

DRAINAGE & DESIGN OF DRAINAGE SYSTEMS

Drainage means the removal of excess water from a given place.

Two types of drainage can be identified:

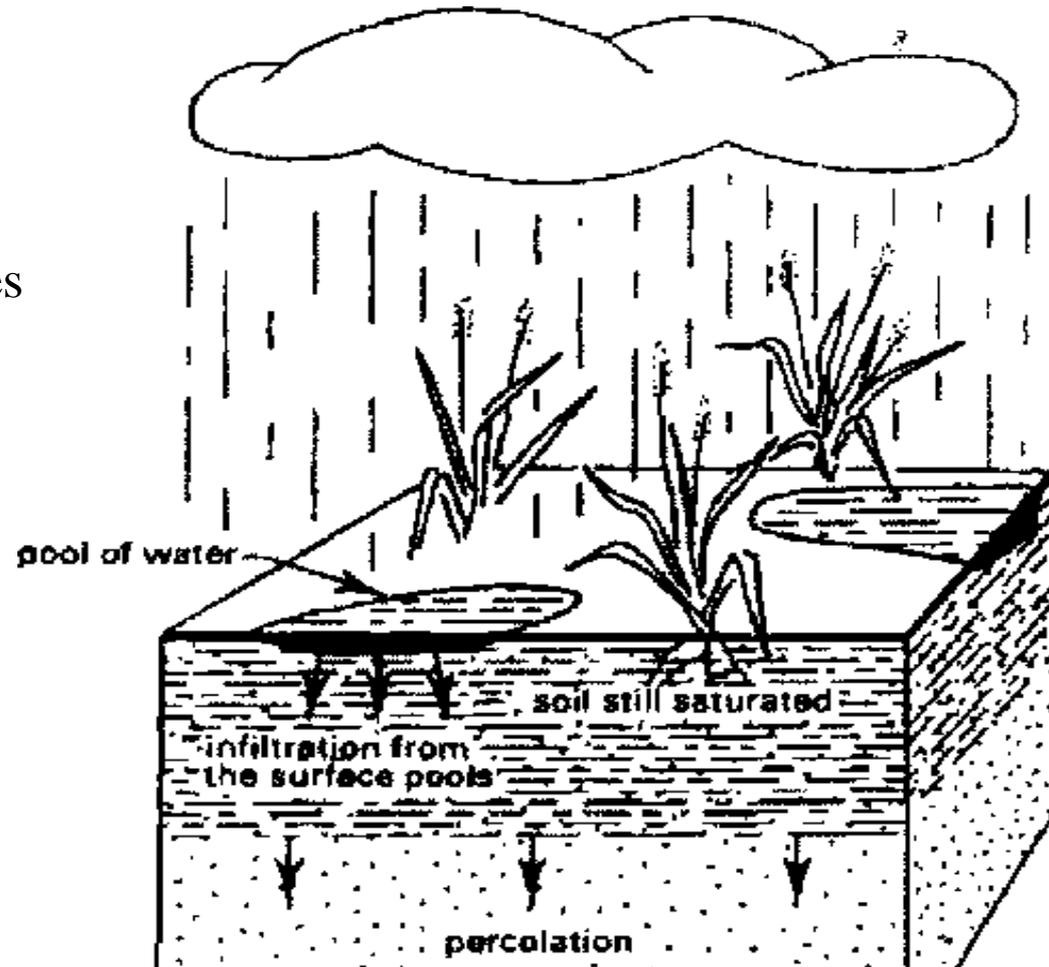
i) Land Drainage: This is large scale drainage where the objective is to drain surplus water from a large area by such means as excavating large open drains, erecting dykes and levees and pumping. Such schemes are necessary in low lying areas and are mainly Civil Engineering work.

ii) Field Drainage: This is the drainage that concerns us in agriculture. It is the removal of excess water from the root zone of crops

