FUNDAMENTALS OF SOIL WATER CONSERVATION AND ENGINEERING

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INDEX

STUDY AND USE OF SURVEYING AND LEVELING INSTRUMENTS

Surveying is defines as the art of determining the relative positions of various points above, on or below the surface of the earth.

The ultimate object of survey is to prepare a map or plant using the data obtained through the survey. The collection of data by linear and angular measurements and elevation difference is called the field work. The processing of data plotting and computation of area and volume are called office work.

Use of agricultural survey

Surveying is primarily divided into two types.

(1) Plane surveying

(2) Geodetic surveying

Agricultural surveying is the simplest form of plane surveying. With the use of survey, the boundaries of fields can be correctly located and area can be accurately computed. Land leveling and grading may be perfectly done if the differences in elevations are known. Alignments of canals for irrigation and drainage can be effectively done by proper surveying. Surveying plays a vital role in soil conservation measures like contour bunding, graded bunding, bench terracing construction of farm ponds and percolation ponds etc. In addition to this, surveying plays a key role in laying underground pipe line system, alignment of irrigation channels, drainage systems, farm roads and farm stead construction etc.

For linear and angular measurements in the plains, chain, compass and plane table surveys are used with necessary instruments. To determine the difference in elevation a dumpy level is used. The details of instruments used in each survey are given below:

1. Chain survey

1. Chain and Tape
2. Cross Staff
3. Ranging rods
4. Offset Rods
5. Arrows

2. Compass Survey

1. Prismatic Compass
2. Chain
3. Ranging Rods
4. Offset Rods

3. Plane Table Survey

1. Plane Table with Tripod Stand
2. Alidade
3. Trough Compass
4. ‘U’ frame with plumb bob
5. Spirit Level
6. Chain
7. Ranging Rods

4. Leveling

1. Dumpy Level
2. Tripod Stand
3. Telescopic Metric Staff

CHAIN AND CROSS STAFF SURVEY

Aim:

To locate the boundaries of a given field and also to determine the area.

Instruments required:

Chain, Cross staff, Arrows, Ranging rods and Offset rods

Procedure:

In order to calculate the area of any irregular shaped field, it is necessary to divide that area into number of right angled triangles and trapezoids.

Corners along the boundary of the field should be first identified and named as A, B, C, D, E, F, G *etc.* in clockwise direction. Any two stations located in opposite sides should be selected in such a way that distance between them is the longest of other stations and almost equal numbers of corners/ stations are located on both sides. Chaining should be started along the base line and offset distance to the corners on both sides to be measured simultaneously after ranging, as already explained. All the details should be entered in the field book.

Care should be taken that no offset is overlooked before the chain is moved forward. To check the accuracy of the field work boundary line between any two corners should be measured directly and compared. After the field work is over the survey data may be plotted to a suitable scale on a drawing paper.

The area enclosed by the boundary lines is divided into a number of triangles and trapezoids as shown in figure. The area of each segment is computed and written in tabular form as given below.

DETAILS OF MEASUREMENTS AND AREA COMPUTATION

S. No. (1)	Figure (2)	Chain distance (m) (3)	Base length (m) (4)	Offset (m) (5)	Mean offset (m) (6)	Area (m^2) *(4) x (6)* (7)
1.	ΔDHC	0 – 18	18	2, 26	13	234
2.	ΔHCJB	18 – 52	34	26, 28	27	918
3.	ΔJBAL	52 – 77	35	28, 22	25	875
4.	ΔLAG	77 – 90	13	22, 0	11	143
5.	ΔFKG	90 – 61	29	0, 22	11	319
6.	ΔFKIE	61 – 35	26	22, 16	19	494
7.	ΔEID	35 – 0	35	16, 0	8	280
				Total area		**3263**

DETAILS OF MEASUREMENTS AND AREA COMPUTATION

S. No. (1)	Figure (2)	Chain distance (m) (3)	Base length (m) (4)	Offset (m) (5)	Mean offset (m) (6)	Area (m^2) *(4) x (6)* (7)
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
				Total area		

COMPASS SURVEY

RADIATION AND INTERSECTION METHOD

Aim:

To determine the area of the given field by radiation and intersection method using a prismatic compass.

Instruments required:

Prismatic Compass, Chain, Arrows, and Ranging rods

Procedure:

After conducting the reconnaissance survey, the surveyor should fix up the positions of all the station, around the given field as usual. The survey may be conducted under the following methods.

(1) Radiation method

(2) Intersection method

RADIATION METHOD

(a) Field work

In this method, the approximate centre of the field is located and the compass is exactly centered over that stations, say ‘O’ by dropping a small pebble to fall from the centre of the compass and hit the peg. Then make the compass needle horizontal by adjusting the ball and socket joint.

After centering and leveling of the compass, raise the sighting vane and prism of compass. The compass box is rotated until the ranging rod at first station ‘A’ hairline of object vane and slit of the sighting vane are in the same line. Then take the reading accurately and note down the bearing of line OA.

In the similar way take bearing of lines OB, OC, OD and OE by rotating the compass box in the respective directions. The readings will indicate the angles with which the line, OA, OB, OC, OD and OE makes with the north line. Then with the help of chain, measure the distances OA, OB, OC, OD and OE on ground, after proper ranging.

(b) Plotting

By knowing the observed bearings and distances to all the stations from the centre 'O' the plan of the plot can be easily drawn by adopting a suitable scale. Join the station points A, B, C, D, E which will indicate the plan of the plot. The area enclosed by the plot may be calculated by splitting the plan into number of triangles.

Result

Area of given field by Radiation method =

INTERSECTION METHOD

(a) Field Work

This method poses a simple change from the previous method. In this method mark two points (P & Q) at a distance of 10 to 15 m in such a way that all the station points around the boundary of the plot can be seen clearly (either inside the area or outside).

Set the compass over the station point 'P' and complete the temporary adjustments. Observe bearings to all the station points, (A, B, C, D & E) in clockwise direction. Take also the fore bearing of the line 'PQ'. Shift the compass to the other station 'Q' and complete the temporary adjustments and observed the back bearing of the line 'QP'. Rotate the compass box to all other station points, (A, B, C, D & E) and note down all the bearings clearly. Also measure the base line distance (PQ). In this method there is no necessity of measuring the internal distances.

(b) Plotting

With observed data, plot the observed bearings taken at P and project the corresponding rays. Set the distance PQ and get point 'Q' by taking a suitable scale. Then draw rays from station 'Q' to all the station points. The intersection of ray pa and qa will give the location of station 'A'. Similarly locate other stations B, C, D & E. For a check, measure the distance AB, of one side, and compare them with the plotted lengths. Then field can be divided into number of triangles and the area can be calculated, summering up all the areas we will get the total area of the field.

Result:

Area of the given field by intersection method =

PLANE TABLE SURVEY

General:

In case of plane table survey, the measurements of survey lines of the traverse and their plotting to a suitable scale are done simultaneously on the field. Following are the cases in which the plane table survey is found to be useful:

(1) Compass survey cannot be carried out with success in industrial areas of the town. Plane table survey will be the best alternative in such cases.

(2) For preparing plans on a small scale, plane table survey proves to be speedy, easy and accurate.

(3) The city or town has expanded within two or three decades and it is required to plot the developed area on the previously plotted plan of the existing area.

Instruments required:

Alidade, Drawing board, Plumbing fork, Spirit level and Trough compass

Temporary adjustments of plane table:

Following three distinct operations at each survey station are carried out for the temporary adjustments of a plane table.

(1) Centering

(2) Leveling

(3) Orientation

(1) Centering

The legs of tripod are well spread out to get the convenient height for working on the board. Then, the operation of centering is carried out by means of plumbing fork or U-frame and plumb bob. This process ascertains the fact that the point on paper represents the station point on ground. The pointed end of the plumbing fork is kept on point on paper and at the other end, a plumb bob is fixed. The table or board is shifted bodily till the plumb bob hangs exactly over the peg of the station.

(2) Leveling

The process of leveling is carried out with the help of spirit level and it consists of making the table level either by ordinary tilting the board or by ball and socket arrangement or by adjusting the legs of tripod.

(3) Orientation

The process by which the position occupied by the board at various survey stations are kept parallel is known as the orientation. Thus, when a plane table is properly oriented, the lines on the board are parallel to the lined on ground which they represent. The methods of orientation are:

(i) *Orientation by magnetic needle:* In this method, the magnetic north is drawn on paper at a particular station. At the next station, the trough compass is placed along the line of magnetic north and then the table is turned in such a way that the ends of magnetic needle are opposite to the zeros of the scale. The board is then fixed in position by clamps. This method is inaccurate in the sense that the results are likely to be affected by the local attraction.

(ii) *Orientation by back sighting:* In this method, the orientation is carried out by the back sighting of a particular line. Suppose a line is drawn from station A on paper representing line AB on ground. The table is centered and leveled at station B and then the alidade is placed along the line ba. The table is turned till the line of sight bisects the ranging rod at A. The board is then clamped in this position. This method is better than the previous one and it gives perfect orientation.

Methods of plane table survey:

Following are the four methods by which an object might be located on paper by plane table:

(1) Radiation
(2) Intersection
(3) Traversing
(4) Resection

RADIATION

This is the simplest method and it is useful only when the whole traverse can be commanded from a single station. The procedure is as follows:

(i) Select a point P so that all the corners of the traverse ABCD are seen.

(ii) Carry out the usual temporary adjustments of centering and leveling. Mark the north line on paper.

