Agricultural TVET College

Small Scale Irrigation Development

LEVEL II

MODEL TTLM

Learning Guide #16

Unit of Competence: Assist Construction of Water Harvesting Structure

Module Title: Assisting Construction of Water Harvesting Structures

LG Code: AGR SSI1 M02 LO1-11

TTLM Code: AGR SSI1 TTLM 1218V_2

Nominal Duration: 50 Hours

Instruction Sheet	Learning Guide #12

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

- Collect and organize all required data
- Identify soil requirement in catchments and cultivated areas
- Select crop type for water harvesting
- Assist design of water storage capacities
- Assist with design and construction of micro catchment techniques
- Assist with design and construction of macro catchment techniques
- Assist with design and construction of flood water harvesting
- Identify construction materials
- Assist construction of roof top water harvesting
- Assist construction of ground surface catchments, diversion canals and sediment ponds
- Assist construction ground surface 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 –

- ✓ Collect data from metrological station
- ✓ Use rain fall data to estimate run off
- ✓ Doing soil sampling
- ✓ Organize and analyzing soil data
- ✓ Identify crop species based on crop requirements
- ✓ Practice identified crops

- ✓ Design capacity of structures
- ✓ Store water based on the demand
- ✓ Identify different micro catchment types
- ✓ Design identified catchment types
- ✓ Construct designed structures
- ✓ Identify different macro catchment types
- ✓ Design identified catchment types
- ✓ Construct designed structures
- ✓ Identify different micro catchment types
- ✓ Design identified catchment types
- ✓ Construct designed structures
- ✓ Identify construction materials
- ✓ Use materials for construction
- ✓ Select site
- ✓ Prepare required materials
- ✓ Construct structures
- ✓ Harvest and supplying water
- ✓ Identify surface catchment, diversion canals and sediment ponds
- ✓ Arrange materials
- ✓ Construct surface catchment, diversion canals and sediment ponds
- ✓ Design structures for catchment area
- ✓ Collect materials
- ✓ Construct structures

Learning Activities

1. **Read the specific objectives of this Learning Guide.**
2. **Read the information written in the "Information Sheet"**
3. **Accomplish the "Self-check".**
4. **If you earned a satisfactory evaluation proceed to the next "Information Sheet". However, if your rating is unsatisfactory, see your facilitator for further instructions or go back to Learning Activity.**

5. **Submit your accomplished Self-check. This will form part of your training portfolio.**
6. **Read and Practice "Operation Sheets".**
7. **If you think you are ready proceed to "Job Sheet".**
8. **Request you facilitator to observe your demonstration of the exercises and give you feedback.**

Information sheet 1	**Collect and organize all required data**

1.1.Collecting data from metrological station

The weather variables for driving the hydrological balance are precipitation, air temperature, solar radiation, wind speed and relative humidity. Required daily data are precipitation, max and min air temperature, solar radiation, wind speed and humidity. These metrological data were collected from local meteorological station.

Rainfall data analysis

Rainfall in dry areas is characterized by short duration, high intensity and poor distribution. The low duration high intensity combination is conducive to high runoff production. The great rainfall variation with time presents the biggest challenge to dry land agriculture. Cropping seasons are usually longer than the rainfall seasons, and drought within the growing season is a common feature of most growing seasons. In water harvesting design, the aim is to use a rainfall figure that will meet the water requirement and produce a crop with a level of certainty. Although the average rainfall value can be used, it is not a good figure since most of the rainfall consists of a few very wet seasons and many drier ones. Therefore there would be many seasons with actual rainfall figures below the average, and designs based on averages are bound to fail. A more appropriate figure is the median. This is the middle value of any set of seasonal rainfall data arranged from the biggest to the smallest. The best design value is the probability rainfall because it is related to the frequency of occurrence of such rainfall. It helps the planner to get a reasonable catchment size to supplement rainfall, rather than one which is inadequate or too large and uneconomical.

1.2.Using rain fall data to estimate runoff

Types of Runoff

Surface runoff: runoff as sheet or rill flow at the surface before it reaches a stream.

Over land flow: is that part of precipitation that flows in undefined channel.

Sub surface runoff: is the part of infiltrated water which flow laterally through the unsaturated zone of soil mass and joins streams.

Stream flow (base flow): runoff in seasonal streams or rivers. In other words the water that percolates to the ground water table, and later after long periods, joins the rivers, streams. Most or the water harvesting methods are related to the harvest of surface runoff.

Occurrence of runoff from rainfall

The rain first of all, intercepted as interception storage (P), then stored in depression as depression storage(S), and then used in removing the soil moisture deficiency. All this has to be accomplished before any stream flow (surface runoff) or ground water accretion can start. The amount of precipitation required to fulfill these needs is generally termed as initial basin recharge.

After the initial basin recharge is filled up the water will infiltrate in to the ground as ground water accretion (G) and excess water will flow as direct runoff (Q).the total precipitation on the basin can be represented by:

$$P = S + G + Q$$

$$Q = P - S - G = \text{excess rainfall}$$

Factors Affecting Runoff:

A. Climatic or characteristics of precipitation- plays an important role in determining the amount of consequent runoff. It includes:

- Type of precipitation
- Intensity of precipitation
- Duration of precipitation
- Distribution of precipitation
- Frequency of preciptation
- Direction of prevailing wind
- Direction of prevailing storm

B. Watershed characteristics (physiographic factors): on which water (rain) falls also plays a significant part in determining the quantity of runoff. It includes:

- Character of catchment surface (its geological formation)
- Soil moisture
- Topography
- Land use
- Shape and size of the catchment
- Vegetal cover

Determination of Runoff

Various methods used for computing runoff:

1. ***Computing runoff by using runoff coefficient (K)***: the volume of runoff Q, (m^3) can be directly computed approximately, by using an equation of the form

Q = k X **P X A**

Where p= mean annual precipitation (m) & A=area of catchment (m^2)

K=runoff coefficient

This method of computing runoff should be avoided for rural areas and for analysis of major storms.

2. The Curve Number Method

For drainage basins where no runoff has been measured, the Curve Number Method can be used to estimate the depth of direct runoff from the rainfall depth, given an index describing runoff response characteristics.

The Curve Number Method was originally developed by the Soil Conservation Service (Soil Conservation Service 1964; 1972) for conditions prevailing in the United States. Since then, it has been adapted to conditions in other parts of the world.

$$Q = \frac{(P - 0.2\,S)^2}{P + 0.8\,S} \text{ for } P > 0.2\,S$$

Where: S = potential maximum retention (mm)

Q = accumulated runoff depth (mm)

P = accumulated rainfall depth (mm) = initial abstraction (mm)

The potential maximum retention S has been converted to the Curve Number (CN) in order to make the operations of interpolating, averaging, and weighting more nearly linear. This relationship is:

$$CN = \frac{25400}{254 + S}$$

Determination of Peak Discharge

3. *Rational method*: used to predict the peak rate defined as the maximum runoff to be used as capacity for a given structure that must carry the runoff.

Peak discharge: is the maximum amount of runoff (discharge) for which structures are designed.

The rational method used the following formula for computing the design runoff.

$$Q_{peak} = \frac{C \times I \times A}{360}$$

Where: Q= peak runoff rate m^3/sec

C =runoff coefficient

I= intensity of rainfall mm/hr for time of concentration =duration for a given recurrence interval

A= watershed area (ha)

Time of concentration: is the time required for the runoff to travel from the remotest point to the out let of the watershed. For determination of time of concentration (Tc), the most widely used

Self check-1	**Written Test**

formula is the equation given by Kirpich (1940).

$$P = 0.01947\ L^{0.77} S^{-0.385}$$

Where: Tc= time of concentration (min)

L=max. Length of travel of water (m)

S= slope of the drainage basin (H/L), H is the difference in elevation b/n the remotest point and the out let of the basin.

Name: ___________________________ Date: ________________

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

1. Define different types of runoff. (5 point)
2. Describe different methods used to estimate runoff. (5 point)
3. Write data to be collected in order to calculate runoff. (5 point)

Note: Satisfactory rating – 15 points above Unsatisfactory - below 15 points
You can ask you teacher for the copy of the correct answers.

Information sheet 2	Identify soil requirement in catchments & cultivated areas

2.1. Doing soil sampling

Soil sampling should reflect tillage, cropping patterns (and corresponding irrigation requirements), soil type (including drainage and slope characteristics).

The most commonly used method for soil sampling would be based on soil types. Fields are split into sampling areas that contain similar soils.

Generally soil sampling in the case of water harvesting is useful to know:

- The physical characteristics of soil which helps to chose soil for cropping or catchment area
- The chemical & biological characteristics of soil
- The constructional aspects of soil
- The bearing capacity of soil – to construct different water harvesting storage structures

2.2.Organizing and analyzing soil sample

Soil sample taken from the field organized based on the location, depth and date of sampling etc. Following the standard procedures we can determine the physical and chemical characteristics of the soil with respect to water harvesting.

2.3.Selecting soil for catchments and cultivation area

Introduction

The physical, chemical and biological properties of the soil affect the yield response of plants to extra moisture harvested. Generally the soil characteristics for water harvesting should be the same as those for irrigation. Ideally the soil in the catchment area should have a high runoff coefficient while the soil in the cultivated area should be a deep, fertile loam.Where the conditions for the cultivated and catchment areas conflict, the requirements of the cultivated area should always take precedence.

Major physical characteristics of soil

The following are important aspects of soils which affect plant performance under water harvesting (WH) systems.

Texture

The texture of a soil has an influence on several important soil characteristics including infiltration rate and available water capacity. Soil texture refers to its composition in terms of mineral particles. A broad classification is:

a. Coarse textured soils - sand predominant - "sandy soils

b. Medium textured soils - silt predominant - "loamy soils"

c. Fine textured soils - clay predominant - "clayey soils"

Generally speaking it is the medium textured soils, the loams, which are best suited to WH system since these are ideally suited for plant growth in terms of nutrient supply, biological activity and nutrient and water holding capacities.

Structure

Soil structure refers to the grouping of soil particles into aggregates, and the arrangement of these aggregates. A good soil structure is usually associated with loamy soil and a relatively high content of organic matter. Inevitably, under hot climatic conditions, organic matter levels are often low, due to the rapid rates of decomposition. The application of organic materials such as crop residues and animal manure is helpful in improving the structure.

Good structure

- Soil contains at least some clay
- Soil contains at least 3 % organic matter
- Soil has formed stable aggregates+ well suited for cropping area

Compact structure

- ✓ Sticky when wet (high clay -content)
- ✓ Low percentage of air (and water)
- ✓ Low infiltration rate
- ✓ more suitable for catchment less suitable for cropping area

Poor structure:

- ➢ Loose grain of sand or silt, gravel or stones
- ➢ Particles not bound together
- ➢ Soil slips through the fingers like grains
- ➢ Structureless soils are not suitable for water harvesting because they have no storage capacity (freely draining).

Depth

The depth of soil is particularly important where WH systems are proposed. Deep soils have the capacity to store the harvested runoff as well as providing a greater amount of total nutrients for plant growth. Soils of less than one meter deep are poorly suited to WH. Two meters depth or more is ideal, though rarely found in practice.

Fertility

In many of the areas where WH systems may be introduced, lack of moisture and low soil fertility are the major constraints to plant growth. Nitrogen and phosphorus are usually the elements most deficient in these soils. While it is often not possible to avoid poor soils in areas under WH system development, attention should be given to the maintenance of fertility levels.

Salinity/sodicity

Sodic soils, which have a high exchangeable sodium percentage and saline soil which have excess soluble salts, should be avoided for WH systems. These soils can reduce moisture availability directly, or indirectly, as well as exerting direct harmful influence on plant growth.

Infiltration rate

The infiltration rate of a soil depends primarily on its texture. Typical comparative figures of infiltration are as follows:

	mm/hour
sandy soil	50
sandy loam	25
loam	12.5
clay loam	7.5

A very low infiltration rate can be detrimental to WH systems because of the possibility of water logging in the cultivated area. On the other hand, a low infiltration rate leads to high runoff, which is desirable for the catchment area. The soils of the cropped area however should be sufficiently permeable to allow adequate moisture to the crop root zone without causing water logging problems. Therefore, the requirements of the cultivated area should always take precedence.

Crust formation is a special problem of arid and semi-arid areas, leading to high runoff and low infiltration rates. Soil compaction as a result of heavy traffic either from machinery or grazing animals could also result in lower infiltration rates.

Available water capacity (AWC)

The capacity of soils to hold, and to release adequate levels of moisture to plants is vital to WH. AWC is a measure of this parameter, and is expressed as the depth of water in mm readily available to plants after a soil has been thoroughly wetted to "field capacity". AWC values for loams vary from 100- 200 mm/meter. Not only is the AWC important, but the depth of the soil is critical also. In WH systems which pond runoff, it is vital that this water can be held by the soil and made available to the plants.

Constructional characteristics

The ability of a soil to form resilient earth bunds (where these are a component of the WH system) is very important, and often overlooked. Generally the soils which should particularly be avoided are those which crack on drying, namely those which contain a high proportion of montmorillonite clay (especially vertisols or "black cotton soils"), and those which form erodible bunds, namely very sandy soils, or soils with very poor structure.

Soil Requirements in the Catchments & Cropping Areas

Soils of different characteristics are required to the catchment as well as cropping areas in a water harvesting scheme.

1. For Macrocatchment system

The Catchment area requires

- Clayey/loamy soils with some clay and silt.
- Sodic soils and rock surfaces
- compact structure

- ➢ Shallow soils (< lm)

The Cropping area requires

- ➢ Medium texture/infiltration
- ➢ Good structure with organic matter
- ➢ 1 -2.5m deep
- ➢ nutrient -rich, low salinity

2) For Microcatchment systems

- ↓ Medium texture, deep soil, crust-forming capability
- ↓ Earthworks
- ↓ Stable soil type subject to piping

NO: -Soils which crack on drying

-High proportion of montmorillonite clay (especially Vertisols "black cotton soils")

NO: Erodible soils

- Sandy soils, silty sandy soils
- Soil with very poor structure

Self check 2	Written test

Name: ___________________________ Date: ________________

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

1. Describe different physical properties of soil with respect to water harvesting (5 points)
2. Describe soil requirements for catchment area. (5 point)
3. Write use of soil sampling. (2 point)

Note: Satisfactory rating – 12 points above Unsatisfactory - below 12 points

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

Information sheet 3	Select crop type for water harvesting

3.1. Identifying crop species based on the water requirements.

For designing water harvesting system, it is necessary to assess the available water resources, its quality and water requirement of crop intended to be grown.

Choices of Crops for WHT

Water harvesting helps crops by providing extra moisture at different stages of growth although timing cannot be controlled. Periods when the extra moisture can make a significant difference are:

- Around sowing time when germination and establishment can be improved;
- During a mid-season dry spell when a crop can be supported until the next rains;
- While the crop is at the vital stages of flowering and grain fill.

Crop choice

The most common cereal crops grown under water harvesting are:

- *Sorghum* (Sorghum bicolor) is the most common grain crop under water harvesting systems. It is a crop of the dry areas, and in addition to its drought adaptation, it also tolerates temporary water logging - which is a common occurrence in some water harvesting systems.
- *Pearl Millet* (Pennisetum typhoides) is grown in the drier areas of West Africa and India, and apart from being drought tolerant, it matures rapidly.
- *Maize* (Zea mays) is occasionally grown under water harvesting but is neither drought adapted nor water logging tolerant - but in parts of East and Southern Africa it is the preferred food grain, and farmers are often reluctant to plant millet or sorghum instead.
- *Legumes* are less frequently grown under water harvesting but should be encouraged because of their ability to fix nitrogen and improve the performance of other crops. Suitable legumes are cowpeas (Vigna unguiculata), green grams (Vigna radiana), lablab (Lablab purpureus), and groundnut (Arachis hypogea). All are relatively tolerant of drought and are fast maturing.
- *Perennial trees* must with stand long periods of drought such as carob.

CROP GROUP	EXAMPLES	WELL SUITED WH TECHNIQUES
Trees	Pistachio, Almond, Fruit trees, Fodder trees, Citrus trees, Eucalyptus	.Microcatchments (bunds, terraces, semi-circular bunds) . Macrocatchments .Flood water diversion
Cereals	Sorghum Millet Wheat	Micro catchment(semi-circular bund) Macro catchment (trapezoidal bunds) .Flood water diversion
Horticultural Crops	Pulses ,(Water) melons	.Flood water diversion
Range land grasses	Local grasses	.Microcatchment (semi-circular bunds)

General sensitivity to drought

Group one - Millet -Sorghum -Ground nut -Safflower	**Low sensitivity = well suited to WH**
Group two –cotton -sun flower	↓
Group three -Beans	↓
Group four -Maize	**High sensitivity= less suited to WH**

Crop tolerance to drought and water logging

Crops	Ideal water req`t per season (mm)	Drought tolerance	Tolerance to water logging
Sorghum	High(450-600)	Yes	Yes
Pearl millet	< Sorghum	Very good	No
Maize	High (450-600)	Yes	No
Grain legumes	As sorghum	Most	No
Fodder &grasses	Low to high	Yes	?
Trees	variable	variable	Some

3.2. Practicing identified crops

Chosen crops which can fulfill the above mentioned characteristics/requirement can be used under different water harvesting techniques.

Self-Check 1	**Written Test**

Name: _________________________ **Date:** _______________

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

1. What mean water requirements of crop?(5Pt)
2. How we can determine crop water requirements of crop?(5pt)
3. List crops grown under water harvesting techniques? (5pt)
4. List crops and identify their sensitivity to drought in lower and higher condition?(5pt)

Note: **Satisfactory rating – 20 points** **Unsatisfactory – below 20 points**

Information sheet 4	**Assist design of water storage capacities**

4.1 Designing capacity of structures

Water data collection

Assessment of water source either it is surface water, ground water or rainwater determine the approach to develop and utilize the water.

In this case we have to measure run off volume, precipitation or discharge depending on the type of water sources.

Types and Shapes of Water Storage

Type of water storage are divided in to two: Short-term storage and Long -term storage

Based on the relative position of the storage structure with respect to normal ground surface storages can be divided into above or below ground.

There are different shapes of storage structures

- Cylindrical
- Spherical
- Hemispherical
- Rectangular
- Bottle shape
- Circular frustum with concrete dome cup
- Circular frustum with brick cup

Required storage capacity

In order to decide the storage tank capacity required for household or small groups. The following step has to be followed.

