IIT KHARAGPUR

NPTEL ONLINE CERTIFICATION COURSES

NPTEL

Irrigation and Drainage

Lecture No:21 Sprinkler Irrigation Design

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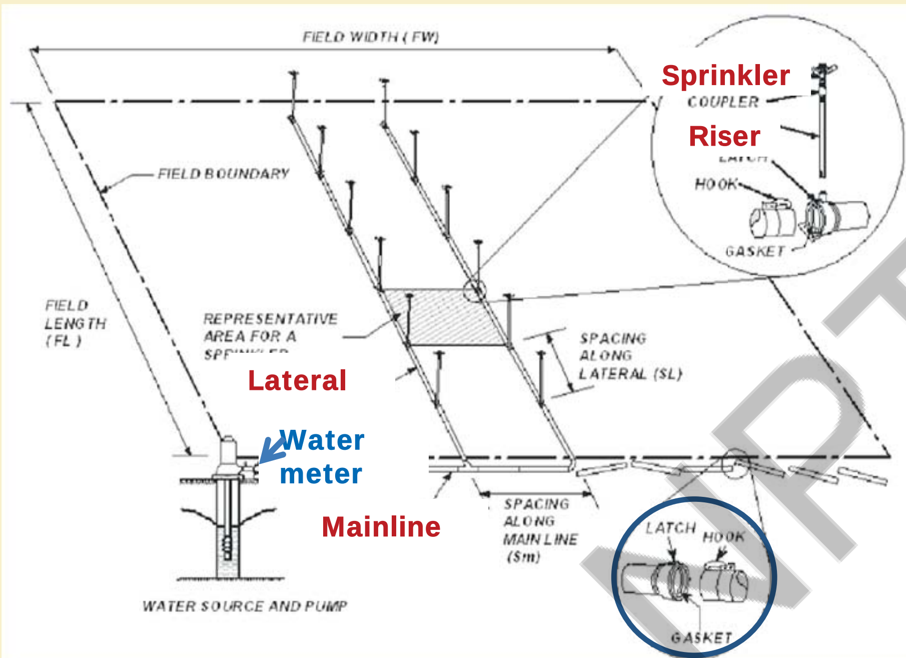
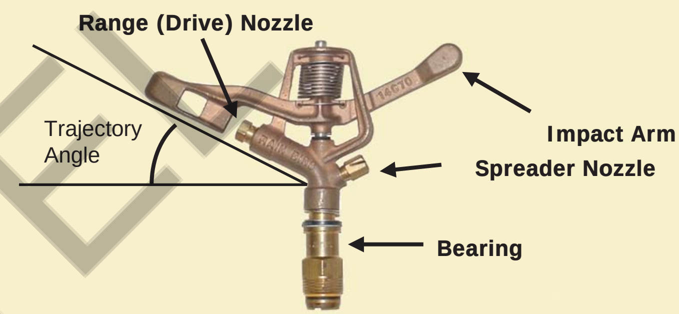
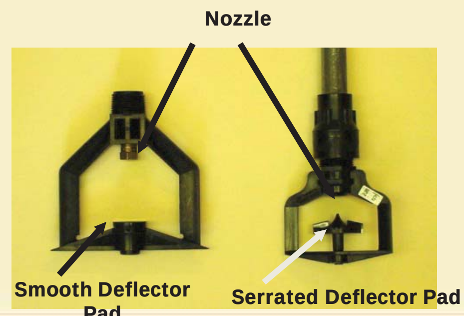
Sprinkler Irrigation System Layout



Impact Sprinklers



Two-nozzle, bronze impact sprinkler



Spray Pad Sprinklers

Sprinkler Irrigation System: Design Aspects

- ✓ System layout
- ✓ Operating pressure, nozzle diameter, sprinklers discharge, and wetted diameter
- ✓ Spacing between sprinklers and laterals
- ✓ Design of main-line and sub-lines
- ✓ Pivot or ranger length
- ✓ System capacity for water supply
- ✓ Pump design

Sprinkler discharge should not vary by more than 10% between the points of highest and lowest pressure in the system

Sprinkler Irrigation System: Design Principles

1) **Estimate application rate** based on planned crop(s)/cropping patterns, atmospheric water demand, and soil intake rate

2) **Draw a layout**

3) **Optimize sprinkler spacing** (between sprinklers and laterals), nozzle size, and operating pressure that provide the design application rate and distribution pattern

4) **Design** sub-mains, main lines, and supply lines such that required water quantities can be conveyed to all operating lateral lines at required pressures

5) **Design pump and power units** such that they are adequate to efficiently operate the sprinkler system at design capacity and total dynamic head

Simple Sprinkler Design: Steps

1) **Determine the daily maximum supply requirement for an area (A) for the target crop as**

$$V_A = \frac{A \times ET_{max}}{E_a}$$

$$ET_{max} = K_C \times K_S \times ET_0$$

Where, V_A = Required volume of water for the area A (m^3)

A = Specific area that is to be irrigated (m^2)

ET_{max} = Daily maximum evapotranspiration (m)

E_a = Design application efficiency of the sprinkler

ET_0 = reference evapotranspiration at peak water demand period

K_C = crop-coefficient at peak water demand period

K_S is the soil moisture stress coefficient

Simple Sprinkler Design: Steps

2. Determine discharge rate (Q) for the area A based on the minimum operating hours

$$Q_A \left({m^3}/{h} \right) = \frac{V_A \, (m^3)}{t(h)}$$

3. Optimize sprinkler and lateral spacing for the individual sprinkler discharge rate and application rate (which is constrained by the soil infiltration rate):

$$q = S_m \times S_l \times I$$

Where, q = discharge rate for the individual sprinkler (m^3/h) for the area ($S_m \times S_l$) m^2

S_m = sprinkler spacing along laterals (m)

S_l= lateral spacing along mainline (m)

I= average application rate (m/h)

$I = \frac{Q_A}{A}$, if not limited by soil intake rate

Simple Sprinkler Design: Steps

S_l= D_{ml} (1 – F/2);
S_m = D_{mm} (1 – F/2)

where D_{ml} and D_{mm} are the manufacturer's rated wetting diameters of lateral sprinkler and mainline sprinkler, respectively; F is the overlapping factor, normally taken as 0.5–0.75.
For windy condition, overlapping factor may be as high as 1.0

4. Number of sprinklers

$$n = \frac{A}{S_l \times S_m}$$

5. Determine System Capacity

$$Q_{ST} = \sum_{i=1}^{n} Q_{Ai}$$

Where i is the number of sub-area like "A"

Simple Sprinkler Design: Steps

6. **Determine the power** requirement to pump the water for a sprinkler system as

$$P = Q_{ST} \times 9.81 \times H_T$$

$$H_T = H_m + H_f + H_r + H_s + H_{sf}$$

P = power (KW)
Q_{ST} = total discharge rate for the system (m^3/s)
H_T = total pumping head (m)
H_m = pressure head required to operate the sprinklers at minimum required pressure (m)
H_f = total frictional head in the lines (m)
H_r = maximum riser height from the pump level (m)
H_s = suction head (vertical difference between pump level and source water level after drawdown) (m)
H_{sf} = friction head loss in suction line (m)

Example 21.1:

A farm of 25 ha is planned to be brought under sprinkler irrigation. The textural class of the soil is loam-to-silt loam, having moisture content at field capacity (FC) and permanent wilting point (WP) of about 42% (by volume) and 26% (by volume), respectively. An infiltration test data showed that constant (basic) infiltration rate is 2 mm/h. A hardpan (relatively impervious layer) exists at a depth of 2.0 m below the soil surface. Long-term average reference evapotranspiration (ET_0) rate in that area is 4.5 mm/d. Vegetable crops are planned to grow in the farm, and the crop coefficient (K_c) at maximum vegetative period is 1.1. The climate is moderately windy in a part of the season. Design the sprinkler irrigation system (various components) for the farm. Assume standard value of any missing data.

Solution:

Given,

Area, A = 25 ha = 250,000 m^2

FC = 42% (by vol.); WP= 26%

I_c = 2 mm/h

ET_0 = 4.5 mm/d

K_c = 1.1

D_{imp} = 2 m below soil surface

Wind status: moderately windy

Now, the solution steps:

1. $ET_{max} = ET_0 \times K_c = 4.5 \times 1.1 = 4.95\ mm/d$

   (Assuming depletion of soil-moisture up to readily available level, so that ET occurs at its maximum rate, i.e., soil moisture stress factor, $K_s = 1$)

2. Daily water requirement for the area, A (i.e., for whole farm here) is

$$V_A = \frac{A \times ET_{max}}{E_a}$$

Assuming application efficiency, $E_a = 80\%$, i.e., 0.8

$$\text{Then, } V_A = \frac{250000 \times (\frac{4.95}{1000})}{0.8} = 1546.875 \text{ m}^3$$

3. Discharge rate, $Q_A = \frac{V_A}{t}$

   Here, t= irrigation period = 4 h (assuming for the prevailing windy condition)

   Thus, $Q_A = \frac{1546.875}{4 \times 3600} = 0.1074$ m³/s

   Discharge rate of individual sprinkler, $q = S_m \times S_l \times I$

$$S_l = D_{ml}\ (1 - {}^{F}/_{2})$$

$$S_m = D_{mm}\ (1 - {}^{F}/_{2})$$

   Assuming overlapping factor, F = 0.7 (higher for windy condition)

   Taking a manufacturer rated wetting diameter for mainline and lateral sprinkler as 12 m and 10 m, respectively, we get

$$S_l = 12\left(1 - {}^{0.7}/_{2}\right) = 7.8\ m$$

$$S_m = 10\ (1 - {}^{0.7}/_{2}) = 6.5\ \text{m}$$

Application rate, $I\ = Q_A/A\ =\ (0.1074 \times 3600)/250000\ = 1.5468$ mm/h, which is less than the soil infiltration rate.

Here, assuming $I\ =\ 2$ mm/h (to minimizing evaporation loss in windy climate)

Putting the values, $q\ =\ [7.8\ \times\ 6.5\ \times\ (2/1000)]\ \times\ (1000/60)\ = 1.69$ l/min

5. Number of sprinklers, $n = \frac{A}{S_l \times S_m} = \frac{250000}{7.8 \times 6.5} = 4930.9 \cong 4931$

Note: The above calculation is for fixed lateral. If moving lateral is used, no. of laterals should be based on the maximum working /pump operating period. Note that each setting requires 4 h for the above calculation, so 16/4 = 4 settings can be operated if 16 h is the working period.

Besides, number of laterals should be based on the dimension of the land, lateral size available in the market, etc.