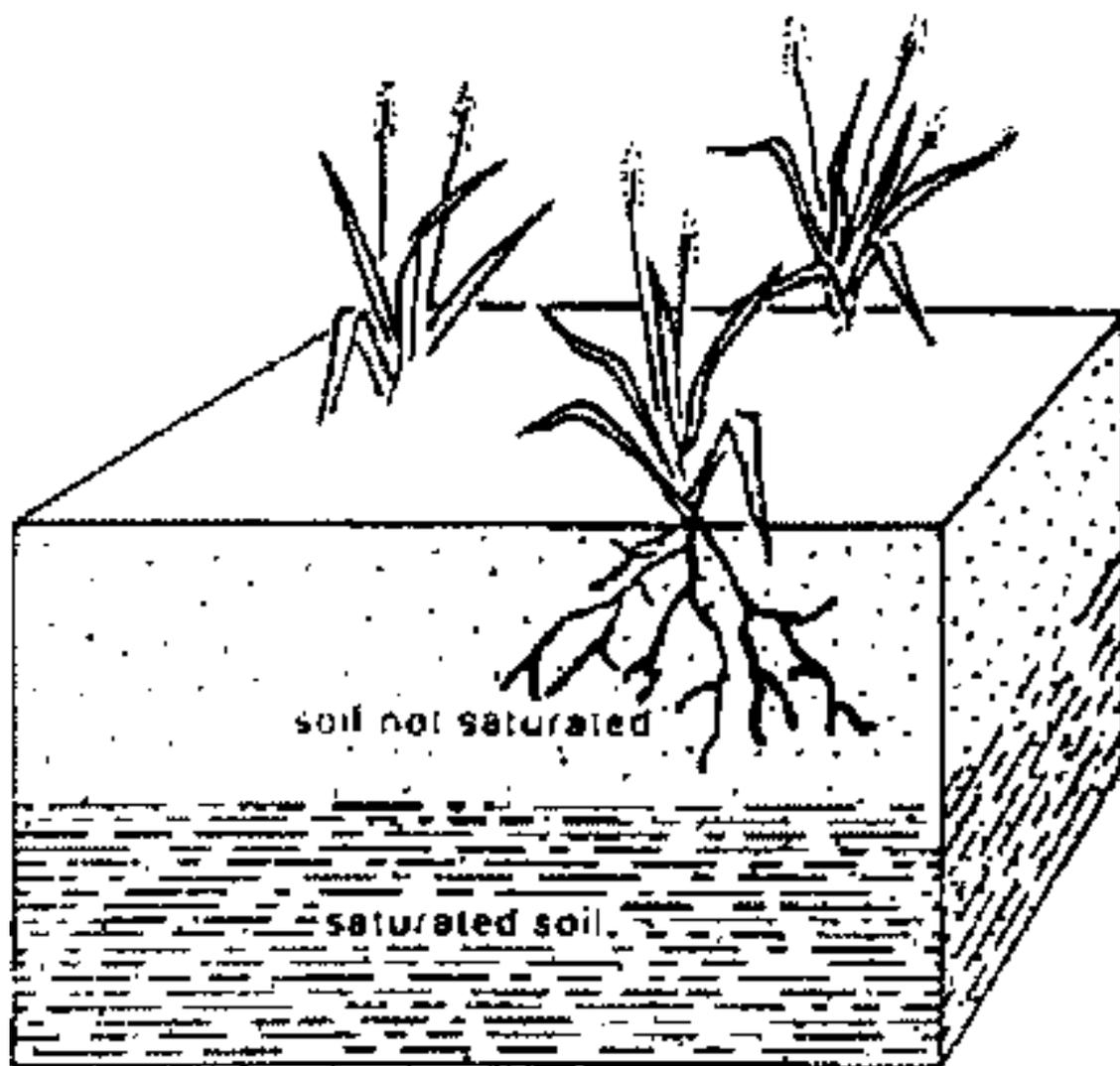
Need of Drainage

During rain or irrigation the fields become wet. The water infiltrate into the soil and is stored in its pores. When all the pores are filled with water, the soil is said to be saturated and no more water can be absorbed; when rain or irrigation continues, pools may form on the soil surface

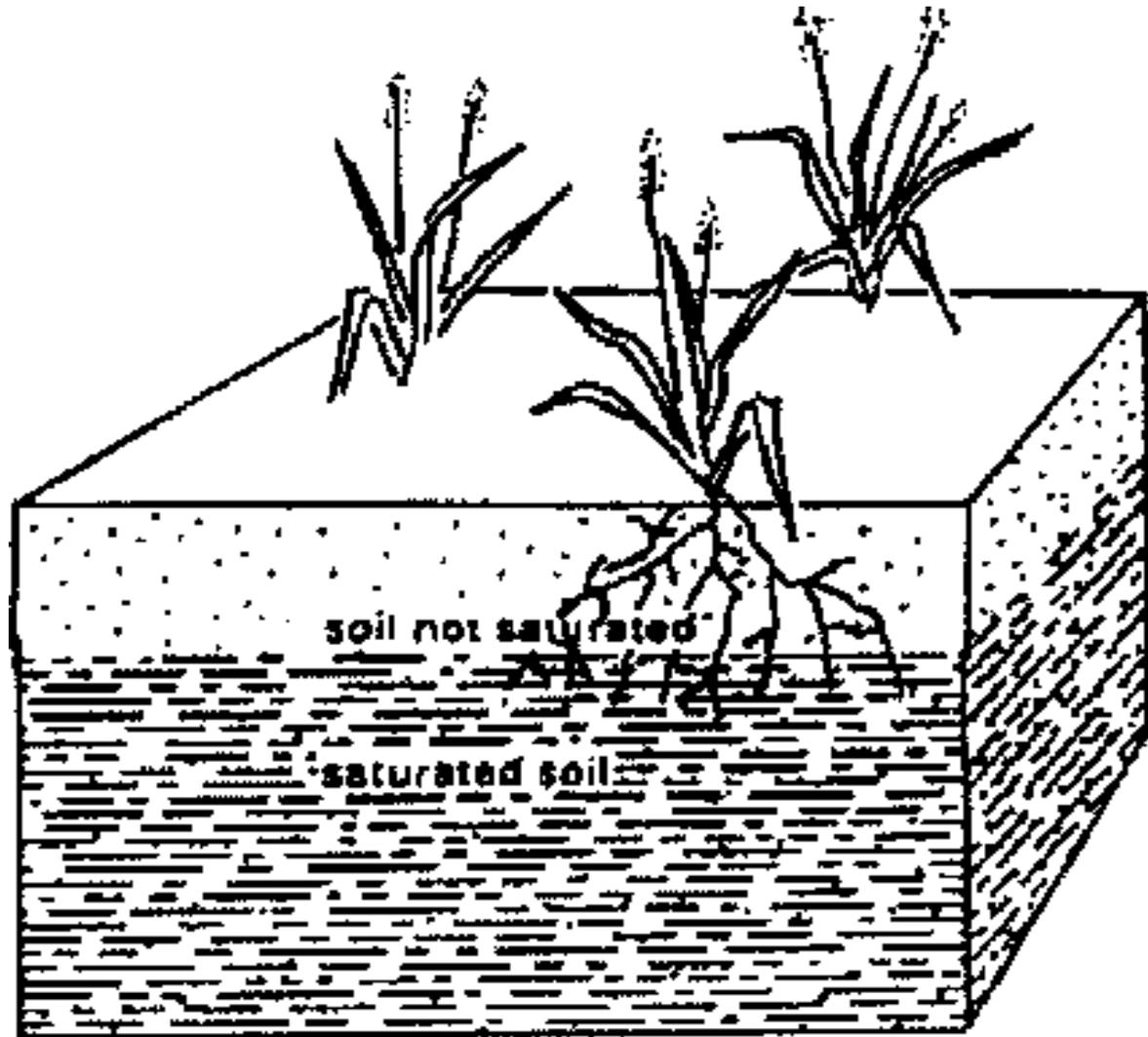
Figure. During heavy rainfall the upper soil layers become saturated and pools may form. Water percolates to deeper layers and infiltrates from the pools



BEFORE HEAVY RAINFALL



Water in Soil After Heavy Rain



The main aims of Field drainage include:

- i) To bring soil moisture down from saturation to field capacity. At field capacity, air is available to the soil and most soils like to grow at moisture less than saturation.
- ii) Drainage helps improve hydraulic conductivity: Soil structure can collapse under very wet conditions and so also engineering structures.
- iii) In some areas with salt disposition, especially in arid regions, drainage is used to leach excess salt.
- iv) In irrigated areas, drainage is needed due to poor application efficiency which means that a lot of water is applied.
- v) Drainage can shorten the number of occasions when cultivation is held up waiting for soil to dry out.

