	AGRICULTURAL TVET COLLEGE	

MODEL TTLM

SMALL SCALE IRRIGATION DEVELOPMENT LEVEL-IV

Learning Guide- 03

Unit of competency: Identify potential water sources for irrigation Development

Module title: Identifying potential water sources for irrigation Development

LG code: AGR SSI4M 03LO1-LO3

TTLM Code: AGR SSI4 TTLM 1218V1

Nominal duration: 20Hrs

Instruction sheet	Learning guide- 03

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:–

- Plan spring and well development
- Design water harvesting structures
- Construct water harvesting structures

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to –

- Plan spring and well development
- Identify potential areas
- Identify surface water
- Identify ground water using simple methods
- Identify and maintaining water contributors
- Assess ground water and soil moisture
- Plan for degrading land
- Plan type and species of trees for afforestation
- Identify SWC and afforestation techniques
- Identify SWC and water harvesting structures
- Design water harvesting structures
- Delineate and characterizing catchment area.
- Delineate and characterizing seasonal water ways
- Identify proper site for water harvesting
- Choose water harvesting techniques
- Select design principles for the chosen water harvesting techniques
- Prepare design drawings for lay outs and different structures
- Design silt trap to settle and clear off sediments
- Construct water harvesting structures

- Identify type of construction materials and equipment
- Determine human power requirements
- Determine all service and running cost
- Prepare bill of quantity
- Conduct land leveling activities
- Interpret lay out drawings and construction specifications
- Select appropriate shade & lining materials
- Reduce evaporation based on environmental issues
- Reduce seepage loss

Learning Activities

1. Read the specific objectives of this Learning Guide.
2. Read the information written in the "Information Sheets.
3. Accomplish the "Self-check" at the end of each learning outcomes.
4. Ifyouearnedasatisfactoryevaluationproceedtothenext"InformationSheet".However, if you acting is unsatisfactory, see your teacher for further instructions or go back to the Learning Activity.
5. Submit your accomplished Self-check. This will form part of your training portfolio
6. Follow the steps and procedure list on the operation sheet
7. Do the "LAP test" and Request your teacher to evaluate your performance

Information sheet -1	Plan spring and well development

Introduction

The possibility of supplying as much water to the irrigation area as is needed during each period of the irrigation season depends primarily on the availability of the water at its source. Availability may vary a lot over the year, or even between one year and another. Secondly, the supply depends on the capacity of the facility installed to withdraw the water from the water source. Further, technicians should be aware that water must be available during each week or month of the growing season.

Water for irrigation has to be carried from the river, the reservoir, the lake or the groundwater to the field. This can be done in two different ways:

- By making use of gravity. A simple gravity system can only be used if the water level of the river or reservoir is higher than the level of the fields in the irrigation scheme;
- By using a pump to lift the water above ground level and then let it flow to the fields.
- The tapping of water from a river or reservoir by gravity, and the pumping of water from a river, lake or groundwater are explained briefly.

In each irrigation area there is a demand for water and a supply of water. The demand for water varies over time and depends on the types of crops, crop growth stages and on the climate. While transporting irrigation water from the water source and applying it to the plant roots, a portion of the water is lost through evaporation, leakage from the canals and percolation below the roots of the crop.

1.1. Identifying potential areas

Irrigation potential: refers to irrigation as the process by which water is diverted from a river or pumped from a well and used for the purpose of agricultural production.

The definition of irrigation potential is not straightforward and implies a series of assumptions about:-

- ✓ Irrigation techniques,

- ✓ Investment capacity,
- ✓ National and regional policies,
- ✓ Social, environmental and health aspects and
- ✓ International relationships

However, to assess the information on land and water resources at the river basin level, knowledge of physical irrigation potential is necessary. The area which can potentially be irrigated depends on the physical resources 'soil' and 'water', combined with the irrigation water requirements as determined by the cropping patterns and climate.

1.1.1. Identifying surface water

Surface water is water on the surface of the planet such as in a river, lake, wetland, or ocean. It can be contrasted with groundwater and atmospheric water.

Non-saline surface water uses is replenished by precipitation and by recruitment from ground-water. It is lost through evaporation, seepage into the ground where it becomes ground-water, used by plants for transpiration, extracted by mankind for agriculture, living, industry etc. or discharged to the sea where it becomes saline.

Surface waters sources

Rivers: A **river** is a natural flowing watercourse, usually freshwater, flowing towards an ocean, sea, lake or another river. In some cases a river flows into the ground and becomes dry at the end of its course without reaching another body of water. Small rivers can be referred to using names such as stream, creek, brook, rivulet, and rill. There are no official definitions for the generic term river as applied to geographic features, although in some countries or communities a stream is defined by its size. Rivers are part of the hydrological cycle; water generally collects in a river from precipitation through a drainage basin from surface run off and other sources such as groundwater recharge, springs, and the release of stored water in natural ice and snow packs (e.g., from glaciers). Pota mology is the scientific study of rivers, while limnology is the study of inland waters in general. Most of the major cities of the world are situated on the banks of rivers, as they are, or were, used as a source of water, for obtaining food, for transport, as borders, as a defensive measure, as a source of hydropower to drive machinery, for bathing, and as a means of disposing of waste.

Fig 1.1 river water source

2. Reservoirs: A reservoir (from French *réservoir* – a "tank") is a storage space for fluids. These fluids may be water, hydrocarbons or gas. A reservoir usually means an enlarged natural or artificial lake, storage pond or impoundment created using a dam or lock to store water. Reservoirs can be created by controlling a stream that drains an existing body of water. They can also be constructed in river valleys using a dam. Alternately, a reservoir can be built by excavating flat ground or constructing retaining walls and levees. *Tank reservoirs* store liquids or gases in storage tanks that may be elevated, at grade level, or buried. Tank reservoirs for water are also called cisterns. Underground reservoirs are used to store liquids, principally either water or petroleum, below ground.

Fig 1.2 lakes and reservoir source

2. Lakes

A **lake** is an area filled with water, localized in a basin, that is surrounded by land, apart from any river or other outlet that serves to feed or drain the lake. Lakes lie on land and are not part of the ocean, and therefore are distinct from lagoons, and are also larger and deeper than ponds, though there are no official or scientific definitions.[2] Lakes can be contrasted with rivers or streams, which are usually flowing. Most lakes are fed and drained by rivers and streams. Natural lakes are generally found in mountainous areas, rift zones, and areas with ongoing glaciation. Other lakes are found in endorheic basins or along the courses of mature rivers. In some parts of the world there are many lakes because of chaotic drainage patterns left over from the last Ice Age. All lakes are temporary over geologic time scales, as they will slowly fill in with sediments or spill out of the basin containing them. Many lakes are artificial and are constructed for industrial or agricultural use, for hydro-electric power generation or domestic water supply, or for aesthetic or recreational purposes or even for other activities.

3. Wetlands

A **wetland** is a distinct ecosystem that is inundated by water, either permanently or seasonally, where oxygen-free processes prevail. The primary factor that distinguishes wetlands from other land forms or water bodies is the characteristic vegetation of aquatic plants, adapted to the unique hydric soil. Wetlands play a number of functions, including water purification, water storage, processing of carbon and other nutrients, stabilization of shorelines, and support of plants and animals. Wetlands are also considered the most biologically diverse of all ecosystems, serving as home to a wide range of plant and animal life. Whether any individual wetland performs these functions, and the degree to which it performs them, depends on characteristics of that wetland and the lands and waters near it. Methods for rapidly assessing these functions, wetland ecological health, and general wetland condition have been developed in many regions and have contributed to wetland conservation partly by raising public awareness of the functions and the ecosystem services some wetlands provide and the functioning of Ecosystems. According to their topographic and morphological peculiarities and Hydrological regime, lakes can be subdivided in three different ways:

- into lowland, foothill and mountain rivers, depending on relief;
- into large, medium and small, depending on river size;
- Into snow-fed, rain-fed, glacier-fed and groundwater-fed, depending on sources of Supply.

Lakes can be also divided according to their size, the origin of their depressions, their Water regime, degree of river channel stability, water exchange character, water balance Structure, temperature regime, dissolved load, etc. Data on the largest rivers and Reservoirs are cited.

About 3.5 million km2 of the earth are covered with wetlands and mires, or peat lands. The article provides a general classification of peat land

Here are the chief potential sources of water listed in their fairly accurate order of preference based on cost, quality of water, need for equipment and supplies:

1.1.2. Identifying ground water using simple methods

Groundwater is the water present beneath Earth's surface in soil pore spaces and in the fractures of rock formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from and eventually flows to the surface naturally; natural discharge often occurs at springs and seeps, and can form oases or wetlands. Groundwater is also often withdrawn for agricultural, municipal, and industrial use by constructing and operating extraction wells. The study of the distribution and movement of groundwater is hydrogeology, also called groundwater hydrology. Typically, groundwater is thought of as water flowing through shallow aquifers, but, in the technical sense, it can also contain soil moisture, permafrost (frozen soil), immobile water in very low permeability bedrock, and deep geothermal or oil formation water. Groundwater is hypothesized to provide lubrication that can possibly influence the movement of faults.

Spring water : Is a place where water that has been filtered through soil and rock reappears from underground. Is formed when the pressure in an aquifer causes some of the water to flow out at the surface A spring may flow the whole year or only sometimes. This depends on the water getting into the ground all of the time (rain) or only once in a while (snow melting).

A spring often sends water down, along the land. This is how rivers start.

Fig1.3 A natural spring

Types of spring outlets

- *Seepage or filtration spring.*
- *Fracture springs,*
- *Tubular springs*

Flow

Spring discharge, or resurgence, is determined by the spring's recharge basin. Factors that affect the recharge include the size of the area in which groundwater is captured, the amount of precipitation, the size of capture points, and the size of the spring outlet.

Springs have been used for a variety of human needs including drinking water, powering of mills, and navigation, and more recently some have been used for electricity generation.

1. SPRINGS

A spring is a place where underground flows to the earth's surface. Spring water typically moves downhill through soils or through cracks and fissures in the bedrock until the ground's surface intersects the water table. A slow hillside seep or trickle where no visible water flow is observed should not be considered a true spring. Spring water is usually of high potable quality and whenever there is a spring occurring within the vicinity of a community priority of using it should be investigated before opting other alternative sources such as dug wells.

Spring Development

Cleaning the ‘eye’ develops a spring. Surface springs occur where groundwater emerges at the surface because an impervious ground layer prevents further seepage downwards. Spring water is usually feed from sand or gravel water bearing ground formation (aquifer), or a water flow through fissured rock. The main parts of a spring capping are a drain under the lowest natural water level (to avoid overpressure in the aquifer system), a protective structure providing stability and a seal to prevent surface water from leaking in. The drain is usually placed in a gravel pack covered with sand and may lead to a conduit or a reservoir. The structure may be made of concrete or masonry. A screened overflow pipe guarantees that the water can flow freely out of the spring at all times. A fence keeps animals out of the spring area. There are many types of spring capping, ranging from a simple headwall with backfill to more complicated structures.

Springs have traditionally been used by allowing people and livestock direct access to the water and spring site. The result of this practice is that springs can quickly become contaminated with livestock manure and become mud holes from livestock traffic.

The main objective of spring development and protection is to provide improved water quantity and quality for human consumption. Proper spring development involves protecting both the spring and its water quality from environmental damage and contamination, as well as improving access to the water for all its intended uses. Before reaching the surface, spring water is generally considered high quality, depending on the composition of the surrounding soils and bedrock. However, groundwater can become contaminated as it exits the ground's surface. Contamination sources include livestock, wildlife, septic systems and other human interference upslope from the spring outlet.

Before a spring is developed, it is essential to check both the quantity and quality of water because springs are highly susceptible to contamination and seasonal changes in flow rate. Springs must have a continuous flow even during the driest season in order that there will be no interruption of supply during this period. The spring should at least supply an average per capita of 15lit/day for the design population. Springs with low flow rates requires a storage tank to collect and store overnight flows and make it available during peak consumption periods. But in conditions where spring yield cannot satisfy to meet peak demands of the design population, the spring can be used in conjunction with other available options like a storage tank can be incorporated in the spring protection structure. This enables the constant flow from the spring over the full 24 hours to be stored and then utilized to meet the varying demand during the day through a faucet in the structure.

Criteria to be applied

The optimum cases are those where the spring is above the community; then, the system won't require energy (gravity flow) and water points could be placed as close to the community as possible (always depending on budget constraints). These systems are more sustainable, with low cost of execution and Operation and Maintenance.

On the other hand, when springs are located below the community, there are two options:

- To place the water point near by the spring, or,
- Pumping to a tank above the community.

Meanwhile the first option has some advantages in the economical and operation and maintenance aspects, the second one offers better service but higher costs and operation and maintenance requirements, thus requiring a deep study on sustainability of:-

Basic Design Features of Springs

Because each spring site is unique and every community has individual water supply needs, there is not a particular spring box design that will fit all circumstances. The design chosen for any particular project will depend on local conditions, spring yield, available materials and community knowledge and requirements.

Although there are many different designs for spring boxes, they all share common features. Primarily, a spring box is a watertight collection box constructed of concrete and masonry. The idea behind the spring box is to isolate spring water from surface contaminants such as rainwater or surface runoff. All spring boxes should be designed with a heavy, removable cover in order to prevent contamination from rainwater while providing access for disinfection and maintenance. Spring box design should include an overflow pipe that is screened for small animal control. It is also important to provide some measure of erosion prevention upslope from the spring box, one need to provide a diversion ditch capable of diverting surface runoff away from the spring box, and an animal fence should be constructed with reasonable radius around the spring box. This protects the water source from livestock and wildlife contamination, as well as from soil compaction that could lead to reduced yields.

Spring Cupping (Constructing the Spring Box)

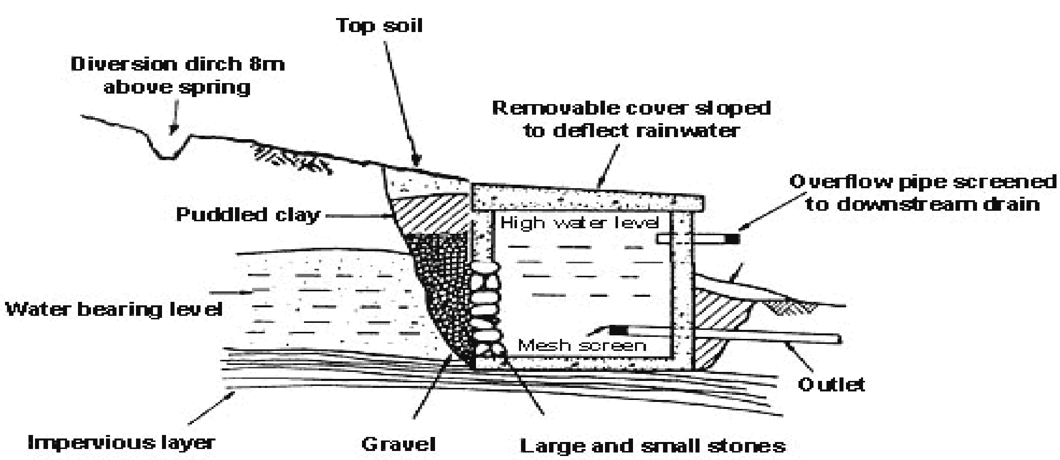
The water must be piped directly from the eye of the spring to prevent any pollution affecting the supply. Gradated filter (stone, gravel and sand) in spring capping is required in order to ensure a better quality of water; installing a mesh in the outlet pipe to avoid problems of blocking in the system (leaves, straw, sand particles, etc.). Overflow pipe placed at the same or lower level of the spring eye is required; in order avoid overpressure in the aquifer.

Different Spring types will have different Cupping options. Some of them are

A-Gravity Springs

If the spring occurs at the base of a slope or hillside, the flow is likely to be gravity driven. Unlike an artesian spring, a gravity spring will most likely have just one impermeable layer (on the bottom). In this case, much less pressure will exist in the system.

Due to the nature of the horizontal flow, and low water pressure, a gravity spring in a hillside will require a spring box with a side entrance for the water. The design will most likely be similar to the structure presented in the illustration below.



Section through a spring tank

Fig 1.4. **Gravity Springs**

B-Seepage Springs

In this case, water will likely be flowing from more than one point. Similar to gravity springs, the flow will result from the force of gravity, and therefore exist almost always at hillsides or the bottom of a slope. Seepage springs have the highest susceptibility for contamination; thus appropriate protection against contamination should be constructed.

A spring box for a seepage spring may be constructed in two ways, depending on the spring characteristics. The ideal design is to dig far enough back into the hill to reach the single source of all of the spring flow. In this case, the seepage spring would simply be a gravity spring covered by a small amount of porous media.

If a single line of water flow cannot be found, it may still be possible to dig far enough back to ensure all of the water flows into the side opening of the spring box, detailed above under ‘Gravity Springs’. However, if the lines of spring flow are too separated and cannot be channeled into one spring box structure, then a different approach is needed. Rather than a spring box, one should construct what is known as a Seep Collection System. Or Possible to construct different collection boxes and combined them in to one other common collection box.

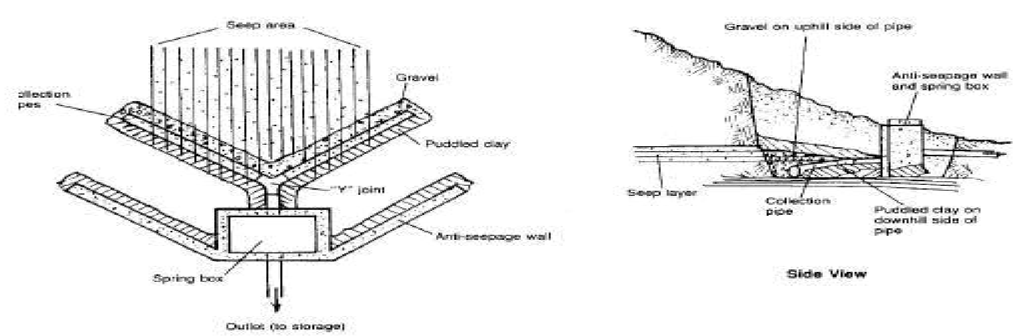


Fig. **1.5 Seepage Springs**

C-Artesian Springs

If the spring is naturally occurring on relatively flat ground, it is likely to be an artesian spring. Water flows vertically out of the ground due to the pressure that is accumulated within a confined aquifer. For this type of spring, a spring box with an open bottom is used.No Gravel filtration media is required for this type of spring. The cover slab of such spring is not supported by filtration media at bottom and therefore it is a re-in forced concrete slab.

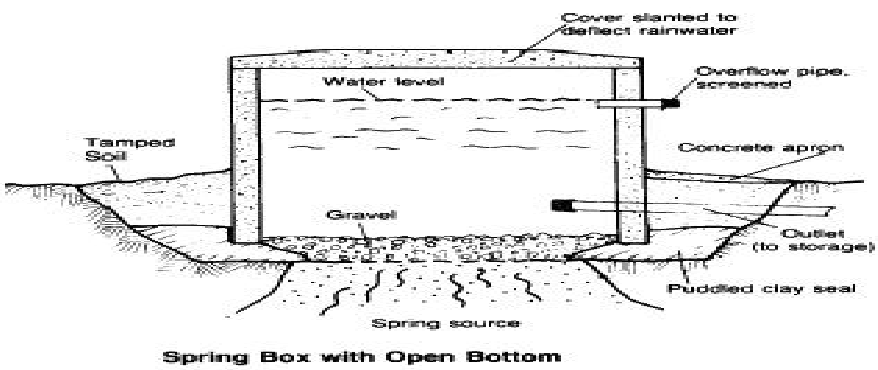


Fig.1.5 C-**Artesian Springs**

1. **Water well**

- ✓ Water 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 an electric submersible pump, a trash pump, a vertical turbine pump, a hand pump or a mechanical pump (e.g. from a water-pumping windmill). It can also be drawn up using containers, such as buckets that are raised mechanically or by hand.
- ✓ Wells can vary greatly in depth, water volume and water quality.

