SWC 311 - SOIL CONSERVATION AND IRRIGATION ENGINEERING (1999) 1+1

THEORY

Surveying and leveling – Chain, compass and plane table survey – Leveling – inverted leveling – Land measurement and computation of area. Soil erosion – Causes of soil erosion – Geologic and accelerated erosion – Water erosion – Splash, sheet, rill, gully and stream bank erosion – Ravines – Land slides - Erosivity and Erodibility – Universal soil loss equation – Evil effects of erosion. Mechanics of wind erosion – Factors influencing wind erosion – Suspension – Saltation – Surface creep – Sand dunes – Shifting cultivation.

Conservation measures for Agricultural Lands – Biological measures – contour cultivation – strip cropping – cropping systems - Structural measures – contour bund – graded bund – Broad beds and furrows, basin listing – Random tie ridging - Structural measures for Hill slopes – Contour trench – Bench terrace – Contour stone wall – Wind breaks and shelter belts - Gully control structures – water harvesting - Watershed management.

Irrigation Engineering – measurement of flow in open channels – Velocity area method – Rectangular weir – Cippoletti weir – V notch – Orifices – Parshall flume - Conveyance of irrigation water – canal lining – underground pipe line system – Surface irrigation methods – Borders, furrows and check basins – Drip and sprinkler irrigation – Duty of water – Irrigation efficiencies – Water conveyance, application, strorage and distribution efficiencies - Agricultural drainage – Surface drainage systems – Drainage Coefficient – Wells and pumps.

PRACTICAL

Study and use of survey instruments – Chain, compass and plane table surveying - Study of leveling instrument - Computation of slopes – Visit to erosion affected sites - Computation of soil loss by universal soil loss equation –Design of contour and graded bund – Volume and cost estimation of bunds, trenches and stone walls. Problems on water measurements – duty of water, water requirements, irrigation efficiencies and drainage.

LECTURE SCHEDULE

THEORY

1. Introduction – Land surveying – Uses in agriculture
2. Chain, cross staff and compass surveying – Computation of angles.
3. Plane table surveying – radiation, intersection and traversing
4. Dumpy level – setting observation and tabulation of readings – computation of land slope – difference in elevation
5. Types of erosion - Causes of soil erosion – geological and accelerated erosion
6. Water erosion – splash, sheet, rill and steam bank erosion – Ravines -Land slides

7. Erosivity and Erodibility – Universal soil loss equation - Evil effects of erosion - Mechanics of wind erosion – Factors influencing wind erosion – Sand dunes - shifting cultivation
8. Conservation measures for Agricultural lands – Biological measures – contour cultivation – strip cropping – cropping system.
9. Mid Semester Examination
10. Structural measures – Contour bund –
11. Graded bund - Broad beds and furrows, basin listing – Random tie ridging - Structural measures for hill slopes
12. Contour trench – Bench terrace – contour stone wall
13. Wind breaks and shelter belts - Gully control structures water harvesting – watershed management.
14. Irrigation Engineering – measurement of flow in open channels – velocity area method – rectangular weir, Cippoletti weir – V notch
15. Orifices - Parshall flume - Conveyance of irrigation water – canal lining – underground pipeline system.
16. Surface irrigation methods – Border, furrows and check basins - Drip and Sprinkler irrigation - Duty of water – Irrigation efficiencies – water conveyance, application, storage and distribution efficiencies.
17. Agricultural drainage – surface drainage systems – drainage coefficient – Wells and pumps.

PRACTICAL

1. Study of survey instruments – chains – compass – plane table – dumpy level.
2. Chains and cross staff surveying – Linear measurement – plotting and finding areas
3. Compass survey – observation of bearings – computation of angles
4. Compass – Traversing
5. Plane table surveying
6. Leveling – fly leveling - Determination of difference in elevation
7. Computation of land slopes
8. Problems on leveling, compass surveying
9. Computation of soil loss by universal soil loss equation
10. Design of contour bund and graded bund
11. Volume and cost estimation of erosion control structure, bunds, trenches and stone walls
12. Visit to erosion control works areas

13. Layout of Sprinkler and drip systems
14. Problems on water measurement, duty of water
15. Problems on irrigation efficiencies
16. Problems on water requirement – agricultural drainage
17. Practical examination

REFERENCE BOOKS

1. Gurmail Singh, 1982, A manual on Soil and Water conservation, ICAR Publication, New Delhi.
2. Michael, A.M. 1977, Irrigation - Theory and Practice, Vikas Publishing house Pvt Ltd, New Delhi.
3. Suresh, R. 1982. Soil and water conservation Engineering, Standard Publishers, New Delhi.

SURVEYING

Surveying is the art of making measurements that will determine the relative position of points on the surface of the earth in order that the shape and extent of any portion of the earth surface may be ascertained and delineated on a map or plan. Surveying includes determination of horizontal distances, differences in elevation, direction, angles, locations, areas and volumes on or near the surface of the earth. It involves the measurement and recording of size and shape of the area on the earth surface.

Primary divisions of surveying

1.Geodetic surveying

In geodetic or Trigonometrical surveying the curvature of land is taken in to account, since the large distance and area is covered. The objective is to determine the precise position on the surface of the earth of a system of widely distant points.

2. Plane surveying

The curvature of the earth is not taken in to account as the survey extent only to small areas. The earth surface is considered as a plane, the line joints between two points as a straight line and all angles are plane angles. The degree of accuracy required in this type of surveying is comparatively low.

Agricultural surveying is simple plane surveying and includes, laying out contour and terrace lines for preservation, drainage lines, profile lines for land leveling and ditch lines for irrigation. Establishing and preparing maps of property, computing field and farm areas and for laying out buildings and roads.

Classification of survey

Survey can be classified in many ways

I. Based on nature of field of survey

a) Land survey b) Marine or Navigation survey c) Astronomical survey

II. Based on Object of Survey

a) Archeological survey b) Geological survey

c) Mine survey d) Military survey

III. Based on method employed in survey

a) Triangular survey b) Traverse survey

IV. Based on instruments used

a) Chain survey b) Theodalite survey c) Tacheometric survey
d) Compass survey e) Plane table survey f)Photography and aerial survey g) Remote sensing h) Levelling

Plan or map: the primary object is the preparation of plan or map. The results of survey when plotted and drawn on a paper constitute a plan. The area plan is therefore the representation of some scale of the ground and the object upon it as projected on a horizontal plane, which is represented by the plane of the paper upon which the plan is drawn. The representation is called map when its scale is small.

Representative fraction (R.F): It is the ratio between any given length on the drawing and the corresponding length on the ground. Scales on the maps are often represented by R.F. One advantage of using R.F is that it is independent of units of measurement.

Example: If 1 cm in the drawing represent 2.5 km on the ground, R.F= 1/250000

Measurement of distance

In plane surveying all distances are measured either in a vertical or a horizontal plane. Horizontal distances are measured by chains, tapes or by pacing. Vertical distances and different in elevation are measured by leveling instrument.

Methods of linear measurement

Pacing or stepping

When approximate distances between two points are required, the pacing is the most rapid method in which the distance between two points is measured by foot steps i.e. by counting the number of walking steps of a man. The walking step of a man is considered as 80 cm.

Passometer

It is a pocket instrument resembling a watch in size and appearance and automatically records the number of paces taken in pacing a given distance. It should be carried vertically. It is being operated by the motion of the body.

Odometer

It can be attached to the wheel of any vehicle such as a cart, bicycle etc. and registers the number of revolutions of the wheel. Knowing the circumference of the wheel the distance traveled may be obtained by multiplying the number of revolutions by the circumference of the wheel.

Speedometer

This is used in automobiles for recording distances

Perambulator

It is wheel fitted with a fork and handle. The wheel is graduated and shows a distance per revolution. It is wheeled along the line whose length is desired. There is a dial which records the number of revolution. Thus the distance can be ascertained.

Chaining

This is an accurate and common method of measuring distance. In this method, the distances are directly measured in the field by chin or tape. Two chain men are normally required to measure with chain and one who goes ahead with chain is called leader or head chain men and one who follows is called rear chain men.

Types of chains

Chains are made up of thick galvanized iron wire and consist of 100 – 150 links. The end of each link are bend in to rings and connected with rings of next piece by two or three oval ring which afford flexibility to the chain. The length of a link with the exception of these at the handles is the distance between the centers of the two consecutive middle rings.

Metric chains: They are usually made in length of 30 or 20 meters and each link is 20 cm long. Tags are fixed at every 2 or 5 m length and small brass rings are provided at every meter except where tags are attached.

Engineer’s chain: This is 100 feet long and is divided in to 100 links, each link 1 foot long. Distances measured with Engineers chains are recorded in chain and feet. At every 10^{th} link in the chain is marked with a tag. The tags at 10 links from each end have one tooth, at 20 links 2 teeth, at 30 links 3 teeth like wise. The tag at the centre of chain is circular.

Gunter's chain: It is 66 feet long and is divided in to 100 links each of 0.66 feet. This is commonly used in land surveying where FPS units are used for measurement.

10 Gunter's chain : 1 furlong 80 Gunter's chain : 1 mile

Tapes: When greater accuracy is required in measurement and the ground to be surveyed is not very rough, then tapes can be used. Commonly available lengths are 1, 2, 5, 7 ½, 10, 15, 30 and 50 meters. For surveying mostly 30 m tape is used. Three types of tapes, namely, the linen or cloth tape, metallic tape and steel tape are available. The linen tape and metallic tape are not suitable for very precise measurement, only used for taking subsidiary measurement. Steel tape is made up of steel ribbon and is very accurate.

Errors in Surveying

a) Instrument error: Due to some defects in the measuring instruments
b) Personal error: Due to personal skill of surveyor
c) Natural error: Due to the natural changes like temperature, humidity, gravity etc. resulting in changes in an accuracy of the instruments.

Errors in length due to incorrect chain

Mostly in chaining the errors are due to human. Miscounting of arrows or misreading of numbers cause large errors. Deviations from a straight line giving too higher reading may arise from not sighting in properly or not ranging where needed or due to failure in correcting for slop or maybe due to sag-in-tape or chain in improper tension. Inaccuracy in the equipment will also cause error. The length of chain should be tested frequently. Measurements taken with a chain which is longer or shorter than standard length can be corrected by calculation using the formula.

$$\text{Correct distance} = \frac{L'}{L} \times \text{Observed distance} = \frac{L + e}{L} \times \text{Observed distance}$$

e = error in length

L' = Incorrect length of chain/tape

= L+ e if the chain is too long (longer than standard length L)

= L – e if the chain is too short (shorter than standard length L)

Example 1

The length of a chain was found to be 180 m when measured with a 20 m chain. If the chain was 7 cm too long, find the correct length of the line.

Answer

L= 20 m

L'= 20 + 0.07 = 20.07 m

Correct length of line = (20.07 / 20) x 180 = 180.63 m

Computation of area and volume using incorrect chain length

True or correct area = $[L' / L]^2$ x measured area

True or correct Volume = $[L' / L]^3$ x measured volume

Cross Staff Survey

The area is divided in to right angles and trapezium, and bases and perpendiculars are measured. Chain and cross staff are the principal instruments in the work. Two chains are usually provided for measuring the chain line and for measuring offsets. The cross staff is used to setup the perpendicular directions for offsets.

LAND MEASUREMENT AND COMPUTATION OF AREA

I. Filed with straight boundary

During the survey work, the entire area is divided in to some geometrical figure, such as triangles, rectangles, squares and trapeziums and then the area is calculated as follows

Area of Triangle = $[s (s-a) (s-b) (s-c)]^{0.5}$

Where a, b and c are the side lengths and $s = (a + b + c) / 2$

Area of Triangle = $(b \times h) / 2$

Where b= base and h= altitude

Area of rectangle = $a \times b$

Where a and b are the sides

Area of square = a^2

Where a is the side of the square

Area of Trapezium = $\frac{1}{2} (a + b) \times h$

Where a and b are the parallel sides, and h is the perpendicular distance between them

II. Field with curved boundary

If a field is bounded on one side by a straight line and other side by a curved boundary any one of the following methods will be useful for calculating area. All these methods are suitable for narrow strips such as grounds occupied by a railway or road. A base line is taken through the straight line and divided in to a number of equal parts. The ordinate at each of the point of division are drawn and scaled.

a. Mid-ordinate rule

The whole area is divided in to number of division, the mid ordinates are measured for each division and then area is calculated by the formula

Area $= (h_1 + h_2 + h_3 + \ldots + h_n) \times (l / n)$

$= (h_1 + h_2 + h_3 + \ldots + h_n) \times d$

Here n is the number of equal parts into which the base is divided,

l is the total length of the line

d is the common distance between the ordinates $h_1, h_2, h_3, \ldots h_n$

b. Average ordinate rule

In this method, instead of the ordinate at the mid point of the division, ordinates ($O_1, O_2, O_3, ... O_{n+1}$) are drawn at each point of division. The average of these ordinates multiplied by the length (l) of the base line gives the required area.

$$\text{Area} = [(O_1 + O_2 + O_3 + ... + O_{n+1}) / (n+1)] \times l$$

c. Trapezoidal rule

The area is divided in to number of trapezoids and the following rule is applied. The sum of the first and last ordinates plus twice the sum of the intermediate ordinates multiplied by half the common distance between the ordinates gives the required area.

$$\text{Area} = (d/2) \times [(O_1 + O_{n+1}) + 2\{O_2 + O_3 + ... + O_n\}]$$

If the base line cuts the boundary at one end or at the both ends, O_0 or O_{n+1} or both are zero.

d. Simpson's rule

The rule assumes that the short lengths of the boundaries between the ordinates are parabolic areas and the rule is therefore also called as parabolic rule. To the sum of the first and last ordinates is added, twice the sum of the remaining odd ordinates and four times the sum of all the even ordinates. This total sum multiplied by one third the common distance between the ordinates gives the required area.

$$\text{Area} = (d/3) \times [(O_1 + O_{n+1}) + 4\{O_2 + O_4 + O_6 + ... + O_n\} + 2\{O_3 + O_5 + O_7 + ... + O_{n-1}\}]$$

The rule requires an even number of division of the area i.e. an odd number of ordinates.

Example 2

The following perpendicular offsets were taken at 10 m intervals from a survey line to an irregular boundary line.

3.82, 4.37, 6.82, 5.26, 7.59, 8.90, 9.52, 8.42 and 6.43 m

Calculate the area (in m^2) enclosed between the survey line and irregular boundary line, by i) the average ordinate rule ii) the trapezoidal rule and iii) the Simpson's rule

Answer

i) By the average ordinate rule

Interval between the offsets d = 10 m
Number of intervals n= 8
Number of offsets (n+1) = 9
Length of survey line n x d = 80 m

Sum of all the ordinates = $O_1 + O_2 + O_3 + ... + O_9$ = 61.13 m

Area = (61.13 x 80) / 9 = 543.38 m^2

ii) By the trapezoidal rule

Area = (10 / 2) x [(3.82 + 6.43) + 2{4.37 + 6.82 + 5.26 + 7.59 + 8.90 + 9.52 + 8.42}]

= 560.05 m^2

ii) By the Simpson's rule

Area = (10 / 3) x [(3.82 + 6.43) + 4{4.37 + 5.26 + 8.90 + 8.42} + 2{6.82 + 7.59 + 9.52}]

= 553.03 m^2

Example 3

A series of offsets were taken from chain line to a curved boundary line at intervals of 10 m in the following order

0, 2.82, 3.96, 6.42, 8.61, 8.90, 5.25, 0 m

Calculate the area (in m^2) enclosed between the survey line and irregular boundary line, by i) the average ordinate rule ii) the trapezoidal rule and iii) the Simpson's rule

i) By the average ordinate rule

d= 10 m, n= 7, l= 70 m, n+1= 8

Area = {(0 + 2.82 + 3.96 + 6.42 + 8.61 + 8.90 + 5.25 + 0) / 8} x 70

= 314.27 m^2

ii) By the trapezoidal rule

Area = (10 / 2) x [(0 + 0) + 2{2.82 + 3.96 + 6.42 + 8.61+ 8.90 + 5.25}]

= 359.60 m^2

ii) By the Simpson's rule

Area = (10 / 3) x [(0 + 5.25) + 4{2.82 + 6.42 + 8.90} + 2{3.96 + 8.61}] + (10 / 2) x (5.25 + 0)

= 343.17 + 26.25 = 369.42 m^2

Offsets at irregular intervals

Area = $\{(d_1/2)*(h_1+h_2) + (d_2/2)*(h_2+h_3) + (d_3/2)*(h_3+h_4) + ... + (d_n/2)*(h_n+h_{n+1})\}$

Example 4

The following perpendicular offsets were taken from a chain line to a hedge

Chainage (m)	0	6.2	15.4	27.2	40.6
Offset (m)	6.52	7.34	4.84	5.26	8.36

Calculate the area (in m^2) enclosed between the survey line and irregular boundary line

Answer

Area = {(6.2 / 2) x (6.52 + 7.34) + (9.2 / 2) x (7.34 + 4.84) + (11.8 / 2) x (4.84 + 5.26) + (13.4 / 2) x (5.26 + 8.36)} = 249.48 m^2

CONTOURING

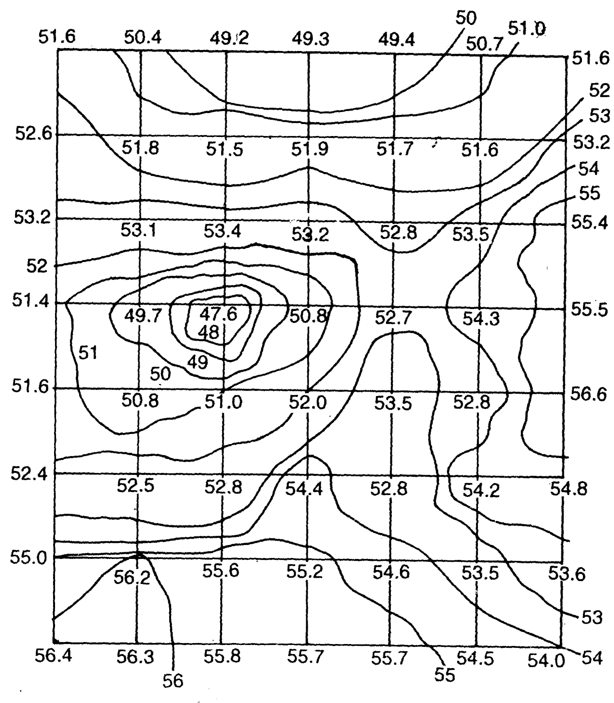
The contour line may be defined as a line joining the points of equal elevations. The contour lines of an area are presented in a map known as contour map or topographic map. The constant vertical distance between two consecutive contour lines is called the contour intervals.

Characteristics of contour lines

1. All points in contour line have the same elevation.
2. Widely spaced contour lines indicate a flat ground and closely spaced contour lines indicate steep ground
3. A series of closed contours with the higher values inside indicate a summit or hill
4. A series of closed contours with the higher values outside indicate a depression
5. Contour lines cannot cross one another or merge on the map except in case of an over hanging cliff

Use of contours

1. By inspection of a contour map, the characters of the terrain is obtained, whether it is flat or undulating, etc.
2. Contour map is very useful for taking up land leveling works and computation of earth work is also possible.
3. With the help of contour map, suitable site for reservoirs, canal, drainage channels, road, railways etc. can be selected.
4. Contour maps are essential for taking up any soil conservation works like terracing, bunding, construction of structures and spillways.
5. From the contour map of agricultural land, most suitable methods of irrigation for a particular crop can be decided



Interpolation method of contouring

This method is widely used, specially for large areas as it is cheap, quick and less tedious. In this method spot levels are taken along a series of lines laid out over the area. Their positions are plotted on the map and contours are drawn by interpolation. The method is also known as contouring by spot levels. Interpolation of the contours is the process of spacing the contours proportionally between the plotted ground points. During the interpolation, the ground between any two spot levels is assumed to be uniformly sloping.

EROSION

Soil erosion is the detachment or transportation of soil particle from one place to another due to action of wind, water-in-motion or by the beating action of the rain drops. Erosion may be broadly classified in to two groups.

a) Geological erosion

b) Accelerated erosion

Geological Erosion

It represents erosion where land is in natural, undisturbed environmental condition under the cover of vegetation. Geological erosion takes place as a result of action of water, wind, gravity and glaciers. The soil loss in this erosion is compensated by soil forming process by natural weathering.

Accelerated erosion

When vegetation is removed, the land is put under cultivation, the soil gets disturbed. i.e. the natural equilibrium between soil bindings is removed. It is also termed as man-made erosion. The soil loss in this erosion is faster than soil forming process by natural weathering.

Soil erosion is the result of Erosivity, Erodability, Detachability and Transportability.

Erosivity: It is the ability of rainfall to cause erosion. Physical characters of reference are intensity, amount and distribution of rain and size of rain drop.

Erodability : Erodability is the vulnerability or susceptibility of the soil to get eroded. It depends upon the physical characteristics and management of soil.

Detachability: It refers to the case where the soil particles are loosened by the action of wind or water. Transportability refers to where the detachable soil particles are transported by velocity of water and wind.

Extension of erosion in India: It is estimated that out of total geographical area of 328 m.ha, about 175 m.ha are affected seriously by water and wind erosion. Out of 175 m.ha 150 m.ha are affected due to shifting cultivation and 25 m.ha due to erosion in wastelands. About 6,000 m.tonnes of soil are eroded every year from about 80 m.ha of cultivated lands, loosing about 84 m.tonnes of nutrients.

FACTORS RESPONSIBLE FOR EROSION

1. Excessive deforestation

   Valuable forest trees are destroyed and due to this erosion are stimulated.

2. Improper agricultural practices

   Erosion is more if slope is more. If cultivation is done along the slope erosion will occur, hence cultivation should take along contours or across the slope due to which water flow is intercepted and erosion is stopped.

3. Over grazing

   Grass forms a cover and helps in prevention of erosion. In barren soils splash of rainfall occurs and soil is displaced. Due to overgrazing, field is subjected to severe erosion.

Evil effects of erosion

1) Loss of productive or fertile soil
2) Deposition of sand on productive land
3) Silting of lakes and reservoirs
4) Lowering of ground water table
5) Fragmentation of land

FACTORS INFLUENCING WATER EROSION

Major factors are climate, topography, vegetation and soil. This is represented as

$$E=f(C,T,V,S)$$

Climate (C) : Climatic factors include rainfall, temperature, wind, relative humidity and solar radiation. Rainfall is the main detaching agent. The impact of raindrops has a pronounced effect on erosion. The raindrops detach the particles and make them available for transport.

Topography (T): Degree and length of topography are two main factors. The velocity of runoff is mainly influenced by topography.

Vegetation (V): The effects of vegetation for erosion are

i. Interception of rainfall: A part of the rainfall intercepted by the canopy vegetation never reaches the soil but it is evaporated directly. This part of rainfall does not contribute with the run-off and thereby minimizes the dispersion of soil.

ii. Decrease in runoff velocities : Any vegetation cover is an hindrance to runoff water. A well distributed, close growing vegetation not only slows the water which travels down the slope but also tends to prevent the concentration of water. Hence the erosive capacity of runoff is minimized.

iii. Root effects: The binding effect of the root system binds the surface layer of the soil aggregates and increases its resistance to erosion. When the root die, decay and increases pore space leads to absorption of water.

iv. Biological influences: The soil fauna are most active in soils having ample vegetative cover. The soil under a thick forest cover is permeated with earthworms and beetles. These channels increase the permeability of the soil, in addition increase the soil aeration which provides a better environment for the activity of beneficial bacteria.

v. Transpiration effects: Vegetation increases the storage capacity of soil by way of transpiration of large quantity of moisture from the soil

Soil (S) : The physical properties of soil that influence soil erosion includes structure, texture, organic matter, moisture content, compactness as well as chemical and biological characteristics of soil.

DIFFERENT FORMS OF WATER EROSION

1. Splash / rain drop erosion: It results from soil splash caused by the impact of falling raindrops. If raindrops strikes on the land covered with thick blanket of vegetation the drop breaks into a spray of clear water which slowly finds its way into soil pores. If the rain drop strikes bare soil considerable splashing occurs. These splashes gradually remove fine materials from soil and leave the land infertile by leaving behind sand and gravel particles. The raindrop sometimes fall at high speed of 50 kmph and the soil particle may be splashed to a height of 60 cm and move laterally to a distance of 150 cm.
2. Sheet erosion: It is the removal of fairly uniform layer of soil from land surface by the action of rainfall and runoff water.

3. Rill erosion: In this stage small finger like rills are formed under landscape. These rills are smoothened by working of small implements. Year after year the rills will increase not only in number but also in shape and size. These gets wider and deeper .Rill erosion is more serious in soils having shallow top soil. It may be regarded as a transition stage between sheet and gully erosion.
4. Gully erosion: It is an advance stage of rill erosion where unaltered rills gets deepened and widened every year and begins to attain the form of gullies. Gullies unless stopped or controlled in the rill stage will get deepened and widened. Cattle paths, tracks, furrows or other small depression along the slope favour concentration of runoff. Every time the rainwater surges down these gullies, they get deepened and widened.

PRINCIPLES OF GULLY EROSION

The rate of gully erosion mainly depends on the runoff characteristics of the watershed, namely watershed area, soil characteristics. Highly derived gully is called as ravines. The main processes involved in the development of gully are

i. Waterfall erosion: water falling over the edge of the gully or bank of a ditch forms deep and rapidly extending gully. The falling water undermines the edge of the bank which caves in. The soil detached is transmitted by large volume of flowing water and the waterfall moves upstream.

ii. Channel erosion: channel or ditch erosion is the scouring of soil by continuous runoff as it flows over unprotected depressions. It may also be caused by a raindrop splash or unprotected soil in the gullies .Channel erosion or waterfall erosion are commonly found in some gullies .The extension of gully head is by waterfall erosion and the scouring of the bottom is by channel erosion.

FOUR STAGES OF GULLY DEVELOPMENT

1. Formation stage; It is forming in channels by downward scouring of the soils.
2. Development stage; It is a stage where the upstream movement in the gully head and enlargement of gully in depth and width takes place.
3. Healing stage; It is the stage where the vegetation begins to grow in the gullies.
4. Stabilization stage; Here the gully bed, reaches a stable condition. The gully walls reach slope and vegetative cover spreads over the gully surface.

CLASSIFICATION BASED ON DEPTH

Sl.No.	Symbol	Description	Specification
1.	G_1	Very small gullies	Up to 3 m deep, bed width not more than 18 m side slopes vary
2.	G_2	Small gullies	Up to 3 m deep, bed width more than 18 m and side slopes 8-15 %
3.	G_3	Medium gullies	Depth 3-9 m, bed width more than 18 m, sides uniformly sloping between 8-15 %.
4.	G_4	Deep and narrow gullies	a) 3-9 m deep, bed width less than 18 m, side slopes vary. b) Depth more than 9 m. Bed width varies and the side slopes vary. Mostly steep or even vertical with intricate and active branch gullies.

Terminal velocity of raindrop

It is the rate of the falling raindrop which equal the resistance offered by air to the fall of the drop. The impact of rain drops per unit area is determined by the number, size and velocity of the raindrops. According to Ellison, 1943, soil loss is directly proportional to the terminal velocity. The diameter of raindrops depends on intensity of rain, air resistance, atmospheric pressure and humidity. The velocity of the raindrops depends on the size, height of fall, wind velocity and air resistance. For 1mm diameter of rain the terminal velocity is 4.5 m/s and for 5mm diameter of rain the terminal velocity is 9 m/s. it has been observed that a single raindrop may splash wet soil as much as 60 cm height and 150 cm around the spot where the raindrop hits. The factors affecting the direction and distance of soil splash are wind, land slope, soil surface conditions, vegetative cover and mulches.

Special forms of erosion

Shifting Cultivation

Shifting cultivation in this means the partial clearing and burning a patch of forest, raising crops mostly by hay culture and to a lesser extent by animal powered farming for a period of two to three years and allow the patch to be cultivated with forest trees for 20-30 years. After these decades the same patch is cleared and cropping is taken up and due to this erosion is accelerated. Trees are essential for weathering for soil minerals, to add organic matter and to break the cycle of insects, weeds and plant diseases. Trees maintained more uniform soil water and temperature conditions which reduce crystallization of iron and aluminium.