TYPES OF FIELD DRAINAGE

1. Horizontal drainage

i. Surface drainage

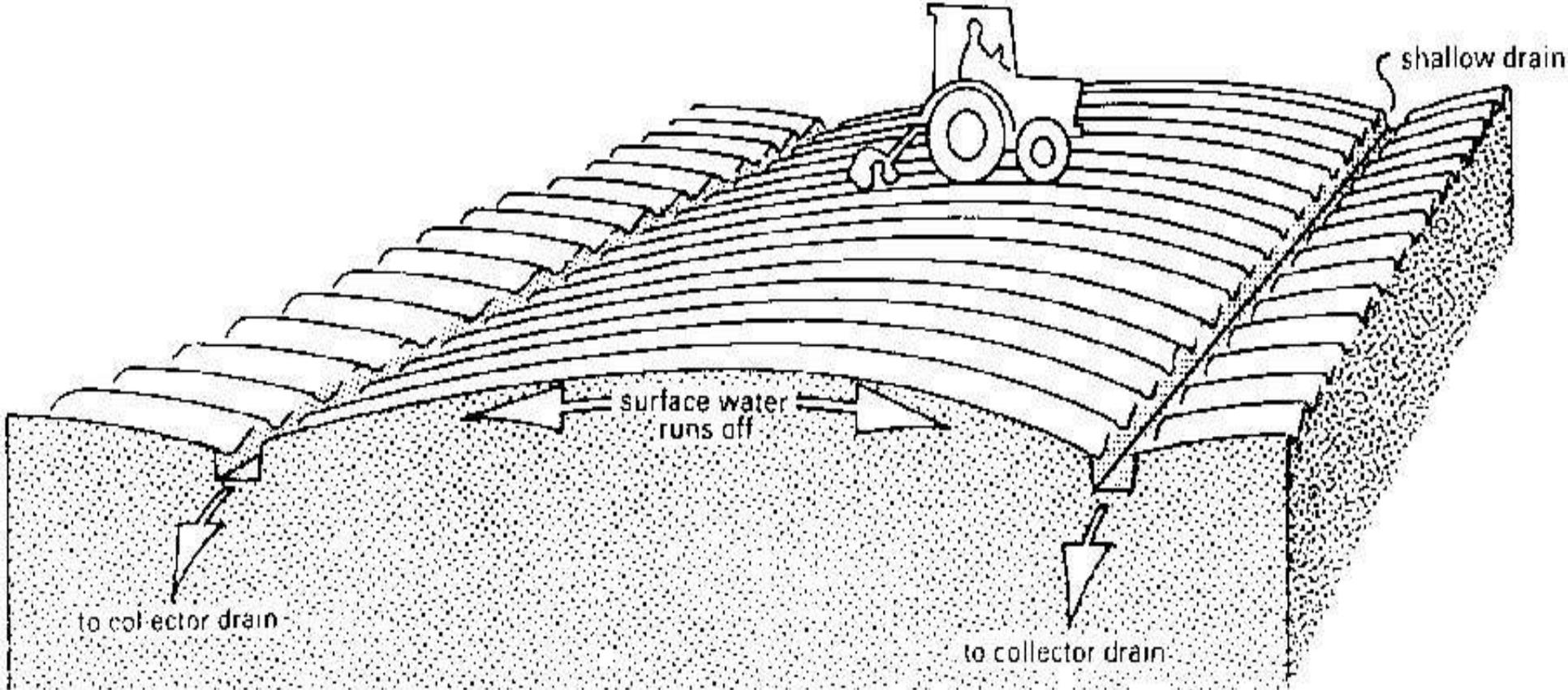
ii. Sub-surface drainage

2. Vertical drainage i.e. Tube wells

DESIGN OF SURFACE DRAINAGE SYSTEMS:

Surface drainage involves the removal of excess water from the surface of the soil.

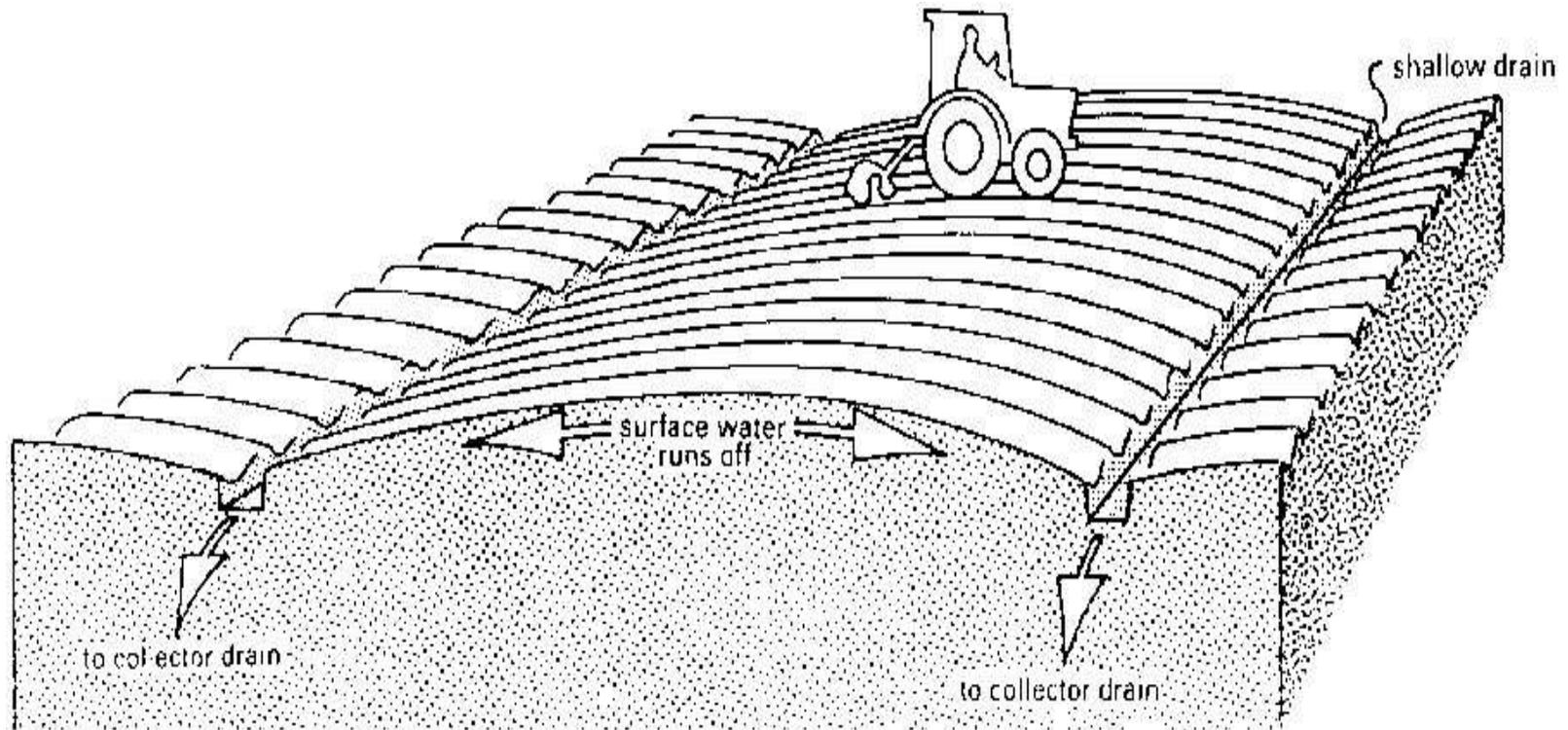
This is done by removing low spots where water accumulates by land forming or by excavating ditches or a combination of the two.



