Chapter 3

Field Irrigation Systems

3-1 Basin Irrigation System:

It is called also “one crop system” or “one irrigation system”, where the land is irrigated only one time for cultivating only one crop per the year. The land receives a depth of water that has to be enough for the growth of the plant.

There are two sources of the water applied to the land as follows:

1) Seasonal Rainfall:
This irrigation system is suitable only for zones of sufficient rainfall.

2) Seasonal Flood of a River:
This irrigation system is not suitable for all rivers.

- For the Nile River, the flood occurs in the summer and the cultivated crop will grow during the winter. Thus, the consumptive use is small due to the small losses of both evaporation and transpiration. So, the water supplied for irrigation will be sufficient for the crop’s growth.

- For the Degla and Forat Rivers, the flood occurs in the spring and the cultivated crop will grow during the summer. Thus, the consumptive use is large due to the large losses of both evaporation and transpiration. So, the water supplied for irrigation will be not sufficient for the crop’s growth.

However, the advantages of the basin irrigation system are:

1) The level of the water table will not increase because the water is provided to the land only once in the year.

2) For the case of a river, this river acts as a natural drain when its water level decreased after the flood.

3-2 Peremnial Irrigation System:

The land is irrigated frequently all the year and many crops can be cultivated. Irrigation water is supplied with certain amounts according to the kind of the crop, the type of the soil and the climate conditions. Also, the irrigation water is provided to the land each intervals of time according to the requirements.

This irrigation system necessitates that the water is available all the year; so, storage processes may be needed. Storing water may be either annual storage or long term storage.

Due to the frequent irrigation, the ground water increases and the water table rises. Thus, drainage networks have to be established in order to reduce the water table and achieve the air-water balance in the root zone of the plants.

In general, the peremnial irrigation system requires the following three conditions:

1) Increasing the water levels in chosen locations along the river. This can be done by either barrages (regulators) or pump stations.

2) Storing water for usage when the discharge of the river is not sufficient.

3) Establishing irrigation and drainage networks.

There are many types for the peremnial irrigation systems as follows:

(1) Flooding (Surface) Irrigation Systems:

The flooding irrigation is to cover the land with a suitable depth of water each irrigation interval. The depth of water is calculated according to the field irrigation requirements, as discussed previously in chapter 1 (item 1-7).

- <u>The common types of the flooding irrigation systems can be summarized as follows:</u>

a) Furrow Irrigation System:

This type of flooding irrigation system is the common irrigation system used in Egypt especially for the old lands. Private mesqas are made to transport irrigation water from the distributary canals to the field. The cultivated land is divided into basins by small banks, as shown in figure (3-1). Banks of basins A are removed till the basins A are filled with the water (to the required depth). Then, the banks of basins B are removed to provide the irrigation water to the basins B with the required depth.

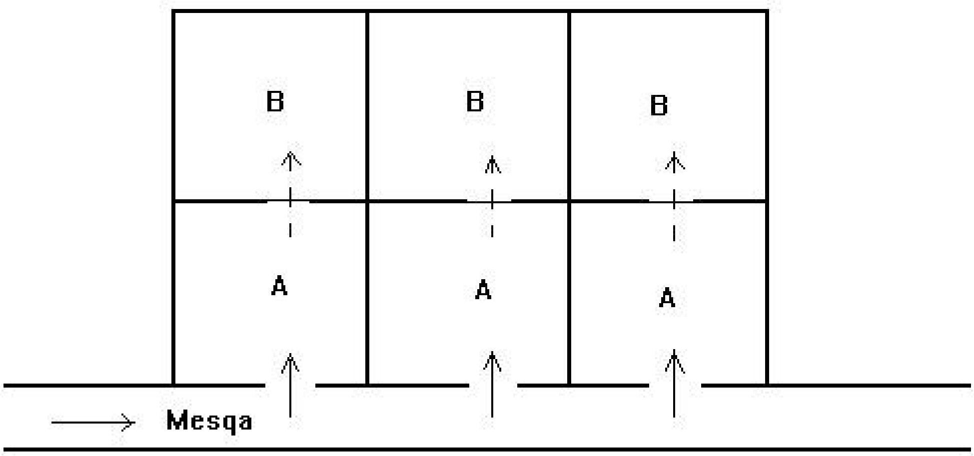


Figure (3-1): Furrow Irrigation System.

b) Border Strip Flooding Irrigation System:

The land is divided into strips, as shown in figure (3-2). Each strip has a width of 10 - 20 m. and a length of 100 - 400 m.

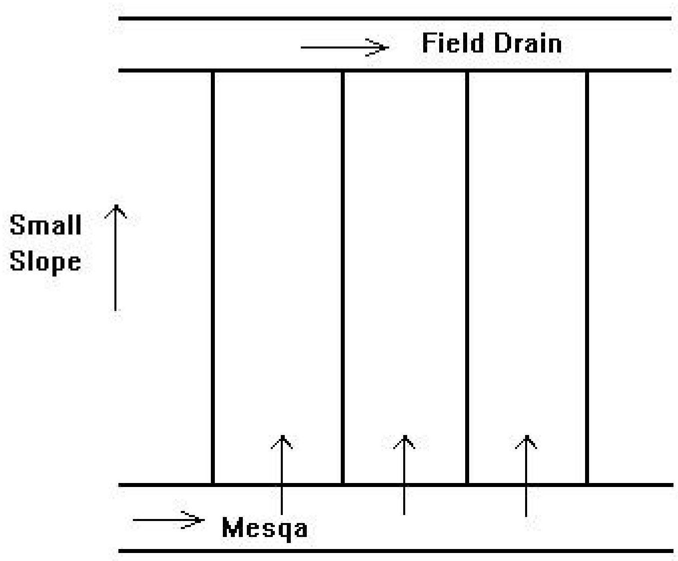


Figure (3-2): Border Strip Flooding Irrigation System.

(2) Pressurized Irrigation Systems:

For these types of irrigation systems, the irrigation water is pressed into pipes.

♦ <u>The common types of the pressurized irrigation systems can be summarized as follows:</u>

a) Sub-surface Irrigation System:

Irrigation water is pressed into plastic pipes that are laid under the ground surface, as shown in figure (3-3). Water reaches to the roots of the plants through small holes in the burried pipes. The advantage of this irrigation system is that the losses are minimized (no evaporation). While the disadvantage of this irrigation system is the required high cost.

