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NPTEL ONLINE CERTIFICATION COURSES

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Irrigation and Drainage

Lecture No: 41 Drainage System Components

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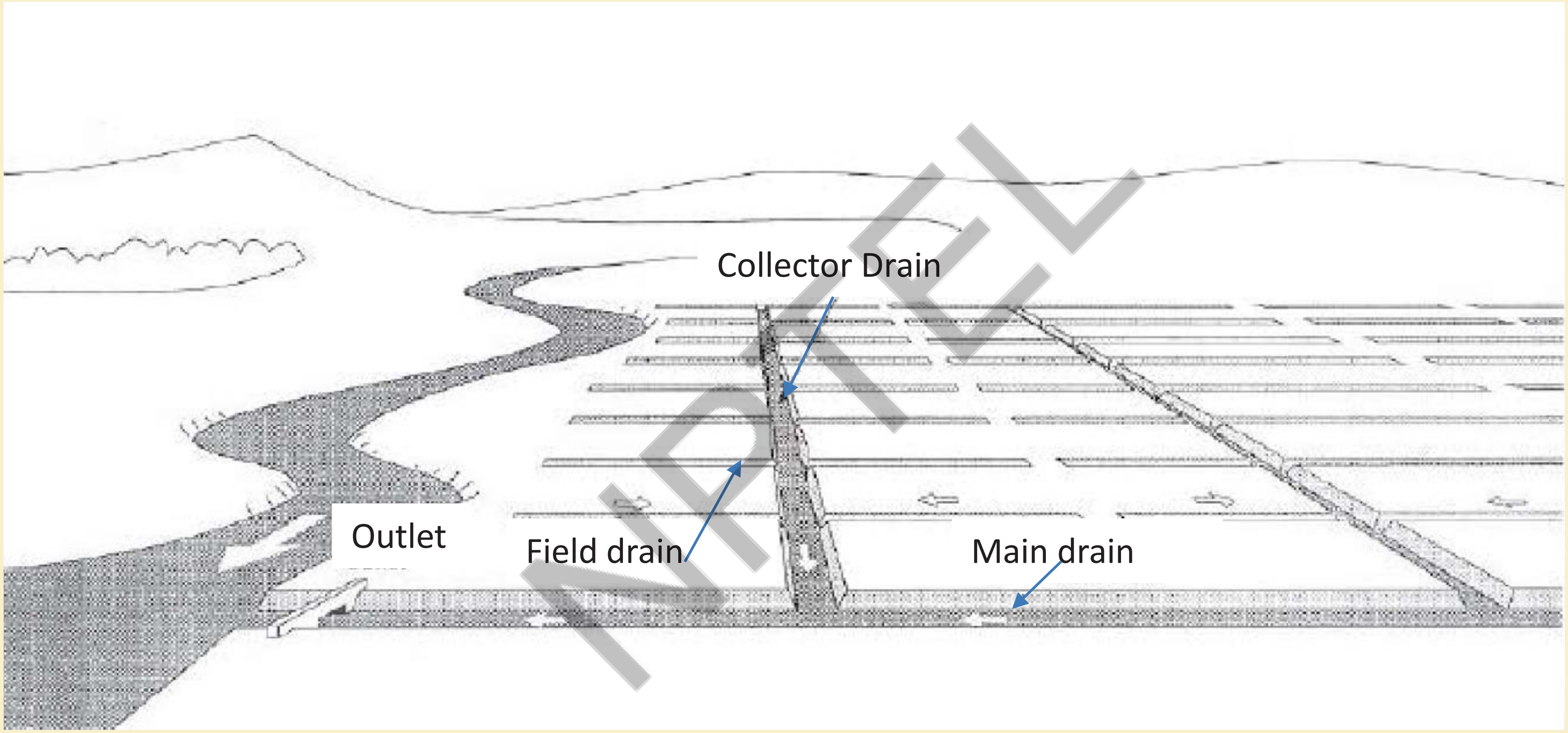
Field Drainage System



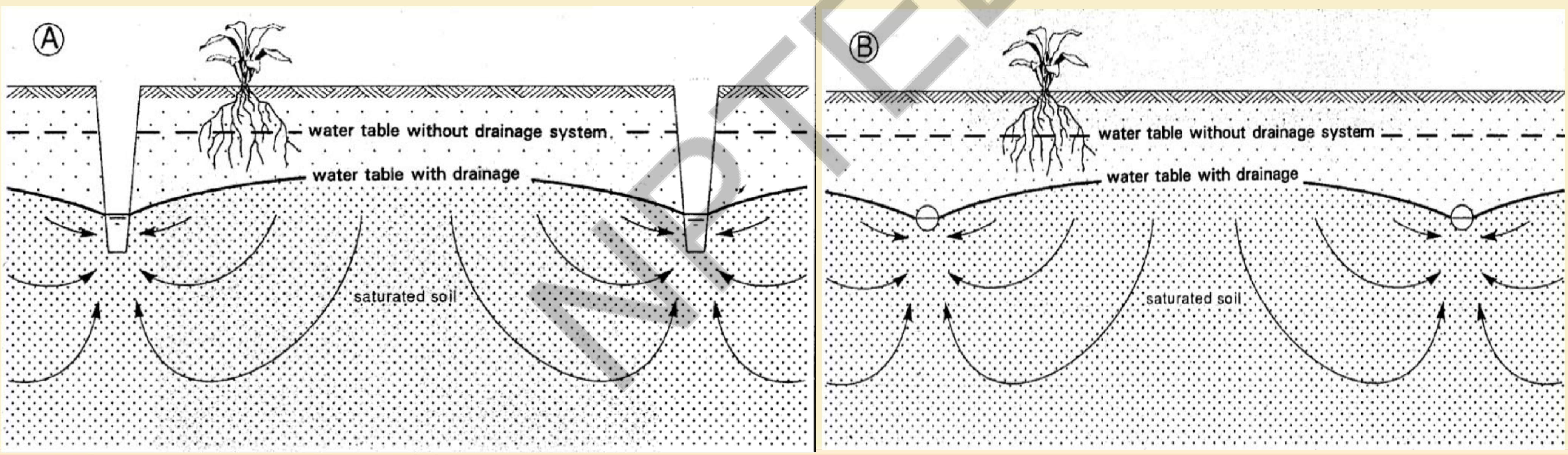
Field Drainage System

a) **Surface Drainage**

- To remove excess water from land surface
- Shallow field drains

b) **Sub-surface Drainage**

- To control water table.
- Deep open or pipe drains



Surface Drainage System

- It is intended to eliminate ponding and prevent prolonged saturation by accelerating flow to an outlet without causing soil erosion or siltation.

✓ **Two components**

  - Open drains to collect ponding water and divert it to collector drains.
  - **Land forming** to enhance the flow of water towards the field drains.

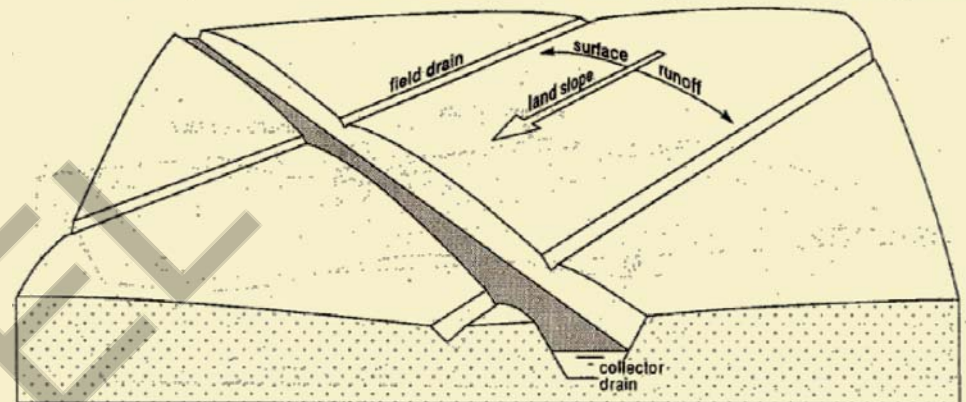
Land forming in Surface Drainage

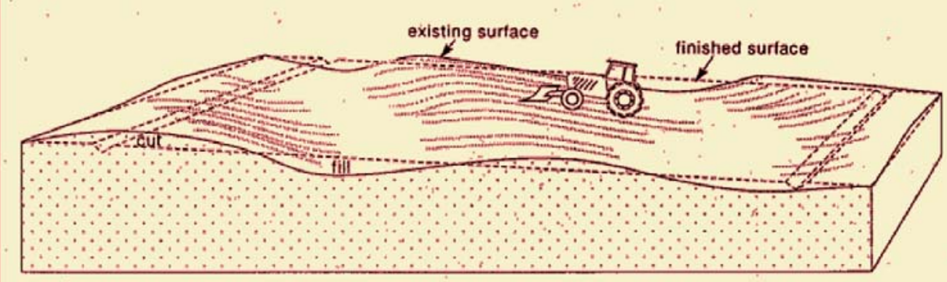
1) Bedding

- Ploughing land to form a series of low beds, separated by parallel field drains.
- Most practicable on flat slopes less than 1.5%.
- Oldest practice, used for grass lands

2) Land grading

- Cutting-filling, smoothing of the land to a predetermined slope.
- Reduces the number of field drains, most of the land is available for farming.
- Economical than bedding.

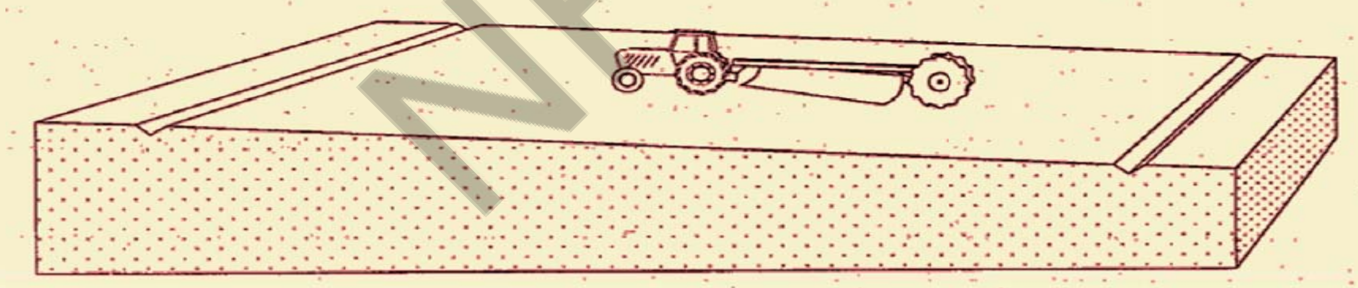




Land forming in Surface Drainage

3) Land Planing

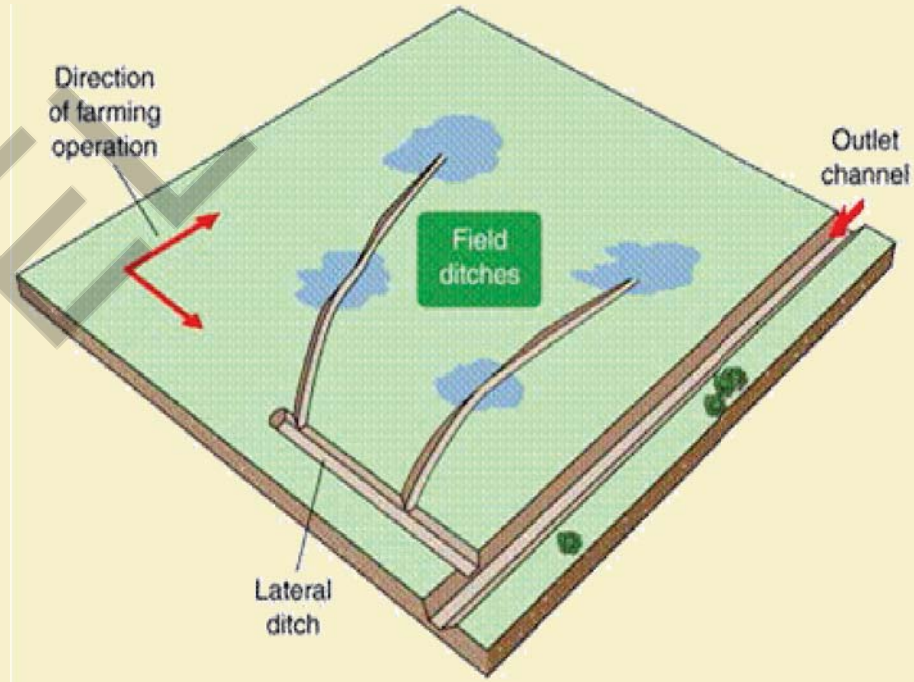
- Smoothing of the land surface by eliminating minor depressions and irregularities
- Topography of the land surface is not changed
- Special equipment used are a land plane or land leveler
- The smoothing operation may ordinarily be directed in the field without detailed surveys or plans, although grid surveys may be needed for some critical parts of the field.



Surface Drainage System Layouts

1) Random field drainage system

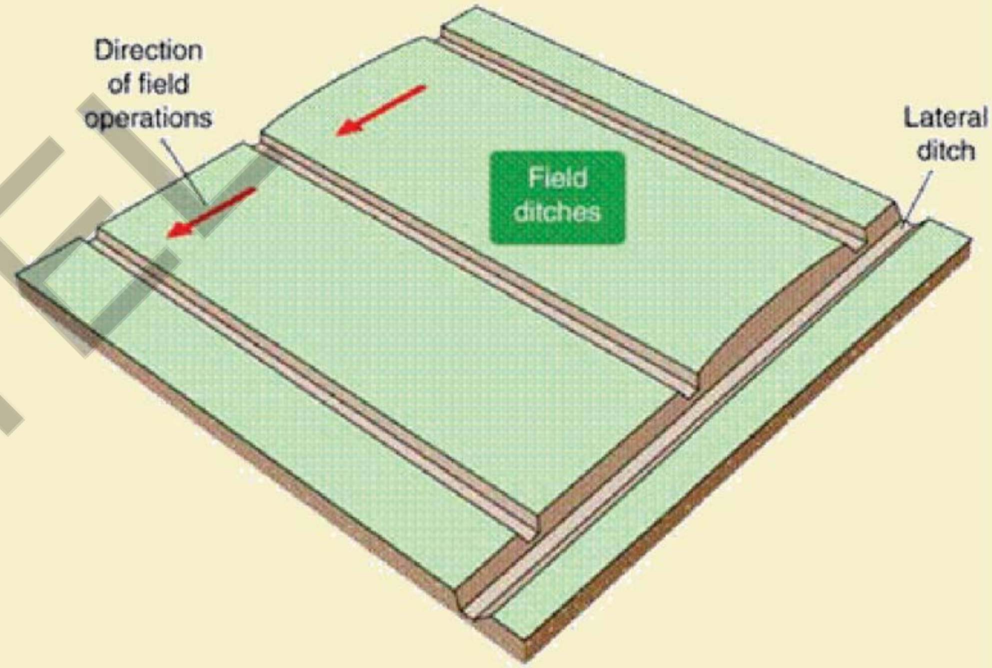
- Applicable when there are a number of large but shallow depressions in a field.
- Field ditches connect the major depressions and remove excess surface water from them.
- Shallow enough to permit frequent crossing by farm machinery.
- Soil from the ditches can be used to fill minor depressions in the field.



