Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani

PRACTICAL MANUAL

Course No. : ENGG – 121 (As per V Dean Committee)

Semester : II (New)

Course Title : Soil and Water Conservation Engineering

Course : B. Sc. (Hons.) Agriculture

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CERTIFICATE

This is to certify that Mr. / Miss -- Reg. No. ------------------- a student of II Semester B. Sc. (Hons.) Agriculture has completed all the exercises successfully of the Course No. ENGG – 121 (New Course) entitled: Soil and Water Conservation Engineering during Summer session of the Academic year 20 - 20 .

Place : Latur

Date : **Course Teacher**

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Exercise No. 1

General status of soil conservation in India

Soil degradation in India is estimated to be occurring on 147 million hectares of land which includes:

- 94 Mha from water erosion
- 16 Mha from acidification
- 14 Mha from flooding
- 9 Mha from wind erosion
- 6 Mha from salinity
- 7 Mha from a combination of factors

The causes of soil degradation are both natural and human-induced. Natural causes include earthquakes, tsunamis, droughts, avalanches, landslides, volcanic eruptions, floods, tornadoes, and wildfires. Human-induced soil degradation results from land clearing and deforestation, inappropriate agricultural practices, improper management of industrial effluents and wastes, overgrazing, careless management of forests, surface mining, urban sprawl, and commercial/industrial development. Inappropriate agricultural practices include excessive tillage and use of heavy machinery, excessive and unbalanced use of inorganic fertilizers, poor irrigation and water management techniques, pesticide overuse, inadequate crop residue and/or organic carbon inputs, and poor crop cycle planning. Some underlying social causes of soil degradation in India are land shortage, decline in per capita land availability, economic pressure on land, land tenancy, poverty, and population increase.

Effects of Soil Erosion in India

- Soil erosion results in huge loss of nutrients in suspension or solution, which are washed away from one place to another, thus causing depletion or enrichment of nutrients.
- Loss of top fertile soil
- Land degradation through creation of gullies and ravines
- Water causes sheet-wash, surface gullies, tunnels and scours banks of rivers
- In hot and dry climate of India, wind blowing is the main cause of soil erosion.

Indian government is adopting adequate measures to reduce the unpleasant effects of soil erosion in India particularly in the states like Punjab, Maharashtra, and Karnataka.

Introduction to Soil Conservation:

Soil and water conservation is essential to protect the productive lands of the world. In our country, where droughts, famines and floods cause crop damage almost every year, soil conservation will not only increase crop yields but also prevent floods and further deterioration of land.

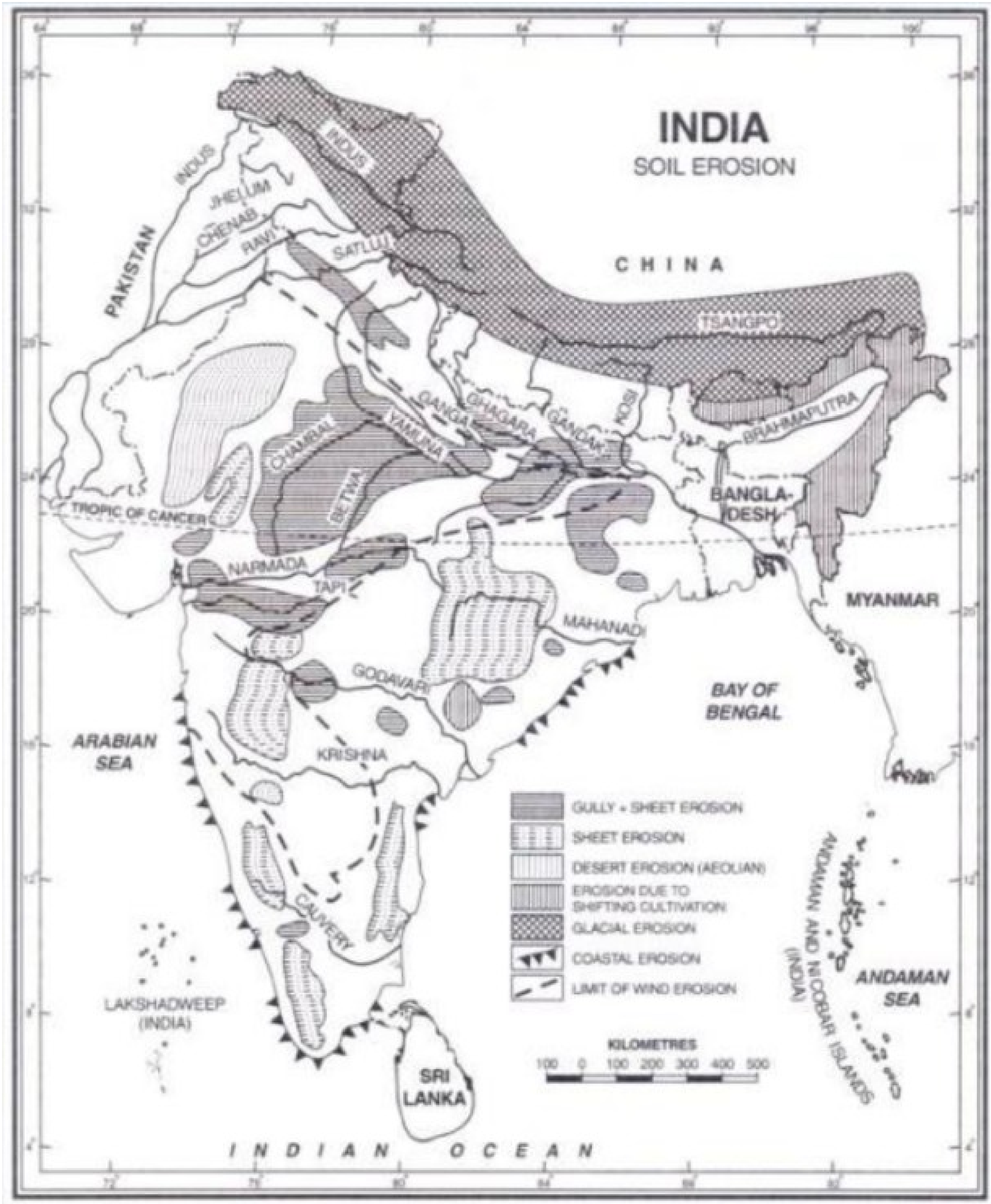


Fig. 1.1 Different forms of soil erosion in India

Prior to the days of independence, while general problems of soil erosion were known, answers to these problems backed by scientific investigations were not known. Consequently, during the framing of the First Five Year Plan and early in the Second Five Year Plan, a chain of 9 Soil Conservation Research Demonstration and Training Centers were established.

Table 1.1 Central Soil and Water Conservation Research Demonstration and Training Centers

Location	Region/Major problem	Date of start
Dehradun	North-Western Himalayan region. Erosion control in Himalayas; training of torrents; stabilization of landsides; development of techniques for crop production; establishment of pastures and forestry.	28.09.1954
Chandigarh	Sub-mountain tracts in the north-western region of India with special reference to Shiwalik hills, erosion control in Shiwaliks; training of chos.	28.09.1954
Ootacamund	Southern hill high rainfall region/soil and water conservation in the Nilgiri hills; development of techniques for crop production; establishment of pastures and forestry.	10.10.1954
Bellary	Semi-arid black soil region. Soil and water conservation in the black soil region.	20.10.1954
Kota	Along the Chambal river in Rajasthan. Ravine problem on the banks of Chambal river and its tributaries; survey, classification and reclamation of ravines for forage production and forestry.	19.10.1954
Vasad	Along the rivers of Gujarat State. Ravine problem specifically along the banks of Mahi river system. Survey, survey, classification and reclamation of ravines for forage production and forestry.	11.05.1955
Agra	Along the Yamuna river and its tributaries. Ravine problems specifically on the banks of Yamuna river; survey, classification and reclamation of ravines for forage production and forestry.	22.07.1955
Hyderabad	Red soil, semi-arid region. Soil and water conservation in the red soils under low to medium rainfall regions.	10.01.1962
Chattra	North-Eastern Himalayan region. Erosion control in the Kosi river catchment.	19.12.1956

Broad objectives of these Centers:

(i) To identify erosion problems and conservation of land and water resources under different land use systems.

(ii) To evolve mechanical and biological methods of erosion control under different land use systems.

(iii) To evolve methods of control of erosion and reclamation of ravines stabilization of landslides and hill torrents.

(iv) To evaluate hydrological behavior and evolve techniques of watershed management under different systems.

(v) To set up demonstration projects for popularizing soil and water conservation measures.

(vi) To impart specialized training in soil and water conservation to gazette and non-gazette officers of state governments.

Important Soil and Water Conservation Programmes Implemented by State and Central Govt.:

- Soil conservation in catchments of river valley project (RVP).
- Integrated Watershed Management in catchments of Flood Prone Rivers (FPR).
- Centrally Aided Drought Prone Area Development Program (DPAP), (as per 1995 guidelines) implemented by Government and NGO, Desert Development Programme (DDP).
- National Watershed Development Program for Rain fed Area (NWDPRA) implemented by Dept. of Soil Conservation & Watershed Management, Govt. of Maharashtra with financial support from Department of Agriculture, Govt. of India.
- Operational Research Projects on Integrated Watershed Management (ICAR).
- World Bank Project on Watershed Development in Rain fed Area.
- Council for People's Action & Rural Technology (CAPART) supported 38 Watershed Development Programs in Maharashtra.
- DPAP & IWDP projects (of 2001 guidelines) in Satara, Sangali & Nashik Districts of Maharashtra state.
- NABARD Holistic Watershed Development Programme.
- Vasundhara Watershed Development Project.
- Maharashtra government has launched a new programme named 'Jalyukta Shivar Abhiyan' in the state on January 26, 2015. The program aim at making 5000 villages free of water scarcity every year and to conserve and protect the soil from further degradation. This mission aims at initiating permanent measures to make the state drought free by 2019 and to harvest rain water within the village boundary, thereby increasing ground water levels.

Exercise No. 2

Study of Surveying Instruments

Instruments for measuring distance:

1. **Chain:** **A) Metric surveying chains** – 20 meter or 30 meter
   B) Non metric surveying chains - (i) Gunter's chain (ii) Revenue chain (iii) Engineer's chains
2. **Arrows**
3. **Tapes** (i) Cloths or Linen tape (ii) Woven metallic tape (iii) Metric steel tape (iv) Invar tape (v) Synthetic tape
4. **Wooden pegs**
5. **Ranging rods**
6. **Ranging poles**
7. **Offset rod**
8. **Laths**
9. **Whites**
10. **Plumb bob**

1. Chain: The chain generally consists of 100/150 links/pieces of steel or iron wire of diameter 4m.m. The ends of the pieces are bent to form loops. Then the pieces are connected to each other by three circular or oval rings. At both ends of the chain a brass handle is provided. These handles are included in the total lengths of chain. Brass rings and tags are provided at fixed intervals in a chain to facilitate counting. First tag has one tooth; second tag has two teeth and so on from both the ends of chain. Middle tag is round in shape. One link means the distance between the centers of adjacent middle rings. The following are the different types of chains.
a) Metric chain b) Steel band c) Engineer's chain d) Gunter's chain e) Revenue chain

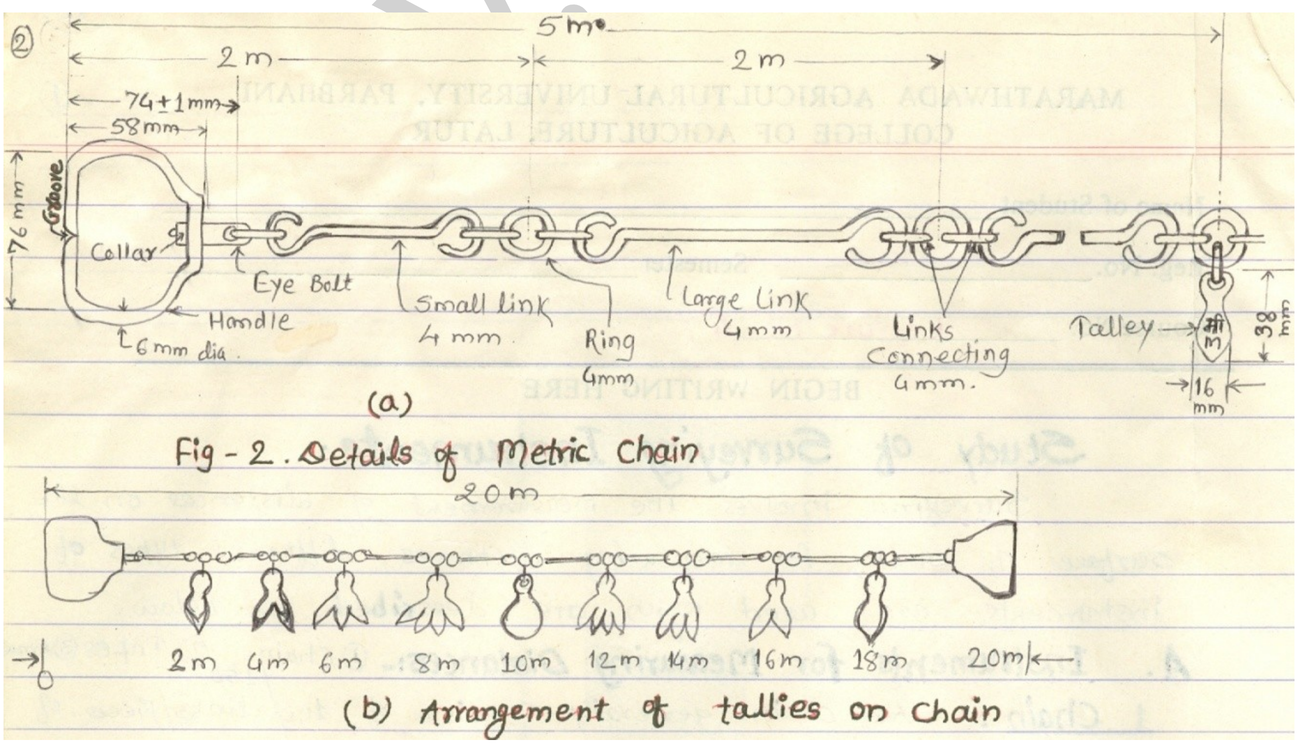
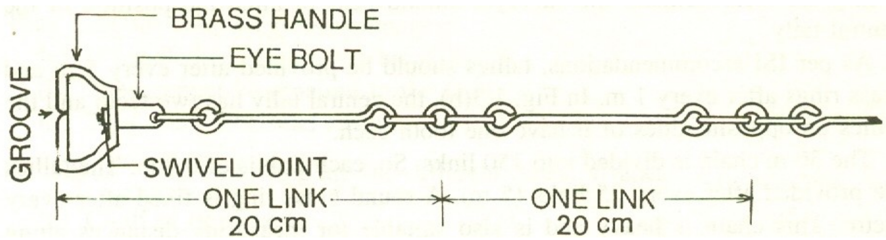
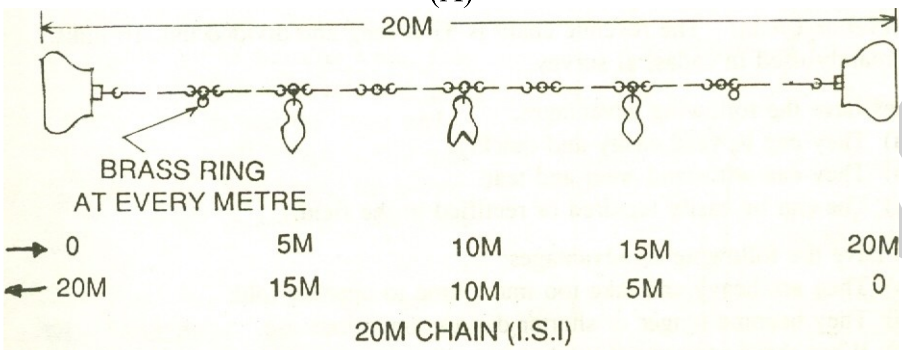


Fig - 2. Details of Metric Chain

(b) Arrangement of tallies on Chain



(A)



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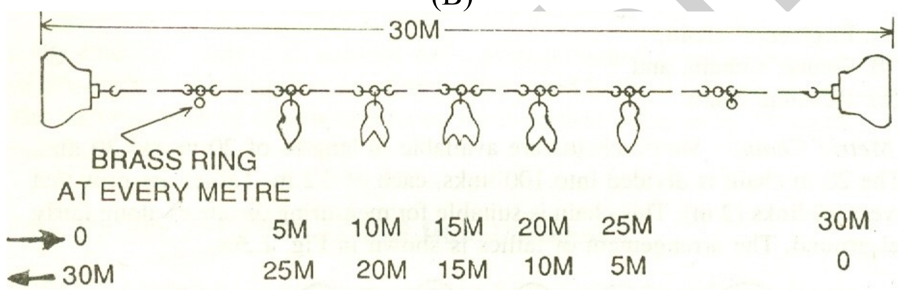


(C)

Fig.2.1 (A) Details of metric chain and (B) Arrangement of tallies on chain (C) 30 m chain

a) Metric chain:

Metric chains are available in lengths of 20m and 30 m. The 20m chain is divided into 100 links, thus each link measures 20cm or 0.2m.Tallies are provided at every 10 links(2m).This chain is suitable for measuring distances along fairly level ground. The arrangement of tallies and length details are given in figure 2.

From the arrangement of tallies we can see that the central tale is round and that the other tallies have one, two ,three or four teeth. As per ISI recommendation tallies should be provided after every 5 m and brass rings after every m.

b) Steel band:

The steel band, also called the band chain, consists of a ribbon of steel with a brass handle at each end. It is a length of 20 or 30 m and is graduated in meters, decameters and centimeters on one side and has 0.2 m links on the other.

c) Engineer's chain:

The engineer's chain is 100 feet long and is divided into 100 links. So each link is of 1 ft. The tallies are provided at every 10 links (10 ft).

d) Gunter's chain:

It is 66 feet long and divided into100 links. So each link is of 0.66 ft. It was previously used for measuring distances in miles and furlongs and convenient for measuring land when the unit of area is in acre. 80 Gunter's chain equal to a mile and 10 Square Gunter's chain is equal to 1 acre.

e) Revenue chain:

The revenue chain is of 33ft long and divided into 16 links. It is mainly used for measuring fields in cadastral survey. 33*33 ft = 1 square chain = 1 Guntha.

2. Tape:

Measurement with tapes results in greater accuracy than with chains. The following are different types of tapes; a) Cloth or linen tape b) Metallic tape c) Steel tape and) Invar tape

a) **Cloth tape:** Such a type of tape is made of closely woven linen and is varnished to resist moisture. It is 15m wide and is available in lengths 10m and 15m .This tape is generally used for measuring offsets and for ordinary works.
b) **Metallic tape:** When linen tape is reinforced with brass or copper wires to make it durable, then it is called a metal tape. This tape is available in lengths of 15,20and 30m .It is commonly used for all survey works.
c) **Steel tape:** It is made of steel ribbon of width varying from 6 to 16mm.The commonly available lengths are10,15,20,30 and50m .It is graduated in meters decimeters, centimeters. It is used for standardizing and for measurements in constructional works.
d) **Invar tape:** Invar tape is made of an ally of steel (64%) and nickel (36%). It is not affected by change of temp. It is made in the form of a ribbon of width 6 mm and is available in lengths of 30, 50 and100 m. It is used for works of the highest accuracy.

