance from the system, or even between clouds. But most lightning damage is preventable. Here are some of the most cost-effective techniques that are generally accepted by power system installers, based on decades of experience. Follow this advice, and you have a very good chance of avoiding lightning damage to your renewable energy (RE) system.

Get Grounded

Grounding is the most fundamental technique for protection against lightning damage. You can't stop a lightning surge, but you can give it a direct path to ground that bypasses your valuable equipment, and safely discharges the surge into the earth. An electrical path to ground will constantly discharge static electricity that accumulates in an aboveground structure. Often, this prevents the attraction of lightning in the first place.

Lightning arrestors and surge protectors are designed to protect electronic equipment by absorbing electrical surges. However, these devices are not a substitute for good grounding. They function only in conjunction with effective grounding. The grounding system is an

important part of your wiring infrastructure. Install it before or while the power wiring is installed. Otherwise, once the system is working, this important component may never get checked off on the "to do" list.

Step one in grounding is to construct a discharge path to ground by bonding (interconnecting) all the metal structural components and electrical enclosures, such as PV module frames, mounting racks, and wind generator towers. The National Electrical Code (NEC), Article 250 and Article 690.41 through 690.47 specify code-compliant wire sizes, materials, and techniques. Avoid sharp bends in ground wires—high current surges don't like to turn tight corners and can easily jump to nearby wiring. Pay special attention to attachments of copper wire to aluminum structural elements (particularly the PV module frames). Use connectors labeled "AL/CU" and stainless steel fasteners, which reduce the potential for corrosion. The ground wires of both DC and AC circuits will also be connected to this grounding system. (Refer to Code Corner articles on PV array grounding in HP102 and HP103 for more advice.)

Ground Rods

The weakest aspect of many installations is the connection to the earth itself. After all, you can't just bolt a wire to the planet! Instead, you must bury or hammer a rod of conductive, noncorrosive metal (generally copper) into the ground, and make sure most of its surface area contacts conductive (that means moist) soil. This way, when static electricity or a surge comes down the line, the electrons can drain into the ground with minimal resistance.

In a similar way to how a drain field dissipates water, grounding acts to dissipate electrons. If a drainpipe doesn't discharge adequately into the ground, backups occur. When electrons back up, they jump the gap (forming an electrical arc) to your power wiring, through your equipment, and only then to ground.

To prevent this, install one or more 8-foot-long (2.4 m), 5/8-inch (16 mm) copper-plated ground rods, preferably in moist earth. A single rod is usually not sufficient, especially in dry ground. In areas where the ground gets extremely dry, install several rods, spacing them at least 6 feet (3 m) apart and connecting them together with bare copper wire, buried. An alternate approach is to bury #6 (13 mm^2), double #8 (8 mm^2), or larger bare copper wire in a trench at least 100 feet (30 m) long. (The bare copper ground wire also can be run along the bottom of a trench that carries water or sewer pipes, or other electrical wires.) Or, cut the ground wire in half and spread it in two directions. Connect one end of each buried wire to the grounding system.

Try to route part of the system into wetter areas, like where a roof drains or where plants are to be watered. If there is steel well-casing nearby, you can use it as a ground rod (make a strong, bolted connection to the casing).

In moist climates, the concrete footers of a ground- or pole-mounted array, or a wind generator tower, or ground rods encased in concrete will not provide ideal grounding. In these locations, concrete will typically be less conductive than the moist soil surrounding the footings. If this is the case, install a ground rod in earth next to the concrete at the base of an array, or at the base of your wind generator tower and at each guy wire anchor, then connect them all together with bare, buried wire.

In dry or arid climates, the opposite is often true— concrete footings may have a higher moisture content than the surrounding soil, and offer an economical opportunity for grounding. If 20-foot-long (or longer) rebar is to be embedded in concrete, the rebar itself can serve as a

ground rod. (Note: This must be planned before the concrete is poured.) This method of grounding is common in dry locations, and is described in the NEC, Article 250.52 (A3), “Concrete-Encased Electrode.”

If you are unsure of the best grounding method for your location, talk with your electrical inspector during the design phase of your system. You cannot have too much grounding. In a dry location, use every opportunity to install redundant ground rods, buried wire, etc. To avoid corrosion, use only approved hardware for making connections to ground rods. Use copper split-bolts to splice ground wires reliably.