Land slide

This form of erosion is common on steep hill slope, which are subject to heavy rainfall hence the gets saturated with water and its weight increases. Also the soaked water alleviates cohesion between the soil particles. Under these conditions, the soil yields to gravity and slides down.

WIND EROSION

Wind erosion is a process by which, loose surface material is picked up, transports and deposited by wind. It is accelerated when

1. Soil is used as loose dry and fine.
2. Soil surface is smooth and bare.
3. Wind is strong

MECHANICS OF WIND EROSION

Wind erosion has the same three phases as water erosion.

(1) Initiation of soil movement
(2) Transportation
(3) Deposition

1. Initiation of soil movement: Movement of soil particle caused by wind forces, exerted against (or) parallel to the surface of the ground. The fluid threshold velocity is defined as, minimum velocity required to produce soil movement by the direction of wind. The impact threshold velocity is the minimum velocity required to initiate movement from the impact of soil particles caused in saltation.

2. Transportation; It is quantity of soil move influenced by particle size, wind velocity, roughness and the soil moisture. The rate of soil movement increases with the distance from the wind ward side of the field and the fine particles accumulate on the leeward side of the field, against wind. The atmosphere has tremendous capacity, to transport soil particles of size 0.1 mm. Basically there are 3 types of soil movement.

(a) Suspension; It is the soil particles and aggregates less than 0.05 mm. The particles once rise up to wind stream, they are kept in suspension by turbulence of air. They may move to great distances in suspension.

(b) Saltation; Intermediate soil particles of size 0.05 –mm moves with wind in series raising into air and falling again, after a relatively short flight. The moving grain, against momentum and energy and which courses the other grains (or) particles from the surface soil to get detached. The movement of soil particles in bounces or jumps is called saltation.

(c) Surface creep; Larger than 0.5 mm diameter, cannot be lifted to wind stream, but those smaller than 1 mm diameter can be rolled along the soil surface.

3. Deposition: It occurs when gravitation force is greater than the forces hitting a particle in air. It is caused by reduction in velocity due to cross section of barrier such as vegetation. Rain drops may also washout the particles in suspension.

EROSION CONTROL

Soil conservation;

Soil conservation is the preservation of soil from deterioration and loss by using it within its capabilities, and applying the conservation practices needed for its protection and improvement. Certain lands are suited to cultivation, while others are not. The natural limitations on the use of land constitute the basis for all soil conservation measures. Soil conservation planning should generally be done on a watershed basis.

Watershed

The watershed is the total lands are above a given point on a water way that contributes run off water to the flow at that point. Soil conservation work should start at the head of such topographical units and proceed in the same way the water flows to the down stream. One of the first principles in a watershed programme is to manage the land so as to get as much of the rainfall to soak in as possible.

Land use capability classification:

The land use capability classification is a systematic arrangement of different kinds of land, to produce on a virtually permanent basis. The classification is arranged according to a number of categories. Standard land capability classes based on land slope and their proposed land use are given as follows.

Table : Land capability classification based on land slope and soil conservation

Class of Land	Slope in %	Adapted land use and soil conservation measures
A-Land suitable for cultivation		
Class I	0-1	Any crop with proper crop rotation and green mannuring to maintain soil fertility
Class II	1-3	Contour farming, contour strip cropping and cover cropping, contour bunding or terracing
Class III	3-5	Intensive agronomical measures such as contour cropping, contour strip cropping and cover cropping. Terracing or contour bunding
Class IV	5-8	Contour bunds or terraces and intensive agronomic measures. Mostly soil building and maintaining crops are to be grown.
B. Land not suitable for cultivation		
Class V	8-12	Permanent pasture with controlled grazing
Class VI	12-18	Pasture, grasses and forestry. Grazing should be restricted
Class VII	18-25	Forest with restricted felling. Contour trenching as conservation measure
Class VIII	> 25	Forests with complete closure to grazing and felling of trees

EROSION CONTROL MEASURES - WATER EROSION CONTROL

A) Biological measures

B) Mechanical methods

C) Other methods

A. Biological measures

Methods adopted for erosion control by using crop or vegetation, tillage practices and land and water management are known as biological measures. These methods can be adopted for lands having a slope up to 2%.

1) contour cultivation

   The agricultural operations like tillage, planting and other intercultural operation are done along the contour. The contour cultivation reduces the velocity of overland slopes and erosion. Crops like maize, sorghum, pearl millet is normally grown in rows are suited for contour cultivation.

2) strip cropping

Different crops are grown in alternative strips, across the slope such that they serve as barriers for soil erosion. There are four types of strip cropping such as

(i) Contour strip cropping

Growing in alternative strips of erosion resisting and erosion permitting crops along the contour is termed as contour strip cropping.

(ii) Field strip cropping

Field strip cropping consists of strips of uniform with running generally perpendicular to the direction of the erosive force, but do not confirm to nay contour

(iii) Buffer strip cropping

Strips of grass or legume crop laid out between contour strips of crops in the regular rotations.

(iv) Wind strip cropping

The strips are laid at right angles to the prevailing wind direction, irrespective of the land slope

3) cropping systems

The sequence of crops grown in an area over a period of time is termed as cropping system. This system should be such that the soil is covered with vegetation during heavy rainfall period.

4) crop rotation

Crops like groundnut, soybean, green gram etc., are commonly used in crop rotation. These crops are having soil binding capacity and act as erosion resisting crop.

5) mixed cropping

Mixed cropping is the system of showing more than one crop together on the same land. Mixed crops varying in root systems helps in utilizing the plant nutrients in the profile. Erosion permitting and erosion resisting crops are raised in the same land in mixed cropping.

6) tillage practices

   The effect of tillage on erosion is a function upon the factors such as aggregation, surface sieving and infiltration. This practice consists of different ploughing operations using disc, harrow and cultivators.

7) mulch tillage/stubble mulching

   It is a soil and crop management practice that utilizes the residual mulches of the preceding crop by leaving a large quantity of vegetative residue on surface of the land. The mulch breaks the rain drops and thus dissipates their energy.

8) cover cropping

   the process of allowing growth of crops having economical value so as to afford productive cover to the bare space in the cultivated lands, without and at the same time interfering or suffocating the growth of the main crops grown in the field is called cover cropping. Example: Leguminous crops, sweet potato, pumpkin and groundnut.

B. Mechanical methods of water erosion control

Mechanical measures play a vital role in controlling and preventing soil erosion on agricultural lands. They are adopted to supplement the agricultural practices (biological methods). The mechanical measures include bunding, terraces etc.,

CONTOUR BUNDING

Contour bunding is the construction of small bund across the slope of the land on a contour so that the long slope is cut 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 increasing soil moisture. Contour bunts 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 relatively low rainfall areas, having an annual rainfall of less than 600 mm, particularly in areas having light textured soils. For rolling and flatter lands having slopes from 2 to 6% contour bunding is practiced.

Dimensions of the contour bund recommended

Type of soil	Bottom width	Top width	Height	Side slope
Gravel soils	1.2	0.3	0.6	0.75:1
Red soils	2.1	0.3	0.6	1.5:1
Shallow to medium black soil	2.4	0.45	0.75	1.3:1
Deep soils	3.3	0.60	0.675	2:1

GRADED BUNDS

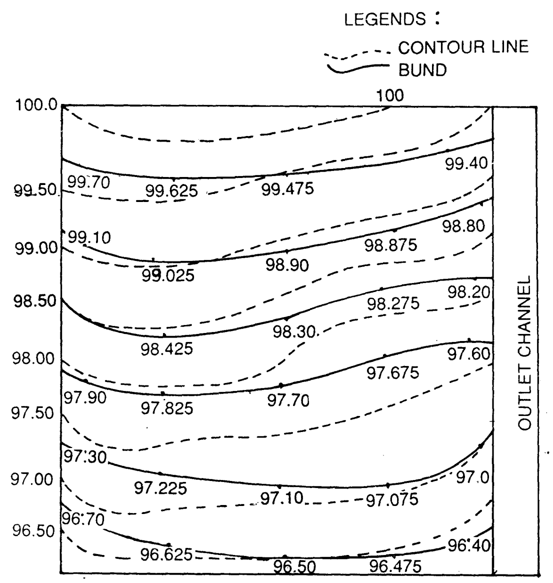
Graded bunds are constructed in medium to high rainfall areas having an annual rainfall of 600 mm and above and in soils having poor permeability (or) those having crust forming tendency (black soils), and in the lands having slopes between 2% and 6%.These bunds are provided with a channel if necessary. Uniformly graded bunds are suitable where the length of bund is less and the discharge behind the bund or in the channel is not much. Variable graded bunds are suitable 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 determined by using the Rational Method.

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.



Alignment of graded bund

Suitability of contour bund and graded bund

Sl.No.	Parameters	Contour bund	Graded bund
1	Land slope	2 - 6%	2 - 6%
2	Rainfall	Low rainfall (< 600 mm)	Medium and high rainfall (> 600 mm)
3	Soil	Light textured (Permeable)	Heavy textured (Poor permeable)
4	Slope along the bund	Nil	0.1 – 0.4 %

BROAD BASE TERRACE

A broad base terrace is a broad surface channel or embankment constructed across the slope of the rolling land for reducing runoff erosion and for moisture conservation. The broad base terrace has a ridge of 25 to 50 cm high and 5m to 9m wide with gently sloping on both sides and a channel along the upper side, constructed to control erosion by diverting runoff at a non-erosive velocity. It is classified as graded i.e. channel type terrace and leveled or ridged type terrace.

Narrow base terrace is similar to a broad base terrace in all respects except the width of ridge and channel. The base width of a narrow base terrace is usually 1.2 to 2.5m. These terraces are made in the lands having slope above 6% and up to 10%.

CONTOUR STONE WALL

In this, cut stones of size around 20 cm are dry packed across the hill slope to form a regular shape of random rubble masonry without mortar. After construction it should be stable enough so that a man can walk on it. They are constructed in lands having slopes between 10 and 16% and above.

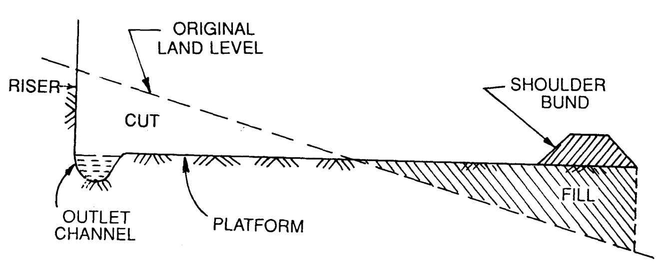
The spacing between two successive stone walls is 10 to 15m. A longitudinal slope of 1 in 500 (or) 0.2% is provided towards the safe outlet. The top portion of the stone wall should be straight. As in the case of contour bunding, plus or minus 25 cm is permitted for laying stonewall along the boundaries to suit the convenience of the land owner. Each stone wall must end in an outlet either natural or artificial. Besides conserving moisture and controlling erosion, these stone walls are constructed to form bench terraces in a gradual manner.

BENCH TERRACING

Bench terracing is one of the most popular mechanical soil conservation practices adopted by farmers of India and other countries for ages. On sloping and undulating lands, intensive farming can be only adopted with bench terracing. It consists of construction of step like fields along contours by half cutting and half filling. Original slope is covered into level fields and thus all hazards of erosion are eliminated. All the manure and fertilizers applied are retained in the field. In slopping irrigated land, bench terracing helps in proper water management. Bench terraces are normally constructed in lands having slope between 16% and 33%.

Components of Bench terrace

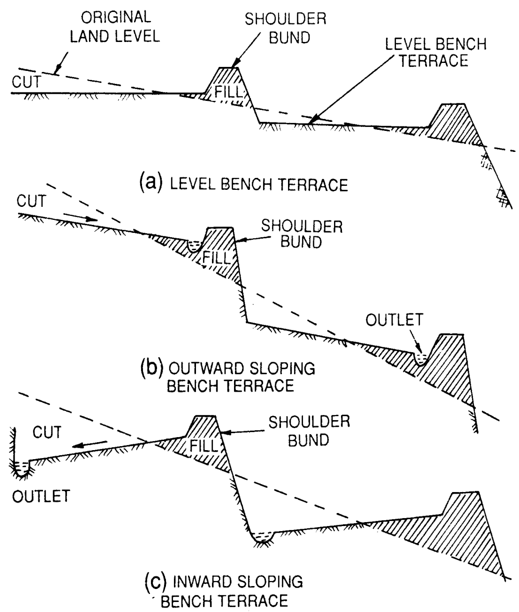
i) Riser ii) Outlet channel iii) Platform iv) Shoulder bund



Components of bench terrace

Type of bench terraces and their adaptability

1. Level bench terrace; Paddy fields require uniform impounding of water. Level bench terraces are used for the same and to facilitate uniform impounding. Sometimes this type of terraces are termed as table top, or paddy terraces, conveying the sense that such bench is as level as top of the table.
2. Inwardly sloping bench terraces; Crops like potato are extremely susceptibly to water logging. In that case the benches are made with inward slope to drain off excess water as quickly as possible. These are especially suited for steep slopes. It is essential to keep the excess runoff towards hill (original ground) rather than on fill slopes. These inwardly sloping bench terraces have a drain on inner side, which has a grade along its length to convey the excess water to one side, from where it is disposed-off by well stabilized vegetated waterway. These are widely used in Nilgiri hills of Tamil Nadu state as well as on steep Himalayan slope in Himachal Pradesh and North-Eastern hill regions.



3. Outwardly sloping bench terraces : Farmers many a time carry out the leveling process in phases, doing part of the job every year. As such outwardly sloping bench is usually a step towards construction of level or inwardly sloping bench terraces. In places of low rainfall or shallow soils, the outwardly sloping bench terraces are used to reduce the existing steep slope to mild slope. In this type of terraces constructed on soils not having good permeability, provision of graded channel at lower end has to be kept, to safely dispose off surplus water to some water way. In every permeable soils a strong bund with arrangement may take care for most of the rainfall events, while during heavy rainfall storm, the excess

water may flow from one terrace to another. Attempt is usually made to dispose-off this to some waterway at an earliest possible spot.

4. Puertorican or California type of terrace: In case of Puertorican type of terrace the soil is excavated little by little during every ploughing and gradually developing benches by pushing the soil downhill against a vegetative or mechanical barrier laid along contour. The terrace is developed gradually over years, by natural leveling. It is necessary that mechanical or vegetative barrier across the land at suitable interval has to be established.

TRENCHES

Contour (or) staggered trenches is adopted in high rainfall hilly areas of lands with slopes steeper than 33% or any slope with badly eroded soil. Length of staggered or contour trench will be 3m to 3.65m while the inter space between trenches in the same row will be only 2.4m to 3m. The trenches will be trapezoidal in cross section with 0.3m to 0.45m bottom width, side slopes of 0.5:1 or 1:1.

In addition for stabilization of soil, steps are to be taken to plant the area with fast growing tree and grass species. Plants are put on the trench side of the bunts along the berms.

INSITU EROSION CONTROL MEASURES

Broad bed and furrow system

The broad bed and furrow system combines of erosion control with surface drainage. The beds could be of different dimensions to suit the cropping patterns adopted. Normal bed width adopted is 150cm with 30cm width furrows at the end of the beds. The broad beds and furrows have been found to be suitable for managing the deep block soils in India where surface drainage during the monsoon period is the problem. The beds function as mini bunds at a grade and they help in reducing the velocity of surface runoff and increase the infiltration opportunity time. The excess water is removed through the furrows.

Basin listing

In this method, scoops or basins are formed in the field, by using the simple implement called “Basin lister”, this implement is essentially a furrower fitted with on eccentric cam arrangement. The furrower which cuts a furrow in the land is lifted and dropped at regular intervals. It does not cut the soil, where it is lifted resulting in a serious of cross bunds to the furrow. These have the appearance of basins and the implement is known as basin lister. It works about 2 to 3 acres a day in heavy soils. In sloping fields the velocity of the runoff water is minimized by throwing the land into pockets and thereby erosion is reduced.

Tied ridging

Tied ridging consists of covering the land surface with closely spaced ridges in two directions at right angles so that a serious closely of rectangular basins is formed. In random tie ridging, basins are formed at random. The purpose of such basins is to retain the rainwater till it infiltrates into the soil. The system can be successful on level ground or when the amount of water which can be stored in the basins, plus the amount infiltrating during the storm, is more than the worst storm likely to occur. Tied ridging is found to be successful on permeable soils rather than on shallow soils, to prevent failure of the ridges, they are constructed on grade with ties lower than the ridges so that the failure and runoff will be along each ridge and not down the slope. It is also advisable to back up the system with other measures like terraces or ground bunds.

WIND EROSION CONTROL

(1) Vegetation and vegetative management

Vegetation is generally the most effective means of wind erosion control. When used for this purpose, vegetation may be grouped into inter tilled crops, close growing crops and woody plants such as shrubs and trees. Crop residues are also of considerable value in preventing soil blowing. Plant covers and residues are capable of taking a portion of the direct force of the wind from the soil particles on the immediate surface.

In general, close growing crops are more effective for erosion control than inter-tilled crops. The effectiveness of such crops as legumes, grasses and small grains are dependent quite largely on the stage is covered with a dense cover crop during the summer.

(a) Strip cropping

Strip cropping for wind erosion control consists of a systematic alternate arrangement of erosion-susceptible and erosion resistant crops in relatively narrow strips whose length runs perpendicular to the direction of the prevailing erosion winds. The less erodible strips of stubble or other crops have some effect in reducing wind velocity across adjacent more erodible strips. The major benefit is, however, trapping of saltating soil particles and thereby controlling soil avalanching. Therefore, the narrower the strip the more effective they are in reducing erosion. It has been estimated that in order to keep erosion to a tolerable limit the width of the erosion susceptible strip should not exceed 6m in sandy soil, 8m in loamy sand and 30m in sandy loam.

(b) Crop rotation

Good management techniques are important. A good crop rotation that will maintain soil structure and conserve moisture should be followed as for as possible. However, deficient moisture often limits the use of soil improving and soil conserving crop such as legumes and grasses. In some regions, emergency crops with low moisture requirements are often planed on summer fallow land before the season of high intensity winds.

(c) Stubble mulching

Stubble mulching is the practice of maintaining crop residues at the ground surface-offers good protection from soil blowing. Crop residues like wheat, straw, stalks of pearl millet, maize, sorghum, etc., are left on the ground. Residues of crops following harvest continue to product the soil against wind erosion, just as does the growing crop. Such residues, if properly managed, can provide excellent control during periods between crops.

Crop residues reduce wind velocity and trap eroding soil. The degree of production depends on the quantity and quality of the residue and planting and the cropping practices used.

(2) Tillage practices to control soil blowing

Tillage machinery and tillage practices can either increase or reduce the soil blowing problem. Machines that tend to pulverize the soil or to diminish the vegetative cover increase soil blowing. Tillage equipment that will prove most effective is that which will do a good job of creating a cloddy surface and at the same time avoid burying the crop residue. The equipment should leave a rough, cloddy, and a residue covered surface with residues well anchored and standing if possible. Deep ploughing to depths of 30 to 45cm has become a common practice in the western countries to improve the wind resistance of sandy soil.

Residues are usually best handled with implements having sweep type furrow openers. Such implement move under the material, leaving it in an erect position, most effective against wind. Both bullock-drawn and tractor-drawn cultivators, equipment with sweep furrows openers are suitable.

(3) Surface roughness

The rate at which soil can be moved by wind varies inversely with the roughness of the surface. Any form of ridging placed perpendicular to the direction of the prevailing erosion winds tends to reduce soil loss. Even ordinary plough furrows, if aligned at right angles to the prevailing wind, will have an appreciable effecting reducing soil movement. Roughness of bare land is made of surface irregularities and large clods. Therefore, ridging should be done at a soil moisture content that will produce clods. In the furrow the direction of air movement is opposite to that of the wind. The decrease in wind velocity and change in wind direction between the ridges cause soil deposition.

(4) Conserving moisture

The conservation of moisture, particularly in the arid and semi-arid regions, is of at most importance for wind erosion control as well as for crop production. Conserving moisture fall into three categories; increasing infiltration, reducing evaporation, and preventing unnecessary plant growth. In practice, these can be accomplished by such practices as contour farming, contour bunding, mulching, and selecting suitable crops. The greater the amount of mulch on the surface the greater the quantity of moisture conserved.

(5) Windbreaks and shelterbelts

Although a windbreak is defined as any type of barrier for protection from winds, it is more commonly associated with mechanical or vegetative barriers for farmsteads, gardens orchards, etc.,

A shelterbelt is a longer barrier than a windbreak and consists of a combination of shrubs and trees indented for the conservation of soil and moisture and for the production of field crops. Any barrier such as a soil ridge, hedge, or tree windbreak, or shelterbelt placed in the path of the wind reduces wind velocity near the ground by exerting a drag on the wind and deflecting the stream. The effectiveness of any such barrier in reducing wind velocity depends on many factors including wind velocity and direction, and shape, width, height and porosity of the barrier.

When the wind direction is at right angles to the belt, wind velocity reductions range from 60 to 80 per cent near and to the leeward of the belt; and 20 per cent at a distance equal to 20 times the height of the belt; and at a distance equal to 30 to 40 times belt height to leeward of the belt no reduction in velocity occurs. Wind velocity reduction on the windward side extends to 5 to 10 times distance of the belt height. The higher the average wind velocity, the closer the belt or other barrier should be spaced to product the soil from-blowing.

An ideal form of shelterbelt is pyramidical with inner rows of fast growing and high branching trees, flanked by slow growing and low branching species and low with shrubs on the outside. A satisfactory wind wall can be formed having the ground level shrubs to wind wards, the small tree species in the middle and the tallest trees on the lee wards side. Shelterbelt with 10, 7, 5, 4, 3 and 2 rows have been recommended.

The minimum length of the belt is about 24 times its height. Thus the trees whose expected height is 10m, require the minimum length of 240m. The belt has to be free of gaps and its ends should be tapered off to low shrubs. Width of strips usually varies from 12 to 20m. The first step in the successful planting of trees is the selection of adaptable trees for particular sites.

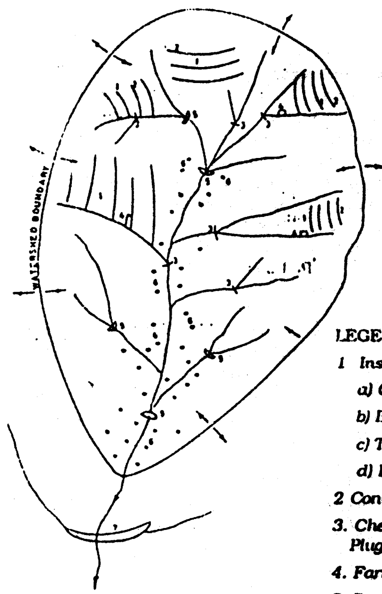
(6) Reclamation of sand dunes

Shifting sands, wherever they are, present a difficult problem. Sands invade roads, railway lines, fields and habitation. The first operation in the reclamation of sand dunes is the leveling of sand crests. As much of the area as possible is then tilled across the prevailing wind with a lister, heavy plough, or a deep furrow cultivator. The area is seeded to rapid growing grasses which can thrive under adverse conditions. These initial operations should be done during periods of the year when rainfall is most plentiful and wind velocity lowest. Operations should begin on the windward side of the area. The suitable species recommended by Central Arid Zone Research Institute, Jodhpur, for sand dune stabilization are Dub grass, star grass, thin napier grass, deshi khejri, sisal, neem, babul and eucalyptus.

WATER HARVESTING

Small reservoirs or farm ponds or percolation ponds are constructed for the purpose of storing water essentially from runoff. They are used for storing water during rainy season and using the same for irrigation subsequently. The design and construction of these water harvesting structures require a through knowledge of the site conditions and requirements.

Farm ponds are small tanks constructed to collect the surface runoff. The water stored can be used for irrigation water supply for the cattle, fish production etc. Some ponds get water from surface runoff and some from groundwater seeping into the pit. Ponds may either be of impounding type for which the existing depressing is chosen for the pond construction or of dugout type which are excavated at the site and the soil obtained by excavation is formed as an embankment around the pond.



LEGEND:
1 Institu conservation
a) Contour Cultivation
b) Basin / Furrow Farming
c) Tie Ridging
d) Broad bed and Furrow
2 Contour Bunds
3. Check Dams. or Gully Plugging
4. Farm Ponds
5. Percolation Ponds
6. Wells
7. Irrigation Tanks

Watershed development for equitable distribution of rainwater.

Percolation ponds are small water harvesting structures constructed across small natural streams and water courses to collect and impound the surface runoff during monsoons so as to facilitate the impounded water to infiltrate into the land and percolate through the substrata thereby recharging the ground water reservoir. The objectives of percolation ponds are (1) to impound surface runoff coming from the catchment and to facilitate percolation of stored water into the sub soil strata with a view to raise the ground water level in the zone of influence of the percolation tank. (2) to hold the silt flow which would otherwise reach the multipurpose reservoirs and reduce their useful life

WATERSHED MANAGEMENT

A watershed is a manageable hydrological unit, an area from which runoff, resulting from precipitation, flows past a single common outlet point into a large stream, a river, lake or a reservoir. A watershed may be only a few hectares as in case of small ponds or hundreds of square kilometers as in case of rivers. All watersheds can be divided into smaller sub-watersheds.

Watershed management implies the proper use of all land and water resource of a watershed for optimum production with minimum hazard to natural resources. The objectives of a watershed management are (1) to control damaging runoff, (2) to manage and utilize runoff for useful purposes, (3) to control erosion, (4) to moderate floods in the downstream areas, (5) to enhance groundwater storage and (6) appropriate use of the land resources in the watershed.

The factors which affect the watershed behavior and which need to be studied in management programmes are (1) size and shape of the watershed, (2) topography, (3) soil and their characteristics, (4) precipitation, (5) land use and (6) vegetative cover.

Data to be collected for planning the watershed, programmes are (1) hydrological information – precipitation climatological data, flow data and sediment flow , (2) Soil and land use data – land use, soil data topography, geology and vegetation and (3) Economic and social data to workout cost benefit of the project.

The watershed management programmes are,

(1) Conservation forming (2) erosion control measures

(3) controlled grazing (4) water management for irrigation and drainage

(5) Agro horticulture (6) Agro forestry and

(7) Socio economic problems correction.

Watershed management works are not confined to agricultural lands alone, but covers the area starting from the highest point of the area (ridge line) to the outlet of the natural stream.

IRRIGATION

Irrigation is defined as the science of artificial application of water to the land, in accordance with the crop water requirements throughout the crop period for full fledged nourishment of the crops.

Important terms in irrigation

I. **Percolation** is the downward movement of water through saturated or nearly saturated soil in response to the force of gravity. Percolation occurs when water pressure or tension in soil is smaller than ½ atmospheres.

II. **Seepage** is the infiltration (vertically) downward and lateral movements of water into soil or substrata from a source of supply such as a reservoir or canal. Seepage rate depends on wetted perimeter of the reservoir or canal and the capacity of the soil.

III. **Permeability** is the specific property governing the rate or readiness with which a porous medium transmits fluids under saturated conditions. According to this definition, equations used for expressing flow, which take into account the properties of the fluid, should give the same permeability value for all fluids which do not alter the medium.

IV. **Hydraulic Conductivity** is the proportionality factor K in Darcy's Law

I.e. $V = Ki$, in which V is the effective flow velocity and I is the hydraulic gradient. Hydraulic conductivity is the effective flow velocity at unit hydraulic gradient and has the dimensions of velocity (LT^{-1}).

CONVEYANCE OF IRRIGATION WATER

A farm irrigation distribution system conveys water to different fields from the source and should convey water to each field with minimum losses and without causing any erosion. The types of channels used for conveyance are

1. Surface channels - (a) unlined channels (b) lined channels
2. Underground pipe lines.

The advantage of unlined channels is their low initial cost. Their disadvantages are (1) loss of water due to seepage (2) low flow velocities and need larger cross sectional areas (3) danger of breaches due to erosion and burrowing by animals and (4) growth of weeds in the channels.

The advantages of lining are (1) Seepage control (2) Prevention of water logging (3) Increase in channel capacity (4) Increase in command area (5) Reduction in maintenance costs (6) Elimination of flood dangers and (7) Eliminates large part of the cleaning job.

The design of open channels consists in designing the cross section for the given discharge and the permissible velocity of flow.

