DKSGACA Manual No. 03/2021

Soil and Water Conservation Engineering

A Laboratory Manual

Prepared by

Dr. Mahesh Prasad Tripathi

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Eternal University, Baru Sahib,
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Foreword

The manual ''Soil and Water Conservation Engineering'' prepared by Dr. Mahesh Tripathi is intended primarily as a manual is for B.Sc. (Hons) Agriculture students of Indian Universities. The manual may be found useful for Students, Engineers and Extension workers. The author in this manual has dealt with general status of soil conservation in India, calculation of erosion, preparation of counter maps and problem of wind erosion the related with subject of Soil and Water Conservation Engineering is very well dealt by author.

This being the first attempt to prepare a manual on ''Soil and Water Conservation Engineering'' is for B.Sc. (Hons.) Agriculture students will surely be welcomed by the teachers and the students alike and in my opinion will be of great help to them, I appreciate the efforts of Dr. Mahesh P. Tripathi Assistant Professor (Agricultural Engineering) for his keen interest and putting his hard work for bringing this manuscript in presentable form for all interested in Soil and Water Conservation Engineering. There always lies a scope for the improvement; similar is the case with this manual.

With these words, I sign off to let the manual speak for itself.

(S.K. Sharma)
Dean

Preface

The present manual Soil and Water Engineering is for B.Sc. (Hons.) Agriculture students of Indian Universities. The Agriculture sector in our country is now facing serious challenges particularly relating to small and marginal farmers. Low productivity increasing cost of cultivation and unremunerated prices are some of the issues facing the farming sector today. In addition water scarcity and climate change coupled with socio-economic changes are aggravating the soil and Water management problems. While various steps are needed for improving the Agricultural sector of the country, Soil and Water management activities are also ideally situated for generating employments for the unskilled workers of rural areas.

It is hoped that the present manual will be useful for the students, researchers, extension workers as well as practicing engineers. Author welcome suggestions and comments for further improvement of this manual.

Eternal University
2021

Mahesh P. Tripathi

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EXERCISE – 1

General Status of Soil Conservation in India

In India soil degradation is estimated to be occurring on **147 million** hectares of land which incorporates;

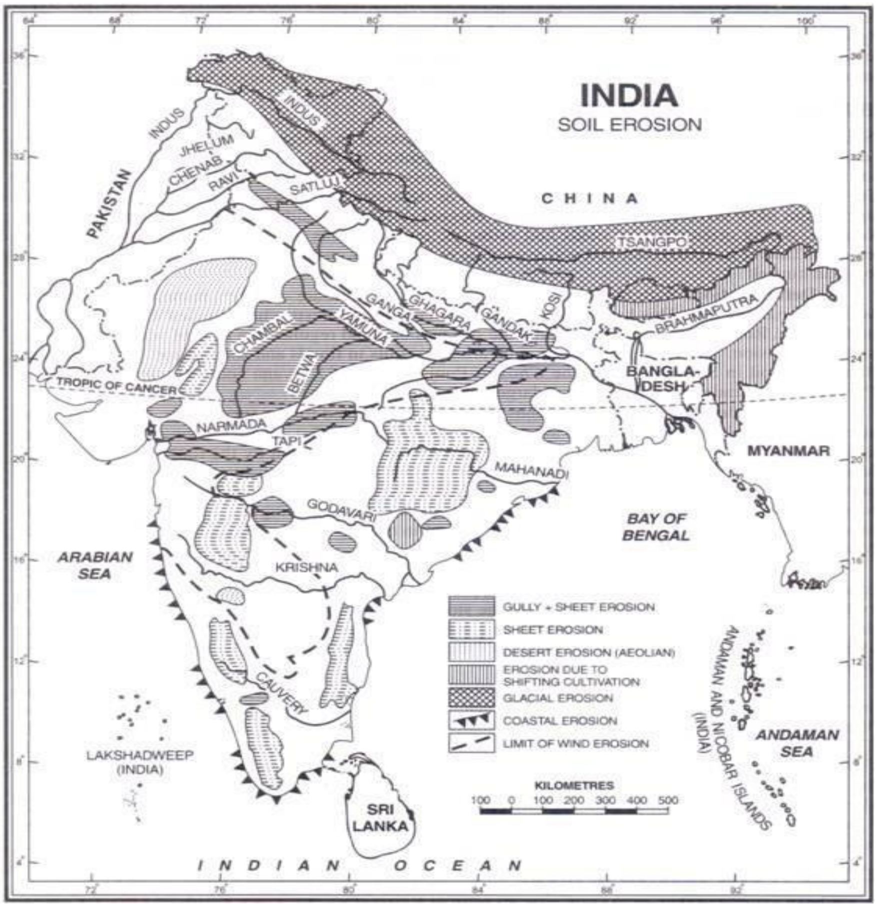
- **94 Million hectares** from water erosion, **16 Million hectares** from acidification,
- **14 Million hectares** from flooding,
- **9 Millon hectares** from wind erosion,
- **6 Millon hectares** from salinity, and
- **7 Millon hectares** from a combination of factors.

The reasons for soil degradation are both normal and human-actuated. Natural causes incorporate earthquakes, tsunamis, dry spells, torrential slides, avalanches, volcanic ejections, floods, twisters, and wild fires. Human-induced soil debasement results from land clearing and deforestation, unseemly rural practices, ill-advised administration of modern effluents and squanders, over-brushing, indiscreet administration of woodlands, surface mining, never-ending suburbia, and commercial/industrial development. Unseemly agricultural practices incorporate inordinate culturing and utilization of large equipment, unreasonable and unequal utilization of inorganic manures, helpless water system and water the board strategies, pesticide abuse, deficient harvest buildup or potentially natural carbon data sources, and helpless yield cycle arranging. Some hidden social reasons for soil degradation in India are land lack, decrease in per capita land accessibility, monetary tension ashore, land occupancy, destitution, and populace increment.

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 exhaustion or enhancement of nutrients.
- Besides the loss of nutrients from the topsoil, there is also degradation through the creation of gullies and ravines.
- Water causes sheet-wash, surface gullies, tunnels and scours banks in rivers.
- In hot and dry climate of India, wind blowing is the main cause of soil erosion.

Government of India 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 preservation is fundamental to secure the lands of the world. In our country, where dry seasons, starvations, and floods cause crop harm consistently, soil preservation won't just build crop yields yet in addition forestall floods and further decay of land.

Before the times of independence, while general issues of soil erosion were known, responses to them supported by scientific investigations were not known. Therefore, during the framing of the first year plan and early in the second five year plan, a chain of 9 Soil Conservation Research Demonstration and Training Centers were established.