Types of Water well.

There are two broad classes of drilled-well types, based on the type of aquifer the well is in:

- ♠ Shallow or unconfined wells are completed in the uppermost saturated aquifer at that location (the upper unconfined aquifer).

- ♠ Deep or confined wells are sunk through an impermeable stratum into an aquifer that is sandwiched between two impermeable strata. Obviously, a well-constructed for pumping groundwater can be used passively as a monitoring well and a small diameter well can be pumped, but this distinction by use is common.

1.2 Identifying water contributors

Sources of irrigation water can be surface water or ground water. Surface water can be withdrawn from rivers, lakes or reservoirs or non-conventional sources like treated wastewater, desalinated water or drainage water or rain water catchment .while the main contributors of ground water may includes :-

1. Spreading Basins:

This method involves surface flooding of water in basins that are excavated in the existing terrain. For effective recharge highly permeable soils are suitable and maintenance of a layer of water over the highly permeable soil is necessary. When direct discharge is practiced the amount of water entering the aquifer depends on three factors—the infiltration rate, the percolation rate, and the capacity for horizontal water movement.

At the surface of aquifer, however, clogging occurs by deposition of particles carried by water in suspension or in solution, by algae growth, colloidal swelling and soil dispersion, microbial activity, etc. Recharge by spreading basins is most effective where there are layer below the land surface and the aquifer and where clear water is available for recharge.

2. Recharge Pits and Shafts:

Conditions that permit surface flooding methods for artificial recharge are relatively rare. Often lenses of low permeability lie between the land surface and water table. In such situation artificial recharge systems such as pits and shafts could be effective in order to access the dewatered aquifer. The rate of recharge has been being found to increase as the side slope of the pits increased.

Unfiltered runoff water leaves a thin film of sediments on the sides and bottom of the pits, which require maintenance in order to sustain the high recharge rates. Shafts may be circular, rectangular or square cross-section and may be back filled by porous materials.

Excavation may be terminating above the water table. Recharge rates in both shafts and pits may decrease with time due to accumulation of fine-grained materials and the plugging effect brought by microbial activity.

3. Ditches:

A ditch is described as a long narrow trench, with its bottom width less than its depth. A ditch system is designed to suit topographic and geological condition that exists at the given site. A layout for a ditch and flooding recharge project could include a series of trenches running down the topographic slope.

The ditches could terminate in a collection ditch designed to carry away the water that does not infiltrate in order to avoid ponding and to reduce the accumulation of fine materials.

4. Recharge Wells:

Recharge or injection wells are used to directly recharge the deep-water bearing strata. Recharge wells could be dug through the material overlaying the aquifer and if the earth materials are unconsolidated, a screen can be placed in the well in zone of injection.

Recharge wells are suitable only in areas where thick impervious layer exists between the surface of the soil and the aquifer to be replenished. They are also advantageous in areas where land is scarce. A relatively high rate of recharge can be attained by this method. Clogging of the well screen or aquifer may lead to excessive buildup of water level in the recharge well.

5. Harvesting in Cistern from Hill Sides:

In this method construction of small drains along contours of hilly area are done so that the runoff in these drains are collected in a cistern, which is located at the bottom of a hill or a mountain. This water is used for irrigation or for drinking purpose and the water is of good quality.

6. Subsurface Dams:

Ground water moves from higher-pressure head to lower one. This will help in semi-arid zone regions especially in upper reaches where the ground water velocity is high. By exploiting more ground water in upper reaches more surface water can be utilized indirectly, thereby reducing inflow into lower reaches of supply. Ground water is stored either in natural aquifer materials in sub-surface dams or in artificial sand storage dam.

7. Farm Ponds:

These are traditional structures in rain water harvesting. Farm ponds are small storage structures collecting and storing runoff waste for drinking as well as irrigation purposes. As per the method of construction and their suitability for different topographic conditions farm ponds are classified into three categories such as excavated farm ponds suited for flat topography, embankment ponds suited for hilly and ragged terrains and excavated cum embankment type ponds.

Selection of location of farm ponds depend on several factors such as rainfall, land topography, soil type, texture, permeability, water holding capacity, land-use pattern, etc.

8. Historical Large Well across Streamlet:

If any historical wells are located near the streamlet, then allow the water into the well from streamlet by connecting drains. In this case the historical wells act as a recharge well so that ground water can be improved.

9. Check Dams: Check dams are small barriers built across the direction of water flow on shallow river and streams for the purpose of rain water harvesting. The small dams retain excess water flow during monsoon rains in a small catchment area behind the structure.

Pressures created in the catchments area send the impounded water into the ground. The major environmental benefit is the replenishment of nearby ground water reserves and wells. The most common case of check dams is to decrease the slope and velocity of a stream to control erosion.

Classification

Water well types.

There are two broad classes of drilled-well types, based on the type of aquifer the well is in:

- Shallow or unconfined wells are completed in the uppermost saturated aquifer at that location (the upper unconfined aquifer).
- Deep or confined wells are sunk through an impermeable stratum into an aquifer that is sandwiched between two impermeable strata. Obviously, a well-constructed for pumping groundwater can be used passively as a monitoring well and a small diameter well can be pumped, but this distinction by use is common.

Environmental problems

A risk with the placement of water wells is soil salinization. This problem occurs when the water table of the soil begins to drop and salt begins to accumulate as the soil begins to dry out. Another environmental problem that is very prevalent in water well drilling is the potential for methane to seep through.

1.3 Identifying Potential water ways

Water ways

- Are Systems in which irrigation water is conveyed from source to the required field of irrigation purpose?
- It consists of diversion structures (diverts water from the source to the canal system) such as weirs, barrage, intake structures and canal system (main canal, sub main canal, distribution canal etc) and pump system for pressurized irrigation systems.

Channels

- ✓ Are the irrigation structure or hydraulic structures through which irrigation water flows into required areas.
- ✓ It is defined as opened or closed conduit structure through which water flow. Example, canal (open) and pipe (closed).

In an irrigation scheme, water is taken from a water source, passes through a network of irrigation canals and is delivered to the farmers' fields by using the following field delivery systems

- Breach
- Gated intake
- Siphons
- Spiles
- Pumping

A breach is a temporary opening in the embankment of the field channel, made by a farmer whose field is to be irrigated

- involves no capital cost, but it has disadvantages:
- frequent opening and closing of breaches weakens the embankment;
- opening and closing a breach changes the cross-sectional shape of the field channel;
- there is no discharge control

A gated intake structure is made of wood, masonry or concrete, and is equipped with a gate (like a door to a room)

- It enables the farmer to control the water inflow, but, in comparison with a breach, it is expensive


Fig 1.6 **gated intake**

A siphon is a curved pipe, often made of a plastic such as PVC.

- The pipe or tube is filled with water and laid over the channel bank at every irrigation
- Good water flow control is possible by changing the number of siphons, the diameter of the siphons or both
- Disadvantage is the price of the pipes.
- Also, for efficient operation, the water **level in the field channel needs to be some 10 cm** above the field.

Fig 1.7 siphon tube

A Spile is a short pipe, commonly made of a hard plastic such as PVC, but clay, wooden (Bamboo) pipes are also used.

- The Spile pipes are **buried in the canal embankment** and water flow through this small pipe
- Good water **intake control can be obtained** either
  - ✓ by adjusting the water level in the field channel,
  - ✓ by use of a water-level regulator, until it is above or below the opening of the Spiles
  - ✓ by closing off individual Spiles with a plug or lid
  - ✓ by a combination of the two methods
- Disadvantages
  - ✓ Can become blocked with mud or plant debris,
  - ✓ Pipes can be expensive.
  - ✓

Fig 1.6 **bamboo**

FIg.1.8 Spile is

Pumping

- Not advisable method of water intake to field is by pumping
- Justified only if the field to be irrigated is at higher place than the canal
- For efficient operation of the pump, the water depth and discharge in the field channel must be comparatively large than all other methods

Fig 1.9 pumping system

Selection of method

- ✓ The water level in the field canal
- ✓ Discharge control
- ✓ Irrigation Method
- ✓ Irrigation schedule
- ✓ Field location

1. **The water level in the field canal**

- When the **water level in the field channel is only slightly higher** (up to 5 cm) than the level of the field (gated intake is good)
    - Breaches used
- If the difference in water level is small to get required volume of water in the field
    - either a large opening through which water is delivered
    - a long time of delivery
- If the difference in water level is small, **siphon will not work**
- If difference in water level is large (say 15 cm) then breach is not recommended, since it will erode canal bank

2. Discharge control

Not only the difference between the water levels between canal and field, but also the **size of the intake opening determines the flow to field**

- The larger the opening, the larger the flow
- Control is almost impossible in breaches
- Control is good when gated intake
- Siphons or Spiles - number can be adjusted or different diameters used according to the discharge required

3. Irrigation method

The mode of water intake should match the irrigation method - whether basin, border or furrow

- Border or basin Irrigation
    - ✓ The water can enter the field at one point.
    - ✓ practiced by using breach or gate intakes,
- Furrow irrigation
    - ✓ Requires more delivery points, as each furrow should have its own delivery point.
    - ✓ Needs the use of Spiles or siphons.

4. Irrigation schedule

Two factors for considering the schedule

a)What is the **duration and frequency of water supply** to the field

- If duration of water delivery to the field is short, gated intake preferred
- Breaches requires some time to open, frequent opening will degrade the bund
- Siphon requires time to get started
- Spile can be used for furrows if time is short

b) How many fields are supplied or are there two or more field to be supplied from one intake

- If more than one uses, breach cannot control delivery for equal discharge
- Levels of field is not equal, hence gated supply not useful
- To ensure equal water intake, siphons or spiles are recommended because the total discharge is determined by the number and diameter of tubes

5. Field location

- If the field to be irrigated is situated in the upper part of a channel, then the use of a breach should be avoided, because
  - breaches can seriously damage the shape of a channel
  - affect the delivery of water to farmers downstream
- When a large opening is needed, a gated intake is much more practical (at head end)

1.4. Checking soil moisture status and level of ground water

Soil moisture is the water that is above the water table extending down from the ground surface is the soil zone or root zone which is defined as being the depth of over burden that is penetrated by the root of vegetation.

Groundwater has an important role in the environment: it replenishes streams, rivers, and wetlands and helps to support wildlife habitat; it is used as primary source of drinking water and also in agricultural and industrial activities. Around the world, groundwater resources are under increasing pressure caused by the intensification of human activities and other factors such as climate changes. Reductions in groundwater stores have implications for the water cycle because groundwater supplies the base flow in many rivers and it supports Evapotranspiration in high water table regions. Reductions in groundwater storage also have major implications for water quality because the salinity of the extracted water frequently increases as the volume of the reservoir decreases. Groundwater resources need to be carefully protected because in many regions, withdrawal rates exceed recharge rates. Once modified or contaminated, groundwater can be very costly and difficult to restore.

In fact the purposes of groundwater monitoring are:

1. collecting, processing and analysing the data as a baseline for assessment of the current state, anticipating changes and forecasting trends in groundwater quantity and quality due to natural processes and human impacts in time and space;
2. Providing information for improvements in the planning, policy and management of groundwater resources.

Groundwater monitoring is a continuous, methodologically and technically standardized process involving in situ, satellite and airborne observations and laboratory analysis of quality variables. In fact a groundwater monitoring programme includes both groundwater quantity (e.g. groundwater level and recharge rates) and quality monitoring (analysis of selected physical and chemical variables) networks. Groundwater monitoring programmes operate at the international, national, regional and local scales: at local scales, groundwater monitoring activities often include a great density of monitoring wells, multilevel groundwater sampling of the unsaturated and saturated zones, high sampling frequency, and analysis of variables chosen; numerical models used on regional scales are valuable to fill in spatial and temporal gaps in in situ monitoring, although their reliability is more uncertain when high quality input data are not available. Satellite observations are now playing an increasingly important role in global groundwater resources assessment and groundwater storage change, but only at lower spatial and temporal resolutions.

All these information types, used synergistically, can yield a consistent picture of the current state of global groundwater resources, so that in the future it will be possible to provide more accurate prediction of variations in groundwater availability.

1. Definitions and units of measurement

Several critical variables must be considered under the heading “groundwater”: groundwater level, groundwater recharge and discharge, well groundwater level and water quality.

Of these, monitoring groundwater levels usually takes priority because it is a direct indicator of groundwater supply and withdrawal rates.

- ***Groundwater level (m):*** defined as the depth or elevation above or below sea level at which the surface of ground water stands. The level of the water table, the upper surface or top of the saturated portion of the soil or bedrock layer that indicates the uppermost extent of groundwater. It can be expressed as a height above a datum, such as sea level, or a depth from the surface.
- ***Groundwater recharges (m/s):*** process that occurs naturally where permeable soil or rock allows water to readily seep into the aquifer. This takes place intermittently during and immediately following periods of rain and snowmelt, which are the principal sources for replenishment of moisture in the soil water system. This depends on the rate and duration of rainfall, the subsequent conditions at the upper land surface boundary, the antecedent soil moisture conditions, the water table depth and the soil type. Monitoring of groundwater recharge allows for estimation of its temporal variability and areal distribution.
- ***Groundwater discharge (m/s)****:* process in which groundwater that enters the terrain in recharge areas leaves the aquifer at discharge points. When the water table intersects the land surface there is a discharge zone. Discharge points typically occur as seepage into wetlands, lakes and streams. Monitoring of natural groundwater discharge (springs, bank seepage and base flow) provides data needed for calculation of groundwater balance and storage.
- ***Well head level (m):*** The elevation of a well top above sea level. A well is an opening in the surface of the earth for the purpose of removing fresh water. Wells represent keyholes to aquifers, which allow groundwater level variations, pressure and quality measurements to be made and thus furnish information from which the health of the aquifer system can be judged. Monitoring wells are located outside of the impact of pollution sources and influence of groundwater abstraction sites on groundwater

system. Monitoring wells serve to observe one aquifer only. Well design should permit separate measurement and testing of individual aquifers.

- ***Water quality*** *is* the composition of constituents dissolved or contained within the water in the functioning of natural processes and human activities. Chemical composition is the most invoked factor in characterizing water quality. Biological, physical, and radiological factors are also considered when discussing water quality.

2. Existing measurements methods and standards

In situ measurements

When holes are drilled they provide unique in-situ data on groundwater resources and the initial test pumping provides key baseline reference information on groundwater quantity and quality.

To determine groundwater elevation above mean sea level, use the following equation:

$$E_W = E - D$$

Where:

Ew = Elevation of water above mean sea level (m) or local datum

E = Elevation above sea level or local datum at point of measurement (m)

D = Depth to water (m)

GROUNDWATER BALANCE EQUATION [C. P. Kumar, National Institute of Hydrology]

The estimation of the groundwater balance of a region requires quantification of all individual inflows to or outflows from a groundwater system and change in groundwater storage over a given time period. The basic concept of water balance is:

Change in storage of the system= Input to - outflow from

(Over a period of time) the system the system

Considering the various inflow and outflow components in a given study area, the groundwater balance equation can be written as:

Rr + Rc + Ri + Rt + Si + Ig = Et + Tp + Se + Og + S

Where:

Rr = recharge from rainfall;

Rc = recharge from canal seepage;

Ri = recharge from field irrigation;

Rt = recharge from tanks;

Si = influent seepage from rivers;

Ig = inflow from other basins;

Et = Evapotranspiration from groundwater

Tp = draft from groundwater

Se = effluent seepage to rivers;

Og = outflow to other basins;

S = change in groundwater storage [C. P. Kumar, National Institute of Hydrology].

Preferably, all elements of the groundwater balance equation should be computed using independent methods. However, it is not always possible to compute all individual components of the groundwater balance equation separately. Sometimes, depending on the problem, some components can be lumped, and account only for their net value in the equation.

Tools of measurement

Different techniques can be used to measure the groundwater level within the piezometer or well, including:

- ***Plopper*****,** where a concave metal casting attached to the graduated tape makes a plopping noise when it hits the groundwater surface.

- ***Electrical sounder,*** where the insulated wires for a pair of electrodes are incorporated into a graduated flat tape. A circuit is completed when the electrodes come into contact with the groundwater surface, which activates a light and/or buzzer
- ***Wetted-tape****,* where a weighted tape that is rubbed with colored chalk is lowered down the piezometer until it is submerged. The water level is indicated by where the chalk has been removed.
- ***Bubble tube***, where a length of plastic tubing marked with depth increments is lowered down the piezometer. Contact with the standing water is distinguished by blowing into the tube and listening for the sound of bubbles.
- ***Automatic water level recorders***, similar to that used in surface water bodies such as pressure transducers, or capacitance probes.

1.5.Checking appropriate practices to identify ground water area and recharge underground water table.

Water table, which is the top most part of groundwater, may be located near or even at land surface and not fixed meaning it fluctuate seasonally.

Two zones can be distinguished in which water occurs in the ground:

a) The unsaturated zone/ Zone of aeration b) The saturated zone

Unsaturated Zone**:** This is also known as zone of aeration or vadose zone. In this zone the soil pores are only partially saturated with water. The space between the land surface and the water table marks the extent of this zone. Further, the zone of aeration has three sub zones: soil water zone, capillary fringe and intermediate zone. The zone below soil water zone (capillary fringe and intermediate zone) are called vadose zone.

The soil water zone lies close to the ground surface in the major root band of the vegetation from which the water is lost to the atmosphere by Evapotranspiration. Capillary fringe on the other hand hold water by capillary action. This zone extends from the water table upwards to the limit of the capillary rise. The intermediate zone lies between the soil water zone and the capillary fringe.

Saturated Zone: Groundwater is the water which occurs in the saturated zone. All earth materials, from soils to rocks have pore spaces although these pores are completely saturated with water below the groundwater table or phreatic surface (GWT).

The vertical distance from the ground surface to the water table varies from place to place - it may be a few feet, or several hundred feet. Generally, the water table is deeper beneath hills and shallower beneath valleys. It is hardly ever flat! In any one place the water table usually rises with increased recharge from precipitation and declines in response to seasonally dry weather, drought, or excessive pumping of ground water. If however the water table is hundreds of feet down, it may take years for the infiltrating water to reach the saturated zone and there will be no seasonal change in water table levels. If ground water is "confined" by overlying impermeable rock formations, the well water levels represent a pressure level and not a water table level.