- Obtain average monthly rainfall over an area for a minimum of 8-10 years
- Rank rainfall data in terms of months with highest rainfall.
- Select the type and also determine size of the catchment that will be available for use
- Calculate the amount of runoff (inflow) from the catchment per day if daily data is available or per month.
- Calculate the demand of water (out flow) for one day or for a month and for each of users.
- Calculate the amount of inflow (supply) and out flow demand for each month.
- Calculate the cumulative inflow and out flow.
- Compute the difference between total water available (inflows) in each month and demand out flow in the same month.
- Subtract the smallest negative differences from the largest positive differences
- The maximum differences between the largest value and the subsequent lowest value of the cumulated difference will be the required storage tank.

Required catchment size (area)

In order to decide the size of the catchment area the following factors must be considered.

- Run off coefficient
- Rainfall of the area
- Construction cost
- Storage capacity

Required storage capacity (V_t)

In order to design the capacity of the storage the following factors must be considered and quantified.

- Number, age and type of beneficiaries
- Length of dry season
- Loss due to seepage and evaporation
- Cost of construction
- Living standard

Storage capacity (V_t):

$V_t = WD + 20\% \ WD = 1.2WD$,where WD is water demand & 20% is loss

Runoff from catchment area (Q):

Q= AxPxK , where P is mean annual rainfall & K is runoff coefficient

$Q = V_t = APK = 1.2 \ WD$

The required catchment area (A) can be calculated as follows

$$A = \frac{1.2WD}{KP}$$

Estimation of Evaporation and seepage losses

Evaporation loss: can be calculated or measured using class A pan evaporimeter. Seepage losses: difficult to assess as it depends on permeability of the prevailing soil. The seepage losses can be assumed equal to ETo losses as a rule of thumb.

<u>Method of estimation of storage capacity</u>

Estimation of volumes of different shapes of containers

a. Cylindrical

V = Base area x height

$V = \Pi r^2 h$

b. Spherical

$V = \frac{4}{3}\Pi r^3$

c. Hemispherical

$V = \frac{2}{3}\Pi r^3$

d. Rectangular

V = L x W x D

Example

A farmer has a house covered with corrugated iron sheet roof (C.I.S) required to fulfill water requirements of his family members consisting of six persons each require 20lit/day, length of dry season 180 days and losses 20% of the water demand. Use the mean annual rainfall =600mm and runoff coefficient of C.I.S =0.8.

Calculate: a). domestic water demand

b). storage capacity

c).the required size of the catchment

Solution:

a). Water demand for domestic uses (WD): $WD = \frac{P_O \times D_C \times T}{1000}$

$= (6 \times 20 \times 180)/1000 = 21.6m^3$

b) Storage capacity: $Vt = WD + 20\%\ WD = 1.2WD = 1.2 \times 21.6\ m^3 = 25.92\ m^3$

c) The required size of the catchment: $A = \frac{1.2WD}{KP}$

$= (25.92m^3)/(0.8 \times 0.6) = 54m^2$

4.2 Storing water based on the demand.

Water demand is the volume of water requested by users to satisfy their needs. A simplistic interpretation considers that water demand equals water consumption.

The amount of water to be harvested and stored is based on the demand, type and nature of storage structures.

Water demand may be for:

- Domestic water supply
- Livestock water supply
- Irrigation purposes

The amount of water of stored is based on:

- Number and age of beneficiaries (domestic and livestock)
- Living standard
- Length of dry seasons
- Area to be irrigated
- Losses (due to seepage ,evaporation and poor water management)

Self-Check 4	**Written Test**

Name: ____________________________ Date: _________________

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

1. What is water demand means?(2Pt)
2. How we can determine water storage capacity?(5pt)
3. Write the factor to decide the size of the catchment area to store water? (4pt)
4. Explain net socio economic benefits of water?(5pt)
5. A farmer has a house covered with corrugated iron sheet roof (C.I.S) required to fulfill water requirements of his family members consisting of six persons each require 40lit/day, length of dry season 365 days and losses 10% of the water demand. Use the mean annual rainfall =800mm and runoff coefficient of C.I.S =0.7.

Calculate: a). domestic water demand (3pt)
b). storage capacity (3pt)
c).the required size of the catchment (3pt)

Note: **Satisfactory rating – 25 points** **Unsatisfactory – below 25 points**

Information sheet 5	**Assist with design and construction of micro catchments techniques**

5.1. Identifying different types of micro catchment

Micro catchments are types of water harvesting methods with Main characteristics:-

- ✓ Overland flow harvested from short catchment length
- ✓ Catchment length usually between 1 and 30 meters
- ✓ Runoff stored in soil profile
- ✓ Normally no provision for overflow
- ✓ Plant growth is even

Types of micro catchment

5.1.1. Negarim Micro catchment

Negarim micro catchments are diamond shaped basin surrounded by small earth bunds with an infiltration pit in the lowest corner of each. Runoff is collected from within the basin and stored in the infiltration pit. Micro catchment is mainly used for growing trees or bushes. This technique is appropriate for small scale tree planting in any area, which has a moisture deficit. Besides harvesting water for the trees, it simultaneously conserves soil.

Technical details

Suitability: Negarim micro catchment's is mainly used for tree growing in arid and semi-arid areas.

Rain fall: -ranges from 150mm-700mm per annum.

Soil*: -*should be at list 1m-2m deep in order to ensure adequate root development and storage of the water harvested.

Slope: -from flat to 8%

Topography: -need not to be even, if uneven a block of micro catchment should be sub divided.

5.1.2. "V" Shaped Micro catchment

Description V-shaped micro catchment is an open ended micro catchment formed by small earth ridges with an infiltration pit in the lowest corner of the basin. Runoff is collected from within the basin and stored in the infiltration pit. The advantage is that surplus water can flow around the tips the bund or ridge. The storage capacity is less than that of the closed system. This kind of bunds is particularly useful on broken and sloppy terrain and for small number of tree planting around homestead.

Technical Details

Suitability "V" shaped micro catchments are mainly used for tree planting in arid, semi-arid, and semi humid areas.

Rain fall:-ranges from 300mm-700mm per annum

Slope:-can be range from 5%-30%

5.1.3. Contour bund for trees

Description: - The contour bunds for trees are very similar to the contour ridges for crops system. The difference is that the system for trees, the harvested water is collected in an infiltration pit instead of in a furrow. As with the contour ridges for crop the efficiency of contour bund for tree is high due to the comparatively short slope length of the catchment area.

Technical Details

Suitability Contour bund for tree planting can be used under the following conditions:

Rain fall:- 200mm-750mm;for semi-arid to arid areas

Soil: must be 1m-2m deep to insure adequate root development and water storage

Slope:- 5%-20%

5.1.4. Semicircular bunds

Description Semi-circular bunds are earth bunds in the shape of a semi-circle with the tips of the bund o the contour. Dimensions vary, from small structure with a radius of 2m t very large structure with a radius of 30m. Large semicircular bunds are used for rangeland rehabilitation and fodder production; smaller semicircular bunds for trees, shrubs and crops. The advantage of these structures is that they are

(i) Easy to construct,

(ii) Labor efficient because a maximum enclosed area is obtained with a minimum of bund volume (thanks to the semicircular shape), and

(iii) Suitable for uneven terrain because the structure are free standing.

Technical details

Suitability:-Semicircular bunds for rangeland improvement fodder production and tree planting can be used under the following conditions. Rainfall:- 300mm-700mm for arid to semi-arid areas Slope:- all soils which are not too shallow or saline Slopes:- for range improvement it can be up to 5%, for tree planting slope can be considered up to 30%

5.1.5. Zai, planting pit

Description Planting pits or zai is the simplest form of water harvesting. The planting pit technique consists of digging small holes of about 10 to 15 cm deep, in which a little manure is put together with some seeds. During rainstorm the planting pits catch runoff and concentrate it around the growing plants. Yields are improved in the first season after the land has been treated, and even in very dry years these techniques ensure some yield.

Technical Details

Suitability Zia are usually constructed on degraded abandoned or unused land that is on crusted, hard, compacted and poorly structured soil of semi-arid areas. The planting pit meets the criteria for three types of construction practices at the same time.

Soil: -it generally applied on silt and clay soils

Slope: - zai can be practiced at a slope of up to 8%-12%, if cutoff drain incorporated with in at appropriate space.

Topography: - the topography must be even

5.1.6. Contour ridges for crop

Description Contour ridges, sometimes called contour furrows, are small earthen banks, with a furrow on the higher side which collects runoff from an uncultivated strip between the ridges. Through their shape soil moisture is increased under the ridge and the furrow, in the vicinity of plant roots. The advantage of this system is that the runoff yield from the short catchment length is very efficient. Labor requirement is relatively low and contour ridges are easy to make using hand tools Thus they are easy to manage for small farmers

This water harvesting technique can work in areas where there is very limited rain fall and excess land. In areas where there is a land shortage, leaving uncultivated land for runoff collection is difficult to apply. Therefore some modification has to be made, by incorporating cutoff drain at a proper interval the technique can apply as water conservation practice without leaving uncultivated land for runoff collection.

Technical details

Suitability Contour ridges for crop production can be used under the following conditions.

Rainfall: -350-750mm

Soils: -all soils which are suitable for agriculture. Heavy and compacted soils may be a constraint to construct of ridges by hand.

Slope: -it can construct up to 12-15%.

Topography: - must be even

5.1.7. Contour trenches

Description Contour trenches are long and deep pits or broken canals constructed along the contours for the purpose of rain water harvesting to support the growth of trees, shrubs and grasses in dry areas and control erosion. The trench collects and store considerable amount of runoff water, this ensures proper catchment protection and rapid growth of trees and grass cover, the trench also accelerates the regeneration of natural and improved grass species which will supply additional animal feed. It also contributes a great role in recharging the ground water table and to supply flow of water for spring and wells.

Technical Details

Suitability Contour trench can be done in areas where there is a shortage of rain fall and sufficient moisture in the soil for the plant growth.

Soils: -it can be done on any soils except verity sole, which is workable

Slope: - for contour trench slope can be range from 0-50%

5.2.Designing identified micro catchments

Negarim

Micro catchmentsize: - The area of each unit is either determined on the bases of a calculation of the plant/tree water requirement or more usually, an estimation of this. Size of micro catchment(per unit) normally range between 10m2 and 100m2 depending on the species of tree to be planted but large sizes are also feasible, particularly when more than one trees will be grown within one unit.

Design of bunds: - The bund height primarily depends on the prevailing ground slope and the selected size of the micro catchment. It is recommended to construct bunds with the height of at least 25 cm in order to avoid the risk of over topping and subsequent damage. Where the ground slope exceeds 2%, the bund height near the infiltration pit must be increase. The top of the bund should be at least 25 cm wide and side slopes should be at least in the range of 1:1 in order to reduce soil erosion during rainstorms. It is advisable to cover the bund with grass in order to protect the bund against erosion.

“V” Shaped Micro catchment

Micro catchment size: - The size of the V shape wing can be range from 2m-5m which joins at right angle.

Size of infiltration pit: - An average **side** width of 1.5m x 1.5m and a maximum depth of 40cm pit is recommended. The pit depth should not be exceeded from 40cm, in order to avoid water loss through deep percolation and to reduce the work load for excavation. The excavated soil from the pit should be used for construction of the bund.

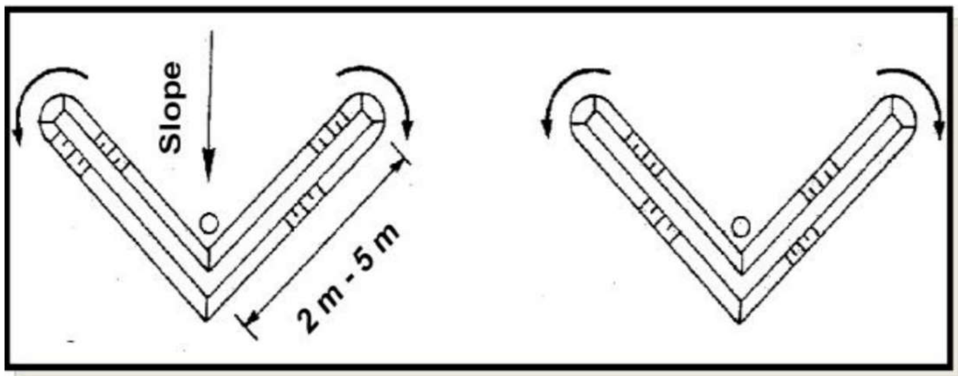


Figure:-Typical Examples of V-shaped or Triangular micro-catchment structures

Contour bund for trees

Overall configuration: - The overall layout consists of a series of parallel, or almost parallel earth bunds approximately on the contour at a spacing of between 5 and 10 meters. The bunds are formed with soil excavated from an adjacent parallel furrow on their up slope side. Small earth ties particular to the bund on the up slope side subdivided the system in to micro catchments. Infiltration pit are excavated in the junction between ties and bunds. A diversion ditch protects the system where necessary.

Unit micro catchment size: - The size of micro catchment per tree is estimated in the same way as for Negarim micro catchment. However the system is more flexible, because adding or removing the cross ties within the fixed spacing of the bunds can easily alter the micro catchment size. Common sizes of micro-catchment area around 10-50m2 for each tree.

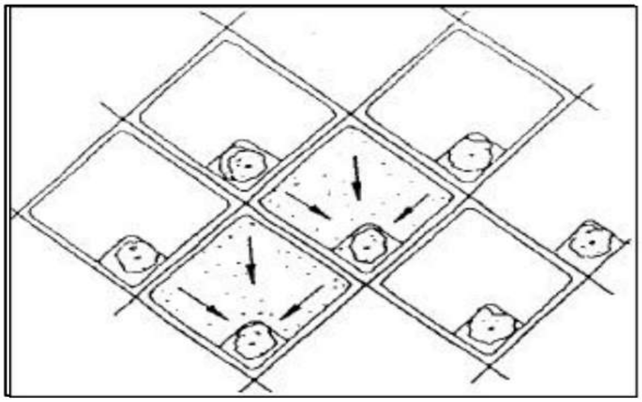
Bund and infiltration pit design. The bund height varies from 30-50m depending on the prevailing slope. It is recommended not to be less than 40cm in height base width must be at least 75cm. Bund should be spaced at either 5m or 10m apart. Cross-tie should be at least 2m long at spacing of 2-10meters. It is recommended to provide 6m spacing between the bunds on the slope of up to 10% and 4m on steeper slopes. Excavated soil from the infiltration pit is used to form the ties. The pit is excavated in the junction of the bund and the cross tie. A pit size of 80cm x 80cm and 40cm deep is usually sufficient. The diversion ditch is aligned on a 0.25%slope and a common dimension is 50cm deep and 1- 1.5m wide, with the soil pile down slope. The diversion ditch should be constructed before the contour bunds are built to prevent damage if rainstorm occur during construction.

5.3.Constructing the designed structures

Negarim

Layout and construction

The first step is to find a contour line using a line level or other equipment's. The first line at the top of the block is marked, if the topography is very uneven, separate small block of micro catchment should be considered. By means of tape measure the tips of the bund are now marked along the straight contour. The first line should be open ended. The distance between a-b depends on the selected catchment size, the formula to find the distance a-b is, ab2=ac2+bc2 for 25 meter selected catchment, length of the catchment will be 5mx5m micro catchment, is held at one tip(a) and the second string of the same length at other tip(b) they will exactly meet at apex (c). the apex is now marked with a peg and the catchment sides (a-c) and (b-c) marked on the ground alongside the string with a hoe. This procedure will be repeated until bund alignment in the first row has been determined. The next row of micro catchments is staked out. The apex of the bunds of the upper row will be the tip for for the second row and the corresponding apex will be found according the first step. Repeat the procedure for the third row.



Negarim

Negarim with bushes; Photo: Oweis

Figure:-Typical examples of Negarim Micro Catchment.

Contour bund for trees

Layout and construction

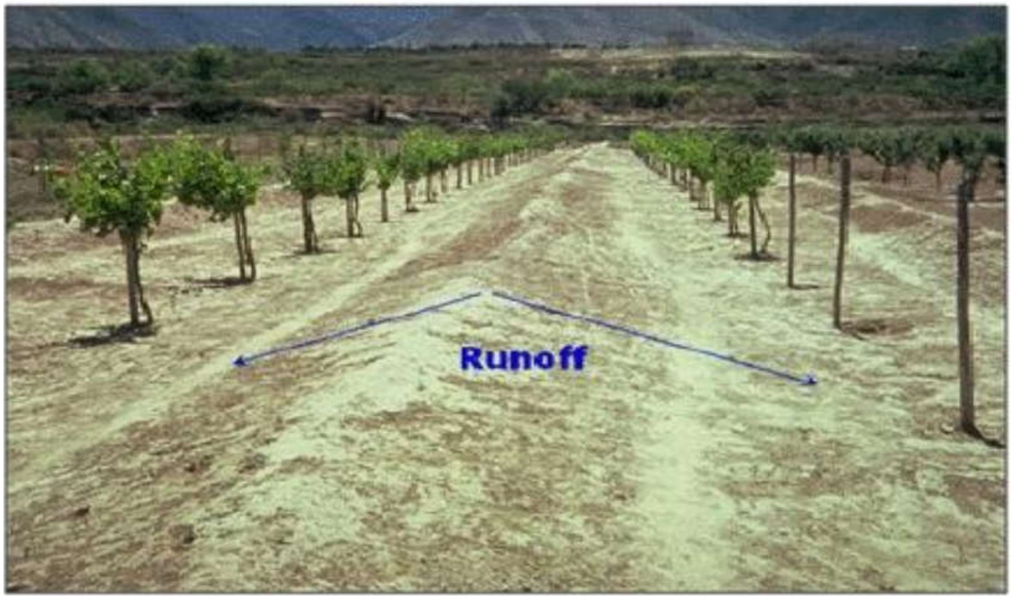
Step one: - Contours are surveyed by a simple surveying instrument such as a water tube level or line level. The real contour should be smoothened to obtain a better alignment for agricultural operations.

Step two: - Contour key lines should be staked out every 10 or 15 meters. The alignment for ridge is then marked in between the key lines according to selected spacing.

Step three: - The furrows are excavated usually by means of a hoe or are ploughed parallel to the marked alignments for the ridges. The excavated soil is placed down slope next to the furrow and the ridge is formed.