6. **Power required** (motor capacity required), $P = Q_{ST} \times 9.81 \times H_T$

Here, $Q_{ST} = 0.1074$ m³/s

$$H_T = H_m + H_f + H_r + H_s + H_{sf}$$

H_m = pressure head required to operate the sprinklers at minimum required pressure (m) = 28.05 m (= 40 psi) (assuming)

H_f = total frictional head in the lines (m) ≈ 5% of H_m = 1.71 m (assuming/estimating)

H_r = maximum riser height from the pump level (m) = 1.5 m (assuming)

H_s = suction head (vertical difference between pump level and source water level after drawdown) (m) = 0 (assuming that water is pumped from the supply canal)

H_{sf} = friction head loss in suction line (if suction line exists) = 0

Thus, $H_T = 31.26$ m

Thus, $P = 0.1074 \times 9.81 \times 31.26 = 32.94$ KW

7. **Summary** design parameters are as follows:

Taking for fixed laterals:

Pump capacity: Q_{ST}= 0.1074 m^3/s

Irrigation period = 4 h

Motor capacity: P = 32.94 KW

Lateral spacing along mainline: S_m = 7.8 m

Sprinkler spacing along lateral: S_l= 6.5 m

Number of total sprinklers: n = 4931 nos **(Ans.)**

Example 21.2:

Determine the required capacity of a sprinkler system to apply water at the rate of 1.25 cm/h. Two 186 m long sprinkler lines are required. 16 sprinklers are spaced at 12 m intervals on each line. The spacing between the lines is 18 m.

Solution:

Given:

$I = 1.25$ cm/h

$S_l = 12$ m

$S_m = 18$ m

Discharge in each sprinkler, $q = 12 \times 18 \times 1.25/100 = 2.7\ m^3/h$

System capacity, $Q = 2.7 \times (16+16) = 86.4\ m^3/h$

Example 21.3:

Allowing 1 hour for moving each 186 m sprinkler line described in the previous example, how many hours would be required to apply a 5 cm irrigation to a square 16 ha field? How many days are required assuming 10-h days?

Solution:

Irrigation time to apply 5 cm irrigation at the rate of 1.25 cm/h

= 5 / 1.25 = 4 h

Time required for moving the lateral = 1 h

Total time per setting = 4+2= 6 h

Area of field = 1,60, 000 m^2 ; Length of field

$$= \sqrt{1,60,000} = 400 \text{ m}$$

The entire length of 400 m is converted by the two 186 m laterals, spaced 18 m apart, hence the number of moves required

$$= \frac{400}{18} = 22.2, \text{ say } 22 \text{ moves}$$

Total time required for irrigation

$$= 22 \times 5 = 110 \text{ h} \qquad = \frac{110}{10} = 11 \text{ days}$$

Example 21.4:

A sprinkler system is to be designed to irrigate 8 ha of vegetable crop (Root zone depth = 60 cm) in deep silt loam soil (Limiting application rate = 1.3 cm/h; Moisture holding capacity = 9.5 cm/m depth) in moderate dry climate.

The field is flat. Assuming the allowable depletion level = 50 %, water application efficiency = 75 % and peak rate of moisture use by crop = 5 mm / day,

Determine the net depth of water per application, the depth of water pumped per application, irrigation period and the required system capacity in ha- cm per day.

Assuming that system is operated for 15 h each day, determine the pump capacity in lps.

Solution:

Total available moisture in the root zone $= 9.5 \times \frac{60}{100} = 5.7$ cm

Net depth of irrigation $= 5.7 \times \frac{50}{100} = 2.85$ cm

Depth of water pumped per application $= \frac{Net\ depth\ of\ irrigation}{Water\ application\ efficiency} = \frac{2.85}{0.75} = 3.8$ cm

Irrigation period $= \frac{2.85}{0.5} = 5.7$, say 6 days

To cover the field in 6 days the system must be able to pump and discharge

$= \frac{3.8 \times 8}{6} = 5.06$ ha-cm per day

The pump capacity, Q_{sys}

From Equation (2)

$Q_{sys} = 2780\ \frac{8 \times 2.85}{6 \times 15 \times 75} = 9.4$ lps

Thank You!!

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Irrigation and Drainage

Lecture No:22 Sprinkler Irrigation: Hydraulic Design

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Hydraulic design of sprinkler systems

i) Discharge of sprinkler nozzles

$$Q = C a_c \sqrt{2gh}$$

Where, Q = Discharge, m^3/s; a_c= Cross sectional area of the nozzle or orifice, m^2; g = Acceleration due to gravity, m/s^2; h = Pressure head, m; C = Coefficient of discharge which is a function of friction and contraction losses (varies from 0.95 to 0.96, for good nozzles)

ii) Water spread area of sprinkler

- **Cavazza** formula for rotating head sprinklers $R = 1.35\sqrt{dh}$

  Where, R = Radius of wetted area, m; d = diameter of nozzle, m; h = pressure head at the nozzle, m

- ✓ Maximum coverage is attained when the jet emerges at an angle of 30^0 to 32^0 above the horizontal.
- ✓ Most rotating sprinklers are standardized at 30^0

iii) Break-up of jet

- ✓ **Index of jet break-up (Tanda Formula)**

$$P_d = \frac{h}{(10Q)^{0.4}}$$

$P_d > 2$, the condition of drop size is good.
$P_d = 4$, the condition of drop size is the best.
$P_d > 4$, the pressure is being wasted.

iv) Water Application Rate

$$A = \frac{Q}{360 \times A_W}$$

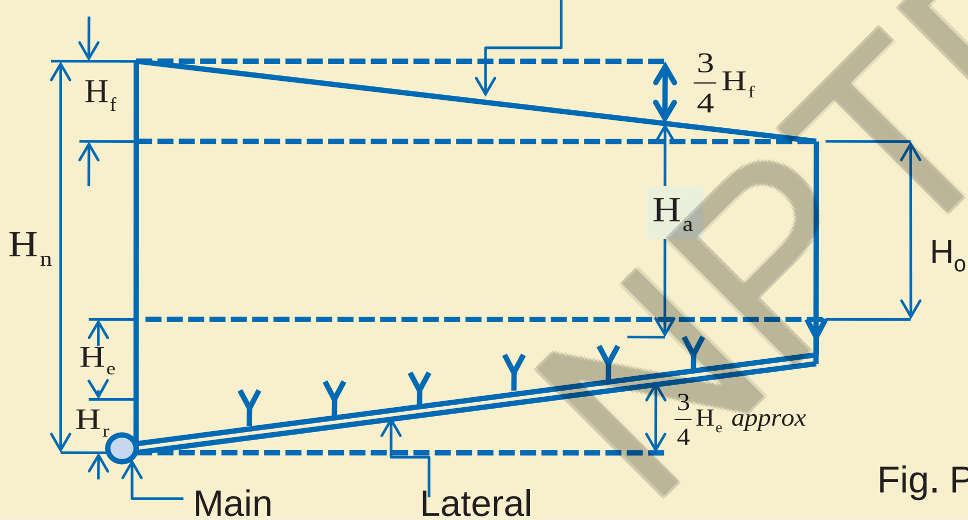
A = Water application rate, cm/h

A_w = Wetted area of sprinkler, m^2

Q = Rate of application, lps

v) Design of sprinkler main, submains and laterals

- ✓ Total pressure variation in the laterals < 20%
- ✓ Design capacity for sprinklers on a lateral is based on the average operating pressure, and
- ✓ Friction loss, H_f, in the lateral is within 20% of the average pressure



H_n = Head (pressure) at the main
H_a = Average head
H_o= Pressure at the farthest sprinkler
H_e= Maximum difference in elevation between the first and last sprinklers on the lateral
H_r = Riser height
H_f = Friction head loss

Fig. Pressure profile in a lateral laid uphill

- Average head H_a, for the design in a sprinkler line: $H_a = H_o + \frac{1}{4} H_f$

  Where, H_o= Pressure at the sprinkler on the farthest end

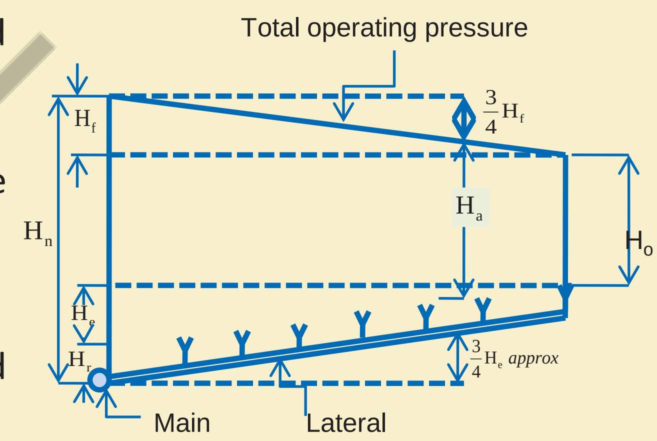
- If the lateral is on nearly level land or on the contour, the head (pressure) H_n at the main is, $H_n = H_0 + H_f$

- By solving for H_0 and substituting in H_n equation and making allowance for differences in elevation along the lateral,

$$H_n = H_a + \frac{3}{4} H_f + \frac{3}{4} H_e + H_r$$

Where, H_e - Maximum difference in elevation between the first and last sprinklers on the lateral, m; H_r - Riser height, m

The term $\frac{3}{4} H_e$ is positive if lateral run up the slope; negative if it runs down the slope



Main Line Pipe Size

- ✓ Function of main lines and sub mains is to convey the required quantity of the water at the desired pressure to all lateral lines under maximum pressure conditions
- ✓ Allowable H_f in main line is 3 m for small systems and 12 m for large systems
- ✓ Friction loss for different pipe materials is estimated by:

$$H_f = \frac{K \times c \times L \times Q^m}{D^{2m-n}} F$$

Where, L = Length of pipe (m, ft); g = acceleration due to gravity (9.81 m/s^2); K_s = for pipe material from standard table; K = Friction factor that depends on pipe material; Q = Flow rate (l/min, gpm); D = Diameter of pipe (mm, in); F = Friction factor (F = 1 if there is no outlet between up and downstream locations along pipe)

Method of computing H_f	c (SI units)	English units	m	n	K
Darcy-Weisbach	277778	1.235	2.00	1.00	K = 0.811 (f / g)
Hazen-Williams	591722	1.000	1.85	1.17	K = $(0.285\ c)^{-1.852}$
Scobey	610042	1.000	1.90	1.10	K = K_s / 348