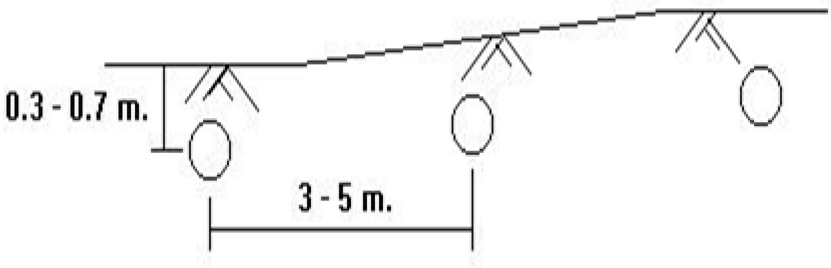


Figure (3-3): Sub-Surface Irrigation System.

b) Drip Irrigation System:

The drip irrigation system, as shown in figure (3-4), is composed of a system head (pump, fertilizer injector and filter) and a distribution network (pipes, emitters and valves). Irrigation water reaches the soil through an emitter (or a dripper), which causes drop in the pressure so that a small flow of water is discharged, as shown in figure (3-5).

Many crops can grow using the drip irrigation system such as trees, vines, vegetables and flowers.

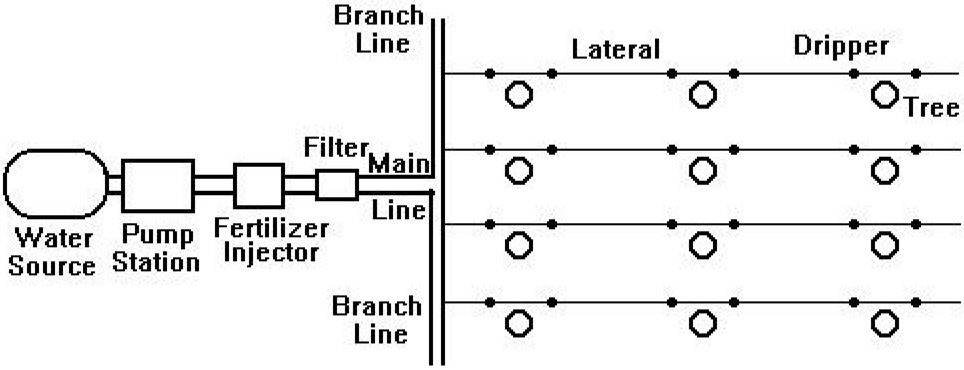


Figure (3-4): Drip Irrigation System.

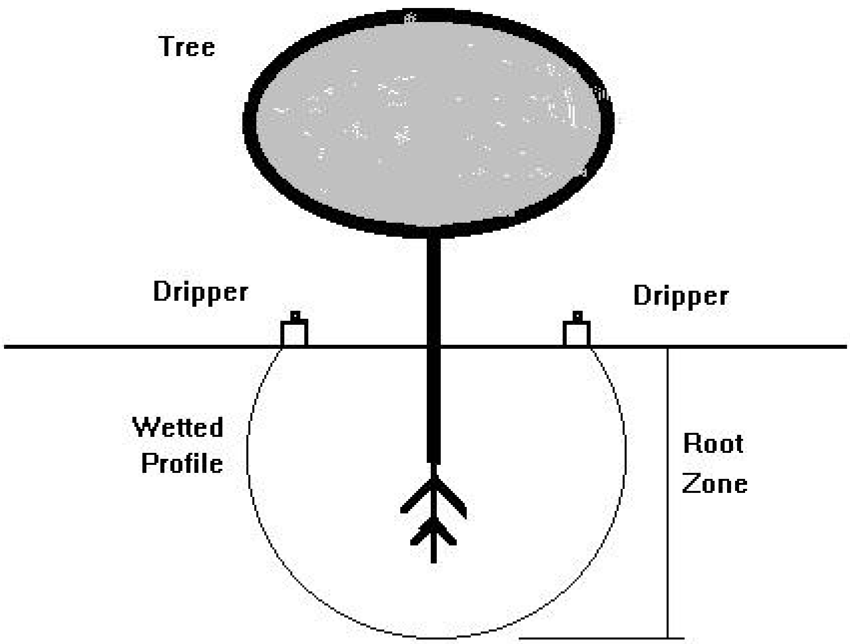


Figure (3-5): Wetted Profile for the Drippers.

There are two types of emitters:

1) Standard emitter: It emits water as a small stream or drip that contacts the ground surface immediately below the emitter.

2) Aerosol emitter: It sprays water through the air for some distance before it contacts the ground surface.

Advantages of the drip irrigation system:

1. Irrigation efficiency is very high (about 85 %). That is because water is given only to the root zone of the soil, where no losses can occur due to seepage or evaporation. Also, the required moisture content is maintained achieving a good air-water balance in the root zone, thus the yield of the crops increases.

2. Water saving.

3. Labor saving.

4. Land saving.

5. Optimum use of fertilizers.

6. Early maturation for some crops such as tomato.

7. Low operation pressure is required.

Disadvantages of the drip irrigation system:

1. High cost compared with the surface or the portable sprinkler irrigation systems.

2. Sensitivity for clogging due to the small opening of the emitter, so filters have to be used increasing the cost.

3. Not all crops can grow using the drip irrigation system.

c) Sprinkler Irrigation System:

The sprinkler irrigation system is composed mainly of the pump and the distribution network, as shown in figure (3-6). Irrigation water is applied to the land through the sprinkler, which sprays the water forming a wetted area around each sprinkler, as illustrated in figure (3-7). However, the sprinkler irrigation system is going to be discussed in detail in the item 3-5.

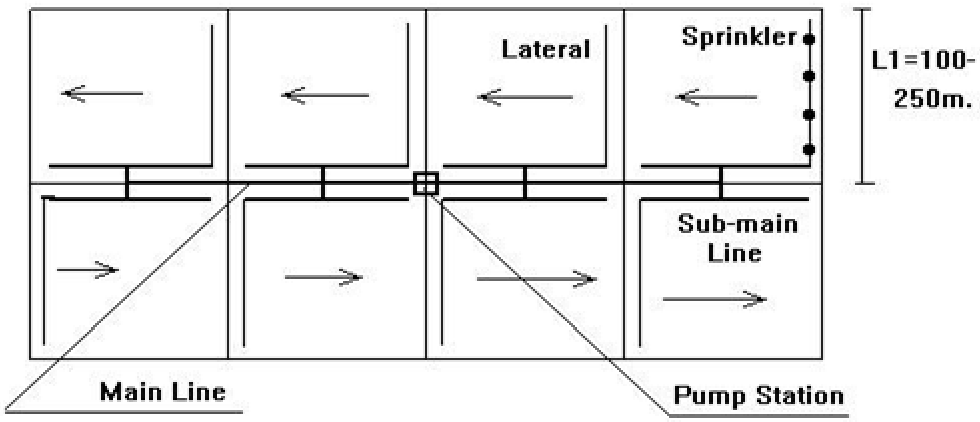


Figure (3-6): Sprinkler Irrigation System.