Table 12.1

Central Soil and Water Conservation Research Demonstration and Training Centres in India (Tejwani, 1980)

Location	Region/major problems	Date of start
(1)	(2)	(3)
Dehradun	North-western Himalayan region. Erosion control in Himalayas; training of torrents; stabilisation of landslides; development of techniques for crop production; establishment of pastures and forestry.	28.9.1954
Chandigarh	Sub-montane tracts in the north-western region of India with special reference to Shiwalik hills. Erosion control in Shiwaliks; training of chos.	28.9.1954
Ootacamund	Southern hill high rainfall region/soil and water conservation in the Nilgiris 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, classification and reclamation of ravines forage production and forestry.	11.5.1955
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.	22.7.1955
Hyderabad	Red soil, semi-arid region. Soil and water conservation in the red soils under low to medium rainfall regions.	10.1.1962
Chattra	North-eastern Himalayan region. Erosion control in the Kosi river catchment.	19.12.1956

Broad objectives of these Centre's are:

(i) To recognize erosion issues and conservation of land and water assets under various land- use systems,

(ii) To develop mechanical and biological methods of erosion control under various land use systems,

(iii)To advance strategies for control of erosion and recovery of ravines stabilization of landslides and hill torrents,

(iv) To assess hydrological activities and advance 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 gazetted and non-gazetted officers of State Governments.

Important Soil and Water Conservation Programmes implemented by Govt.

- Soil conservation in catchments of river valley project (RVP).
- Integrated Watershed Management in the catchments of flood Prone Rivers (FPR).
- Centrally Aided Drought Prone Area Development Program (DPAP), (according to 1995 rules) implemented by Government and NGO. Desert Development Programme (DDP)
- National Watershed Development Program for Rain fed Area (NWDPRA) carried out by Dept. of Soil Conservation & Watershed Management, Government with monetary help from Department of Agriculture, Gov. of India.
- Operational Research Projects on Integrated Watershed Management (ICAR)
- World Bank Project on Watershed Development in Rain fed Area.
- Council for Peoples Action & Rural Technology (CAPART) supported 38 Watershed Development Programs in Maharashtra.
- DPAP & IWDP projects (of 2001 guidelines) in Satara, Sangali& Nasik Districts of Maharashtra state.
- NABARD Holistic Watershed Development Programme
- Vasundhara Watershed Development Project
- Maharashtra government has launched an programme named as

Jalyukta Shivar Abhiyan' in a state on January 26, 2015. The programme aim to make5000 villages liberated from water shortage every year and to conserve and protect the soil from additional degradation. This Abhiyan aims at initiating permanent measures to make the state dry spell free by 2019 and to collect rain water inside the village boundary thereby increasing ground water levels.

EXERCISE – 2

Calculation of Erosion Index by Ei30 Method

EI_{30} Index Method

This method was introduced by Wischemier (1965). It depends on the fact that the product of kinetic energy of the storm and the 30-minute highest rainfall intensity gives the best assessment of soil loss. The maximum average intensity experienced in any 30 minutes time during the storm is computed from recording rain gauge charts by locating the maximum amount of rain which falls in 30 minutes period and later converting the same to intensity in mm/hour. This measure of erosivity is referred to as the EI_{30} index and can be computed for individual storms, and the storm values can be added over periods of time to give weekly, monthly or yearly values of erosivity.

Wischemier (1965) gave following equation for calculation of kinetic energy (E)

$$= 916 + 331\ _{10} \qquad (1)$$

Here, *E* is the kinetic energy in ft-tonnes/acre and *I* is the rainfall intensity in inch/ hour.

or

$$= 210.3 + 89\ _{10} \qquad (2)$$

Here, *E* is the kinetic energy in m-tonnes/ha-cm and *I* is the rainfall intensity in cm/ hour.

or

Wischemier and Smith (1978) gave the following equations for the calculation of Kinetic energy (E)

$= 0.119 + 0.0873\ _{10}$ for ≤ 76 (3)

$= 0.283$ for > 76 (4)

Where, E= Kinetic energy in mega joules/hectare mm, and I is the rainfall intensity in mm/h.

Limitation of Method

The EI_{30} index method was developed under American condition and is not found appropriate for tropical and sub-tropical zones for estimating the erosivity.

Calculation Procedure: Table 1 illustrates the determination of EI directly from rainfall data.

1. The rainfall hyetograph is separated into increments where strength is assumed to be uniform (Column 1). Cumulative rainfall amounts are given in column (2). Duration, Amount, and Intensity for the increments are shown in column (3), (4) and (5).
2. Unit energy for each increment is exposed in column (6). These values are obtained by substituting intensity for the increment (column 5) into Eq. 3 and 4 (in this example).
3. Rainfall energy for an increment (column 7) is the product of energy (column 6) and the volume of rainfall increment (column 4).
4. Total energy for the storm is the sum of the energies for each increment (column 7) or 8.64 MJ/ha in this case.
5. Maximum 30- minutes intensity, $30 = 2 \times (6 + 18 + 3) = 54 /h$.
6. Therefore, EI_{30} for this storm is$_{30}$ = 8.64 × 54 = 466.56 MJ-mm/ha h.

Table 1. Example computation of energy for a rainstorm

Chart Readings		**Storm Increments**			**Energy**	
Time	Depth (mm)	Duration (min)	Amount (mm)	Intensity (mm/h)	Per Unit Rainfall (MJ/ha-mm)	For Storm Increment (MJ/ha)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
4:00	0					
: 20	1	20	1	3	0.161	0.16
: 27	3	7	2	17	0.226	0.45
: 36	9	9	6	40	0.259	1.55
: 50	27	14	18	77	0.283	5.09
: 57	30	7	3	26	0.243	0.73
5:05	32	8	2	15	0.222	0.44
: 15	32	10	0	0	0	0
: 30	33	15	1	4	0.219	0.22
Totals		90	33			8.64

Conclusion: EI30 for this storm is 8.64 × 54 = 466.56 MJ-mm/ha h.

Exercise: CalculateEI_{30} for different storm/ or changing values of depth, duration amount and intensity.

References:

1. Land and Water Management Engineering by V. V. N. Murthy and Madan K. Jha, Kalyani Publishers (6th edition). pp- 434.

2. Principles of Agricultural Engineering, Vol. II, by A. M. Michael and T. P. Ojha, Jain Brothers Publication. pp- 524.

3. Fundamentals of soil and water conservation engineering by R. Suresh, Standard Publishers Distributors. pp: 334-336.

EXERCISE – 3

Estimation of Soil Loss (Usle)

The universal soil loss equation (USLE) given by Wischmeier & Meyer; & the same was published in the year 1973 by Wischmeier & Meyer.

This equation was designated as Universal Soil Loss Equation, and in brief it is known as USLE. Since, simple & powerful, tool for predicting the average annual soil loss in specific situations. The related factors of equation can be predicted by easily accessible meteorological & soil data.

The term 'Universal' refers consideration of all possible factors affecting the soil erosion/soil loss; and also its general applicability. The USLE is given as under:

A=R.K.LS.C.P.

Where,

A = Computed soil loss, expressed in t/ha/y for a given storm event.

R = Rainfall erosivity factor, which is the measurement of the kinetic energy of a specific rain event or an average year's rainfall.

K = Soil erodibility factor. It is the soil loss rate per erosion index unit for a given soil as measured on a unit plot. (22.1 m long with 9 % slope in continuous clean –tilled fallow)

L = Slope length factor. It is the ratio of soil loss from the field plot under existing slope length to that from the 22.1 m slope length (Unit plot) under identical conditions.

S = Slope gradient factor. It is the ratio of soil loss from the field slope gradient to that from the 9% slope (unit plot) under identical conditions.