- ✓ F can be determined as follows

When the distance from the pipeline to the first outlet equals the outlet spacing $F = \frac{1}{m+1} + \frac{1}{2N} + \frac{\sqrt{m-1}}{6N^2}$

When the distance to the first outlet is half of the outlet spacing $F = \frac{1}{2N-1} + \frac{2}{(2N-1)N^m}\left(\sum_{i=1}^{N-1}(N-i)^m\right)$

Where, m and n = appropriate m and n values in Head loss equations Table (previous slide); N = Number of sprinklers

v) Pumps and Power units

- ✓ Maximum total head against which the pump is working,

$$H_t = H_n + H_m + H_j + H_s$$

Where, H_t=Total design head against which the pump is working, m; H_n= Maximum head required at the main to operate the sprinklers on the lateral at the required average pressure, including the riser height, m; H_m =Maximum friction loss in the main and in suction line, m; H_j= Elevation difference between the pump and the junction of the lateral and the main, m; H_s= Suction head (elevation difference between the pump and the source of the water after drawdown, m

Design specifications of sprinkler with different nozzle size and operating pressure for **high pressure models**

Design specifications of sprinkler with different nozzle size and operating pressure for **low pressure models**

Model HP

Nozzle Size		Operating Pressure		Dia of Spray		Discharge		Application rate									
								12 x 12		12 x 18		18 x 18		18 x 24		24 x 24	
Range	Spread	Kg/cm²	psi	m	ft	L s⁻¹	gpm	cm/h	in/h	cm/h	in/h	cm/h	in/h	cm/h	in/h	cm/h	in/h
7/32" 5.5563mm	1/8" 3.175mm	2.11	30	27.7	92.3	0.588	7.76	1.50	0.58	NA	NA	NA	NA	NA	NA	NA	NA
		2.47	35	29.9	99.7	0.637	8.40	1.60	0.63	1.10	0.42	0.71	0.28	NA	NA	NA	NA
		2.82	40	32.0	106.7	0.680	8.97	1.70	0.67	1.10	0.45	0.76	0.30	NA	NA	NA	NA
		3.17	45	33.9	113.0	0.721	9.51	1.80	0.71	1.20	0.47	0.80	0.32	NA	NA	NA	NA
		3.52	50	35.8	119.3	0.760	10.03	1.90	0.75	1.30	0.50	0.74	0.33	0.63	0.25	NA	NA
		4.23	60	39.2	130.7	0.833	10.99	2.10	0.82	1.40	0.53	0.93	0.36	0.69	0.27	0.52	0.20
9/32" 7.1438mm	1/8" 3.175mm	2.11	30	31.4	104.7	0.878	11.59	2.20	0.86	1.50	0.58	0.98	0.39	NA	NA	NA	NA
		2.47	35	34.0	113.3	0.950	12.54	2.40	0.94	1.60	0.62	1.10	0.42	NA	NA	NA	NA
		2.82	40	36.3	121.0	1.016	13.41	2.50	1.00	1.70	0.67	1.10	0.44	0.85	0.33	NA	NA
		3.17	45	38.5	128.3	1.077	14.21	2.70	1.10	1.80	0.71	1.20	0.47	0.90	0.35	NA	NA
		3.52	50	40.6	135.3	1.135	14.98	2.80	1.10	1.90	0.74	1.30	0.50	0.95	0.37	0.71	0.28
		4.23	60	44.5	148.3	1.244	16.42	3.10	1.20	2.10	0.82	1.40	0.54	1.00	0.41	0.78	0.31
3/8" 9.525mm	1/8" 3.175mm	2.11	30	36.3	121.0	1.449	19.12	3.60	1.40	2.40	0.95	1.60	0.63	1.20	0.48	NA	NA
		2.47	35	39.2	130.7	1.568	20.69	3.90	1.50	2.60	1.00	1.70	0.69	1.30	0.51	0.98	0.39
		2.82	40	41.9	139.7	1.676	22.12	4.20	1.60	2.80	1.10	1.90	0.73	1.40	0.55	1.00	0.41
		3.17	45	44.5	148.3	1.777	23.45	4.40	1.70	3.00	1.20	2.00	0.70	1.50	0.58	1.10	0.44
		3.52	50	46.9	156.3	1.872	24.71	4.70	1.80	3.10	1.20	2.10	0.82	1.60	0.61	1.20	0.46
		4.23	60	51.4	171.3	2.052	27.08	5.10	2.00	3.40	1.30	2.30	0.90	1.70	0.67	1.30	0.50

NA-Not Applicable
(*Source* : M/S NOCIL, Akola, Maharashtra)

Model LP

Nozzle Size		Operating Pressure		Dia of Spray		Discharge		Application rate									
								6 x 6		6 x 9		9 x 9		6 x 12		12 x 12	
Range	Spread	Kg/cm²	psi	m	ft	L s⁻¹	gpm	cm/h	in/h	cm/h	in/h	cm/h	in/h	cm/h	in/h	cm/h	in/h
7/32" 5.5563mm	1/8" 3.175mm	1.06	15	19.6	65.3	0.417	5.50	4.20	1.60	2.80	1.10	1.90	0.73	2.10	0.82	1.00	0.41
		1.41	20	22.6	75.3	0.481	6.34	4.80	1.90	3.20	1.30	2.10	0.84	2.40	0.95	1.20	0.47
		1.76	25	25.3	84.3	0.537	7.08	NA	NA	3.60	1.40	2.40	0.94	2.70	1.10	1.30	0.53
		2.11	30	27.7	92.3	0.588	7076	NA	NA	3.90	1.50	2.60	1.00	2.90	1.20	1.50	0.58
		2.47	35	29.9	99.7	0.637	8.40	NA	NA	4.20	1.70	2.80	1.10	3.20	1.30	1.60	0.63
		2.87	40	32.0	106.7	0.680	8.97	NA	NA	4.50	1.80	3.00	1.20	3.40	1.30	1.70	0.67
13/64" 5.1594mm	1/8" 3.175mm	1.06	15	18.9	63.0	0.374	4.93	3.70	1.50	2.50	0.98	1.70	0.65	1.90	0.74	NA	NA
		1.41	20	21.8	72.7	0.431	5.68	4.30	1.70	2.90	1.10	1.90	0.75	2.20	0.85	1.11	0.42
		1.76	25	24.3	81.0	0.482	6.36	4.80	1.90	3.20	1.30	2.10	0.84	2.40	0.95	1.20	0.47
		2.11	30	26.7	89.0	0.527	6.95	NA	NA	3.50	1.40	2.30	0.92	2.60	1.00	1.30	0.52
		2.47	35	28.9	96.3	0.571	7.53	NA	NA	3.80	1.50	2.50	1.00	2.90	1.10	1.40	0.56
		2.82	40	30.8	102.7	0.610	8.05	NA	NA	4.10	1.60	2.70	1.10	3.10	1.20	1.50	0.60
5/32" 3.9688mm	1/8" 3.175mm	1.06	15	16.5	55.0	0.263	3.47	2.60	1.00	1.80	0.69	1.20	0.46	1.30	0.52	NA	NA
		1.41	20	19.1	63.7	0.303	4.00	3.00	1.20	2.00	0.80	1.30	0.53	1.50	0.60	NA	NA
		1.76	25	21.3	71.0	0.339	4.47	3.40	1.30	2.30	0.89	1.50	0.59	1.70	0.67	0.88	0.35
		2.11	30	23.4	78.0	0.371	4.89	3.70	1.50	2.50	0.97	1.60	0.65	1.90	0.73	0.93	0.37
		2.47	35	25.3	84.3	0.401	5.29	4.00	1.60	2.70	1.10	1.80	0.70	2.00	0.79	1.00	0.39
		2.82	40	27.0	90.0	0.429	5.66	4.30	1.70	2.90	1.10	1.90	0.75	2.20	0.84	1.10	0.42

NA-Not Applicable
(*Source* : M/S NOCIL, Akola, Maharashtra)

Example 22.1

Design a sprinkler irrigation system to irrigate 5 ha Wheat crop; Assume the following

Soil type	= silt loam
Infiltration rate at field capacity	= 1.25 cm/hr
Water holding capacity	= 0.15
Root zone depth	= 1.5 m
Daily consumptive use rate	= 0.6 cm/d
Sprinkler type	= Rotating over head

Solution:

Step I

Total water holding capacity of the soil = 0.15 x 1.5 = 22.5cm

Let the water be applied at 50% depletion, hence the depth of water to be applied = 0.50 x 22.5 = 11.25cm

Step II

Let the water application efficiency be 90 per cent

Depth of water to be supplied = 11.25 / 0.9 = 12.5 cm

Step III

For daily consumptive use rate of 0.60 cm

Irrigation interval = 11.25 / 0.6 = 19 days

In period of 19 days, 12.5 cm of water is to be applied on an area of 5 ha. Hence assuming 10 h of pumping per day, the sprinkler system capacity would be

$$= \frac{5\times10^{4}\times12.5\times10^{-2}}{19\times10\times3600} = 0.009 \text{ m}^3\text{s}^{-1}$$

Step IV

Take Spacing of lateral (S_m) = 18 m

Spacing of Sprinklers in lateral (S_l) = 12 m

This selection is made after considering the following:

Operating pressure of nozzle = 2.5 kg/cm^2

Maximum application rate = 1.25 cm/h

From the manufacturer's **M/S NOCIL, Akola chart**,

Nozzle size : 5.5563 x 3.175 mm

Operating pressure : 2.47 kg/cm^2 and

Application rate : 1.10 cm/hr (which is less than the maximum allowable application rate)

Diameter of coverage: 29.99 ≈ 30.0 m

Discharge of the nozzle: 0.637 lps = $0.637 \times 10^{-3}\ m^3/s$

Step V

Total no. of sprinklers = 0.009/0.000637 ≈ 14 sprinklers

Therefore 7 no. of sprinklers on each lateral.

Step VI

The sprinklers will be spaced at 12 m intervals on each of two lateral lines spaced 18 m apart.

