" FUNDAMENTALS OF SOIL WATER CONSERVATION ENGINEERING"

Prof. P.P. Patil and Prof. T.B. Bastewad
DEPARTMENT OF AGRICULTURAL ENGINEERING
COLLEGE OF AGRICULTURE, DHULE- 424 004

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FUNDAMENTALS OF SOIL AND WATER CONSERVATION ENGINEERING

Lecture: 1

INTRODUCTION TO SURVEYING

Surveying :

It is the art of making such measurements to determine the relative positions of points on the surface of earth, in a horizontal plane.

Leveling :

It is the art of determining and representing the relative heights or elevations of different points (i.e. in a vertical plane).

Object of surveying:

Following are the objects of surveying -

(i) Preparation of a plan or map
(ii) To draw the results of survey on paper
(iii) To know the relative positions of point on ground
(iv) To collect different information.
(v) To collect data for analysis.

Map:

If the scale of representation is small then it is called as map, e.g. a map of India.

Plan:

If the scale of representation is large then it is called as plan. e.g. a plan of a building or plan of an estate. Horizontal distances are shown on a plan. Vertical distances are also shown on a plan sometimes, represented approximately by means of contour lines, or other systems.

Section:

On a plan vertical distances are correctly shown by means of vertical sections called as section.

1.1 Primary Divisions of Surveying:

(A) Geodetic Surveying (B) Plane Surveying

(A) Geodetic Surveying:

Geodetic Surveying is also called as trigonometrically surveying. In this surveying, it is necessary to take into account the curvature of earth, since large distances and areas are covered. The earth is spheroidal; the line connecting any two points on the surface of earth is curved. It is not a straight line. In this type of surveying, the figure formed by the lines joining three points on the mean surface of earth is a spherical triangle with spherical angles. The sides of spherical triangle are arcs of great circles. The main object of geodetic surveying is to determine the precise positions of points on the surface of earth; e.g. Engineering survey, Topographical survey, Cadastral survey etc.

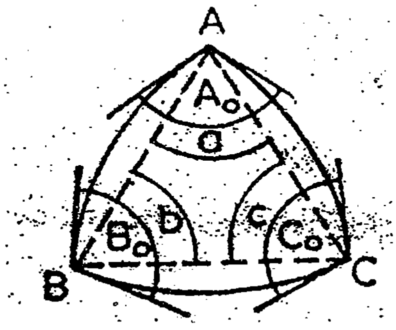

Fig. 1.1

In Fig. 1.1 shows a spherical triangle ABC. The angles A_0, B_0 and C_0 are the spherical angles. In the figure are AB, are BC and are CA are the sides of spherical triangle. The arc sides are showing the curvature of earth. If we ignored the curvature of the earth the figure thus formed is a plane triangle ABC, which is shown by dotted straight lines. Straight lines AB, BC and CA are the sides of a plane triangle. The angles a, b, and c are plane angles.

(B) Plane Surveying:

As the plane survey extend over small areas, therefore in this surveying the curvature of the earth is not taken into account. In plane surveying, the earth's surface is considered as a plane surface. The lines connecting any two points on the surface of earth are considered as straight lines. The angles formed by any geometrical figures are considered as plane angles. To do the plane surveying knowledge of geometry and plane trigonometry is required. In this type of surveying, the degree of accuracy required is comparatively low. If the survey area is less than 250 sq. kilometres, it is termed as plane surveying. Plane surveying methods are frequently employed for surveys of areas large extent, when great accuracy is not required. The difference in arc and chord is about 0.1 m in 18.2 km and difference between sum of angles of a spherical triangle and plane triangle is 1 second for every 195.5 sq. kilometres of area.

1.2 Classification of surveying:

Variety of ways are there for classifying the survey as :

(A).. Classification based upon the nature of field survey:

(i) Astronomical Surveys

(ii) Marine or Navigation Surveys

(iii) Land surveys:

Types of Land surveys:

(a) Topographical survey -To determine natural features of a country such as valleys, hills, rivers, nalls, lakes, woods, roads, railways, canals, towns, villages etc.

(b) Cadastral Survey - Additional details such, as boundaries of houses, pathways and fields are determined in this survey.

(c) City survey - Survey is used for laying out plots, construction of streets, sewers and water supply systems.

(d) Engineering Survey - This type of surveying is used for determining quantities and collecting data for the design of engineering works, e.g. roads, railways, reservoirs etc.

Engineering Survey is subdivided into:

(I) Reconnaissance Survey- Survey is used for determining the feasibility and rough cost of the project

(II) Preliminary Survey - Survey is used for collecting more precise data and to estimate the exact quantities and costs.

(III) Location Survey - Survey is used for setting out the work on the ground.

(B). Classification based upon the object of survey:

(i) Archaeological Survey - Survey is used for unearthing relics of antiquity.

(ii) Mine Survey - Survey is used for exploring mineral wealth, such as gold, coal etc.

(iii) Military Survey - Survey is used for determining points of strategic importance both defensive and offensive.

(iv) Geological Survey - Survey is used for determining different strata in the earths crust.

(C). Classification based upon the instrument used:

(i) Compass survey

(ii) Plane Table Survey

(iii) Chain Survey.

(iv) Photographic Survey.
(v) Aerial Survey.
(vi) Cross-staff survey.
(vii) Theodolite Survey.
(viii) Tacheometric Survey.

(D). Classification based upon the methods employed in survey:
(i) Triangulation Survey.
(ii) Traverse Survey.
  (a) Open Traverse Survey.
  (b) Closed Traverse Survey.

1.3 Principles of Surveying:

The two principles on which various survey methods are based as :

(A) To work from the whole to the part

(B) To fix the positions of new survey stations by at least two independent processes.

(A) To work from the whole to the part:

In extensive surveys such as topographical or town survey a system is established of control points with high precision. The points are established by triangulation or precise traversing for the horizontal control. In triangulation, the area to be surveyed is divided into large triangles with great accuracy. The big triangles are further sub-divided into small triangles. Due to this one can prevent the accumulation of error and have a control and localise minor error. If we work from the part to the whole, small errors get magnified in the process of expansion of survey. Due to this the errors become uncontrollable at the end.

(B) To fix the positions of new stations by at least two independent processes:

The positions of new stations are fixed from points already fixed by different methods as:
(i) Linear measurement.
(ii) Angular measurement.
(iii) Both linear and angular measurements.

e.g. The measurements and plotting of the main lines and the station points are checked by means of check or tie lines in case of chain surveying.

1.4 Uses of Surveys:

Surveying is an art and science of map making. The earliest surveys were confined to measurement of land and establishment of boundaries. The engineers must be familiar with the principles and practice of surveying. All engineering and construction projects extends over large areas, such as highways, irrigation, water supply, railways etc. are based on elaborate and complete surveys. The preparation of accurate plans and sections is the first necessity in all-engineering projects.

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Lecture : 2

CHAIN SURVEYING

Purpose of Land Surveying:

(i) To obtain data for exact description of the boundaries of a land or tract.

(ii) To determine area of land

(iii) To obtain the required data for making a plan.

(iv) To locate or re-establish the boundaries of a land which is previously surveyed.

(v) To divide the land into number of units as per the requirement.

Methods of Land Surveying:

(A) Triangulation and

(B) Traversing

2.1 Triangulation Survey:

It is the basis of trigonometrical or geodetic surveys. In triangulation survey, the lines of survey form a network of triangles. it is the system of surveying in which the area is divided into simple geometrical figures and the work is carried out by taking its measurements.

Chain triangulation or chain surveying is suitable when: (i) The area is small (ii) The ground is fairly level and open with simple detail & (iii) Plans are required on a large scale such as those of estates. Chain surveying is unsuitable for areas crowded with many details and large areas. For wooded country also this survey is difficult.

Principle of Triangulation:

A survey in which the given field or area is divided into number of suitable triangles and measurement of all the sides of triangles is done is known as triangulation survey. Triangle is only a plain geometrical figure, knowing the three sides of which it can be plotted exactly in size and shape. No angular measurement is required. For this survey field must be accessible and vision free stations. The exact arrangement of triangles to be adopted depends upon the shape and configuration of the ground. If the arcs interest at 90^0, displacement of point due to errors in the radii is minimum, if the said point is located by the intersection of two arcs. Each of the three angles of a triangle should be nearly 60^0, i.e. the triangle should be equilateral. An equilateral triangle be more accurately plotted than an obtuse-angled triangle. Therefore triangles formed should be approximately equilateral triangles, so that errors in measurement and plotting should be minimum. Such triangles formed known as "well conditioned" or "well shaped". When a triangle contains no angle smaller than 30^0 and no angle greater than 120^0, then a triangle is said to be well conditioned or well proportioned. (Fig 2.1) is a ill-conditioned triangles having angles less than 30^0 or greater than 120^0 should always be avoided.

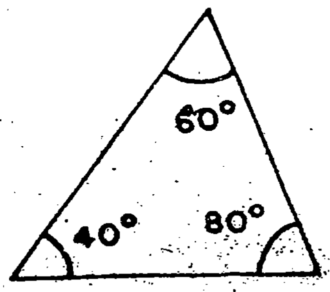

Fig 2.1

2.2 Survey Stations:

It is a point of importance at the beginning and end of a chain line. There are two types of survey stations as:

(i) Main Survey Station, and

(ii) Subsidiary or Tie stations.

(i) Main Survey Station:

Main stations are located at the ends of the lines which command the boundaries of the survey. The lines joining the main stations are called as the main survey lines or chain lines. Stations are usually denoted with a small circle round the station point o. They are lettered or numbered (Fig 2.2), capital letters being used to denote main stations e.g. A, B or 1, 2. Sometimes the letters denoting stations are written within the circle e.g A Survey lines are indicated by the letters of the stations, e.g. AB, BC etc. The system of lines of triangles covering the area to be surveyed is called the skeleton or framework of a survey.

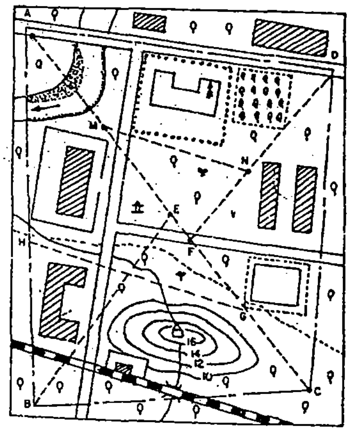

Fig 2.2

(ii) Subsidiary or tie stations :

The subsidiary or tie stations are the points selected on the main survey lines, where it is necessary to run auxiliary lines to locate the interior details such as fences, buildings, hedges etc. When these objects are distant from the main lines, then tie stations are taken. They are conveniently fixed while the chaining of the main lines is in progress. The lines joining the subsidiary or tie stations are called as subsidiary or tie lines. They are lettered, small letters being used to denote tie stations, e.g. a, b, etc. Tie lines are indicated by the letters of the station, e.g. ab, bc, etc.

2.2.1 Selection of Stations:

Following points are considered while arranging the frame work of a survey as :

(a) The main principle of surveying, viz. working from the whole to the part, should be strictly observed. If it is found necessary to produce any line on paper, after it is plotted, the part of line produced should be as short as possible. In this case small errors in plotting will be magnified when the line is produced.

(b) Main stations should be mutually visible.

(c) The sides of the larger triangles should pass as close as possible to the boundaries, buildings, roads etc., to be located in order to have short offsets. Tie lines should be placed close to the detail.

(d) A long line, if possible should run roughly through the center of the area. Long line should be laid off, as for as possible on level ground. "The longest line of survey possible, approximately through the centre of the area is called as Base line".

(e) All triangles should be well conditioned.
(f) The survey lines should be as few as practicable.
(g) Each triangle should be provided with at least one check line.
(h) The survey lines should lie over on level ground as possible.
(i) The survey lines should be so arranged as to avoid obstacles to ranging and chaining.
(j) A number of tie lines should be run to locate the detail and to avoid long offsets.

2.3 Important Survey Lines:

(i) Base Line (ii) Check Line
(iii) Tie line (iv) Offsets

(i) Base Line:

"The longest of the chain line approximately passing through centre of a field is called as Base line". It is the most important line of survey. It fixes up the directions of all other lines (Fig 1.2). On the base line the framework of a survey is built-up. It should be laid off on as level ground as possible. It should pass through the centre and the length of the area. It should be measured horizontally and correctly. It should be measured twice or thrice, to obtain its accurate length. Great care should be taken to ensure the straightness of the base line. If possible, two base lines in the form of letter "X" should be laid out.

(ii) Check Line:

"Check line is a line joining the apex of a triangle to some fixed point on the side apposite" or it is a line joining some fixed points on any two sides of a triangle (Fig 1.2). It is also termed as a "proof line". To check the accuracy of the framework, a check line is measured.

The length of the check line as measured on the ground should agree with its length on the plan. Due to check line, there is a complete check on the field measurements as well as on the accuracy of the plotting work.

(iii) Tie Line:

A tie line is a line joining some fixed points as tie stations or the main survey lines. In (fig 1.2) line MN is a tie line. The tie line checks the accuracy of the framework also it enables the surveyor to locate the interior details.

(iv) Offsets:

The lateral measurements i.e. the distance of the object from the chain line are called as offsets. In a survey the positions of the details such as buildings, nallas, boundaries, fences, roads etc., are located with respect to the main survey lines. There are two types of offsets as :

(a) Perpendiculars offsets and
(b) Oblique offsets:

(a) Perpendicular offsets: Offsets taken at right angles to the survey line are called as perpendicular or right angled offsets. In figure 1.3 is perpendicular offset.

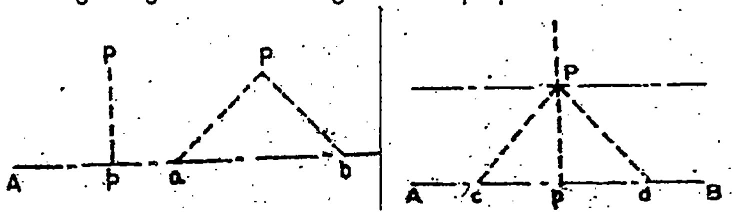

Fig. 1.3

For offset two measurements are taken as :

(1)The distance along the chain line up to the foot of the offset, (Ap) and (2) the length of the offset (pP). These measurements are taken and noted in a field book. This operation is known as taking offset. When the length of the offset is less than 15 m, then the offset is called as short offset. If the length of the offset exceeds 15 m, then the offset is called as long offset. When the offset is short, the offset is taken by judging by eye only or using swinging tape. When the offset is long and important, the offset is taken with the help of a cross-staff or optical square or by a box sextant. Short offsets may be measured more quickly and accurately than long ones. The offsets should be as short as possible, since they are less liable to error due to incorrect length of tape or incorrect direction.

(b) Oblique Offsets: Oblique offsets should be taken, when the object to be located is at a long distance from the chain line or when it is an important one. The oblique offsets are taken for the corner of a building or the intersection of the two adjoining properties. These offsets are also taken to check the accuracy of perpendicular offsets. In (Fig. 1.3), offsets cP and dP are called as oblique offsets to check the accuracy of perpendicular offset pP (Fig 1.3). With the help oblique offset point 'P' is accurately located.

3.4 Instruments and Procedure of Chain Survey:

(a) Instruments required:

(i) Chain (ii) Tape
(iii) Ranging rods (iv) Arrows (v) Drawing material.

(b) Procedure:

(i) Erect ranging rods at all the corner point stations of the field.

(ii) Prepare a rough figure of a field on a page of field book and divide this into number of "well conditioned" triangles, in which no angle is too acute or obtuse i.e. not less than 30^0 and not more than 120^0.

(iii) By direct ranging, measure the length of all sides of all the triangles and note down the measurements in a field book and also on a rough drawing.

(c) Plotting:

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

(ii) With this selected scale, plot one side of any triangle. With the same scale draw two arcs by a compass from the ends of this side, equal to the lengths of remaining sides of a triangle. The intersection of these two arcs, fix the third station. Join this station with the ends of the side previously plotted. A triangular portion of a field is plotted.

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

(d) Calculation of Area of a field:

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

$$\text{Area of } \Delta ABC = \sqrt{s(s-a)(s-b)(s-c)}$$

$$\text{Where s, Semi-perimeter} = \frac{a+b+c}{2}$$

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

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Leacture No. : 3

PLANE TABLE SURVEYING (RADIATION)

'Plane table surveying or plane tabling is a graphical method of surveying in which the field work and plotting are done simultaneously'. It is particularly adapted for small scale or medium scale mapping. It is used for locating the field boundaries and filling in the details between the stations previously fixed by triangulation.

3.1 Parts/Accessories of Plane Table:

1) Drawing board mounted on tripod.
2) Alidade
3) Trough compass or a circular box compass
4) Plumbing fork (U-frame).
5). Water-proof cover, paper, clamps etc.

1) Drawing Board: The drawing board is made of well-seasoned wood such as teak or pine. The size of the board varies from 40 cm x 30 cm to 75 cm x 60 cm or 50 cm to 60 cm square. It had plain and smooth top. It is mounted on a tripod in such a manner that it can be leveled, and revolved about a vertical axis. The board is clamped on a tripod in any position. Some board and tripod are provided with leveling screen or ball and socket arrangement for accurate leveling (Fig 3.1).

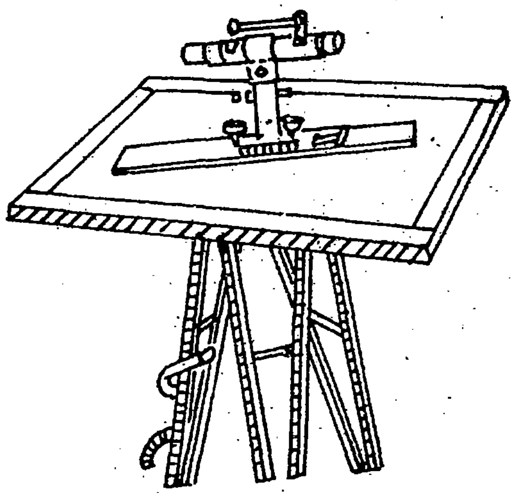


Fig 3.1

2) Alidade: Alidade consists of two vertical sight vane fitted at the end of straight edge. It consists of a metal or boxwood straight edge or ruler about 50 cm long. The bevelled (working or ruling) edge of the alidade is called as the fiducial edge. The alidade may be plain or telescopic. One of the sight vanes is provided with a narrow slit and the other with a central vertical wire or hair (Fig 3.2). It is used for drawing the rays towards the stations or objects.

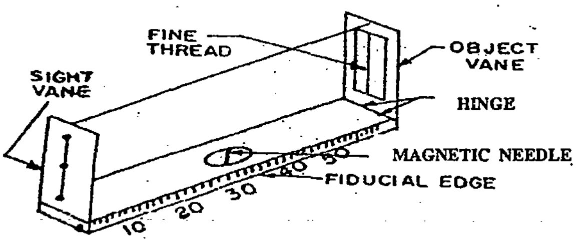


Fig 3.2

3) Trough Compass or a Circular Box Compass: It consists of two bubble tubes at right angles to each other mounted on a square brass plate. It has a magnetic needle, which shows the north and south direction. It is used for marking the direction of the magnetic meridian on drawing paper. It is also used in orientation of the table by the magnetic needle.

4) Plumbing Fork or U-Frame: It consists of a plumb bob fitted to metallic fork with the help of thread (Fig 3.3). It is used for centering the table.

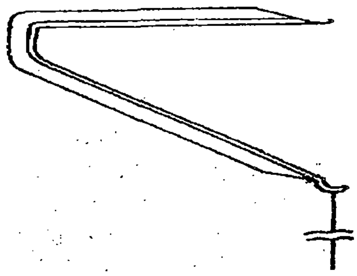


Fig. 3.3

5) Water Proof Cover, Paper etc : Waterproof cover is used to protect the drawing sheet from rain. The drawing paper used should be of the best quality. Paper should be well seasoned. It should be never folded or rolled. It should be carried flat in a portfolio. The paper should be tinted faint grey or green. Celluloid or zinc sheets are used for work in damp climates. The drawing paper is fixed on the board by means of clips, suitable clamp or pins. The other drawing material required during plane tabling are pins, pencils, scales, eraser etc.

3.2 Merits and Demerits of Plane Tabling:

Merits:

1) It is most suitable for preparing small-scale map or surveying small area.
2) It is most rapid method.
3) Field book is not necessary.
4) No great skill required for satisfactory map.
5) It is particularly suitable for a magnetic area where prismatic compass is not reliable.
6) Contour and irregular objects may be represented accurately.
7) It is less costly.
8) There is no possibility of omitting the necessary measurements as the map is plotted in the field.
9) Errors of measurement and plotting may be readily detected by check lines.

Demerits :

1) It is not suitable for work in a wet climate.
2) There are several accessories to be carried, and therefore they are likely to be lost.
3) It is not suitable for accurate work.
4) Plane table is heavy, cumbersome, and awkward to carry.

3.3 Setting the Plane Table :

The plane table should be set at a convenient height for working (about 1 m). It should be approximately leveled. The legs of the tripod should be spread well apart. The legs should be firmly fixed into the ground.

3.3.1 Centering the Table :

' The operation of placing the table over the station on the ground that the point plotted on the drawing sheet corresponding to the station occupied should be exactly over the station on the ground', known as the centering of the table.

Centering is done by means of plumbing fork. To do this, place the pointed end of the upper leg of the fork coinciding with point on the paper and shift the table bodily until the plumb bob hangs exactly over the centre of the station peg. If no plumb bob is available, centering of the table may be done by dropping a stone from a point on the under side of the board which is directly under the point of the paper. The degree of accuracy required in centering is necessary only in large-scale work. When the scale is small, it may be approximate, as the error even of 30 cm would not show on the map.

3.3.2 Leveling of the Table:

The table is then leveled by means of the leveling screws. Leveling of the table is checked by means of level tube paced on the table, first parallel to two screws and then over the third screw. The leveling is done by tilting the board by hand, if the table is provided with a ball and socket head. If no leveling head or ball and socket arrangement is fitted, the leveling is done by adjusting the legs only.