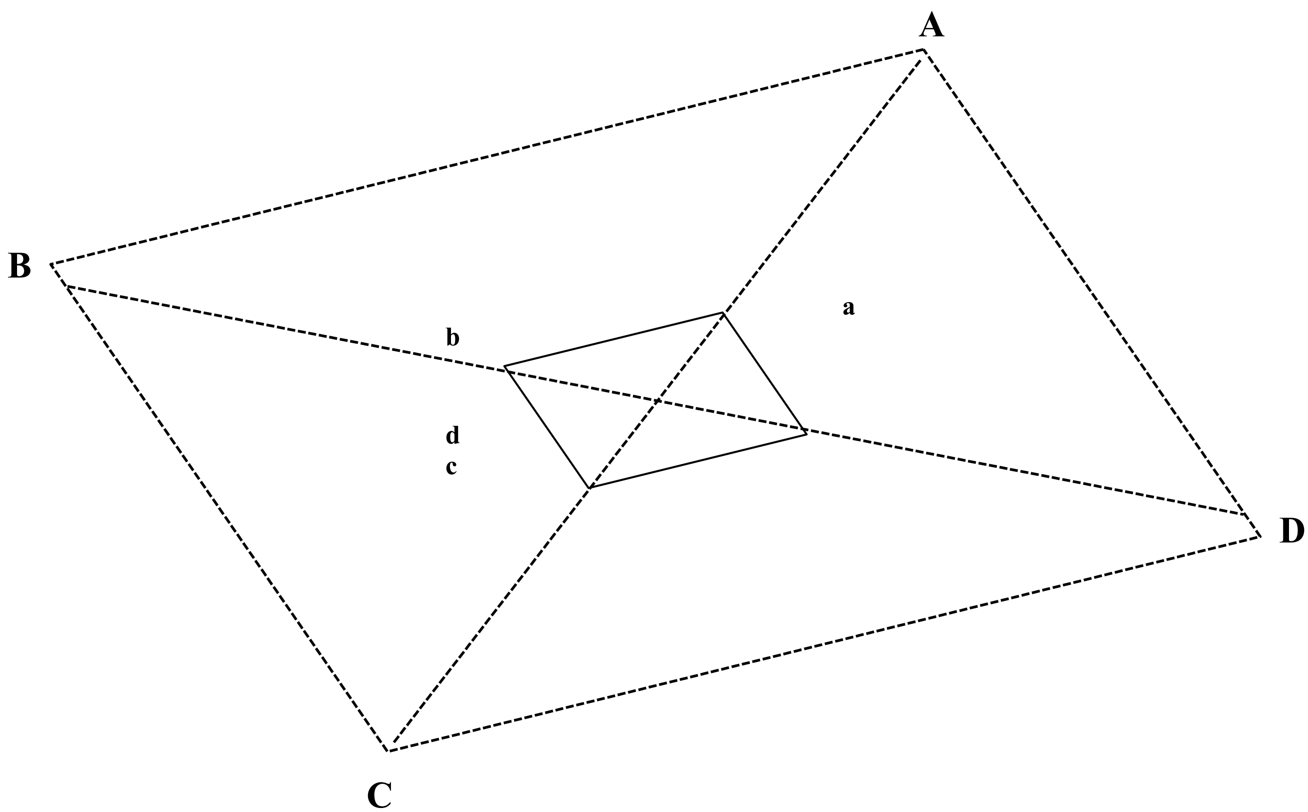
(iii) Put the alidade on point P and dram a line of sight for station A.

(iv) Measure the distance PA on ground and put this length to a suitable scale on paper which will give point a.

(v) Similarly, obtain points b, c and d on paper by drawing lines of sight for stations B, C and D and measuring the distances PB, PC and PD on ground respectively.

(vi) Join points a, b, c and d on paper, as shown in figure.

(vii) For checking the accuracy of work, measure the distances AB, BC, CD and DA on ground and compare them with the lengths ab, bc, cd and da respectively on paper.



Radiation method

INTERSECTION

This method is useful where it is not possible to measure the distances on ground as in case of a mountainous country. Hence, this method is employed for locating inaccessible points, the broken boundaries, rivers, fixing survey stations, etc. The procedure is as follows:

(i) Select two stations P and Q so that the points to be located on paper are easily seen from them.

(ii) Plot the line pq, which is known as the base line, on paper. This can be done in one of the two ways:

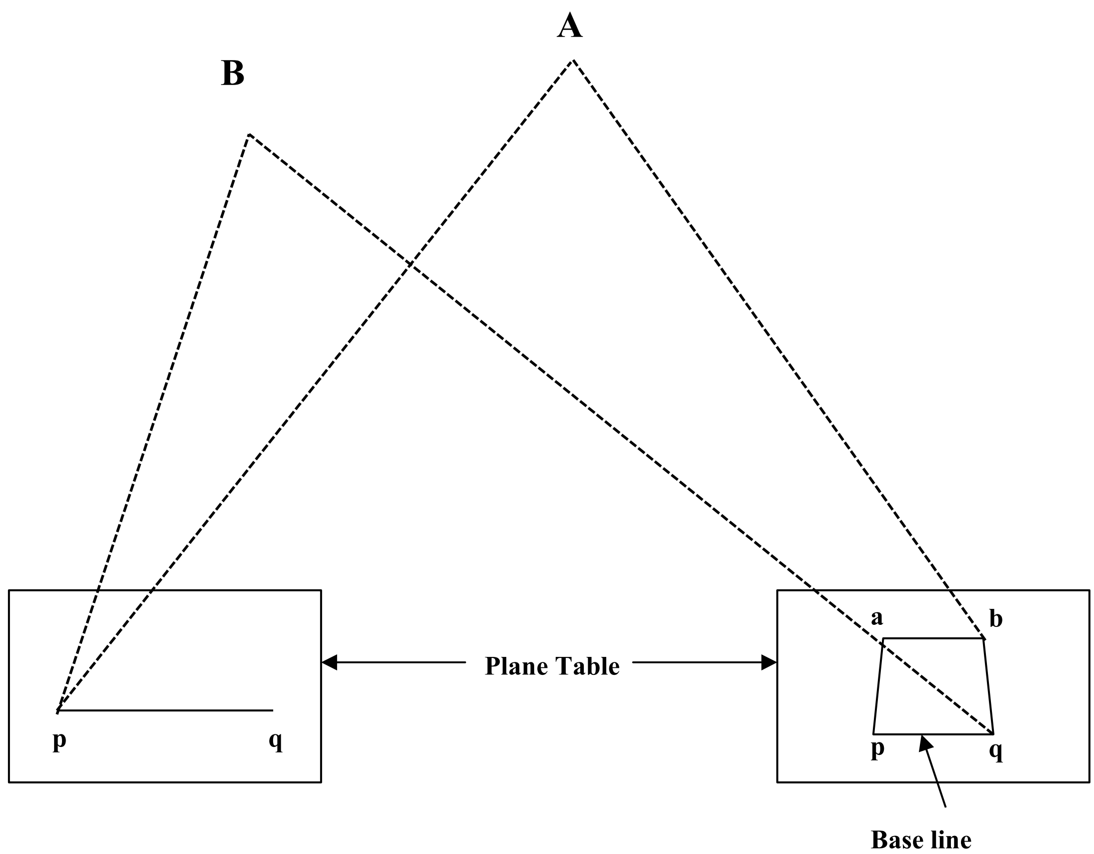
  a. The table can be centered and leveled at station P and then after orienting at station Q, the distance PQ can be accurately measured and put up to some scale on the paper.
  b. The line pq can be drawn to some scale on the paper and then the board can be adjusted from station P by back sighting at station Q.

(iii) From station P, draw rays for stations A, B, etc.

(iv) Shift the table to station Q and after proper orientation, take rays of stations A, B etc.,

(v) The intersection of rays from stations P and Q will give points a, b etc. on paper, as shown in figure.

(vi) For checking the accuracy of work, measure the distance AB on ground and compare it with its corresponding length ab on paper.



Intersection method

DUMPY LEVEL

HEIGHT OF COLLIMATION AND RISE & FALL METHOD

Aim:

To determine to difference in elevation between the given points adopting height of collimation (HC) and rise & fall method.

Instruments required:

Dumpy Level with stand, Telescopic Metric Staff

HEIGHT OF COLLIMATION

Procedure:

Compound leveling in also called as differential or fly leveling. This leveling is resorted under the following circumstances.

1. When the two stations are quite apart beyond the reach of telescope.
2. Difference in elevation is too great.
3. There is an obstacle between the two stations.

Under the above circumstances, a number of settings of the instrument are required. We have to start the levels from one station and carry out upto the end station continuously. Hence we have to conveniently install some change points.

After setting the instruments, the first reading we have to take it on a station of known elevation, called as Bench Mark and the sight is known as 'Back Sight'. The reading taken on the staff held at last point whose elevation is to be determined, just before shifting the instrument is called 'Fore Sight'. Normally the back sight distance and fore sight distance should be approximately equal to eliminate instrumental errors.

The sights that are taken on the intermediate stations are called 'Intermediate Sights' normally. Changed point is a point where we take two readings one fore sight, from the previous station and one back sight from the successive station.

Suppose we want to determine the difference in elevation between P & Q stations which are quite apart, we have to select number of change points as required. As shown in figure first set the instrument at O_1, and take a back sight on station P_1 of known elevation. Then keep the staff at CP_1 and take a foresight. Then shift the instrument to station O_1 and set it. Then take a back sight to CP_2. Similar way repeat the procedure till the station Q is touched. If any intermediate sights are needed that also can be taken. Then the reduced levels can be worked out systematically tabulating the reading. There is a separate field book available for working out reduced levels (RL). The RL can be computed in two ways (1) Height of Collimation (2) Rise and Fall method. The HC method is a very simple method, less tedious method quicker than rise and fall method. It can be used when there are no inter sights.

Back sight *(1)*	**Inter sight** *(2)*	**Fore sight** *(3)*	**HC** *(4)*	**RL** *(5)*	**Remarks** *(6)*
0.500			100.500	100.00	Bench mark, P
0.750		0.890	100.450	99.700	CP_1
0.650		1.250	99.850	99.200	CP_1
		1.300		98.550	Station Q
1.900		3.350		1.450	

Arithmetical check:

$\sum$ Back - $\sum$ Fore = Difference between point first RL and last RL

Result:

The difference in elevation between stations P & Q,

100.000 – 98.550 = 1.450 m

Back sight *(1)*	**Inter sight** *(2)*	**Fore sight** *(3)*	**HC** *(4)*	**RL** *(5)*	**Remarks** *(6)*

RISE AND FALL METHOD

The following table shows a page of level book for rise and fall method. There are seven columns. The first three columns are exactly same as in the previous table. Instead of columns HC there are two columns marked rise and fall respectively. The last two columns are also identical with previous table.

Back sight *(1)*	**Inter sight** *(2)*	**Fore sight** *(3)*	**Rise** *(4)*	**Fall** *(5)*	**RL** *(6)*	**Remarks** *(7)*
2.150					100.000	Back bearing on P
1.64		1.650	0.500		100.500	CP_1
	2.345			0.700	99.800	Inter
		1.965	0.380		100.180	CP_2
1.425		1.825		0.400	99.780	Station
5.220		5.440	0.880	1.100	0.220	

Arithmetic check

The calculations is based on the principle that two consecutive readings from same instrument station give the difference of levels, which may be rise from the proceedings station or fall. The RL of the various stations are computed by adding rise to the preceding station or by subtracting the fall. The major advantage of this system is it gives a visual picture of topography. The RL of intermediate station is also checked under this method, and this method is recommended for a long run of differential leveling for important and accurate works.

$\sum$ Back sight - $\sum$ Fore sight = $\sum$ Rise - $\sum$ Fall = Last RL – First RL

Result:

The difference in elevation between the given station =

Back sight *(1)*	Inter sight *(2)*	Fore sight *(3)*	Rise *(4)*	Fall *(5)*	RL *(6)*	Remarks *(7)*

COMPUTATION OF AREA AND VOLUME

Aim:

One of the main objectives of the surveying is to compute the areas and volumes. Generally, the lands will be of irregular shaped polygons. There are formulae readily available for regular polygons like, triangle, rectangle, square and other polygons. But for determining the areas of irregular polygons, different methods are used.

