Design of Drip Irrigation System

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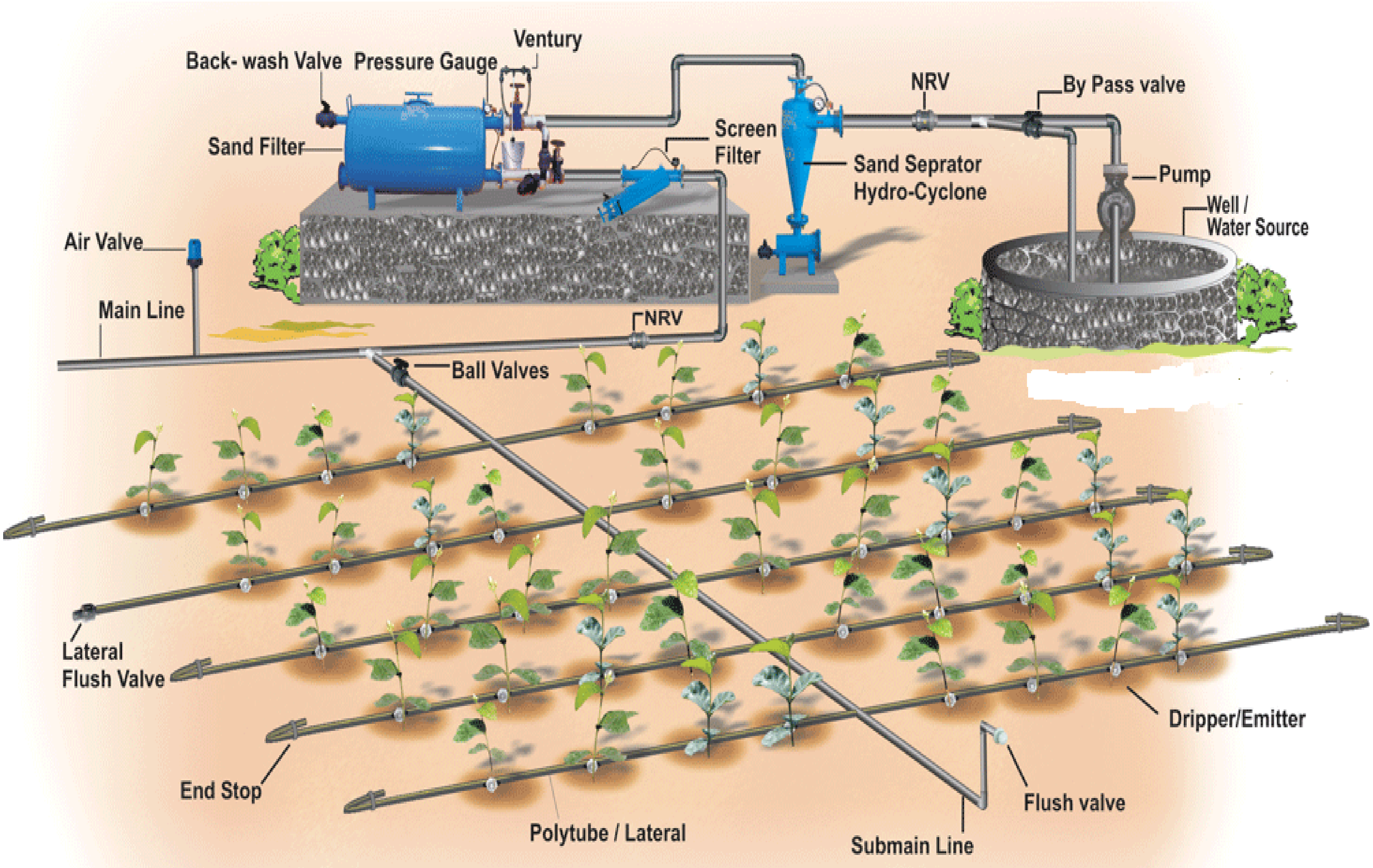
Drip Irrigation?

Drip irrigation is the slow, precise application of water and nutrients directly to the plants' root zones in a predetermined pattern using a point source.