Step four: - Small cross ties are built at intervals of about 5 meters dividing each furrow in to a number of segments. The ties are 15-20 cm high and 50-70 cm long.

Step five: - A diversion ditch should be provided above the block of contour ridges if there a risk of damage caused by runoff from outside the system. The diversion ditch should be 50 cm deep and 1-1.5m wide, with a gradient of 0.25%. The excavated soil should be placed down the slope.



Semicircular bunds

Layout and construction

The layout for both designs is similar, only diminution differs.

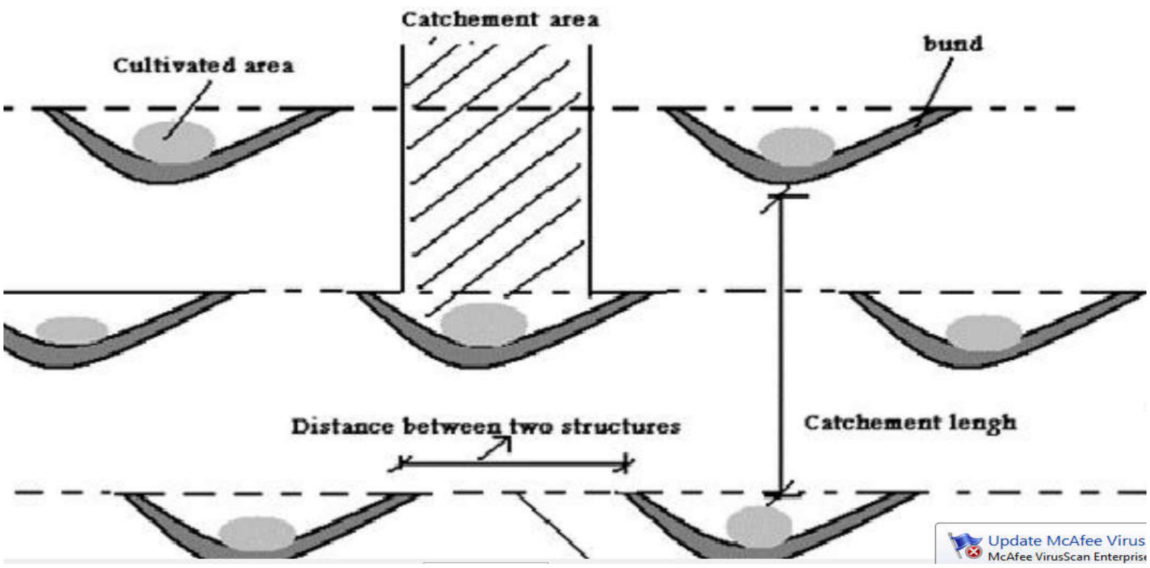
Step one: -The first contour, at the top of the scheme, is staked out using a simple surveying instrument like line leveling.

Step two: -A tape measure is now used to mark the tip of the semicircular bund on the contour. For design semicircular bund for tree planting having a radius of 3m, the tips of one structure are 6meters apart (2times the radius) and the distance to the next unit is 1.5m, which is half of the radius of the semi-circle.

Step three: -The center point between the tips of each semicircular unit is marked. A piece of string as long as the selected radius is now fixed at the center point by a means of pegs. Holding the string tight at the other end, the alignment of the semi-circle is defined by swinging the end of the string from one end to the other. The alignment can be marked by pegs or scratching the earth with the peg.

Step four: - It is important that the structures in each row are staggered in relation to structure in the row above. It must be ensured that the space between bund from one row to another is according to the chosen distance that is half of the radius of the bund, which is 1.5m.

Step five: -After setting out, bund construction is started with excavation of small trench inside the bund. Further excavation should always be from inside the bund as evenly as possible. This will increase the storage capacity of the semicircular bund, the bund height must be greater than 40cm when the slope exceed 20%. The bund bottom width is 75cm with the side slope 1:1. It is advisable to provide one or more diversion ditches within the block as a safety factor.



Semi-circular Bunds

Zai, planting pit

Layout and construction

ZAI are series of pits dug following the contours, the diameter of the pit can be between 40-50cm at the depth of 15-20cm, and the spacing between two Zai can be range 60-80cm. The second line of pit must be arranged in a staggered configuration against the first line of pits. The spacing between two lines of pits is 60-75cm. the excavated soil could be piled down ward of each pit. After construction apply organic matter like compost, crop residues or dung at each pit.

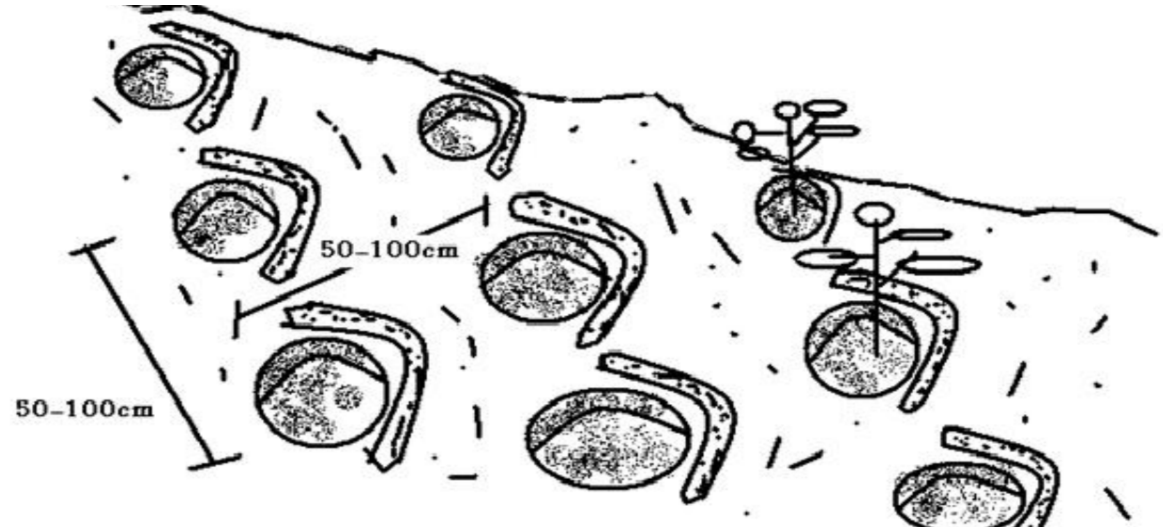
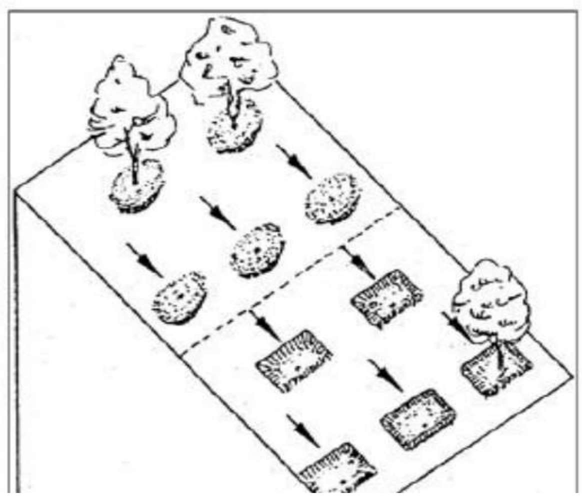


Fig. Field with planting pit



Contour ridges for crops

Layout and construction

The overall layout consists of parallel, earth ridges approximately on the contour at a spacing of between one and two meters. Contour key lines should be staked out every 10 or 15 meters. The alignment for the ridges is then marked in between the key lines according to selected spacing. On uneven trains the contour may come closer together at one point or widen at other points. Soil is excavated and placed down slope to form a ridge and the excavated furrow above the ridge collects runoff from the catchment strip between ridges. Small earth ties in the furrow are provided every few meters to ensure uneven storage of runoff. The ties are 15-20cm high and 50-

70cm long. Ridges need only be as high as necessary to prevent over topping by runoff. For slopes up to 5% as runoff is harvested only from a small strip between the ridges, a height of15-20cm is sufficient. If slope is exceeding 5% and if bunds are spaced at more than two meters the ridge height must be increased. On flat slopes up to 5% ridge can be made by "Sefidigir" by ploughing and deepening furrow twice. This kind of techniques have been practiced at Kobo north wollo and it gives a good result in conserving sufficient moisture and provide a yield difference than before for teff crop. A diversion ditch may be necessary above the block of contour ridge to protect the system against runoff from outside.

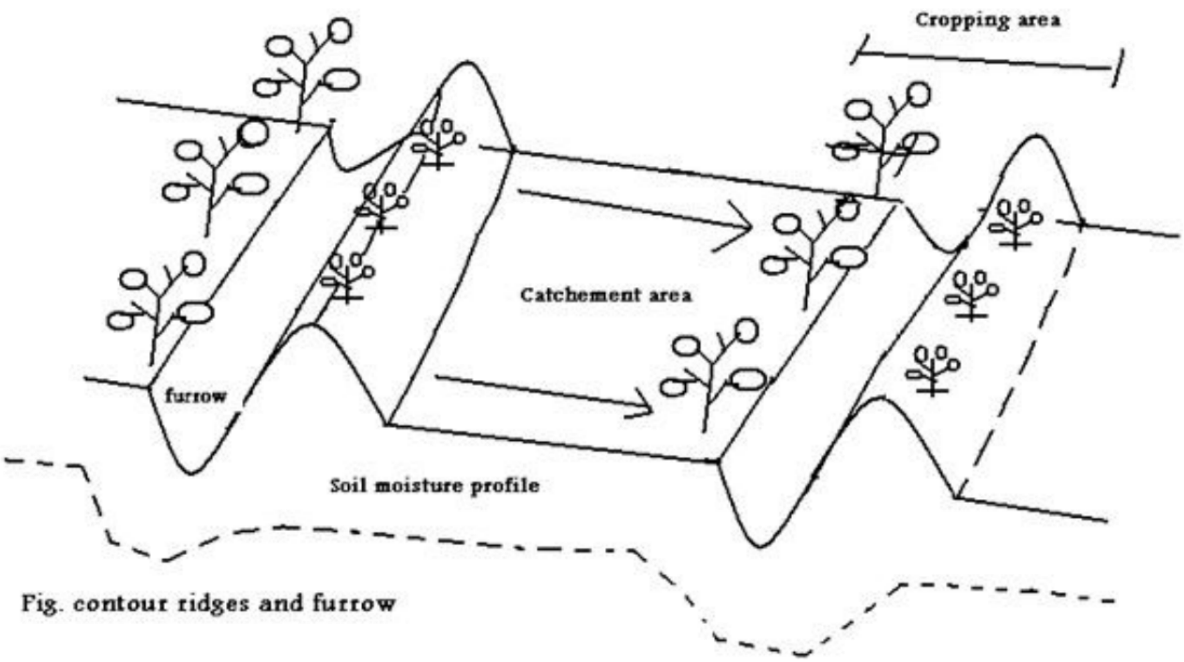


Fig. contour ridges and furrow

Contour trenches

Layout and construction

Contour trench for tree planting:

- Start from the top of the hill or the block, using an frame or line level
- The two tips of the "A" frame can be spaced at 5-3metere which is the length of a single trench

- By the contour mark a trench having a length of 5-3 meter by leaving 50cm spacing between two horizontal trenches continuously
- The spacing between two contour trench vertically is 3m
- The arrangement of trench in the second contour line should be staggered as of the first contour trench
- Then start to dig a trench by measuring 50cm trench width down from the marked contour line at a depth of 40-50cm.(that is 3m x 50cm x 40cm trench size)
- At a center of a trench length leave 50cm un dug space for planting pit to be dug at the end
- Then 30cm x 30cm x 30cm pit is dug in the middle of a trench
- The excavated soil can be put at down slope of the trench
- A diversion ditch may be necessary above the block of contour trench to protect the system against runoff from outside.

Self-Check 1	**Written Test**

Name: __________________________ **Date: ________________**

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

1. What is water harvesting? Explain it. (5 pts)
2. List micro water harvesting techniques; at least three? (5pts)
3. What is the purpose of constructing contour trench on grazing lands? (5pts)
4. Write the steps used for the construction stone bunds for tree? (5pts)

Note: **Satisfactory rating - 15 points and above Unsatisfactory - below 15 points**

You can ask your teacher for the copy of the correct answers

Operation Sheet 1	Constructing Negarim micro-catchment

Objective:- To develop design and construction skills of micro catchment structure

Tools and Equipment required

- Line level/A-frame, String, Graduated staff, A-frame, Clinometers, Altimeter, Measuring tape, Digging instruments

Procedures;

- Identifying the site
- Determine catchment to cultivated area
- Laying out the structure to be constructed
- Construct the structure based on the dimensions

Information Sheet 6	Assist Design and construction of macro catchments techniques

6.1. Identifying different macro catchment types

6.1.1. Contour stone bunds

Description Contour stone bunds are used to slow down and filter runoff thereby increasing infiltration and capturing sediments. The water and sediment harvested lead directly to improve crops performance. This technique is well suited to small scale application on farmer’s field and give an adequate supply of stone can be implemented quickly and cheaply. Making bunds or merely lines of stones is a traditional practice in parts of sahelianwest Africa, notably in Burkina faso. Improved construction and alignment along contour makes the technique considerably more effective. The great advantage of systems based on stone is that there is no need of spill ways, where potentially damaging flows are constructed.

Technical Details

Suitability Stone bunds for crop production can be used under the following conditions:

Rain fall:- 200-750mm from arid to semi-arid areas

Soils:- agricultural soils

Slopes:- preferably below 2%

Topography:- need not be completely even

Stone availability:- must be good local supply of stone

6.1.2. Trapezoidal bund

Description Trapezoidal bunds are used to enclose larger areas (up to 1ha) and to impound larger quantities of runoff which is harvested from an external or “long slope” catchment. The name is derived from the layout of the structure which has the form of a trapezoid a base bund connected to two side bunds or wing walls which extend up slope at an angle of usually 135 degree. Crops are plants within the enclosed area of over flow discharges around the tips of the wing wall. The concept is similar to semi-circular bunds; in this case, three sides of a plot are enclosed by bunds while the fourth (up slope) side is left open to allow runoff to enter the field.

The simplicity of design and construction and the minimum maintenance required are the main advantages of this technique.

Technical details

Suitability Trapezoidal bunds can be used for growing crops, trees and grasses. Their most common application is for crop production under the following site conditions.

Rain fall: -250-500mm arid to semi-arid areas

Soils: agricultural soils with good constructional properties

Slopes: - from 0.25%-1.5%, but most suitable below 0.5%.

Topography: -area within bunds should be even

Limitation: - this technique is limited to low ground slopes. Construction of trapezoidal bunds on slopes steeper than 1.5% is technically feasible, but involves prohibitively large quantities of earth work.

6.2.Designing identified macro catchments

Contour stone bunds

Overall configuration Stone bunds follow the contour, or the approximate contour, across fields or grazing land. The spacing between bunds ranges normally between 15 and 30 meter depending largely on the amount of stone and labor availability. There is no need for diversion ditches or provision of spillways.

Trapezoidal bunds

Overall configuration: - Each unit of trapezoidal bunds consists of a base bund connected to two wing walls which extend upslope at an angle of 135 degrees. The size of the enclosed area depends up on the slope and can vary from 0.1 to 1ha.they are arranged in staggered configuration when several trapezoidal bunds are constructed. A common distance between the tips of adjacent bunds within one row is 20m with 30m spacing between the tips of the lower row and the base bunds of the upper row. It is not recommended to build more than two rows because the third and the fourth rows receive significantly less runoff. The configuration of bund is dependent on land slope, and is determined by the designed maximum flooded depth of 40cm at the base bund. Consequently as the gradient becomes steeper the wing walls extended less far up slope.

Slope%	Length of base bund (m)	Length of wing wall(m)	Distance between tips (m)	Earth works per bund(m^3)	Cultivated area per bund(m^2)	Earth works per ha cultivated(m^3)
0.5	40	114	200	355	9600	370
1	40	57	120	220	3200	670
1.5	40	38	94	175	1800	970

Constructing the designed structures

Contour stone bunds

Step one: -Determined the average slope of the field by a simple surveying instrument to decide on the spacing of the bunds. A horizontal distance of 20 meter is recommended for slopes of up to 1%, and 15 meters apart for 1-2% slopes.

Step two: -After the exact contour is laid out, the line should be smoothed by moving individual pegs up to down slope. as a guideline, for ground slopes up to 1% pegs can be moved 2 meters up slope or down slope to create a smoother curve.

Step three: -A shallow trench is now formed along the smoothed contour. The trench is formed by hand tools or ploughed by oxen and then excavated by hand. The trench need only be 5-10 cm deep and equal to the base width of the bund(35-40 cm). The excavated soil is placed up slope.

Step four:- Construction begins with large stones laid down at the base and the down slope side of the trench, and then smaller stones laid in front and on top of this ”anchor” line. Small stones should be used to plug gaps between the larger ones. Where possible, a line of small or gravelly stones should run along up slope face of the bund to create a fine filter.