They are:

(1) Graphical method

(2) Co-ordinate method

(3) Planimeter

Out of these three methods, the co-ordinate method is popularly used, in land surveying for computing catchment area, drainage area, cross section of rivers, channels etc. Under this method the given area is split into two with a base line run at the centre. There are two important rules available.

1. Trapezoidal Rule

In this method, boundaries between the ends of ordinates are assumed to be straight. Thus the area enclosed between these line and the irregular boundary lines are considered as trapezoids.

$$A = \frac{d}{2}\left[O_1 + O_n + 2\left(O_2 + O_3 + O_4 + \ldots + O_{n-1}\right)\right]$$

A = distance between ordinate/ 2*[{first ordinate + last ordinate} + 2{sum of other ordinates)

2. Simpson's Rule:

$$A = \frac{d}{3}\left[O_1 + O_n + 4\left(O_2 + O_4 + \ldots\right) + 2\left(O_3 + O_5 + \ldots\right)\right]$$

$$A = \frac{\text{Common distance (d)}}{3}\left[\left(\text{First ordinate} + \text{Last ordinate}\right) + 4\left(\text{Sum of even ordinates}\right) + 2\left(\text{Sum of odd ordinates}\right)\right]$$

Limitations:

The rule is applicable only when the number of divisions is even or the number of ordinates are odd sometimes one or both end ordinates may be zero. However hey must be taken into account while applying rules.

WORKOUT PROBLEMS

1. The following offsets were taken from a chain line to an irregular boundary line at an interval of 10 m. 0, 2.50, 3.50, 5.00, 4.60, 3.20, 0 m. Compute the area between the chain line, the irregular boundary line and the end offsets by:

(a) Trapezoidal Rule

(b) Simpson's Rule

(a) Trapezoidal Rule

Here d = 10

$$\text{Area} = \frac{10}{2}\left\{0 + 0 + 2\left(2.50 + 3.50 + 5.00 + 4.60 + 3.20\right)\right\} = 5 * 37.60 = \mathbf{188\ m^2}$$

(b) Simpson's Rule

D = 10

$$\text{Area} = \frac{10}{3}\left\{0 + 0 + 4\left(2.50 + 5.00 + 3.20\right) + 2\left(3.50 + 4.60\right)\right\} = \frac{10}{3} * 59.00 = \mathbf{196.66\ m^2}$$

2. The following offsets were taken from a survey line to a curved boundary line:

Distance (m)	0	5	10	15	20	30	40	60	80
Offset (m)	2.50	3.80	4.60	5.20	6.10	4.70	5.80	3.90	2.20

Find the area between the survey line, the curved boundary line and the first and last offsets by (a) Trapezoidal Rule and (b) Simpson's Rule.

Here, the intervals between the offsets are not regular throughout the length. Soothe section is divided into three compartments.

Let,

Δ_1 = Area of the 1st section

Δ_2 = Are of the 2nd section

Δ_3 = Area of the 3rd section

Here,

d_1 = 5 m

$d_2 = 10$ m

$d_3 = 20$ m

(a) Trapezoidal Rule:

$$\Delta_1 = \frac{5}{2}\left\{2.50 + 6.10 + 2\left(3.80 + 4.60 + 5.20\right)\right\} = 89.50 \text{ m}^2$$

$$\Delta_2 = \frac{10}{2}\left\{6.10 + 5.80 + 2\left(4.70\right)\right\} = 106.50 \text{ m}^2$$

$$\Delta_3 = \frac{20}{2}\left\{5.80 + 2.20 + 2\left(3.90\right)\right\} = 158.00 \text{ m}^2$$

Total Area = 89.50 + 106.50 + 158.00 = **354.00 m^2**

(b) By Simpson's Rule

$$\Delta_1 = \frac{5}{3}\left\{2.50 + 6.10 + 4\left(3.80 + 5.20\right) + 2\left(4.60\right)\right\} = 89.66 \text{ m}^2$$

$$\Delta_2 = \frac{10}{3}\left\{6.10 + 5.80 + 4.70\right\} = 102.33 \text{ m}^2$$

$$\Delta_3 = \frac{20}{3}\left\{5.80 + 2.20 + 4\left(3.90\right)\right\} = 157.33 \text{ m}^2$$

Total area = 89.66 + 102.33 + 157.33 = **349.32 m^2**

EXERCISE

The following offsets were taken at 15 m intervals from a survey line to an irregular boundary line. 3.50, 4.30, 6.75, 5.25, 7.50, 8.80, 7.90, 6.40, 4.40, 3.25 m. Calculate the area enclosed between the survey line, the irregular boundary line and the first and last offsets by:

(a) Trapezoidal Rule

(b) Simpson's Rule

COMPUTATION OF VOLUMES

The computation of volumes of various quantities from the measurements done in the field is required in the design and planning on many engineering works. The volume of earth work is required for suitable alignment of road works, canal and sewer lines, soil and water conservation works, farm pond and percolation pond consent.

The computation of volume of various materials such as coal, gravel and is required to check the stock files, volume computations are also required for estimation of capacities of bins tanks etc.

For estimation of volume of earth work cross sections are taken at right angles to a fixed line, which runs continuously through the earth work. The spacing of the cross sections will depend upon the accuracy required. The volume of earth work is computed once the various cross-sections are known, adopting Prismoidal rule and trapezoidal rule.

Trapezoidal rule : $V = \frac{D}{2}\left[A_1 + A_n + 2\left(A_2 + A_3 + \ldots + A_{n-1}\right)\right]$

Prismodial rule : $V = \frac{D}{3}\left[A_1 + A_n + 4\left(A_2 + A_4 + \ldots\right) + 2\left(A_3 + A_5 + \ldots\right)\right]$

Where,

D - common distance between sections

$A_1, A_2, \ldots A_n$ = cross sectional areas

WORKOUT PROBLEMS

1. Compute the cost of earth work involved in cutting open a trench of following size. Length 200 m, side slope 2: 1, depth of trench 4 m, bottom, width of trench 1.5 m. Cost of earth work Rs. 50 per m^3.

Cross sectional area of trench, $A = (b + sh)*h$

$A = (1.5 + 2*4)*4$

$A = 9.5 * 4 = 38\ m^2$

$\therefore$ Volume of earth work, $V = A*L = 38 * 200 = 7600\ m^3$

$\therefore$ Cost of earth work = 7600 * 50 = **Rs. 3,80,000.00**

2. Compute the volume of earth work involved in constructing a farm pond of the following size: size, at bottom 6 x 4 m. Side slope 2: 1, depth of pond 4 m work out the cost of earth work also if it costs Rs. 50 per m^3.

Size of pond at bottom = 6 x 4 m

Area at bottom = 24 m^2 (a_1)

Size of pond at ground level:

Length of pond = 6 + 8 + 8 = 22 m

Breadth of pond = 4 + 8 + 8 = 20 m

Cross sectional area of pond at ground level = 20 * 22 = 440 m^2 (a_3)

Area of pond at mid height = $\frac{(22+6)}{2} * \frac{(20+4)}{2}$ = 14 *12 =168 m^2 (a_2)

Using prismoidal rule, $V = \frac{D}{2}\left[a_2 + a_3 + 2(a_2)\right]$

$$V = \frac{D}{2}\left[24 + 440 + 2(168)\right]$$

$$V = \frac{2}{2}\left[464 + 336\right] = 800 \ m^3$$

$\therefore$ Cost of earth work = 50 * 800 = **Rs. 40, 000**

EXERCISE

1. The three cross section of embankment at an interval of 30 m. Compute the volume of earth required to form the embankment?

SOIL EROSION CONTROL

MECHANICAL MEASURES

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

Contour Bunding

As discussed in exercise 8.

Design of contour bunds

Vertical Interval between bunds (V.I)

$$V.I = \left(\frac{S}{a} + b\right)0.3$$

where,

S – land slope (%); a and b are constants

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

a = 2 and b =2 for low rainfall zones

Horizontal Spacing in between bunds (H.I)

$$H.I = \frac{V.I}{S} \times 100$$

Length of bund per hectare (L.B)

$$L.B.\ \text{per ha} = \frac{100S}{V.I} \text{ or } \frac{10,000}{H.I}$$

Depth of water impounding before the bund (h)

$$h = \sqrt{\frac{D^* R}{500}}$$

where,

D – vertical interval (m)

R – maximum rainwater on area basis (mm)

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

DIMENSIONS OF THE CONTOUR BUND

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

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

Graded Bunds

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

The spacing between two graded is based on the formula

$$V.I = \left(\frac{S}{a} + b\right) 0.3$$

where
,

V.I – vertical interval (m)

S – slope (%)

a – constant value ranging from 3 to 4; b = 2

GRADED BUND SPECIFICATION

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

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

Broad Base Terrace

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

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

Design of board base terrace

1. Horizontal Interval (H.I.) in meters

$$H.I = \frac{200}{S} + 10$$ where S is slope in %

2. Vertical Interval (V.I) in meters

$$V.I = 2 + \frac{S}{10}$$

3. Length of the terrace per hectare

$$L = \frac{10,000}{H.I}$$

4. Channel design

The channel capacity is calculated by using the rational formula and the dimensions of the channels are predicted by using the Manning's formula and the permissible velocities.