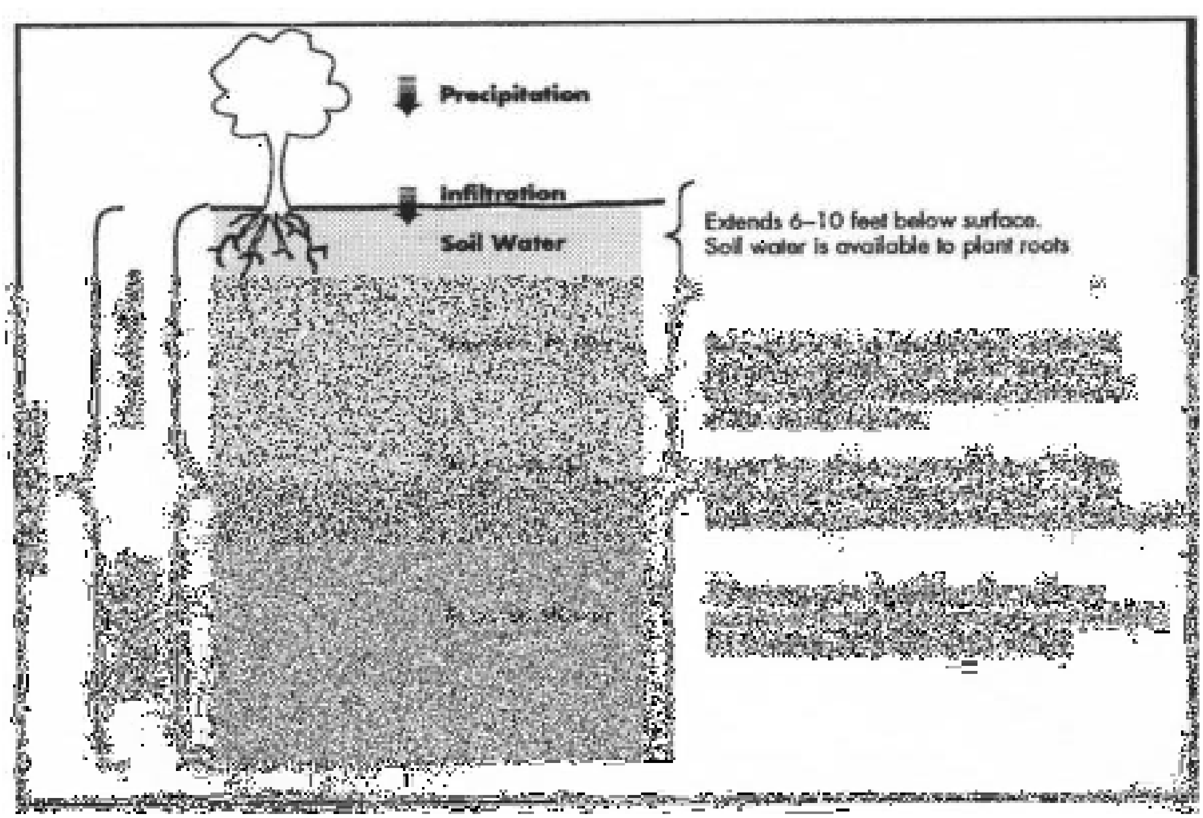


Fig: 2.0: Subsurface water and its contributors

The spaces between soil or sediment particles and cracks in solid rock are called ***voids or pores***. Each sediment and rock type has differences in porosity, (the amount of water a rock formation can hold).

Porosity is expressed as the ratio of pore space to solid material per unit volume. For example, saturated sand may have 30% pore space to 70% solid material, while fractured granite may have 1% pore space to 99% solid rock. The sand is therefore more porous than the fractured granite.

Imagine a cubic foot of granite and a cubic foot of sand with porosity of 1% and 30%. Now add water to each. The granite will "fill up" first because there is less pore space. If it were a real aquifer, the water table level in the granite would rise faster. Similarly, because there is less storage than in the sand, the fractured granite water table would decline more rapidly in response to pumping or drought. Ground water is always on the move, although usually very slowly. The discharge (or outflow) of water from aquifers occurs as part of the natural movement of water in the hydrologic system. Water table levels in aquifers therefore represent the combined effects of rates of recharge and rates of discharge. If pumping of aquifers takes place in excess of recharge then resource use will eventually not be sustainable. Careful monitoring of water levels in wells can show how water table levels change, and well data, with water levels and dates of the measurement are very important for ground water management. For any well data however it is very important to know exactly which rock formations the well penetrates.

There can be more than one aquifer beneath the surface! Water table information, in addition to other information about geology, precipitation and pumping rates are of great value when assessing ground water potential.

Ground water can be recharged by using two methods these are:

By natural method: these methods includes

- Rainfall filtrates into the underground.
- Snow melt filtrates into the underground.
- Stream flow that soaks into the ground and in underlying aquifer.

By artificial method: these methods includes

- ♠ Recharge ponds
- ♠ Injection wells
- ♠ Storm water/drain
- ♠ Irrigation
- ♠ Surface run off

1.6 Identifying appropriate type and species of trees for afforestation of degraded Land.

Afforestation is planting of trees in areas that have not previously held by forests or is the planting of trees in deforested areas.

It is the restocking of existing forests and woodlands which have been depleted, an effect of deforestation.

2.1 Before afforest 2.2 After afforestation

Figure: 2.1. *Areas before and after afforestation*

Trees may be planted:

- ♠ To provide timber and wood pulp;
- ♠ To provide firewood in countries where this is an energy source;
- ♠ To bind soil together and prevent soil erosion and to act as windbreaks.

A sustainable and well-planned afforestation project helps improve soil conservation**,** management and water quality**.** Afforestation projects undertaken without a complete understanding of the surroundings can cause additional environmental damages. For instance, fast-growing trees commonly used in timber plantations consume huge amounts of water, hence depleting water resources around the area. There are also concerns about irreversible changes in the soil caused by exotic species. For example, pine trees are known to turn the soil acidic. The water from the soil eventually trickles down to local streams and water bodies, which, in turn, causes harm to both the water and land ecosystems. In areas of highly degraded land, afforestation is the main solution to retard soil erosion and it also enhances or improve soil water holding capacity or intake rate of the soil.

Self-Check 1	**Written Test**

Name: ___________________________ Date: ________________

Directions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers.

1. Define irrigation Potential areas? (3point)
2. How to identify & maintained contributors of irrigation water resource? (2point)
3. Write the purpose of ground water monitoring (4point)
4. Write definition and measurement unit for the following variables of groundwater": groundwater level, groundwater recharge and discharge, well head level and water quality. (10point)
5. Write the artificial methods used for recharging ground water (4point)
6. Discuss different techniques used to measure underground water level. (4point)
7. What is water table and saturated zone as well as unsaturated zone? (3point)
8. What is afforestation and its purposes (3point)

Note: Satisfactory rating - 16points above Unsatisfactory - below 16 points

You can ask you teacher for the copy of the correct answers.

Information sheet 2	Design water harvesting structure

2.1. Delineating and characterizing catchment area

A catchment or watershed, defined as a land area from which all rainfall would drain by gravity into a common outlet point. In hydrology, the boundary of a catchment is called the hydrological divide. This is the place in a landscape where rainfall will be partitioned into different catchments depending on which side of the divide the rain falls. The size of a catchment is a dynamic phenomenon that is determined by the position of the outlet point. If the outlet point is moved further downstream, the catchment size increases. When this point is finally located at the entrance to the ocean or inland water body, the catchment above that point is regarded as a drainage basin. Catchments and drainage basins do not normally follow village, district, regional or country borders. A basin is normally divided into several catchments that are in turn divided into several sub-catchments (Figure 13).

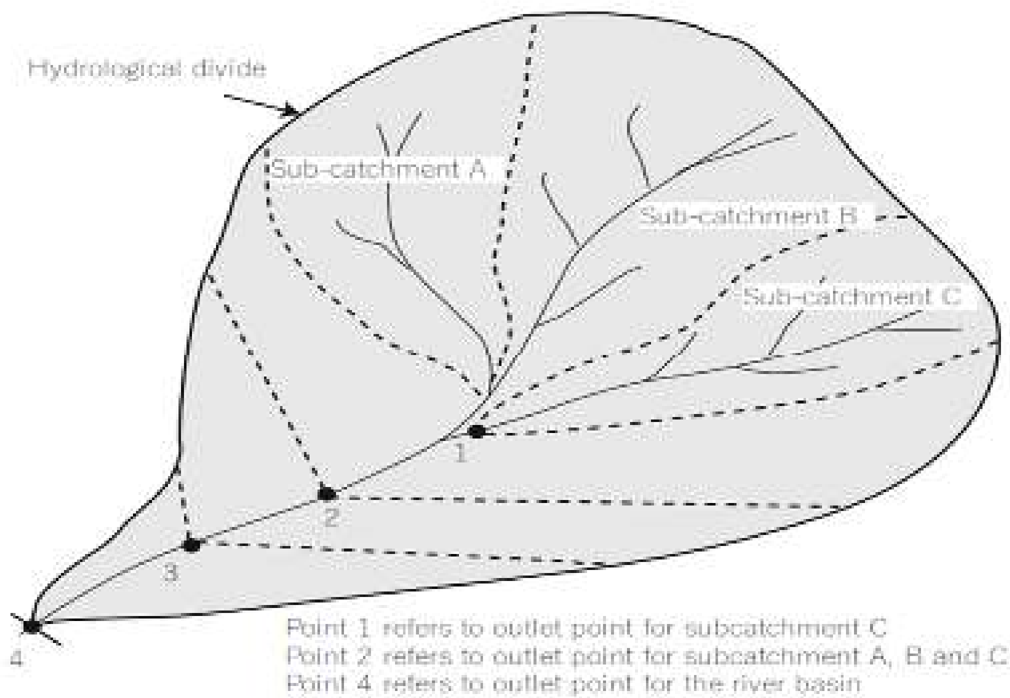
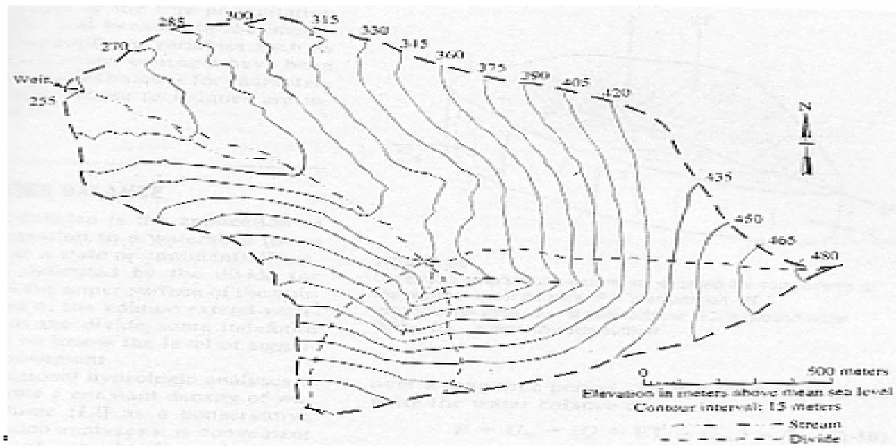


Figure 3.1 an example of a river basin showing associated catchments

Delineation of watersheds is of fundamental importance because the characteristics of the drainage basin control the paths and rates of movement of water to the outlet and the magnitude and timing of outputs via all modes: stream-flow, ground-water outflow, and evapotra transpiration. In most regions, at least a large proportion of the water passing through the stream cross section at the watershed outlet originated as precipitation on the drainage area.



(Figure 2.2). This section discusses the concept of water balance in relation to a given catchment.

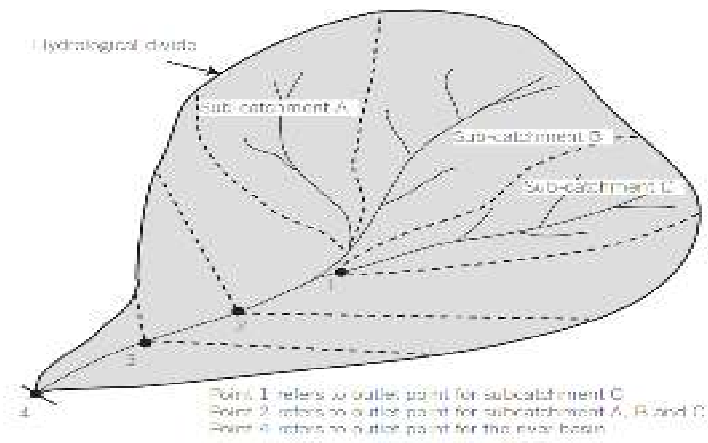


Figure 2.2 *An example of a river basin showing associated catchments.*

Fig 3.2 example of a river basin showing associated catchment

(Figure 2.2). This section discusses the concept of water balance in relation to a given catchment.

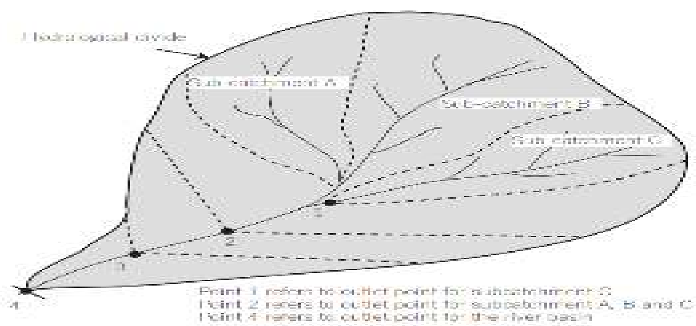


Figure 2.2 *An example of a river basin showing associated catchments.*

Fig.3.3. example of watershed delineation (manually).

The location of the stream cross section that defines the watershed is determined by the purpose of analysis. Hydrologists are most often interested in delineating watersheds above stream gauging stations or above points at which some water resource activity takes place in order to determine the region contributing stream flow.

Watershed Delineation

The conventional manual method of watershed delineation requires a topographic Map (or stereoscopically viewed aerial photographs). To trace the divide, start at the location of chosen stream cross-section. Then draw the line away from the left or right bank, maintaining it always at right angles to the contour lines. Continue the line until its trend is generally opposite to the direction in which it began and is generally above the headwaters of the stream network. Then return to starting point and trace the divide from the other bank, eventually connecting with the first line.

Frequently visual inspection of the contour pattern is required as the divide is traced out to ensure that an imaginary drop of water falling stream ward of the divide would, if the ground surface were imagined to be impermeable, flow down slope and eventually enter the stream network upstream of the starting point. A divide can never cross stream. The lowest point in a drainage basin is always the basin outlet-that is starting point for the delineation. The highest point is usually, but not necessarily, on the divide.

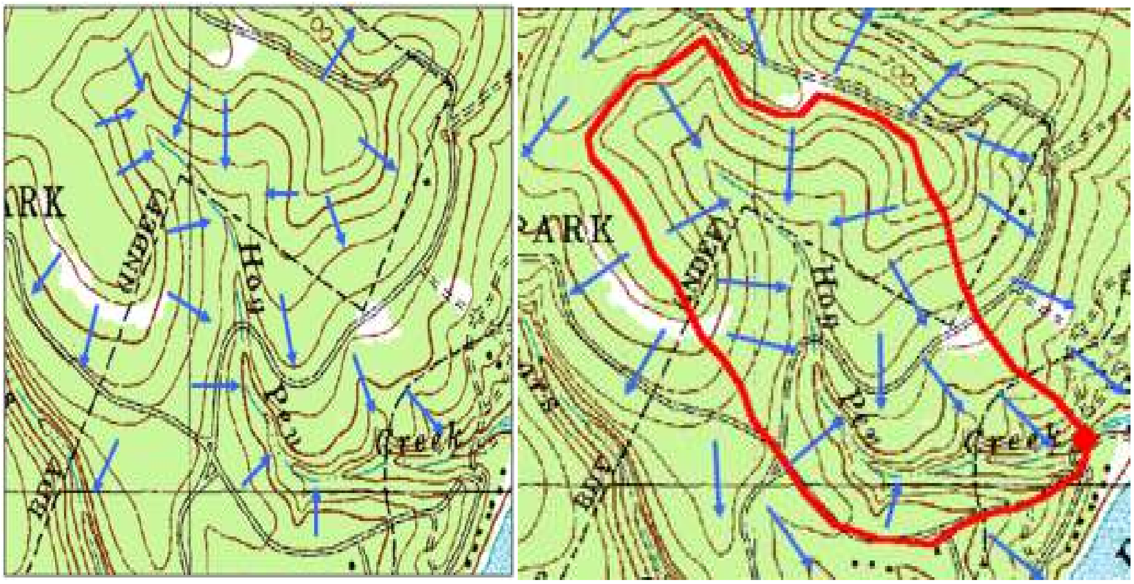


Fig.3.4. Example of manual watershed delineation.

The automated approach to watershed delineation allows the concomitant on watershed characteristics that could previously be obtained only by very tedious manual methods. The automated watershed delineation can be done with the aid of GIS and digital elevation model (DEM) & other GIS layer such as top map as an input.

Catchment/watershed characteristics

A catchment is characterized by its various features. Some of these features are explained below.

Watershed Geomorphology

Watershed geomorphology refers to the physical characteristics of the watershed. Certain physical properties of watersheds significantly affect the characteristics of runoff and as such are of great interest in hydrologic analyses.

The principal watershed characteristics are:

Area of the watershed: The area of watershed is also known as the drainage area and it is the most important watershed characteristic for hydrologic analysis. It reflects the volume of water that can be generated from a rainfall. Thus the drainage area is required as input to models ranging from simple linear prediction equations to complex computer models.

Length of watershed: Conceptually this is the distance traveled by the surface drainage and sometimes more appropriately labeled as hydrologic length. This length is usually used in computing a time parameter, which is a measure of the travel time of water through a watershed.

The watershed length is therefore measured along the principal flow path from the watershed outlet to the basin boundary. Since the channel does not extend up to the basin boundary, it is necessary to extend a line from the end of the channel to the basin boundary. The measurement follows a path where the greatest volume of water would generally travel.

Slope of watershed: Watershed slope affects the momentum of runoff. Both watershed and channel slope may be of interest. Watershed slope reflects the rate of change of elevation with respect to distance along the principal flow path. It is usually calculated as the elevation difference between the endpoints of the main flow path divided by the length. The elevation difference may not necessarily be the maximum elevation difference within the watershed since the point of highest elevation may occur along a side boundary of the watershed rather than at the end of the principal flow path.

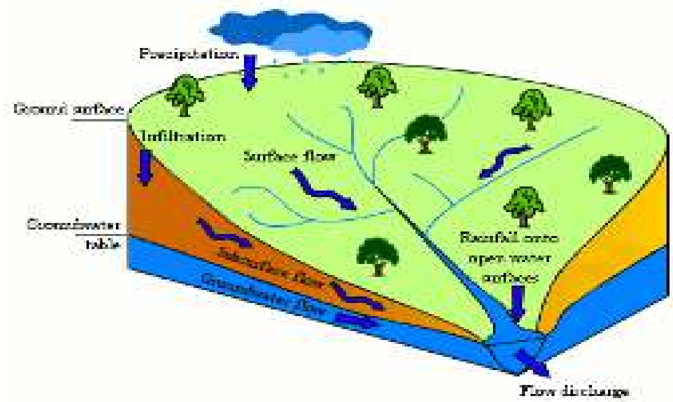


Fig.3.5. Watershed boundary and flow components

Shape of Watershed

Watersheds have an infinite variety of shapes, and the shape supposedly reflects the way that runoff will "bunch up" at the outlet. A circular watershed would result in runoff from various parts of the watershed reaching the outlet at the same time. An elliptical watershed having the outlet at one end of the major axis and having the same area as the circular watershed would cause the runoff to be spread out over time, thus producing a smaller flood peak than that of the circular watershed.

A number of watershed parameters have been developed to reflect basin shape. Following are few typical parameters:

1. Length to the centroid of area (L_{ca}):

The distance measured along the main channel from the basin outlet to the point on the main channel opposite the center of area (centroid).

2. Shape Factor (L_l)

$$L_l = (LL_{ca})^{\alpha}$$

Where L is the length of the watershed (α = 0.3 for length measurements in miles)

3. Circularity ratio (Fc):

$$F_c = P/(4\pi A)^{0.5}$$

Where P and A are the perimeter an area of the watershed, respectively

4. Circularity ratio (R_c):

$$R_c = A/A_o$$

Where A_0 is the area of a circle having a perimeter equal to the perimeter of the basin

5. Elongation Ratio (R_e):

$$R_e = 2/L_m(A/\pi)^{0.5}$$

Where, L_m is the maximum length of the basin parallel to the principal drainage lines.