3. Arrows: Arrows are made of tempered steel wire of diameter 4 mm. One end of the arrow is bent into a ring of diameter 50 mm and the other end is pointed. Its overall length is 400 mm. Arrows are used for counting the number of chains while measuring a chain line.

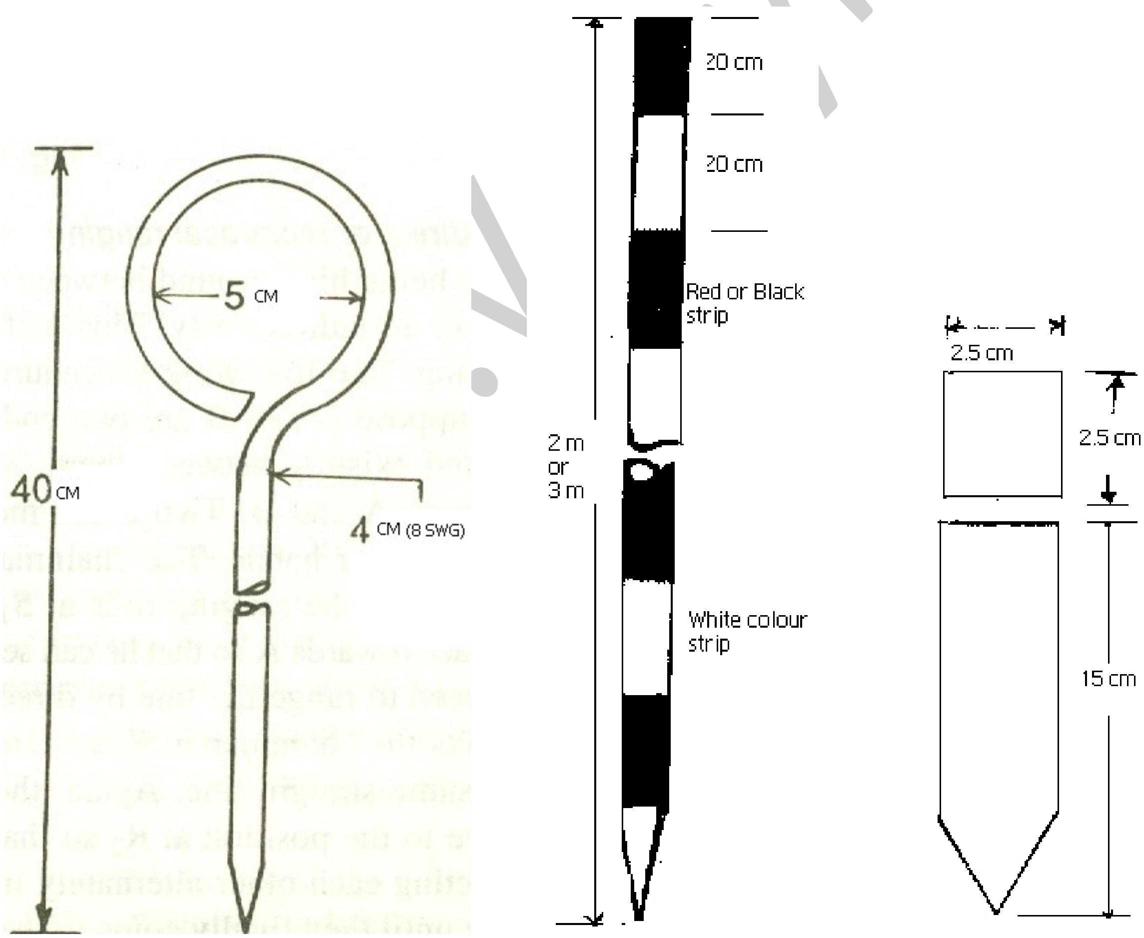


Fig.2.2 (a) Arrow (b) Ranging rod (c) Wooden peg

4. Ranging rods: Rods which are used for ranging (i.e. the process of making a line straight)a line are known as ranging rods. Such rods are made of seasoned timber or bamboo or GI pipes of 25 mm diameter and length 2/3/2.4 m. The rod is divided into equal parts of 20cm each and the divisions are painted black and white or red and white alternately so that the rod is visible from a long distance the lower end of the rod is pointed or provided with an iron shoe (fig 3) It is used for marking the position of stations.
5. Offset rods: Similar to the ranging rod. It is usually 3m long and is divided into parts each 0.2m length. Top is provided with a open ring for pulling or pushing the chain through a hedge. It has two short narrow vertical slots. It is used for aligning the offset line and measuring short offsets.
6. Plumb bob: A plumb bob is essentially a pointed metal weight suspended by a string or thread. It is used for locating points directly below or above another point. It is required when measuring distances along slopes in a hilly country.
7. Pegs: Wooden pegs are used to mark the position of the stations. They are made of hard timber and are tapered at one end. They are usually 2.5cm square and 15 cm long. But in the soft ground 40 to60 cm in length and4 to cm square pegs are suitable. They should be driven in the ground with about 4 cm lengths projecting above the ground. (Draw figure)

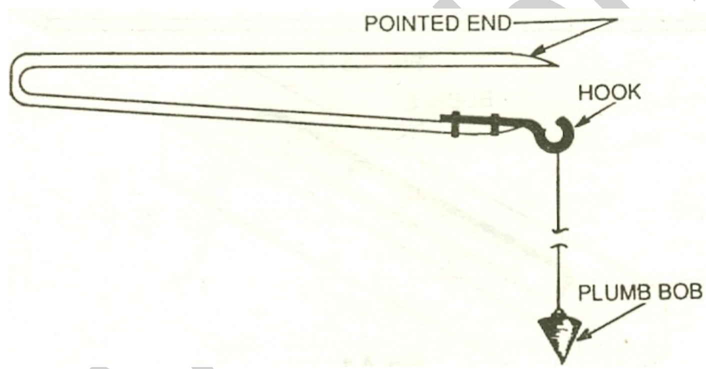


Fig. 2.3 Plumb bob with plumbing fork

8. Laths: Useful for ranging long lines. Also used over uneven ground when the ranging rod is not visible due to obstructions. They are light, cheap .Being white, they are easily visible at a great distance usually 1.0 m long.
9. Whites: When the ranging rods are not available or insufficient whites are used. These are the strip of bamboo and 40 cm to 1m in length. One end is sharp and the other end is split for inserting pieced of white papers. They are also useful for temporary marking of contour points.

Exercise No. 5

Study Levelling Instruments

Levelling: The art of determining the relative heights of different points or objects on or below the surface of the earth is known as levelling. Levelling deals with measurements in vertical plane.

Objectives:
1. To study the parts of dumpy level
2. To study setting up dumpy level
3. To take readings from levelling staff

Instruments required: Dumpy level with stand, levelling staff, chain or tape and level field book.

Dumpy level: It is short, simple, compact, stable and stout instrument, hence called dumpy level. It is most commonly used in levelling operations.

Parts of dumpy Level:

1. Levelling head	2. Telescope
3. Eye piece	4. Focusing screw
5. Diaphragm	6. Object glass
7. Level tube	8. Level tube nuts
9. Cross bubble tube	10. Levelling screw

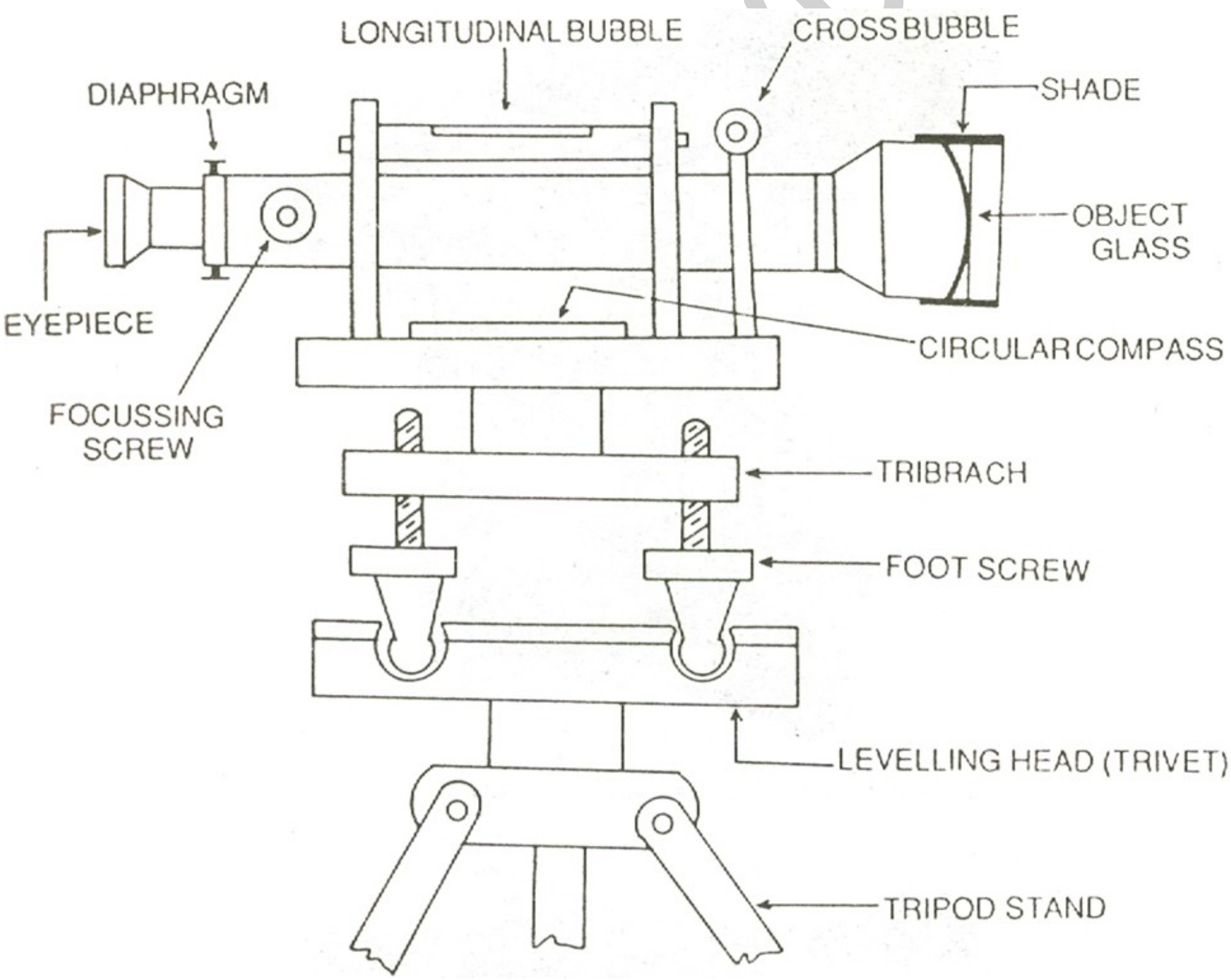


Fig. 3.1 Dumpy Level with parts

Levelling staff: There are various types of graduated staffs available. It is made up of timber or aluminium, usually 4 m long. It is folding type and has three segments. The solid top segment is 1.25 m long and slides into central bore of 1.25 m long, which in turn slides into the bottom box of 1.5 m in length. Each segment when pulled out to its full length is held in position by means of a brass spring catch. It is graduated into meters, decimetres and centimetres. Each meter is divided into 100 divisions, each division being 1cm. The meter numeral is in red and marked to the right and the decimetre numeral is in black and marked to the left. When viewed through modern dumpy level telescope, the staff appears as it is and readings are taken from bottom upwards.

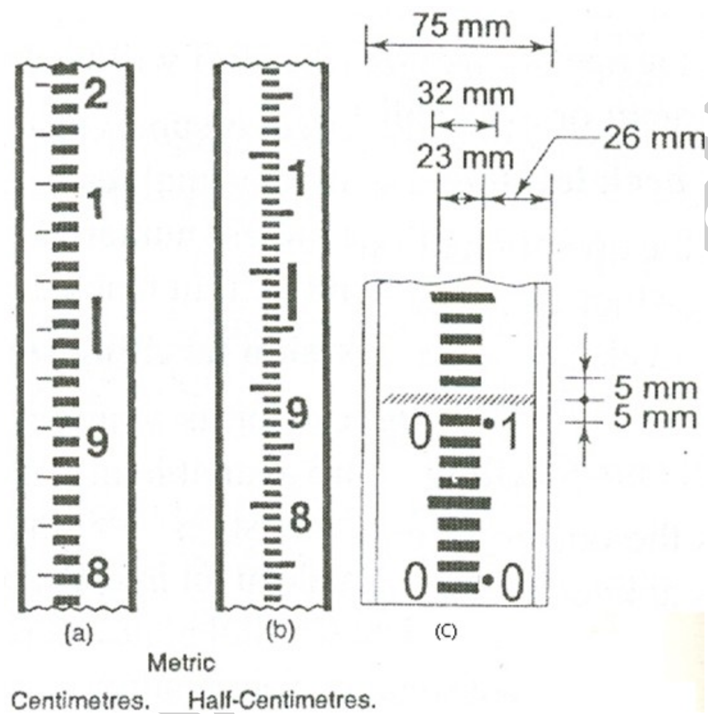


Fig. 3.2 Levelling staff and taking reading on it

Adjustments of the Level: The level has to be adjusted in two ways before use – 1) temporary and 2) permanent

Temporary adjustments: These are the adjustments performed at each set up of the level and include (a) setting up the level and (b) focusing the eyepiece and object glass to remove parallax.

(a) Setting up the level:

(i) Fixing instrument on the tripod: Spread the legs of tripod on the ground, hold the instrument in one hand and fix it on tripod by turning round lower part of levelling head with other hand.

(ii) Leg adjustment: Instrument is placed at a convenient height by spreading legs such that the eyepiece comes at eye level. Bring all foot screws in the centre of their run. Fix any two legs firmly into the ground and move third leg in or out till the bubble in cross level tube is approximately in the centre. Finally legs should be such fixed that both bubbles are in centre approximately.

(iii) Levelling with screws: Place the telescope parallel to any pair of foot screws and bring the bubble to the centre of its run by turning these screws equally either both inward or outward. Turn telescope through 90 and bring it over third screw. Turn this screw to bring the bubble to the centre.

Again bring the telescope over first pair of foot screw and centre the bubble. Repeat these two operations alternately until the bubble remains at centre for all directions of telescope.

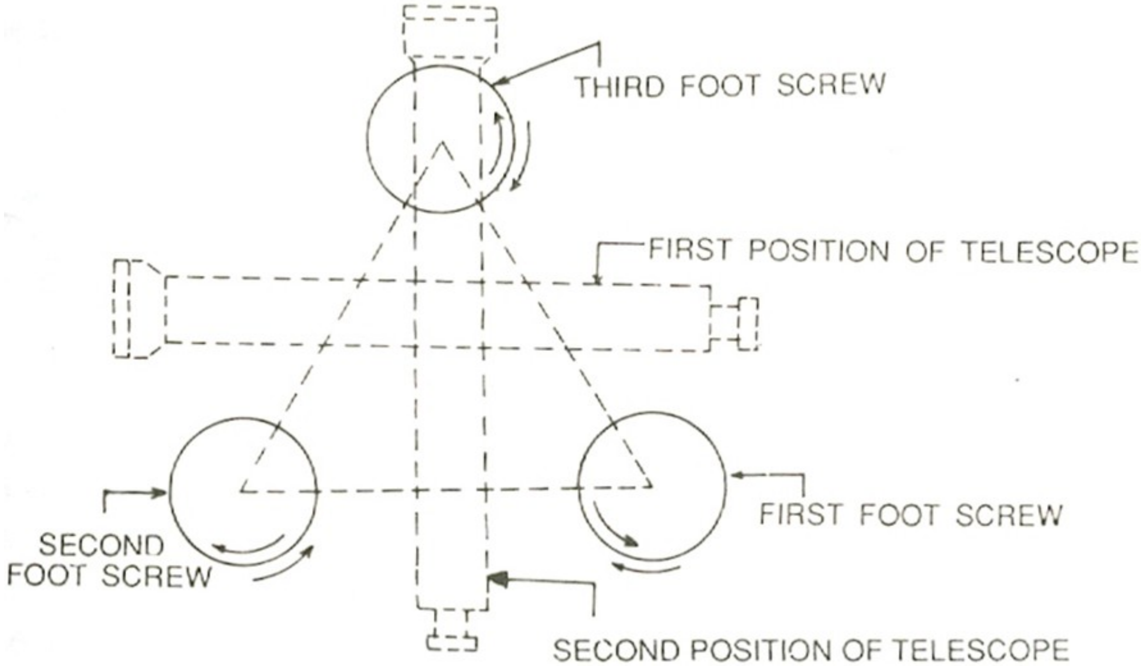


Fig. 3.3 Levelling the Dumpy Level with foot screws

(iv) Focusing the eyepiece: Remove the lid of the object glass and hold a sheet of white paper in front of it. Move the eyepiece in and out until the crosshairs are clearly seen.
(v) Focusing the object glass: Direct the telescope towards the staff and see through the eyepiece, bring the image of the staff between two vertical hairs of the diaphragm. Turn the focusing screw until the image is clear or distinct.

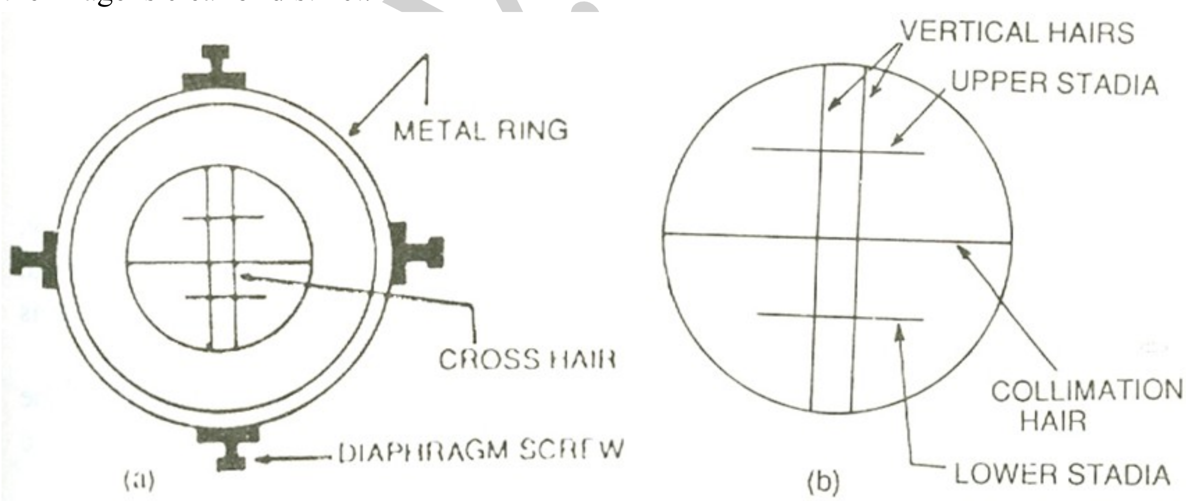


Fig. 3.4 Observing the image (a) Through eyepiece (b) Image on diaphragm

Reading the Staff:

1) After setting up and levelling the instrument carefully, direct the telescope towards the staff held vertically on the staff station and focus it. 2) Bring the staff between the two vertical hairs and always

use the portion of the horizontal cross-hair between them in reading the staff. First note the nearest meter reading, then decimetre, centimetre and finally count the spaces between two centimetre lines. Note the reading in field book.