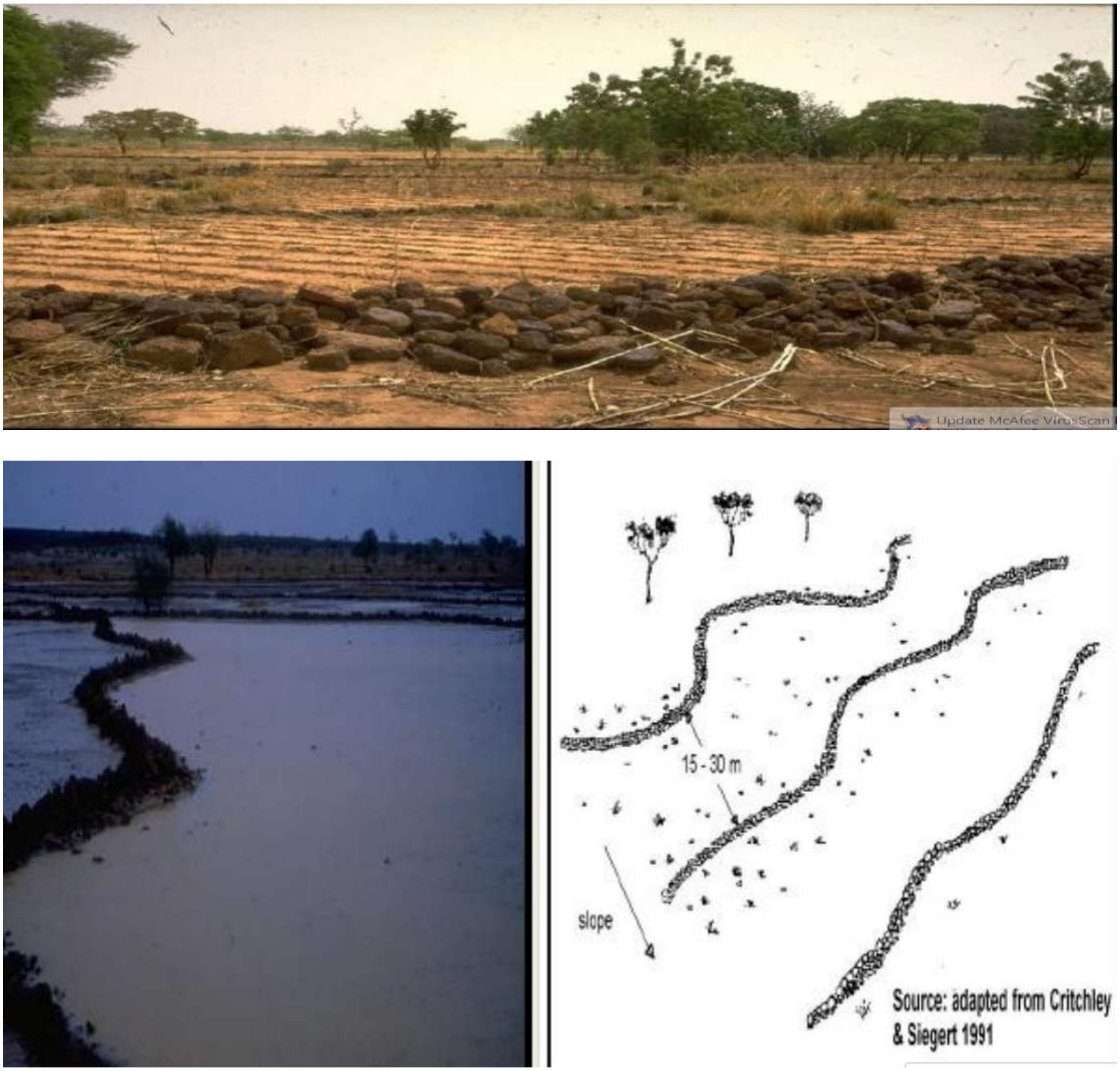


Figure:-Typical Example of contour Stone bund.

Trapezoidal bunds

Layout and construction

Step one: - When the site for the bund has been decided, the first thing to do is to establish the land slope using an abney level or line level. The dimensions of bund vary with the slope of the area. Starting at the top of the field a peg is placed which will be the tip of one of the wing walls.

The second wing wall tip is at the same ground level at the distance obtained from table above.

Step two: -Stake out the four dimensions of the bund and measure the right angle using a woodn right angle triangular template

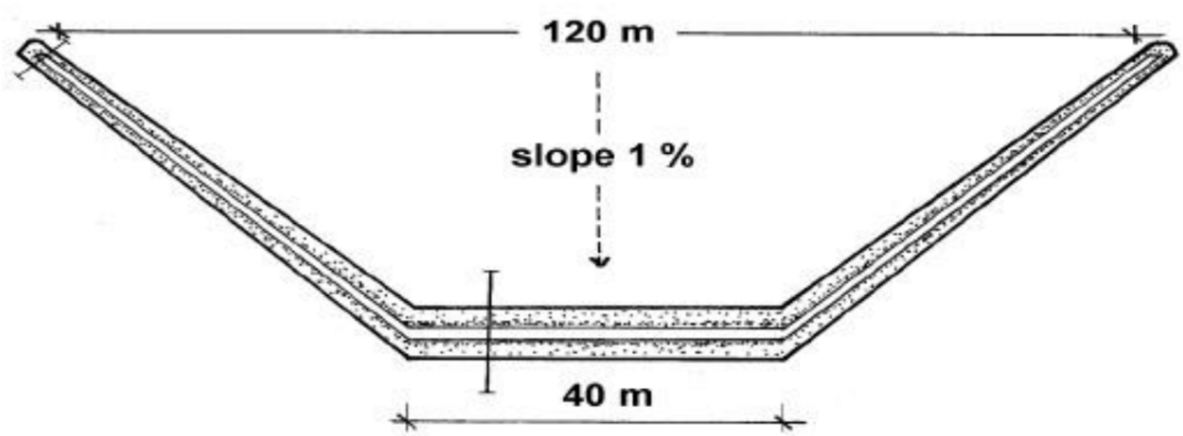
Step three: - The accuracy of the setting can be checked by measuring the distances between points 4ocm.

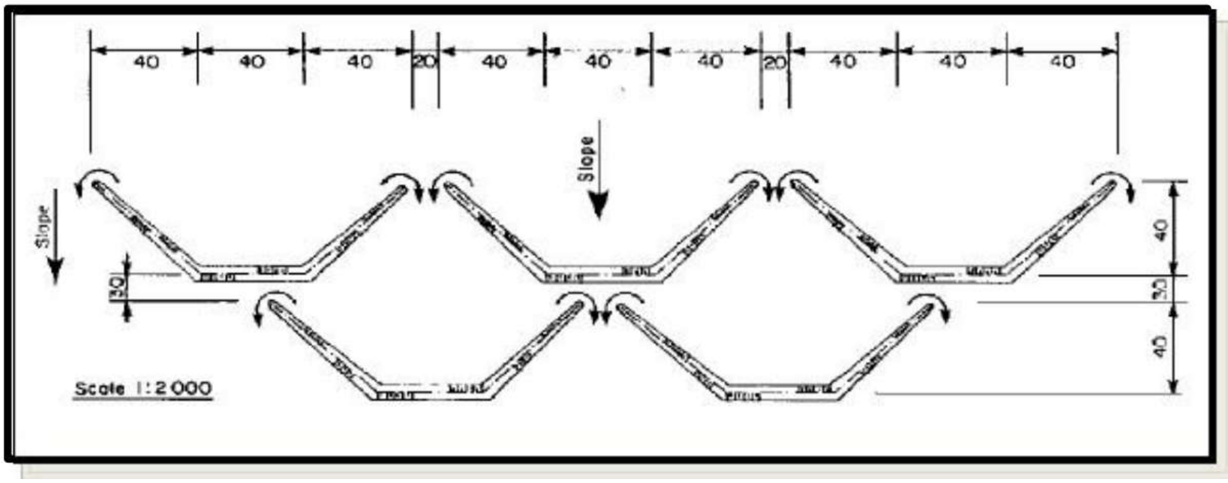
Step four: -Having the main points of the bund it is necessary to set out pegs or stones to mark the earth work limits.

Step five: -Construction of a set of trapezoidal bunds must start with the row furthest up-slope. The bund is constructed in two layers each having a maximum thickness of 0.3m, the thickness of the first layer will gradually taper off to zero as filling proceeds up slope along the wing bunds.

Step six: -The tips of the bunds are only 20 cm high and exceed runoff drains around them. To prevent erosion of the tips they should be shaped with a small extension or "lip" to lead water away.

Step seven: -Where the catchment is large in relation to the bunded area it is advisable to construct a diversion ditch to prevent excess water or inflow to the bunds. This ditch usually 50cm deep and of 1-1.5 meters width, and is usually graded at 0.25%.





Figures. Layout of Large Trapezoidal bund

Self-Check 6	Written Test

Name: __________________________ Date: ________________

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

1. Differentiate micro and macro water harvesting techniques? Explain it. (5 pts)
2. List macro water harvesting techniques? (5pts)
3. Select one macro water harvesting technique and discuss how it constructs? (1o pts)

Note: **Satisfactory rating - 15 points and above Unsatisfactory - below 15 points**

You can ask your teacher for the copy of the correct answers

Operation sheet	**Constructing Large Trapezoidal bund**

LAP Test/ Job Sheet	**Practical Demonstration**

Time started: ________________________ Time finished: ________________

Instructions:

1. You are required to perform the following activity:

- Present for your friends about the main procedures during the construction of macro catchment water harvesting measures.
- In which condition is preferable to construct macro structures than micro structures?

2 . Request your teacher for evaluation and feedback

Information Sheet 7	Assist with design and construction flood water harvesting techniques

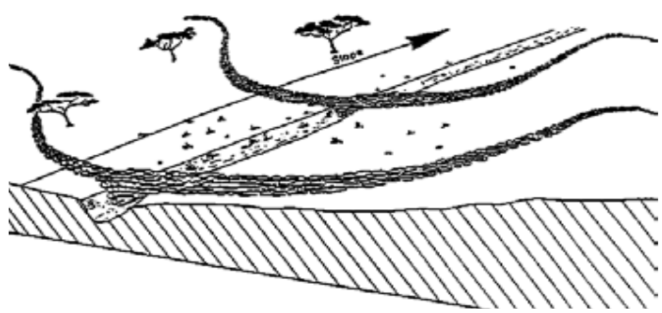
7.1. Identifying different flood water harvesting types

Floodwater farming (floodwater harvesting) often referred to as "Water Spreading" and sometimes "Spate Irrigation."
Main Characteristics:- turbulent channel flow harvested either (a) by diversion or (b) by spreading within channel bed/valley floor
Typical Examples:

- Permeable Rock Dams (for crops)
- Water Spreading Bunds (for crops)

A. Permeable Rock Dams

Permeable rock damns are a floodwater fanning technique where runoff waters are spread in valley bottoms for improved crop production. Developing gullies are healed at the same time. The structures are typically long, low dam walls across valleys.



Permeable rock dams

B. **Water Spreading Bunds**

Water spreading bunds are often applied in situations where trapezoidal bunds are not suitable, usually where runoff discharges are high and would damage trapezoidal bunds or where the crops to be grown are susceptible to the temporary water logging, which is a characteristic of trapezoidal bunds. The major characteristic of water spreading bunds is that, as their name implies, they are intended to spread water, and not to impound it.

They are usually used to spread floodwater which has either been diverted from a watercourse or has naturally spilled onto the floodplain. The bunds, which are usually made of earth, slow down the flow of floodwater and spread it over the land to be cultivated, thus allowing it to infiltrate.

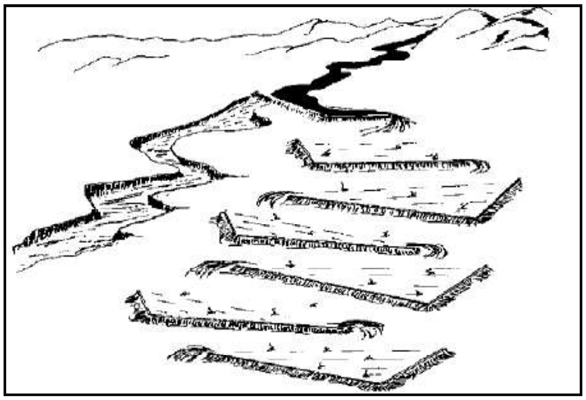


Figure 28. Flow diversion systems with water spreading bunds

C. Sand Dams Water Harvesting Techniques

Water is taken from rivers for domestic and agricultural purposes in many places. If it concerns an ephemeral river however, water will not be available all year around. The water in the river will flow away, leaving behind a dry riverbed.

In order to bridge periods of drought water can be retained by building a dam. In many cases a dam can be built behind which surface water is stored. However, surface water storage has some negative side effects, such as evaporation. To overcome such problems the water can be stored subsurface, if the local conditions allow subsurface storage. This storage can be reached by building a dam, behind which sand accumulates, enlarging the natural aquifer. The groundwater in the riverbed is obstructed by the dam and retained in the pores in the sand .The water can be harvested using scoop holes or wells.

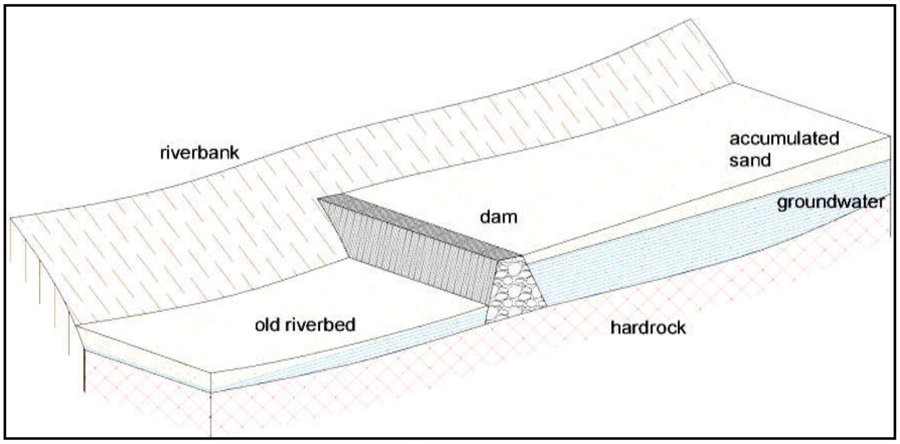


Figure29: Principle of a sand storage dam

Site Selection for construction

The best site for construction of groundwater dams are on gently sloping land (typically slopes of from 1:500 to 1:25) where the soil consists of sands and gravels, with rock at a depth of a few meters. Ideally the dam should be built where rainwater from a large catchment area flows through a narrow passage:

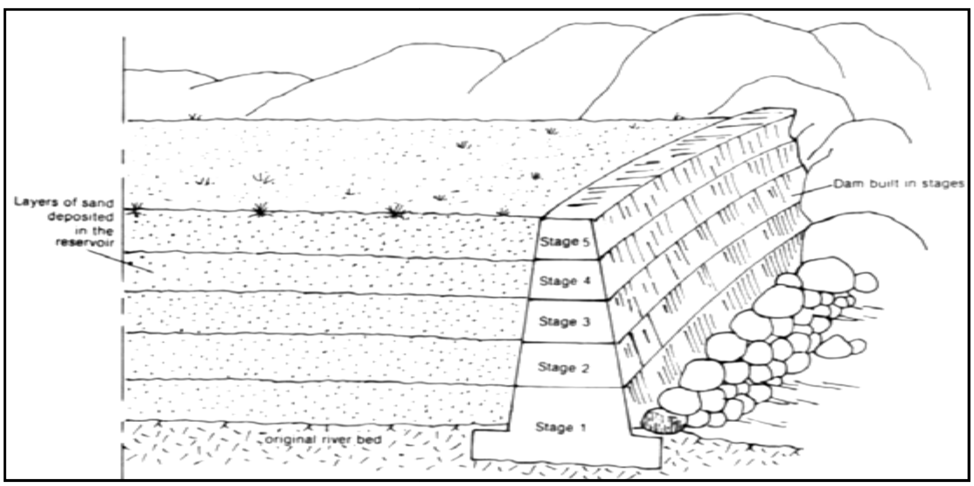


Figure 30: Construction principle of sand-storage dam

7.2.Designing identified flood water harvesting

1. Design of Permeable Rock Dams

Dam design

The main part of the dam wall is usually about 70 cm high although some are as low as 50 cm. However, the central portion of the dam including the spillway (if required) may reach a maximum height of 2 in above the gully floor. The dam wall or "spreader" can extend up to 1000 meters across the widest valley beds, but the lengths normally range from 50 to 300 meters. The amount of stone used in the largest structures can be up to 2000 tons.

The dam wall is made from loose stone, carefully positioned, with larger boulders forming the "framework" and smaller stones packed in the middle like a "sandwich". The side slopes are usually 3:1 or 2:1 (horizontal: vertical) on the downstream side, and 1: 1 or 1:2 on the upstream side. With shallower side slopes, the structure is more stable, but more expensive.

The horizontal spacing between adjacent dams can be determined from the selected and the prevailing land slope according to the formula.

$$HI = \frac{(VIx100)}{\%\ slope}$$

Where:
HI= horizontal interval (m)
VI= vertical interval (m)
%Slope= land gradient expressed as a percent

For example, for a VI of 0.7m and a 2% land slope

$$HI = \frac{(0.7x100)}{2} = 35m$$

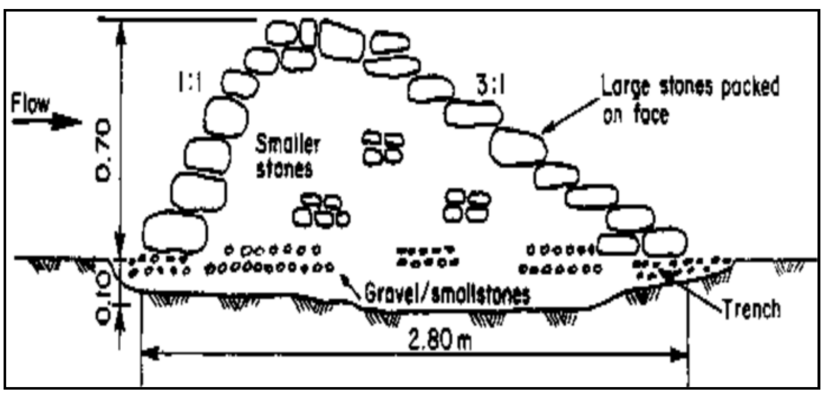


Figure 31: Dimension of dam

Site selection criteria

Permeable rock darns for crop production can be used under the following conditions:

Rainfall: 200 -750 mm; from arid to semi-arid areas.

Soils: all agricultural soils - poorer soils will be improved by treatment.

Slopes: best below 2% for most effective water spreading.

Topography: wide, shallow valley beds.

Work norms: Considerable labor may be required to collect, and sometimes break stone. Labor requirements, based on field estimates, are in the range of $0.5m^3$ of stone per person per day-excluding transport.

2. Design of Flood spreading bunds

Bund design

a. Slopes of less than 0.5%

Where slopes are less than 0.5%, straight bunds are used to spread water. Both ends are left open to allow floodwater to pass around the bunds, which are sited at 50 meters apart. Bunds should overlap - so that the overflow around one should be intercepted by that below it. The uniform cross section of the bunds is recommended to be 60 cm high, 4.1 meters base width, and a top width of 50 cm. This gives stable side slopes of 3:1. A maximum bund length of 100 meters is recommended (figure 32).