Contour Stone Wall

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

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

Design of contour stone wall

1. Vertical Interval (V.I) in meters

$$V.I. = \frac{S}{8} + 4$$

2. Horizontal Interval (H.I) in meters

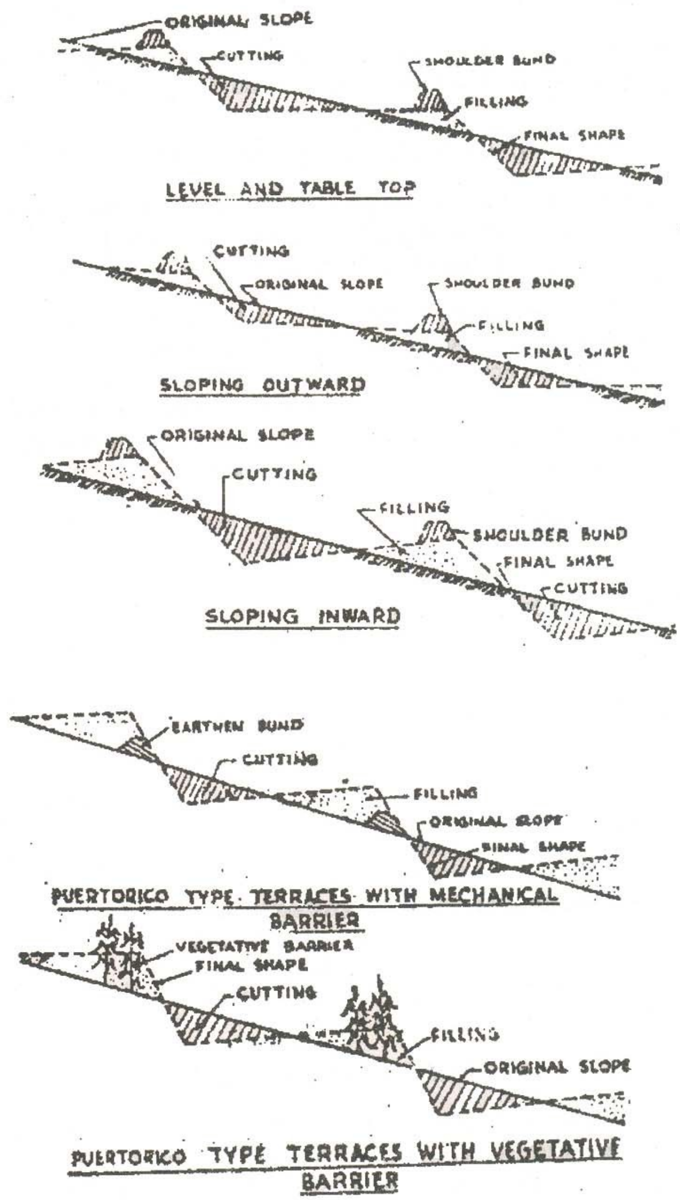
$$H.I = \frac{V.I}{S} \times 100$$

3. Length per hectare

$$L = \frac{10{,}000}{H.I}$$

4. Volume of stones required ($m^3\ ha^{-1}$)

V = Cross sectional area of the stone wall x Length per hectare



Bench Terracing

Bench Terracing

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

Type of bench terraces and their adaptability

1. ***Level Bench Terrace:*** Paddy fields require uniform impounding of water. Level bench terraces are used for the same and to facilitate uniform impounding. Sometimes this type of terraces are termed as table top, or paddy terraces, conveying the same that such bench is as level as top of the table.
2. ***Inward Sloping Bench Terrace:*** Crops like potato are extremely susceptible to water logging. In that case the benches are made with inward slope to drain off excess water as quickly as possible. These are especially suited for steep slopes. It is essential to keep the excess runoff towards hill (original ground) rather than on fill slopes. These inwardly sloping bench terraces have a drain on inner side, which has a grade along its length to convey the excess water to one side, from where it is disposed-off by well stabilized vegetated waterway. These are widely used in Nilgiri hills of Tamilnadu state as well as on steep Himalayan slope in Himachal Pradesh and North-Eastern hill regions. Longitudinal slope of 1 in 120 and inward slope of 1 in 40 is adopted in Nilgris.
3. ***Outward Sloping Bench Terraces:*** Farmers many a times carry out the leveling process in phases, doing part of the job every year. As such outward sloping bench is usually a step towards construction of level or inward sloping bench terraces. In places of low rainfall or shallow soils, the outwardly sloping bench terraces are used to reduce the existing steep slope to mild slope. In this type of terraces constructed on soils not having good permeability, provision of graded channel at lower end has to be kept, to safely dispose off surplus water to some

water way. In very permeable soils a strong bund with arrangement may take care for most of the rainfall events, while during heavy rainfall storm, the excess water may flow from one terrace to another. Attempt is usually made to dispose-off this to some waterway at an earliest possible spot.

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

Design of Bench Terraces

1. Type of Bench Terrace

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

2. Terrace Spacing and Width

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

Steps for terrace spacing design

i. Find the maximum depth of productive soil range

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

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

$W = \frac{200d}{S}$ where W and d are in meters and S in %

and $d = \frac{D}{s}$ where D – vertical interval

iv. For a batter slope of 1: 1 riser, the vertical interval is

$$D = \frac{WS}{100 - S}$$

and for a batter of 0.5: 1 riser, the vertical interval is

$D = \frac{2WS}{200 - S}$ and the width of the terrace will vary suitably.

3. Terrace Gradient

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

4. Terrace Cross Section

The design of terrace cross section involves the batter slope, cross section area of the shoulder bund, inward or outward slope of the terrace field.

Trenches

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

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

Example

On a 20% hill slope, it is proposed to construct bench terraces. If the vertical interval is 2 m, calculate (i) length per hectare, (ii) earthwork, and (iii) area lost both for vertical cut and batter slope of 1: 1. The cut should be equal to fill.

Solution:

For vertical cut,

$$W = \frac{100 * D}{S} = \frac{100 * 2}{20} = 10 \text{ m}$$

$$\text{Length per hectare} = \frac{10,000}{10} = 1000 \text{ m}$$

$$\text{Earthwork} = \frac{1}{2} * 5 * \frac{2}{2} * 1000 = 2500 \text{ m}^3$$

Since it is vertical cut, no area is lost for cultivation, except the area for shoulder bund.

When the batter slope 1: 1

$$W = \frac{100(100 - S)}{S} = \frac{2(100 - 20)}{20} = 8 \text{ m}$$

$$\text{Length per hectare} = \frac{10,000}{8 + 1 + 1} = 1000 \text{ m}$$

$$\text{Earthwork per hectare} = \frac{1}{2} * 4 * 1 * 1000 = 2000 \text{ m}^3$$

Area lost for cultivation = 21.57%

SOIL EROSION

1. Soil erosion
2. Soil erosion - three phase phenomena

   * Detachment
   * Transportation   By wind, H_2O and gravity
   * Deposition
3. Action of wind and water
4. Two forms of energy

   Potential energy PE = mgh (head)

   Force N = kgm / sec^2 Nm/sec = watt = kg m^2

   mgh = sec^2

   2. Kinetic energy

   $\frac{1}{2} mv^2$
5. **Factors affecting soil erosion**

   * Rainfall * Runoff * Wind * Soil * Slope * Plant cover * Temperature
6. **Two broad classification**

   1. Geologic / natural / normal erosion

   Formation and loss simultaneously which maintain the balance between formation and losses.

   2. Acceleration

   Deterioration by mankind by wind, water, gravity & glaciers

Water erosion

- Rain drop erosion
- Sheet erosion
- Rill erosion
- Gully erosion

- Stream bank erosion

Mechanics of water erosion

i) Hydraulic action

The force exerted by the air in the voids

ii) Abrasion

Shear force of water to scour the soil

iii) Attrition

Mechanical breakdown of loads.

iv) Solution

Chemical action between soil and H_2O

v) Transportation

Depends on velocity / type of load

vi) Deposition

Whenever the velocity is lower than the carrying capacity, then the loads will be deposited on the bed of the water course.

GULLY EROSION

❖ It is an advanced stage of rill erosion in which the size of the rill is so enlarged which cannot be rectified by ordinary tillage implemnts.

❖ Process of gully formation follows sheet and rill erosion

❖ It also occurs when runoff volume from a sloppy land increases sufficiently or increase in flow velocity to cut deep inversions or when concentration of runoff water is long enough in the same channel

1. It can be formed by unchecked rills.
2. It can be formed on natural depressions where runoff water accumulates.
3. It can be formed on the track formed by vehicle movements.

Gully Developing process

Stage 1 : Initiation stage

During this stage the channel erosion and deepening of gully bed takes place. This stage normally process slowly where the top soil is resistant to erosion.

Stage 2 : Development stage

In this stage, both depth and width of the gully are getting increased due to waterfall action of the flowing velocity. So the loose soil materials will be washed away. Lot of soil erosion takes place in this stage.

Stage 3. Healing stage

After the developmental stage the further degradation slowly comes to halt. Then the healing stage takes place. In this stage the vegetations are slowly coming up in the bed as well as in the side slopes of the gully.

Stage 4 : Stabilization stage

Almost in this stage, gully, stabilization takes place. Here the healing process is fully completed and the channel obtained a stable bed gradient and side slopes. Vegetation will grow abundantly to cover the soil surface and develop new top soil.

Classification of gully

I. Based on shape

i) 'U' shaped gully

This type is formed in alluvial plains where surface and subsurface soils are easily erodable. The runoff flow undermines and then the gully banks are collapsed which results in the formation of vertical side walls and in this way the 'U' shaped gullys are formed.

ii) 'V' shaped gully

I is developed where the sub soils are tough to resist the rapid cutting of soil by runoff flow. As resistance to erosion increases with depth, the width of cut decreases and so 'V' shaped gullys are formed.

In hilly regions the 'V' shaped gullys are quite common because of this high flow velocity in steep slope and also the flow volume is common.

II. Based on state of the gully

1. Active gully

Whole dimensions are enlarged with time. The size enlargement is based on the soil characteristics land use and volume of runoff passing through the gully. The guly's found in plain areas are active in nature.

2. Inactive gully

Whose dimensions are constant with time. The gullys found in rocky areas are inactive, because rocks are very tough to erosion by the runoff flow.

III. Based on the dimension of the gully

1. Small gully

These are these, that can be easily crossed by farm implements and removed by ploughing and smoothing operations and by stabilizing the vegetation.

2. Medium gully

Are those that cannot be easily crossed by farm implements. They can be controlled by terracing or ploughing operations. The sides are stabilized by creating vegetative growth on them.

3. Large gully

Those which went beyond their reclaimable stage and for stabilization tree planting may be done as an effective method.

Gully control

The following methods are to be followed to control the gullys

a) Treatment of catchment area

b) Division of gully

c) Stabilization of gully head

d) Stabilization of gullys

i) Biological measures

ii) mechanical measures

a) Treatment of catchment area

Catchement area can be treated as per the requirements.

1 - 3% slope	-	Contour bunds, vegetative bunds
4-10% slope	-	Graded bund, graded trench
11-15% slope	-	Bench terraces, inward sloped bench terraces, outward sloped bench terraces
16-33% slope	-	Countour stone wall, staggered stone wall, staggered stone wall
> 33%	-	Afforestation ie. planting of trees

b) Diversion of gully

The gully can be directed for a small distance inorder to stabilize the head of the gully. The head of the gully can be stabilized by stone pitching, masonry construction, sodding of grasses inorder to control further scouring.

The diverted water course can join the main gut after some time.

d) Stabilization of gully

i) Biological measures

If the vegetation is increased on the gully bed then the velocity of flow could be reduced thereby the transformed matter could be deposited on the head of the gully so thick vegetation would start coming up on the side bed. If biological measures, are not effective, then we can go for mechanical measures.

ii) Mechanical measures

It consists of masonry structure across the gully as well as along the side slope of the gully.

Check dams

Check dams can be constructed across the gully the check dam consists of body wall and side walls apron may be provided in d/s side to preventing scouring of water.

Retaining walls

Retaining walls can be constructed invulnerable places along the side walls of the gullys. Retaining walls can be plastered or even without plastered. In the case of without plastered, it is called 'dry stone pitching'

Different types of check dams

i. Brush wood dam

ii. Loose rock dam or rock fill dam Temporary structures

iii. Gabion or netting dam

Causes : Gully erosion

There are several causes to activate the gully formation. Some examples are given below.

1. Creating the land surface without vegetation

2. Adoption of faulty tillage practice
3. Overglazing and other forms of biotic pressure on the vegetative cover existing on the land surface.
4. Absence of the vegetative cover
5. Not smoothening of rills, channels or depressions present on the ground surface.
6. Improper construction of water channels, roads, rain line, cattle trails etc.