Surface Drainage System Layouts

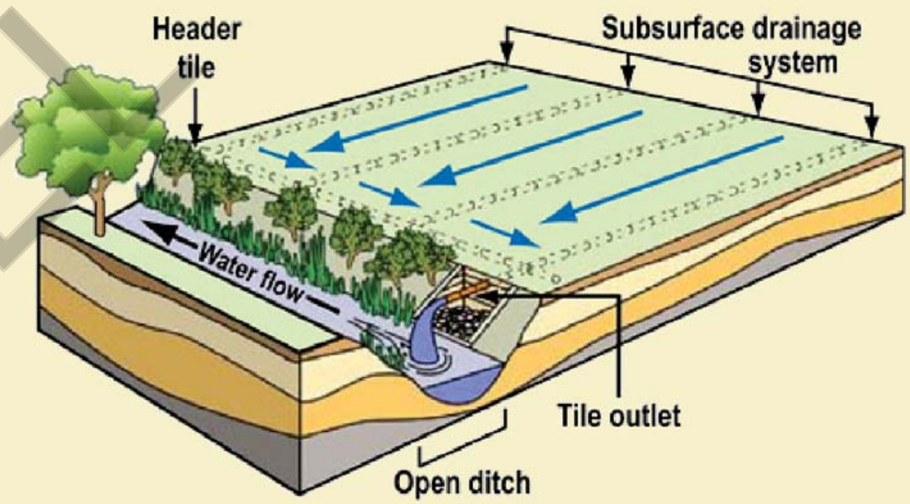
2) Parallel field drainage system

- Suitable for flatter, poorly drained soils that have numerous shallow depressions.
- Installed across the slope to break the field into shorter units of length and make it less susceptible to erosion.
- The field should be farmed in the direction of the greatest slope.
- Ditches must be parallel but need not be equal distances.
- Most effective method of surface drainage system



Sub-surface drainage system

- ✓ For removal of excess water and dissolved salts from the rootzone through deep ditches or pipes
- ✓ **Advantages of sub-surface drainage system**
  - o Aeration of the soil
  - o Increased length of growing season
  - o Improvement of soil water condition
  - o Removal of toxic substances, such as salts
  - o Greater storage capacity for water



Sub-surface drainage system

Selection of Open drains or Pipe drains

a. Open drains

- Can receive overland flow and also serve as surface drainage.
- Some of the land is lost in construction of drains.
- Interferes with the irrigation system and farm operations and high maintenance cost.

b. Pipe drains

- The most widely used subsurface drainage method worldwide.
- There are two options for collectors
  - ✓ Open drains – Singular pipe drainage system
  - ✓ Pipe drains – Composite pipe drainage system

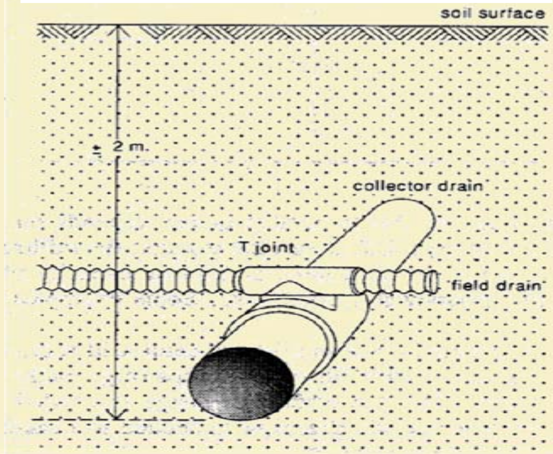
Sub-surface drainage system

a) **Singular drainage system**

- Each field pipe drain discharges into an open collector drain.

b) **Composite drainage system**

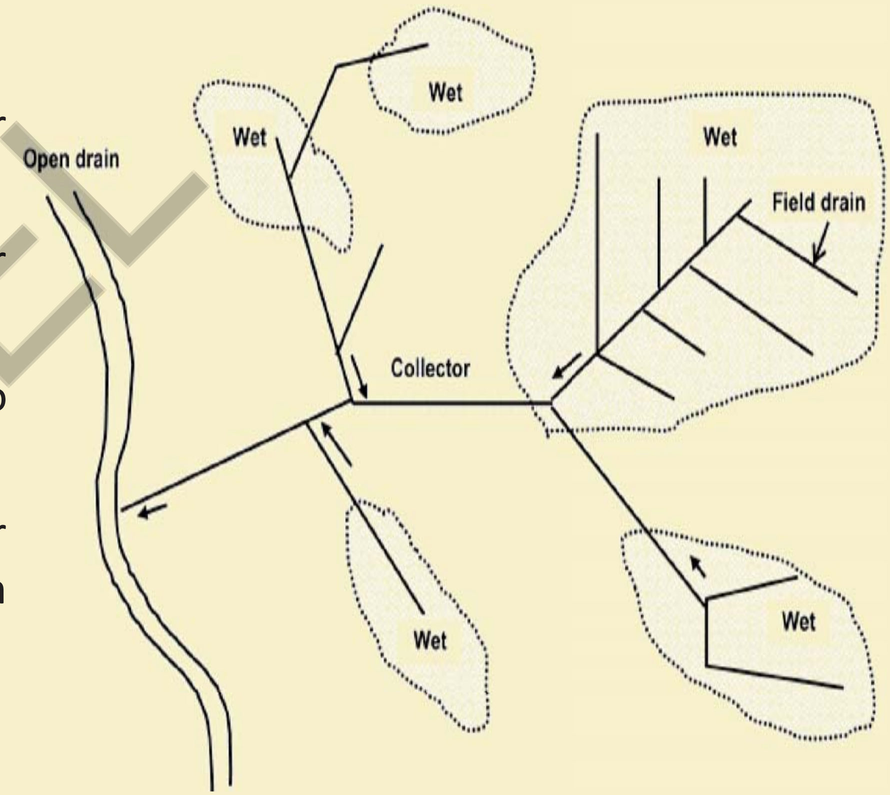
- Field pipe drains discharge into a pipe collector, which in turn discharges into an open main drain.
- All field drains and collector drains are burried pipes



Sub-surface Drainage System Layout

a) Random System

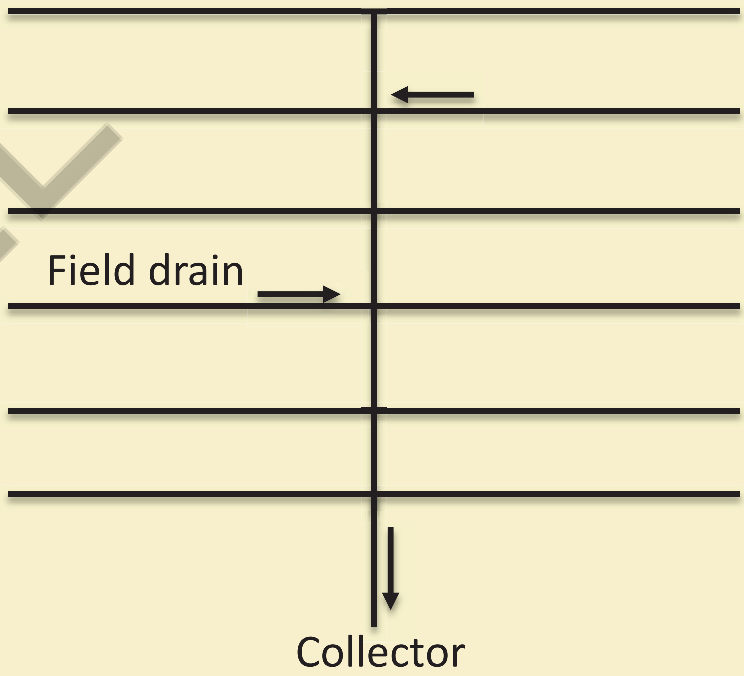
- The random pattern is suitable for undulating or rolling land that contains isolated wet areas.
- The main drain is usually placed in the swales rather than in deep cuts through ridges.
- The laterals in this pattern are arranged according to the size of the isolated wet areas.
- Thus, the laterals may be arranged in a parallel or herringbone pattern or may be a single drain connected to a sub-main or the main drain.



Sub-surface Drainage System Layout

b) Parallel grid system

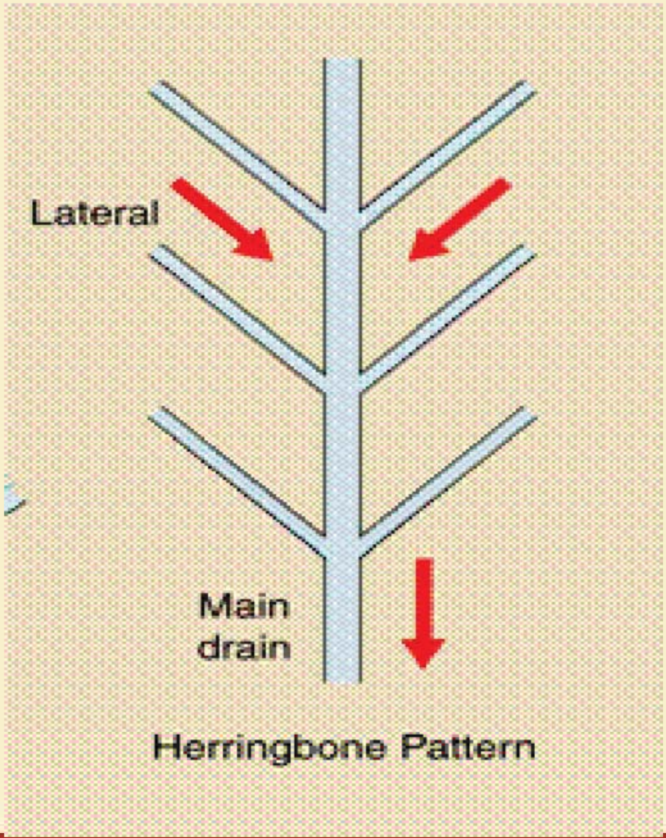
- Field drains joins the collector at right angle.
- The laterals in the pattern may be spaced at any interval consistent with site conditions.
- This pattern is used on flat, regularly shaped fields and on uniform soil.
- Variations of this pattern are often combined with others.



Sub-surface Drainage System Layout

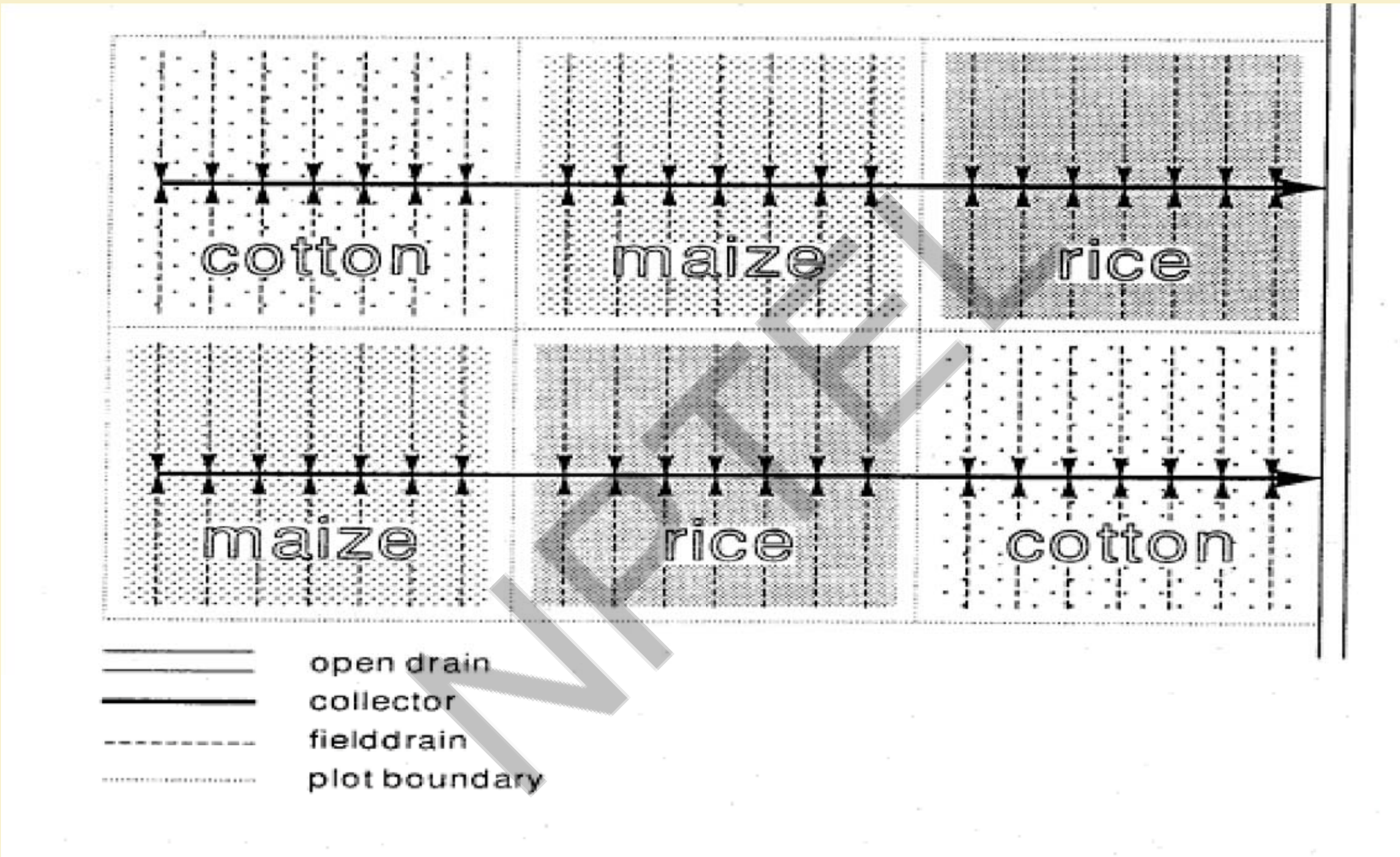
c) Herringbone system

- Field drains joins the collector at sharp angles usually from both sides.
- The main is located on the major slope of the land, and the laterals are angled upstream on a grade.
- This pattern is often combined with others to drain small or irregular areas.
- Can provide the extra drainage needed for the less permeable soils.
- Disadvantages: cause double drainage; cost more than other patterns because it contains more junctions.