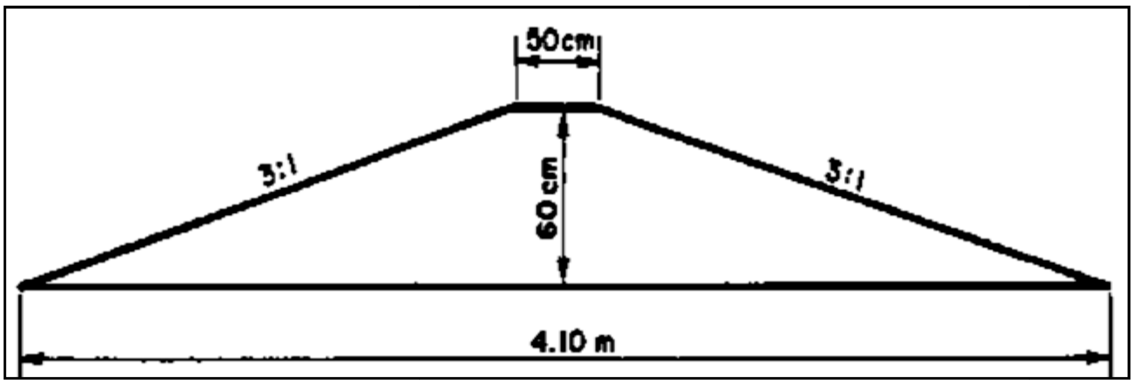


Figure 32. Bund dimensions

b. Slopes of 0.5% to 1%

In this slope range, graded bunds can be used (Figure 35). Bunds, of constant cross-section, are graded along a ground slope of 0.25%. Each successive bund in the series down slope is graded from different ends. A short wing wall is constructed at 135° to the upper end of each bund to allow interception of the flow around the bund above. This has the effect of further checking the flow. The spacing between bunds depends on the slope of the land.

Site selection criteria

Water spreading bunds can be used under the following conditions:

Rainfall: 100 mm - 350 mm; normally hyper-arid/arid areas only.

Soils: alluvial fans or floodplains with deep fertile soils.

Slopes: most suitable for slopes of 1% or below.

Topography: even.

The technique of floodwater fanning using water spreading bunds is very site-specific. The land must be sited close to a wadi or another watercourse, usually on a floodplain with alluvial soils and low slopes. This technique is most appropriate for arid areas where floodwater is the only realistic choice for crop or fodder production.

7.3.Constructing designed structures

1. Lay out and construction of permeable rock dams

Step One

Site selection depends both on the beneficiaries and the technicians. Theoretically it is best to start at the top of the valley, though this may not always be the people's priority. After site identification it is necessary to determine whether the structure needs a defined spillway: as a rule of thumb no spillway is required if the gully is less than one meter deep. For greater depths, a spillway is recommended.

Step Two

Where a spillway is required, this should be built first. Gabions are best for spillways, as loose stone is easily destabilized by heavy floods. The following should be noted:

a. A foundation of small stones, set in a trench, is required.

b. An apron of large rocks is needed to break the erosive force of the overflow.

c. The downstream banks of the watercourse should be protected by stone pitching to prevent enlargement of the gully.

Step Three

The alignment of the main dam walls can be marked out, starting at the centre of the valley (where there may/may not be a spillway). This alignment is ideally along the contour, or as close to the contour as possible. Thus the extension arms sweep backwards in an arc like the contours of a valley on a map. The arms end when they turn parallel to the watercourse.

Step Four

The first action after aligning the extension arms of the dam is to dig a trench at least 10 cm deep and 280 cm wide (according to the base width of the bund). The earth should be deposited upslope and the trench filled with gravel or small stones.

Step Five

The skill of construction is in the use of large stones (preferably of 30 cm diameter or more) for the casing of the wall. This should be built tip gradually following the required side slope, and the centre packed with smaller stones. The whole length of the bund should be built simultaneously, in layers. This layered approach reduces the risk of damage by floods during construction.

Step Six

If a series of permeable rock dams is to be built, an appropriate vertical interval (VI) should be selected. Technically speaking it is correct to:

a. start at the top of the valley and work down;

b. use a VI equal to the height of the structure - so that the top of one structure is at the same level as the base of the one above it (see Figure below).

Therefore for dams of 70 cm height, the VI should theoretically be 70 cm. However in practice this may not be practicable due to the amount of stone and labour involved. As a compromise, a V.I. of 100 cm might be more realistic. Even wider spacing could be adopted, and the "missing" structures "filled in" afterwards. The vertical interval can be determined most easily by the use of a line-level.

The horizontal spacing between adjacent dams can be determined from the selected VI and the prevailing land slope according to the formula:

$$HI = \frac{(VI \times 100)}{\%slope}$$

where:
HI = horizontal interval (m)
VI = vertical interval (m)
% slope = land gradient expressed as a percentage.

For example, for a VI of 0.7 m and a 1% land slope,
HI = (0.7 x 100)/1 = 70 meters
For a VI of 0.7 m and a 2% land slope,
HI - (0.7 x 100)/2 = 35 meters

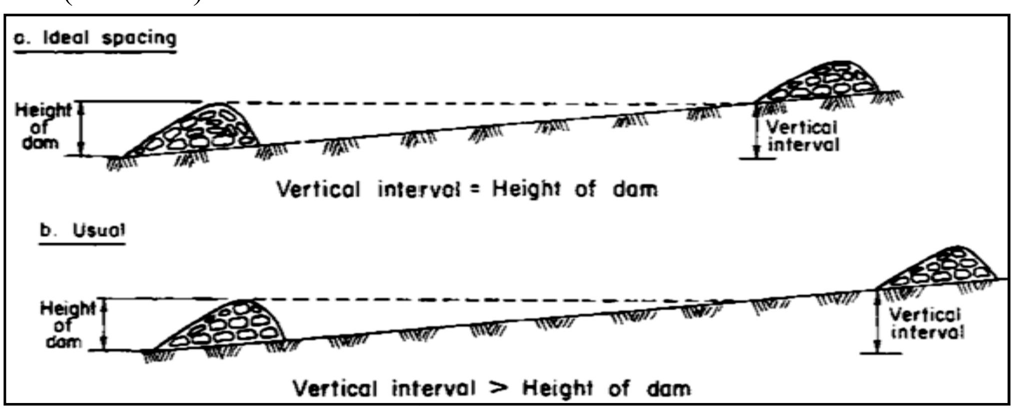


Figure 33. Spacing of rock dams

2. **Layout and construction of flood spreading bunds**

Step One

The first step is to measure the slope of the land, in order to select the appropriate bunding system.

Step Two

Straight bunds are used for ground slopes of less than 0.5% and are spaced at 50 m intervals. The bunds should, however, be staggered as shown on Figure 33, which also illustrates the setting out procedure.

Having selected the starting point at the upslope end of the bund system point A is marked with a peg.

Using a line or water level and, if necessary, a tape, point B is pegged on the contour 100 m away from A.

Line AB is then the centre line of the first bund and should be marked with pegs or stones.

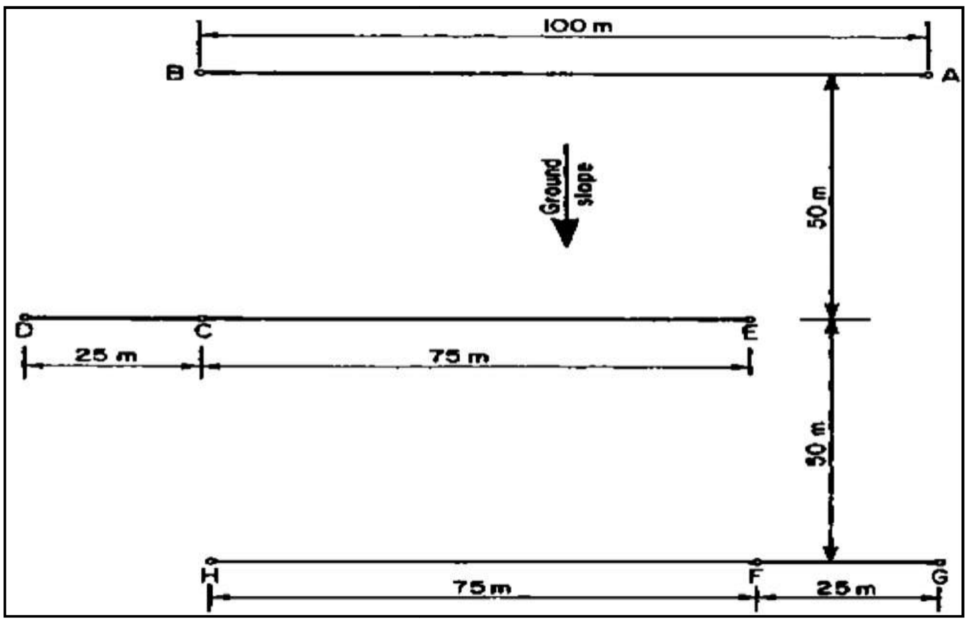


Figure 34. Setting out of level bunds: ground slope < ft 5%

Point C is 50 in down slope from point B and can be established by marking of a right angle perpendicular to AB, using a wooden triangular right angle frame (sides: 100 cm, 60 cm, 80 cm) and a tape. Point D is then established with level and tape at the same ground level as C, at a distance of 25m from C to allow overlap with AB. Point D is then pegged. Point F is also on the same ground level as point C, but 75m distant in the opposite direction to point D. The line DE is the centre line of the second bund and should be marked with pegs or stones. Point F is 50 m down slope of point F and is established in a similar manner as point C. Point G is then established on the same ground level as point F but 25 m distant to allow overlap with DE. Similarly point H is at the same ground level as point F but 75 m distant, in the opposite direction to point G. This process can be repeated down the slope to lay out the field of bunds.

Step Three

For ground slopes above 0.5% bunds aligned with a 0.25% gradient are used and are termed "graded bunds".

Having selected the starting point (A) at the upslope end of the bund system, it is marked with a peg. Using a line, or water level, and a tape, the line AB is set out on a 0.25% gradient. As the distance AB is 100 in, the ground level at B is 25 cm below that at A. Point B is then marked with a peg and the line AB, forming the centre line of the first bund, is marked with pegs or stones.

Point C, on the centre line of the second bund, is at a distance of 25 m immediately down slope of point B. It is most easily found by using the line or water level to establish the maximum field gradient between B and C, and by measuring from B through that point a distance of 25 m.

Having established C the 0.25% slope line is again established and point D located along that line 25 in from C. Note that point D will be at a slightly higher ground level than point C and should provide overlap with the line AB, as shown in Figure below. The other end of the bund centre line, point F, is 75 m on the opposite side of C along the 0.25% slope line. The points D and F should be pegged and mark the centre line of the second bund.

The wing bund always starts from the overlapping end of the base bund, in this case point D. The wing bund is 25 in long and at an angle of 135° to the base bund. It is most easily found by extending the line ED a distance of 17.7 m from D to give point X. Point Y is then a distance of 17.7m upslope from point X, and at a right angle to the line XDE. It can be located using a tape and right angle template as described above.

The first point on the next bund line, point F, is located in a similar manner to point E and the bend centre line HFG can be set out as above. The end of the wing bund, W, can be located in a similar manner as Y. This process is continued down the field.

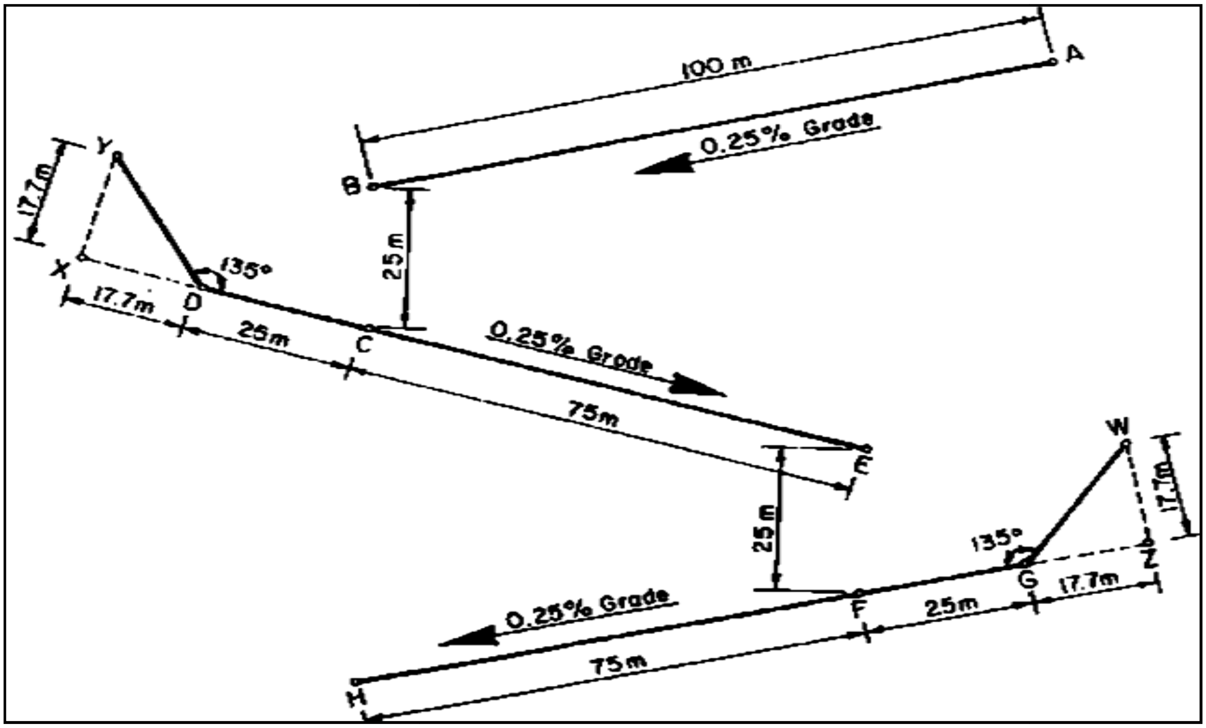


Figure 35: Setting out of graded bunds: ground slope> 0.5%

Step Four

Having marked out the centre lines of the bunds, the limits of fill can be marked by stakes or stones placed at a distance of 2.05 m on either side of the centre lines.

Step Five

Construction begins at the top of the field as in all water harvesting systems. Earth should be excavated from both sides to form the bunds, and in the shallow trenches formed, earth ties should be foreseen at frequent intervals to prevent scouring. The earth beneath the bunds should be loosened to ensure a good mating with the bund.

The bunds are constructed in two layers of 30 cm each, and compaction by trampling is recommended on the first course and again when the bund is complete.

Step Six

At the ends of the contour bunds, and at the tip of the wing walls of the graded bunds, stone pitching should be placed - if loose stone is available - to reduce potential damage from flow around the bunds.

Self-Check 7	Written Test

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

1. What is flood water harvesting? (3 pints)
2. What are the different types of flood water harvesting? (5 points)

Note: Satisfactory rating – 8 points above Unsatisfactory - below 8 points
You can ask you teacher for the copy of the correct answers.

Information Sheet 8	Identify construction material

7.1. Identifying construction materials

Basic categories of construction materials

A building or Water Harvesting schemes may have two basic parts

I. The super-structure- is above ground level, which serves the intended use. For example wall, column, roof, ceiling etc.

II. Sub-structure /foundation - is part of a structure which has a direct contact with the ground to which the loads are distributed.

<u>Foundation & wall construction materials</u>

Soils for foundations should have firmness and less porous nature and required soils are like clay soil, reed ash etc. Foundation also requires stone, gravel and so on.

- ✓ **Stones** are one of the most prevalent building material from the olden days due to its availability in abundance from the natural rocks. These stones possess strength and durability and are therefore used in the construction of structures like dams, retaining walls and roads, etc. Stones are load bearing materials that add to the look in addition to providing strength to the construction aspect
- ✓ **Sand**- dirty sand must be washed & should be clean. If the sand is too wet, it is needed to dry the sand.
- ✓ **Water**- dirty water contains impurities & may not be appropriate. Water fit for dirking is usually fit for making cement -mortar
- ✓ **Cement-** should be stored in dry place
    - Open storage requires plastic sheet cover
    - The plat form at the bottom must be raised
- ✓ **Reinforcement** – These includes steel bars, mesh wire and some of other materials required at construction are bricks, block nails, paints, gypsum, wood, soil, grass, straw etc.
- ✓ **Reinforcing materials**- barbed wires withstand the tensile stresses.
    - Mesh wire helps to hold the plaster together
    - The joints require extra enforcement as well as extra plastering to avoid cracks.

Roofing materials- these includes Thatch-grass straw, CIS & Al sheet, Brick Tiles, cement concrete Tiles etc.

Lining Materials – are essential to control loss due to seepage (binding materials).These includes materials for finishing purpose. E g. Cement, lime, gypsum, fine sand, paints. Geo-membrane, etc.

Pipes & fittings – these includes washout pipe, outlet pipes, down pipes, vent pipes, vents and overflow pipes etc.

N.B All pipes should be installed at the proper place. If over flow pipe is installed at half of the height of the wall, volume of the structure above the overflow pipe is always empty. Therefore, we must install at the top of the structure.

Form working materials: - materials required for formwork are hard board; ply wood, timber, steel, etc.

Concrete & Mortar

All water tanks require the use of cement including tanks made up of metal, plastic or fibre grass, because they need concrete foundations

- **Concrete** - is mixture of cement, coarse sand, crushed stones (aggregates) & water. Commonly tank floors or waterproof slab should be with a mix ratio of 1:2:3 (cement, sand, Gravel)
- **Mortar** -is a mixture of cement, sand & water without crushed stone.

Type of mortar (cement: sand)

Ordinary masonry	1:4
Reinforced brick slabs	1:3
1st coat plaster	1:4
Rough plaster (2nd coat)	1:3
Final plaster (3rd coat)	1:2

- **Nil** -is cement slurry made from mixing cement & water, which can be used as a substitute for waterproofing.

Block work

- **Brick masonry** -is the term used for mortar to build with burnt brick
- **Rubble stone Masonry** -is the term used mortar with uncut, undressed rubble stone
- **Stone masonry-** Is the term used for mortar with regular dressed stones & brick.
- **Ferro- cement** -mortar reinforced with welded mesh, chicken mesh, and barbed wire.
- **Pointing** -is the processes of finishing joints in brick or masonry work with mortar
- **Curing** - is the process of assisting the hardening of mortar by keeping it moist.