Finding out the reduced levels of points: There are two systems of finding out the elevations of points from the staff readings taken in the field viz. (1) The collimation or height of instrument system and (2) the rise and fall system.

1. The Collimation System: In this system the height of plane of collimation (H.I.) is found out for every set up and then reduced levels of points are obtained with reference to respective plane of collimation.

(i) R.L. of plane of collimation for first set up of the level is determined by adding back sight to R.L. of B.M.
(ii) The R.L. of intermediate point and first change point are obtained by subtracting the respective staff readings from the R.L. of plane of collimation.
(iii) When the instrument is shifted to second position a new plane of collimation is set up. The first staff reading is taken on change point (C.P.) from the new set up. The R.L. of two planes of collimation are correlated by means of B.S. and F.S. on C.P. The R.L. of new plane of collimation is obtained by adding B.S. to the R.L. of C.P. The R.L. of other points and second C.P. are obtained by subtracting their staff readings from the R.L. of second plane of collimation.

Arithmetic Check: The correctness of calculation of R.L. of points is determined by following check: $\sum$ B.S. - $\sum$ F.S. = R.L. of last point – R.L. of first point

2. The Rise and Fall System: In this system the difference of level between two consecutive points is determined by comparing each forward reading with the staff reading at the immediately preceding point. If the forward staff reading is greater than the immediately preceding staff reading, it means there has been a fall and if it is smaller, there will be a rise. The R.L. of each point is then found by subtracting the fall from, or adding the rise to the R.L. of preceding point.
Arithmetic Check: In this system the accuracy of reductions is determined by three checks:
$\sum$ B.S. - $\sum$ F.S. = $\sum$ Rise - $\sum$ fall = R.L. of last point – R.L. of first point

Problem 1: Series of levels from A to B were taken for longitudinal levelling at every 10 m distance with dumpy level and levelling staff:

On A – 0.535, 2.143, 2.435, 1.584, 1.326, 0.460, 0.631, 1.533, 2.015, 3.342, 2.164, 3.490, 3.825, 3.925, 0.485, 1.432, 2.644 on B.
The instrument was shifted after 7th and 14th reading. The R.L. of A is 632.280 m. Rule out the page of level field book and find out the R.L. of different points. Apply usual check.

Ans:
1. Collimation system:

Station	Distance	Readings			R.L of H.I.	R.L. of points	Remarks
		B.S.	I.S.	F.S.			
A1	0	0.532			632.812	632.280	B.M. Point
2	10		2.143			630.669	
3	20		2.435			630.377	
4	30		1.584			631.228	
5	40		1.326			631.486	
6	50		0.460			632.352	
7	60	1.533		0.631	633.714	632.181	C.P.
8	70		2.015			631.699	
9	80		3.342			630.372	
10	90		2.164			631.55	
11	100		3.490			630.224	
12	110		3.825			629.889	
13	120	0.485		3.925	630.274	629.789	C.P.
14	130		1.432			628.842	
B15	140			2.644		627.630	Last point
Arithmetic check	∑	2.550		7.200			
	∑BS-∑FS	-4.650				-4.650	

Arithmetic Check:

∑ B.S. – ∑ F.S. = R.L. of last point – R.L. of first point

2.550 – 7.200 = 627.630 – 632.280

-4.650 = -4.650

2. Rise and Fall System:

Station	Distance (m)	Readings (m)			Rise	Fall	R.L. of points	Remarks
		B.S.	I.S.	F.S.				
A1	0	0.532					632.280	B.M. Point
2	10		2.143			1.611	630.669	
3	20		2.435			0.292	630.377	
4	30		1.584		0.851		631.228	
5	40		1.326		0.258		631.486	
6	50		0.460		0.866		632.352	
7	60	1.533		0.631		0.171	632.181	C.P.
8	70		2.015			0.482	631.699	
9	80		3.342			1.327	630.372	
10	90		2.164		1.178		631.550	
11	100		3.490			1.326	630.224	
12	110		3.825			0.335	629.889	
13	120	0.485		3.925		0.100	629.789	C.P.
14	130		1.432			0.947	628.842	
B15	140			2.644		1.212	627.630	Last point
Arithmetic check	∑	2.550		7.200	3.153	7.803		
	∑BS-∑FS		**-4.650**			**-4.650**	**-4.650**	

Arithmetic Check:

$\sum$ B.S. – $\sum$ F.S. = $\sum$ Rise – $\sum$ Fall = R.L. of last point – R.L. of first point

2.550 – 7.200 = 3.153 – 7.8036 = 627.630 – 632.280

-4.650 = -4.650 = -4.650

Slope of Line AB: slope of line AB can be calculated using the following equation

$$\text{Slope of line AB} = \frac{Elevation\,difference\,between\,A \wedge B}{Horizontal\,distanve\,beween\,A \wedge B} \times 100$$

$$= \frac{4.650}{140} \times 100$$

$$= 3.3\%$$

Exercise No. 4

Chain Triangulation Survey

Land surveys are made to secure data for exact description of the boundaries of a piece of land ,to determine its area, to secure necessary data for making a plan, to reestablish the boundaries of a piece of land which has been previously surveyed and to divide a piece of land into a number of units.

There are two general methods of land surveying:

1. Triangulation and
2. Traversing

1. Triangulation survey:

In triangulation survey, the lines of survey form a net work of triangles. It is the system of surveying in which the area is decided into simple geometrical figures and the work is carried out by taking its measurement.

2. Traversing:

A traverse survey is one in which frame work consists of series of connected lines, the lengths and directions are measured by chain or tape and with an angular instruments respectively. It is classified as- a) Open traverse b) Closed traverse

a) **Open traverse:** It consists of series of lines but not returning to the starting point. Also it does not start and end at points whose positions on plan are known.
b) **Closed traverse:** It is said to be closed traverse, when a complete circuit is made i.e. when it returns to the original position and forms a closed polygon.

The principle of chain surveying is triangulation. It is the simplest kind of surveying in which the sides of various triangles are measured directly in the field.

Field Survey By Triangulation Method

Principle of Triangulation: A survey in which the given field or area is divided into number of suitable triangles and measurement of all the sides of triangles is done is known as triangulation survey. Triangle is only a plain geometrical figure knowing the three sides of which it can be plotted exactly in size and shape. No angular measurement is required. For this survey field must be accessible and vision free stations.

Instruments and material: Chain, tape, ranging rods, arrows, and drawing material.

Procedure:

1. Erect ranging rods at all the corner point stations of the field.

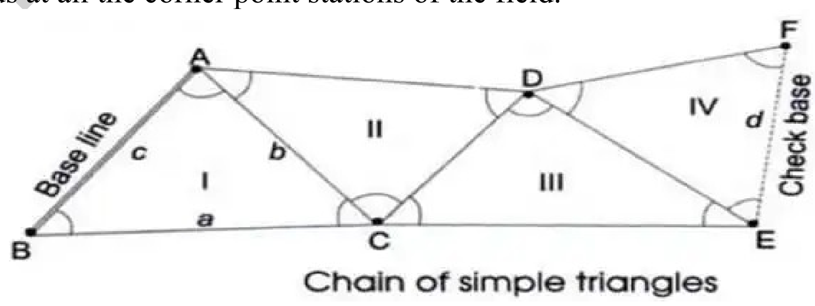


Fig. 4.1 Chain triangulation survey

2. Prepare a rough figure of a field on a page of field book and divide this into number of suitable triangles. A suitable triangle is that in which no angle is too acute or obtuse i.e. not less than 30º and not more than120 º

3. By direct ranging measure the lengths of all the sides of all the triangles and note down the measurements in a field book and also on a rough drawing.

Observation table

Sr.No.	Line	Length (m)	Remarks
1			
2			
3			
4			

Plotting:

1. Select a suitable scale for the preparation of a plan taking into consideration the size of paper and field measurements.

2. With this selected scale, plot one side of any triangle. With the same scale draw two arcs by a compass from the ends of this side, equal to the lengths of remaining sides of a triangle.

The intersection of these two arcs fixes the third station. Join this station with the ends of the side. A triangular portion of a field is plotted.

3. Construct next triangular portion by taking a suitable side of the triangle by the same procedure. In this way plot all the triangular areas. After plotting all the triangular areas, plan of field is obtained.

Calculation of area of a field:

For calculation of area of a field, calculate individual areas of all the triangles by a semi perimeter formula which is as unde

$$S=\frac{a+b+c}{2}$$

Area of triangle ¿ $\sqrt{S(S-a)(S-b)(S-c)}$

A, b and c are the three sides of any triangle. The sum of all the triangular areas is equal to total area of a field.

Sr. No	Triangle	Area, m^2
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
Total area		

Exercise No. 5

Plane Table Survey (Radiation Method)

Materials: Plane table, alidade, trough compass, sprit level, plumbing fork, drawing material, etc

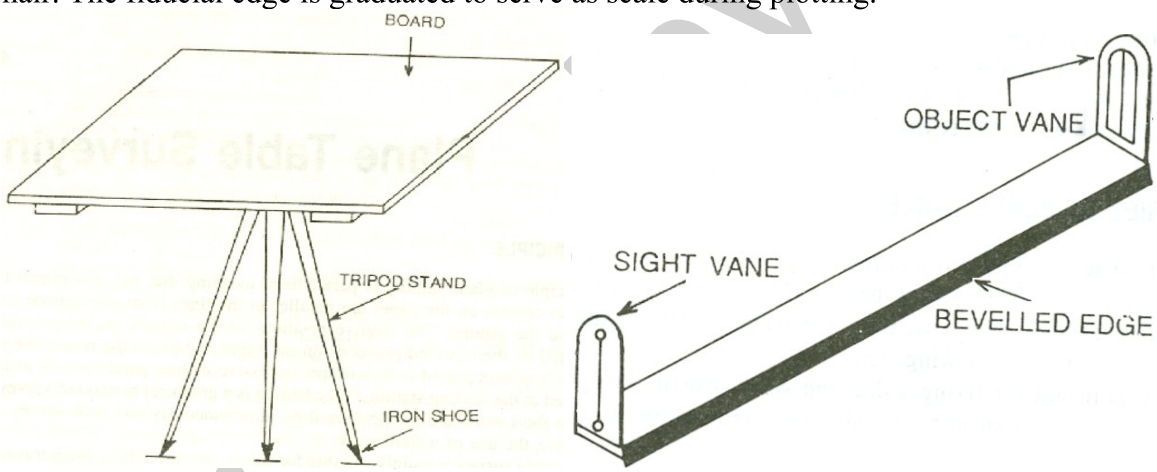
Theory:
Plane table surveying is a graphical method in which field work and preparation of map is done simultaneously. It is adapted for small and medium scale mapping where work has to be completed fast and requires less accuracy.

Parts of plane table:
It consists of two parts:

1. Drawing board mounted on tripod stand and
2. Straight edge called alidade

Drawing board:
The board is made of well-seasoned teak or pinewood with size of 40*30cm or 75*60cm. The board is mounted on tripod stand in such a way that it can be leveled and rotated about vertical axis. It is fitted with leveling head or ball and socket joint and clamp.

Alidade:
The alidade consists of a straight edge or ruler made up of brass or box wood. It is 50cm long. The working edge (bevelled) of the alidade is called as fiducial edge. It can be plain or telescopic with sighting vanes on both sides. One sight vane is provided with a narrow slit and the other with central hair. The fiducial edge is graduated to serve as scale during plotting.



(a) (b)

Fig. 5.1 (a) Plane table with board and tripod stand (b) Metallic alidade

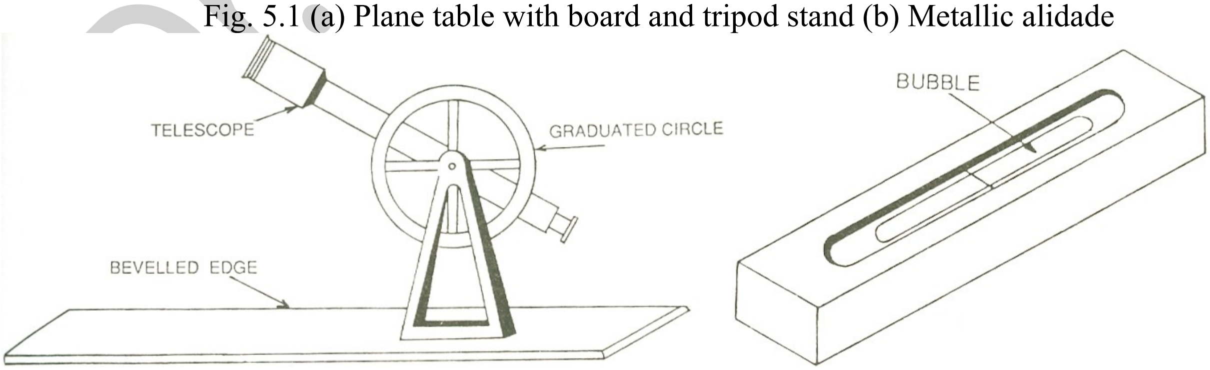


Fig. 5.2 (a) Telescopic alidade (b) Spirit level

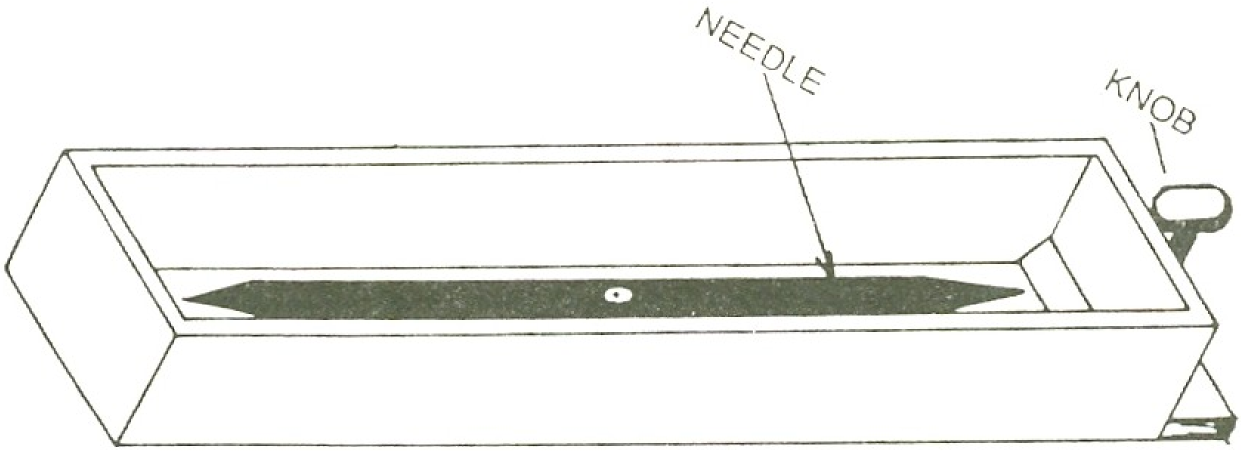


Fig. 5.3 Trough compass

Accessories of plane table

1. A trough compass for marking on paper the direction of magnetic meridian.
2. A sprit level for leveling the table.
3. A forked plumb bob for centering the table.
4. A water proof cover to protect the sheet from rain.

Setting up the plane table:

The following operations should be followed for setting up the table at any station.

1. Fixing:

Table should be set at a convenient height for working. The legs of tripod stand should be spread apart and firmly fixed on the ground.

2. Centering:

The table should be centered such that the point plotted on the sheet corresponding to the ground station should be exactly over the ground station. Using plumbing fork do this operation. Put the pointed upper leg of fork coinciding with point on the paper. Now shift the table until the plumb bob hanging on the lower leg of fork is exactly over the ground station. Dropping a piece a stone from a point under the board can also do it.

3. levelling:

Level the table with the help of leveling screws so that the spirit level is placed parallel to the screws and then over the third screw. The pair of cross-levels is also used for leveling with the ball and socket joint Table can be tilted during leveling.

Orientation of plane table:

Orientation is the operation of keeping the table at each of the successive stations parallel to the position, which it has occupied at the first station. Orientation is necessary when table has to set up at more than one station.

1. Orientation by magnetic needle:

Set up the table at first station ‘a’ draw the line of magnetic meridian using trough compass (Fig. 5.4). Now shift the table to second station ‘b’. Place the through compass along the line of magnetic meridian, which is drawn previously. Then turn the board until the ends of needle in through compass are at opposite the zeros of scale. Then clamp the board. This method is for rough and small scale mapping and where local attraction is absent.

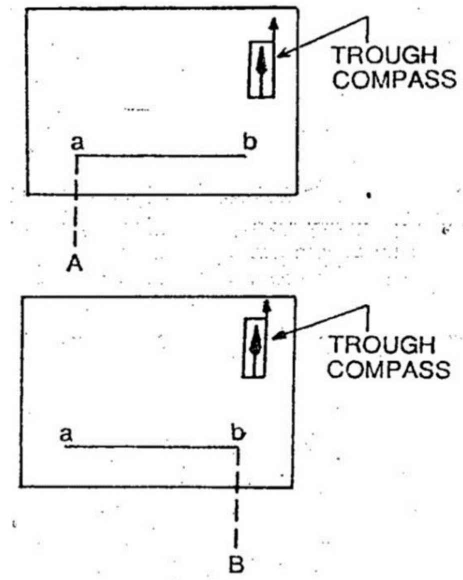


Fig. 5.4 Orientation by magnetic needle

2. Orientation by back sighting:

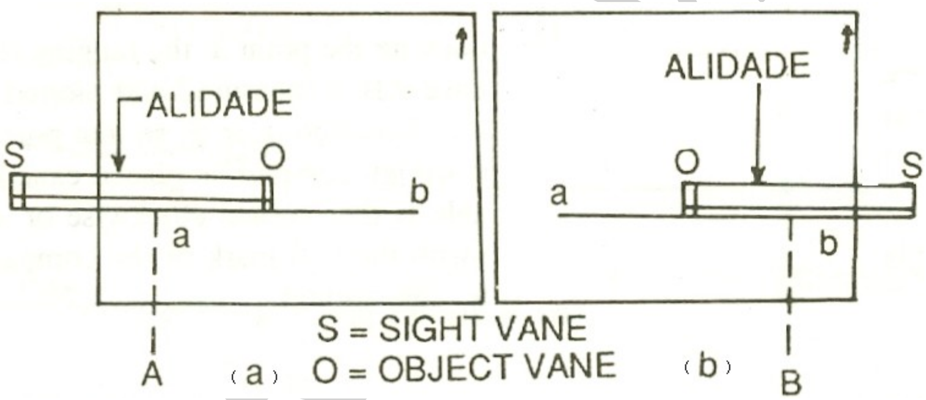


Fig. 5.5 Orientation by back sighting

Set up the table at station 'a'. Sight another station 'q' and draw a line ab on the paper. Now shift the table at station 'b'. Place the alidade along the line ab (Fig. 5.5). Now turn the board until the line of sight from 'b' bisects the ranging rod at 'a'. Clamp the board. This method is most accurate and preferable.

Methods of plane tabling:

1. Radiation:

In this method the point is located on plan by drawing a ray from the plane table station to the point, and plotting to scale along the ray the distance measured from the station to the point. The method is suitable for the survey of the small areas, which can be commanded from a single station.