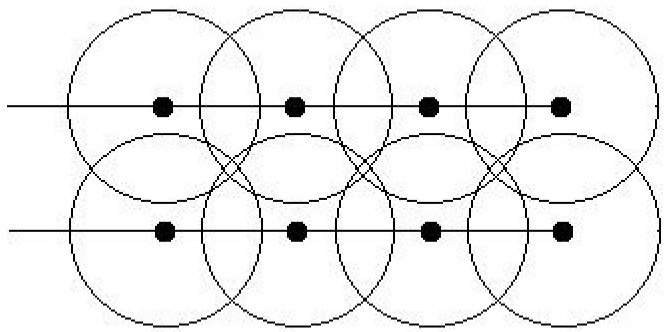


Figure (3-7): Wetted Area for the Sprinklers.

3-3 Combined Irrigation Systems:

In some cases, the land is covered by the flood water of a river in the summer and then is cultivated by a winter crop. For cultivating the land in the other seasons, the ground water is used for irrigation through wells. These wells are not operated during the flood time, while they supply the water for the irrigation network during the other times. Thus, the wells have two functions: (1) irrigating the land in the required seasons & (2) draining the land (vertically) together with the river that acts as a natural drain when its water level is decreased.

3-4 Irrigation Efficiency:

Example (3-1):

A canal with a discharge of 4100 lit./sec. irrigates a field by covering it by 135000 m^3 of water. The irrigation time is 12 hours. It is found that 14500 m^3 of water is lost by seepage to the ground water. Also, the existing drain receives 0.8 m^3/sec. of water from the canal.

♦ **It is required to:**

1) Calculate the conveyance efficiency of the canal?

2) Determine the irrigation efficiency?

The Solution:

1) The discharge entering the field = $\frac{135000}{12 \times 60 \times 60} = 3.12\ m^3/sec$

∴ The conveyance efficiency = $\frac{3.12}{4100/1000} \times 100 = 76\ \%$

2) Volume of the drained water = 0.8 x 60 x 60 x 12 = 34560 m^3

Volume of water used for plant growth = 135000 - 34560 - 14500
= 85940 m^3

$\therefore$ Irrigation efficiency = $\frac{85940}{135000} \times 100 = 64\ \%$

Example (3-2):

An irrigation network has a conveyance efficiency of 78 %, delivers its area served 3.2 m^3/sec. of irrigation water, and escapes 500 lit./sec. to the drains. It is found that 2100 lit./sec. of the irrigation water is stored in the root zone of the soil.

♦ **It is required to:**

1) Find the rate of irrigation water that should be supplied to the irrigation network?

2) Determine the irrigation efficiency?

3) Calculate the rate of irrigation water lost by seepage to the ground water?

The Solution:

1) The rate of irrigation water that should be supplied to the irrigation network = $\frac{3.2}{0.78} = 4.1\ m^3/sec$

2) The irrigation efficiency = $\frac{2100 / 1000}{3.2} \times 100 = 66\ \%$

3) The rate of irrigation water lost by seepage to the ground water

$$= 3.2 - \frac{2100}{1000} - \frac{500}{1000} = 0.6\ m^3/sec$$

3-5 Sprinkler Irrigation System:

The sprinkler irrigation system is a pressurized irrigation system. Water is supplied to the land in the form of spray from the sprinklers. Each sprinkler is connected to a vertical pipe (a riser) that has to be higher than the plant by 25-30 cm. The sprinklers take the irrigation water from pipes called “sprinkler (or flying) lines”. These sprinkler lines take the water either from the pump directly or from other buried pipes called “sub-main and main lines” that are connected to the pump according to the type of the sprinkler irrigation system.

Advantages of the sprinkler irrigation system are:

1. High irrigation efficiency, where the losses due to seepage and evaporation are minimized.
2. Water saving.
3. Labor saving.
4. Land saving.
5. Optimum use of fertilizers.
6. Increasing the crop yield for many crops.

Disadvantages of the sprinkler irrigation system are:

1. High cost compared with the surface irrigation system.
2. Sensitivity for the wind velocity.

The main types of the sprinkler irrigation system are:

1. Portable sprinkler irrigation system:

The pump and the sprinkler line are connected to each other, where they are moved each irrigation interval along the irrigation canal. The irrigation canal is preferred to be lined. This system can be used for small area served.

2. Semi-fixed sprinkler irrigation system:

The pump feeds a main line that consequently feeds sub-main lines. Both the sub-main and the main lines are fixed and buried under the ground surface. The sprinkler line is movable and takes the water from the sub-main lines.

3. Fixed sprinkler irrigation system:

All the lines (pipes) are fixed including the sprinkler line. This system requires high cost for construction but it needs minimum labor.

4. Moving sprinkler irrigation system:

The sprinkler line only moves on wheels or circularly (pivot irrigation).

General Remarks:

1) From the basic given data, the maximum period between irrigation processes are calculated.

2) Each sprinkler covers a wetted area around it with a diameter "D".

3) Interference between the wetted areas of the sprinklers is a must in order to cover all the area served. The interference ratio depends on the wind velocity and direction. There are two interference ratios: an interference ratio for the sprinklers on the sprinkler line & and another interference ratio for the sprinkler lines.

4) **a_1 = (1 - Interference Ratio) x D**

Where, a_1 : The spacing between the sprinklers on the sprinkler line.
Interference ratio for the sprinklers on the sprinkler line.
D: The diameter of the wetted area of the sprinkler.

5) **a_2 = (1 - Interference Ratio) x D**

Where, a_2 : The spacing between the sprinkler lines.
Interference ratio for the sprinkler lines.
D: The diameter of the wetted area of the sprinkler.

6) Each sprinkler line serves a strip of a width “a_2” in each one irrigation interval.

7) Each sprinkler line serves a piece of land of an area “L_1 x L_2”.

Where, L_1 = The length of the sprinkler line (100 - 250 m).
L_2 = a_2 x No. of irrigation processes each day x Period between irrigation processes.

8) **Number of sprinklers on the sprinkler line = L_1 / a_1**

9) The sprinkler line has to be put in a perpendicular direction to the wind direction.

10) For the semi-fixed sprinkler irrigation system, the area served is divided into pieces.

Area served of each piece = L_1 x L_2

No. of pieces = Total area served / (L_1 x L_2)

It has to be noted that it is preferred that the number of pieces are symmetrical with respect to the pump location for economic purposes, as shown in figure (3-8).

11) **Design of the sprinkler:**

♦ ***The discharge (q_{sp}):***

$$AR_d = \frac{1000}{a_1 \times a_2} \times q_{sp}$$

Where, AR_d = Application rate for design (mm/hour).
q_{sp} = Discharge of the sprinkler (m^3/hour).
a_1 = Spacing between the sprinklers on the sprinkler line (m).
a_2 = Spacing between the sprinkler lines (m).

♦ ***The diameter of the nozzle (d_{sp}):***

$$q_{sp} = C_d \; a_{sp} \; (2 \, g \; h_{sp})^{1/2}$$

Where, C_d = Discharge coefficient (0.85 - 0.95).
a_{sp} = Cross sectional area of the nozzle (m^2).
h_{sp} = Head of the sprinkler (m).
(1 atm = 10.3 t/m^2 = 14.7 lb/in^2) & P = γ x h

12) **Design of the pipe lines:**

It has to be noted that the design is executed in an ascending order. That is to design first the sprinkler line, then the sub-main line, and finally the main line.