3.4 Orienting the Plane Table:

'The operation of keeping the table at each of the successive stations parallel to the position which is occupied at the first station' is known as orientation. When the table is properly oriented, the lines on the paper are parallel to the lines on the ground, which they represent. It is necessary when the instrument has to be set up at more than one station.

There are two methods of orientating the table

(a) Orientation by the magnetic needle and
(b) Orientation by back sighting.

3.4.1 Orientation by the Magnetic Needle:

To orient the table at any subsequent station, the trough compass is placed along the line representing the magnetic meridian, which has been drawn on the paper at the first station. Then the board is turned until the ends of the needle are opposite the zeros of scale. The board is then clamped in position. This method is sufficiently accurate provided there is no local attraction.

3.4.2 Orientation by Backsighting:

This method is always preferred as it is the most accurate method of orientation. Suppose the table is set up over the station Q on the line PQ that has been previously drawn as pq from the station P. The alidade is placed along the line qp. The board is then turned until the line of sight bisects the ranging rod at P. The board is then clamped in position. Care should be taken to place table at each successive stations in such position that the centering of the table is least altered when the table is turned in azimuth for orientation.

3.5 Methods of Plane Tabling:

There are four methods of plane table survey:

(a) Radiation
(b) Intersection
(c) Traversing, and
(d) Resection

3.5.1 Radiation Method of Plane Tabling:

This method is suitable when an area is accessible, small and without too many obstacles. It is chiefly used for locating the details from stations, which have been previously established by other methods of surveying (fig 3.4).

Procedure:

(a) Find out a suitable point nearly at the centre of a given field from which all corner points are visible and accessible. This selected point is an instrument station (P)
(b) Set a plane table exactly above the ground instrument station with the help U- frame and level it by spirit level.

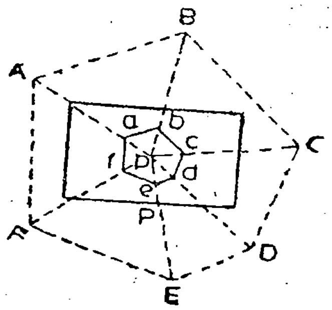


Fig 3.4

(c) Select a point 'p' on the sheet so that it is exactly over the station 'P' on the ground by the use of U-frame.

(d) Mark the direction of the magnetic meridian with the help of the trough compass.

(e) With the help of alidade draw rays for all the corner points of the field from the ground station on a paper (p).

(f) Measure the length of all the rays (instrument station to corner points) with a chain or tape.

(g) Note down the length of any side of field for checking an accuracy of a fieldwork.

(h) With suitable scale, mark the positions of ground stations on a paper and join all the corner points to give the outline of the survey.

3.5.2 Checking an Accuracy of a Field Work:

Measure the length of line on paper for which ground measurement is taken and convert paper length into ground length by the scale used for preparation of plan. Find out the difference between actual ground length and calculated length from paper length. Express this difference in terms of percentage.

Lecture 4

STUDY OF OPEN CROSS STAFF AND OPTICAL SQUARE

The following Instruments may be used for (1) Finding the foot of the perpendicular from a given point to a line and (2) Setting out a right angle at a given point on a line.

4.1 Cross staff : There are three forms / types of cross staff, namely -

1) The Open Cross Staff
2) The French Cross Staff
3) The Adjustable Cross Staff

4.1.1 Open Cross Staff:

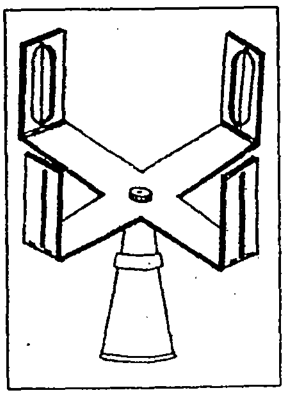


Fig 4.1

It mainly consists of the head and leg. The head is made of wooden block. The head is octagonal or round about 15 cm side or diameter. Head has four arms at right angles to each other of which two adjoining arms are provided with vertical slits, while remaining two has vertical slots. The slots have black horse hair or black thin wire in the centre. Head is fixed on wooden pole. (fig 4.1).

To find the foot of the perpendicular from a given point to a given survey line, the cross staff is held vertically on the survey line where the offset is likely to occur. Cross staff is turned until one pair of opposite slits is directed to the ranging rod placed at the forward end of the survey line. Then looking through the other pair of slits, it is seen whether the line sighted coincides at the center of the point under consideration. If it is not coinciding the cross staff is moved forward or backward on the survey line until line of sight at right angles to the survey line falls at the center of the point under consideration.

4.1.2 French Cross Staff:

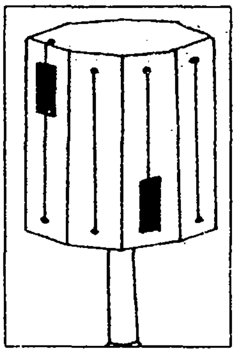


Fig 4.2

It is an octagonal form of cross staff. This cross staff consists of an octagonal brass tube. It is having slits on all eight sides. It has an alternate vertical sight slit and an opposite vertical window with a vertical horse hair or a fine black wire on each of the four sides. These are used for setting right angles, also for setting out angles of 45^0 (Fig 4.2).

4.1.3 Adjustable Cross Staff:

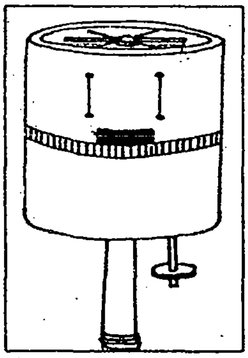


Fig 4.3

It consists of brass cylindrical tube about 8 cm in diameter and 10 cm deep. It is divided in the centre. The upper cylinder can be restated relatively to the lower one by a circular rack and pinion arrangement actuated by a milled headed screw. Both the parts are provided with sighting slits. The lower part is graduated to degrees and subdivisions, while the upper part carries a vernier. These cross staffs may be used for setting out angles of any magnitude (Fig 4.3).

4.2 Right Angle with Optical Square:

4.2.1 Optical Square:

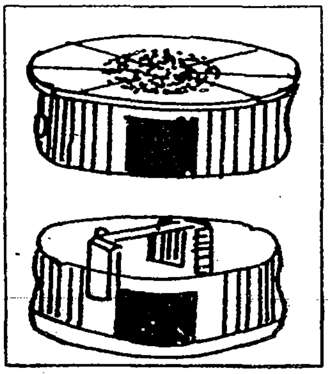
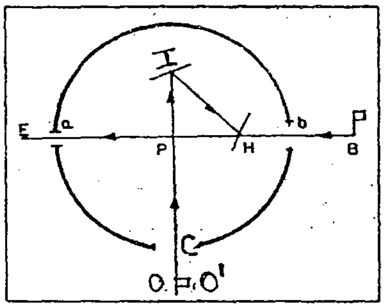


Fig. 4.4

Optical square is also used for making right angle line with survey line. It is more accurate than cross staff. Optical square consists of a metal box about 5 cm in diameter and 1.2 cm deep (Fig. 4.4). It is protected by a metal cover. Metal cover protects the mirrors from dust when not in use.

Fig. 4.5



From the (fig. 4.5), "H" and "I" are the two mirrors placed at an angle of 45⁰ to each other. The mirror "H" is called as "Horizon Glass". It is half silvered and half plain glass. The mirror "I" is called as the "Index Glass". It is fully silvered. The horizon glass is fitted in a frame, which is attached rigidly to the bottom plate of the box. The index glass is also fitted in a frame, which is attached to the bottom plate. Three openings are cut in the rims of the box and cover as (i) 'a' is a pin hole for the eye sight; (ii) 'b' is a small rectangular slot for horizon sight and (iii) 'c' is a large rectangular slot for index sight. the index glass is adjusted with small circular hole on the top of the cover. The line 'ab' joining the centres of the eye sight hole and small slot, is called as the eye horizon sight. The line "CI" is called as index sight. Both the sights are at right angle to each other. The horizon glass in placed opposite to the eye hole at an angle of 120⁰ to the horizon sight. The index glass is placed opposite to slot at 'c' at an angle of 150⁰ to the index sight.

A ray of light from the ranging rod "O" on the line "OI" strikes the index glass "I" and is reflected along "IH". This reflected ray again strikes the silvered portion of the horizon glass "H" and is finally reflected along HE. The observer looking through the sight hole 'a' in the direction "EH" sees the ranging rod at "B" directly through the un-silvered portion of the horizon glass. At the same time observer sees the image of the ranging rod at "O" in the silvered portion of the horizon glass exactly above or below. If the both the images that of ranging rod O and ranging rod B coincides to each other then line "OP" is perpendicular to line EB (Fig 4.6).

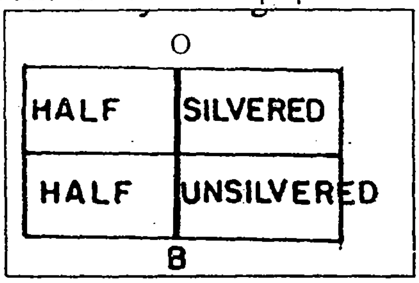


Fig 4.6

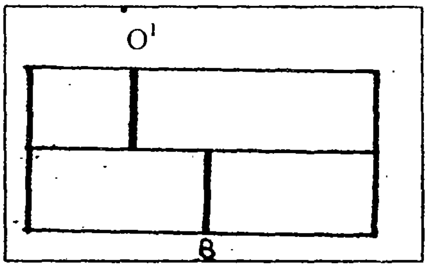


Fig. 4.7

From Fig. 4.7, if the image of "O" will be seen to one side of the ranging rod "B", then the ∠BPO is not a right angle.

4.2.2 How to Use Optical Square:

Line "AB" is given. Point "C" is an object outside of line AB. Offset is to be taken from point "C" to line "AB". In this case the foot of the perpendicular from point "C" has to be determined located on line "AB". The observer holding the optical square in his hand quite erect stands on the chain line AB .

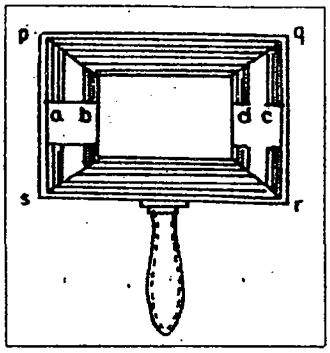


Fig 4.18

(Fig 4.8). He turns the open face 'pqrs' towards the object "C". The observer sights the ranging rod at the forward station "B" by looking through the openings in the direction of 'ad' or 'cb', accordingly the object "C" is to his left or right. He walks along "AB" backward or forward until the images of the objects at ranging rod at "C" coincides with ranging rod at "B". The point vertically under the instrument is the foot of the perpendicular drawn from point "C" to the chain line "AB".

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Lecture 5

COMPUTATION OF AREAS – REGULAR AND IRREGULAR FIELDS

To determine the area of the tract of the land surveyed is one of the primary object of land surveying. The term "area" is meant the area of a tract of land as projected upon a horizontal plane.

For measurement of area two units are commonly used as : (i) The square metre, and (ii) The hectare. Area can be determined by either the direct use of field notes or from the previously plotted plan.

5.1 Computation of Areas From field Notes:

When the object of surveying is to calculate the area directly from field measurements, the survey lines should be so arranged as to include the whole area. The calculations consist of two parts as (i) Calculation of the area of the skeleton of the survey, and (ii) Calculating the area enclosed between the survey lines and the boundaries of the survey.

(i) Calculation of the Area of skeletons:

It can be measured by two way (a) By geometry or (b) By co-ordinates.

(a) Calculation of Area by Geometry : The areas of the triangles forming skeletons may be calculated by the formulae (fig 5.1) as

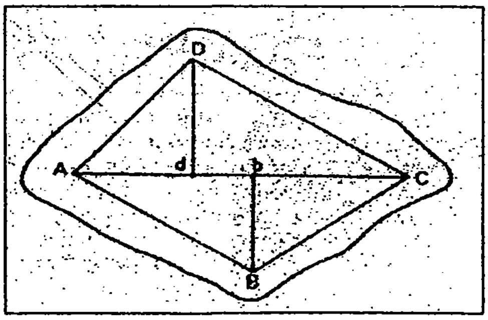


Fig 5.1

(1) Area of triangle = $\sqrt{s(s-a)(s-b)(s-c)}$

where,

a, b and c are the three sides of the triangle and

s, the Perimeter, = $\frac{a+b+c}{2}$

(2) Area of triangle = $\frac{b \times h}{2}$

Where, b is the length of any side and h is the perpendicular distance of the opposite vertex from this side.

(b) Calculation of Area along Boundaries:

The area of the irregular strip of land may be calculated by multiplying the mean of each successive pair of adjacent offset by the distance between them.

If S_1 = Length of the offset at chainage x_1

S_2 = Length of the offset at chainage x_2

And the distance between the offsets = $x_2 - x_1$

Then, mean offset = $\frac{S_1 + S_2}{2}$

$$\text{Area } (\Delta) = \frac{S_1 + S_2}{2} (x_2 - x_1)$$

5.2 Calculation of Area from Plan:

There are two general methods for determining area from a plan as (A) Graphical and (B) Instrumental.

(A) Graphical Methods:

In these methods the required data are obtained from measurement on the plan. There are two graphical methods as (a) Graphical method for entire area and (b) Graphical method for area along boundaries. Again the graphical method for entire area is sub-divided into (1) By division into triangles, (2) By division into squares and
(3) By division into trapezoids.

5.2.1 By Division into Triangles Method:

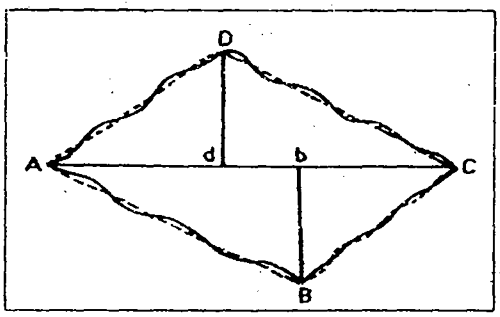


Fig 5.2

In this method figure is divided into a number of triangles. The base and altitude of each triangle are scaled. Its area is found by multiplying half the base by the altitude. When the boundaries are irregular, they are replaced by straight lines termed as 'give' and 'take' or equalising lines (fig 5.2). These boundary lines are so drawn that they exclude as much as they include.

5.2.2 By Division into Squares Method:

In this method a piece of tracing paper ruled out into squares is placed over the drawing. Each square representing a definite number of square metres or square centimetres. From the figure the number of complete squares is then counted. Also the portions of the squares broken by the curved boundary are

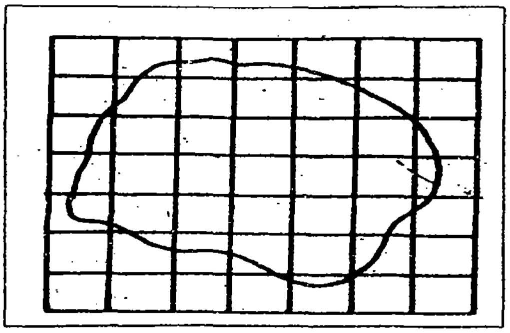


Fig 5.3

estimated in terms of a whole square. The required area under consideration is equal to the total number of squares multiplied by the square metres etc., which each square represents as per the scale of the drawing (fig 5.3).

5.2.3 By Division into Trapezoids:

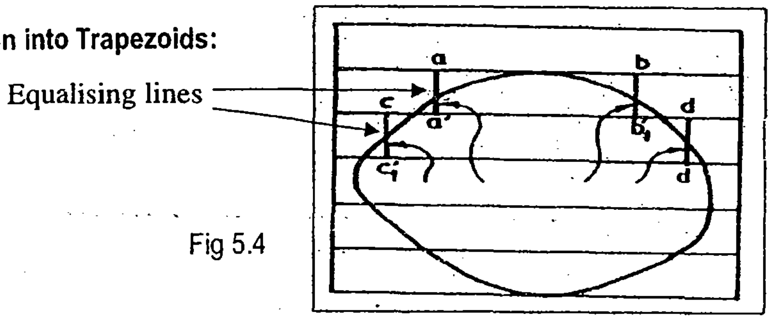


Fig 5.4

In this method a series of equidistant parallel lines are ruled on a tracing paper. The constant distance between two consecutive lines represents some round number of metres or centimetres. Then the tracing paper is placed over the plan. The total area of the plan is exactly enclosed between two of the parallel lines (fig 5.4). The figure of the plan is divided into a number of strips. The curved ends of each strips are replaced by a perpendicular 'give' and 'take' lines. Take sum of the lengths of the rectangles obtained and multiply it by common breadth, gives the required area. The computing scale is a device for simplifying the process of measuring lengths (fig 5.5). It carries a sliding cursor with a fine wire upon it at right angles to the scale. Since the cursor line serves the purpose, there is no need to draw the 'give' and 'take' lines on the paper.

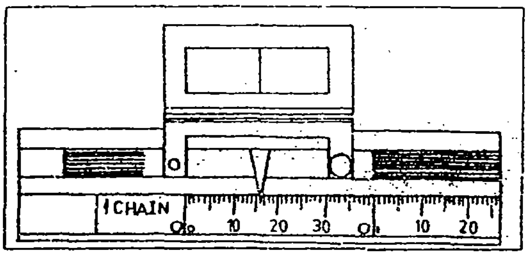


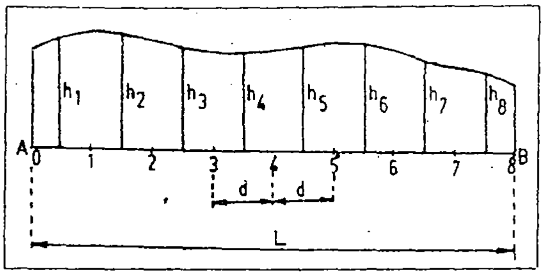
Fig 5.5

5.3 Graphical Method for Area Along Boundaries:

This method is suitable for the case of a long narrow strip of ground such as the strip occupied by a railway or road. The areas enclosed between the adjacent survey lines and the curved boundaries are determined by ordinates. In this method a base line is taken through the area and it is divided into number of equal parts. At each of the points of division the ordinates are drawn and scaled. Then the area may be calculated from these lengths and their common distance apart, by four methods as (a) The Mid-Ordinate Rule (b) The Average Ordinate Rule (c) The Trapezoidal Rule and (d) Simpson's Rule.

5.3.1 The Mid-Ordinate Rule Method :

Fig 5.6



In Mid-ordinate Rule method, the ordinates are measured at the mid points of each division and then the area is calculated by the formula, (fig 5.6) as

$$\text{Area}(\triangle) = \frac{h_1 + h_2 + h_3 + \ldots\ldots + h_n}{n} \times L$$

$$\text{or Area}(\triangle) = (h_1 + h_2 + h_3 + \ldots\ldots + h_n) \times d$$

Where, h_1, h_2 .... h_n = the ordinates at the mid-points of each division

L = total length of the base line

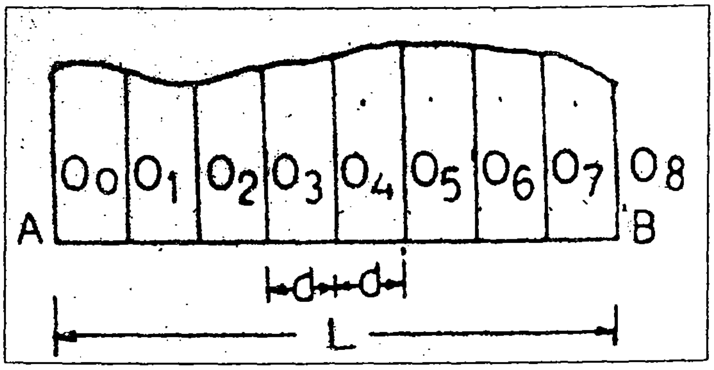
n = the number of equal parts into which the baseline is divided.

d = the common distance between the ordinates.

or d = L/n

5.3.2 The Average Ordinate Rule Method:

Fig 5.7



In the average ordinate rule method the ordinates are drawn at each of the points of division of the base line and they are scaled. The average of these ordinates is taken and it is multiplied by the total length of the base line to get the required area (fig 5.7).

The formula is as follows.

$$\text{Area}(\triangle) = [O_0 + O_1 + O_2 + O_3 + \ldots\ldots O_n] = \frac{L}{n+1}$$

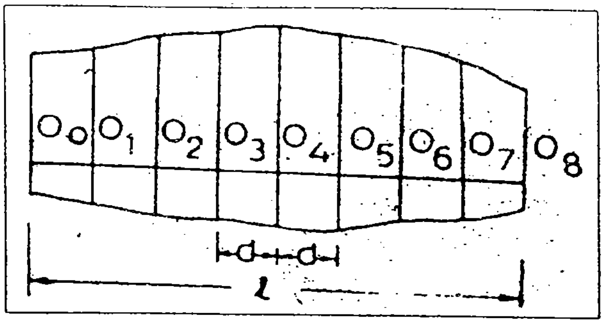
Where O_0, O_1, O_2, ...O_n = the ordinates at each of the points of division

L = total length of the base line

n = the number of equal parts into which the base line is divided.

5.3.3 The Trapezoidal Rule Method:

Fig5.8



This rule is more accurate than mid-ordinate rule and average ordinate rule. The area is divided into a series of trapezoids (fig 5.8).