Generally, the shape factor (L_l) is the best descriptor of peak discharge. It is negatively correlated with peak discharge (i.e. as the L_l decreases, peak discharge increases).

Land use and soil characteristics of water

Land use and soil characteristics affect both the volume and timing of runoff. During a rainstorm, flow from an impervious, steeply sloped, and smooth, surface make a little retardation and no loss to the flow. In comparison, flow along a pervious grassy hill of the same size will produce retardation and significant loss to the flow due to infiltration. Surface roughness, soil characteristics such as texture, soil structure, soil moisture and hydrologic soil groups also affect the runoff in various ways.

Slope: The channel slope is determined as the elevation difference between the endpoints of the main channel divided by the channel length. In addition, the term drainage density is often used. Drainage density is the ratio of the total length of streams within a watershed to the area of the watershed. Thus drainage density has the units of the reciprocal of length. A watershed with a high drainage density is characterized by quick response.

ChannelGeomorphology

In addition to the drainage area and the watershed length, the channel length is used frequently in hydrologic computation. The runoff produced by a watershed is also highly dependent on the channel characteristics. Two computational schemes are used to compute the channel length:

1. The distance measured along the main channel from the watershed outlet to the end of the channel as indicated on the figure below, which is denoted as L_c. This is different to watershed length, which extends to the boundary. However, there is some subjectivity in the estimation of channel length as it depends on the scale of the topographic map.

2. The distance measured along the main channel between two points located 10 and 85% of the distance along the channel from the outlet, which is denoted at $L_{10\text{-}85}$.

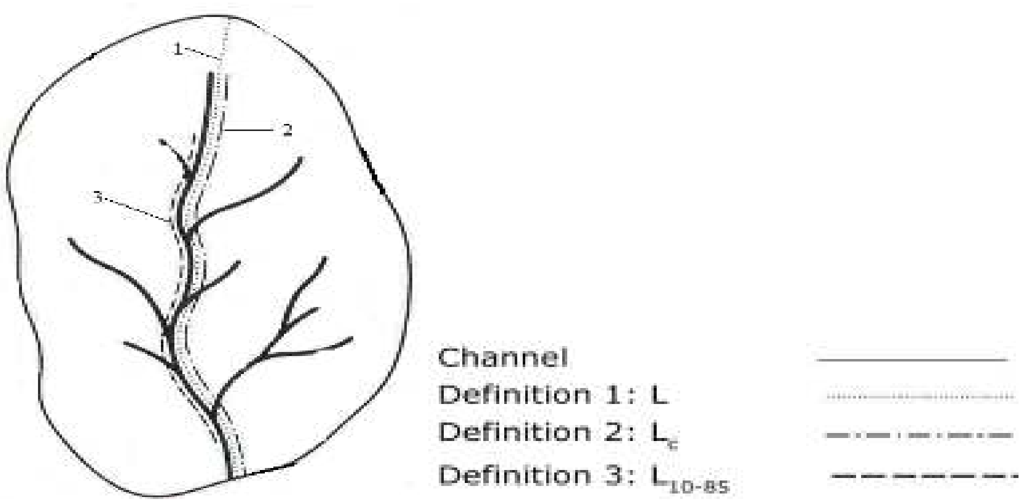


Fig.3.6. Channel length definition

The channel slope can be described one of the following computation schemes.

1. The most common is the difference of elevation between the points defining the upper and lower ends of the channel divided by the length of the channel between the same to points.

2. The 10-85 slopes can also be used:

$$S_{10-85} = \frac{\Delta E_{10-85}}{L_{10-85}}$$

For cases where the channel slope is not uniform, a weighted slope may provide an index that better reflects the effect of slope on the hydrologic response of the watershed.

Drainage Density

The drainage density, D is the ratio of the total length of streams within a watershed to the total area of the watershed; thus D has units of the reciprocal of length (1/L). A high value of the drainage density would indicate a relatively high density of streams and thus a rapid storm response. A value typically ranges from 1.5 to 6 mi/mi^2

$$D = Lc/A$$

2.2. Identifying and characterizing seasonal water ways for flood water level

River as a watercourse concept of natural drainage network consisting of a main water course and its tributaries and of river basin as a geographically defined area that is drained by a drainage network are certainly quite insightful and have been understood for long time.

A. Stream corridors

The stream channel: contains flowing water for at least a portion of the year.

The floodplain: the floodplain, the land adjacent to stream channel, receives floodwaters and concomitant sediment when the stream channel overflows. The nature and size of floodplain vary both along river systems and between river systems. Depending on the surrounding topography, the floodplain may include land on one or both sides of the channel, and the area may vary considerably along a river.

The transitional upland fringe: the upland area on one or both sides of the floodplain that delineates the floodplain from the surrounding landscape.

Fig. 3.7: The Major Cross-Sectional Components of the Stream Corridor

B. Stream Channel

Flowing water and the sediment it carries form, maintain and modify the stream channel. Although the form of a stream channels can vary greatly, from meandering gentle streams to fast flowing rivers, it tends to take on a rounded u-shape. When scientists study a stream cross-section, they invariably examine two key attributes of the stream flow system -and channel size. Stream flow is the volume and velocity of water entering the channel.

Precipitation takes after falling to the earth affect the quantity, quality and timing of the stream flow. The two basic flow pathways are storm flow and base flow. Storm flow is precipitation that reaches the channel very soon after precipitation via overland or underground routes. Base flow is precipitation that percolates to the ground water and moves slowly through the substrate before reaching the channel. Base flow provides stream flow during periods of little or no precipitation. The measure of stream flow used by those studying river systems is known as the discharge rate. Discharge rates depend both on the average velocity at which the water is moving downstream and the size of the channel through which the water is flowing.

Channel size is determined by stream flow and sediment load. Sediment load refers both to the amount of sediment the stream is transporting and depositing and to its characteristics. A stream balance equation formally describes the dynamic relationship between channel size and sediment load and stream flow. This equation states that the channel is in equilibrium when the sediment load is balanced with stream flow.

Stream managers categorize streams based on the balance and timing of the storm flow and base flow components. **There are three main categories:**

- **Ephemeral streams** flow only during or immediately after periods of precipitation. They generally flow less than 30 days per year.
- **Intermittent streams** flow only during certain times of the year. Seasonal flow in an intermittent stream usually lasts longer than 30 days per year.
- **Perennial streams** flow continuously during both wet and dry times. Base flow is dependably generated from the movement of ground water into the channel.

Discharge Regime: Discharge is the term used to describe the volume of water moving down the channel per unit time.

Discharge is calculated as: Q=AV, where Q = Discharge

A = Area through which the water is flowing and V = Average velocity in the downstream direction Stream flow is one of the variables that determine the size and shape of the channel.

There are three types of characteristic discharge.

1. Channel-forming (or dominant) discharge. To envision the concept of channel-forming discharge, imagine placing a water hose discharging at constant rate in a freshly tilled garden. Eventually, a small channel will form and reach equilibrium geometry. At a larger scale, consider a newly constructed floodwater-retarding reservoir that slowly releases stored floodwater at a constant flow rate. This flow becomes the new channel forming discharge and will alter channel morphology until the channel reaches equilibrium. An estimate of channel forming discharge for a particular stream reach can, with some qualifications, be related to depth, width, and shape of channel.

2. Effective discharge. The effective discharge is the calculated measure of channel forming discharge. Computation of effective discharge requires long-term water and sediment measurements, either for the stream in question or for one very similar. Since this type of data is often not available for stream restoration sites, modeled or computed data are sometimes substituted. Effective discharge can be computed for either stable or evolving channels.

3. Bankfull discharge. This discharge occurs when water just begins to leave the channel and spread onto the floodplain. Bankfull discharge is equivalent to channel-forming (conceptual) and effective (calculated) discharge for alluvial streams at equilibrium.

C. Structural Changes in the Stream Corridor

The physical structure of the channel and floodplain changes as a river travels from its headwaters to its outlet. Channel width and depth increase downstream as the drainage area and discharge increase. A simplified longitudinal model captures these observed changes by disaggregating the river into three zones (Fig. 19):

- **Headwaters zone**: generally has the steepest slope. As the water moves over these slopes, sediment erodes and is carried downstream.
- **Transfer zone:** receives sediment from upstream, the gradient decreases. The river widens as smaller streams merge and
- **Depositional zone**: the gradient flattens from a build-up of sediment over time. The river widens further and meanders toward its mouth.

These same three zones are also evident on a much smaller scale within the watersheds of contributing streams. The size and structure of watersheds vary significantly due to geologic, morphologic, vegetative, soil and climatic differences. Differences in topographic and geologic structure also influence watershed drainage patterns.

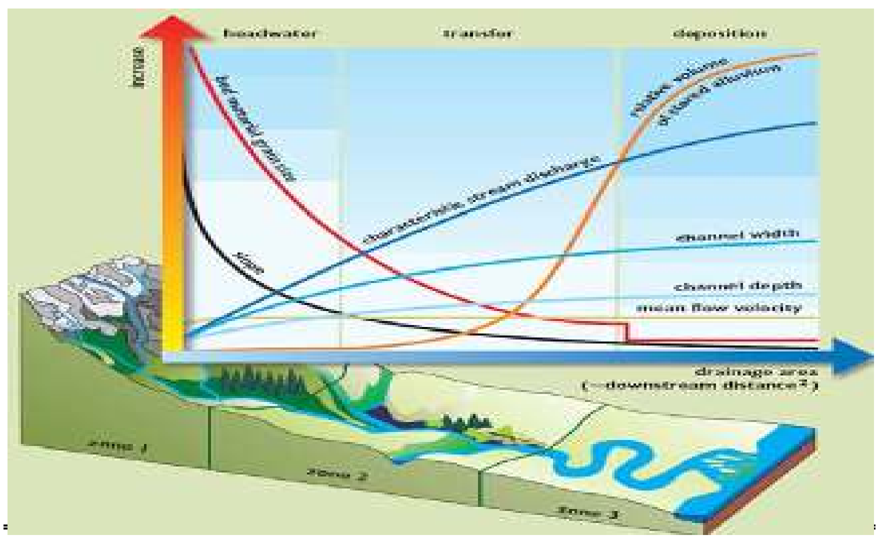


Fig. 3.8: Typical changes in the stream channel characteristics along its length.

D. Stream Order Models

As water moves along pathways of least resistance in the watershed, it forms streams that join larger and yet larger streams. The resulting river is branched like a tree; the particular form of the branching depends on the watershed through which the water flows. A method of classifying the hierarchy of natural channels according to their position in the drainage system, referred to as stream order, permits comparison of the behaviour of a river with others similarly situated. In the most commonly cited and used system (Strahler, 1957), small headwater streams are designated Order I. Streams formed by the confluence of two Order I streams are referred to as Order II, and so on, with larger numbers indicating larger rivers with multiple tributary streams (Fig.27). Stream order correlates generally with gradient, drainage area, channel width, and discharge; but because of multiple intervening factors, the statistical variance of the correlations is large.

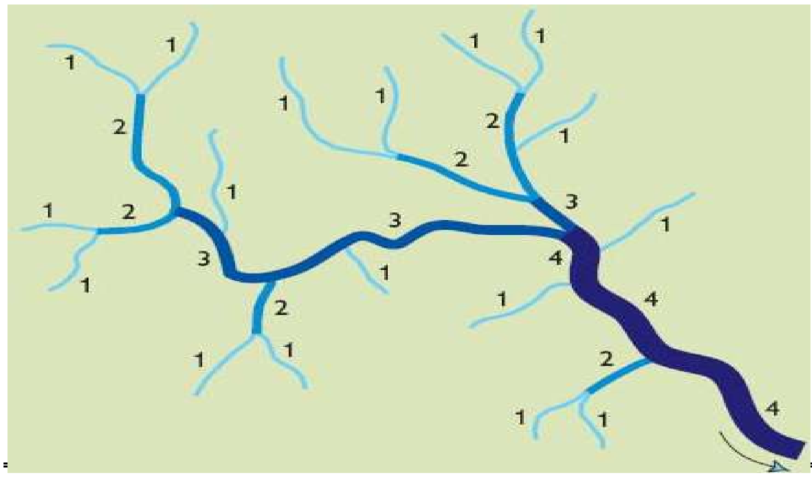


Fig. 3.9: Stream ordering in a drainage network

Analysis of hydrological data for irrigation

The feasibility of using rivers for irrigation can be determined by a statistical analysis of long- term river flows. For most major rivers, these data are available from the departments or organizations responsible for hydrological data. For most small rivers, flow measurements are not easily available. It is thus difficult to determine the water flow during the growing seasons. Nevertheless, a clear indication is needed, especially during the latter part of the dry season when minimum river flow normally coincides with maximum evapotranspiration. There are ways of obtaining some idea about the flow regime, such as by talking to local (preferably elder) people, visiting the area during the dry season, analyzing satellite imagery data (remote sensing) and by carrying out flow measurements with current meters or isotope and salt dilution methods. Whether data are available or not, one has to come up with a safe water yield, which in turn determines the possible irrigation area.

Once this is known, one should apply for an appropriate water right or water abstraction permit from the relevant authority in the country. It is equally important to have knowledge of high floods in order to properly design diversion structures and flood protection works near the river. Again, it is useful to talk to the local people, who can often indicate flood marks, for example on trees. Many rivers carry large amounts of sediments especially during the rainy season. This has to be verified and, if so, the designs of the headwork have to cater for sediment flushing arrangements to avoid it entering the canal system. The stability of especially meandering rivers has to be considered in order to avoid placing headwork in unstable parts of the river.

2.3. Identifying proper site for water harvesting

Proper site is a suitable location which can deliver the required quantity and quality of water to harvest the desired amount of water in the water harvesting structure to satisfy the water requirement of crops.

Parameters for Identification of Suitable Rain and Floodwater Harvesting Areas

The most important parameters to be considered in identifying areas suitable for rain and floodwater harvesting are as follows:

a) **Rainfall**: The knowledge of rainfall characteristics (intensity and distribution) for a given area is one of the pre-requisites for designing a water harvesting system. The availability of rainfall data series in space and time and rainfall distributions is important for rainfall-runoff process and also for determination of available soil moisture. A threshold rainfall events is used in many rainfall- e.g. of 5 mm/event runoff models as a start value for runoff to occur. The intensity of rainfall is a good indicator of which rainfall is likely to produce runoff.

Useful rainfall factors for the design of a rain or floodwater harvesting system include: (1) Number of days in which the rain exceeds the threshold rainfall of the catchment, on a weekly or monthly basis. (2) Probability and occurrence (in years) for the mean monthly rainfall. (3) Probability and reoccurrence for the minimum and maximum monthly rainfall. (4) Frequency distribution of storms of different specific intensities.

b) Land use or vegetation cover: Vegetation is another important parameter that affects the surface runoff. It is known that from an increase in the vegetation density results in a corresponding increase in interception losses, retention and infiltration rates which consequently decrease the volume of runoff. Vegetation density can be characterized by the size of the area covered under vegetation. There is a high degree of congruence between density of vegetation and suitability of the soil to be used for cropping.

c) Topography and terrain profile: The land forms along with slope gradient and relief intensity are other parameters to determine the type of water harvesting. The terrain analysis can be used for determination of the length of slope, a parameter regarded of very high importance for the suitability of an area for macro-catchment water harvesting. With a given inclination, the runoff volume increases with the length of slope. The slope length can be used to determine the suitability for macro- or micro- or mixed water harvesting systems decision making.

d) Soil type & soil depth: The suitability of a certain area either as catchment or as cropping area in water harvesting depend strongly on its soils characteristics viz. (1) surface structure; which influence the rainfall-runoff process, (2) the infiltration and percolation rate; which determine water movement into the soil and within the soil matrix, and (3) the soil depth incl. soil texture; which determines the quantity of water which can be stored in the soil.

e) Hydrology and water resources: The hydrological processes relevant to water harvesting practices are those involved in the production, flow and storage of runoff from rainfall within a particular project area. The rain falling on a particular catchment area can be effective (as direct runoff) or ineffective (as evaporation, deep percolation). The quantity of rainfall which produces runoff is a good indicator of the suitability of the area for water harvesting.

f) Socio-economic and infrastructure conditions: The socio-economic conditions of a region being considered for any water harvesting scheme are very important for planning, designing and implementation. The chances for success are much greater if resource users and community groups are involved from early planning stage onwards. The farming systems of the community, the financial capabilities of the average farmer, the cultural behaviour together with religious belief of the people, attitude of farmers towards the introduction of new farming methods, the farmers knowledge about irrigated agriculture, land tenure and property rights and the role of women and minorities in the communities are crucial issues.

g) Environmental and ecological impacts: Dry area ecosystems are generally fragile and have a limited capacity to adjust to change. If the use of natural resources (land and water), is suddenly changed by water harvesting, the environmental consequences are often far greater than foreseen. Consideration should be given to the possible effect on natural wetlands as on other water users, both in terms of water quality and quantity. New water harvesting systems may intercept runoff at the upstream part of the catchment, thus depriving potential downstream users of their share of the resources. Water harvesting technology should be seen as one component of a regional water management improvement project. Components of such integrated plans should be the improvement of agronomic practices, including the use of good plant material, plant protection measures and soil fertility management (Oweis et al. 1999).

The site which is used for water harvesting must be satisfying the following points. These are:

- The area must collect sufficient runoff water.
- The runoff water collected from the area should be easily diverted to the storage tank.
- The area should be located sufficiently away from pollution sources.
- The area must generate as little sediment as possible.
- For the construction of water harvesting tank availability of suitable materials is crucial.
- The site should not be exposed to land erosion, near gullies or not on tops of swampy ground
- Storage tank must be set on good foundation or soil for the constructions of foundation firm soil need less depth and sandy or loose soil requires deep foundation.

2.4. Choosing appropriate water harvesting technique

Application areas

Rainwater harvesting systems can be installed in both new and existing buildings/landscape and harvested rainwater used for different applications that do not require drinking water quality such as toilet flushing, garden watering, irrigation, cleaning and laundry washing. Harvested rainwater is also used in many parts of the world as a drinking water source. As rainwater is very soft there is also less consumption of washing and cleaning powder. With rainwater harvesting, the savings in potable water could amount up to 50% of the total household consumption.

Criteria for selection of rainwater harvesting technologies

Several factors should be considered when selecting rainwater harvesting systems for domestic use:

- type and size of catchment area
- local rainfall data and weather patterns
- family size
- length of the drought period
- alternative water sources
- Cost of the rainwater harvesting system.

To choose roof water harvesting technique

- Availability of roof catchment
- Availability of skilled technician
- Availability of command area close to the building
- Availability of finance
- Applicability and adaptability of the technology
- Climatic condition of the area
- Type of crop to be grown

To choose flood water harvesting technique

- Availability of appropriate catchment based on soil, slope, land cover, size, etc
- Availability of trained manpower who can design, construct and maintain different types of water harvesting techniques
- Availability of command area
- Applicability and adaptability of the technology
- Climatic condition of the area
- Type of crop to be grown

When rainwater harvesting is mainly considered for irrigation, several factors should be taken into consideration. These include:

- rainfall amounts, intensities, and evapotranspiration rates,
- soil infiltration rate, water holding capacity, fertility and depth of soil
- crop characteristics such as water requirement and length of growing period
- hydrogeology of the site
- socio-economic factors such as population density, labor, costs of materials and
- Regulations governing water resources use.

2.5. Selecting design principles for the chosen water harvesting techniques

Designing a rainwater harvesting system

The main consideration in designing a rainwater harvesting system is to size the volume of the storage tank correctly. The tank should give adequate storage capacity at minimum construction costs.