Combined Drainage System

- Combination of surface and sub-surface drainage systems may be needed when
  - Cropping patterns include rice rotation with 'dry-foot' crops (maize or cotton).
  - Sub-surface drainage is needed for salinity control for maize or cotton.
  - Surface drainage is needed for paddy to remove ponding water.
- Areas with occasional high-intensity rainfall (> 50 mm/day), which causes surface ponding, even when a sub-surface drainage system has been installed. This pattern is often combined with others to drain small or irregular areas.
- In both of above examples, the standing water could be removed by the subsurface drainage system, but this would either take too long or require drain spacings that are so close as to be economically unjustifiable.


cotton
maize
rice
maize
rice
cotton
open drain
collector
fielddrain
plot boundary

Thank You!!

Irrigation and Drainage

Lecture No: 42 Drainage system: Drain Pipe

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Choice between Singular and Composite System

1) **Surface water**
   - Singular system provides an outlet for excess surface water.
2) **Field size and land use**
   - **Pipe laterals**: < 300 m and **field width**: < 300 m (for single side) or 600 m (double sided).
   - Loss of land in constructing ditches may add up to 2-3%.
3) **Blockages**
   - Out flow from field drain to ditch collector is easy to inspect in singular system.
   - Blockage affects small area in case of singular system.
   - It is liable to continue over a longer period as malfunction is not so evident.

Choice between Singular and Composite System

4) **Maintenance**
   - Ditch collectors require much more maintenance than pipe collectors.
5) **Outlets**
   - The pipe outlets in the singular system represent weak spots as they are easily damaged i.e. during ditch maintenance.
6) **Hydraulic gradient**
   - Pipe collector requires 5-10 times more gradient than a ditch collector because of the smaller wet cross-section.
   - When the available land slope is constraint, this may restrict the length of pipe collector.
   - It will lead to pumping of the drained water using pumping sumps.

Choice between Singular and Composite System

7) Cost

- o Installation costs for singular systems are lower than composite system.
- o Maintenance cost is higher for singular systems.

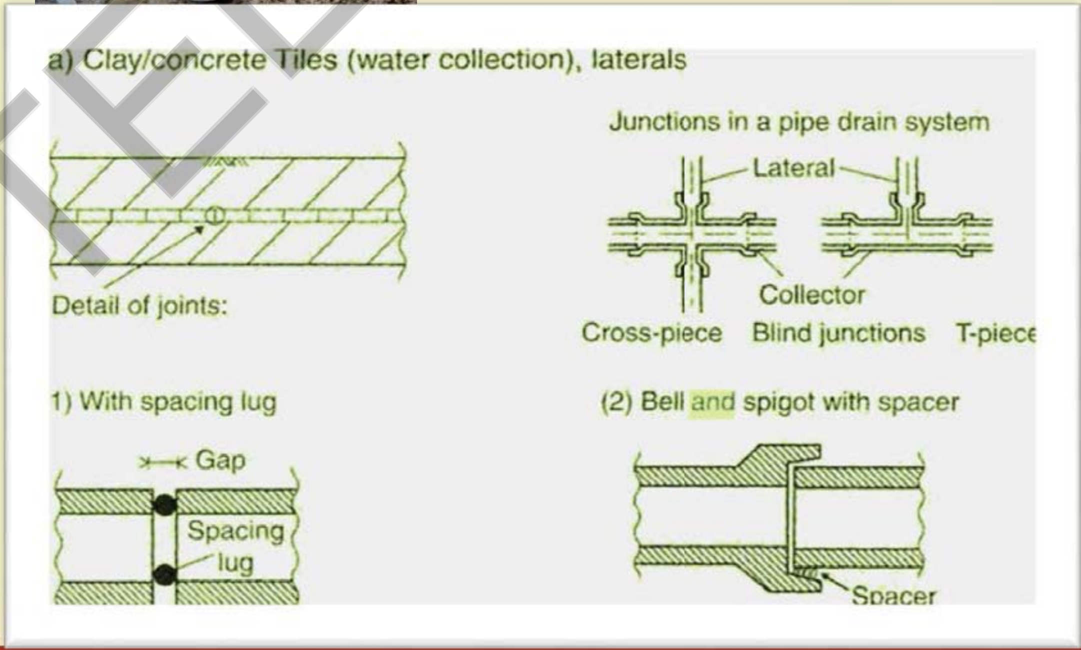
- ✓ Singular systems are most suitable for flat plains under humid climatic conditions.
- ✓ Composite systems are most suitable for lands with high slope and saline soils.

Drain Pipe

- Pipe drain has evolved since the first time use of some 300 years ago.
- Clay pipes were introduced in 18^{th} century.
- In a place without tile industry, the drain pipe was usually made of concrete.
- Plastic pipe was introduced in 1960, since then it conquered the almost all of the drain pipe market in almost all countries.

Drain Pipe

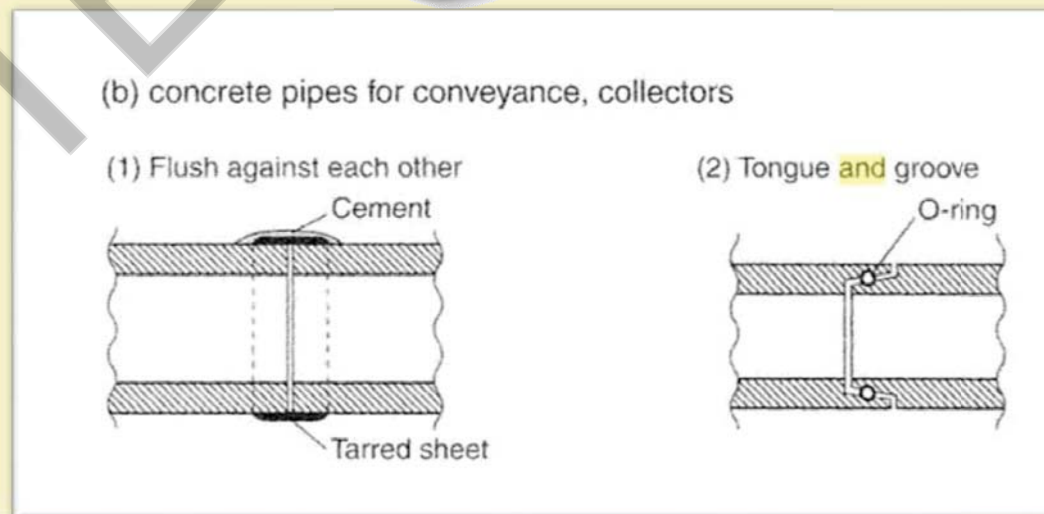
1. **Clay tile pipe**
    - o Size of the pipe vary between countries.
    - o Typical pipe sections are 30 cm long and have internal diameters (ID) equal to 5, 6.5, 8, 10 up to 20 cm.
    - o Highly resistant to deterioration and corrosion
    - o Water enters through the joints.



Drain Pipe

2. Concrete Pipe

- o Diameter: 30-50 cm.
- o Length: 30 cm (small diameter pipe) or 50 cm (large diameter pipe)
- o Made of Portland cement
- o Deteriorate in acidic or salt affected soils
- o Water entry occurs through the joints



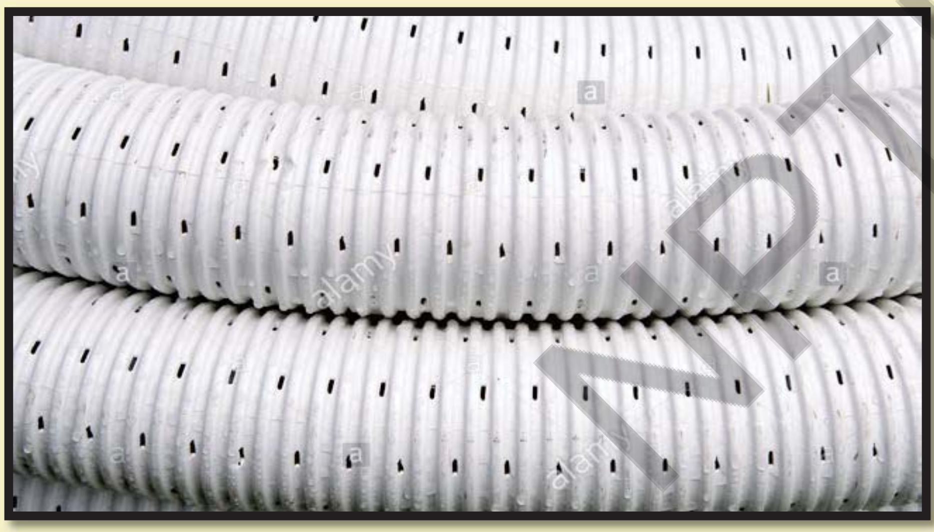
Drain Pipe

3. Plastic pipe

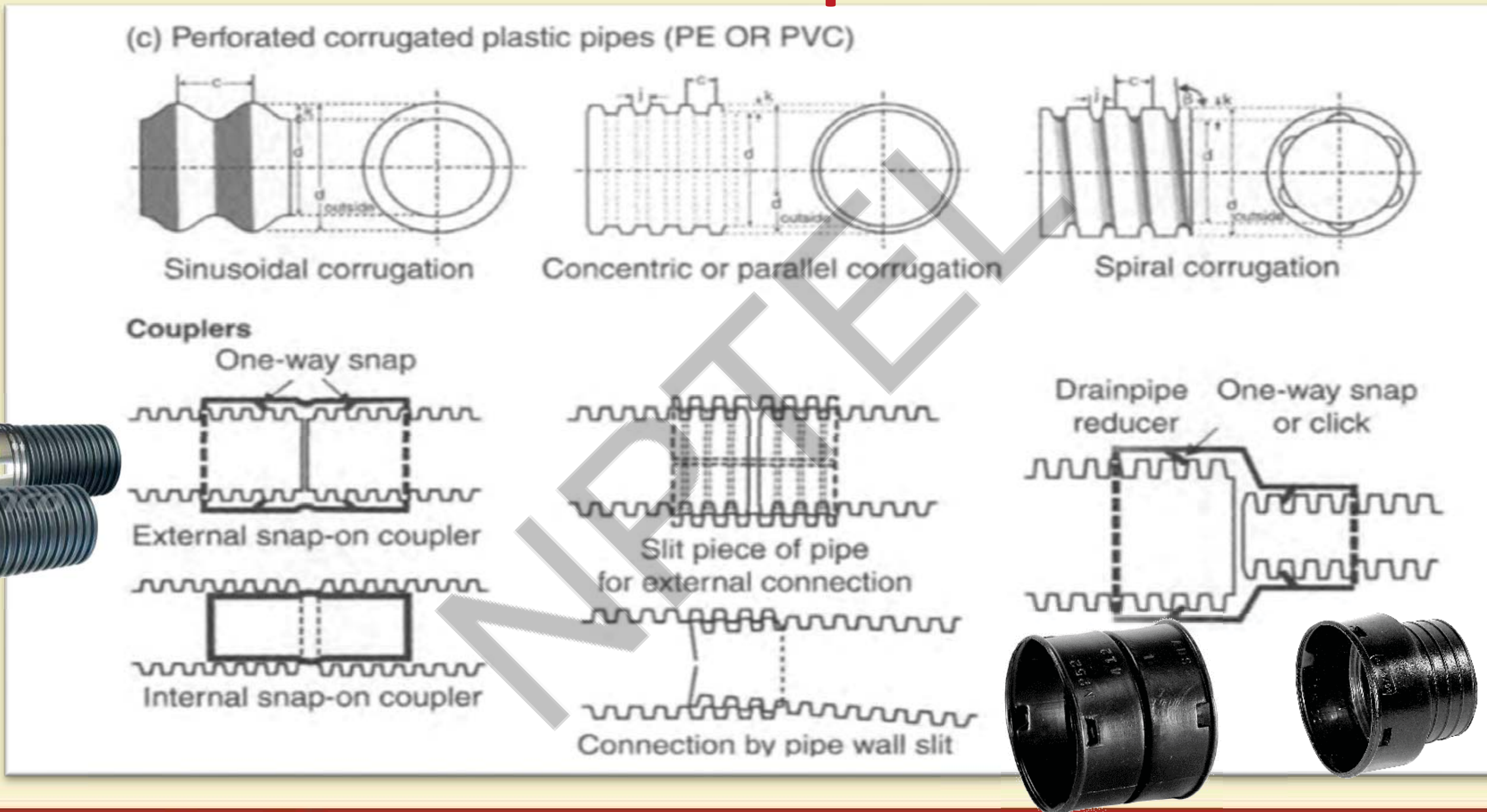
- Made from PE (polyethylene) or PVC (poly vinyl chloride).
- Length: 30 cm (small diameter pipe) or 50 cm (large diameter pipe).
- Very durable; deteriorate by long exposure to the ultra-violet radiation.
- PVC becomes brittle with freezing temperatures.
- Most of the plastic pipes are supplied with corrugations either spiral or parallel.
  - ✓ Higher hydraulic roughness and require 20% increase in diameter to carry same flow as smooth pipe.
  - ✓ Cost of corrugated and smooth pipes are same.
  - ✓ ID ≈ 0.9 × OD; where OD = 50, 60, 80, 100, 125, 160 and 200 mm

Drain Pipe

- ✓ Perforations on the pipe may have any pattern that provides even distribution around the circumference.
- ✓ The open area should be minimally 800 mm^2 for m-length of the pipe.