Trapezoidal Rule: "To the sum of the first and the last ordinates, add twice, the sum of the intermediate ordinates. Multiply the total sum obtained by the common distance between the ordinates. One half of this product is the required area".
The formula is as :

$$\text{Area}(\ ) = \left[\frac{(O_0 + O_n) + 2(O_1 + O_2 + \ldots\ldots\ldots + O_{n-1})}{2}\right] \times \frac{L}{n}$$

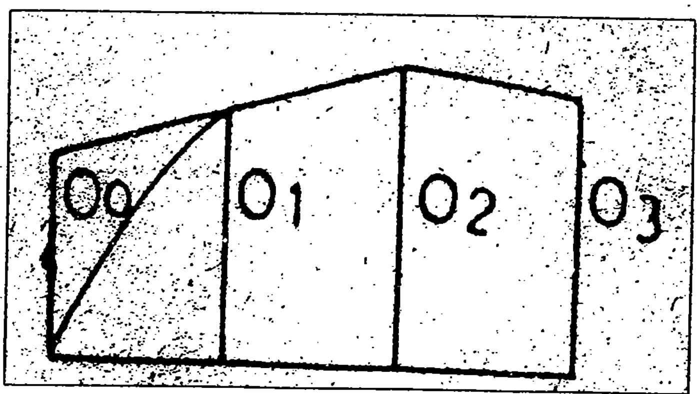
$L/n = d$

$$\text{Area}(\triangle) = (O_0 + O_n) + 2(O_1 + O_2 + O_3 + \ldots\ldots\ O_{n-1}) \times \frac{d}{2}$$

When the base line cuts the boundary at one or both ends of the figure, O_0 or O_n or both are zero. Though, they must not be omitted from the formula.

Derivation of Trapezoidal Rule:

Fig 5.9



The trapezoidal rule assumes that the boundaries between the ends of the ordinates are straight. Therefore the area enclosed between the base line and the irregular boundary is now divided into series of trapezoids (fig 5.9)

Let $O_0, O_1, O_2, O_3 \ldots. O_n$ = the ordinates taken at equal intervals.

d = the common distance between the ordinates.

Area of trapezoids = (half the sum of the two parallel sides) x (the perpendicular distance between two parallel sides)

∴ Area of 1st trapezoid = $\left(\frac{O_0 + O_1}{2}\right) \times d$

Area of 2nd trapezoid = $\left(\frac{O_1 + O_2}{2}\right) \times d$

Area of 3rd trapezoid = $\frac{(O_2 + O_3)}{2} \times d$

Area of 4th trapezoid = $\frac{(O_3 + O_4)}{2} \times d$

and Area of last trapezoid = $\frac{(O_{n-1} + O_n)}{2} \times d$

The sum of all the trapezoidal area is equal to total areas of the figure as.

$$\text{Total Area} = \frac{d\,[O_0 + 2O_1 + 2O_2 + 2O_3 + \dots\dots + 2O_{n-1} + O_n]}{2}$$

$$\text{Total Area} = \frac{d}{2} \dots\dots [(O_0 + O_n) + (O_1 + O_2 + O_3 + O_{n-1})]$$

5.3.4 Simpson's Rule Method:

Statement of Simpson's Rule: " To the sum of the first and last ordinates, add twice the sum of the remaining odd ordinates and four times the sum of remaining all the even ordinates. Multiply the total sum obtained by one third of the common distance between the ordinates, will gives the required area. (fig. 5.7 and 5.8).

The formula is as follows:

$$\text{Total Area} = \frac{d}{3} \dots [(O_0 + O_n) + 2\,\Sigma \text{ odd ordinates} + 4\Sigma \text{ even ordinates}]$$

Where, O_0 and O_n = first and last ordinates

O_1, O_3, O_5, O_7 etc. from end = 2nd, 4th, 6th, 8th, etc. are even ordinates

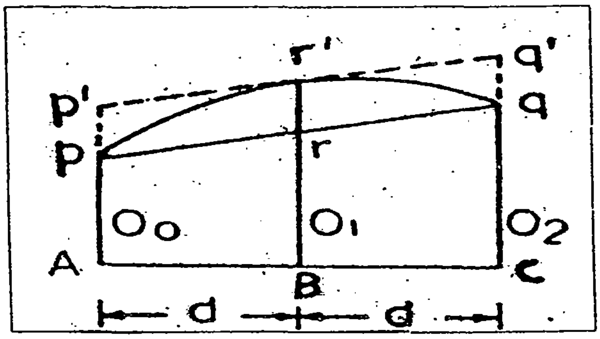
O_2, O_4, O_6, O_8, etc. from the end = 3rd, 5th, 7th, 9th, etc. are odd ordinates.

This method necessitates an even number of divisions of the area. **The total number of ordinates must be odd.** When one or both of the end ordinates are zero, they must not be omitted from the formula.

If there are an odd number of divisions resulting an even number of ordinates, then the area of the last division must be calculated separately and added to the result obtained by applying Simpson's rule to the remaining division.

Derivation of Simpson's Rule:

Fig 5.10



Simpson's rule is also called as the **'Parabolic Rule'**. It assumes that "the boundaries between the ordinates are the arcs of a parabola" (fig 5.10)

From fig. 5.10, Let, AP = O_0, Br¹ = O_1 and cq = O_2 are any three consecutive ordinates with at equal distances 'd' apart.

The required area ($\triangle_1$) = The area, Apr'qC, enclosed between the base line AC, the end ordinates AP & Cq and the parabolic arc pr'q.

Draw p'r'q' through r' parallel to the chord pq.

∴ The area Apr'qC = Area of the trapezoid ApqC + area of the segment pr'qrp.

Now area of the trapezoid ApqC = $\frac{Ap + Cq}{2} \times AC$

$$= \frac{(O_0 + O_2)}{2} \times 2d$$

$$= (O_0 + O_2) \times d$$

Area of the segment pr'qrp = $\frac{2}{3}$ x Area of the enclosing parallelogram p p'q'q

$$= \frac{2}{3}(rr' \times AC)$$

$$rr' = Br' - Br = O_1 - \left(\frac{O_0 + O_2}{2}\right)$$

$$AC = 2d$$

∴ The required area ($\triangle$)

$$= \left[\frac{(O_0 + O_2)}{2} \times 2d\right] + \frac{2}{3}\left[O_1 - \frac{(O_0 + O_2)}{2}\right] \times 2d$$

$$= \frac{d}{3}\left[(3O_0 + 3O_2 + 4\left(\frac{2O_1 - O_0 - O_2}{2}\right)\right]$$

$$= \frac{d}{3}(3O_0 + 3O_2 + 4O_1 - 2O_0 - 2O_2)$$

$$= \frac{d}{3}(O_0 + 4O_1 + O_2)$$

In similar way the area for the next two divisions ($\triangle$)

$$= \frac{d}{3}(O_2 + 4O_3 + O_4) \text{ and so on.}$$

∴ The total area ($\triangle$) = $\frac{d}{3}$ [$O_0 + 4O_1 + 2O_2 + 4O_3 + \ldots\ldots\ldots$

$\ldots\ldots + 2O_{n-2} + 4O_{n-1} + O_n$]

Numerical 1 : The following perpendicular offsets were taken at 20 m intervals from a survey line to an irregular boundary line as :

3.62, 4.47, 6.72, 5.16, 7.49, 8.80, 9.42, 8.32 and 6.33 m.

1 2 3 4 5 6 7 8 9

Calculate the total area in sq. metres enclosed between the survey line, the irregular boundary line and the first and last offset by the application of (i) Simpson's Rule (ii) Trapezoidal Rule, and (iii) Average Ordinate Rule.

Solution :

Let d = the common interval between the offsets

= 20 m

= the required area.

(i) **Calculation of required area by Simpson's Rule :**

$\therefore$ Required area (Δ) $= \frac{20}{3} [\, 3.62 + 4\,(4.47 + 5.16 + 8.80 + 8.32)$

$+ 2\,(6.72 + 7.49 + 9.42) + 6.33\,]$

$= \frac{20}{3} (\, 3.62 + 107.00 + 47.26 + 6.33\,)$

$= \frac{20}{3} (164.21)$

= **1094.73** Sq. metres

(ii) Calculation of required area by Trapezoidal Rule:

$\therefore$ Required area (Δ) $= \frac{20}{2} [\, 3.62 + 2\,(\, 4.47 + 6.72 + 5.16 + 7.49 + 8.80$

$+ 9.42 + 8.32\,) + 6.33]$

$= 10\ (\, 3.62 + 100.76 + 6.33\,)$

$= 10\ (\, 110.71\,)$

= **1107.10** Sq. metres.

(iii) Calculation of required area by the Average Ordinate Rule:

Common interval between the offsets = d = 20 m

Number of intervals = n = 8

Number of perpendicular offsets = n+1 = 8+1 = 9.

Length of the survey line, L = n x d = 8 x 20 = 160 m

$\therefore$ Required area (Δ) = [3.62 + 4.47 + 6.72 + 5.16 + 7.49 + 8.80

$+ 9.42 + 8.32 + 6.33\,] \times \left[\frac{(160)}{(8+1)}\right]$

$= \frac{60.33}{9} \times 160$

= **1072.53** Sq.metres.

***

Lecture 6

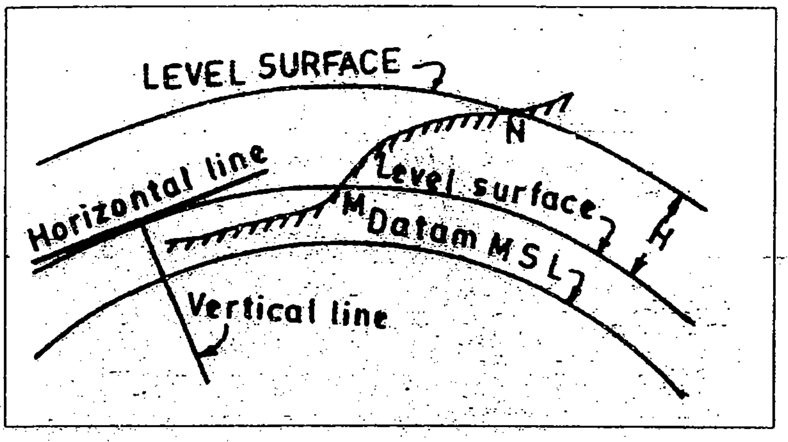
LEVELLING

Levelling : The art determining relative heights or elevations of points or objects on the surface of earth is called levelling. Levelling deals with measurements in a vertical plane.

6.1 Terms used in Levelling :

1) **Level surface** : A level surface is any surface parallel to the mean spheroidal surface of the earth (fig. 6.1), e.g. the surface of a still lake. Every point on this surface is equidistant from the centre of the earth. It is normal to the plumb line at all points.

Fig. 6.1



2) **Level line:** It is a line lying in a level surface. It is also normal to the plumb line at all points.
3) **Horizontal Plane:** A horizontal plane through a point is a plane tangential to the level surface at that point. It is normal (perpendicular) to the plumb line (the direction of gravity) at the tangent point.
4) **Horizontal Line:** It is any line lying in the horizontal plane. It is straight and tangential to a level line.
5) **Vertical Line:** Vertical line at any point is a line normal to the level surface through that point e.g. a plumb line.
6) **Vertical Plane:** It is a plane, which contains the vertical line at a place.

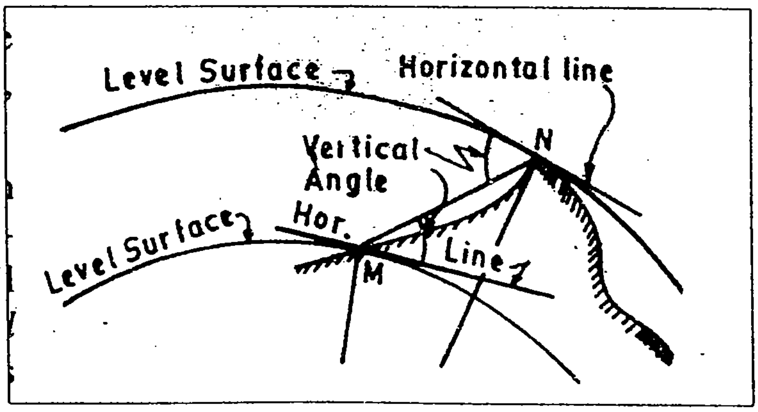


Fig. 6.2

7) **Vertical Angle**: It is an angle between the intersecting lines in a vertical plane. One of the two lines is commonly taken as horizontal in surveying (fig. 6.2)

8) **Datum Surface**: A datum surface or line is any arbitrarily assumed level surface or line from which vertical distances are measured. In India the datum adopted for G.T.S. bench mark is the mean sea level at **Karachi.**

9) **Elevation/Reduced Level (R.L.):** The elevation of a point is its vertical distance above or below the datum. The elevation of a point is plus or minus according as the point is above or below the datum.

10) **The difference in Elevation (H):** The difference in elevation b two points is the vertical distance between the level surfaces passing through points.

11) **Bench Mark (B.M.):** A relatively fixed reference point of known e is called a bench mark. There are four kinds of bench marks as

   (i) G.T.S. (Great Tri-gonometrical Survey) bench mark,
   (ii) Permanent bench mark,
   (iii) Arbitrary bench mark, and
   (iv) Temporary bench mark

   (i) **G.T.S. Bench Mark**: These bench marks are established with very high precision of an interval of about 100 Km all over the country by the survey of India Department. Their positions and elevations above the mean sea level at Karachi (the standard datum) are given in the catalogue published by the survey of India Department. G.T.S. bench marks are also shown on G.T.S. maps.

   (ii) **Permanent Bench Mark**: These are the fixed points of reference.

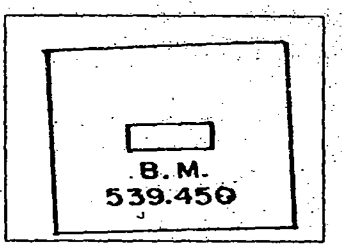


Fig. 6.3

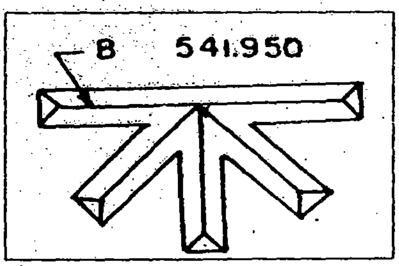


Fig. 6.4

They are established between G.T.S. bench marks by the survey of India or other government agencies such as P.W.D., on clearly defined and permanent points such as the top of a parapet wall of a bridge or culvert, a corner of the plinth of a building, a gate pillar, a kilometre stone, etc. Their positions are marked on a flat surface by a rectangle (Fig 6.3). On a vertical surface such as a wall, they are marked in the form of a broad arrow and a horizontal groove (fig 6.4).

(iii) **Arbitrary Bench Marks**: These are the reference points whose elevations are arbitrarily assumed, used in small levelling operations. The elevations of these bench marks are usually assumed as 100.00m.

(iv) **Temporary Bench Marks**: When there is a break in the work these reference points are established, from where levelling is continued next day in the absence of a permanent bench mark. These bench marks should be carefully established on definite and comparatively permanent objects, such as top of stone, gate post, parapet etc.

12) **Line of Collimation**: It is the line joining the intersection of the cross hair to the optical centre of the object glass and its continuation. It is also called the line of sight.

(13) **Axis of the Telescope**: It is a line joining the optical centre of the object glass to the centre of the eye-piece.

(14) **Axis of the level Tube / Bubble Tube**: It is an imaginary line tangential to the longitudinal curve of the tube at its middle point. It is horizontal when the bubble is at centre.

(15) **Vertical Axis**: It is the centre line of the axis of rotation.

(16) **Station**: It is a point whose elevation is to be determined. It is a point where the staff is held.

(17) **Instrument Station**: The point where instrument is set up for observation.

(18) **Height of Instrument (H.I.)**: It is the elevation (or the R.L.) of the plane of collimation (plane of sight) when the instrument is correctly levelled. it is also called the "height of plane of collimation".

(19) **Plane of collimation/Plane of Sight**: When a level is accurately levelled, the line of collimation will revolve in horizontal plane known as the plane at collimation.

(20) **Back sight (B.S)/Back sight Reading**: It is the first staff reading taken after the level is set up and levelled. It is a staff reading taken on a point of known elevation, such as a bench mark or a change point. It is also called a plus sight.

(21) **Foresight (F.S.) / Foresight Reading**: It is the last staff reading denoting the shifting of the instrument. It is a staff reading on a point whose elevation is to be determined as on a change point. It is also termed as a minus sight.

(22) **An Intermediate Sight (I.S.)**: The reading (s) taken on a levelling staff held at point(s) between two change points, to determine the elevation of the point(s), is known as intermediate sight. All sights taken between the back sight and the foresight are intermediate sights.

(23) **Change Point (C.P.)/ Turning Point (T.P.)**: It is a point denoting the shifting of the level. It is a point on which the foresight and backsight are taken. The change point is always selected on a relatively permanent point such as boundary stone, rail, curb stone, rock etc.

(24) **Focussing**: Setting of the eye-piece and the objective at the proper distance apart for the clear vision of the object sighted is called focussing. The focuss of the objective and that of the eye-piece must coincide with the cross hair of the diaphragm. This can be done by first focussing the eye-piece and then objective. In focussing the eye-piece, hold a sheet of white paper in front of the telescope and then move the eye-piece in and out until the cross-hairs appear clear and distinct. For focussing the objective, direct the telescope to the desired object and rotate the focussing screw until the image of the object appears clear and sharp. When the focussing is correct, there will be no movement of the image with respect to the cross-hair and the object image will appear stationary as the eye is moved up and down.

25) **Parallax:** When the image of the object formed by the objective does not fall in the plane of the diaphragm there is an apparent movement of the image relatively to the cross-hairs. This is due to poor focussing of the objective. The image appears fixed to the cross-hair when the eye is moved up and down, if the focussing is correct. The objective must be moved inwards by the focussing screw, if the image appears to move in the same direction as that of the eye. In this case the image is in front of the diaphragm. When the image appears to move in the direction opposite to that of the eye, the objective must be moved outwards by the focussing screw. In this case the image is beyond the diaphragm towards the eye piece. Parallax is eliminated first by focussing the eye-piece for distinct vision of the cross-hairs and then by focusing the objectives.

6.2 The Level

There are several types of levels as

(i) The Dumpy Level
(ii) The Wye or Y Level
(iii) The Cooke's reversible level
(iv) The Cushing's level

(v) The Tilting level and
(vi) The Automatic Level

The common level used in levelling is the Dumpy level.

6.2.1 **The Dumpy Level**

It consists of (1) The levelling head (2) The tripod (3) The telescope and (iv) The level tube.

(1) **Levelling Head**

The levelling head consists of two parallel plates with three or four screws. The upper plate is called as tribarch and the lower plate as trivet. It has an arrangement by which it can be fixed on the tripod. The levelling head performs the three distinct functions as (a) It supports the telescope (b) It attaches the level to the tripod and (iii) It provides a means for the level.

(2) **The Tripod**

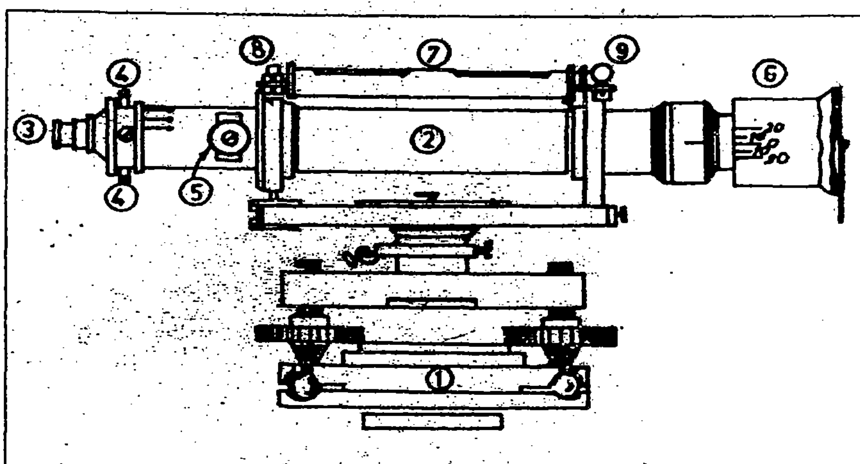
It consists of three solid or framed legs. When in use, the level is supported on a tripod. The legs are provided with pointed iron shoes at the lower and to fix the tripod firmly on to the ground. At the upper surface, the tripod head carries an external screw to which the foot-plate (trivet) can be fixed.

(3) **The Telescope**

It is most important part of the level. It is an optical instrument used for magnifying and viewing the images of distant objects. There are two types of the telescope as (i) External focussing telescope and (ii) Internal focussing telescope.

(4) **The Level Tube**

The level tube consists of a glass tube placed in a brass tube. It is also known as bubble tube. The bubble tube is nearly filled with either ether or alcohol or a mixture of both and it is sealed. The remaining space is occupied by an air bubble. When the Dumpy level is accurately levelled then air bubble is exactly at the centre of the bubble tube.



1. Levelling head
2. Telescope
3. Eye-piece
4. Diaphragm screws
5. Focussing screws
6. Ray-shade
7. Level tube
8. Level tube nuts
9. Cross bubble tube

Fig 6.5

The dumpy level is simple, compact and stable. In Fig 6.5 the various parts of the Dumpy level are shown. The telescope is rigidly fixed to its supports. It has greater stability of adjustments than the Y-level. Levelling head generally consists of two parallel plates with three screws. The lower plate (trivet) is screwed on to the tripod before setting up.

6.3 The Levelling Staff:

Levelling staff is a straight, rectangular wooden or metal rod graduated into metres and further smaller divisions. Zero reading is represented at the bottom of the staff. The reading given by the line of sight on a levelling staff held vertically is the height of the line of collimation above the point on which staff is held. There are various levelling staffs available as

(a) Folding type 4-metre levelling staff
(b) Target staff
(c) Invar precision levelling staff
(d) Sopwith telescopic staff

6.3.1 Folding Type 4-Metre Levelling Staff

The staff is made of well-seasoned timber such as cyprus, deodar, blue pine or metal. I.S. 1779-1961 covers the specifications of 4-metre levelling staff. It consists of two 2 metre wooden (metal) pieces with the joint assembly.