Main theory of gully control structures are

1. Velocity is reduced, so carrying capacity of soil is reduced.
2. The slope is being cut in to small flat terrain
3. The water will stagnate and has the opportunity to percolate inside the ground water resources.

Stream bank erosion

It is a kind of water erosion in which soil is removed either by the runoff flowing over the sides of the stream, coming into the stream from U/S areas or by scouring and undercutting of soil below the water surface.

Land slide

Movement of soil mass from upper portion of the mountain to the lower portion is called land slide. To prevent land slide vegetative cover has to be increased in the land slide prone areas. To arrest land slide completely is a very difficult task. Retaining walls could arrest land slide to some extent.

Erosivity

It is defined as the potential ability of rainfall to cause erosion. It is rainfall factor it depends upon the physical characteristics of rainfall which include raindrop size, drop size distribution, kinetic energy, terminal velocity etc.

Erodibility

It is defined as the vulnerability or susceptibility of the soil to be eroded. It is the function of physical characteristics of the soil. It is a soil factor. The physical character includes the texture, structure, organic matter content.

Mid Semester Examination

Best of Luck

DESIGN OF CONTOUR BUND

Contour Bunding

Contour bunding is the construction of small bund across the slope of the land on a contour so that the long slope is cut into a series of small ones and each contour bund acts as a barrier to the flow of water, thus making the water to walk rather than run, at the same time impounding water against it for increasing soil moisture. Contour bunds divide the length of the slope, reduce the volume of runoff water, and thus preventing or minimizing the soil erosion.

Contour bunds are constructed in relatively low rainfall areas, having an annual rainfall or less than 600 mm, particularly in areas having light textured soils. For rolling and flater lands having slopes from 2 to 6% contour bunding is practiced, in red soils.

Design of contour bunds

Vertical Interval between bunds (V.I)

$$V.I = \left(\frac{S}{a} + b\right)0.3$$

where,

S – land slope (%); a and b are constants

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

a = 2 and b =2 for low rainfall zones

Horizontal Spacing in between bunds (H.I)

$$H.I = \frac{V.I}{S} \times 100$$

Length of bund per hectare (L.B)

$$L.B. \text{ per ha} = \frac{100S}{V.I} \text{ or } \frac{10,000}{H.I}$$

Depth of water impounding before the bund (h)

$$h = \sqrt{\frac{D * R}{100}}$$

where,

D – vertical interval (m)

R – maximum rainwater on area basis (mm)

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

DIMENSIONS OF THE CONTOUR BUND

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

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

Example:

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

Solution:

$$V.I. = \frac{30S}{3} + 60 = 90 \text{ cm} = 0.9 \text{ metres}$$

$$\text{Horizontal spacing} = 0.9 * \frac{100}{3} = 30 \text{ metres}$$

$$\text{Length of bund per hectare} = \frac{10000}{30} = 333 \text{ metres}$$

RUNOFF COMPUTATION AND UNIVERSAL SOIL LOSS EQUATION

Prediction of runoff is difficult as it depends upon several factors. The following method is generally used in soil and water conservation for estimating the rate or the maximum rate of runoff that could occur from a particular catchment.

Rational Method: In this method, the peak rate of runoff is given by the equation.

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

where,

Q = Peak rate of runoff ($m^3\ s^{-1}$)

I = Intensity of rainfall ($cm\ h^{-1}$) for a duration equal to the time of concentration and for the given frequency

C = Runoff coefficient, and

A = Area of the catchment (ha)

Runoff coefficient C is defined as the ratio of the peak runoff rate to the rainfall intensity. Values of C for different slopes and land use conditions, determined from field observations are given in table below.

VALUES OF ‘C’ FOR USE IN RATIONAL FORMULA

Soil Types	Land use		
	Cultivation	**Pasture**	**Forest**
With above average infiltration rate usually sandy or gravelly	0.29	0.15	0.10
With average infiltration rates, no clay pans, loams and similar soils	0.40	0.35	0.30
With below average infiltration rates, heavy clay soils or soils with a clay pan near the surface, shallow soils above impervious rock	0.50	0.45	0.40

Example: Estimate the peak rate of runoff for a 10 year frequency from a watershed of 25 hectares, having 15 hectares under cultivation (C = 0.5), 5 hectares under forests (C = 0.4) and 5 hectares under grass cover (C = 0.45). There is fall of 5 metres in a distance of 700 metres. The distance from the remotest point in the watershed to the outlet is 700 metres.

Solution:

$$\text{Weighted value of C for the entire watershed} = \frac{15 * 0.5 + 5 * 0.4 + 5 * 0.45}{25} = 0.47$$

For L = 700 m, S = 5/ 700

Time of concentration, $T_c = 0.02 L^{0.77} S^{-0.385}$

where,

T_c = Time of concentration (min); L = Length of channel reach (m)

S = Average slope of channel reach (m/ m)

$$T_c = 0.02 * 700^{0.77} * \left(\frac{5}{700}\right)^{-0.385} = 21 \text{ min}$$

1 hour rainfall intensity for 10 years frequency = 100 mm h^{-1}

Intensity for 21 minutes rainfall = 17.5 mm h^{-1}

$$\text{Peak runoff rate, } Q = \frac{0.47 * 17.5 * 25}{360} = 5.7 \text{ cumecs.}$$

Universal Soil Loss Equation

Wischmeier in 1959 presented the universal soil loss equation, which has adaptability to wide range of conditions. The factors involved in the equation and its applicability to some situations in India.

The equation is given by:

A = RKLSCP

where,

A = Average soil loss for the given period

R = Rainfall erosivity index

K = Soil erodibility factor

C = Cropping management factor

L = Length of slope factor

S = Steepness of slope factor, and

P = Conservation practice factor

The different factors in the above equation are to be selected to suit the units under considerations.

Average Soil Loss, A: This is normally expressed in tones per hectares. It may be computed for any period and also on probability basis (*e.g.* once in two years, once in five years etc.) using the rainfall erosivity index 'R' for the corresponding period.

Rainfall Erosivity Index, R*:* This is the product of the kinetic energy and the maximum 30 minutes intensity of the rain storm. Values may be expressed for any length of period (like daily, monthly or annual) or for any desired probability level.

Soil Erodibility Factor, K: This factor is expressed as tones of soil loss per hectare per unit of rainfall erosion index for a slope of specified dimensions (9 per cent and 22.0 metres long) under continuous cultivated, fallow without the influence of crop cover.

The estimated k will be given by,

$$K = \frac{\text{Total adjusted soil loss (A)}}{\text{Total EI}}$$

K values varied from 0.03 to 0.69 under gravel and silt loam conditions respectively in USA conditions. For a silt loam soil at Dehradun an average values of 0.30 tonnes ha^{-1} per EI was obtained.

Slope Length, L and Slope Factor, S: The slope length factor is the ratio of soil loss from any length of slope to that from the slope length specified (22 m generally) for a given soil erodibility value.

$$LS = \frac{\sqrt{L_p}}{100}\left(0.76 + 0.53S + 0.076S^2\right)$$

where

,

L_p = Slope length; S = per cent slope

Conservation Practice Factor, P: This is the ratio of soil loss for a given practice to that for up and down the slope farming.

CONSERVATION PRACTICES FACTOR VALUES

Slope (%)	Contouring	Contouring and Strip Cropping
1.1 – 2.0	0.60	0.30
2.1 – 7.0	0.50	0.25
7.1 – 12.0	0.60	0.30
12.1 – 18.0	0.80	0.40
18.1 – 24.0	0.90	0.45

CONSERVATION PRACTICE FACTORS FOR 4% SLOPE AS COMPARED TO 1% FOR UP AND DOWN SLOPE FARMING

Contour Cultivation : 4.74

Strip Cropping 3: 1 (Maize: Cowpea): 0.51

Strip Cropping 4: 1 (Maize: Cowpea): 0.62

By evaluating the factors of the soil loss equation, the soil loss from a field under a given set of conditions can be determined. If the soil loss is higher than the soil loss permissible for maintaining productivity, suitable changes in the crop management and conservation practices should be made to reduce the expected soil loss.

Example:

In an area subjected to soil erosion, the following information is available.

Rainfall erosivity index = 1200 metre tonned ha^{-1}; Soil erodibility index = 0.20

Crop factor = 0.60; Conservation practice factor = 1.0

Slope length factor = 0.1

What will be estimated annual loss? Explain how this soil loss will decrease by adopting conservation practices.

Solution:

Using the Universal soil loss equation, the soil loss is obtained as,

A = 1200*0.20*0.60*1.0*0.1 = 14.4 tonnes ha^{-1} $year^{-1}$

To reduce the soil loss, if conservation practices are introduced, let us say the factor P is now 0.6.

A = 14.4*0.6 = **10.44 tonnes ha^{-1} $year^{-1}$**

RAINWATER HARVESTING

What is Rainwater Harvesting?

It is the principle of collecting and using precipitation (rainfall from a catchment's surface.

An old technology is gaining popularity in a new way. Rainwater harvesting is enjoying a renaissance of sorts in the world, but it traces its history to biblical times. Extensive rainwater harvesting apparatus existed 4000 years ago in the Palestine and Greece. In ancient Rome, residences were built with individual cisterns and paved courtyards to capture rainwater to augment water from city's aqueducts. As early as the third millennium BC, farming communities in Baluchistan and Kutch impounded rainwater and used it for irrigation dams.

Storage

Groundwater Reservoirs

Rooftop rainwater collected may be recharged to groundwater reservoir through:

- Abandoned dug well
- Abandoned/ running hand pump
- Recharge shaft
- Defunct bore well
- Trench/ pit with injection well

Small storages tank above ground level (suitable for individual houses)

A simple rooftop rainwater harvesting as practiced in some villages using split pipe or GI valley sheets or Bamboo directing the flow from rooftop to a small drum or plastic tank.

If there is a group of houses, the owners can collectively lead the rainwater into a subsurface tank situated in a common place.

Another simple method of storage is letting the rainwater into the exiting well through a filter media consisting of the following.

Layer 1: Layer of sand – fine to medium (150 to 300 mm)

Layer 2: Layer of gravel (200 mm)

Layer 3: Layer of medium pebbles bed (500 mm)

There are certain limitations in adopting storage method, in places where the monsoon period is only 3 to 4 months as we require a large quantity of storage tanks of bigger dimensions, and preservation of water in the tanks for longer period is also hazardous. Hence, we have to go in for recharging method.

Rooftop Rainwater Harvesting

The groundwater available in urban localities and Metropolis could not cope up with the ever increasing demand and results in the over-exploitation of groundwater with inadequate replenishment due to urbanization. The rainwater runs off into sea as the ground area available for percolation for recharging is meager/ insignificant. Hence the rooftop rainwater harvesting method is best suitable for conservation of rainwater and recharging the groundwater aquifer.