Step VII

Total length of each lateral = 12 x 7 = 84 m

Model HP

Nozzle Size		Operating Pressure		Dia of Spray		Discharge		Application rate									
								12 x 12		12 x 18		18 x 18		18 x 24		24 x 24	
Range	Spread	Kg/cm^2	psi	m	ft	$L\,s^{-1}$	gpm	cm/h	in/h	cm/h	in/h	cm/h	in/h	cm/h	in/h	cm/h	in/h
7/32" 5.5563mm	1/8" 3.175mm	2.11	30	27.7	92.3	0.588	7.76	1.50	0.58	NA	NA	NA	NA	NA	NA	NA	NA
		2.47	35	29.9	99.7	0.637	8.40	1.60	0.63	1.10	0.42	0.71	0.28	NA	NA	NA	NA
		2.82	40	32.0	106.7	0.680	8.97	1.70	0.67	1.10	0.45	0.76	0.30	NA	NA	NA	NA
		3.17	45	33.9	113.0	0.721	9.51	1.80	0.71	1.20	0.47	0.80	0.32	NA	NA	NA	NA
		3.52	50	35.8	119.3	0.760	10.03	1.90	0.75	1.30	0.50	0.74	0.33	0.63	0.25	NA	NA
		4.23	60	39.2	130.7	0.833	10.99	2.10	0.82	1.40	0.53	0.93	0.36	0.69	0.27	0.52	0.20
9/32" 7.1438mm	1/8" 3.175mm	2.11	30	31.4	104.7	0.878	11.59	2.20	0.86	1.50	0.58	0.98	0.39	NA	NA	NA	NA
		2.47	35	34.0	113.3	0.950	12.54	2.40	0.94	1.60	0.62	1.10	0.42	NA	NA	NA	NA
		2.82	40	36.3	121.0	1.016	13.41	2.50	1.00	1.70	0.67	1.10	0.44	0.85	0.33	NA	NA
		3.17	45	38.5	128.3	1.077	14.21	2.70	1.10	1.80	0.71	1.20	0.47	0.90	0.35	NA	NA
		3.52	50	40.6	135.3	1.135	14.98	2.80	1.10	1.90	0.74	1.30	0.50	0.95	0.37	0.71	0.28
		4.23	60	44.5	148.3	1.244	16.42	3.10	1.20	2.10	0.82	1.40	0.54	1.00	0.41	0.78	0.31
3/8" 9.525mm	1/8" 3.175mm	2.11	30	36.3	121.0	1.449	19.12	3.60	1.40	2.40	0.95	1.60	0.63	1.20	0.48	NA	NA
		2.47	35	39.2	130.7	1.568	20.69	3.90	1.50	2.60	1.00	1.70	0.69	1.30	0.51	0.98	0.39
		2.82	40	41.9	139.7	1.676	22.12	4.20	1.60	2.80	1.10	1.90	0.73	1.40	0.55	1.00	0.41
		3.17	45	44.5	148.3	1.777	23.45	4.40	1.70	3.00	1.20	2.00	0.70	1.50	0.58	1.10	0.44
		3.52	50	46.9	156.3	1.872	24.71	4.70	1.80	3.10	1.20	2.10	0.82	1.60	0.61	1.20	0.46
		4.23	60	51.4	171.3	2.052	27.08	5.10	2.00	3.40	1.30	2.30	0.90	1.70	0.67	1.30	0.50

NA-Not Applicable

(*Source* : M/S NOCIL, Akola, Maharashtra)

Maximum allowable pressure variation = 0.2 x 2.47 = 0.494 kg/cm^2 = 4.94 m

Variation of pressure due to elevation = 2m

Permissible head loss due to friction = 4.94 – 2 = 2.94 m

Total flow through the lateral = 7 x 0.637 x 10^{-3} = 4.459 x 10^{-3} m^3/s

Considering DW (friction head) Eq.

Reduction factor (F) = $\frac{1}{3} + \frac{1}{2\times7} + \frac{1}{6\times7^2}$ = 0.333 + 0.071 + 0.0034 = 0.407

Head loss due to friction $(H_f) = \frac{0.811\times0.04\times277778\times84\times(4.459\times60)^2}{9.81\times D^5} \times 0.407$

$$2.94 = \frac{0.811 \times 0.04 \times 277778 \times 84 \times (4.459 \times 60)^2}{9.81 \times D^5} \times 0.407$$

Hence diameter of lateral = 60 mm

The head required to operate the lateral lines (H_m) = 24.7 + 2.94 + 2 + 1 = 30.6 m

Mainline:

Frictional head loss in main pipe line (H_f) = 30.6 x 0.2 = 6.12m (20%)

Calculating in the same way as done in case of lateral

$$6.12 = \frac{0.811 \times 0.04 \times 277778 \times 84 \times (4.459 \times 60)^2}{9.81 \times D^5} \times 0.407 \qquad \text{or } D = 69.10 \approx 70\text{mm}$$

Total design head $(H) = H_m + H_f + H_j + H_s$

Where, H_j = Difference in highest junction point of the lateral and main from pump level = 0.5 (assume)

H_s = Suction lift (20 m, assume)

H = 30.6 + 6.12 + 0.5 + 20 = 57.22m

The pump has to deliver 0.009 m^3/s of water against a head of 57.22 m

Hence, the capacity of power unit for a pump with 60% efficiency $= \frac{0.009 \times 57.22 \times 10^3}{0.6 \times 75}$ = 11.44 hp

Thank You!!

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Irrigation and Drainage

Lecture No:23 Drip Irrigation-1

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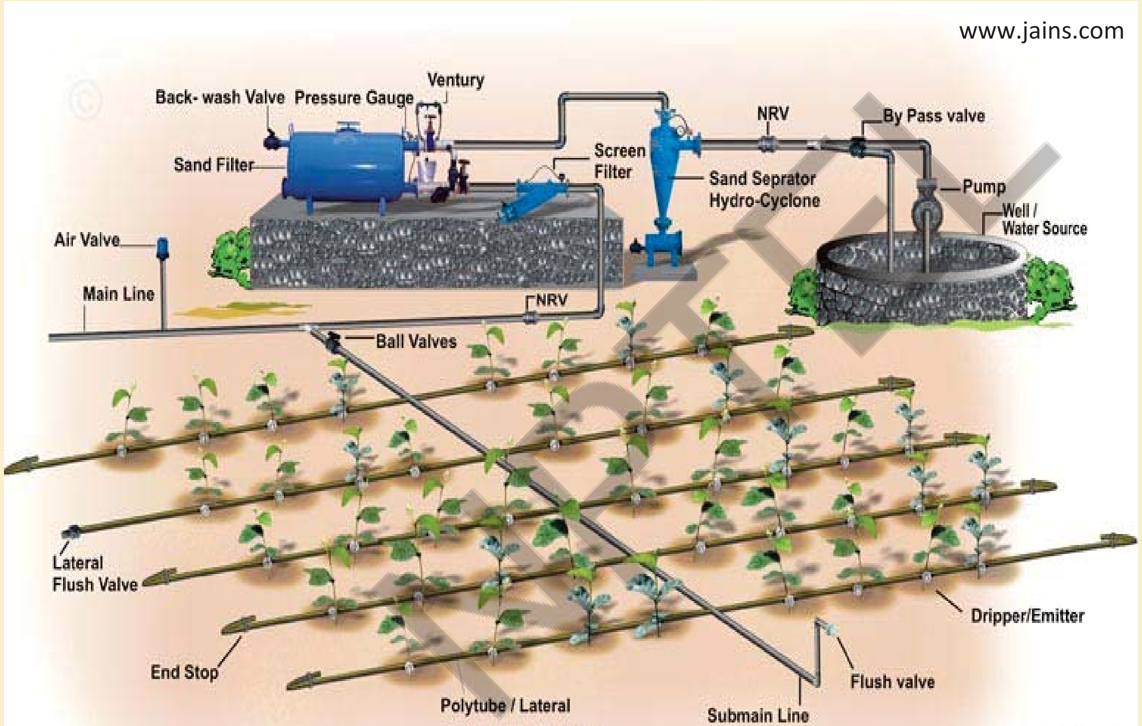
Typical layout of Drip Irrigation



Types of Drip Systems

i) On Line Emitter / Dripper System

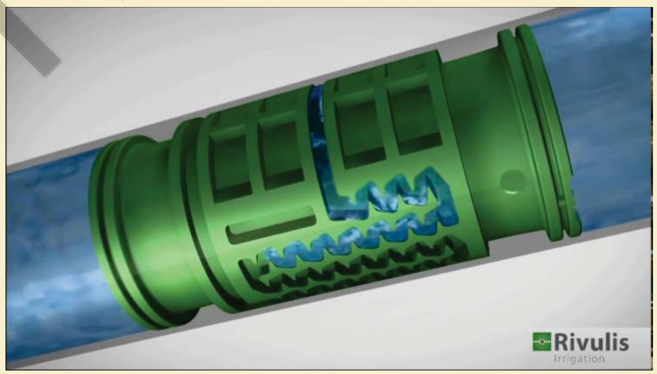
- Drippers are fixed externally on the laterals at the designed spacing
- Dripper spacing can be changed any time in future to cover the increased root zone of the plant with its age
- Commonly used for horticultural plants having large spacing; Mango, Coconut, Citrus, Orange, Lemon, Banana, Grapes, Pomegranate, Papaya, Sapota etc.

Different colors are used to identify the discharge rate of Turbo Key plus dripper

Types of Drip Systems

ii) Emitting Pipe System (In-line Drip System)

- Drippers are fixed in the lateral tube at the time of manufacturing based on crop spacing
- Once installed, the dripper spacing can not be changed
- Very effective for row crops like cotton, sugarcane, groundnut, vegetables and floriculture



- ✓ Point source Emitters can also be classified as
  - Long path
  - Orifice
  - Pressure –compensating
- ✓ Classification depend on the exponent

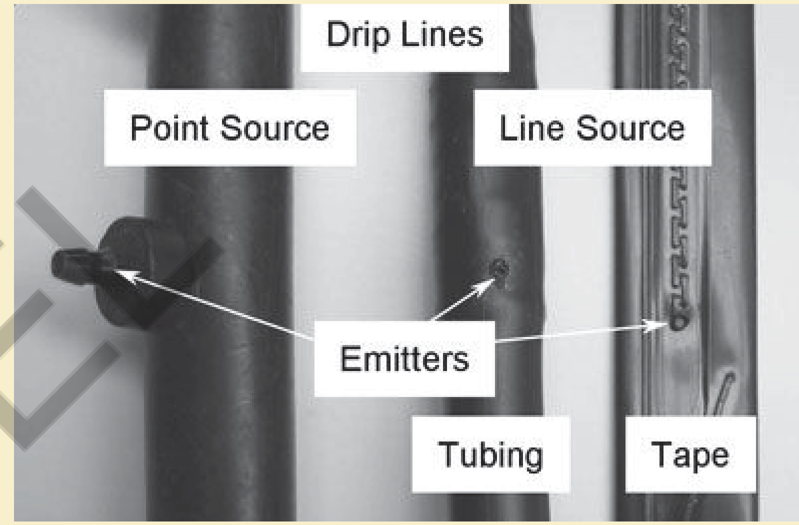
$$Q = kp^x$$

Q= Emitter Discharge, lph

P = Operating Pressure, kpa

k and , x = Constants for specified emitter

- For long path or laminar flow type emitter, x =1 (Sensitive to operating pressure fluctuation)
- For orifice type, x =0.5
- For Pressure-Compensating, x = 0 (Useful in undulating terrain or where large variation due to system operation expected)