Table. Permissible velocities for various soil textures (Michael, 1970)

Type of soil	Max. permissible velocity (cm/sec)
Sand and slit	45
Loam, sandy loam and slit loam	60
Clay loam	65
Clay	70
Gravel	100

Procedure for designing the channel:

For the required cross sectional area, the dimensions of the channel section are assumed. Using the hydraulic properties of the assumed section, the average velocity of flow through the channel section is calculated using the Manning's formula.

Velocity V (in m/sec) = $(1/n) R^{2/3} S^{1/2}$

Where n = Manning's coefficient

R = Hydraulic radius in meters

S = Slope in fraction

If the velocity calculated, exceeds the permissible velocity, the cross section is suitably altered and the velocity is calculated again. This process is repeated till the desired velocity is obtained with selected cross section.

CHANNEL LINING

Various types of channel linings which are commonly used are,

A) HARD SURFACE LININGS: (1) Concrete lining (2) Shot Crete or plaster lining (3) Brick till or concrete till lining (4) Asphaltic lining (5) Plastic fabric lining.

B) EARTH TYPE LINING; (1) Compacted earth (2) soil cement (3) Bituminous lining.

A. HARD SURFACE LININGS

(1) **Concrete lining:** Concrete mixture usually recommended for lining is 1:2:4 (cement: sand: gravel), and thickness of lining 4 to 5cm. The side slopes of the channel should not be steeper than 1:1. The sides and bottom of the channel should be compacted at suitable moisture content. Joints must be provided in order to localize and control the crack. Pre fabricated concrete channels with 1:2:4 concrete mixtures are also used to convey minimum water.

(2) **Shotcrete lining:** A mixture of cement and sand in the radio of 1:4 is applied under pressure through a nozzle on the surface of the channel. Sand is having a maximum size of 0.5cm. Shotcrete lining is laid in a thickness of about 3.5 cm. This lining is useful for repair works and in rehabilitation of old channels.

(3) **Brick or concrete tile lining:** A single or double layer of brick masonry or tiles laid in mortar. Sometimes a layer of tiles laid over a layer of brick masonry. The top layer of tiles is laid over 15mm thicklayer of 1:3 cement plaster. The size of the tiles is generally restricted to 30 x 150 x 53mm.

(4) **Asphaltic lining:** A controlled mixer of asphalt and graded stone aggregate mixed, placed and compacted in hot plastic state.

(5) **Plastic Fabric lining:** The sheet of polythene and alkathene for channel lining is placed on the surface with an earth cover, and should be efficiently laid and secured on the sides. These linings are cheap, weeds do not grow on them, but they are subjected to puncture and deterioration.

B. EARTH TYPE LININGS

(1) **Compacted earth:** Soil graded to obtain the required characteristics and containing enough fines, so as to make it impervious, is thoroughly compacted at optimum moisture content for a thickness of 30 to 90 cm.

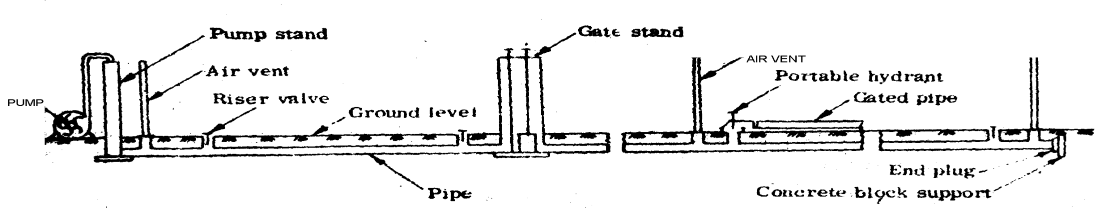
(2) **Soil cement lining:** Portland cement up to the extent of 2 to 8% is added to the fine soil, mixed well, laid and compacted. It should be cured for seven days with moist soil cover.

(3) **Bituminous lining:** Strictly soil with wheat straw or rice husk at the rate of 3% by weight of the soil is allowed to rot for 7 days in water. Cow dung at the rate of 5% by weight of the mixture is added. This puddle is thoroughly mixed. One or two hours before the application of plaster, a bituminous compound at the rate of 1 part for every 15 part of dry soil by weight is added and puddle.

Common bituminous compounds are (1) Bitumen and creosote oil in the ratio of 4:1 (2) Janatha emulsion and (3) liquid Asphalt.

UNDERGROUND PIPE LINE SYSTEM

An efficient means of conveying and distributing farm irrigation water is through buried pipes. This method practically eliminates conveyance loss. Concrete, asbestos, cement, vitrified clay, P.V.C. and steel are the materials used for the underground pipe lines. The main disadvantage is the higher initial cost as compared to open channels. The underground pipe line system consists of (1) pump stand, (2) pipe lines (3) distribution stands (4) risers and valves (5) air vents (6) drain and flushing valves and (7) other structures for special conditions.



The Pump stand is a vertical pipe extending above the ground from the buried pipeline. It carries the flow from the source (pump) into the pipe system and provides necessary hydraulic head. The distribution stands (or) Gate stands are provided where branches of pipe lines are taken. These are generally made of brick masonry. Risers and valves are provided along the pipe line for delivering water to the fields. Drain and flushing valves are provided at the end of the pipeline to remove sediment accumulating in the system. Vertical air vent pipe structures are provided to release air entrapped in the pipeline and to prevent vacuum.

The diameter of the pipe line is determined by taking into consideration the rate of flow and the frictional losses in the pipe line. The frictional loss is given by
Darcy – Weisbach as

$$h_f = 2flv^2 / gd$$

where, h_f = Head loss due to friction,

f = Roughness coefficient i.e. coefficient friction

l = Length of pipe, meters

v = Velocity of water in pipe, meters per second

g = Acceleration due to gravity, (9.81 m/sec^2)

d = Diameter of pipe, meters

The value of f can be obtained from the standard table. The diameter of the pipe, d, can be decided by selecting it from the standard table containing the bead loss 'h_f', discharge Q and diameter of pipe.

Water flow measurement

The measurement of irrigation water permits more intelligent use of this valuable natural resource. Irrigation water could be applied at rates to suit the infiltration rates of soils based on the crop water requirement and depth of application of water needed by the crop. It reduces excessive wastage of irrigation water and allows the water to be distributed among users according to their needs and right. If the government agencies desired to charge the water rates to the farmers on volume basis rather than area basis, then measurement is essential.

Units of measurement

The commonly used units of measurement of water at rest are the litre, cubic meter and hectare–centimeter. When water is flowing in pipes, field channels and canals, it is said to be in motion. Flowing water is measured in cubic meters per second, litres per second and litres per minute, which is the volume of water passing through a section per unit time.

Methods of water measurement

I.VOLUME METHOD:

Running water is collected in a container of known volume for a measured period of time

Discharge rate in liters per second = Volume of container / Time required to fill

II. VELOCITY AREA METHODS

Floats and current meters are used to find the velocity of flow. The rate of flow (discharge) is determined by multiplying this velocity by the area of cross section of the channel.

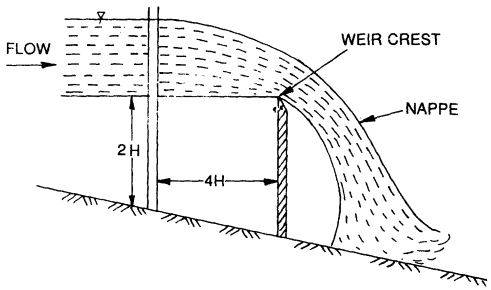
1. **Float method:** A straight uniform section of the channel about 25 meters long is selected. The time required to traverse the distance by a floating object is measured and the velocity is calculated. Mean velocity for the channel is obtained by multiplying the surface velocity with 0.8. The area of cross section of the channel is determined and it is multiplied by the average velocity to get the rate of flow.

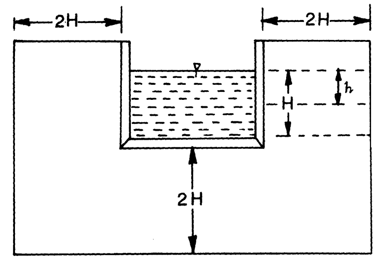
2. **Current meter method:** The current meter is a small instrument containing a revolving wheel or vane that is turned by the action of flowing water. The number of revolutions of the wheel in given time interval is obtained. The corresponding velocity is reckoned from the calibration table or graph of the instrument. The mean velocity of flow is obtained from the average of readings taken at 0.2 and 0.8 of the depth below the surface.

III. **DIRECT DISCHARGE METHODS**

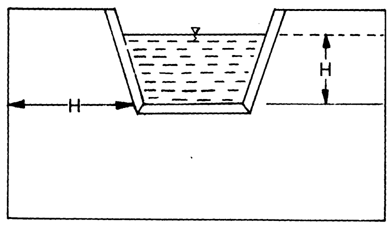
Rates of flow are measured directly by using devices like weirs, orifices and flumes.

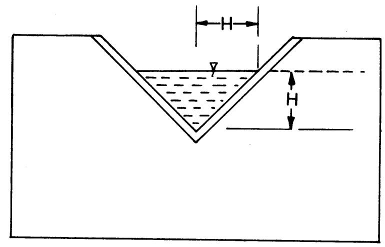
1. **Weirs:** A weir is a notch of regular form through which water flows. Only sharp crested weirs are commonly used on the farm. These are a) Rectangular weir which has a level crest and vertical sides b) Trapezoidal or Cipolletti weir, which has a level crest and sides of the notch sloping outward from the vertical at one horizontal to four vertical and c) 90^{o} triangular weir formed by the sides of the notch sloping outward from vertical at 45^{o} angle.



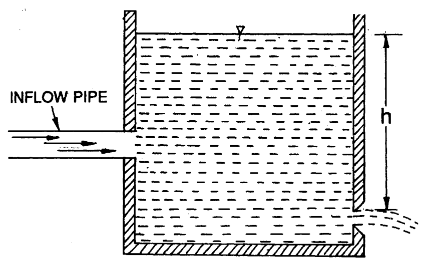


Sharp crested weirs **Rectangular weir**





Trapezoidal or Cipolletti weir **Triangular weir or 90º V-notch**



Orifice

In case of rectangular weir, the discharge is given by

$Q= 0.0184\ LH^{3/2}$ for suppressed rectangular weir and

$Q= 0.0184\ (L-0.1nH)\ H^{3/2}$ for contracted rectangular weir,

in which Q= discharge in liters per second,

L= Length of crest in cm

H= Head on the crest in cm and

n = The number of end contractions

Horizontal distance from the end of the crest to the side of the channel is known as end contraction. If the length of crest is less than the channel width, n=2, and if length of crest is equal to channel width, n=0.

The discharge from the trapezoidal weir is given by

$$Q = 0.0186\ LH^{3/2}$$

The discharge from a triangular weir is given by

$$Q = 0.0138\ H^{5/2}$$

2. **Orifices:** An orifice is an opening with closed perimeter and of a regular shape through which water flows. The orifice acts as a weir when the opening flows only partly. Circular or rectangular orifices are common in use. The discharge through an orifice is given by

$$Q = 0.61 \times 10^{-3}\ a\ (2gh)^{0.5}$$

Where Q= Discharge in liters per second

a = Cross section area of the orifice in square cm

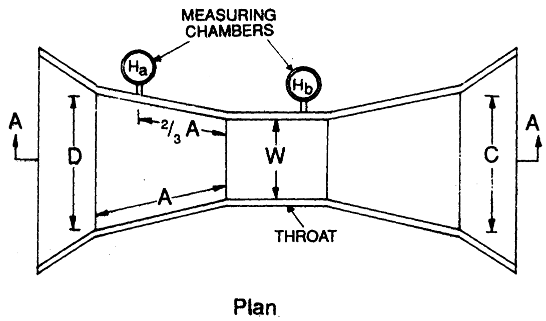
g = Acceleration due to gravity (981 cm/s^2) and

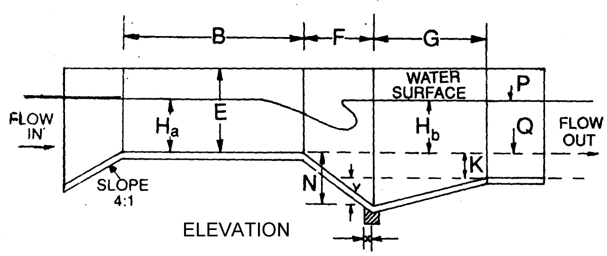
h = depth of water over the centre of the orifice on the upstream side in case of a free flow orifice (or) the difference in elevation between the water surface at the upstream and down stream faces of the orifice plate in case of submerged orifices in cm.

3. **Parshall flume** : It consist of three principal sections (1) A converging or contracting section at its upstream end, leading to (2) a constricted section or throat and (3) a diverging or expanding section downstream. The floor of the converging section is level both longitudinally and transversely. The floor of the throat inclines downward and that of the diverging section slops upward.

For determining the rate of flow, the depth of flow at H_a and H_b are to be taken. The flow is termed as free flow when the elevation of the water surface near the downstream end of the throat section is not high enough to cause any retardation of flow. The free flow limits of H_b/H_a vary with the widths of the throat as given below

Width of throat	**Free flow limit of H_b/H_a**
2.5 to 7.5 cm	0.5
15 to 22.5 cm	0.6
0.3 to 2.5 m	0.7





Parshall flume

Under the free flow conditions, the measurement of water level in the converging section (H_a) is sufficient to determine the rate of flow from the standard table. When the flow is submerged i.e. when H_b/H_a exceeds the free flow limits, values of H_a and H_b are measured and the rate of flow is determined from the standard table.

IV) Tracer method:

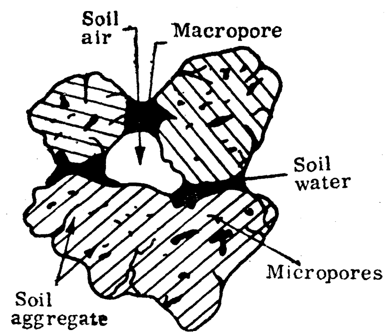
Salt or a dye with known concentration is added in to water flow and its concentration is measured both in upstream and in downstream.

Rate of flow $Q = q_1 (c_2 - c_1) / (c_0 - c_2)$

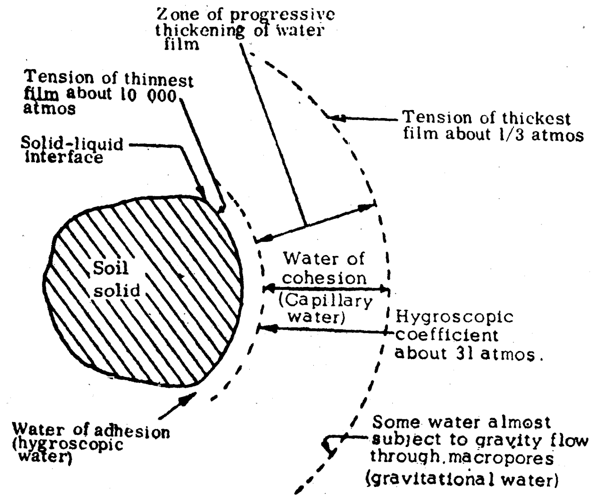
Where, c_0 – the initial concentration in u/s ; c_1 – concentration of the solution being added; c_2 – concentration measured downstream and q_1 – the rate at which the solution is added.

SOIL MOISTURE

When water is added to a dry soil by either rain or irrigation, it is distributed around the soil particles where it is held by adhesive and cohesive forces, displaces air in the pore spaces and eventually fills the pores. When all the pores are filled, the soil is said to be saturated and is at its maximum retentive capacity.



Soil moisture within soil aggregates



Progressive thickening of water film

The water in the large pores moves downward freely under the influence of gravity is called gravitational water or free water. When water supply is cutoff, water continues to drain from the large pores for a few days. In well drained soils, the free water near the surface has moved out and the large pores are filled with air.

Water in the small pores moves because of capillary forces and is called capillary water. Operation from land surface and absorption of moisture by growing plants further reduces the amount of water in the soil until no longer moves because of capillary forces. The remaining water is held so tightly that it can not be used by plants, called hygroscopic water. Irrigation is concerned with gravitational and capillary water since hygroscopic water is not available to plants.

Available Water: The difference in the moisture content of the soil between field capacity and the permanent wilting point is called the available moisture. Field capacity is the moisture content of a soil expressed as percentage of oven dry weight, after gravitational or free water has been allowed to drain, usually for two or three days. It is also known as capillary capacity or field carrying capacity. The permanent wilting point or percentage is the soil moisture content at which plants can no longer obtain enough moisture to meet their transpiration requirements. The moisture tension of a soil at permanent wilting point ranges from 7 to 32 atmospheres and 15 atmospheres is the common value used for this point. The wilting range is the range in soil moisture content through which plants undergo a progressive degree of permanent or irreversible wilting is observed from the wilting of the oldest leaves to complete wilting of all leaves.

SOIL MOISTURE MEASUREMENT

Soil moisture measurements often become essential to know the moisture utilization rate of the crops at different periods, for scheduling of irrigation and estimating the amount of water to apply in each irrigation.

Units of measurement

1) Dry weight basis M_{dw}

$$M_{dw} = \frac{\text{(Weight of wet soil - weight of oven dry soil)}}{\text{Weight of oven dry sample}} \times 100$$

$$= \frac{W_1 - W_2}{W_2 - W} \times 100$$

Where W = weight of the container

W_1 = weight of the container + wet soil

W_2 = weight of the container + oven dry soil

2) Wet weight basis M_{ww} = (weight of water / weight of wet sample) x 100

$$= \frac{W_1 - W_2}{W_1 - W} \times 100$$

It may not indicate the amount of water available to plants, unless the soil moisture characteristics curve or the field capacity and permanent wilting point is known.

3) Volume percentage ($M_v = M_{dw} \times A_s$)

Moisture content in percent On volume basis	=	moisture content percent by weight	x	bulk density

It is numerically equal to centimeter of water per meter depth of soil. Moisture content on volume basis is more useful as it gives the idea about the centimeter of moisture present in one meter depth of soil. Similarly how many centimeter of water is required to be applied in a root zone of specified depth can be known from the volumetric moisture content.

Depth of moisture (cm) in the root zone d = M_v x depth of root zone in m

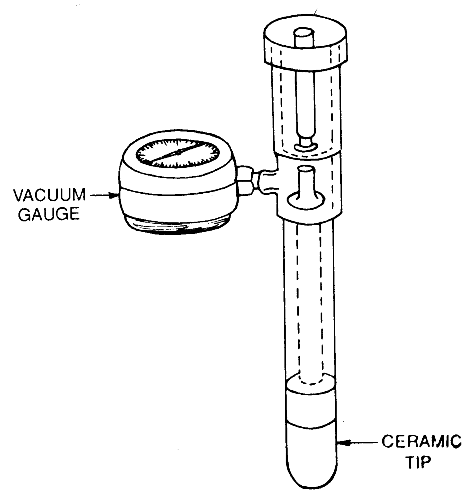
Method of measurement

Several methods have been developed for determination of soil moisture. The choice of a particular method depends mostly on the objectives of the measurement and also on the time and labour available for measurement.

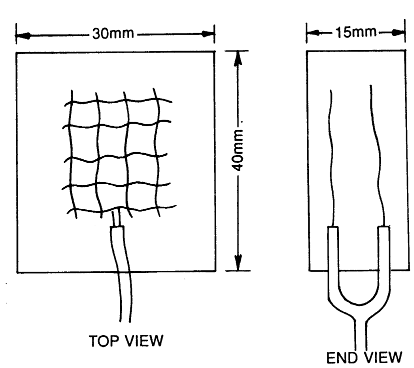
1. Soil sampling method or Gravimetric method: Soil samples are taken, weighted, dried in an oven at 105^0 C for 24 hours, and then weighted again. The difference in weight is the amount of moisture in the soil usually expressed as percentage on dry weight basis.

2. Measuring instruments: These instruments are less cumbersome.

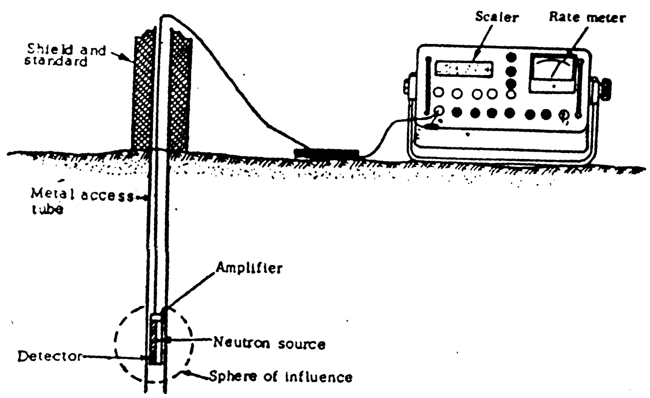
a) Tensiometers: Tensiometers consists of a porous cap filled with water and connected by a continuous water column to vacuum measuring device, either a dial type gauge or a mercury monometer. The porous cap is placed in the soil at the desired depth. A balance is established between the water inside the cap and the water in the soil outside. The water moves out or in the cap depending upon the tension of the soil water increases or decreases. Fluctuations of the soil moisture tension are read above ground on the vacuum indicator. The tensiometer continues to record fluctuations in soil – water content up to 0.85 atmospheres.



b) Electrical resistivity meter: Electrodes permanently mounted in conductivity units made of plaster of Paris, nylon, fiber glass or gypsum is buried at the depths to be studied. Resistance or conductance meters measure the changes in electrical resistance in the blocks associated with changes in the moisture content of the soil. The blocks used should be calibrated for each soil and a calibration curve indicating the moisture content and resistance is prepared. Salts in the soil are found to affect the working of the conductivity units. Gypsum blocks operate best at tensions between 1 – 15 atmospheres.



c) Neutron moisture meters: The instrument consists of two main parts, the probe and a scalar or rate meter. In the area where soil moisture measurements are desired an access tube suitable to the probe is installed. The probe contains a fast neutron source which emits neutron radiation as well as a detector of slow neutrons. The fast neutrons are emitted radically into the soil. They colloid elastically with various nuclei present in the soil and are slowed down. Some of these return to the probe where a detector of slow neutrons counts them. The counts are transmitted to the scalar are indicated by a rate meter. The count rate depends upon the volumetric water content of the soil.



SOIL – PLANT – WATER RELATIONSHIPS

Soil serves as storage of reservoir for water. When ample water is in the root zone, plants can obtain there daily water requirement for proper growth and development. As the plants continue to use the water, the available supply diminishes and unless more water is added, the plants stop growing and finally die. Plants should be able to draw water from the soil fast enough to provide for plant growth in addition to offsetting losses by transpiration. Excess water during early stages, causes the soil to remain cold and makes the young plants more susceptible to seedling diseases. Excess water in later stages of maturity results in too much vegetation growth.

Effective root zone depth is the depth from which the roots of an average mature plant are capable of reducing soil moisture to the extent that it should be replaced by irrigation. It is not necessarily the maximum root depth of the plant especially for plant having long tap root.

The moisture extraction shows the relative amounts of moisture extracted from different depths within the crop root zone. About 40% of the total moisture used is extracted from the first quarter of the root zone, 30% from the second, 20% from the third and only 10% from the last (bottom) quarter. Root zone of pasture grasses and common vegetables is within 45 cm. crops like potatoes, small grains maize and other seasonal crops have root zone depths ranging from 70 – 180 cm.

Available water holding capacity of soils

Soil type	Percent moisture based on dry weight of soil		Depth of water available per unit depth of soil
	Field Capacity	Permanent Wilting %	cm per meter depth of soil
Fine sand	3 – 5	1 – 3	2 – 4
Sandy loam	3 – 15	3 – 8	4 – 11
Silt loam	12 – 18	6 – 10	6 – 13
Clay loam	15 – 30	7 – 16	10 – 18
Clay	25 – 40	12 – 20	16 – 30

TOTL SOIL WATER POTENTIAL

Total soil water potential can be considered as the sum of the separate contributions of the various forces i.e.

$$\Psi = \psi_g + \psi_{p(m)} + \psi_0.$$

Where, Ψ = Total potential,

ψ_g = Gravitational potential,

$\psi_{p(m)}$ = Pressure or matric potential and

ψ_0 = Osmotic potential.

Gravitational potential is the amount of work that a unit quantity of water in an equilibrium soil – water system at an arbitrary level is capable of doing when it moves to another equilibrium identical in all respects except that it is at a reference level.

Pressure Potential is the amount of work that a unit quantity of water in an equilibrium soil – water system is capable of doing when it moves to another equilibrium system identical in all respects except it is at a reference pressure.

Matric Potential of soil water is the amount of work that a unit quantity of water in an equilibrium soil – water system is capable of doing when it moves to another equilibrium system identical in all respects except that there is no matric present.

Osmotic Potential is the amount of work that a unit quantity of water in an equilibrium soil – water system is capable of doing when it moves to another equilibrium system identical in all respects except that there are no solutions.

IRRIGATION METHODS

Irrigation water can be applied below the surface of the soil, at the surface of the soil or over the surface of the soil. The terms subsurface, surface and overhead or sprinkler are used to describe these three methods of irrigations respectively.

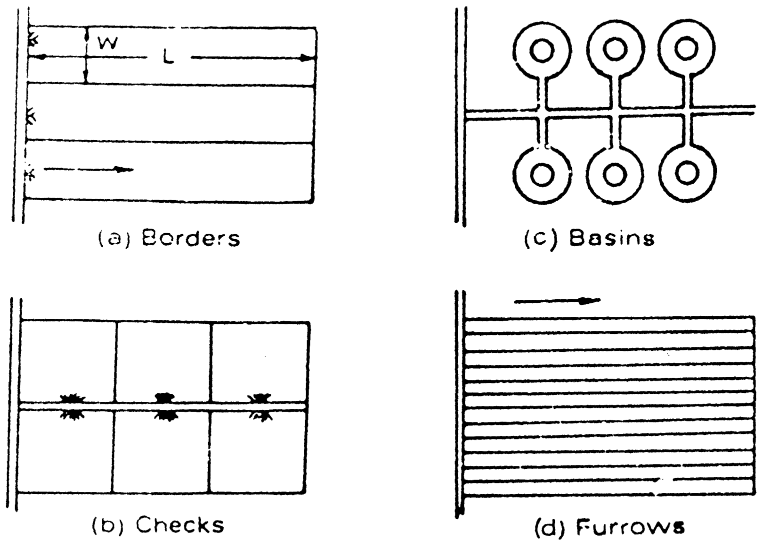
SURFACE IRRIGATION METHODS

In the surface methods of irrigation, water is applied directly to the soil surface from a channel located at the upper reach of the field.

1. **Border strip**: Border strip method of irrigation or border irrigation is a method of surface flooding wherein the water is applied to the field divided in to strips separated by parallel ridges. Close growing crops like wheat, barley, groundnut, etc,. are conveniently irrigated by this method. Borders may be laid along the general slope of the field i.e. straight borders may be laid across the general slope of the field as contour borders. Each strip of the border is in the order of 3-15 m in width and 100-400 m in length. The size of the irrigation stream is selected based on the infiltration rate of the soils.

Border lengths and slopes recommended for different soils are

Types of soil	Length (m)	Slope (%)
Sandy and sandy loam soils	60 – 120	0.25 – 0.65
Medium loam soils	100 – 180	0.20 – 0.40
Clay loam and clay soils	150 – 300	0.05 – 0.20



2. **Check basin:** The check basin method of irrigation consists of dividing the area in to square or rectangular plots and irrigating each plot. The plots are generally level or have a very mild slope. It is suited to irrigate grain, fodder crops, row crops and orchards. In the design of the check basin the selection of the size of the check basin and the size of the irrigation stream are selected. The size of the check basins may vary from 1 m^2 for vegetable crops and as large as 1-2 ha for growing rice. The size of basins in rice fields vary with the size of the irrigation stream available and the size of the land holding.
3. **Ring basin:** Ring basin method of irrigation is a modification of the check method used for irrigation of orchards. Basins are constructed for each tree or a group of trees. Water is conveyed to each basin, either by flowing through one basin in to another or through a channel separately constructed.
4. **Furrow irrigation:** Furrow irrigation consists of making the land in to ridges and furrows and irrigating the area through the furrows. This method is suitable for all the row crops and the crops like potato, maize, sugarcane etc. grown on ridges.