Grounding Power Circuits

For building wiring, the NEC requires one side of a DC power system to be connected—or “bonded”—to ground. The AC portion of such a system must also be grounded in the conventional manner of any grid-connected system. (This is true in the United States. In other countries, ungrounded power circuits are the norm.) Grounding the power system is required for a modern home system in the United States. It is essential that the DC negative and the AC neutral are bonded to ground at only one point in their respective systems, and both to the same point in the grounding system. This is done at the central power panel.

Producers of some single-purpose, stand-alone systems (like solar water pumps and radio repeaters) recommend not grounding the power circuit. Refer to the manufacturer’s instructions for specific recommendations.

Array Wiring & “Twisted Pair” Technique

Array wiring should use minimum lengths of wire, tucked into the metal framework. Positive and negative wires should be of equal length, and be run together whenever possible. This will minimize induction of excessive voltage between the conductors. Metal conduit (grounded) also adds a layer of protection. Bury long outdoor wire runs instead of running them overhead. A wire run of 100 feet(30 m) or more is like an antenna—it will receive surges even from lightning in the clouds. Similar surges can still occur even if the wires are buried, but most installers agree that buried transmission wiring further limits the possibility of lightning damage.

A simple strategy to reduce susceptibility to surges is the “twisted pair” technique, which helps equalize and cancel out any induced voltages between the two or more conductors. It can be difficult to find suitable power cable that is already twisted, so here’s what to do: Lay out a pair of power wires along the ground. Insert a stick between the wires, and twist them together. Every 30 feet (10 m), alternate the direction. (This is much easier than trying to twist the whole distance in one direction.) A power drill can sometimes be used to twist wiring as well, depending on the wire size. Just secure the ends of the wiring into the drill's chuck and let the drill's action twist the cables together. Make sure to run the drill at the lowest possible speed if you try this technique.

The ground wire need not be twisted with the power wires. For burial runs, use bare copper wire; if you use conduit, run the ground wire outside the conduit. The additional earth contact will improve the grounding of the system.

Use twisted-pair cable for any communication or control cables (for example, a float-switch cable for full-tank shutoff of a solar water pump). This smaller gauge wire is readily available in pre-twisted, multiple, or single pair cables. You also can purchase shielded twisted-pair cable, which has a metallic foil surrounding the twisted wires, and typically a separate, bare "drain" wire as well. Ground the cable shield and drain wire at one end only, to eliminate the possibility of creating a ground loop (less direct path to ground) in the wiring.

Additional Lightning Protection

In addition to extensive grounding measures, specialized surge protection devices and (possibly) lightning rods are recommended for sites with any of the following conditions:

- Isolated location on high ground in a severe lightning area
- Dry, rocky, or otherwise poorly conductive soil
- Wire runs longer than 100 feet (30 m)

Lightning Arrestors

Lightning (surge) arrestors are designed to absorb voltage spikes caused by electrical storms (or out-of-spec utility power), and effectively allow the surge to bypass power wiring and your equipment. Surge protectors should be installed at both ends of any long wire run that is connected to any part of your system, including AC lines from an inverter. Arrestors are made for various voltages for both AC and DC. Be sure to use the appropriate arrestors for your application. Many system installers routinely use Delta surge arrestors, which are inexpensive and offer some protection where the threat of lightning is moderate, but these units are no longer UL listed.

PolyPhaser and Transtector arrestors are high quality products for lightning-prone sites and larger installations. These durable units offer robust protection and compatibility with a wide variety of system voltages. Some devices have indicators to display failure modes.

Lightning Rods

"Lightning rods" are static discharge devices that are placed above buildings and solar-electric arrays, and connected to ground. They are meant to prevent the buildup of static charge and eventual ionization of the surrounding atmosphere. They can help prevent a strike, and can provide a path for very high current to ground if a strike does occur. Modern devices are spike-shaped, often with multiple points.