2. Intersection:

In this method the point is fixed on plan by the intersection of the rays drawn from the two instrument stations. The line joining these stations is called the base line. The method requires only the linear measurements of this line.

3. Traversing:

This method is similar to that of compass or transit traversing. It is used for running survey lines between stations, which have been previously fixed by other methods of surveying to locate the topographical details. It is also suitable for the survey of roads, rivers, etc.

4. Resection:

This method is used for establishing the instrument stations only. After fixing the station, details are located either by radiation or intersection. The characteristic feature of resection is that the point plotted on plan is the station occupied by the plane table.

1. Radiation method:

Procedure:

1. Select a point p so that all points to be located are visible from it.
2. Set up the table at p and after leveling it, clamp the board.
3. Mark the direction of the magnetic meridian with through compass in the top corner of sheet.
4. Select the point p on the sheet so that it is exactly over station p on the ground by the use of u frame.
5. Centering the alidade on p, sight the various points a b c etc. and draw the rays along fiducial edge of the alidade.
6. Measure the distance PA, PB, PC etc. from p to various point with chain or tape and plot them to scale along the corresponding rays. Join the points a, b, c, etc. to give outline of survey.

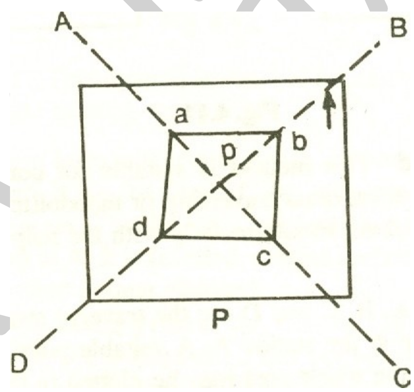


Fig. 5.6 Plane table survey by Radiation method

Exercise No. 6

Estimation of Runoff by Rational Method

Rational Method:

To design soil conservation structures with the proper capacity and to meet the need of respective condition it is necessary to estimate peak runoff rate, There are number of formulae and methods for calculating the maximum rate of runoff for given area. The rational method is used for calculating the maximum rate of runoff for a given area. The rational method is commonly used in predicting peak runoff rate of small watershed. The rational formula proposed by C.E. Ramser is expressed in F.P.S. unit as

$$Q = CIA$$

Where, Q = design peak runoff rate, ft^3/sec.

C = run off coefficient

I = maximum average rate of rainfall over the entire drainage area which may occur during the time of concentration, inches/hr

A = watershed area in, acres.

Since "C" is dimensionless coefficient, formula may be readily converted into metric unit as under

$$Q = 0.0276\, CIA$$

Where, Q = design peak run-off rate, m^3/sec

C = run off coefficient.

I = maximum average of rainfall over the entire area which may occur during the time of concentration, cm/hr

A = watershed area, ha

Value of 'C' in Rational formula:

Slope %	Sandy loam	Clay and silt loam	Stiff clay
1.Woodland			
0-5%	0.10	0.30	0.40
5-10%	0.25	0.35	0.60
10-30%	0.30	0.50	0.60
2.Pasture land			
0-5%	0.10	0.30	0.40
5-10%	0.16	0.36	0.55
10-30%	0.22	0.42	0.60
3.Cultivated land			
0-5%	0.30	0.50	0.60
5-10%	0.40	0.60	0.70
10-30%	0.52	0.72	0.82

The rational method is applicable for watershed area less than 1300 ha. This method is based upon two assumptions.

1. Rainfall occurs at uniform intensity for duration at least equal to time of concentration.
2. Rainfall occurs at uniform intensity over entire area of watershed.

Since there are hardly rainfalls satisfying both the conditions. The estimation of runoff based on this method is rather approximate. However, the method is considered sufficiently accurate for run-off estimation on design of expensive structure where the consequence of failure is limited. Design run-off is the rate to measure surface runoff by basic hydrograph method and unit hydrograph method.

Time of Concentration, T_c:

The time of concentration of watershed is the time required for runoff water to flow from the most remote (in time of flow) point area to outlet. When duration of storm is equal to the time of concentration, it is assumed that all parts of watershed are contributing simultaneously to the discharge of outlet. Time of concentration vary greatly with the nature and extent of vegetation in a given watershed. However, reasonable estimation of time of concentration can be obtained by dividing distance from the most remote point to the outlet of the area by the average velocity selected. Average velocity is used to determine the time of concentration.

Average slope of channels measured from farthest point of watershed to outlet	Velocity, m/s
1-2%	0.6
2-4%	0.9
4-6%	1.2
6-10%	1.5

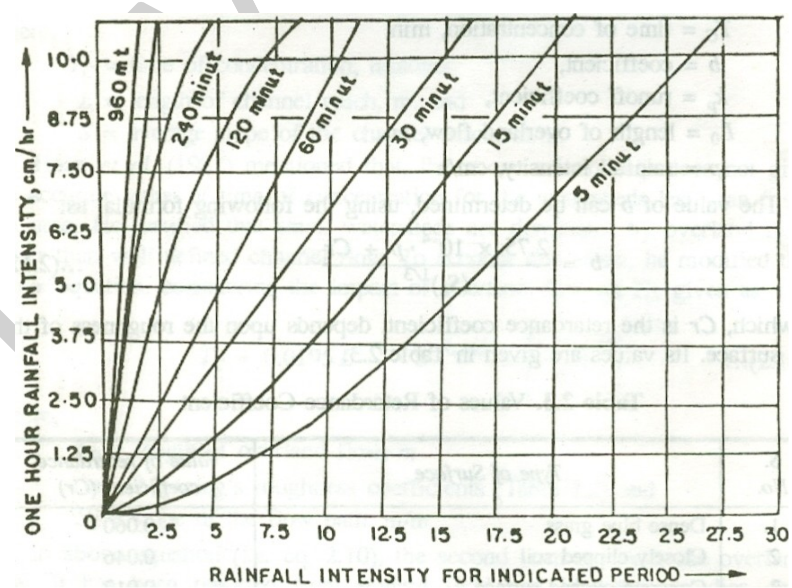


Fig. 6.1 Relationship between intensities of indicated duration and 1-hr rainfall intensity

Another approach to estimate the time of concentration is by the application of following empirical formula.

$$T_c = 0.0195\, L^{0.77}\, S^{-0.385}$$

Where, T_c = time of concentration, minutes
L = maximum length to flow, m
S = average slope of area, m/m

Problem 1: A catchment consists of 15 ha of cultivated land with silt loam on 2.5%, 20 ha grass land with sandy laom on 7% slope and 15 ha of woodland with sandy soil on 12% slope. The rainfall intensity equal to time of concentration is 2.3 cm/hr (Fig. 9.1). Estimate the peak runoff from the catchment.

Ans: Step I – Given data

1. Cultivated land, a_1 = 15 ha
2. Grass land, a_2 = 20 ha
3. Woodland, a_3 = 15 ha
4. Total area, A = 50 ha
5. Runoff coefficients from Table 1for respective soils on given slope, c_1=0.52, c2=0.16 and c_3=0.3
6. Rainfall intensity equal to time of concentration, I = 2.3 cm/hr
7. Peak runoff, Q =?

Step II: The weighted value of runoff coefficient C can be calculated by using the formula

$$C = \frac{c1 \times a1 + c2 \times a2 + c3 \times a3}{A}$$

$$¿ \frac{15 \times 0.52 + 20 \times 0.16 + 15 \times 0.3}{50} = 0.31$$

Step III: The peak runoff from the catchment can be estimated by using the Ramsers' equation as

$$Q = \frac{CIA}{36}$$

$$¿ \frac{0.31 \times 2.3 \times 50}{36} = 0.99 \approx \mathbf{1.0\ m^3/s}$$

Problem 2: In a watershed the most remote point is located at a distance of 3540 m and the common outlet point is 22.6 m below the remote point. Calculate the time of concentration.

Ans: Step I - Given data: 1) Distance between the remote and outlet point, L=3540 m
2) Elevation difference between remote and outlet point, H = 22.6 m
3) Time of concentration, Tc = ?

Step II: The Time of concentration is given by the following equation

$$T_c = 0.0195\, L^{0.77}\, S^{-0.385}$$
$$= 0.0195\ L^{0.77} (H/L)^{-0.385}$$
$$= 0.0195\ L^{0.77} (L/H)^{0.385}$$
$$= 0.0195 \times (3540)^{0.77} \times (3540/22.6)^{0.385}$$
$$= 0.0195 \times (3540)^{0.77} \times (156.637)^{0.385}$$
$$= 73.7 \text{ min}$$

Problem 3: In a catchment the remote point is 1890 m away from the common outlet point. The reduced levels of outlet and remote point are 252.340 and 261.516 m respectively. Calculate the time of concentration.

Ans: Step I: Given data –

1) Distance between the remote and outlet point, L =1890 m
2) Reduced level of common outlet point = 252.340 m
3) R.L. of remote point = 261.516 m
4) Elevation difference between remote and outlet point, H = 9.176 m
5) Time of concentration, Tc = ?

Step II: The Time of concentration is given by the following equation

$$T_c = 0.0195\, L^{0.77}\, S^{-0.385}$$

$$= 0.0195\ L^{0.77}\, (L/H)^{0.385}$$

$$= 0.0195 \times (1890)^{0.77} \times (1890/9.176)^{0.385}$$

$$= 0.0195 \times (1890)^{0.77} \times (205.97)^{0.385}$$

$$= 50.5 \text{ min}$$

Problem 4: In a watershed the most remote point is 4550 m away from the outlet point. The average slope of the land is 8% and the average velocity of water flow is 1.5 m/s. Calculate the time of concentration?

Ans: Step I: Given data- 1) Length of water flow path= 4550 m
2) Average slope, S= 8%
3) Average velocity of water flow = 1.5 m/s
4) Time of concentration, T_c =?

Step II: The time of concentration can be calculated as

Time of concentration, $= Tc = \dfrac{\text{Length of water flow path}}{\text{Velocity of water flow}} = \dfrac{4550}{1.5} = 3033.3\, s = 50.55\, min$

Exercise No. 7

Estimation of Soil Loss (USLE)

Universal soil loss equation (USLE) is an erosion prediction model for estimating the long-time averages of soil losses from a specified land in a specified cropping and management system. The equation predicts only the losses from sheet and rill erosion under specified conditions.

The equation has been developed by Wischmeier and Smith.

$$A = R\ K\ L\ S\ C\ P$$

Where, A = Average annual soil loss, metric tonnes/ha.

R = Rainfall-runoff erosivity factor

K = soil erodibility factor

L = Length slope factor

S = Slope steepness factor

C = Plant cover management factor.

P = Conservation practice factor.

Factors of USLE:

R = rainfall erosivity factor:

It is the measurement of kinetic energy of a specific rain event or an average years rainfall of erosion index units in a normal year's rain. Erosion index is a measure of the erosive force of a specific rainfall.

K = Soil erodibility factor:

It is the soil loss rate per erosion index unit for a specific soil on a unit plot (22.1 m long on 9% slope) in continuous clean – tilled fallow.

L = Slope length factor:

It is ratio of soil loss from the field plot under existing slope length to that from a 22.1 m length (unit plot) under identical conditions.

S = Slope gradient factor:

It is the ratio of soil loss from the field gradient to that from a unit area with 9% slope.

C = Cropping management factor:

It is ratio of soil loss from a field with specified cropping and management to that from the fallow condition on which the factor K is evaluated.

P = Erosion control management factor: It is the ratio of soil loss with contouring, strip cropping or terracing to that with straight-row farming, up and down slope.

Example 1: Workout the soil erodibility factor K for the plots given below:

1. Length of runoff plot = 30 m
2. Slope gradient = 5%
3. R factor = 800
4. Soil loss from the plot= 50 tonne / ha.
5. LS factor for a plot of 30 m length 92.6 on 5% = 0.54

Ans. Adjusted soil loss can be calculated as:

$$Adjusted\ soil\ loss = \frac{Observed\ soil\ loss}{LS\ factor} = \frac{50}{0.54} = 92.6\ tonnes/ha$$

$$Soil\ erodibility\ factor\ , K = \frac{Adjusted\ soil\ loss\,(tonnes/ha)}{R} = \frac{92.6}{800} = 0.116$$

Example 2: Calculate the annual soil loss from a given field subject to soil erosion problem, for the following information:

1. Rainfall erosivity index, R = 1000 m.tonnes/ha
2. Soil erodibility index, K = 0.2
3. Crop management factor, C = 0.5
4. Conservation practices factor, P = 1.0
5. Slope length factor, L = 0.1

Also explain, how the soil loss is affected by soil conservation practices.

Ans: The annual soil loss from a field can be calculated by using the USLE as

A = R K L S C P

The slope steepness factor is not given in this problem. So L and S factor can be considered here as LS = 0.1

Therefore, A = 1000x0.2x0.1x0.5x1.0 = **10 tonnes/ha/year**

Effect of Soil Conservation practices on erosion:

The soil conservation practices include biological practices including agronomical practices and mechanical or engineering measures adopted for reduction of runoff and control of erosion. The biological and cultural practices include contour cultivation, crop rotation, strip cropping, soil covering and leguminous crops; creation of vegetation cover on land surface; tillage, sowing and intercultural operations across the slope. The engineering measures include constructing contour bunding, terracing, graded terraces, contour trenching, nala bunding, farm pond and gully control structures for reduction of slope length and runoff velocity, retention of runoff water, temporary water storage and minimizing the soil erosion.

Example 3: A field is cultivated on the contour for growing maize crop. The other details regarding USLE factors are as follows:

1. R = 175 t/acre = **437.5 t/ha**
2. K = 0.40
3. C = 0.50
4. P = 0.55
5. LS = 0.70

Compute the value of soil loss likely to take place from the field. Also, make a comment on soil loss when same field is kept under continuous pasture with 95% cover. Assume the value of factor C for new crop 0.003 by soil conservation practices.
Ans: The annual soil loss from a field can be calculated by using the USLE as

$$A = R\ K\ L\ S\ C\ P$$

$$A = 437.5x0.4x0.7x0.5x0.55 = 33.6875 = \mathbf{33.69\ t/ha/year}$$

If the same filed is kept under continuous pasture with 95% cover, then grass cover on the land surface offers protection against the raindrop by absorbing the kinetic energy that prevents the splash erosion. The accumulated surface rainwater on land gets infiltrated along the grass roots and reduces net runoff quantity. The obstruction of standing grass to the surface water flow reduces the runoff velocity and thereby, erosion potential of lowing runoff. The binding effect of grass roots prevents or reduces the rill and gully erosion which otherwise would have taken place on cultivated lands.

The effect of such conservation practices can be seen from the given example i.e. C = 0.003.

The annual soil loss for new crop, A = 437.5x0.4x0.7x0.003x0.55 = **0.202 t/ha/year**

So, there is huge reduction in soil loss due to continuous pasture.

6.

Exercise No. 8

Measurement of Soil Loss (Multi-slot divisor)

Theory:

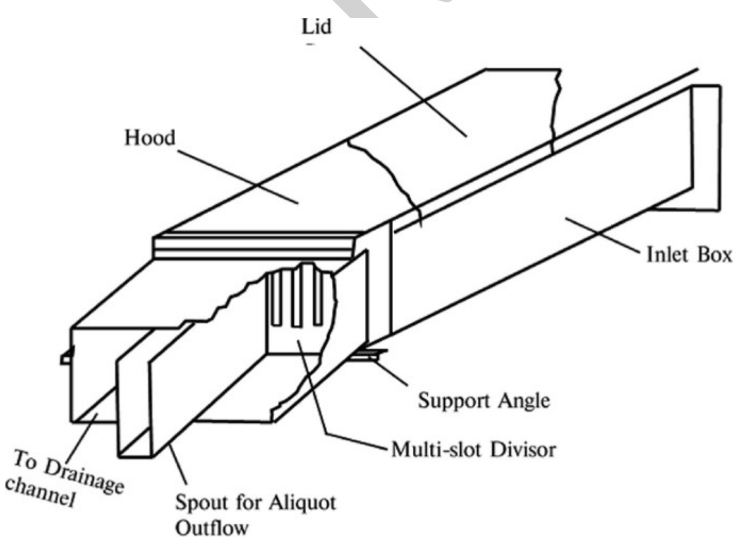
Multi slot divisor is useful for measuring runoff from small plots. It can measure quantity of runoff & can estimate soil loss from field. It's Design and application is very easy. Mostly used for experiment purpose.

Collection Tank:

The tank has 4 compartments of different dimensions. The dimensions of collection tank are 1.5m x 2m x 0.62m. The collection tank is provided with roof cap to avoid rain water falling into the tank. The collection tank is provided with a provision to attach slot divisor it first compartment filled with runoff water then passed to next compartment. For this purpose, compartment partition wall having openings at 30 cm from bottom of tank.

Fig.8.1 Collection Tank

Slot Divisor: The slot divisor with 11 slots can be used for experimentation, in which one slot is connected to the cistern tank. It is always provided with the odd number of slots. It is also covered with cap on it's top. The middle slot connected to the cistern tank, to collect excess runoff.



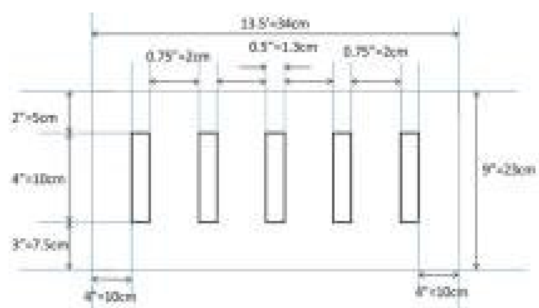


Fig. 8.2 Arrangement of multi slot divisor in experimental setup and divisor plates

Fig. 8.3 Attachment of multi slot divisor to runoff tank

Cistern Tank (Circular Drum):

It is cylindrical shaped with a lid provided to the tank. The hole is closed using rubber cork. It is installed at height of 5-10 cm from ground to avoid corrosion. It is connected with the slot divisor.

Fig.8.4 Cistern Tank

The capacity of drum is 500 litres with radius of 0.42 m and height of 0.90 m.

Procedure of Layout:

To conduct this experiment a particular place with a slope of 60% and 90% was selected. After making the area into slopes of 60% and 90%, the soil was compressed to be firm as shown figure. After compacting plot area, it was separated into 4 plots. The dimensions of plots are 15m x 4m in both the 60% and 90% slopes. The separation is done by utilizing GI sheets. The GI sheets acts as a boundary walls separating the plots and protecting soil from erosion. The runoff collection channels were constructed for each plot to collect runoff. Plots and pipes are provided to convey runoff water into tank for both 60% and 90% slopes. The collection channel is constructed of bricks using cement of 35cm height. Below the collection channel 30cm basement is provided to stabilize the channel.

Fig. 8.5 60% slope plot

Fig. 8.6 90% slope plot

Construction of Runoff Channels:

The pit was made of size 3.6m x 1.4m to install runoff tank. The cistern tank was also installed in this pit by extending the length of the pit. The collection tank installed in the pit it is divided into 4 compartments as shown in figure. Then runoff tank is connected with slot divisor to collect excess runoff into cistern tank.

Fig 8.7 Runoff Channels

Runoff Water Collection:

The runoff water collected in the compartments is calculated by measuring the height of water present. Then the runoff water is stirred well in the tank itself, so that the soil gets distributed uniformly in water. Then runoff water is filled into two bottles of one litre each. Then these bottles are handed over in lab for analysis of soil loss.