Land forming is mechanically changing the land surface to drain surface water, done by smoothing, grading, bedding or leveling.

Land smoothing is the shaping of the land to a smooth surface in order to eliminate minor differences in elevation and this is accomplished by filling shallow depressions using bulldozers or scrapers.

There is no change in land contour. Smoothing is done using land levelers or planes.



Design of Drainage Channels or Ditches

Estimation of Peak Flows:

This can be done using the Rational formula, Cook's method, Curve Number method, Soil Conservation Service method etc.

Drainage coefficients (to be treated later) are at times used in the tropics especially in flat areas and where peak storm runoff would require excessively large channels and culverts.

This may not apply locally because of high slopes.

a) The Rational Formula:

It states that:

$$q_p = (CIA)/360$$

where

q_p = peak flow (m^3/s);

C = dimensionless runoff coefficient;

I = rainfall intensity for a given return period.

(Return period is the average number of years within which a given rainfall event will be expected to occur at least once)

A = area of catchment (ha).

Diagram Showing Two Catchments



Using the Rational Method

- i) Obtain area of catchment by surveying or from maps or aerial photographs.
- ii) Estimate intensity using the curve in Hudson's Field Engineering,
- iii) The runoff coefficient C is a measure of the rain which becomes runoff. On a corrugated iron roof, almost all the rain would runoff so $C = 1$, while in a well drained soil, nine-tenths of the rain may soak in and so $C = 0.10$. The table (see handout) from Hudson's Field Engineering can be used to obtain C value. Where the catchment has several different kinds of characteristics, the different values should be combined in proportion to the area of each.

Runoff Coefficient, C

Table 3.3
Values of run-off coefficient C

Topography and vegetation	Soil texture		
	Open sandy loam	Clay and silt loam	Tight clay
Woodland			
Flat 0-5 per cent slope	0.10	0.30	0.40
Rolling 5-10 per cent slope	0.25	0.35	0.50
Hilly 10-30 per cent slope	0.30	0.50	0.60
Pasture			
Flat	0.10	0.30	0.40
Rolling	0.16	0.36	0.55
Hilly	0.22	0.42	0.60
Cultivated			
Flat	0.30	0.50	0.60
Rolling	0.40	0.60	0.70
Hilly	0.52	0.72	0.82
Urban areas	30 per cent of area impervious	50 per cent of area impervious	70 per cent of area impervious
Flat	0.40	0.55	0.65
Rolling	0.50	0.65	0.80

From Schwab, Frevert, Edminster, and Barnes,
Soil and water conservation engineering, Wiley, New York.

b) Cook's Method:

Three factors are considered:

1. Vegetation,
2. Soil permeability and
3. Slope.

These are the catchment characteristics.

For each catchment, these are assessed and compared with Table 3.4 of Hudson's Field Engineering

Table 3.4: Hudson's Field Eng'g (CC)

Table 2
Catchment characteristics (CC)

Cover		Soil type and drainage		Slope	
Heavy grass	10	Deep, well drained soils	10	Very flat to gentle	5
Scrub or medium grass	15	Deep, moderately pervious soil	20	Moderate	10
Cultivated lands	20	Soils of fair permeability and depth	25	Rolling	15
Bare or eroded	25	Shallow soils with impeded drainage	30	Hilly or steep	20
		Medium heavy clays or rocky surfaces	40	Mountainous	25
		Impervious surfaces and waterlogged soils	50		

Select the most appropriate factor from each of these three lists and add them together.

Example

Heavy grass (10) on shallow soils with impeded drainage (30) and moderate slope (10):
 $CC = 10 + 30 + 10 = 50.$

From Dept. of Conservation and Extension, Government of Rhodesia.
Handbook of basic instruction for dam construction.

Surface Drainage Channels

The drainage channels are normally designed using the Manning formula. The required capacity of a drainage channel is calculated from the summation of the inflowing streams.

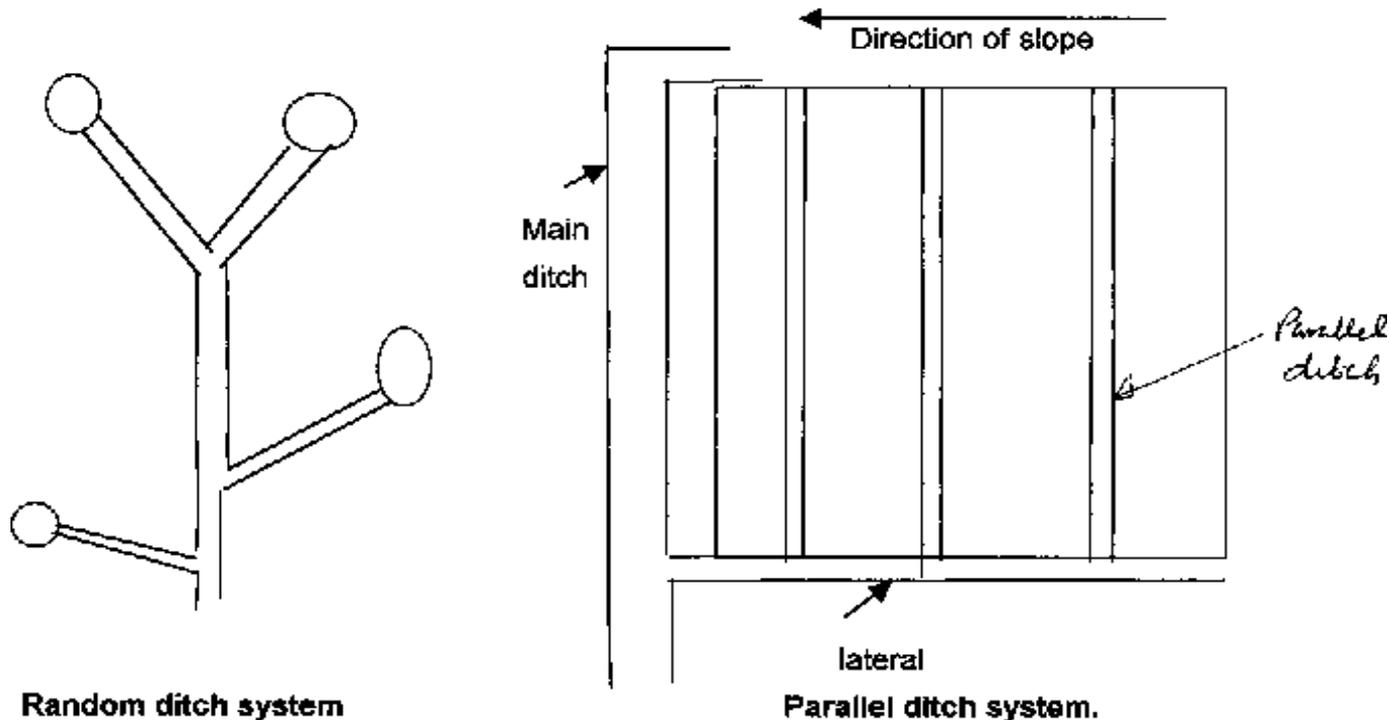
The bed level of an open drain collecting flow from field pipe drains should be such as to allow free fall from the pipe drain outlets under maximum flow conditions, with an allowance for siltation and weed growth. 300 mm is a reasonable general figure.