   For furrow irrigation design, the spacing, length and slope of furrows and a suitable size of irrigation stream and duration of water application are decided. The common size of furrow for row crops, such as cotton, tobacco and potato is about 25 cm wide and 8 cm deep. Furrows of 7-12 cm depth are appropriate for vegetables and 20-30 cm is common for orchards and some row crops. A minimum furrow grade of 0.05 % is needed and for most conditions in India, furrow grades between 0.2 and 0.5 % will be satisfactory. Furrow stream usually varies from 0.5 to 2.5 liters per second. The optimum length of run is usually the longest furrow that can be safely and efficiently irrigated. The length may be as short as 45 m for soils having infiltration rate more than 5 cm per hour and as much as 300 m for heavy soils.

5. **Corrugation method:** Corrugations or rills are shallow furrows running down the slope from the irrigation channel. Water moves down through several corrugations at a time. Corrugation irrigation is well adopted for medium and heavy textured soils. The bullock drawn corrugator is a simple wooden frame with short lengths of circular bamboos fitted on it. It is drawn over a well prepared field forming the corrugations on the surface. This method is useful in irrigating small grain crops like wheat etc.

DUTY OF WATER

Duty of water is the relationship between the irrigation water and the area that can be irrigated with that water for a particular crop from sowing to harvest. The duty of water can be expressed as

1. Area per unit rate of flow [‘d’ ha/cumec or Acres/cusec]

In canal irrigation, duty is usually expressed as the area that can be irrigated with an amount of water flowing at a rate of one unit volume per second throughout the crop period. If one cumec is covering d hectares then the duty is d ha/cumec.

2. Duty expressed in terms of depth of water (▲ cm)

Delta (▲) is the total depth of water required for the entire crop period and is expressed in cm.

3. Volume in terms of depth over unit area (ha-cm)

It represents the total quantity of water needed for a crop per unit area. It is expressed as ha-cm or ha-m.

4. Impounded water (or) stored water (ha/million cubic meter)

In case of tank irrigation, duty may be expressed as the area that can be irrigated by a particular quantity of stored water. The unit is hectares per million cubic meters.

Relation between different expressions of duty of water

Let d is the duty expressed as number of hectares per cubic meters per second, the duty expressed in cm over the area as ▲ cm and B the base period in number of days.

Total quantity of water required to irrigate 'd' ha for 'B' days $= 1 \times 60 \times 60 \times 24 \times B$ m^3

Total quantity of water required to irrigate '1' ha $= \dfrac{1 \times 60 \times 60 \times 24 \times Bm^3}{d}$ m^3 ---- (1)

If duty is ▲cm over the area, to irrigate 1 hectare of crop then

Quantity of water needed $= 10{,}000 \times \dfrac{▲}{100} = 100$ ▲ m^3 ---- (2)

Equating the above two equations,

We get ▲ $= 864 \dfrac{B}{d}$

Relation between cubic meter per second and hectare-cm

If the flow is 1 cumec then the total

flow in one day $= 1 \times 60 \times 60 \times 24\ m^3 = 86400\ m^3$

If this water is allowed for an area of 1 hectares then the depth of water applied is given by $86400\ m^3 / 10{,}000\ m^2 = 8.64m$

i.e. the duty is 8.64 ha-m

This means that if 1 cumec flow is allowed for one day for an area of 1 hectares then the depth of water applied is 8.64m or 864 cm.

Duty helps in designing an efficient cancel irrigation system. Knowing the total available water at the head of a main cancel, and the overall duty for all the crops required to be irrigated in different seasons of the year, the area which can be irrigated can be worked out.

Table: Duty for certain important crops

Crop	Duty in hectares / cumec
Sugar cane	730
Rice	775
Other kharif	1500
Rabi	1800
Perennials	1100
Hot fodder	2000

IRRIGATION EFFICIENCIES

Even under the best method of irrigation not all the water applied during irrigation is stored in the root zone. The concept of efficiency, which is an input output relationship, is applied to irrigation practice in order to achieve better utilization of the irrigation water.

(1) Water conveyance efficiency takes in to account the losses that occur while conveying the water from the source to the farm. It is expressed as

$$\text{Water conveyance efficiency} = E_c = \frac{W_f}{W_r} \times 100$$

Where, W^f = Water delivered to the field and

W^r = Water diverted from source.

(2) Water application efficiency gives an indication of the quantity of water that is stored in the root zone of soil out of the quantity that is delivered in to the field. It denotes the losses that take place through runoff and deep percolation. It is expressed as

$$\text{Water application efficiency} = E_a = \frac{W_s}{W_f} \times 100$$

Where, W_s = Water stored in the root zone during irrigation and

W_f = Water delivered to the field.

Neglecting evaporation losses during time of water application, $W_f = W_s + R_f + D_f$

Where R_f is the surface runoff from the farm and D_f is the deep percolation below the root zone.

(3) Water distribution efficiency is a measure of the uniformity of depth of irrigation within the field. It depends upon the infiltration opportunity time which in turn depends upon the proper land grading and design of irrigation system.

$$\text{Water distribution efficiency} = E_d = \left[1 - \frac{y}{d}\right] 100$$

Where, y = Average numerical deviation in depth of water stored from average depth stored during irrigation.

d = Average depth of water stored during irrigation.

(4) Water storage efficiency is useful in evaluating irrigation methods especially under limited water supply conditions. It gives an idea as to how much the root zone has been filled with the required amount of water. It is expressed as

$$\text{Water storage efficiency} = E_s = \frac{W_s}{W_n} \times 100$$

Where, W_s = water stored in the root zone during irrigation and

W_n = water needed in the root zone prior to irrigation.

By applying large quantity of water it is possible to achieve 100 % storage efficiency. But the application efficiency reduces considerably. Similarly almost 100 % efficiency may be achieved with poor storage efficiency.

(5) Consumptive use efficiency is useful in evaluation of the irrigation methods and the crop response to irrigation. From the concept of consumptive use efficiency, loss of water by deep percolation and surface evaporation followed by an irrigation can be evaluated.

$$\text{Consumptive use efficiency} = E_{cu} = \frac{W_{cu}}{W_{nd}} \times 100$$

Where, W_{cu} = consumptive use of water by the crop and

W_{nd} = amount of water depleted from the root zone of the soil

$$\text{(6) Crop water use efficiency} = \frac{\text{Crop yield in kg (Y)}}{\text{Evapo-transpiration in ha-cm (ET)}}$$

$$\text{(7) Field water use efficiency} = \frac{\text{Crop yield in kg (Y)}}{\text{Total water used in the field in ha-cm (WR)}}$$

(8) Project efficiency is the ratio of the irrigation water diverted at the main source of supply to the water that is stored in the soil and is available for consumptive use by the crops.

SUB IRRIGATION

In sub irrigation water is applied below the ground surface by maintaining an artificial water table at some depth, depending upon the soil texture and the depth of the plant roots. Water reaches the plant roots through capillary action. Sub irrigation is done through deep trenches of depth varies from 30 cm – 1 m with 15 – 30 m apart through underground pipelines. Sub irrigation can be used for soils having a low water holding capacity and a high infiltration rate where surface irrigation methods cannot be used. This method is used only in few areas for vegetable crops and for coconut palms.

Peak water requirements for different crops

Sl.No.	Crop	Peak water requirement ** liter / plant / day
1	Banana	16 – 20
2	Coconut	80 – 150
3	Grapes	12 – 20
4	Pomegranate	40 – 60
5	Guava	80 – 120
6	Mango	150 – 200
7	Lemon, Orange, Mosambi	80 – 120
8	Sapota	150 – 200
9	Papaya	18 – 20
10	Fig	40 – 80
11	Custard apple	60 – 80
12	Ber	40 – 60
13	Cashew nut	80 – 100
14	Tamarind, Amla	150 – 200
15	Mulberry	10 – 15
16	Cotton	12 lit / meter / day
17	Sugarcane	16 – 20 lit / meter / day
18	Vegetables	10 – 12 lit / meter / day
19	Groundnut	10 lit / meter / day
20	Beetle vine	12 – 16 lit / meter / day

** Varies with spacing and climatic conditions

DRAINAGE

National commission on agriculture (1976) has defined an area as waterlogged when water table rises to an extent that soil pores in the root zone of a crop became saturated resulting in restriction of the normal circulation of air, decline in the land of oxygen and decrease in the level of carbon-di-oxide.

Drainage is the removal of excess water and salt from the soil at a rate which will permit normal plant growth. The primary objective should be to design and construct a drainage system which has optimum integration of soils, crop and irrigation. The excess water normally results from over irrigation or excess rainfall. The process of removing the excess water from the land surface is known as surface drainage. If the excess water saturates the pore space of the soil, the process of its removal by downward flow through the soil is known as subsurface drainage or internal drainage. Artificial drainage of soil water consists of providing man made channels through which the free water is carried away to natural drains such as natural drainage ditches and rivers.

The irrigated lands in India, under major and minor projects, even through had shown a higher productivity initially, now show the need to improve the productivity by constructing drainage systems for lowering water table, leaching of salts as well as removal of excess water from fields. Hence an integrated approach to irrigation and drainage systems is required. The benefits achieved by drainage are

1. Better soil aeration
2. Better soil moisture for tillage operations
3. Better soil structure can be developed
4. Soils warm-up more quickly, results in better seed germination and plant growth
5. An increased supply of nitrogen to plants from the soil is achieved.
6. Larger growing season can be achieved, which helps in selecting better crop
7. Toxic substances and disease organisms are removed from soil
8. Winds are less liable to uproot the plants due to deeper roots and better soil strength.
9. Saves fuel and reduces wear and tear of machinery and implement.
10. Controls salinity and alkalinity in arid and semi arid regions.
11. Drainage reduces diseases that thrive on wetlands.

12. Soil erosion is minimized by sub-surface drainage or it maintains open pores for absorption of rain water.
13. Weeds growths around the plants are minimized.

DRAINAGE CO-EFFICIENT is the amount of water that must be removed in 24 hours period. It is expressed in centimeters or millimeters of water drained off from a given area in 24 hours. The coefficient varies with the geographical location, land use and size of area to be drained. It ranges from 6 to 25 mm for average small drainage projects.

TYPES OF DRAINS

Important drainage methods are (1) Surface drainage (2) Sub surface drainage or pipe drainage and (3) Special forms of drainage. The factors which influence drainage are topographic factors, soil factors, water and climatic factors and crop factors.

1. SURFACE DRAINAGE

The primary methods of surface drainage are (i) Land smoothing (ii) Bedding (iii) Parallel field drains (iv) Parallel open ditches and (v) Cross slope ditches.

(a) **Land smoothing,** sometimes called land forming or grading, is the operation of producing a plane land surface with a uniform slope. The practice is usually necessary to supplement field surface drainage or irrigation. In land smoothing, the elevated areas on the land surface are reduced and minor depressions are filled up and the land is smoothened and not leveled, so that the water will runoff due to the natural fall of the land. The depth of grading is controlled to prevent exposure of harmful subsoil.

(b) **Field surface drainage** may be carried out singly or in combination with pipe drainage. Types of these drainage methods are

(i) **Random field drainage:** The drainage system is suitable in areas where depressions are deep enough that it is not technically or economically feasible to fill up the depressions. The location and direction of these drains are determined by the Topography. The random field ditches carry excess water from one depression to the next and eventually away from the field. The side slopes of the channel may be as flat as 10:1 when depth of drain is more than 0.6m to 4:1 with smaller depths. A minimum cross section area of 0.45 m^2 is recommended. The maximum grade for sandy soils is 0.2% and for clay soils it is 0.4%. The minimum velocity should be in the range of 0.3 to 0.6 m/sec for depth of flow below 0.9m.

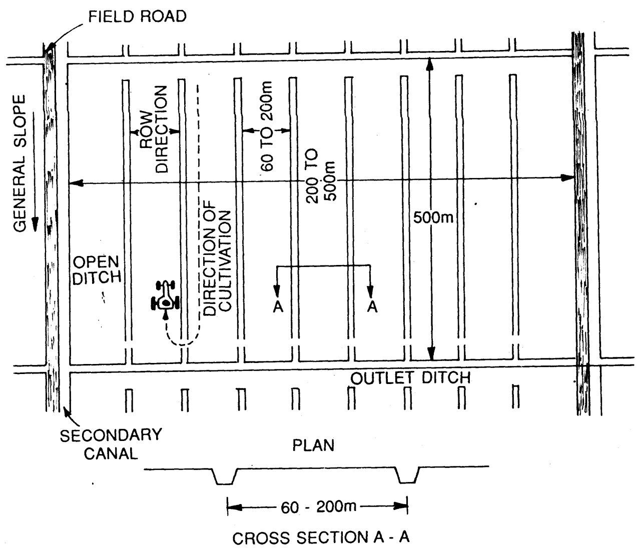
(ii) **Bedding system:** The bedding system of surface drainage is designed, constructed and maintained so that excess surface water drains laterally from crowned strips of lands (beds) into dead furrows, then into collection ditches and finally into an outlet. The area between two adjacent dead furrows is known as a dead. The beds should be laid out with the dead furrows running in the direction of greatest slope.

The design layout of a bedding system involves the proper spacing of dead furrows, depth of bed and grade in the channel. Bed with vary from 7 to 11 m for soils with very slow internal drainage and from 13 to 15 m for slow internal drainage. The depth of the bed varies from 15 to 45 cm allowing one- half of this depth for the dead furrow. Length of bed varies from 90 to 300 m.

The collector drains are placed at regular intervals across the slope of the land.

(iii) Parallel field ditch system : Parallel field ditches are similar to bedding, except that the ditches are spaced farther apart and have a greater capacity than dead furrows. This system is adapted to flat, poorly drained soils in which there are numerous shallow depressions.

The design and layout are similar to that for bedding except that the ditches are not equidistant. The size of the ditch varies with grade, soil and drainage area. The minimum depth and cross sectional area of the ditch is 22.5cm and 0.5 sq.m, respectively. The side slopes should be 8:1 or flatter to permit crossing with farm machinery. As in bedding, ploughing is done parallel to the ditches, but planting and cultivating are done perpendicular to them. The crop rows should have a continuous slope to the ditches. The maximum length of rows having a continuous slope in one direction is 180 m, allowing a maximum spacing of 360 m where the land drain in both directions.



Parallel open ditch system

(iv) Parallel open ditch system : It is similar to field ditch system except that these drains are deeper and have side slopes less than 4:1 and a minimum depth of 0.6m. These drains are also control the water table. When financial or other constraints do not allow pipe drainage this system is installed to control the water table.

(v) Cross slope ditches : The cross slope ditches system of drainage is used to drain sloping land. This type of drainage resembles terracing in that the drainage ditches are constructed around the slope on a uniform grade according to the lay of the land. The method is adapted to sloping wet fields of 4% slope or less, where internal drainage is poor and where shallow depressions hold water after rains.

2. SUBSURFACE DRAINAGE

Subsurface drains are underground artificial channels through which excess water may flow to a suitable outlet. Their purpose is to lower the ground water level below the root zone of the plants.

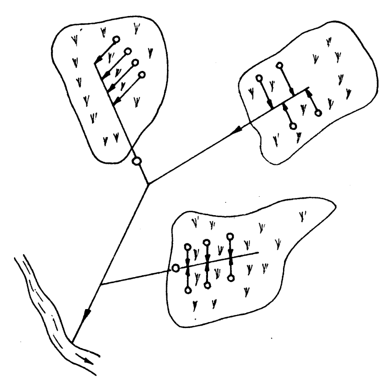
Advantages of subsurface drain:

1. Removes the gravitational or free water which is not directly available to plants and thus provides aeration and optimum soil temperature
2. Increases the volume of the soil from which roots can obtain food
3. Permits increase of the bacterial activity in the soil, which improves the soil structure and makes the plant food more readily available

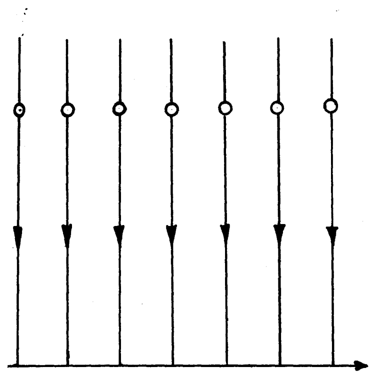
4. Increase the moisture available to the plants, because the root zone (from which food and water are drawn) is deepened
5. Reduces soil erosion, since a well drained soil has more capacity to hold rainfall, resulting in less runoff
6. Improves soil moisture conditions in relation to the operations of tillage, planting and harvesting machines and
7. Drainage removes toxic substances such as alkali from the root zone.

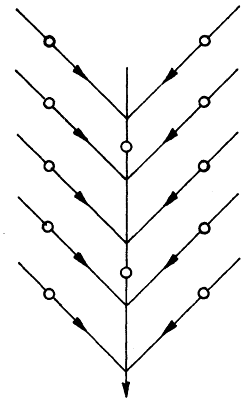
TILE DARINAGE : Tile drainage is accomplished by means of a series of tiles laid in a continuous line at a specified depth and grade so that the free water entering the system will flow out by gravity. A tile drainage system consists of a drainage outlet, tile main, sub-mains and laterals. The laterals remove the free water from the soil and the sub-mains and mains carry the tile water to the drainage outlet. Tile drainage systems, in general are the random, herringbone, gridiron and interceptor type.

i. Random : The random or natural system of tile is used, where there are scattered wet areas in a field somewhat isolated from each other. Tile lines are laid more or less at random to drain these wet areas. In most cases the tile main follows the largest natural depression in the field and sub-mains and laterals extend to the individual wet areas.



ii. Herringbone : The herringbone system consists of parallel laterals that enter the main at an angle, usually from both sides. This system is used where the main or sub-main lies in a narrow depression. In this system, there is considerable double drainage where laterals and mains join and the system may not be very economical. However, it is particularly suitable where laterals are long and the area requires thorough drainage.





Parallel drainage system **Herringbone system**

iii. Grid iron or Parallel system: This system is similar to the herringbone system expect that the laterals enter the main from only one side. It is used on flat regularly shaped fields and on uniform soil. It is more economical than the herringbone system because the number of junctions and the double drained areas are reduced. Where there is a broad, flat depression which is frequently a natural water course, a main may be placed on both side of the waterway. This system, known as a double main system, is essentially two separate gridiron patterns.

iv. Interceptor : The interceptor or cutoff system is used to intercept seepage water from hillsides or from a nearby canal, wet area are formed by seepage water moving horizontally through permeable layers which lie over an impermeable layer. This condition is indicated by seepage along a horizontal plane near the foot of the slope or at a break in grade interceptor drain should be laid along the bottom of the permeable layer in order to intercept the seepage causing the damage.

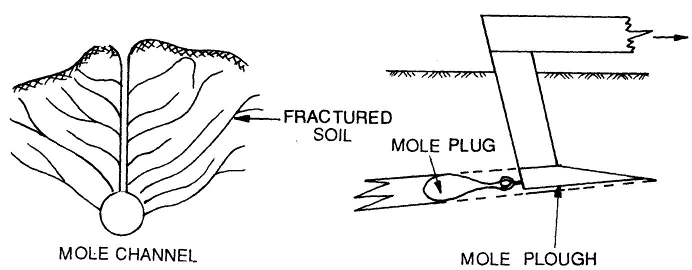
v. Relief drains : These are installed to lower the water table in a low lying area. They are oriented parallel to the direction of ground water flow. Water seeps into it from either side of the drain.

3. SPECIAL FORMS OF DRAINAGE

a) Vertical drainage is the disposal of drainage water through vertical wells in to a porous layer of earth or an open rock formation capable of taking large volumes of water rapidly.

b) Mole drainage is unlined underground channels formed by mole plough, without a trench having to be dug. The attraction of this method lies in its low installation costs as compared with those of pipe drainage. Mole drains may be effective in cases where pipe drains are economically not feasible. Mole drainage is particularly appropriate in dense, poorly pervious clay soils which have a certain general slope. Its primary aim is not to control the ground water table, which may be very deep, but to remove excess water from field surface or from the top soil, where it may constitute a perched water table.

Mole drains should have a continuous slope in the direction of the outlet. Since most machines can only draw the channel parallel to the land surface, the land should have a certain slope. Flat land and land with irregular topography are less suitable. Since unlined mole channels tend to deteriorate rapidly near the outlet, normally 2 to 3 m length of mole channel will be lined close to the outlets.



To ensure fissuring of soil throughout the area spacing between 2 m and 5 m are commonly applied. The channels should be sufficiently deep to be protected from the effects of drought and bed from heavy farm machinery. In practice, mole depths of 45 cm and 60 cm are normal. Installation cost increases with the depth and reduced spacing. The length of each mole channel reaches as much as 200 m.

c) In well drainage the artificial removal of ground water can be effected either by horizontal subsurface pipes or pumping groundwater through tube wells. The tube well drainage is capable of draining the ground water table deeper when compared with gravity drainage by pipes. General principles of water flow, number, spacing, drawdown, layout and arrangement of wells, construction and maintenance of the system are important in the performance of the well drainage.

d) Bio-drainage : In area where land topography does not permit gravity surface drains and where ground water is saline, water table control can be obtained by bio-drainage to some extent. The potential of certain forest species to draw more water than the agricultural crops because of their deeper root system, higher transpiration rates throughout year and the ability to minimize recharge from rain. By intercepting it on their foliage, provides a technique for keeping water table under control. These plantations work as biological pumps, which can transpire large quantities of water. The interception by Pinus Padiata tree is the highest (1 mm) followed by Eucalyptus (0.8 mm) and Acacia Longiflora (0.6 mm). Eucalyptus is fast growing tree and works as a water pump in soil and pumps as deep as 20 m. Eucalyptus grow well in problem soils and give a wood yield of 20 m3/ha/year and pumps 3-6 mm/day water from soil.

GROUND WATER AND WELLS

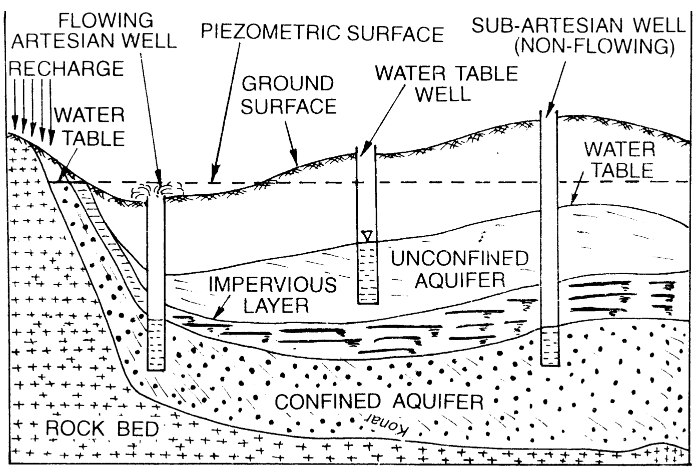
Ground water is the underground water that occurs in the saturated zone of variable thickness and depth, below the earth’s surface. Cracks and pores in the existing rocks and unconsolidated crystal layers, make up a large underground reservoir, where part of precipitation is stored. The ground water is utilized through wells and tube wells.

GROUND WATER AQUIFERS

A permeable stratum or geological formation of a permeable material, which is capable to yield appreciable quantities of ground water under gravity, is known as Aquifer. When an aquifer is overlaid by a confined bed of overburden is called an Aquiclude. The types of aquifers are

1. Unconfined Aquifer or Non-Artesian Aquifer: An unconfined Aquifer is one which is not confined by an upper impermeable layer. It is also known as water table aquifer. Water in these aquifers is at atmospheric pressure. The upper surface of the zone of saturation is known as water table. When a well is constructed in these aquifers the level of the water table is the level of water in the well.

2. Confined Aquifers or Artesian Aquifers : When an aquifer is confined on its upper and under surface, by impervious rock formations i.e. aquicludes, and is also broadly inclined so as to expose the aquifer somewhere to the catchment area or recharge area at a higher level for the creation of sufficient hydraulic head, it is called a confined aquifer or an artesian aquifer. Water in this aquifer is under pressure above atmospheric pressure. When a well is put in these aquifers water will rise to a level above the bottom of the upper confining layer because of the pressure under which water is held. The imaginary level to which water will rise in wells located in an artesian aquifer is known as the piezometric level. Should the piezometric surface lie above ground surface, flowing (artesian) well results



Different types of aquifers

3. Perched Aquifer : Perched aquifer occurs whenever a ground water body is separated from the main ground water by a relatively impermeable stratum of small areal extent.

TYPES OF WELLS

Water well consist essentially a pit, shaft or a bore constructed in the earth with the purpose of extracting groundwater. The wells are classified as

a). Based on the type of aquifer supplying water to the well

A well tapping an unconfined aquifer, is referred to as a water table well or gravity well and a well tapping a confined aquifer is known as an artesian well. An artesian well may again be classified as flowing artesian well or non-flowing well depending upon the fact whether the piezometric level is above or below the ground level.

b) Depending upon the method of construction

1. Dug wells or open wells: Dug wells are wells of comparatively large diameter and excavated manually, these wells extend to a depth of 4- 10 m below the water table. The types of open wells are,

(a) Unlined wells are generally constructed for temporary use and are dug up to the water table in harder soils which can stand vertically without lining.

(b) Masonry wells have a masonry constructed either with stone or brick. Water enters these wells from the pervious bottom.

(c) Wells with pervious lining are lined with dry brick or stone masonry or brush wood. They are constructed in areas where good water bearing strata is not available within a reasonable depth.

(d) Open wells in rocky substrate are constructed in rocky substrate having water. In such strata water usually comes from joints, cracks and fissures.

(e) The open wells are also classified as shallow wells or deep wells depending upon whether the well draws water from the first sandy stratum or the well penetrates the impervious stratum and draws from below.

2. Driven-wells are constructed by driving into the ground a pointed screened cylindrical section called strainer and the pipes are connected to it directly into the water bearing formation. Water enters the well through the strainer. Diameter of driven wells vary from 3 cm – 10 cm. Depths are also within 30metres. These wells are suited for domestic supplies.

3. Jetted wells are constructed by the cutting action of a water jet. High velocity water jet is used for this purpose. In unconsolidated formations, 3 – 8 cm diameter wells are constructed in this method.

4. Bore wells having a maximum diameter of 15 – 20 cm and a depth of about 20 meters are constructed by using augers either operated by hand or mechanically. In order to increase the availability of water in dug well, sometimes a combination of a dug-cum bored well is adopted. For such wells to be successful, a confined aquifer should be available below the dug wells.

5. Tube wells consist of a pipe or a tube fixed in a deep bore of small diameter passing through many strata, some of them water bearing and some non water bearing. Tube wells are classified as

(a) Cavity type of tube wells do not have a strainer and draw water from one stratum only. A cavity well is installed in a soil formation where a thick clay layer lies over a sandy water bearing formation. It draws water through the cavity formed at the bottom of the pipe in the water bearing formation.

(b) Strainer type wells – In these wells, drilling is continued through different layers and after ascertaining the water bearing strata, strainers are fixed opposite to these strata to allow water entry into the tube well. Plain pipes are located against the non-water bearing layers. For the strainer type wells, drilling is to be started with pipes of larger diameter known as casing pipes than the strainer and these pipes are to be extracted after the strainers are installed.

(c) Gravel packed wells or shrouded wells are an improvement over the strainer type wells. Shrouding refers to filling of the surrounding strata of the strainer with gravel of suitable size. In shrouded wells, slotted pipes are used as strainers and as such these wells are referred to as slotted tube wells also.

(d) Filter point well is a shallow tube well. There is no separate suction pipe for the pumping plant, the pipe of the filter point is directly connected to the suction side of pump. Filter points are possible only at locations where the pumping level of the spring water table is not lower than 7 meters below the ground level. They are normally sunk in sandy aquifers. They are successful in Cauvery delta of Tamil Nadu and the Krishna and Gothavari deltas of Andhra Pradesh. The major types of filter points used are

(i) Metal type filter point is made from a 10 – 15 cm diameter pipe with 8 – 15 mm diameter holes drilled at a spacing of 2.5 of 4 cm. About 20 cm blank space is left at both ends. The bottom is plugged with a conical driver point and the upper end threaded for screwing to blank pipes. The pipe with the drilled holes is covered with copper or brass wire mesh. This type of filter point is costly and the life is 5 – 7 years.

(ii) Coir filter points are cheap and popular in coastal areas of South India. It consists of a cylindrical frame work made of steel rods with circular bands of flat steel held in position by riveting or welding. At the bottom a conical wooden plug is fitted with the apex pointing downward and on the top a coupling is welded to the spacers for screwing blank pipes. Twisted coir rope of 3mm – 5mm thickness is wound round the cylindrical frame work.