Runoff Water Measurement:

Fig.8.8 Measurement of height of runoff

Fig 8.9 Stirring of runoff water

Runoff Volume and Soil loss Calculation:

The runoff water collected in the tank is measured in the form of volume.

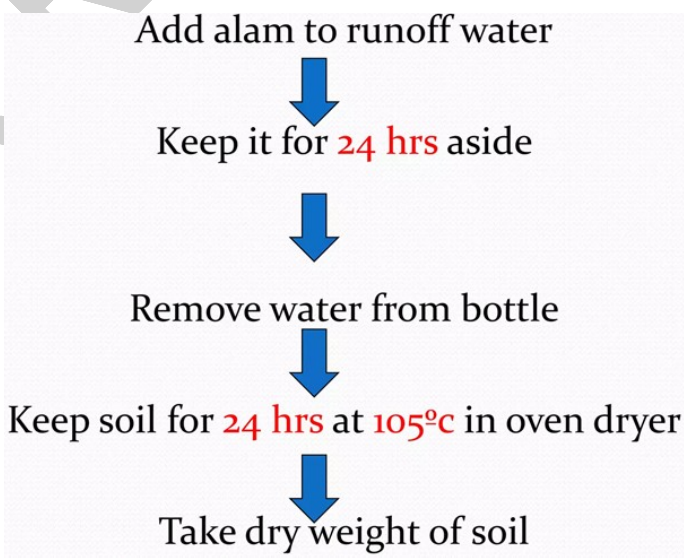
i.e. V = L x B x H

Runoff = Volume/area

Volume(m^3) = $\pi r^2 h$

Where r = Radius of cistern tank and h = Height of water in cistern tank

Soil loss Estimation:



SOIL LOSS (kg/ha) = Runoff (lit) x Soil loss (kg/lit) x (10000/60)

Exercise No. 9

Study of Grassed Waterway

Definition: Vegetated or grassed waterways are natural or constructed water courses covered with erosion resistant grasses, used to carry surface runoff from crop land.

These are used to convert gullies/unstable channels into stable one. Also used to handle natural concentration of runoff and act as outlet to carry the discharge from terrace, bunds, contour furrows, diversion channels, emergency spillway of farm ponds. Used to handle runoff for 10 years recurrence interval.

Waterways are foundation of water management for all soil erosion control practices except level terraces.

Outlets must be ready before bunds, terraces, diversions are excavated and grass should be established before water is turned into it.

Fig. 9.1 Grassed waterway

Necessity of Waterways:

- Considerable energy (20,000 W) is dissipated as flow proceeds down a slope (if 1.4 m^3/s for 30 m down 5% slope)
- Impact of this energy upon bare soil, detach particles & transported by water
- Erosion over long periods forms gullies
- Resultant gullies divide field into several parts
- Smaller, shortened & numerous fields obstruct movement in field
- Farm value decreased
- Gully development jeopardize roads, bridges, buildings, fences
- Eroded soil contributes to costly downstream sedimentation damage & pollution
- Basic approach to control such gullies: A complete solution
  - Reduction of peak flow rates through gully
  - Provision of stable channel that can handle the remaining flow

Types of Waterways:

Categorized into three types based on cross sectional shape of waterway

1. Trapezoidal waterway:

This cross section is preferred in constructed channels.

Broad bottom T. channels require less excavation depth than that required for other types.

Constructed with V-ditcher & buck scraper.

2. Triangular waterway:

Preferred in constructed channels.
Constructed with V-ditcher with Top width, t=2dx

3. Parabolic waterway: this cross section preferred

When Natural depressions are shaped into watercourses

It approximates to that of natural channels

Top width, t = A/0.67d & A = 2/3td

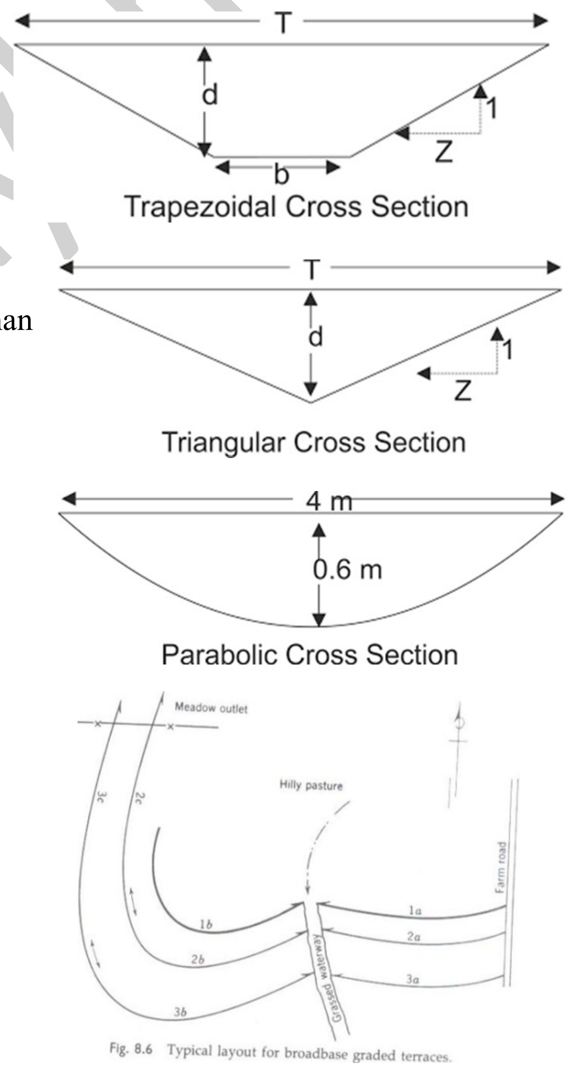


Fig. 9.2 Grassed waterway shapes and layout

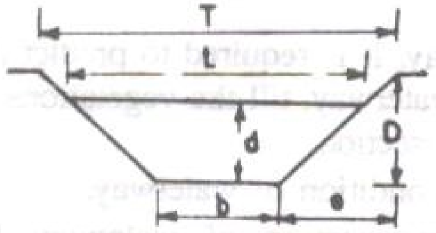
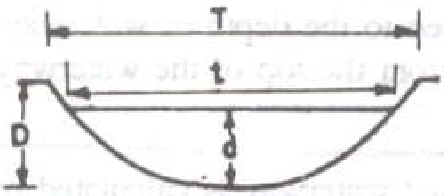
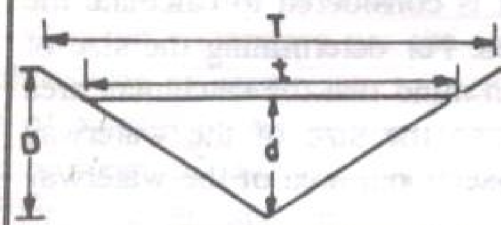
	Area (A)	Wetted Perimeter (P)	Hydraulic Radius (R)	Top Width (T)
	$bd + zd^2$ where, $z = \frac{c}{d}$	$b+2d\sqrt{z^2+1}$	$\frac{bd + zd^2}{b+2d\sqrt{z^2+1}}$	$t = b + 2dz$ $T = b + 2Dz$
	$\frac{2}{3}\ t.d.$	$t + \frac{8d^2}{3t}$	$\frac{t^2.d}{1.5t^2 + 4d^2}$	$t = \frac{A}{0.67d}$ $T = t\left(\frac{D}{d}\right)^2$
	zd^2	$2d\sqrt{z^2+1}$	$\frac{zd}{2\sqrt{z^2+1}}$	$t = 2\ .\ dz$ $T = \frac{D}{d}\ t$

Fig. 13.1. Geometric characteristics of different tyeps of grassed waterways.

Design of Vegetated Waterways:

1. Shape of waterway – C/s shape may be trapezoidal, triangular or parabolic

2. Waterway location – generally located in natural drainage way. Constructed waterways should be located along field boundaries.

3. Design velocity – permissible velocity depends on the type, condition and density of vegetation.

Low velocity – 1-1.5 m/s for channel with grass cover
Medium velocity – 1.5-1.8 m/s for good quality grass cover
High velocity – 2-2.5 m/s for established sod

4. Channel grade – channel slope should not exceed 10%. It is normally desirable to keep the grade within 5%.

5. Channel dimensions – After the runoff, channel grade and design velocity have been determined, the next step is to decide on the channel dimensions. Design of vegetated waterway is based on Manning's formula. Coefficient of roughness (n) usually assumed in grassed waterway design is 0.04, side slopes of channel 4:1 or flatter to facilitate crossing of farm equipments. A free board of 10-15 cm should be provided to take care of the sediment deposition and variation in the value of ‘n’.

The permissible flow velocity to be fixed in grassed waterway depends upon type and condition of vegetation and its density to resist erosion.

Uniform vegetative cover in waterway is important -

1. To provide better channel stability
2. To decide permissible flow velocity

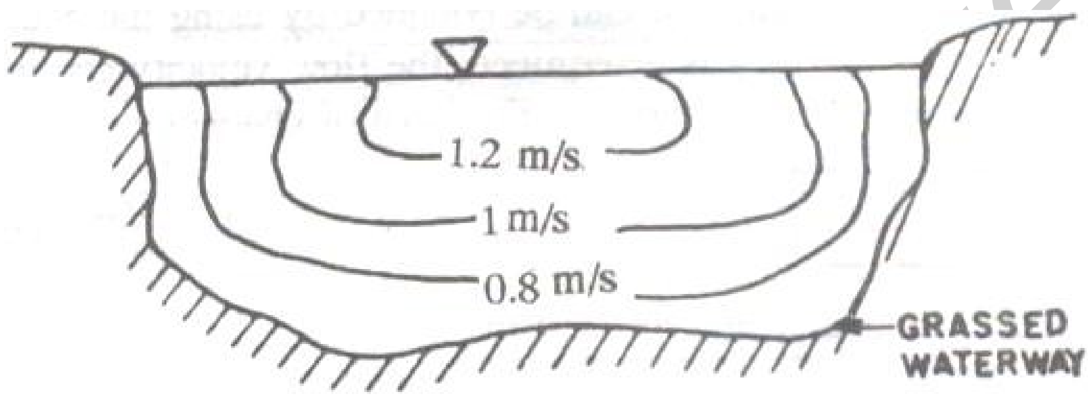


Fig. 9.3 Velocity distribution in grassed waterway

Exercise No. 10

Study of Graded Bunds

Definition: graded bunds or graded or channel terraces are the bunds or terraces laid along a pre-determined longitudinal grade very near but not exactly on the contour.

Adaptability or suitability: graded bunds used in India are comparable to narrow base terraces.

Used in heavy rainfall areas receiving rainfall >700 mm and in areas where impervious clay soil is present. Also used in low rainfall area but soil should be heavy in texture.
Used for safe disposal of excess runoff.
Farming operations are not done on bunds or bund channel
Non erosive grade of bund – 0.1 to 0.5%.
Grade of channel must be less than actual land slope.

Functions:

1. Primarily act as drainage channel.
2. It reduces length of slope.
3. Dispose of excess runoff safely at non erosive velocity
4. To make runoff water to trickle rather than to rush out

Limitations:

1. Requires establishment of grassed waterway as outlet
2. Graded contour bunding not recommended on slope <2%
3. Grassed waterway requires extra care about control of grazing

Types of graded bunds: Based on provision of channel, graded bunds classified as:

1. Bunds with channel
2. Bunds without channel OR

Based on provision of channel grade, classified as:

1. Uniform graded – suitable for less length of bund & less runoff
2. Variable graded – length of bund & runoff carried are more

Construction of Graded bunds:

It consists of constructing wide & relatively shallow channels across slope near the contour ridges & at critical interval. Field plan is prepared & location of terrace outlet fixed.

Graded bunds designed by (1) providing parabolic channel & earthen bund or (2) providing bund along suitable grade.

Design involves:

1. Selection of V.I.
2. Suitable grade =>0.2%,
3. Cross section for bund &
4. C/s of channel 0.5 to 0.75 m2
5. Free board of 15-20% of design depth
6. C/s of bund by fixing side slopes, height, base widh & top width
7. Height of bund =>45 cm
8. Side slopes= 1:1, 1.5:1, 2:1

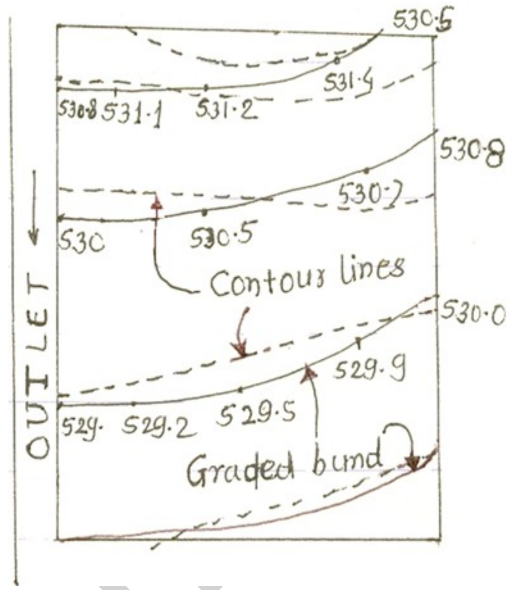


Fig. 10.1 Layout & construction of graded bunds

Exercise No. 11

Study of Contour Bund and Compartmental Bunding

Contour Bunds:

Contour bunding is carried out in many parts of India- notably in Maharashtra, Gujarat, Tamilnadu, Karnataka and Andhra Pradesh. This practice first initiated in Maharashtra as famine relief work. It is good practice for controlling runoff & erosion on sloping cultivated fields.

Definition: It consists of building earthen embankment across the slope of the land, following the contour as closely as possible. Formation of bunds passing through points of equal elevation (i.e. on contour) of land is termed as contour bunding. A series of such bunds divide the area into strips and act as barriers to water flow, thus reducing the amount and velocity of runoff.

Cultivation is not allowed on the earthen embankments of contour bunds. Therefore, under contour bunds an area of 5 per cent is lost and is not available for cultivation. It maintains soil fertility and increases water infiltration into the soil considerably.

Location of contour bund:

Located on moderate slopes up to 6% with light or medium soil texture and less than 700 mm rainfall per year.

Objectives or Purpose of contour bunds:

1. To reduce the length of slope
2. To reduce the runoff velocity
3. To retain the runoff water and increase the infiltration rate
4. To reduce soil erosion
5. To increase soil moisture

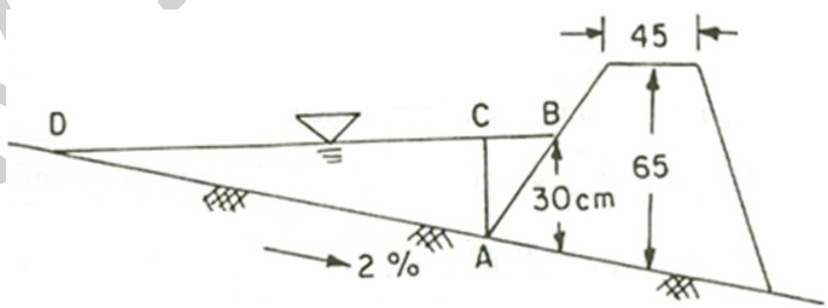


Fig. 11.1 Vertical section of contour bund & storage area

Functions of Contour Bund:

1. Reduces length of slope in turn reduce soil erosion
2. Impound & recharge more water that is utilized for crop cultivation

Advantages of contour bunds:

1. Simple to build
2. Bunds conserve top soil and improve productivity
3. They keep water in the soil, allowing chemical fertilizers to be utilized effectively
4. They can be used both on cultivated and uncultivated land

Limitations:

1. Suitable for areas receiving annual rainfall < 600 mm
2. On permeable soils only
3. Not used on clayey or black soils as it creates temporary waterlogging.
4. Technically not feasible on land slopes > 6% & soil depth less than 7.5 cm.
5. May interfere with farm operations if bunds are too close to each other

General principles and design of contour bund:

1. Spacing of bund: Bund spacing is expressed as the vertical or the horizontal distance between two corresponding points on two adjacent bunds. Horizontal spacing is useful in determining the row arrangement. Vertical distance is commonly known as vertical interval i.e. V.I (Fig. 11.2). Bund spacing should not be so wide as to cause excessive soil erosion between adjacent bunds. Spacing may be increased or decreased 10 to 20% to suit local conditions.

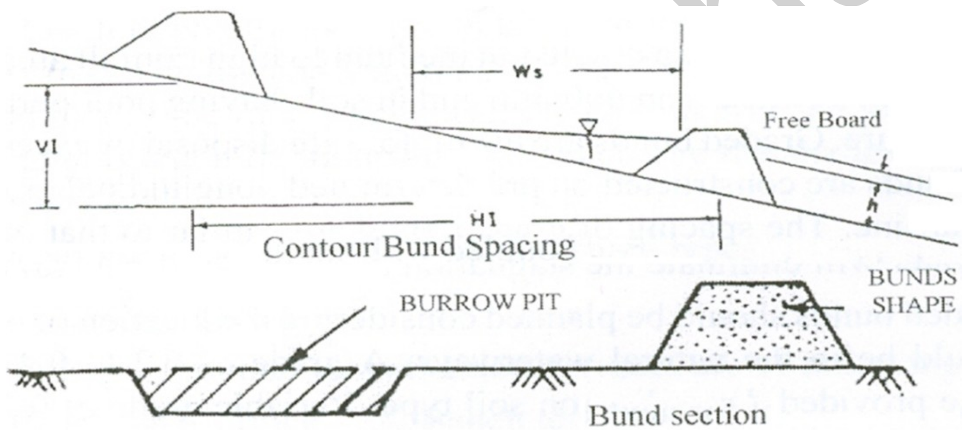


Fig. 11.2 Spacing of contour bund

Spacing of Contour bunds: Recommended by Gadkary

Slope of land (%)	Vertical Interval (V.I.), m	Approx. Horizontal Interval (V.I.), m
0 to 1	1.05	105
1 to ½	1.2	98
½ to 2	1.35	75
2 to 3	1.5	60
3 to 4	1.65	52

2. Bund grade: These are level bunds as the bunds are laid along the contours.

3. Bund length: In general, 400 to 500 m is the maximum length of bund. The bund retains the runoff and carries it over the distance equal to bund length in one direction. The length of bund should be such that the velocity of water flowing between bunds should be non-erosive.

4. Bund cross section: the height of the bund should provide sufficient storage above the bund to handle the expected runoff. In normal practice, sufficient freeboard is provided to take care of runoff from rains expected in 10 years recurrence interval. The cross sectional area of the storage space required can be calculated by the following formula:

$$Cross\ section\ area\ of\ water\ storage = \frac{Runoff\,(cm) \times H.I.of\ bund\,(m)}{100}$$

The cross sectional area of water storage behind the bund is given in Fig. 11.3. The water storage area in this figure is equal to sum of a_1 and a_2.