Five steps to be followed in designing a RWH system:

Step 1 Determine the total amount of required and available rainwater

Step 2 Design your catchment area

Step 3 Design your delivery system

Step 4 Determine the necessary size of your storage reservoir

Step 5 Select suitable design of storage reservoir

These steps are described below.

Step 1: Total amount of required and available rainwater

Estimating domestic water demand

The first step in designing a rainwater harvesting system is to consider the annual household water demand. To estimate water demand the following equation can be used:

Demand = Water Use × Household Members × Length of dry period

Calculating potential rainwater supply by estimating run-off

The amount of available rainwater depends on the amount of rainfall, the area of the catchment, and its run-off coefficient. For a roof or sloping catchment it is the horizontal plan area which should be measured (figure 28).

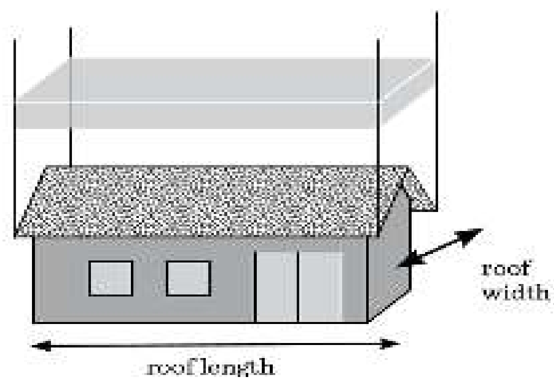


Figure 3.10: Horizontal plan area of the roof for calculating the catchment surface

The run-off coefficient (RC) takes into account any losses due to evaporation, leakage, overflow and transportation. For a well- constructed roof catchment system it is 0.9. An impermeable roof will yield a high run-off. An estimate of the approximate, mean annual run-off from a given catchment can be obtained using the following equation:

$$S = R \times A \times C_r$$

Supply = Rainfall × Area × Run-off coefficient (RC)

Where:

S = Mean annual rainwater supply (m^3)

R = Mean annual rainfall (m)

A = Catchment area (m^2)

C_r = Run-off coefficient

In the next example the mean annual rainfall is 500 mm/year (= 0.5 m/year) and the catchment area 3 m × 4 m = 12 m^2: S = 0.5 m/year × 12 m^2 × 0.9 = 5.4 m^3 / year = 15 liters/ day

Step 2: Designing your catchment area

Roofs provide an ideal catchment surface for harvesting rainwater, provided they are clean. The roof surface may consist of many different materials. Galvanized corrugated iron sheets, corrugated plastic and tiles all make good roof catchment surfaces. Flat cement roofs can also be used. Traditional roofing materials such as grass or palm thatch may also be used.

The roof size of a house or building determines the catchment area and run-off of rainwater. The collection of water is usually represented by a run-off coefficient (RC). The run-off coefficient for any catchment is the ratio of the volume of water that runs off a surface to the volume of rainfall that falls on the surface.

Table 2: Run-off coefficients for traditional roofing materials and other various catchments

Type	**Run-off coefficient**
Galvanized iron sheets	>0.9
Tiles (glazed)	0.6-0.9
Aluminium sheets	0.8-0.9
Flat cement roof	0.6-0.7
Organic (e.g. thatched)	0.2
Rock/stone floor	0.7-0.8
Agricultural field	0.15-0.3
Soil compacted	0.4-0.55
Grass covering (sparse)	0.08-0.15
Grass covering (dense)	0.06-0.15

Since roofs are designed to shed water, they have a high run-off coefficient and thus allow for quick run-off of rainwater. The roof material does not only determine the run-off coefficient, it also influences the water quality of the harvested rainwater. Painted roofs can be used for rainwater collection but it is important that the paint be non-toxic and not cause water pollution.

Step 3: Designing your delivery system

The collected water from a roof needs to be transported to the storage reservoir or tank through a system of gutters and pipes, the so-called delivery system or guttering. Several other types of delivery systems exist but gutters are by far the most common. Commonly used materials for gutters and downpipes are galvanized metal and plastic (PVC) pipes, which are readily available in local shops. There is a wide variety of guttering available from prefabricated plastics to simple gutters made on-site from sheet metal.

Gutters are readily available in different shapes (Figure 22); they can be rounded, square, V-shaped, and have open or closed ends with attached downpipe connectors. They can be made in small workshops in sections that are later joined together or they can even be made on-site by plumbers.

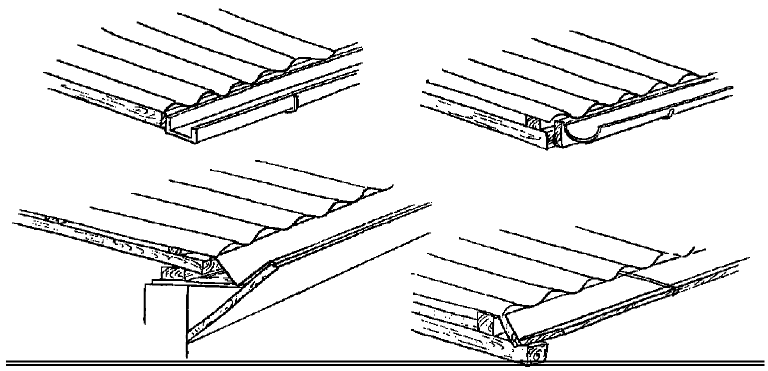


Figure 3.11: Different types of gutters: square, rounded, V-shaped

Gutters must be properly sized and correctly connected around the whole roof area. When high intensity rainfall occurs, gutters need to be fitted with so-called splash guards to prevent overshooting water losses.

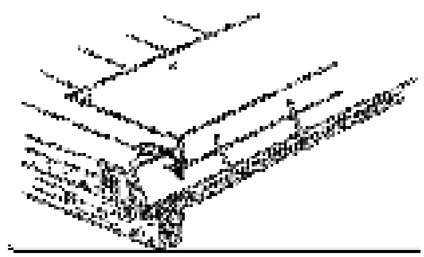


Figure 3.12: Splash guards

During intensive rainfall, large quantities of run-off can be lost due to gutter overflow and spillage if gutters are too small. To avoid over- flow during heavy rains, it makes sense to create a greater gutter capacity. A useful rule of thumb is to make sure that there is at least 1 cm^2 of gutter cross-section for every 1 m^2 of roof surface.

The following tables give some examples of guttering systems. The guttering requirement for a typical household roof of 60 m^2 is shown in table 1. Typical gutter widths for such roofs are presented in table 2.

Table 1: Examples for guttering systems

Section	**Roof size**	**Slope**	**Cross sectional area**	**Gutter sizes**
Square	40-100 m^2	0.3-0.5%	70 cm^2	7 × 10 cm
Rounded	40-60 m^2	0.3-0.5%	63 cm^2	125 mm bore **[?]**
45° V-shaped	Not specified	1.0%	113 cm^2	15 cm on each side

Table 2: Gutter sizes quoted in literature

	Square	**Square**	**Rounded**	**45° V-shape**
Gutter width (at top)	71 mm	63 mm	96 mm	124 mm
Cross sectional area	47 cm^2	39 cm^2	36 cm^2	38 cm^2

Step 4: Sizing your storage reservoir

There are several methods for sizing storage reservoirs. These methods vary in complexity and sophistication.

1. Demand side approach (dry season demand versus supply)

2. Supply side approach (graphical methods)

The first method is the simplest method and most widely used. The second method uses statistical indicators of the average rainfall for a given place.

Method 1: Demand side approach (dry season demand versus supply)

This is the simplest method to calculate the storage requirement based on the required water volume (consumption rates) and occupancy of the building. This approach is only relevant in areas with a distinct dry season. The tank is designed to meet the necessary water demand throughout the dry season. To obtain required storage volume the following equations can be used:

Demand = Water Use × Household Members × Length of dry period

Required storage capacity = demand × dry period

As an example we can use the following typical data. Assuming that:

Water use (consumption per capita per day) = 20 liters

Number of people in the household = 5

Dry period (longest average dry period) = 4 months (120 days)

Minimum storage capacity = T

Then: the water demand = 20 l × 5 persons × 365 days/year = 36,500 liters/year or about 3,000 l/month. For a dry period of four months, the required minimum storage capacity (T) is thus 12,000 liters (T = 4 ×3,000); this calculation is however a rough estimate.

Method 2: Supply side approach (graphical methods)

Another method to estimate the most appropriate storage tank capacity for maximizing supply is to represent roof run-off and daily consumption graphically. This method will give a reasonable estimation of the storage requirements. Daily or weekly rainfall data is required for a more accurate assessment.

This method will give an estimation of the storage requirements. There are three basic steps to be followed:

1. Plot a bar graph for mean monthly roof run-off for a specific house or building in a specific location. Add a line for the demand per month.
2. Plot a cumulative roof run-off graph, by summing the monthly run- off totals.
3. Add a dotted line showing cumulative water use (water withdrawn or water demand).

Step 5: Selection of a suitable storage reservoir design

Suitable design of storage reservoirs depends on local conditions, available materials and budget, etc. In the following sections, the materials, construction and costs of storage reservoirs are described in detail. This information is needed to select the most suitable design and realize the construction of the RWH system.

A per capita water consumption of (x) liters per day for the domestic drinking and cooking purposes is found optimum. Adding 20% towards additional water requirement for visitors, festivals and wastage, a per capita water requirement of 1.2(x) liters per day shall be considered for selecting the size of water storage tank (UNICEF-AFPRO, 1997).

2.6. Preparing design drawings for different structures & lay outs

Working Drawings

Three different types of drawings are needed to show the builder exactly how the building should look, on the inside and the outside. These include the elevations and sections, as well as the plans. Here we describe the different types of plans which have to be made: the foundation plan, floor plan, and roof plan.

FOUNDATION PLAN: A foundation plan, along with its sections, shows the builder how deep the foundations should be laid and gives all the dimensions for the foundation and the footings. Sometimes the corners of the rising walls are indicated on the footings.

FLOOR PLAN: This plan should show the builder the size of the building and the verandahs, the thickness of the walls, and where to place the doors and windows. It also shows which way the doors are meant to open.

ROOF PLAN: Roof plans are made to show the builder what shape the roof should be and how it is to be built. The roof plan should contain such information as the angle of the roof, the shape, and the materials to be used.

The drawing here illustrates the types of plans and what it is they show to the builder.

Elevations and cross sections are of course essential parts of the working drawings. These are examined in detail after some further examples of plans in the next pages.

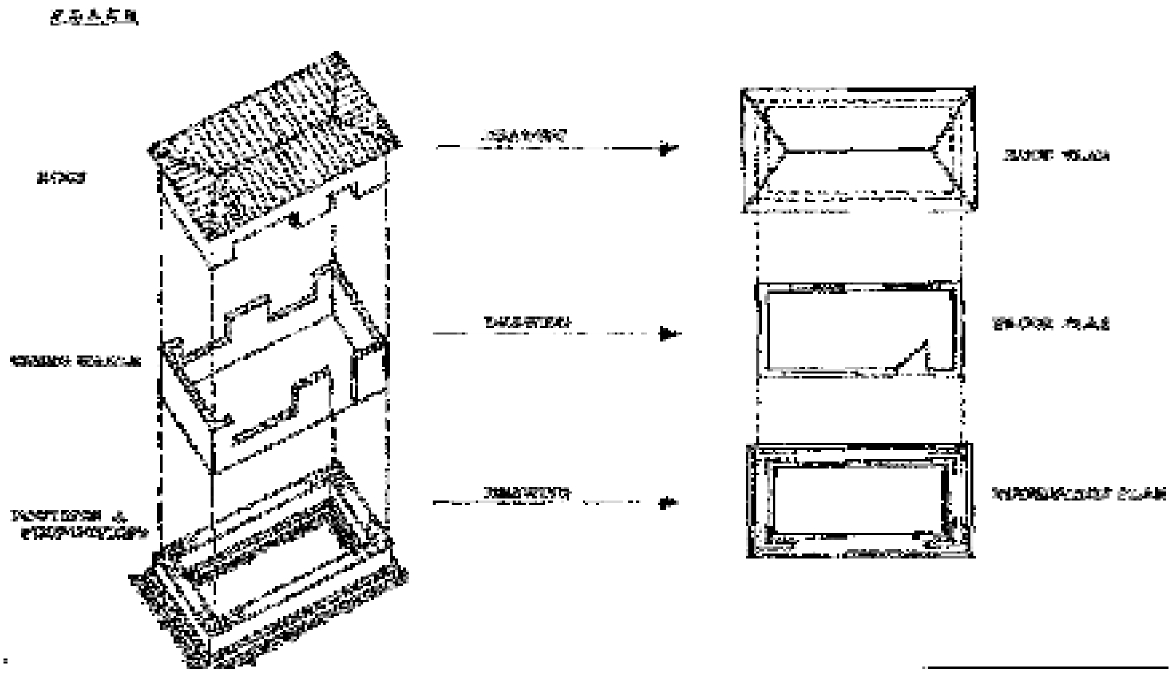


Figure 3.13: plan

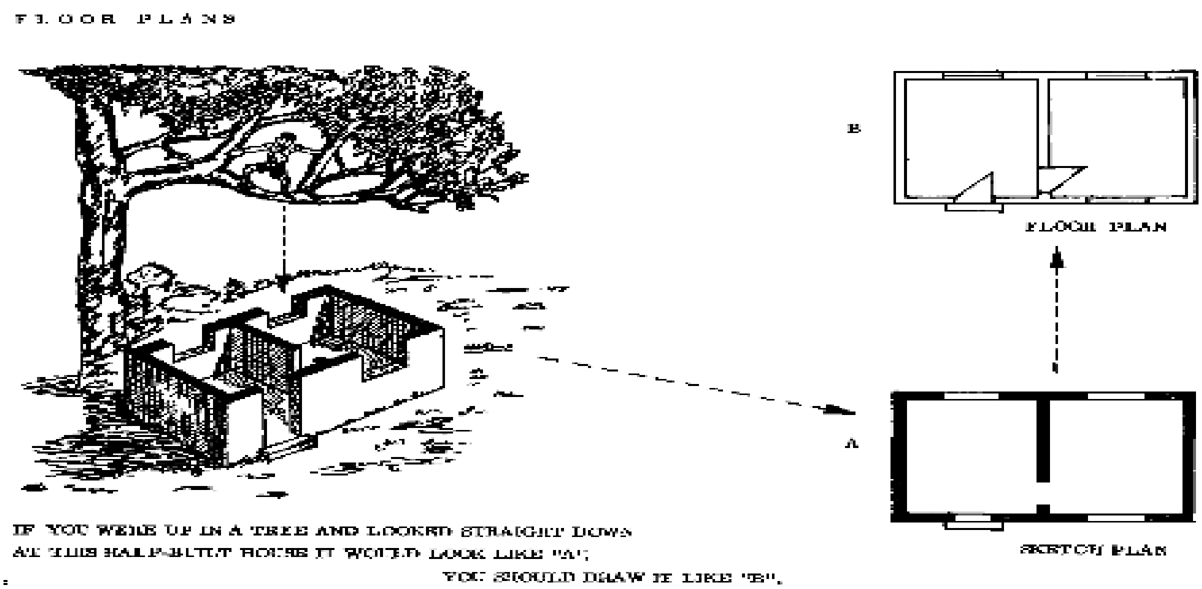


Figure 3.14: floor plan

Elevations

A special type of drawing is used to show what a building will look like from the outside. These drawings are called “elevations” and they show what you would see if you looked straight on at the side of the house. Of course a house has more than one side, and so there are always a number of elevations. There are as many elevations as there are sides of the house. Houses usually have four sides and so there are usually four elevations.

It is not always necessary to draw all the possible elevations of a building, especially if some of the sides look very similar to each other.

The drawing here shows the front elevation of a small house. You should notice that the sides of the house are not drawn. This is because if you stand directly in front of the house you cannot see the sides. The front elevation shows the sizes and positions of the doors and windows as well as the height and length of the house itself.

The building shown on the next page faces south. The front elevation is therefore called the “south elevation”. The other three elevations are the east elevation, the north elevation, and the west elevation.

In general only main features are shown on the elevations. Small details of the doors, windows, etc. are given in the detail drawings.

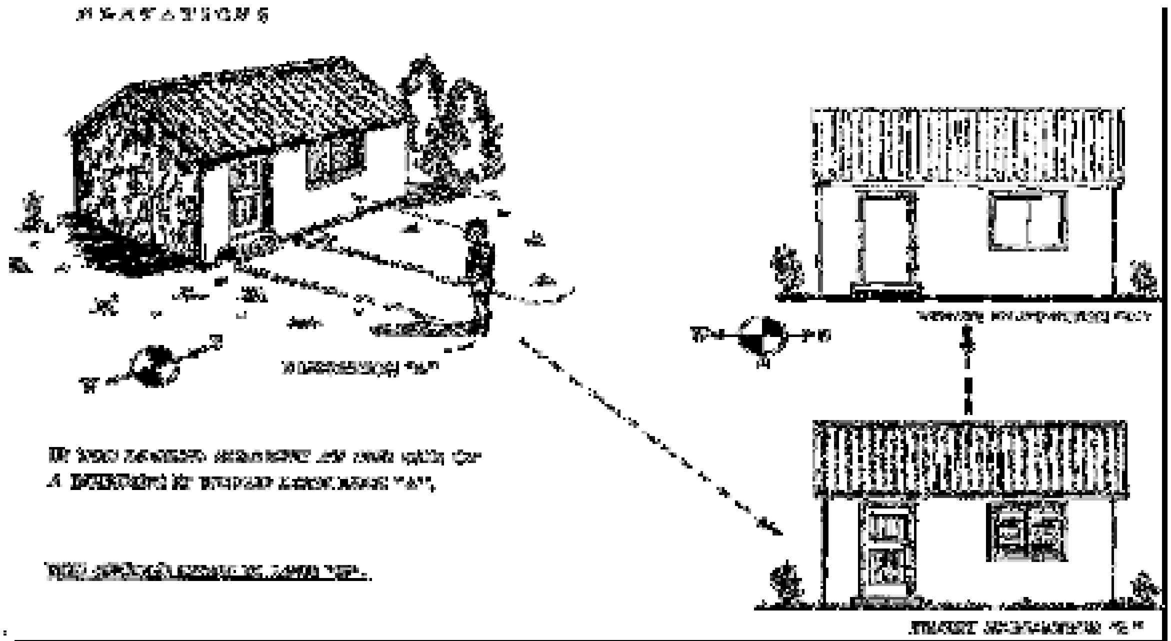


Figure 3.15: elevation

Sections

Suppose you were able to cut right through a building and then take away one part. What you would see would look something like the diagram on the next page (1). If you now look at the building straight on, you will see a "cross section" of the building (2). The cross section shows the insides of the roof and the room as well as the footings and foundations.

Sections are useful because they give a lot of information about the building which is not found in the elevations and the plans. For example, on a section you can see the height of a room inside the building, the thickness of the ceiling, and the floor and roof construction. You can also see the thickness and width of the foundation, which is not given in the plans and elevations.

Choosing Sections: You will usually find it necessary to take at least two sections through the building. You can take any section through any part of the building, but of course the best sections are the ones which are the hardest to draw! When you take a section through a building, you have to mark on the plan exactly where you have "cut" and the direction from which you look at the section.

On the right page you can see the conventional way of doing this. The place where the building is cut is marked by a broken line which has arrows at its ends to show which way the section faces. All sections should be marked on the plan, and you should label each end of the line with a letter. On the plan here, the section has the letter “A” at each end. When this cross section is drawn, it is labelled as “cross section A-A”. The next section would be “cross section B—B” etc.