C = Cover or crop rotation (management) factor. It is the ratio of soil loss from the area under specified cover and management to that from an identical area is tilled continuous fallow (unit plot).

P = Erosion control practices or soil conservation practices factor. It is the ratio of soil loss under a support practice like contouring, strip cropping or terracing to that under straight – row farming up and down the slope.

Rainfall Erosivity Factor (R):

It refers to the rainfall erosivity index, which expresses the ability of rainfall to erode the soil particles from an unprotected field. It is a numeral value. From long term field studies, it has been observed that the extent of soil loss from a barren field is directly proportional to the product of two rainfall characteristics: 1) kinetic energy of the storm; and 2) its 30- minute maximum intensity.

Soil Erodibility Factor (K):

This factor is associated to the different soil properties, by virtue of which a particular soil becomes prone to get erode, either by water or wind. Physical characteristics of the soil to a great extent influence the rate at which different soils are eroded. In general, the soil properties such as the soil permeability, infiltration rate, soil texture, size & stability of soil structure, organic content and soil depth, affect the soil loss in huge extent.

Slope Length and Steepness Factor (LS):

The LS factor represents the erosive potential of a particular soil with particular slope length and slope steepness. This factor basically affects the transportation of the separate particles due to surface flow of rainwater, either that is the overland flow or surface runoff and consequently affects the value of soil erosion due to any given rainfall. The capability of runoff/overland flow to detach and transport the soil materials gets increased rapidly with increase in flow velocity. On steep ground surface the runoff gets increase because of increase in runoff rate. The factors- L and –S are described as under:

Slope Length Factor (L):

The slope length is the horizontal space from the point of origin of overland flow to the point where either the slope gradient gets reduce adequate to start deposition or overland flow gets concentrate in a defined channel.

Slope Steepness Factor (S):

Steepness of land slope influences the soil erosion in different ways. In general, as the steepness of slope increases the soil erosion also increases, because the velocity of runoff gets increase with increase in field slope, which allows more soil to separate and transport them along with surface flow.

Crop Management Practices Factor (C):

The crop management practices factor (C) is defined as the ratio of soil loss from a land under specific crop to the soil loss from a continuous fallow land, provided that the soil type, slope & rainfall conditions are identical. The crop & cropping practices affect the soil erosion in several ways by the different features such as the type of crop, quality of cover, root growth and water use by rising plants etc.

Soil Conservation Practices Factor (P):

It is defined as the ratio of soil loss under a certain conservation practice to the soil loss from up and down the slope. The conservation practice consists of mainly the contouring, terracing and strip cropping in which contouring appears to be most efficient practice on medium slopes ranging from 2 to 7 per cent.

Example 1: Calculate the annual soil loss from a given field subject to soil erosion problem, for the following information:

- Rainfall erosivity index = 1000 m. tonnes/ha
- Soil erodibility index = 0.20
- Crop management factor = 0.50
- Conservation practices factor = 1.0
- Slope length factor = 0.10

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

Example 2: A field is cultivated on the contour for growing maize crop. The other details regarding USLE factors are as follows:

K = 0.40

R = 175 t/acre

LS = 0.70

P = 0.55

C = 0.50

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 percent cover. Assume the value of factor- C for new crop is 0.003.

EXERCISE – 4

Measurement of Soil Loss (Multi Slot Divisor)

Object: Measurement of soil loss from the field by using multi slot divisor.

Multi slot divisor is valuable for measuring runoff from small plots. It can measure quantity of runoff and can calculate approximately soil loss from field. Its design and application is very simple. Mostly used for experiment purpose. It has mainly three parts:

- Collection tank
- Slot divisor (spout)
- Cistern tank

1. Collection tank:

The collection tank is used to collect the runoff water from the plot. The water is abstracted from the plot and discharged into the collection tank. The tank has four compartments of different dimensions. The dimension of the collection tank varies according to the size of the plot and probable runoff to be collected. The probable runoff is calculated taking into consideration the plot size and maximum daily rainfall of the area. The collection tank is provided with roof cap to avoid rain water falling into the tank. The tank is provided with a provision to fix slot divisor.

2. Slot Divisor:

The slot divisor with number of slots is used for experimentation, in which one slot is connected to the cistern tank. The divisor is always provided with the odd number of slots. The number of slot are firm as per the volume of water is collected from the experimental plot. Larger the quantity of runoff, more are the slots and vice versa. It is also covered with cap on its top. The middle slot connected to the cistern tank, to collect excess runoff.

3. Cistern tank:

Cistern tank connected to the slot divisor to collect the runoff water for final measurement. The capacity of the cistern tank is determined as per the probable runoff and numbers of slots.

Procedure:

1. Select the particular field from where soil loss is to be calculated.
2. Generally, the size of the field is selected as 15 x 4 m.
3. Mark the plot border line by erecting GI sheets along the boundary of plot such that no runoff water will enter into the experimental field.

4. The runoff collection channel is constructed to divert the runoff water towards collection tank.

5. Pipe is used to pass on the runoff water into the tank.

6. At the end of the plot pit is excavated to install the multi slot assembly to collect runoff water and runoff samples.

Calculation of runoff volume and soil loss:

Runoff volume: The runoff water collected in the Cistern tank is measured by using following formula

Where, V = volume of runoff water, m^3

r = radius of cistern tank, m

h = height of tank, m

This is the volume of runoff water collected all the way through one slot. Convert it into total volume of water collected from the plot in view of the number of slots of the divisor. Then, calculate total volume of runoff water collected from one hector of land.

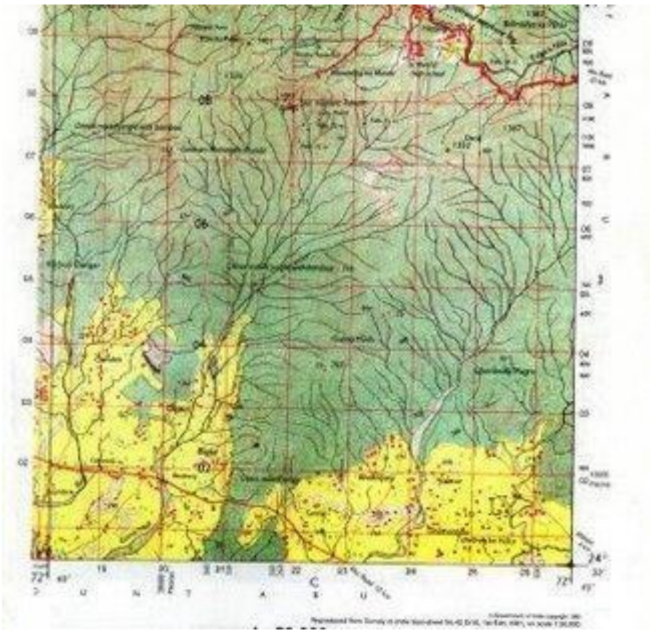
Soil loss:

1. The runoff samples are collected from the collection tank in the bottles with constant stirring of water.
2. Add alum to the water samples to allocate the settlement of sediment in the sample bottles.
3. Keep it for 24 hrs for settlement.
4. Remove water from bottles.
5. Keep the soil/sediment for 24 hrs at 105 ^{0}C in oven dryer.
6. After that take dry weight of soil.
7. Calculate the soil loss in kg per hectare.