Lighting rods are typically only used at sites that experience extreme electrical storms. If you think your site falls into this category, hire a contractor who has experience in lightning protection. If your system installer is not so qualified, consider consulting with a lightning protection specialist before the system is installed. If possible, select a North American Board of Certified Energy Practitioners (NABCEP) certified PV installer (see Access). Although this certification isn't specific to lightning protection, it can be an indication of an installer's level of overall competence.

Out of Sight, Not Out of Mind

A lot of lightning protection work is buried, and out of sight. To help ensure that it gets done correctly, write it into your contract(s) with your system installer, electrician, excavator, plumber, well driller, or anyone who is doing earthwork that will contain your grounding system.

Annex XVI: Example of Thrust Block Design

Design of Thrust Block:

Design a thrust block for a 100 mm diameter main conveying water at a pressure, p of 10.5kg/ cm^2, at a location where the deviation angle,φ is 600 in a horizontal plane. The subsoil is sandy and has a density,ϒ of 1800 kg/m^3, angle of internal friction Φ = 300 and zero cohesion, c = 0, for sandy soil. Assume velocity of flow, V as 2.00 m/s. Take density of concrete, Dc = 2400.00 kg/m3. Assume soil cover, H = 0.60 m. Take unit weight of water, ω = 1000 kg/m^3.

Design Criteria:

- Factor of Safety should be at least 2.00.
- Minimum surface reinforcement should be not less than 5 kg/ m^2.
- Center to center spacing of bars not exceeding 500mm.

Solution:

1. Calculate Cross Sectional Area of Pipe, A = (π * 102)/4

   = 78.54 cm^2

2. Calculate Horizontal Thrust exerted, P = 2 p A Sin φ/2

   = 2*10.5*78.54*0.50 kg

   = 824.25 kg

Horizontal resistance (Pr), against horizontal thrust, P comprises 3 components: Lateral Resistance of Thrust Block, Lateral Resistance of Soil against the block (i.e. passive earth pressure, Pp) and Lateral Resistance of Soil when the block is free to yield away from the soil mass (i.e. active earth pressure, Pa)

Thrust Block Size Trail:

Let us try a thrust block of 0.90 m*0.90m*0.90m.

3. Lateral resistance of thrust block, μ*W = μ *[Weight of block (Wb)+ Weight of soil (Ws) + Weight of water (Ww)]

3.1 Calculate, Wb = (L*B*H)b*Dc

=0.9*0.90*0.0.90*2400 kg

= 1749.60 kg

3.2 Calculate, Ws = L*B*H *γ

= 0.90*0.90 *0.60*1800 kg

= 874.80 kg

3.3 Calculate, Ww = ω*L*(3.14*D2)/4

=1000* 0.90*(3.14*0.102)/4 kg

= 7.07 kg

W = (1749.6 +874.80 +7.07) kg

= 2631.47 kg.

Coefficient of frictional resistance, μ = 0.30

Lateral Resistance of Block W*μ = 0.30*2631.47 kg

= 789.44 kg

4. Calculate, Passive Resistance of Soil ,Pp

Coefficient of passive resistance, kp = (1+ sin φ)/(1-sin φ)

= (1 + sin 300)/ (1 - sin 300)

= 3

Pp = kp*γ*H2*L/2

= 3*1800*0.602*0.90/2 kg

= 874.8 kg

5. Calculate Active Earth Pressure, Pa

Coefficient of Active earth pressure, ka = (1- sin φ)/(1+sin φ)

= (1 - sin 300)/ (1 + sin 300)

Pa = ka*γ*H - 2 *c* ka 0.50, c = 0,

=1/3*1800*0.60 kg

= 360 kg.