Runoff coefficient for various surfaces

Type of catchment	Coefficients (m sec^{-1})
Roof catchments	
Tiles	0.80 – 0.90
Corrugated metal sheets	0.70 – 0.80
Ground surface coverlings	
Concrete	0.60 – 0.80
Brick Pavements	0.50 – 0.60
Untreated ground catchments	
Soil on slopes less than 10 per cent	0.00 – 0.30
Rocky natural catchments	0.20 – 0.50

Under this method, the rain pouring on the top of the roof (whatever be the roof material) is drained thorough down pipes into a recharging pit (1 x 1 x 1 m) or 0.60 x 0.60 x 0.60 m made up of broken brick jelly for 0.60 m from the bottom of the top layer is filled with river sand for 0.40 m height of the pit covered by perforated precast RCC slab.

If the water source for the building is a bore well, the recharging pit is extended to at least 10 – 15 m depth by means of a tube well or 200 mm. Diameter filled with broken brick jelly and pebbles.

Rainwater harvesting for individual house of < 100 m^2 (*Recharging pit method*)

Pit Size: 1 x 1 x 1 m

S. No.	Description	Quantity	Rate	Amount
1.	Earthwork excavation for percolation pit	1 m^3	41	41
2.	Filling the pit with 40 mm size brick jelly	0.6 m^3	312.42	188
3.	Filling the pit top with river sand	0.4 m^3	326.92	131
4.	Perforated precast RCC slab 40 mm thick for covering the pit	1 m^3	175	175
5.	Connecting the drain pipe to the pit through 150 mm diameter PVC pipe including earth works, laying, joining and sand gravel packing	10 m	400	4000
6.	Unforeseen items			465
			Total	Rs. 5000

Rainwater harvesting for multi storied building of size 20 x 30 m

(*Recharging trench method*) Trench size: All round the building 1 x 1 x 1.5 m

S. No.	Description	Quantity	Rate	Amount
1.	Earthwork excavation for open trench	126	41	5766
2.	Filling the trench with brick jelly	84	312.42	26243
3.	Filling the trench with river sand	42	326.92	1373
4.	Provision of PVC pipe 150 mm diameter including bends and clamps	24 m	275	6600

5.	Filling with pebbles in the top layer of the trench	10 m	1500	15000
6.	Unforeseen items and petty supervision charges			8260
			Total	Rs. 75000

Recharge trench cum injection well

This technique is ideally suited for areas where permeable sandy horizons within 3 to 5 m below ground level and continuous up to the water level under unconfined conditions, by which copious water available can be easily recharged.

In this technique, 1 to 2 m, wide and 2 to 3 m, deep trench is excavated, the length of which depends on the site availability and volume of water to be handled. An injection well of 100 to 150 mm diameter is constructed, piercing through the layers of impermeable horizons to the potential aquifer reaching about 3 to 5 metres below water levels (1 to 10 m) from the bottom of the trenches. Depending upon the volume of water to be injected, the number of injection wells can be increased to enhance the recharging rate.

Benefits of rainwater harvesting

- Groundwater level is increased
- Recharges the well
- Reduces crack formation in walls and structures
- Dilutes the salt content of water in the wells *i.e.* improves the groundwater quality
- Improves moisture content in the soil
- Aids the growth of plants and trees
- Seawater intrusion into the land is arrested
- Reduces the soil erosion
- Improves the groundwater quality

DESIGN OF FARM POND

Farm ponds are small tanks or reservoirs constructed for the purpose of storing water essentially from surface runoff. Farm ponds are useful for irrigation, water supply for the cattle, fish production etc.

The design and construction of farm ponds require a thorough knowledge of the site conditions and requirements. Some sites are ideally suited for locating the ponds and advantage of natural conditions should always be taken.

Types of Ponds

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Dugout Ponds are excavated at the site and the soil obtained by excavation is formed as embankment around the pond. The pond could either be fed by surface runoff or groundwater wherever aquifers are available. In case of dugout ponds, if the stored water is to be used for irrigation, the water has to be pumped out.

Surface water ponds are the most common type of farm ponds. These are partly excavated and an embankment is constructed to retain the water. Generally a site which has a depression already is chosen for this pond construction.

Spring or creek fed ponds are those where a spring or a creek is the source of water supply to the pond. Construction of these ponds, therefore, depends upon the availability of natural springs or creeks.

Off-stream storage ponds are constructed by the side of streams which flow only seasonally. The idea is to store the water obtained from the seasonal flow in the streams. Suitable arrangements need to be made for conveying the water from the stream to the storage ponds.

Components of a Farm Pond:

Figure below shows a typical layout of a farm pond. The pond consists of the storage area, earthen dam, mechanical spillway and an emergency spillway. The mechanical spillway is used for letting out the excess water from the pond and also as an outlet for taking out the water for irrigation. The emergency spillway is to safeguard the earthen dam from overtopping when there are inflows higher than the designed values.

Design of Farm Pond

The design of farm ponds consists of

(1) Selection of site

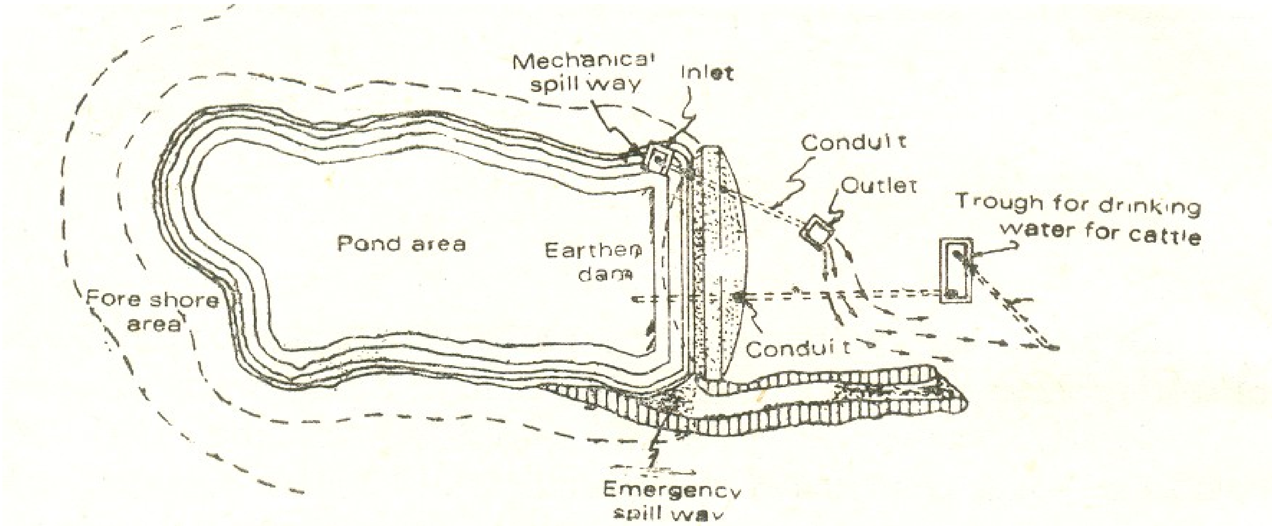
(2) Determination of the capacity of the pond

(3) Design of the embankment

(4) Design of the mechanical spillway

(5) Design of the emergency spillway

(6) Providing for seepage control from the bottom



(1) Selection of site

Selection of suitable site for the pond is important as the cost of construction as well as the utility of the pond depend upon the site. The site for the pond is to be selected keeping in view of the following considerations:

1. The site should be such that largest storage volume is available with the least amount of earth fill. A narrow section of the valley with steep sides slopes is preferable.
2. Large areas of shallow water should be avoided as these will cause excessive evaporation losses and also cause water weeds to grow.
3. The site should not cause excessive seepage losses.
4. The pond should be located as near as possible to the area where the water will be used. When the water is to be used for irrigation, gravity flow to the areas to be irrigated is preferable.

Capacity of the Pond

The capacity of the pond is determined from a contour survey of the site at which the pond is to be located. From the contour plan of the site the capacity is calculated for different stages using the trapezoidal or simpson's rule.

For this purpose, the area enclosed by each contour is measured using a planimeter. According to the trapezoidal rule, the volume V between two contours at an interval H and having areas A_1 and A_2 is given by,

$$V = \frac{H}{2}\left(A_1 + A_2\right)$$

Using Simpson's rule the volume between any odd number of contours is given by,

$$V = \frac{H}{3}\begin{bmatrix}\text{Twice the area of odd contours + 4 times area of even contours +} \\ \text{Area of the first and last contours}\end{bmatrix}$$

This formula is also known as the prismodial rule. For using this equation, the number of contours should be odd i.e. the number of intervals considered should be even.

Example:

Calculate the capacity of a pond given the area enclosed by different contours at the site as follows:

S. No.	Contour Value (m)	Area Enclosed (m^2)
1.	250	220
2.	251	290
3.	252	340
4.	253	370
5.	254	480
6.	255	550
7.	256	620

Contour interval = 1 m

Solution:

Using trapezoidal formula,

$$V = 1 * 100\left(\frac{2.2 * 6.2}{2} + 2.9 + 3.4 + 3.7 + 4.8 + 5.5\right) = 2450 \text{ m}^3$$

Using prismoidal formula,

$$V = \frac{1}{3} * 100\left[2.2 + 4(2.9 + 3.7 + 5.5) + 2(3.4 + 4.8) + 6.2\right] = 2440 \text{ m}^3$$

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Contour value	Area enclosed	Volume increment	Cumulative volume
250	220	-	-
251	290	255	255
252	340	315	570
253	370	355	925
254	480	425	1350
255	550	515	1865
256	620	585	2450

DESIGN OF FARM POND

Farm ponds are small tanks or reservoirs constructed for the purpose of storing water essentially from surface runoff. Farm ponds are useful for irrigation, water supply for the cattle, fish production etc.