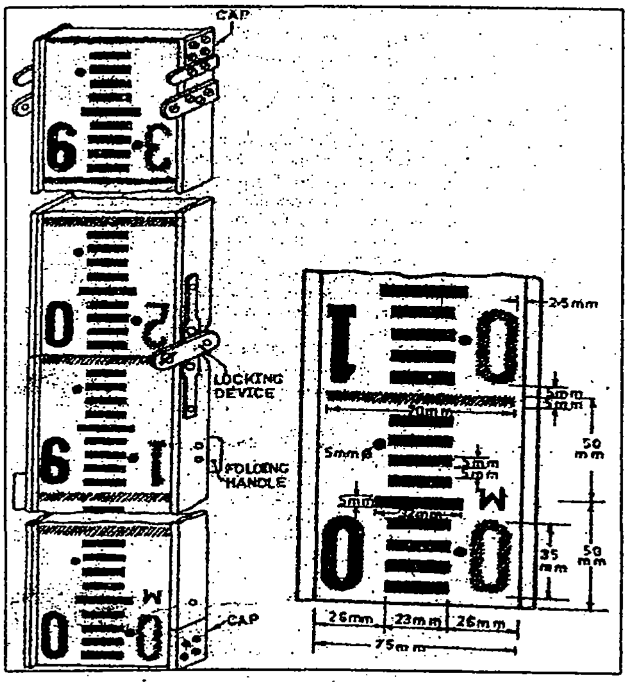


Fig 6.6

The width of the staff is 75 mm and thickness is 18 mm. The folding joint is of the detachable type with a locking device at the back. The staff is jointed together in such a way that (a) the two pieces may be detached from one another when required (b) the staff may be folded to a 2-metre length and (c) when the two pieces are locked together they become rigid and straight. The staff has a brass cap at the bottom. It has two folding devices with spring action locking or any ordinary folding device.

Graduations: In this staff each metre is subdivided into 200 divisions. The thickness of the graduations is 5 mm fig 6.6. Space indicating the decimeter readings are marked in red; all other spaces are marked in black against a white background. Each decimeter length is figured with the corresponding numerals. The metre numeral is in red and marked to the right while the decimetre numeral in black and marked to the left. The decimetre markings are continuous throughout the length of the staff. The graduations are inverted so that they appear to be erect when sighted through the telescope.

6.4 Principles of Levelling

Levelling is classified into two types as

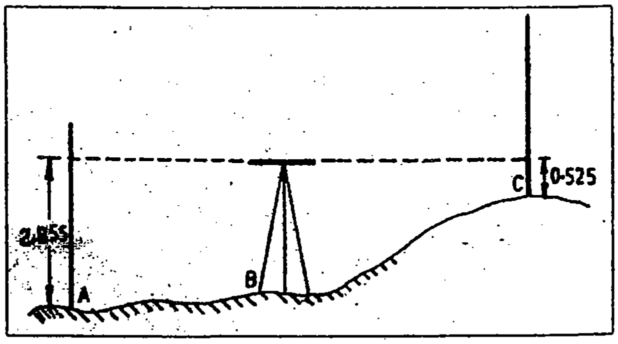
(a) Simple levelling &

(b) Differential levelling

6.4.1 Simple Levelling:

It is required to find the difference in elevation between two points, simple levelling method is used. It is the simplest operation in levelling. In this method both the stations are visible from the instrument station (fig 6.7). From figure, suppose A and C are two points whose difference in elevation is required with a level set at instrument station B. The instrument station B is approximately midway between station A and C to eliminate the effect of the curvature of earth and instrument error.

Fig 6.7



Procedure :

(i) First level the instrument correctly, approximately at midway between stations.
(ii) Turn the telescope towards the staff held vertically on station A.
(iii) Focuss the telescope carefully to obtain clear graduations.
(iv) Note down the reading of the central horizontal hair of the diaphragms where it appears to cut the staff.
(v) While taking the reading ensure that the bubble is at centre.
(vi) Shift the staff to the other station point C.
(vii) Turn the telescope towards the staff held vertically on station C.
(viii) Focuss the telescope carefully to obtain clear graduations and note down the reading, ensuring the bubble is at centre.

Let the respective readings on staff A and staff C be 2.855 m and 0.525 m respectively. The difference in elevation of point A and C = 2.855 - 0.525 = 2.330m.

If R.L. of the point A = 100.00m

then R.L. of the line of sight = 100 + 2.855 = 102.855m.

Then R.L. of the point C = 102.855 - 0.525 = 102.330 m.

6.4.2 **Differential Levelling:**

This method is used in order to find the difference in elevation between two points

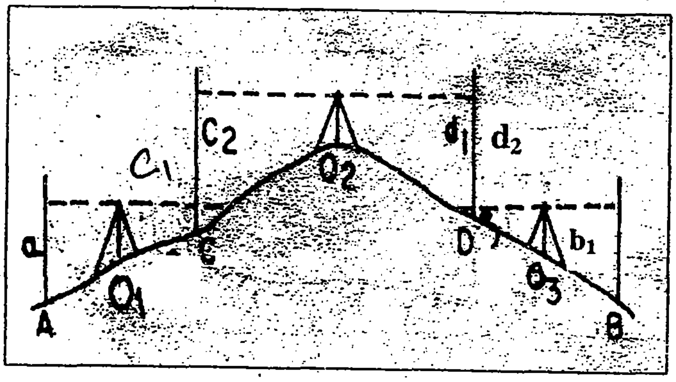
(a) If the difference in elevation between them is too great.

(b) If there are obstacles intervening and

(c) If they are too for apart

In such a case, it is necessary to set the instrument at several positions and to work in a series of stages. Simple levelling method is employed in each of the successive stages. (fig 6.8). This method of levelling is also known as compound or continuous levelling.

Fig 6.8



Procedure

(i) Set the level at instrument station O_1 and correctly level it.

(ii) Note down the reading on the staff held vertically at A, ensuring that the bubble is at centre. This reading is called as backsight reading.

(iii) Select a point C and take the foresight reading on the staff held vertically at "C" with same set up.

(iv) Shift the instrument to O_2 and set and level it correctly from this position both the points C and next point D are visible.

(v) Note down the on the staff held vertically at "C" ensuring that the bubble in the centre of its run. This reading is called as back sight-reading of C.

(vi) Select a point "D" and take the foresight reading of D on the staff held vertically at D with same setup.

(vii) Repeat the process until the point B is reached.

The following points may be noted during differential levelling as

(a) Each of the successive points C, D etc. is called as change point (C.P.) or Turning point (T.P.) and is read twice as foresight and back sight reading from two different successive instrument stations.

(b) Setting of the level should not be disturbed while the staff is being carried forward.

(c) The staff at the turning point must not be moved, but kept on the same spot white the level is carried forward. It should be turned round to face the telescope when a second reading is to be taken.

(d) A turning point or change point must be taken on stable and definite object. The distance of the change point from the instrument should not exceed 100m.

(e) The bubble must be brought to the centre of its run each time a staff reading is taken.

(f) The instrument must be set up on firm ground. The staff reading (a) taken at station A from the instrument station O_1 is the back sight and the staff reading (c_1) at C the foresight. The staff reading (c_2) taken at C from the instrument station O_2 is the back sight and the staff reading (d_1) at D the foresight and so on.

Therefore, the difference of level between station A and station C = a- c_1 and the difference of level between C and D= c_2- d_1 so on.

The difference of level between station A and Station B is equal to the algebraic sum of these differences or equal to the difference between the sum of the back sights and the sum of the foresights (∑B.S.-∑F.S.). If the difference is positive, it indicates that the point B is higher in elevation than the point A. If the difference is negative the point B is lower than the point A.

If the R.L. of point A is known then R.L. of point B = R.L. of point A + (∑B.S.-∑F.S.)

The R.L. of the intermediate points, if required may be found as

R.L. of a point = R.L. of Bench Mark + Back sight - I.S.

6.5 Reduction of the Levels

There are two methods for working out the reduced levels of points as

(A) Height of instrument method or collimation method.

(B) Rise and fall method.

6.5.1 Height of Instrument Method/Collimation Method

In this method, height of the instrument (H.I.) is calculated for each setting of the instrument by adding the back sight reading (B.S.) to the elevation of the bench mark (B.M.). The reduced level (R.L.) of the first station is obtained by subtracting its foresight (F.S) from the height of instrument for that particular setting and so on. For the second setting of the instrument, the height of instrument is calculated by adding the back sight taken on last point of the previous setting to its reduced level. The reduced level of the last point is obtained by subtracting the foresight (F.S.) of the last point from the height of instrument at the last setting. If an intermediate sight (I.S.) is observed to an intermediate station, its reduced level (R.L.) is obtained by subtracting its intermediate sight (I.S.) from the height of the instrument for its setting.

Arithmetic Check: We can apply the arithmetic check for collimation method. The difference between the sum of the back sights and the sum of the foresights should be equal to the difference between the Reduced level of the last station and the reduced level of the first station.

Therefore, ∑B.S.-∑F.S. = Last R.L. - First R.L.

6.5.2 Rise and fall Method

This method consists of determining the difference of level between two consecutive points. The staff readings of two consecutive points is calculated.

The difference between their staff readings indicate a rise if the back staff reading is more than the fore staff reading (i.e. the difference is positive). It is a fall, if the back staff reading is less than the fore staff reading (i.e. the difference is negative). The rise and fall worked out for all the points give the vertical distance of each point relative to the preceding one. If the reduced level of the back staff point is known, then reduced level of the following point may be obtained by adding its rise or subtracting its fall from the R.L. of preceding point.

Arithmetic check: We can apply two way arithmetic check in this method. The difference between the sum of the backsights and the sum of the foresights should be equal to the difference between the sum of rises and the sum of falls and should also be equal to the difference between the reduced level of the last point and the reduced level of first point, therefore,

∑B.S.-∑F.S.=∑Rise-∑ Fall = Last R.L. - First R.L.

Example 6.1: following readings were taken with an levelling instrument in levelling work as 0.32, 0.53, 0.62, 1.78, 1.91, 2.35, 1.75, 0.35, 0.69, 1.24 and 0.98 m. The position of the instrument was changed after 3rd, 7th and 9th readings. Draw out the Page of field book for level and enter the above readings properly. Assume R.L. of the first point as 81.93 m. Calculate R.L. of all points by (a) collimation method and (b) Rise and fall method, and apply usual checks.

Solution : (a) Collimation method / H.I. method:

Station	B.S.	I.S.	F.S.	H.I.	R.L.	Remark
1	0.32			81.85	81.53	
2		0.53			81.32	
3	1.78		0.62	83.01	81.23	C.P.1
4		1.91			81.10	
5		2.35			80.66	
6	0.35		1.75	81.61	81.26	C.P.2
7	1.24		0.69	82.16	80.92	C.P.3
8			0.98		81.18	

Arithmetic check :

∑ B.S. - ∑ F.S. = Last R.L. - First R.L.
3.69 - 4.04 = 81.18 - 81.53
- 0.35 = -0.35 (O.K.)

(b) Rise and Fall Method :

Station	B.S.	I.S.	F.S.	Rise	Fall	R.L.	Remark
1	0.32			-	-	81.53	
2		0.53			0.21	81.32	
3	1.78		0.62		0.09	81.23	CP1
4		1.91			0.13	81.10	
5		2.35			0.44	80.66	
6	0.35		1.75	0.60		81.26	CP2
7	1.24		0.69		0.34	80.92	CP3
8			0.98	0.26		81.18	

Arithmetic check:

∑ B.S. - ∑ F.S. = ∑ Rise - ∑ Fall = Last R.L. - First R.L.
3.69 - 4.04 = 0.86 - 1.21 = 81.18 - 81.53
- 0.35 = - 0.35 = -0.35 (O.K.)

Example 6.2. The following consecutive readings were taken with a level and 4 m staff on a continuously slopping ground at a common interval of 20 metres. 0.755 (Q), 1.655, 2.465, 3.125, 3.835, 0.565, 1.475, 2.165, 2.865, 3.545, 0.475,1.160, 1.755, 1.870, 2.855 and 3.865 (R). The level was shifted after 5th and 10th readings. Enter, the readings as on a field book page. Assume R.L. of the first point as 200 .00 m. Calculate R.L. of all points by (a) Collimation method and (b) Rise and fall method, and apply usual checks.

Solution : **(a) Collimation / H.I. Method :**

Change (m)	B.S.	I.S.	F.S.	H.I.	R.L.	Remark
0	0.755			2.00.755	200.00	B.M. (Q)
20		1.655			1.99.100	
40		2.465			198.290	
60		3.125			197.630	
80	0.565		3.835	197.485	196.920	CP1
100		1.475			196.010	
120		2.165			195.320	
140		2.865			194.620	
160	0.475		3.545	194.415	193.940	CP2
180		1.160			193.255	
200		1.755			192.660	
220		1.870			192.545	
240		2.855			191.560	
260			3.865		190.550	(R)

Arithmetic Check:

∑ B.S. - ∑ F.S. = Last R.L. - First R.L.
1.795 - 11.245 = 190.550 - 200.000
-9.45 = -9.45

(b) **Rise and Fall Method:**

Chainage (m)	B.S.	I.S.	F.S.	Rise	Fall	R. L.	Remark
0	0.755			-	-	200.00	B.M.(Q)
20		1.655			0.900	199.100	
40		2.465			0.810	198.290	
60		3.125			0.660	197.630	
80	0.565		3.835		0.710	196.920	CP1
100		1.475			0.910	196.010	
120		2.165			0.690	195.320	
140		2.865			0.700	194.620	
160	0.475		3.545		0.680	193.940	CP2
180		1.160			0.685	193.255	
200		1.755			0.595	192.660	
220		1.870			0.115	192.545	
240		2.855			0.985	191.560	
260			3.865		1.01	190.550	(R)

Arithmetic Check:

∑ B.S. - ∑ F.S. = ∑ Rise - ∑ Fall = Last R.L. - First R.L.
1.795 - 11.245 = 00.00 - 9.45 = 190.550 - 200.000
-9.45 = -9.45 = -9.45

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Lecture 7

CONTOURING

Introduction

A contour may be defined as the line of intersection of a level surface with the surface of the ground. The elevation and depressions of the surface of the ground are shown on map by mean of contour lines. For example suppose there is a pond which is partly filled with water and the elevation of water surface is 100 m. The shoreline of the pond will be then represent by the 100 m contour. If the level of the water raised by 1 m, 2m, 3m the successive shore lines will represent 101, 102, 103 m contours and so on as show in fig 7.1 It shows that all the points on single contour have the same elevation above the datum surface.

Definitions

(1) **Contour line:** The line joining the points on the contour map is called contour line or a contour.

(2) **Contour Interval:** The vertical distance between any two consecutive contoured is called contour interval.

(3) **Horizontal equivalent:** The least horizontal distance between two consecutive contoured is called horizontal equivalent.

7.1 Uses of Contour map :

(1) By inspection of a contour map the character of a tract of the country is obtained whether it is undulating or mountainous or flat etc.

(2) In agricultural work contour map are useful as guidelines in planning of land improvement projects.

(3) The most economical site the construction work such as reservoir, canal, road, sewage line, drainage lines or railway may be approximately selected.

(4) Quantities of road, canals, reservoir, and earthwork may be computed from the contour map.

(5) Contours are used to determine the capacity of reservoirs and area of the drainage basin.

(6) Contour maps are used for watershed planning.

(7) Contour maps are used for irrigation planning and design the irrigation system.

7.2 Characteristics of contour lines

The following characteristics of contours are observed while preparing an reading a contour map.

(1) All points on a contour have the same elevation

(2) Contour lines close to each other represent very steep ground.

(3) Contour lines are widely separated represent flat ground.

(4) A uniform slope is indicated when the contour lines are uniformly spaced and a plane surface when they are straight, parallel and equally spaced.

(5) A series of closed contour lines on the map represent a hill it the higher values are inside (fig.7.1)

(6) A series of closed contours on the map indicate depression if the higher values are outside. (fig 7.2)

(7) Contour lines cross ridge or valley lines at right angles. If the higher values are outside the bend, it represent valley (fig 7.3) and if the higher values are inside the bend or loop in the contour represent ridge (fig 7.4)

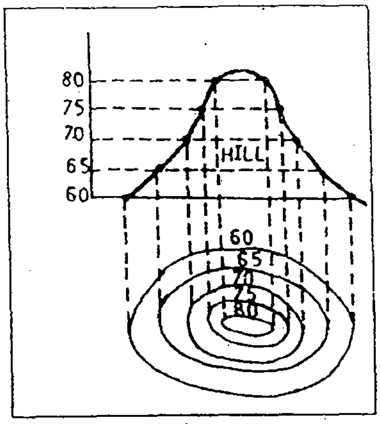

Fig 7.1

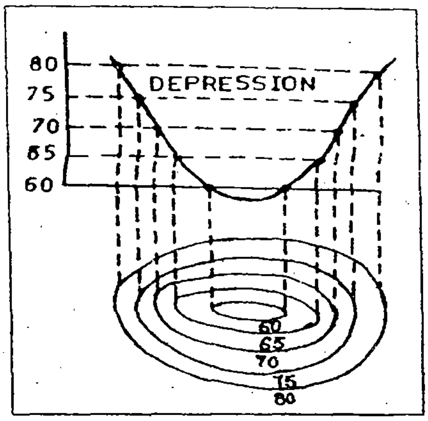

Fig 7.2

(8) Contour lines cannot end any where but close in themselves either within or outside the limits of the map.(fig 7.1, 7.2, 7.3, 7.4).

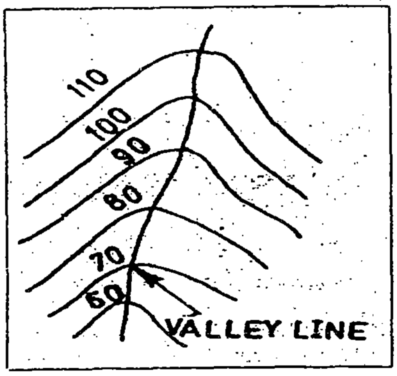

Fig 7.3

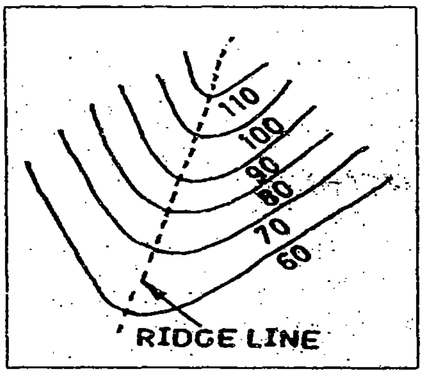

Fig 7.4

(9) Contour lines cannot merge or cross one another on map except in the case of an over hanging cliff. (fig. 7.5).

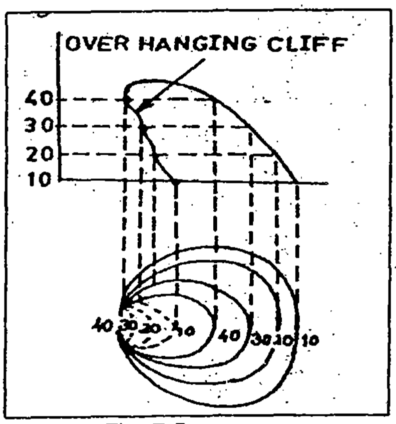

Fig. 7.5

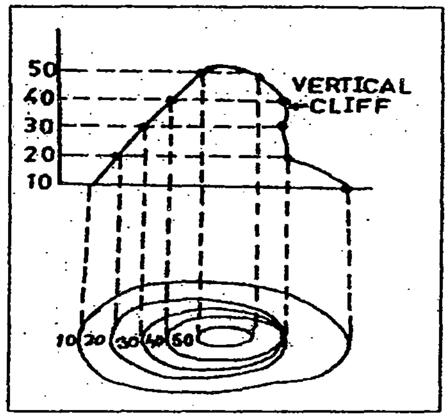

Fig 7.6

(10) As contour lines represent level lines they are perpendicular to the lines of the steepest slope.

(11) Contours never run into one another except in the case of vertical cliff (fig 7.6). In this case several contours coincide and the horizontal becomes zero.

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Lecture 8

PRINCIPLES OF SOIL AND WATER CONSERVATION

In general, depth of soil various from place to place to great extent. But the top 30 cm soil depth is very useful for both human being and wild life. This layer is continuously exposed to the action of atmospheric activities. Two main active forces, water and wind always tend to detach the top soil layer and to transport them from one place to another.

8.0 Soil Erosion :

It is three phase phenomenon consisting the detachment of individual soil particles for the soul mass and their transport by erosive agents such as running water and wind when energy to transport the particles is not avilable then third phase called "deposition" take place.

Difinition :

"It is defined as detachment, transportation and deposition soil particles from one place to another place under influence of wind, water or gravity forces."

Important Points

1. When eroding agents have sufficient capacity to transport more quantity of materials than the materials supplied through detachment then erosions is termed as "Detachment limited".
2. When materials supplied are greater than materials transported then erosion is termed as transport limited.

Two energy forms are involved in erosion process:

1. Potential
2. Kinetic

1] PE = m. g. h.

PE = Potential energy in joules

m = Mass of body in kg.

g. = Acceleration due to gravity

h. = Elevation difference.

1] $KE = \frac{Mv^2}{2}$

KE = Kinetic energy in Joutes

m = Mass of body in kg.

v = Velocity of running water or falling rain drops.

3. A large amount of energy is lost against frictional resistance of soil surface.
4. Only 3 to 4% energy is remained with running water to detach soil particles.
5. Critical water velocity responsible for soil erosion is a function of particle size.
6. Critical velocity value increases with increase in grain diameter [greater than 0.5 mm]
7. Fine particles are harder to get erode by water flow due to cohesiveness of clay minerals,
8. A soil particles of 0.01 mm in diameter requires a flow velocity of 60m/s and to detach the soil particles but not deposited until the flow velocity reduces below 0.1 m/s.

TYPES OF EROSION
It broadly classified into two :
A) Geologic Erosion
B) Accelerated Erosion
   i) Wind erosion
   ii) Water erosion
a) Raindrop/splash erosion
b) Sheeet erosion.
c) Rill erosion.
d) Gully erosion.
e) Stream bank erosion.
C) Other Types of Soil Erosion
a) Glacial erosion. [Due to mass of ice moving very slowly]
b) Snow erosion. [due to slow and creeping movement of snow towards slope]
c) Organic erosion. [caused by living organism]
d) Anthropogenic erosion. [due to activities of human being]

8.1.1
A) Geologic Erosion :

It refers to the formation and loss of soil simultaneously which maintain the balance between formation and various losses.