Assume the velocity (1 - 2.5 m/sec).

A = Q / v

Calculate the diameter (d).

It has to be noted that the diameters of all pipes have to be 1", 1.5", 2", 3", ... etc.

Get the actual diameter (d_{act}) and the actual velocity (v_{act}).

Determine the head losses due to the friction in the pipe (h_f):

$$\mathbf{h_f = \frac{4\,f\,l\,v^2}{2\,g\,d}}$$

For the sprinkler line, the discharge is decreased along the pipe line. Thus:

$$\mathbf{h_f = \frac{4\,f\,l\,v^2}{2\,g\,d}\,K}$$

Where, K : constant. Take K = 0.4

13) **Design of the pump:**

- ***The discharge:***

Q_p = Discharge of the sprinkler line x Number of pieces

Where one sprinkler line serves one piece.

- ***The head:***

$$\mathbf{H_P = h_{sp} + \sum h_f + X \pm Z}$$

Where, h_{sp} : The head of the sprinkler.

$\sum h_f$: Sum of all friction losses in all pipe lines.
X : Head of suction.
Z : Position head according to the topography of the ground.

- ***The power of the pump (HP):***

$$\mathbf{P_P = \gamma \; Q_P H_P \; / \; 75 \; \eta_P}$$

- ***The power of the motor (KW):***

$$\mathbf{P_m = P_P \; / \; 1.36 \; \eta_m}$$

<u>Example (3-3):</u>

A portable sprinkler irrigation system is used to serve a horizontal cultivated area along a lined mesqa. The sprinkler line has a length of 120 m. The wetted area of each sprinkler has a diameter of 30 m. and the interference ratios are 60 % for the sprinklers on the sprinkler line and 40 % for the sprinkler lines. The sprinkler is operated at a pressure of 2.5 atm. The maximum daily water requirement for the cultivated crop is 28 m^3/fed/day. There are two irrigation processes daily with maximum 8 hours for each irrigation process. The application rate for design is 5.5 mm./hour. The friction coefficient for the used pipes is 0.005 and the suction head of the pump is 3 m.

It is required to:

(1) Calculate the area served by the portable sprinkler irrigation system ?

(2) Draw a sketch for the layout of the alignment of the portable sprinkler irrigation system showing in detail the following:
a. Executing the irrigation process ?
b. The dimensions ?

(3) Design all components of the portable sprinkler irrigation system ?

The Solution

(1) $a_1 = (1 - 0.6) \times 30 = 12$ m.

$a_2 = (1 - 0.4) \times 30 = 18$ m.

The equivalent depth for the daily water requirements $= \frac{28 \times 1000}{4200} = 6.67 \frac{mm.}{day}$

The equivalent depth for the applied irrigation water $= 5.5 \times 8 = 44$ mm.

Maximum period between irrigation processes $= \frac{44}{6.67} = 6.6 \approx 6$ days

For the sprinkler line:

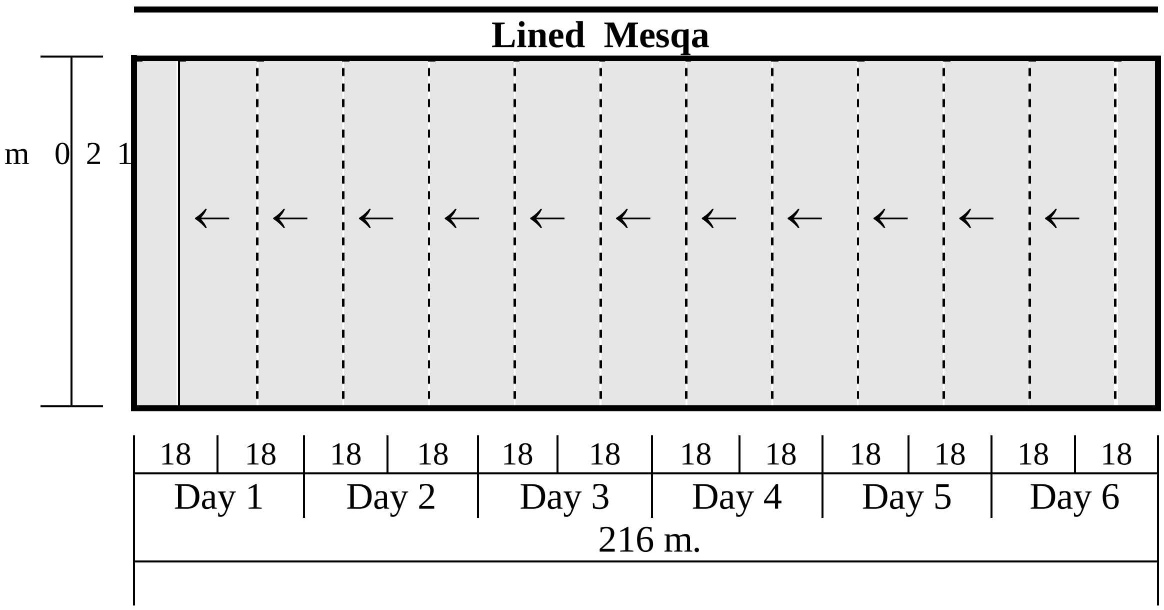
Width of the strip served in one irrigation process = 18 m.

Width of the strip served in one day = 18 x 2 = 36 m.

Width of the strip served in the irrigation interval = 36 x 6 = 216 m.

∴ The area served by the sprinkler irrigation system $= \frac{216 \times 120}{4200} = 6.17$ Fed.

(2) <u>The layout of the alignment of the portable sprinkler irrigation system:</u>



(3) <u>Design of all components of the portable sprinkler irrigation system:</u>

1. Design of the sprinkler nozzle:

$$AR_d = \frac{1000}{a_1 \times a_2} \times q_{sp}$$

$$5.5 = \frac{1000}{12 \times 18} \times q_{sp}$$

$$\therefore q_{sp} = 1.188 \ m^3/hr.$$

$$q_{sp} = C_d \ a_{sp} \ (2 \ g \ h_{sp})^{1/2}$$

$$h = 2.5 \times (10.3 / 1) = 25.75 \ m.$$

Assume $C_d = 0.9$

$$\frac{1.188}{60 \times 60} = 0.9 \times \frac{\pi d^2}{4} \times (2 \times 9.81 \times 25.75)^{1/2}$$

$$\therefore d = 0.0046 \ m.$$

Take d = 5 mm.