Surface Ditch Arrangements

The ditch arrangement can be random, parallel or cross- slope.

Random ditch system: Used where only scattered wet lands require drainage.

Parallel ditch system: Used in flat topography. Ditches are parallel and perpendicular to the slope. Laterals, which run in the direction of the flow, collect water from ditches.



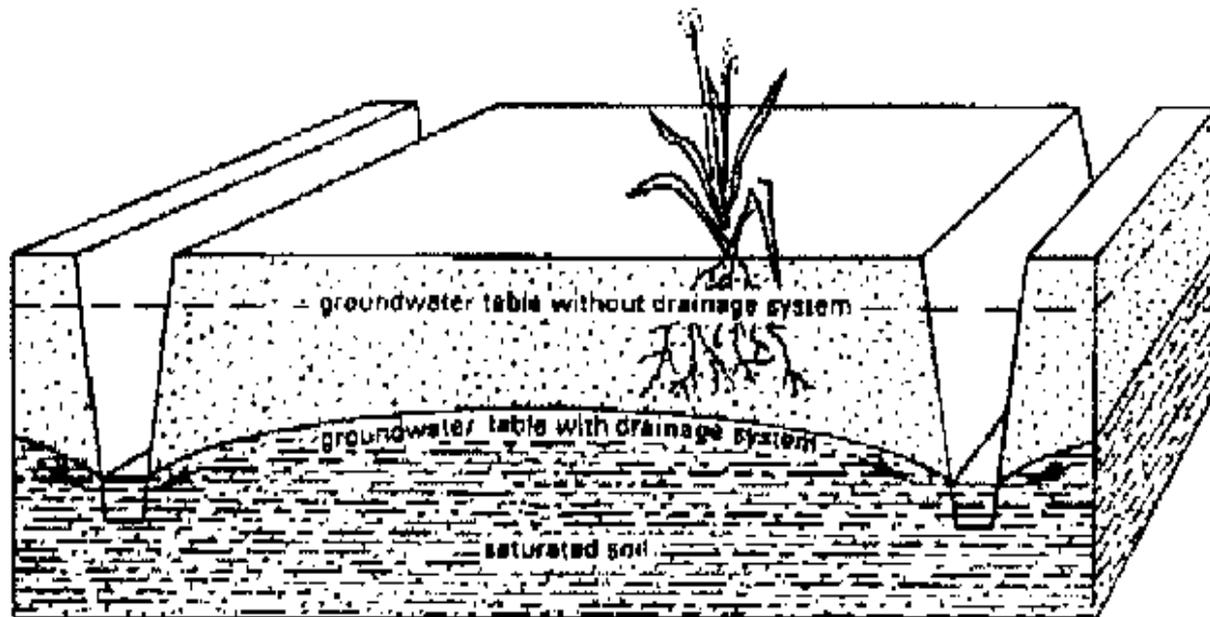
DESIGN OF SUB-SURFACE DRAINAGE SYSTEMS

Sub-surface drainage is the removal of excess groundwater below the soil surface.

It aims at increasing the rate at which water will drain from the soil, and so lowering the water table, thus increasing the depth of drier soil above the water table.

Sub-surface drainage can be done by open ditches or buried drains.

Fig. 99. Control of the groundwater table by means of deep open drains



Sub-Surface Drainage Using Ditches

Ditches have lower initial cost than buried drains;

There is ease of inspection and ditches are applicable in some organic soils where drains are unsuitable.

Ditches, however, reduce the land available for cropping and require more maintenance than drains due to weed growth and erosion.

Sub-Surface Drainage Using Buried Drains

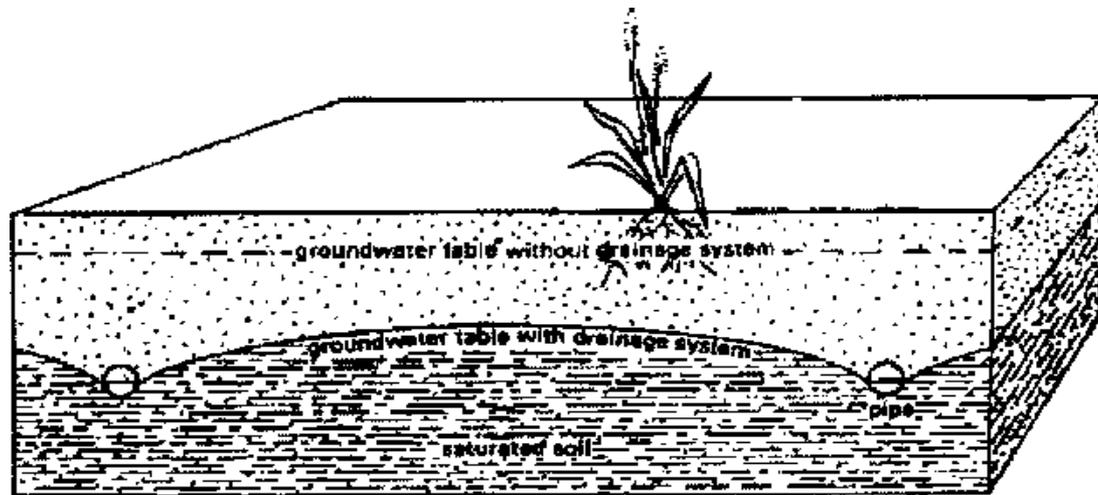
Buried drains refer to any type of buried conduits having open joints or perforations, which collect and convey drainage water.