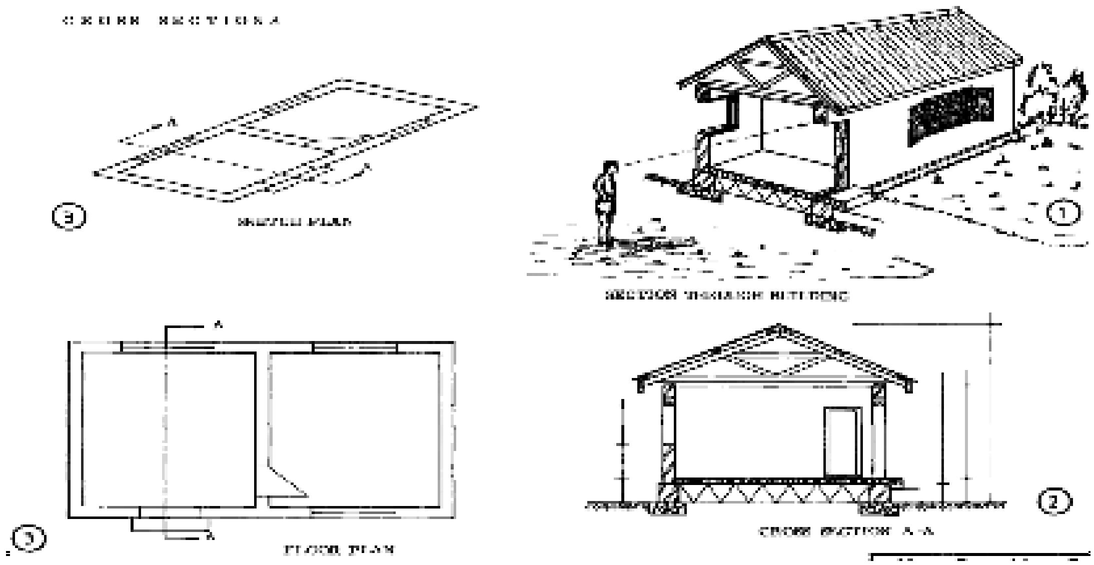


Figure 3.16: cross section

Plan and cross sectional views WH storage structures

Carrying out layout of different water harvesting structures

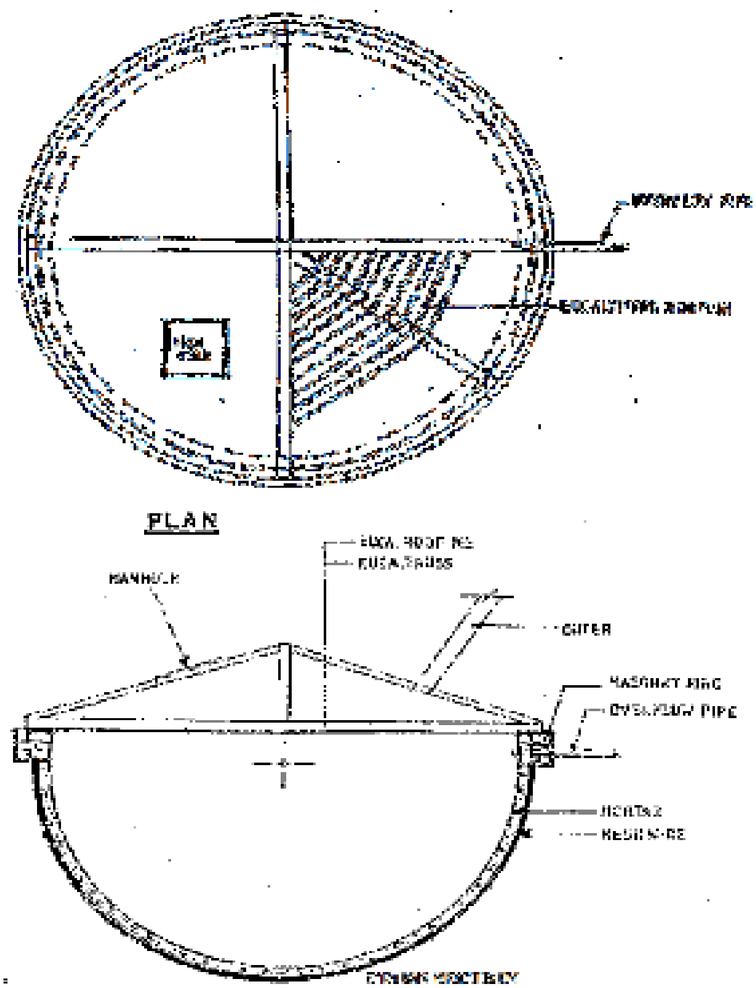
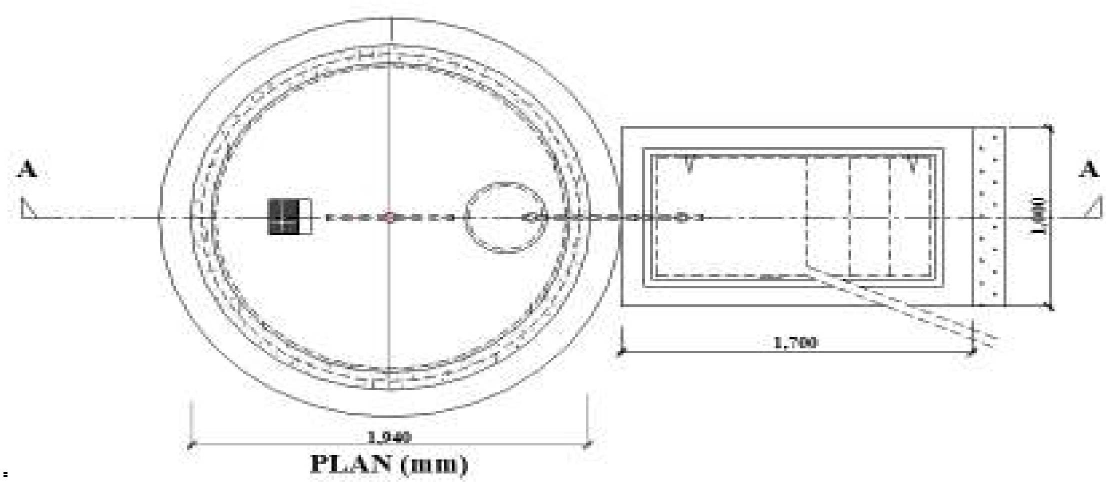
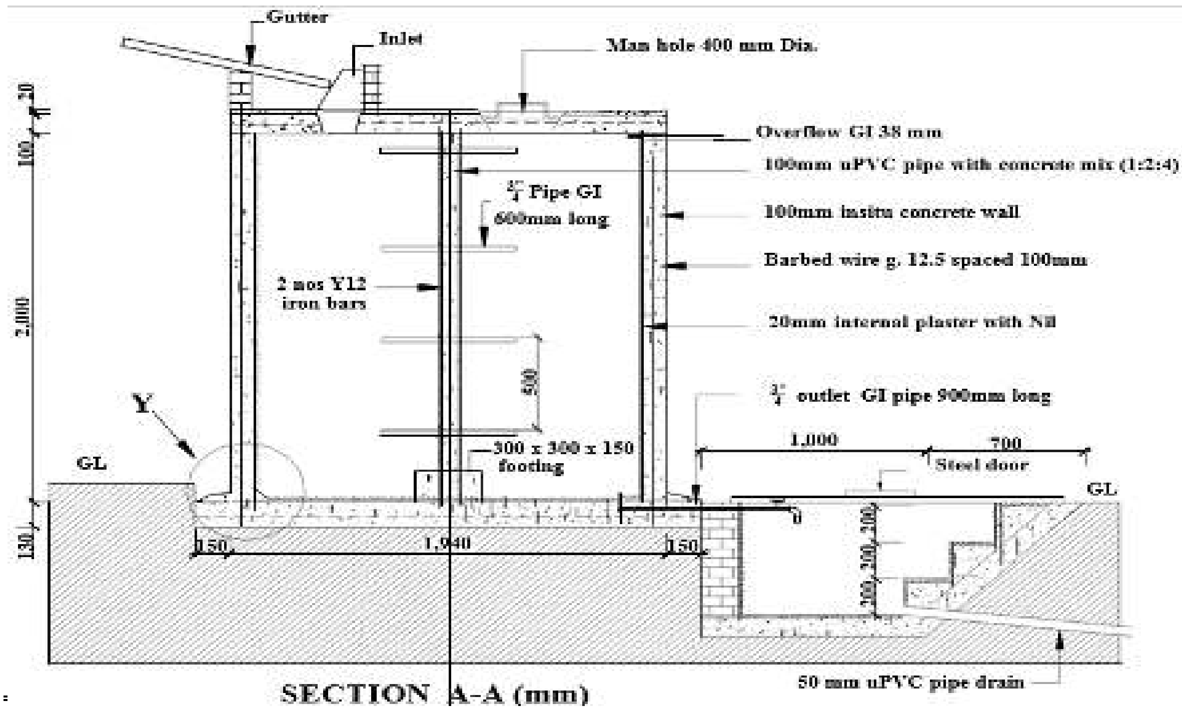


Figure 3.17: Plan and Cross Sectional View of Hemispherical Storage Tank





DETAIL Y (mm)

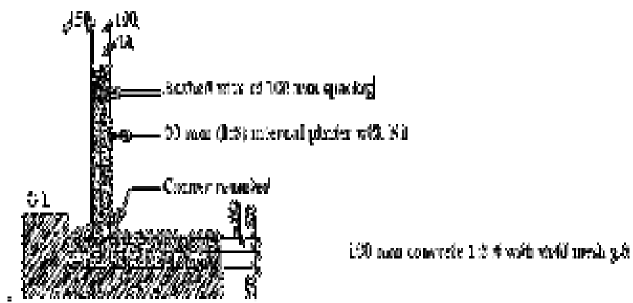


Figure 3.18: Standard design for a 5 m^3 tank built of concrete in situ

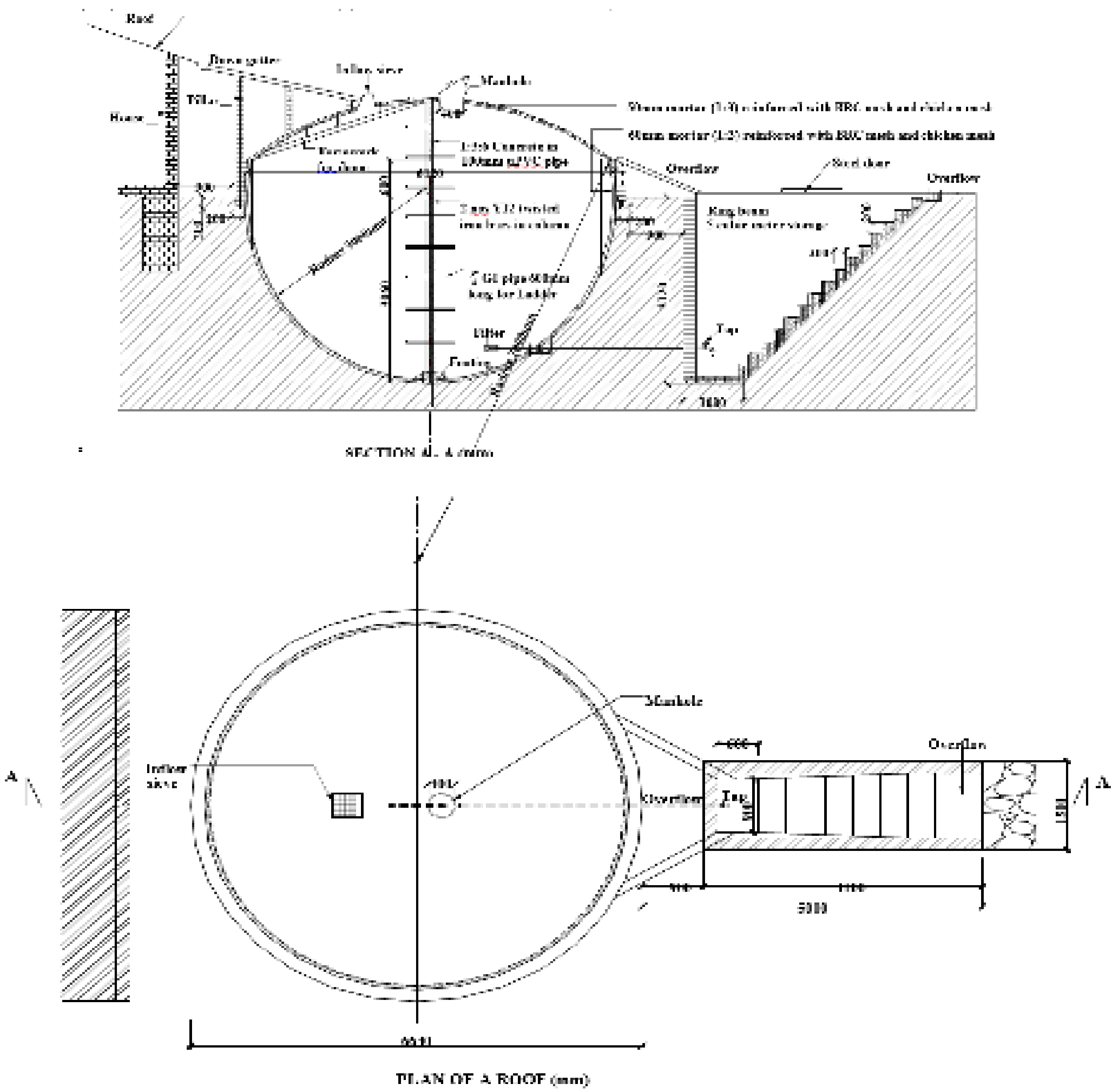


Figure 3.19: Standard design of a 90 m^3 hemispherical storage tank

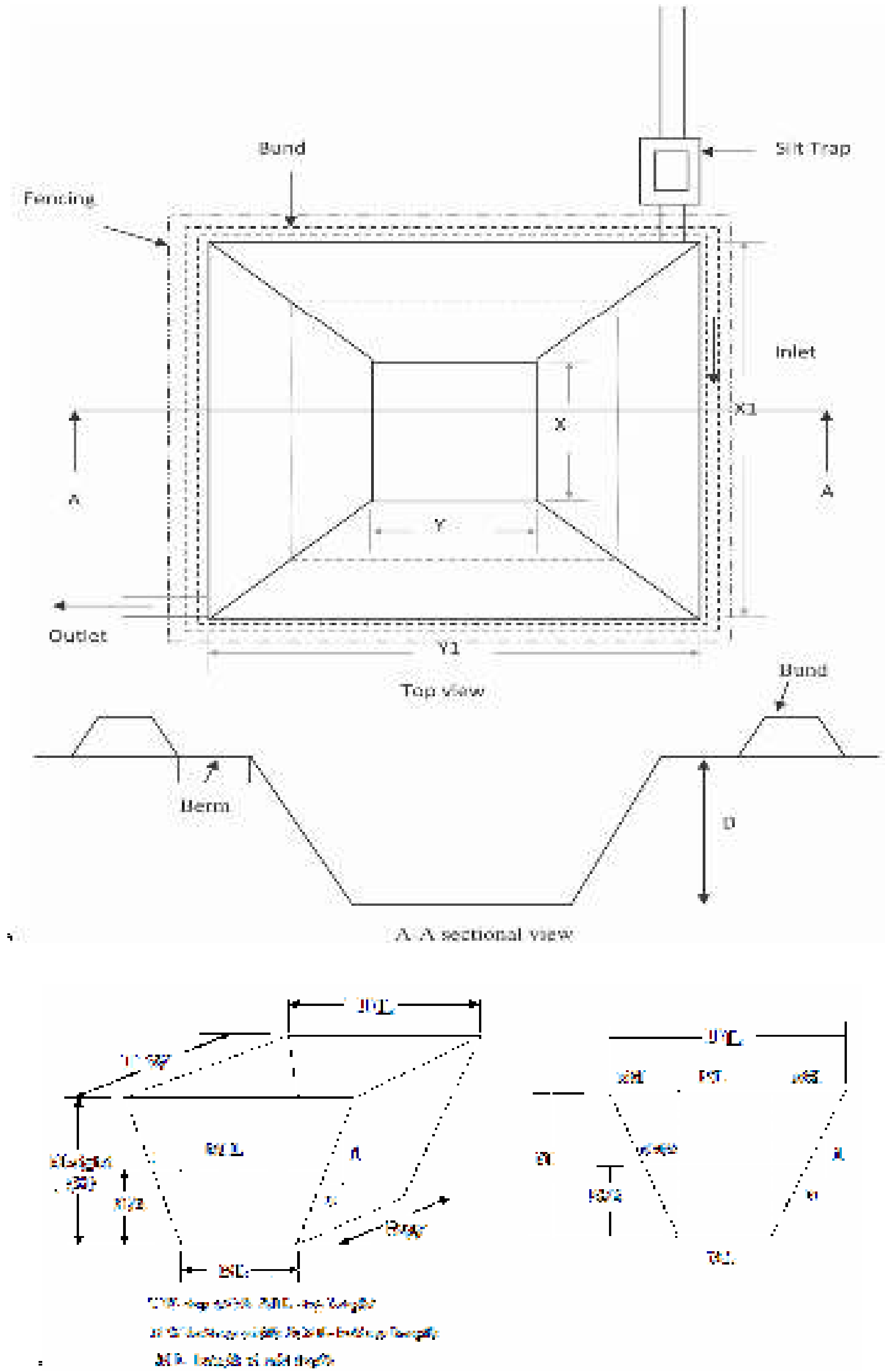


Figure 3.20: Layout of the dugout farm pond

2.7 Designing silt trap to settle and clear off sediments

Sediment pond is used to settle sediment or silt carried in the runoff. It should be located 3m away from the storage facility.

The size of sediment pond should be determined accurately, to the silt characteristics, flow discharges and size of the catchment. Most widely used silt trap is rectangular in shape.

For simple storage up to 60m^3 capacity the following dimensions are used.

- Max depth 100 cm
- Max length 250 cm
- Max width 100 cm
- Partition is made at a length of 150 cm from the inlet.

It should be constructed with locally available materials.

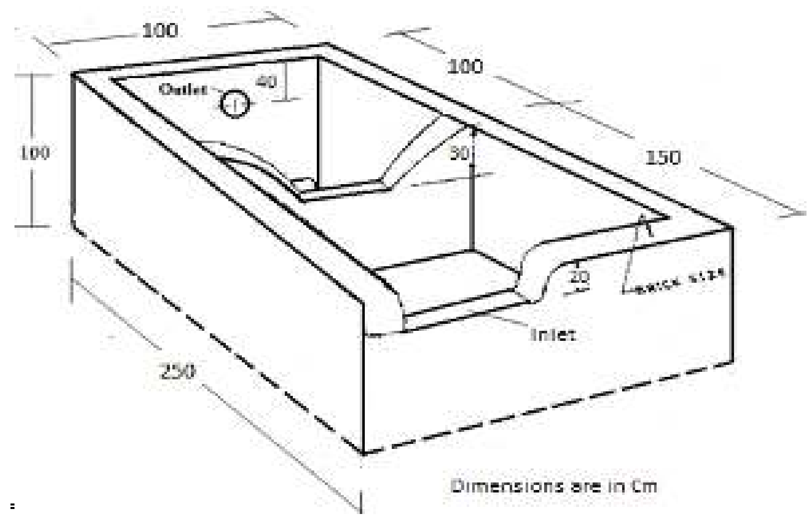


Fig3.21. Silt trap

- The channel from catchment should be connected to the inlet of the sediment pond at a depth of 20 cm and width 40cm.
- The partition at 150 cm should have a trapezoidal or rectangular spillway at 30 cm depth and 50 cm length.