N.B. Standard dimension for wooden box (Batching box) that used for mixing is:

Length=50cm

Width= 40cm

Depth= 20cm

i.e. volume(v) = 0.5m x 0.4m x 0.2m =$\underline{0.04\ m^3}$

8.2.Using materials for construction

The different construction material mentioned above should be used based on:

- The type of water harvesting structures i.e. above or below ground surface water harvesting structures.
- Availability
- Skill of workmanship

Self-Check 8	Written Test

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

1. What is sub-structure? (3 pints)
2. What is super-structure? (2 points)
3. Write material used to control seepage? (2 points)
4. Write material used to control evaporation/ roofing materials? (3 points)

Note: Satisfactory rating – 10points above Unsatisfactory - below 10 points
You can ask you teacher for the copy of the correct answers.

Operation sheet	**Identification and demonstration of different Construction material required for water harvesting schemes.**	
Purpose:	To make a student acquainted with the construction materials and their purpose in addition, to create understanding among the students where the construction materials are used.	
Conditions for The operation:	The design	
Equipment, Tools And materials:	-Sand - Water - Cement - Bricks - Block nail - Paints - Soil - Grass straws - Overflow pipe	- Barbed wire (wire mesh) - Corrugated iron sheet/Aluminum sheet - Lime - Fine sand - Washout pipe - Outlet pipe - Down pipe - Vent pipe
Procedure		It is good if the identification proceed from simple to complex

Information sheet 9	Assist construction of roof top water harvesting structures

9.1. Selecting site

The assessment and selection of site for roof top water harvesting is related to both the catchment and storage tank. For the construction of water harvesting tank availability of suitable roofs 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. As our catchment area is roof of houses & available rainfall of the areas are very much important.

The storage tank must be set

- Wherever possible storage tanks designed for domestic use or watering animals should be constructed at nearby to the village so that travelling to the tank should not be difficult.
- The site should be selected such that the expected seepage and evaporation losses are kept as minimum as possible.
- The catchment area size should be sufficient enough (not too big or too small) to produce sufficient amount of run-off to the tank.
- Storage tank should be located where construction materials are easily available in the near vicinity
- Near the catchment area (the root and the house or around 3m away)
- With good foundation (firm soil condition)
- With necessary parts or components
- It should be away from latrine, drainage etc.
- Large trees near the structure and over hanging braches near the rooftop should be avoided, thus roots can penetrate the tank wall and cause seepage
- The site should be free from ant- hills (‘kuyissa’), old latrine and waste pits
- The foundation should be stable (i.e. in situ test like: - strength compressibility or settlement and other engineering properties of the foundation should be identified.

Estimation of household water demand

D or V_d = t * n * q where: V_d = household demand

t = number of days without rain in the longest dry

Period of the year (days)

n = number of people in the house hold

q = consumption per day (liters)

Estimation of water demand for a given community (village, town) or communal water demand

In order to estimate the total water demand of a given community or villagers, first the population must be forecasted for the given design period. Thus, the total water demand of the community (village) can be calculated as:

$$D = P_N * Q * T$$

Where: **D** = the design period total water demand of the community
P_N = Total no of community at the end of N year
Q = average daily per capita water demand at the end of N years.
T = the length of dry & period (days)

Estimation of amounts of runoff

C. Calculating the area of catchments (roof top area) (A)

Area = Length*Width

D. Calculating the amount of rain water (runoff) that can be harvested Q (m^3)

$Q = P*A*R_C$ where: - P = Mean annual rainfall (m)
A = Area of catchment. (m^2)
R_C = Runoff coefficient

Table 4: runoff coefficient (R_C) for various catchments

	Rainfall region (mm)		
Surface type	250-500	500-1000	1000-1500
Corrugated iron sheet	0.8-0.9	0.8-0.9	0.8-0.9
Organic (thatch)	0.2	0.2	0.2
Concrete	0.75	0.75	0.75

Estimating the required capacity of a tank

First, estimate the demand of water (Vd) for the dry season by: -

- ✓ Determining the number of persons in the house hold (n)
- ✓ Determining the number of liters of water consumed per person per day (q)

- ✓ Determining the number of days with no rain in the longest dry period of the year (t)
- ✓ Determining the loss due to seepage and evaporation, usually 20%of the estimated house hold water demand, then

$$V_t = t*n*q + V_d*20\% = V_d + V_d*0.2 = V_d(1+0.2) = 1.2V_d$$

9.2. Preparing required materials

The design on the paper needs to be interpreted and apply on the real ground. Hence, to apply this, the construction materials play the pivotal role. During construction, the material required for super structure and substructure /foundation/ of water harvesting schemes should have to be identified and make use of necessary material for desired objective. The quantity of each and every construction materials can be obtained from the bill of quantities estimated from the design plan.

Materials:

- Sand
- Water
- Cement
- Bricks
- Capped nail
- Paints
- Soil
- Grass straws
- Overflow pipe etc.
- Reinforcement bar of different diameters
- Barbed wire /(wire mesh)
- Corrugated iron sheet (CIS)/Aluminium sheet/
- Lime
- Fine sand
- Washout pipe
- Outlet pipe
- Down pipe
- Vent pipe
- Gravel

9.3. Constructing structure

Lay out and construction of roof top water harvesting storage structures (ferrocementtank).

Rainwater harvesting is a means of taking water out of hydrological cycle for either for human or agricultural uses.

Roof top water harvesting is the collection and concentration of water from impervious surface (roof covering) for human or agricultural uses for growing of crops.

Material used:

- Digging hoe
- Shovel axes
- Measuring tape
- Cement
- Brick
- Gravel
- CIS
- Galvanized pipe

- Sand -Sheet metal
- Gutter -Valves and Fittings, etc
- etc.

Construction Procedures:

The steps followed during construction of Ferro-cement tank (capacity $5m^3$) of cylindrical shape.

1. Calculate the radius of the tank. The height (h) need to be not more than 1.5meter, otherwise it will more reinforcement.

$V= \Pi r^2 h$ where, h =1.5m then, r = 1.1meter.

2. Select the construction site which is 3meter away from the wall of the building (home)

3. Clear soft top soil off the site so that the tank is constructed on firm ground.

4. At the centre of the cleared site, hammer one wooden peg, tie a rope to the centre peg equal to 1.3 meter long (1.1 m radius + 10cm foundation footing + 10cm thickness).

5. Draw a circle using the tied rope (1.3 meters long).

6. Remove the soil inside the marked circle to a depth of 50 cm (if the soil is stable, otherwise the depth can be more)

7. Fill stone foundation to the depth of 38cm.

8. On the top of the stone foundation, put one ring made from steel diameter of 10/12mm at the radius of 1.15 meter (1.10m + 0.05m).

9. Calculate the circumference of the circle (r =1.15m) and then install 1.62 meter long steel bar of diameter 10 or 12mm at 40cm interval.

10. On the top of stone foundation fill 10 cm thick concrete with the ratio of 1:3:4.

11. Be sure the steel poles are vertical. To be more precise prepare one additional ring similar to the foundation and put at the top of the poles. Tie firmly with soft wire to the poles.
12. On the top of the concrete floor, lay steel bars diameter 8/10/12 mm at 40 cm interval across the circumference, and tie them with the vertical firm poles.

13. On the top of stretched steel bars, fill 10cm thick concrete having a ratio of (1: 2: 3).
14. On the next day, make the concrete floor damp and spread 25mm of cement mortar (1:3)

across the floor of the tank. Make the surface of the mortar flat, but scratch it to make little bit rough.

15. Install a galvanized pipe 3/4" for drainage with elbow joints.

16. Before the cement hardened, place one or two layer of wire mesh (chicken mesh wire across the floor of the tank. bend it up ward at least 300cm behind the steel poles so it can be cart in the wall formed outside the poles. tie the chicken mesh wire to the poles.

17. Stand or kneel on planks of wood to spread your weight and not to damage the first layer of mortar. Sprinkle water on the first mortar surface. If it has begun to dry out, then quickly add another 25mm later of mortar.

18. Install a galvanized pipe for delivery of water. The pipe should be equipped with elbow, nipple and gate valve.

19. Put bamboo or any sheet metal (for form work) at the inside of the tank & tie firmly to the poles.

20. Strengthen the outside wall by winding 6 mm diameter steel and the distance between each winding should be 20cm apart.

21. Prepare the wall reinforcement by winding chicken mesh wire on the top of the steel rings. You can use one or two layers of chicken mesh wire. The chicken mesh wire should be stretched very well in order to have uniform plastering.

22. Begin plastering the tank wall from the outside with cement- sand ratio of 1: 3 mortars to a thickness of 20 mm. scratch the surface to make it rough, then apply the second layer of 20 mm thick mortar to the dampened area of the outside surface of the tank in order to give a smooth finish.

23. Three days later, carefully remove the bamboo and plaster the inside part of the tank with cement- sand mortar to a thickness of 20 mm. After a day, add a second layer of 20 mm thick mortar to dampen inside surface of the wall, giving it a smooth finish.

24. Apply the final coat for the walls (inside and outside surface) and the floor in order to make the surface water proofing. To do this coat cement and water (nil) will mix and apply on the same day. Again keep the surface damp all the time. Make the wall and floor thicker, where the pipes go through it.

25. Make a small pit under the tap, so that a bucket can fit beneath it.

26. Cover the tank with Ferro-cement the same thing as prepared for floor foundation, but the spacing for steel bars should be 20 cm apart. The steel bar should be strengthen with chicken mesh wire reinforce.

27. Put the prepared roofing material at the top of the tank, tie firmly with the poles.

28. Prepare different lengths of wooden poles and by standing at the centre of the tank (inside part) push it with one king post until completely stretched them with other wooden poles. Push the roofing at all direction until it becomes dome shape.

29. Then, apply cement-sand mortar plastering from the outside as it was used for inside wall plastering. The thickness is similar with inside wall plastering. Leave the support poles for a minimum of 7 days, remove the poles and apply plastering from the inside. The total thickness should not be more than 10cm.

30. The roofing should have a man-hole 60 cm*60 cm and an inlet 20 cm*20 cm.

31. Fill the tank very slowly with water. Leave some water in the tank to prevent from drying. The tank should be watered three times a day for about 21 days.

32. If you find any cracks you can repair them when the tank is empty by chipping away the mortar from the mesh and then filling the hole with fresh mortar. Keep the repair damp for at least two weeks.

9.4. Harvesting and supplying water

Distribution system

The distribution of harvested rainwater consists of two basic processes: providing sufficient pressure to move water out of the tank and providing a means to deliver water to its intended use. Harvested rainwater can be moved out of the tank using gravity flow or using more complex electric or solar powered systems. Piping, hoses, and in many cases irrigation technology are used to deliver water to its intended use. Note that hose threads and pipe threads are not the same size although there are parts that allow connections between hose and pipe threads. Different types of pipes have different inside diameters, just as different brands of drip lines have different diameters.

It is important to note that distribution systems can be responsible for more water waste than tank collection, conveyance, and storage systems combined. If you forget to turn off a hose that taps a tank, tank water can quickly drain away. When a pressurized pipe leaks 24 inches below ground, it will often go unnoticed until a large volume of water has been wasted. When a pump or irrigation system gets stuck in the "ON" position, it does not take long for a tank to drain. Paying close attention to good design, maintenance, and operation of the distribution system is key to efficient tank water use.

Water Use Management

Control over the quantity of water abstracted from the tank is important to optimize water use. Water use should be managed so that the supply is sufficient to last through the dry season. Failure to do so will mean exhausting all the stored water. In effect it will mean going back to where the user began, i.e. trekking long distances for poor quality water. On the other hand, underutilization of the water source due to severe rationing may leave the user dissatisfied with the level of the service provided.

Self-Check 9	**Written Test**

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

1. What is roof water harvesting?(5pt)
2. In what area roof water harvesting is applicable?(5pt)
3. What are materials needed for roof water harvesting and explain the advantage of the materials?(5pt)
4. Write the distribution systems of roof water harvesting?(5pt)

Note: **Satisfactory rating – 20 points** **Unsatisfactory – below 20 points**

Operation Sheet	Identify roof top water harvesting storage structure

Tools and equipments used:

Line level/A-frame, String, Graduated staff, Clinometers, Altimeter, Measuring tape, Digging instruments, watering can, Double-ring infiltrometer, Soil sampler(Auger), Stop-watch, Ranging pole, Strings, Pegs, Water tank /pump, Hooker, Soil texture chart, Compass, GPS, Aerial photographs, Top maps, Automatic level and Gabion Wire box

The following procedures should be taken into account to identify the crucial techniques of water harvesting:

1. Check whether there is a suitable catchment type
2. Check the soil type, slope and land cover of the catchment
3. Measure the size of the command area
4. Know the type of crop to be irrigated
5. Check construction material availability
6. Check availability of skilled manpower

Information sheet 10	Assist construction of ground surface catchments, diversion canals & sediment ponds

10.1.Identifying surface catchments, diversion canals and sediment ponds

Basic components of ground surface water harvesting:

- Catchment area
- Diversion channel
- Sediment pond
- Storage

Catchment area: - It is a natural or manmade unit draining runoff water to a common point.

Water can be made available by damming a natural rainwater catchment area, such as a valley, and storing the water in the reservoir formed by the dam, or diverting it to another reservoir. Important parameters in the planning of dams are: the annual rainfall and evaporation pattern; the present use and runoff coefficient of the catchment area (e.g. bare rock catchments have high runoff coefficients, around 0.9); water demand; and the geology and geography of the catchment area and building site.

Dams can consist of raised banks of compacted earth (usually with an impermeable clay core, stone aprons and a spillway to discharge excess runoff), open rock reservoir catchments, and masonry or concrete (reinforced or not).

Open reservoirs behind a retaining structure have storage capacities ranging from 20 – 4,000 m^3. Alternatively, a volume of water could be stored directly into covered storage tanks that collect water directly from the catchment.

The water stored behind a dam should normally be treated before entering a distribution system

Classification of catchment area:-

- Natural catchment
- Borrowed catchment
- Constructed catchment

Diversion Canals:-The purpose of a diversion canal is to lower a watercourse's downstream water level. Such a canal is most often water supplied by a spillway on levees located along a main watercourse. Generally, these canals must make up for a watercourse's insufficient local conveyance, and join together further downstream.

The hydraulic function limit of a diversion canal is its section, which will impose the maximum flow that can be diverted. Although it is possible to consider diverting flows corresponding to frequent floods, it is not advisable to consider diverting rare or exceptional floods unless considerable works can be undertaken for instance divert water up to the sea.

Sediment pond: - a small, temporary ponding basin formed by an embankment or excavation to capture sediment

Purpose To detain sediment-laden runoff and trap the sediment to protect receiving streams, lakes, drainage systems, and protect adjacent property

Conditions where practice applies specific criteria for installation of a temporary sediment trap are as follows:

- At the outlets of diversions, channels, slope drains, or other runoff conveyances that discharge sediment-laden water.
- Below areas that are draining 5 acres or less.
- Where access can be maintained for sediment removal and proper disposal.
- In the approach to a storm water inlet located below a disturbed area as part of an inlet protection system.
- Structure life limited to 2 years.

A temporary sediment trap should not be located in an intermittent or perennial stream.

Planning considerations select locations for sediment traps during site evaluation. Note natural drainage divides and select trap sites so that runoff from potential sediment-producing areas can easily be diverted into the traps. Ensure the drainage areas for each trap does not exceed 5 acres. Install temporary sediment traps before land disturbing takes place within the drainage area. Make traps readily accessible for periodic sediment removal and other necessary maintenance. Plan locations for sediment disposal as part of trap site selection. Clearly designate all disposal areas on the plans. In preparing plans for sediment traps, it is important to consider provisions to protect the embankment from failure from storm runoff that exceeds the design capacity. Locate bypass outlets so that flow will not damage the embankment. Direct emergency bypasses to undisturbed natural, stable areas. If a bypass is not possible and failure would have severe consequences, consider alternative sites. Sediment trapping is achieved primarily by settling within a pool formed by an embankment. The sediment pool may also be formed by excavation, or by a combination of excavation and embankment. Sediment-trapping efficiency is a function of surface area and inflow rate. Therefore, maximize the surface area in the design. Because porous baffles improve flow distribution across the basin, high length to width ratios is not necessary to reduce short-circuiting and to optimize efficiency. Because well planned sediment traps are key measures to preventing off-site sedimentation, they should be installed in the first stages of project development.

10.2.Arranging materials

Catchment can be constructed if the existing catchment is not sufficient or suitable to generate the required amount of runoff for example if the roof is organic thatch it can be covered with plastic sheets or corrugated iron sheet (CIS).

Construction of diversion channel and sediment pond can be constructed from locally available materials such as soil, stone, cement, sand etc.

10.3.Constructing surface catchments, diversion canals and sediment ponds

A. <u>Constructed catchment</u>

It is an area specifically designed and constructed for runoff water collection. Can be constructed necessarily in areas where the existing catchment is not sufficient and suitable for harvesting requirements, such as concrete, plastic tiles(floors),compacted clay soil, stone- paved floors etc.

<u>Important points to be considered for catchment area selection</u>

- Sufficient runoff should be collected to meet the designed storage capacity.
- The runoff water collected from the catchment area should be easily diverted to the storage facility.
- The catchment area selected should not affect other production activities.
- The catchment area selected should be located sufficiently away from sources of pollution, and it should be protected against pollution.

<u>How much runoff can be collected (generated) from a certain catchment area?</u>

Runoff yield varies with the size and texture of the catchment area. In principle, 1mm of rainfall on an impervious catchment area, can generate 1 liter of runoff water per square meter. However, due to several factors the rainfall on a particular catchment must not be totally resulted as runoff.

The expected runoff is therefore, the expected design rainfall multiplied by the runoff coefficient and the area of the catchment.

$$\mathbf{R = K \times P \times A}$$

Where R= annual runoff (m^3)

K= runoff coefficient =R/P

P= annual rainfall (design R.F) m

A = area of catchment (m^2)

Runoff coefficient denotes the percent of rain water which flows down the land slope as surface runoff.

<u>Factors influencing runoff coefficient</u>

- ✓ Rainfall characteristics (amount, intensity, duration)
- ✓ Infiltration rate of the soil
- ✓ Slope gradient of the catchment
- ✓ Soil moisture content
- ✓ Vegetative cover
- ✓ Soil type
- ✓ Geology
- ✓ Size of the catchment

B. <u>Diversion channels</u>

Are flow ways of runoff water collected from the catchment area to silt trap. If the catchment area is rooftop the diversion channel could be gutter attached to the roof edges. Diversion channels should have a certain gradient, for lined channel the gradient should not be greater than 0.33% (1/300) and not greater than 0.2% (1/500) for earth compacted channel.