EXERCISE – 5

Preparation of Contour Maps

What are contour lines? Contour lines join a series of points of equal elevation and are used to illustrate relief on a map. They demonstrate the height of ground above mean sea level (MSL) either in meters or feet, and drawn at any preferred interval. For example, numerous contour lines that are close to one another show hilly or mountainous terrain; when further apart they indicate a gentler slope; and when far apart they indicate flat terrain.



Purposes of Contouring Contour survey is carried out at the starting of any engineering project such as a road, a railway, a canal, a dam and a building.

1. For preparing contour maps in order to select the most reasonable or appropriate site.
2. To establish the alliance of a canal so that it should follow a ridge line.
3. To mark the alignment of roads and railways so that the amount of earthwork both in cutting and filling should be minimum.
4. For getting information about the ground whether it is flat, undulating or mountainous.
5. To set the physical features of the ground such as a pond depression, hill, steep or small slopes.

Contour Interval & Horizontal Equivalent Contour Interval: The constant vertical space between two consecutive contours is called the contour interval. Horizontal Equivalent: The horizontal distance between any two adjacent contours is called as horizontal equivalent. The contour distance is constant between the consecutive contours while the horizontal equivalent is variable and depends upon the slope of the ground.

Characteristics of Contours

1. All points in a contour line have the similar elevation.
2. Flat ground is indicated where the contours are widely estranged and steep-slope where they run close together.
3. A uniform slope is indicated when the contour lines are uniformly spaced and
4. A plane surface when they are straight, parallel and equally spaced.
5. A series of closed contour lines on the map represent a hill, if the higher values are inside
6. A series of closed contour lines on the map indicate a depression if the higher values are outside.
7. Contour line cross ridge or valley line at right angles. If the higher values are inside the bend or loop in the contour, it indicates a Ridge. If the higher values are outside the bend, it represents a Valley.
8. Contour lines cannot merge or cross one another on map except in the case of an overhanging cliff.
9. Contour lines never run into one another except in the case of a vertical cliff. In this case, several contours coincide and the horizontal equivalent becomes zero.

METHODS OF CONTOURING

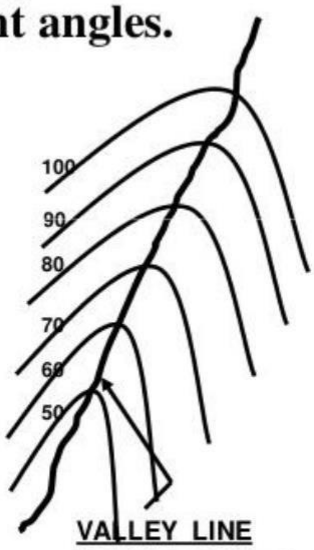
There are mainly two methods of locating contours:-

(1) **Direct Method:** Direct Method: In this method, the contours to be situated are directly traced out in the field by locating and marking a number of points on each contour. These points are then surveyed and plotted on plan and the contours drawn through them.

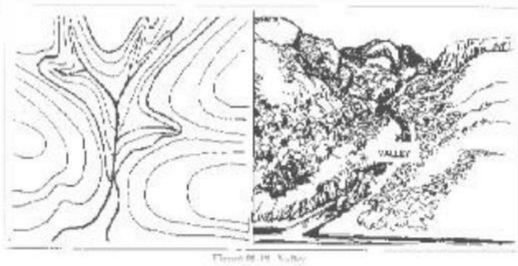
(2) **Indirect Method**: In this method the points located and surveyed are not necessarily on the contour lines but the spot levels are taken along the series of lines laid out over the area .The spot levels of the some representative points representing hills, depressions, ridge and valley lines and the changes in the slope all over the area to be contoured are also observed. Their positions are then plotted on the plan and the contours drawn by interpolation. This method of contouring is also known as contouring by spot levels.

CHARACTERISTICS OF CONTOURS

vii) Contour line cross ridge or valley line at right angles.

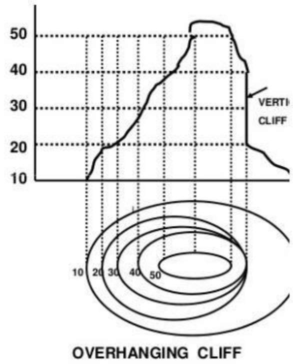


If the higher values are outside the bend, it represents a Valley



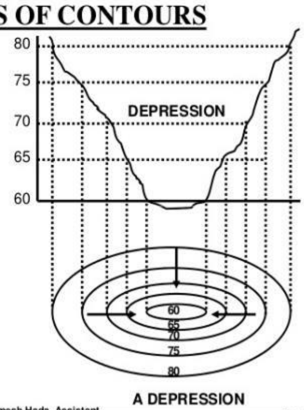
CHARACTERISTICS OF CONTOURS

x) Contour lines never run into one another except in the case of a vertical cliff. In this case ,several contours coincide and the horizontal equivalent becomes zero.



CHARACTERISTICS OF CONTOURS

vi) A series of closed contour lines on the map indicate a depression if the higher values are outside



EXERCISE – 6

Design of Grassed Waterways

Vegetative waterways are natural or waterways shaped constructed to require dimensions and vegetated for safe disposal of runoff from a field, diversion, terrace or other structures. Satisfactory performance of vegetated waterways depends on its having the proper shape, as well as the preparation of the area in a manner to provide favourable condition to vegetation growth. The grass in the waterways should be established before any water turned into it. The velocity in the grassed waterways should be reserved within the permissible limit for various types of soil and these limits are presented below table.

Permissible velocity in grassed waterways for different soil types

Type of soil	Maximum permissible velocity (cm/sec)
Sand and silt	45
Loam, sandy loam and silt loam	60
Clay loam	65
Clay	70
Gravelly soil	100

Design

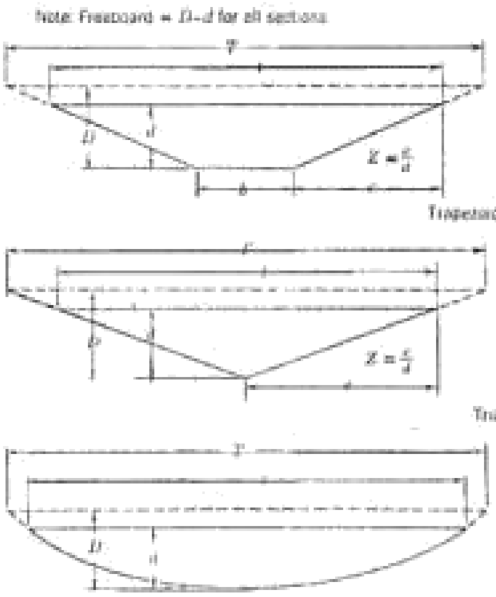
Vegetative waterways are generally designed to hold the maximum runoff from a storm of 10-year recurrence period. Runoff can be estimated by the Rational Method.

