PT DAYA SANTOSA REKAYASA
A Complete Irrigation Solution

Drip Irrigation *System Design*

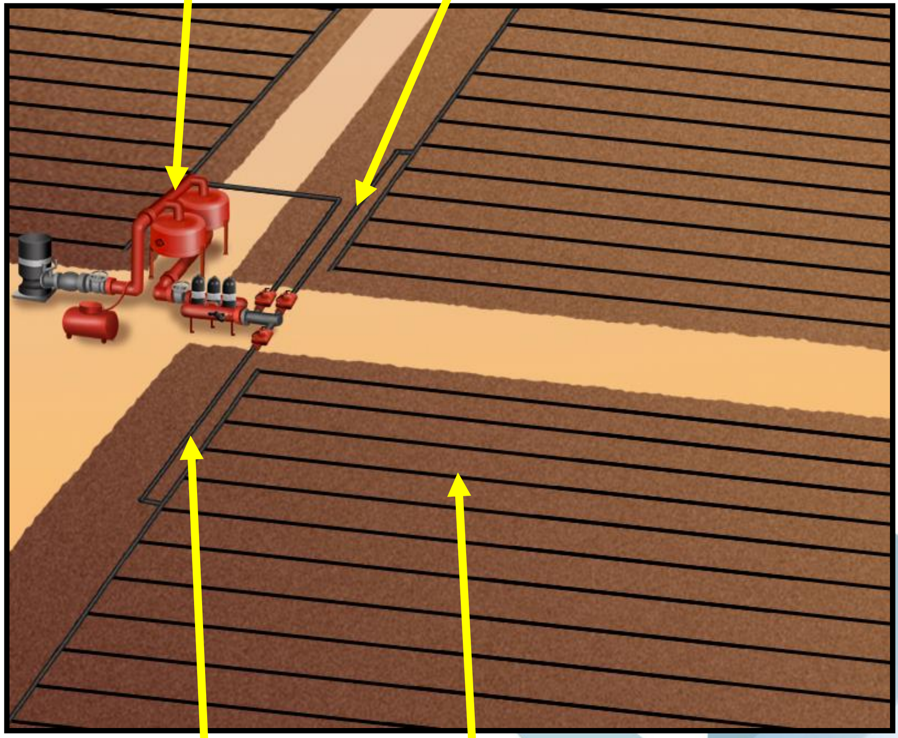
- ***Introduction***
- ***Design Steps***
- ***Non-PC Dripperline Lateral Design***
- ***PC Dripperline Lateral Design***
- ***SDI Lateral Design***
- ***Main Pipe Design***
- ***Submain Pipe Design***
- ***Collecting Design Data***

Introduction

Drip Irrigation System

Sample outline of a system, containing:

- Water source and control head
- Main pipes from the water source to the plot irrigated with drip
- Secondary (sub-main) pipes taking water from the main pipes to the dripperlines
- Dripperlines, including accessories such as initial connectors, fittings and end connectors



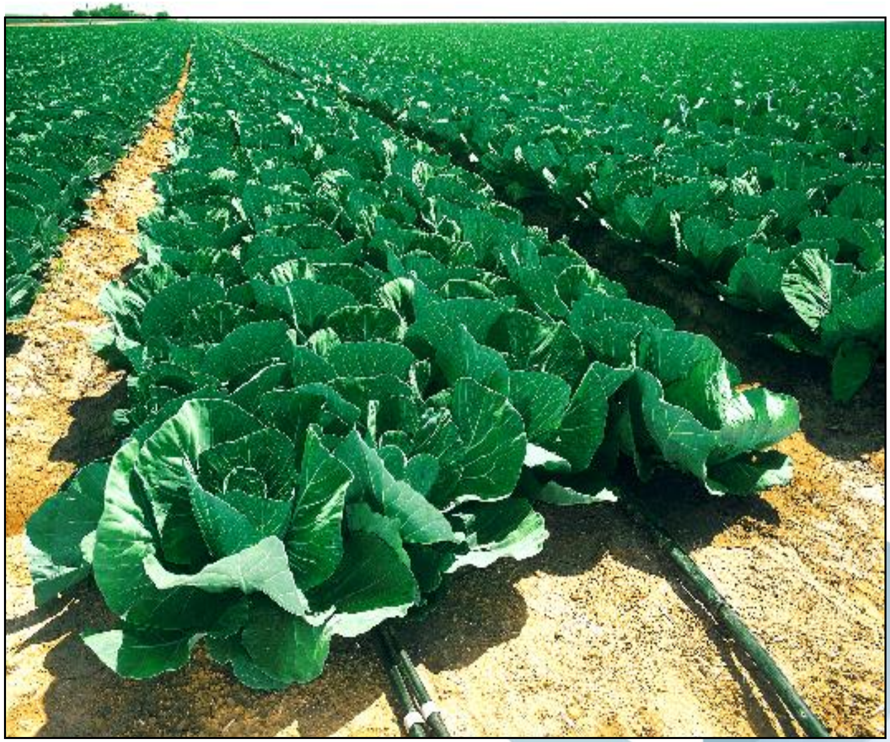
Units & Symbols

- Units and symbols in drip feed system planning.
- The contents of the table include the unit name, and its abbreviation.

Length	L	meter,inch	
Area	A	$meter^2$,$inch^2$	
Volume	V	m^3,liter	
Weight	W	ton,kg	
Pressure	P	kg/cm	
Head Lose	H	meter	
Flow Rate	Q	m^3/h	
Velocity	V	meter/sec	

Irrigation Water Requirements

- In order to design an irrigation system we must know the seasonal and peak Irrigation Water Requirements for the designed crop.
- Irrigation Water Requirement (IWR) is the volume of water needed to maintain the desired level of soil moisture and salinity during the crop season.
- IWR requirements are usually expressed in "cm" or " mm"



Main Considerations for IWR

- **Transpiration -** evaporation of water from plant surfaces directly into the atmosphere.
- **Evapotranspiration -** sum of transpiration and water evaporated from the soil.
- Evaporation measured by: Pan class "A".

Water Requirements - Sugarcane

Sugarcane Irrigation Program

1. First 2 weeks- germination (technical irrigation)
2. From germination until beginning of ramification- 40% from evaporation.
3. From ramification until 80% covering factor 60% from evaporation
4. From 80% covering factor until 30-40 days before harvest – 80% from evaporation.
5. Last stage until 10-15 days before harvest 25% from evaporation

Evaporation measured by: Pan class "A".

Water Requirements - Cotton

- 1st period - pre planting plus germination, wetting the soil to a depth of 100 cm.
- 2nd period - from germination until 21 days before 1st flower - no irrigation
- 3rd period - from 21 days before,until 1st flower until 21-days - 40 %from evaporation*
- 4th period - from 1st flower +21 days - 40-70% from evaporation
- 5th period - next 30 days, until full fruit stage - 70-90% from evaporation.

Evaporation measured by: Pan class "A".

Water Requirements - Vineyards

Example for Northern Hemisphere	Mediterranean Climate	Desert Climate
Period /days	**mm/day**	**mm/day**
1/5-20/5	1.5	1.5
21/5-10/6	2.0	2.3
11/6-20/6	2.0	2.6
21/6-10/7	2.0	3.0
11/7-31/7	2.0	3.5
1/8-20/8	1.5	2.3
21/8-10/9	1.0	1.5
11/9-30/10	-	1.0
Total water	**200 mm**	**350 mm**

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Water Requirements - Tomatoes

Processing Tomato Irrigation Scheduling

- **1st period** - pre planting wet the soil to 100 cm
- **2nd period** - 45 days – **40%** from evaporation.
- **3rd period** - from fruit set until large green fruit (20-30 days) - **50%-90%** from evaporation.
- **4th period** - from green fruit until **50%** red fruit (20-30 days) - **40%- 70%** from evaporation**.** (semi stress)
- **5th period** - from **50%** red fruit until harvesting - **no irrigation**

Measured by: Pan class "A"

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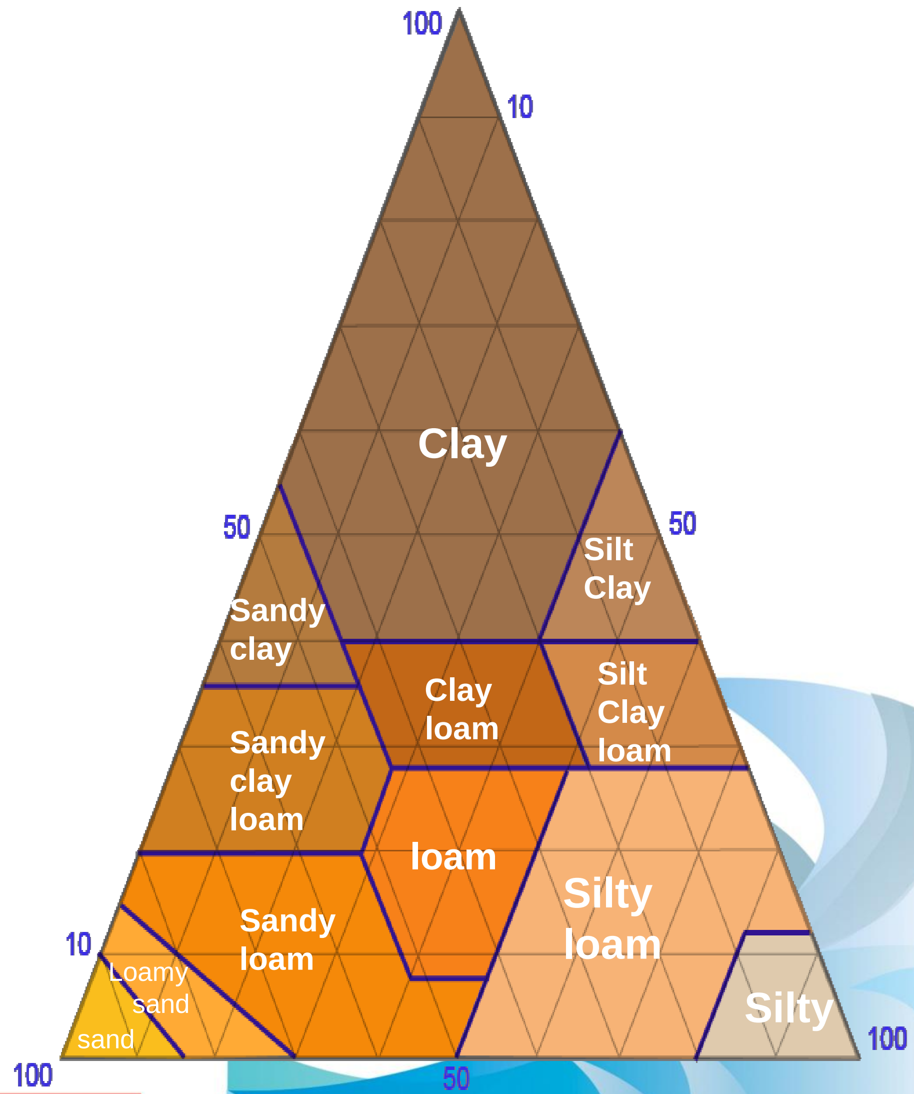
Soil Classification