The capacity of diversion channel can be calculated using the following equation.

$$\mathbf{Q = V \times A}$$

Where Q = runoff discharge (m^3/sec)

V= velocity of flow (m/sec)

A= cross sectional area of the diversion channel (m^2)

The velocity of flow is given Manning's equation:

$$\mathbf{V = 1/n\ R^{2/3} S^{1/2}}$$

Where n= Manning's roughness coefficient

R= hydraulic radius = A/P

S = longitudinal slope of the channel (%)

C. <u>Sediment pond</u>

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.

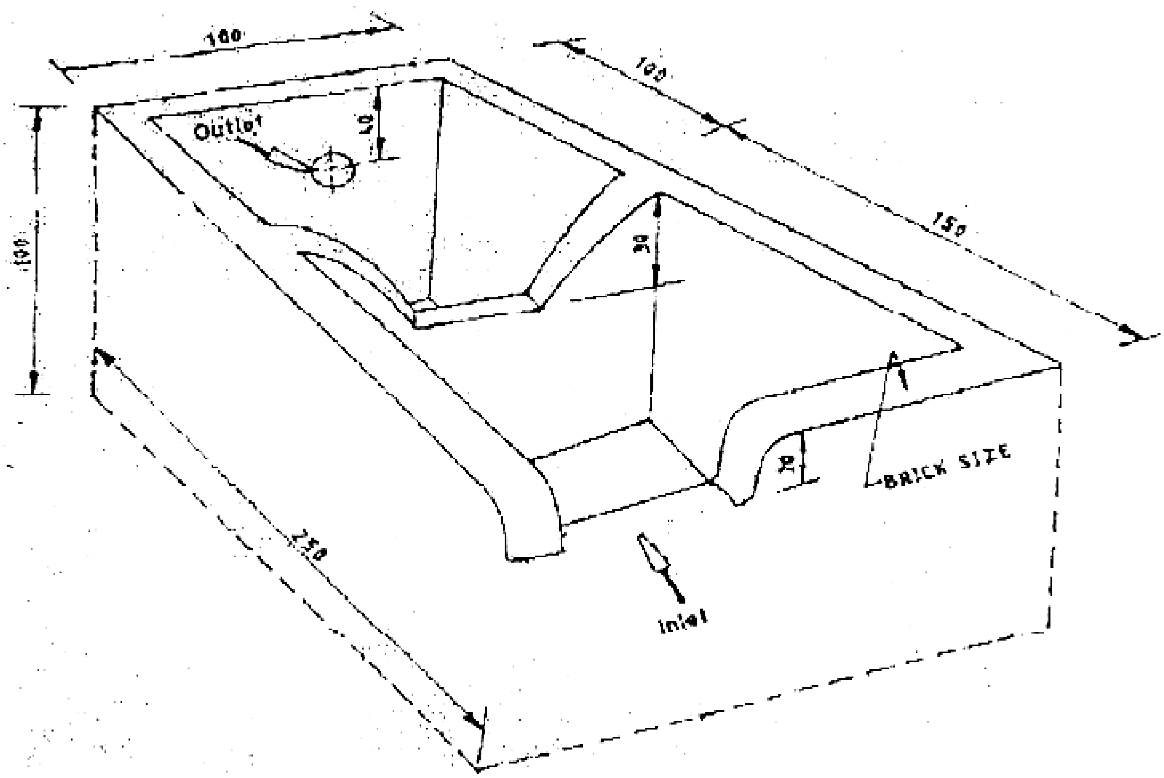


Figure. Silt trap

- 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 10	Written Test

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

1. Explain the component of ground surface water harvesting structure?(5pt)
2. List down the materials used to construct ground surface water harvesting structures?(5pt)
3. Write the factors to consider in the construction of surface water harvesting?(5pt)

Note: **Satisfactory rating – 15 points** **Unsatisfactory – below 15 points**

Operation Sheet	Identify ground surface water harvesting storage structures

Tools and equipments used:

Line level/A-frame, String, Graduated staff, Clinometers, Altimeter, Measuring tape, Digging instruments, watering can, Double-ring infiltrometer, Soil sampler(Auger), Stop-watch, Ranging pole, Strings, Pegs, Water tank /pump, Hooker, Soil texture chart, Compass, GPS, Aerial photographs, Top maps, Automatic level and Gabion Wire box

The following procedures should be taken into account to identify the crucial techniques of water harvesting:

1. Check whether there is a suitable catchment type
2. Check the soil type, slope and land cover of the catchment
3. Measure the size of the command area
4. Know the type of crop to be irrigated
5. Check construction material availability
6. Check availability of skilled manpower

Information Sheet-11	Assist construction of ground surface water storage structures

10.1.Designing structures for catchments area

Below/underground storage structures can be constructed to store rain water runoff from rooftops and/or ground surfaces. Below ground storage tanks are cheaper than the above ground storage structures because the soil profile provides structural support (i.e. reinforcement requirement is less). Typical examples of ground surface water storage structure are ***hemispherical, dome cap, farm pond & small dam.***

A. Hemispherical storage structure

Required catchment size (area)

In order to decide the size of the catchment area the following factors must be considered.

- Run off coefficient
- Rainfall of the area
- Construction cost
- Storage capacity

Required storage capacity (V_t)

In order to design the capacity of the storage the following factors must be considered and quantified.

- Number, age and type of beneficiaries
- Length of dry season
- Loss due to seepage and evaporation
- Cost of construction
- Living standard
- Irrigation requirement & area

Storage capacity (V_t):

$V_t = WD + 30\%\ WD = 1.3WD$,where WD is water demand & 30% is loss

Runoff from catchment area (Q):

$Q= AxPxK$, where P is mean annual rainfall & K is runoff coefficient

$Q= V_t = APK = 1.3\ WD$

The required catchment area (A) can be calculated as follows

$$A = 1.3 \frac{WD}{KP}$$

Estimation of Evaporation and seepage losses

Evaporation and. Seepage losses are controlled by applying roofing and lining material respectively. A 30% loss accounts for siltation and management.

Design specification and standard size of hemispherical tank

Wall- lining materials cement-sand mortar (1:3) or soil –cement mortar (1:6) chicken mesh wire if the soil is unstable.

Masonry ring- 60 cm high and 30 cm wide, cement-sand mortar (1:3) for binding and plastering.

Roof cover - corrugated iron sheet /poly ethane sheet/ canvas and nailed on wooden beam of 10 cm diameter and rafter 4-6 cm diameter.

Silt trap -stone /brick masonry with cement –sand mortar (1:3) for binding and plastering.

Standard size of hemispherical storage:

Capacity (m^3):- 89, 82, 75, 68, 62, 56, 51, 45, 41, 36, 32, 28, 25, 22, 19, 16, 14 and 10.

Suitability

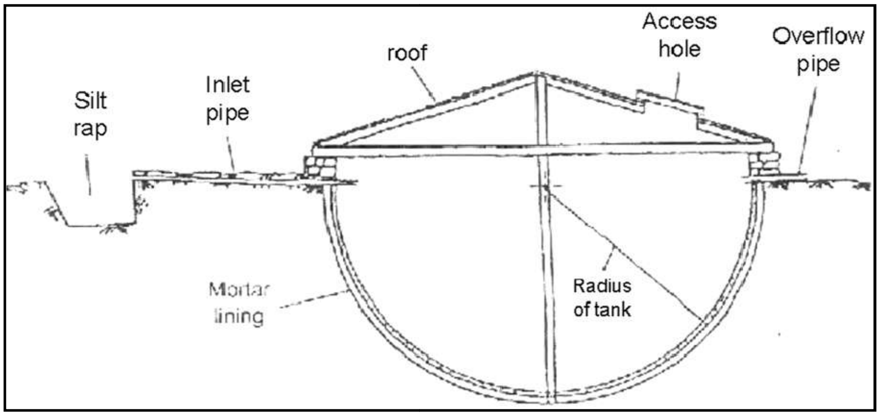
- Deep or shallow soils (not less than 3 m)
- Soils which are not too sandy or clayey .If the soil is too sandy or clayey use stone, brick or steel (mesh wire).
- Suitable for horizontal pumps like rower pump or treadle pump, not suitable for rope and washer pump.

Site selection of storage tanks

- Locate the tank where the largest storage volume obtained can be i.e. with least excavation
- Locate the storage where it is to be used
- Avoid pollution of stored water by selecting suitable unpolluted catchment area
- Avoid sites near unstable ground, such as gullies, landslides or near deep-rooted trees. Do not plant trees with deep roots near the tanks.
- Select appropriate and low cost option construction materials/availability of construction materials on site.
- Select suitable water sources (i.e. C.A) with minimum sediment load
- Be sure that no buried pipes or cables across the proposed site
- To check the soil requirement- depth and texture, excavate test pit before selecting the site for construction.
- The catchment should be treated with soil &water conservation measures on the watershed basis.
- The site should be selected so that the expected seepage and evaporation losses are kept as minimum as possible.

- Catchment area should be sufficient enough (not too big or too small) to produce sufficient amount of runoff to fill the tank. Avoid also the silting of the tank in an area where the actchment is not adequately protected.
- Avoid selection of water courses, which carry sediment and stone load, as these would cause in immediate sedimentation problem or failure.

Components Of The Structure



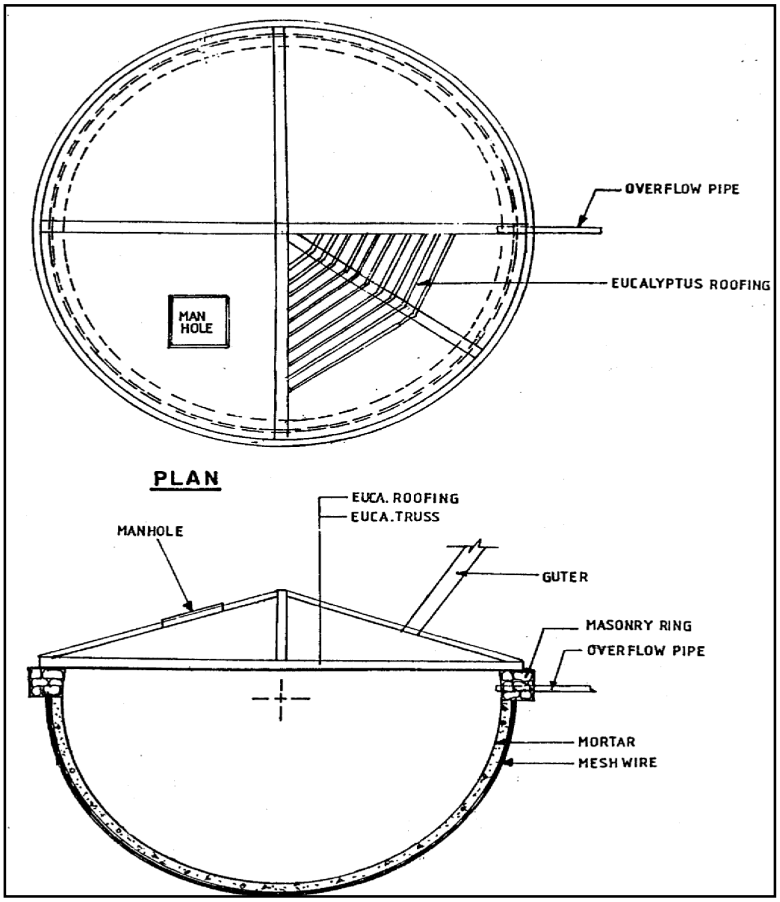


Figure 37.Cross sectional view of hemispherical storage tank

B. Design and construction of Farm ponds

Farm ponds are small tank or reservoir like constructions, are constructed for the purpose of storing the surface run off, generated from the catchment area. The farm ponds are water harvesting structure; solve several purposes of farm needs such as supply of the water for irrigation, domestic, fish production etc.

Types of Farm Pond

In broad sense, the farm ponds are divided in following two general categories;

1. Embankment type and
2. Excavated or dugout type

1. ***Embankment type***- farm ponds are generally construction across the stream or water course such ponds consist of are earthen dam, which dimensions are evaluated on the basis of volume of water to be stored etc. These farm ponds are usually built in that area

where land ranges from gentle to moderately steep and also where stream valleys are sufficiently depressed to permit a max, storage volume with least earth work.

2. ***Excavated type/dugout type***- farm ponds are constructed by excavating the soil from the ground relatively in level areas. The depth of pond is decided on the basis of its desired capacity which is obtained almost by excavation .The use of this type of pond is suitable, particularly where a small supply of water is required.

The farm ponds are also divided in to two more types i.e. spring or creek fed and off stream storage pond, depending up on the sources of water available for feeding them,

Components of farm pond

A form pond essentially consists of following components

1. Poundage storage area
2. Earthen embankment
3. Mechanical emergency spillway

Site Selection

- ❖ From an economic point of view a pond should be located at the site where the largest storage volume can be obtained with least amount of earth work.
- ❖ Watershed must be capable to furnish the annual run off, sufficient to fill the dugout pond
- ❖ The site should such that from where stored water can be utilized at low cost and very easily
- ❖ The yield of sediment from the watershed area and their reaching to the pond is also one of the main factors taken in to consideration for pond construction (should be kept under vegetative cover)
- ❖ The soil permeability should be low, as this property significantly affects the loss of water through deep-percolation and seepage
- ❖ Observe the average slope direction in the farm area in which farm pond is to be planned for construction
- ❖ If the slope is towards left bottom corner of the field (Figure 38a), a farm pond must be constructed in the left corner of the plot.
- ❖ If the slope is towards bottom right corner of the field (Figure 38b), a farm pond must be constructed in the right hand corner
- ❖ If the slope is towards the bottom of the field (Figure 38c), a farm pond must be constructed to the corner of either side with proper field channel at the bottom of the field connecting to the inlet of the structure.
- ❖ If the farm area has multiple slopes in different directions (Figure 38d), a farm pond must be located in a portion of area in which water is drained into the structure, may be at centre of the field or near to it.

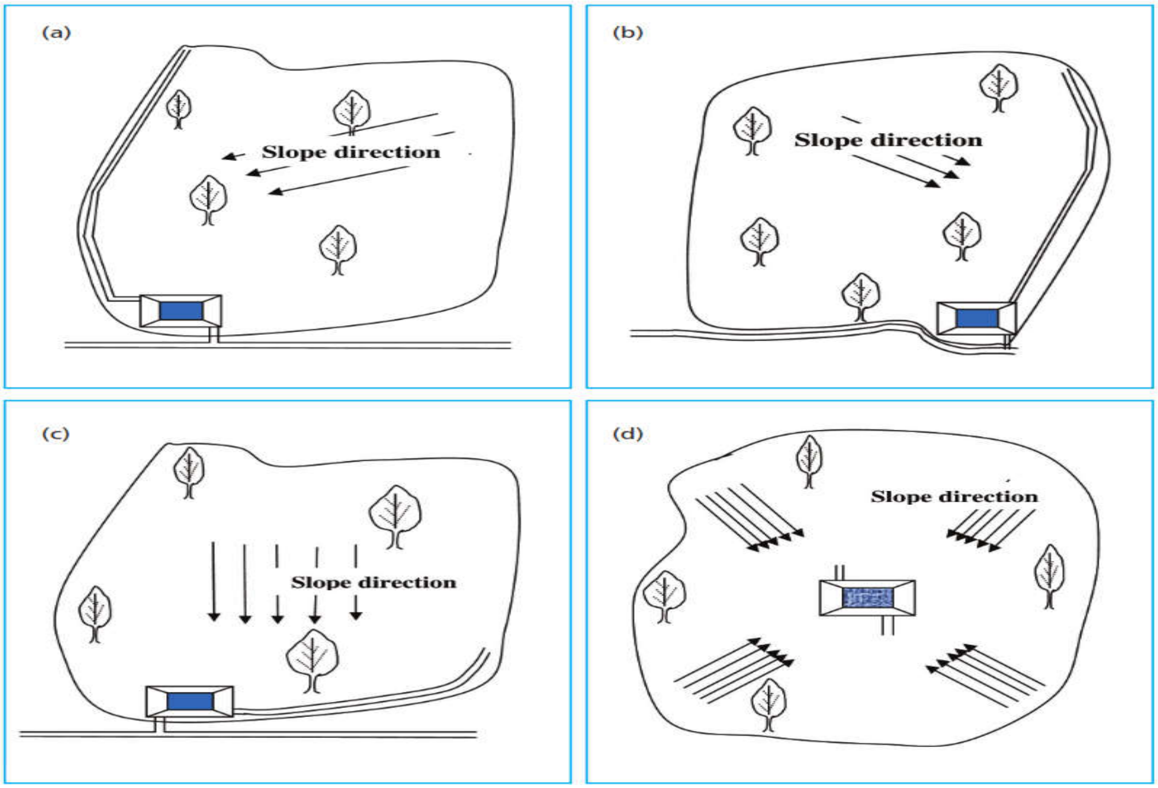


Figure 38. (a, b, c,.& d) : Planning and selection of site for farm pond location in farm catchment areas with different slopes.

The design of excavated or dugout pond include the determination of specifications for the following:

- Pond capacity,
- Shape of pond,
- Dimensions (depth, top & bottom widths and side slopes),
- Inlet channels and
- Emergency spillway or Outlet.

Pond Capacity

The capacity of the dugout pond depends on purpose for which water is needed and by the amount of inflow that can be expected in a given period. The seasonal water yield can be estimated using past historical weather data. The storage losses such as seepage, evaporation and percolation losses would also influence the storage capacity of pond. The type of soil in the catchment area contributes to the siltation and this has to be considered as it affects the storage capacity of pond. The capacity of the pond depends upon the catchment size and factors affecting its water yield.

Shape of Pond

Excavated farm ponds may normally be of three shapes, viz; (a) square, (b) rectangular, and c) inverted cone. (Square and rectangular shape refers the top & bottom but their walls are slant ie. They are trapezoidal in shape)

Dimensions of farm pond

The selection of dimensions for excavated pond depends on the required capacity, soil type, purpose and type of machine available for pond construction. The size of a pond should be relative to the size of the catchment area contributing surface runoff to the site.

Depth and side slope of farm ponds

The depth of pond is generally determined by soil depth, kind of material excavated and type of equipment used. The selected pond depth should have a depth equal to or greater than the minimum required for the specific location as depth of pond is most important dimension among the three dimensions.