- The outlet to the storage need to be made with 10 to 20 cm diameter pipe (concrete or pvc) at depth of 50 cm. If pipes are not available in the area the runoff from the silt trap can diverted to the storage tank through lined open channel.
- To reduce the sediment/silt load as much as possible excavate a primary silt trap along the flow way before the sediment pond. Filter mesh should be fixed in the inlet part of the flow pipe.

Self-check-2	Written test

Name: ___________________________ Date: ________________

Directions: Answer the following questions.

1. What is catchment area? (1pts)
2. Describe characteristics of watershed or catchment? (5pts)
3. Explain steps to be followed in designing a RWH system. (4pts)
4. Write important parameters used to identify suitable site for rain water harvesting? (5pts)
5. Describe the purpose of selecting site for water harvesting structure? (5pt)
6. Differentiate rain water harvesting from flood water harvesting techniques? (5pt)

Note: Satisfactory rating – 20 points and above Unsatisfactory - below 20 points

You can ask you teacher for the copy of the correct answers.

INFORMATION SHEET#3	Constructing water harvesting structures

3.1 Identifying type of construction materials and equipment

Common types of Construction materials for water harvesting structures are:-

- Soil of different types- sandy soil, clay, silt clay
- Stone - basaltic, sand stone
- Sand - of different size
- Iron bars- deformed reinforcement iron bars of different diameter (6 mm, 8mm, 10mm, 12mm, 14mm etc.…)
- Nails /pegs – of different sizes

- Corrugated iron sheets- of different thickness (G28, G32, G35)
- Clay tiles
- Hollow concrete blocks
- Cement
- Gravel – of different sizes
- Stirrups
- Black wire 1.5 mm diameter
- Timber(formwork)
- Woods
- Water
- Steel pipes
- PVC pipes
- Sheet metals of different thickness (1 mm, 2mm, 3 mm, 4 mm, etc...)

Types of construction equipment

The following are the lists of construction equipments used during the construction of water harvesting structure. These are:

Surveying equipments

Surveying sets, range pole, line level, string, tape meter and peg etc

Excavation equipment

Excavator machine, tractor, bulldozer, hoe, shovel, spade etc

Mason's equipments

Mixer, hawk, trawl, batching box and plumb bob

Carpentry equipments

Hammer, saw, sprit level etc

3.2 Determining man power requirements

Typical productivity guidelines need to reflect what each worker can achieve in a day by working approximately 8 hrs. These are called task rates. Examples are as follows:

Activity	Task Rate
Vegetation clearing	150 – 300 m^2/md
Excavation, soft soil	3 – 4 m^3/md
Wheelbarrow hauling:	
0 – 40 m	10.5 m^3/md
40 – 60 m	8.0 m^3/md
60 – 80 m	6.5 m^3/md
80 – 100 m	5.5 m^3/md

Deciding Task Rates

The task rates mentioned so far in this book are guidelines only. A reasonable task rate for each activity must be decided on site bearing in mind such factors as:

- the **difficulty of the work** e.g. soil hardness/wetness, bush thickness, throwing distances;
- the **condition of the tools**;
- the **temperature/weather conditions**;
- the **fitness/health of the laborer's** and **their experience** of work.

To decide a task rate for an activity follow this procedure:

Step 1 Set aside one day for a trial on the activity. Organise the labourers on a day-work basis on this activity.

Step 2 Supervise the labourers closely, making sure that they all work hard for an eight-hour period.

Step 3 Stop works after eight hours and measure the quantity of work completed. Divide the quantity by the number of labourers on the activity. This gives an average task rate for the activity.

$$\textbf{Task rate} = \frac{\text{Total work completed in 8 hours}}{\text{Number of labourers on activity}}$$

Repeat this exercise frequently and adjust the task rate so that all labourers work on site for at least six hours a day.

Typical Task Rates

TASK RATES/PRODUCTIVITY NORMS			
ACTIVITY		**TASK RATE**	**REMARKS**
Clearing of garbage		daily paid	
Tree & stump removal		daily paid	Roughly 1 wd for every 20 cm Ø of tree
Grubbing Light ground cover up to 5 cm thick		150-300m^2/wd	Considering grubbing the entire clearing area
Boulder removal		daily paid	From experience
Slotting (for road base)		2 – 4 slots/wd	Check according to the volume of earthwork
Excavation only	Soft/loose soil	3 – 4 m^3/wd	Maximum throwing distance of 4.0 m
	Hard soil	2 – 3 m^3/wd	
	Very hard soil	1 – 1.5 m^3/wd	
Excavate laying of pipe refill		2 – 3 m/wd	Depends on the hardness of the soil and the underground infrastructure
Excavation & loading	Soft/loose soil	3 – 3.5 m^3/wd	
	Hard soil	1.75 – 2.5 m^3/wd	
	Very hard soil	1 – 1.5 m^3/wd	
Sloping	Soft/loose soil	3 – 4 m^3/wd	Sloping includes shaping the slope to the right gradient, e.g. for drains
	Hard soil	2 – 3 m^3/wd	
	Very hard soil	1 – 1.5 m^3/wd	
Formation of camber (for roads)	First spreading	90 m^2/wd	Spread material from ditching or from imported material
Gravel excavation including loading	Normal weathered material	1.5 –2.5 m^3/wd	
	Very hard material with boulders	1 – 1.5 m^3/wd	
Gravel spreading	0.20 m thick	50 – 70 m^2/wd	
Stone collection and loading		2.5 – 3 m^3/wd	
Sand collection and loading		3 – 4 m^3/wd	
Stone masonry		2 – 2.5 m^3/wd	This includes hand laying of the stones only. Mixing of mortar and preparation of stones is not included
Bricklaying for walls		8 – 10 m^2/wd	This includes hand laying of the bricks only. Mixing of mortar and preparation of bricks is not included

where: wd is = worker day

3.3.Determining all service and running cost for the project life time

In order to analyze the life cycle costs of a Constructing water harvesting structures, it is necessary to estimate the operation and maintenance costs over time after the startup of the facility. The stream of operating costs over the life of the facility depends upon subsequent maintenance policies and facility use. In particular, the magnitude of routine maintenance costs will be reduced if the facility undergoes periodic repairs and rehabilitation at periodic intervals.

Since the tradeoff between the capital cost and the operating cost is an essential part of the economic evaluation of a facility, the operating cost is viewed not as a separate entity, but as a part of the larger parcel of life cycle cost at the planning and design stage. The techniques of estimating life cycle costs are similar to those used for estimating capital costs, including empirical cost functions and the unit cost method of estimating the labor, material and equipment costs. However, it is the interaction of the operating and capital costs which deserve special attention.

3.4 Preparing bill of quantity

Bill Of Quantity form: It is the format which is used in a bill of quantity to list (include) a short description of the specification along with its measuring unit, quantity and unit prices to determine the total cost for each trade of item.

Project: XY					
Item	Description	Unit	Quantity	Unit price	Amount

There are four clearly defined steps in preparation of Bill of Quantities:

1) Taking off
2) Squaring
3) Abstracting
4) Writing the final Bill of Quantity

1) Taking off:

This is the process of preparing /defining a detailed list of all labor and materials necessary for the work and entering the items on properly dimensioned paper. The standard form used for entering the dimensions taken or scaled from drawings to determine the accurate quantity in each trade of work, except reinforcement steel, is called take off sheet or dimension paper.

The dimension paper used for taking off is usually double – ruled as shown below (A4 size).

Title				Title			
1	2	3	4	1	2	3	4
			Page___				Page __

- ***Column 1*** is used for stating the number of times an item occurs and is called the timising column.
- ***Column 2*** is called dimension column as it is used to enter the dimensions of the items of wo rks. The dimensions are entered in the order indicated below: Length, Width, Height or thickness.
- ***Column 3*** is called squaring column. The stated dimensions in column 2 are multiplied to determine the quantity of the work either in ml, m^2, m^3 or in Pcs. or No.
- ***Column 4*** is called description column and description of the work item is briefly stated

A separate sheet (Bar Schedule) is used to prepare reinforcement quantities as shown below.

No.	Location	Shape	Dia. (mm)	Length (m)	Number of-		Total length (m)	Dia.6	Dia.8	Dia.10	Dia.12	Dia.14	Dia.16	Dia.20
					Bar in member	Member (Pcs)								
				Total Length (m)										
				Unit Weight (Kg/m)				0.22	0.39	0.61	0.88	1.20	1.57	2.467
				Total Weight (Kg)										

The following tasks are part of the taking off (used to facilitate defining the quantities):
Describing the item, bracketing (relating the description to the quantity), timising, dotting on (adding to the timising factor), the ampersand (ditto), waste calculations, deduction of items, correction of dimensions (nullifying).

2) Squaring:

The dimensions entered in Column 2 are squared or cubed as the case may be, multiplied by the timising factor, and the result entered in Column 3. This task is called squaring. All squared dimensions should be carefully checked by another person before abstracting, and if correct the item should be ticked with red.

3) Abstracting

The squared dimensions are transferred to abstract sheets and all similar dimensions are collected in the same category to obtain the total quantity of each item.

4) Writing the Final Bill

After the abstract sheets have been completed and checked, the final bill of quantity is written. The dimensions are copied from the abstracts, and as each item is transferred it should be ticked by a vertical line from the abstract sheets. The description of each item in the final BoQ should be short, precise and descriptive as per the specification.

To measure production or set tasks on labor-based works, you must estimate the quantity of work to be done. Data for estimating the quantity of work can be collected using:

- design drawings;
- simple surveying tools such as boning rods, profile boards, line level, special templates, etc.;
- Tape measure.

Once data has been collected in the field, from the drawing and the Bill of Quantities (if available), the detailed quantities of work for each activity need to be calculated.

Example for Rooftop Rain Water Harvesting Structure Cost Estimation

Cost Estimation of Rooftop rain water harvesting structure involves the cost of conveyance of the materials, material cost and labor cost. However, the overall cost of the structure depends on the orientation of the building and lead (distance).

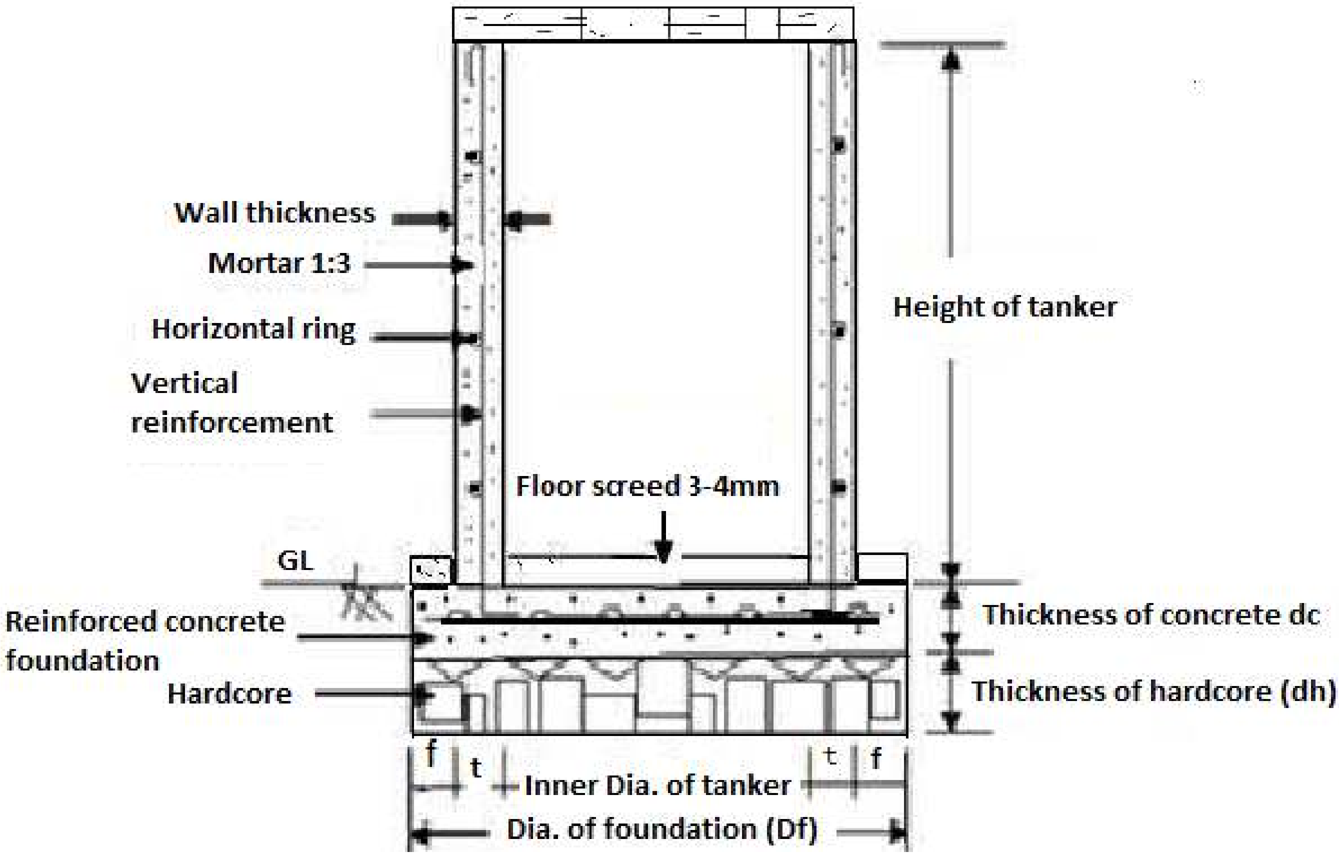


Fig31. Sectional view of Ferro cement tank

1. **Design specification or Details of construction**

For water tank let the height of the tanker be h

$\mathbf{V_t = \pi r^2}$ h where: r= radius of tanker
h= height of the tanker
V_t = volume of the tanker

So that,

$$r = \sqrt{V_t / \Pi h}$$

To estimate the radius of excavation we have to consider the following

- Thickness of internal and external paltering
- thickness of wall filled with concrete
- 10-15cm edge of the foundation (footing)

Diameter of foundation (D= 2R) = inner diameter of the taker+ 2(f +t)

Radius of excavation (R) = inner radius of tanker (r) + thickness of wall (t) + footing (f)

Volume of excavation=base area x depth of foundation.

$\mathbf{V_{ex} = \pi R^2 D}$

Volume estimation for foundation

$\mathbf{V_{hard\ core} = \pi R^2 d_h}$ Where $d_h =$ depth of hard core

$\mathbf{V_{concrete} = \pi R^2 d_c}$ Where d_c == depth of concrete

For shrinkage and wastage (quality control) add 50% of the volume.

$V_t = \mathbf{1.5V_{concrete}}$

Since volume of concrete with a ratio of 1:2:3.Out of the total volume 1/6 or 16.6% is cement, 2/6 or 33.3% is sand and 3/6 or 50% is gravel and the respective volume of cement, sand and gravel is: -

$V_{cement} = 1/6 * V_t$

$Vs = 2/6 * V_t$

$Vg = 3/6 * V_t$

$\mathbf{V_{mortar} = R^2 d_f}$, where d_f is depth of floor

The volume mortar with the ratio of 1:3 and taking shrinkage and wastage percent 35% will give us:

$\mathbf{V_{mortar}} = \mathbf{R^2 d_f} * 1.25$

$\mathbf{V_{cement}} = 1/4 * \mathbf{V_{mortar}}$

$\mathbf{V_{sand}} = 3/4 * \mathbf{V_{mortar}}$

Estimation of reinforcement required for the foundation and the super structure.

Length of Ferro required for foundation

To estimate the number of bar that lie horizontally for foundation:

$$\text{No. of bars used for foundation.} = \frac{C}{\text{Spacing b/n bars}}$$

In order to estimate the number of circumference which lies on the foundation parts are:

$$\text{No. of circumference} = \frac{\text{radius}}{\text{Spacing b/n circumference}}$$

Length of Ferro or bar required for super structure

Total length of vertical bar for the wall = height of tanker + depth of foundation + 0.1m bend length. The number of vertical bars required to reinforce the wall =circumference/spacing b/n bars

$$\text{Total number of rings required} = \frac{\text{height of tanker}}{\text{Spacing b/n rings}}$$

The total length of rings = circumference of the ring X number of rings

Total length of bar for super structure is the sum of vertical bars and the total length of ring. Therefore, the total length of bar required to construct the storage is the sum of total length of the bar for foundation and super structure.

Estimation of materials for super structure (wall)

$V_{mortar} = 2\pi r \times t \times h$

Where r=inner radius, m; t= thickness of the wall, m and h= height of tanker, m.

Then determine the element of mortar

$V_{cement} = 1/4 * V_{mortar}$

$V_{sand} = 3/4 * V_{mortar}$

Table shows the details of cost estimation made for 5000 liters capacity of storage tank.

Item	Unit	Quantity	Unit cost Birr*	Total cost Birr
MATERIALS				
Cement	Bag			
Sand	M^3			
Stone and hard core	M^3			
Gravel	M^3			
Chicken mesh wire	M^2			
Corrugated iron sheet	Pcs.			
Purlin	Pcs.			
Truss	Pcs.			
Nail	Kg			
Wire (6mm∅)	Kg			
Galvanized pipe (3/4'')	M			
Tap (3/4'')	Pcs.			
Nipple (3/4'')	Pcs.			
Gate valve (3/4'')	Pcs.			
Steel (8mm∅)or bars**	bars			
Total cost for materials				
LABOUR				

Mason	Man day			
Daily labourers	Man day			
Total cost for labours				
Contingency (10%)				
Grand total cost				

*** Assumed unit cost price.**
** 1 bar length is 12 meter.

3.5 Conducting land leveling activities

Land leveling is the process of modifying the surface relief by smoothening it. It is the process of flattening or modifying existing (natural) slopes or undulations and thereby creating a level surface. Normally land leveling requires excavation and movement of earth from higher elevations to lower elevations. Land grading is modifying the slope of land to a planned grade (slope) and specifications for Constructing water harvesting structures. The operations are usually accomplished using special equipments to eliminate the minor irregularities but not to change the general topography of the land surface. Most land leveling activities is accomplished with tractor drawn loading - type scraper and grader equipment.

Purpose of Leveling and Grading of Land

The art of determining relative altitudes of points on the surface of the earth or beneath the surface of the earth is called leveling. For the execution of **constructing water harvesting structures** it is necessary to determine the elevation of different points along the alignments of the proposed elevations. Leveling is employed to provide an accurate network of heights, covering the entire area of a project. Land grading involves reshaping the ground surface to planned grades as determined by an engineering survey, evaluation, and layout. Land grading provides more suitable topography for **Constructing water harvesting structures** and other land uses and helps to control surface runoff, soil erosion and sedimentation from the ungraded land during and after construction. Land grading is applicable to sites with uneven or steep topography or easily erodible soils, because it stabilizes slopes and decreases runoff velocity.

Methods of Leveling and Grading

Leveling may be categorized into two types.

- ✓ Simple leveling
- ✓ Differential leveling

Simple Leveling

Land leveling can be accomplished with the aid of leveling instruments (Theodolite, line level, etc) and farm implements (shovel, rakes, spades, rope, hoe, etc)

Water Level

This instrument is used for setting out levels on the site as well as to transfer and control levels over large distances. It consists of a transparent plastic tube filled with water (Fig. 42 Left). The level of the water at one end of the tube (a) will be at exactly the same height as the level at the other end (b), provided that there is no air bubble in the tube and it is not buckled.

The water level enables us to level over large distances with a high degree of accuracy.

If there is no transparent plastic tube available and some rubber hose can be found, the Rural Builder can ach end take two glass bottles knock out the bottoms and fit the bottle necks to each end of the hose. This apparatus is then filled with water until the water is seen in the bottles. Levels can be read as easily with this device as with any other water level (Fig.42 Right).