Drain Pipe



(c) Perforated corrugated plastic pipes (PE OR PVC)
Sinusoidal corrugation
Concentric or parallel corrugation
Spiral corrugation
Couplers
One-way snap
External snap-on coupler
Internal snap-on coupler
Slit piece of pipe
for external connection
Connection by pipe wall slit
Drainpipe
reducer
One-way snap
or click
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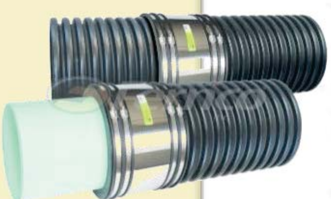
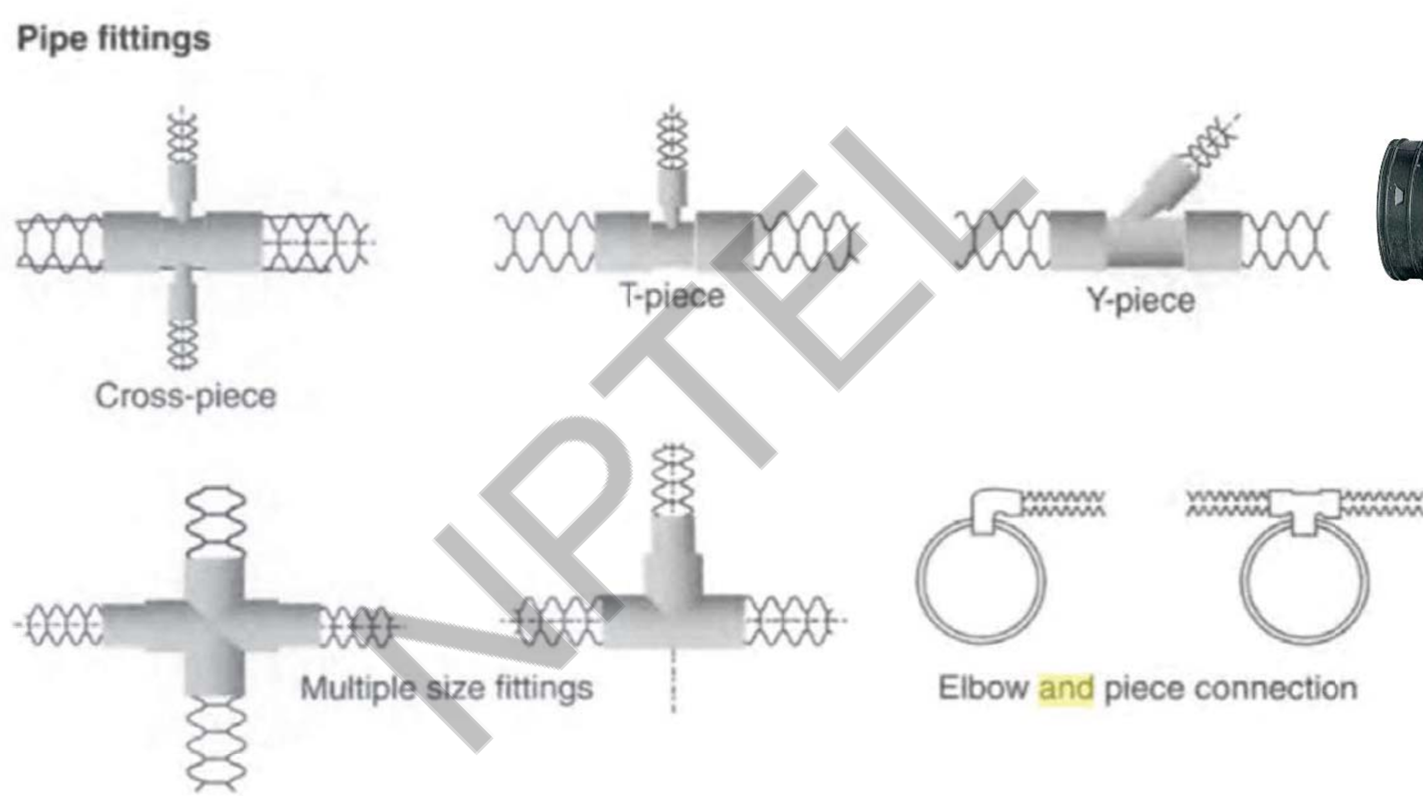
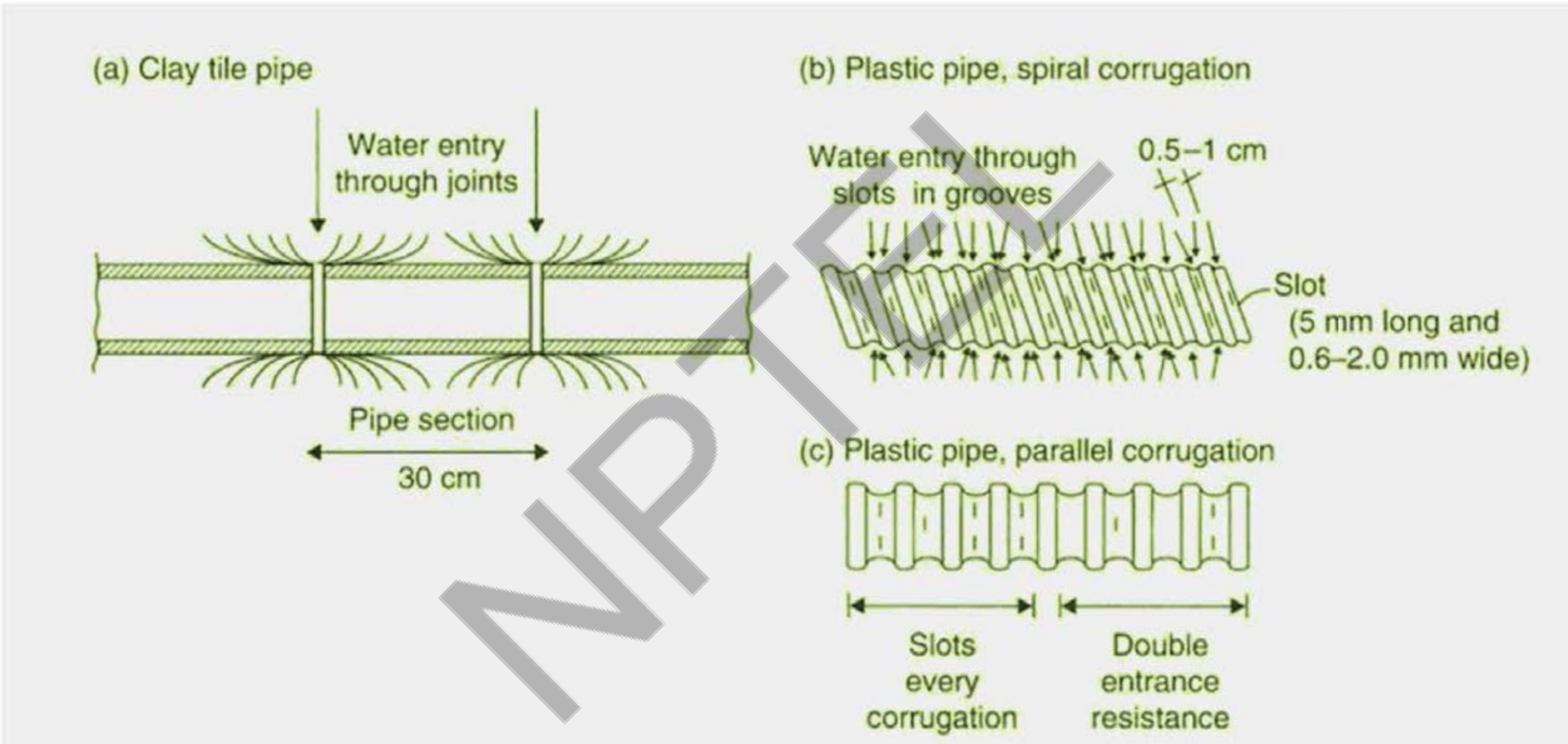


Drain Pipe


Pipe fittings
Cross-piece
T-piece
Y-piece
Multiple size fittings
Elbow and piece connection

Drain Pipe



(a) Clay tile pipe
Water entry
through joints
Pipe section
30 cm
(b) Plastic pipe, spiral corrugation
Water entry through
slots in grooves
0.5–1 cm
Slot
(5 mm long and
0.6–2.0 mm wide)
(c) Plastic pipe, parallel corrugation
Slots
every
corrugation
Double
entrance
resistance

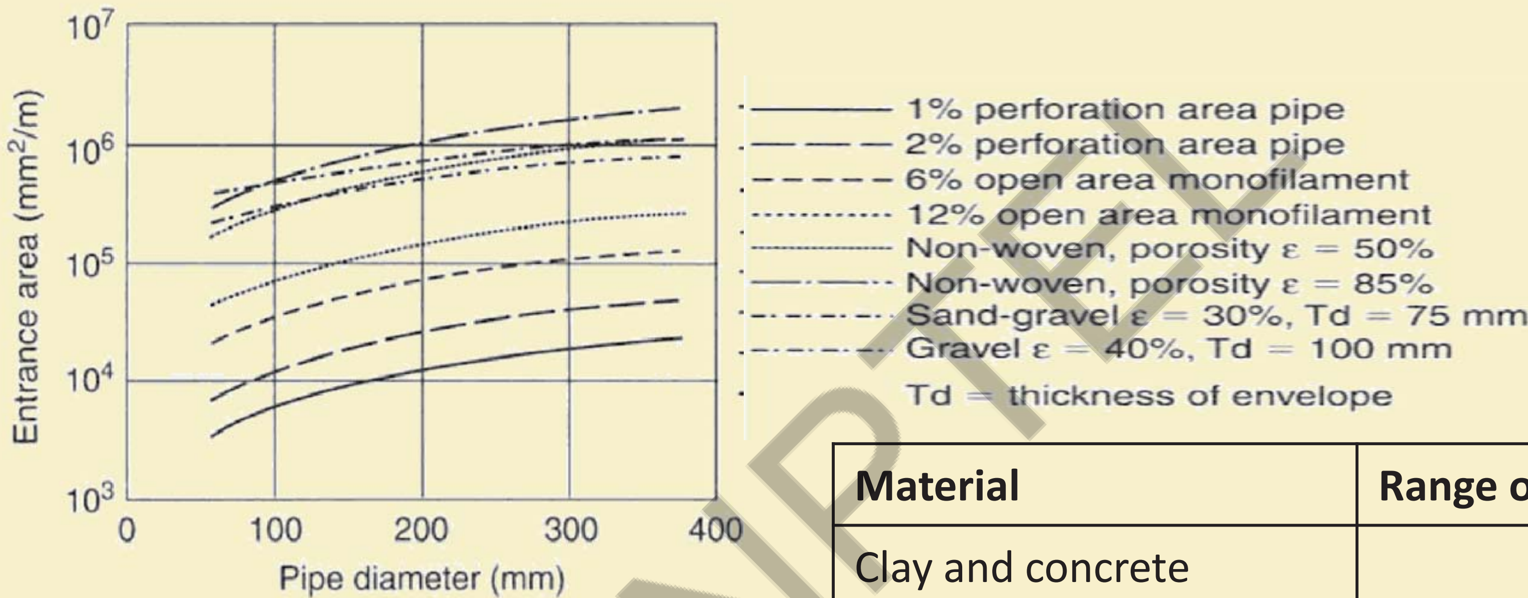
Entry Losses

- ✓ Pipes with small open area will have higher head loss and vice-versa.
- ✓ When drains have envelop around it, entrance losses can be reduced significantly.
- ✓ High entry resistance is mostly due to clogging or blocking of the openings of the pipe
- ✓ Entry characteristics of the different pipes/envelop may be compared using a standardized resistance factor α.

$$h_e = \alpha \frac{Q}{k}$$

Where, h_e is the head loss at entry, m; α = resistance factor (-); Q = inflow rate to pipe /m length of pipe, ($\frac{m^3}{m} d$); k = hydraulic conductivity of envelop material, $\frac{m}{d}$

Entry Losses



Material	Range of α
Clay and concrete	0.4 – 2.0
Smooth plastic	0.4 – 0.6
Corrugated plastic	0.05 – 0.1

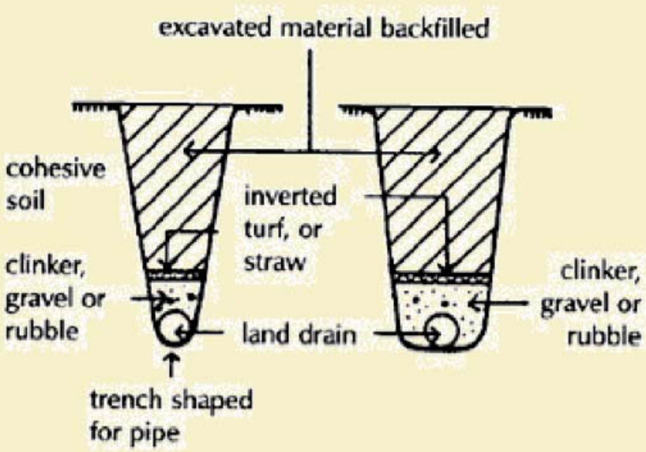
Selection Criteria for Drain Pipe

1. Clay or concrete pipes are suitable where pipe drains are not locally available. Concrete pipes are economically feasible for large areas.
2. Where all types are available the use corrugated plastic pipe often has distinct advantages.
   - Light weight
   - Delivery in long lengths
   - Low transport cost
3. Plastic pipes are most suitable for mechanical installation.
   - Performance is less affected by poor installation
4. Prices of smaller diameter (< 10 cm) are usually of the same for all material
   - Larger diameter plastic pipes are more expensive

Pipe Envelope

The functions of Envelope around the drain pipe are:

1. **Filter function:** To prevent the entry of the fine particles into pipe.
2. **Hydraulic function:**
   - To provide a porous medium of high porosity around the drain.
   - To reduce the head loss at the entry.
3. **Mechanical support**
   - To provide passive mechanical support to the pipe.
4. **Bedding function**
   - To provide stable base to the drain pipe.