2. Design of the sprinkler line:

No. of sprinklers on the sprinkler line = $\frac{120}{12}$ = 10 Sprinklers

$$Q = (10 \times 1.188) / (60 \times 60) = 0.0033 \ m^3/sec.$$

Assume v = 2 m./sec.

$$\therefore A = \frac{\pi d^2}{4} = 0.0033 / 2$$

$\therefore d = 0.046$ m. (1.84 ")

Take $d_{act} = 0.05$ m. (2")

$$\therefore v_{act} = \frac{0.0033 \times 4}{\pi \times (0.05)^2} = 1.68 \text{ m./sec.}$$

$$\therefore h_f = \frac{4 f l v^2}{2 g d} \times K = \frac{4 \times 0.005 \times 120 \times (1.68)^2}{2 \times 9.81 \times 0.05} \times 0.4 = 2.76 \text{ m.}$$

3. Design of the pump:

$Q_P = 0.0033$ m/sec.

$H_P = h_{sp} + \sum h_f + X \pm Z$

$H_P = 25.75 + 3 + 2.76 + 0 = 31.51$ m.

$P_P = \gamma \; Q_P H_P \; / \; 75 \; \eta_P$

Assume the efficiency of the pump is 0.8.

$\therefore P_P = 1000 \times 0.0033 \times 31.51 / (75 \times 0.8) = 1.73$ HP

4. Design of the motor:

$P_m = P_P \; / \; 1.36 \; \eta_m$

Assume the efficiency of the motor is 0.8.

$\therefore P_m = 1.73 / (1.36 \times 0.8) = 1.6$ KW

Example (3-4):

A horizontal area of sandy soil has the dimensions of 1200 m. x 800 m. This area has a level of (16.00) m. and is to be irrigated using a semi-fixed sprinkler irrigation system. A well is located at the middle of the bigger side and has a water level of (8.00) m. The wind direction is parallel to the smaller side of the area. The maximum daily water requirement for the cultivated crop is 24 m^3/fed./day and the application rate for design is 6 mm./hour. There are two irrigation processes daily with 8 hours for each irrigation process. The diameter of the wetted area of the chosen sprinkler is 50 m. and the interference ratios are 50 % for both directions. In order to reduce the losses, one valve serve 4 locations for the sprinkler lines. The operating head for each sprinkler is 2.5 atm. and the friction coefficient for all the used pipes is 0.005.

It is required to:

(1) Draw a sketch for the layout of the alignment of the sprinkler irrigation system showing the following:

a. The pump station location ?
b. The distribution network ?
c. The valves ?
d. The operating sprinkler lines ?
e. The directions for moving the sprinkler lines ?
f. Executing the irrigation process in detail for only one piece of the land served by one sprinkler line ?
g. The dimensions ?

(2) Design all the elements of the sprinkler irrigation network, the pump and the motor ?

The Solution

(1) $a_1 = (1 - 0.5) \times 50 = 25$ m.

$a_2 = (1 - 0.5) \times 50 = 25$ m.

The equivalent depth for the daily water requirements $= \frac{24 \times 1000}{4200} = 5.7 \frac{mm.}{day}$

The equivalent depth for the applied irrigation water = 6 x 8 = 48 mm.

Maximum period between irrigation processes = $\frac{48}{5.7}$ = 8.4 ≈ 8 days

For one sprinkler line:

Width of the strip served in one irrigation process = 25 m.

Width of the strip served in one day = 25 x 2 = 50 m.

Width of the strip served in the irrigation interval = 50 x 8 = 400 m.

The wind direction is parallel to the smaller side of the area, thus:

The sprinkler line has to be perpendicular to the smaller side of the area.

∴ No. of pieces for the smaller side of the area = 800 / 400 = 2 Pieces

For the other side of the area served (length = 1200 m.), assume that the length of the sprinkler line is 200 m.

∴ No. of pieces for the bigger side of the area = 1200 / 200 = 6 Pieces

∴ Total no. of pieces for all the area served = 2 x 6 = 12 Pieces

Dimensions of each piece are 400 m. x 200 m.

∴ Area of each piece = $\frac{400 \times 200}{4200}$ = 19 Feddans

∴ The area served by the sprinkler irrigation system = 12 x 19 = 228 Fed.

"Summary of the Layout"

- The pump is located at the well at the middle of the bigger side.
- The pump feeds a main line.
- The main line feeds 3 sub-main lines.
- Each sub-main line feeds 4 sprinkler lines.
- Each sprinkler line serves a piece of land of 400 m. x 200 m. (19 Feddans).
- Total no. of pieces are 12 pieces.
- Total area served = 228 Feddans.

The layout of the alignment of the semi-fixed sprinkler irrigation system is illustrated in the figure drawn in the next page.

(2) Design of all the elements of the semi-fixed sprinkler irrigation system:

1. Design of the sprinkler nozzle:

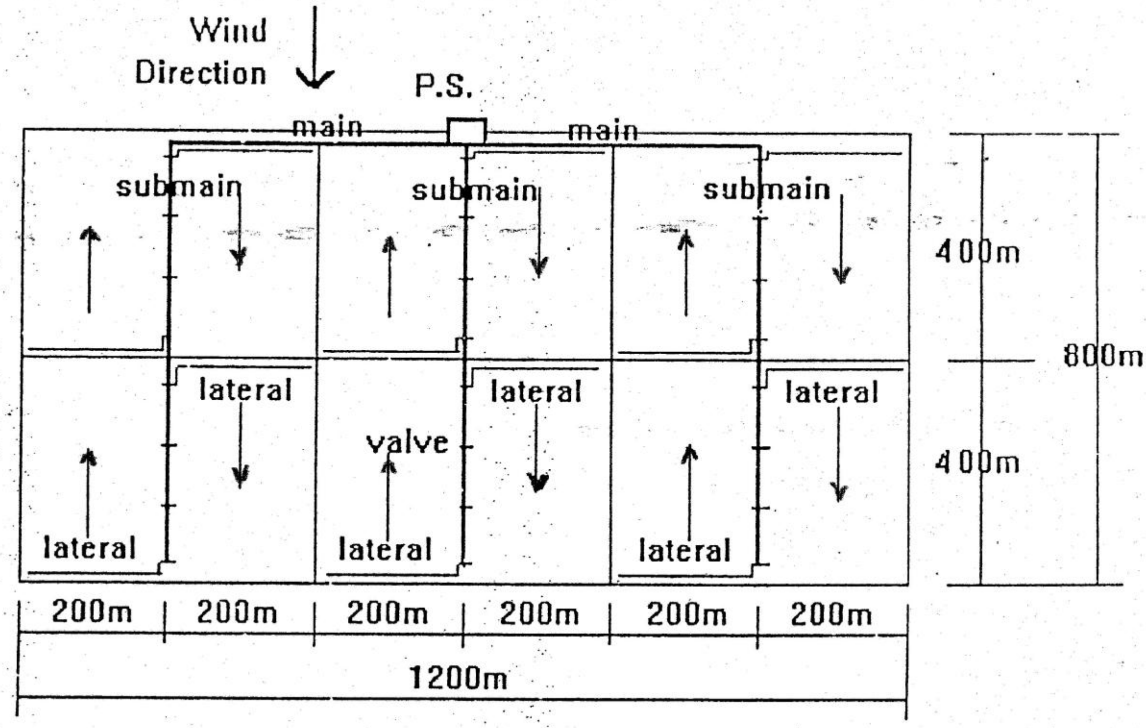
$$AR_d = \frac{1000}{a_1 \times a_2} \times q_{sp}$$