It is normal process which represents the erosion of soil in its normal condition without the influence of human being. It is also known as natural or normal erosion. The various topographical features such as existing of stream channels, valleys etc., are the results of geologic erosion.

B) Acclerated Erosion :

It is in excess of geologic erosion. It is activated by natural and man's activities due to changes in natural cover and soil conditions.

Accelerated erosion takes place by the action of water, wind, gravity and glaciers. Various forces involved m this are :

1) Attracking force of water or wind which remove and transport the soil particle from one place to another.
2) Retarding force which resists the erosion. In general accelerated erosion known as soil erosion or erosion.

It is sub classified as :
i) Water Erosion :
   Rain drop erosion
   Sheet erosion
   Rill erosion
   Gully erosion
   Stream bank erosion
ii) Wind Erosion :
Water Erosion :

It is defined as the movement of soil by rain water running rapidly over exposed land-surface. It is affected by land slope, soil types, density of vegetative cover, amount and intensity of rainfall..

Wind Erosion :

It is the process of detachment transportation and deposition of soil particles by the action of wind. Basic causes of wind erosion are :

1. Soil is loose, finely divided and dry
2. Soil surface is smooth and bare
3. Wind is strong to detach the soil particles from soil surface.

Raindrop Erosion (Splash Erosion) :

It is also known as splash erosion. It results from soil splash caused by the impact of falling raindrops. Factor influencing the rate of raindrop erosion are :

1] Climate, rainfall, temperature

2] Soil, its resistance to dispersion and its infiltration rate.

3] Topography - steepness and length of slope

4] Plant cover - living or dead vegetation

Falling raindrops breaks soil aggregate and detach soil particles from soil mass. Fine soil particles are taken into suspension and the splash thus become muddy. The major effect of surface flow of water is to cany off the soil loosened by splash erosion.

8.2.1 Sheet Erosion :

Sheet erosion may be defined as :

1. Removal of a fairly uniform layer of soil from the land surface by the action of rainfall and runoff .
2. More or less uniform removal of soil in the form of thin layer or in "sheet" form by flowing water from a given width of sloping land.

In sheet erosion, two basic erosion processes are involved :

a] Soil particles are detached from the soil surface by falling rain drop.

b] The detached soil particles are transported away by runoff from their original place.

The eroding and transporting power of sheet flow are dependent upon the depth and velocity of sheet flow for a, given size, shape and density of soil particle.

8.2.2 Rill Erosion :

Ii is sometimes known as micro channel erosion.

It is the removal of soil by running water with the formation of a series of small -branching channels. There is no sharp time of demarcation where sheet erosion ends and more readily visible than sheet erosion.. It is regarded as a transition stage between sheet erosion and - gully. Rill of small depth can be smoothed by ordinary form tillage.

8.2.3 Gully Erosion :

It is removal of soil by excessive concentration of running water, resulting in the formation of channels ranging in size from 30 cm to 10m or more. It is the advance stage of rill erosion and last stage of water erosion. A galley is to a large to be filled by normal tillage practice.

8.2.4 Stream Bank Erosion :

Stream channel [bank] erosion is the scouring of material from the side and bottom of a stream or water channel and the cutting of bank by running water. It is mainly due to removal of vegetation, over grazing or cultivation on the area near to the stream banks.

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Lecture: 9

RUNOFF, TYPES AND FACTORS AFFECTING RUNOFF

Rainfall is the primary source of water for runoff generation over the land surface. In common course of rainfall occurence over the land surface, a part it is intercepted by the vegetations, buildings and other objects, lying over the surface and prevent, to reach them on ground surface, called as interception. Some parts of rainfall are also stored in the surface depressions, referred as depression storage, which in due course of time gets infiltrated or evaporated. When all these losses are satisfied, then excess rainfall moves over the land surface and reaches to the smaller rills, known as overland flow. It again involves building of greater storage over the land surface and draining the same into channels / streams is termed as runoff.

Thus, runoff may be defined as that portion of rainfall as well as any other flow, which makes its way towards the river, stream or oceans etc.

9.1 RUNOFF CYCLE :

It is a descriptive term, used to denote that part of the hydrologic cycle, which falls between the phase of precipitation and its subsequent discharge in the stream channels or direct return to the atmosphere through evaporation and evapotranspiration. There are following four critical conditions, which are associated with the runoff cycle :

1. This refers to the end of dry period and beginning of the intense and isolated storm. At this stage, what happens, all surface and channel storages gel depleted, except in reservoirs, lakes and ponds, from the previous storms. Under this condition, the source of stream flow, is only the ground water flow. The flow decreases with time (fig.9.1)
2. It is the stage after beginning of rainfall and before saturation of interception and depression storage. In this condition, whatever precipitation takes place, falls directly on the land surface or on stream surface, known as channel precipitation; this provides an immediate increment of stream flow. Most of the rain water, reaching the ground are either retained on the surface or passed into the soil by infiltration. Once it is infiltrated into the soil, it starts to replenish the soil moisture deficiency, without contributing to the ground water. At this stage, overland flow takes place, only from those portions of watershed which are in impervious nature such as roads etc., while over the soil surface it does not occur, as rain water is consumed by several losses such as depression storage and infiltration loss. The evaporation and evapotranspiration in this stage, are negligible or very less compared to those at fair weather conditions, which is because of high atmospheric humidity.
3. This stage refers to the condition, approaching the end of an isolated intense storm. After a long period of continuous intense storm, all losses such as interception by vegetative foliage and depression storages on land surface are satisfied; and infiltration rate is reduced to the minimum, causing the overland flow to reach at maximum and it becomes as one of the major source of surface flow from entire drainage basin. In addition, sub-surface flow is also started and meets to the stream flow.
4. This is the stage indicating after end of the rainfall. In this stage rainfall causes the overland flow, base flow and development of channel storage. A Large amount of water is lost from soil moisture, interception and depression storage due to evaporation. In addition, stored water in surface depressions also starts to percolate down and meets to the water- table.

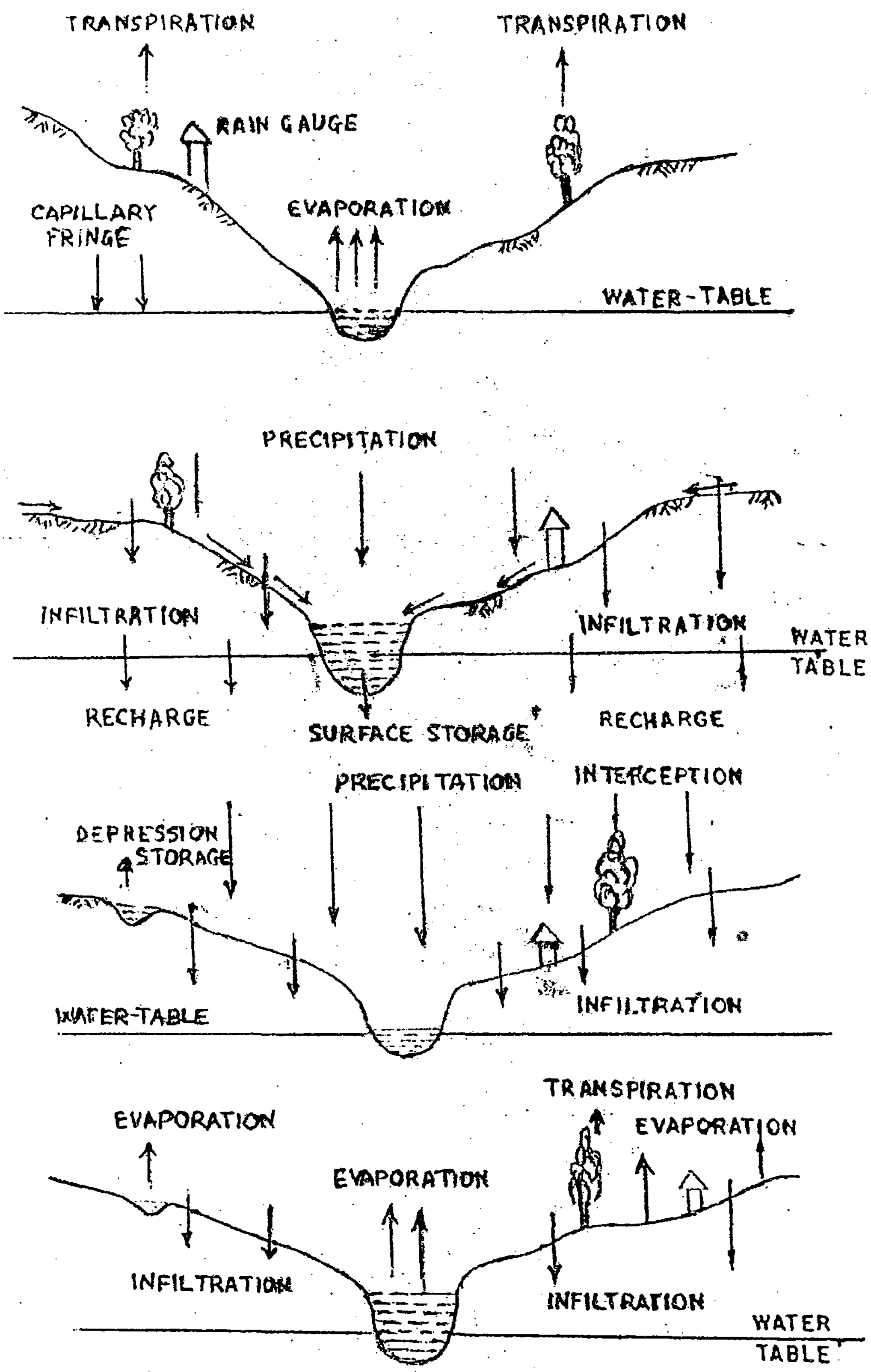

Fig 9.1 Stages of run - off Cycle

9.2 TYPES OF RUNOFF

Based on the time delay between rainfall and runoff, it may be classified into following three types:

1. Surface runoff,
2. Sub-surface runoff, and
3. Base flow.

1. Surface Runoff : It is that portion of rainfall, which enters the stream immediately after the rainfall. It occurs, when all losses are satisfied and if rain is still continued, with the rate greater than infiltration rate; at this stage the excess water makes a head over the ground surface (surface detention), Which lends to move from one place to another, known as overland flow. As soon as the overland flow joins to the streams, channels or oceans, terms as surface runoff.

2. Sub-surface Runoff : That part of rainfall, which first leaches into the soil and moves laterally without joining the water-table, to the streams, rivers or oceans, is known as sub-surface runoff. Sometimes sub-surface runoff is also treated under surface runoff due to reason, that it takes very little time to reach the river or channel in comparison to ground water. The sub-surface runoff is usually referred as interflow..

3. Base flow: It is delayed flow, defined as that part of rainfall, which after failing on the ground surface, infiltrated into the soil and meets to the Water – table and flow to the streams, oceans etc. The movement of water in this type of runoff, is very slow, that is why it is also referred as delayed runoff. It takes a long time to join the rivers or oceans. Some times base flow is also known as ground water flow.

Thus,

Total Runoff = Surface runoff + Base flow
(including sub-surface runoff)

FACTORS AFFECTING RUNOFF :

The runoff rate and its volume from an area, mainly influenced by following two factors :

(a) Climatic factors, and
(b) Physiographic factors.

(A) Climatic factors

The climatic factors of the watershed affecting the runoff, are mainly associated with the characteristics of precipitation, which include:

1. Type of precipitation
2. Rainfall intensity
3. Forms of precipitation
4. Duration of rainfall
5. Rainfall distribution
6. Direction of prevailing wind, and
7. Other climatic factors.

1. **Types of precipatation.** Types of precipitation have a great effect on the runoff. For example, a precipotation which occurs in form of rainfall, starts immediately in form of surface flow over the land surface, depending upon its intensity as well as magnitude, while a precipitation which takes place in form of snow or hails, the flow of water on ground surface will not take place immediately, but after melting of the same. During the time interval of their melting, the melted water infilterates into the soil and results a very little surface runoff generation.
2. **Rainfall intensity :** The intensity of rainfall has a dominating effect on runoff yield. If rainfall intensity is greater than infilteration rate of soil, the surface runoff takes place very shortly, while in case of low intensity rainfall therer is found a reverse trend of the same. Thus high intensities rainfall yield higher runoff and vice-versa.

3. **Duration of rainfall :** Rainfall duration is directly related to the volume of runoff, due to the fact, that infilteration rate of the soil goes on decreasing with the duration of rainfall, till it attains a constant rate. As a result of this, even a mild intensity rainfall lasting for longer duration may yield a considerable amount runoff.
4. **Rainfall distribution :** Runoff from a watershed depends very much on distribution of rainfall. The rainfall distribution for this purpose can be expressed by a term distribution coefficient, which may be defined as the ratio of maximum rainfall at a point to the mean rainfall of the watershed. For a given total rainfall, if all other conditions are the same, the greater the value of distribution coefficient, greater will be the peak runoff and vice-versa. However for the same distribution coefficient, the peak runoff would be resulted from the storm, falling on the lower part of the basin i.e. near the outlet.
5. **Direction of prevailing:** The direction prevailing wind, affects greatly the runoff flow. If the direction of prevailing wind is same, as the drainage system then, it has a great influence on the duration of surface flow, to reach at the outlet. A storm moving in the direction of stream slope, produces a higher peak in shorter period of time than a storm moving in opposite direction.
6. **Other Climatic factors:** The other climatic factors, such as temperature, wind, velocity, relative humidity annual rainfall etc. affect the water losses from the watershed area to a great extent and thus the runoff is also affected accordingly. If the losses are more, the runoff will be less and vice-versa.

B) Physiographic Factors :

Physiographic factors of watershed consist of, both, the watershed as well as channel characteristics. The different characteristics of watershed and channel which affect the runoff, are listed below :

1. Size of watershed
2. Shape of watershed
3. Slope of watershed
4. Orientation of watershed
5. Land use
6. Soil moisture
7. Soil type
3. Topographic characteristics, and
9. Drainage Density.

1. Size of waterhsed : Regarding the size of watershed, if all other factors including depth and intensity of rainfall are being same, then two watersheds irrespective of their size, will produce about the same amount of runoff . However, a large watershed takes longer time for draining the runoff to the outlet, as a result the peak flow expressed as depth, is being smaller and vice-versa.

2.1 Shape of watershed: The shape of watershed has a great effect on runoff. The watershed shape is generally expressed by the terms "form factor" and "compactness coefficient"

The form factor may be defined as the ratio of average width to the axial Length of the watershed, expressed as:

$$\text{Form Factor : } \frac{\text{Average width of the watershed}}{\text{Axial length of the watershed}} = \frac{B}{l}$$

Regarding, axial length (l) of the watershed, it is the distance between outlet and remotest point of the area, whereas the average width (B) is concerned, It is obtained by dividing the area (A) to the axial length (l) of the watershed.

Thus, Form factor

Thus, Form Factor

$$\frac{B}{l} = \frac{A/l}{l}$$

$$or = \frac{A}{l^2}$$

The compactness coefficient of watershed is the ratio of perimeter of watershed circumference of a circle, whose area of the watershed is expressed as

$$\frac{\text{Perimeter of the watershed}}{\text{Circumference of a circle, whose area is equal the watershed}}$$

Where

$$\frac{P}{2\sqrt{\pi A}}$$

P = perimeter of the watershed
A = area of the watershed
π = 3.14

Regarding the watershed's shape, there are two types of watershed's shape are commonly assumed, in which one is fan shape and other is ferm shape. The fan shape watershed, tends to produce higher peak rate of runoff very early, than the fern shape, due to the fact that in former one, all parts of the watershed contribute the runoff to the outlet, simultaneously, comparatively in little period of time, than the fern shaped watershed.

3. **Slope of watershed :** The slope of the watershed has an important role over runoff, but its effect is complex. It controls the time of overland flow and time of concentration of rainfall in the drainage channel, which provide, a cumulative effect on resulting peak runoff, for example, in case of a slopy watershed, the time to reach the flow at outlet is less, because of greater runoff velocity, which results into formation of peak runoff very soon and vice-versa.
4. **Orientation of watershed:** This factor affects the evaporation and transpiration losses from the area by making influence on the amount of heat to be received from the sun. The north or south orientation of watershed, affects the time of melting of collected snow. In a mountaineous watershed, the part located on the wind ward side of the mountain, receives high intensity of rainfall resulting into more runoff yield, while the part of watershed lying towards, leeward side has a reverse trend of the same.
5. **Land use:** The land use pattern and land management practices, used have great effect on the runoff yield. For example, an area which is under forest cover, where a thick layer of mulch of leaves and gasses etc. has been accumulated, there formed a little surface a little surface runoff, due to the fact that more rain, water is absorbed by the soil. While in a barren field, where not any type of is available, a reverse trend is obtained.
6. **Soil moisture:** The magnitude of runoff yield, depends upon the amount moisture present in the soil at the time of rainfall. If rain occurs over the soil which has more moisture, the infiltration rate becomes very less, which results in more runoff yield. Similarly, if the rain occurs after a long dry spell of time, when the soil is dry, causing to absorb huge amount of rain water. In this condition even intense rain, may fail to produce appreciable runoff. But on she other hand, if the rain occurs in a close succession, as in the rainy season, runoff yield has reverse effect.

7. **Soil type. :** In the watershed, surface runoff is greatly influenced by the soil type, as loss of water from the soil, is very much dependent on infiltration rate, which varies with the types of soil.
8. **Typographic Characteristics :** Topographic characteristics include those topographical features of watershed, which create their effect on runoff; it is mainly undulating nature of the watershed. Undulate land has greater runoff than the flat land, because of the reason that runoff water gets additional power to flow due to slope of the surface and litlie time to infiltrate the water into soil.

   Regarding channel characteristics, to describe their effect on runoff, the ratio channel cross-section, roughness, storage and channel density are, mainly considered. These also have significant effect on runoff..
9. **Drainage Density. :** The drainage density is defined as the ratio of the total channel length in the watershed to the total watershed area. It is expressed as:

$$\text{Drainage density} = \frac{\text{Channel length (Total)}}{\text{Watershed area}}$$

$$\text{D.D.} = \frac{L}{A}$$

- A watershed having greater D.D., includes formation of peak runoff, very shortly to that of lesser D.D. watershed.

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Lecture : 10

MEASURES FOR SOIL AND WATER CONSERVATION

It is technique in which deterioration of soil and its loses are conserved by using within its capabilities and applying conservation techniques for production as well as improvement of soil.

Soil and water conservation measures.

A) Agronomical measure (Biological)	B] Engineer practices
1] Contour cultivation	**1] Terracing**
	a] Diversion terrace
2] Strip Cropping	i] Magnum type
a] Contour strip cropping	ii] Nichols type
bl Field strip cropping	iii] Broad based .type
c] Buffer strip cropping	iv]. Narrow based type
d] Wind strip cropping	
3] Tillage practices	b] Retention terrace
a] Mulch tillage	c] Bench terrace
b] Vertical mulching	**2] Bunding :**
c] Minimum tillage	a] Contour bunding
d] Conventional tillage	i) Narrow based
e] Listing	ii) Broad based
	b) Graded Bunding
	i) Narrow based
	ii) Broad based
4] Soil management practices	c] Side bunds
	d] Lateral bunds
	e] Supplemental bunds
5] Supporting practices	f] Marginal bunds
[interplanting, fertilizer application]	g] Shoulder bunds
6] Vetiver grass planting	

10.1 Agronomical Measures :

Agronomical measures or practices if growing vegetation on mild sloppy land to cover them and to control the erosion from there. Agronomical measures include contouring, strip cropping and tillage practices to control the soil erosion. The use of these measures is entirely dependent upon the soil types, land slope and rainfall characteristics. It plays second line at defense alter mechanical or engineering measures. It is more economical, long lasting and effective.

10.1.1 Contour Cultivation:

It refers to all the tillage practices, mechanical treatments like planting; tillage and interculture, performed nearly on the contour of the area applied across the land slope.

Inflow rainfall regions the primary purpose of contour cultivation is to conserve the rain water into soil as much as possible.

In humid regions its basic purpose is to reduce the soil erosion or soil loss by retarding the overland flow. In this system, the furrows between the ridges made on the contours hold the runoff water and stored them into the soil. Thus, they reduce the runoff and soil erosion.

10.1.2 Strip Cropping :

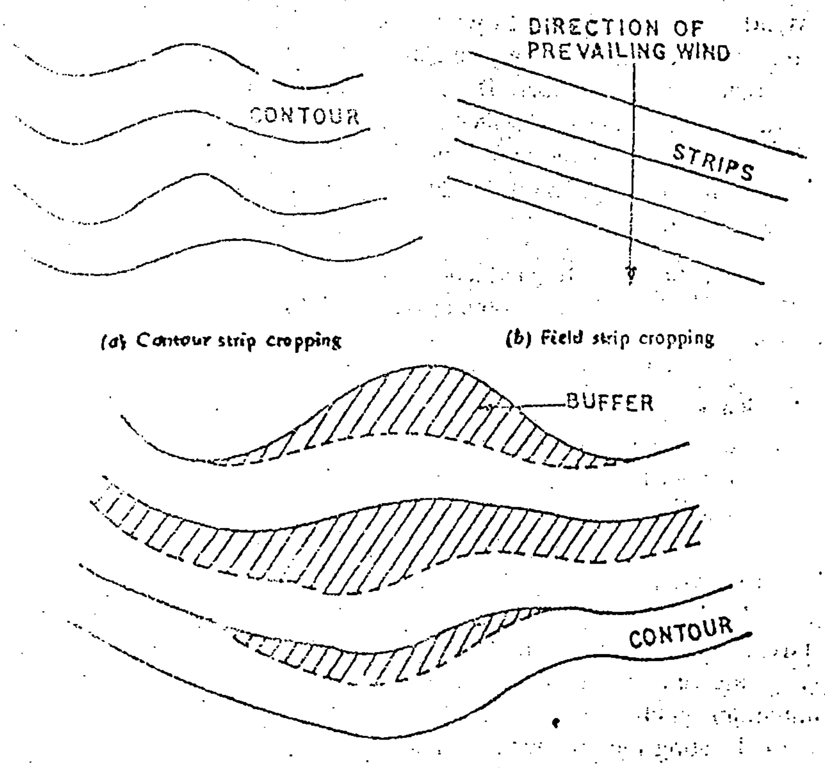
It is also a kind of agronomical practice, in whiph ordinary crops arc planted or grown in form of relatively narrow strip across the land slope. These strips are so arranged, that the strip crops should always be separated by strips of close-growing and erosion resistance c3rops. Strip cropping check the surface runoff and forces them to infiltrate into the soil, which facilitates to the conservation of rain water. It is snore effective than contouring [about twice, effective as contouring] but it does not effect on soil erosion.