- **Sand**: loose and single-grained, high percolation
- **Sandy loam**: Contains much sand but has enough silt and clay
- **Loam**: A mixture of sand silt and clay in similar proportion
- **Silt loam:** moderate amount of fine sand and a small amount of clay
- **Clay loam:** Fine texture clods and lumps together when dry
- **Clay**: slow but high absorption of water, soil forms very hard lumps and clods



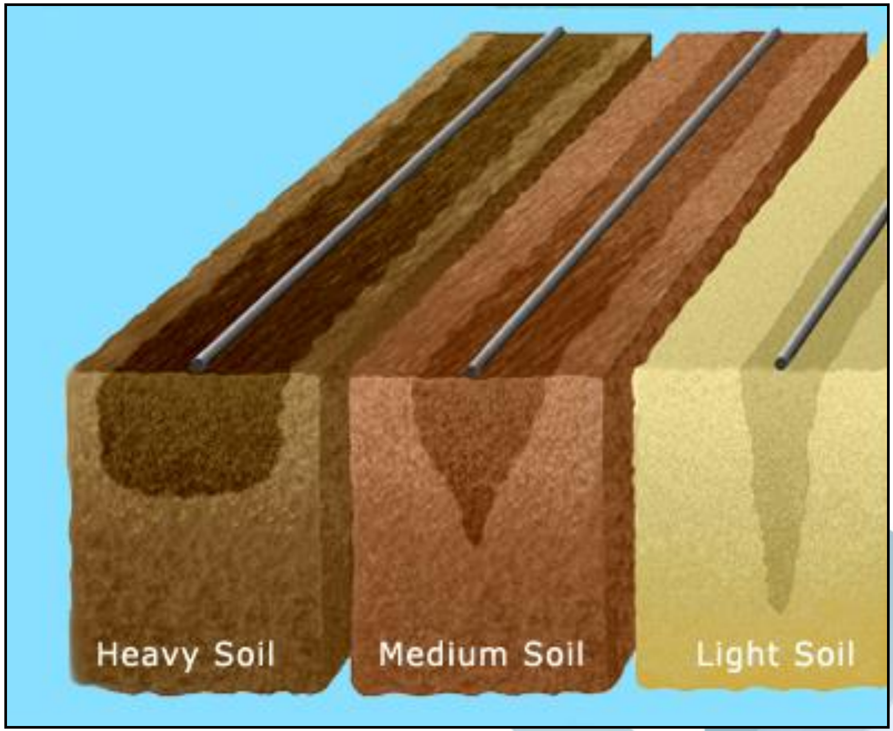
Soil Types

Soil Types

The shape of the wetted zone depends on the physical properties of the soil:

- In light soils, water distribution will be narrow and deep.

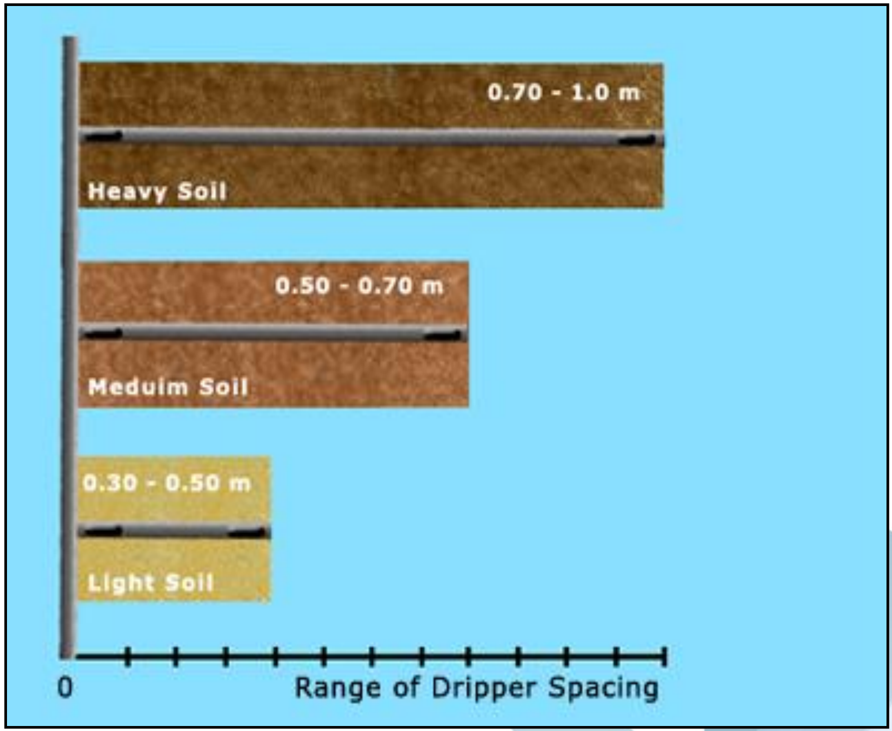
- In heavy soils, water distribution will be in a relatively spherical shape, wider with less depth.



Dripper Spacing

Recommended Space Between Drippers

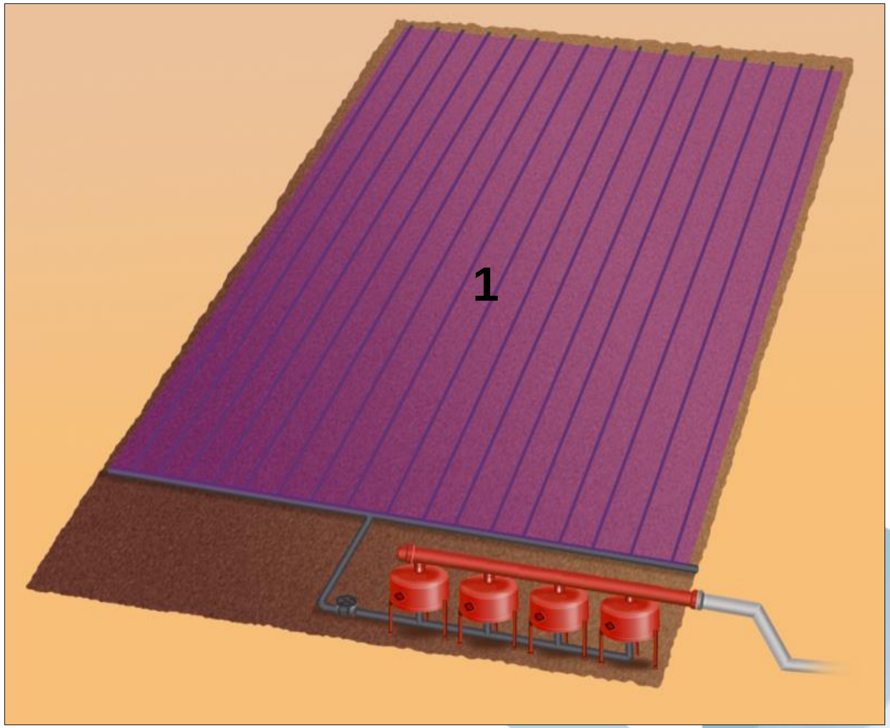
- Heavy soil - 0.50 to 1.00 meter *
- Medium soil - 0.40 to 0.75 meter *
- Light soil - 0.20 to 0.50 meter *



*   ***Actual dripper spacing depends on crop root depth.***

Design Steps

Efficient Division



First step:

Division of the area and number of operations

- Division of the area into the maximum number of operations makes it possible to plan a more efficient system, at a lower cost..
- Division of the area into operations makes it possible to reduce costs for filtering and conducting the water.
- This slide shows the planning of a drip-irrigation system, with the area of only one shift.

Efficient Division

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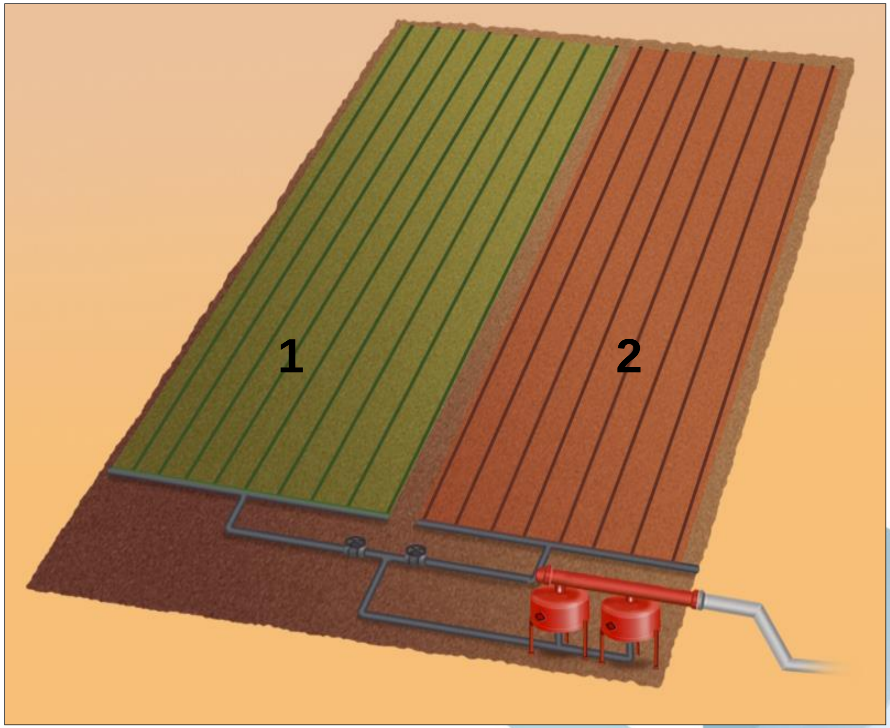
- Division of the area into operations makes it possible to reduce costs for filtering and conducting the water.
- This slide demonstrates the planning of a drip irrigation system, with the area divided into two shifts.