A Typical Layout for Drip Irrigation



Components of Drip Irrigation System

Head Unit

Prime Mover (Motor/Engine)

Water Pump

G. I pipe fittings

By pass valves

Air release valves

Filters

Flow meter

Non-return valves

Fertigation unit

Field Unit

Main line

Sub-main line

Manifolds

Lateral line with emitters

Valves (By pass, Flush and Air release)

End Plug

Pressure gage

1 bar = 10.2 m of water = 14.05 psi = 0.987 atms = 100 kPa = 1.02 kg/cm^2

Focus of Design

- Apply water to meet peak crop water requirement
- Maintain application and uniformity efficiencies at a desired level
- Energy and water efficient system to keep initial capital and operation cost as low as possible
- Simple in operation and maintenance so that farmers can use these systems without extensive training

Criteria for System Selection

- Economic
- Topographic (location, elevation, field boundary, shape/slope, area, location of pumping unit etc.)
- Soil (type, soil moisture holding capacity, depth, intake rate)
- Water supply (quantity, quality, temporal variation)
- Crop factors (crop, row-to-row and plant-to-plant spacings)

Design Parameters

- Area to be irrigated, type of plants, plant spacing and number of plants per unit area
- Peak water requirement of crop or plant
- Selection of emitter type, number of emitter per plant and amount of water discharge per hour through each emitter
- Water required to be pumped from the well. This depends upon hydrogeological conditions in the area and water requirement of plants/crop
- Layout of the system considering topography, field shape and location of the water source
- Calculating sectional flow based on number of emission devices and their discharge against known pressure
- Design of main and lateral drip lines. This depends upon friction head losses
- Selection of filters and other equipment
- Horse power of a pump set. This depends on discharge and the total head including friction losses over which water is to be lifted/pumped

Command Area Information

- A command area map giving layout is necessary to plan and design a drip irrigation system

- It may not be necessary to have a detailed contour plan but it is helpful if a plan showing the highest and lowest points along with well location is given

- This enables proper design of main line and laterals

Discharge Capacity of a Pump

$Q = 27.78\ (AD/RT)$

Where:

Q = Discharge of pump (lps)

A = Area (ha)

D = Depth of irrigation (cm)

R = No of days for which water is pumped

T = Duration of pumping (hrs/day)

Example

A= 5 ha

D = 100 cm

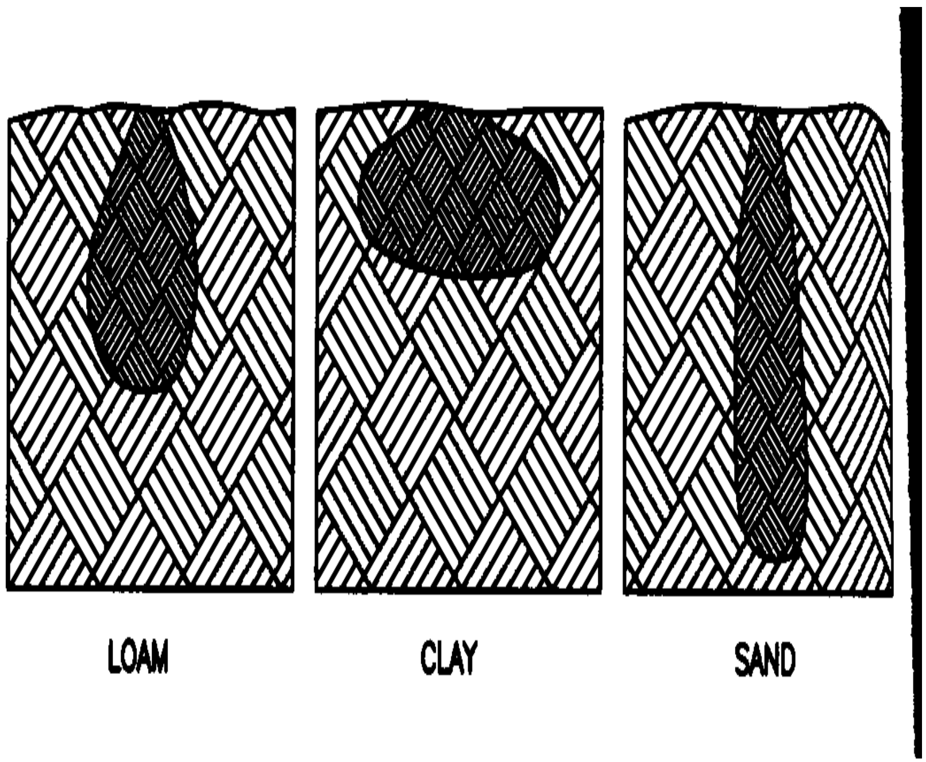
R = 150 days

T = 6 hrs/day

Q = 15 lps

Selection of Type and Number of Emitters

- Selection of type and number of emitters depends on the soil types, plant to plant distance of crop, age of the plant
- The emitter is so selected that application rate equals to the absorption rate of soil
- Generally, 30-70% of the area is wetted depending upon plant spacing, nature and development of root zone
- Some times a loop with 3 to 4 emitters is placed around each plant to provide the required wetted area. This should be away from the plant stem
- If single emitter is provided, it must be placed 15-30 cm. from the base of the plant