Pipe Envelope

For Gravel Envelope:

Developed by USSCS

$$\frac{D50_F}{D50_s} = 12 \text{ to } 58$$

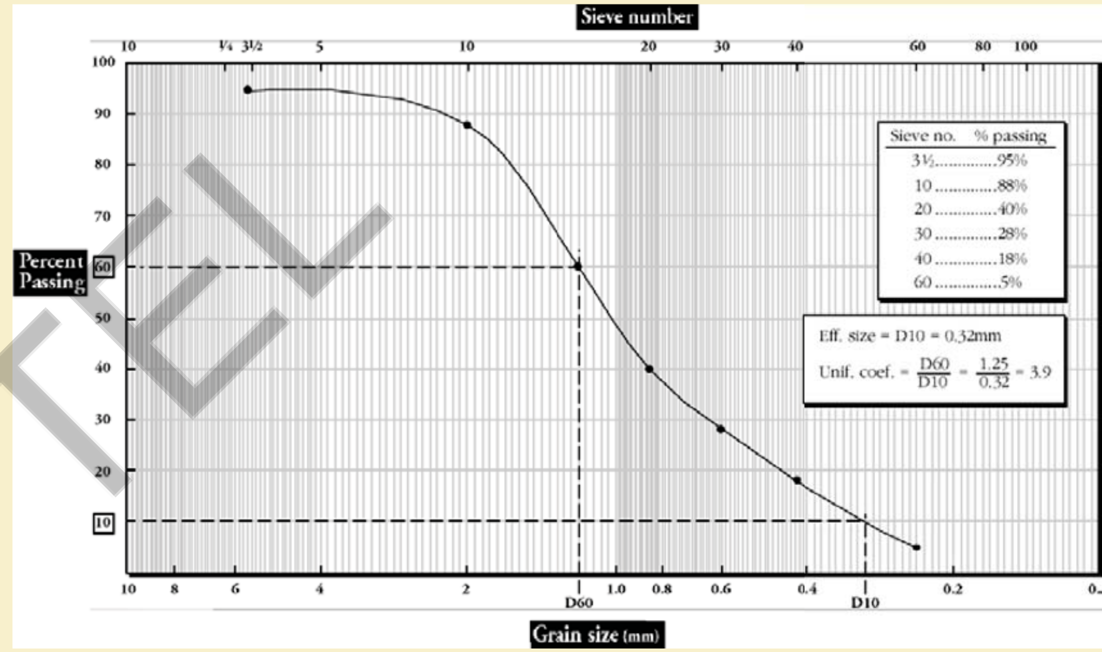
$$\frac{D15_F}{D15_s} = 12 \text{ to } 40$$

For stability of filter:

$$\frac{D15_F}{D85_s} \leq 5$$

$D85_F \geq$ half of the width of the pipe perforated

$D5_F \geq 0.42$ mm (FAO, 1980)



F is filter material

S is soil material

Thank You!!

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Irrigation and Drainage

Lecture No: 43 Drainage System: Structures

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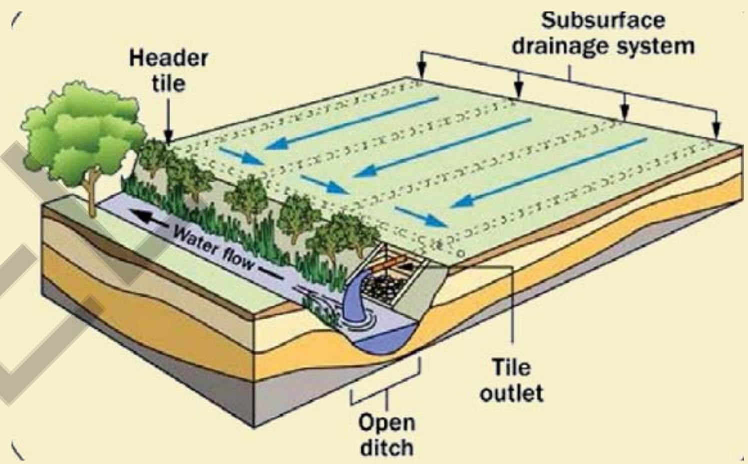
Structures in Pipe Drain System

a) **Outlet of a pipe drain into a ditch or canal**

Structure should meet the following requirements

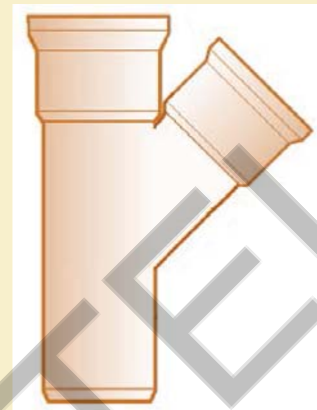
- ✓ Prevent erosion of the side slopes
- ✓ Preferably not interfere with ditch maintenance
- ✓ Prevent entry of animals into the drain

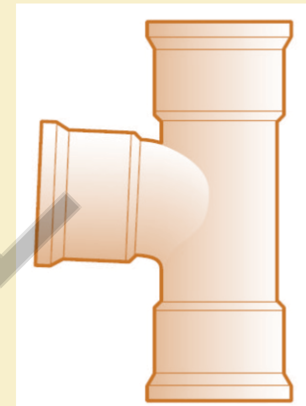


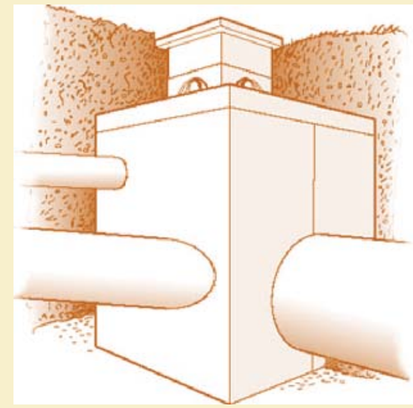
Structures in Pipe Drain System

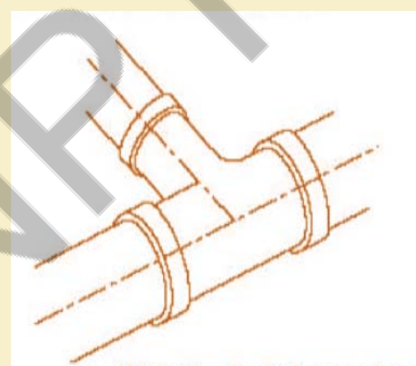
b) Junctions and inspection chambers

- ✓ These are used in composite drain pipes
- ✓ May have junction boxes with a provision to trap silt and repair interceptor/maintenance
- ✓ Buried chambers do not interface with farm operations
- ✓ Most connections are made using blind junctions which cannot be inspected after installation

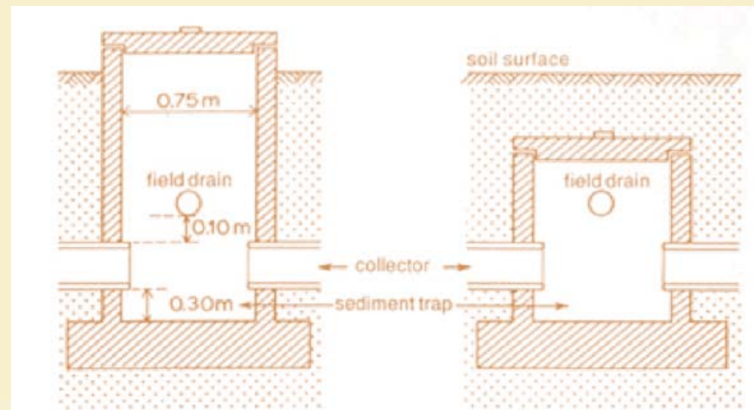








Y-junction in drainage pipes.



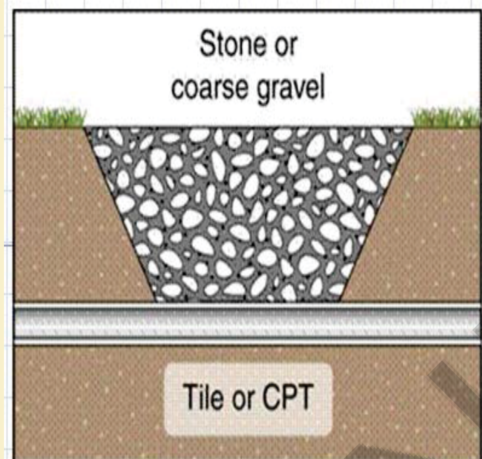
Structures in Pipe Drain System

Junction boxes

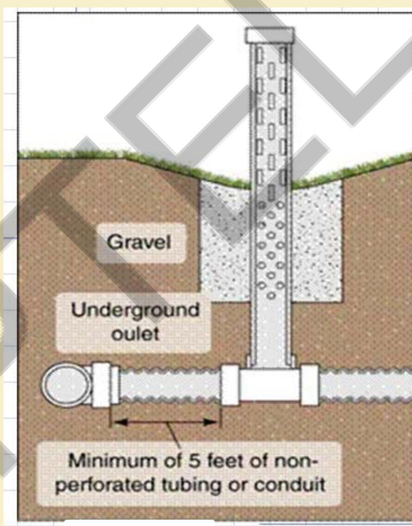
Structures in Pipe Drain System

c) **Surface water inlets:**

✓ Used for incidental discharge of surface water



Blind inlets remove both surface and subsurface water and are suitable where there are relatively small amounts of impounded water.

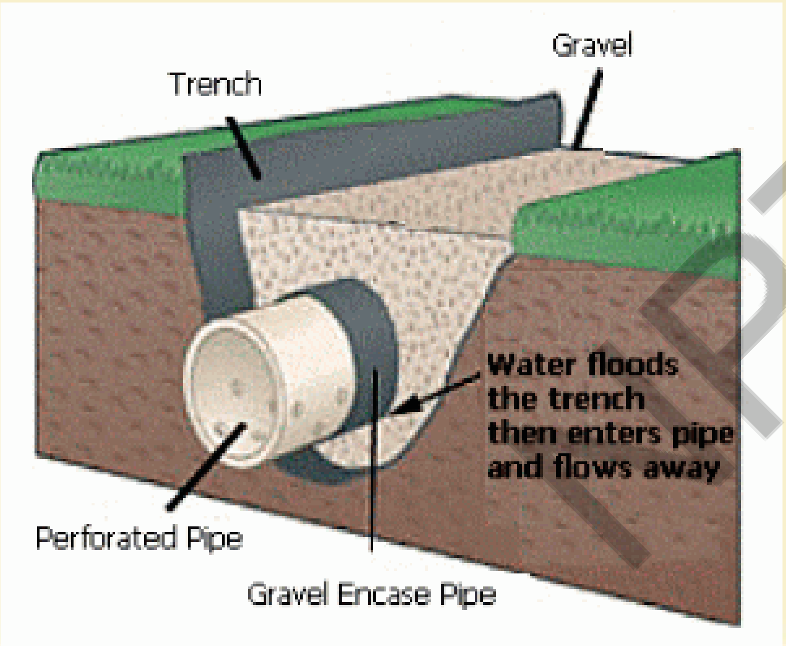


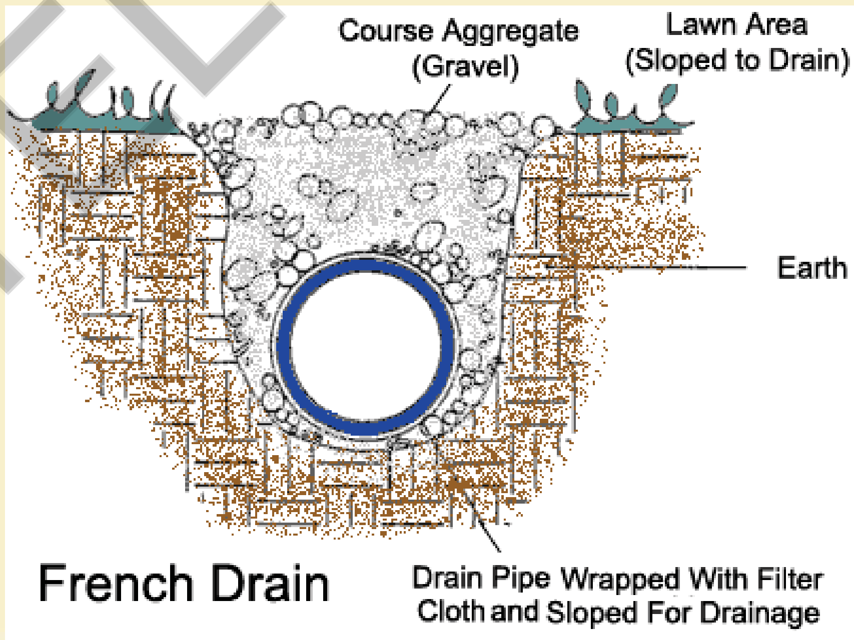
A surface-water inlet offset from the subsurface drain line to reduce potential damage to the line.

Structures in Pipe Drain System

d. Bedding:

- ✓ Gravel bed is most suitable for corrugated pipe lateral

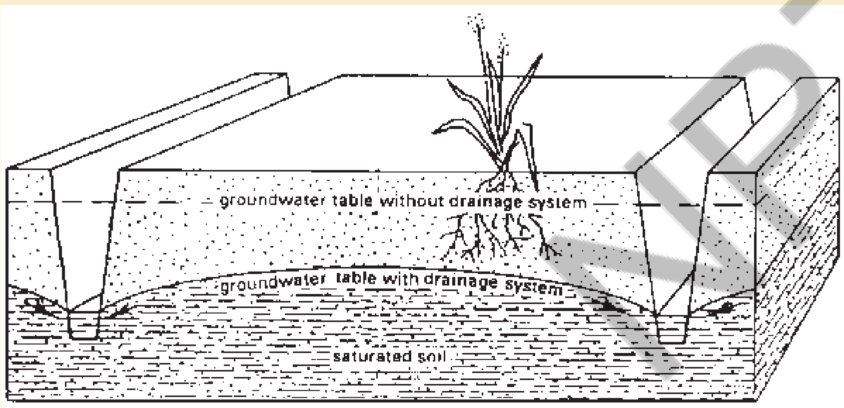




Structures in Pipe Drain System

✓ **Ditch Systems**

- Consists of ditches laid out in various pattern
- Drains laid deep enough for effectively pond water drainage(1-1.5m below)
- Trapezoidal shape (side slope : 1:1 to 1:2)