$$6 = \frac{1000}{25 \times 25} \times q_{sp}$$

$$\therefore q_{sp} = 3.75 \ m^3/hr.$$

$$q_{sp} = C_d \ a_{sp} \ (2 g \ h_{sp})^{1/2}$$

$$h = 2.5 \times (10.3 \times 1) = 25.75 \ m.$$


Wind
Direction
P.S.
main
main
submain
submain
submain
lateral
lateral
lateral
valve
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400m
400m
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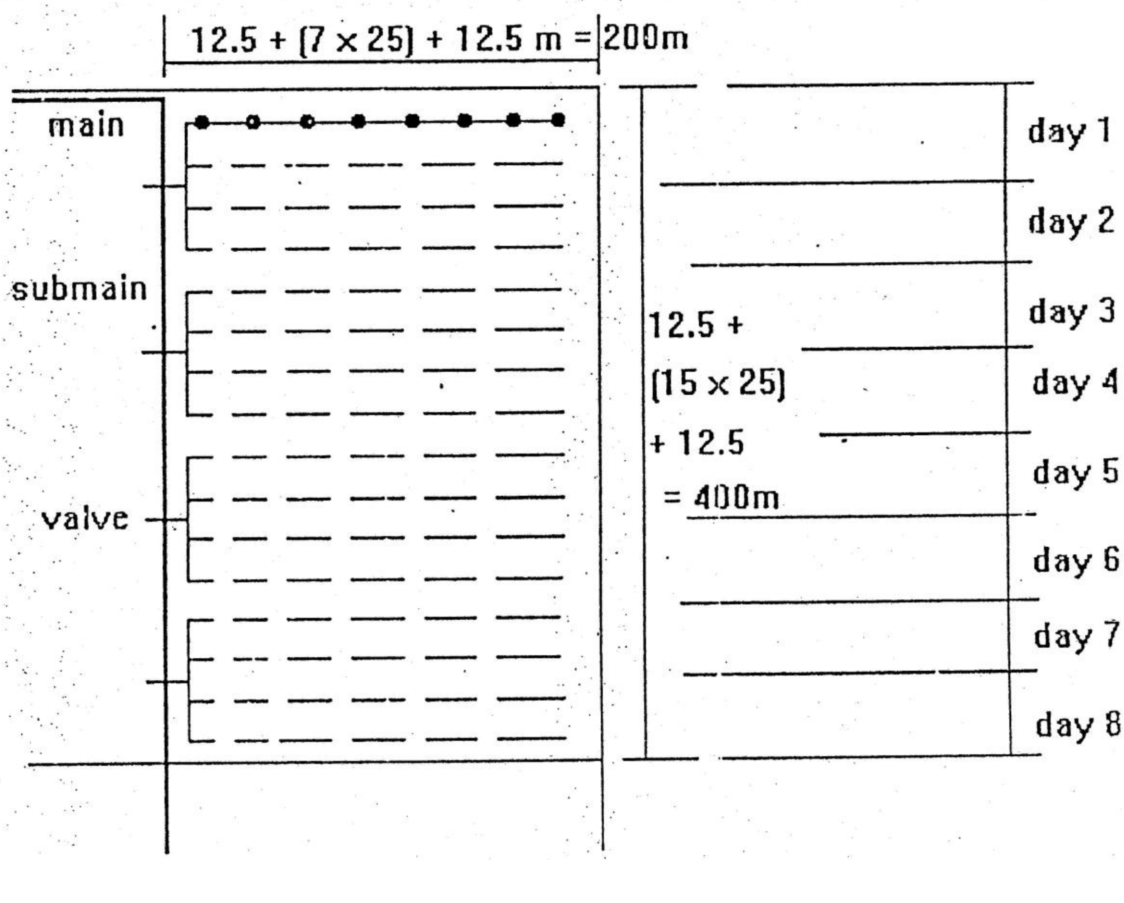
200m
200m
200m
1200m


12.5 + (7 x 25) + 12.5 m = 200m
main
submain
valve
12.5 +
(15 x 25)
+ 12.5
= 400m
day 1
day 2
day 3
day 4
day 5
day 6
day 7
day 8

Assume: $C_d = 0.9$ & The sprinkler consists of two nozzles.

$$\frac{3.75}{2 \times 60 \times 60} = 0.9 \times \frac{\pi d^2}{4} \times (2 \times 9.81 \times 25.75)^{1/2}$$

$\therefore d = 0.0057$ m.

Take d = 6 mm. for each of the two nozzles.

2. Design of the sprinkler line:

No. of sprinklers on the sprinkler line = $\frac{200}{25}$ = 8 Sprinklers

$Q = (8 \times 3.75) / (60 \times 60) = 0.0083$ m^3/sec.

Assume v = 1 m./sec.

$$\therefore A = \frac{\pi d^2}{4} = 0.0083 / 1$$

$\therefore d = 0.103$ m. (4.12 ")

Assume v = 1.5 m./sec.

$$\therefore A = \frac{\pi d^2}{4} = 0.0083 / 1.5$$

$\therefore d = 0.084$ m. (3.36 ")

Take $d_{act} = 0.075$ m. (3")

$$\therefore v_{act} = \frac{0.0083 \times 4}{\pi \times (0.075)^2} = 1.88 \text{ m./sec.}$$

$$\therefore h_f = \frac{4\ f\ l\ v^2}{2\ g\ d} \times K = \frac{4 \times 0.005 \times 187.5 \times (1.88)^2}{2 \times 9.81 \times 0.075} \times 0.4 = 3.6 \text{ m.}$$