Space emitters equally apart
2 – 180°
3 – 120°
4 – 90°

Layout of Drip Irrigation System

- Water source and pumping plant location should be located as close to the center of the irrigated area as possible
- The main line/manifold in a drip system preferably should follow land contour as closely as possible
- If there is a slope, it should be used for compensating pressure differences due to change in elevation
- When water flows down slope, it allows longer laterals for a given pipe size or smaller pipe for a given length of lateral
- A fall of 1 m in elevation is equivalent to an increase in pressure of about 0.1 bar
- Running laterals uphill should be avoided wherever possible.

Design of Mainline and Laterals

- The design of lateral pipe involves selection of required pipe size for a given length which can carry the required quantity of water to the plant
- In designing the lateral, the discharge and operating pressure at emitters are required to be known
- The allowable pressure drop in mainline and laterals depend upon the operating pressure required at emitters
- Pressure variation along the lateral line should not exceed 10% of the design lateral pressure

Energy/Head Losses

Energy losses occur in the pipeline due to friction and elevation changes. The most commonly used equation in irrigation calculations is the Hazen-Williams formula:

$$h_f = [\{ K(Q/C)^{1.852}\}/ \{ D^{4.87}\}] * (L + Le)$$

Where:

H_f is the frictional head loss (m)

$K = 1.21 \times 10^{10}$

Q is the pipeline discharge (lps)

C is the friction coefficient for pipe sections

D is the inside diameter (mm)

L is the pipeline length (m)

Le is the equivalent length of pipe and accessories

Hazen-Williams Equation (C=150)

$$\Delta H = 15.27 \left(\frac{Q^{1.852}}{D^{4.871}}\right) L$$

Δ H = Energy drop by friction (m)

Q = Flow rate of the pipe (litre/sec)

L = Length of the pipe (m)

D = Diameter of pipe (m)

Friction Coefficients

Pipe material	F – mm (Darcy-Weisbach)	C (Hazen-Williams)
PVC and PE	0.0015 - 0.007	140 -150
Asbestos-cement	0.3	130-140
New steel	0.045 - 0.09	110-120
Five year old steel	0.15 - 4.0	80 - 90
Steel with internal concrete coating	0.3 - 1.0	110 - 120
Concrete	0.3 - 5.0	90 - 100

Frictional Head Losses (m/100 m) for 13 mm of PE pipe used as laterals

Discharge (lps)	Fractional Losses (m/100 m)			
	C = 120	C = 130	C = 140	C = 150
0.01	0.13	0.11	0.10	0.08
0.02	0.46	0.39	0.34	0.30
0.03	0.97	0.84	0.73	0.64
0.04	1.65	1.43	1.24	1.09
0.05	2.50	2.15	1.88	1.65

Source: PARC (2001)

Frictional Head Losses (m/100 m) for 16 mm Diameter PE Pipe used as Laterals

Discharge (Lps)	Fractional Losses (m/100 m)			
	C=120	C=130	C=140	C=150
0.01	0.05	0.04	0.03	0.03
0.02	0.17	0.14	0.13	0.11
0.03	0.35	0.30	0.27	0.23
0.04	0.60	0.52	0.45	0.40
0.05	0.91	0.78	0.68	0.60
0.06	1.27	1.10	0.96	0.84
0.07	1.70	1.46	1.27	1.12
0.08	2.17	1.87	1.63	1.44
0.09	2.70	2.33	2.03	1.79
0.10	3.28	2.83	2.47	2.17

Source: PARC (2001)

Frictional Head Losses (m/100 m) for 25 mm Diameter of PE pipe used as Manifolds

Discharge (Lps)	Fractional Losses(m/100 m)			
	C=120	C=130	C=140	C=150
0.10	0.37	0.32	0.28	0.25
0.12	0.52	0.45	0.39	0.35
0.14	0.70	0.60	0.52	0.46
0.16	0.89	0.77	0.67	0.59
0.18	1.11	0.96	0.83	0.73
0.20	1.35	1.16	1.01	0.89
0.22	1.61	1.39	1.21	1.06
0.24	1.89	1.63	1.42	1.25
0.26	2.19	1.89	1.65	1.45
0.28	2.51	2.17	1.89	1.66
0.30	2.86	2.46	2.15	1.89
0.32	3.22	2.78	2.42	2.13
0.34	3.60	3.11	2.71	2.38
0.36	4.00	3.45	3.01	2.65
0.38	4.43	3.82	3.33	2.93
0.40	4.87	4.20	3.66	3.22