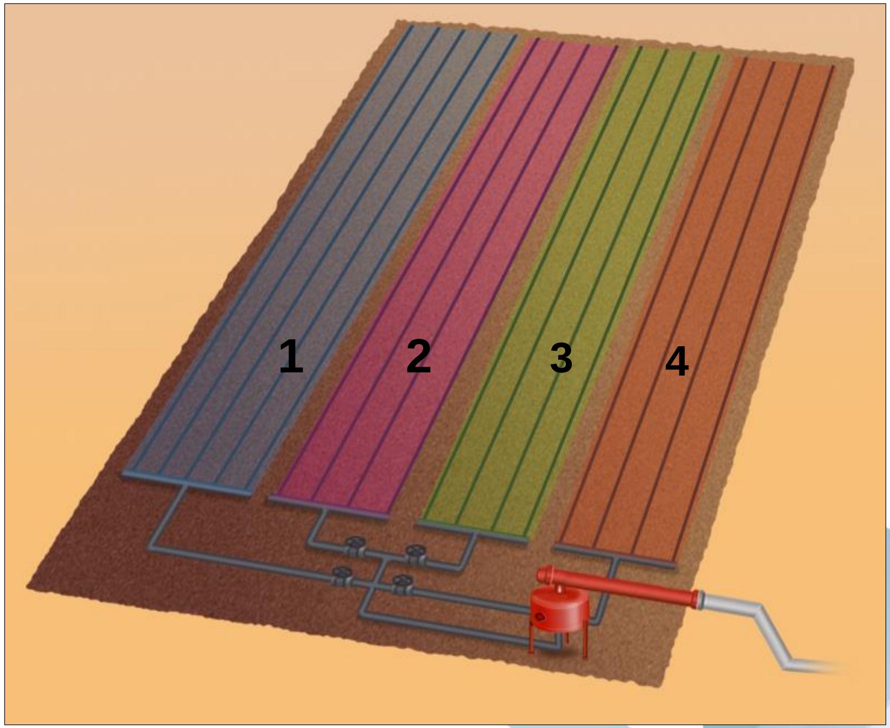


Efficient Division

First step:

Division of the area and number of operations

- Division of the area into the maximum number of operations makes it possible to plan a more efficient system, at a lower cost..
- Division of the area into operations makes it possible to reduce costs for filtering and conducting the water.
- This slide demonstrates the planning of a drip-irrigation system, with the area being divided into four shifts.



Irrigation Rate

Second step:

Calculation of irrigation rate

The irrigation rate is the quantity of water supplied by the planned system per hour per unit of area.

For example:

1. The formula for calculating irrigation rate is as follows:

$$\frac{Q \times n}{AD \times AL} = \text{I.R. (mm/area)}$$

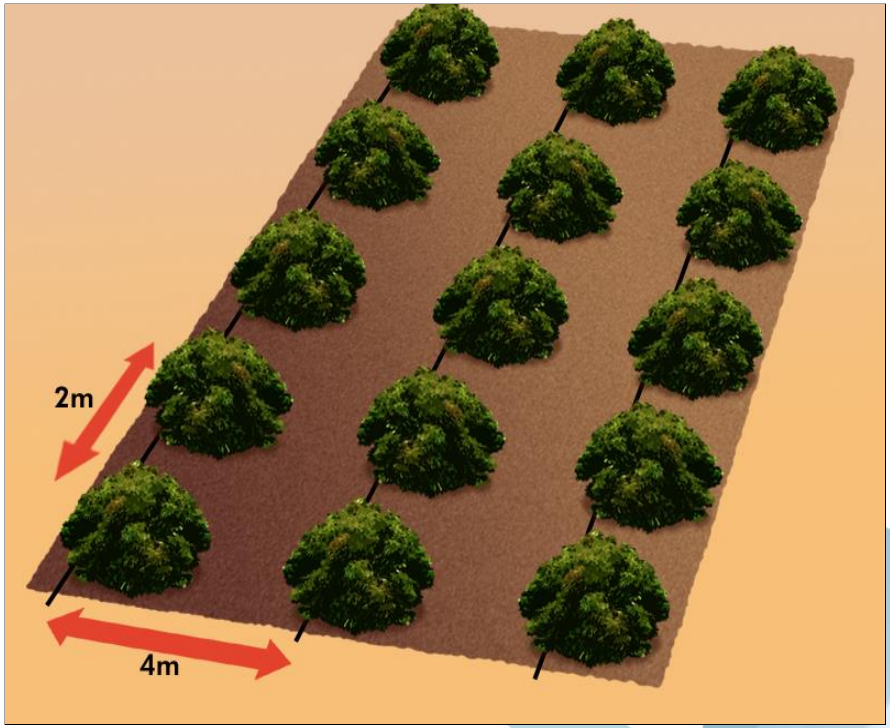
Where:

Q = Dripper discharge (liters/hour)

AD = Dripper spacing.

AL = Dripper lateral spacing.

n = Number of laterals per row.



2. Calculating the irrigation rate intuitively

Irrigation Rate - Training

Irrigation rate exercise

	Dripper Discharge (litter/hour)	Dripper Spacing (meter)	Row Spacing (meter)	Laterals Per Row	Irrigation Rate (mm/hour)
1	2	0.50	2.0	2	
2	4	0.60	3.0	2	
3	4	1.00	2.5	1	
4	6	0.80	4.0	1	
5	8	1.00	6.0	2	

Formula for calculation: $I.R. = \dfrac{Q \times n}{AD \times AL} = \text{(mm/hour)}$

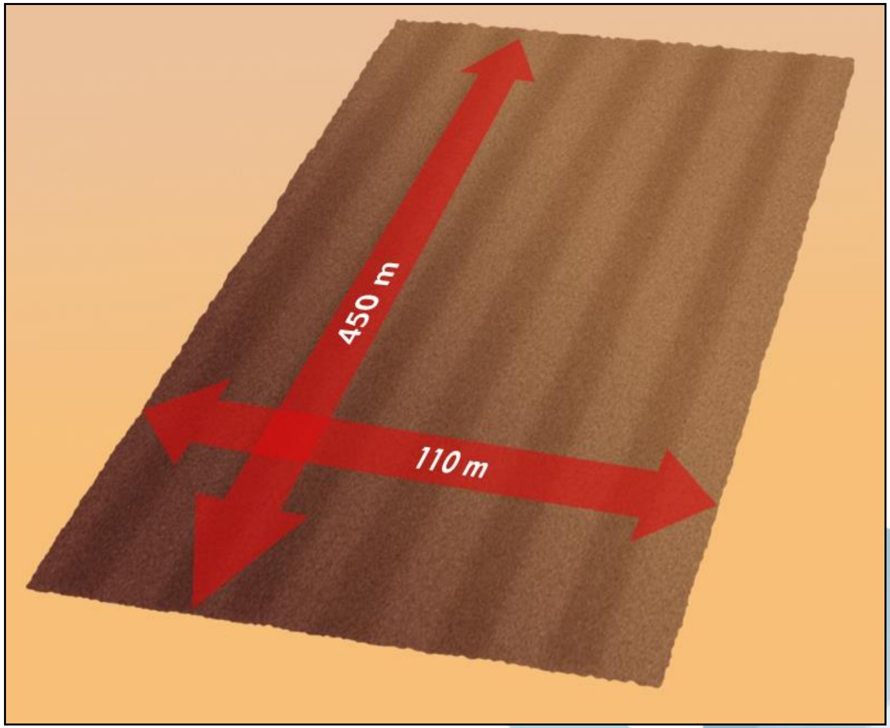
Q= Dripper discharge
n= Number of laterals per row

AD= Dripper spacing
AL= Row spacing

Design Samples

Sample plot with planning data:

Area dimensions – directions of planting rows

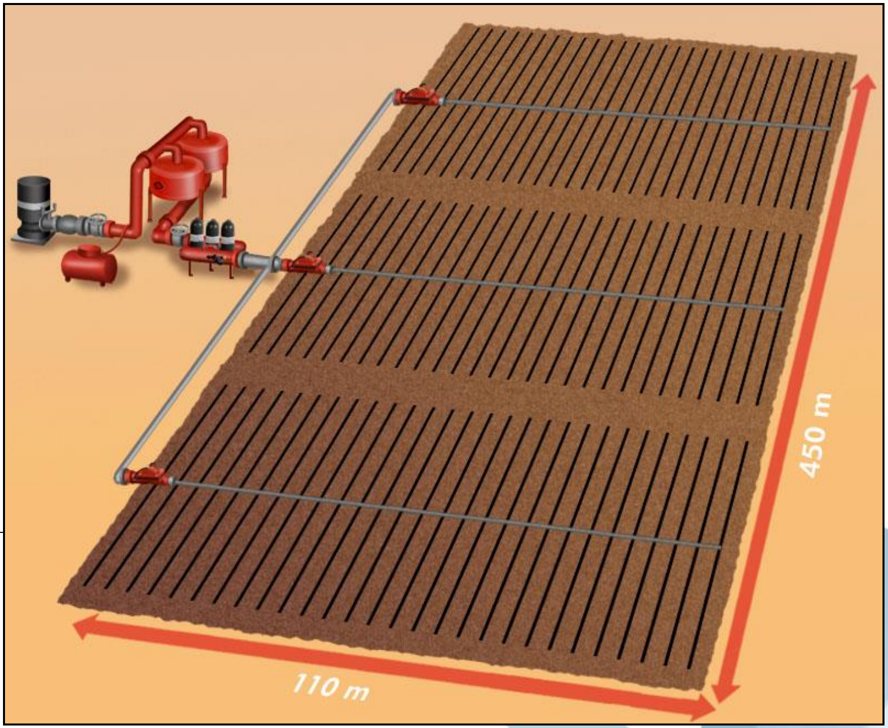


- Crop: vineyard.
- Dripper discharge: 4 L\H
- Dripper spacing: 1.0 meter
- Laterals per row: 1

- Daily consumption according to evaporation coefficient: 7 mm\day
- Type of soil: Heavy
- Irrigation interval: 1 or 3 days
- Control head pressure: 3.5 bar

Design Examples

Hydraulic calculation in the planning example accompanying the presentation.



Design Data

- Crop: Vineyard
- Planting Distance: 4.0x2.0M
- Number of laterals per row: 1
- Dripper flow rate: 4 L / h
- Total area: 5Ha

Daily Water Requirements

- Irrigation interval: 3 days
- Type of soil: heavy
- Pressure: 35M or 3.5 bar
- Daily I.W.R.: 7 mm/day

Max Number of Shifts.

Calculation:

Maximum number of shifts per 24-hour period

$$\frac{\text{Daily water supply (hours)}}{\text{Daily water requirements}} = \text{Number of shifts}$$

Calculation of irrigation rate.