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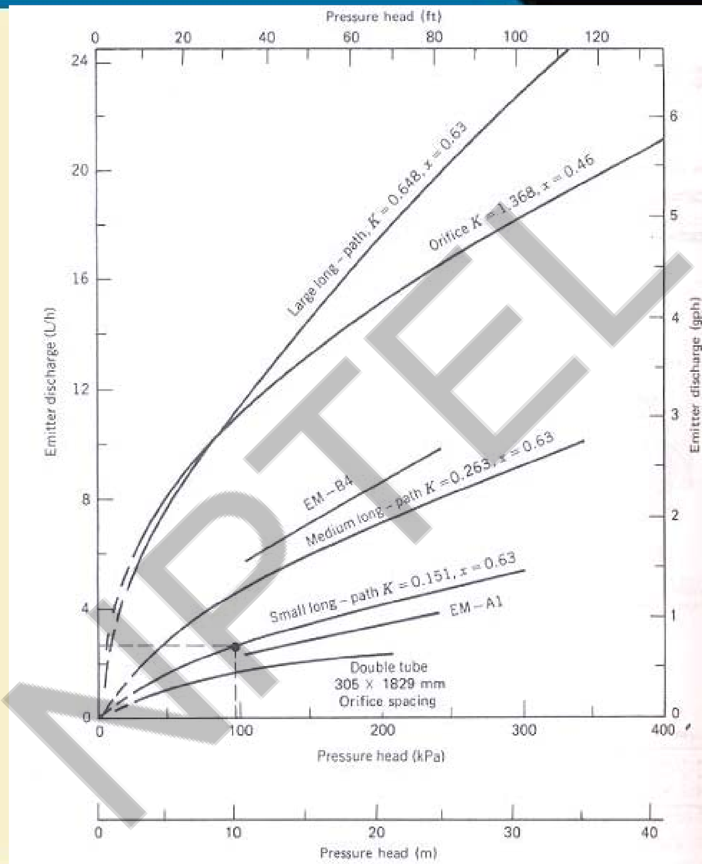
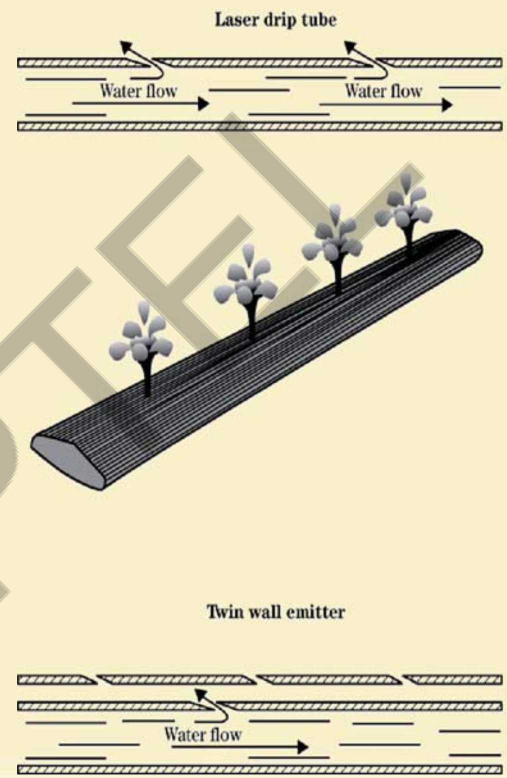
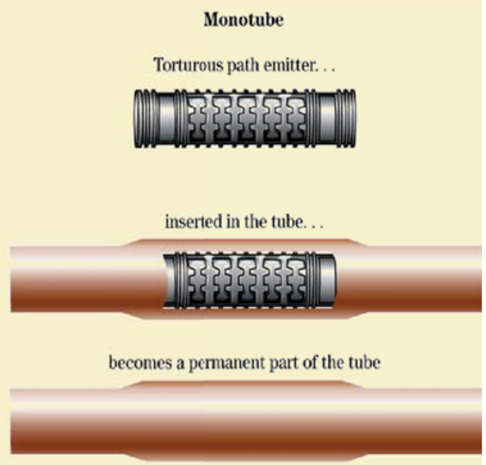


Pressure head (ft)
Emitter discharge (L/h)
Emitter discharge (gph)
Large long - path, K = 0.648, x = 0.63
Orifice K = 1.368, x = 0.46
EM - B4
Medium long - path K = 0.263, x = 0.63
Small long - path K = 0.151, x = 0.63
EM - A1
Double tube
305 X 1829 mm
Orifice spacing
Pressure head (kPa)
Pressure head (m)

Types of Drip Systems

- ✓ **Line Source Emitters**
  - o Porous pipe or tape that discharges water along its entire length
- ✓ Primarily used for row cops
  - ✓ Bubblers Discharging into furrows
- ✓ Mono-walled or bi-walled polyethylene pipes are commonly used





Drip Irrigation laterals

- ✓ Laterals deliver water from main lines and submains to the emission devices
- ✓ Material : Polyethylene and PVC commonly used
- ✓ Diameter :
  - o For point source emitters 10-20 mm
  - o For line source emitters >20 mm
- ✓ Designed to maintain an acceptable variation of emission device discharge along their length
- ✓ Manufacturer's coefficient of variation (discharge) determines the acceptability
- ✓ Determined from flow rate measurements for several identical emission devices and is computed with the following Equation.

$$C_v = \frac{\left(q_1^2 + q_2^2 + \ldots\ldots\ldots. + q_1^2 - nq^{-2}\right)^{1/2}}{\bar{q}(n-1)^{1/2}}$$

Where, C_v = manufacturer' coefficient of variation

q_1, q_2……. q_n =discharge of emission device ,l/hr

$\bar{q}$ = Average discharge of emission devices tested, l/hr

n= number of emission devices tested

Recommended Classification of Manufacturer's Coefficient of Variation (ASAE recommendation)

Emitter Type	Cv Range	Classification
Point Source	< 0.05	Good
	0.05 to 0.10	Average
	0.10 to 0.15	Marginal
	>0.15	Unacceptable
Line Source	< 0.10	Good
	0.10 to 0.120	Average
	>0.20	Marginal to unacceptable

Emission uniformity

$$EU = 100\left(1 - \frac{1.27}{\sqrt{N_e}}(C_v)\right)\frac{Q_{min}}{Q_{avg}}$$

Where,

EU= design emission uniformity, %

N_e= Number of point source emitters per emission point

C_v = Manufacture's coefficient of variation

Q_{min}=minimum emitter discharge rate in the system, L/h

Q_{avg} = average or design emitter discharge rate, L/h

Recommended Ranges of Design Emission Uniformity (EU)

Emitter Type	Soil Topography	EU Range for Arid Area[e]
Point Source on permanent crops[a]	Uniform[c] Steep or undulating[d]	90 to 95 85 to 90
Point Source on permanent or semi-permanent crops[b]	Uniform Steep or undulating	85 to 90 85 to 90
Line Source on annual row crops	Uniform Steep or undulating	80 to 90 70 to 85

a: Spaced > 4m
b: Spaced < 2 m

c: slope < 2 %
d: slope > 2%
e: for humid areas values may be lowered upto 10%

Example 23.1:

For the given data, compute the emission uniformity for drip lateral for an arid region and check whether the design is acceptable

Point source emitters on a permanent crop

$C_v = 0.07$

$Q_{min} = 30$ lph

$Q_{avg} = 33$ lph

$N_e = 1$

Uniform terrain with slopes less than 2%.

Solution:

$$EU = 100\left(1 - \frac{1.27}{\sqrt{N_e}}\,(C_v)\right)\frac{Q_{min}}{Q_{avg}}$$

$$EU = 100\left(1 - \frac{1.27}{\sqrt{N_e}}(C_v)\right)\frac{Q_{min}}{Q_{avg}} = 100\left(1 - \frac{1.27}{\sqrt{1}}(0.07)\right)\frac{30}{33}$$

$$= 82.8\%$$

- Based on ASAE criteria (Table on previous slide) this design is not acceptable, since EU should exceed 90%
- EU in the example could be improved by
  - ✓ increasing N_e
  - ✓ using an emitter with a lower C_v
  - ✓ reducing difference between Q_{min} and Q_{avg}
  - ✓ using larger diameter and/or shorter laterals
  - ✓ using pressure compensating emitters

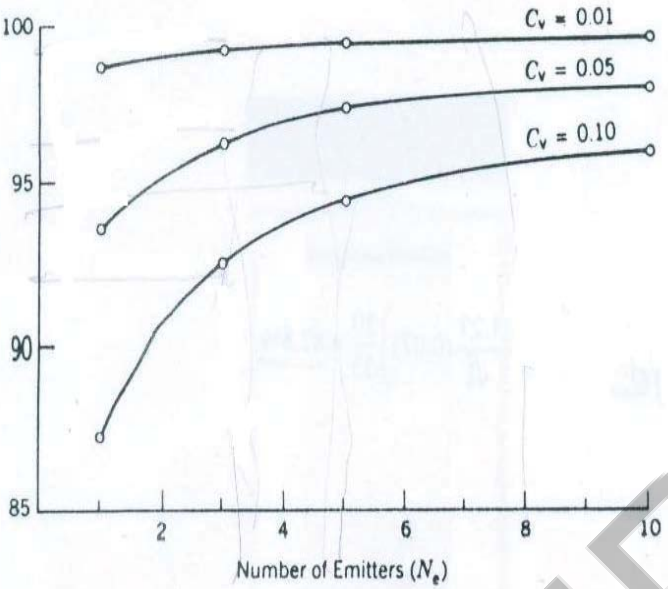


Figure Relationship between emission uniformity, C_v and number of emission devices for Q_{min}/Q_{avg} = 1.0.