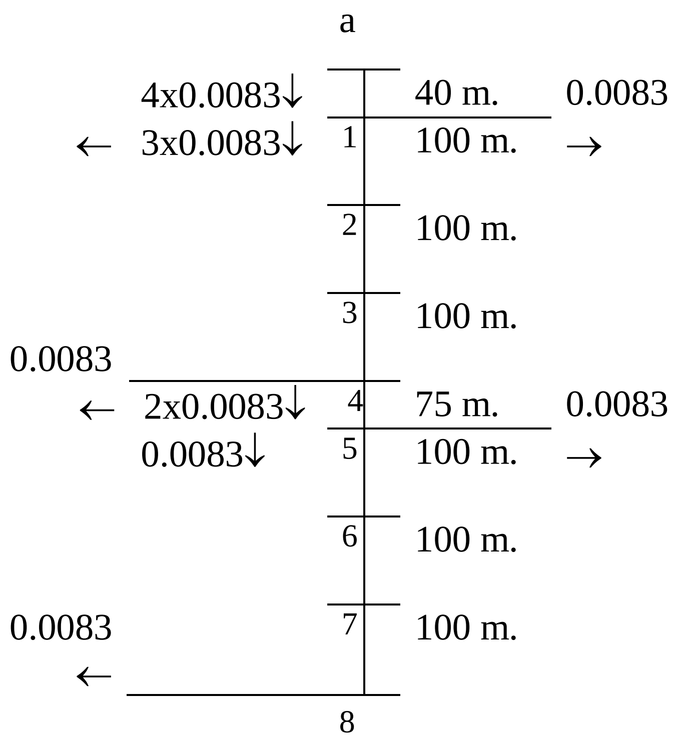
Take the pipe between the valve and the sprinkler line with the same diameter (d = 0.075 m. = 3"), thus:

$$\therefore h_f = \frac{4\ f\ l\ v^2}{2\ g\ d} = \frac{4 \times 0.005 \times 37.5 \times (1.88)^2}{2 \times 9.81 \times 0.075} = 1.8 \text{ m.}$$

The area served is horizontal, thus:

- The head at the end of the sprinkler line = h = 25.75 m.
- The head at the beginning of the sprinkler line = 25.75 + 3.6 = 29.35 m.
- The head at the end of the sub-main line = 29.35 + 1.8 = 31.15 m.

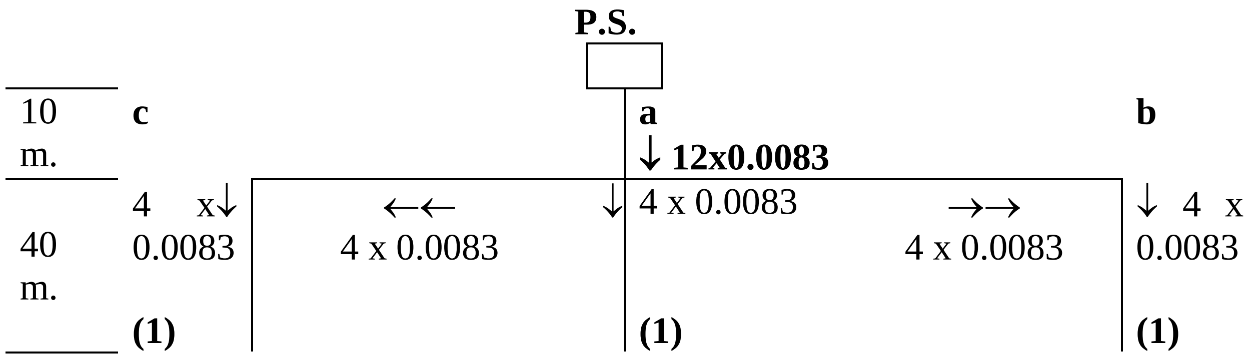
3. Design of the sub-main line:



Name	**(1) - (4)**	**(4) - (5)**	**(5) - (8)**	
l (m.)	300	75	300	
Q (m^3/sec.)	3 x 0.0083	2 x 0.0083	0.0083	
v_{ass} (m./sec.)	2			
d_{ass} (m.)	0.126 (5.04")			
d_{act} (m.)	0.125 (5")	0.125 (5")	0.100 (4")	
v_{act} (m./sec.)	2.03	1.35	1.06	
h_f (m.)	10.08	3.42	1.11	**$\sum h_f$ = 14.61**

♦ The head at beginning of sub-main line V(1) = 31.15 + 14.61 = 45.76 m

4. Design of the main line:



Assume, v = 2.5 m./sec.

A = (4 x 0.0083) / 2.5 = $\pi d^2 / 4$

d_{ass} = 0.13 m. (5.2")

Take d_{act} = 0.15 m. (6")

$\therefore v_{act} = 1.88$ m./sec.

$$\therefore h_f \{a - (1)\} = \frac{4 f l v^2}{2 g d} = \frac{4 \times 0.005 \times 440 \times (1.88)^2}{2 \times 9.81 \times 0.15} = 10.57 \text{ m.}$$

- The head at beginning of the main line (at a) = 45.76 + 10.57 = 56.33 m

5. Design of the pump:

<u>For the part between the pump and (a):</u>

$Q_P = 12 \times 0.0083$ m^3/sec.

Assume v = 2.5 m./sec.

$A = (12 \times 0.0083) / 2.5 = \pi d^2 / 4$

$d_{ass} = 0.225$ m. (9") $= d_{act}$

$$\therefore h_f = \frac{4 \times 0.005 \times 10 \times (2.5)^2}{2 \times 9.81 \times 0.225} = 0.28 \text{ m.}$$

- The head just outside the pump = 56.33 + 028 = 56.61 m.

$Q_P = 0.0996$ m^3/sec.

$H_P = (56.61 \times 1.1) + 8 = 70.3$ m.

$P_P = \gamma \ Q_P H_P \ / \ 75 \ \eta_P$

$$\therefore P_P = \frac{1000 \times 0.0996 \times 70.3}{75 \times 0.8} = 116.7 \text{ HP}$$

$P_m = P_P \ / \ 1.36 \ \eta_m$

$$\therefore P_m = \frac{116.7}{1.36 \times 0.8} = 107.3 \text{ KW}$$

3-6 Drip Irrigation System:

It is a low pressurized irrigation system (0.5 - 2.0 atm.). A small flow of water (drops) is discharged directly to the root zone with small rates depending on the water requirements of the plant and the type of soil. It is used mainly for trees and raw crops. Areas between trees are not irrigated, so the water losses due to seepage and evaporation are minimum.

The drip irrigation system, as shown before in figures (3-4) and (3-5), is composed of a system head (pump, fertilizer injector and filter) and a distribution network (pipes, drippers and valves).

There are two types of drippers:

1) Standard dripper: It emits water as a small stream that contacts the ground surface immediately below the emitter.

2) Aerosol dripper: It sprays water through the air for some distance before it contacts the ground surface.

Advantages of the drip irrigation system:

1. Irrigation efficiency is very high (about 85 %). That is because water is given only to the root zone of the soil, where no losses can occur due to seepage or evaporation. Also, the required moisture content is maintained achieving a good air-water balance in the root zone, thus the yield of the crops increases.

2. Water saving.

3. Labor saving.

4. Land saving.

5. Optimum use of fertilizers.

6. Early maturation for some crops such as tomato.

7. Low operation pressure is required.

Disadvantages of the drip irrigation system:

1. High cost compared with the surface or the portable sprinkler irrigation systems.

2. Sensitivity for clogging due to the small opening of the emitter, so filters have to be used increasing the cost.

3. Not all crops can grow using the drip irrigation system.

3-6-1 Planning the Drip Irrigation System:

The system head is established at the location of the water source. The distribution network consists of different types of pipes. The drippers are connected to pipes called laterals, laterals are connected to submain pipes, the submain lines are connected to a main pipe (or more), and the main line is connected to the pump (the system head).

a- For flat lands:

Water is prefered to be distributed symmetrically from the submain lines to the laterals.

b- For sloping lands:

The submain lines have to be as short as possible and in the slope direction. Also, the laterals have to be parallel to the contour lines as possible. However, the ideal planning has to be associated with minimum costs (the initial cost and the maintenance and operation cost).