(iii) Slotted pipe filter consists of round metal pipes on which rectangular slots of 2.5 – 6.5 mm width and 5 – 7.5 cm length are cut. This slot to slot spacing is 6 – 20 mm and the row to row spacing of slots is 25 to 40 mm. Gravel packing is provided around the slotted pipe.

PUMPS

The mechanical device or arrangement by which water is caused to flow at increased pressure is known as a pump and the process of using a pump for this purpose is known as pumping. Irrigation pumps, in general, are driven either by engines or electric motors. Basically, the following four principles are involved in pumping water. They are atmospheric pressure, centrifugal force, positive displacement and movement of columns of fluid caused by differences in specific gravity. Pumps are classified on the basis of mechanical principles of operation as

i) Positive displacement pumps a) Reciprocating b) Rotary

ii) Variable displacement pump

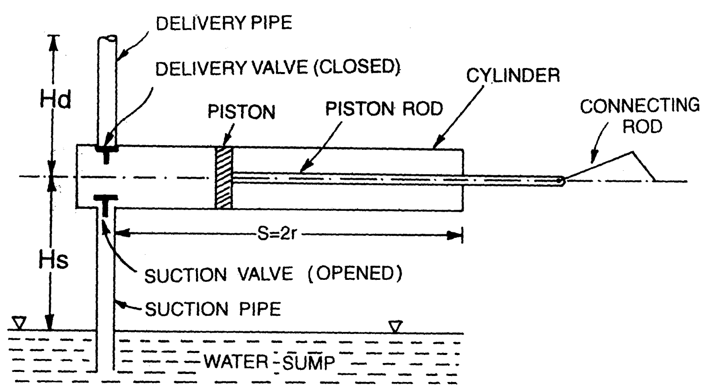
- a) Centrifugal pump
- b) Turbine pump 1) Deep well turbine 2) Submersible pump
- c) Propeller pump
- d) Jet pump and
- e) Air lift pump

I.POSITIVE DISPLACEMENT PUMPS

In a positive displacement pump, the fluid is physically displaced by mechanical devices such as the plunger, piston, gears, cams, screws etc,. In this type of pump, a vacuum is created in a chamber by mechanical means and then water is drawn in this chamber. The volume of water thus drawn in the chamber is then shifted or replaced mechanically out of chamber.

a) Reciprocating pump

In this type of pump, a piston or a plunger moves inside a closed cylinder. On the intake stroke, the suction valve remains open and allows water to come in to the cylinder. The delivery valve remains closed during intake stroke. On the discharge stroke, the suction valve is closed and water is forced in delivery pipe through delivery valve, which opens during discharge stroke. The reciprocating pump may be single acting or double acting. In the former type water is discharged only on the forward stroke of the piston and in the latter type, water is discharged on forward and return strokes of the piston. This type of pump is quite suitable for grater discharge under high head of water. The theoretical suction head is equal to atmospheric pressure which is 10 m of water but in practice it cannot exceed 8 m

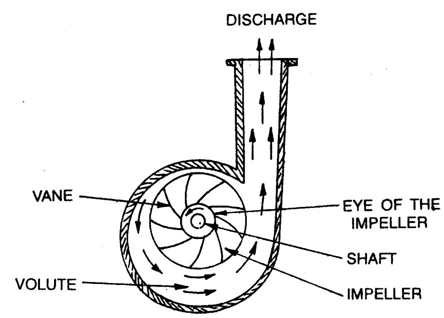


Single acting reciprocating pump

b) Rotary pumps: In this type of pump, the reciprocating motion is replaced by the rotary motion. The rotary motion is achieved by cams or by gears. There are two cams or gears, which fit with each other. They rotate in opposite directions. The water enters through the suction pipe and it is trapped between cams or teeth of gears and casting. It is then thrown with force into the discharge pipe. This type of pump is useful for moderate heads and small discharges not greater than 40 litres per second.

II. VARIABLE DISPLACEMENT PUMPS

The distinguishing feature of variable displacement pumps is the inverse relationship between the discharge rate and the pressure head. As the pumping head increases, the rate of pumping decreases. They are also termed as Roto dynamic pumps.



A) Centrifugal pump: A centrifugal pump may be defined as one in which an impeller rotating inside a close – fitting case draws in the liquid at the center and, by virtue of centrifugal force, throws out through an opening at the side of the casing. In operation, the pump is filled with water and the impeller rotated. The blades cause the liquid to rotate with the impeller and, in turn, import a high velocity to the water particles. The centrifugal force causes the water particles to be thrown from the impeller reduces pressure at the inlet, allowing more water to be drawn in through the suction pipe by atmospheric pressure. The liquid passes into the casing, where its high velocity is reduced and converted into pressure and the water is pumped out through the discharge pipe. The conversion of velocity energy into pressure energy is accomplisher either in a volute casing or in a diffuser. It is most commonly used for irrigation purpose. The suction limit of the pump is 10 m.

Priming

While positive displacement pumps, especially piston pump, can move and compress all fluids, including air, centrifugal pumps are very limited in their capacity to do so. Hence they are to be primed, or filled with water up to the top of the pump easing to initiate pumping. Priming is done by using 1) A foot valve to hold the water in the pump 2) an auxiliary piston pump to fill the pump 3) connection to an outside source of water under pressure for filling the pumps and 4) use of a self priming construction.

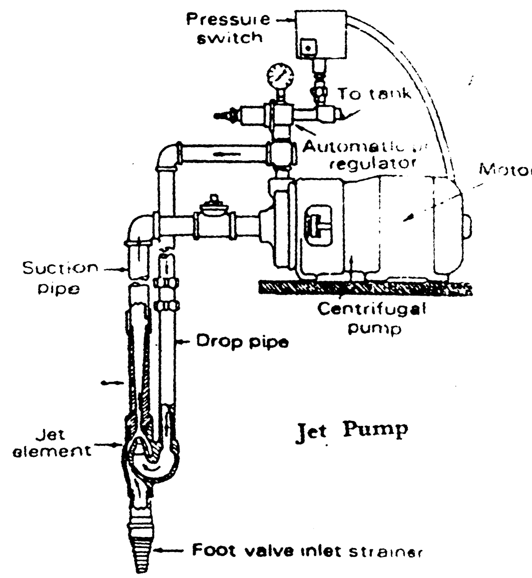
B. Turbine Pumps: Turbine pumps consist of impellers placed below the water level and are driven by a vertical shaft rotated by an engine or motor placed at the ground level or under the water.

(i) Vertical Turbine pump (or) Deep well Turbine pump, is a vertical axis centrifugal or mixed flow type pump comprising of stages which accommodate rotating impellers and stationary bowls possessing guide vanes with the motor fixed on the ground level. The pump bowl is surrounded by a screen to keep coarse sand and gravel away from entering the pump. These pumps are adapted to high lifts and high efficiencies under optimum operating conditions. The pressure head developed depends on the diameter of the impeller and the speed at which it is rotated. Since the pressure head developed by a single impeller is not great, additional head is obtained by adding more bowl assemblies or stages. Turbine pumps could be water lubricated or oil lubricated. It is preferable to use oil-lubricated pumps for wells giving fine sand along with water.

(ii) Submersible pump is a turbine pump coupled to a submersible electric motor. A cable will be passing through the water supplies power to the motor. Both the pump and the motor are suspended and operate under the long shaft and bearings that are necessary for a turbine pump. Submersible pumps are cheaper than the vertical turbine pumps. Suitable for deep settings and also for crooked wells, which are not perfectly vertical. The installation of the pump is easy and the initial cost of installation low. The repair of the submersible pumps, when they go out of order, is not easy and requires technical skill. Submersible pump requires little maintenance, after 6000 hours of operation or two years of service life. It may be necessary to withdraw the pump from the bore hole and overhaul it. Selection of the submersible pump is mainly depending upon the bore well size, type, well discharge etc.

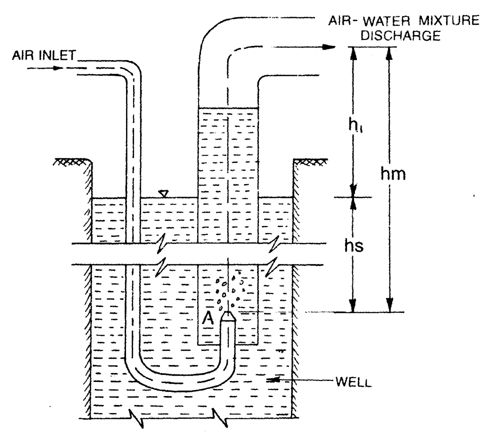
(c) **Propeller pumps:** The principal parts of the propeller pumps and method of operation are similar to the turbine pumps. The main difference is in design of the impellers, which give high discharges at low heads. Two types of impellers i.e. axial flow type and mixed flow type are used in this pump. In single stage pumps only one impeller is used and in multistage pumps more than one impeller is used.

(d) **Jet pumps:** Consist of a combination of a centrifugal pump and a jet mechanism or ejector. Jet pump is used when the suction lift of the centrifugal pump exceeds the permissible limits. A portion of the water from the centrifugal pump is passed through the throat opening, creating a vacuum, which causes water to be drawn from the well. The boosted up water is carried up through the diffuser where the high velocity energy is converted into useful pressure energy, forcing the water up through the delivery pipe to the centrifugal pump.



Jet Pump

(e) A**irlift pump** operates by the injection of compressed air directly into the water inside a discharge pipe at a point below the water level in the well. The injection of the air results in a mixture of air bubbles and water. This composite fluid is lighter in weight than water so that the heavier column of water around the pipe displaces the lighter mixture facing it upward and out of the discharge pipe and a smaller air pipe. Air – lift pumping is extensively used in the development and preliminary testing and cleaning of tube wells. The advantages of airlift pumps are simplicity, tube well need not be perfectly straight or vertical, and impure water will not damage the pump. The main disadvantage is its low efficiency about 30 percent.



Selection of pumps

Selection of pumps are based on the characteristic curves namely,

1. **Head capacity curve – which shows, how much water a given pump will deliver with a given head at one particular speed.**
2. Overall efficiency curve – represents the relationship between the efficiency of the pump and discharge for different speeds and
3. Brake – horsepower curve – gives the relation between the discharge, speed and horsepower. In case a centrifugal pump has to be selected for pumping from an open water source, the total head has to be calculated for selecting the suitable pump. In case of wells, the head – capacity curve of the well is matched with the pump head – efficiency – horsepower curves and the pump is selected.

Specific speed of a pump may be defined as the speed of a geometrically similar pump when delivering one cubic meter / second of water against a total head of one metre (Church and Jegadish Lal, 1973). The value of specific speed is useful in comparing the performance of different pumps.

$$\text{Specific speed in rpm} = n_s = \frac{n\,Q^{1/2}}{H^{3/4}}$$

Where, n = pump speed in rpm; Q = Pump discharge in m3 / sec; H = Total head in m

General maintenance of pumps for maximum working efficiency

1. The suction lift should be periodically checked and it should be within the permissible limits.
2. The gland packing in the pump should be checked and replaced if necessary. The water should drip through the packing at a rate of 15 to 30 drops per minute.
3. Periodical inspection of impeller of the pump is necessary for wear.
4. The rpm of the prime mover should be at the rated value.
5. The alignment of the pump and motor shaft should be checked periodically.

SOIL CONSERVATION AND IRRIGATION ENGINEERING

Practical Manual for the course SWC 311 of

Third year B.Sc. (Ag)
2004-2005

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CERTIFICATE

Certified that this is the bonafide record of

Thiru / Selvi -- I.D No. ---------------------

--------------- of IIIrd year B.Sc.(Ag) during the year 2004-2005 for SWC 311

Soil conservation and Irrigation Engineering (1+1)

External Examiner

Course Teacher / Internal Examiner

CONTENTS

1. CHAINS AND CROSS STAFF SURVEYING

Chaining a line

It means measurement of lines between two stations either with the help of a chain or a tape. At the time chaining, two persons called chainmen are used. The chainman at the rear end is called the follower and the chainman at the forward end is called the leader. The follower should be more experienced and skilled, as he has to direct the leader about the different steps of chaining.

1. The follower holds the handle in one hand and throws the chain forward with the other hand.
2. Leader takes one handle of the chain and ten arrows and moves forward till he reaches approximately one chain length. The kinks etc. are removed by jerk
3. The follower places the zero end of the chain with the peg at the starting of the line and directs the leader to range in line with end of the station.
4. The leader inserts an arrow on the ground at the outer edge of the chain to mark the end of one chain length.
5. The leader moves forward with one handle of the chain, at the end of the second chain length, the leader inserts the second arrow.
6. The follower picks up the first arrow and the moves forward carrying out the chaining process in the similar manner.
7. At the end of station, fractional measurement is taken by counting the links with the help of brass tags fixed to the chain.
8. After the work is over, the chain is folded and fastened with a leather strap, starting from the middle; two pairs of links are taken at a time in the right hand and placed obliquely across the other in the left hand.

CROSS STAFF SURVEY

The area is divided in to right angles and trapezium, and bases and perpendiculars are measured directly in the field and no angular measurements are taken. Chain and cross staff are the principal instruments in the work. Two chains are usually provided for measuring the chain line and for measuring offsets. This is the simplest form of surveying and suitable to small land when ground is fairly level and open.

Accessories in chain surveying

Arrows or pins

They are made up of metallic wires or thin rods. The arrow is pointed at one end for fixing on the ground and a loop is provided at the top for holding it. While measuring distances, arrows are used to mark the end of the chain or tape.

Ranging rods

In order to measure accurate length between two stations, it is necessary that the chain line joining the stations should be straight. Ranging rods are used for ranging lines and to mark stations, which must be seen from a long distance. They are made of light strong and thin seasoned wood or mild steel rods. Pointed metal shoe is provided at the bottom to facilitate fixing in the ground. The rod is alternately painted white and black. They are generally 2 to 3 m length.

Cross-Staff

It is used for marking right angles in the field. It consists of four arms fixed on a hollow cone, which fits in the wooden rod. Two fine slits are cut at right angles to each other on four arms of the head. To find the perpendicular from a given point on the chain line, the cross-staff is held vertically on a point and both the ends of the ranging rods are seen. Now from the other two arms, the ranging rod is bisected, if not, the cross-staff is moved to and fro till the ranging rod is bisected. This is the required point from which offset is taken. Optical Square which works on the principle of reflection, can also be used for setting out right angles. Optical Square is more accurate than the cross staff and it can be used for locating objects situated at longer distances.

Terminology

Survey stations: Main stations are the lines, which command the boundaries of the field. Lines joining the main stations are the main survey lines or the chain lines.

Offset line: It is the particular distance taken for any point from chain line to any object.

Base line: The longest of chain line in making a survey is generally regarded as the base line. It should be laid off on level ground as far as possible and should pass through the centre of the area.

Check line: A line joining the apex of the triangle to some fixed point on the opposite side or a line joining some fixed points on any two sides of a triangle. It is also called as proof line.

Tie line: Line joining two fixed points on the main survey line called tie line.

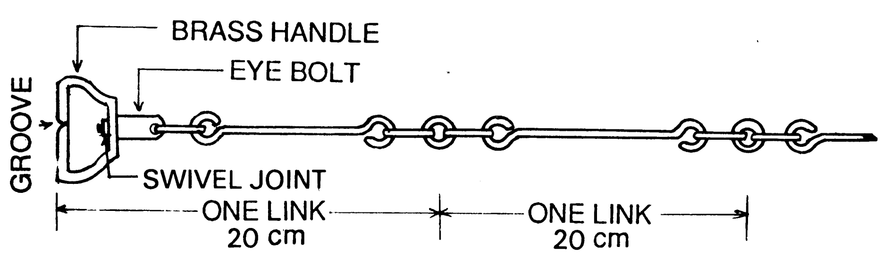
The fieldwork in the chain survey may be detailed as follows.

1. On arriving the ground the surveyor walks over the entire area and thoroughly examines the ground so as to decide upon the best possible arrangement of the work. This preliminary survey is called reconnaissance survey. “Index sketch” is prepared showing the boundaries and principal features as buildings, roads, ditches etc.

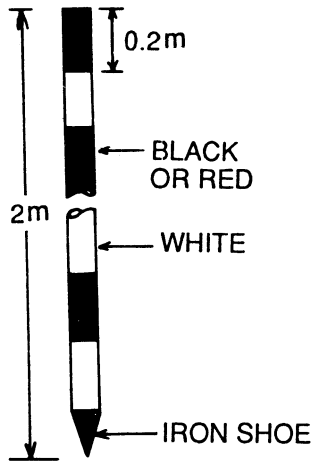
2. Survey stations are marked on the ground so that they can be easily identified during survey work. Wooden pegs are placed when the chain lines accompany and ground features are measured. After preliminary work is finished the lines and offsets are measured. To take offsets the chain is kept lying on survey line and offsets are taken to the adjacent objects by means of another chain/tape. The direction of the first line is usually determined by prismatic compass. These measurements are noted simultaneously in the field book showing the offsets to the left or right according to their position. The station marks are preserved carefully until fieldwork is completed.

Practical activity

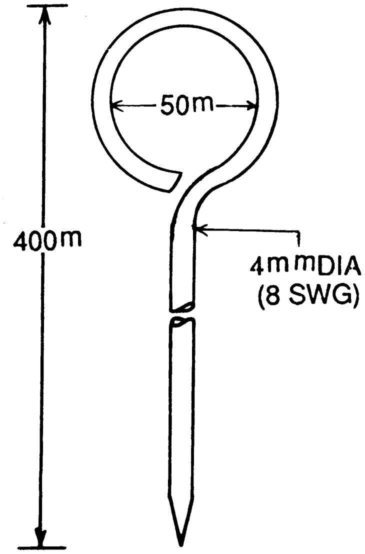
1. Identify the parts of a metric chain and practice for unfolding and folding the chain.
2. Identify the accessories required to conduct the chain and cross staff survey
3. Find the area of a given field using chain and cross staff survey after plotting it



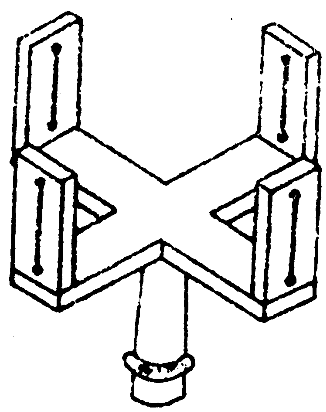
Metric Chain



Ranging rod



Arrow



Cross Staff

2. COMPASS SURVEY

Compass surveying is a branch of surveying in which directions of survey lines are determined with a compass and the lengths of the lines are measured with a tape or a chain. The compass is generally used to run a traverse, which means to pass across. A traverse consists of a series of straight lines connected together to form an open or closed polygon.

A traverse may be classified as

1. Closed traverse

   When the connected lines form a closed figure the traverse is termed as closed i.e. the survey will finally finish at the station from which it has started. It is used for locating boundaries of fields, lakes etc.

2. Open traverse

   The traverse in which last line does not coincide with the starting station is known as open traverse, the connected line does not form a closed polygon

Terminology

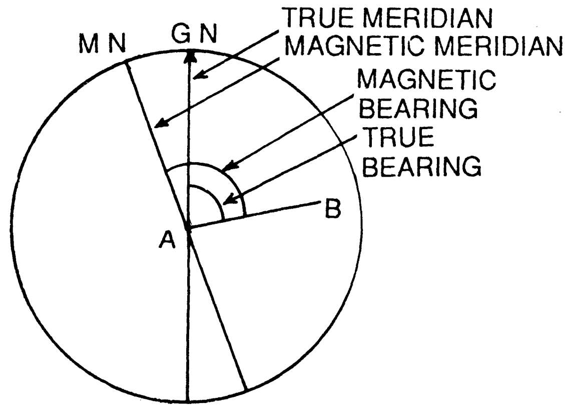
Bearing: It is the angular measurement with respect to some fixed direction, which is known as meridian.

True meridian: The direction indicated by an imaginary circle passing round the earth through the place in question and north and south geographical pole is known as true meridian. The horizontal angle between this meridian and a line is called the true bearing.

Magnetic meridian: The direction indicated by a freely suspended and properly balanced magnetic needle unaffected by forces due to local attraction is called the magnetic meridian. It is used in plane surveying. The horizontal angle between this meridian and a line is called the magnetic bearing.

Assumed meridian: Any arbitrary line chosen as the meridian is called assumed or arbitrary meridian. In small survey, it is usually the first line of survey. The horizontal angle which makes with this meridian is called arbitrary or assumed bearing.

Local attraction: the deviation of the magnetic needle under the effect of external attractive forces, such as iron ore, magnetic rock, electric field etc. is called local attraction.



Meridians and Bearings

There are two forms of compass in common use

a) Prismatic compass: It is useful for speedy and rough work but with less accuracy
b) Surveyor’s compass: For precise surveying work

Prismatic compass

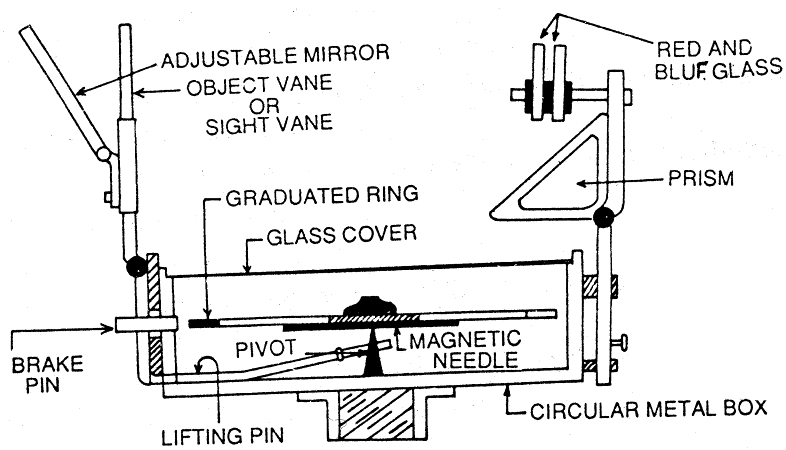
It is the instrument designed for the measurement of magnetic bearings. It mainly consist of a magnetic needle, a thin aluminium ring, graduated in degrees and minutes throughout the circle, object vane and eye vane with prism. Object vane and eye vane are opposite to each other. The hair or the wire of the object vane coincides with the object and reading is taken below the focusing vane. The graduation of the ring should be such that if an object is pointing exactly towards north. Then the reading below the eye vane should be 0^o. But, when north side of the needle is pointing towards the object, then opposite to it i.e. below the eye vane, will be south side. So in order to get the reading zero, the graduations have to start from south, i.e. zero degree should lie exactly on the south, instead of north as in ordinary cases.

The eye vane is so constructed that reading and sighting is simultaneously done. It is provided with a prism, which has both its faces convex. The convex prism gives magnified image of the graduations. The focusing of the prism, to suit different eyes, is done by the focusing stud of prism. Sunglasses are provided to take the observations, evening in the direction of the sun.

Working of the prismatic compass

The prismatic compass is mounted on a tripod by screwing it to a vertical spindle in a ball and socket joint. With this arrangement, the compass can be easily be leveled in a horizontal plane. After this the following three steps are followed.

1. Centering: The compass is placed approximately over the station and a stone is dropped from below the centre of the compass.
2. Levelling: By means of the ball and socket arrangement, the compass is leveled so that the graduated ring along with magnetic needle can swing freely.
3. Observation of bearing: After centering and leveling the prism is adjusted till the graduations on the ring are visible when looked through the prism. The compass box is turned until the ranging rod to be sighted is bisected by the horse hair when looked through the slit above the prism. As soon as the ring comes to rest, reading is taken through the prism sighting the ranging rod simultaneously.



Prismatic compass

Designation of bearing

The bearings are expressed in two ways 1) the whole circle system and 2) the quadrantal system

1. The whole circle bearing (W.C.B) of a line is the horizontal angle, which, the line makes with the magnetic north meridian. It is measured in the clockwise direction and can have any value between 0^o and 360^o. The bearing measured by a prismatic compass is WCB.

2. The quadrantal bearing (Q.B) or reduced bearing of a line is the acute angle which the line makes with north or south direction of the meridian. Thus the Q.B is measured either clockwise or anti-clockwise from the north point or the south point, whichever is nearer. The Q.B. of a line can not be greater than 90^o. The surveyor's compass measures the bearing in the quadrantal system.

The W.C.B of a line can be converted to the qaudrantal bearing and wise versa by using the following table

Value of WCB	Quadrant	Relationship between WCB and QB
0^o to 90^o	NE	WCB = QB
90^o to 180^o	SE	WCB = 180^o - QB
180^o to 270^o	SW	WCB = 180^o + QB
270^o to 360^o	NW	WCB = 360^o - QB

.Example 1

Convert the following WCB to QB

Problem

Line	WCB
AB	$45^o30'$
BC	$125^o45'$
CD	$222^o15'$
DE	$320^o30'$

Answer

Conversion from WCB to QB
N $45^o30'$ E
180^o - $125^o45'$ = S $54^o15'$ E

.Example 2

Convert the following QB to WCB

Problem

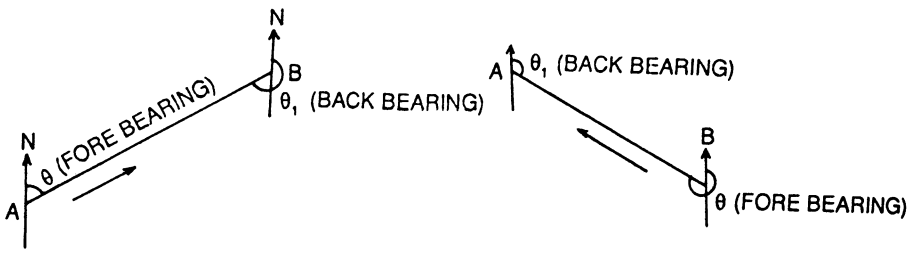
Line	QB
AB	S $36^o30'$ W
BC	S $43^o30'$ E
CD	N $26^o45'$ E
DE	N $40^o15'$ W

Answer

Conversion from QB to WCB
$180^o0'$ + $36^o30'$ = $216^o30'$

Types of bearing

The bearing of a line in the direction of the progress of the survey is called the fore bearing (F.B) and the bearing of the line in the opposite direction of the progress of the survey is called the back bearing (B.B). it could be seen that the fore and back bearings are having a difference of 180^o.



BB of a line = FB of that line + 180^o (if the value of FB is less than 180^o)

= FB of that line - 180^o (if the value of FB is more than 180^o)

Example 3

Following are the observed fore bearing of the lines in WCB system, find their back bearings

Problem

Line	FB
AB	$38^o14'$
BC	$142^o18'$
CD	$208^o37'$
DE	$318^o26'$

Answer

Conversion from FB to BB
$38^o14' + 180^o = 218^o14'$

Example 4

Following are the observed fore bearing of the lines in QB system, find their back bearings

Problem

Line	FB
AB	S $30^o30'$ E
BC	N $40^o30'$ W
CD	S $60^o15'$ W
DE	N $45^o30'$ E

Answer

Conversion from FB to BB
N $30^o30'$ W

Calculation of included angles from the bearings

When two lines meet at one point, two angles are formed. They are interior and exterior angles. The interior angles are usually small one. However, some times, the smaller angle may be exterior angle. The sum of these two angles is equal to 360^o.

Case I. When the bearing of two lines measured at their point of intersection

Rule: The difference between the grater angle and smaller angle

- Gives the interior angle, if the value is less than 180^o
- Otherwise, the interior angle is obtained by subtracting the difference from 180^o

Case II. When the bearing of two lines not measured at their point of intersection

Rule: The bearing of the two lines at their point of intersection is determined first and

- Then the rule for case I is applied to get the included angles

Example 5

Find the angle between the lines AB and AC if their respective bearings are as follows

Problem

AB	AC
$30^o45'$	$140^o15'$
$20^o30'$	$340^o45'$

Answer

Angle BAC
$140^o15' - 30^o45' = 109^o30'$
$340^o45' - 20^o30' = 320^o15'$ Since the difference is greater than 180^o, it is an exterior angle. Hence the interior angle = $360^o - 320^o15' = 39^o45'$

Example 6

Find the included angle between the lines AB and BC if their respective bearings are

a) $40^o20'$ and $150^o30'$ b) 120^o and 45^o

Answer

Since the bearing of the two lines are not given at their point of intersection, at first both the bearings should be changed as if measured at the point of intersection (B) and then the included angles can be found out.

a) F.B of line BA = B.B of line AB = $40^o20' + 180^o = 220^o20'$

Angle ABC= $220^o20' - 150^o30' = 69^o50'$ (which is interior included angle)

b) F.B of line BA = B.B of line AB = $120^o + 180^o = 300^o$

Angle ABC= $300^o – 45^o = 255^o$ (which is exterior angle, so the interior angle = $360^o – 255^o = 105^o$

Example 7

The bearings of the sides of a triangle ABC are as follows. Calculate the angles of the triangle and apply geometrical check.