Source: PARC (2001)

Frictional Head Losses (m/100 m) for 31.25 mm Diameter PE Pipe used as Manifolds

Discharge (lps)	Fractional Losses (m/100 m)			
	C=120	C=130	C=140	C=150
0.20	0.45	0.39	0.34	0.30
0.22	0.54	0.47	0.41	0.36
0.24	0.64	0.55	0.48	0.43
0.26	0.74	0.64	0.56	0.49
0.28	0.85	0.73	0.64	0.56
0.30	0.96	0.83	0.72	0.64
0.32	1.09	0.94	0.82	0.72
0.34	1.21	1.05	0.91	0.80
0.46	1.35	1.16	1.02	0.89
0.38	1.49	1.29	1.12	0.99
0.40	1.64	1.42	1.23	1.09
0.42	1.80	1.55	1.35	1.19
0.44	1.96	1.69	1.47	1.30
0.46	2.13	1.83	1.60	1.41
0.48	2.30	1.98	1.73	1.52
0.50	2.48	2.14	1.87	1.64
0.52	2.67	2.30	2.01	1.77
0.54	2.86	2.47	2.15	1.89
0.56	3.06	2.64	2.30	2.02
0.58	3.27	2.82	2.46	2.16
0.60	3.48	3.00	2.61	2.30

Source: PARC (2001)

Frictional Head Losses (m/100m) for 37.5 mm Diameter of PE pipe used for Manifolds

Discharge (Lps)	Fractional Losses (m/100 m)			
	C=120	C=130	C=140	C=150
0.30	0.40	0.34	0.30	0.26
0.32	0.45	0.39	0.34	0.30
0.34	0.50	0.43	0.38	0.33
0.36	0.56	0.48	0.42	0.37
0.38	0.61	0.53	0.46	0.41
0.40	0.68	0.58	0.51	0.45
0.42	0.74	0.64	0.56	0.49
0.44	0.81	0.69	0.61	0.53
0.46	0.88	0.75	0.66	0.58
0.48	0.95	0.82	0.71	0.63
0.50	1.02	0.88	0.77	0.68
0.52	1.10	0.95	0.83	0.73
0.54	1.18	1.02	0.89	0.78
0.56	1.26	1.09	0.95	0.83
0.58	1.34	1.16	1.01	0.89
0.60	1.43	1.23	1.08	0.95
0.62	1.52	1.31	1.14	1.01
0.64	1.61	1.39	1.21	1.07
0.66	1.71	1.47	1.28	1.13
0.68	1.80	1.56	1.36	1.19
0.70	1.90	1.64	1.43	1.26
0.72	2.01	1.73	1.51	1.33
0.74	2.11	1.82	1.59	1.40
0.76	2.22	1.91	1.67	1.47
0.78	2.33	2.01	1,75	1.54
0.80	2.44	2.10	1.83	1.61
0.82	2.55	2.20	1.92	1.69
0.84	2.67	2.30	2.01	1.77
0.86	2.79	2.40	2.10	1.84
0.88	2.91	2.51	2.19	1.92
0.90	3.03	2.62	2.28	2.01
0.92	3.16	2.72	2.37	2.09
0.94	3.29	2.83	2.47	2.17
0.96	3.42	2.95	2.57	2.26
0.98	3.55	3.06	2.67	2.35
1.00	3.69	3.18	2.77	2.44

Source: PARC (2001)

Frictional Head Losses (m/100 m) for 50 mm Diameter of PE pipe used for Mainlines

Discharge (Lps)	Fractional Losses (m/100 m)			
	C=120	C=130	C=140	C=150
1.0	0.91	0.78	0.68	0.60
1.2	1.27	1.10	0.96	0.84
1.4	1.69	1.46	1.27	1.12
1.6	2.17	1.87	1.63	1.43
1.8	2.70	2.33	2.03	1.78
2.0	3.28	2.83	2.46	2.17
2.2	3.91	3.37	2.94	2.59
2.4	4.60	3.96	3.45	3.04
2.6	5.33	4.60	4.01	3.53
2.8	6.11	5.27	4.60	5.04
3.0	6.95	5.99	5.33	4.60

Source: PARC (2001)

Frictional Head Losses (m/100 m) for 62.5 mm Diameter of PE pipe used for Mainlines