Shape

Vegetated waterways may be built to three general shapes or cross-sections, namely, parabolic, trapezoidal or V-shaped. Parabolic waterways are most familiar and generally are the most acceptable. It is the shape normally found in nature. V-shaped channels can be easily constructed with a V-ditcher and trapezoidal channels with a V-ditcher and a buck scrapper, and hence these sections are preferred constructed channels. Broad-bottom trapezoidal channels require less depth of excavation than parabolic or V-shapes for the same capacity. Thus there are number of factors which govern the selection of shape.

Channel Grades

Grassed waterways generally run down the slope and the channel grade is usually governed by land slope. In any case, channel slope should not exceed 10 % while it is normally desirable to keep the grade within 5%.



Cross-section	Cross-Sectional Area a	Wetted Perimeter, p	Hydraulic Radius $R = \frac{a}{p}$	Top Width
Trapezoidal cross section	$bd + Zd^2$	$b + 2d\sqrt{Z^2+1}$	$\frac{bd + Zd^2}{b + 2d\sqrt{Z^2+1}}$	$t = b + 2dZ$ $T = b + 2DZ$
Triangular cross section	Zd^2	$2d\sqrt{Z^2+1}$	$\frac{Zd}{2\sqrt{Z^2+1}}$ or $\frac{d}{2}$ approx.	$t = 2dZ$ $T = \frac{D}{d}t$
Parabolic cross section	$\frac{2}{3}td$	$t + \frac{8d^2}{3t}$	$\frac{t^2d}{1.5t^2 + 4d^2}$ or $\frac{2d}{3}$ approx.	$t = \frac{a}{0.67d}$ $T = t\left(\frac{D}{d}\right)^{\frac{1}{2}}$

(After Schwab et al)

Channel Dimensions

After the runoff, channel grade and design velocity have been estimated, the next step is to decide on the channel dimensions. Design of vegetated waterways is based on the Manning's formula. The coefficients of roughness (n) usually unspecified in grassed waterways design is 0.04. Side slopes of channel should be 4:1 or flatter to facilitate crossing of farm equipment. A freeboard of 10 - 15 cm should be provided to take care of the sediment deposition and variation in the value of 'n'.

Size of Waterway

The size of the waterway depends upon the expected runoff. A 10 year reappearance interval is used to calculate the maximum predictable runoff to the waterway. As the catchment area of the waterway increases towards the outlet, the expected runoff is calculated for different reaches of the waterway and used for design purposes. The waterway is to be given greater cross-sectional area towards the outlet as the amount of water gradually increases towards the outlet. The cross-sectional area is calculated using the following formula:

$$a = \frac{Q}{V}$$

where, a = cross-sectional area of the channel,

Q = expected maximum runoff, and

V = velocity of flow.

Shape of Water Way

The shape of the waterway depends upon the field situation and type of the manufacture equipment used. The three common shapes adopted are trapezoidal, triangular, and parabolic shapes. In course of time due to flow of water and sediment depositions, the waterways assume an irregular shape nearing the parabolic shape. If the farm machinery has to cross the waterways, parabolic shape or trapezoidal shape with very flat side slopes are preferred.

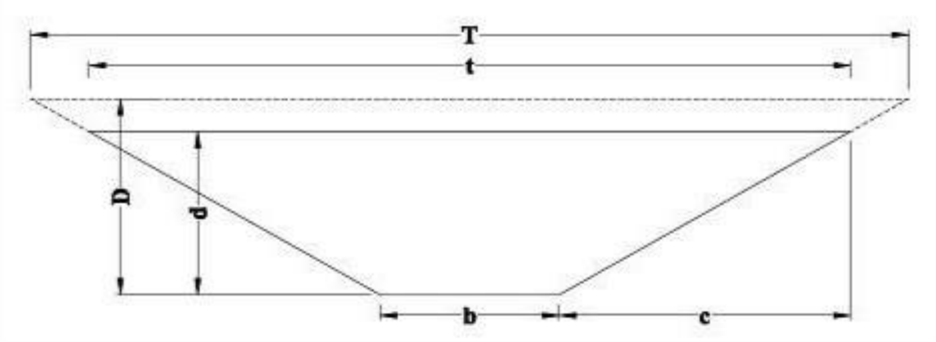


Table Design Dimensions for Trapezoidal Cross-section

Cross-sectional Area, a	Wetted perimeter, P	Hydraulic Radius, $R = \frac{a}{p}$	Top width
$bd + zd^2$ Where, $Z = c/d$	$b + 2d\sqrt{Z^2 + 1}$	$\frac{bd + zd^2}{b + 2d\sqrt{z^2 + 1}}$	$T = b + 2dz$ $T = b + 2Dz$

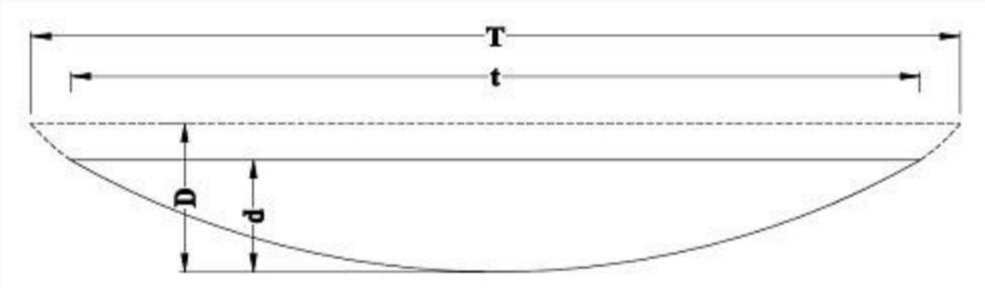


Fig. Parabolic Cross-section.

Table Design Dimensions for Parabolic Cross-Section

Cross-sectional Area, a	Wetted perimeter, P	Hydraulic Radius, $R = \frac{a}{p}$	Top width
$\frac{2}{3}td$	$t + \frac{8d^2}{3t}$	$\frac{t^2 \times d}{1.5t^2 + 4d^2}$ $\frac{2d}{3} approx$	$t = \frac{a}{0.67d}$ $T = t\left(\frac{D}{d}\right)^{\frac{1}{2}}$

Design of Cross-Section

The design of the cross-section is complete by using Equation 27.1 for finding the area required and Manning's formula is used for cross checking the velocity. A trial procedure is adopted. For required cross-sectional area, the dimensions of the channel section are assumed. Using hydraulic property of the assumed section, the average velocity of flow through the channel cross-section is calculated using the Manning's formula as below:

$$V = \frac{S^{1/2} R^{2/3}}{n} \tag{27.2}$$

where, V = velocity of flow in m/s; S = energy slope in m/m; R = hydraulic mean radius of the section in m and n = Manning's roughness coefficient.

The Manning's roughness coefficient is to be selected depending on the existing and proposed vegetation to be established in the bed of the channel. Velocity is not an independent parameter. It will depend on n which is already fixed according to vegetation, R which is a function of the channel geometry and slope S for uniform flow. Slope S has to be adjusted. If the existing land slope gives high velocity, alignment of the channel has to be changed to get the desired velocity.

Problem : Design a grassed waterway of parabolic shape to carry a flow of 2.6 m^3/s down a slope of 3 percent. The waterway has a good stand of grass and a velocity of 1.75 m/s can be allowed. Assume the value of n in Manning's formula as 0.04.