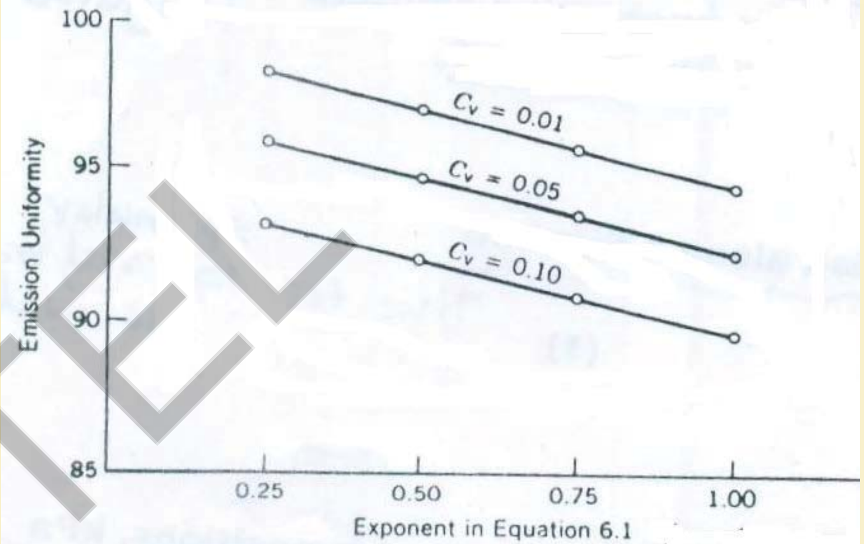


Figure Relationship between emission uniformity, C_v, and emission exponent (x in Eq. 6.). The graph is based on the assumptions of a 5-percent pressure variation and five emission devices per emission point.

If C_v is higher, Ne should be large to get desired EU

EU is high for emitters with lower x ($q = kp^x$)

Pressure variation along a pipeline

$$P_d = p_u - K(h_1 \pm \Delta Z)$$

Where,

P_d, p_u = Pressure at downstream and upstream positions, Kpa

h_1= Energy loss in pipe, m

ΔZ=Elevation difference, m (+ ve for uphill)

K = 9.81

$$h_1 = FH_1 + M_1$$

Where,

F = constant; f(number of outlets and method used to estimate H_1)

H_1 = friction loss, m

M_1 = minor losses through fitting (from Tables)

For H1, Darcy- Weisbach, Hazen- Willams or Scobey Equation is used (Lecture 22)

$$H_1 = \frac{KCLQ^m}{D^{2m+n}}$$

Where,

K = friction factor that depends on pipe material (equation to calculate, in next slide)

L = Length of pipe, m

Q = Discharge , l/min

D = Diameter of pipe, mm

C, m and n= Constants

For trickle, Darcy-Weisbach Equation is preferred. The constants c, m and n

for D-W are 277778, 2.0 &1.0

for H-W 591722, 1.85 & 1.17

for Scobey 610042, 1.90 & 1.10

✓ K is given by (For D-W) $K = 0.811\left(\frac{f}{g}\right)$

Where,

f = friction factor from the moody diagram

f for small-diameter trickle tubing, is also related to the

Knowing the Reynolds number (N_R),

For N_R less than 2000 (laminar flow) $f = \frac{64}{N_R}$

For N_R between than 2000 and 100000 (turbulent flow) $f = 0.32 N_R^{-0.25}$

For N_R greater than 100000 (Fully turbulent flow) $f = 0.80 + 2\ \log\left(\frac{N_R}{\sqrt{f}}\right)$

- ✓ Losses due to barbs from online emitters or supply tubes for bubblers or microsprinklers must be included.

- ✓ (from Figure) losses as equivalent pipe lengths

- ✓ This is multiplied by the number of barbs and added to **L** in Darcy- Weisbach, Hazen- Willams or Scobey Equation; $H_1 = \frac{KCLQ^m}{D^{2m+n}}$

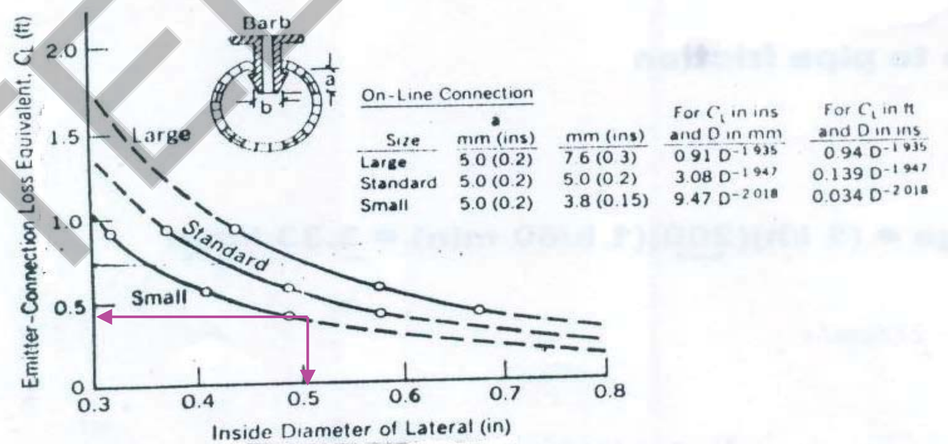


Figure Emitter-connection loss (C_L) values for various sizes of barbs and inside diameters of laterals. (From Section 15, Chapter 7 of the *SCS National Engineering Handbook*, 1984.)

Example 23.2:

Computing **head loss due to pipe friction** in a drip lateral with on-line emitters for the following data

16-mm internal diameter lateral

200 m long lateral with standard on-line emitters spaced 1 m

Design discharge of each emitter is 1 lph

Water temperature is 20°C

Solution:

Total discharge = (1 l/hr) (200) (1hr/60min) = 3.33 l/min

$$V = \frac{Q}{A} = \frac{3.33\ l/min}{\frac{\pi}{4}(16mm)^2} = 27.6 \text{ cm/sec}$$

$$N_R = \frac{\rho DV}{\mu} = 4406 \qquad (\rho = 998.2 \text{ kg/cu m}; \mu = 1.002 \text{ x}10\text{-}3 \text{ N-S/m}^2)$$

Since N_R is between 2000-10^5, use Reynolds number (turbulent flow) equation to compute f

$$f = 0.32 N_R^{-0.25} = 0.32(4406)^{-0.25}$$

$$K = 0.811\left(\frac{f}{g}\right) = 0.811\left(\frac{0.0393}{9.81}\right) = 3.25 \times 10^{-3}$$

Correcting L in Darcy- Weisbach, Hazen- Willams or Scobey Equation for barb losses

L = 200 m + (number of emission devices) C_L

from Figure C_L = 0.36 ft, = 0.11m

L = 200 + 200 (0.11) = 222 m

$$H_1 = \frac{KCLQ^m}{D^{2m+n}} = \frac{(3.25 \times 10^{-3}) \times 277778 \times 222 \times (3.33)^2}{16^{2\times 2+1}} = 2.12$$

F = 0.33 (Table value)

$$h_1 = FH_1 + M_1 = 0.33 \times 2.12 + 0 = 0.70 \text{ m}$$

Table 5.9 Values of F (in Eq. 5.17a) Used When the Distance to the First Sprinkler Equals the Sprinkler Head Spacing

Number of Outlets	$m = 1.85$	$m = 1.90$	$m = 2.00$
1	1.0	1.0	1.0
2	0.639	0.634	0.625
3	0.535	0.528	0.518
4	0.486	0.480	0.469
5	0.457	0.451	0.440
6	0.435	0.433	0.421
7	0.425	0.419	0.408
8	0.415	0.410	0.398
9	0.409	0.402	0.391
10	0.402	0.396	0.385
11	0.397	0.392	0.380
12	0.394	0.388	0.376
13	0.391	0.381	0.373
14	0.387	0.381	0.370
15	0.384	0.379	0.376
16	0.382	0.377	0.365
17	0.380	0.375	0.363
18	0.379	0.373	0.361
19	0.377	0.372	0.360
20	0.376	0.370	0.359
22	0.374	0.368	0.357
24	0.372	0.366	0.355
26	0.370	0.364	0.353
28	0.369	0.363	0.351
30	0.368	0.362	0.350
35	0.365	0.359	0.347
40	0.364	0.357	0.345
50	0.361	0.355	0.343
100	0.356	0.350	0.338
More than 100	0.351	0.345	0.333

Thank You!!

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Irrigation and Drainage

Lecture No:24 Drip Irrigation Design

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Example 24.1: Design a drip irrigation system for the following data

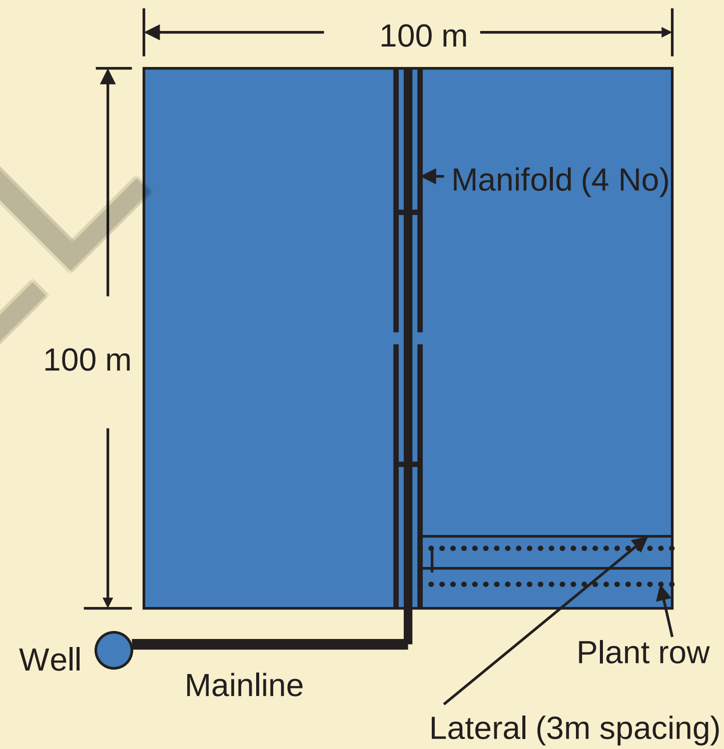
Crop	: Banana
Spacing	: 1.5 m x 1.35 m
Area	: 1 ha (100 m x100 m)
Slope	: 0.3 to 0.4%
Water Source	: Well
Static Head	: 10 m
Pan Evaporation	: 12 mm/day

Soil characteristics

- Clay soil
- Field capacity: 48%
- Wilting Point: 25%
- Bulk Density: 1.3 g/cm^3
- Effective Root Zone Depth: 60 cm

Wetted Area: 60%

Maximum Pump Discharge: 2.5 lps



Solution: Design Steps

1. **Calculation of depth of irrigation**

   $ET_{crop} = ET_0 \times K_c = E_p \times K_p \times K_c = (12) \times (0.7) \times (1.0) = 8.4$ mm/d