AB = $50^o15'$ BC = $150^o50'$ CA = 280^o

Answer

FB of BA = BB of AB = $50^o15' + 180^o = 230^o15'$

Angle ABC = $230^o15' – 150^o50' = 79^o25'$

FB of CB = BB of BC = $150^o50' + 180^o = 330^o50'$

Angle BCA = $330^o50' – 280^o = 50^o50'$

FB of AC = BB of CA = $280^o - 180^o = 100^o$

Angle BAC = $1000^o – 50^o15' = 49^o45'$

Summation of the three angles of the triangle = $79^o25' + 50^o50' + 49^o45' = 180^o$

Check for closed traverse

Sum of all the interior included angles of any polygon must be = $(2n – 4)\ 90^o$

Where n is the number of sides of the traverse.

Sum of all the included angle of triangular shape traverse = $[(2 \times 3) – 4]\ 90^o = 180^o$

Checked and found correct

Practical Activity

1. Record the bearings of boundary line of a given field by using a prismatic compass and check for closed traverse
2. Plot the field and determine the area.

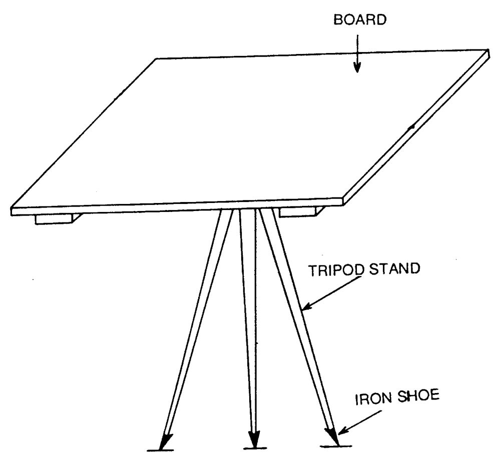
3. PLANE TABLE SURVEYING

The plane table surveying is a method of surveying in which the field work and plotting is done simultaneously, it is therefore a graphical method of surveying which does not require a field book. It is adopted for small and medium scale mapping.

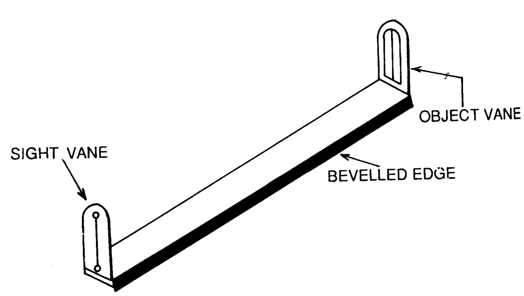
Equipments

The following equipments and accessories are used for plane table surveying.

1. Plane table: It is essentially a drawing board mounted on a tripod stand. The board is made of well seasoned teak or other good quality wood. It is plain, well polished and soft so that drawing papers can be fixed on it with drawing pins and lines can be drawn with out difficulty. The normal size of the board varies from 50to60cm square to rectangle of 75cm into 60cm. It is mounted on a tripod, can be revolved on a vertical axis and clamped. Levelling can be done by adjusting the legs of the tripod.
2. Alidade: It is a straight edge ruler made of brass or teak wood and is about 50cm long. It may be plain or telescopic.

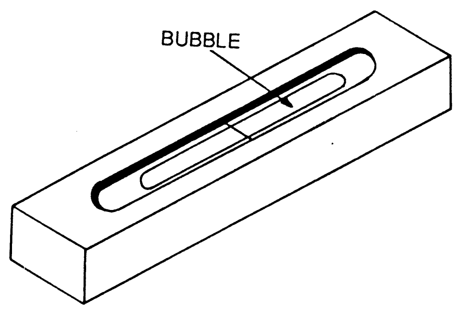


Plane table

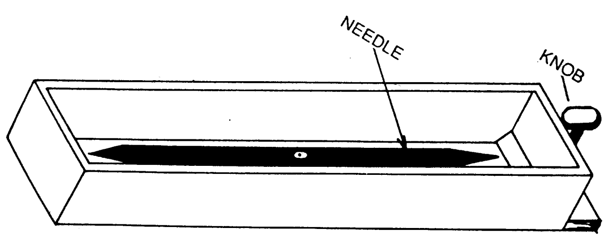


Plain alidade

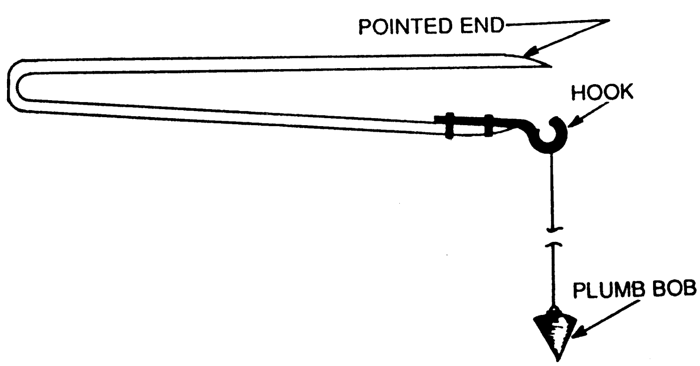
3. Trough compass: It is used for marking the direction of the magnetic meridian on the drawing sheet.
4. U-fork with plum bob: It is used for centering the table. Centering is the process of placing the table in a manner such that the point on the paper is exactly vertically over the point on the ground, which it represents.
5. Sprit level: This is used for leveling the plane table. It has a level base and is kept on the plane. It has an air bubble. Keeping the level perpendicular and bringing the air bubble to the centre, the plane table is leveled.
6. Drawing sheet: A drawing sheet of desired size is used.
7. Chain, Pencil, Eraser, Pin, etc.: These are accessories required during the plane table surveying. The chain is used to measure the distance on the ground.



Sprit level



Trough compass



U-Fork with plumb bob

Setting up the table

Three operations are required in setting up the table on a station.

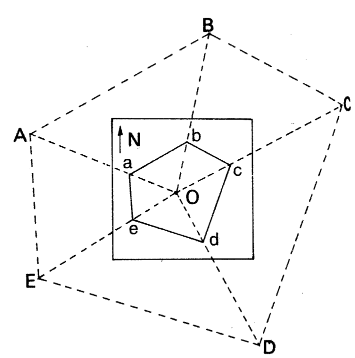
1. Levelling: The table is approximately leveled and kept at a convenient height by expanding the legs of the tripod. Then orientation and centering are done. After finishing this table is finally leveled by making use of ball and socket joint. The level is checked by sprit-level.
2. Orientation: The process of keeping the plane table at successive station parallel to the position, which it occupied at the very first station, is known as orientation. Orientation is done by two ways a) by back sighting b) by magnetic needle
3. Centering: It is necessary that the station made on the sheet should lie exactly over the station on the ground. The pointed end of the upper leg of U-fork should coincide with the point on the paper and the plumb bob suspended from the lower edge should touch the peg fixed over the station

Methods of plane table survey

Following methods are used for plane table survey.

Radiation

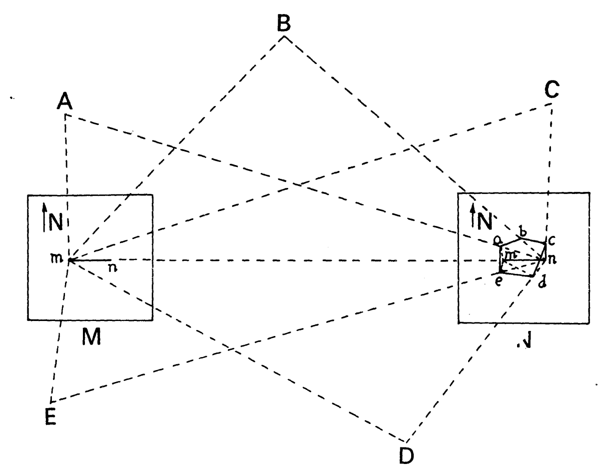
It is required to plot the field ABCDEFGA by radiation method. Place the table at some convenient point O approximately in the centre of the field. Draw radial lines for corners the ABCDEFG with alidade touching O. Measure the distance OA, OB, OC, OD, OE, OF and OG. By selecting some convenient scale, fix the points on the respective lines drawn for each corner. Joint a, b, c, d, e, f, g and a, to finish the survey. Area of the filed can be calculated by dividing the field in to number of triangles.



Radiation Method

Intersection

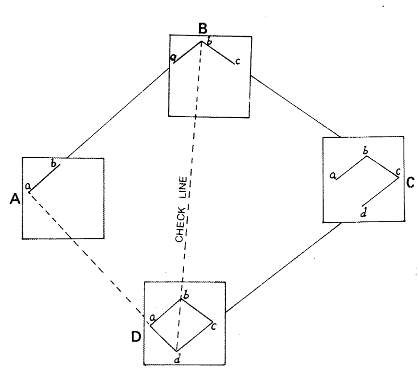
It is method most frequently used and provides very accurate result as only measurement of the base line is taken. In order to plot the filed ABCDEF select two stations P and Q such that all the points are visible from these two stations. Set up table on P. Touching the point p on the paper draw lines on the sheet with alidade, sighting towards each point. Draw the base line pq, measure the distance PQ and fix the point q. Shift the table to station Q. Touching the point q place the alidade on the sheet, sighting stations A, B, C, D, E and F, draw lines, which will cut the corresponding lines drawn from p at a, b, c, d, e and f. Join the intersecting points and finish the work.



Intersection method

Traversing

After selecting the station A, B, C and D, setup the table at station A. Touching the point a on the paper draw radial line for AB with the alidade. Measure the distance and fix the point b on the sheet. Shift the table to station B and draw the radial line bc. From the station C draw cd, and from the D draw da thus the plotting is completed.



Traversing method

Merits and demerits of plane table survey

Sl.No.	Merits	Demerits
1	It is most suitable for preparing small scale maps.	It is not suitable for big scale map
2	As the plotting is done along with measurement, no need for filed book	The plane tale is not suitable for work in rainy season
3	It is advantageous in magnetic area where compass survey is not reliable	It is difficult to re-plot it to a different scale
4	It is less costly and no skill is required	It is not intended for accurate work
5	It is most rapid method of surveying	It is difficult to carry the plane table etc and there is likelihood of loosing small items

Practical activity

1) Identify the accessories required for conduction plane table survey.
2) Plot the field by different methods of plane table survey and determine the area.

4. LEVELLING

Leveling may be defined as the art of determining the relative heights or elevations of points on the surface of the earth. Therefore it deals with the measurements in vertical plane. The common applications of leveling are

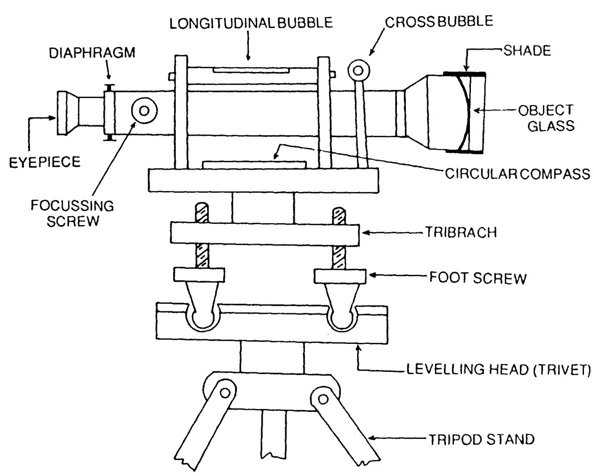
1) Leveling the foundations of farm buildings
2) Running grade lines for irrigation and drainage channels
3) Establishing grades for land leveling
4) Laying out of contour lines for strip cropping, contour bunds, terraces etc.

Field equipments

To carryout the leveling of different points the essential equipments required are leveling instrument, leveling staff, ranging rod, chain, arrows, field book and pencil.

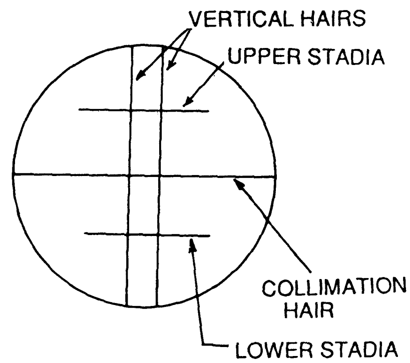
Dumpy level

The dumpy level is the most commonly used leveling instrument. The dumpy level consists of a base plate, telescope and bubble tubes. The telescope of the dumpy level is casted to the frame, which provides compactness and rigidity to the instrument. Out of the three foot screws in the base plate, two are operated simultaneously in or out to bring the bubble tube to centre. The longitudinal bubble tube is provided for leveling the instrument along the line of sight. After setting the dumpy level focusing of the eye piece and object piece are to be done. Screws are provided for adjusting the eye piece and the diaphragm.



Dumpy Level

The leveling staff is sighted through eye-piece and the image comes on the diaphragm, which is provided with cross hairs and readings are recorded. The vertical hair in the diaphragm indicates the vertical line and allows the surveyor to see the leveling staff vertically. There are three sets of horizontal hairs. The central hair gives the line of sight. The other two horizontal hairs are called stadia wires and are used for distance measurement.



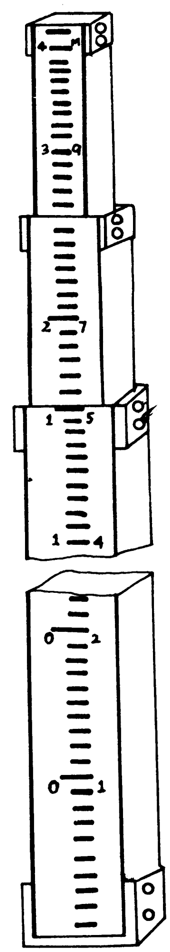
Stadia wires

Levelling staff

Telescopic type of leveling staff is widely used. This is made up of three pieces. The upper piece is solid. The middle and bottom pieces are hollow. The uppermost piece, slides in the middle piece, the middle piece finally slide in to the bottommost piece and the whole staff becomes a compact piece, which could be easily handled. The leveling staff is 4 m in length consist of three pieces one slides within the other. Each black or white colour strip represents 5 mm.

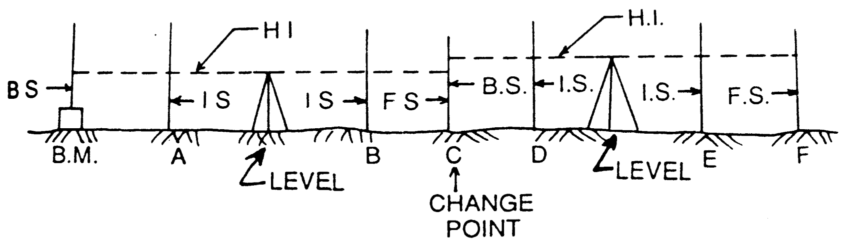
DEFINITIONS IN LEVELING

1) Datum is plane or a line with reference to which all vertical measurements are taken. Its elevation is zero. In our country the datum adopted is the mean sea level at Chennai.
2) Bench mark (B.M) is a fixed reference point or station of known or assumed elevation from which relative elevations of other stations are calculated.
3) Line of collimation is the line joining the intersection of cross hairs to the optical centre of object glass and its continuation. It is the line of sight through the leveling instrument.



Telescopic metric staff

4) A Back Sight (B.S) is a staff reading taken on a point of known elevation. It is the first staff reading taken after the dumpy level is setup and leveled and is taken for the purpose of obtaining the height of the instrument (H.I).
5) A foresight (F.S) is the staff reading taken on a point for which the elevation is to be determined. It is the last staff reading and denotes the shifting of the instrument.
6) An intermediate sight (I.S) is the staff reading, other than B.S and F.S, taken on a point of unknown elevation from the same setup of the dumpy level. All the staff readings taken between the back sight and the fore sight are intermediate sights.
7) A turning point or change point (T.P) is an intermediate point between the starting and the end points. It denotes the shifting of the dumpy level.
8) The reduced level (R.L) of a point is its height above datum. It is also called the elevation of the point
9) The height of instrument is the reduced level of the line of sight. It is also called height of plane of collimation or simply collimation.
10) Station is a point where the staff is held and the elevation is measured.



Definitions of staff readings

Two systems used for working out the elevations of points from the staff readings are

b) The collimation or the height of instrument system and

b) The rise and fall system

The Collimation or the Height of Instrument System

At first the RL of the plane of collimation (i.e. height of the instrument) is found out for every setting of the instrument and then RL of different stations are calculated with reference to the height of the instrument. In first setting, the HI is calculated by adding the BS reading with the RL of the benchmark. By subtracting all the readings of all the intermediate sights and that of the first change point (FS) from the HI, their RL are calculated. The instrument is shifted and setup at a new place. The new HI is calculated. The process is repeated till the entire line is covered.

Arithmetic check

$$\sum BS - \sum FS = \text{RL of last point} - \text{RL of first point}$$

The rise and fall system

The level readings taken on different stations are compared with the reading taken from the intermediate preceding stations. The difference between the staff readings indicate a rise or a fall, depending on whether the staff reading at the point is smaller or greater than that at the preceding point. The elevation of each point is then found by adding the rise to or subtracting the fall from the elevation of the preceding point.

Arithmetic check

$$\sum BS - \sum FS = \sum \text{Rise} - \sum \text{Fall} = \text{RL of last point} - \text{RL of first point}$$

Example 1

The method of calculation of RL by the height of instrument system

Station	Staff reading in m			H.I m	R.L m	Remarks
	B.S	I.S	F.S			
A	0.565			100.565	100.000	B.M
B		0.850			99.715	I.S
C		0.945			99.620	I.S
D	0.645		1.005	100.205	99.560	C.P
E		0.650			99.555	I.S
F		0.785			99.420	I.S
G	0.630		0.800	100.035	99.405	C.P
H		1.135			98.900	I.S
I		1.420			98.615	I.S
J			1.625		98.410	L.P
Total ∑	1.840		3.430			

Arithmetic check:

$\sum BS - \sum FS$	= 1.840 – 3.430	= - 1.590
RL of last point – RL of first point	= 98.410 – 100.00	= - 1.590 (checked)

Example 2

The method of calculation of RL by the rise and fall system

Station	Staff reading in m			Rise m	Fall m	R.L m	Re-marks
	B.S	I.S	F.S				
A	0.565					100.000	B.M
B		0.850			0.285	99.715	I.S
C		0.650		0.200		99.915	I.S
D	0.645		1.005		0.355	99.560	C.P
E		0.550		0.095		99.655	I.S
F		0.785			0.235	99.420	I.S
G	0.430		0.600	0.185		99.605	C.P
H		1.420			0.990	98.615	I.S
I		1.135		0.285		98.900	I.S
J			1.625		0.490	98.410	L.P
Total ∑	1.640		3.230	0.765	2.355		

Arithmetic check:

$\sum$ BS - $\sum$ FS = 1.640 – 3.230 = - 1.590

$\sum$ Rise - $\sum$ Fall = 0.765 – 2.355 = - 1.590

RL of last point – RL of first point = 98.410 – 100.00 = - 1.590 (checked)

Practical activity

1) Identify the accessories required to conduct the leveling
2) Compute the difference in elevation at different stations in a straight line at the field using both the systems.

5. PROBLEMS ON LAND LEVELING, COMPUTATION OF AREA AND VOLUMES

Problem 1

The following consecutive staff readings were taken with a level.

2.100, 2.305, 2.900, 3.940, 3.100, 2.400, 3.150

Level was shifted after 4th reading and reduced level of the first station is 200 m. Enter the reading by collimation method and get reduced level of other station. Give the level difference between first and last station. Find the slope in percentage, if the distance between first and last point is 150 m.

Problem 2

The following consecutive staff readings were taken with a level at 30 m intervals.

3.81, 5.33, 8.89, 12.24, 13.16, 5.26, 9.43, 11.06, 6.42, 5.22, 11.32, 9.42, 6.14, 3.74

The position of the level was changed after the fifth and tenth readings. RL of the B.M was 262.35. Makeup a level book and calculate the RL of points by rise and fall method. Apply usual checks. Determine the gradient of the line.

Problem 3

The following consecutive readings were taken with a dumpy level and a 5 meter staff on a continuously sloping ground at a common interval of 25 meters.

0.50, 0.85, 1.35, 2.28, 3.75, 4.10, 0.45, 1.20, 2.55, 3.15 and 4.25

The RL of the first point was 100 m. Rule out a page of a level field book and enter the above readings. Calculate the RL of the point by height of instrument method. Find the slope in percentage. Apply usual checks.

Problem 4

The following is a page of level field book during the process of leveling with a dumpy level. Fill in the missing readings and calculate the reduced levels of the station. Apply arithmetical check.

Station	Staff reading in m			H.I M	R.L m	Remarks
	B.S	I.S	F.S			
1	X			107.70	104.55	B.M
2		4.65			X	
3		X			100.38	
4	2.95		4.26	X	X	C.P
5		5.00			X	
6	X		X	104.29	99.54	C.P
7	4.71		X	X	98.84	C.P
8			4.56		X	L.P
Total ∑						

Arithmetic check:

∑ BS - ∑ FS =

RL of last point – RL of first point =

Problem 5

The page of a level book is shown below. The reading of the cross marks (X) are missing. Determine the missing reading. Apply arithmetical check.

Station	Staff reading in m			Rise m	Fall m	R.L m	Re- marks
	B.S	I.S	F.S				
1	X					100.000	B.M
2		2.355			X	X	
3		2.605			X	X	
4	X		1.845	X		99.805	C.P
5		1.955		0.510		X	
6		X			0.885	99.430	
7	2.440		3.415		X	98.855	C.P
8		X			0.210	X	
9			2.450	0.200		98.845	
Total ∑							

Arithmetic check:

∑ BS - ∑ FS =

∑ Rise - ∑ Fall =

RL of last point – RL of first point =

Problem 6

The topographic survey of a filed gave the following elevations in meters at grid point

Stations	1	2	3	4	5
A	10.56	10.34	10.02	9.84	9.76
B	10.37	10.24	9.98	9.68	9.57
C	10.22	10.04	9.94	9.56	9.48
D	9.92	9.84	9.76	9.31	9.02

Calculate the elevation of the centroid of the field. Stakes are to be put to guide the leveling of this field in to a playground. Calculate the cut or fill at the grid point.

Answer

$$\text{Elevation of the centroid} = \frac{\sum \text{Elevations of all the stations}}{\text{Number of stations}} = \frac{197.45}{20} = 9.8725 \text{ m}$$

Cut or fill at various grid point = Elevation of centroid – elevation of grid point

For example: Cut or fill at the grid point A1 = 9.8725 – 10.56 = - 0.6875 m

Negative sign indicates cut and positive sign indicates fill at the stations. The following table indicates the height of cut of fill at the grid point to level the field in to play ground.

Stations	1	2	3	4	5
A	-0.6875			+0.0325	
B					
C					
D					

Check: $\sum$ Cut = $\sum$ Fill

Problem 7

Following offsets were taken in a surveying of a boundary line. Find the area by Trapezoidal and Simpson method.

Distance (m)	0	5	10	15	20	30	40	60	80
Offset (m)	2.5	3.8	4.6	5.2	6.1	4.7	5.8	3.9	2.2

Problem 8

Calculate the quantity of earth fill in a trapezoidal bund 50 m long, if the bund has a bottom width of 4 m and top width of 1 m on both of its ends. The height of one end of the bund is 1.2 m and that of the other is 1.5 m.

Volume of earth fills in a trapezoidal c/s bund

$V = ½ (A_1 + A_2)$ I

Where V = volume of earth fill in m^3

A_1 and A_2 are the end areas of the respective c/s

I = distance between the two end c/s

Answer

$A_1 = ½ (1 + 4) 1.2 = 3.00$ m^2 $A_2 = ½ (1 + 4) 1.5 = 3.75$ m^2 I=50 m

V= ½ (3 + 3.75) 50 = 168.75 m^3

Problem 9

The earth dam of a farm pond is trapezoidal in cross section. The section of the dam is 20 m long and has a top width of 1.5 m. On one side, it has a bottom width of 9.5 m and height of 4 m, and on the other side, the bottom width is 8.5 m and height of 3.5 m. Calculate the earth fill in this section of the dam.

Problem 10

The area within the contour lines at a site of a proposed reservoir and dam are as follows

Contour (m)	100	102	104	106	108	110	112
Area (m^2)	200	8,540	60,400	1,15,300	1,80,500	3,45,400	4,50,600

If 100 m RL represents the bottom of the reservoir and 112 m RL represents the water surface, find the volume of water that the reservoir will be able to hold by

a) Trapezoidal method b) Prismoidal formula

Answer

a) V= (2/2) x [(200+ 450600) + 2{8540+60400+115300+180500+345400}]

= 18,71,080 m^3 = 1.871 M m^3

b) V= (2/3) x [(200+ 450600)+4{8540+11530+345400}+2{60400+ 180500}]

= 1.873 M m^3

Problem 11

The area within the contour lines at a site of a proposed reservoir and dam are as follows

Contour (m)	100	105	110	115	120	125	130
Area (m^2)	400	10,000	50,500	1,50,000	2,70,000	4,80,000	11,15,000

If 100 m RL represents the bed level of the reservoir and 130 m RL is the water surface, what will be the maximum volume of water in the reservoir?

6. COMPUTATION OF SOIL LOSS BY UNIVERSAL SOIL LOSS EQUATION

This equation was developed and reported by Wischmeier and smith in 1965.

$$A=RKLSCP$$

Where A= Estimated average annual soil loss in t/ha.

R=Rainfall and runoff factor in joules per hectare.

K=Soil erodibility factor in tons per joules

L= slope Length factor (dimensionless)

$=[l / 22.13]^m$

where l is the actual length of slope in m

m constant selected base the slope using

Slope s in %	< 1	2 – 3	3 – 5	> 5
Constant m	0.2	0.3	0.4	0.5

S = Steepness factor (dimensionless)

$=0.065 + 0.045\ s + 0.0065\ s^2$

s is the actual slope in percentage

C= crop management factor

P= erosion control support Practice factor (dimensionless)

The factors of the equation was developed using an evaluation unit called as the standard plot. A standard plot is of size 72.6’ x 6’ forming 1 cent with an uniform longitudinal slope of 9%.

Problem 1

Estimate the soil loss of a land using the following data

Data

a) Erosivity index - 200 joules / ha
b) Soil Erodibility index - 0.028 tons / joules
c) Field length - 199.87 m
d) Slope of field - 6 %

e) Cropping factor - 0.2

f) Conservation factor - 0.65

Answer

R=200, K= 0.028 l=199.87 s=6 %, m= 0.5 C=0.2 P=0.65

$L=[199.87 / 22.13]^{0.5} = 3.01$

$S = 0.065 + 0.045 (6) + 0.0065 (6)^2 = 0.569$

A = 200 x 0.028 x 3.01 x 0.569 x 0.2 x 0.65

= 1.25 ton/ha/year

Problem 2

Estimate the annual soil loss in kg / m^2 using the following data

Data

a) Erosivity index - 300 joules / ha

b) Soil Erodibility index - 0.42 tons / joules

c) Field length - 250 m

d) Slope of field - 4 %

e) Cropping factor - 0.35

f) Conservation factor - 0.5

7. DESIGN OF CONTOUR BUND AND GRADED BUND

Design of contour bunds

1) Vertical interval between bunds (V.I)

$V.I=\{(s/a)+b\}\ 0.3$

Where s=land slope in %

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.