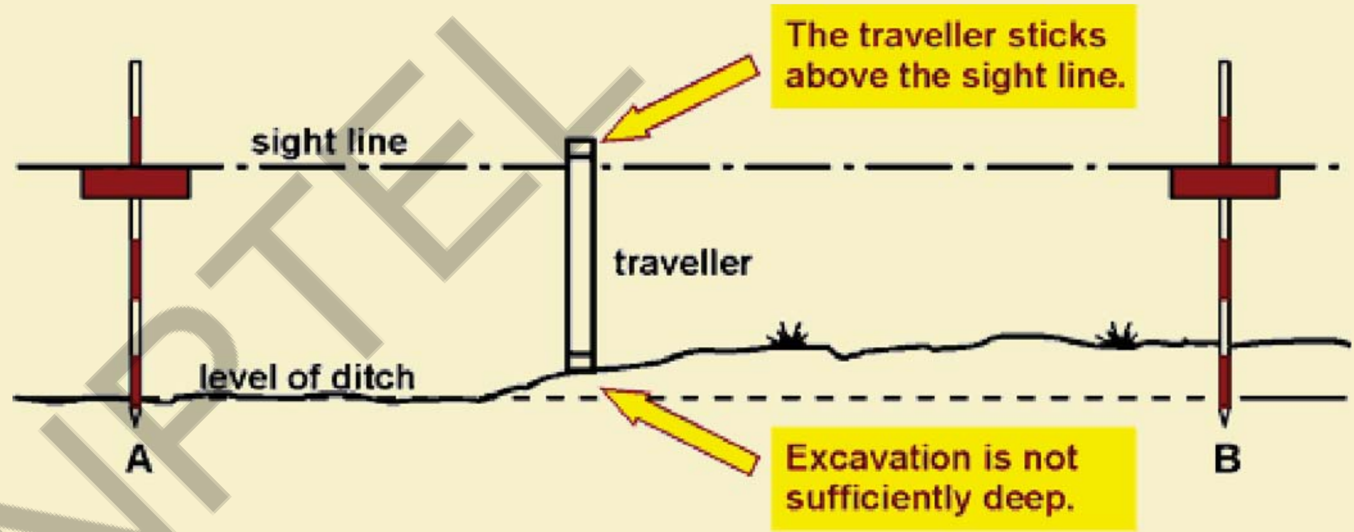
Construction of Pipe Drains

Two Activities:

- ✓ Setting out of alignments and levels
- ✓ Installation of drain pipe in the soil

Setting out

- ✓ Sightline should parallel with the pipe drain time
- ✓ heavy rods may be used to check the level



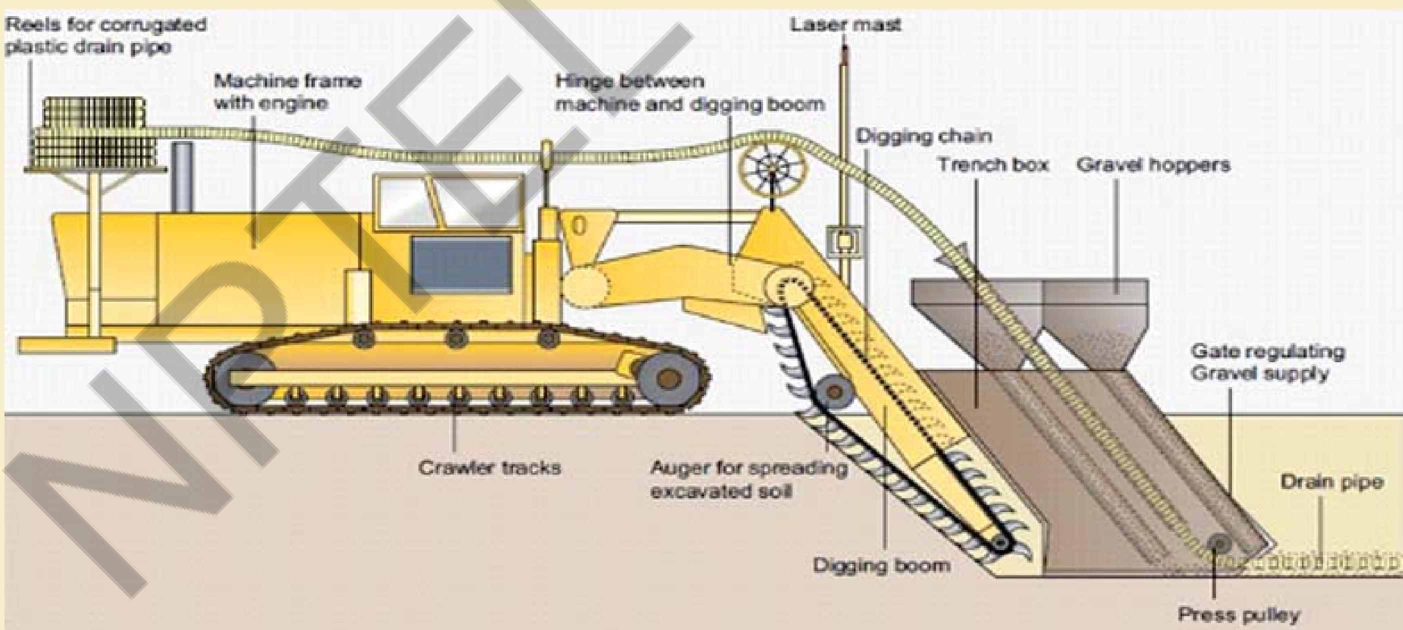
Construction of Pipe Drains

✓ **Backacter**

- 40-65hp
- 4m depth
- 0.2-0.6m width trench

Construction of Pipe Drains

- ✓ **Continuous Crawler Trench**
  - o Up to 200 hp
  - o 3-3.5m depth
  - o 0.2-0.45m width trench



Construction of Pipe Drains

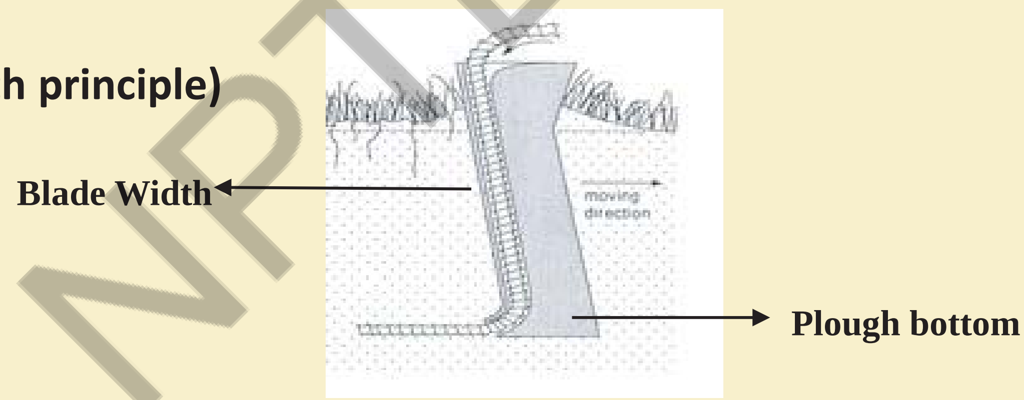
- ✓ **Trenchless Crawler**
  - o 135-200hp
  - o 1.6-2.0m dep

Construction of Pipe Drains

✓ **Trench installation involves**

- Excavation of the trenches
- Laying of the pipe with or without envelope
- Backfilling of the trenches
- Excavation, installation and the envelope can be done intense by machines
- Manual operations are needed when there is level lands and unavailable of machine

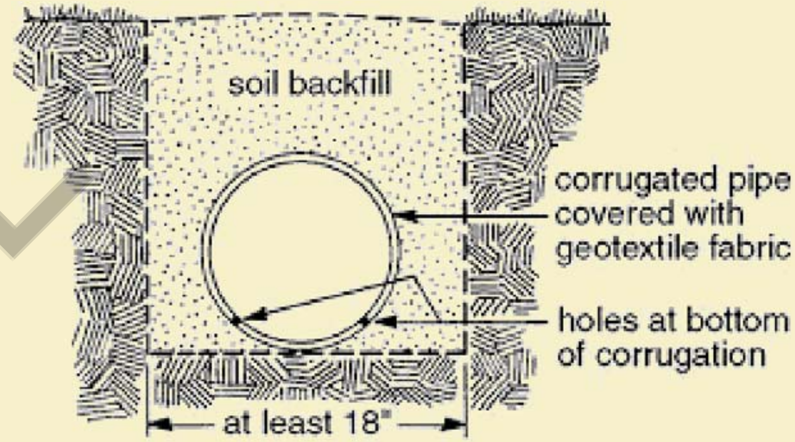
✓ **Trenchless drains (critical depth principle)**



✓ **Timing of installation should be during dry season when the soil supports heavy load**

Construction of Pipe Drains

- ✓ **Backfilling**
  - o Done by filling top soil first by hand or blade
  - o Combination of trench backfilling and consolidation under humid or irrigated soils
  - o Each layer is sprinkled with water with tamping
  - o Any remaining fill should finally be formed into a low bund to prevent water ponds
- ✓ **Maintenance**
  - o Pipe drains need to be cleaned regularly when there is a danger of deposition of fines or of iron compounds or the flow is restricted by any other reason.
  - o Deposits of fine or iron compounds be removed from the pipe by flushing
  - o In composite system, special access points may be provided.



Drain pipe cleaning by means of jetting nozzle

Useful Videos

https://www.youtube.com/watch?v=_5hfE8ReeiI

https://www.youtube.com/watch?v=njFvJIulMno

Thank You!!

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Irrigation and Drainage

Lecture No: 44 Drainage System Design

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Ground Water Flow

Laplace's Equation for Groundwater flow

It combines Darcy's equation and mass continuity equation.

Darcy's equation can be written as $q = V \times i = K \quad \times i = K\frac{dh}{dS}$

K is the hydraulic conductivity, i is the hydraulic gradient, dh is the head difference with the distance dS.

For a three-dimensional system $V_x = K\frac{dh}{dx}, V_y = K\frac{dh}{dy}, V_z = K\frac{dh}{dz}$

For steady-state condition (no change in storage), **mass continuity equation** can be written as

$$\frac{dV_x}{dx} + \frac{dV_y}{dy} + \frac{dV_z}{dz} = 0$$

Ground Water Flow

Laplace's Equation for Groundwater flow

Putting the values of V_x, V_y, *and* V_z *,we get*

$$K_x \frac{d^2h}{dx^2} + K_y \frac{d^2h}{dy^2} + K_z \frac{d^2h}{dz^2} = 0$$

For homogeneous and isotropic soil system, $K_x = K_y = K_z$

Thus,

$$\frac{d^2h}{dx^2} + \frac{d^2h}{dy^2} + \frac{d^2h}{dz^2} = 0$$

which is the well-known Laplace's equation for groundwater flow.

Exercise 44.1:

A 1.2 m deep soil column consists of three layers, having 0.50, 0.4, and 0.3 m depth of the layers. The horizontal hydraulic conductivity of the layers are 0.20, 0.15, and 0.25 m3/m2/h, respectively. Determine the resultant horizontal hydraulic conductivity of the soil column.

Solution:

We know,

$$K_H = \frac{\sum K_i d_i}{\sum d_i}$$

Putting the value in equation

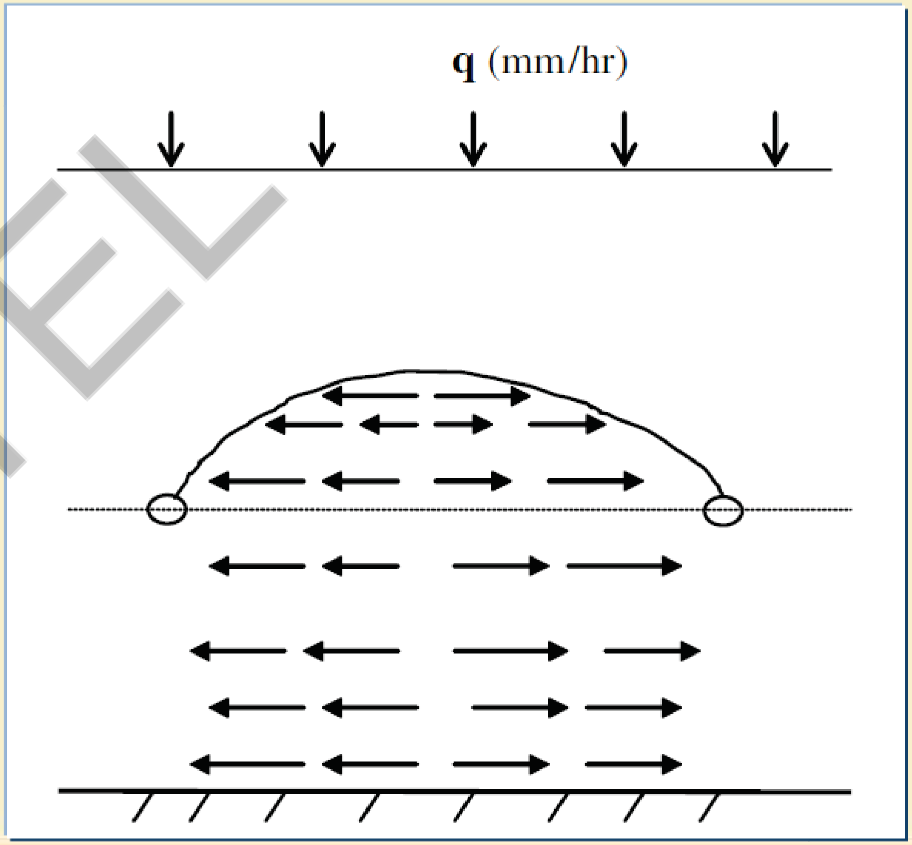
$$K_H = \frac{(0.20 \times 0.50) + (0.15 \times 0.4) + (0.25 \times 0.3)}{1.2}$$

$$\boldsymbol{K_H = 0.235} \textbf{ m}^3\textbf{/m}^2\textbf{/h (Ans.)}$$

Ground Water Flow to Drain

Steady-State Problem:

- ✓ A constant uniform accretion rate, I, is recharging the water table and the drain tubes are simultaneously draining the soil profile.
- ✓ After some time, a state of equilibrium will be established in which the water table does not change shape, and the drain discharge is constant.



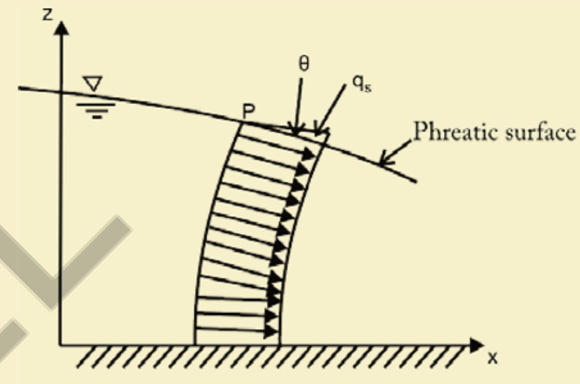
Ground Water Flow to Drain

Steady-State Problem

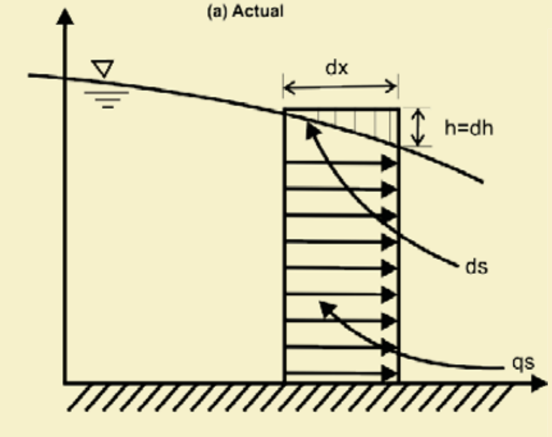
✓ **Horizontal flow based solution**

(Dupuit-Forcheimer assumptions)

- The flow lines (streamlines) are horizontal
- The equipotential lines are vertical
- The flow velocity in the plane at all depths is proportional to the slope of water table only and independent of the depth in the flow system.