Statge :

It controls erosion by

1) Reducing the runoff flowing through the close growing sod strips
2) Increasing the infilteration rate of soil under cover condition

Types of Strip Cropping (Fig 10.1)



(a) Contour strip cropping (b) Field strip cropping

Fig 10.1 Types of strip cropping

a) Contour strip cropping
b) Field strip cropping
c) Buffer strip cropping
d) Wind strip cropping

10.1.3 Tillage Practices :

It is defined as mechanical manipulation of soil to provide a favorable environment for good germination of seed and crop growth, to control the weeds, to maintain infiltration capacity and soil aeration. Tillage practice protects and maintain a strong soil structure to fight against erosion.

Types of Tillage Operation [practices]

a] Mulch tillage: Application of any plant residues or other material to cover top soil surface

Mulching Materials are namely :
Cut grasses, straw materials, Wood chips, saw dusts, paper, sand stones, glass wools, metal foils, and stones, plastic.

Types of Mulch :
Natural, Synthetic, Petroleum, Conventional, Inorganic, Organic.

b) Vertical Mulching :
Insertion of stuffed plant residue vertically into subsoiler marks to keep the slot open.
c) Minimum tillage
Preparation of seedbed with minimum disturbance of soil
d) Conventional Tillage.
Ploughing, Secondary Cultivation with harrowing and planting.
e) Listing :
Used for controlling soil erosion.
i) Hard ground listing.
ii) Loose ground Listing

10.1.4 Soil Management Practices :
Various soil and land management practices are

a) Those practices which helps to maintain the soil infilteration rate at high level to reduce runoff to a negligible amount.
b) Practices, which helps in safe disposal of runoff from field.

The cultural practices which are helpful for creation of high infiltration rate are essentially based on farming techniques, tillage or minimum tillage and use of cover crops. Whereas the safe deposal of runoff from the field is carried out by physical manipulation of soil surface including land shaping, levelling, construction of ridges, bunds, water ways.

10.1.5 Supporting Practices :

It involves application of fertilizers to soil either to make more fertile or to recover the fertility loss during different physical action. Application of fertilizer plays sometimes a significant role to developed abundance vegetative growth e.g. Grassed waterways and terrace outlet are generally established on low – fertile sub soil.
Interplanting – Referes to seeding of grass or legume crops in combination or maize or other crops to achieve better result on erosion control.

10.1.6 Vetiver Grass planting
It is most effective vegetative material for soil and water conservation and rehabilitation and embankment stabilization. Vegetative hedge formed with thick growth of vetiver grass forms a protective barrier across slope which slows down sheet erosion and deposit the silt behind hedges.

10.2.1 : Engineering Practices :

It is used to control the soil erosion in highly sloped areas

10.2.1 Terracing

a) Diversion Terrace
   i) Magnum Type
   ii) Nichols type
   iii) Broad based type
   iv) Narrow based type

b) Retention terrace

c) Bench terrace (fig 10.2)

10.2. 2 Bunding

a) Contour banding
   i) Narrow Based
   ii) Broad based

b) Graded banding
   i) Narrow based
   ii) Broad based

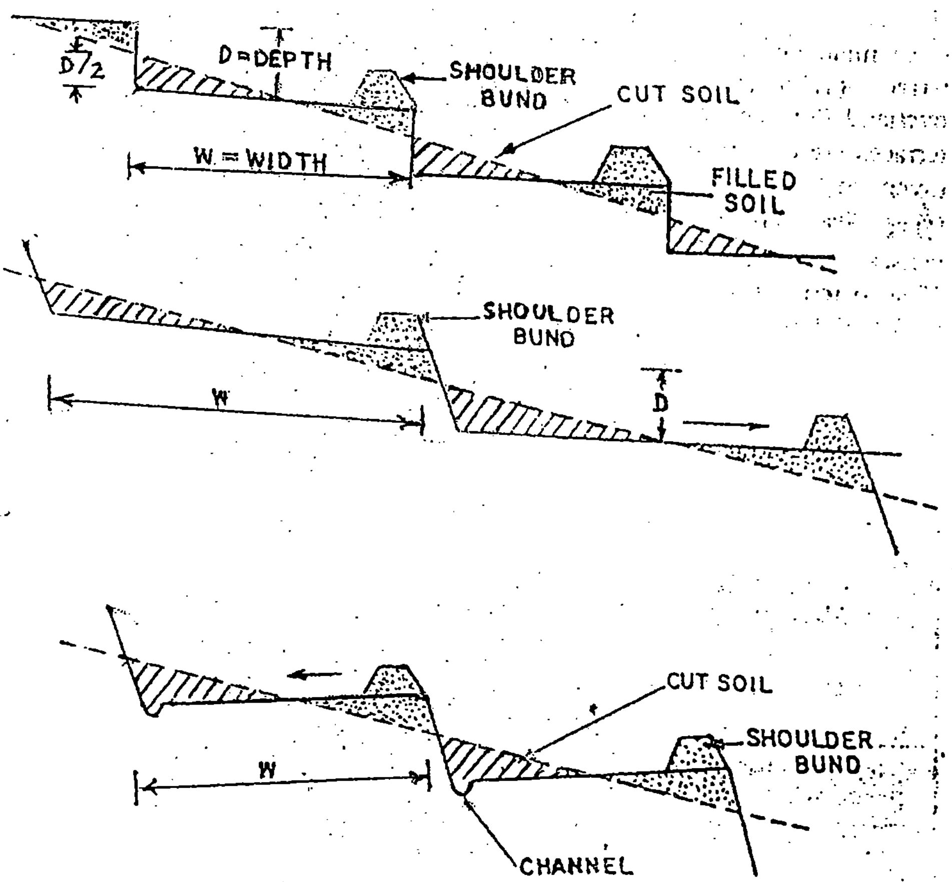
c) Side bunds [formed at extreme ends of contour bunds running along the slopes of land]

d) Lateral bund : [Constructed between two side bunds along slope]

e) Supplemental bunds– [Between two contour bunds so as to limit horizontal spacing]

f) Marginal bunds – [Formed at margin points of watershed]

g) Shoulder bund – [Formed at outer edge of terraces]



10.2 Types of bench terraces

Lecture 11

FLOW (RUNOFF WATER) MEASURING DEVICES

Commonly used devices for measuring runoff/water are weirs, parshall flumes, and orifices. With the help of these devices the rate of flow is measured directly by making a reading on a scale, and computing the discharge rate with the help of standard formulae, tables or calibration curves. These devices can be made locally for farm use. These devices give accurate results when constructed, installed and operated properly.

11.1 Weirs

Weirs are used to measure the flow from the discharge of well, canal outlet or irrigation channel: "A weir is a notch of regular form through which the irrigation stream is made to flow. A weir consists of a weir wall of concrete, timber or metal with a sheet metal plate fixed to it. Weirs may be a stationary structure or it may be a portable one. There are three types of weirs as

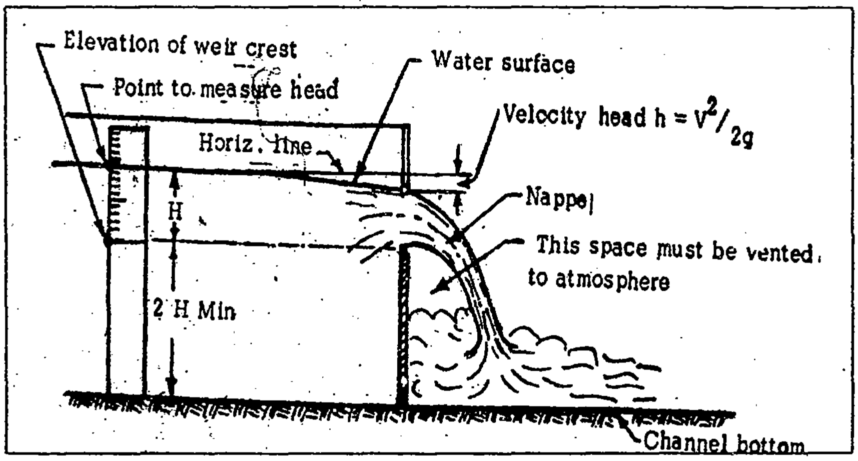
(a) A rectangular weir
(b) Trapezoidal weir/Cipoletti weir
(c) Triangular weir/ 90 ° V- notch.

It is advised to install the weir at a point where there is a drop in the elevation of the channel bed.

11.1.1 Important Terms used

(a) **Head** : The depth of water flowing over the weir crest measured at some point in the weir pond.
(b) **Weir Pond:** Portion of the channel immediately upstream from the weir.
(c) **Weir Crest** : The bottom of the weir notch.
(d) **Nappe**: The sheet of water which overflows a weir.
(e) **Sharp crested Weir**: A weir having thin edged crest such that the overflowing sheet of water has the minimum surface contact with the crest.

Fig 11.1



(f) **Bottom Contraction** : The vertical distance from the weir crest to the bottom of the weir pond.
(g) **End Contraction:** The horizontal distance from the ends of the weir crest to the sides of the weir pond.

(h) **Weir scale (Gauge)** : The scale fastened on the side of weir or on a stake in the weir pond to measure the head on the weir crest. (fig 11.1)

Broadly there are two classes of weirs as

(i) Sharp crested weir, and

(ii) Brad crested weir.

Sharp crested weirs are commonly used for water measurement on the farm.

Again these weirs are divided into two types as :

(i) Weirs with end contraction, and

(ii) Weirs without end contraction.

When width of the notch or the crest length is less than the channel width end contractions are provided for suppressed weirs the crest extends across the full width of the channel and no contractions are produced. The flow is said to be free, when the water surface downstream from the weir wall is far enough below the crest so that air has access around the nappe. In other case it is said to be submerged flow.

The basic formula for calculating discharge through a weir is as

$Q = CLH^m$

L = Length of crest

H = Head on the crest

C = A coefficient, depends on the nature of the crest and approach conditions.

m = An exponent, depending upon the weir opening.

11.1.2 Rectangular Weirs

The shape of the notch is rectangular. These weirs are used to measure comparatively large discharges.

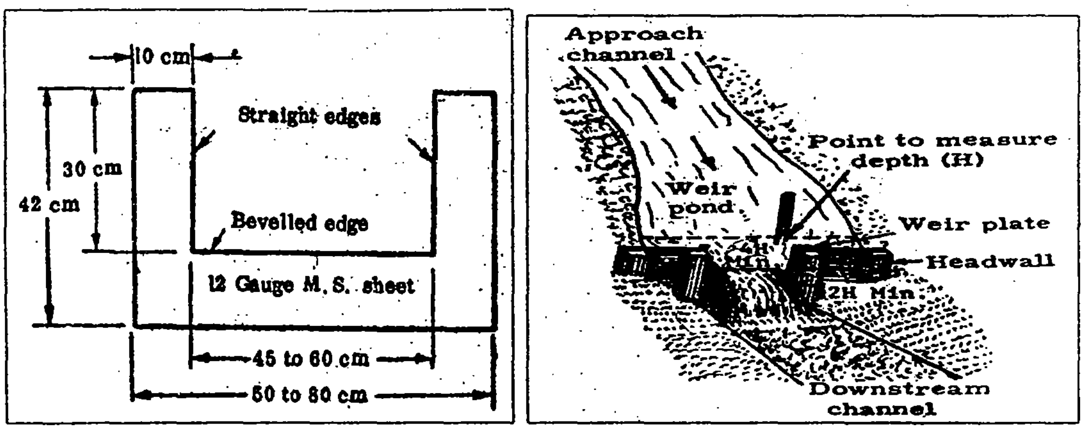


Fig 11.2 (a & b)

The weir has a horizontal crest and vertical sides (fig 11.2 a & b). These weirs may be either contracted rectangular weirs or suppressed rectangular weirs. These are having sharp crest and bevelled on the downstream side. The sides of the weirs are not bevelled. The formula for computing discharge through rectangular weir is stated below (Francis formula):

(a) For Suppressed rectangular weirs,

$$Q = 0.0184\, L\, H^{3/2}$$

in which, Q = Discharge, litres/second.

L = Length of crest, centimetres.

H = Head over the crest, centimetres.

(b) For contracted rectangular weir with end contractions.

a = $0.0184\,(L - 0.1\,n\,H)\,h^{3/2}$

in which,
- Q = Discharge, litres/second
- L = Length of crest, centimetres.
- H = Head over the crest, centimetres.
- n = Number of end contractions.

Example 11.1: Compute the discharge of a rectangular weir 40 cm. long with a head of 10 cm under the following conditions.

(a) With no end contraction
(b) With one end contraction
(c) With two end contraction

Solution : Using Francis formula

(b) With no end contraction:

$Q = 0.0184\,L\,H^{3/2}$

$L = 40$ cm, $H = 10$ cm

$\therefore\ Q = 0.0184 \times 40 \times 10^{3/2}$

$= 23.274$ litres/second

(ii) With one end contraction:

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

$= 0.0184\,(L - 0.1\,H)\,H^{3/2}$

$= 0.0184\,(40 - 0.1 \times 10)\,10^{3/2}$

$= 22.693$ litres/second.

(iii) With two end contractions.

$Q = 0.0184\,(L - 0.1\,n\,H)\,H^{3/2}$

$= 0.0184\,(L - 0.2\,H)\,H^{3/2}$

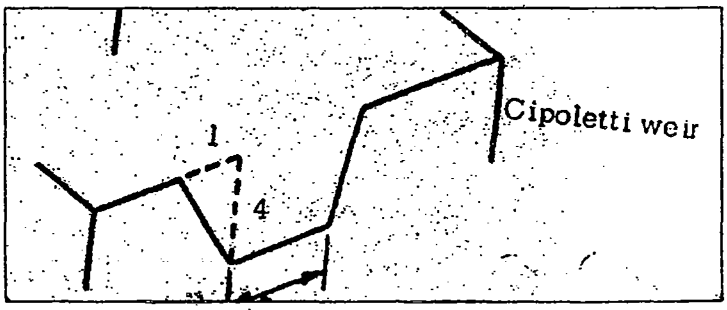
$= 0.0184\,(40 - 0.2 \times 10)\,10^{3/2}$

$= 22.111$ Litres/second.

11.1.3 Trapezoidal Weir (Cipoletti Weir)

Cipoletti weir is a contracted trapezoidal weir for this weir each side of the notch has a slope of 1:4 (H:V). It is invented by an Italian engineer named Cesare Cipoletti. Side slopes of 1 to 4 to the sides are just sufficient to correct for the end contractions of the nappe and that the flow is proportional to the length of the weir crest. Therefore it does not require corrections for end contractions.

Fig11.3



Cipoletti weir has sharp crest and sharp sides, bevelled from the downstream side only (fig 11.3). These are commonly used to measure medium discharge. The discharge through Cipoletti weir is computed with the help of following formula.

Q = $0.0186 \, L \, H^{3/2}$

Where, Q = Discharge, litres/second

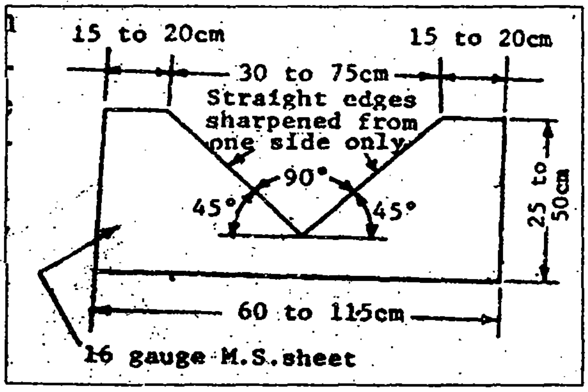
L = Length of the crest, centimetres.

H = Head over the crest, centimetres.

11.1.4 Triangular Weir (90 ° V-notch)

It is commonly used to measure small and medium discharges 90 ° V-notch measures small flows accurately. It has both its sides sharp, bevelled from the downstream side only (Fig11.4).

Fig 11.4



The discharge through a 90 ° V-notch weir is computed with the help of following formula.

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

Where Q = Discharge, litres/second.

H = Head, centimeters.

Example 11.2 : A cipoletti weir has a breadth of 60 cm at its crest. The head of water flowing over the crest is 30 cm. Determine its discharge.

Solution : $Q=0.0186 \, L \, H^{3/2}$

$=0.0186 \times 60 \times 30^{3/2}$

=183.378 litres/second.

Example 11.3 : Compute the discharge through a 90°V-notch under the head of 7 cm and 19 cm.

Solution:

(a) Under the head of 7 cm.

Q = $0.0138 \, (7)^{5/2}$

= 1.789 litres/second.

(b) Under the head of 19 cm

Q = $0.0138 \, (19)^{5/2}$

= 21.715 litres/second.

Example 11.4: Compute the discharge over a rectangular weir having suppressed end contraction, if the weir crest is 75 cm long with head of water over the crest as 15 cm. If the same discharge passes over the 90°V-notch, find head of it.

Solution: (a) Using Francis's formula for suppressed rectangular weir.

Q = $0.0184 \, LH^{3/2}$

$= \quad 0.0184 \times 75 \times 15^{3/2}$

$= \quad 80.171$ litres/second.

Same discharge now passes over 90°V-notch,

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

$\therefore \quad 80.171 = \quad 0.0138\ H^{5/2}$

$\therefore \quad H\ 5/2 \quad = \quad 5809.493$

$\therefore \quad H \quad = \quad (5809.493)$

$= \quad 32.037$ cm.

$\therefore$ Head over 90°V-notch = 32.037 cm.

11.2 General requirements for the setting and operation of weirs

For irrigation water, the weir, when properly constructed and installed is one of the simplest and most accurate device. Improper setting and operation may result in large errors in discharge measurement with weir. In general, approaching flow should be the same as tranquil flow in long straight canals, of the same site.

To ensure reliable results in measurement, following precautions are taken while using weirs:

(a) The velocity of the approaching flow should not exceed 15 cm/s. Baffles may be out in the weir pond if necessary to reduce velocity and equalize the flow.

(b) The weir should be installed at the lower end of a long pool sufficiently wide and deep to give an even, smooth flow of the stream.

(c) To measure the discharge from pumps a portable weir pond made of sheet metal is constructed or the weir plate is fixed at its outlet when a built-in weir pond made of brick is constructed.

(d) The gauge used for measuring the head should be located at a distance of about four times the approximate head. The zero of the scale or gauge should be exactly on the same level as the crest level of the rectangular or cipoletti weir or the apex of a V-notch weir.

(e) The depth of water flowing over the rectangular weir should not be less than about 5 cm, and not move than about two-third the crest width.

(f) The weir wall must be vertical and must extend for enough into the bank to be secured.

(g) The centre line of the weir should be parallel to the direction of flow.

(h) The crest of the weir should be level.

(i) The notch should be of a regular shape and its edges must be rigid and straight.

(j) The weir crest should be above the bottom of the weir pond by at least about twice the depth of water flowing over the weir.

(k) The crest of the weir is placed high enough so that water will fall freely blow the weir.

11.2.1 Limitations in the Use of Weir

(i) Weirs are not always suitable although they are easy to construct and convenient to use

(ii) Unless proper conditions for measurements are maintained, they are not accurate.

(iii) They require a considerable loss of head, often not available in channels on flat grades.

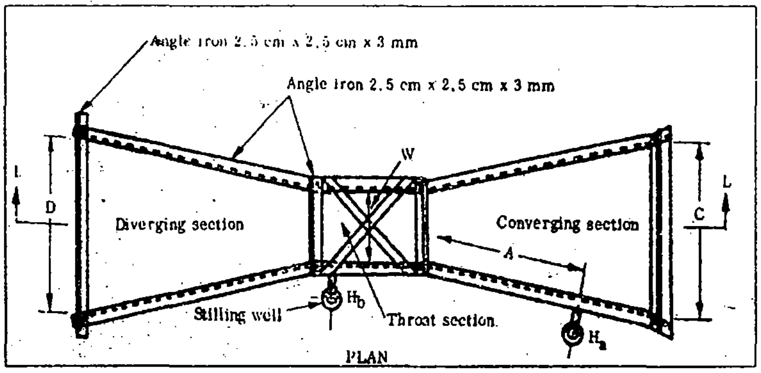
(iv) They are not easily combined with turnout structures.

(v) Weirs are unsuitable for water carrying silt.

11.3 Parshall flume

It is an open channel type-measuring device that operates with a small drop in head. It is a self-cleaning device. The loss of head for free flow limit is only about 25 percent of that of weir. Its operation and accuracy is not affected by sand or silt in the flowing water (fig 11.5). Even when partially submerged, parshall flumes allow reasonably accurate measurements.

Fig 11.5



The velocity of the approaching stream has very little influence on its operation. The floor of the upstream section of the flume is level. The walls of this section converge towards the throat section. The walls of the downstream section diverge towards the outlet and the floor is inclined upward. The walls of the throat section are parallel and the floor is inclined down ward. Small flumes are made of sheet metal. Large flumes are made of concrete, and have an approach section and wing walls at the upstream end. The width of throat will determine the size of flume. Sites ranges from 7.5 cm to several metres in throat width. They have been calibrated and formulas tables are developed. If turbulence is present, stilling wells can be used to measure the water surface elevation in the flume. A plastic scalp fixed to the inside of the flume will be sufficient to measure the head, when the flow is smooth. The zero of the scales should be set at the same level as the floor level of the converging section.