Discharge (lps)	Fractional Losses (m/100 m)			
	C=120	C=130	C=140	C=150
2.0	1.11	0.95	0.83	0.73
2.2	1.32	1.14	0.99	0.87
2.4	1.55	1.34	1.17	1.03
2.6	1.80	1.55	1.35	1.19
2.8	2.06	1.78	1.55	1.36
3.0	2.34	2.02	1.76	1.55
3.2	2.63	2.28	1.98	1.75
3.4	2.95	2.55	2.22	1.95
3.6	3.28	2.83	2.47	2.17
3.8	3.63	3.13	2.73	2.40
4.0	3.99	3.44	3.00	2.64
4.2	4.37	3.77	3.28	2.89
4.4	4.76	4.11	3.58	3.15
4.6	5.17	4.46	3.89	3.42
4.8	5.60	4.82	4.21	3.70
5.0	6.04	5.20	4.54	3.99

Source: PARC (2001)

Frictional Head Losses (m/100 m) for 75 mm Diameter of PE pipe used for Mainlines

Discharge (Lps)	Fractional Losses (m/100 m)			
	C=120	C=130	C=140	C=150
3.0	0.96	0.83	0.72	0.64
3.2	1.09	0.94	0.82	0.72
3.4	1.22	1.05	0.91	080
3.6	1.35	1.17	1.02	0.89
3.8	1.49	1.29	1.12	0.99
4.0	1.64	1.42	1.23	1.09
4.2	1.80	1.55	1.35	1.19
4.4	1.96	1.69	1.47	1.30
4.6	2.13	1.84	1.60	1.41
4.8	2.30	1.99	1.73	1.52
5.0	2.48	2.14	1.87	1.64
5.2	2.67	2.30	2.01	1.77
5.4	2.86	2.47	2.15	1.89
5.6	3.06	2.64	2.30	2.03
5.8	3.27	2.82	2.46	2.16
6.0	2.48	3.00	2.62	2.30
6.2	3.70	3.19	2.78	2.45
6.4	3.92	3.38	2.95	2.60
6.6	4.15	3.58	3.12	2.75
6.8	4.39	3.78	3.30	2.90
7.0	4.63	3.99	3.48	3.06
7.2	4.88	4.21	3.67	3.23
7.4	5.13	4.43	3.86	3.40
7.6	5.39	4.65	4.05	3.57
7.8	5.66	4.88	4.25	3.74
8.0	5.93	5.11	4.46	3.92
8.2	6.21	5.35	4.67	4.11
8.4	6.49	5.60	4.88	4.29
8.6	6.78	5.85	5.10	4.49
8.8	7.08	6.10	5.32	4.68
9.0	7.38	6.36	5.54	4.88
9.2	7.68	6.62	5.77	5.08
9.4	8.00	6.89	6.01	5.29
9.6	8.31	7.17	6.25	5.50
9.8	8.64	7.45	6.49	5.71
10.0	8.97	7.73	6.74	5.93

Source: PARC (2001)

Frictional Head Loss (m/100 m) for 100 mm Diameter of PE pipe used for Mainlines

Discharge (lps)	Fractional Losses (m/100 m)			
	C=120	C=130	C=140	C=150
5.0	0.61	0.53	0.46	0.40
5.2	0.66	0.57	0.49	0.44
5.4	0.71	0.61	0.53	0.47
5.6	0.75	0.65	0.57	0.50
5.8	0.81	0.69	0.61	0.53
6.0	0.86	0.74	0.64	0.57
6.2	0.91	0.79	0.68	0.60
6.4	0.97	0.83	0.73	0.64
6.6	1.02	0.88	0.77	0.68
6.8	1.08	0.93	0.81	0.72
7.0	1.14	0.98	0.86	0.75
7.2	1.20	1.04	0.90	0.80
7.4	1.26	1.09	0.95	0.84
7.6	1.33	1.15	1.00	0.88
7.8	1.39	1.20	1.05	0.92
8.0	1.46	1.26	1.10	0.97
8.2	1.53	1.32	1.15	1.01
8.4	1.60	1.38	1.20	1.06
8.6	1.67	1.44	1.26	1.10
8.8	1.74	1.50	1.31	1.15
9.0	1.82	1.57	1.37	1.20
9.2	1.89	1.63	1.42	1.25
9.4	1.97	1.70	1.48	1.30
9.6	2.05	1.77	1.54	1.35
9.8	2.13	1.83	1.60	1.41
10.0	2.21	1.90	1.66	1.46
10.2	2.29	1.98	1.72	1.52
10.4	2.38	2.05	1.79	1.57
10.6	2.46	2.12	1.85	1.63
10.8	2.55	2.20	1.91	1.68
11.0	2.64	2.27	1.98	1.74
11.2	2.72	2.35	2.05	1.80
11.4	2.82	2.43	2.12	1.86
11.6	2.93	2.51	2.19	1.92
11.8	3.00	2.59	2.26	1.99
12.0	3.10	2.67	2.33	2.05