(a) Actual



(b) Dupuil approximation

Design of Surface Drainage System

1. **Estimation of Design Surface Runoff**

✓ Surface runoff to be generated from an area (design runoff) can be determined from the equations such as "**Rational method**" or "**SCS method**."

✓ Peak surface runoff rate (Q) using **Rational** method,

$$Q = CIA$$

Where, Q = runoff rate (m^3/h)

A = area from where runoff generates (drainage area) (m^2)

I = peak rainfall intensity (m/h)

C = runoff coefficient (0.5 to 0.7)

✓ For design purpose, the value of I can be taken from long-term (20–50 years) peak rainfall records.

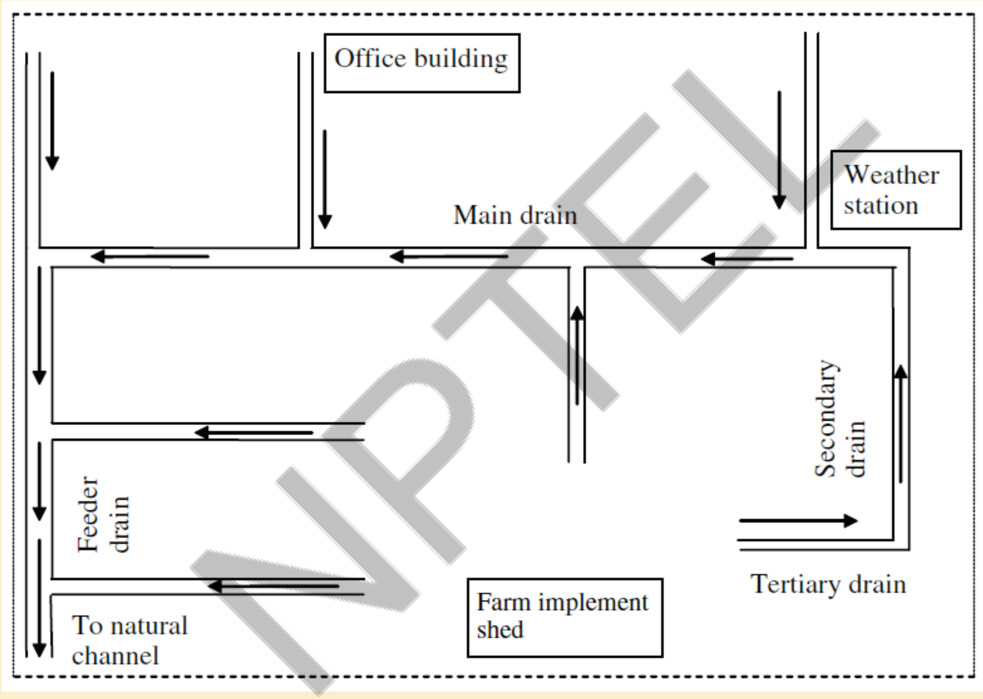
Design of Surface Drainage System

2. ***Design Considerations and Layout of Surface Drainage System***

- ✓ Drain layout should be based on
  - ✓ Topography
  - ✓ shape of the farm/catchment
  - ✓ direction of natural slope
  - ✓ position of farm buildings and roads
  - ✓ and position/existence of natural depression, channel, or river.
- ✓ Drain layout should be done with consideration of minimum length of run and minimum crossing of roads.
  - ✓ Minimizes wastage of land and minimize cost for culverts.
- ✓ Land grading serves the purpose of surface drainage.

Design of Surface Drainage System

2. Design Considerations and Layout of Surface Drainage System



Sample layout of surface drainage system in an agricultural farm

Design of Surface Drainage System

3. **Hydraulic Design of surface drain (drainage channel)**
   - ✓ It is similar to the design of an open irrigation channel.
   - ✓ The capacity should be based on the design peak surface runoff from the "drainage area".
   - ✓ For concrete channel, both rectangular and trapezoidal types can easily be constructed.
   - ✓ For earthen channel (or earthen vegetative waterway), only trapezoidal type with smoothing of bottom corners is recommended.

Exercise 44.2:

Surface drainage should be planned for a new agricultural farm to drain out irrigation tail-water and seasonal rainfall runoff. Maximum rainfall intensity at the site in 20 years record is 35 mm/h. The tertiary drain would have to carry runoff from 4 ha land. The secondary drain would have to carry thrice of tertiary, and the main drain to carry discharge of four secondary drain (of similar flow). Determine the design discharge capacity of the (a) tertiary, (b) secondary, and (c) main drain.

Solution:

We know, $Q = CIA$

Here,

Drainage area, $A = 4$ ha

$= 4 \times 10,000 \text{m}^2$

$= 40,000 \text{ m}^2$

Design rainfall intensity, I = 35 mm/h

$= 9.72\times 10^{-06}$ m/s

Runoff coefficient, C = 0.6 (as of agricultural land)

Putting the values, discharge capacity for the **tertiary drain**,

$$Q_t = 0.6 \times 9.72\times 10^{-06} \times 40000 \text{ m}^3/\text{s}$$

$$= 0.233\, m^3/s$$

Discharge capacity for the **secondary drain**, $Q_s = Qt \times 3 = 0.233 \times 3$

$$= 0.7 \text{ m}^3/\text{s}$$

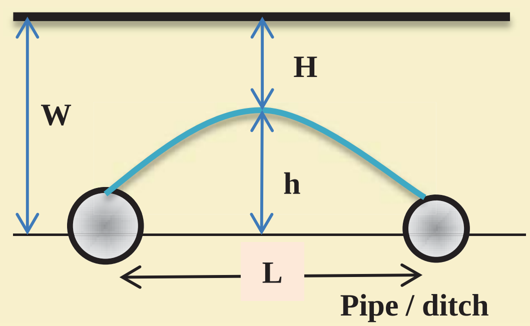
Discharge capacity for the **main drain**, $Q_m = Qs \times 4 = 0.7 \times 4$

$$= \mathbf{2.8\ m^3/s (Ans.)}$$

Pipe Drainage System – Design variables

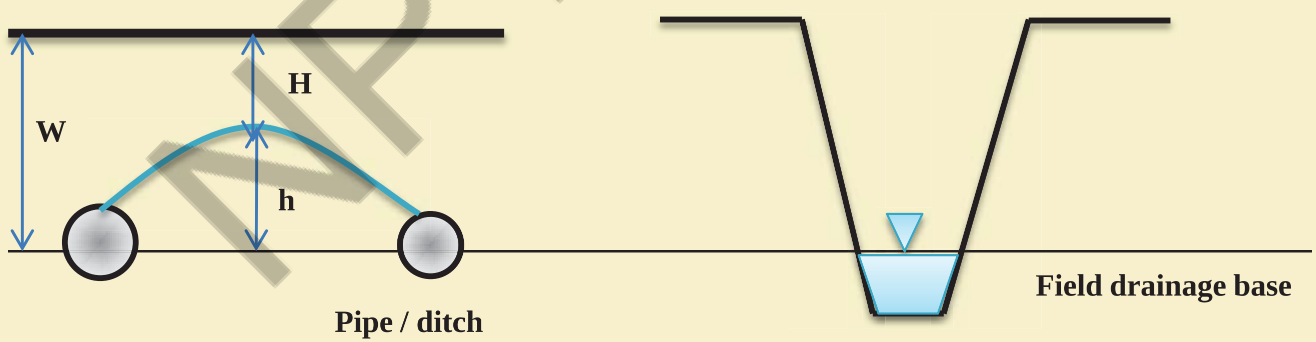
The following main variables need to be determined

- ✓ Type and layout of the system
- ✓ Discharge capacity (q)
- ✓ Water table depth to be maintained in the field relative to soil surface (H)
- ✓ The field drainage base width (W)
- ✓ Spacing of the field drainage (L)

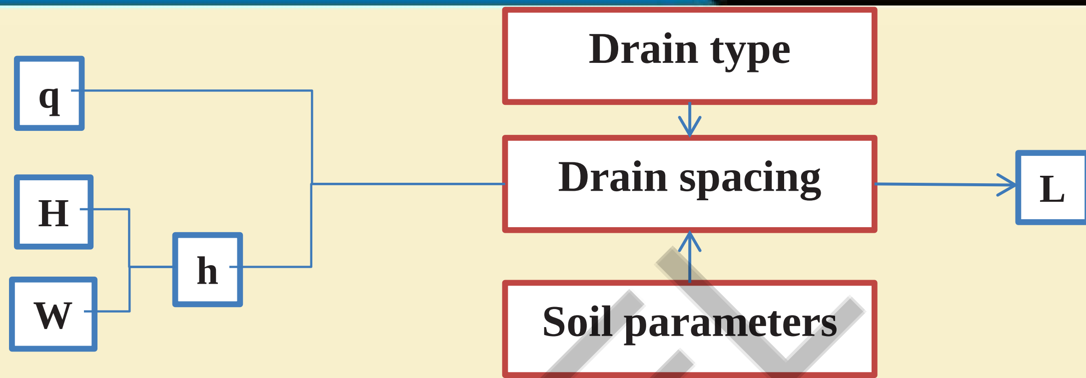


Drain Spacing Formula

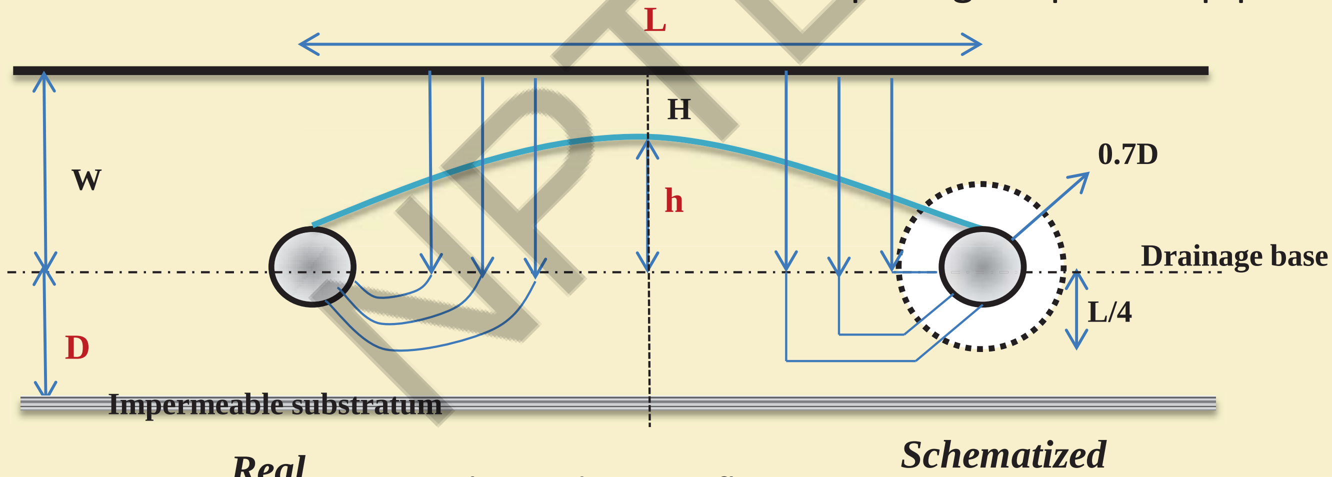
- ✓ **Steady-state formula**
  - o Steady constant flow occurs through the soil to the drain
  - o Discharge equals to recharge
  - o 'h' constant
- ✓ **Unsteady-state formula**
  - o All the parameters vary



Drain Spacing Formula



Procedure for determination of drain spacing for parallel pipe drainage



Typical pipe drainage flow pattern

Flow Patterns

- ✓ The streamlines towards parallel pipe drains typically shows a pattern
- ✓ In saturated zone below the water table the flow continues more or less in a vertical downward direction but soon turns into a lateral flow towards the drain.
- ✓ Towards end of its path, the flow converges radially into the drain
- ✓ The relative magnitude of h, D and L determines the type of flow dominates
  - ✓ When L >> (h, D) → predominantly horizontal
  - ✓ When L ≈ D → an extensive radial flow
  - ✓ When L << h → distinct vertical flow
- ✓ The horizontal depth may extend to depths down to L/4 below the drainage base
- ✓ The radial flow zone is roughly confined to a circle with radius ≈ 0.7 D
  - ✓ Total head loss (h) = $h_v + h_h + h_r + h_e$

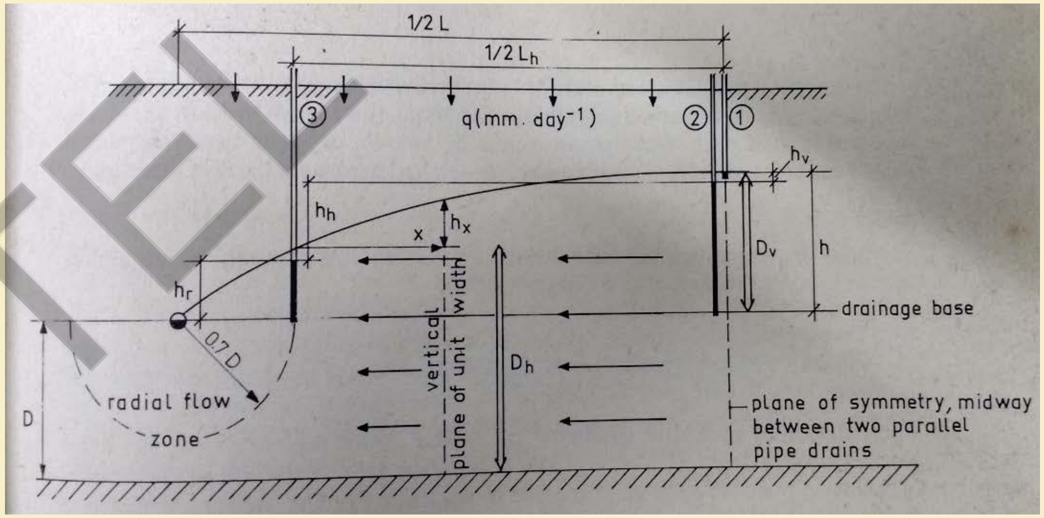
a) Vertical flow

The head loss due to a vertical flow of q through a soil layer of thickness D_v and a vertical hydraulic conductivity of K can be calculated by applying **Darcy's Law**: $q = K\frac{h_v}{D_v}$

$$h_v = \frac{qD_v}{K}$$

- ✓ h_v is significant only when it passes through very poor permeable soil (heavy clay, impeding layer)
- ✓ h_v increases when K decreases