6. Total Resistance, Pr = W*μ + Pp + Pa

= (789.44 +874.8 + 360) kg

= 2024.24 kg

7. Calculate Factor of Safety, f = Pr/ P

= 2024.24/824.25

= 2.45

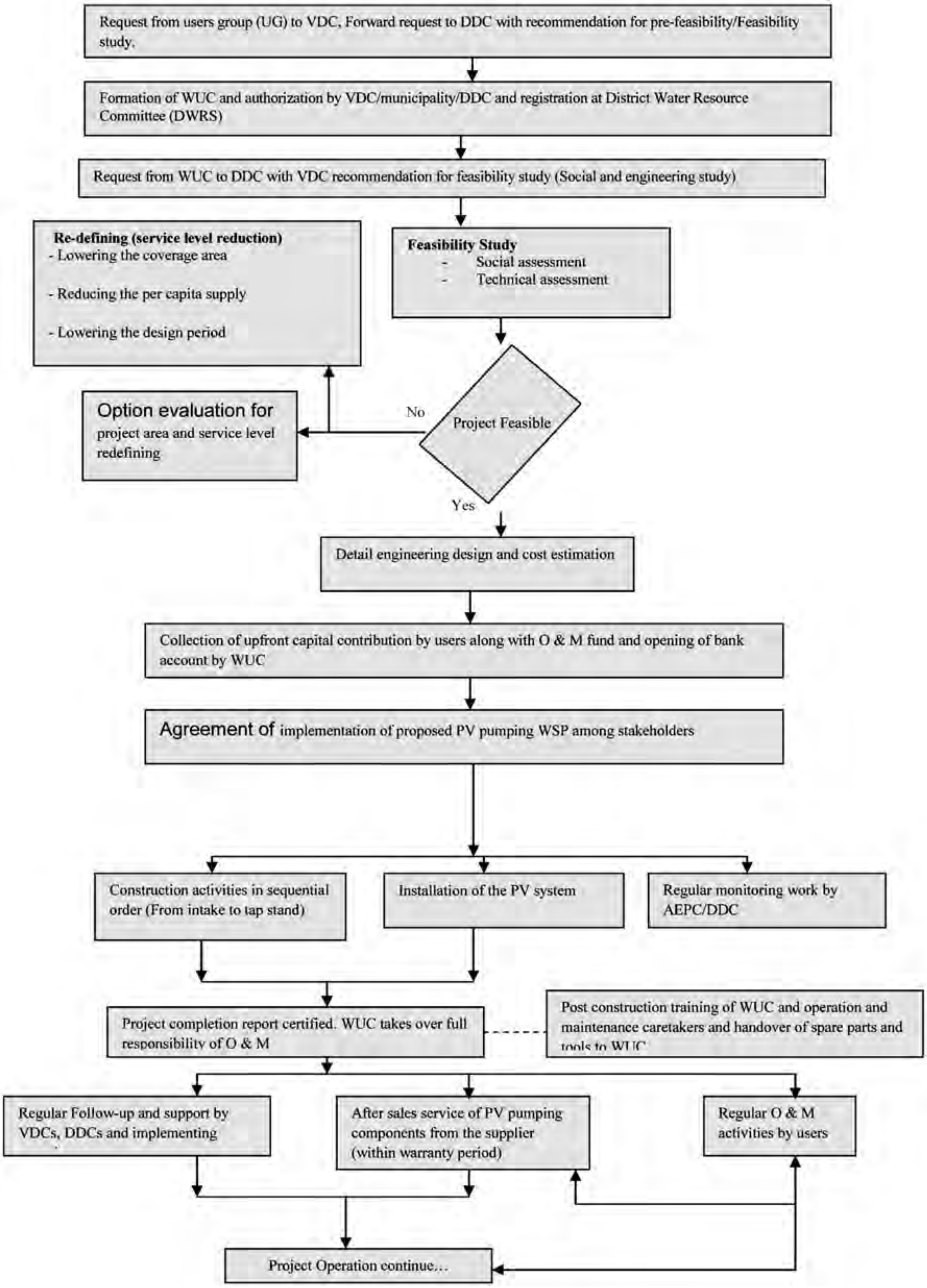
Since, Factor of Safety 2.45 is greater than minimum factor of safety 2, the block size (0.90*0.*90*0.90) m is acceptable.

If factor of safety is less than 2 it can be increased by increasing block size and vise versa.

8. Provide minimum surface reinforcement 5 kg/m^2 with c/c spacing of bars not exceeding 500 mm.

(Ref.: DESIGN GUIDELINES FOR COMMUNITY BASED GRAVITY FLOW RURAL WATER SUPPLY SCHEMES VOLUME-II: DESIGN CRITERIA by Government of Nepal, Department of Water Supply and Sewerage 2002.)

Annex XVII: Implementation Flow Chart for Community Based Solar PV Pumping Water Supply System



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