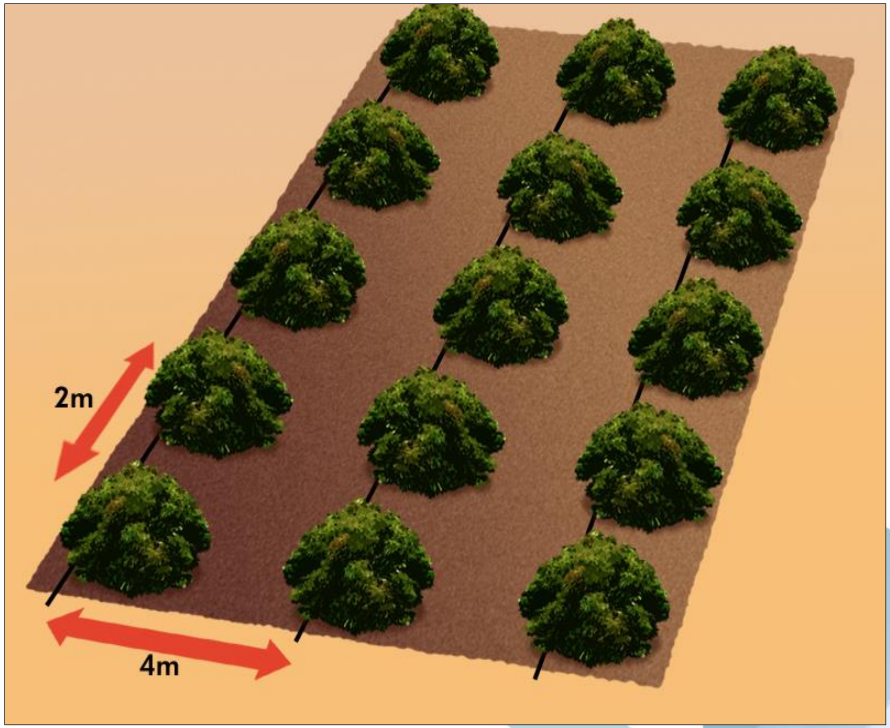
$$\frac{Q}{AD \times AL} = \frac{4\ \text{l/h}}{1\ \text{m} \times 4\text{m}} = 1\ \text{mm/h}$$

Calculation of daily hours of operation

$$\frac{\text{Daily IWR}}{\text{Irrigation rate}} = \frac{7\ \text{mm/day}}{1\ \text{mm}} = 7\ \text{h/day}$$

Calculation of number of daily shifts

$$\frac{\text{Daily water supply (hours)}}{\text{Daly water requirements}} = \frac{24\ \text{hours}}{7\ \text{hours}} = 3\ \text{shifts/day}$$



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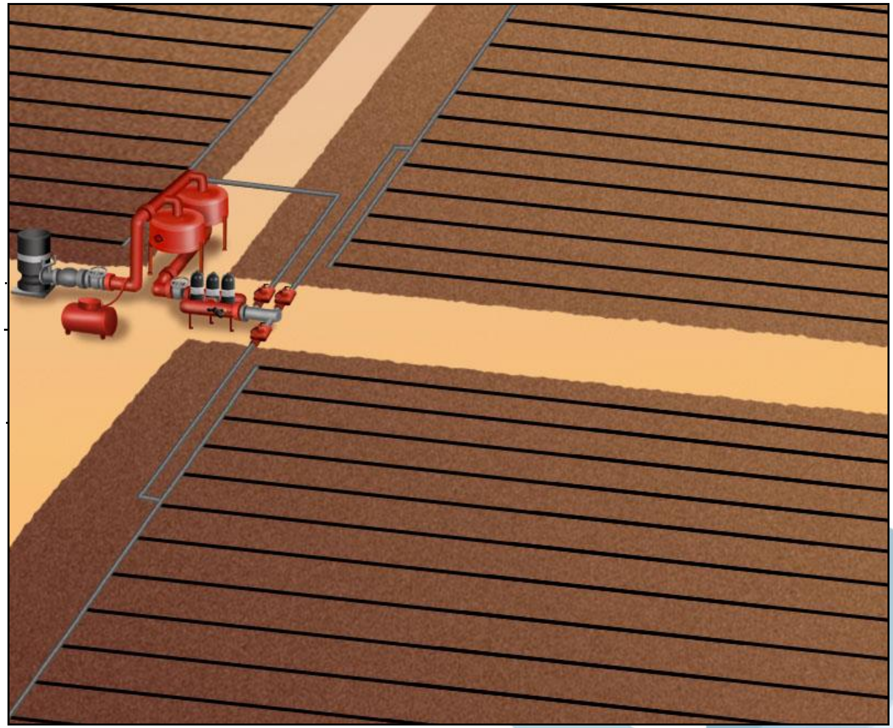
Number of Daily Shifts - Training

Daily water supply (hours)	Daily water requirement (mm/area)	Number of daily shifts	Reserve (hours)
24	6	4	0
20	5	4	0
16	3	5	1
12	3.5	3	1.5
8	6	1	2



How to calculate:

$$\frac{\text{Daily water supply}}{\text{Daily water requirement}} = \text{Number of daily shifts}$$

Maximum Number of Shifts - Training

Daily I.W.R. (mm)	Irrigation Rate (mm/hours)	Daily Hours of Operation (hours)	Daily Hours of Water Supply (hours)	Max Number of Shifts
7	1.0	7	24	3
12	1.5	8	24	3
8	0.5	16	24	1
10	1.8	5.5	24	4
6	2.0	3	24	8

Designing Under Water Limitations - Training

Example no.	Size of Area (Ha)	Irrigation Rate (m^3/Ha)	No. of Shifts	Water Limitations for Irrigation Per m^3/h
1	20	8	2	70 (False)
2	3	12	3	10 (False)
3	0.8	10	2	6 (True)
4	1.6	9	4	4 (True)
5	10	7	4	15 (False)

False / **True**

How to calculate: (example no.1)

Total flow rate per area I.R x Area = 20 Ha x 8 m^3/h= 160 m^3/h

Flow Rate Per Operation

$$\frac{\text{Total flow rate}}{\text{No. of operations}} = \frac{160 m^3/h}{2} = 80 m^3/h$$

Flow Rate limitation = 70 m^3/h
(needs another design)

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Irrigation Schedule - Example

Interval of Irrigation:

	I.W.R. (mm/area)	Irrigation Rate (mm/h)	No. of Shifts	Time
DAILY	7	1	3	21 hours Every day
EVERY 3 DAYS	21	1	3	63 hours Every 3 days
WEEKLY	49	1	3	147 hours Every 7 days

Irrigation Schedule –Daily Irrigation- Example

Data:

- 3 shifts
- 7 hours/day
- Interval 1 day

Hour	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
0.0						
1.0						
2.0						
3.0						
4.0	I	I	I	I	I	I
5.0						
6.0						
7.0						
8.0						
9.0						
10.0						
11.0	II	II	II	II	II	II
12.0						
13.0						
14.0						
15.0						
16.0						
17.0						
18.0	III	III	III	III	III	III
19.0						
20.0						
21.0						

Irrigation Schedule- Every 3 Days - Example

Data:

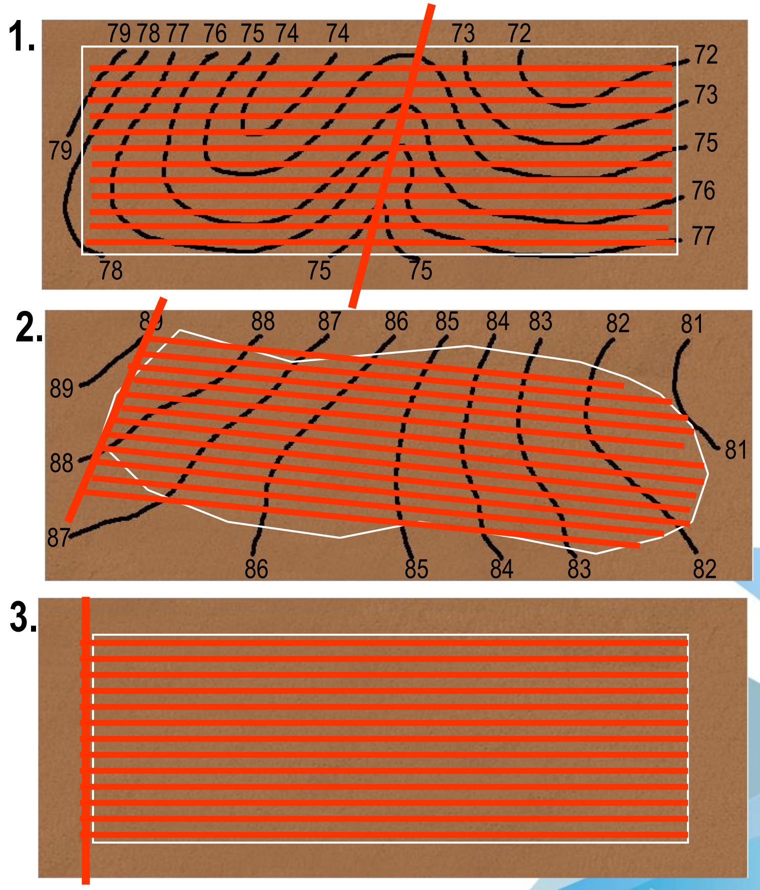
- 3 shifts
- 21 hours of operation
- Interval, every 3 days

Hour	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
0.0						
1.0						
2.0						
3.0						
4.0						
5.0						
6.0						
7.0						
8.0						
9.0						
10.0						
11.0	I	II	III	I	II	III
12.0						
13.0						
14.0						
15.0						
16.0						
17.0						
18.0						
19.0						
20.0						
21.0						

Dripperline Design

Areas with Variable Structure and Topography.

Adaptation of the dripperline tube laterals to areas of varying topographical structure.



Area Options:

1. Sloping, rectangular area.
2. Sloping, irregularly shaped area.
3. Flat area

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Lateral Lengh – Design Rules

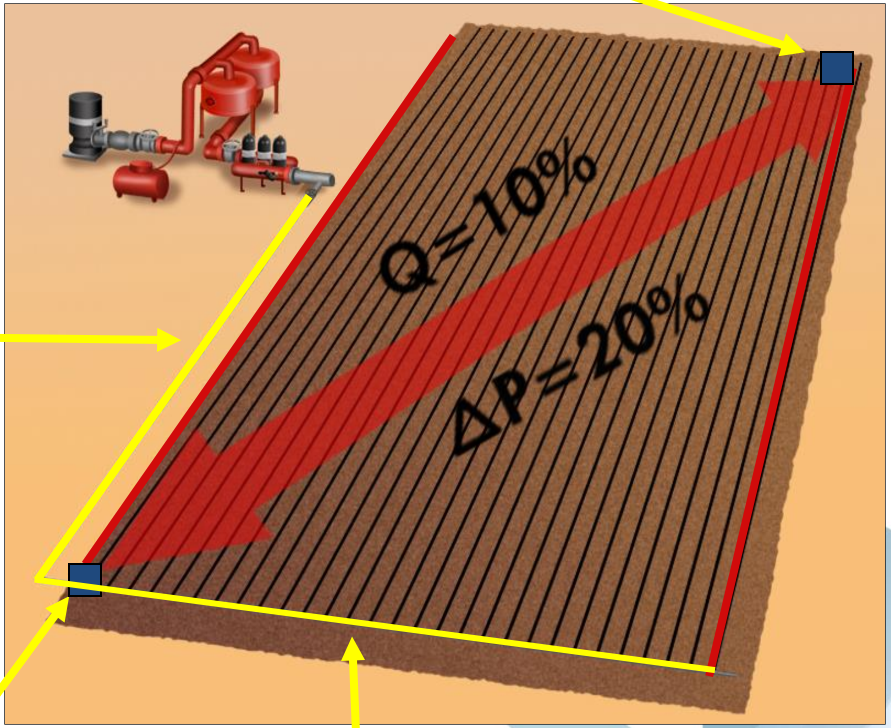
Design rules for non-pressure compensated dripperlines.