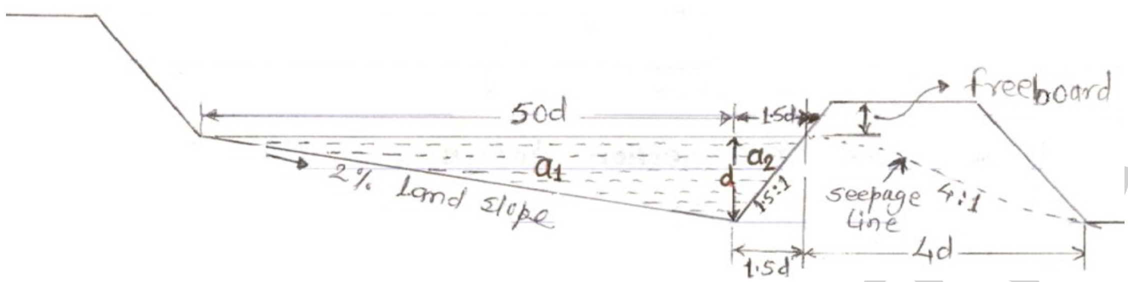


Fig. 11.3 Cross section of bund and water storage area behind the bund.

Table1. Specifications for bund cross-section:

Sr.No.	Soil depth, cm	Base width, m	Top width, m	Height, m	Side slope	Area c/s, m^2
1	Shallow 7.5 – 22.5	2.67	0.38	0.75	1.5:1	1.14
2	Medium 22.5 - 45	3.12	0.60	0.85	1.5:1	1.56
3	Medium deep 45 - 90	4.25	0.60	0.90	2:1	2.18

From JL. o f S. . Cons. In India Vol. 10, Nos. 1.2.

Compartmental Bunding:

Compartmental bunding means the entire field is divided into small compartments with pre-determined size to retain the rain water where it falls and arrest soil erosion. The compartmental bunds are formed using bund former. The size of the bund depends upon slope of the land. compartmental bunds provide more opportunity time for runoff water to infiltrate into the soil and help in conserving moisture.

Salient features of compartmental bunds:

- Compartmental bunding is an effective moisture conservation measure in dryland.
- It is suitable for less rainfall areas and the slope is < 1%.
- The land is divided into small compartments with the dimension of 8x5 m.
- Small compartments store the rainwater for longer period.
- It increases water holding capacity of the soil.
- It can be formed while ploughing itself or before early sowing.
- Reduces the formation of cracks
- It overcomes the disadvantages of contour bunding.

Exercise No. 12

Study of Terraces

Terrace

Definition: A terrace is an embankment or ridge of earth constructed across a slope to control runoff and minimise soil erosion.

A terrace reduces the effective length of hill side slope to large extent and thereby reducing sheet and rill erosion and prevents formation of gullies. Experimentally it has been found that the soil loss is directly proportional to the length of slope of power 0.5.

Terracing cannot be justified on crop land that can be protected by less expensive conservation measures like agronomical practices. But the land which is more erodible, with steep slope receiving heavy rainfall, agronomical practices are insufficient and terracing becomes an alternative measure.

Features of terracing:

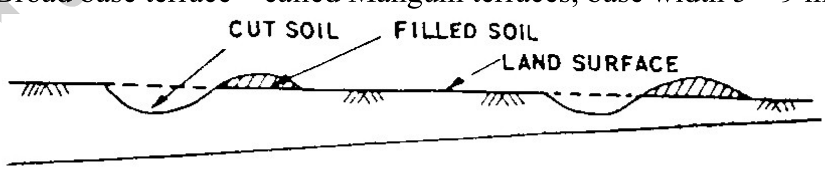
- Terraces reduce the length of slope by splitting the slope length in different parts.
- These are constructed across the land slope to intercept the surface runoff and convey it to a suitable outlet at non-erosive velocity.
- Adopted for soil and water conservation on lands steeper than 8% with erodible soils receiving heavy rainfall.
- Terrace produces a barrier to partially stop the downhill movement of soil.
- Control sheet erosion and trap soil particles in splash erosion.
- Terracing not possible on land slopes with less soil depth.

Types of Terraces: In India terraces are classified in two major types

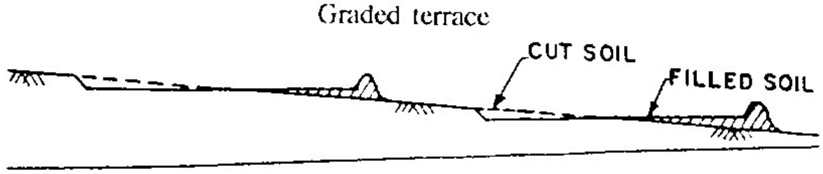
1. **Bench terraces:** (i) Level/table top (ii) Slopping inward (iii) Slopping outward
   (iv) Puertorican type
2. **Broad base terraces:** (i) Level terrace (ii) Graded terrace–(a) uniform & (b) variable graded

Terraces are also classified as:

1. **Channel type** – used on soils where controlled removal of runoff is important
2. **Ridge type** – used where the water holding capacity is the main function. Depending upon width of the base, ridge type terraces further classified as
   - (i) Narrow base terrace – width of base 3 – 4 m.
   - (ii) Broad base terrace – called Mangum terraces, base width 5 – 9 m.



Graded terrace



Level terrace.

Fig. 12.1 Graded terrace and Bench terrace

Terrace Types	Description
1. Diversion terrace	Used for intercepting the overland flow from hilly slopes and channel it across the slope to a suitable outlet *i.e.* grassed water way etc. built at slight down slope grade from contour
(*a*) Magnum type	It is constructed by taking the soil from both sides of the embankment
(*b*) Nichols type	Formed by taking the soil from side of upslope of the embankment, only
(*c*) ~~Board~~-based type Broad	These terraces are constructed with embankment and channel occupying a width of about 15 m
(*d*) Narrow based type	These terraces are only 3 to 4 m wide; the banks have steeper slope which can not be cultivated. For cultivation to make possible, the bank should not exceed 14° slope for use of small machines, otherwise it should be 8.5°, for large size machines.
2. Retention terraces	These are level terraces, used particularly when water is required to conserve by making storage on hill sides.
3. Bench terrace	Such type of terraces are constructed in form of alternate series of shelves and risers, used to cultivate the steep slopes.

Bench Terraces:

A bench terrace is a platform or shelf like embankment of earth with a level top and a steep or vertical downhill face constructed along the contour of a sloping land. These are generally constructed only on lands steeper than 15% [more than 8%]. In this system the hilly land is modified in the form of several steps running across the slope, which intercept the flowing water from the soil surface. These benches or platforms are separated by almost vertical risers and used for cultivation purpose. Considering cost of construction bench terraces can be justified for cash crops like tea, coffee or sugarcane, etc.

Fig. 12.2 Bench terraces on hill side

Classification of bench terraces: They are classified based on purpose. Rama Rao (1974) has classified bench terraces based on slope of the bench.

Based on Purpose/use	**Based on Slope**
1. Irrigated type (level benches)	a) Level/Table top
2. Hill type (reverse grade towards hill)	b) Sloping inward
3. -	c) Sloping outward
4. Orchard type terrace (intermittent terrace)	d) Puertorican/California type

In orchard benches narrow width terraces (about 1 m) for individual trees are prepared.

Hill type bench terrace are generally used in those hilly areas, which have inward land slope towards the hill. Irrigated type terraces called level terrace are used for irrigated lands. Orchard type bench terraces are prepared in the form of narrow width terrace (about 1 m) for individual trees. These are also referred as intermittent terraces and step terraces.

Classification based on slope:

a. Level bench terrace: This type of terrace has level top surface of the bench. Table top bench terraces are suitable for areas receiving medium rainfall which is evenly distributed and which have highly permeable and deep soils. It may be used in paddy fields for slopes as mild as 1% to facilitate uniform impounding of water.

Fig. 12.3 Level bench terrace

b. Sloping inward bench terrace: Bench terraces having the bench slope towards the hill side are adopted in the areas receiving heavy rainfall and having less permeable soils. Such terraces have a provision of drainage channel on hill side for removal of excess runoff water. It is also called hill type terrace. It prevents impounding of water and useful for crops susceptible to water-logging.

Fig. 12.4 Sloping inward bench terrace

c. Sloping outward bench terrace: In such terraces the bench has slope towards outside and the terrace is provided with shoulder bund. These are also known as orchard type bench terrace. The shoulder bund helps in retaining the surface runoff on the bench that is either absorbed or drained. These are effective in low rainfall areas with permeable soils of medium depth.

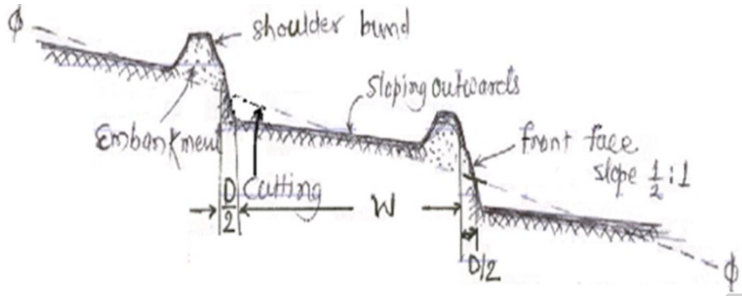


Fig. 12.5 Sloping outward bench terrace

d. Puertorican/California type terrace: In this type of terrace, the soil is excavated little by little during every ploughing and gradually develops into benches by pushing the soil downhill against a vegetative or mechanical barrier laid along the contour. The mechanical/vegetative barrier is established across the land at suitable interval and the terrace is developed gradually over the years, by pushing the soil downhill and subsequent natural levelling.

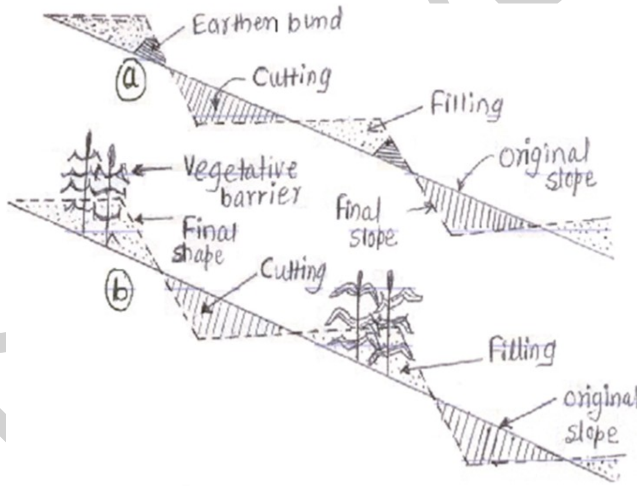


Fig. 12.6 Puertorican/California type bench terrace

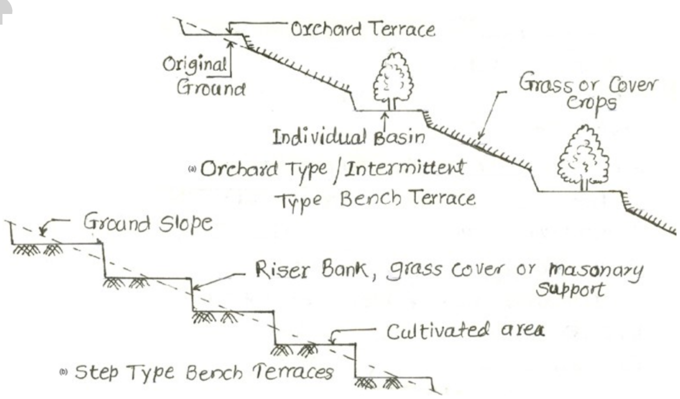


Fig. 12.7 Orchard type bench terrace

Exercise No. 13

Study of CCT and Staggered Trenches

As per land capability classification, the land classes from V to VIII have severe limitations in bringing them under cultivation. These limitations may be in terms of higher slope, severity of erosion, stoniness, rock structures, shallow soil depth, water logging, flooding, etc. Such lands are referred to as non-agricultural or denuded or waste lands. However, these lands can be used to achieve some returns by adopting the engineering measures like contour or staggered trenching on hill slopes. Contour trenching is one of the practices used as soil conservation measure to intercept and retain the runoff on steep slopes of hill sides.

A. Contour Trenches:

Definition: Contour trenching is a practice of excavating trenches along a uniform level across the slope of the land in non-agricultural areas in the top portion of the watershed.

Objectives:
1. To cut down the velocity of the overland flow and intercept it.
2. To store the rain water for the benefit of the plants.
3. Allow to percolate rainwater through the soil and travels downside to recharge ground water in the middle and lower section of watershed.
4. Protect the bund in lower section from the runoff coming from the upper portion of watershed.

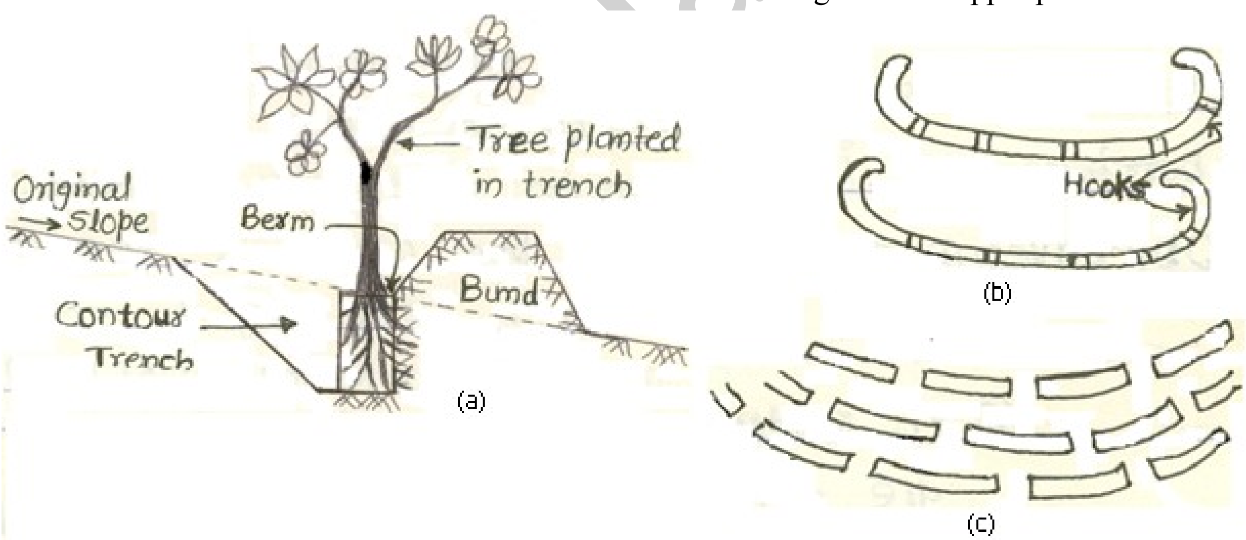


Fig. 13.1 (a) Typical section of contour trench (b) contour trenches (c) Staggered trenches

Types of Trenches: There are four types of trenches.

1. Contour trenches: These are excavated along contour across slope of the land with bunds on downstream side. It is one of the important water conservation measure adopted to intercept and store the runoff on sides of hills. This practice consists of excavating the trenches along the contour across the slope on top portion of the hills or in non-agricultural areas for providing adequate moisture conditions in order to raise trees or grass species. The excavated earth material is placed downstream side of the trench, to make bund along it. The bund is made leaving suitable berm from trench for planting trees.

2. Staggered trenches: Staggered trenching is excavating trenches of shorter length in a row along the contour with inter-space between them (but not in straight line). Staggered arrangement helps in making the system more effective in controlling the runoff and soil erosion. As compared to continuous trenches, per hectare length of staggered trenches is reduced to half of CCT due to its staggered arrangement.

3. Graded trenches: These are similar to contour trench, except that they are excavated with a longitudinal bed grade. These are suited to areas receiving high annual rainfall.

4**. Continuous Contour Trenches (CCT):** When trenches are excavated continuously along the contour without any inter-space between them then it forms CCT. They are similar to contour trenches except that they are continuous without inter-space between them and run across the slope of the hills. CCT collect the runoff from uphill areas or from space between them and store. As these are continuous, runoff accumulates from relatively greater area and may get over-flooded causing erosion. So vertical disposal drains are provided at suitable locations to take the excess runoff from many CCT and flow down the slope of the land. The length of CCT may be greater than 60 m and these are meant to intercept the runoff and convey it to vertical disposal drain excavated along natural folds of hillocks or valley without causing erosion. The bunds are put up at downside of trenches similar to contour trench.

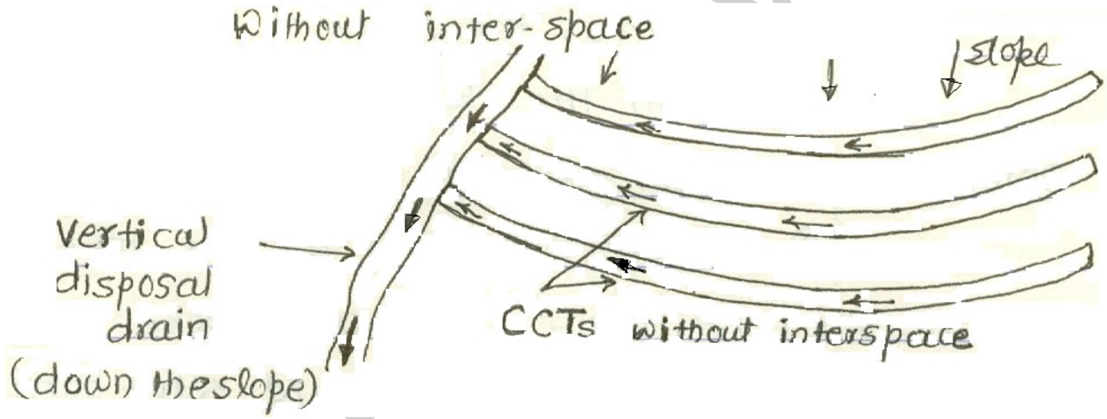


Fig. 13.2 Continuous contour trenches (CCT) and alignment with vertical disposal drain

Design and construction details of Contour trench:

1. Contour trenches are made with minimum depth and width of 0.3 x 0.3m at spacing of 10 to 30 m depending upon land slope.
2. Their cross-sections are designed to collect and convey the runoff expected from the inter-space between the successive trenches. This inter-space acts as catchment area to determine the trench size.
3. Usually they are designed to hold one day rainfall at 2 year frequency.
4. Trenches are staggered (5–10 m length) to tap and store maximum water.
5. Sometimes contour trenches are made continuous (CCT) to cover large areas and run over longer lengths and drain the excess runoff in vertical drains.
6. Trenches should run perfectly level to use their full capacity.
7. Side slopes of the trench range from 1:1 to 0.5:1 depending upon the nature of soil.

Exercise No. 14

Study of Gully Plug, Nala Bund, Check Dams and K.T. Weirs

Nala Bund (Earthen dam):

Nala bunds are the structures constructed across nalas for checking runoff velocity, impounding water, increasing water percolation and improving moisture regime.

Objectives:

1. To impound surface runoff coming from the catchments & facilitate percolation of stored water into soil sub-strata with a view to raise ground water level in the zone of influence of nala bund.
2. To hold the silt flowing which would otherwise reach the multipurpose reservoirs and reduce their useful life.