2) Horizontal spacing in between bunds (H.I)

$H.I=(V.I/s)*100$

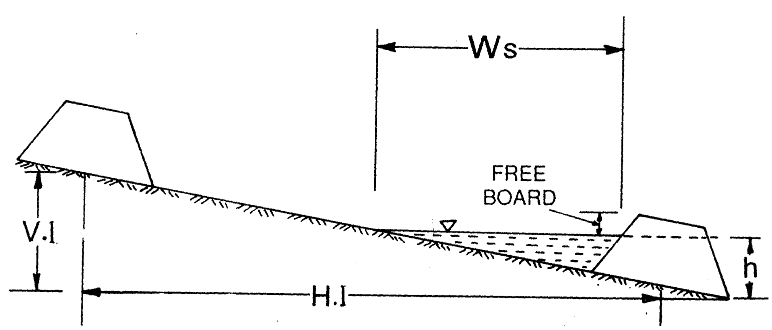
3) Depth of water impounding before the bund ‘h’

$h=[(R \times VI) / 50]^{0.5}$ Where R is excess rainfall in cm

Rainfall excess = actual rainfall - infiltration

4) Actual height of the bund H =h+20% of h as free board.

5) Water spread length $W_s=\{(H.I \times h) / V.I\}$



6) Length of contour bund (L)

L= (Area / H.I)

7) Top width of bund (T)

T = 0.45 m for low rainfall area,

= 0.50 m for medium and heavy rainfall area

8) Bottom width B = T + 2zH The side slope of the bund is z:1

9) Cross section area of the bund a =½ (B+T) H = ½ (T+2zH+T)H = (T+zH)H

10) Volume of earth work V in m^3 = a x L

11) Percentage of area lost in forming the bunds = (bunded area / Total area) x 100

= {(B x L) / Total area} x 100

Problem 1

A land having an area is 25 ha lying in low rainfall region, with average slope of 3 % and rainfall excess of 14 cm. Design the contour bund suitable for this area with side slope of bund 1.25:1. Compute volume of earth work and percentage of area lost.

Answer

1) Vertical interval between bunds (V.I) = {(3/2) + 2} 0.3 = 1.05 m

2) Horizontal spacing in between bunds (H.I) = (1.05/3)*100 = 35 m

3) Depth of water impounding before the bund $h=[(14 \times 1.05) / 50]^{0.5}$ = 0.54 m

4) Actual height of the bund H=h+0.2 h = 0.65 m

5) Water spread length $W_s=\{(35 \times 0.54) / 1.05\}$ = 18 m

6) Length of contour bund (L) = $(25 \times 10^4 / 35)$ = 7142.86 m

7) Top width of bund (T) = 0.45 m

8) Bottom width B =0.45 + (2 x 1.25 x 0.65) = 2.08 m

9) Cross section area of the bund a = {0.45+(1.25 x 0.65)}0.65 = 0.82 m^2

10) Volume of earth work V= 0.82 x 7142.86 = 5857.15 m^3

11) Percentage of area lost in forming the bunds = $\{(2.08 \times 7142.86) / (25 \times 10^4)\} \times 100$

= 5.94 %

Problem 2

Design the contour bund cross section, volume of earth work and percentage of area lost using the data given below

Land area	= 100 ha	Land slope	= 5 %
Rainfall	= 20 cm	Infiltration	= 8 cm
Bund side slope	= 2:1	Region	= High rainfall zone

8. DESIGN OF BENCH TERRACE

The terrace design is influenced by the conditions of soil depth, slope, rainfall, farming practice etc. The design includes (a) type of bench terrace (b) terrace spacing (c) terrace grade and length and (d) Terrace cross-section

(a) Type of bench terrace

It is selected among the three types depends upon rainfall, soil conditions, land use etc.

(b) Terrace spacing and width

It is normally expressed in terms of the vertical interval at which the terraces are constructed. It depends upon factors like slope, soil and surface condition, grade and agricultural use.

Steps for terrace spacing design

(i) Find the maximum depth of productive soil range

(ii) Having the above consideration in view, find out the maximum admissible cutting (d), for the desired land slope (s) and the crops to be grown.

(iii) Having fixed depth of cutting, the width of terrace (W) can be computed for the slope (s) by using the formula i.e. for vertical cut.

Recommended width of the platform

Land slope in %	Width of platform in m
10 – 15	8
15 - 25	5 to 8
25 – 33	3

$$V.I = [(W \times s) / (100- s)] \quad \text{for 1:1 riser slope}$$

$$V.I = [(2W \times s) / (200- s)] \quad \text{for ½:1 riser slope}$$

(c) Terrace gradient

In high rainfall areas, for quick disposal of the excess water, a suitable gradient has to be provided for newly laid out terraces. The following steps may be followed.

1. The area of the terrace that has to be drained by the channel is calculated by the formula $A= [(LxW) / 10^4]$

where A = area to be drained in ha, L= length of terrace in m, W = width of terrace in m.

2. The peak discharge can be calculated by using any standard method, such as rational formula.
3. Non-erosive velocity for the specific soil condition should be selected from standard table.
4. Cross-sectional area (A) of the channel can be approximated calculated as the value of Q and V are known.
5. Suitable dimensions of the channel are assumed to get the cross-sectional area calculated in step 4. From the dimensions hydraulic radius R is calculated. The grade of the channel is calculated by using the Manning's formula

   $v = 1/n \times R^{2/3} S^{1/2}$ m/s   Where n is the Manning's roughness coefficient
   S is the slope in fraction.
6. The value of S is rounded off and V is recalculated. It should be less than the maximum non-erosive velocity. If needed, the cross section should be changed and calculation repeated. Generally a slope of 0.75 % has been found to be safe under the most of the conditions.

(d) Terrace cross section

The soil excavated from the upper half is deposited on the lower half. Therefore, the volume of cut should be equal to the volume of fill. The shoulder bund is constructed with a trapezoidal shape and a height of 15 to 30 cm is provided. A bottom width of 75 cm is provided for stability.

Problem 1

Design a 120 m long bench terrace in a forest for a sandy loam soil with an average slope of 18 %. The entire width of the terrace acts as a channel which is provided with a uniform grade of 0.4 %. Assume the width of terrace as 6 m and riser slope of 1:1. Rainfall intensity for 10 year recurrence interval and for the time of concentration is 24 cm/hr.

Answer

For high rainfall area inward slopping bench terrace is suitable.

First let us assume the inward slope of 5 %.

Hence the inner end depth of terrace = (5/100) x 6 = 0.3 m

Vertical Interval V.I = [(W x s) / (100- s)] = [(6 x 18) / (100 – 18)] = 1.317 m

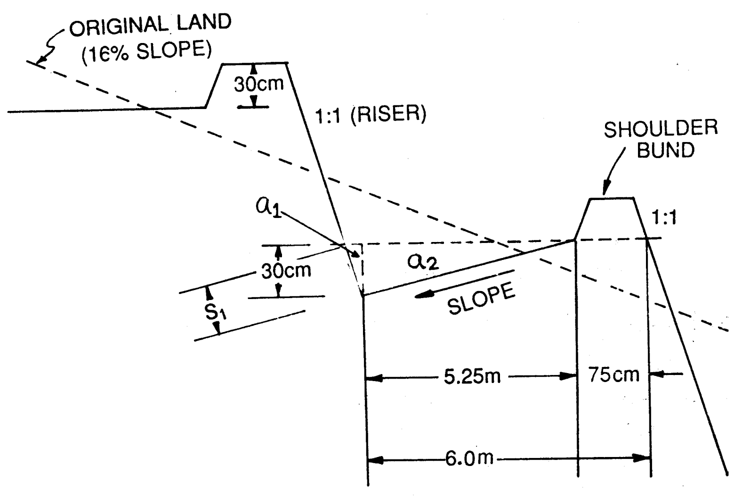
Area of terrace = [(Width of Terrace x Length) / 10^4] = [(6 x 120) / 10^4 = 0.072 m^2

Peak discharge to be handled is obtained from the rational runoff formula

Discharge Q_p = [(CIA)/36] = [(0.30 x 24 x 0.072)/36] = 0.0144 m^3/s

Values of runoff coefficient, c

Land type	Slope range (%)	Sandy loam	Clay and silt loam	Tight clay
Forest	0 – 5 5 – 10 10 - 30	0.10 0.25 0.30	0.30 0.35 0.50	0.40 0.50 0.60
Pasture	0 – 5 5 – 10 10 - 30	0.10 0.15 0.20	0.30 0.35 0.40	0.40 0.55 0.60
Arable land	0 – 5 5 – 10 10 - 30	0.30 0.40 0.50	0.50 0.60 0.70	0.60 0.70 0.80



Area of flow in bench terrace

a_1 = ½ x 0.3 x 0.3 = 0.045 m^2

a_2 = ½ x 5.25 x 0.3 = 0.7875 m^2

Total area of flow = $a_1 + a_2$ = 0.8325 m^2

Wetted perimeter in bench terrace

$P_1 = (0.3^2 \times 0.3^2)^{0.5}$ = 0.42 m

$P_2 = (0.3^2 \times 5.25^2)^{0.5}$ = 5.259 m

Total wetted perimeter = P_1+P_2 = 5.679 m

Velocity of flow by Manning's formula $v = 1/n \times R^{2/3} S^{1/2}$ m/s

$n = 0.04$

$R = a/P = 0.8325 / 5.679 = 0.1466$ m

$S = (0.4/100)$

$v = \{(1/0.04) \times (0.1466)^{2/3} \times (0.004)^{1/2}]$ = 0.4396 m/s which is non-erosive velocity

Permissible velocity for various soil texture

Type of soil	Maximum permissible velocity in m/s
Sand and silt	0.45
Loam, Sandy loam and silt loam	0.60
Clay loam	0.65
Clay	0.70
Gravel	1.00

The discharge carrying capacity of the channel $Q_c = a \times v = 0.366$ m^3/s

The discharge carrying capacity of the channel is greater than the peak discharge. The terrace when acts as a channel, it has sufficient carrying capacity. The design is safe

Problem 2

Design a 150 m long bench terrace for a pasture land having an average slope of 20 %. The soil is clay loam. The terrace channel has a uniform grade of 0.2 %. Maximum rainfall intensity expected during 10 year recurrence interval and for the time of concentration is 10 cm/hr. Assume width of the terrace as 4.5 m and riser slope of ½ : 1

9. VISIT TO EROSION CONTROL WORKS AREAS

10. PROBLEMS ON WATER MEASUREMENT

Problem 1

The discharge rate of a shallow tube well was estimated by collecting the pumped water in a drum and noting the average time required to fill the drum. The measured time interval required to fill the drum to its 200 liters capacity mark, were 27 sec, 28 sec and 27.5 sec. Estimate the discharge rate of the well.

Answer

Average time required to fill the drum = (27 + 28 + 27.5) / 3 = 27.5 seconds

Discharge rate = 200 / 27.5 = 7.27 lps = (7.27 / 1000) x 60 x 60 = 26.17 m^3/hr.

Problem 2

A rectangular weir of crest length 30 cm is installed at the centre of a rectangular channel of 50 cm width. The height of water above the weir crest is 10 cm. Calculate the discharge.

Answer

Data given n=2, L=30 cm, H = 10 cm

$$\text{Discharge} = 0.0184\,(L-0.1nH)\,H^{3/2} = 0.0184\,(30 - 0.1 \times 2 \times 10) \times 10^{3/2}$$

$$= 16.29 \text{ lps}$$

Problem 3

Water flows through a contracted weir 120 cm long to a depth of 30 cm, it then flows along a rectangular channel 150 cm wide and over a second weir which has its length equal to the width of the channel. Determine the depth of water over the second weir.

Problem 4

A cipoletti weir of 50 cm crest length is installed in a straight channel and the head over the crest of the weir is 15 cm. Calculate the discharge.

Problem 5

A channel flow was measured with 90^o V notch, as 20 cm. If the same flow is to be measured with a cipoletti weir with a crest length of 10 cm, what will be the depth of flow?

Problem 6

A circular orifice has a diameter 10 cm and the depth of water on upstream side is 17 cm above the bottom of the orifice. If the coefficient of discharge is 0.61, calculate the discharge for free flow condition

Problem 7

Find the discharge through a rectangular standard submerged orifice 45 cm long and 20 cm deep, if the upstream surface is 15 cm vertically above the downstream water surface.

Problem 8

Water flows through an orifice of diameter 7.5 cm under a head of 35 cm then the water passes through an earthen channel. The conveyance loss is 25 % in the channel. Then it passes over a V notch fixed at the end of channel. Find out the head over notch.

Discharge Q $= 0.61 \times a \times 10^3 \times (2\ g\ h)^{0.5}$

$=0.61 \times (\pi/4 \times 7.5^2) \times 10^3 \times (2 \times 981 \times 35)^{0.5}$

$=7.062$ lps

Flow at the end of earth channel = 7.062 x 0.75 = 5.30 lps -------- (1)

Flow over the V notch Q $= 0.0138 \times H^{5/2}$ -------- (2)

By equating (1) and (2) we get

$0.0138 \times H^{5/2} = 5.30$

$H^{5/2} = 384.06$

$H = 10.8$ cm

11. PROBLEMS ON SOIL MOISTURE MEASUREMENT AND IRRIGATION SCHEDULING

Problem 1

A sharp edged cylinder 15 cm in diameter is carefully driven in to the soil so that there is no compression of soil. The cylinder was driven inside to a depth of 20 cm. If the wet weight and dry weight of the soil sample collected are 5780 g and 5180 g respectively. Calculate

a) The percentage moisture content on dry basis

b) The apparent specific gravity or bulk density and

c) The percent moisture content on volume basis

Answer

a) Dry weight basis $M_{dw} = \frac{\text{(Weight of wet soil - weight of oven dry soil)}}{\text{Weight of oven dry sample}} \times 100$

$$= \frac{5780 - 5180}{5180} \times 100 = 11.58\ \%$$

b) Bulk density = (weight of dry soil / volume of soil)

$$= [5180 / \{(\pi/4) \times 15^2 \times 20\}]\ cm^3 = 1.47\ g/cc$$

c) $M_v = 11.58 \times 1.47 = 17.02$ cm per meter depth of soil

Problem 2

Undisturbed soil sample was collected from a field two days after irrigation when the soil moisture was near field capacity. The inside dimension of the core sampler were 7.5 cm diameter and 15 cm deep. Weight of the core sampling cylinder with moist soil was 2.76 kg and weight with oven dry soil was 2.61 kg. The weight of the core sampling cylinder was 1.56 kg. Determine the available moisture holding capacity of the soil in cm/m depth of soil.

Problem 3

Compute the total profile moisture for the following data

Soil sampler diameter = 7 cm

Soil sampler length = 7 cm

Details of soil sampling

Sl. No.	Soil depth (cm)	W	W_1	W_2
1	0 – 18	28.5	464.5	370.1
2	18 – 45	26.7	458.5	362.5
3	45 – 75	29.8	432.5	348.8
4	75 – 90	31.5	441.5	353.2

Answer

The volume of the soil sampler = $\{(\pi/4) \times 7^2 \times 7\}$ = 269.39 cc

$W_1 – W_2$	W_2 - W	M_{dw}	A_s	M_v	Depth of moisture (cm)
94.4	341.6	27.63	1.27	35.05	6.31

Total profile moisture content is -------------- cm

Problem 4

Calculate the total volume of water (m^3) to be applied to bring the moisture content to the field capacity level of an area of 0.2 ha. Compute the time required to irrigate the land with 0.05 m^3/s discharge.

Details of soil sampling

Depth of root zone cm	Field Capacity %	Existing moisture %	Bulk density g/cc
0 – 30	21	10.5	1.15
30 – 60	22	11.5	1.20
60 – 90	24	13.5	1.25
90 – 120	25	14.5	1.25

Answer

Required water FC-EMC	Moisture Content M_v	Depth of moisture $d=M_v.As$
10.5	12.08	3.62

Depth of water to be applied = 15.35 cm

Volume of water to be applied = Depth of water to be applied x Area

= 15.35 x 0.2 = 3.07 ha-cm

= 307 m^3

Time required irrigating the land = (307 / 0.05) = 1 hr 42 min 20 sec

IRRIGATION SCHEDULING

Once the Evapo-Transpiration values of the crops and their critical stages are understood, it is necessary to apply the irrigation water to the crops. This scheduling of irrigations is involve with (1) When to irrigate? (2) How much to irrigate? and (3) How many days or hours of irrigation is to be given?

(1) How much to irrigate: The gross amount of water to be applied is the net amount required to refill the crop root zone plant the special needs if any.

$$d = \frac{(\text{Field capacity} - \text{Wilting point}) \times \text{Depletion} \times \text{Bulk density gm/cc} \times \text{Depth of root zone in cm}}{100}$$

(2) To decide the number of days between irrigation the methods used are

(a) Based on soil moisture levels the number of days between irrigations is given by

Irrigation interval I in days = (d / Consumptive use)

(b) Daily monitoring for evapotranspiration: The moisture status of the soil is calculated at various times using the estimated evapotranspiration values and the crop is irrigated when the estimated soil moisture level attains a predetermined value.

(c) Based on IW / CPE radio: Irrigation is applied to the field once the cumulative pan evaporation value attains the predetermined depth of irrigation water selected based on the crops.

(d) Based on physiological stages of the crop: Irrigation is given based on the distinct growth stages of the crop.

(e) Base on plant factors: Different plant characters like colour, leaf movement and growth and leaf water potential are used as indicators of plant water stress. Irrigation is given based on the identifications of water stress, which will vary from crop to crop.

$$\text{(3) Time required to irrigate a given area in hours} = \frac{\text{Quantity of water required to give the Desired depth of irrigation to the given area in } m^3.}{\text{discharge rate in } m^3 / \text{hr.}}$$

Q x t = A x d

Therefore t = {(A x d) / Q} hours

Problem 5

Find the application depth, irrigation interval and duration of irrigation using the following data

i.	Consumptive use of the crop	= 5 mm/day
ii.	Root zone depth	= 80 cm
iii.	Field capacity	= 30 %
iv.	Wilting point	= 15 %
v.	Bulk density of the soil	= 1.2 g/cc
vi.	Flow rate Q	= 15 m^3/hr
vii.	Plot size	= 50 m x 40 m
viii.	Allowable soil moisture depletion	= 60 %

Answer

Depth of water to be irrigated = (30 – 15) x 0.60 x 1.2 x 0.80 = 8.64 cm

Irrigation interval = (8.64 / 0.5) = 17.28 days

Time required to irrigate the given plot size with given discharge = {(50 x 40 x 8.64) / (100 x 15)) = 11.52 hours

Problem 6

Schedule the irrigation for the following data

i.	V-notch reading at field	= 20 cm
ii.	Plot size	= 50 m x 25 m
iii.	ASMD	= 50 %
iv.	Root zone depth	= 120 cm
v.	Consumptive use	= 8 mm/day
vi.	Moisture measurement details is given below	

Soil depth (cm)	FC (%)	WP (%)	A_s (g/cc)	Depth of moisture
0 – 20	29.5	15.2	1.30	1.86
20 – 55	32.8	17.0	1.26	
55 – 95	31.5	16.7	1.28	
95 – 120	30.8	16.4	1.30	

Total depth of water to be applied = ------- cm

Irrigation interval = (------- / 0.8) = ------- days

Discharge rate at the field = 0.0138 x $(20)^{5/2}$ = ------- lps

Time required to irrigate = {(50 x 25 x ------) / (100 x ------)) = 5807 second

= --- hr --- min --- sec

Problem 7

Find the consumptive use of a crop from the following data

Soil depth (cm)	MC at volume basis immediately after irrigation	MC at volume basis after 10 days of irrigation	Depth of moisture depletion in cm
0 – 20	32.5	21.5	2.20
20 – 40	34.6	26.2	
40 – 60	38.5	27.8	
60 – 80	36.2	32.6	
80 – 100	37.5	37.5	

Total depth of moisture depleted during 10 days = ------ cm

Consumptive use = (depth of water depleted / irrigation interval) = (----- / 10)

= -------- cm/day = ------ mm/day

12. PROBLEMS ON DUTY OF WATER

Problem 1

A tank has a catchment area of 30 km^2 which receives an annual rainfall of 90 cm. Assume the only 10 % of the rainfall as runoff from catchment. Calculate the area of command which is under paddy crop, if duty of water for paddy is 100 cm.

Answer

Catchment area = 30 km^2

Rainfall = 90 cm

Available water from rainfall = $[(30 \times (1000)^2 / 10^4) \times 90]$ = 2,70,000 ha-cm

Water stored in the tank due to runoff = 2,70,000 x (10 /100) = 27,000 ha-cm

$$\text{Area of command} = \frac{\text{Volume of water available in tank}}{\text{Duty}} = \frac{27{,}000}{100} = 270 \text{ ha}$$

Problem 2

Estimate the storage capacity of tank to irrigate the following crop. Assume 25 % application loss, 15 % canal loss and 5 % storage loss.

Data given

Crops	Area	Duty in ha per cumec	Base period in days
Paddy	50	900	120
Sugarcane	35	850	300
Banana	30	1000	250
Cotton	45	1250	180

Answer

Duty in ▲ cm	Volume in ha-cm
115.20	5760.00

Volume of water required = 28511.66 ha-cm = ---------- m^3 = ----- Mm^3

Amount required at field outlet = (----- / 0.75) = ----- Mm^3

Amount required at source (tank outlet) = (----- / 0.85) = ----- Mm^3

Amount required for entire season = (----- / 0.95) = ----- Mm^3

Problem 3

How many hectares of paddy can be irrigated by a tank with water spread of 20 ha and average depth of water is 5.2 m, if the duty of water

i) 150 ha-cm ii) 110 ha/Mm^3 Assume the base period of the crop = 120 days

Answer

Volume of the water in tank = 20 x 5.2 = 104 ha-m = 10400 ha-cm = 1.04 Mm^3

i) Area that can be irrigated, if the duty is 150 ha-cm = (10400 / 150) = 69.33 ha

ii) Area that can be irrigated, if the duty is 110 ha/Mm^3 = 110 x 1.04 = 114.4 ha

Problem 4

How many ha of wheat crop can be irrigated by a pump having a discharge of 11000 lph. The depth of irrigation is 5 cm and irrigation interval is 15 days. The pump works for 10 hours each day.

Answer

Amount of water required to irrigate 1 ha = 10^4 x (5 / 100) = 500 m^3

Volume of water available in 15 days = (11000 / 1000) x 10 x 15 = 1650 m^3

Area = (1650 / 500) = 3.3 ha

13. PROBLEMS ON IRRIGATION EFFICIENCIES

Problem 1

A soil with an apparent specific gravity of 1.5, field capacity 24 % and permanent wilting point of 10 % is to be irrigated when 60 % of the available moisture is depleted. A crop with 1 m effective depth of root zone is grown in the soil. A stream of 100 lps was diverted from the source and 80 lps was delivered to the field. An area of 2 ha was irrigated in 8.5 hours. Moisture sampling shows that the depth of water stored along 50 m long border during irrigation are 12.5, 11.8, 10.6, 9.5, 8.3 and 7.5 cm at 0, 10, 20, 30, 40 and 50 m respectively. Calculate

i) Conveyance efficiency ii) Application efficiency

iii) Water storage efficiency iv) Distribution efficiency

Answer

i) Water conveyance efficiency = $E_c = \frac{W_f}{W_r} \times 100 = \frac{80}{100} \times 100 = 80\ \%$

ii) Water application efficiency = $E_a = \frac{W_s}{W_f} \times 100$

W_s= depth of irrigation x area = {(12.5 + 11.8 + 10.6 + 9.5 + 8.3 + 7.5) / 6} x 2
= 10.03 cm x 2 ha = 20.06 ha-cm

W_f=water delivered to field = $\{(80 \times 3600 \times 8.5) / (10^3 \times 10^2)\}$ = 24.48 ha-cm

E_a= (20.06 / 24.48) x 100 = 81.94 %

iii) Water storage efficiency = $E_s = \frac{W_s}{W_n} \times 100$

$$W_n = \frac{(FC-WP) \times ASMD \times A_s \times D}{100} = \frac{(24-10) \times 60 \times 1.5 \times 1}{100} = 12.6 \text{ cm}$$

E_s= (10.03 / 12.6) x 100 = 79.6 %

y

iv) Water distribution efficiency = $E_d = [\,1 - \frac{y}{d}\,]\,100$

	Depth of water stored in cm	Numerical deviation from the average depth
	12.5	2.47
	11.8	1.77
	10.6	0.57
	9.5	0.53
	8.3	1.73
	7.5	2.53
Total	60.2	9.6

Average depth d = (60.2 / 6)
=10.03 cm
y = (9.6 / 6) = 1.6
E_d= {1 – (1.6 / 10.03)} x 100
= 84.47 %

Problem 2

Estimate the different forms of irrigation efficiency for the following data

i.	Root zone depth	= 180 cm
ii.	Time required to irrigate 1.6 ha of land	= 8 hrs
iii.	Field capacity	= 32 %
iv.	Wilting point	= 16 %
v.	Bulk density	= 1.25 g/cc
vi.	Allowable soil moisture depletion	= 50 %
vii.	Water diverted from the source	= 135 lps
viii.	Water delivered at the field	= 100 lps
ix.	Volume of surface runoff from the field	=432 m^3

The total profile moisture content of effective root zone during irrigation at five points from the head to tail line are 72, 67, 64, 60 and 55 cm. Analyze this data for possibility of deep percolation.

i) Water conveyance efficiency = $E_c = \frac{W_f}{W_r} \times 100 = \frac{100}{135} \times 100 = 74.07\ \%$

ii) Water application efficiency = $E_a = \frac{W_s}{W_f} \times 100$

$W_f = W_s + R_f$
$W_f = \{(100 \times 8 \times 3600) / 10^3\} = 2880\ m^3$
$W_s = W_f - R_f = 2880\ m^3 – 432\ m^3 = 2448\ m^3$
E_a= (2448 / 2880) x 100 = 85 %

iii) Water storage efficiency = $E_s = \frac{W_s}{W_n} \times 100$

$$W_n = \frac{(FC-WP) \times ASMD \times A_s \times D}{100} = \frac{(32 - 16) \times 60 \times 1.25 \times 1.8}{100} = 18\ cm$$

W_n (on volume basis) = $(18 / 100) \times 1.6 \times 10^4 = 2880\ m^3$
E_s= (2448 / 2880) x 100 = 85 %

iv) Water distribution efficiency = $E_d = \left[1 - \frac{y}{d}\right] 100$

	Depth of water stored in cm	Numerical deviation from the average depth
	72	8.4
	67	3.4
	64	0.4
	60	3.6
	55	8.6
Total	318	24.4

Average depth d = (318 / 5)
=63.6 cm

y = (24.4 / 5) = 4.88

E_d= {1 – (4.88 / 63.6)} x 100
= 92.32 %

Profile MC at FC
=32 x 1.25 x 1.80
= 72 cm

Depth of water stored in all the points is less than the profile moisture at field capacity. Hence there is no deep percolation

Problem 3

Pump delivers 450 lpm at well, but at the field 90^o V notch reading was 12 cm. If the profile moisture content after irrigation from head to tail end of the field are 60, 47, 44, 42 and 40 cm respectively. Find E_c and E_d.