- * Maximum flow rate tolerance = **10%**
- * Maximum head loss = **20%**

Calculation formula:

$$Q = Q_0 P^x$$

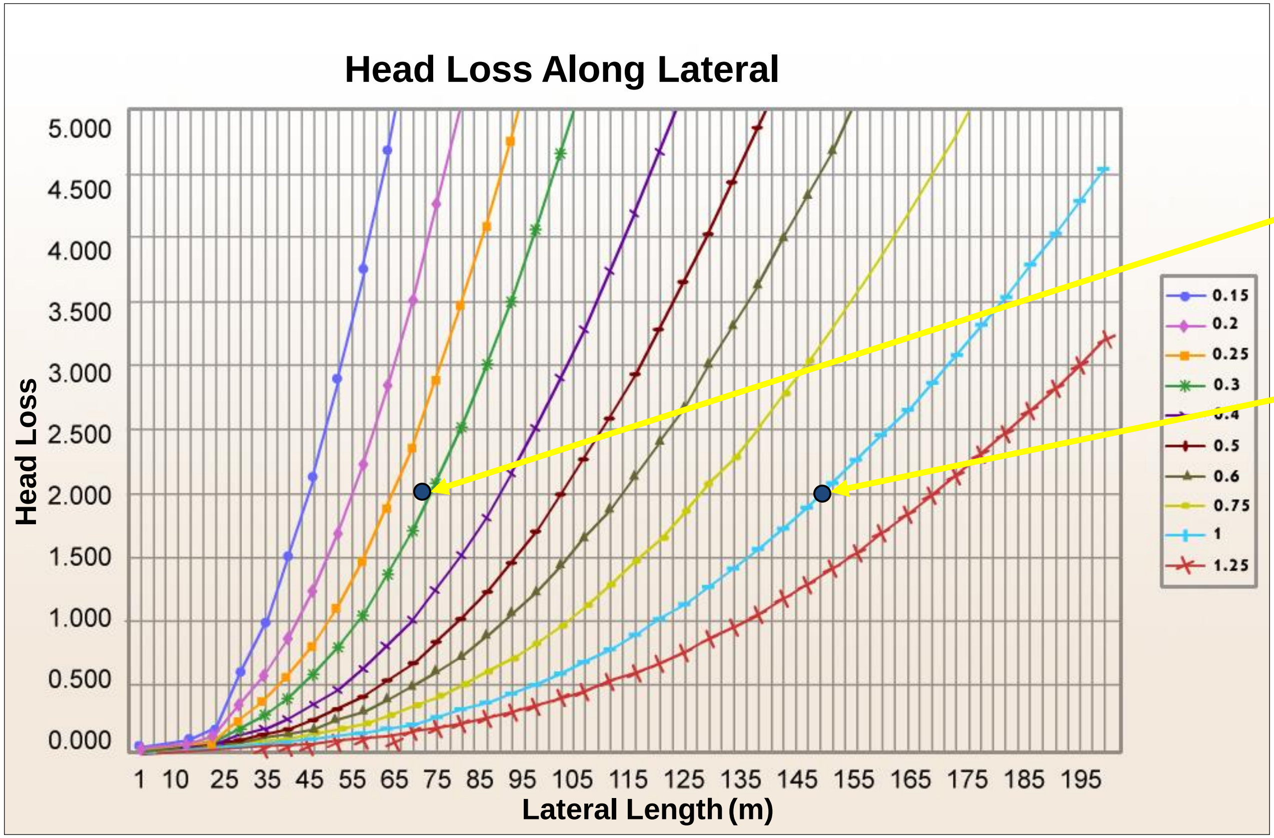
Suitable for cases: X=0.5



Design Curves

Tables for calculation of non pressure-compensated lateral length in flat terrain

Data: O.D: 17mm   I.D: 15.2 mm   Q = 2.0 L\H



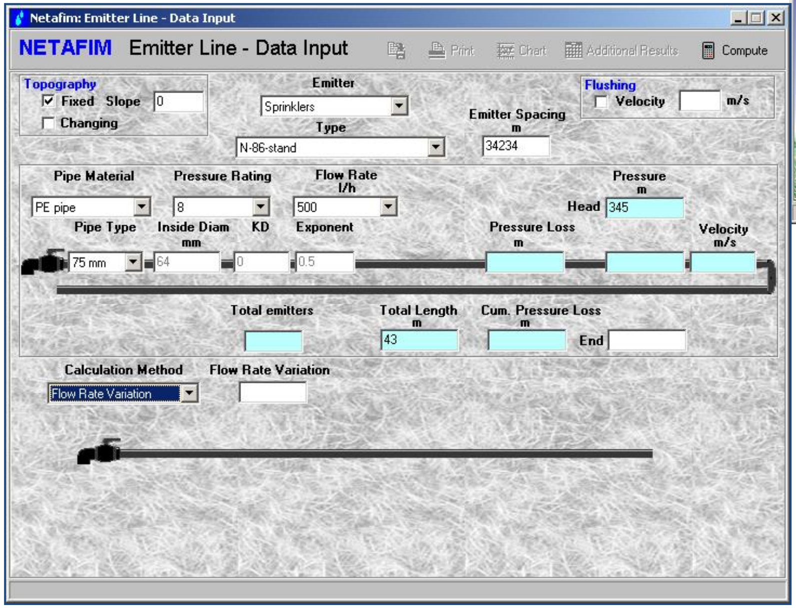
Examples:

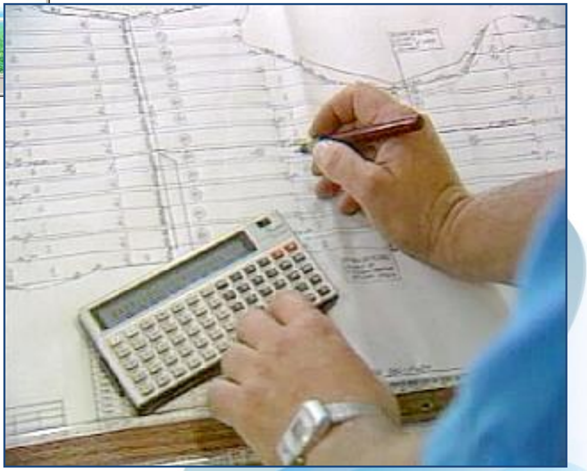
1) Distance between drippers:: 0.3 M
Max Length: 67M

2) Distance between drippers:: 1.0 M
Max Length: 147M

Hydraulic Calculation

Use of Hydro Calculator for calculation of lateral length in flat terrain





Dripperline Design Example

Hydraulic calculation in the planning example accompanying the presentation

Design data:

Division: 3 shifts (1,2,3)

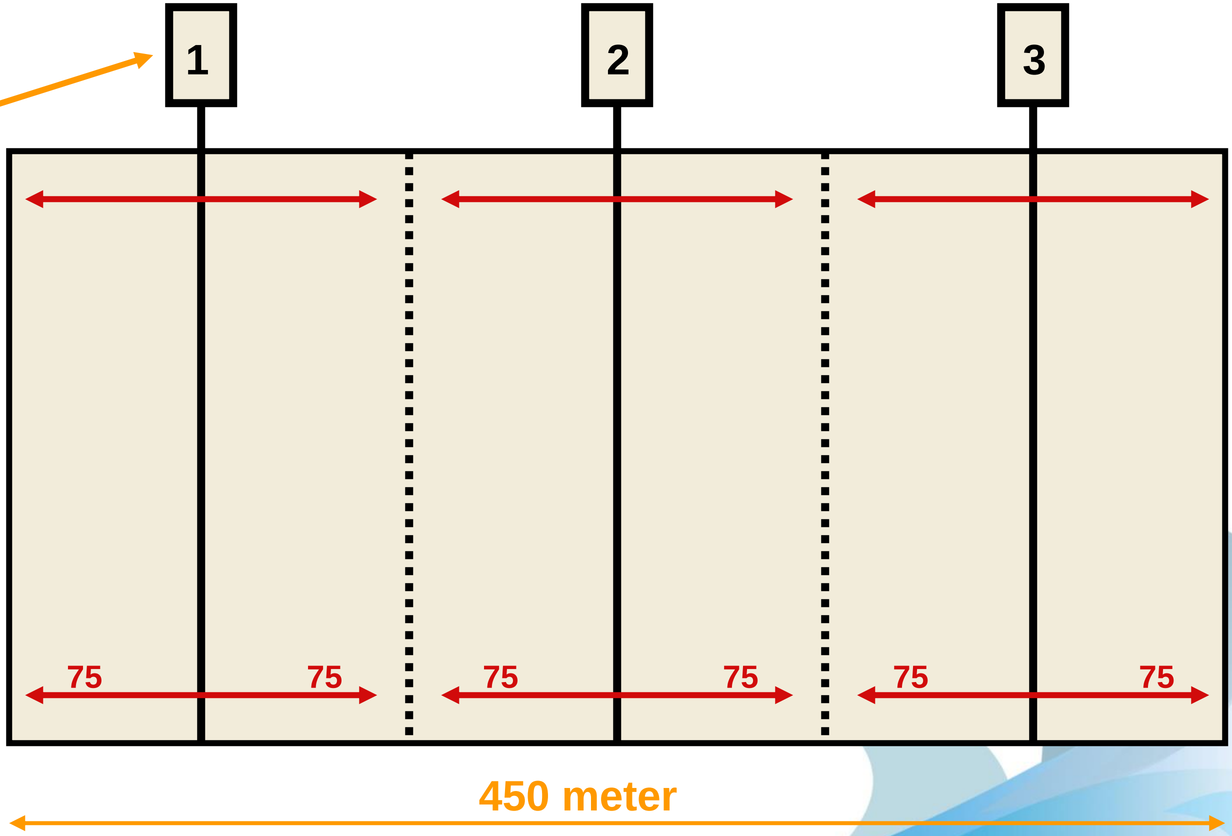
Total length: 450 meter

O.D Dripper line: 16 mm

Dripper flow rate: 4 L/H

Dripper spacing: 1 meter

Dripper line length: 75 meter

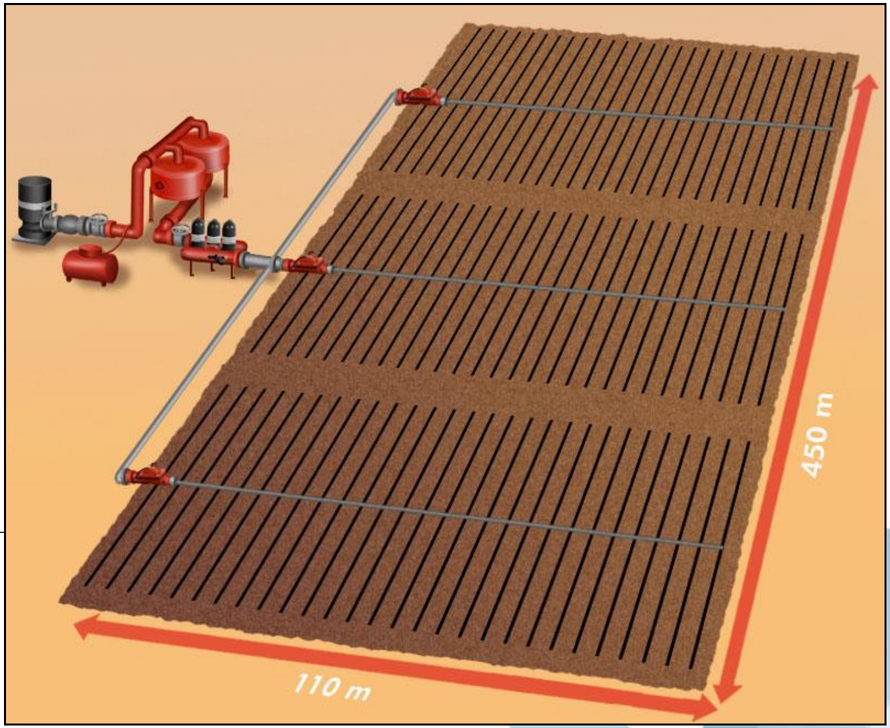


Design Examples

Hydraulic calculation in the planning example accompanying the presentation.