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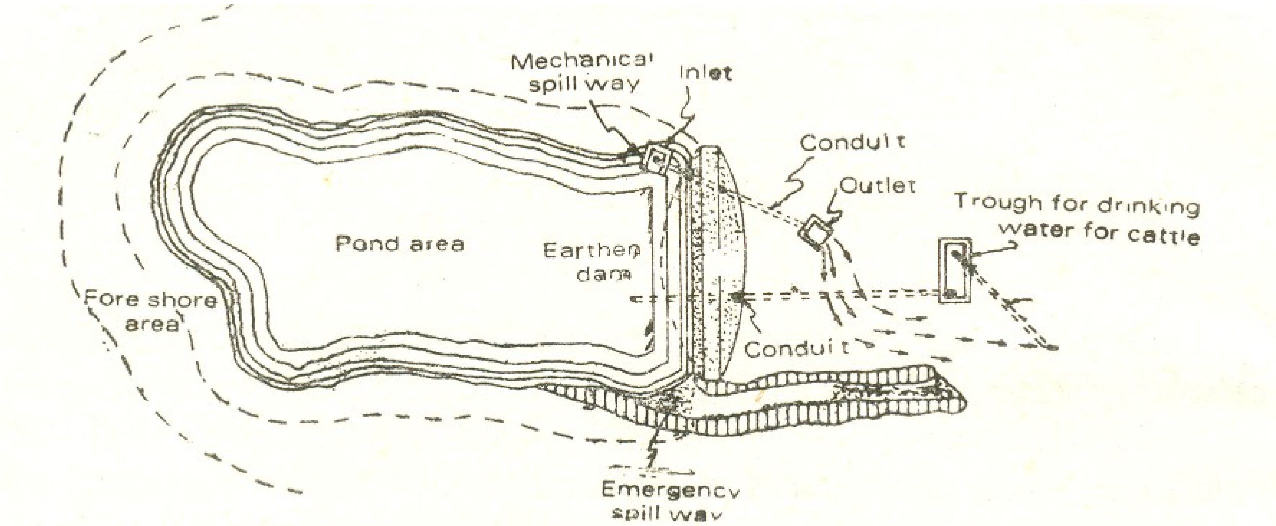

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STUDY OF AQUIFERS

Groundwater is the underground water that occur in the saturated zone of variable thickness and depth, below the earth's surface. Cracks and pores in the existing rocks and unconsolidated crystal layers, make up a large underground reservoir, where part of precipitation is stored. The groundwater is utilized through wells and tubewells.

Groundwater Aquifers

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

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

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

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

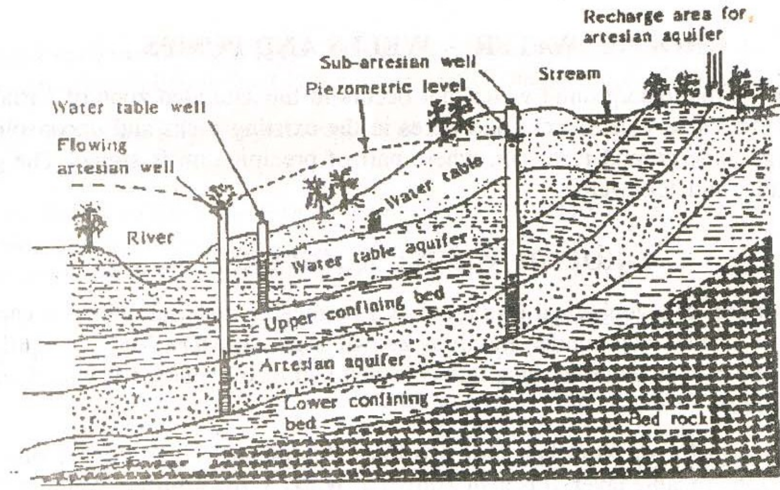
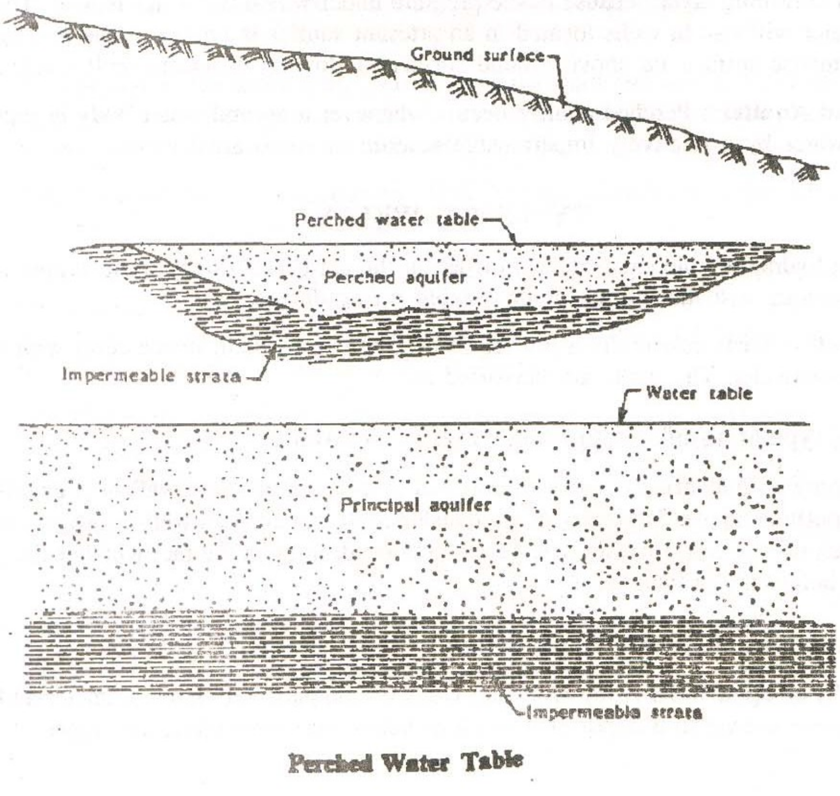


Diagram illustrating artesian and water table aquifers, water table well, flowing artesian well, sub-artesian well and potential recharge area for the artesian aquifer



Perched Water Table

TYPES AND SELECTION OF PUMPS

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

Positive Displacement Pumps

(a) Reciprocating Pump

(b) Rotary Pump

Variable Displacement Pumps

(a) Centrifugal Pump

(b) Turbine Pump

   a. Deep well turbine

   b. Submersible pump

(c) Propeller Pump

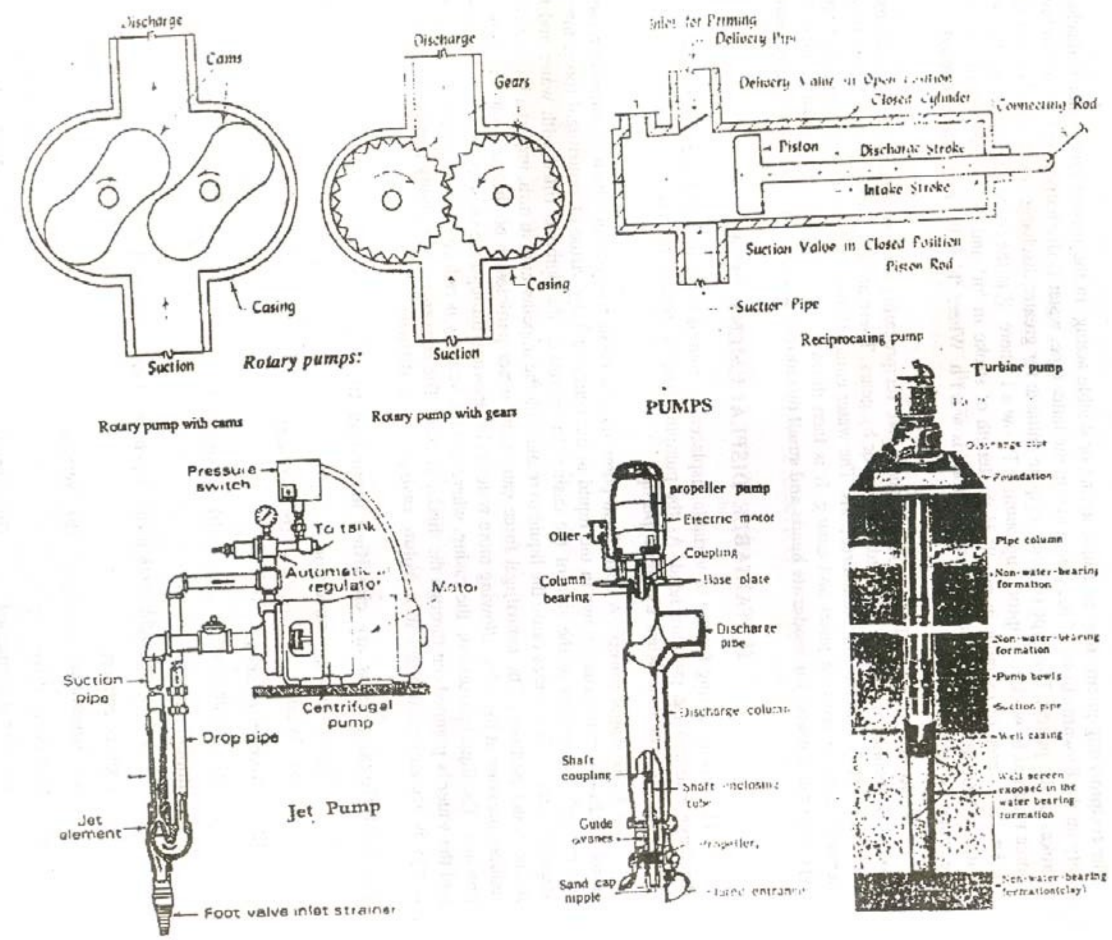
(d) Jet Pump

(e) Air Lift Pump

Positive Displacement Pump

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

(a) ***Reciprocating Pumps:*** In this type of pump, a piston or a plunger moves inside a closed cylinder. On the intake stroke, the suction valve remains open and allows water to come into the cylinder. The delivery valve remains closed during intake stroke. On the discharge stroke, the suction valve is closed and water is forced in delivery pipe through delivery pipe through delivery valve which opens during discharge stroke.



The reciprocating pumps may be single acting or double acting. In the former type water is discharged only on the forward stroke of the piston and in the latter type, water is discharged on forward and return strokes of the piston. This type of pump is quite suitable for greater discharge under high head of water. Force required to work a reciprocating pump is P = w*a*1 where, 'P' is the force required to lift the piston in kg, 'a' is area of cylinder in m^2, 'l' is the length of stroke in m and 'w' is the specific weight of water is 1000 kg m^{-3}. Work done in one upstroke is w*a*1*h, where 'h' is the total height through which the water is raised, m.