Source: PARC (2001)

Minor Head Losses

The head loss associated with fittings/valves is calculated using equation

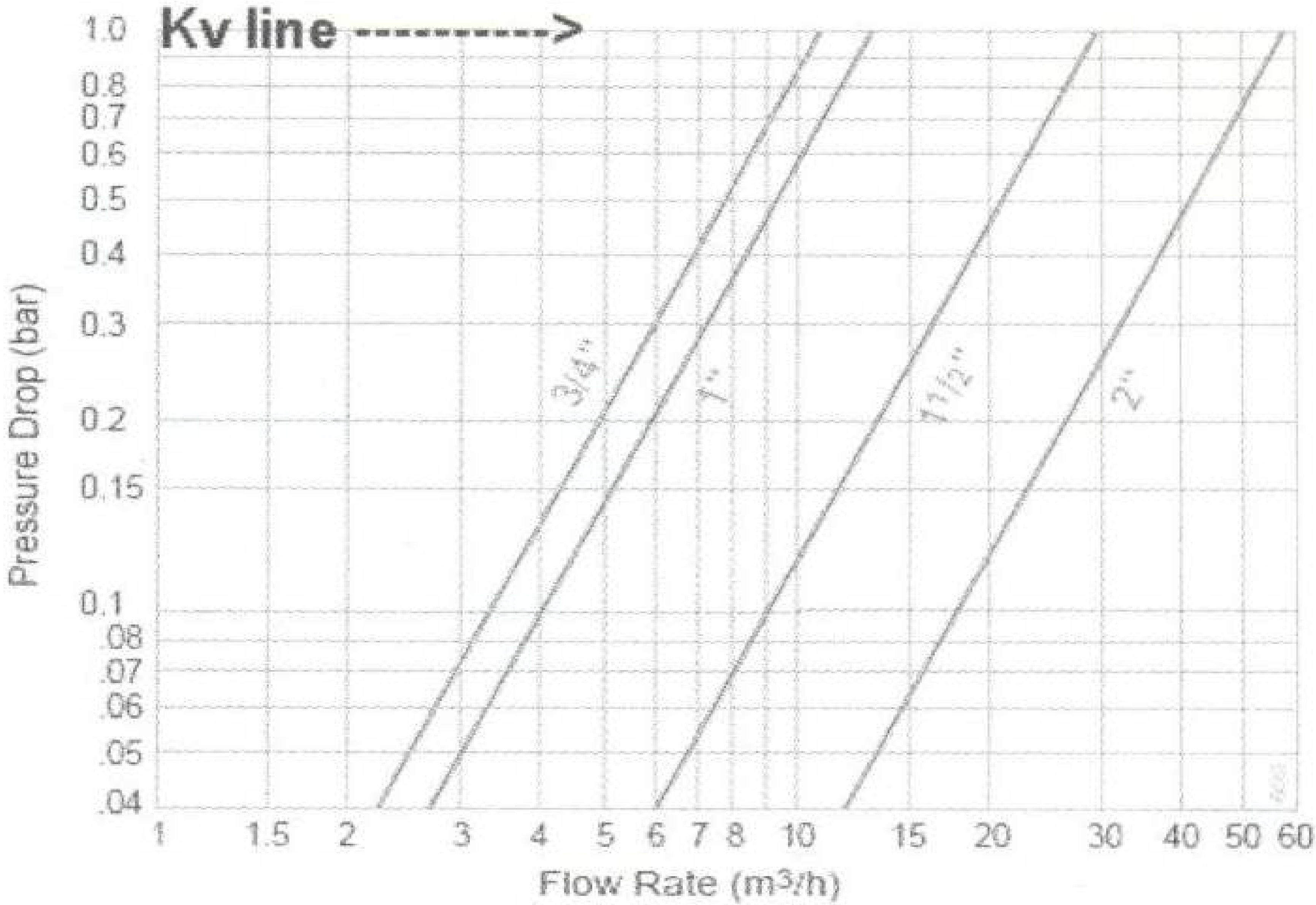
$Kv = (Q/\Delta P)^{0.5}$ where

Kv = Flow factor (m^3/hr), Q = Flow rate (m^3/hr) and ΔP = Pressure drop (bars)