Design Data
- **Crop:** Vineyard
- **Planting Distance:** 4.0x2.0M
- **Number of laterals per row:** 1
- **Dripper flow rate:** 41 L\H
- **Total area** 5 Ha
- **Dripper spacing:** 1 M

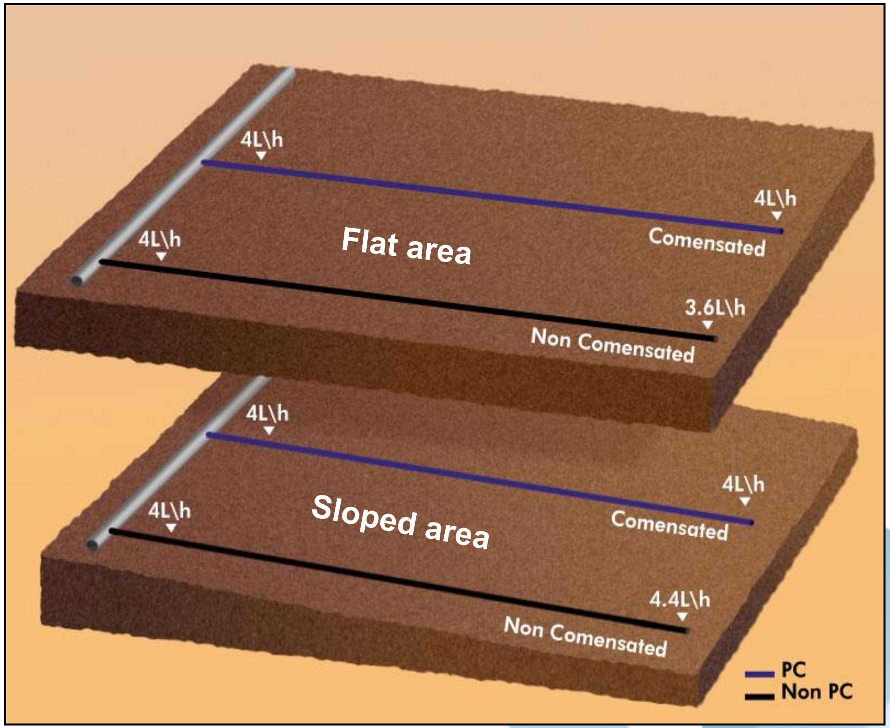
Daily Water Requirements
- **Irrigation interval:** 3 days
- **Type of soil:** heavy
- **Pressure:** 3.5 bar



Design rules

Advantages of pressure compensated dripperlines in sloping terrain.

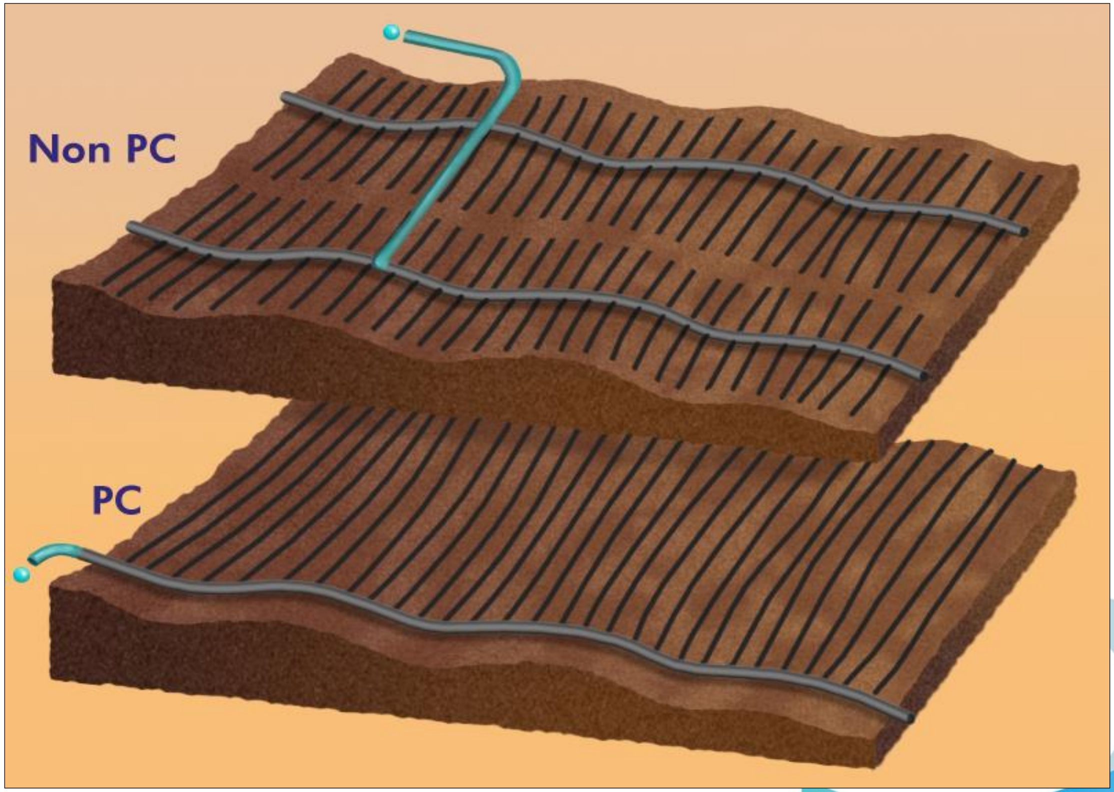
- Uniformity of irrigation.
- Pressure compensated design: range of head loss per dripperline lateral fluctuates between 5 and 40 meters.
- Non-compensated design: restricted to a head loss of 2 meters



PC Dripperline Design

PC vs. Non Compensated - Example

Example of laterals designed with non-compensated dripperlines



Dripperline Design

Flushing Flow Velocity

Design dripperline - recommended flow velocity

- The recommended pressure for flushing dripperlines is 0.5meter/second. Open the dripperline ends one by one.

- To achieve the pressure required for flushing dripperlines, open only part of the line ends at a time.

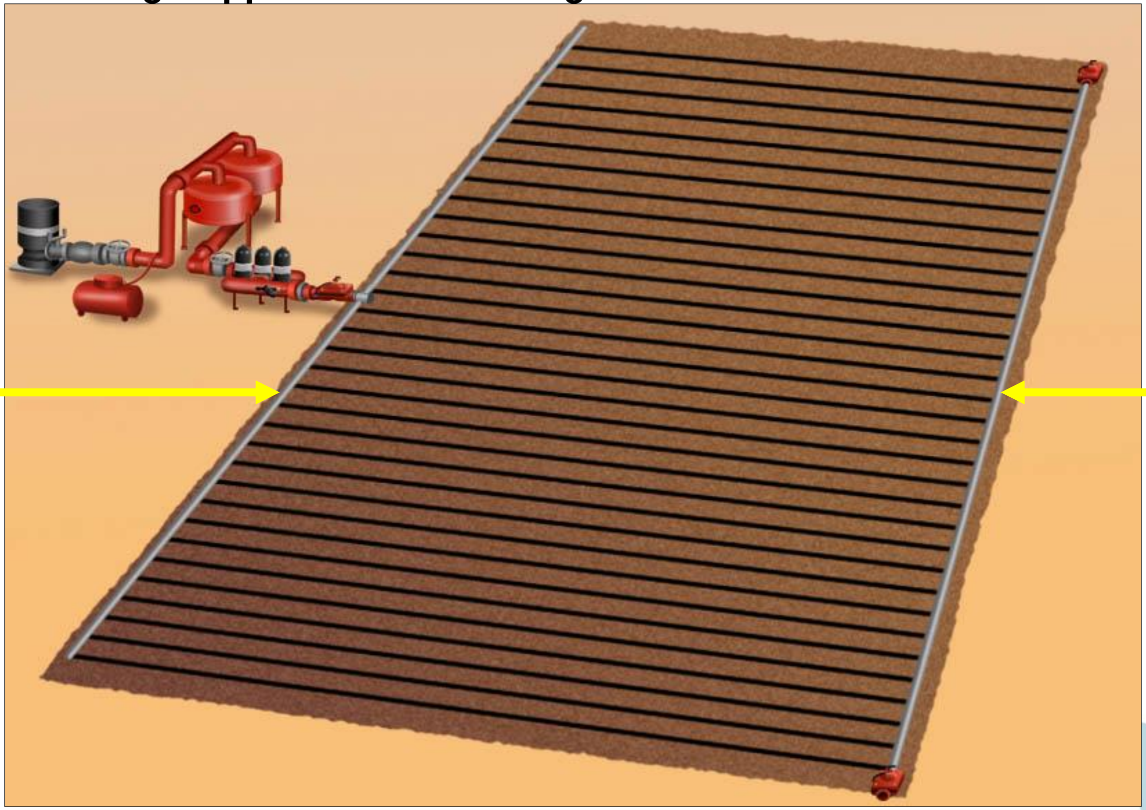
- If limited pressure is available, don't open more than 10 line ends for each flushing.

SDI Dripperline Design

Collector Pipe Design

Flushing dripperlines in SDI irrigation.