Example: q = 10 mm/d, k = 0.5 m/d, D_v = 1 m, h_v = 2 cm

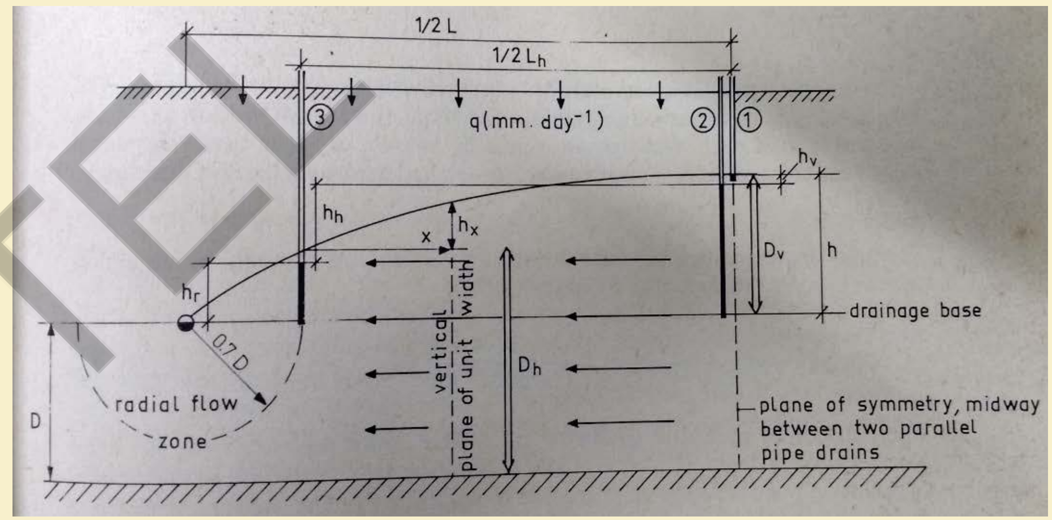


Head losses of Pipe drainage flow

b) Horizontal flow

- An analytical expression for this head loss maybe derived by considering the horizontal flow Q_x through a vertical plane of unit width.
  - $Q_x = q\left(\frac{L_h}{2} - x\right)$
  - $Q_x = KD_h\frac{dh}{dx}$

  Where, dh = conceptual average thickness of the horizontal flow zone ($D_h = D + 0.5h$)
- Equating these two expressions and solving the resulting differential equation for x=0; h_x=0 and x=L_h/2, h_x=h_h



Head losses of Pipe drainage flow

b) Horizontal flow

$$q\left(\frac{L_h}{2} - x\right) = KD_h \frac{dh_x}{dx}$$

$$q\int_0^{\frac{L_h}{2}} \left(\frac{L_h}{2} - x\right) dx = KD_h \int_0^{h_h} dh_x$$

$$q\left(\frac{{L_h}^2}{4} - \frac{{L_h}^2}{8}\right) = KD_h h_h$$

$$h_h = \frac{q{L_h}^2}{8KD_h}$$

c) Radial flow

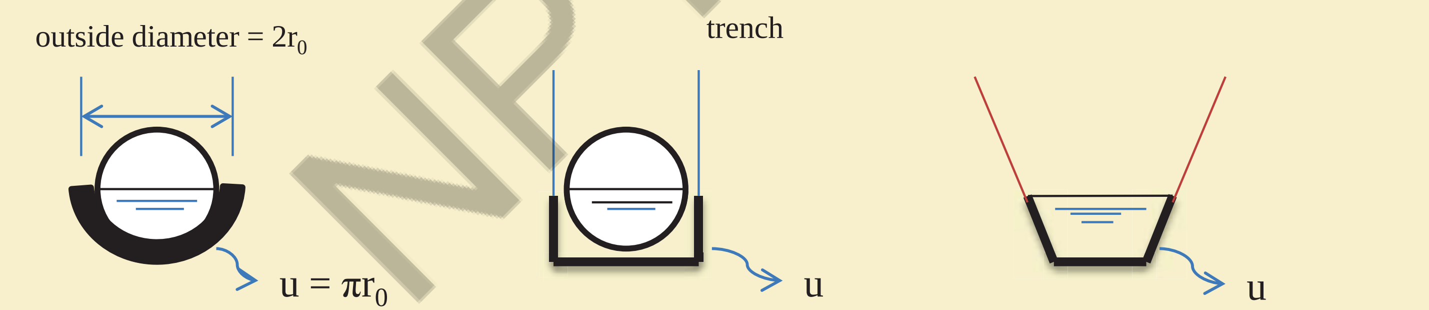
The following equation has been derived by Earnst, 1962 (hr, is the head difference in piezometer 3)

$$h_r = q\frac{L}{\pi K}\ln\frac{aD_r}{u}$$

Where ***aD$_r$*** is an indicative geometric parameter, which varies with the location of the drain relative to the impermeable stratum

u represents the wet entry parimeter of the drain

Value of u for different types of drain



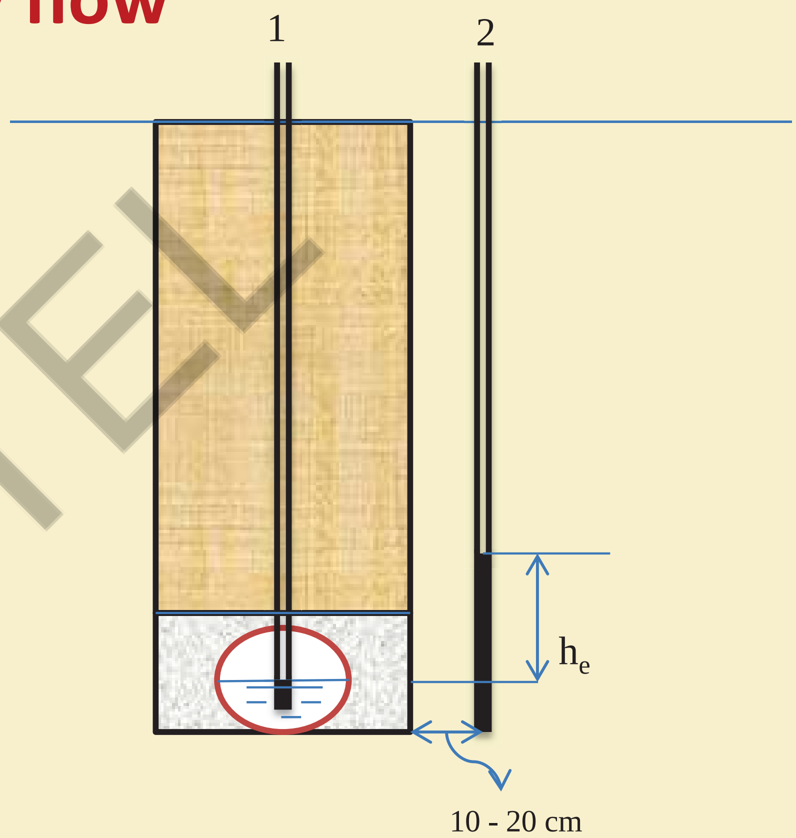
Wet entry parameter of circle **Wet entry parameter of rectangle** **Wet entry parameter of traphezium**

d) Entry flow

✓ The head loss h_e incurred in the flow through pipe surrounds (envelope) and to pipe openings and to the pipe

✓ The aim is to get h_e=0, which is possible when the envelope K should be at least 10 times the surrounding soil stratum

✓ For h_e=0 , $K_{envelope} > 10 \times K_{soil}$



Thank You!!

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Irrigation and Drainage

Lecture No: 45 Tutorial: W9

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Example W9.1:

Mole drain is the most suitable drainage system for **heavy clay soil** **(GATE 2015)**

Example W9.2:

During land leveling of agricultural land for irrigation and drainage purposes, the acceptable deviation in elevation from the design value in meter is **0.015** **(GATE 2013)**

Example W9.3:

The gridiron pipe drainage system is more economical than the herringbone pipe drainage system because **the number of junctions and the double-drained area are reduced** **(GATE 2013)**

Example W9.4:

In a subsurface drainage system, the peak discharge through tile drain under full flow condition is given by

$Q = 6.715 \times 10^{-4} \times S^{0.5} \times n^{-1}$

Where, Q = discharge,m^3/s, S = drain bed slope and n = Manning's roughness coefficient.

Size of the drain in mm is **(GATE 2016; GATE 2002)**

Solution:

Given,

$$Q = 6.715 \times 10^{-4} \times S^{0.5} \times n^{-1} \quad (1)$$

As we know that,

$$Q = A \times V$$

Where, A= area

V= velocity

From Manning equation

$$V = \frac{1}{n} \times R^{2/3} \times S^{0.5}$$

Now,

$$Q = A \times \frac{1}{n} \times R^{2/3} \times S^{0.5}$$

$$Q = \frac{\pi}{4} \times d^2 \times \frac{1}{n} \times \left(\frac{\pi d^2}{4\pi d}\right)^{2/3} \times S^{0.5}$$

$$Q = \frac{\pi}{4} \times d^2 \times \frac{1}{n} \times \frac{d^{2/3}}{4^{2/3}} \times S^{0.5}$$

$$Q = \frac{\pi}{4 \times 4^{2/3}} \times d^2 \times d^{2/3} \times \frac{1}{n} \times S^{0.5}$$

$$Q = \frac{\pi}{4^{5/3}} \times d^2 \times d^{2/3} \times \frac{1}{n} \times S^{0.5}$$

$$Q = 0.31 \times d^{8/3} \times \frac{1}{n} \times S^{0.5} \qquad (2)$$

From equation (1) and (2)

$$6.715 \times 10^{-4} = 0.31 \times d^{8/3}$$

$$d = 0.10 \text{ m}$$

$$\boldsymbol{d} = \mathbf{10\ cm\ (Ans.)}$$

Example W9.5:

In a sub-surface drainage system, the tile drains are laid with a slope of 0.28% to carry a peak discharge of 3 L/s per drain. If the Manning's n is 0.011, the practical diameter of tile required is **(GATE 2008)**

Solution:

Given,

slope = 0.28%

Discharge =3 L/s

n = 0.011

$$Q = \frac{\pi}{4} \times d^2 \times \frac{1}{n} \times \left(\frac{d}{4}\right)^{2/3} \times S^{0.5}$$

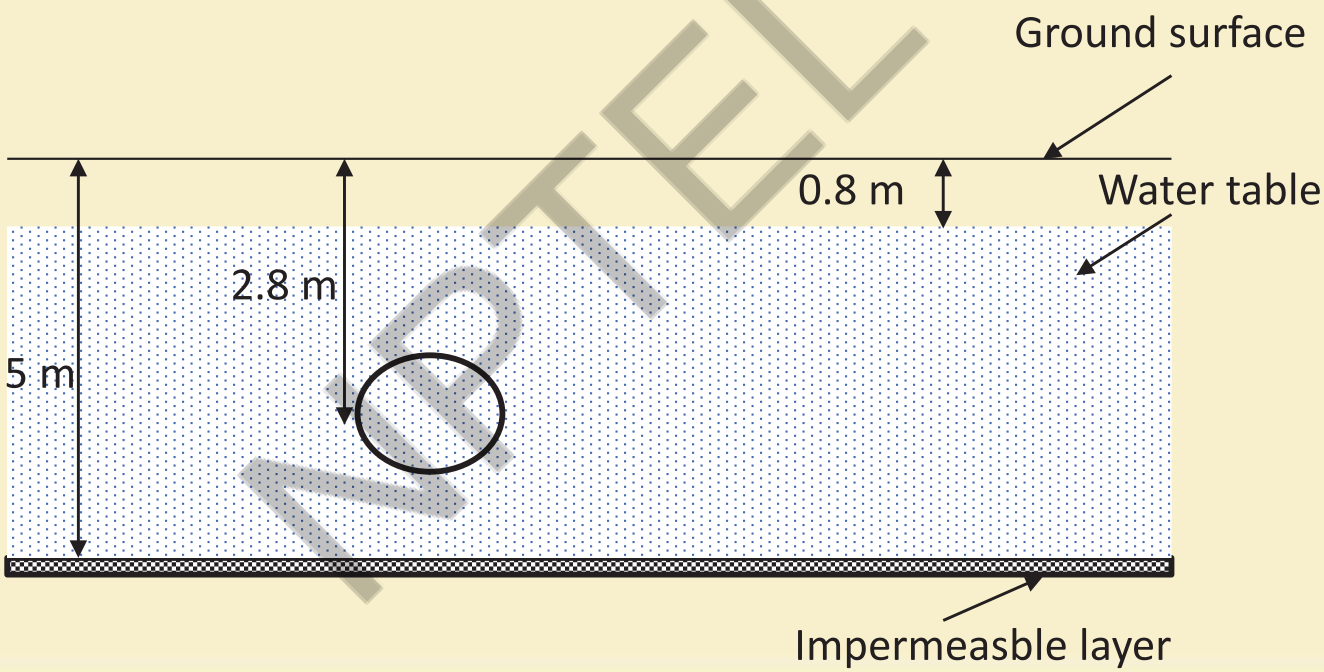
$$0.003 = 0.31 \times d^{8/3} \times \frac{1}{0.011} \times 0.28^{0.5}$$

$$d = 0.097m = \mathbf{97.46\ mm}$$ **(Ans.)**

Example W9.6:

The depths from the soil surface to subsurface tile drains, impermeable soil layer and the highest water table are measured as 2.8 m, 5.0 m and 0.8 m, respectively. The effective hydraulic head for drainage in meter is **(Gate 2018)**

Solution:



Given,

Depth from soil surface to drain = 2.8 m

Water table depth = 0.8 m

From the figure,

Effective hydraulic head of drainage = 2.8-0.8

=2 m (Ans.)

Thank You!!