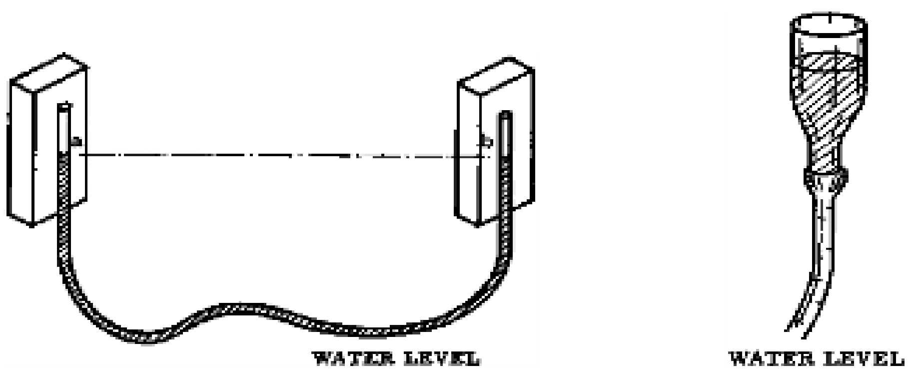


Fig. 32 Water Level

Boning Rods

Boning rods are T-shaped wooden tools, usually 120 cm high and 20 cm wide at the top. They are used in sets of three to help the Rural Builder to level between two given points (Fig.43).

Points a and b are marked with the water level and any point in between them can be obtained by using the third boning rod and sighting along the rods (Fig. 43).

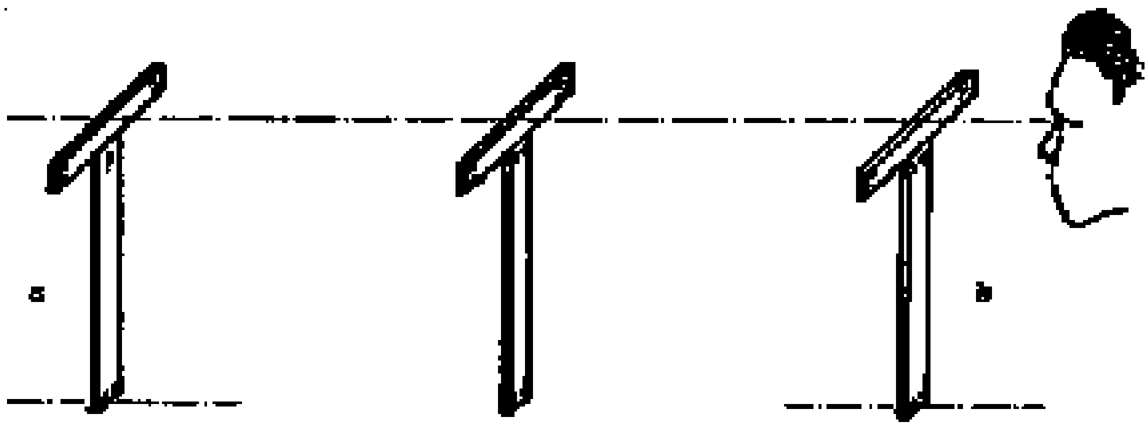


Fig. 33 boning rod

Line level

1. The line level is a simple surveying instrument which can be used to lay out contours and gradients, and also to measure the slope of land. It is simple to operate and is easier to transport than other similar surveying tools such as the A- frame. It is especially quick and very accurate when used properly. However a line level does require three people to operate it.

2. A line level consists of two poles, between which a length of string is suspended. A spirit level is hung on the string. The level is the type used by builders, but has small hooks at either end.

3. The poles should be of even height (about 1.5 m) and the string (about 2 mm in diameter) and precisely 8 meters in length. A notch is made in each pole at exactly the same height (say 1.4 m above ground level) and the ends of the string tied around these notches.

4. The center of the string (4 m from each end) is marked and the level itself is suspended there.

Laying out a contour

5. The poles are held apart by operators with the string extended and the spirit level positioned exactly in the middle of the string. When the bubble in the level is between the two marks this means that the poles are positioned on level points on the land - in other words on the contour. The poles must be held vertically.

6. To lay out a contour across a slope, the teams begin at the edge of the field. The operator holding the pole at the field's edge (operator A) remains stationary while the operator holding the other pole (operator B) moves up and down the slope until the third operator is satisfied that the bubble is centered. Points A and B are then marked (with stones or pegs). Operator A then

moves to B and operator B moves onwards and the process is repeated. This continues until the contour line reaches the far end of the field.

7. Care should be taken that small obstacles, such as minor high spots, or rills, are avoided by skipping forward a pace or two. This avoids sharp irregularities in the contour.

8. When the contour has been laid out, the curves can be smoothed by eye according to the guidelines given for stone or earth bunds.

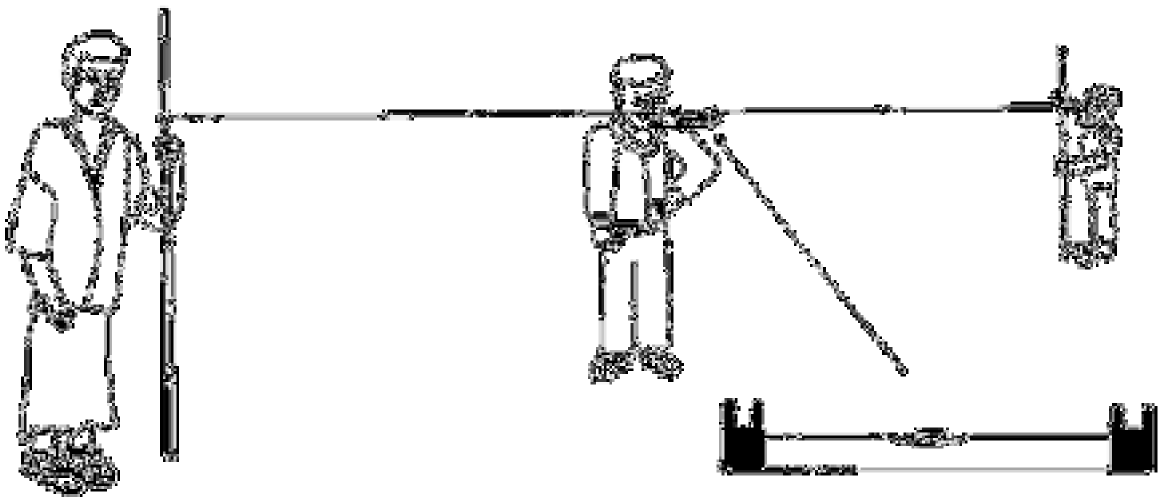


Figure 34. Use of the line level

Laying out a graded contour

9. A graded contour deviates slightly from the true contour and is normally used to align a channel, such as a diversion ditch, or to stake out a graded earth bund.

10. In order to lay out a graded contour, further notches must be made on one of the poles. These notches are made below the original notch at intervals of 2 cm.

11. The usual gradient for a structure such as a diversion ditch is 0.25%. The string of the near side operator (A) should be affixed to the second notch down his pole (2 cm below the original) and the far operator (B) retains his string at the original notch. When the bubble in the level is between the two marks, this now implies that A is 2 cm above B, which is equivalent to a 0.25% slope over the distance of 8 meters. For a slope of 0.5%, Operator A fixes his string to the third notch down his pole (4 cm below the top notch) and, when Operator B finds a position where the

level reads dead center, he is at a ground level 4 cm below that of Operator A. Over a distance of 8 meters the slope is then 0.5%.

12. The operation now proceeds as before, operator A moving forward to the spot occupied by B, and B moving onwards - slightly down slope. Once again minor irregularities should be avoided and the curve smoothed.

13. If a diversion ditch must follow a precise field boundary it can be excavated so that the bottom of the ditch is given a suitable gradient. Surveying will therefore take place during excavation.

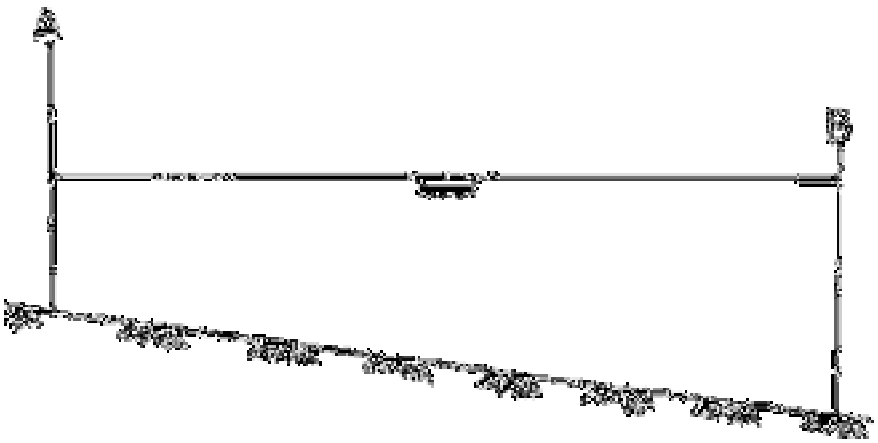


Figure 35. Measuring the slope with a line level

Measuring the slope of the land

14. It is simple to use the line level to measure the slope of the land. Operator A stands exactly upslope of Operator B and adjusts the string to the notch which gives a level reading. For example if this notch is the 3rd (i.e. 4 cm below the top notch) the gradient is 0.5%, if the notch is the eleventh (i.e. 20 cm below the top notch) the gradient is 2.5%, etc.

16. Always check the spirit level - by placing it on a horizontal surface and noting the position of the bubble which should be between the two marks.

17. Check the center point of the string each day and its length also,

18. Remember that when laying out a gradient that operator (A) is upslope.

19. Make sure poles are held vertically.

20. Avoid placing the poles in depressions or on top of minor high spots in the field.

Using Theodolite

The operation of leveling for determining the difference in elevation, if not too great, between two points visible from a single position of the level is known as simple leveling. Suppose A and C are the two points whose difference in elevation, is required to be measured with a leveling instrument set up at B. To eliminate the effect of the earth's curvature and instrumental errors, it is advisable that the level is set up at equal distance from points A and C but not necessarily on the line joining them. (Fig….)

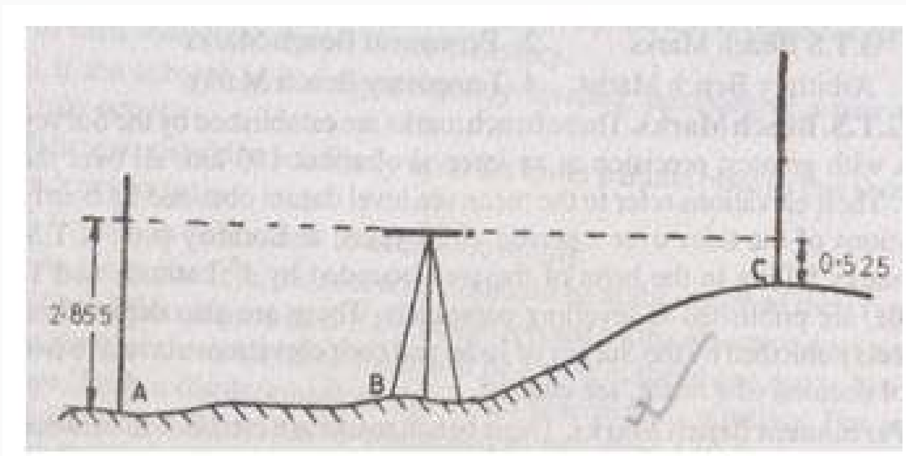


Fig 36 Simple Leveling (Source: Venkatramaiah, 1996)

Following steps should be used

- The telescope of the instrument should be leveled using standard procedure.
- The telescope is focused on the leveling staff held vertically on A.
- Readings of the central horizontal hair of the diaphragm where it appears to intersect the staff is taken ensuring that the bubble of the level is central.
- The staff is shifted to C.
- The telescope is directed towards C and again focused.
- Initial leveling should be such that even after rotating the telescope, the telescope remains horizontal.

- Reading of the central horizontal line is then taken.

Illustration I

Let the respective readings on staff A and staff C be 2.855 and 0.525m respectively. The difference of level between A and C: 2.855 – 0.525 = 2.330 m

If Reduced Level (R.L.) of A = 500.000 m, R.L of B may be calculated as:

R.L of point A = 500.000m

R.L. of the line of sight = 500.000 + 2.855 = 502.855 m

R.L. of the point C = 502.855 – 0.525 = 502.330 m

Illustration II

If one of the points is on the floor and the other is on the ceilings such as in tunnels or buildings, the staff at the elevated point, may be held vertically inverted (Fig.24.2).

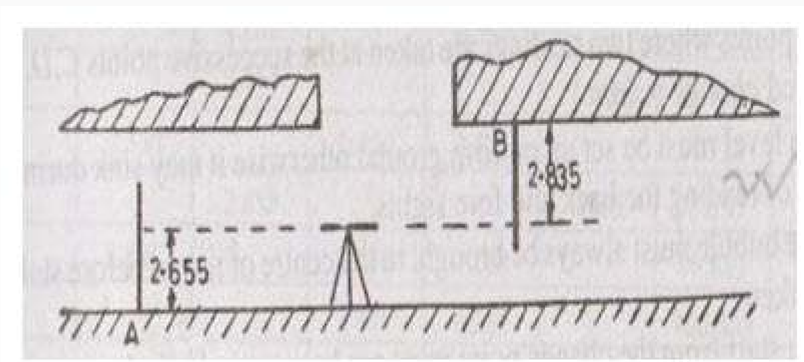


Fig. 37 Simple Leveling with Inverted Staff. (Source: Venkatramaiah, 1996)

If the elevation of A = 200.000 m

Back sight reading on A = 2.655 m

Fore sight reading on B = 2.835 m

R.L. of the line of sight = 200.000 + 2.655 = 202.655 m

So, R.L. of the point B = 202.655 + 2.835 = 205.490 m

Differential Leveling

The method of leveling for determining the difference in elevation between two points either too far apart or obstructed by an intervening ground, is known as differential leveling. In this method, the level is set up at a number of points and the difference in elevation of successive points, is determined as in the case of a leveling.

3.6 Interpreting lay out drawings and construction specifications

To do this, you will have to locate the element of construction you are reviewing to implement a portion of your work. If you are laying out the location of the structure, you will first look at the site plan for location of existing buildings, structures, or property lines so you have a reference point to begin measuring to your building footprint. Some plans simply give a coordinate grid position using Northing and easting, and you will need a "total station" surveyor's transit to locate these points. Here is what you'll need to do to lay out a WH structures from the plans:

- Lay out your building on the site by either the above referenced plan or the measurements given on the site plan. Measure to locations, preferably corners, on one side of the building, and check for any "checkpoints" to verify the accuracy of your layout. If you cannot absolutely establish an exact building line, you may have to suppose the location is correct and continue. This is widely accepted in cases where the site is very large, allowing for tolerance, but on a crowded lot or site, the location must be exact.
- Establish the elevation you will work from. This may be a height relative to a nearby roadway, or an elevation determined from sea level. Your site plan should have a bench mark (a bench mark refers to some item, such as a manhole lid or survey waypoint with a known elevation) elevation or a "height above existing grade" as a starting point.
- Use your plan to measure the location of each corner of the building, including offsets. Remember what exact element of construction you are using for your layout.

3.7 Selecting appropriate shade & lining materials

Definition

Shading materials: It is a kind of material constructed on the roof of water harvesting structure to prevent the loss of water via evaporation and protect the entrance of un wanted materials as well as people and animals.

Lining materials: it is a kind of material constructed on the floor and wall of the water harvesting structure to prevent the loss of harvested water via seepage and de-percolation.

Types of shading and lining materials

Shading materials

- **Thatch, plastic , reinforced concrete and GI sheet**

Lining materials

- Red clay
- Termite mound.
- Cement mortar
- Concrete
- Stone or brick with cement mortar
- Polyphone sheet (plastic lining) - the thickness should not be less than 0.5 mm.

Uses of shading and lining materials

The main advantage of using shades and lining materials for water harvesting structures is

- ✓ To reduce evaporation and seepage loss respectively.

Seepage losses

- ♠ Appropriate and low cost lining materials should be used in order to reduce the water losses through seepage.
- ♠ The following materials are mostly used for lining water tanks.

Evaporation losses

- ♠ Reducing evaporation is an important way to increase the supply of water.
- ♠ Therefore, the following measures should be taken:
  - The storage tank should be covered with appropriate roofing materials that inhibit vaporization.
  - Surface area of the storage tank should be minimizing to reduce the cost of tank roofing.

Self-check-3	Written test

Name: ____________________________ Date: ________________

Directions: Answer the following questions.

1. List down all the necessary construction materials required for water harvesting structures? (3 pt)
2. Mention all the required construction equipments for water harvesting structures? (3 pt)
3. what is land leveling means and explain the purpose of leveling and grading of land?(5pt)

4. write the purpose of preparing of bill of quantity to construct water harvesting structures?(5pt)
5. Define shading and lining materials? (3 pt)
6. Mention the typical examples of shading and lining materials? (3 pt)
7. Describe the uses of shading and lining materials? (3pt)

Note: Satisfactory rating – 20 points and above Unsatisfactory - below 20 points

You can ask you teacher for the copy of the correct answers.

Operation Sheet	Construct water harvesting structures

Objective: To understand how to construct different water harvesting structures.

Materials, Tools and equipment's used are:-

Planimeter, Tape meter, line level, theodolite, chaining pins, ranging pole, staff, clinometers, Global positioning system, compass, Auger, core sampler, spatula, oven, pressure apparatus, sensitive balance, sieve, soil grinder, hydro meter, shaker and measuring cylinder, thermometer, stop watch, flasks, shovel, rakes, spades, rope, plumb bob, hoe, mixer, tracing paper, pencil, graph paper, fixer, topographic map, drawing compass set.

Procedures

The following procedures should be taken into account to construct different water harvesting structures:

- ✓ Identify potential areas
- ✓ Identify proper site
- ✓ Identify availability of construction materials in that area
- ✓ Assess soil moisture statues of the area
- ✓ Delineate the catchment area
- ✓ Choose appropriate water harvesting techniques
- ✓ Conduct land leveling activities
- ✓ Select the design principles for the chosen technique of water harvesting
- ✓ Prepare design drawing for the selected technique
- ✓ Prepare bill of quantities
- ✓ Finally lay out the selected area and implement the selected technique of water harvesting structure.

LAP Test/ Job Sheet	Practical Demonstration

Name: ____________________________ Date: _______________

Time started: ________________________ Time finished: _______________

Instructions:

1. You are required to perform the following activity:

- Request your teacher to arrange materials, tools and equipment used in constructing water harvesting structure, in order to handle materials and equipment.
- Request your teacher for evaluation and feedback.

REFERENCE

- Assessment of Best Practices and Experience in Water Harvesting; Rainwater Harvesting Handbook; African Development Bank
- Chao-Hsien Liaw and Yu-Chuan Chiang (2014): Framework for Assessing the Rainwater Harvesting Potential of Residential Buildings at a National Level as an Alternative Water Resource for Domestic Water Supply in Taiwan
- John Ndiritu, Adesola Ilemobade, and Paulo Kagoda (2018): Guidelines for rainwater harvesting system design and assessment for the city of Johannesburg, South Africa
- Manual for Rooftop Rainwater Harvesting Systems in the Republic of Yemen, (Sharafaddin , Prof. Dr. Taha Taher and Prof. Dr. Abdulla Noaman - Faculaty of Eng. Sana'a University)