They can be fabricated from clay, concrete, corrugated plastic tubes or any other suitable material.

The drains can be arranged in a parallel, herringbone, double main or random fashion.

Drain pipes are made of clay, concrete or plastic.

They are usually placed in trenches by machines.



In clay and concrete pipes (30 m long and 5-10 cm in dia.) drainage water enters the pipes through the joints

Flexible plastic drains are much longer (up to 200 m) and water enters through perforations distributed over the entire length of the pipe.

Buried Drains

Land drainage
and sub-surface irrigation
pipes and fittings



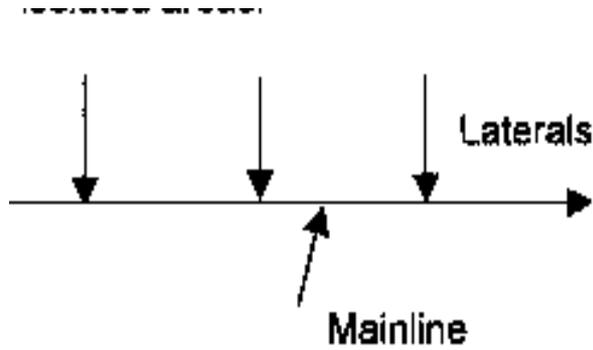
The advertisement features three main images: a large roll of pipe on the left, a top-right inset showing four different pipe diameters (360mm, 260mm, 110mm, 60mm) and three lengths (160mm, 80mm, 35mm), and a bottom-right inset showing various pipe fittings and connections.

Sizes to suit customers' needs both in coil size and pipe diameter.

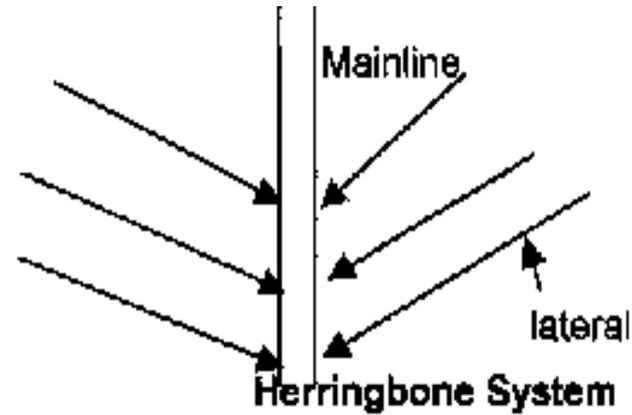
All junctions and connections available.

Aqua-Pipe is fully approved by M.A.F.F.

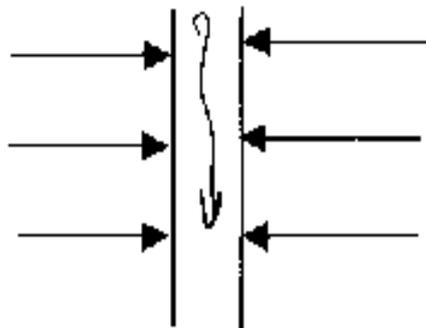
Arrangements of Sub-Surface Drains



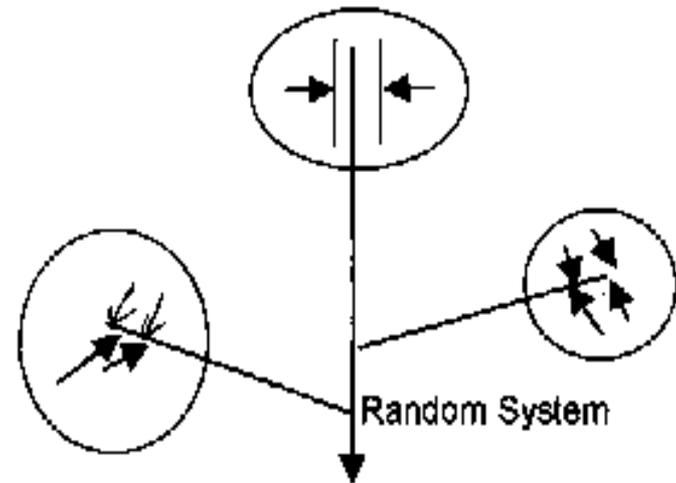
Parallel System



Herringbone System



Double Main System



Random System

Sub-Surface Drainage Designs

The Major Considerations in Sub-surface Drainage Design Include:

- 1.Drainage Coefficient;
- 2.Drain Depth and Spacing;
- 3.Drain Diameters and Gradient;
- 4.Drainage Filters.

1. Drainage Coefficient

This is the rate of water removal by a drain to obtain the desired protection of crops from excess surface or sub-surface water and can be expressed in mm/day, m/day etc.

Drainage is different in Rain-Fed Areas and Irrigated Areas.

This is chosen from experience depending on rainfall.

Table 4.1 : Drainage Coefficient for Rain-Fed Areas*

Mean Annual Rainfall (MAR) Drainage coefficient (mm/day)

<i>(mm/yr)</i>	<i>Ministry of Agric.</i>	<i>Hudson</i>
2000	25	20
1950	25	19.5
1500	19	15
1000	13	10
875	10	10
< 875	7.5	10

.....
*From Ministry of Agric., U.K (1967) & Hudson (1975)

Other Methods For Obtaining Drainage Coefficient in Rain-Fed Areas

A. Hudson suggests:

MAR > 1000 mm, drainage coefficient is MAR/1000 mm/day

MAR < 1000 mm, drainage coefficient is 10 mm/day.