Where the elevation of the water surface downstream from the flume is high enough to retard the rate of discharge, the flow is considered as submerged flow. Discharge through the flume can occur either free flow or submerged flow conditions.

To determine the discharge, two seats, Ha and Hb are provided are provided at the upstream and downstream of the flume. Only Ha needs to be measured under free flow conditions.

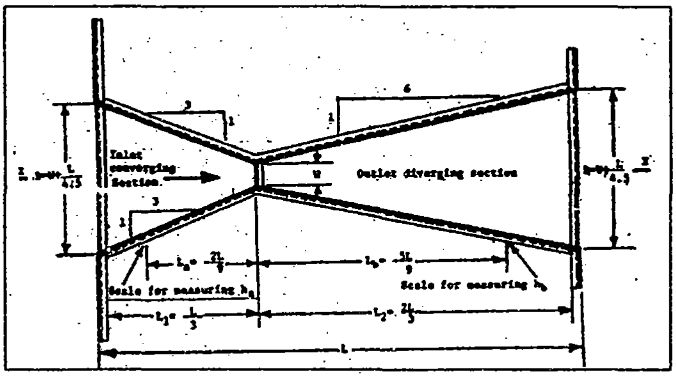
Width of threat	Free flow limit (Hb/Ha)
2.5 to 7.5 cm	0.5
15 to 22.5 cm	0.6
0.30 to 2.40 m	0.7

It is desirable to develop calibration curves of the flume to avoid the risk of inaccuracies in the dimensions of the flume.

11.4 Cutthroat flume

The cutthroat flumes is an attempt to improve on the parshall flume. They are simple in construction as compared to parshall flume. The cutthroat flume has a flat bottom, vertical walls and a zero length throat section (fig 11.6). It was given name cutthroat, as it has no throat section, i.e. throat length is zero.

Fig 11.6



This flume has been developed by skogerboe, Hyatt, Anderson and Eggiestone in 1967. The advantage of a cutthroat flume is economy. The flume length is in-between 0.45 m to 3m with throat width between 2.5 m to 1.8 m can be used. The cutthroat flume can operate either as a free or a submerged flow structure for free flow the ratio of inlet flow depth, ha to flume length should preferably be less than 0.4. The relationship between flow rate Q and upstream depth of flow ha in cutthroat flume under free flow conditions is given by the following experimental relationship as

$$Q = C_1 \, ha^{n_1}$$

Where Q = Flow rate,

$C1$ = Free flow coefficient, which is the value of Q when ha is 1.0 foot.

n_1 = exponent, whose value depends only on the flume length.

The value of n_1 is a constant for all cutthroat flumes of the same length.

Submergence (s) : It is defined as the ratio of the downstream depth to the upstream depth expressed as a percentage.

The cutthroat flume should be installed in a straight section of the channel. It should not be located too near a gate because of unstable and surging effect which might result from the gate operation.

Example 11.5 Calculate the discharge through a cutthroat flume assuming that,

Length of cutthroat flume, L = 4.0 feet
Width of cutthroat flume, W = 1.167 feet
The flume length coefficient, K1 = 4.15
Exponent, n1 = 1.75
Depth of inlet flow, ha = 1.20 feet.

Solution:

$$C1 = K1 \, W^{1.025}$$
$$= 4.15 \times (1.167)^{1.025}$$
$$= 4.86$$

$$\therefore \quad Q = C_1 \, ha^{n1}$$
$$= 4.86 \times (1.20)^{1.75}$$
$$= 6.70 \text{ cu.feet/second.}$$

11.5 Orifices:

These are usually circular or rectangular openings in a vertical bulkhead through which water flows. They are often constructed of metal and the edges of the openings are sharp. The cross sectional area of the orifice is small in relation to stream cross-section. Orifices may operate under free flow or submerged flow conditions. Under free flow conditions the flow from the orifice discharges entirely into air, while in submerged flow orifices the downstream water level is above the top of the opening.

11.5.1 Free flow orifices:

They consists of sheet iron, steel or aluminium plates that contain accurately machined circular opening or orifices usually ranging from 2.5 cm to 7.5 cm. A plastic scale may be fixed directly on the upstream face of the orifice plate. The zero reading of the scale must coincide with the centre of the orifice. Orifice plates can be used for level channels and no silting pond is required on its upstream side.

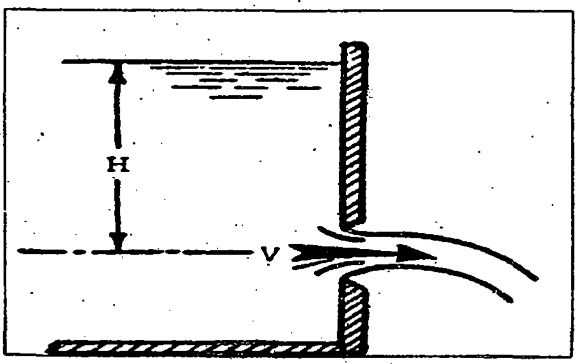


Fig 11.7

Free flow orifice plates can be used to measure comparatively small streams like the flow into border strips, furrow or check basins, (fig 11.7).

The discharge through on orifice is calculate by the formula:

$$Q = 0.61 \times 10^{-3} \times a \sqrt{2gH}$$

Where,

Q	=	Discharge through orifice, litres/second
a	=	Area of cross -section of the orifice, cm^2
g	=	Acceleration due to gravity (981 cm/sec^2)
H	=	Depth of water over the centre of the orifice, cm

for free flow orifice, H, is the depth of water over the centre of the orifice on the upstream side for submerged orifice, H is the difference in elevation between the water surface at the upstream and downstream faces of the orifice plate.

11.5.2 Submerged Orifices

There are two types of submerged orifices as

(A) Those having orifices of fixed dimensions

(B) Those in which the height of opening may be varied,

A standard submerged orifice has fixed dimensions. In this case the opening is sharp edged and usually rectangular. The width of the opening is 2 to 6 times the height of the opening. The adjustable submerged orifice is one in which the height of opening and head may be varied to suit the requirements. It should be calibrated to obtain the discharge under varying head conditions. The ordinary form of submerged orifice is a simple head gate used to control flow from one channel to another (fig11.8 and fig11.9)

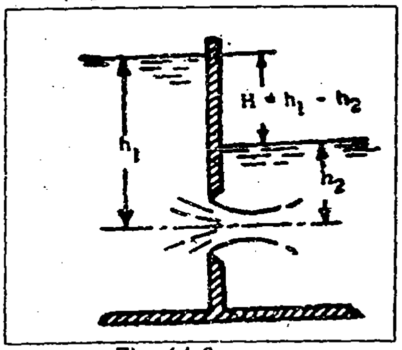


Fig. 11.8

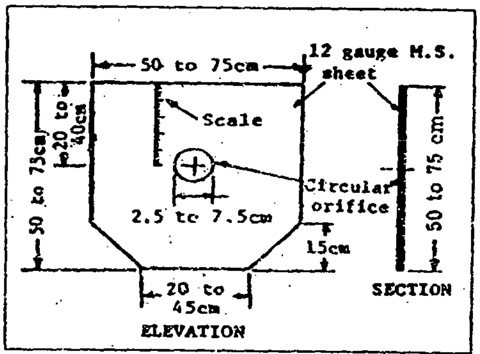


Fig. 11.9

The discharge through a standard submerged orifice may be obtained using equation.

$$Q = 0.61 \times 10^{-3} \times a \sqrt{2gH}$$

Where,

Q	=	Discharge through orifice, litres/second
a	=	Area of cross - section of the orifice, cm2
g	=	Acceleration due to gravity, 981 cm/sec2
H	=	The difference in elevation between the water surface at upstream and downstream faces of the orifice plate.

Example 11.6 Calculate the discharge through a free flow orifice having circular opening with 5.00 cm diameter. The depth of water over the centre of orifice is 15 cm.

Solution

$$Q = 0.61 \times 10^{-3} \times a \sqrt{2gH}$$

$$= 0.61 \times 10^{-3} \times \left(\frac{\pi}{4} \times 5 \times 5\right) \times \sqrt{2 \times 981 \times 15}$$

$$= 0.61 \times 10^{-3} \times 19.635 \times 171.552$$

$$= 2.0\ 55 \text{ litres/second}$$

Lecture 12

ESTIMATION OF RUNOFF

METHODS OF RUNOFF COMPUTATION :

Accurate computation of runoff amount is difficult, as it depends upon several factors concerned with atmosphere and watershed characteristics, to evaluate which effect on runoff is not so easy. On the basis of field experience and water conservation for estimating the maximum or peak runoff rate of a particular watershed to design the conservation structures.

12.1 Rational method

This is a most common method used to predict the peak runoff rate defined as the maximum runoff, to be used as capacity for a given structure that must carry the runoff Rational method used the following formula for computing the design runoff (Ramser, C.E.) :

$$Q_{peak} = \frac{1}{360}$$

Where,

Q_{peak} = runoff rate, m^3/s

C = runoff coefficient

I = rainfall intensity (mm/h) for a duration equal to time of concentration and for a given recurrence interval and

A = watershed area, hectare.

Assumptions of Rational method

The above equation was developed, using the following assumptions:

1. Rainfall occurs with a uniform intensity for the duration, at least equal to the time of concentration of watershed area and
2. Rainfall occurs at a uniform intensity throughout the watershed area. If all these assumptions are satisfied to a given rainfall, then the relationship between rainfall and runoff for the watershed, may be represented graphically, as shown in Fig. 12.1

   The Fig.12.1 indicates, that if a specific rainfall of uniform intensity occurs for the duration greater than time of concentration, the runoff rate would be less than the peak value, because the rainfall intensity would be less than the intensity, resulting the peak runoff rate. Similarly a rain that takes place for the duration less than the time of concentration, the runoff rate will also be less than peak value, because the entire watershed area would not be able to yield the discharge simultaneously to the outlet

12.1.1 **Runoff coefficient (C) :** It may be defined as the ratio of the runoff and rainfall. It is a dimensionless factor. It values are assigned on the basis of land use and soil type (Table 12.1)

Table 12.1 : Values of 'C' for use in Rational formula

Sr. No.	Land use and Topography	Soil Type		
		Sandy Loam	Clay and silt Loam	Tight Clay
1.	**Cultivated Land**			
	a) Flat	0.30	0.50	0.60
	b) Rolling	0.40	0.60	0.70
	c) Hilling	0.52	0.72	0.82
2.	**Pasture Land**			
	a) Flat	0.10	0.30	0.40
	b) Rolling	0.16	0.36	0.55
	c) Hilling	0.22	0.42	0.60
3.	**Forest Land**			
	a) Flat	0.10	0.30	0.40
	b) Rolling	0.25	0.35	0.60
	c) Hilling	0.30	0.50	0.60
4.	**Populated area**			
	a) Flat	0.40	0.55	0.65
	b) Rolling	0.50	0.65	0.80

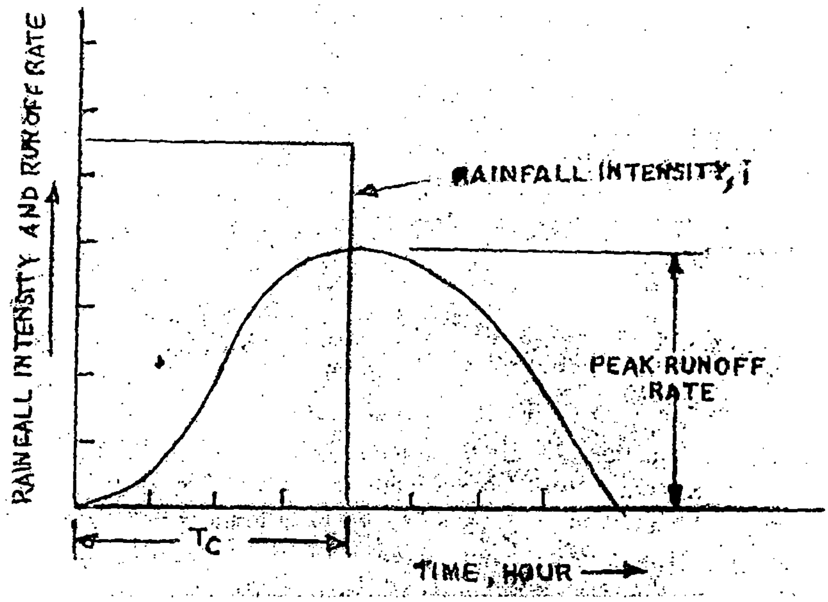


Fig 12.1 Relationship between rainfall and runoff

The runoff coefficient can be expressed as

$$C = \frac{X_d}{\sum_{M=1}^{n} R_m}$$

Problem 12.1. Calculate the run-off coefficient for the storm by which 1.33, 2.50, 4.08, 5.00 and 0,05 mm rainfall occurred during 8-h duration, if run-off depth produced by the storm is 7.50mm.

Solution. R_m = 1.33 + 2.50 + 4.08 + 5.00 + 0.05 mm

= 12.96 mm

$$C = \frac{x_d}{12.96} = \frac{7.5}{12.96}$$

= 0.578 Ans.

Problem 12.2. Determine run-off coefficient using following rainfall and stream flow data:

Time (h)	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Stream flow m³/s)	200	250	275	500	1500	2000	1000	750	500	450	200
Rainfall (cm)		0.40	5.70	8.50	6.6	0.30					

Assume base flow 200 m³/s, and catchment area is 50 km²

Solution. We know that run-off coefficient

$$C = \frac{x_d}{\sum_{M=1}^{n} R_m}$$

The computation of x_d is shown as under

Time (h)	Stream flow (m³/s)	Base flow (m³/s)	Direct runoff m³/s	Computation of x_d
0	200	200	0	$c \times d = \frac{5425 \times 30 \times 60}{50 \times 106}$
0.5	250	200	50	
1.0	275	200	75	
1.5	500	200	300	= 0.19.53 m
2.0	1500	200	1300	
2.5	2000	200	1800	= 1953 cm
3.0	1000	200	800	
3.5	750	200	550	$C \frac{19.53}{21.50}$
4.0	500	200	300	
4.5	450	200	250	
5.0	200	200	0	= 0.908 Ans
	Total		**5425 m³/s**	

Total rainfall from begning of direct run-off (ΣRm) = 0.40 + 5.70+8.50+6.6+0.30 = 21.50 cm

When a watershed has different features regarding its land use and soil types, then weighted value of runoff coefficient is calculated. A sample example, for computing the weighted value of runoff coefficient is shown as under :

Let, a watershed has been divided into five sub parts, on the basis of its soil types and land use, having the area as a_1, a_2, a_3, a_4 and a_5, with the values of runoff coefficient as c_1, c_2, c_3, c_4, and c_5, respectively. Then the value of weighted runoff coefficient 'C' is given by

$$C = \frac{c_1 a_1 + c_2 a_2 + c_3 a_3 + \ldots + c_5 a_5}{a_1 + a_2 + a_3 + a_4 + a_5}$$

In which, A is total area of watershed

12.1.2 Rainfall Intensity : Rainfall intensity is defined as the rate of fall of rainfall, expressed as depth per unit time i.e. mm/hour. It is also given by

$$I = \frac{\text{Total rainfall (P)}}{\text{Total duration (T)}}$$

In which, I is rainfall intensity, P is amount of rainfall and T is the duration of rainfall. In the rational method to compute peak runoff rate, the rainfall duration should always be equal to the time of concentration (i.e. time required to move the surface flow from remotest point of the watershed to the outlet).

Rainfall intensity is classified into following three categories, as

(1) Light intensity – 2.5 mm/h
(2) Moderate intensity – 2.5 to 7.5 mm/h
(3) Heavy intensity – more than 7.5 mm/h

12.2.3. Time of concentration (Tc) : The time required to move the surface runoff from remotest point of the watershed to its outlet, is known as time of concentration. When duration of rainfall becomes equal to the time of concentration, then all parts of the watershed are able to contribute the discharge to the outlet, simultaneously and the cumulative discharge takes the form of maximum runoff which is referred as peak discharge.

Computation of Time of Concentration : There are several empirical relations are available for computing the time of concentration, Kirpich (1940) developed and equation for computing the Tc on the basis of channel length and its average slope. The equation is given as:

$$Tc = 0.0195 \ L^{0.77} \bar{S}^{0.385}$$

Where,

Tc = time of concentration, minutes

L = length of channel reach, m. and

S = average slope of the channel reach, m/m.

12.1.4. One Hour Rainfall : The intensity of severest rainfall during a given recurrence interval of a particular region, during the time interval of one hour is called as one hour rainfall for that return period / frequency. In the Rational method, for computing the peak runoff, the intensity of rainfall should be equal to the time of concentration; in this case one hour rainfall intensity is converted accordingly with Tc value. For this purpose Fig. 12.2 may be used.

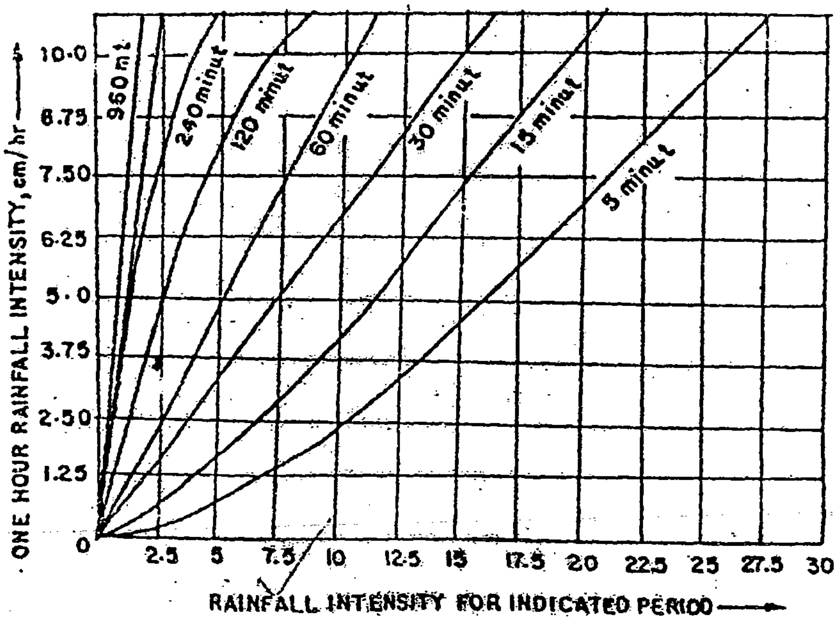


Fig.12.2 Relationship between intensities of indicated duration and 1-hr rainfall intensity

12.1.5. Limitation of Rational Method : Following limitations are observed in use of Rational method:

1. Rational method assumes, that intensity of rainfall is uniformly distributed throughout the watershed, but it never happens.
2. This method does not care the initial losses, such as depression storage, initial infiltration, channel storage etc., to start the runoff flow.
3. The runoff coefficient value is related as the function of watershed characteristics, such as landuse, topography soil types etc., not provide correct value. The runoff coefficient is also dependent upon the atmospheric characteristics like, season and rainfall etc.

Problem 12.3 Calculate the peak runoff rate for a 10 years return period from a micro-watershed area of 75 hectares. The watershed is divided into three parts, based on its land use and soil texture, in which first part of 25 hectares with 1% slope is under cultivation, second part of 30 hectares with a slope of 7% is under pasture and rest of the land with slope of 12% is under farm forestory. The maximum length of flow path is 3000 meters to the outlet. The average slope of channel is 5%. And the maximum rainfall intensity of 1-h rainfall is 5 cm/h during the 10 year return period.

Solution.