The side slope of the pond is decided based on their angle of repose of the material being excavated and this angle of repose varies with type of soil. For the most cases, the side slopes of 1: 1 to 1.5:1 are recommended for practical purpose.

Volume of pond – The following formula can be used for determining the volume of excavation required, (prismoidal formula)

Once the volume, depth and side slope are known, the dimensions of different shape of farm ponds can be calculated using the prismoidal formula as given below as per the definition sketch (Figure 39).

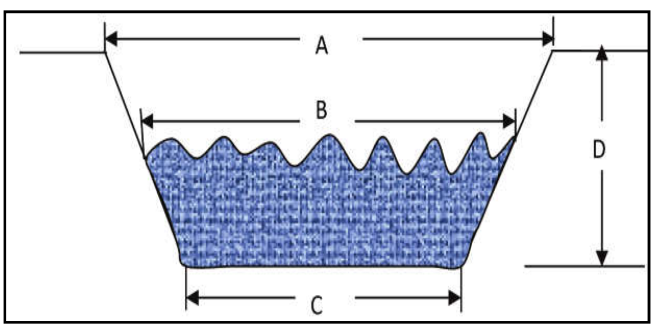


Figure 39: Definition sketch of farm pond for estimation of top and bottom areas

$$V = \frac{A+4B+C}{6} \times D$$

Where,

V = volume of excavation (m^3)

A = area of excavation at the ground surface (m^2)

B = area of excavation at the mid- depth point (D/2) (m^2)
C = area of the excavation at the bottom of pond (m^2); and
D = average depth of the pond (m).

Example

Calculate the volume of excavation required to construct a dugout farm pond if

1. Average depth of pond is 4.5m
2. Bottom width is 12m
3. Bottom length is 25m
4. Side slope to be used as 2:1

Solution

Using the following formula

$$V = \frac{A+4B+C}{6} \times D$$

$D/x = 1/2$

X= 2D = 9m

At mid depth

X = $2(D/2)$

= D = 4.5m

Computation of A

A = Top length x Top width

= (25+2(9) x 12+2(9))

= 43x30

= $1290m^2$

Computation of 4B

Mid length =25+2(4.5) = 34m

Mid width = 12+2(4.5) = 21

4B= 4*(34x21) =$2856m^2$

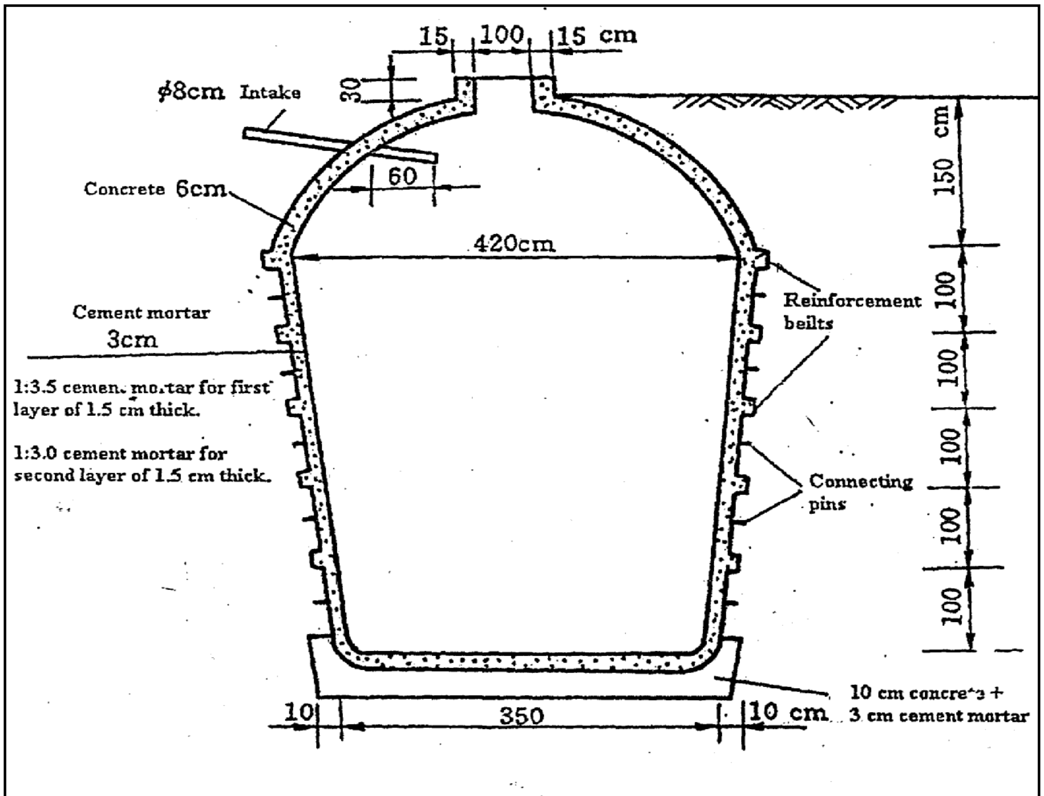
Computation of C

C= 12x25= $300m^2$

Volume $= \frac{(1290 + 2856 + 300)}{6} \times 4.5 = 3334.5m^3$

C. Dome cap water tank

It is a type of under ground water storage structure which is mostly excavated and constructed to a shape of dome at the upper part & circular frustum at the lower part. Excavation of dome cap water tank carried out below ground with top dome built first. And can be used to store runoff water collected from ground surface or rooftops.



Concrete dome tank

10.1.Collecting materials

Material requirement

Cement
Stone
Gravel
Mesh wire
C.I.S
Caped nail
Wooden purlins & rafter
PVC/concrete pipe

PVC pipe for inlet and outlet/over flow

11.3.Constructing structures.

I. Construction Procedures of hemispherical storage structures

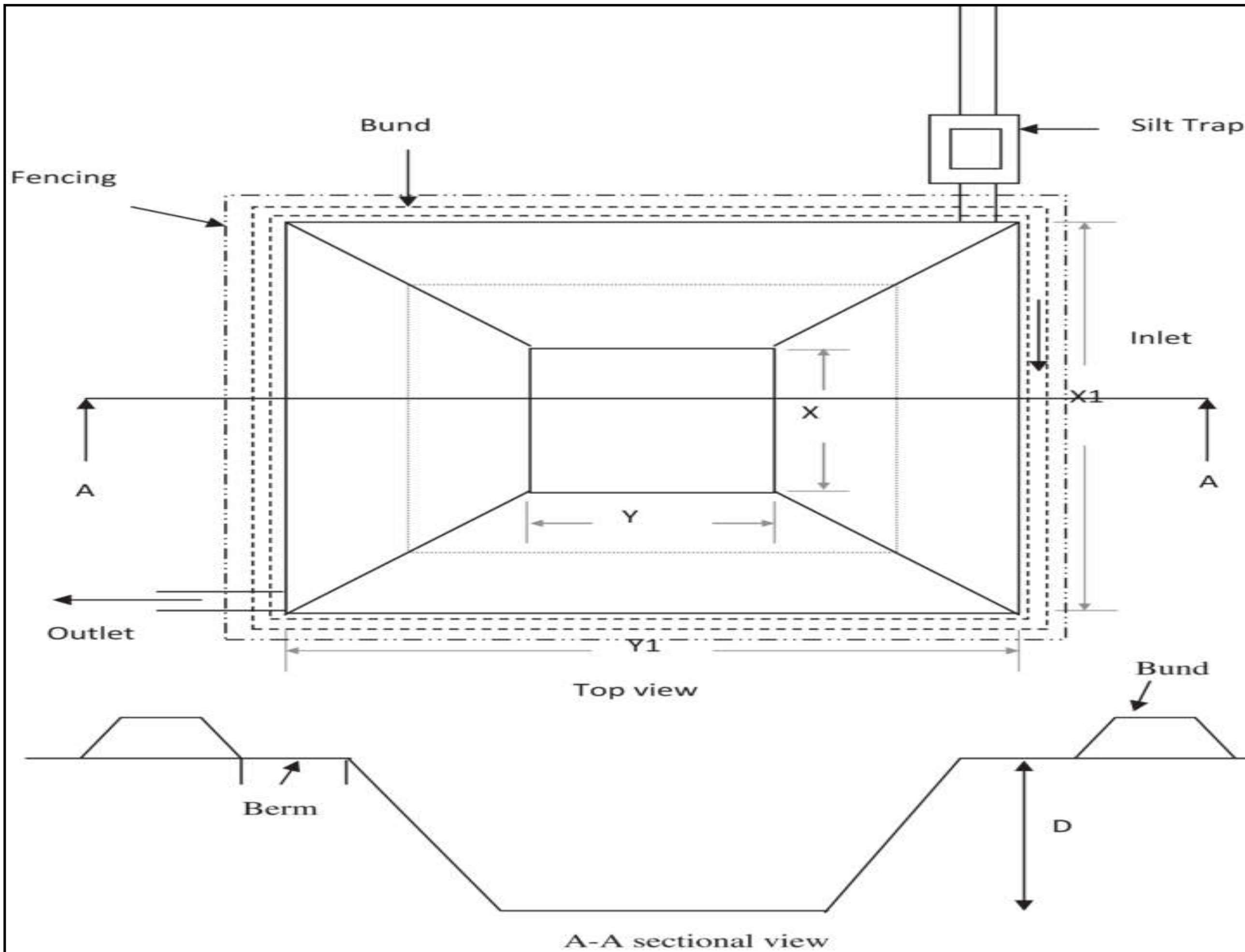
1. Determine the total volume of water to be stored
2. Calculate the capacity of the storage by adding 20% of the demand
3. Determine the lining material to be used
4. Find the size of hemisphere using $V= 2/3\pi R^3$
5. Level the area and clear the site to a depth of 20 cm to remove the top soil
6. Locate the position of silt trap and level it with respect to the storage
7. At the center of the selected site hammer one wooden peg
8. Add the thickness of the selected lining material to the radius of the hemisphere to get the external radius R_o.
9. Tie a rope to a center peg and make a loop at R_o meter put a nail through the loop and draw a circle
10. Put a wooden pole of length $2R_o$ +2 meter across the center peg: put a nail at the center of a wooden pole at $(2R_o+2)/2$ position .The nail should be at position of the center peg.
11. Remove the center peg and tie the plastic (nylon) string of R_o to the nail on the wooden pole.
12. Using the rope R_o (i.e. length of rope=R_o) at all times, the soil inside the marked circle should be excavated to the shape of a hemisphere.
13. To prevent the wall from collapsing construct two layers of masonry ring .The first ring 30 cm high and 30 cm thick built below ground surface and the second layer 30 cm X 30cm on the upper profile of the hemisphere.
14. Watering the wall of excavated hemispherical tank, and then apply one layer (first) of cement sand mortar (1:3) to a thickness of 1.5 cm including the first layer of masonry ring. The work should be completed within one day.
15. The next day, put the chicken mesh wire across the surface area of the tank. To fix the mesh wire use capped nail at 15 to 20 cm spacing.
16. Construct the second layer of masonry ring and black wire embedded in the masonry wall to enable tie roofing materials (i.e. wooden pole/beam and truss).
17. Then apply the second coat with cement –sand mortar (1:3) of 1.5 cm thick over the mesh wire including the second masonry ring.
18. At the third day, apply 2 cm thick cement –sand mortar coat. For water proofing a coat of cement slurry (nil) on the same day as the final coat of plaster.
19. The roof is constructed from two wooden poles each 10 cm diameter and a length o $2R_o$ plus half the thickness of the masonry ring. They are placed at a right angle across the center of the tank and tied down with black wire embedded in the masonry wall. At the center, where they cross, a wooden post of 10 cm diameter and 60 cm long is erected, and then the truss and rafter will be installed.

20. Cover the roof with corrugated iron sheet. Opening 60 cm x 60 cm and 20 cm x 20cm should be provided for man hole and inlet respectively.
21. Damp the structure for about 21 days.

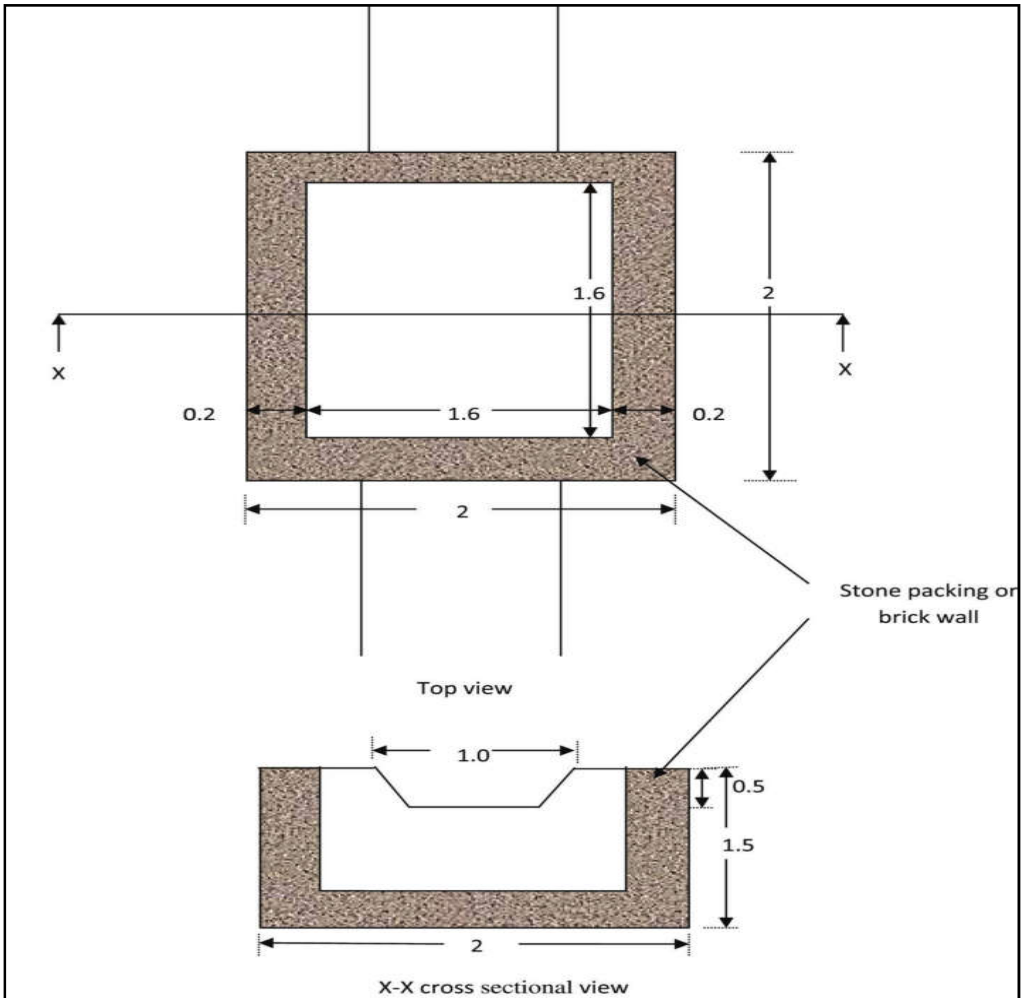
II. Construction of dugout Farm ponds

These ponds are constructed on the principle to expose a minimum water surface area in proportion to their volume. This feature of dugout pond proves beneficial particularly where evaporation losses are high and water is very scares.

After the site selection and pond dimensions decided, the pond site should be cleared of all stones and woody vegetation. Before construction of farm pond, proper layout should be made for proper construction. The design drawings for farm pond with silt trap, inlet and outlet construction are given in Figure 40 (a, b, c &d). Stakes are used to mark the limits of the excavation and spoil placement areas and the depth of cut from the ground surface to the pond bottom should be indicated on the stakes. Excavation and placement of the dugout material are the principal items of work required in the construction of pond.



a. Layout of the dugout farm pond



b. Plan and sectionof silt trap for the farm pond

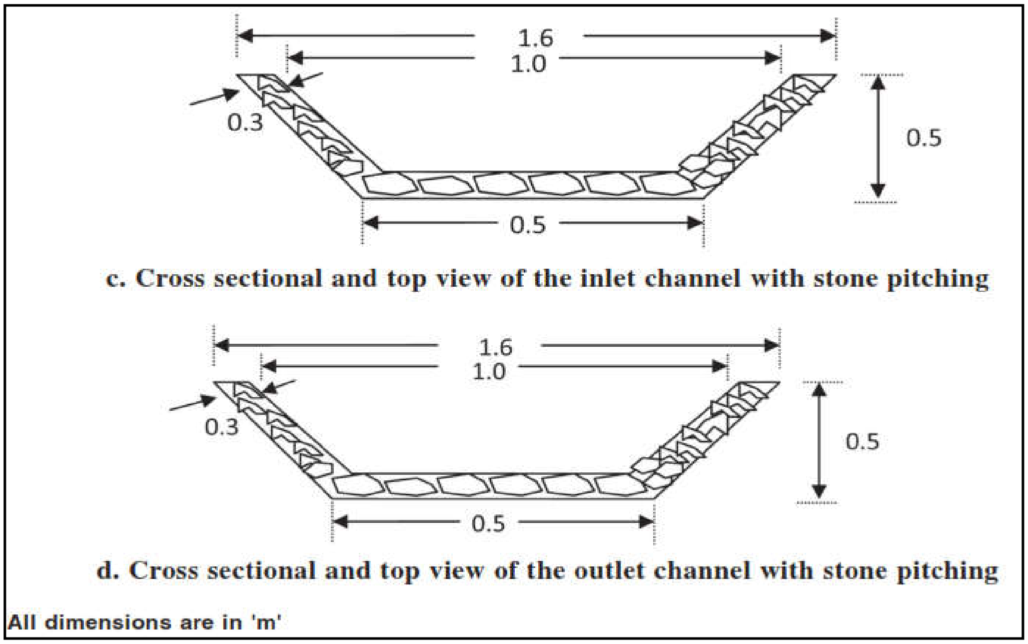


Figure 40 (a, b, c & d) Design drawings of farm pond with silt trap, inlet and outlet structures

Self-Check 11	**Written Test**

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

1. List and explain examples of ground surface water storage structures?(5pt)
2. Write the site selection criteria to construct ground surface water storage structures?(5pt)

Note: **Satisfactory rating – 15 points** **Unsatisfactory – below 15 points**