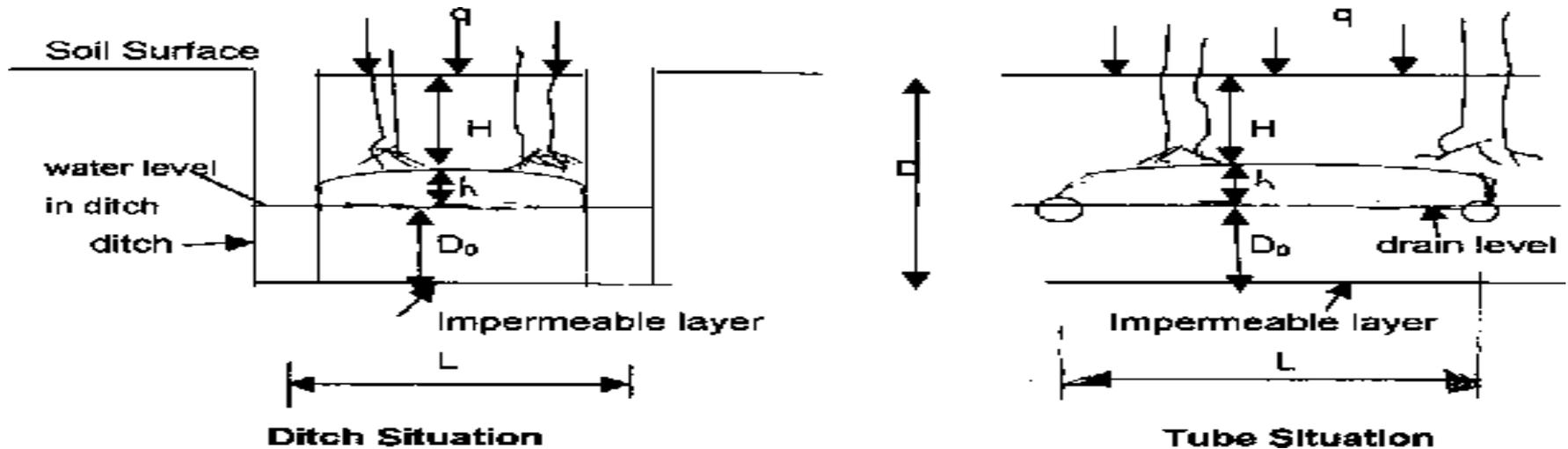
B. From rainfall records: determine peak rainfall with a certain probability depending on the value of crops or grounds to be protected e.g. 5 day rainfall for 1: 2 return period.

C. Divide the rainfall of the heaviest rainfall month by the days of the month e.g. if in an area, the heaviest rainfall month is August with 249 mm.

i.e. Drainage discharge = $249/31 = 8.03$ mm/day.

Use this method as a last resort.

2. Drain Depth and Spacing



L = drain spacing;

h = mid drain water table height (m) above drain level;

D_0 = depth of aquifer from drain level to impermeable layer(m);

Q = water input rate(m/day) = specific discharge or drainage coefficient;

K = hydraulic conductivity(m/day);

H = depth to water table.

Design Water table depth (H):

This is the minimum depth below the surface at which the water table should be controlled and is determined by farming needs especially crop tolerance to water.

Typically, it varies from 0.5 to 1.5 m.

Design Depth of Drain

The deeper a drain is put, the larger the spacing and the more economical the design becomes.

Drain depth, however, is constrained by soil and machinery limitations.

Table : Typical Drain Depths(D)

Soil Type	Drain Depth (m)
Sand	0.6
Sandy loam	0.8 - 1.0
Silt loam	0.8 - 1.8
Clay loam	0.6 - 0.8
Peat	1.2 - 1.5

Drain Spacing (L)

This is normally determined using the Hooghoudt equation. It states that for ditches reaching the impermeable layer:

$$L^2 = \frac{8KD_o h}{q} + \frac{4Kh}{q}$$

For tube drains which do not reach the impermeable layer, the equation can be modified

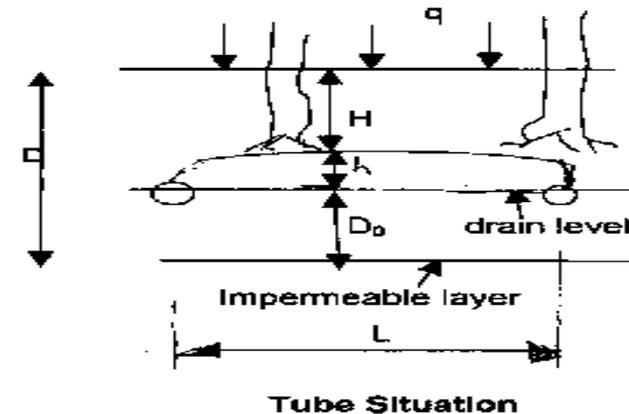
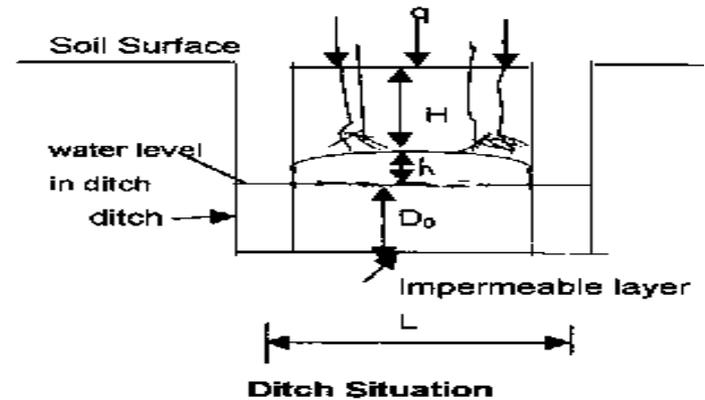
as:

$$L = \frac{8Kdh}{q} + \frac{4Kh^2}{q}$$

Where

d = Hooghoudt equivalent

The equation for tube drains can be solved using trial and error method or the graphical method.



3. Drain Diameters and Gradients

There are two approaches to design:

(a) **Transport approach:**

- Assumes that pipes are flowing full from top to end of field.
- Assumes uniform flow.
- Widely used in United States, Canada and Germany.
- Used to design collector drains.

(b) **Drainage approach:**

- Assumes that water enters the pipe all down the length as it is perforated.
- This is more realistic.
- Widely used in United Kingdom, Holland and Denmark.
- This is used to design lateral drainage pipes.

Parameters Required to use Solution Graphs

(a) Types of pipes: Pipes can be smooth or rough:

Clay tiles and smooth plastic pipes are smooth; while

Corrugated plastic pipes are rough.

(b) Drainable area: The area drained by one lateral. It is equal to the maximum length of a lateral multiplied by drain spacing.

The whole area drained by the laterals discharging into a collector represents the drainable area of the collector.

c) Specific discharge: Earlier defined. Same as drainage coefficient.

d) Silt safety factors: Used to account for the silting of pipes with time by making the pipes bigger. 60, 75 and 100 % pipe capacity factors are indicated. This means allowing 40, 25 and 0% respectively for silting.

e) Average hydraulic gradient(%): It is normally the soil slope.