1. Computation of Runoff coefficient 'C' :

   From table 12.1 we have the following 'C' values

   25 hectares land with cultivation, on 1% slope, C = 0.50

   30 hectares land with pasture, on 7% slope, C = 0.36

   20 hectares land with farm forestory, on 12% slope, C = 0.50

   Weighted value of runoff coefficient:

$$C = \frac{c_1 a_1 + c_2 a_2 + c_3 a_3}{a_1 + a_2 + a_3}$$

$$= \frac{25 \times 0.50 + 30 \times 0.36 + 20 \times 0.50}{25 + 30 + 20}$$

$$= 0.44$$

2. Computation of Time of Concentration:

$$Tc = 0.0195 \; L^{0.77} \bar{S}^{0.385}$$

$$= 0.0195 \times 3000^{0.77} \left(\frac{5}{100}\right)^{-0.385}$$

$$= 30.15 \text{ minutes}$$

3. Computation of rainfall intensity for the period equal to the time of concentration (Tc = 30.15 minutes)

   Referring figure 12.2, the rainfall intensity for the time equal to Tc as 30.15 m, is obtained as 7.5 cm/h when 1-h rainfall intensity is 5cm/h

4. Computation of Peak runoff rate:

$$Q = \frac{1}{36} \times C.I.A.$$

$$= \frac{1}{36}\, 0.44 \times 7.5 \times 75$$

Problem 12.4 Calculate the peak runoff rate, expected to occur once in 10 year return period from the catchment area of 40 ha flat, cultivated clay loam and 15.5 ha of sloping land having the slope ranges from 5 to 10 percent, sandy loam texture, wood land. The elevation drop along the longest flow path of 2000m was obtained as 40m. The other details are as under:

(i) 1-h rainfall for 10 yrs return period was 7.50 cm

(ii) The relationship between 1-h rainfall intensity and rainfall intensity for the duration equal to Tc is I = 1.50 If for Tc = 31 minutes

Solution

(i) Given that,

Watershed area (ha)	Land use	Soil type
40.0 15.5	Flat, cultivated wood land (5 to 10%)	Clay loam Sandy loam

(ii) Longest path length (L) = 2000 m

(iii) Drop in elevation of the flow path = 40 m

(iv) 1-h rainfall (I_F) = 7.50 cm

Time of concentration Tc = $0.0195\ K^{0.77}$

$$= 0.0195 \times \left[\sqrt{\frac{(2000)^3}{40}}\right]^{0.77} \text{min.}$$

= 30.61 minutes

or = 31.0 minutes

Rainfall intensity for the time equal to Tc as 31 minutes

I = 1.50 x 7.50 = 11.25 cm/h

Weighted runoff coefficient C:

As per land use and soil types, the values of C for different sub-parts of watershed are obtained from the table 12.1 and weighted C is computed in following table:

Watershed area (ha)	C	Computation of weighted C'
40	0.5	$C = \frac{c_1 a_1 + c_2 a_2}{a_1 + a_2}$
15.5	0.25	$= \frac{0.5 \times 40 + 0.25 \times 15.5}{55.5} = 0.43$

Peak runoff Rate obtained as under by using Rational formula

$$Q_{peak} = \frac{CIA}{36}$$

$$= \frac{0.43 \times 11.25 \times 55.5}{36}\ m^3/s$$

$= 7.45\ m^3/s$ Ans

Problem 12.5 : Determine the peak runoff rate for a return period of 25 years to design a gully control structure in a catelument area of 10 km². The maximum depth of rainfall during 25-years return period is as follows

Rainfall duration (min)	5	10	20	30	40	50	60
Rainfall depth (mm)	20	25	40	70	85	100	115

(Assume slope of catchment as 0.5% average runoff coefficient of catchment is 0.45 and longest length of water course is 1000m)

Solution: The rational method is employed to determine the peak runoff rate, which is performed as under :

(1) Time of concentration (Tc):

$$Tc = 0.01954\ L^{0.77} \cdot S^{-0.385}$$
$$= 0.01954\ (1000)^{0.77}\ (0.005)^{-0.385}$$
$$= 30.68 \text{ min.}$$

(2) Maximum depth of rainfall for the Tc = 30.68 min.

$$= \frac{85 - 70}{10} \times 0.68 + 70.0 = 71.02\text{mm}$$

(3) Average rainfall intensity (I) :

$$= \frac{71.02}{30.68} \text{ mm/min}$$
$$= 138.89\text{mm/h}$$

$$\therefore \text{Qpeak} = \frac{CIA}{3.6} = \frac{0.45 \times 138.89 \times 10}{3.6} \text{ m3/s} = 173.61 \text{ m}^3\text{/s} \quad \text{Ans.}$$

Problem 12.6 : Determine the peak runoff rate for 30 years return period to design a gully control structure. The essential data are as follows:

1. Catchment slope is 0.6%
2. Intensity-return period relationship is used as,

   $$I = \frac{5.827\ 0.160}{(t + 0.40)\ 0.75}$$

3. Length of longest water course is 1500 m
4. Catchment area is 15 km2
5. Average runoff coefficient for catchment is 0.55

Solution : To determine peak runoff rate, the Rational method is used, which is described as under:

1. Time of concentration (Tc) :

$$Tc = 0.01954\ (L)^{0.77}\ (S)^{-0.385}$$
$$= 0.01954\ (1500)^{0.77}\ (0.006)^{-0.385}$$
$$= 39.08 \text{ min.}$$

12.2 Computation of Runoff by Empirieal Formulas :

Runoff coefficient Method - In this method runoff is computed simply by multiplying the runoff coefficient to the rainfall amount, given as under :

R = K. P.

Where R = Runoff, cm K = runoff coefficient and

P = Rainfall depth, cm

The values of runoff coefficient for different land use conditions are given in Table –

Table : Values of runoff coefficient (k)

Sr. No.	Area	K
1.	Urban area covered by residential (a) buildings (b) garden apartments	0.3 0.5
2.	Commercial and industrial area	0.9
3.	Forest areas	0.5 to 0.2

Inglis Formula : C. C. Inglis provided the following two empirieal formulae for determining the runoff rate for different types of area. These are given as :

1) for ghat areas $R = 0.85\,P - 30.5$

2) for non ghat areas $R = \dfrac{P - 17.8}{254}$

In the above equation R is for Runoff dept (cm)
and P is for rainfall amount (cm).

Khosla's Formula : This formula was developed by assuming the temperature as a factor in yield of surface runoff. The formula is given by :

$$R = P\,\frac{T - 32}{3.74}$$

In which, R and P are the same as in Inglis formula and T is the average temperature (^{0}f) of the watershed.

Problem 12.6 The following rainfall magnitudes were recorded on a catchment ares of 0.85 km^2 during rainy season, determine the average runoff and average valume of runoff generated over the catchment

Rainfall Number:	1	2	3	4	5	6
Rainfall magnitis (cm)	1.25	2.75	5.0	0.50	0.75	3.0

(Assume runoff coefficient of the catchment is 0.50)

Solution: The runoff depth is computed, using the formulas.

R = K. P.

The computation is shown in the table:

Rainfall number	Rainfall depth (cm)	Rainfall depth cm (R = pk)
1	1.25	0.625
2	2.75	1.375
3	5.0	2.500
4	0.50	0.250
5	0.75	0.375
6	3.00	1.500
	Total	6.625 cm

$$\therefore \text{ Average runoff depth} = \frac{6.625}{6} = 1.1042 \text{ cm}$$

$$\text{And Average volume of runoff} = \frac{1.1042}{100} \times 0.85 \times 10^6 \text{ m}^3$$

$$= 9385.70 \text{ m}^3 \text{ Ans.}$$

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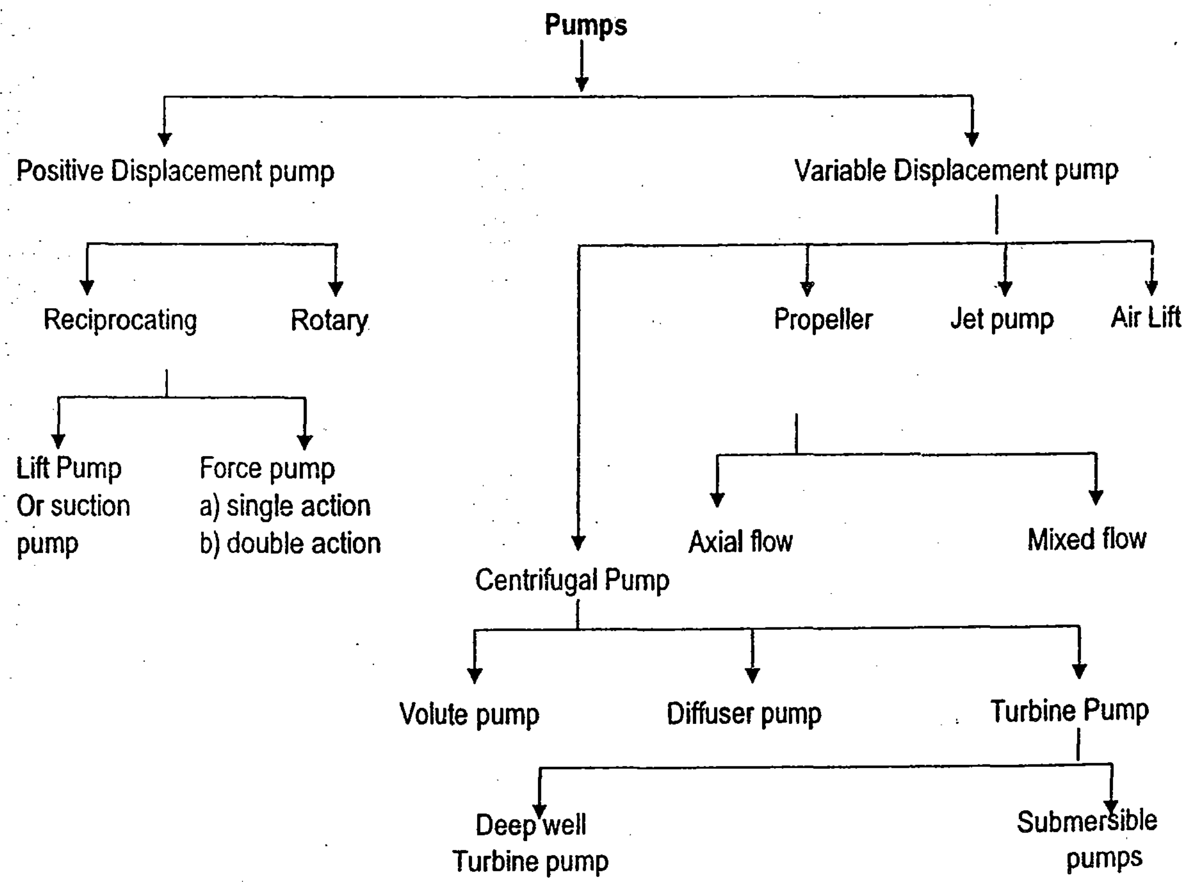
Lecture : 13

IRRIGATION PUMPS

13.1 Types of Pumps :

Basically four principles involved in pumping water:-

i) Atmospheric pressure
ii) Positive displacement
iii) Centrifugal force
iv) Movement of columns of water caused by the difference in specific gravity.



13.2 CENTRIFUGAL PUMPS

Definition :

It may be defined as one in which an impeller rotating inside a close fitting case draws in the liquid at centre and by virtue of centrifugal force throws out the liquid through an opening at the side of casing.

Centrifugal pumps are most widely used in irrigation practice. These simple in construction, easy to operate, low initial cost and produce constant steady discharge. This type of pump is well adapted to usually pumping services such as irrigation, water supply and sewage services.

Centrifugal pumps

Principles of Operation :

A centrifugal pump is rotary machines consisting of two basic parts –

1] Rotary element or impeller, and

2] Stationary element or casing

Principles :

The underlying hydraulic principle is the production of high velocity and the partial transformation of this velocity in pressure head.

Impeller is a wheel or disc mounted on shaft and provided with a number of vanes or blades usually curved in form.

In some pumps, a diffuser consisting of series of guide vanes or blades surrounds the impeller.

Operation :

The pumps filled with water and the impeller is rotated. The blades cause the liquid to rotate with the impeller and in turn impart high velocity to the water. Centrifugal force causes it to be thrown outward from the impeller into casing.

Outward flow through impeller reduces pressure at the inlet allowing more water to be drawn in through suction pipe. Due to conversion of high velocity into pressure, water is pumped through discharge pipe. It is done either in volute casing or in diffuser casing.

Technique Used for Priming :

1) A foot valve to hold the water in pump.
2) An Auxiliary piston pumps to fill the pump casing and suction line with water.
3) Connection to an outside source of water under pressure for filling the pump.
4) Use of self-priming construction.

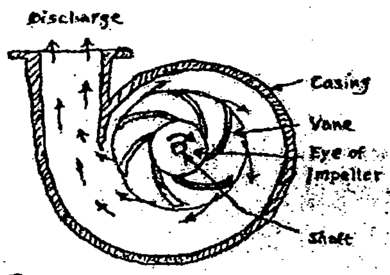


Fig. 13.1. Volute type centrifugal pump.

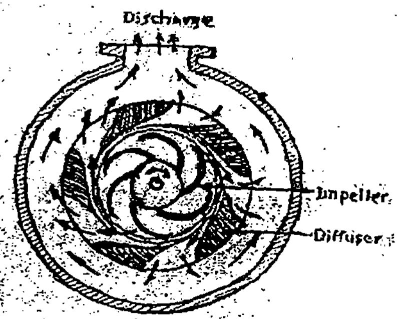


Fig. 13.2 Diffuser type centrifugal pump.

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Lecture 14

CALCULATION OF DISCHARGE, HEAD AND H.P. OF PUMPS

Water Horse Power (W.H.P.) is the theoretical horse power required for pumping. It is the head and capacity of the pump expressed in terms of horse power.

$$\text{WHP} = \frac{\text{Discharge (Lit/sec)} \times \text{Total head (m)}}{75}$$

OR

$$\text{WHP} = \frac{\text{Discharge } (m^3/\text{sec}) \times \text{Total head (m)}}{273}$$

Shaft horse power is the power required at the pump shaft.

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

Shaft Horse Power is used up in the pump in water horse power, disc friction, circulation, losses, stuffing box and bearing friction and hydraulic losses. It is always greater than water horse power.
Efficiency is the ratio of the power output to power input.

$$\text{Pump efficiency} = \frac{\text{Water horse power}}{\text{Shaft horse power}}$$

Brake horse power is the actual horse power required to be supplied by the engine or electric motor for driving the pump.

i) With direct driven pump (drive efficiency 100%)
   Brake horse power = shaft horse power
ii) With belt or other indirect drives:

$$\text{BHP} = \frac{\text{Water Horse Power}}{\text{Pump efficiency} \times \text{drive efficiency}}$$

$$\text{Horse Power Input to electric motor} = \frac{\text{Water Horse Power}}{\text{pump efficiency} \times \text{drive efficiency} \times \text{motor efficiency}}$$

$$\text{Kilowatt input to electric motor} = \frac{\text{Brake horse power} \times 0.746}{\text{Motor efficiency}}$$

EXAMPLE 14.1 : What size of electric motor is required for pumping a discharge of 450 Litre per min, against the head of 50 metre?

Assume pump efficiency as 65 per cent.

Solution –

Given

Discharge = 450 litres/minute

$$= \frac{450}{60} = 7.5 \text{ litres/sec.}$$

Head = 50 m

Pump efficiency = 65%

$$\text{WHP} = \frac{\text{Discharge (lit/sec) x head (m)}}{75}$$

$$= \frac{7.5 \times 50}{75} = 5 \text{ hp}$$

$$\text{Shaft horse power} = \frac{\text{WHP}}{\text{Pump efficiency}} = \frac{5}{0.65} = 7.69 \text{ hp}$$

Hence, Electric Motor of 8 hp is required.

Question :

a) What is power required to pump 250 litres of water per minute against a head of 50 metres, assuming pump efficiency 65%. What size electric motor is required.

b) Explain the following termes.

(i) Total discharge head (ii) Total suction head.

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Lecture 15

WATERSHED MANAGEMENT – CONCEPTS

Soil, vegetation and water are most important vital natural resources for the existence of man and his animals. These three inter-dependent resources can be managed collectively, conveniently, simultaneously and efficiently on watershed basis (unit of management.)

15.1 Watershed :

Definition : "Watershed can be defined as a unit of area which covers all the land which contributes runoff to a common point or outlet and surrounded by a ridge line". It is also known as ridge line.

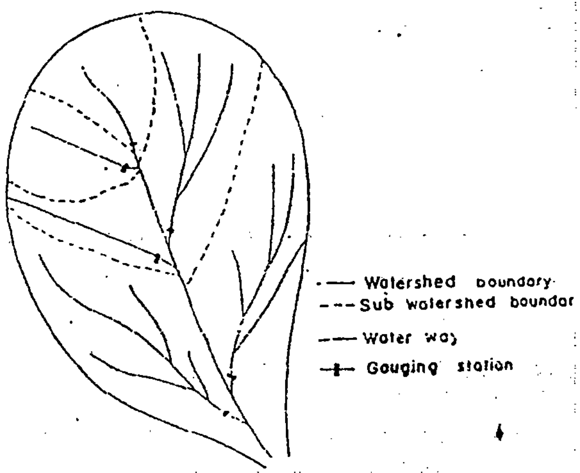

Fig 15.1 : Division of watershed into subwatersheds for determing priority areas.

15.2 delineation procedure of watershed:-

Watershed delineation is to describe or sketching out the area bounded by ridge line, contributing runoff at common point and dividing or separating it from the adjoining area.

The delineation of priority area can be performed to some extent by reconnaissance survey and study of topo-sheets. However, this technique is slow and also not provides very accurate information. Normally, the photographas of 1:60,000 scales serves more efficient, but photographs of larger scale such as 1:15,000 can also be used for the purpose.

The demarcation of priority areas should be accomplished on watershed basis, because a comprehensive watershed management approach is essential for carrying out for proper soil conservation measures. It is also necessary that, the size of watershed to be delineated should be ranges from 10,000 to 20,000 ha, because for small watersheds the formulation of soil conservation working plans and their execution over reasonable period is practically possible and easy, too.

The steps for demarcation of small size watershed are described as under :

1) Divide the entire watershed into different sub-watersheds following important tributaries.
2) Again, divide each sub-watershed into small size, following distinct tributaries and streams passing through respective sub-watersheds.
3) Further, sub-divide each small part of watershed [as obtained in step (2) in size ranges from 10,000 to 20,000 ha.]

15.3 Classification of Watershed:-

A] A large number of terms are very frequently and loosely used to classify watersheds in different sizes [based on size]

a) Micro watersheds

b) Small watersheds

c) Large watersheds, etc.

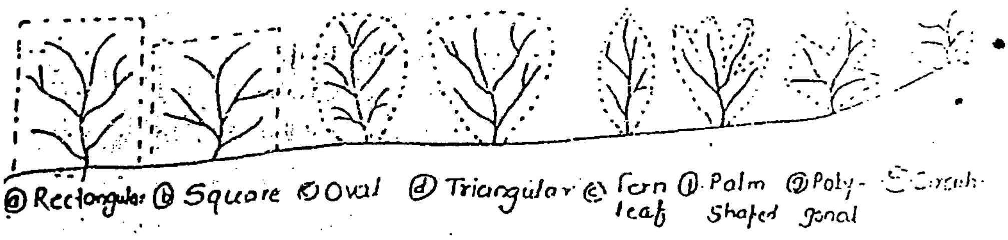

Fig 15.2 Different shapes of watershed

Small Watersheds:

"Small watersheds are those where the overland flow is the main contributor to peak runoff / flow and channel characteristics do not affect the overland flow."

Large Watersheds :

"Large watersheds are those give peak flows are greatly influenced by channel characteristics and basin storage"

B] Watersheds are also classified in different categories based on area that the watershed contains :

			Other way
a)	Micro watershed	0 to 10 ha	Less than 100 ha
b)	Small watershed	10 to 40 ha	100 – 1000 ha
c)	Mini watershed	40 to 200 ha	or
d)	Sub-watershed	200 to 400 ha	1000 – 5000 ha
e)	Macro watershed	400 to 1000 ha	5000 -10000 ha
f)	River basin	above 1000 ha	above 10000 ha

Classification based on shape :

a) Square	b) Triangular	c) Rectangular
d) Oval	e) Fern leaf shaped	f) Palm shaped
g) Polygon shaped	h) Circular	i) Secator shaped

Function of Watershed :

- The main function of watershed is to receive the incoming precipitation and then dispose it off. This is the essence of soil and water conservation.

15.4 Morphological Characteristics of Watershed :

Each individual watershed has several remarkable characteristic which affect its functioning. Seven such characteristics have been identified.

1) Size [area]
2) Shape
3) Topography
4) Geology, rock and soil

5) Climate
6) Vegetation
7) Land use.

1) Size :

Size of watershed determines the quantity of rainfall received retained and disposed off [runoff]. Larger the watershed, larger be the channel and storage of water in basin. Large watershed characteristics are topography, geology, soil, climate, land use and vegetation.

2) Shape :

Watershed may have several shapes like square, triangular, rectangular, oval, palm, fern, leaf shape. etc.

Shape of watershed determines the shape index: $= \frac{L}{W}$ or $\frac{L^2}{A}$

Shape index is the length / width ratio which in turn has a great effect on runoff disposal. Larger the watershed, higher is the time of concentration and more water will infiltrate, evaporate or get utilised by the vegetation. Reverse is the situation when watershed is shorter in length as compared to width.

Compactness coefficient Cc:- "Compactness coefficient of a watershed is the ratio of perimeter of watershed to circumference of circular area which equals the area of the watershed". The C. C. is independent of size of watershed and dependent only on the slope.

3] Topography :

a) Slope, Length, degree and uniformity of slope affect both disposal of water and soil loss. Degree and length of slope also affect time of concentration [Tc] and infiltration of water.

$$S = \frac{MN}{A} \times 100$$

Where M = Total length of contours (m)
N = Contour interval (m)
A = Size of watershed (m^2)

b) Drainage :

Topography regulates drainage. Drainage density [length of all drainage channels ÷ unit area], length, width, depth of main and subsidiary channel, main outlet and its size depend on topography. Drainage pattern affect time of concentration.

4] Geology Rock and Soil :

Geological formation and rock types affect extent of water erosion, erodibility of channels and hili faces, sediment production. Rocks like shale's, phyllites erode easily whereas igneous rocks do not erode.

Physical and chemical properties of soil, specially texture, structure and soil depth influence disposition of water by way of infiltration, storage and runoff.

5] Climate :

Climatic parameters affect watershed functioning and its manipulation in two ways.

i) Rain provides incoming precipitation along with its various characteristics like intensity, frequency and amount of rainfall.
ii) Parameters like rainfall, temperature, humidity, wind velocity, etc. regulates factors like soil and vegetation.

6] Vegetation :

Depending upon the type of vegetation and its extent, this factor regulates the functioning of watershed such as, infiltration, water retention, runoff production, erosion, sedimentation etc.

7] Land Use :

Type of land use, its extent and management are the key factors which affect watershed behavior. Judicious land use by users [human being] is of vital importance to watershed management and functioning.

Assignment :

1) Write a short note on the concept of watershed development.
2) Give the classification of watershed. Draw a neat sketches of watershed, classified on the basis of shape.
3) Explain in brief the various characteristics of watershed.
4) Define delineation of watershed and describe W.S. delineation.

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Lecture 16

STEPS IN EVALUATION OF WATERSHED.

Evaluation : It is a process to see the assessment of impact of watershed development programme. Evaluation of watershed management work should be done on two terms -

1) By achievement of management objectives / practices: fllod, control, sediment control, water supply etc. and
2) Financial returns.

   The financial returns are evaluated in terms of benefit cost ratio. The B:C ratio should be minimum 1.5 : 1. Cost includes expenditure incurred on watershed development programme and benefit concerns the change or improvement in each activities and measures in terms of money.

Evaluation of watershed development programme is carried out by comparing the situation between the pre-development conditions (untreated w.s.) and post development conditions (Treated w.s.)

1. Collection of technical data on agronomical & engineering measures adopted in watershed.
2. Socio – economical data collection (before & after w.s. development project)
3. Impact on ground water recharging, irrigated areas.

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