2. **Volume of water to be applied**

   Volume = Area × Depth

   Wetted area

   $= (1.5 \times 1.35) \times (0.6) \times (8.4) = 10.21\ m^3$

3. **Number of Emitters per plant**

   Number of Emitters per plant is to be selected (based on layout)

   Say, One emitter per plant (4 l/h Capacity)

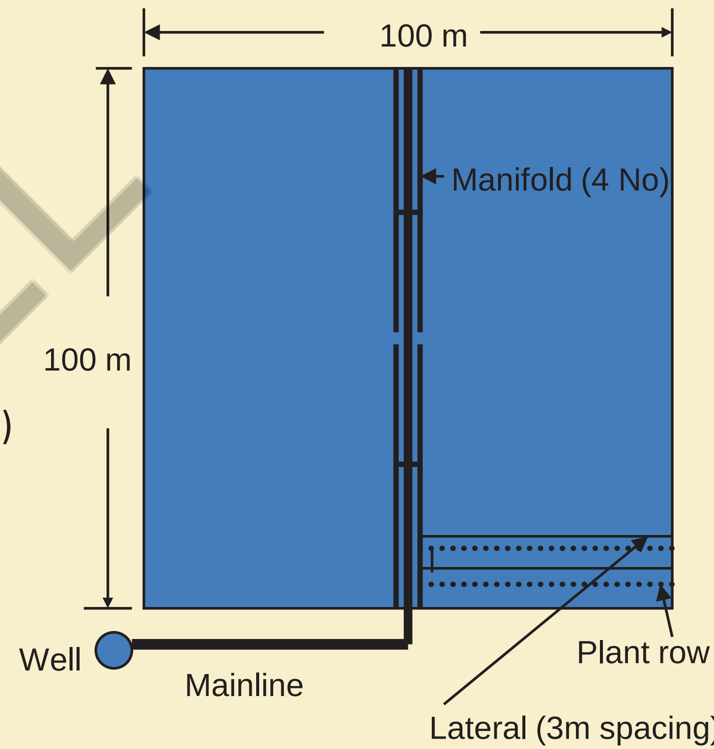
4. **Irrigation Time**

   Irrigation time =Volume/Discharge rate

   10.21/4 =2.55 h say 2.5h

5. **Number of Emitters per lateral**

   Length of field =100 m



- ✓ The submain is laid at the centre (layout), hence lateral length = 50 m

  Emitter spacing on lateral = Plant spacing =1.35 m

  Number of emitters per lateral =50/1.35=37

6. **Discharge through one lateral**

   $Q_{Lateral}$ = 37× 4 =148 l/h

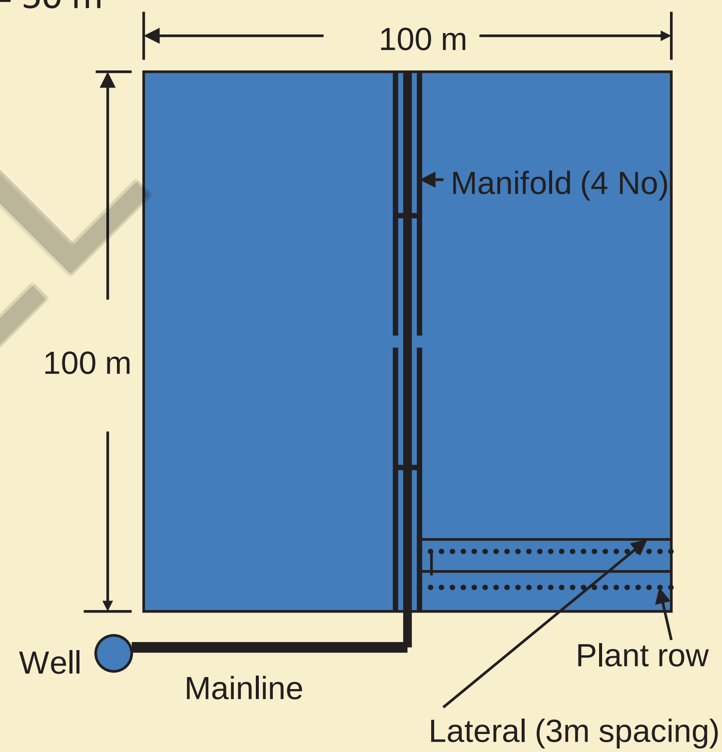
7. **Number of laterals per manifold**

   Pump Discharge = 2.5 lps = 9000 l/h

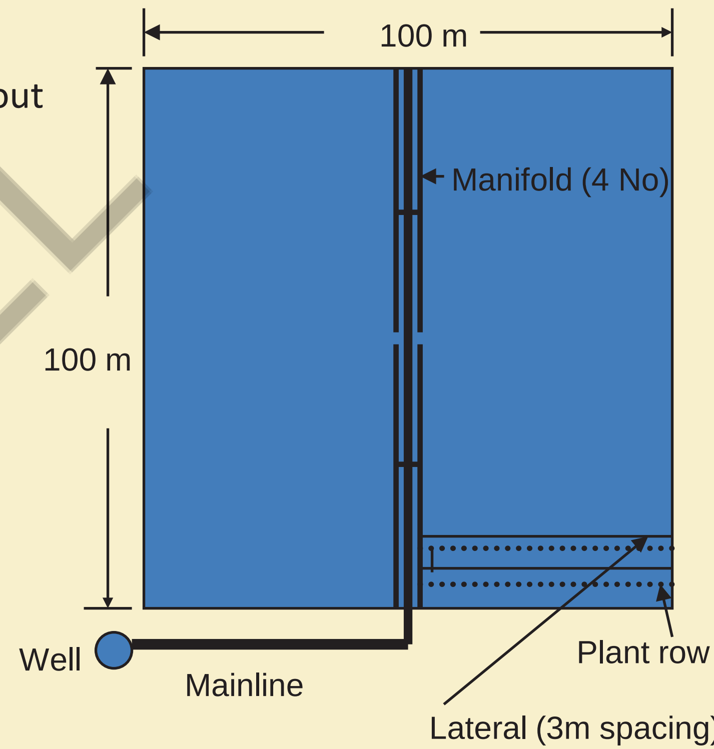
   Number of lateral that can be operated

   =9000/148 =60.81 say 61

- ✓ Breadth of the field =100 m
- ✓ Number of laterals along the breadth depend on row spacing
- ✓ Distance between two laterals = 1.5 m



- ✓ Number of laterals on one side =100/1.5 = 67
- ✓ Total number of laterals = 67×2 =133
- ✓ Number of manifolds = 133/61 = 2.2 say, 4 for uniformity in layout
- ✓ Number of Laterals per manifold = 133/4 = 33.25, say 34



8. Size of lateral

D-W eq $H_1 = \frac{KCLQ^m}{D^{2m+n}}$

Let us assume a lateral of 12 mm diameter

$V = \frac{Q}{A} = \frac{2961\ l/h}{\frac{\pi}{4}(12mm)^2} = 72.7$ cm/sec

$N_R = \frac{\rho DV}{\mu} = 8704$

Since N_R is between 2000-10^5 , use Reynolds number (turbulent flow) equation to compute f

$$f = 0.32 N_R^{-0.25} = 0.32(8704)^{-0.25} = 0.033$$

$$K = 0.811\left(\frac{f}{g}\right) = 0.811\left(\frac{0.033}{9.81}\right) = 2.73 \times 10^{-3}$$

Correcting L in Darcy- Weisbach, Hazen- Willams or Scobey Equation for barb losses

L = 50 m + (number if emission devices) C_L

C_L= 0.6 ft from figure = 0.18 m

L = 50 + 37(0.18) = 54.86 m

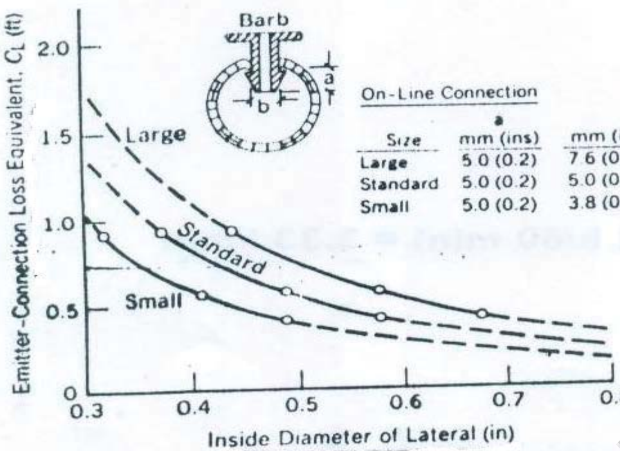
$$H_1 = \frac{KCLQ^m}{D^{2m+n}} = \frac{(2.73\times10^{-3})\times277778\times63.32\times(4.93)^2}{12^{2\times2+1}} = 4.08 \text{ m}$$

$h_1 = FH_1 + M_1 = 0.347 \times 4.08 + 0 = 1.415$ m

Too high; should be maximum 5% of static head , i.e., 0.5 m

Increase the lateral size , Let us take 16 mm lateral

$$V = \frac{Q}{A} = \frac{5032\ l/h}{\frac{\pi}{4}(50mm)^2} = 40.90\text{cm/sec} \ ; N_R = \frac{\rho DV}{\mu} = 6528$$



On-Line Connection

Size	a mm (ins)	mm (ins)	For C_L in ins and D in mm	For C_L in ft and D in ins
Large	5.0 (0.2)	7.6 (0.3)	$0.91\ D^{-1.935}$	$0.94\ D^{-1.935}$
Standard	5.0 (0.2)	5.0 (0.2)	$3.08\ D^{-1.947}$	$0.139\ D^{-1.947}$
Small	5.0 (0.2)	3.8 (0.15)	$9.47\ D^{-2.018}$	$0.034\ D^{-2.018}$

Figure Emitter-connection loss (C_L) values for various sizes of barbs and inside diameters of laterals. (From Section 15, Chapter 7 of the *SCS National Engineering Handbook*, 1984.)