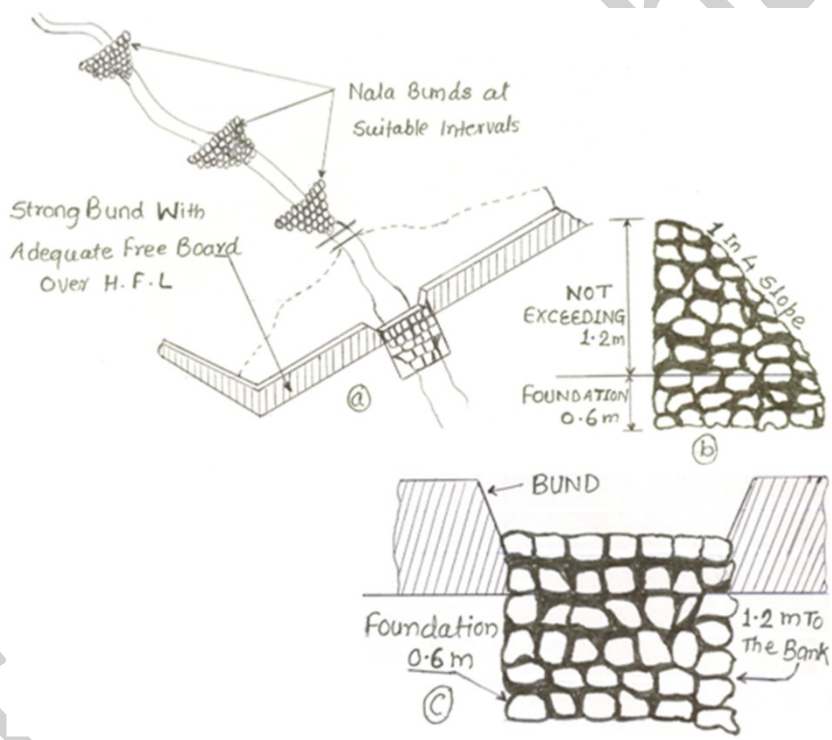


Fig. 14.1 Loose boulder structure (LBS) and constructed Nala bund

Specific Site Conditions: The feasibility of the site for locating nala depends upon technical and economic considerations such as:

1. The site should be selected in relatively flatter nala reach
2. Slope of nala should not be more than 2%.
3. Catchment area of the nala bund should not be less than 40 ha.
4. There should be proper site for construction of emergency spillway by the side of nala bund.

5. The nala bed should have soils with adequate permeability & consists of at least 1 m depth of sand.
6. Medium or small width nala, generally of 30 to 50 m should be selected
7. Depth of water behind bund should not be more than 6 m
8. Generally bund should be located at downstream of well.

Earthwork Computation:

To estimate the earthwork volume required should include the dam, allowances for settlement, backfill for the cut-off trench, backfill for the existing stream channels and the holes in the foundation area, etc. The common methods of estimating the volume of earth fill i.e. the sum of the end area method, with the fill height, side slope and top width. The end area of the cross section at each station along with chainage at the centre line is used for computation of earth work.

Side slopes of Embankment:

The side slopes of a dam depend primarily on the stability of the material in the embankment. The greater the stability of fill material, the steeper can be the side slope; and more the unstable material, flatter should be the side slopes.

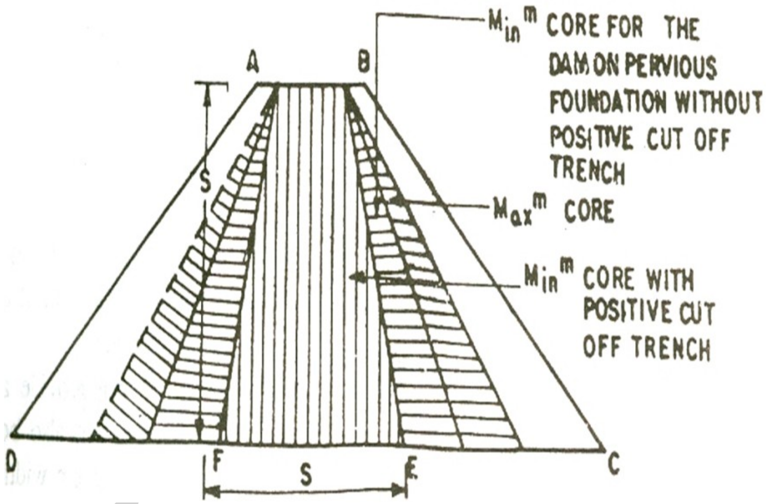


Fig. 14.2 Location and size range of central impervious core in zoned type of earthen dam/bund

Table 14.1 Recommended side slopes for earthen embankment.

Sr. No.	Soil classification	Slope (Horizontal to Vertical)	
		Upstream	**Downstream**
1.	Well graded gravel, pervious and hence not suitable sand gravel mixture.	Pervious and hence not suitable	
2.	Clayey gravels, silty gravels, gravel sand clay mixtures and gravel sand silt mixtures.	2.5:1	2:1
3.	Sandy clays, silty clays, lean clays, inorganic silt and clays.	3:1	2.5:1
4.	Inorganic clays of high plasticity and inorganic silts.	3.5:1	2.5:1

Free Board:

Free board is added to the height of dam. Normally 15% additional height is provided as free board for the safety of dam.

Allowance for settlement:

Settlement includes the consolidation of the fill material and the consolidation of the foundation material due to the self-weight of the fill material and the increased moisture caused by the storage of water. The design height of earth dam should be increased by an amount equals to 5% of the design height.

Execution:

1. A detailed survey of the nala at suitable location with a suitable grid of minimum of 15 m or 5 m.
2. Detailed longitudinal survey of nala is carried out and the longitudinal section is drawn.
3. Position of nala bund on the survey plan is fixed.
4. Decide the Full supply level (FSL), high fall level (HFL) and free board.
5. Decide the total length of bund.
6. Excavate the puddle trench up to full length of bund.
7. Fill the puddle trench with black soil (Fig. 14.2)
8. Construct the core wall with side slope 1:1 and height upto HFL with black soil
9. Construct earthen embankment over core wall (Fig. 14.2).
10. Stone pitching is done on upstream side of bund upto HFL.

Construction of Waste Weir:

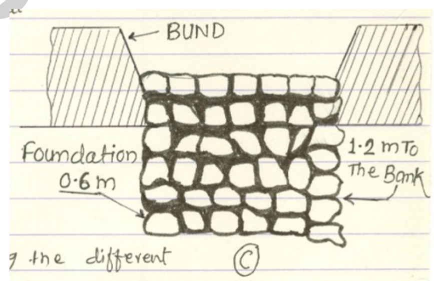
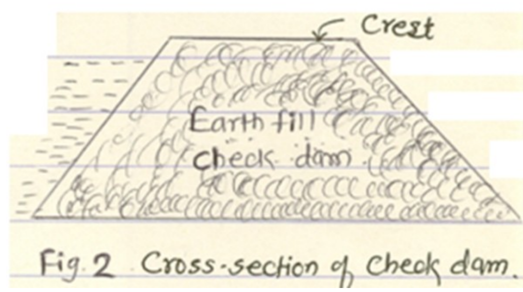


Fig. 14.3 waste weir of Nala bund

1. From the contour map or topographic sheet calculate the catchment area draining water to nala bund
2. Divide it in cultivated and uncultivated area
3. Calculate peak runoff rate for cultivated and uncultivated area
4. Sum up the runoff rate for cultivated and uncultivated area
5. Fix the depth of water flow over the crest of weir and is equal to HFL – FSL
6. Assume width of crest
7. Calculate area of cross section of waste weir
8. Calculate design velocity

Check Dam:



Definition: The structures which are constructed to check the velocity of flowing water in the gully, are known as check dams

Working Principle:

Fig. 14.4 Check dam

1. They reduce the degree of slope of the gully bed by constructing series of check dams.
2. Reduce the velocity of running water
3. They force silt to deposit in the gully bed

4. Series of such breaks (checks) increases time of opportunity of flow water in gully
5. Increase percolation rate of runoff water.

Classification of Check dams:

A. Temporary Earthen check dams: earthen check dams are constructed across the bed of a gully to

(i) Collect enough soil and retain water to ensure growth of protective vegetation, and
(ii) Check channel erosion until sufficient vegetation can be established.

Suitability/site: adapted to gullies with small drainage area.

- These are used where stones are not available
- These dams should be coupled with water surplussing arrangement.
- A borrow pit should be constructed on the upstream side so that it will act as barrier to control runoff velocity and conserve water for ground water recharge (Fig. 14.4).

2. Woven-wire dams:

These are used as temporary aids in establishment of vegetation for the permanent control of erosion.
Specific Site: used in gullies of moderate slope and small drainage areas
Design: Dam built in crescent/half-moon shape with open end on upstream (Fig. 14.5).

Construction: A row of posts is set along curve of the proposed dam at intervals - 1.2 m & depth 60 - 90 cm.
A trench -15 cm in depth & width is dug along the upstream of row of posts.
Heavy gauge woven wire is placed against the posts, with lower part set in the trench & 25 - 30 cm projecting above ground surface across the gully.
The wire should be tightly attached to the posts.

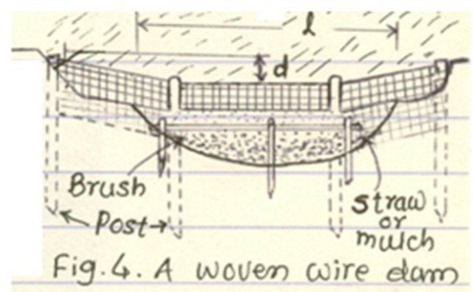


Fig. 14.5 Woven-wire dam

Enough brush is laid to make an apron at least 1.2 m long extending at least 60 cm on each side of the posts.
Woven-wire dams & rock fill dams are more lasting than loose rock dams.

3. Brush Dam:

These are least permanent of all types of check dams, but these are cheap and easy to build. Many types of brush dams can be used depending upon amount of brush available and size of the gully to be controlled.

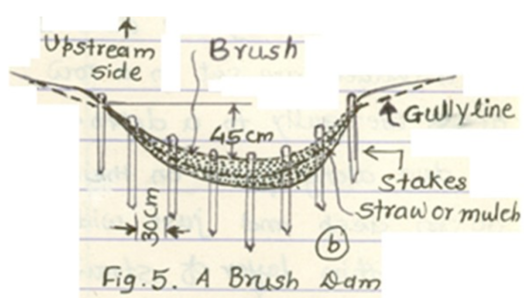


Fig. 14.6 Brush dam

Suitability: Best suited to gullies with small drainage area.
Construction:

For a distance of 3 to 4.5 m along the site of structure, the sides and bottom of the gully are covered with a thin layer of straw or similar fine mulch, which is slightly countersunk, in order to form a bond between the structure and the soil.
Brush with butts pointing upstream is packed over mulch to ½ of dam height proposed.
Several rows of stakes are then fixed 30 to 60 cm apart in row on gully bottom.
The brush filling is then completed and heavy galvanised wire stretched along the row of stakes and fastened to them.
The stakes are then driven down until the wire firmly compresses the brush in place.

4. Loose Rock Dam:

Where stones or rocks of appreciable size and suitable quality are available, these may be used to make semi-permanent type of check dam in gullies that have small to medium size drainage areas.

These dams have longer life and no maintenance.

No requirement of assistance of vegetation.

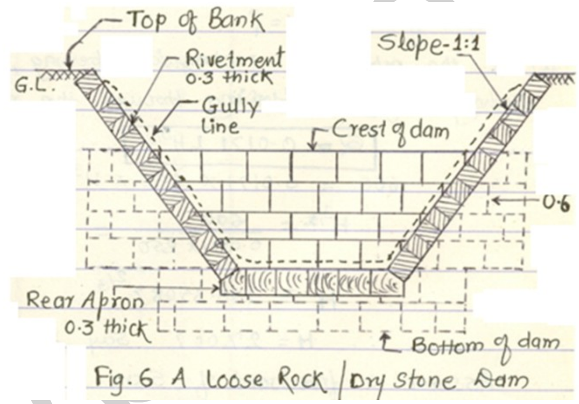


Fig. 14.7 Loose rock dam

Construction:

A trench is first made across the gully to a depth of 30 cm. This forms the base of the dam on which the stones are laid in rows and are brought to the required height. The centre of the dam is kept lower than the sides to form spillway.

5. Plank / Slab Dam:

These are generally used in gullies with larger drainage areas than in case of woven-wire dam.

Suitability: in areas where timber is more available.

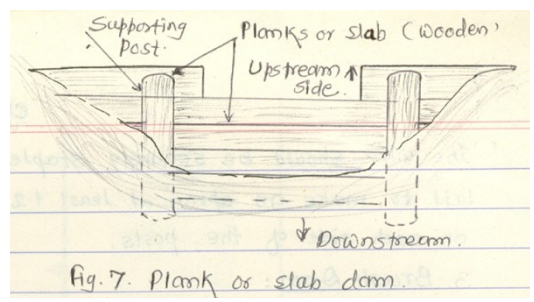


Fig. 14.8 Plank or slab dam

Construction:

The posts are set in a row across the gully to a depth of 1 m and 1.2 m apart. After the posts are set up, a narrow trench is dug along posts on their upstream side. The trench is made about 30 cm deep and just wide enough to permit placing of the headwall and a thin layer of straw or grass as a seal.

6. Log and Pole dam:

These are used where plentiful timber and semi-skilled labour is available. With log and pole dam there is difficulty in getting a good bond between the dam and bottom and sides of gully.

Construction:

Its construction is similar to slab dam.

Two rows of vertical wooden posts are formed by inserting posts into gully bed and extending up to the sides above the flood level.
Logs are placed between the two rows.
The vertical poles are 10 cm in diameter and 2 m long.
The pole spacing in rows is 1 m and two rows of post 0.5 m apart are fixed firmly across the gully.

Design of Notch for Spillway of Check Dam:

Problem 1: Design the notch dimension of wooden slab dam to carry a peak flow 0.75 m^3/s. The notch has rectangular opening and width of gully channel is 3.0 m.

Ans: Step I: Given data –

(1) Water flow through notch, Q = 0.75 m^3/s =750 lit
(2) Channel width = length of notch, L = 3.0 m = 300 cm
(3) Depth of water over notch crest, H=?

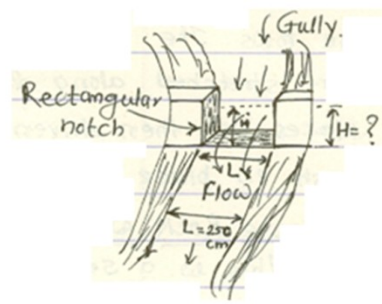


Fig. 14.9 Notch dimensions

Step II: As the notch has rectangular opening, the discharge of gully flowing through the notch is

$$Q = 0.0171\ LH^{3/2}$$
$$H^{3/2} = 146.1988$$
$$H = 27.66 \text{ cm}$$

Step III: Assuming a freeboard of 5 cm,

H = 27.66 + 5 = **32.66 cm**

The design dimensions of the rectangular notch are:

1. Crest length = 300 cm
2. Depth of water flow over notch crest = 32.66 cm

Problem 2: Design the notch dimensions of a wooden slab dam to carry a peak flow of 0.6 m^3/s. The notch has rectangular opening. Width of gully channel is 2.5 m.

B. Permanent gully control structures:

When temporary structures are insufficient, then permanent gully control structures such as masonry, reinforced, earth structures using concrete or steel spillways should be provided to convey the runoff over critical portions of the gully.

Use: in medium to large gullies with medium to large drainage areas.
Three basic permanent structures are employed in stabilizing the gullies.

1. Drop Spillway:

The main objective is to reduce runoff velocity to non-erosive level.
These are efficient in controlling low heads and limited to 3 – 4 m drops,

Use: for tile and drainage ditches and in water courses.

Components of drop spillway:

1. Head wall and head wall extension
2. Weirs
3. Side walls
4. Apron
5. Wing walls
6. Longitudinal sills
7. Cut off walls

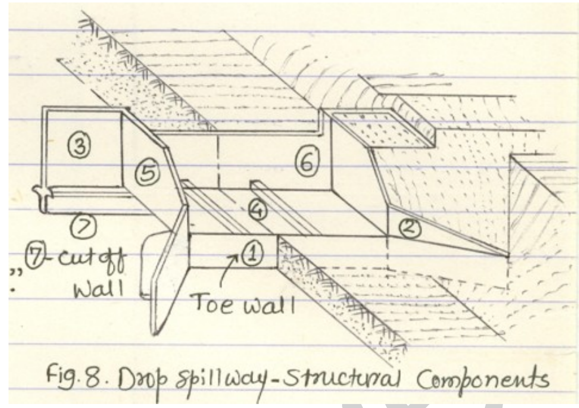


Fig. 14.10 Drop spillway

2. Chute Spillway:

Objective is to serve as spillway for surplussing water from ponds. It is efficient in carrying high runoff discharges.

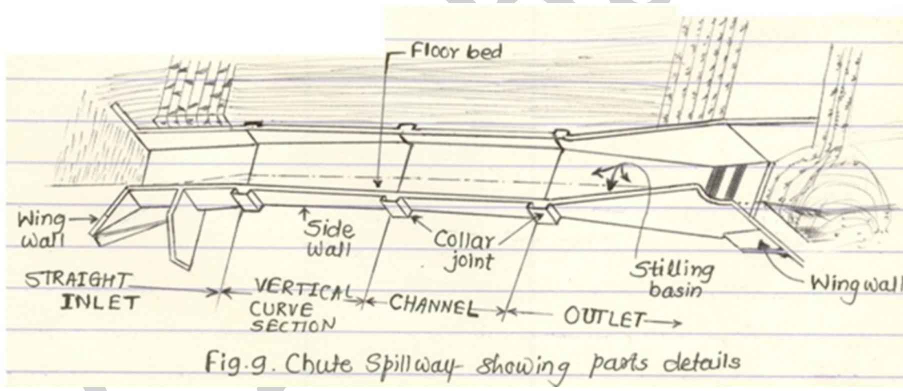


Fig. 14.11 Chute spillway

3. Drop Inlet Spillway:

Efficient structures for controlling relatively high heads above 3 m and Use: for head water flood control and as outlets for farm ponds and reservoirs.
These may be pipe conduit of concrete or corrugated metal.

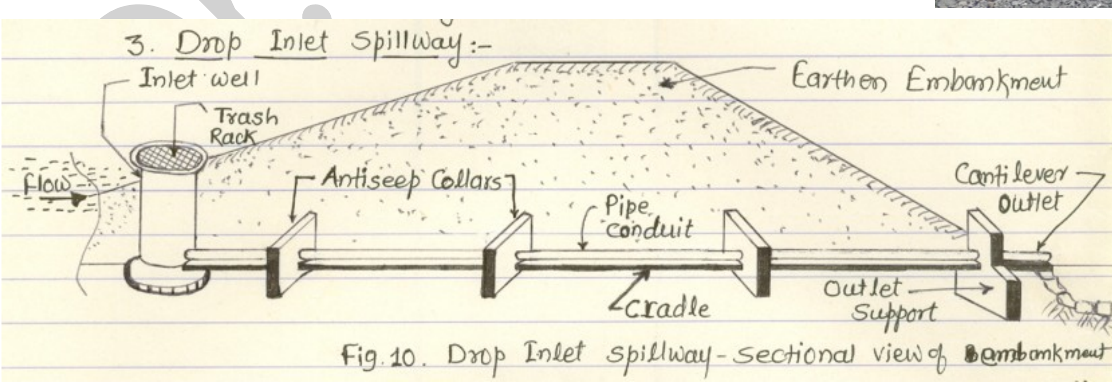


Fig. 14.12 Drop inlet spillway

K. T. Weir:

Kolhapur type weir is one of the most suitable and commonly constructed permanent gully control structure. The series of such structures develops a continuous check to the flow of water, causing deposition of sediment. These are constructed with masonry or RRC material. A number of rectangular weirs are provided in the head wall to pass excess water with safe velocity. The main feature of the K.T. weir is that the rectangular weirs are provided with removable metal gates. The purpose of the gate is to avoid the siltation of the structure. These gates are manufactured as sandwich structure of fabricated remoulded plastic (FRP) skin with M.S. structure baking. Water side is covered by FRP skin plate. Maintenance will be less and life of gate will be more. FRP gates can operate only up to five meter water head. These gates have a life upto 5 years.