3-6-2 Design the Drip Irrigation System:

1- The drippers:-

$$Q_t = \frac{IW_d \times S_d \times S_l}{P_i}$$

Where,
- Q_t : Total discharge at each tree (lit./hr.).
- IW_d : Required irrigation water depth in each irrigation process (mm./irrigation process).
- S_d : Spacing between drippers (m.).
- S_l : Spacing between laterals (m.).
- P_i : Period of one irrigation process (hr.).

$$N_d = \frac{Q_t}{Q_d}$$

Where,
- N_d : Number of drippers at each tree.
- Q_d : The discharge of one dripper (2 - 12 lit./hr.).

$$Q_d = a\ h^b$$

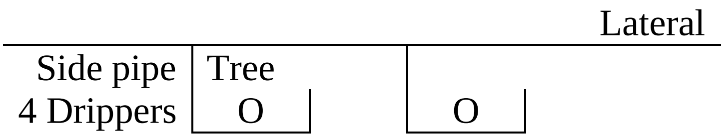
Where,
- h : Operating head of the dripper (m.).
- a & b : Constants according to the type of the dripper.

In general, drippers are connected to the laterals by one of the forms:

1- Directly on the laterals.

O O Trees
-o--------o- Lateral
Drippers

2- On side pipes outside the laterals if many drippers are needed.



2- The distribution network:-

It is composed of different pipes (laterals, submain lines and a main line or more). The main and submain lines are generally PVC pipes that are burried into the soil. The laterals are generally PE pipes with common diameters of 8 - 20 mm. that are laid on the ground surface. The steps of design for pipes are similar to that of the sprinkler irrigation system.

3- The pump:-

Design of the pump is also similar to that of the sprinkler irrigation system.

Example (3-5):

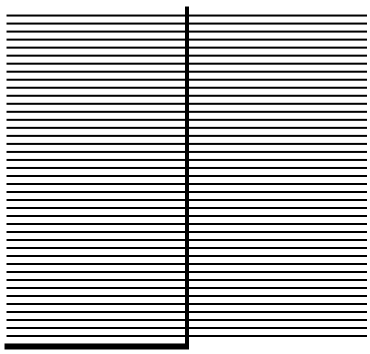
A square horizontal land has an area of 10 feddan, is irrigated using a drip irrigation system, and is cultivated by vines. The spacing of trees is 2.5 m. x 5.0 m. and the water requirement is 20 m.^{3}/fed./day. The source of water is located at the beginning of the lower side of the land with 4.0 m. suction head.

1- Draw a planning of the drip irrigation system for the land ?

2- Design the main components of the drip irrigation system ?

Solution:

1- The Planning:



The area is 205 m. x 205 m.

The length of the main line = 205 / 2 = 102.5 m.

The length of the submain line is 205 m.

The length of each lateral is 205 / 2 = 102.5 m.

Number of trees served by each lateral = 102.5 / 2.5 = 41

Number of laterals = (205 / 5) x 2 = 82

2- The Design:

1- The drippers:-

$$Q_t = \frac{IW_d \times S_d \times S_l}{P_i}$$

Assume the daily working hours = 8 hr.

$$Q_t = \frac{(20x1000)x2.5x5}{4200x8} = 7.44 \text{ lit./hr.}$$

Assume, Q_d = 4 lit./hr.

$$N_d = \frac{Q_t}{Q_d} = \frac{7.44}{4} = 1.86 \cong 2$$

∴ There are 2 drippers at each tree.

2- The laterals:-

$$Q = \frac{41 \times (2 \times 4)}{1000x60x60} = 0.91 \times 10^{-4} \text{ m.}^3\text{/sec.}$$

Assume, v = 1 m./sec.

$$A = \frac{\pi d^2}{4} = \frac{0.91 \times 10^{-4}}{1}$$

d = 0.0108 m. = 10.8 mm.

Take d_{act} = 12 mm.

$$v_{act} = \frac{0.91 \times 10^{-4} \times 4}{\pi \times (0.012)^2} = 0.8 \text{ m./sec.}$$

$$h_f = \frac{4 f \; l v^2 \times K}{2 g d} = \frac{4 \times 0.005 \times 102.5 \times (0.8)^2 \times 0.4}{2 \times 9.81 \times 0.012} = 2.23 \text{ m.}$$

3- The submain line:-

$Q = 0.91 \times 10^{-4} \times 82 = 7.462 \times 10^{-3}$ m.^{3}/sec.

Assume, v = 1 m./sec.

$$A = \frac{\pi d^2}{4} = \frac{7.462 \times 10^{-3}}{1}$$

d = 0.097 m. = 9.7 cm. = 3.8 ″

Take d_{act} = 4 ″ = 10.16 cm.

$$v_{act} = \frac{7.462 \times 10^{-3} \times 4}{\pi \times (0.1016)^2} = 0.92 \text{ m./sec.}$$

$$h_f = \frac{4 f \; l v^2 \times K}{2 g d} = \frac{4 \times 0.005 \times 205 \times (0.92)^2 \times 0.4}{2 \times 9.81 \times 0.1016} = 0.70 \text{ m.}$$

4- The main line:-

For this case, there is only one submain line.

So, the main line is taken similar to the submain line.

$\therefore$ d = 4 ″ = 10.16 cm.

$$h_f = \frac{4\ f\ l\ v^2}{2\ g\ d} \times K = \frac{4 \times 0.005 \times 102.5 \times (0.92)^2 \times 0.4}{2 \times 9.81 \times 0.1016} = 0.35 \text{ m.}$$

5- The pump:-

$Q_P = 7.462 \times 10^{-3}$ m.^{3}/sec.

$H_P = h_d + \sum h_f + X \pm Z$

Assume, h_d = 1 atm. = 1 x (10.3 / 1) = 10.3 m.

$H_P = 10.3 + (2.23 + 0.70 + 0.35) + 4 + 0 = 17.58$ m.

$P_P = \gamma\ Q_P\ H_P\ /\ 75\ \eta_P$

Assume the efficiency of the pump is 80 %.

$\therefore P_P = 1000 \times 7.462 \times 10^{-3} \times 17.58 / (75 \times 0.8) = 2.2$ HP

Exercise (3-1):

For the area given in the last example:-

1- Give another planning and its complete design ?

2- Give a planning and its complete design applying 2 daily working periods ?

3- Compare the results of the three cases ?

4- Give your comment concerning the three cases ?