Fitting Valve	Loss coefficient K	Fitting, valve	Loss coefficient K
45° standard elbow	0.35	Gate valve, open	0.20
90° standard elbow	0.75	Three-fourths open	0.90
Coupling or union	0.04	One-half open	4.50
Tee, along run	0.40	One-fourth open	24.00
Branching flow	1.00	Globe valve, open	6.40
Ball check valve, open	70.00	One-half open	9.5

Example: If Kv = 50 m^3/hr and Q = 30 m^3/hr, then ΔP = 0.36 bar = 3.6 m

Head Losses in Valves and Accessories



Power Requirement

- The HP of pump set required is based upon design discharge, total operating head and efficiency of pumping system
- Where the total head is the sum of total static head and friction losses in the system
- Overall efficiency recommended for high pressure pumping systems is as under:
    - Electric motor operated systems = 50%
    - Diesel engine operated systems = 40%

Design of Prime Mover

Power requirement for the prime mover can be determined by:

$$HP = QH/(76 \times \text{Engine efficiency})$$

Where:

Q = Discharge (lps)

H= Total head (m)

Example:
H = 30 m
Q = 15 lps
Engine HP: 12
Motor HP: 15

Pump Selection

Pump selection is based on the:

- Required pressure
- Designed discharge and
- Size of prime mover

Example

Design a drip irrigation system for the following data:

Area: 30 acre = 400 m x 300 m

Topography: Flat

Crop: Citrus

Spacing: 6.1 m x 6.1 m

Water source: Tubewell at the center of the field

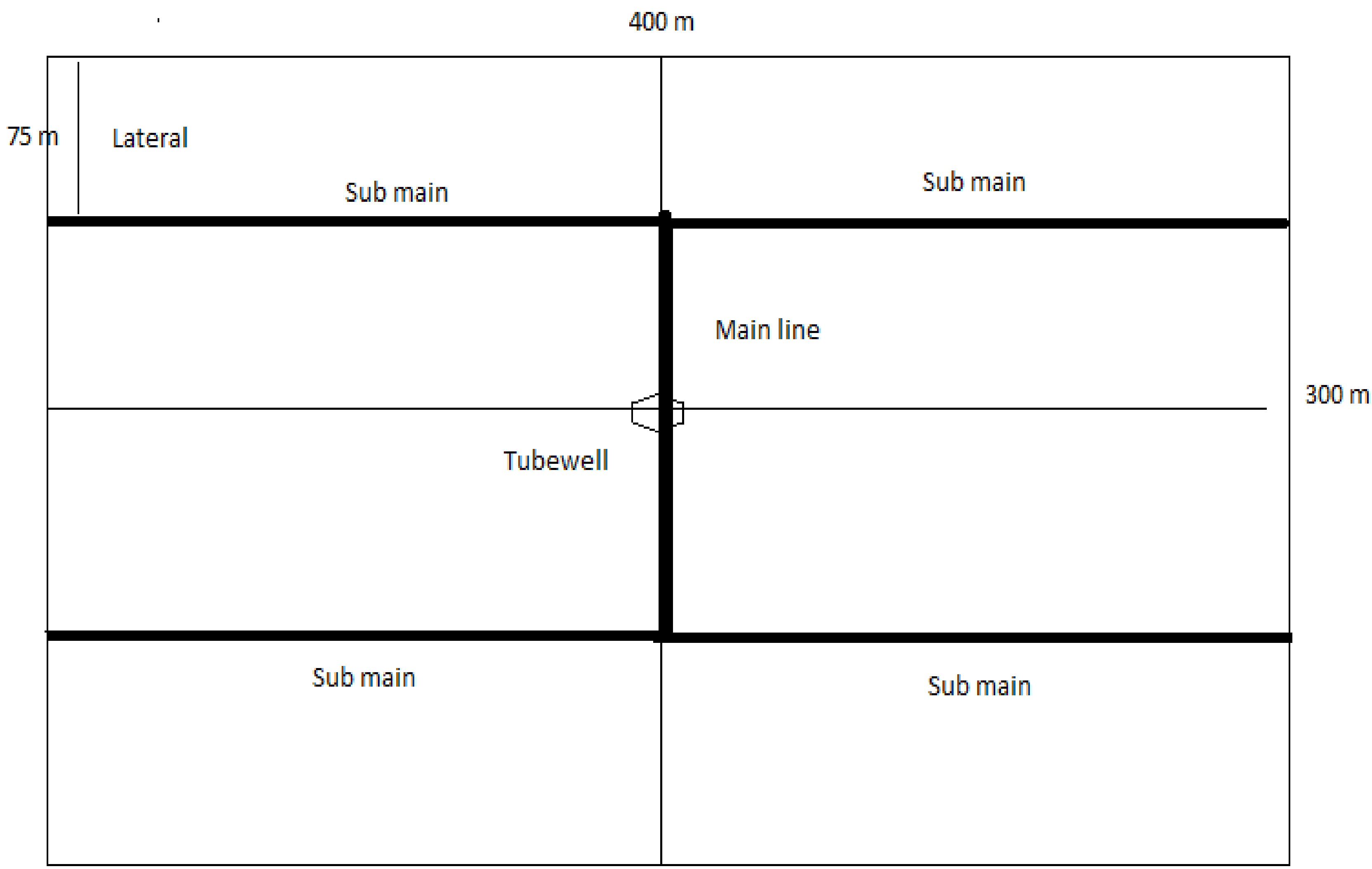
Suction lift: 3 m

Delivery lift: 3 m

Tubewell discharge: 15 lps

Total no. of plants: 3225
Emitter discharge: 4 lph
Total emitters (4 per plant): 12900
Total flow rate: 51599 lph = 14.3 lps

Layout of the Farm



Example (cont)

- Divide the area into 4 blocks (7.5 acre x 4)
- Lateral length : 75 m
- Lateral inside diameter : 16 mm
- No. of emitters/lateral: 49
- Discharge of emitters: 197 lph = 0.05 lps
- Head loss in lateral (0.91 m/100 m): 0.68 m
- Sub main 1
- Length : 200 m
- Diameter: 62.5 mm
- No. of laterals on the sub main: 66
- Total discharge of the sub main: 12984 lph = 3.6 lps
- Head loss in sub main (2.78 m/100 m): 5.56 m
- No. of sub mains: 4
- Total discharge of main line (4 sub mains): 51934 lph: 14.4 lps
- Diameter of main line : 100 mm
- Length of main line: 150 m
- Head loss in main line (2.67 m/100 m): 4 m

Total Head

- Operating pressure : 10 m
- Suction lift: 3 m
- Elevation lift: ± 0
- Delivery lift: 3 m
- Head loss in laterals: 0.68 m
- Head loss in sub mains: 5.56 m
- Head loss in main line: 4 m
- Misc head losses (fittings, valves etc): 10 m
- Total dynamic head : 36.2 m
- Discharge:14.4 lps
- Motor HP (50% efficiency) 13.7
- Engine HP (40% efficiency) 17.2

Irrigation Scheduling

- Crop : Citrus
- Area: 30 acres
- Root zone depth: 80 cm
- Maximum allowable deficit (MAD): 40%
- ETo (mm/day): 8 mm/day
- Kc: 0.9
- Soil texture: Loamy clay
- Bulk density: 1.4 gm/ml
- Field capacity: 32%
- Wilting point: 15%
- Available moisture: 17%
- Daily peak season water demand: 7.2 mm/day
- Gross daily demand (mm/day), assuming 90% efficiency: 8 mm/day
- Available moisture by volume: 0.24 cm^3 of water/cm^3 of soil
- Total available moisture: 19.04 cm
- Water content at 40% MAD: 7.62cm
- No. of day after irrigation is due: 10 days

Irrigation Scheduling

Canopy diameter (m)	Gross CWR (liters/day)	Time of irrigation with 4 emitters (hrs/day)
2	25	1.3
3	57	2.8
4	100	5.0

Thanks

Energy/Head Losses

Head loss in pipes with Multiple , equally Spaced Outlets

Flow of water in a pipe having multiple, equally spaced outlets will have less head loss than a similar pipe transmitting the entire flow over its length because the flow steadily diminishes each time an outlet is passed. Christiansen developed the concept of a "F factor", which accounts for the effect of the outlets. When the first outlet is one outlet spacing from the lateral or manifold inlet:

$$F = [1/(m+1)] + [1/2N] + [\ \{m-1\}^{0.5} / 6N^2]$$

in which,

F = fraction of the headloss under constant discharge conditions expected with the multiple outlet case;
m = 1.85 for Hazren-Williams equation;
m = 2.0 for the Darcy-Weisbach equation; and
N = number of outlets along the pipe.

Increase the length of the pipe for:

Elbow (90°) : 60 times the internal diameter of the pipe

Elbow (45°): 30 times the internal diameter of the pipe

Gate valve (side): 50 times the internal diameter of the pipe

Gate valve (straight): 150 times the internal diameter of the pipe