Solution: Using, Q = AV for a velocity of 1.75 m/s, a cross-section of 2.6/1.75 = 1.485 m2 (~1.5 m2) is needed. Assuming, t = 4 m, d = 60 cm.

$$A = \frac{2}{3}t \times d = \frac{2}{3}4 \times 0.6 = 1.6m^2$$

$$P = t + 8\frac{d^2}{3t} = 4 + 8\frac{(0.6)^2}{3 \times 4} = 4.24m$$

$$R = \frac{A}{P} = \frac{1.6}{4.24} = 0.377m$$

$$V = \frac{S^{1/2} R^{2/3}}{n} = \frac{(0.03)^{1/2} \times (0.377)^{2/3}}{0.04} = 2.26m/s$$

The velocity exceeds the permissible limit. Assuming a revised t = 6 m and d = 0.4 m

$$A = \frac{2}{3}t \times d = \frac{2}{3}4 \times 0.6 = 1.6m^2$$

$$P = t + 8\frac{d^2}{3t} = 6 + 8\frac{(0.4)^2}{3 \times 6} = 6.45m$$

$$V = \frac{S^{1/2} R^{2/3}}{n} = \frac{(0.03)^{1/2} \times (0.248)^{2/3}}{0.04} = 1.70m/s$$

The velocity is within the permissible limit.

Q = 1.6 × 1.7 = 2.72 m3/s

The carrying capacity (Q) of the waterway is more than the necessary. Hence, the design of waterway is satisfactory. A suitable freeboard to the depth is to be provided in the final dimensions.

EXERCISE - 7

Design of Contour Bunds

Contour Bunding is the creation of small bund across the slope of the land on a contour so that the long slope is slash into a series of small ones and each contour bund acts as a barrier to the flow of water, thus making the water to walk rather than run, at the same time impounding water against it for rising soil moisture. Contour bunds divide the length of the slope; reduce the volume of runoff water, and thus preventing or minimizing the soil erosion. Contour bunds are constructed in comparatively low rainfall areas, having an annual rainfall or less than 700 mm, particularly in areas having light textured soils. For undulating and flater lands having slopes from 2 to 6% contour bunding is accomplished, in red soils.

Location of contour bund:

Moderate slopes (up to 6%) with light or medium soil texture and less than 700 mm of rain per year.

Purpose of contour bund: -

To reduce soil erosion and to increase the amount of water the soil can hold.

Advantages of contour bund: - Simple to build. Bunds conserve topsoil and improve productivity. They keep water in the soil, allowing chemical fertilizers to be used effectively. They can be used both on cultivated and uncultivated land. Farmers can build contour bunds themselves without outside help.

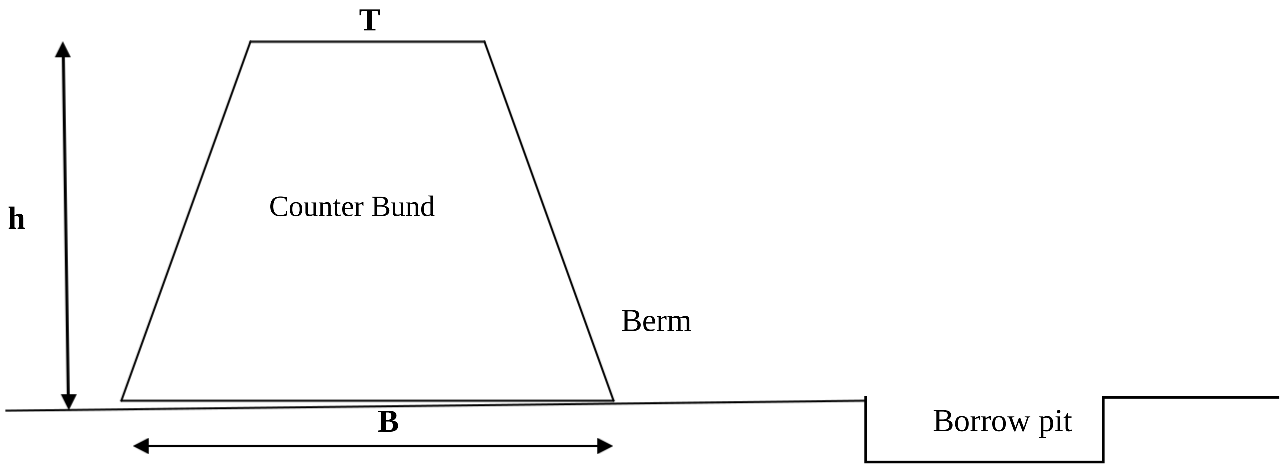
Limitations of contour bund: - The bunds take some land away from cultivation (though some types of crops can be grown on the bunds to stabilize them). May create impermanent water logging problems in heavy soil. May obstruct with the farm operations if the bunds are too close collectively. A lot of labour is needed to sustain and repair the bunds.

General principles and design of contour bund:

1. **Spacing of Contour bund**:

   Bund spacing is expressed as the vertical or the horizontal distance between subsequent points on two adjacent bunds. Horizontal spacing is useful in influential the row arrangement. Vertical distance is commonly known as the vertical interval or V. I. Bund spacing should not be so broad as to cause excessive soil erosion between adjacent bunds. Spacing may be increased or decreased 10 to 20% to suit local conditions.

Slope of land (%) vertical.	Interval (m) Approx	Horizontal distance (m)
0 to 1	**1.05**	**105**
1 to 1.5	**1.2**	**98**
1.5 to 2	**1.35**	**75**
2 to 3	**1.5**	**60**
3 to 4	**1.65**	**52**



2. **Bund length:**

   In general, 400 to 500m 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.

3. **Bund cross section**: The height of bund should provide adequate storage above the bund to handle the estimated runoff. In normal adequate practice is provided to take care of runoff from rains predictable in 10 year recurrence interval. The cross section area of the storage space required can be calculated by the following formula

Cross section area of storage space = [Runoff, cm] X [Bund horizontal interval in m] / 100

Design steps:

Vertical Interval between bunds (V.I)

$$VI= \{S/a + b\}\ 0.3$$

Where, S – land slope (%);

a and b are constants a = 3 and b =2 for medium and heavy rainfall zones

a = 2 and b =2 for low rainfall zones

Horizontal Spacing in between bunds (H.I)

$$HI = (VI/S) \times 100$$

Length of bund per hectare (L.B)

L. B. per ha = (100 S)/VI or 10000/H.I.

Depth of water impounding before the bund (h), $h = \{(D \times R)/500\}^{1/2}$

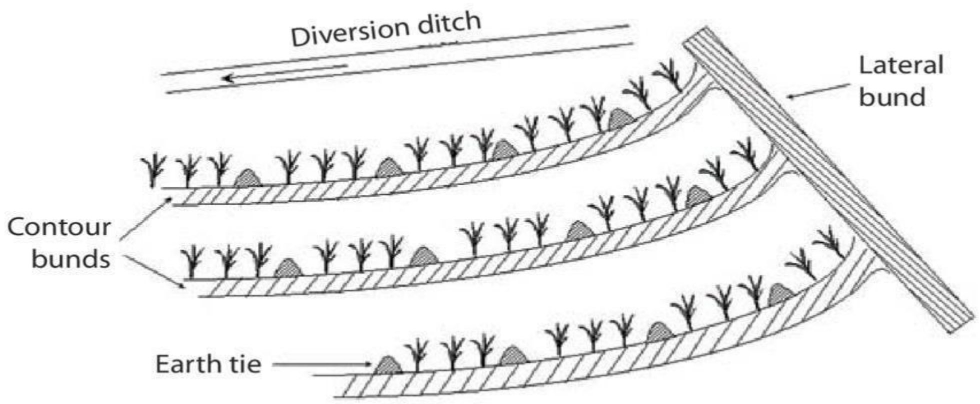
Where, D – vertical interval (m)