4. Drainage Filters

Filters for tile drains are permeable materials e.g. gravel placed around the drains for the purpose of improving the flow conditions in the area immediately surrounding the drains as well as for improving bedding conditions.

Filters provide a high hydraulic conductivity around the drains which stabilizes the soil around and prevent small particles from entering the lateral drains since they are perforated.

Soils that Need Filters

a)Uniform soils will cause problems while non-uniform ones are widely distributed stabilize themselves.

b)Clays have high cohesion so cannot be easily moved so require no filters.

c)Big particles like gravel can hardly be moved due to their weight.

* Fine soils are the soils that will actually need filters especially if they are uniform.

Drainage Filters Continued

- a) Filters are needed to be gravel with same uniformity with the soil to be protected.
- b) $D_{15} \text{ Filter} < 5 D_{85} \text{ Soil}$; $D_{15} \text{ Filter} < 20 D_{15} \text{ Soil}$; $D_{50} \text{ Filter} < 25 D_{50} \text{ Soil}$.

These are the filtration criteria.

To give adequate hydraulic conductivity,

$D_{85} \text{ Filter} > 5 D_{15} \text{ Soil}$.

These criteria are difficult to achieve and should serve as guidelines.

Laying Plastic Pipes:

A Trench is excavated, the pipe is laid in the trench, permeable fill is added, and then the trench is filled.

This is for smooth-walled rigid plastic pipes or tile drains.

A Flexible Corrugated Pipe can be laid by machines, which lay the pipes without excavating an open trench (trench less machines).

TYPES OF FIELD DRAINAGE

The different field drainage methods can be classified as:

1. Horizontal drainage
 - i. Surface drainage
 - ii. Sub-surface drainage
 - a. Tile/Mole drains
 - b. Interceptor drains
2. Vertical drainage i.e. Tube wells

VERTICAL DRAINAGE (DRAINAGE TUBEWELLS)

The areas where there is sweet water, the pumped water is directly utilized for irrigation.

In case of saline sub-soil water and availability of fresh surface water, the drainage water can be used for irrigation after mixing with appropriate ratio.

Drainage tube wells have larger pumping capacity.

In the Indus basin most of the drainage wells are having the 0.08 cumecs capacity. In the Indus basin even 0.17 cumecs wells have been found economically viable.

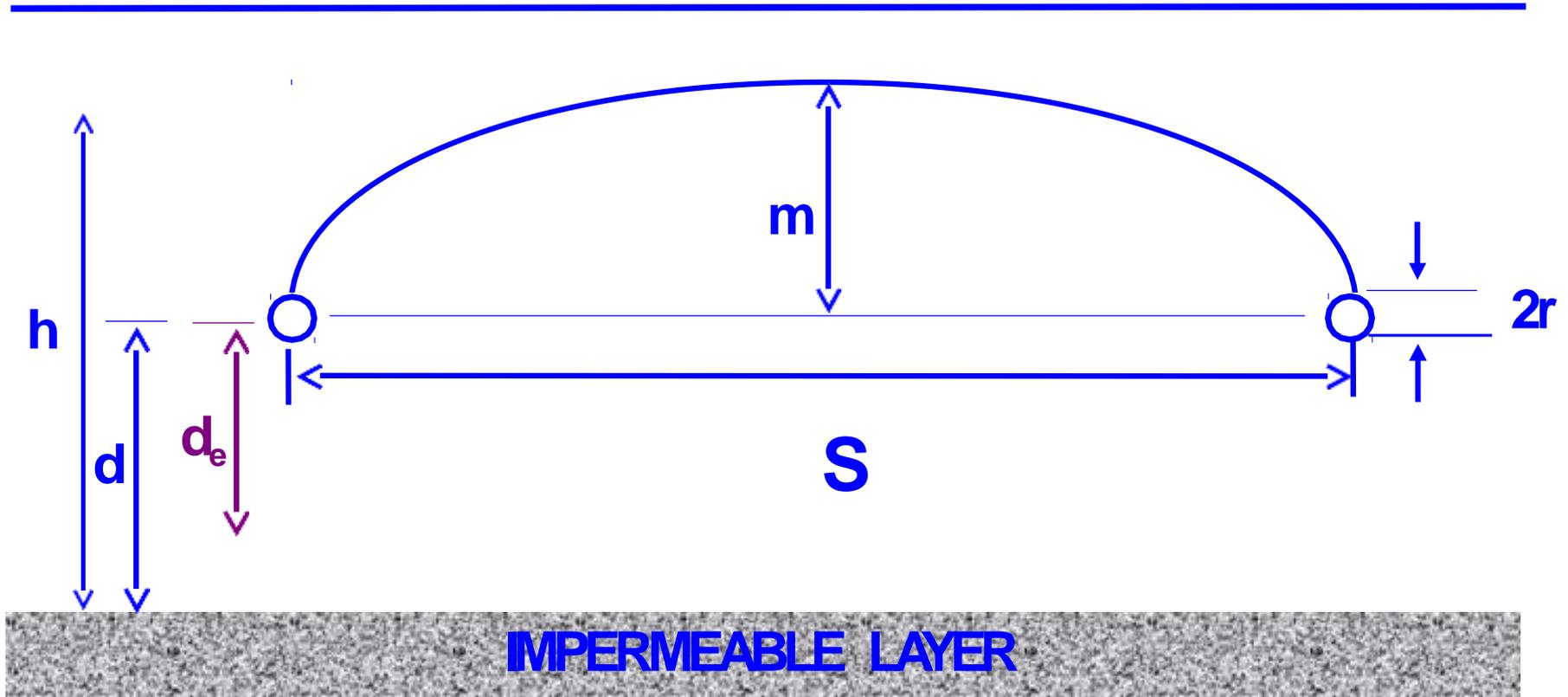
Drainage tube wells are installed in groups in such a way that cone of depression of individual wells overlap each other sufficiently.

The Conditions Required for Vertical Drainage

If the following conditions are present, then vertical drainage is preferred over the surface or sub-surface methods:

- a. An aquifer of adequate transmissivity;
- b. Adequate vertical permeability between the root zone and the water table;
- c. Extremely flat land, natural/surface drains are non-existent;
- d. Highly developed land where other forms of drainage may become expensive or not possible; and
- e. Pumped drainage water can be utilized for irrigation purposes; etc.

Hooghoudt Equation



$$q = \frac{4Km(m + 2d_e)}{s^2}$$