Problem 4

Estimate the different forms of irrigation efficiency for the following data

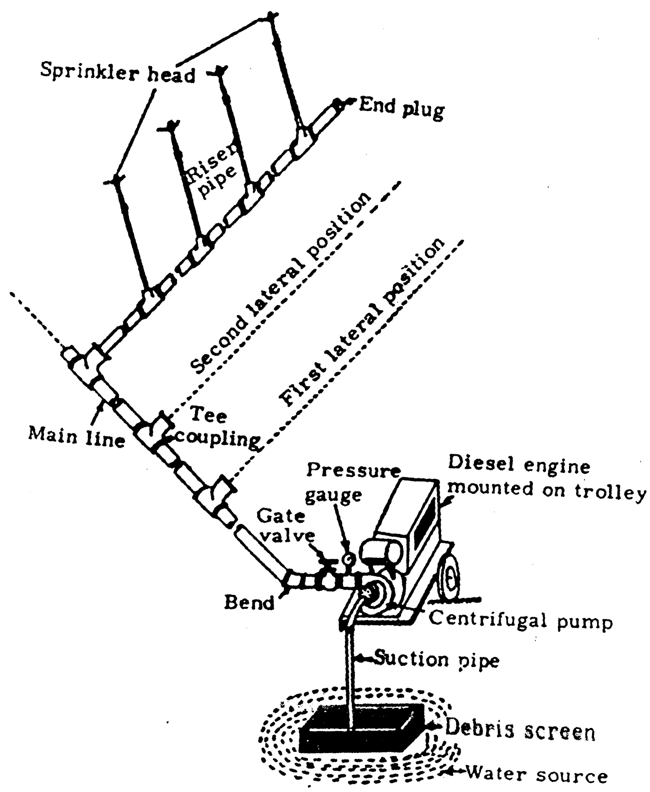
i.	Root zone depth	= 120 cm
ii.	Time required to irrigate 1 ha of land	= 8 hrs
iii.	Field capacity	= 30 %
iv.	Wilting point	= 15 %
v.	Bulk density	= 1.3 g/cc
vi.	Allowable soil moisture depletion	= 50 %
vii.	V notch reading at source	= 30 cm
viii.	V notch reading at field	= 25 cm
ix.	Volume of surface runoff from the field	= 350 m^3

14. LAYOUT OF SPRINKLER AND DRIP SYSTEMS

SPRINKLER IRRIGATION

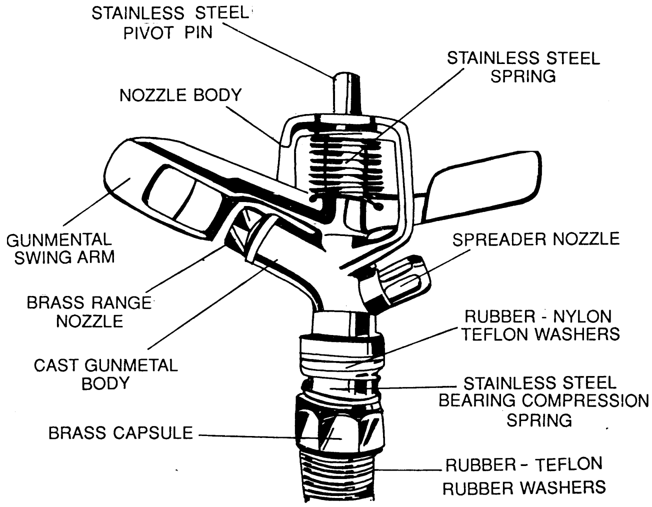
The method of applying water above the ground surface as that of rainfall is known as sprinkler irrigation. The spray is obtained by the flow of water under pressure through small orifices or nozzles referred to as sprinklers.

The components of a sprinkler system consist of a pumping unit, main line, laterals, risers and sprinkler heads. Additional devices consist of debris screen, de-silting devise, flow regulators and fertilizer applicators.



Sprinkler irrigation system layout

The type of pumping unit is decided depending on the source. In order to develop the required pressure, in case of centrifugal pumps booster pumps may sometimes be needed. Main pipe lines may be permanent or portable depending upon the situation. In case of permanent mains, they could be buried under ground at appropriate locations along the farm boundaries. Lateral lines are usually made portable so that they can be moved after each setting. Light weight aluminium pipes can conveniently be used both for the mains and laterals. Quick setting couplers enable the movement of the laterals quickly during irrigation.



Sprinkler head

Sprinkler systems classifications

(a) Permanent systems: These types of systems are those having the pipes permanently located. Usually they are buried and do not interface with tillage operations. Used for orchards and nurseries.

(b) Semi permanent systems usually have the main lines buried and the laterals portable. The water supply is from a fixed point.

(c) Portable systems have both main lines and laterals portable. These systems are designed to be moved around the farm from field to field or even from farm to farm.

Design criteria of sprinkler system

1. Determine optimum rate of water application (I)
2. Determine the depth of application (D)
3. Determine the capacity requirements of the system
4. Determine the sprinklers capacity and nozzles size
5. Determine the combination of sprinkler spacing, operating pressure and nozzle sizes.

6. Determine optimum number of sprinklers to operate simultaneously
7. Determine the best layout of sprinkler, laterals and main
8. Determine the sizes of laterals and mains
9. Selection of proper pumping unit
10. Selection of suitable power unit

Christiansen's coefficient of uniformity for sprinkler irrigation system is given by

$$C_u = 100 - \frac{\sum \overline{d}}{m \times n} \times 100$$

where, C_u = Coefficient of uniformity

$\overline{d}$ = absolute value of the deviation of the individual observation of depth applied from the mean value 'm'.

n = Number of equally spaced observations.

To determine this coefficient of uniformity, open cans are set around the sprinklers in a grid pattern. The cans are spaced about 1.5 m apart when the sprinklers are less than 10 m and about 3 m apart when the sprinklers are more than 10 m apart. The depth of water collected in each can is used to determine the coefficient of uniformity. Uniformity coefficients of 0.85 or more are considered to be satisfactory.

Advantages and adaptability of sprinkler system

1. Very light textured porous soils which can not be properly irrigated by surface methods can be efficiently irrigated by the sprinkler method
2. Land having steep slopes can easily be irrigated
3. Land leveling is not necessary and cost of leveling is saved
4. Most of the crops except those requiring ponded water can be irrigated
5. Gross water requirement is lower as the application loss is low
6. At the early stages of the crop, small quantity can be more precisely applied
7. Labour requirement for irrigation is low, specially for a permanent installation
8. Fertilizer can be applied to the crops in measured quantities through the system and they do not percolate beyond the root zone.
9. Field channels and bunds are not required. Therefore, more land area is available for cultivation

Disadvantages and limitations

1. Initial capital investment is very high compared to ay other surface method of irrigation
2. Operation of the sprinkler system requires a pressure generally in the range of 1 to 4 kg/cm^2
3. For clay with a very low infiltration rate of 2.5 mm/h, this method is not suitable
4. In a place of high wind, the distribution of water will not be uniform and evaporation will increase
5. The water used for irrigation should be relatively clean. Water containing dissolved salts, debris etc. can not be used.
6. Skilled personnel are required for the maintenance of the sprinkler components, specially the nozzles.

DRIP IRRIGATION SYSTEM

In drip irrigation, the application of water is directly to the root zone of the crops through a network of pipelines as small droplets or miniature sprays or small continuous heads. This system more suitable to row crops and the application rate should be less than the infiltration rate of soil. The crops that can be irrigated through drip are coconut, mango, sapota, guava, ber, acid lime, papaya, grapes, banana, vegetables and flowers.

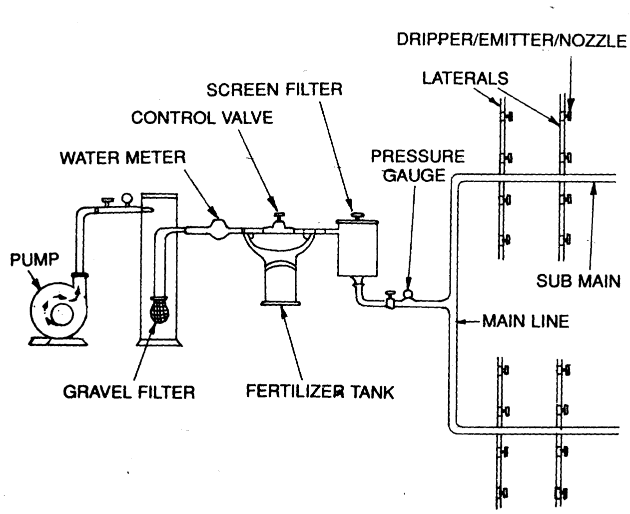
Components of drip system

This system consists of a source of water supply pumping unit, main lines, laterals and emitters. Auxiliary components include filters, pressure regulators, valves and equipment for mixing fertilizers. Piping system is usually made of PVC pipes. The emitters are also made of PVC. Appropriate connections are to be used between the pipelines and other equipments. The emitters which are also known as drip nozzles or drippers allow the water to be applied at a very slow rate. The types of drippers are

1. Hole and sleeve type
2. Micro tubes
3. Constant discharge drippers which may be pressure compensating or non pressure compensating
4. Bi-wall tubing
5. In line drippers and

6. Micro sprinklers or spitters

The drippers are available in discharge rate of 2 lph, 4 lph and 8 lph and are selected depending upon the soil and crop.



Drip irrigation system Layout

Design criteria of drip system

1. Calculate the consumptive use of the crop in millimeter per day
2. The daily water requirement of the crop is determined in litre per day
3. Determine the number of drippers per plant
4. Determine the number of hours of pumping required.
5. Asses the length and size of laterals
6. Determine the length and size of sub mains
7. Determine the length and size of main lines
8. Determine the capacity of filter
9. Determine the capacity of pump required based on the required pressure, discharging rate and friction loss

Advantages of drip irrigation system

1. Irrigation is possible with low available discharge
2. Deep percolation and evaporation losses are minimum and therefore, high application efficiency is achieved
3. Labour requirement is minimized.

4. Soil crusting is reduces
5. Root penetration is better
6. Optimum use of fertilizer is possible
7. Weed growth is minimized
8. Soil with low as well as high intake rates can be irrigated.
9. Land area required for bunds and ridges is saved

Disadvantages of drip irrigation system

1. Initial capital investment is very high
2. High skill is required for design, installation and maintenance of the system
3. Clogging of emitters may create problem
4. In case of salinity problem salt can not be leached
5. Uniform distribution of water is difficult unless very carefully designed

15. POWER REQUIREMENTS FOR PUMPING

1. **Water Horse Power (WHP)** is the theoretical horsepower required for pumping.

$$\text{WHP} = \frac{\text{Discharge in litres per sec} \times \text{total head in m}}{75}$$

2. **Shaft Horse Power** is the power required at the pump shaft

$$\text{Shaft Horse Power} = \frac{\text{Water Horse Power}}{\text{Pump efficiency}}$$

3. **Pump efficiency =** $\dfrac{\text{Water horsepower}}{\text{Shaft horsepower}} \times 100$

4. **Brake Horse Power (BHP)** is the actual horsepower required to supply by the engine or electric motor for driving the pump.

(i) For direct driven pump BHP = Shaft horsepower.

(ii) With belt or indirect drives BHP = $\dfrac{\text{Water Horse Power}}{\text{Pump efficiency} \times \text{Drive efficiency}}$

5. **Horse Power input to electric motor =** $\dfrac{\text{Water Horse Power}}{\text{Pump efficiency} \times \text{Drive efficiency} \times \text{Motor efficiency}}$

6. **Kilowatt input to electric motor (or) Energy Consumption in Kilowatts hours**

$$\text{Energy in Kilowatts} = \frac{\text{Brake Horse Power} \times 0.746}{\text{Motor efficiency}}$$

7. **Cost of operation for electric motor** = Energy in Kilowatts x Hours of Pumping x cost per Kilowatt hour

The pump efficiency of most of the pumps generally ranges from 60 to 70 per cent and the drive efficiency of motor is about 80 per cent. The overall efficiency of the system may be approximately 50 to 55 per cent.

Problem 1

A centrifugal pump at its best efficiency discharges 0.03 m^3/s against total head of 40 m. If the pump speed is 1450 rpm, calculate the specific speed of pump.

Answer

$$\text{Specific speed in rpm} = n_s = \frac{n\,Q^{1/2}}{H^{3/4}} = \frac{1450 \times (0.03)^{1/2}}{(40)^{3/4}} = 15.79$$

Problem 2

Calculate the power requirement for pumping 450 lpm against the head of 50 m. If the pump efficiency is 65 %, what size of electric motor is required?

$$\text{WHP} = \frac{\text{Discharge in litres per sec} \times \text{total head in m}}{75}$$

$$= [\{(450/60) \times 50\} / 75] = 5.0$$

SHP or size of electric motor = (WHP / pump efficiency) = (5 / 0.65) =7.69 hp

Problem 3

A centrifugal pump delivers 1,36,380 lph from a head of 7.44 m. It is directly driven by an electric motor with the input hp of 6.66 and 75 % motor efficiency. What is the efficiency of pump?

Problem 4

A pump lifts 93,600 lph against a total head of 21 m. Compute the water horsepower. If the pump has an efficiency of 72 %, what size of prime mover is required to operate the pump? If a directly driven electric motor having efficiency of 80 % is used to operate the pump, compute the cost of electrical energy in a month of 30 days. The pump is operated for 12 hours daily for 30 days. The cost of electrical energy is, say, 75 paise per unit.

16. PROBLEMS ON AGRICULTURAL DRAINAGE

Problem 1

Runoff water from a watershed enters into a drainage area for 24 hours at the rate of 5 m^3/s. The total rainfall during 24 hours period is 10 cm and infiltration during the same period is 2 cm. If the total drainage area is 500 hectares and the crop can tolerate a ponding of 14 cm, calculate the drainage coefficient of the land.

Answer

Total volume entering the area in 5 hours = 5 x 3600 x 24 = 432000 m^3

This is equivalent to a depth of 432000 / (500 x 10^4) = 0.0864 m = 8.64 cm

Total depth of input on the area = 10 + 8.64 = 18.64 cm

Therefore total depth to be removed = Depth input – depth of infiltration - Depth of ponding allowed

= 18.64 – 2 – 14 = 2.64 cm (drainage coefficient)

Problem 2

A ditch discharges at 0.32 m^3/s and drains 260 ha. Compute the drainage coefficient.

Answer

Total water discharged in a day = 0.32 x 24 x 60 x 60 = 27648 m^3

Drainage coefficient = (Discharge in a day / drain area) = 27648 / (260 x 10^4)

= 0.01 m = 1 cm

Problem 3

The drainage coefficient of a land is 22 mm. Calculate the capacity of the outlet of the watershed having an area of 200 ha.

Answer

Drainage coefficient = 22 mm = 0.022 m

Area = 200 x 10^4 m^2

Capacity of outlet of watershed = Drainage coefficient x Drain area

= 0.022 m x 200 x 10^4 m^2

= 44,000 m^3/day = 0.51 m^3/s

Problem 4

A tile drain system is laid along a length of 300 m with laterals spaced 25 m apart. The outflow through one lateral span ia measured to be 5.5 m3/s. calculate the drainage coefficient.

Answer

If the drainage coefficient is D_c then,

D_c x 300 x 25 = 5.5 x 24

D_c = {(5.5 x 24) / (300 x 25)}

= 0.0176 m = 1.76 cm

Problem 5

How many ha will a 25 cm diameter tile drain with a slope of 0.3% control, if the tiles are placed on an area where drainage coefficient can be taken as 2 cm. Assume the value of manning's coefficient as 0.01

Answer

The velocity in the tile drain $V = 1/n \times R^{2/3} S^{1/2}$ m/s
For circular drain $R = D/4$

$$V = (1 / 0.01) \times (0.25 / 4)^{2/3} \times (0.003)^{1/2}$$
$$= 0.566 \text{ m/s}$$

Discharge = Velocity x area of flow
$= 0.566 \times (\pi / 4) \times (0.25)^2 = 0.0425 \text{ m}^3\text{/s} = 153 \text{ m}^3\text{/h}$

For Drainage coefficient of 2 cm

Drainage area = $\{(153 \times 24) / (0.02 \times 10^4)\} = 18.36$ ha

Problem 6

In a subsurface drainage system, the drains are located at spacing of 30 m and the drainage line is 300 m long with a slope of 0.25 %. What size of tiles will be required if the drainage coefficient is 3 cm? Assume the value of manning's coefficient as 0.011

Answer

Volume of water to be drained in 24 hours $= (3 \times 30 \times 300) / 100 = 270 \text{ m}^3$

Discharge $Q = 270 / (24 \times 60 \times 60) = 0.003125 \text{ m}^3\text{/s}$

Discharge = Area x Velocity $\quad Q = A \times V = A \times 1/n \times R^{2/3} S^{1/2}$

$$A \times R^{2/3} = \{(Q \times n) / s^{1/2}\} = (0.003125 \times 0.011) / (0.0025)^{1/2} = 6.875 \times 10^{-4}$$

For full flow condition $R = D/4$ and cross sectional area $A = (\pi / 4) \times (D)^2$

Therefore $(\pi / 4) \times (D)^2 \times (D/4)^{2/3} = 6.875 \times 10^{-4}$
$0.31169 \times D^{8/3} = 6.875 \times 10^{-4}$
$D^{8/3} = 22.0575 \times 10^{-4}$
$D = 0.1009$ m

A 10 cm diameter tile with slightly higher slope will be most economical. If the slope cannot be increased at all, the next higher size of 12.5 cm diameter will be required.

TAMIL NADU AGRICULTURAL UNIVERSITY

Anbil Dharmalingam Agricultural College and Research Institute, Trichy-620 009.

III Year B.Sc.(Ag) SWC 311Soil Conservation and Irrigation Engineering Marks: 40

Vth Semester Time: 2 hours

Final Practical Examination (28.12.2001)

PART – I TEST (Answer any five questions) 5 x 5 = 25

1a) The bearings of the sides of a triangular shape of field ABC are as follows. Calculate the angles of the triangle field and apply geometric check. (3)

AB=50°15’, BC=150°50’, CA=280°

1b) Explain the steps that are required for conducting the Traversing type of plane table surveying. Draw explanatory sketches. (2)

2a) Explain the use of stadia hairs in a dumpy level (1)

2b) Pump delivers 350 lpm at well but at field 90° V notch reading was 10 cm only. If profile moisture content after irrigation from head to tail end of field are 50 cm, 48 cm, 45 cm, 42 cm, and 40 cm respectively. Find the distribution and conveyance efficiency. (4)

3) Find volumetric moisture content of soil using the following data. (5)

(i)	Container weight	= 25 g
(ii)	Container and wet soil weight	= 225 g
(iii)	Container and oven dry soil weight	= 195 g
(iv)	Soil sampler diameter	= 50 mm
(v)	Soil sampler length	= 70 mm

4a) The earth dam of a farm pond is trapezoidal in cross section. The section of the dam is 20 m long and has a top width of 1.5 m. On one side, it has a bottom width of 9.5 m and height of 4 m and on the other side the bottom width is 8.5 m and height of 3.5 m. calculate the earth fill in this section of the dam. (3)

4b) The total length of contour bund constructed in 25 ha area is 7000 m. If the bottom width of contour bund is 2 m, calculate the percentage of area loss (2)

5) Estimate the storage capacity of a tank required to irrigate following crops. Assume 30% application loss, 20 % conveyance loss and 10% storage loss. (5)

Sl.No.	Crop	Area (ha)	Duty (ha/cumec)	Base period (days)
1	Paddy	100	900	120
2	Sugarcane	50	850	300
3	Banana	50	1000	250

6a) With the help of a sketch, explain the working principle of an air lift pump (3)

6b) Write down the formula to calculate the theoretical power requirement for pumping and explain the parameters involved. (2)

PART II Record and Assignment submission (10)

PART III Viva voce (5)

TAMIL NADU AGRICULTURAL UNIVERSITY

Anbil Dharmalingam Agricultural College and Research Institute, Trichy-620 009.

III B.Sc.(Ag) SWC 311Soil Conservation and Irrigation Engineering Marks: 20

Vth Semester Mid Semester Examination (26.10.2002) Time: 1 hours

PART – A. Answer any eight questions. If you have answered extra questions the first eight answers will be evaluated. 8 x ½ = 4

State whether the following statements are true or false

1. Using Representative Fraction (R.F.) on the map is independent of units of measurement.
2. The fore and the back bearing of a line in the compass surveying, differ exactly by 90^{o}.
3. If the chain is too short, then the measured distance will be more and the correction is negative.
4. The leader should be more experienced and skilled as he has to direct the follower about the different steps of chaining.
5. In surface creep type wind erosion, soil particles of smaller than 0.05 mm diameter are carried.
6. The stadia wires in the dumpy level are used for distance measurement.
7. The texture of a soil is a variable and can be controlled by tillage.
8. Sheet erosion carries away the most fertile part of the soil
9. Contour interval is the constant horizontal distances between two consecutive contour lines
10. The stage where the vegetation begins to grow in the gullies is called Healing stage.

PART – B. Answer any six questions. If you have answered extra questions the first six answers will be evaluated. 6 x 1 = 6

Justify the following statements

1. Agriculture and its associated activities accelerate water induced soil erosion.
2. Agricultural surveying is a plane surveying.
3. Plane table surveying is adopted for small and medium scale mapping.
4. Soil conservation planning should generally be done on a watershed basis.
5. Design of graded bund involves the design of dispose channel.
6. Bunds in black cotton soil are failure.
7. Inwardly slopping bench terraces are suitable for cultivating crops like Potato
8. Land slide erosion is common on steep hill slope.

PART – C. Answer any five questions. If you have answered extra questions the first five answers will be evaluated. 5 x 2 = 10

Explain the following

1. Any four methods of linear measurement in surveying.
2. Factors responsible for soil erosion and list out the evil effects of erosion.
3. Different techniques of controlling wind erosion.
4. Different structures for water harvesting.
5. Different components of underground pipeline system for irrigation.
6. Compute the percentage of area lost in contour bunding for an area of 25 ha, if the bottom width and length of contour bunds are 2 m and 7 km respectively.

TAMIL NADU AGRICULTURAL UNIVERSITY

Anbil Dharmalingam Agricultural College and Research Institute, Trichy-620 009.

III Year B.Sc.(Ag) SWC 311Soil Conservation and Irrigation Engineering Marks: 40

Vth Semester Time:2½hours

Final Practical Examination (11.12.2002)

PART A TEST (Answer any three questions) 3 x 5 = 15

1. An extract of the field notes of a cross staff survey is given in Table. Draw the sketch of the field and find the area in hectares. (5)

Right side offset distance (m)	Chain line distance (m)	Left side offset distance (m)
	96 (D)	
(E) 48	72	
	48	45 (C)
(F) 36	30	
	15	30 (B)
	0 (A)	

2 a) A rectangular weir of crest length 30 cm is installed at the centre of a rectangular channel of 50 cm width. The height of water above the weir crest is 10 cm. Calculate the discharge. (3)

b) Calculate the capacity of the outlet of the watershed having an area of 300 ha, if the drainage coefficient of the area is 20 mm (2)

3 a) Write in detail about the different methods of soil moisture measurement with neat sketches. (3)

b) Explain about the irrigation scheduling with necessary formulas (2)

4 a) Explain the different irrigation efficiencies in an irrigation system (3)

b) Explain the procedure for calculating the power requirement for pumping and cost of operation of electric motor (2)

PART B Identification of surveying equipments and accessories (10)

PART C Record and Assignment (10)

PART D Viva-voce (5)

TAMIL NADU AGRICULTURAL UNIVERSITY
Anbil Dharmalingam Agricultural College and Research Institute, Trichy-620 009.

III B.Sc.(Ag) SWC 311Soil Conservation and Irrigation Engineering Marks: 20
Vth Semester Mid Semester Examination (13.08.2003) Time: 1 hours

PART – A. Answer any eight questions. If you have answered extra questions the first eight answers will be evaluated. 8 x ½ = 4
Fill in the blanks

1. If the approximate distance is to be measured in the field, it can be best done by ______________.
2. In Dumpy leveling, the station where F.S and B.S readings are taken is called ______________.
3. The most accurate method for the measurement of area between a straight line and a curved boundary is called ______________.
4. Graded bunding is suitable for ______________ rainfall areas.
5. Gully erosion is an advanced stage of ______________.
6. Shifting cultivation is followed in ______________.
7. The angle, which a line makes with the magnetic meridian, is called ______________.
8. In case of raindrop erosion, as the particle size increases, the ______________ also increases.
9. In Universal Soil Loss Equation, the factor 'C' represent ______________.
10. Application of any plant residues or other material to cover the top soil surface for soil and water conservation is called ______________.

PART – B. Answer any six questions. If you have answered extra questions the first six answers will be evaluated. 6 x 1 = 6

1. Write short notes on two primary divisions of surveying
2. If a field is bounded on one side by a straight line and on the other side by a curved boundary, how to find the area of the field by average ordinate rule?
3. If the included angles between sides of a field during compass surveying are 140^o,65^o,135^o,150^o and 50^o. check whether these sides form a closed polygon.
4. How the land slid erosion occurs?
5. Differentiate between the geological erosion and accelerated erosion.
6. Runoff from black soil is more than red soil. Justify
7. What is basin listing? Where it is used?
8. What are the characteristics of contour lines?

PART – C. Answer any five questions. If you have answered extra questions the first five answers will be evaluated. 5 x 2 = 10

1. Write down the evil effects of soil erosion. Mention the four major factors influencing water erosion.
2. Explain the four stages of gully development
3. Enumerate the conditions for adoption of contour and graded bunds
4. Explain the types of bench terraces with their specific uses.
5. Explain biological erosion control measure against water erosion.
6. What is wind erosion? Explain the types of soil movement by wind.

TAMIL NADU AGRICULTURAL UNIVERSITY

Anbil Dharmalingam Agricultural College and Research Institute, Trichy-620 009.

III Year B.Sc.(Ag) Vth Semester	SWC 311Soil Conservation and Irrigation Engineering	Marks: 40 Time:2½hours

Final Practical Examination (11.10.2003)

PART A TEST (Answer any four questions) 4 x 5 = 20

1. The following consecutive readings were taken with a dumpy level and a 5 meter staff on a continuously sloping ground at a common interval of 25 meters.

   0.50, 0.85, 1.35, 2.28, 3.75, 4.10, 0.45, 1.20, 2.55, 3.15 and 4.25

   The RL of the first point was 100 m. Rule out a page of a level field book and enter the above readings. Calculate the RL of the point by height of instrument method. Find the slope in percentage. Apply usual checks.

2. A channel flow was measured with 90^{o} V notch, as 20 cm. If the same flow is to be measured with a cipoletti weir with a crest length of 10 cm, what will be the depth of flow?

3. Calculate the total volume of water (m^3) to be applied to bring the moisture content to the field capacity level of an area of 0.2 ha. Compute the time required to irrigate the land with 0.05 m^3/s discharge.

   Details of soil sampling

Depth of root zone cm	Field Capacity %	Existing moisture %	Bulk density g/cc
0 – 30	21	10.5	1.15
30 – 60	22	11.5	1.20
60 – 90	24	13.5	1.25
90 – 120	25	14.5	1.25

4. a) A ditch discharges at 0.32 m^3/s and drains an area of 260 ha. Compute the drainage coefficient.
   b) How many ha of wheat crop can be irrigated by a pump having a discharge of 11000 lph. The depth of irrigation is 5 cm and irrigation interval is 15 days. The pump works for 10 hours each day.

5. Explain any one of the advanced irrigation method with neat sketch of its layout. Write the advantages and limitations of this method of irrigation.

PART B Identification of surveying equipments and accessories (5)

PART C Record and Assignment (10)

PART D Viva-voce (5)

TAMIL NADU AGRICULTURAL UNIVERSITY

Anbil Dharmalingam Agricultural College and Research Institute, Trichy-620 009.

III B.Sc.(Ag) SWC 311Soil Conservation and Irrigation Engineering(1+1) Marks: 20

V Semester Mid Semester Examination (11.09.2004) Time: 1 hours

PART – A. Answer any eight questions. If you have answered extra questions the first eight answers will be evaluated. 8 x ½ = 4

State whether the following statements are true or false

1. Contour stonewalls are constructed in lands having slopes between 10 and 16%.
2. Scales on the maps are often represented by R.F, which is independent of units of measurement.
3. If the chain is too long, then the measured distance will be more and the correction is negative.
4. The velocity of runoff is not influenced by the topography.
5. In surface creep type wind erosion; soil particles of smaller than 0.5 mm diameter are carried.

Fill in the blanks

1. In leveling staff, each black or white colour strip represents _____________ mm.
2. The broad beds and furrows have been found to be suitable for managing the _____________ soils.
3. _____________ planning should generally be done on a watershed basis.
4. The rate of soil movement _____________ with the distance from the wind ward side of the field.
5. The stage where the gully bed reaches a stable condition in the gullies is called _____________.

PART – B. Answer any six questions. If you have answered extra questions the first six answers will be evaluated. 6 x 1 = 6

1. Write short notes on two primary divisions of surveying.
2. If a field is bounded on one side by a straight line and on the other side by a curved boundary, how to find the area of the field by Simpson's rule?
3. If the included angles between sides of a field during compass surveying are 140^o,65^o,135^o,150^o and 50^o. Check whether these sides form a closed polygon.
4. How the land-slid erosion occurs?
5. Differentiate between the geological erosion and accelerated erosion.
6. Write down the nature of errors in surveying.
7. Differentiate between the closed traverse and open traverse in compass surveying.
8. What are the characteristics of contour lines?

PART – C. Answer any five questions. If you have answered extra questions the first five answers will be evaluated. 5 x 2 = 10

Explain the following. Draw neat sketches wherever necessary.

1. Any four methods of linear measurement in surveying.
2. Explain the evil effects of erosion.
3. Different forms of water erosion
4. Any two mechanical methods of water erosion control with their suitability
5. The different steps to be followed during chaining a line
6. Any two methods of plain table surveying.