Table 5.9 Values of *F* (in Eq. 5.17a) Used When the Distance to the First Sprinkler Equals the Sprinkler Head Spacing

Number of Outlets	$m = 1.85$	$m = 1.90$	$m = 2.00$
1	1.0	1.0	1.0
2	0.639	0.634	0.625
3	0.535	0.528	0.518
4	0.486	0.480	0.469
5	0.457	0.451	0.440
6	0.435	0.433	0.421
7	0.425	0.419	0.408
8	0.415	0.410	0.398
9	0.409	0.402	0.391
10	0.402	0.396	0.385
11	0.397	0.392	0.380
12	0.394	0.388	0.376
13	0.391	0.381	0.373
14	0.387	0.381	0.370
15	0.384	0.379	0.376
16	0.382	0.377	0.365
17	0.380	0.375	0.363
18	0.379	0.373	0.361
19	0.377	0.372	0.360
20	0.376	0.370	0.359
22	0.374	0.368	0.357
24	0.372	0.366	0.355
26	0.370	0.364	0.353
28	0.369	0.363	0.351
30	0.368	0.362	0.350
35	0.365	0.359	0.347
40	0.364	0.357	0.345
50	0.361	0.355	0.343
100	0.356	0.350	0.338
More than 100	0.351	0.345	0.333

Since N_R is between 2000-10^5 , use Reynolds number (turbulent flow) eqationto compute f

$$f = 0.32N_R^{-0.25} = 0.33(6528)^{-0.25} = 0.035$$

$$K = 0.811\left(\frac{f}{g}\right) = 0.811\left(\frac{0.035}{9.81}\right) = 2.94 \times 10^{-3}$$

Correcting L in Darcy- Weisbach, Hazen- Willams or Scobey Equation for barb losses

L= 50 m + (number of emission devices) C_L

C_L = 0.33 ft from figure = 0.11 m

L = 50 +37 (0.11) = 54.07 m

$$H_1 = \frac{KCLQ^m}{D^{2m+n}} = \frac{(2.73\times10^{-3})\times277778\times58.14\times(4.93)^2}{12^{2\times2+1}} = 1.02 \text{ m}$$

$h_1 = FH_1 + M_1 = 0.338 \times 1.02 + 0 = \mathbf{0.35m}$ (<0.5 m)

Acceptable from Table for 37 outlets, Thus, Lateral Size = 16 mm

9. Size of Manifold

$Q_{manifold} = Q_{lateral} \times$ No. of lateral per manifold

= 148 × 34 = 5032 l/hr

Manifold design is similar to lateral design

Assume Manifold Diameter = 50 mm

$$V = \frac{Q}{A} = \frac{5032\ l/h}{\frac{\pi}{4}(50mm)^2} = 71.18 \text{ cm/sec}$$

$$N_R = \frac{\rho D V}{\mu} = 35502$$

N_R is between 2000-10^5, use Reynolds number (turbulent flow) equation to compute f

$$f = 0.32 N_R^{-0.25} = 0.32(35502)^{-0.25} = 0.023$$

$$K = 0.811\left(\frac{f}{g}\right) = 0.811\left(\frac{0.023}{9.81}\right) = 1.92 \times 10^{-3}$$

L = 50 m

$$H_1 = \frac{KCLQ^m}{D^{2m+n}} = \frac{(1.92\times10^{-3})\times277778\times50\times(83.86)^2}{50^{2\times2+1}} = 0.06\text{m}$$

$$h_1 = FH_1 + M_1 = 0.347 \times 0.06 + 0 = 0.22\text{m}$$

Head loss in manifold = **0.21 m**

For 34 outlets

Head at inlet of manifold = $H_{emitter} + H_{lateral} + H_{slope} + H_{manifold}$

= 10 + 0.35 + 0.18 + 0.21 0.35% of 50 = 0.18

= 10.74 m

10. Size of main

Length of main = 100 m F (well location)

$Q_{main} = Q_{manifold}$ = 5032 l/hr = 1.4*10^{-3} m^3/sec

Assume main diameter = 50 mm

$$V = \frac{Q}{A} = \frac{5032\ l/h}{\frac{\pi}{4}(50mm)^2} = 71.18 \text{ cm/sec}$$

$$N_R = \frac{\rho DV}{\mu} = 35502$$

Since N_R is between 2000-10^5 use Reynolds number (turbulent flow) equationto compute f (f = 0.023)

$$H_1 = \frac{KCLQ^m}{D^{2m+n}} = \frac{(1.92\times10^{-3})\times277778\times150\times(83.86)^2}{50^{2\times2+1}} = 1.815\text{m}$$

$$h_1 = FH_1 + M_1 = \underbrace{0.469}_{\text{4 outlets}} \times 1.21 + 0 = 0.851 \text{ m}$$

11. Total Head

Total Head = Head $_{manifold\ inlet}$ + H_{main}+ H_{static}+ H_{local}

= 10.74+0.851+10+2.16

= 23.75 m

($H_{local}$is continued as 10% of all other heads)

12. Pump Horse Power

$$h.p. = \frac{\gamma \times h \times Q}{75 \times \eta}$$

$$= \frac{1000 \times 23.75 \times (1.4 \times 10^{-3})}{75 \times 0.70}$$

$$= \ 0.63{\sim}1\ hp$$

- ✓ Discharge capacity of an Emission Device

$$C = \frac{K D_a A_i}{(H - T_m) E_a}$$

Where,

C = Emission device Capacity (l/hr)

D_a = Depth of water applied (mm)

A_i= Area irrigated by the emission device (m^2)

H = Hours of irrigation (i.e. time used to apply D_a)

T_m= Off time for maintenance, soil aeration, etc.

E_a = Application Efficiency (%)

K = unit constant =100

Thank You!!

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IIT KHARAGPUR

NPTEL ONLINE CERTIFICATION COURSES

NPTEL

Irrigation and Drainage

Lecture No: 25 Tutorial: W5

Dr. DAMODHARA RAO MAILAPALLI

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Exercise W5.1

In a sprinkler irrigation system, the lateral spacing along the mainline is 20 m and sprinkler spacing along laterals is 15 m. The application rate for fulfilling the peak demand of the proposed crop should be 8 mm/d. Find the discharge rate per sprinkler.

Solution

We know application rate, $I(\text{mm/h}) = \dfrac{3600 \times q_s(\text{l/s})}{S_m(m) \times S_l(m)}$ Or, $q_s = \dfrac{I \times S_m \times S_l}{3600}$

Given, I = 8 mm/d

Assuming that the sprinkler will operate 12 h a day,

I = 8mm/12h = 0.667 mm/h, and S_m = 20 m; S_l = 15 m

Putting the values, q_s = 0.055 l/s; Or, 200 l/h (Ans.)

Exercise W5.2

In a sprinkler irrigation system, the required total capacity of the system is 0.5 m^3/s. Determine the pump capacity. Assume that head loss in pipe and bends and velocity head required = 3 m of water.

Solution:

Pump capacity, $P = (Q \times 9.81 \times H)$ [KW]

Here $Q = 0.5$ m^3/s

Total head = 3 m

Putting the values, $P = 0.5 \times 9.81 \times 3 = 14.7$ KW (Ans.)

Exercise W5.3

A solid set permanent micro-irrigation system is installed in a vegetable field of 1 ha area. The spacing between the micro sprinklers is 2.5 m and spacing between laterals is 5 m. The peak evapotranspiration rate is 10 mm/day. The application efficiency is 80%. Irrigation system operates 5 hours in a day. The total operating head of the pump is 30 m. At 65% pump efficiency, the horse power of the pump is _______________ **(GATE 2016)**

Solution:

Given,

Area=1 ha

Evapotranspiration rate = 10 mm/day

Application efficiency = 80%.

Total operating head of the pump = 30 m

Pump efficiency = 65%

ET= 10 mm=0.01 m

$$Volume = Area \times ET = 10000 \times 0.01 = 100 \text{ m}^3$$

$$Actual\ volume = \frac{Volume}{\text{Application efficiency}} = \frac{100}{0.8} = 125 \text{ m}^3$$

$$Q = \frac{Actual\ volume}{Time}$$

$$Q = \frac{125}{5 \times 60 \times 60} = 0.00694 \text{ m}^3/\text{sec}$$

$$hp = \frac{Q \times H \times \rho}{75 \times \eta}$$

$$hp = \frac{0.00694 \times 30 \times 1000}{75 \times 0.65}$$

$$= \mathbf{4.27hp\ (Ans.)}$$

Exercise W5.4

Several identical sprinkler nozzles, each having discharge *Q* (litre per minute), are spaced in a grid of size *L* (metre) × *S* (metre). The application rate in mm/h is ________ **(GATE 2014)**

Solution:

As we know that, $Q = L \times S \times I$

$$I = \frac{Q\ (L/min)}{L(m) \times S(m)}$$

$$I = \frac{0.001 \times 60\ Q\ (\frac{m^3}{h})}{L(m) \times S(m)}$$

$$\boldsymbol{I = \frac{60\ Q\ (\frac{mm^3}{h})}{L(mm) \times S(mm)}}$$ **mm/h (Ans.)**

Exercise W5.5

A sprinkler system consists of two 192 m long laterals. On each lateral, 16 sprinklers are located at an interval of 12 m. The spacing between the laterals is 10 m. The required capacity (in l/s) of the sprinkler system for an application rate of 1 cm/h is **(GATE 2007)**

Solution:

Spacing between the laterals = 10 m

Application rate (I)= 1 cm/h

Spacing of sprinkler along the lateral (S_l)= 12

Spacing of lateral along the main (S_m)= 10

$$q = \frac{S_l \times S_m \times I}{360}$$

$$q = \frac{S_l \times S_m \times I}{360}$$

$$q = \frac{12 \times 10 \times 1}{360} = 0.333 \text{ l/s/sprinkler}$$

$$System\ capacity = total\ discharge\ of\ all\ sprinkler$$

$$= 0.333 \times 32$$

$$= \mathbf{10.56\ l/s\ (Ans.)}$$

Example W5.6

Calculate the flow rate for the following emitters (laminar, turbulent, and pressure compensating) at 50 and 100 kPa pressure (coefficient k for units of LPH and kPa).

k = 0.02 and x = 1 laminar

k = 0.2 and x = 0.5 turbulent or orifice

k = 2 and x = 0 pressure compensating

X=1	X=0.5	X=0
$q=0.02\ (50)^{1} = 1$LPH	$q=0.\ 2\ (50)^{0.5} = 1.4$ LPH	$q = 2\ (50)^{0} = 2$LPH
$q=0.02\ (100)^{1} = 2$LPH	$q=0.\ 2\ (100)^{0.5} = 2$ LPH	$q= 2\ (100)^{0} = 2$LPH

Exercise W5.1

The discharge from a sprinkler nozzle depends on

a) Operating pressure and nozzle geometry.

b) Operating pressure and distribution pattern.

c) Application rate and nozzle angle.

d) Operating pressure and application rate.

(GATE 2018)

Solution:

a) Operating pressure and nozzle geometry (Ans.)

Thank You!!