R – Maximum rainwater on area basis (mm)

Actual height of the bund = h + 20% of h as freeboard

Type of soil	Bottom width (m)	Top width (m)	Height (m)	Side slope
Gravel soil	1.2	0.3	0.6	0.75:1
Red soil	2.1	0.3	0.6	1.5: 1
Shallow to Medium Black Soil	2.4	0.45	0.75	1.3: 1
Deep Soil	3.3	0.6	0.675	2: 1

By knowing the cross section area of the bund, the volume of earthwork per hectare and the cost of earthwork per hectare can be determined.



Salient features:

- Bunding is a valuable moisture conservation measure in dry land.
- It is appropriate for lesser rainfall areas and the slope is< 1%.
- The lands are divided into small compartments with the dimension of 8 x 5 m.
- Store the rainfall 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 will overcome the disadvantages of contour bunding.

Exercise:

On a 3 per cent land slope calculate the horizontal spacing of bunds in medium rainfall zone and the length of bunds per hectare.

$VI = \{S/a + b\}\ 0.3$, VI = $\{3/3 + 2\}\ 0.3$ = 0.9 m

Horizontal spacing = 0.9 x (100/3) = 30 meters

Length of bund per ha = 10000/30 = 333 meters

EXERCISE – 8

Design of Graded Bunds

Graded bund

Graded bunds are constructed in medium to high rainfall areas having an annual rainfall of 600 mm and above and in soils having poor permeability (or) those having crust forming tendency (black soils), and in the lands having slopes between 2% and 6%.These bunds are provided with a channel if essential. Uniformly graded bunds are suitable where the length of bund is not as much of and the discharge behind the bund or in the channel less. Variable graded bunds are appropriate when the length of bunds and discharge are more. Variable grades are provided in different sections of the bund. For uniform graded bund, a grade from 0.1% to a maximum of 0.4% is adopted and for variable graded bund the grade will vary with the length of the bund. The required capacity of the channel can be resolute by using the Rational Method.

Function:

- These terraces act primarily as drainage channel to standardize and perform runoff at non erosive velocity.
- To make the runoff water to trickle rather than to rush out.

For graded bunds, the horizontal, length per hectare and cost estimation are similar as that of contour bunding

Design of Graded bund

Graded bund specifications

Type of soil	Bottom width (m)	Top width (m)	Height (m)	Side slope
Shallow soil	1.1	0.3	0.4	1:1
Red and alluvial soil	1.5	0.5	0.5	1:1
Heavy soil	2.1	0.5	0.5	1.5:1

For graded bunds, the horizontal, length per hectare and cost estimation are similar as that of contour bunding.

EXERCISE – 9

Study of Terraces

DESIGN OF BENCH TERRACING SYSTEM

A terrace is an embankment or ridge of earth constructed across a slope to control runoff and minimize soil erosion. Terracing is an agricultural practice for collecting surface runoff water thus increasing penetration and controlling water erosion known from an ancient history and used to transform landscape to steeped agro-systems in many mountainous regions.

Features of terracing:

- These are constructed across the slope to intercept the surface runoff and convey it to a suitable outlet, at non erosive velocity.
- They reduce the length of slope by splitting the slope length in different parts.
- The terracing practice is adopted for soil and water conservation in that area where land slope is greater than 10%; soil is more erodible and prevails high rainfall intensity.
- Terraces not only control the soil loss by sheet flow, but also play an important role in trapping the splashed soil particles.
- This practice is not possible, particularly on those hill sloped areas, where soil depth is not sufficient.

Classification of terraces:

- **Diversion terraces** : Used for intercepting the overland flow from hilly slope and channel it across the slope to a appropriate outlet i.e. grassed water ways etc. built at slight down slope grade from contour. These are constructed in high rainfall area.
- **Magnum type**: It is constructed by taking the soil from both side of the embankment
- **Nichols type**: formed by taking the soil from side of up slope of the embankment, only.
- **Broad based type**: This terrace is constructed with embankment and channel occupying a width of about 15 m.
- **Narrow based type**: These terraces are only 3 to 4 m wide; the banks have steeper slop which cannot be cultivated. For cultivation to make possible, the bank should not

exceed 140 slop for use of small machines, otherwise it should be 8.50 for large size machines

- **Retention terraces**: these are levelled terrace, used particularly when water is required to conserve by making storage on hill sides. These are constructed in low rainfall areas.
- **Bench terrace**: Such types of terrace are constructed in form of alternating series of shelves and risers, used to develop the steep slopes. These are constructed in medium rainfall areas.

Bench Terrace:

A bench terrace is shelf like embankment of earth with a level or nearly level top and a step or vertical downhill face constructed along the contour of sloping land.

Bench terracing consists of transforming moderately steep land into a series of levee or nearly level strips or steps running across the slope. The strips are divided by almost vertical risers. The risers if sloping may be of earth construction. Steep risers are supported by masonry [stones]. Bench terracing is adopted only on slopes steeper than 15% [for more than 8%] and where soil conditions are favourable. The use of bench traces retard erosion losses and makes cropping operations on these slopes probable and safe.

Types of bench Terraces

A. Based on slope	B.Based on use /application
1] Level and table top	1]Hill type
2] Sloping inwards	2]Irrigated type
3] Sloping outwards	3]Orchard type
4] Puertorican or California type	

A. Classification based on slope

1. Table top bench terrace:

Table top bench terrace is suitable for areas receiving medium rainfall which is evenly distributed and which have highly permeable and deep soils .in paddy fields it may be used for slopes as mild as 1% and used where irrigation facilities are available.

2. Sloping in words bench terrace:

In heavy rainfall areas, bench terraces of sloping inwards type are more effective. It prevents impounding of water and useful for crops susceptible to water logging.

3. Sloping outwards bench terrace:

Bench terraces sloping outwards are effective only in low rainfall areas whit a permeable soil of medium depth at lower ends graded channels are provided for safe disposal of runoff

4. Puertorican Type:

In this type of terrace, the soil is excavated little during every ploughing and gradually developing bench by pushing the soil downhill against a mechanical of vegetative barrier. Mechanical or vegetative barrier is established across the land at suitable interval and the terrace is developed gradually over the years, by pushing soil downhill and subsequent natural levelling.

B] Classification based on use:

Depending upon the purpose for which they are used, bench terraces are classified as follows:

1. Hill type Bench Terraces: It is used for hilly areas with a reverse grade towards the hill.

2. Irrigated Bench Terraces: Level benches are adopted under irrigated conditions. The level table top terraces are referred to as irrigated bench Terries.