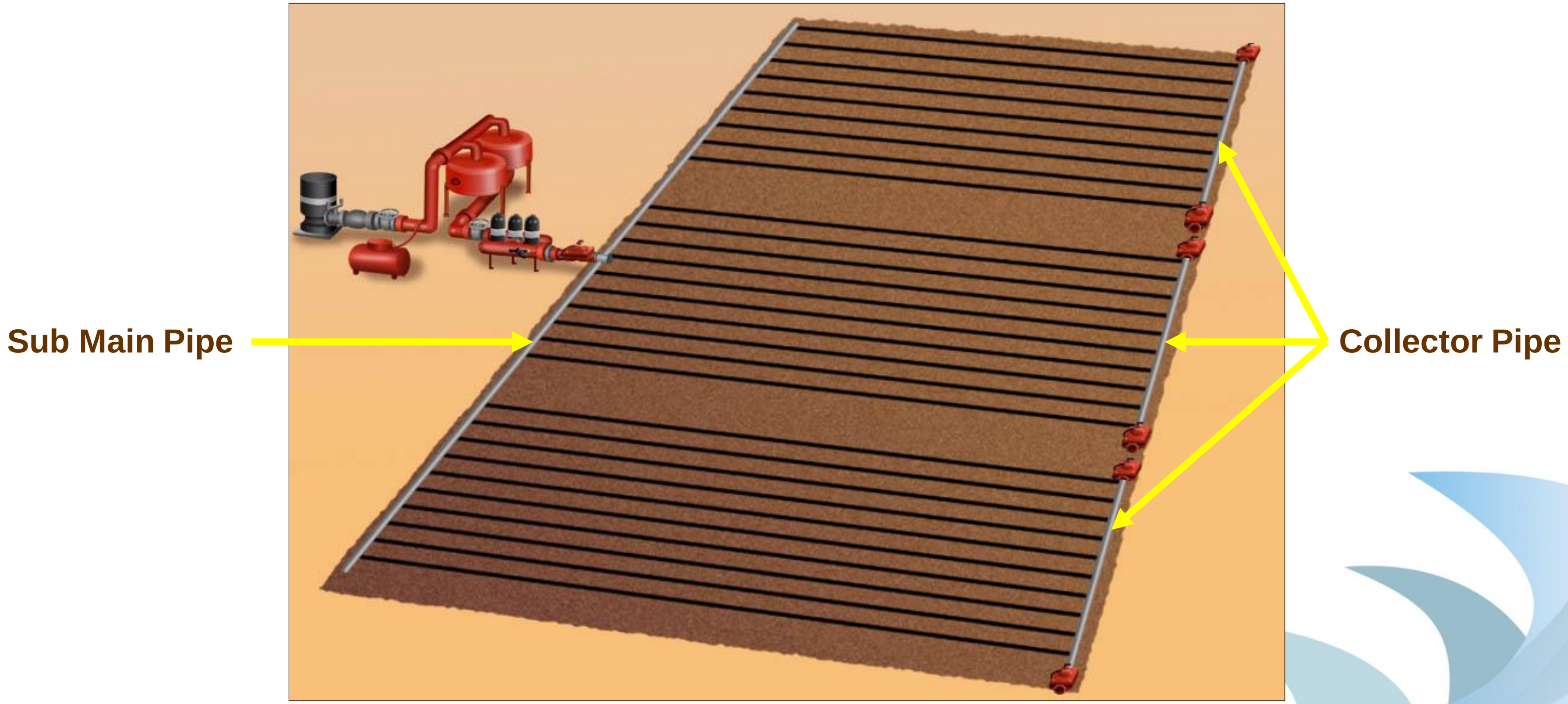
Sub Main Pipe



Collector Pipe

Collector Pipe Flushing

Flushing dripperlines by sectors



Main Pipe Design

Main Pipe Characteristics

Calculation of main water pipes:

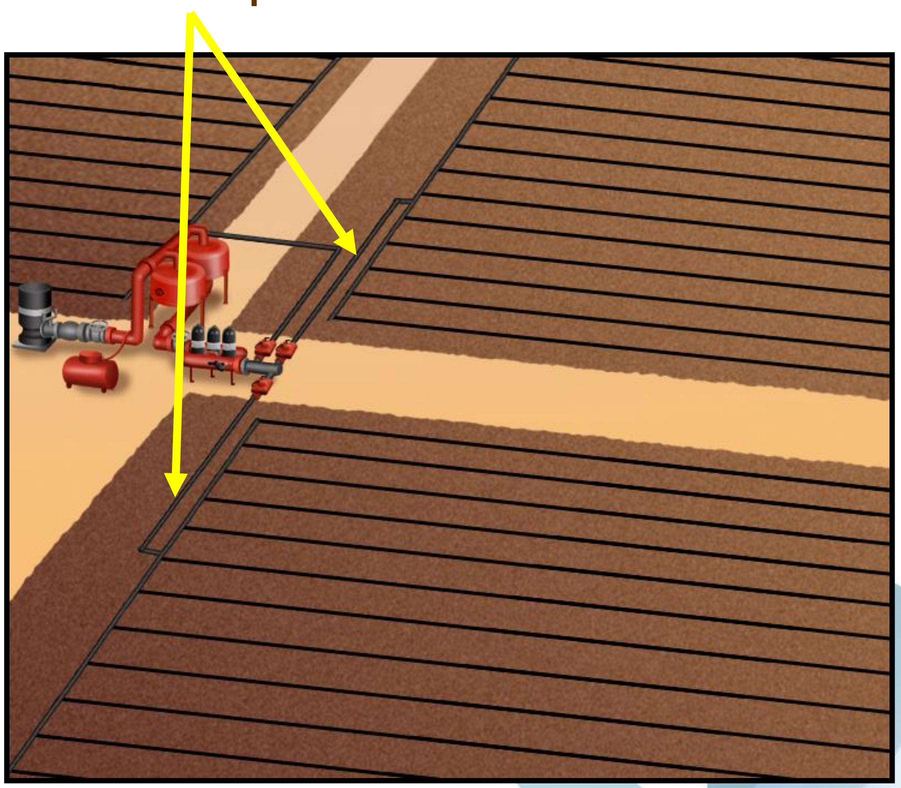
Definition: A main pipe is one in which the water flow at the entrance is identical to that at the exit.
Figures for calculation of the head loss in a main pipe.

Coefficient per type of raw material:

C = 150 P.E.
C = 150 P.V.C.
C = 100 Asbestos*(capital)
C = 90 Iron

Where:

Outside Diameter OD (mm)
Inside Diameter ID (mm)
Pipe cross-section A (mm^2)
Length L (meter)
Volume V (m^3)
Wall thickness G (mm)



Calculation Formulas

Cross section:

A = (π*D²/4

(Units mm²)

Velocity:

V = Q/A

(Units m/sec)

Flow rate:

Q = A*V

(Units m³/h)

Where:

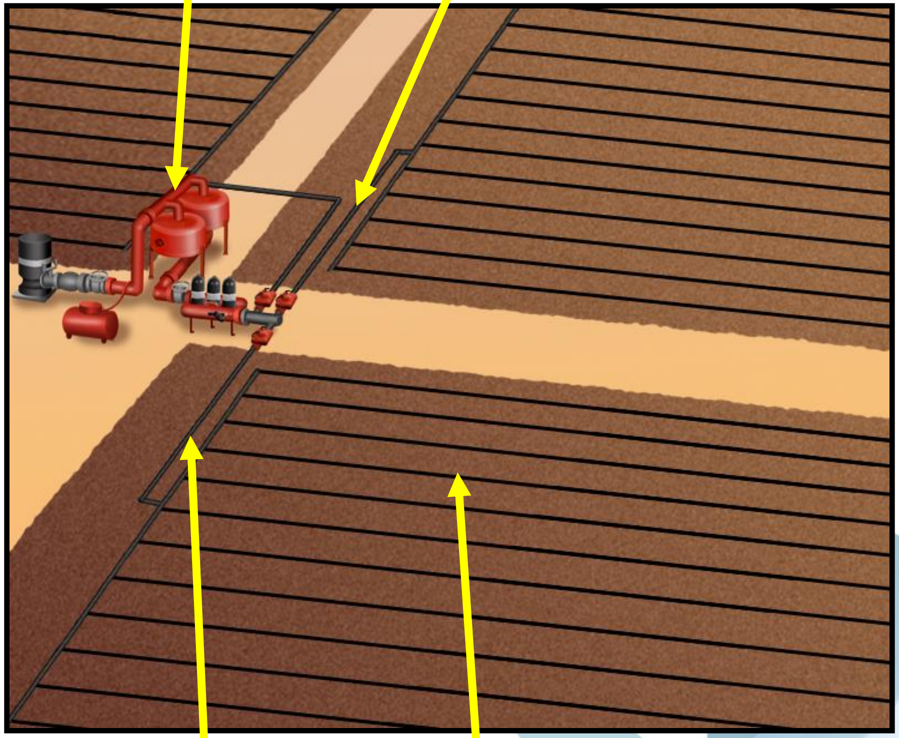
Outside Diameter = OD (mm)

Inside Diameter=ID (mm)

Pipe cross-section A (mm²)

Length L (meter)

Volume V (m³)

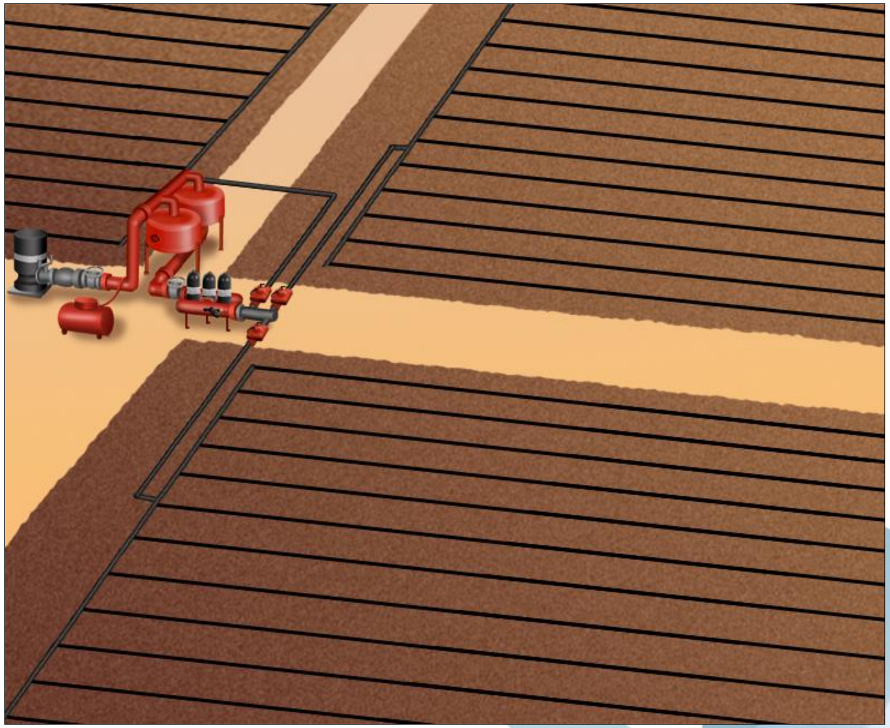


Main Pipe Design - Exercise

Hydraulic Exercises

1) Calculate the flow velocity for a tube of ID=200 mm and a 100 m^3/h flow rate.