Components of drop structure:

1. Head wall and head wall extension
2. Weirs
3. Side walls
4. Wing walls
5. Apron
6. Longitudinal sills
7. Cut off walls

Weir Design:

1. Determine the peak rate of runoff by using Rational formula

$$Q = \frac{CIA}{36}$$

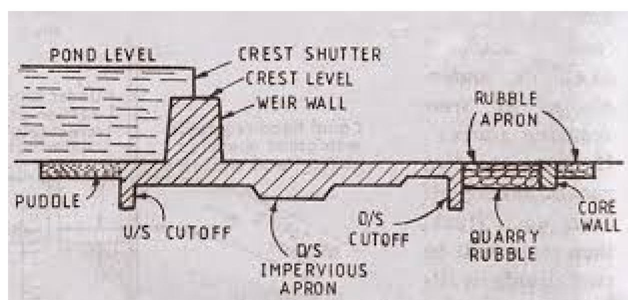


Fig. Masonry weir

Where, Q = peak flow rate, m^3/s

C = runoff coefficient

I = rainfall intensity, cm/hr

A = area of catchment, ha

2. Considering the length of the head wall and number of notches to be provided determine (assume) the length of each weir.

Fig. 14.13 K.T. weir

3. The shape of the weir is rectangular, so using the formula for flow through rectangular weir, determine height of weirs to be kept adding free board.

Problem 1: Design the weir dimensions of the K.T. weir having the head wall length of 20 m. The expected peak flow is 1.8 m^3/s and the number of weirs to be provided are 3.

Assignment: Draw the typical cross sections of the following structures

1. Temporary check dams
2. Permanent check dams
3. Nala bund
4. K.T weir

Exercise No. 15

Determination of Pond Capacity

Farm pond: These are small tank or reservoirs, made either by constructing embankment or by excavating a pit across a water course for the purpose of storing the surface runoff, available in the catchment. It is one of the important water harvesting structures.

Water harvesting: This term was first used in Australia by H.J. Fgedders to denote the collection and storage of runoff or stream flow in creeks and gullies, for giving supplemental irrigation to crops in drought-prone areas. In many regions local thumb rules are used for designing the structure. For hydrological design a more or less universal criterion is followed which is basically 'the ratio of the catchment area to the cultivated area'.

Objectives:

1. To provide water storage for life saving irrigation in limited area.
2. Provide drinking water for livestock and human beings in arid areas
3. Provide critical irrigation to fruit plants for establishment purpose
4. Moderate the hydrology of small watersheds

Types of farm pond: In broad sense farm ponds may be divided in two general categories

1. Embankment type and
2. Excavated / Dugout type

Embankment Type Farm Pond: It is generally constructed across a watercourse or stream where the largest storage volume can be obtained with the least amount of earth fill. This type of pond consists of small earthen dam of which dimensions are evaluated on the basis of volume of water to be stored, topography, etc. Embankment type ponds built in areas where land slopes are gentle to moderate and side slopes of valley are relatively steep which permit maximum water storage.

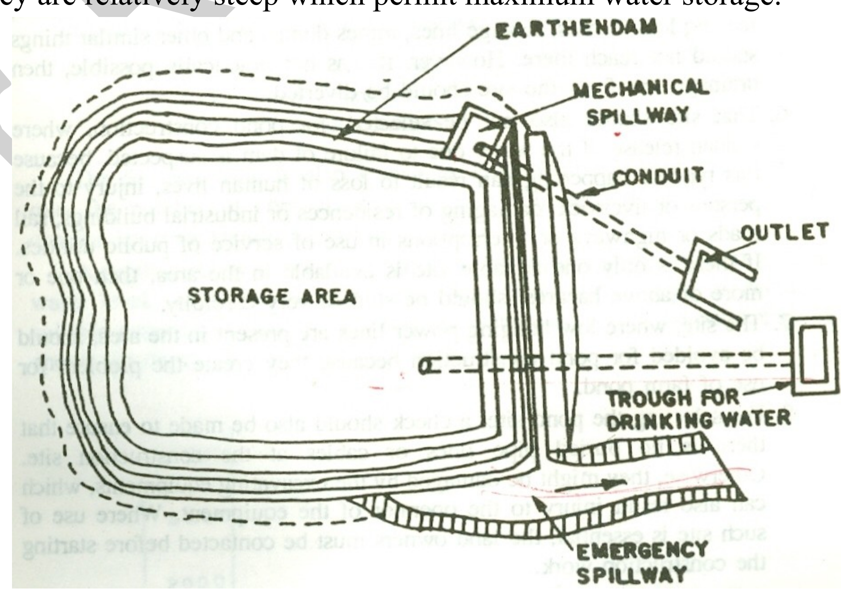
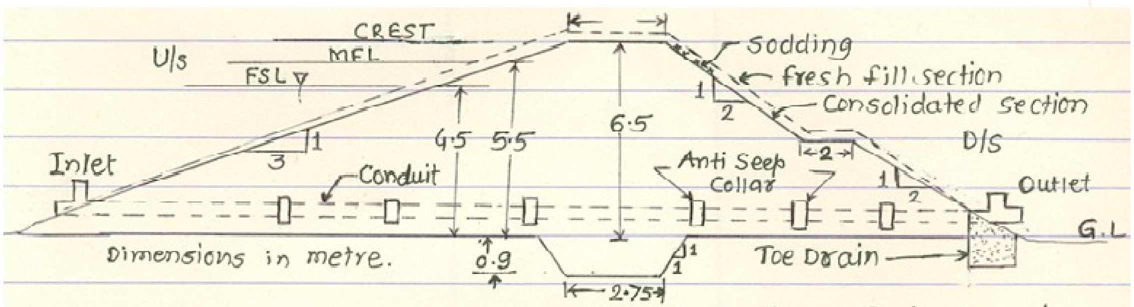


Fig. 15.1 Layout of embankment type farm pond



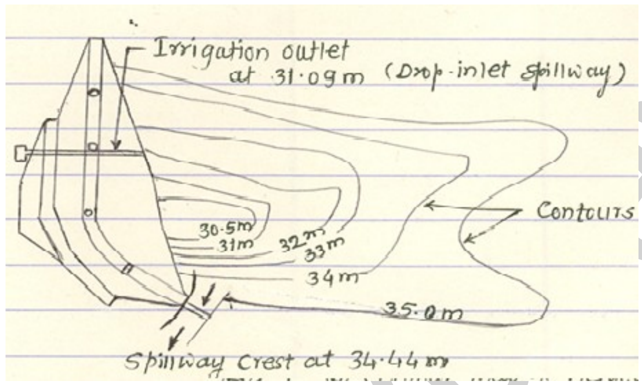


Fig.15.2 (a) Section of Embankment (b) Contour map of water storage in farm pond

2. Dugout Type Farm Pond: Dugout ponds are generally created by excavating pits in areas having flat topography and mostly in situations where water table is close to the ground level. The depth is limited up to the desired capacity of pond and is obtained almost entirely by excavation. It is useful only for small water supply.

Advantages of dugout type farm pond: Advantageous where the evaporation losses are high and water is scare, since in dugout farm ponds minimum water surface area is exposed in proportion to volume.

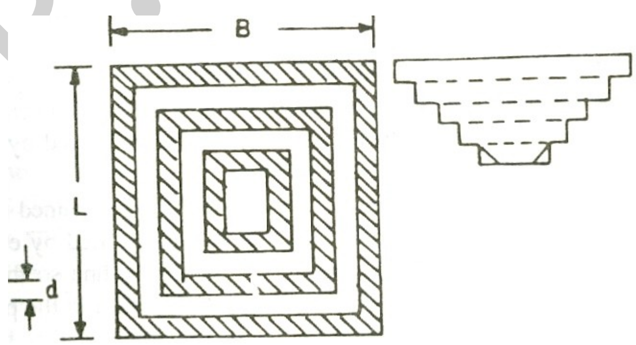


Fig. 15.3 Construction of dugout type farm pond

Specific site selection: The important physical features that are considered in location of dugout farm pond are watershed characteristics, silting possibilities, topography and soil type. Important features of site selection are:

1. The catchment must be capable of fulfilling the runoff requirement of the pond

2. Excavated in level areas water table is close to the ground level
3. Economical to locate at point where high water storage obtained with least earthwork.
4. Soil at site should not have high permeability to prevent excessive seepage losses
5. Natural depression is good location to minimize earthwork excavation
6. Soil strata underlain by limestone containing crevices, sinks or channels should be avoided
7. It should be located at a convenient distance from farmhouse or animal shelter

Planning: Dugout ponds may be excavated to any shape desired but rectangular shape is preferred. Size of pond is decided based upon water requirement, catchment area contributing runoff and soil type.

Design: The design and excavation of farm pond consists of following parameters:

1. Selection of site
2. Pondage or pond capacity
3. Embankment design
4. Mechanical spillway design
5. Emergency spillway design
6. Arrangement for seepage control from bottom of pond

Capacity of Pond:

The capacity of embankment type pond is determined using contour map of the watershed area where pond is to be located. From the contour map the capacity is calculated for different depths, using Trapezoidal or Simpson's rule. Simpson's rule gives more accurate values than Trapezoidal rule.

The area enclosed by each contour is measured using Planimeter. According to Trapezoidal rule the volume of water V between two successive contours spaced at an interval of H with areas A_1, A_2 is given by:

$$V = \frac{H}{2} \times (A1 + A2)$$

Using Simpson's rule volume V between odd contours is given by

$$V = \frac{H}{3} ¿$$

$$+4\left(\sum of\ even\ contours\right)\}$$

This rule has the limitations that the numbers of contours should be odd.

A depth capacity curve of the pond is also prepared for different water level using the depth capacity data. This curve helps in deciding a suitable height of embankment with respect to the available capacity of pond. Figure shows capacity curve of the pond.

Estimation of Volume of Dugout Pond:

Dugout pond may be excavated square or rectangular in shape. The volume of water storage or excavation of dugout pond can be estimated using Prismoidal formula:

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

Where, V = volume of excavation, m^3

A = area of excavation at top section of pond, m^2

B = area of excavation at mid depth section of pond, m^2

C = area of excavation at bottom section of pond, m^2

D = depth of pond, m

After fixing the capacity of pond next step is to work out the dimensions of pond. Side slope is taken as 1:1.5 or 1:2 (vertical to horizontal). Decide the depth; minimum length and width are to be calculated on trial and error basis to obtain the required capacity of the proposed pond.

Provision of Spillway:

All dugout ponds must have provision for removal of excess runoff water when pond is full. Dugout pond must be provided with masonary chute spillway at entrance and sod spillway or emergency spillway at outlet to dispose of over-flow water after heavy rains. Spillway at outlet should have 1:25 times the inlet spillway capacity.

Disposal of excavated material: A berm with a width equal to the depth of pond may be provided. Excavated material should be used to construct bund around the pond to increase the capacity of pond.

Problem 1. Calculate the volume of water stored in farm pond given that the area closed by different contours at site as follows and contour interval (H) = 1 m:

Ans: **Using Trapezoidal rule**

Sr. No.	Contour value	Area enclosed (m^2)	Average area (A1+A2)/2, (m^2)	Volume=(A1+A2)/2*H (m^3)
1	250	220	0	0
2	251	290	255	255
3	252	340	315	315
4	253	370	355	355
5	254	480	425	425
6	255	550	515	515
7	256	620	585	585
	Total			2450

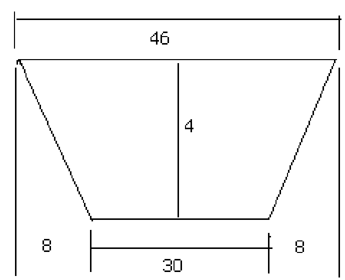
Using Simpson's rule:

$$V = 1/3\{(220+620) + 2(340+480) + 4(290+370+550)\}$$
$$= 1/3(840 + 2 \times 820 + 4 \times 1210)$$
$$= 2440 \text{ m}^3$$

Problem 2. Calculate the volume of excavation required for constructing a dugout type farm pond having average depth 4, bottom length and width are 30 and 12 m respectively with side slopes 2:1.

Ans: Step I: Given data

1. Dpeth of pond, D = 4 m
2. Bottom width, W = 12 m
3. Bottom length, L = 30 m
4. Side slopes of pond = 2:1
5. Volume of excavation, V = ?



Step II: Determination of top dimensions of pond

(a) Top length, l $= 30 + 4 \times 2 + 4 \times 2$
$= 46$ m

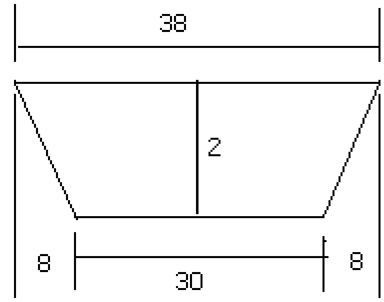
(b) Top width, $w = 12 + 4 \times 2 + 4 \times 2 = 28$ m

$\therefore$ Area of cross section of pond at top, $A = 46 \times 28$
$= 1288\ m^2$

Step III: Determination of Mid-Depth dimensions

(a) Mid-length $= 30 + 2\times2 + 2 \times 2 = 38$ m

(b) Mid-width $= 12 + 2 \times 2 + 2 \times 2 = 20$ m



$\therefore$

Area of cross section of pond at mid section,

$B = 38 \times 20 = 760\ m^2$

Step IV: Area of excavation at bottom section of pond,

$C = 30 \times 12 = 360\ m^2$

Step V: The volume of excavation required to construct the dugout pond can be estimated by using the Prismoidal formula

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

$$= \frac{1288 + 4 \times 760 + 360}{6} \times 4 = \mathbf{3125\ m^2}$$

Exercise No. 16

Visit to Watershed and Case Study of Watershed

Objectives: Following are the objectives of watershed development and management.

1. To control excess damaging runoff and thereby degradation of land.
2. To conserve soil and water in the watershed
3. To manage, harvest and recycle runoff for its efficient use in crop production
4. To reduce silt deposition in dams, ponds, lakes, etc.
5. To reduce soil erosion and sediment yield
6. To manage and control flood in downstream reaches of watershed
7. To increase vegetation by forestation of waste and degraded land
8. To recharge underground water resources
9. To increase production and productivity
10. To reduce poverty and pollution
11. To increase employment generation
12. To protect and improve the ecosystem and environment

The watershed development refers to the conservation, regeneration and the judicious use of all the resources – natural (land, water and vegetation) and human – within the watershed area. Man, animal and their environment are interdependent. The changes in the environment directly affect the lives of the people depending on it. A degraded environment means a degraded quality of life. Therefore, the watershed development programme is directly related to socio-economic condition of rural people. The upliftment of socio-economic status of rural people is only the parameter which is showing the positive effect of watershed development programme.

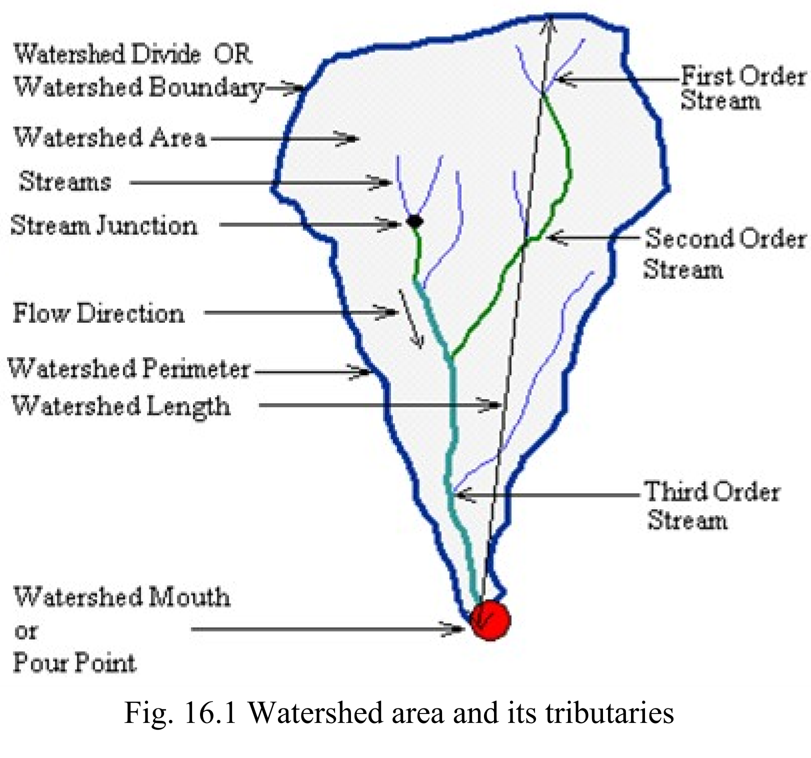


Fig. 16.1 Watershed area and its tributaries

The watersheds put under different land uses and land treatment produce different amount of runoff and soil loss. It is therefore, essential to determine the efficacy of various soil and water conservation measures in controlling runoff and soil loss.

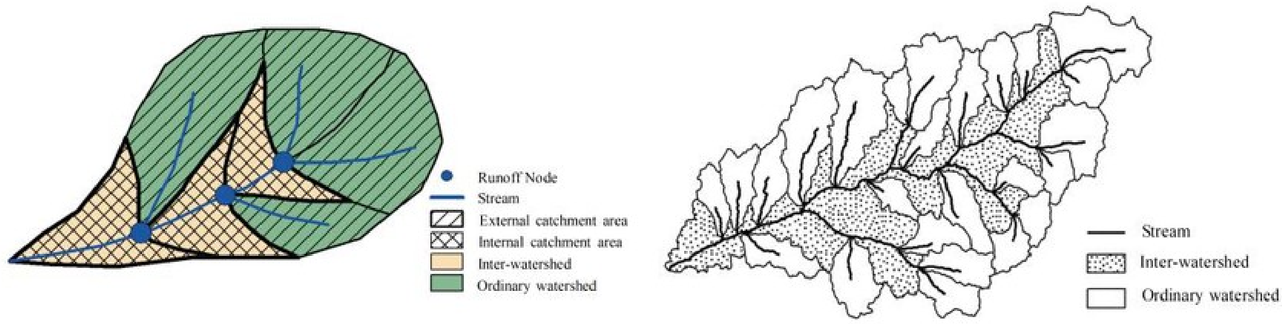


Fig. 16.2 Watershed delineation

Evaluation and monitoring of watershed programme should be carried out at various stages like planning, implementation and completion. Evaluation and monitoring are the indicators of project performance, output, benefit and impact; and useful for updating the development activities. It is carried out by comparing the situation between predevelopment and post development conditions.

The visit should be arranged for study of watershed development work (soil and water conservation work) carried out in a watershed project with following objectives:

1. Observation and technical data collection regarding different agronomical and engineering measures adopted in watershed (Format).
2. Socio-economical data collection (before and after w/s development project).
3. Impact of soil and water conservation work on ground water recharging (through discussion), irrigated area (actual field visit) and socio-economic conditions of the watershed dwellers.