3. Orchard Bench Terraces: Narrow width terraces [about 1 mm] for individual trees are prepared in this type. These are also referred as intermittent terraces and step terraces. The conversion of land into bench terraces over a period of time is referred as gradual bench terracing.

EXERCISE – 10

Problem of Wind Erosion

Wind erosion is a serious environmental problem. It is in no way less severe than water erosion. High velocity winds strike the bare lands (having no cover), with increasing force. Fine, loose and light soil particles blown from the land surface are taken miles and miles away and thereby, causing a great damage to the crop productivity. It is a common phenomenon occurring mostly in flat, bare areas; dry, sandy soils; or anywhere the soil is loose, dry and finely granulated and where high velocity wind blows. Wind erosion, in India, is commonly observed in arid and semi-arid areas where the precipitation is inadequate, e.g. Rajasthan and some parts of Gujarat, Punjab and Haryana.

Factors Affecting Wind Erosion

Climate, soil and vegetation are the major factors affecting wind erosion at any particular location. The climatic factors that affect the wind erosion are the characteristics of wind itself (velocity and direction) in addition to the precipitation, humidity and temperature. Soil moisture conditions, texture, structure, density of particles, organic matter content are the soil characteristics that influence erosion by wind. Soil movement is initiated as a result of wind forces exerted against the surface of the ground. For each specific soil type and surface condition there is a minimum velocity required to move soil particles. This is called the threshold velocity. Once this velocity is reached, the quantity of soil moved is dependent upon the particle size, the cloddiness of particles, and wind velocity itself. Surface features like vegetation or other artificial cover (mulching etc) have the protective effect on wind erosion problem as surface cover increases the roughness over the land surface and thus reduces the erosive wind force on the land surface.

Mechanics of Wind Erosion

The overall occurrence of wind erosion could be described in three distinct phases. These are:

1. Initiation of Movement
2. Transportation
3. Deposition.

Movement of soil particles is caused by wind forces exerted against or parallel to the ground surface. The erosive wind is turbulent at all heights except very close to the surface. The lowest velocity occurs close to the ground and increases in proportion to the logarithm of the height above the surface. Soil particles or other projections on the surface absorb most of the force exerted by the wind on the surface. However, if the soil particles are lighter and loose, wind may lift them from the surface in the initiation process. A minimum threshold velocity (wind) is required to initiate the movement of soil particles. Thus, the threshold velocity is the minimum wind velocity needed to initiate the movement of soil particles. The magnitude of the threshold velocity is not fixed for all places and conditions but it varies with the soil conditions and nature of the ground surface. For example, for the most erodible soils of particle size about 0.1 mm; the required threshold velocity is 16 km/h at a height of 30 cm above the ground.

Initiation of Movement: The soil particles are first detached from their place by the impact and cutting action of wind. These detached particles are then ready for movement by the wind forces. After this initiation of movement, soil particles are moved or transported by distinct mechanisms.

Transportation: The transportation of the soil particles are of three distinct types and occur depending upon size of the soil particles. Suspension, saltation, and surface creep are the three types of soil movement or transport which occur during wind erosion. While soil can be blown away at virtually any height, the majority (over 93%) of soil movement/transportation takes place at or within one meter height from land surface.

Suspension: It occurs when very fine dirt and dust particles are lifted into the atmosphere. They can be thrown into the air through impact with other particles or by the wind itself. These particles can be carried very high and be transported over very long distances in the atmosphere by the winds. Soil moved by suspension is the most spectacular and easiest to recognize among the three forms of movement. The soil particles of less than 0.1 mm size are subjected to suspension and around 3 to 40 % of soil weights are carried by the suspension method of soil transport under the wind erosion.

Saltation: The major fraction of soil moved by the wind is through the process of saltation. Saltation movement is caused by the pressure of the wind on soil particles as well as by the collision of a particle with other particles. Soil particles (0.1 to 0.5 mm) move in a series of bounces and/or jumps. Fine soil particles are lifted into the air by the wind and drift horizontally across the surface increasing in velocity as they move. Soil particles moved in the process of saltation can cause severe damage to the soil surface and vegetation. They travel approximately four times longer in distance than in height. When they strike the surface again they either bounce back into the air or knock other soil particles from the soil mass into the air. Depending on soil type, about 50 to 75% of the total weight of soil is carried in saltation. The height of the jump varies with the size and density of the soil particles, the roughness of the soil surface, and the velocity of the wind.

Surface Creep: The large particles which are too heavy to be lifted into the air are moved through a process called surface creep. In this process, the particles are rolled across the surface after coming into contact with the soil particles in saltation. In this process the largest of the erosive particles having diameters between 0.5 to 2 mm are transported and around 5 to 25% of the total soil weights are carried in this fashion. Overall, the mass of soil moved by wind is influenced primarily by particle size, gradation of particles, wind velocity and the distance along the eroding area. Winds being variable in velocity and direction produce eddies and cross-currents that lift and transport soil. The amount of soil moved/transported depends on the median particles (soil) diameter and the difference in threshold and actual wind velocity. The mass of soil moved can be related to the influencing parameters by the following equation:

Quantity of soil moved $(V - V^{th})^3 / D^{0.5}$

Where V = wind velocity, V^{th} = threshold velocity, and D = particle diameter.

Deposition: Deposition of soil particles occurs when the gravitational force is greater than the forces holding the particle in the air. This generally happens when there is a decrease in the wind velocity caused by vegetative or other physical barriers like ditches or benches. Raindrops may also take dust out of air.

PRACTICAL - 11

Identification of Different Types of Erosion as per Field Visit

OBJECTIVE: Identification of different types of erosion as per field visit.

Sheet erosion

Sheet erosion is the uniform removal of soil in thin layers by the forces of raindrops and overland flow. It can be a very effective erosive process because it can cover large areas of sloping land and go unnoticed for quite some time.

Rill erosion

Rill erosion is the removal of soil by concentrated water running through little streamlets, or head cuts. Detachment in a rill occurs if the sediment in the flow is below the amount the load can transport and if the flow exceeds the soil's resistance to detachment.

Gully erosion

Gully erosion is the removal of soil along drainage lines by surface water runoff. Once started, gullies will continue to move by headword erosion or by slumping of the side walls unless steps are taken to stabilize the disturbance.

Stream bank erosion

Rivers and streams are products of their catchments. They are frequently referred to as dynamic systems which mean they are in a constant state of change. The factors controlling river and stream formation are composite and interrelated.

These factors comprise the amount and rate of supply of water and sediment into stream systems, catchment geology and the type and extent of vegetation in the catchment. As these factors change over time, river systems respond by altering their shape, form and/or location. In stable streams the rate of these changes is generally slow and imperceptible.

Exercise: Identification of different types of erosion observed during field visit

- Date of visit-
- Location of visit-
- Observations-

SN	Name of Erosion	Land slope	Soil Type	Soil depth	Location of affected area	Area affected (approx.) in ha	Suggested control measures	Remarks
1	Sheet erosion							
2	Rill erosion							
3	Gully Erosion							Width= Depth=
4	Stream Bank Erosion							
5	Any other							