2) Calculate the diameter of a tube with a flow velocity 1 m/s and a flow rate of 360 m^3/h.



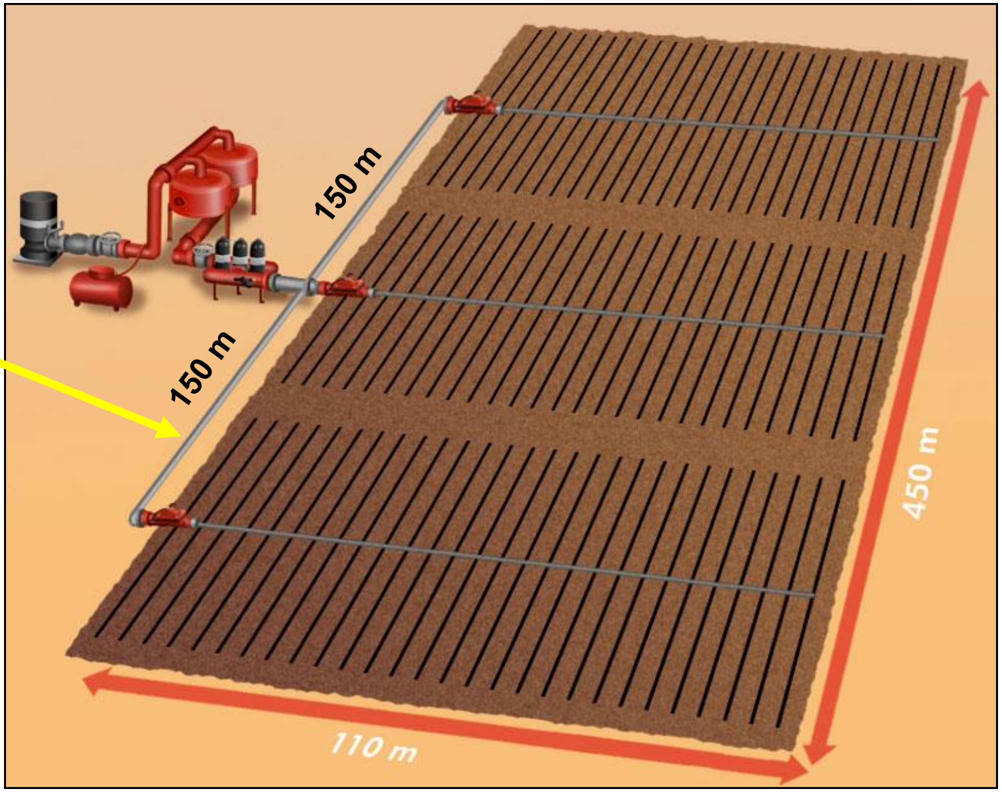
Main Pipe Design

Main Pipe Design - Training

Main pipe calculation in the planning example accompanying the presentation.

Main pipes use of hydro calculator, for example:

Main Pipe



Data for calculation:

Flow rate: 16800 lit.
Length: 150 meter.
Flat soil.
Max.pressure: 4 bar
Head loss: 0.5 bar

Results of calculation:

Submain Main Pipe Design

Submain Pipe Charectaristics

Hydraulic calculations - Submain pipe

Calculations of head loss in a sub main pipe according to the Hazen-Williams formula.

J o/oo= 1.131*10^12* (Q/C)^1.8528*D^-4.87

Where:

J = Head loss along the pipe in percentage.

H = Head loss per meter. (m)

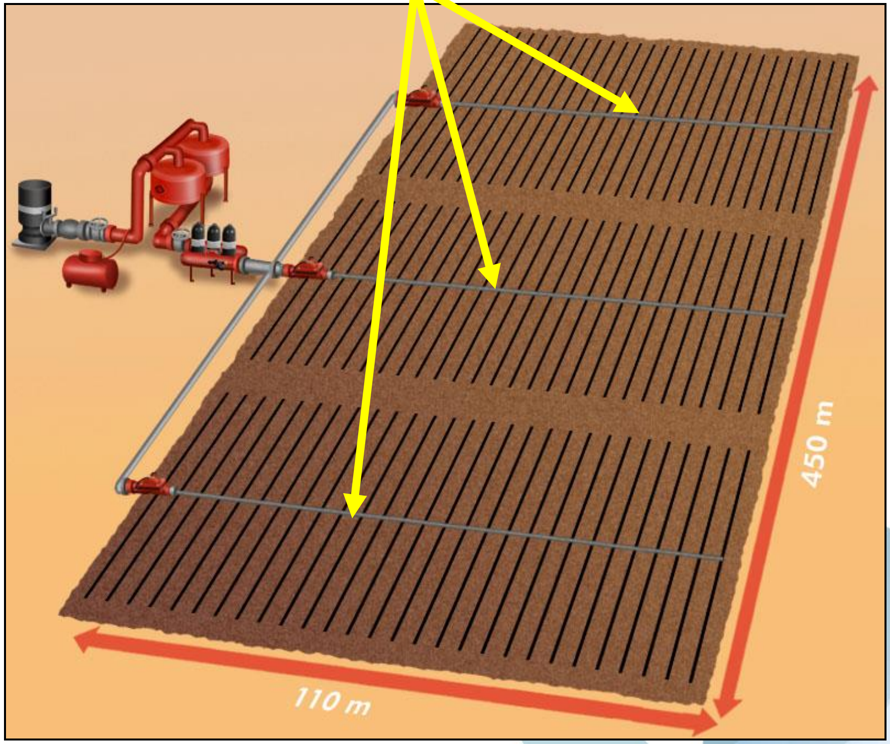
L = Length of the pipe. (m)

Q = Pipe flow rate. (m^3/h)

C = Flow resistance coefficient (PVC / P.E.)

D = Internal diameter of the pipe. (mm)

Submain Pipe



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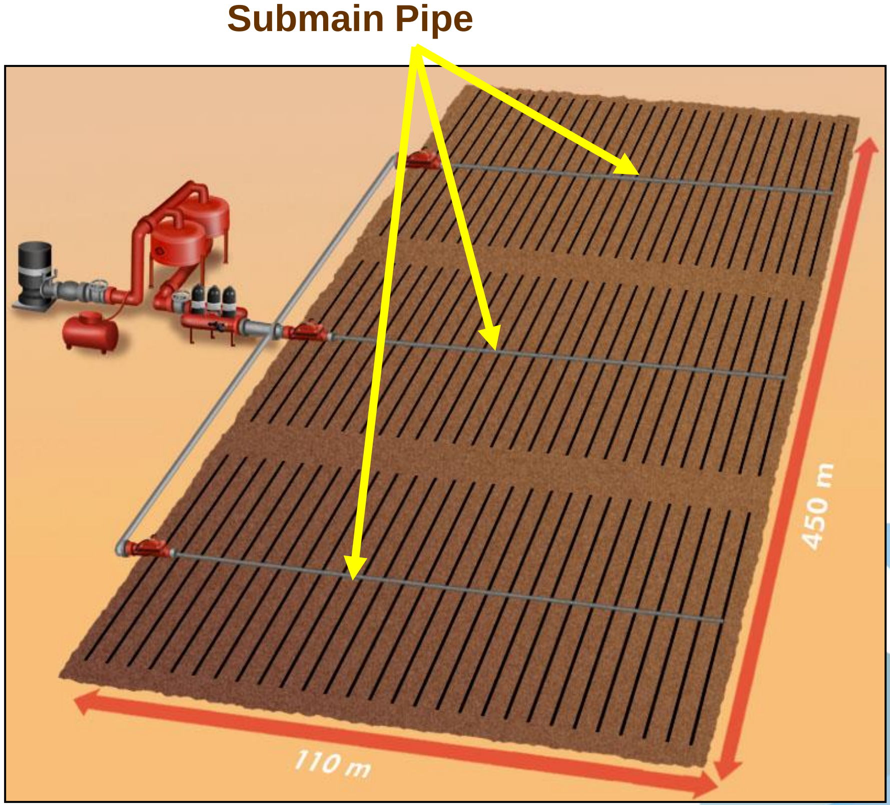
Submain Pipe Design

Submain calculation, in the planning example accompanying the presentation

Data for calculation:

Flow rate: 16800 lit.
Length: 110 met.
Flat soil.
No of outlets: 28
Max.pressure: 4 bar
Head loss: 0.1 bar

Results of calculation:



Submain Main Pipe Design

Submain Pipe – Irregular Areas

Submain calculation for irregular areas

Structure of the area	0.23	0.29	0.38	0.47	0.57
No. of outlets					
2	0.50	0.54	0.65	0.80	1.00
3	0.38	0.45	0.55	0.67	0.83
4	0.33	0.40	0.50	0.62	0.76
5	0.31	0.38	0.47	0.58	0.71
6-10	0.27	0.34	0.43	0.53	0.65
11-15	0.25	0.32	0.40	0.50	0.61
16>	0.23	0.29	0.38	0.47	0.57

Collecting Design Data

Questionnaire – Soil/Crop

OPEN FIELD QUESTIONNAIRE

Country:____________________

Customer data:

1. Customer/ farm name:
____

2. Farm location: __________________________

Tel./Fax: ___________________

Crop data:

3. Crop: _________________________. Varieties:
____________. Age: _______

4. Row/ bed spacing: _______(m). Plant spc.:
________(m). No. of rows/ bed___

5. Max. water requirement: ________ mm/d.
________l/plant per day

Soil data

6. Soil type: __________. Percent of: clay ____.
Silt _____. Sand

Questionnaire– Water/Climate

OPEN FIELD QUESTIONNAIRE

Water data

7. Indicate water source: lake/ dam/ river/ borehole

8. Existing pump:

make: ___________

type: _________

model:___________

R.P.M. ___________.

9. Diameter of impeller: ________mm.

good _________

moderate ___________

bad ___________

Questionnaire– Technical/Operational

OPEN FIELD QUESTIONNAIRE

Climate data

10. Mean max.:

Evaporation _______ mm/d.

Temperature _______°C

Technical/ operational data

11. Max. allowed irrigation time: hr per day: _______.
Days per week: ________

12. Irrigation interval: ________days.

13. Required type of irrigation: drip/ mini spr./ overhead.

14. Required type of sprinkler/ dripper and flow rate:
______________ ___l/hr.

Questionnaire– Technical/Operational

OPEN FIELD QUESTIONNAIRE

Technical/ operational data

15. Spacing between: emitters _______ m. , laterals ______m.

16. Required type of filtration: ____

17. Required type of fertilization: venture / pressure tank _ / injector________

18. Required type of automation / control: non / automatic metering valve / manual remote control / computer r. control / automatic back flushing.

Questionnaire– Phisical

Physical Data/Sketch (drawing)

OPEN FIELD QUESTIONNAIRE

Row direction ____
Slopes (%) and their directions (down hill)_____
Roads ____
Water canals/ structures _____
Location of water source and its altitude _____
Future expansion ___
North arrow ____

SKETCH

Thank You