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

Variable Displacement Pump

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

(a) ***Centrifugal Pump*:** A centrifugal pump may be defined as one in which an impeller rotating inside a close – fitting case draws in the liquid at the centre and, by virtue of centrifugal force, throws out through an opening at the side of the casing. In operation, the pump is filled with water and the impeller rotated. The blades cause the liquid to rotate with the impeller and, in turn, import a high velocity to the water particles. The centrifugal force causes the water particles to be thrown from the impeller reduces pressure at the inlet, allowing more water to be drawn in through the suction pipe by atmospheric pressure. The liquid passes into the casing, where its high velocity is reduced and converted into pressure and the water is pumped out through the discharge pipe. The conversion of velocity energy into pressure energy is accomplished either in a ***Volute casing* or in a *Diffuser*.**

The centrifugal pumps are classified according to

1. Type of energy conversion:

(a) Volute	(b) Diffuser	

2. Number of stages

(a) Single stage	(b) Multi stage	

3. Impeller types

(a) Single or double action	(b) Open, semi-open or closed	

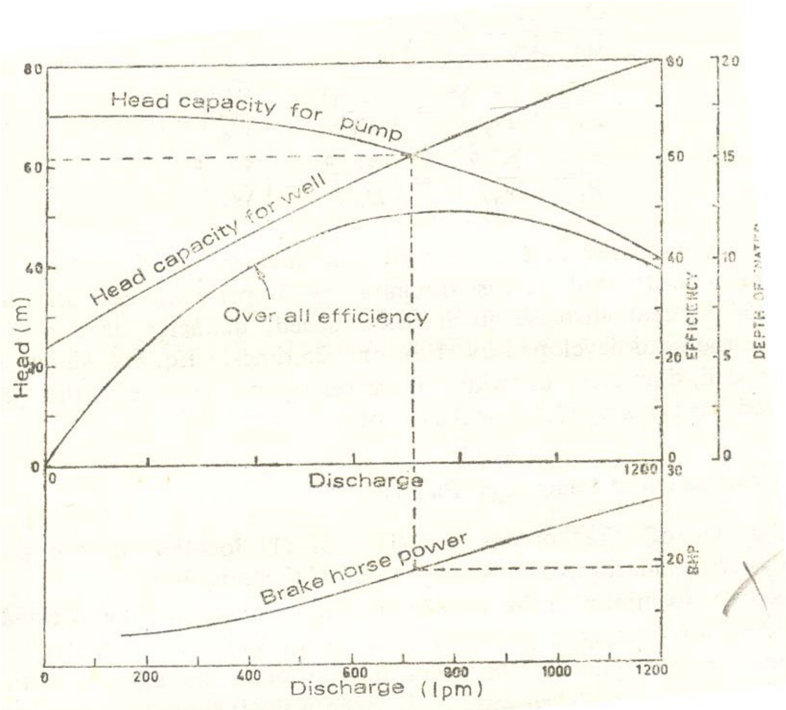
4. Axis of rotation

(a) Horizontal	(b) Vertical	

5. Method of drive

(a) Direct connected	(b) Geared	(c) Belt or chain driven

Selection of centrifugal pumps are based on the characteristic curves namely (1) ***Head capacity curve*** which shows how much water a given pump will deliver with a given head at one particular speed. (2) ***Overall efficiency curve*** represents the relationship between the efficiency of the pump and the discharge for different speeds and (3) ***Break-Horse Power curve*** gives the relation between the discharge, speed and horse power. In case a centrifugal pump has to be selected for pumping from an open water source, the total head has to be calculated for selecting the suitable pump. In case of wells, the head capacity curve of the well is matched with the pump head-efficiency-horse power curves and the pump is selected.



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

Common troubles and their remedies for a centrifugal pump are as follows:

1. ***Pump fails to deliver water:*** (i) Air leak in suction line, mainly in threaded connections are to be located with white lead (ii) Gaskets admitting air should be tightened (iii) Defective foot valve should be checked for its flap and replaced.

2. ***Pump fails to develop sufficient pressure or capacity:*** (i) Pump speed should be checked and corrected (ii) Suction line and foot valve clogging to be checked (iii) Check the suction lift (iv) Check for worn out impeller.

3. ***Pump takes for much power:*** (i) Speed may be high (ii) Head may be lower and pumping too much water (iii) Mechanical defects in installation.

4. ***Pump leaks excessively at the stuffing box:*** (i) Worn out packing or incorrectly inserted packing (ii) Worn out shaft to be renewed.

5. ***Pump is noisy:*** (i) Too high suction lift (ii) Mechanical defects such as bent shaft, broken bearing etc.

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

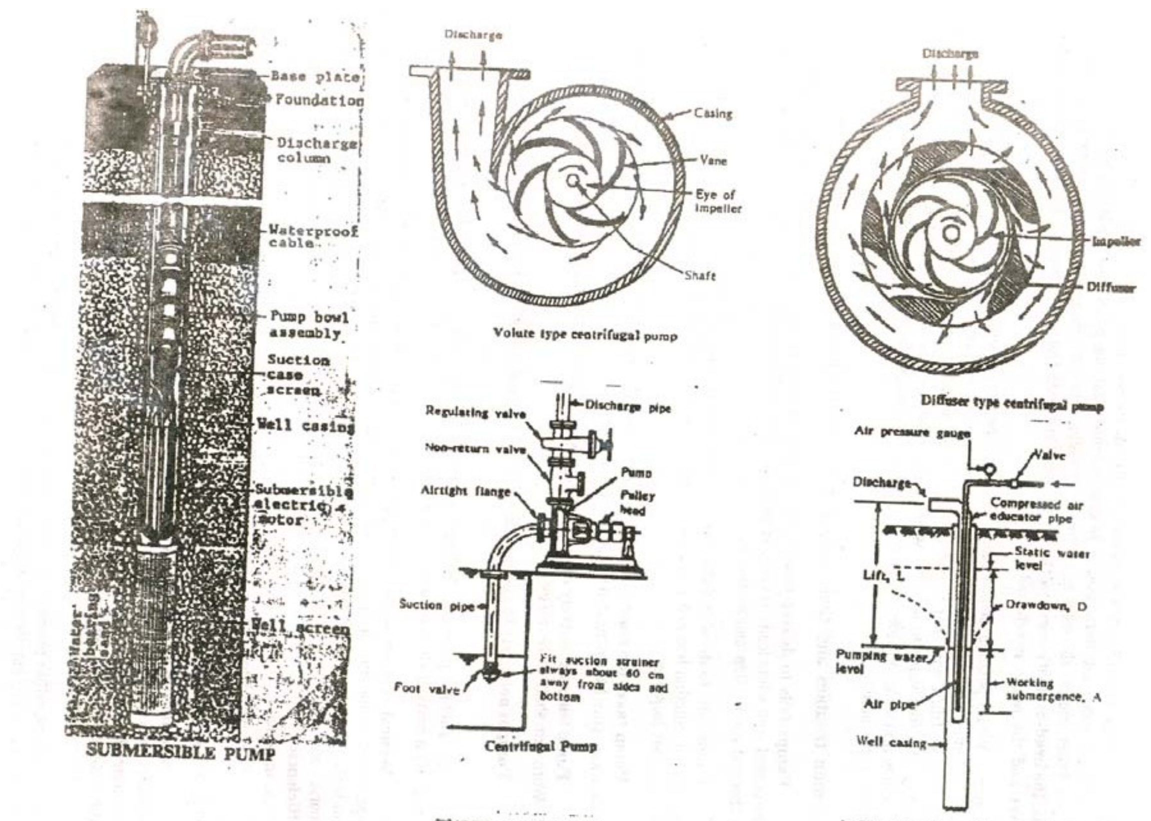
1. ***Vertical Turbine Pump (or) Deep well Turbine Pump:*** is a vertical axis centrifugal or mixed flow type pump comprising of stages which accommodate rotating impellers and stationary bowls possessing guide vanes with the motor fixed on the ground level. The pump bowl is surrounded by a screen to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

Selection of Turbine Pumps: Characteristics curves giving the relationship among the head capacity, efficiency, horse power and speed are available for turbine pumps also. For turbine pump selection accurate data about the well is essential. Besides the head capacity curve of the well, the seasonal fluctuations of water table should also be known so that the pump bowls are installed such that they are always under water.

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

3. ***Propeller Pumps:*** The principal parts of the propeller pumps and method of operation are similar to the turbine pumps. The main difference is in design of the impellers, which give high discharges at low heads. Two types of impellers *i.e.* axial flow type and mixed flow type are used in this pump. In single stage pumps only one impeller is used and in multistage pumps more than one impeller is used. The selection of a propeller pump is done based on the characteristic curves compared with the well discharge and head.

4. ***Jet Pumps:*** Consist of a combination of a centrifugal pump and a jet mechanism or ejector. Jet pump is used when the suction lift of the centrifugal pump exceeds the permissible limits. A portion of the water from the centrifugal pump is passed through the drop pipe to the nozzle of the jet assembly. This water is forced through the throat opening of the diffuser, creating a vacuum which causes water to be drawn from the well. The water mixed with the boost water is carried up through the diffuser where the high velocity energy is converted into useful pressure energy, forcing the water up through the delivery pipe to the centrifugal pump.



TYPES OF PUMPS

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

Specific Speed of a pump may be defined as the speed of a geometrically similar pump when delivering one $m^3\ s^{-1}$ of water against a total head on one metre. The value of specific speed is useful in comparing the performance of different pumps.

Specific Speed (rpm), $n_s = \dfrac{n * Q^{1/2}}{H^{3/4}}$

where, n = Pump speed (rpm); Q = Pump discharge ($m^3 s^{-1}$); H = Total head (m).

POWER REQUIREMENTS FOR PUMPING

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

$$\text{WHP} = \frac{\text{Discharge (litres sec}^{-1}\text{)} * \text{Total head (m)}}{75}$$

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

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

3. ***Pump Efficiency*** = $\frac{\text{Water Horse Power}}{\text{Shaft Horse Power}} * 100$

4. ***Brake Horse Power (BHP)*** is the actual horse power required to be supplied by the engine or electric motor for driving the pump.

(i) For direct driven pump, BHP = Shaft Horse Power

(ii) With belt or indirect drives, BHP = $\frac{\text{Water Horse Power}}{\text{Pump Efficiency} * \text{Drive Efficiency}}$

5. ***Horse Power Input to electric motor*** =

$$\frac{\text{Water Horse Power}}{\text{Pump Efficiency} * \text{Drive Efficiency} * \text{Motor Efficiency}}$$

6. Kilowatt Input to electric motor (or) Energy Consumption in Kilowatt Hours

$$\text{Energy in Kilowatts} = \frac{\text{Brake Horse Power} * 0.746}{\text{Motor Efficiency}}$$

7. Cost of operation for electric motor

= Energy in Kilowatts*Hours of pumping*Cost per Kilowatt Hour

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

General maintenance of pumps for maximum working efficiency

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

EXERCISE

1. A centrifugal pump delivering 851.25 litres per minute irrigates 1.619 hectares working 8 hours in a day. What is the depth of irrigation per day?
2. A pump delivers 22,730 litres of water to a height of 45.6 metres in every five minutes. If the efficiency of the pump is 75 per cent, what is the horsepower required to drive the pump?
3. A pump driven by an electric motor delivers 454.6 litre of water to a height of 30.4 metres in every minute. If the efficiency of the pump is 70 per cent and the motor takes 19 amps at 200 volts, what is the efficiency of the motor?
4. A centrifugal pump driven by an oil engine delivers 851.25 litres per minute. If the pump works for 10 hours a day how many hectares of paddy crop can be irrigated by the discharge, interval of irrigation being 10 days and depth of irrigation being 2.54 cms.
5. Calculate the cost of pumping 4 million litres of water from a well with a centrifugal pump from the following data.

Suction head = 3 metres; Delivery head = 7 metres; Friction head = 1.5 metres

Output of the pump = 40,000 litres/ hour; Pump efficiency = 70 per cent

Motor efficiency = 85 per cent; Cost of electricity = 10 paise per unit.

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